Review of Radio Spectrum Management 2002

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March 2002

Review of Radio Spectrum Management

by
Professor Martin Cave

for
Department of Trade and Industry
Her Majesty's Treasury

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HM Treasury

Review of Radio Spectrum Management

An independent review for Department of Trade and Industry and HM Treasury

by Professor Martin Cave

March 2002

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FOREWORD

Dear Chancellor of the Exchequer and Secretary of State,

In March 2001 you appointed me to undertake an independent review of radio spectrum management in the UK, and I now take pleasure in sending you my final report. Since March, the review team has published a consultation document to which 80 responses have been received, and also has met or communicated directly with a wide variety of organisations, including firms, public sector organisations, Government departments, consumer groups and overseas regulators. I am grateful to these bodies for the considerable help which they have given the review.

In the June consultation document, I set out a possible approach to spectrum management over the next ten to fifteen years which was designed to ensure that all the spectrum users take into account the costs of the spectrum which they were using. This was likely to encourage efficiency in spectrum use and create opportunities for innovation. Respondents have generally welcomed this approach, but have expanded on it in a number of important ways.

In particular, it is clear that major technological changes are giving the spectrum much greater importance in the prosperity of the British economy and the attainment of the Government's social objectives. In the field of communications, major new services will shortly be provided, in the form, for example, of 3G mobile communications and broadband internet access, delivered by terrestrial wireless or by satellite. Digital broadcasting transmitted terrestrially or by satellite will deliver a much broader range of services to an increasing proportion of the population, and soon to all of us. Other commercial uses of spectrum – for example in the provision of airline services – are also growing in importance.

At the same time, the public services are increasingly reliant upon spectrum. In defence, the importance of gathering and communicating information is growing all the time. Emergency services increasingly require information to be conveyed fully and immediately to the scene of any incident. Technologies to achieve these objectives are currently being deployed. Almost invariably, they place additional demands on spectrum use. I have referred above solely to technologies under commercial exploitation or on the verge of it. But it is clear that over the ten to twenty year period which my proposals are intended to cover, there will be a very large number of further innovations. Some of these, such as software-defined radio and ultra wideband transmission, are under development. Others are not yet known.

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These circumstances place an important premium on flexibility – particularly the ability to make unused spectrum in the higher bands available to users, and to redeploy existing spectrum for new purposes. In the past, such decisions have predominantly been made by international or national regulatory bodies. Particular bands of spectrum have been allocated by international agreement to specified purposes; national governments have then assigned the spectrum through an administrative process to particular firms.

Guided by many of the responses which I have received, particularly from commercial organisations, I have concluded that this system is no longer sufficiently flexible to meet the needs of the twenty-first century. The benefits which it brings in terms of preventing interference from one spectrum user to another, nationally or internationally, and from achieving harmonisation of spectrum use at a European or global level, can generally be achieved by other means – in the case of interference, by a proper specification of the rights of the licensees, and in the case of harmonisation, by intelligent decisions taken by firms, rather than regulators, designed to reduce the cost of service to customers and supported by the vigorous application of competition law to prevent collusive behaviour. Accordingly, I recommend that the Government undertake a policy of selective deregulation of spectrum use where it can within the UK, and argue in international fora for increasing reliance upon the market, rather than administrative systems, for the management of spectrum.

In the case of spectrum utilised by firms for purely commercial purposes, this objective can best be achieved by the introduction of spectrum trading, combined with the auctioning of new spectrum as it becomes available. Trading will give firms an incentive to husband the nation's resources of spectrum and direct it into the most profitable uses. Where demand grows for a service which utilises spectrum, spectrum will increasingly be deployed for that purpose. Firms that do not utilise, or under-utilise, spectrum will have an incentive to lease or sell it. This will require a much clearer specification of the duration and the extent of the rights of users flowing from the licensing process, but these challenges have already been overcome in other countries, and in that relatively small part of the spectrum in the UK which has been subject to auctioning. The Government will also have to resolve questions of capital gains made by firms which were initially assigned spectrum by an administrative process, but which henceforth may have the right to sell that spectrum and my report indicates a number of ways in which this issue might be addressed. In my opinion, the combination of auctioning of new spectrum used for commercial purposes and secondary trading will introduce a much wider

and better functioning allocation mechanism than exists at present when only the auctioning of new spectrum is permitted. Accordingly, I recommend that spectrum trading be progressively introduced in the case of all spectrum used for commercial purposes, as soon as such trading becomes permissible under EU legislation – probably from the middle of 2003.

In relation to spectrum used for public services, such as defence, the emergency services, science and aeronautical radar, I recommend that the Government adopt a policy of reserving spectrum for such purposes, combined with a system of levying an administrative charge on its use, based upon the value of that spectrum to users. The Radiocommunications Agency has been a pioneer in the development of administrative pricing of spectrum, and I recommend that this process be developed further and utilised more widely, to cover all public service spectrum which has an alternative use. When government departments and other bodies face charges of this kind, they will have an incentive to reduce the amount of spectrum which they use in order to reduce their costs. They may, for example, switch to wire-based rather than wireless technology; they may advance investment to install equipment which uses spectrum more economically. Over time, the effect will be to release public service spectrum for alternative commercial and non-commercial uses as the price mechanism begins to work. In the longer term as spectrum trading develops, the Government should look to expose more public services' spectrum use to this market mechanism.

This process of levying charges for spectrum does not entail any reduction in the level of provision of defence, emergency services, public service broadcasting or other public services within the economy. The Government will still be able to make appropriate budgetary allocations to such services, to permit expenditure on spectrum as well as on other inputs. Care must be taken to ensure that this is done in a way which still gives the suppliers of public services an incentive to economise on costs. My report discusses at some length how this can be achieved. The key point is that public services users of spectrum receive a genuine monetary incentive to use their best efforts to economise. I also recommend that public service spectrum users be given the right to share spectrum with commercial users, by leasing it to them on a time-limited or interruptible basis at commercially agreed rates.

One of my abiding concerns throughout the preparation of the report has been a widespread perception that spectrum charging is simply a device to raise money for the Government from private sector bodies or organisations such as the BBC. Revenue raising has not been an objective which has governed my recommendations. On the contrary,

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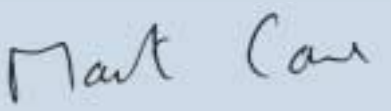
I am concerned that the current régime, in which inflexible allocations of spectrum are made to particular purposes, generates artificial scarcities which limit entry into spectrum-using industries and ultimately lead to higher prices paid by consumers. In the short term, spectrum charges may increase government revenues. In the medium and long term, however, the effect of redeploying spectrum to high value uses will reduce both scarcity and price. In an ideal world, most wave bands would be priced, but the price would be low, as firms respond to the challenge of bringing more of the spectrum into use and economising on it. In my opinion, the gains to the British economy from this process are enormous. For it to be achieved, what is required is that the Government makes a firm commitment to the use of prices for spectrum; the precise date at which they come into effect are a matter of lesser importance provided that a credible commitment is made.

In summary, my recommendations start from the belief that the country needs radically to change the way in which spectrum is allocated, in order to reap the rewards of efficiency and innovation in spectrum use. This can best be achieved in the medium term by a two-pronged approach: the use of markets (spectrum trading and auctions) to allocate spectrum in commercial use, and the continued reservation of spectrum for public service use, coupled with an administrative charge designed to ensure economy and efficiency of its use. For the country to gain full benefit from these changes, the Government should indicate its intentions swiftly and commit itself to a programme of phased implementation.

These proposals will impose new responsibilities on those with the task of managing the UK spectrum – currently the Radiocommunications Agency and, in the future, Ofcom. Fortunately, the RA is among the foremost spectrum management organisations in the world, and I am confident that, within Ofcom, it will rise to the challenge of implementing my proposals, if the Government adopts them.

Finally, I must express my gratitude to the invaluable work of the team which assisted me with the review (named at the front of this report).

Yours faithfully



Professor Martin Cave
February 2002

EXECUTIVE SUMMARY

Remit of review

1. The radio spectrum is a key resource for many new and developing technology-based industries. At the same time, it is a vital input into the delivery of many public services. The management and development of the spectrum will therefore play an important role in creating a knowledge-driven economy and society. To help ensure that the spectrum management framework is at the forefront of change, the Chancellor of the Exchequer and Secretary of State for Trade and Industry commissioned Professor Martin Cave[1] in March 2001 to lead an independent review of radio spectrum management.

2. The review was charged with advising on the principles that should govern spectrum management, and what more needs to be done to ensure that all users, including non-commercial users, are focused on using spectrum in the most efficient way possible. In doing so, it has considered the use of spectrum management tools such as spectrum valuation, pricing and trading.

3. In December 2000, the Government published the Communications White Paper, which set out the future for regulation in the communications sector. The proposed new unified regulator of the sector, the Office of Communications (Ofcom), will encompass a wide range of economic and content regulation, including spectrum management currently conducted by the Radiocommunications Agency. At the time of submitting this report, the Government had introduced the paving legislation to establish Ofcom as a corporate entity, but had yet to publish the substantive Communications Bill which would define in detail the powers of Ofcom. The review was charged with advising on this proposed legislation as it related to spectrum management, but not to revisit the institutional arrangements set out in the Communications White Paper.

4. In line with the remit to consult widely in order to produce a fully informed and authoritative report, the review published a wide-ranging consultation document in June 2001. This set out a preliminary exposition of the potential benefits from, and constraints on, applying economic principles more comprehensively to spectrum management in the UK. Some 80 written responses were received[2], and the review held meetings with around 60 interested parties.

[1] Director of Centre for Management under Regulation at Warwick Business School, formerly Vice Principal, Brunel University.

[2] Published on the review's website at www.spectrumreview.radio.gov.uk.

Purpose of review

5. The use of radio spectrum has become an integral part of society's infrastructure. For decades, viewers have taken for granted the reception of clear TV signals, travellers have relied upon assured communications and radio-location for aircraft, and all citizens have benefited from radio connectivity for the public safety services. More recently, the phenomenal growth in personal mobile communications has turned wireless access via mobile phones from a luxury to a necessity for many people.

6 This value to individuals, businesses and the public sector of access to radio spectrum is becoming increasingly recognised. Radio makes a substantial and increasing contribution to the economy. Recent studies by the Radiocommunications Agency show that even for selected sectors of the economy[3], the value of radio to the economy as a whole exceeds £20 billion per annum[4], over two per cent of UK output. Success in managing access to radio spectrum should thus boost the performance of the UK economy.

7. Looking forward, spectrum is an essential raw material for many of the UK's most promising industries of the future. Wherever consumers demand mobile and ubiquitous access to communications, wireless products using radio signals will provide the solution. Radio is a uniquely versatile communications medium, essential to connecting up the information society. New products and services typically complement rather than replace existing ones, so adding to the demands on the radio spectrum. Furthermore, the boundaries between new services are blurring, transcending current business models, reducing the predictability of spectrum use, and challenging current regulatory categorisations.

8. So spectrum management is becoming simultaneously more difficult and more important. But the UK is well placed to respond to this regulatory challenge. The Radiocommunications Agency has a well-deserved reputation as one of the most forward-looking and progressive spectrum managers in the world, having enabled the development of flourishing wireless services in one of the world's most congested radio environments. In recent years, it has garnered valuable experience of the new market-based tools introduced under the Wireless Telegraphy 1998. The Communications Bill and prospective unified regulator provide a further opportunity to refine the regulatory 'toolbox' and make cross-sectoral regulation more effective.

9. The review's purpose at this juncture is to look forward to the principles which should guide the Government and Ofcom in managing access to the radio spectrum in the years ahead, in order to derive most value from this national asset for the UK as a whole. The review aims to build on the UK's experience to date, which reflects a strong central regulatory approach to mandating spectrum use for particular purposes, and co-ordinating users to minimise

[3] Principally mobile telephony, broadcasting, satellite, fixed links, private mobile radio, but excluding commercial aviation, defence and consumer benefits of some low power devices.

[4] *The Economic Impact of Radio*, A Study by the Radiocommunications Agency, February 2001.

harmful interference. But market mechanisms should play a much broader role in allocating and assigning spectrum to its best use, building on regulatory foundations which are essential for any market to work efficiently.

Challenges facing spectrum management

10. The fundamental building blocks of regulating access to radio spectrum have remained essentially the same during the hundred-year history of radio. Spectrum blocks are **allocated**, through international agreement, to broadly defined services. National regulatory authorities then **assign** licences for use of specific frequencies within these allocations within their jurisdictions. The current UK primary legislation for spectrum management, the Wireless Telegraphy Act 1949, is largely based on the Wireless Telegraphy Act 1904.

11. This regulatory task involves an inherently complex balancing act in a range of dimensions, in each of which there are conflicting considerations:

- **Interference**. Transmissions interfere unless sufficiently separated in terms of frequency, geography or time. Regulators must strike a balance between reducing the extent of harmful interference, through careful planning, and enabling new and potentially valuable new services to enter the market.
- **International co-ordination**. The effective use of radio spectrum in the UK will typically require careful co-ordination with neighbouring countries, to mitigate the extent of harmful interference. The Government must weigh up the benefits of co-ordinated and harmonised use of spectrum across Europe against the constraints which this imposes on spectrum management in the UK.
- **Investment in equipment**. Most radio equipment can operate over only a limited range of frequencies, and so relies on predictable access over time to defined frequency bands. Stability in spectrum to encourage investment in equipment can slow the pace of spectrum re-use. Increasingly, technical specifications are determined internationally to reap economies of scale in production. National regulators need to balance stability and international harmonisation with responsiveness to new technologies.

12. Developments in technology over the last century have opened up the range of useable radio spectrum, so enabling ever-greater access to new allocations and assignments. While demand from consumers, businesses and public services for wireless communications kept pace with this increased supply over much of the twentieth century, the regulatory regime has proved sufficiently flexible to cope. But with a sharp acceleration in demand in recent years, change in the market place is outpacing the ability of the national and international regulatory regime to respond.

13. Fundamentally, the spectrum manager is called upon to devise procedures to ration current and future demand for radio spectrum between competing commercial and public service users. To do so centrally would require a detailed knowledge of supply and demand trends, technology developments, and the relative value to society of alternative services. This represents a mammoth central planning task, which is now beyond the scope of any regulatory body, no matter how well staffed and managed. The central regulator is becoming less able to accumulate and assimilate sufficient information to make a correct assignment of spectrum to optimise use over time.

14. Instead, spectrum managers will tend, inevitably, to bias decisions in favour of the *status quo* for a variety of reasons:

- **Demand for spectrum.** Incumbent users, facing few if any continuous incentives to economise on spectrum use, will tend to 'over occupy' spectrum, making wasteful use of it and reducing the amount which can be assigned to new users.
- **Interference management**. New services could potentially create additional interference to the detriment of incumbent operators. Technical studies can clarify the potential extent of interference, but judgements about results will tend to favour incumbents' interests.
- **Demand for services**. New services will be based upon uncertain projections of future demand, against data on actual usage for current operators. The weight of regulatory evidence is likely to be in favour of the latter, particularly where new services will compete with existing ones.

15. This systemic deficiency of a central planning approach does not detract from the significant steps which the RA has taken in recent years to help meet demands for spectrum from new services. Measures taken include:

- promoting the use of more efficient trunked radio services;
- making spectrum available for the early licensing of competing cellular mobile telephony services, and the recent licensing of Third Generation mobile services;
- moving users of fixed radio links to less congested higher frequencies; and
- enabling the introduction of more spectrally efficient digital technologies in mobile radio and broadcasting.

16. But it does highlight the need to complement the regulatory regime with other approaches to managing access to radio spectrum, in order to enable continued growth of radio-using services in the UK. The DTI itself identified in the mid-1990s the weaknesses and limits of the traditional approach to spectrum management in proposing the addition of market-based tools to the RA's 'toolkit'[5]:

- **Regulatory burden**. Attempting to tackle 'hoarding'[6] by increased regulation alone would be excessively burdensome and intrusive, as well as requiring substantial additional resources.
- **Inefficiency**. Regulation is inherently inflexible and reduces choice. Users have to meet the regulatory requirements irrespective of whether or not this is economically desirable.
- **Ineffectiveness**. Given the rapid pace of change, it is likely that relying on regulation alone would not achieve the optimal distribution of spectrum and would discourage innovation.

17. The net result is that a narrow regulatory approach can reduce the ability of spectrum users to respond adequately to changing demands and technologies. The increasing pace of change in both consumer tastes and technologies accentuates the drawbacks of the current regime. The growing role of radio-based services in the UK economy, including the provision of public services, means that undue reliance on regulation is likely to become an increasing brake on economic growth.

Enabling productive and innovative spectrum use

18. Spectrum is a finite but non-exhaustible resource which is a vital input into an ever widening range of services. The utility of the resource depends crucially on the management of interference from competing users. This has been, and will continue to be, the primary role of the UK's national spectrum management authority. But the value derived from the economy's use of radio spectrum also depends on the ability of the system to accommodate shifting demands for spectrum use driven by market changes in technology and consumer preferences. Finally, UK society derives unquantified value from spectrum use by a wide range of public services, from defence to broadcasting, whose reasonable demands for spectrum have to be accommodated within any spectrum allocation regime.

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[5] *Spectrum Management: into the 21st Century*, DTI White Paper, June 1996.

[6] 'Hoarding' can be defined as demand in excess of current need, a rational response if spectrum access is under-priced, future needs are likely to rise, and incumbents are conferred rights.

19. These competing objectives of spectrum management can be expanded under three headings[7]:

Spectrum management objectives

Economic efficiency

- Market allocation of spectrum to users, and to uses, that derive higher value from the resource.
- Provide for responsiveness and flexibility to changes in markets and technologies, accommodating new services as these become technically and commercially feasible.
- Transactions costs, entry barriers and other constraints on a competitive efficient market should be minimised.

Technical efficiency

- Intensive use of scarce spectrum consistent with adherence to technical interference limits.
- Promote development and introduction of new spectrum-saving technologies where the cost of such technologies is justified by the value of the spectrum saved.

Public policy

- Consistent with Government policy towards broadcasting, competition in the telecoms market, and consumer choice.
- Safeguard interests of spectrum use for efficient functioning of defence, emergency and other public services.
- Changes to UK spectrum use should remain consistent with the UK's international and European obligations.

20. In some cases, the technically efficient solution may not be the same as the economically efficient solution. For instance, a user of spectrum may place a high value on a particular method of establishing a telecoms link between two sites even though that method happened to use more spectrum than other ways of establishing the same link. If the value it attached to the extra spectrum were higher than any other potential user then the technically less efficient solution would be the most economically efficient, i.e. it would maximise the benefits to the UK economy from spectrum use.

[7] This table is derived in part from *Deregulation of the Radio Spectrum in the UK*, a report for DTI by CSP International, March 1987. The fact that, 15 years later, Government is reviewing again the balance between these objectives highlights the fundamental challenge of the spectrum management task.

21. The RA has taken significant steps in recent years to shift its emphasis towards enabling greater economic efficiency in spectrum management. Having assessed the challenges facing spectrum management in the coming years, the review considers that there is an opportunity, and an economic imperative, to move significantly further in this direction. The evidence to date, and prospectively from analysis commissioned by the review[8], suggests that such a move can be made consistently with maintaining standards of technical efficiency in spectrum use, and with the delivery of a range of public policies which depend upon spectrum as an input.

22. The fundamental mechanism by which the spectrum management regime could contribute to economic growth is through ensuring that users face continuing incentives towards more productive use of this resource. The review considers that these incentives should be financial and based on the opportunity cost[9] of spectrum use. In this way, spectrum would be costed as any other input into the production process. Price signals about the cost of using spectrum would be disseminated throughout the economy. This information should enable dispersed economic agents to make their own judgements about their use of spectrum and the alternatives open to them to meet their organisational goals.

23. As with many other input markets, the operation of market mechanisms for spectrum will continue to take place within a framework set by regulation. The intangible nature of radio spectrum and the adverse impacts of unconstrained transmissions on others mean that a considerable degree of regulation will continue to define specific rights to spectrum use. But the review considers that there is considerable scope:

- to increase the range of spectrum users subject to financial incentives;
- to move such incentives closer to levels at which they reflect the cost to the economy of the spectrum occupied; and
- to increase the flexibility which spectrum users have to respond to these financial incentives.

[8] *Implications of international regulation and technical considerations on market mechanisms in spectrum management*, Aegis Systems and Indepen Consulting, November 2001.

[9] Opportunity cost is the value of an asset or resource in the next best alternative that is foregone by virtue of its actual use.

24. The application of incentives towards economically efficient spectrum use will vary sector by sector, but can be encompassed by the review's overarching vision:

Driver	Regulatory response
Rapidly changing environment	***Maximum flexibility*** Generic allocations, secondary trading of licences, facilitating more rapid 'refarming' from one use to another, within a transparent and predictable regulatory framework.
Maximising economic benefits	***Market mechanisms*** Auctions and trading of licences where feasible, administratively set spectrum pricing elsewhere.
Protecting social priorities	***Reserved allocations*** Make sufficient spectrum available by regulatory rationing for delivery of public services, apply spectrum pricing and positive incentives to share and/or release spectrum into the private sector.

25. The net result of the proposed regime should be to place more information in the hands of spectrum users about the costs of the spectrum they occupy, and more freedom to respond to this information in the choices they make about delivery of their organisational objectives. The aim is to move spectrum as far as possible towards a comprehensive competitive input market, where continuing incentives to economise drive spectrum users towards more innovative and productive use over time.

26. The benefits of this approach, building on the progress already made in this direction by the RA, will take time to emerge fully. Spectrum use is intimately tied to investment in specific technologies, and major gains in spectrum productivity and innovation are often only possible at step changes in the re-equipment cycle. Lead times between international policy decisions on allocations for new services and the development of commercially viable businesses and technologies can run to decades. Nevertheless, a consistent and comprehensive programme of reforms by the UK should start to bring tangible economic benefits over the next decade. The review sets out an indicative plan for these actions.

International regulatory framework

Flexibility within international allocations

27. The international co-ordination of radio spectrum management is an inevitable constraint on the ability of a single country to conduct an autonomous policy for spectrum use within its own jurisdiction. For the UK, as a medium-sized country in a densely populated region, this multilateral approach can bring benefits to consumers and operators. In many areas, the economic value of spectrum in the UK is driven to a great extent by

international agreements on technology development and spectrum allocations. Within this framework, though, the review considers that there remain many opportunities for the UK to take a more flexible and market-driven approach to spectrum management, while continuing to benefit from international harmonisation.

28. To assess whether the international regulatory framework could constrain application of a market-based approach, it is necessary to consider the impact of International Telecommunication Union (ITU), European Community (EC), Electronic Communications Committee (ECC) of the European Conference of Postal and Telecommunications Administrations (CEPT), and bilateral agreements and regulations. Of these, EC regulations and bi-lateral agreements are likely to be the most binding constraints, particularly when considering the scope for enabling market-driven change of use of particular spectrum bands.

29. If the band in question is subject to an EC Directive or is judged to be harmonised under the proposed Spectrum Decision, then the new use must be compliant with these regulations. This is an absolute constraint until the band(s) in question is removed from the list of harmonised bands. This seems most likely if the services in question are a commercial failure (e.g. ERMES), or become obsolete (e.g. analogue technology replaced by digital). ECC Decisions become mandatory once signed by administrations (although signing itself is optional).

30. Bilateral agreements, within the context of ITU regulations which determine which services have primacy in each band, may constrain what actually happens in practice. These are generally framed in terms of the division of frequencies used in border areas and the level of permitted emissions in preferred/non-preferred frequencies across the band and out of band. If the bandwidth of new services differs from that of existing services, then the agreed sharing pattern may not apply and the new use may face harsh emission constraints. This may prevent service deployment in border areas.

31. Studies for the review[10] estimate that, in frequencies around 900 MHz and above, up to 5 per cent of the UK population resides within areas where co-ordination is likely to be required for most services. The extent to which this would impact on the value of the spectrum would depend on the application and whether additional, unconstrained spectrum were available to support the service. For example, a national broadcaster or fixed wireless access operator could achieve a viable service with less than 100 per cent coverage and would be relatively unaffected by such a constraint, as would a mobile operator which used the spectrum to complement its existing GSM or 3G mobile assignment. The effect of bilateral constraints is likely to affect the UK less than some other European countries which have multiple land borders and/or significant proportions of their populations lying within co-ordination zones.

[10] *Implications of international regulation and technical considerations on market mechanisms in spectrum management*, Aegis Systems and Indepen Consulting, 2001.

32. In summary, the harmonisation of spectrum use under an EC Directive or Decision and bilateral agreements will permit the application of a market-based approach, including secondary trading of spectrum licences, where this does not involve a major change of use. Where the allocated use of a band would change as a result of applying a market approach (e.g. trading, auctions) then the situation is less clear. In some cases, EC Directives could effectively prevent a change of use. Bilateral agreements place a stronger constraint in lower as compared with higher frequency bands. ITU and ECC regulations are a weaker constraint.

33. So within the current framework of international agreements, the review considers that the UK has significant freedom of action to implement a more market-based approach to spectrum management. The review's analysis of particular market mechanisms and their application to particular radio services identifies in more detail the limits of this room for manoeuvre.

34. To take advantage of this latitude within international allocations, the Government should seek to widen the range of technically feasible services which can be deployed within specific bands. This could be achieved through increasing the number of services which are designated co-primary in particular bands, subject to technical studies identifying the extent of service compatibility within and across bands. In the longer term, there may also be scope to widen the definition of these services to encompass a greater range of compatible applications.

Harmonisation of spectrum

35. The review has also considered the UK policy stance towards the multilateral harmonisation of spectrum for specific uses and/or technologies. This process relies on a complex interplay between technology development, industry business planning, and national regulators. The review's general approach here, as elsewhere, is to emphasise the role of firms (operators and manufacturers) in delivering the benefits of timely and effective harmonisation, within a framework set by the regulators.

36. The review recognises that, for many services, there are enduring benefits from global or regional co-ordination of spectrum use for a variety of overlapping reasons:

- Cross-border movement of transmitters (e.g. maritime, aviation and increasingly personal mobile phones) requires that equipment operate in harmonised channels internationally.
- Significant propagation of signals across regions (e.g. satellite services, broadcasting) and neighbouring countries require some co-ordination of transmissions.
- Allocation of bands across regions to particular services or technologies enables manufacturers to achieve economies of scale in the production of equipment, enabling more rapid and economical rollout of new services.

Within this generally accepted framework, though, there remain many decisions about the level at which this co-ordination takes place, and how tightly it constrains individual countries.

37. The review's consultation revealed strong support, particularly among telecoms operators and equipment manufacturers, for spectrum to be harmonised to particular technologies. The global open technology standards identified with specific frequency bands enable manufacturers to focus their research and development effort, thus reducing time to market. Economies of scale from producing for multinational markets and competition between manufacturers for standardised equipment can help deliver better quality and value for end users.

38. These arguments are compelling for a wide range of wireless terminal product categories. There remain though two major policy choices:

- Where do the costs of harmonisation, in terms of reduced innovation, regulatory delay and constraints on alternative uses, start to outweigh the potential consumer benefits of regionally standardised technology and spectrum?
- Where harmonisation of frequency bands is economically desirable, to what extent do national governments need to mandate this approach through international regulations?

39. Both questions can only be answered definitively in specific cases by an empirical examination of the facts. But the review considers that there are generic steps which the UK Government and regulator could take to help ensure that harmonisation proposals deliver economic benefits.

40. First, where proposals are made for harmonisation at the European Community level, the UK should encourage the Commission and Member States to assess carefully the economic costs and benefits of this approach. Proposals should be tested against the European Commission's criteria for harmonisation:

- technical spectrum efficiency: e.g. satellite broadcasting with regional footprints, requiring some degree of co-ordination across the EU;
- single market in services: e.g. to enable international roaming for mobile telephones, it may be necessary to harmonise spectrum and technology; and
- single market in goods: e.g. to support economies of scale, particularly in markets with high R&D costs and potentially high volume manufacture (although this factor on its own should not be over-emphasised, as it could unduly restrict competition).

41. Second, where EU Member States have agreed to harmonise spectrum to a particular service and/or technology standard, the UK should seek to ensure that harmonisation constrains the minimum number of parameters necessary to achieve the policy goals of economic and technical efficiency. Wireless

technology working in specified harmonised bands may have wide applications across a range of services, so European regulations should enable market operators to decide where and how to deploy such technology.

42. Harmonisation should also be time limited. Once it has achieved its goal of enabling manufacturers and operators to deliver a cost-effective service to the European market, other developing services and technologies should be able to contest for access to the spectrum. If, on the other hand, harmonisation fails to stimulate the development of a commercially viable market, or the market has plateaued without requiring the full anticipated spectrum allocation, then the regulatory constraint on use of the spectrum should be freed.

43. Third, where harmonisation is proposed, the technology standards developed for specified bands should be open and led by industry bodies. This should support innovation and competition in technology throughout the harmonisation process, and enhance competition in production of equipment. Governments have an important role to play in this process through the linkages and interfaces between spectrum harmonisation decisions and the associated technology standards. The UK Government stance towards particular harmonisation proposals should be focussed primarily on achieving consumer benefits through competition on price and quality. This would act as a countervailing weight to pressures from industrial players to use harmonisation processes to restrict competition.

44. Finally, any proposals for harmonisation within Europe of licensing procedures should be subject to a clear demonstration of the benefits this will bring to the single European market. Otherwise, the UK should retain autonomy over the manner in which it assigns spectrum to particular users, which will need to take account of the balance of supply and demand for particular frequencies and the state of competition in the relevant markets.

Interference management

45. Interference is unavoidable and ever present. The impact of this ranges from simple inconvenience to individual users to, in the very extreme cases, serious commercial or safety consequences. National regulatory authorities throughout the world have, therefore, regarded it as one of their central duties to ensure both an acceptable interference environment as well as maximising the use of the spectrum.

46. In pursuing the objective of achieving a market-led approach to spectrum management, the review has made a series of recommendations which would devolve to operators considerably more freedom and flexibility over the use of licensed spectrum. But increased rights over spectrum use would need to be balanced by greater responsibility on the part of operators to participate actively in interference management. This would entail shifting the balance of responsibility for interference management, from the regulators further towards industry. Thus, decisions would be taken at the appropriate level – by those operators who are directly affected. The RA should therefore explore

fully the scope for, and means of, transferring more responsibility to operators for interference management, in support of wider moves towards using market mechanisms for spectrum management. There would be a continuing need, though, for the central regulator to monitor interference and take enforcement action against breaches of licence terms and illegal spectrum use.

47. The review considers that a key first step in this process would be the creation of a public on-line database of spectrum assignments. This frequency register should contain a core set of technical and location-based information which would form the basis for operators to carry out the necessary interference co-ordinations associated with any proposed change of use and/or trade within a given band. The RA should also, in conjunction with industry, agree a common understanding of the technical criteria for calculating interference levels.

Legislative framework

Ofcom's remit and objectives

48. The Government announced in the Communications White Paper, December 2000, the creation of Ofcom, as a new statutory, independent and unified regulator for the communications industry. The spectrum management role of the Secretary of State for Trade and Industry, operating through the RA, will become a cornerstone function of the new regulator. This role will sit alongside the other economic and content regulation functions which Ofcom will inherit from the telecoms and broadcast regulators.

49. The creation of Ofcom provides an opportunity for more effective linkages to be made between spectrum management and the other regulatory decisions affecting the provision of telecommunications and broadcasting services. The review takes this as its starting point. But the benefits of unified regulation will only be realised if Ofcom operates under clear statutory objectives, for which it is accountable. This requires the functions and duties of Ofcom, and the division of responsibilities between Ministers and Ofcom, to be spelt out clearly in the legislation.

50. The Communications White Paper proposed that Ofcom's central regulatory objectives should be:

- protecting the interests of consumers in terms of choice, price, quality of service and value for money, in particular through promoting open and competitive markets;
- maintaining high quality of content, a wide range of programming, and plurality of public expression; and
- protecting the interests of citizens by maintaining accepted community standards in content, balancing freedom of speech against the need to protect against potentially offensive or harmful material, and ensuring appropriate protection of fairness and privacy.

It also proposed that in all its activities the regulator give proper weight to, amongst other factors, the promotion of efficiency, including efficient use of spectrum.

51. The review considers that spectrum management is a sufficiently distinct and important activity of Ofcom for it to be defined as a distinct objective of Ofcom. Many of the regulator's spectrum management activities will be directed towards the first of the proposed objectives, delivering consumer benefits, particularly as regards the regulation of spectrum used for telecommunications and broadcasting. In these areas, spectrum management will contribute, along with economic regulation of networks and services and content regulation of broadcasting, to Ofcom's central objectives. However, the concern of spectrum management stretches far wider than consumers of communications services, and this should be recognised and protected via a separate regulatory objective.

52. To date, the RA and Ministers have faced few statutory constraints or guides on their regulation of radio spectrum. The primary legislation[11] gives wide discretion to Government to license wireless apparatus as it sees fit, with a particular emphasis on allowing the rationing of licences 'for the purpose of ensuring the efficient use and management of the electro-magnetic spectrum'. The legislation which introduced market-based tools to spectrum management[12] gives more guidance as to the factors of supply, demand, promotion of technical efficiency and economic benefits which Government shall have particular regard to in applying such tools.

53. Ofcom will inherit these spectrum management functions and the limited constraints applying to them. To help guide Ofcom further in the delivery of this remit, the review considers that the Communications Bill should place an explicit duty on Ofcom to manage spectrum with the objective of maximising the value of benefits derived by UK society from spectrum use. This would focus Ofcom on enhancing the economic efficiency of spectrum use, where economic efficiency is broadly defined to encompass both public and private sector outputs, marketed and non-marketed services to consumers and citizens. This would put the onus on Ofcom to quantify, where feasible, these societal benefits. It would not imply reducing all Ofcom spectrum decisions to monetary cost benefit analyses of competing allocations, as it would also recognise the unquantifiable social benefits derived from spectrum use.

54. In addition to clarifying the objectives of Ofcom with regard to spectrum management, the Communications Bill should also establish clearly the dividing line between Ofcom's independence in spectrum matters and the continuing role for Ministers in giving Ofcom political direction.

[11] Wireless Telegraphy Act 1949.

[12] Wireless Telegraphy Act 1998.

55. Many of the fundamental decisions about the allocation of spectrum across public and private sector uses are best made at the political level. Such decisions affect UK citizens in general as well as consumers of telecommunications and broadcasting services, who are the core constituency of Ofcom. Ministers are better placed than Ofcom to weigh up the competing interests of different sectors to reflect the interests of UK society as a whole. As now, the balance between defence and civil, public and private sector uses should continue to be set by the Government as a whole, operating through and advised by a Cabinet committee of officials, the UK Spectrum Strategy Committee. With the creation of Ofcom, the constitution and resourcing for this central Governmental spectrum policy group should be reviewed to ensure that it remains an effective forum within Government for balancing the competing societal demands on radio spectrum.

56. The review recognises therefore the need for Ministers to retain a strategic power of direction over Ofcom in order to reserve spectrum allocations for identified uses or users to fulfil public policy goals which may fall outside the remit of Ofcom. In practice, this could enable Ministers to protect, for example, civil aviation communications bands on public safety grounds, but not to direct Ofcom to restrict commercial spectrum for a specific service, such as broadband wireless access. The separation of Ofcom from Government would require any directions to be made by secondary legislation under the new Communications Act, providing transparency about the extent to which Ofcom was operating solely towards its statutory objectives or towards a wider Government objective which required a spectrum input.

57. But the review considers that it should not be necessary for Ministers to take further powers to direct Ofcom in the specifics of its spectrum assignment, licensing and charging activities. This could risk undermining the regulatory independence of Ofcom in carrying out its well defined remit, potentially creating uncertainty in the market about the stability and direction of spectrum regulation. It could also undermine the accountability of Ofcom for the delivery of its statutory functions and duties, reducing the incentives on the organisation to perform. As with other spheres of economic activity, the review considers that the Government should aim to bolster the independence of the statutory spectrum regulator and reduce Ministerial involvement in the detail of specific regulatory decisions.

Licensing tools

58. Ofcom will inherit the apparatus licensing tool which is currently deployed by the RA under the WT Act 1949. This has proved to be a robust and flexible means of regulating legitimate access to radio spectrum and taking action against transmissions which infringe these rules. The RA has considerable freedom to specify the terms on which particular frequencies are used, which allows a single licensing regime to be tailored to a vast range of radio applications, from individual amateur radio users right up to national mobile phone operators.

59. Looking forward, there will be growing pressures on Ofcom to provide for greater flexibility in the use of spectrum in response to changing markets. The review's general proposition is that the regulator should foster and enable these developments, rather than stand in their way, and should deploy the necessary regulatory tools to do so. In this context, the review has considered the merits of introducing a new form of licensing, based upon regulating access to spectrum defined by the parameters of frequency, geography and time.

60. Licensing access, rather than apparatus, would lend itself more readily to a regime where greater freedom about the use of spectrum were devolved from the regulator to the licensed user. With the licence defined in terms of neutral parameters, designed to constrain the interference caused outside the area or frequency occupied by the licensee, the regulator (and other spectrum users) could be indifferent to transmissions within these parameters. The parameterisation of spectrum in this way would enable division and amalgamation of originally issued spectrum licences into new access licences, combining frequencies and/or coverage. This changing geometry of spectrum use is one of the anticipated benefits of spectrum trading, to which the Government is already committed.

61. The review's consultation identified strong support for spectrum access licensing, particularly in commercial telecoms bands where operators may wish to reconfigure their use of spectrum and equipment over time in face of changing market pressures. Analysis commissioned by the review[13] suggests that, provided the boundaries of such spectrum access licences are defined not in terms of absolute power limits, but in terms of thresholds which would trigger co-ordination between neighbouring licensees, then service-independent licensing could be introduced. This would be a complement to the current licensing approach. It is envisaged that WT Act licensing would continue where it remains necessary, for interference management or other public policy reasons, to define more closely the equipment and/or service deployed in particular bands.

62. The review therefore recommends that the Communications Bill provide a new power for Ofcom to regulate spectrum use via a complementary form of spectrum access licensing, which could be applied as an alternative to a traditional apparatus licence for certain frequency bands. This new form of licence should grant the licensee some exclusivity and protection from interference for transmission and/or reception of radio signals within specified frequencies and geographical areas.

Market mechanisms for managing spectrum

63. Creating incentives and opportunities for users to make the most economically productive use of radio spectrum is the primary focus of this review. The review's over-arching principle is to expose all spectrum users to the opportunity cost of the spectrum which they occupy. Market-based spectrum

[13] *Implications of international regulation and technical considerations on market mechanisms in spectrum management*, Aegis Systems and Indepen Consulting, 2001.

management tools, in conjunction with greater flexibility for spectrum users, are the primary means to this end.

64. In the vast majority of cases, there are realistic alternatives to the current use of particular frequencies. These alternatives may involve the provision of the same service using more spectrum-efficient technology, or the delivery of a different service using the same or different technology. The transition to alternative uses may only be viable over an extended period, and may involve regulatory action to enable such change. Nevertheless, the existence of these alternatives provides the basis for deriving an opportunity cost of spectrum, based on the full value in the best alternative use to which they could be put.

Financial incentives

65. The review recommends that all classes of users should face financial incentives to economise on the spectrum they occupy. For the majority of frequency bands, where demand exceeds supply, this will entail paying a positive price to obtain access to spectrum. Where trading has been implemented, users will face the opportunity of a positive financial gain from selling access to occupied spectrum.

66. For some spectrum uses, though, the opportunity cost will be zero. This will occur where use of a particular band in the UK has been exclusively defined through international agreements and incumbents have no scope to change their spectrum use. It will also occur in licence-exempt spectrum where interference is so localised that different spectrum users impose no material constraints on each other's transmissions.

67. For other commodity inputs, current market prices generally reflect opportunity costs, because households and firms have the best knowledge of their own costs and preferences and a strong incentive to respond to market signals and put resources to their best possible use. The review's general approach is to advocate the expansion of a fully-fledged market in spectrum, through the use of auctions to make primary assignments of spectrum and the introduction of secondary trading. Where this is not feasible, either because spectrum is reserved for delivery of public services or because the frequency assignments are not suitable for trading, then the review advocates the application of administratively set incentive prices, based upon technical studies to estimate the opportunity cost of spectrum.

68. The introduction of market-based spectrum management tools is designed to help guide spectrum to those who value it highly. But for the UK to benefit from the incentives to innovation and efficiency which auctions, trading and pricing of spectrum are designed to bring, spectrum users need some latitude to respond to market signals. The international allocation process imposes some constraints, as discussed above. But the national regime for assigning licences very often imposes additional constraints which further limit flexibility. These restrictions are typically imposed to achieve other policy objectives which fall outside the remit of spectrum management. They also provide a partial substitute for market-based incentives towards spectrum efficiency.

69. The review therefore recommends, as a general approach, the reduction of restrictions on spectrum use to the greatest extent possible. This stance should be consistent with the UK's international harmonisation and co-ordination obligations, and with the maintenance of an effective interference management framework. As market mechanisms are developed further, this should allow the RA to remove licence restrictions (such as requirements for service rollout) which had been designed to mimic the incentives operating in more competitive markets.

Trading

70. Spectrum trading is the most significant step towards a market-based spectrum management regime. It offers great potential benefits to spectrum users, enabling them to enter the wireless market and develop a service by purchasing access to the spectrum they need, when they need it. This in turn should bring benefits to consumers from innovation, greater choice and competition. It should also ease Ofcom's task, by devolving many complex commercial judgements to the market to resolve, and opening up telecommunications and broadcasting networks to greater competition.

71. The review strongly advocates the earliest and widest application of spectrum trading possible. Once the necessary liberalising European legislation[14] has been passed, and implemented in the UK, Ofcom should move purposefully and progressively towards converting those licences currently used for fully commercial purposes to tradable form.

72. For trading to bring consumer benefits, then firms must have some freedoms to combine spectrum with other inputs in innovative ways. Ofcom will therefore need to move further than the RA has in defining a generic set of rights and responsibilities for the holder of a spectrum licence. Boundaries of licences will, as ever, need to be carefully defined to help manage interference. But within such boundaries, and subject to any international harmonisation constraints, licensees should be as free as possible to determine the wireless service they provide and the technology they choose to deploy.

73. Trading should be introduced in a way which minimises transactions costs, consistent with maintaining the integrity of the spectrum management regime. This will entail giving licensees the freedom to divide and partition their licences by frequency and geography for subsequent sale. In these cases, rights and regulatory responsibilities for interference management would be sold together. Spectrum users should also be able to lease access to frequencies to others. In these cases, the original licensee would share access to frequencies while retaining responsibility to the regulator for the conduct of the licence.

74. As with other markets, trading of spectrum could potentially enable one or more operators to gain and abuse dominance in the spectrum market or in a 'downstream' market, which uses spectrum as an input. Government needs

[14] The proposed Framework Directive (COM/2000/0393) for the regulation of electronic communications.

to be vigilant against such an outcome, but should deploy the same competition policy tools in spectrum trading as it does for other input markets.

75. The review recommends that the general competition regime, relying on an *ex post* analysis of the impact of spectrum trading on competition in defined markets, should be the primary safeguard. Where spectrum is an input into a market which is subject to sector-specific regulation, then the objectives of this regulatory regime may be furthered by a more interventionist approach towards spectrum trading, such as *ex ante* approval of specific trades. These arrangements should be consistent with the UK's obligations, under the EU Framework Directive, to ensure that competition is not distorted as a result of spectrum trading.

76. The role of Ofcom in this regime will be to define the initial bundle of rights and interference co-ordination requirements attached to each licence, assign this licence via auction, and then ensure compliance with these requirements, and management of the system as a whole, as the licence trades through the market. In all cases, Ofcom will need to monitor and register trades. Provided Ofcom publishes a comprehensive register of frequency assignments, enabling the market to identify changes in licensee, further reporting requirements, such as publication of transaction prices, may be unnecessary. Evidence from spectrum trading elsewhere suggests that specialist brokers can rapidly fill any information gaps.

77. To reap the benefits of trading, Ofcom should extend this opportunity to as wide a range of licences as possible, and not restrict trading to those which have been assigned initially by auction. This will entail defining more clearly the property rights of non-auctioned licences, which are renewable on an annual basis but provide significantly longer *de facto* tenure. The review recommends that Ofcom consider, band by band, how best to provide some certainty for licensees to engage in trading and some ability for Ofcom to retrieve spectrum where necessary for any future strategic replanning of frequency bands. Options include converting the terms of licences to a rolling five to ten year period, or to perpetual licences with a compulsory purchase provision for Ofcom.

78. Once spectrum trading is enabled, then licensees will face a market-determined opportunity cost of their spectrum use. They will also benefit from 'planning gain' through acquiring a more flexible, tradable licence. There is no reliable means to calculate this benefit and any *ex ante* charge for it could deter trading. So the review considers that trading rights should be granted free rather than sold.

79. Although not directly related to spectrum management, the Government may have wider concerns about windfall gains, particularly in the early years of spectrum trading, where trading rights are granted to licensees which had not purchased their spectrum via auction. One way of addressing these might be to levy a trading duty based on a proportion of the net gain from a particular spectrum trade. This, however, could involve Ofcom in complex

assessments of individual transactions, and may distort the market towards modes of leasing rather than outright trades. A less direct but simpler approach could be to maintain administratively set annual spectrum charges until licences are re-assigned via auction. As administratively set and market prices converge, this should in itself reduce the scope for windfall gains.

Auctions

80. Auctions were first used for the assignment of spectrum licences in the UK in 2000 with the high profile sale for £22.5bn of five licences to use spectrum for Third Generation mobile telephones. They have been used extensively during the 1990s in a number of other countries (notably the USA), for the competitive assignment of commercial wireless licences. Auctions have also been deployed in the UK and elsewhere for the assignment of other scarce resources rationed by regulation (such as commercial broadcasting franchises and mineral extraction rights). The advantages of auctions over comparative selection by regulators are well documented and have been recently validated by the National Audit Office's report on the 3G auction.

81. The review strongly supports the use of auctions to assign spectrum licences to competing users. This should become the default means of assigning licences to exclusive frequency bands. The specific design of individual auctions should be decided on a case by case basis, taking account of competition, marketing and technical analysis.

82. Where licensees are granted tailored access to shared spectrum which is managed by the RA, such as in fixed links and certain private mobile radio bands, the RA should move progressively to converting the spectrum to auctionable form. Regional or national licences for whole bands with exclusive management rights to the relevant frequencies could then be auctioned. This would enable commercial operators to add value by combining market-driven spectrum management with other aspects of communications services.

83. The review rejects claims by opponents of auctions that the competitive bidding process will inevitably lead to a number of negative effects, including the raising of prices to consumers and the delay of deployment of services. The review endorses the NAO assessment of the 3G auction, that there is no strong evidence that consumer benefit would be reduced through higher prices or slower access to services. Rather, the review considers that its proposed combination of auctions, together with secondary trading of licences and fewer restrictions on usage, should bring benefits to companies, which will have more information and choice about spectrum supply than they do at present. Entry barriers would come down and, with a more liquid market in spectrum, the impact of any one particular auction on an operator's business plans should be less critical.

Pricing

84. The RA has been in the vanguard of national regulators in applying pricing to the use of spectrum, with the aim of incentivising more efficient use over time. The review considers that this is a valuable complement to the direct market incentives for those licences which have not been assigned by auction, because they have either been reserved for the delivery of public services or assigned under the traditional 'first come, first served' basis. Given that there will continue to be large swathes of spectrum reserved for public services, the review considers that spectrum pricing would need to be maintained for the foreseeable future. As spectrum trading develops over the coming decade, Ofcom should also incorporate price information from marginal transactions in competitive markets into its own administrative pricing policies.

85. Administratively set spectrum prices are currently based upon technical assessments of the least cost practicable options for enhancing spectrum efficiency. Prices also vary according to factors such as bandwidth, coverage, degree of sharing, and geographical location. The review agrees with the fundamentals of this approach to deriving spectrum prices.

86. But the review has concerns that the price levels are currently too low in areas of high spectrum demand to create the incentives towards efficiency. When the Government originally proposed the introduction of spectrum pricing in 1996[15], it decided that only half the amount of the increases suggested by the preparatory technical study should be implemented. Spectrum prices have now plateaued at this 50 per cent level. The review recommends that, following a re-evaluation of the technical parameters incorporated in the pricing model, the RA should move to full implementation of the prices thus derived. Abstracting from any changes in technology and costs since the original pricing study was undertaken, this move would lead to a near doubling of prices in the sectors and areas of high demand which are currently subject to spectrum pricing.

Commercial spectrum use

87. The review has considered the application of market-based mechanisms to a range of commercial spectrum uses. Spectrum is not homogenous, and the propagation of signals varies considerably across the frequency range. This has direct implications for the interference management regime, including the degrees of freedom which can be granted to spectrum users. The markets for wireless services are also widely differing, with consequences for the competition regime applying to the auction and trading of spectrum licences. The review has therefore made specific recommendations sector by sector. Although broadcasting use of spectrum is increasingly commercial, it is considered separately, given the extensive regulation of free-to-air and public service broadcasting which affects spectrum management.

[15] *Spectrum Management: into the 21st Century*, DTI White Paper, June 1996.

Public mobile telecoms

88. The auction in early 2000 of five licences for Third Generation mobile telecommunications services has set the framework for the future of mobile telephony in the UK. In the meantime, four operators continue to exploit the spectrum licences for Second Generation mobile services, which had been assigned through comparative selection and are which are now subject to spectrum pricing. The majority of spectrum for public mobile telephony is subject to European Union or CEPT decisions harmonising the use of particular frequencies to specific technologies.

89. The review recommends that spectrum trading be introduced as soon as practicable for all public mobile telecoms spectrum. Trading could bring significant benefits, in allowing operators to tailor their spectrum licences to their own needs and enabling new entrants to obtain spectrum for innovative services using compatible technology. Change of use within these bands would initially be constrained somewhat by the European harmonisation decisions. The review recommends that the UK push for the early retirement of the GSM harmonisation directive, which has now served its purpose, to enable operators more flexibility in the range of technologies and services they deploy. Other harmonisation decisions, which have outlived their usefulness (such as the ERMES public paging directive), should also be retired.

90. New licences for commercial services should be assigned by auction, with trading rights and maximum flexibility attached to spectrum use. In the medium term, such auctions may include new licences for spectrum identified for the expansion of 3G mobile, consistent with the Government's regulatory commitments given in the context of the 3G auction. Where licences had previously been assigned by comparative selection and are now subject to spectrum pricing, they should be converted to tradeable form, with greater flexibility on spectrum use. If the Government is concerned about windfall gains accruing to licensees, then Ofcom could levy a duty on a proportion of the net gains from spectrum trades, or continue to impose spectrum prices.

Licence-exempt spectrum use

91. Many users of spectrum are exempt from individual licensing. In the case of user terminals (such as mobile telephones or televisions), this is because spectrum use is controlled by the licence granted to the system operator. The other broad category of licence-exempt spectrum uses are those where the propagation of radio signals (defined by the permitted power levels and technology standards for the band) is so localised that they do not materially interfere with other spectrum users. In other words, the costs of regulating via licensing outweigh the potential benefits. These uses are typically confined to bands which are dedicated to licence-exempt use, often those which had originally been designated for industrial, scientific and medical uses.

92. Use of licence-exempt spectrum is on a 'non-interference, non-protected basis'. Users of such deregulated spectrum must not cause interference to other authorised spectrum users, nor can they claim protection from

interference from such services. With short-range propagation and few devices in any given location, the risk of interference caused by such low power licence-exempt spectrum use has historically been relatively low. At the same time, the absence of regulations covering receivers' standards has meant that in some cases equipment can be very vulnerable to interference from other services. Technology now offers the prospect of increasing the intensity of spectrum use in these unregulated bands through the use of systems which are automatically self-protecting and 'polite'. These avoid interference coming into the band and minimise transmitting over other signals within the band.

93. Licence-exempt spectrum provides an alternative paradigm to regulating for economically efficient spectrum use. Instead of minimising harmful interference through exclusive access to spectrum, the regulator enables multiple re-use of the same spectrum space by limiting the geographical coverage of transmissions. This provides significant flexibility for users, which in turn creates demand for innovative applications of radio technology within these bands. Technology developments are increasingly enabling more valuable broadband applications to be delivered across licence-exempt spectrum.

94. The review recognises the significant consumer benefits which this highly innovative and increasingly ubiquitous use of spectrum can bring. The potential drawbacks of this regulatory approach are that the quality of transmissions cannot be guaranteed, and the utility of the spectrum may ultimately be degraded through excessive use. The review considers, though, that a combination of market forces and regulation is capable of resolving these challenges:

- Users will decide between licence-exempt and licensed spectrum use, depending on the quality of service they require.
- Interference from local congestion is often internal to a user's premises and can therefore be regulated by that user.
- Ultimately, if particular bands show signs of becoming congested, then manufacturers can improve the resilience of radio equipment to interference and regulators can restrict the propagation of signals through power limits.

95. The review therefore considers that further liberalisation of use of licence-exempt bands, by opening up such spectrum to a range of technologies and services, is likely to deliver significant consumer benefits. In particular, the review recommends that the current constraint on the use of licence-exempt bands for the provision of public access communications services (as opposed to private use) be removed.

Private mobile radio

96. Private mobile radio is a complex licence sector, with over 55,000 licensees across the UK including a large number of emergency service and other public safety operators. The RA currently issues a wide variety of licences tailored to

the spectrum use defined under the licence. Frequency planning is primarily managed by the RA, to enable a large number of localised users to share a single national channel. Demand for spectrum in this sector is rationed by the RA, through the application of spectrum prices and the careful assignment of licences. For some bands, spectrum management is devolved to organisations catering for the radio needs of defined groups (such as the utilities).

97. This central planning approach in a changing market environment inevitably gives rise to inefficiencies and rigidities, with the result that spectrum may be trapped in inefficient uses, exacerbating perceived shortages. The review recommends a much greater role for the market in future in helping manage access to spectrum currently reserved for private mobile radio.

98. As a first step towards allowing the market to determine spectrum use, the review recommends that restrictions in licences unrelated to interference management are removed and licences be converted to tradeable form. With the publication of a frequency assignment database, these steps should enable a market to develop in spectrum currently allocated to private mobile radio.

99. In the longer term, the review recommends that a significant amount of the RA's current frequency planning role be devolved to commercial spectrum management organisations. Evidence of increased intensity and flexibility of spectrum use in bands managed by such organisations suggests that there could be significant economic gains from extending this approach. The review recommends that Ofcom assign via auction a number of competing national band managers for a range of private mobile radio bands, in parallel with Ofcom's continued management of the rest of the private mobile radio spectrum. Incumbent licensees within such bands would retain their existing rights to spectrum use, and would become lessees of the commercial band manager. If successful in enabling innovative and intensive use of congested frequencies, this approach could ultimately be extended across the majority of private mobile radio spectrum.

Fixed terrestrial services

100. The RA currently makes individual assignments for fixed terrestrial point-to-point links, and for uplink transmissions by fixed satellite earth stations within the same bands. It also assigns exclusive geographical area licences for fixed wireless access, such as the recent and ongoing auction for regional 28 GHz licences for broadband services.

101. For those fixed links bands which remain under RA/Ofcom management, the review recommends the continued application of spectrum pricing, on a technology-neutral basis and at the full opportunity cost level. Trading of individual fixed links should also be introduced, to enable operators to reconfigure their networks.

102. To enable commercial operators to make best economic use of the spectrum, the review recommends that fixed wireless access operators should also be

able to deploy fixed links within the geographic and frequency bounds of their licence. This could be for their own use, or they could lease spectrum access to third parties (once spectrum trading has been introduced). Interference management within and at the boundaries of the licence would remain the responsibility of the licensee, subject to co-ordination requirements embedded within the licence.

103. This would remove the exclusive reservation of certain bands for the rollout of broadband wireless access. The review judges that providing operators with extra flexibility in use and trading of the spectrum should enable the deployment of a range complementary broadband access and other fixed wireless technologies. This approach would enable operators to respond directly to the changing market demands for broadband and other telecommunications services.

104. The review recommends that a number of fixed links bands should, over time, be converted from RA management into area licences for firms to use, trade or lease access as they see fit (within the technical parameters of the licence). Commercial operators would have greater scope, information and incentives than any regulator to make intensive economic use of the spectrum. With the introduction of spectrum trading, the licence holder would have the regulatory freedom and commercial incentives to deploy a variety of fixed wireless infrastructure links or broadband access systems, or to trade or lease access to others to do so. This approach has been successfully adopted in US with the auction of spectrum at 39 GHz for microwave services and at 4.7 GHz for so called General Wireless Communications Services. This could best be trialled in the UK by auctioning a number of national licences in spectrum which has yet to be exploited (such as at 32 GHz).

Satellite services

105. Access to spectrum for transmissions to and from satellites is subject to extensive international planning and co-ordination. There may therefore be limited opportunity to improve on the use of spectrum within the UK by satellite systems through the use of market-based spectrum management tools. In particular, given that satellite frequencies are tied to specific satellite systems, often for the delivery of international services, then it is unlikely that trading of such frequencies within the UK's jurisdiction would be feasible. There should, however, be scope to clarify the spectrum access rights and responsibilities of satellite systems for their operation in the UK, and to ensure that they face the opportunity cost of the UK spectrum which they occupy.

106. The RA currently licenses uplink transmissions from UK-based equipment. Traditionally this has been limited to a relatively small number of permanent earth stations. There is now increasing demand for spectrum for mobile transmitters (so called satellite interactive and user terminals). Where fixed satellite uplinks share the same RA-managed bands as terrestrial services, their presence constrains the deployment of these services. The review therefore supports the application of full opportunity cost pricing for these transmissions.

107. Where satellite downlinks operate in their own exclusive bands, there is no spectrum scarcity. The same frequencies can be reused by many satellites in different orbital slots. As such, there is no need or basis for the UK regulator to apply spectrum pricing.

108. Mobile and interactive satellite terminals present a greater spectrum management challenge in sharing bands with terrestrial systems. To date, the RA has restricted, through regulatory means, deployment of fixed links in some bands to protect reception in the UK of satellite signals. The review recommends that Ofcom use new powers to license spectrum access, regardless of the location of the transmitting equipment, to provide greater clarity for operators of satellite systems as to the spectrum they can use for reception in the UK. This would help define the interference protection afforded to satellite and terrestrial systems respectively operating in the same bands. It could be applied to both space to earth and earth to space segments of a satellite system. To the extent that satellite systems constrain the deployment of fixed terrestrial systems, such as communication links and wireless access, operating in the same bands, then Ofcom should impose a spectrum price on satellite system spectrum use, based on the opportunity cost of the spectrum in alternative terrestrial use.

Public services

109. Public services consume significant swathes of valuable spectrum for the delivery of primarily non-marketed outputs. For example, terrestrial TV broadcasting occupies 40 per cent of the spectrum below 1 GHz, while defence users are allocated nearly 50 per cent of bands in the range 3-10 GHz as well as extensive frequencies elsewhere. It is vital for the productivity of the economy as a whole that such public services face strong and enduring incentives to economise on the spectrum needed to deliver their public service outputs. Without such incentives, there is a growing risk that spectrum hoarding by the public sector will constrain the growth of private enterprise.

110. The review recognises that there will remain a number of public services for which spectrum is a vital input and for which, in the absence of a fully fledged spectrum market, the current regime of reserving sufficient frequency bands for the delivery of these services should continue through the medium term. In the longer term, as spectrum trading develops, the Government should look to expose more public services' spectrum use to this market mechanism. In the interim, therefore, the primary means of encouraging spectrum efficiency should be administratively set spectrum pricing, based on the opportunity cost of spectrum occupied. The review recommends that all public services should be subject to this regime, which should provide durable incentives where necessary to economise on spectrum consumption. As noted above, though, for some spectrum, the opportunity cost may be zero as a result of international agreement on the use of the band which gives the UK negligible scope to make alternative use of the spectrum.

111. The executive summary highlights the application of this approach for a number of major public service spectrum users: defence, broadcasting, and

aeronautical and maritime. The review's report also assesses and makes recommendations covering spectrum use for public safety and science services.

Defence

112. The Ministry of Defence occupies a privileged position as the largest single user of radio spectrum in the UK. It has *de facto* management rights over its bands, and with the RA co-chairs the cross-Government UK Spectrum Strategy Committee which decides on national allocation policy. Historically, the MOD has released a number of valuable bands for civil use (for example, the spectrum used for First Generation mobile telephony). More recently, since 1999 MOD has also faced spectrum prices for those bands which it manages where the comparable civil users are charged. It currently pays some £23m per year for the majority of its mobile radio and fixed links bands.

113. The review welcomes the application of financial incentives to MOD's spectrum use. This is starting to affect decision-making about rationalising defence needs and release of spectrum for civil use. But major improvements in spectrum utilisation will only be realised through consistent impact of spectrum pricing on long term decisions about equipment design, procurement and deployment. It should also be recognised that with military requirements for real-time information in 'battlespace' and training situations rising, then the MOD's internal demand for spectrum, even when priced, will often contend with commercial pressures on the spectrum.

114. The review recommends that the financial incentives on MOD's spectrum use should be strengthened and widened. Following the recommended revalidation of the opportunity cost calculation of spectrum prices, those mobile and fixed links bands which are currently subject to pricing should be charged at the full opportunity cost level. In addition, MOD's use of spectrum for ground-based radar in the UK should also be subject to spectrum pricing, in line with the review's recommendations for the civil aeronautical and maritime sectors.

115. This recommendation could see MOD's annual spectrum charge rise to over £100m (depending crucially on the basis for charging for radar spectrum use). Although this would still be less than one half of one per cent of MOD's total annual budget, the review recommends that the Treasury take account of the proposed additional charge on MOD's programme expenditure in future public spending reviews. It also recommends that the Treasury enable the MOD to respond more flexibly to financial pressure on spectrum use. MOD should have the scope to propose the acceleration of equipment expenditure, within agreed long term totals, where this 'spend to save' can be demonstrated to lead to faster release of spectrum for civil use.

116. Where bands are retained for military use but are not fully utilised, MOD should also face positive financial incentives to sharing access to their spectrum with commercial users. Within an agreed public spending framework, and consistent with the Wider Markets Initiative to encourage

departments to enable commercial use of public assets, MOD should retain revenues from leasing access to spectrum.

117. To encourage more informed assessment within Government and in the wider economy about current and future military spectrum demands, and the scope for spectrum release and/or sharing, the review recommends greater information disclosure by MOD. The review welcomes steps in this direction, such as the publication of the military spectrum strategy. Subject to the protection of national security interests, the review recommends that MOD release more detailed information to RA/Ofcom about its prospective spectrum utilisation, and that it makes sufficient information available to commercial operators to enable them to assess the scope for spectrum sharing in MOD bands.

Broadcasting

118. The review agrees with the Government's commitment in the Communications White Paper[16] that broadcasters, like other major users of spectrum, must use spectrum efficiently, and there should be effective mechanisms to ensure this. Regulation will continue to play a major role in planning the terrestrial transmission of broadcasting services, given the continuing policy interest in the delivery of public service broadcasting objectives (concerning positive content obligations, free-to-air services, and universal service coverage). But the review is concerned that, in the absence of spectrum pricing across the broadcasting sector, major decisions affecting economically significant spectrum would not properly reflect the opportunity cost of the spectrum asset denied to other users. This is particularly relevant in the approach to digital switchover, which presents a strategic opportunity to improve significantly the spectrum efficiency of broadcasting, and release valuable resources to the rest of the economy.

119. The Government's key strategic broadcasting goal is that public service broadcasts should be available to everyone, as now, free at the point of consumption. As alternative delivery platforms (cable and satellite) become more popular, the need for reserved and restricted spectrum for one particular platform (terrestrial transmission) becomes less of a fundamental input for the delivery of public service or commercial broadcasting. Conversely, the convergence of communications services and technologies increases the demand for spectrum which can be used flexibly to deliver a range of wireless broadcast, voice and data services in fixed and mobile environments. So restrictions imposed on spectrum for broadcasting policy reasons become less necessary just as they become more costly in terms of opportunities foregone.

120. In order to ensure such restrictions are no more onerous than is necessary, the review believes the Government should be fully aware of the economic costs, alongside the benefits, of its broadcasting policy as far as it affects the use and availability of spectrum. In the interests of full transparency, the size of these costs should be in the public domain.

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[16] *A New Future for Communications*, DTI/DCMS White Paper, December 2000.

121. In the longer term, the review considers that Government could, and should, aim to separate the delivery of its broadcasting goals from the management of the spectrum inputs to broadcasting. This would entail a less restrictive and exclusive approach to licensing spectrum, with greater application of market incentives on the use to which broadcast spectrum is put. Broadcasting regulation could continue to define positive content requirements, but may over time become more flexible as to delivery platforms.

122. Achieving this structure could take over a decade. It will depend crucially on how the markets for cable, terrestrial and satellite broadcasting evolve over time. It may also require major changes in the way terrestrial TV spectrum is allocated and co-ordinated at an international level. The review's recommendations therefore focus on a number of medium term measures which could be taken, consistent with this long-term goal.

123. Focusing on terrestrial TV transmissions, the review recognises the current particular circumstances of broadcasting, including the substantial payments already made under the Broadcasting Acts by commercial broadcasters, the level of public service obligations undertaken by the broadcasters, and the forthcoming switchover to digital broadcasting. The review's recommendations are designed to take account of the various regulatory agreements between Government, broadcasting regulators and individual broadcasters. They also recognise the particular circumstances of public sector broadcasters (the BBC and Channel 4), and those of private sector and investor-owned broadcasters. They are also aimed at supporting the Government's objective of achieving digital switchover in the coming decade.

124. The review recommends that spectrum pricing should be applied over the coming decade to all spectrum which is used for broadcasting. The level of prices would be determined by the RA/Ofcom using the methodology outlined by the RA's original spectrum pricing study[17] and would be based on the opportunity cost of spectrum use. Broadcasters should have greater flexibility over the type of transmissions made over spectrum licensed to them, and greater scope to lease spectrum to other users where it is not fully utilised for broadcasting services. Ofcom should also have greater oversight of the BBC's spectrum use. The implementation and timing of this approach will vary according to the regulatory regime affecting each broadcaster, recognising that some broadcasters, including Channel 3 licensees and Channel 5, have acquired the use of spectrum through a competitive financial bidding process.

125. Both the BBC and Channel Four have argued strenuously that the universal coverage requirements imposed by the Government mean that they have no discretion on the amount of spectrum which they use; as a consequence, there would be no efficiency gains from imposing a spectrum charge on them. The review has considered this argument carefully, but considers that spectrum charges on these broadcasters are justified. The review believes that,

[17] *Study into the Use of Spectrum Pricing*, by NERA and Smith System Engineering Ltd, published by the Radiocommunications Agency, June 1996.

notwithstanding current constraints, spectrum pricing can play a role in encouraging more efficient spectrum use by public sector broadcasters. For example, with digital switchover in prospect, the broadcasters can take action which helps create the conditions for switchover. The Government's Digital Television Action Plan highlights a range of spectrum planning and market preparation activities for the broadcasters to help achieve this overall goal. Also, the review recognises that most users of spectrum for public services are constrained to some extent by a combination of their past investment decisions and their obligation to provide services. In the longer term, it is likely that these constraints will either be relaxed or changed. In order to gain efficiency benefits, it is essential that decisions begin to be taken now on the expectation of future spectrum charges.

126. The review believes that the timing of any pricing regime should take into account the Government's current agreements with the BBC and Channel 4 with regards to financing and delivery of public service broadcasting. Channel Four has such a regulatory contract through a Broadcasting Act licence which expires at the beginning of 2003, whereas the BBC's current Charter and Agreement run until 2006. Spectrum pricing should not be applied before the renewal of these respective regulatory agreements, at the earliest. Spectrum pricing should also take into account the Government's wider commitment to promote and support the take-up of digital TV, for example through some abatement of spectrum prices for digital transmissions.

127. The review considers that commercial independent analogue TV licensees have already paid for their analogue spectrum via their initial bids and ongoing franchise fees for Broadcasting Act licences which allow them to use terrestrial TV spectrum. When these licences are renewed, the review recommends that Ofcom levy a separate administratively set price for the broadcasters' analogue TV spectrum. This would be separate from the mechanism used by Ofcom to assign and charge for broadcasting rights – although the existence of a spectrum charge would clearly influence the value of those rights. In the meantime, Channel 3 licensees will continue to benefit from the so-called 'digital dividend' which provides a partial incentive towards spectrum efficiency by reducing the franchise fees paid in line with the rise in digital take-up.

128. Digital terrestrial TV (DTT) is currently provided through six multiplexes. Each multiplex occupies the frequency of a single analogue channel but can deliver at least six broadcast services. The BBC multiplex operates under its Charter and Agreement, while the five other multiplexes operate under Broadcasting Act licences awarded in 1997 or 1998, for 12 years, with an option to renew for a further 12 years. At the time of the award, the Government committed to a zero-rated levy on the revenues from the commercial multiplexes up to their renewal point, in order to stimulate the development of digital terrestrial TV.

129. The review recognises the benefit of this approach towards DTT in the early years of its development, as a pragmatic means of encouraging investment which could lead to substantial spectrum efficiencies to the benefit of the whole economy. But in the longer term, the review considers that users of spectrum for DTT should face ongoing financial incentives to spectrum efficiency. The review therefore recommends that for the non-BBC DTT multiplexes, Ofcom should levy a spectrum price from the renewal of such licences, scheduled for 2009 or 2010. This cost should be taken into account in setting broadcasting licence fees.

130. This timing is consistent with the plans for digital switchover. Commitment now to future pricing should help broadcasters and their transmission operators to respond in an informed manner to the Government's current consultation on the principles for DTT spectrum planning. In this context, the review recommends that the Government undertake a full cost-benefit analysis of the options for spectrum currently used for analogue TV transmissions. This analysis would take into account estimates of consumer and producer benefits from broadcasting and from alternative uses of the spectrum released by switchover. Subject to this, and in line with the review's general approach towards flexibility in spectrum use, the review also recommends that Government should seek to maximise the amount of spectrum available for re-use following switchover. As a corollary, it should, subject to an assessment of economic and social costs, minimise the spectrum reserved for the delivery of defined public service broadcasting outputs.

131. Spectrum pricing should also be applied to radio broadcasting in order to increase spectrum efficiency. The BBC's digital radio multiplex could thus have a charge, based on the opportunity cost of spectrum use, applied from 2006 onwards. Payment of an opportunity cost price for spectrum should also become a pre-condition for renewal of commercial analogue radio and digital radio multiplex licences. New licensees would also be charged an explicit fee for the opportunity cost of the spectrum used. In areas where demand for spectrum was low in relation to supply, the opportunity cost would be commensurately low.

132. In addition to the major step of digital switchover, there is scope to improve the utilisation of broadcasting spectrum at the margin by providing broadcasters greater freedom to carry a wider range of non-broadcasting services. On both analogue and digital transmissions, there is technically room to transmit data (using broadcast technology standards and within the constraints of international co-ordination). The review recommends that the regulatory and financial constraints on such developments be reduced. The current limits on non-broadcast services carried by digital TV and radio multiplexes should be removed, subject to the condition that licensees continue to meet any public service broadcasting obligations. The review also recommends that the Government clarify the BBC's ability, under its Charter, to develop revenue-generating non-broadcast services for transmission on its spectrum, again subject to fulfilment of its primary public service mission.

133. This package of measures will ensure that all broadcasters face financial incentives and opportunities to economise, over time, on spectrum, notably by moving to more efficient transmission technologies. At the same time, it starts to widen the use to which spectrum allocated to broadcasting can be used, enabling market development of digital information services. It should also enable the gradual separation of broadcasting policy objectives from spectrum management, which should bring wider economic benefits while protecting the economic and social benefits of public service broadcasting.

Aeronautical and maritime

134. The Civil Aviation Authority and the Maritime and Coastguard Agency make extensive use of spectrum reserved for radiolocation, navigation and communications for vessels within UK territory. Marine and aeronautical radars, for example, occupy some 30 per cent of the spectrum in the range 1-3 GHz. Given the global mobility of on-board communications and radar equipment, much spectrum use and associated technology standards in these sectors are subject to extensive and detailed international harmonisation.

135. The review has explored the scope, within these constraints, of incentivising greater spectrum efficiency within the UK through the application of market-mechanisms. It concludes that the application of administratively set spectrum prices would assist in delivering the best utilisation of spectrum reserved for aeronautical and maritime uses. Auctions and secondary trading are unlikely to be feasible in these sectors.

136. In particular, pricing should apply to the use of spectrum by UK ground-based radars, where UK operators subject to pricing have some discretion, over time, to optimise their portfolio of radars and other location devices, in light of the cost of equipment and spectrum. The review recommends that, in light of the current study for RA of the UK's civil radar deployment and the technical scope for reducing spectrum consumption, the RA develop a pricing regime, in conjunction with CAA and MCA, for the spectrum used by UK-based radionavigation and radiolocation equipment. In the aeronautical sector, the spectrum charge (which is unlikely to be significant relative to total aviation costs) would be borne initially by NATS and major airport operators, such as BAA. This may necessitate a phased introduction of spectrum pricing around the middle of the decade, aligned with the CAA's periodic reviews of regulation on BAA and NATS.

137. For spectrum reserved for on-board navigation and communications systems, the review considers that the opportunity cost to individual users is, in most cases, effectively zero, since use of this spectrum is mandated internationally, and users are required to adopt specific technologies. The review recommends, though, that where UK-based users face some technology choice for their on-board systems, that the CAA and MCA consider applying differential licence fees to encourage moves to narrower band, more spectrally efficient equipment, thus easing congestion over time.

Implementation

138. Reforming the practice of spectrum management based on the principles and recommendations set out by the review will be a long term endeavour, requiring concerted action on a number of fronts. The review's proposals entail a major programme of regulatory reform over the coming decade. Many recommendations build on actions which are already in train by the RA, but which would require a change of emphasis and priority from the Agency. Others would fall within the remit of Ofcom, operating with wider powers and scope, or would be orchestrated by Ofcom in conjunction with other public sector spectrum users. A further set of proposals would require shifts in policy and practice by other Government departments involved in spectrum management.

139. The review has therefore mapped out a potential timetable of steps to be taken by Government and Ofcom over the next decade, to provide an indication of timing of the reforms proposed. The most important new reform, which should be given priority in forthcoming European and national communications legislation and in regulatory effort by RA/Ofcom, is the introduction of spectrum trading. This should be augmented by the application of stronger financial incentives on major public service users to economise on spectrum use. The review anticipates that the combination of these actions should lead to significantly greater innovation and productivity in spectrum use by the latter half of this decade.

140. As the Ofcom Regulators' Steering Group has already identified[18], in the long run the move to spectrum trading would lead to a reduction in work associated with designing, pricing and monitoring some spectrum licences. Some new work, particularly the introduction of spectrum trading, is likely to lead to an increase in activity in the short to medium term. The implementation of the review's recommended approach to spectrum management would amplify these conclusions.

141. It is difficult at this stage to judge the consequences of the long-term decline in work for the regulator in terms of the reduction in staff employed on spectrum management policy and implementation. Net reductions in staffing might be achieved during the second half of this decade, after the licensing of 3G expansion bands, the realignment of private mobile radio bands, progress towards digital TV switchover, and early experience of spectrum trading.

[18] *OFCOM SCOPING PROJECT*, Towers Perrin report to Regulators' Steering Group, October 2001.

RECOMMENDATIONS

International regulatory framework

4.1 The Government should, wherever technically and operationally feasible, facilitate greater flexibility in the use of a given frequency band. This can be achieved by a broader interpretation of the internationally agreed radio communications service definitions, or by adding additional services to a given frequency band through negotiations at ITU and CEPT level.

4.2 Where proposals are made for harmonisation at the European Community level, the UK should encourage the Commission and Member States to assess carefully the economic costs and benefits of this approach. Proposals should be tested against the European Commission's technical and single market criteria for harmonisation.

4.3 Where the UK agrees with a collective European decision to harmonise spectrum to a particular service and/or technology standard, it should seek to ensure that harmonisation constrains the minimum number of parameters necessary to achieve the policy goals of economic and technical efficiency. In the medium term, this implies moving towards harmonisation of broad service categories (e.g. mobile, fixed, etc) within defined bands, rather than specific technology descriptions (such as DECT, UMTS etc). This should provide the future spectrum certainty necessary for large-scale research and development investments, while allowing scope for technology competition and innovation.

4.4 Harmonisation should be time limited and subject to periodic review. Once it has achieved its goal of enabling manufacturers and operators to deliver a cost-effective service to the European market, other developing services and technologies should be able to contest for access to the spectrum. If, on the other hand, harmonisation fails to stimulate the development of a commercially viable market, or the market has plateaued without requiring the full anticipated spectrum allocation, then the regulatory constraint on use of the spectrum should be freed.

4.5 Where harmonisation is proposed, the technology standards developed for specified bands should be open and led by industry bodies. This should support innovation and competition in technology throughout the harmonisation process, and enhance competition in production of equipment.

4.6 Any proposals for harmonisation within Europe of licensing procedures should be subject to a clear demonstration of the benefits this would bring to the single European market. Otherwise, the UK should retain autonomy over the manner in which it assigns spectrum to particular users, which will need to take account of the balance of supply and demand for particular frequencies and the state of competition in the relevant markets.

Interference management

5.1 The RA should explore fully the scope for, and means of, transferring more responsibility to operators for interference management, in support of wider moves towards using market mechanisms for spectrum management.

5.2 The RA should seek to implement an on-line frequency register covering all the civil radiocommunications bands and the radio systems utilising them. The frequency register should contain a core set of technical and location-based information which would form the basis for operators to carry out the necessary interference co-ordinations associated with any proposed change of use and/or trade within a given band. The RA should also, in conjunction with industry, agree a common understanding of the technical criteria for calculating interference levels.

Legislative framework

6.1 Ofcom should operate under a distinct spectrum management duty, which should provide an ongoing requirement on the regulator to maximise the value of benefits derived by UK society from spectrum use. One potential formulation for such a duty would be: 'to maximise, by ensuring the efficient allocation and use of the spectrum, the overall value derived by society from using the radiofrequency spectrum'.

6.2 With the transfer of spectrum management functions from the RA to Ofcom, the constitution and resourcing of the Cabinet Office UK Spectrum Strategy Committee should be reviewed to ensure that it can continue to balance the competing requirements of civil and military, public and private sector spectrum users.

6.3 The Government should limit its powers to intervene in the details of spectrum licensing. Ministers should retain powers to intervene with Ofcom over the distribution of radio spectrum, in order to make essentially political judgements about: the allocation of spectrum between different classes of use; and the reservation of spectrum for specified uses (such as defence) or for specified users (such as the BBC to enable it to meet its current universal terrestrial coverage requirement). Ministers should also retain a power to specify other public policy objectives and criteria which Ofcom should take into account in regulating spectrum access. Such powers should be clearly defined, transparent and limited in scope, in order not to compromise Ofcom's responsibilities for efficient spectrum management. Ministers should refrain from taking powers to direct Ofcom in the specifics of spectrum management tools, such as assignment methods, auction design, administrative incentive pricing, and exemptions from licensing.

6.4 The Government should introduce, in the Communications Bill, a power for Ofcom to regulate spectrum use via a complementary form *of spectrum access licensing*, which could be applied as an alternative to a traditional apparatus licence for certain frequency bands. This new form of licence should grant the licensee some exclusivity and protection from interference for transmission and/or reception of radio signals within specified frequencies and geographical areas. *Spectrum access licences* should be capable of being cast in neutral terms with respect to the type and coverage of the service deployed in the band and the technology used.

Market mechanisms for managing spectrum

7.1 All classes of users should face incentives to economise on the spectrum they occupy. For the majority of frequency bands, where demand exceeds supply, this will entail paying a positive price to obtain access to spectrum, provided there are potential alternative users or uses of a block of spectrum (i.e. the opportunity cost is greater than zero).

7.2 The RA should aim to minimise the licence conditions to those necessary for efficient spectrum use. Existing licences should be amended to remove restrictions which are not needed for reasons of international co-ordination or interference management, and new licences should be issued with the minimum number of restrictions possible.

7.3 Spectrum trading should be implemented in the UK as soon as possible. The trading regime should be designed to minimise the transactions costs of trading, and it should allow operators to change the use of traded spectrum within international allocations and the national interference management framework.

7.4 The general competition regime, relying on an *ex post* analysis of the impact of spectrum trading in defined markets, should be the primary safeguard against any anti-competitive behaviour. Where spectrum is an input into a market which is subject to sector-specific regulation, then the objectives of this regulatory regime may be furthered by a more interventionist approach towards spectrum trading, such as *ex ante* approval of specific trades. In all cases, Ofcom will need to monitor and register trades.

7.5 There should be greater legal clarity than at present about the tenure of incumbent licensees. Ofcom should consider, band by band, how best to provide some certainty for licensees to engage in trading, together with some ability for Ofcom to retrieve spectrum where necessary for any future strategic replanning of frequency bands. Options include converting the terms of licences to a rolling five to ten year period, or to perpetual licences with a compulsory purchase provision for Ofcom.

7.6 Trading rights should be extended to extant commercial licences regardless of the method of original assignment (auction, comparative selection, or 'first come, first served'). These rights should be granted for free. The Government should assess the case for levying a duty on net gains from spectrum trades and/or continuing with spectrum pricing for tradable licences, against its objectives of encouraging efficient use of spectrum and achieving full economic value for consumers, industry and the taxpayer.

7.7 Auctions should become the default means of assigning spectrum licences between competing users, to achieve an efficient market-driven outcome.

7.8 Where licensees are currently granted tailored access to shared spectrum which is managed by the RA, such as in fixed links and certain private mobile radio bands, the RA should move progressively to converting the spectrum to auctionable geographic licence blocks. Competing commercial licensees would then manage access for their own and/or third party use of this spectrum.

7.9 Spectrum pricing should be applied at more realistic levels and more comprehensively across spectrum uses. Where spectrum pricing has already been implemented, and where there is evidence of continuing shortage of spectrum, then incentive prices should be set at the full opportunity cost level, rather than at the current 50 per cent of the levels derived from pricing models, which should themselves be subject to regular review.

Commercial spectrum use

8.1 **Public telecoms:** Auctions should be used to assign spectrum available for public telecoms use. Where spectrum pricing is currently used, prices should be raised to the full opportunity cost levels. Once spectrum trading is introduced, public telecoms operators should be able to trade spectrum subject to international constraints.

8.2 **Licence-exempt spectrum use:** The current constraint on the use of licence-exempt bands for the provision of public access communications services should be removed as soon as possible.

8.3 **Private mobile radio:** Current restrictions on the use of PMR bands should be removed, and PMR licences should be made tradable. Area licences should be auctioned in a number of different bands. This approach could, if successful, be extended across the majority of PMR spectrum.

8.4 **Fixed terrestrial services:** Current restrictions on the use of fixed wireless access bands should be removed so as to allow the deployment of any fixed service. Licences should also be converted to allow spectrum trading. The RA should begin to auction area licences in fixed bands which would allow the licensees to deploy any fixed service, or trade the rights to do so.

8.5 **Satellite systems:** Opportunity cost pricing should be applied to satellite systems' use of spectrum where such use shares with, and constrains, the deployment of UK-based terrestrial services. Spectrum pricing should continue to apply to permanent earth stations but at full opportunity cost levels. Transmissions from user/interactive terminals should also be licensed with an appropriate spectrum charge. Spectrum access licensing could be used to clarify the rights and responsibilities of satellite transmissions into the UK and, where appropriate, to apply opportunity cost pricing to such spectrum use.

Public services:

Defence

10.1 The RA should publish the (unclassified) UK Peacetime Frequency Allocation Table, identifying which bands are under MOD management.

10.2 MOD should invest in a comprehensive audit of all frequency assignments, including patterns of usage by time and location, in order to inform its own tactical and strategic management of the military spectrum asset. This data should be periodically updated, and should be disclosed to RA to improve RA's own visibility and understanding of military spectrum use. MOD should combine this data capture with investment in new frequency management tools, to enable more sophisticated sharing of military frequencies by time and location.

10.3 MOD should, without prejudice to security, disclose to industry those bands where spectrum sharing may be feasible as a result of the patterns of military usage. MOD should identify the pre-emption terms and interference management requirements for military systems, to enable commercial operators to judge the viability of sharing such spectrum on a subordinate basis.

10.4 The value of UK spectrum effectively given over to NATO for management should be more clearly and publicly identified, through disclosure of an annual 'shadow' charge which would apply if the bands were MOD-managed.

10.5 MOD should bear the full opportunity cost of spectrum which is currently subject to incentive pricing (fixed and mobile bands subject to MOD management), with comparable tariffs applying to comparable civil and military uses. MOD should also be subject to a spectrum charge for all of its radar bands, with the tariff unit equal to that applied to civil aeronautical and maritime radar usage. New spectrum charges should be introduced for MOD as soon as practically possible after the preparatory technical studies to determine the standard tariff units.

10.6 Decisions on MOD's departmental budget should be made consistent with the maintenance of credible and enduring incentives on MOD from spectrum pricing and leasing, to provide positive financial benefits to MOD from efficient spectrum use over time.

10.7 The MOD should consider making specific proposals to Treasury for bringing forward budgeted equipment spending which would enable re-equipment and thus an earlier opening of identified military spectrum for release to, or sharing with, the civil sector. Where MOD has agreed to vacate spectrum for commercial licensing, RA should enable rapid refarming through assigning overlay licences which provide for new licensees to compensate MOD for early departure from the bands.

10.8 MOD should have the ability to retain income generated from arrangements to lease access to spectrum which remains under active MOD management. Such spectrum should continue to bear the full spectrum charge, to be paid by MOD to RA/Ofcom.

Broadcasting

11.1 Market-based spectrum management tools should be applied to the broadcasting sector so that usage of spectrum by all broadcasters is exposed to the full opportunity cost of spectrum use.

11.2 Broadcasters should be given the ability to lease spectrum to other uses and/or users, once they have met their public service broadcasting commitments and other obligations. Broadcasters leasing spectrum would be able to keep the resulting revenues.

11.3 The spectrum used for broadcasting should be valued and the valuations released into the public domain. From the overall valuation, a value for each national analogue channel and digital multiplex should be derived, based upon relevant factors such as geographical coverage and bandwidth used.

11.4 Spectrum pricing should be applied to all broadcasters. The timing of the introduction of spectrum pricing should take account of extant regulatory agreements between broadcasters and the Government (including commercial broadcasters' current franchise fees, which encompass access to spectrum). It should also take into account the Government's commitment to promote and support the take-up of digital TV.

11.5 The Government, its agencies and broadcasting regulators should explore options for using variable spectrum pricing and/or spectrum efficiency grants to contribute to the Government's aim of promoting and supporting the take-up of digital TV. The Government should also consider using overlay licences as a mechanism for achieving digital switchover.

11.6 Limits on the proportion of digital broadcasting multiplex capacity which can be used for non-programme related data services should be relaxed as soon as possible, and ultimately eliminated. Spectrum released in the future which can potentially be employed for broadcasting should not be confined to broadcasting use alone, but should be made available for other uses through a competitive auction.

11.7 Once Ofcom is established, the Government should devolve detailed spectrum planning to the independent regulator, subject to Ministerial direction where necessary in particular circumstances, e.g. to reserve spectrum for BBC services. In order to ensure that the entire volume of spectrum is used in the most efficient way, Ofcom should be given responsibility to plan all the broadcasting spectrum, including that currently used by the BBC.

Aeronautical and maritime

12.1 For spectrum reserved for on-board navigation and communications systems, the opportunity cost to individual users is, in most cases, effectively zero, since use of this spectrum is mandated internationally, and users are required to adopt specific technologies. But where UK-based users face some technology choice for their on-board systems, then the RA, working with the CAA and MCA, should apply differential licence fees to encourage moves to more spectrally efficient equipment, thus easing congestion over time.

12.2 In light of the current study for RA of the UK's civil radar deployment and the technical scope for reducing spectrum consumption, the RA should develop a pricing regime, in conjunction with CAA and MCA, for the spectrum used by UK-based radionavigation and radiolocation equipment. This should be phased in over the next five to seven years, consistent with outstanding economic regulation agreements in the aviation sector between companies and the CAA.

Public safety services

13.1 Public safety users should continue to benefit from guaranteed access to radio spectrum, subject to full spectrum pricing applicable to comparable private mobile radio uses.

13.2 The RA should rationalise existing disparate assignments and widen the pool of spectrum reserved specifically for the delivery of public safety services, under the management of the Public Safety Spectrum Management Group. Wherever possible, a technology neutral approach should be taken to the systems adopted for use to allow for competition.

13.3 The remit of the Public Safety Spectrum Management Group should be broadened to encompass an expanded group of approved users, including: commercial and local government organisations with a public safety remit; and specialist users whose spectrum needs are currently met from within Home Office-managed bands. Bands currently managed by the Home Office which provide access for users not migrating to Airwave should be placed under the control of PSSMG.

Science services

14.1 UK-based radio astronomy sites should be subject to an administratively set spectrum charge for those bands where the UK has scope, under ITU regulations, to deploy other actively transmitting radio services on a co-primary basis in the band. The charge should be directly related, as elsewhere, to the geographic area and bandwidth sterilised, and should be based on the spectrum pricing which would apply to the active use of the band in that region. Where radio astronomers allow other services to deploy within their defined spectrum access, they should be compensated, for example, by the RA passing on the spectrum fee levied on fixed links which it assigns within the protection zones around observatories.

INTRODUCTION

1.1 This report sets out the analysis and recommendations to Government of the review of radio spectrum management, hereafter referred to as the review. The introduction highlights the characteristics of radio spectrum which underlie its importance to the economy, and describes the current framework for spectrum management.

Radio spectrum: background

1.2 The radio frequency spectrum, a limited and valuable resource, is used for all forms of wireless communication, including mobile telephony, radio and television broadcast, broadband links, aeronautical and maritime navigation, and satellite command, control and communications. The radio frequency spectrum (referred to simply as spectrum in this report) is used to support a wide variety of commercial and public sector uses. Because the spectrum cannot support all of these uses simultaneously to an unlimited extent, its use must be managed or co-ordinated to prevent signal interference.

The Electromagnetic Spectrum

Electromagnetic radiation is the propagation of energy that travels through space in the form of waves. It includes the visible spectrum (light), as well as infrared, ultraviolet and X-rays. The radio frequency spectrum is the portion of electromagnetic spectrum that carries radio waves. The boundaries of radio spectrum are defined by the frequencies of the transmitted signals, and are usually considered to range from 9 kiloHertz (thousand cycles per second) up to 3000 GHz (billion cycles per second).

Frequency (lower bound)	Band	Example use
9 kHz	Very Low Frequency	long distance radio
30 kHz	Low Frequency	naval broadcast
300 kHz	Medium Frequency	aeronautical communications
3000 kHz	High Frequency	sound broadcasting
30 MHz	Very High Frequency	private business radio
300 MHz	Ultra High Frequency	TV broadcasting
3000 MHz	Super High Frequency	radar
30 GHz	Extremely High Frequency	broadband wireless access
300 GHz	Not designated	

The key characteristics of spectrum are the propagation features and the amount of information which signals can carry. In general, the higher the frequency, the lower the propagation distance, but the higher the data-carrying capacity of the signal. These physical characteristics of the spectrum limit the range of applications for which any particular band is suitable, although some spectrum (such as in the UHF band, 300-3000 MHz) is suitable for a wide variety of services and is thus in great demand. The charts in **Annex A** summarise the allocation of spectrum use in the UK.

1.3 The growth in telecommunications services and radio technologies has led to an ever increasing demand for the use of spectrum among competing business, public sector and other users. Some relatively established uses, such as analogue sound broadcasting, have continued to expand rapidly; for example, there are now over 250 UK commercial radio stations. Other established uses, such as defence and aeronautical radar, continue to utilise significant swathes of spectrum. On top of this, society's growing appetite for mobile communications has led to a massive increase in demand for mobile radio-based applications. There are now 43 million mobile telephones in the UK, compared to just 4 million in 1995. This growth, against the background of maintained demand elsewhere, is placing increasing pressure on the regulatory system to manage rapidly rising and shifting demand.

Value of spectrum to the economy and society

The economic importance of the radio spectrum was vividly demonstrated by the outcome of the auction of licences for Third Generation (3G) mobile services in the spring of 2000. Looking more widely, the Radiocommunications Agency's latest study on the impact of radio[1] has demonstrated that:

- the economic value of the radio industry (excluding civil aviation, defence and other public sector use of radio) is some £20 billion per annum at 2000 prices;
- broadcasting and public mobile radio together account for around three-quarters of the estimated benefits; and
- consumer benefits account for around 80 per cent of the total value from radio services surveyed, producer benefits and licence fees for the remaining 20 per cent.

In addition to these measured benefits to consumers, companies and the taxpayer, there is a wide range of benefits from use of radio for delivery of public services which are not expressed through market transactions. The defence of the UK and its national interests, supported by the use of military radio spectrum, is an extreme example of this. Regulating supply of spectrum between commercial and non-commercial uses is one of the most difficult challenges facing any spectrum management regime.

[1] *The Economic Impact of Radio*, Radiocommunications Agency, February 2001.

Spectrum management: regulatory framework

1.4 The task of strategic spectrum planning is becoming increasingly complicated. It must take account of the complex interaction between technical developments, market forces and social trends. It must also reflect international developments, as radio waves do not stop at national frontiers and most major radio services are now developed for a global, or at least a European market. The following section summarises the institutional framework established for regulating access to and use of radio spectrum in the UK.

Assignment and Licensing

Spectrum management operates at two principal levels:

- **Allocation:** reserving frequency bands for one or more broad service categories, such as mobile radio, radar, satellite-to-earth transmission. Overlaying this service allocation may be a further reservation of spectrum to particular users, such as the Ministry of Defence; and
- **Assignment:** granting use of specific frequencies for transmissions within a given location to a particular user, consistent with the allocated service.

The Wireless Telegraphy Act 1949 has for many years provided the primary mechanism for spectrum management at the assignment level. Under it, the use of radio equipment and apparatus in the UK is required to be authorised by the Secretary of State. Most radiocommunications networks and services are licensed under Section 1 of the Act. However, low power services are increasingly being exempted from licensing through Regulations which can be made under the Act, provided that the apparatus or equipment used complies with the Regulations. Government users require no licence but most of their services are now subject to equivalent agreements with the Agency.

UK spectrum allocation

The UK Spectrum Strategy Committee (UKSSC), an interdepartmental Cabinet Office Committee, provides the official forum for formulating the policy governing the planning and allocation of frequencies. It is jointly chaired by the Radiocommunications Agency (RA) and the Ministry of Defence (MOD), because the allocation of spectrum for civil radio services is the responsibility of the RA, while the management of military spectrum (around 30 per cent of the total) is the responsibility of the MOD.

A number of other Government departments and regulators have a major involvement in spectrum management. These include the:

- Department of Culture, Media and Sport (DCMS), which has policy responsibility for broadcasting;
- Independent Television Commission (ITC) and the Radio Authority who deal with the regulation and planning of commercial television services and commercial radio respectively;
- Oftel, which is responsible for the regulation of telecommunications;
- Department of Transport, Local Government and the Regions (DTLR), whose Maritime and Coastguard Agency (MCA) is responsible for the management of maritime radio services;
- Civil Aviation Authority (CAA), responsible for the management of aeronautical frequencies;
- Home Office and Scottish Executive, who are responsible for the detailed management of the frequency requirements of the police, and some other security services; and

- Particle Physics and Astronomy Research Council (PPARC), which has a major interest in policy on radioastronomy and space services.

The UKSSC's subordinate committee structure includes the National Frequency Planning Group (NFPG) and the International Frequency Planning Group (IFPG). The NFPG is responsible for maintaining the national frequency allocation tables and considering all proposals for change. The IFPG concentrates on the preparations for ITU World Radio Conferences and its membership extends beyond Government to include major operators, broadcasters, industry and other interested parties.

1.5 Since radio waves do not stop at national frontiers, the need for international planning of frequency allocations and protection of the legitimate use of radio spectrum has long been recognised. On the global level, the task falls to the International Telecommunication Union (ITU) which is part of the United Nations family. ITU agreements on spectrum allocation are set out in the ITU Radio Regulations (ITU RR) which have treaty status. The Radio Regulations regulate the use of radio spectrum internationally and form the global framework for regional and national planning (although nations remain sovereign in their use of the radio spectrum in their own territory and Article 48 of the ITU Constitution states that ITU members may retain their freedom with regard to military radio use). The Radio Regulations are regularly revised through World Radio Conferences, which take place every two to three years.

1.6 At the European level, there are two major influences on UK spectrum usage. The European Conference of Postal and Telecommunications Administrations (CEPT) conducts detailed spectrum planning, while European Union legislation sets the framework for spectrum licensing, equipment approval and harmonisation of use across Member States.

European Conference of Postal and Telecommunications Administrations

More detailed spectrum planning is conducted at the European level through the Electronic Communications Committee (ECC)[2] of the CEPT (European Conference of Postal and Telecommunications Administrations), which currently has 44 member countries. Frequency allocation issues are handled through the Frequency Management Working Group and there are also committees dealing with Radio Regulatory and Spectrum Engineering issues. The ECC produces Reports, Recommendations and Decisions on spectrum usage. When implemented by member countries, these form the basis for European harmonisation of spectrum usage at the allocation level.

The ECC co-ordinates long-term spectrum planning in Europe and has produced the European Common Allocation Table (ECA), a harmonised frequency table for Europe covering most of the usable spectrum. The ECC also provides the forum for co-ordinating European preparations for WRCs through its Conference Preparatory Group (CPG).

[2] Formerly European Radiocommunications Committee (ERC)

1.7 The European Union is also playing an increasingly important role in the field of spectrum management. To date, this has mainly been focused on the adoption of certain common legal requirements for spectrum assignment and authorisation. However, the EU has also adopted spectrum harmonisation measures. During the 1990s, four significant frequency harmonisation Directives/Decisions were adopted, on GSM (2G mobile), DECT (cordless telephony), ERMES (paging), and UMTS (3G mobile). Unlike ECC Recommendations and Decisions, these EU measures are binding on Member States. Chapter 4 explores in more detail the international regulatory framework affecting use of radio spectrum in the UK.

The European Union 1999 Communications Review

In 1999 the European Commission started a wide-ranging review of all communications legislation. This was driven by an assessment that the Licensing Directive was not working consistently across all Member States, and that the current regulatory regime needed major updating to take account of convergence of services and technologies.

In July 2000 the Commission therefore brought forward a suite of new draft Directives and Decisions. These included a Framework Directive with supporting Directives on Authorisation, Access and Interconnection, Universal Service and Data Protection and Privacy. They also proposed a Spectrum Decision. These proposals were agreed by the European Parliament in December 2001, and are likely to be implemented by Member States by the middle of 2003.

Authorisation of radio services would primarily be affected by the terms of the Authorisation Directive, which is subject to the general principles of the Framework Directive. The main effect of the anticipated legislative changes will be to put more emphasis on justifying the need for licensing. Specific individual authorisation (such as licensing) will only be allowed if objectively justified in terms of the need to avoid harmful interference. Otherwise a general authorisation is suggested (on the lines of the UK's Wireless Telegraphy Exemption Regulations). The Directive also requires that conditions attached to licences for use of radio spectrum shall be limited to those directly relevant to good spectrum management.

The Spectrum Decision, which is also expected to come into force during 2002, primarily concerns the arrangements for spectrum allocation rather than licensing and assignment. Its main effect will be to permit the Commission to adopt delegated harmonisation measures, using comitology procedures (where measures will be adopted through a committee of Member States, rather than through the European Parliament and Council of Ministers). However, this will only apply to 'technical implementing measures' necessary to give effect to a policy which has been agreed through the Council of Ministers and European Parliament. The Decision will also require Member States to publish information on national frequency allocations and other information relating to the use of radio spectrum, including such matters as licensing conditions, application procedures, and licence fees.

Summary

1.8 The current regulatory framework and practice of central planning has proved remarkably robust over the last hundred years in dividing access to the radio spectrum between competing economic and social uses, and ensuring that each authorised user's signals were consistent with those of others. This approach was relatively straightforward until comparatively recent times. The approach to licensing of most services was essentially 'first-come, first-served', as there was enough spectrum to accommodate most, if not all, potential users and permit adequate separation between potentially incompatible uses.

1.9 That is no longer true. The proliferation of services and uses is such that, in the UK, the spectrum is fully occupied, or at least committed, up to around 60 GHz. The task of finding spectrum for new applications is therefore extremely difficult. Chapter 2 highlights some of the major drivers of rising spectrum demand across commercial and public service users.

1.10 Chapter 3 sets out the review's assessment of the limitations of the current spectrum management approach which overly relies on central planning to balance competing demands against limited supply of spectrum. It has also set out the review's generic proposal for tackling these limitations, by ensuring that users face continuing incentives towards more productive use of spectrum and have greater flexibility in responding to these signals. The review's analysis in subsequent chapters highlights potential at international, national, and sectoral levels for moving from the current central planning approach to one where more decisions on spectrum use are devolved to users facing incentives to economise.

2 DRIVERS OF SPECTRUM DEMAND

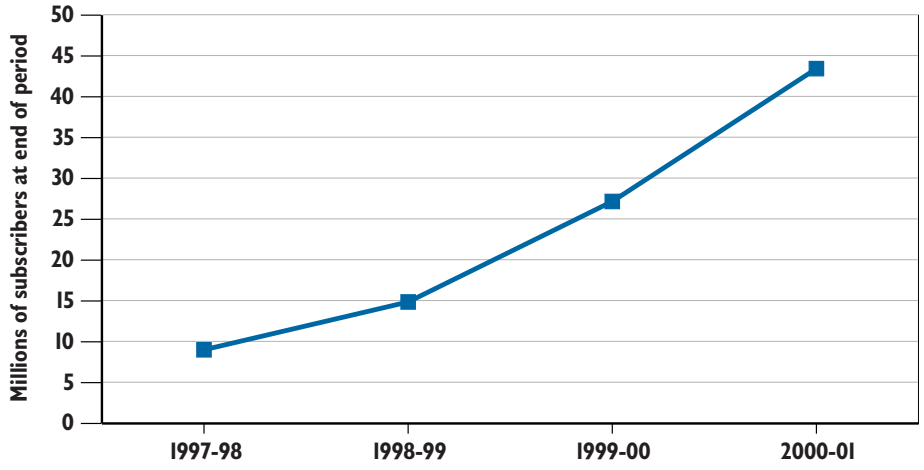
Introduction

2.1 Users of spectrum want spectrum not for its own sake, but because they wish to use it to provide some other service. These other applications are many and diverse; they include space science, radar, business mobile radio and broadcasting. Inevitably, therefore, the demand for spectrum rises as the demand for the services which use spectrum rises. In recent years, the increase in demand has been huge. Perhaps more importantly, it has changed its character. This chapter explores some of the reasons for these changes, and considers the implications for the way in which spectrum is managed.

Lessons from mobile telephony

2.2 As users of public transport and cinema-goers will readily testify, the use of mobile phones has increased dramatically in recent years. As can be seen from the chart below almost three-quarters of the UK population now have a mobile phone.

Chart 2.1: Growth of mobile telephony in the UK



Source: Oftel, September 2001

2.3 When mobile telephony was first launched in the UK in 1985, there were only two network operators. The availability of more spectrum, coupled with the launch of digital mobile technology, meant that two more operators could enter the market in the early 1990s. When licences for Third Generation mobile phones were auctioned in 2000, more spectrum was made available which allowed a new entrant into the market. The availability of more spectrum has produced growing competition, causing prices to fall, which in turn has led to rising demand for mobile phones. A product once confined to the select few has thus become ubiquitous.

2.4 New technologies have also driven the adoption of mobile phones. Where network operators once offered only voice communication, data services have now become a rising proportion of their total revenues. Some data services have become more widely used than others. Short messaging services (SMS), more commonly known as texting, have been very successful – a success largely unforeseen by the network operators. But the use of wireless application protocol (WAP) technology for mobile internet access has been rather less than expected.

2.5 The new services, coupled with the growing numbers of subscribers, have increased the demand for spectrum for mobile applications. The launch of 3G mobiles will allow operators to offer a wide range of new services including broadband internet access and broadcasting-type services, and this may increase the demand for spectrum still further.

Changes in spectrum demand

2.6 The example of mobile telephony illustrates a number of features about the demand for spectrum.

Demand depends on broader changes ...

2.7 As society has become more mobile, so more spectrum is required for services such as mobile telephony. This increased mobility affects public service users of spectrum too. In the defence sector, for instance, the move towards flexible, highly-mobile joint task forces, together with a growing emphasis on accurate and timely information from the operational arena, is increasing the demand for spectrum. Similar operational pressures are also stimulating demand for broadband mobile communications among civilian public safety services.

More services use radio spectrum ...

2.8 In the past, there was a much clearer demarcation between services which used spectrum and services which did not. Television, for instance, required spectrum but telephony did not. This is no longer the case as improvements in technology have opened up new possibilities for spectrum use. Typically, the new products and services complement, rather than replace, existing ones, e.g. mobile phones have not replaced their fixed-line equivalents. This increases the demand for spectrum. It also makes the level of demand more problematic to predict, since it is difficult to forecast the precise mix of services which use spectrum and services which do not.

2.9 Convergence between telephony, broadcasting and information technology and the advent of broadband networks also make it possible to offer hybrid kinds of services. A digital broadcasting multiplex for instance can, in theory, be used to transmit data to mobile phones. These hybrid services, too, make spectrum use more difficult to predict. Technologies such as software-defined radios mean hybrid technologies are likely to become increasingly common.

Software-defined radio

In the past most radio equipment could only operate over a limited range of frequencies. It hence relied on access to defined frequency bands. But the advent of software-defined radios, which are likely to be commercially available in the next few years, could change this. In a software-defined radio, functions that were formerly carried out solely in hardware, such as the generation of the transmitted radio signal and the tuning of the received radio signal, are performed by software. This means that the radio is programmable, allowing it to transmit and receive over a wide range of frequencies and in different transmission formats. This capability breaks the linkage between equipment and frequencies, and thus allows much more flexibility over how spectrum is used.

2.10 The regulation of spectrum has been built up around the basic technology of radio systems, which are designed to operate within well defined frequency bands. This enables the spectrum manager to assign exclusive use of given frequencies to given users. Software-defined radio systems could increase the flexibility for users, enabling them to access a wider range of licensed frequencies with the same equipment. In addition, there are other technologies, such as ultra wideband, which could give rise to radically different types of demand for radio spectrum.

Ultra wideband

Ultra wideband (UWB) systems have very large bandwidths and are likely to be low powered and short range[1], designed to operate 'underneath' the spurious emission levels which conventional radio systems can tolerate. Advanced coding techniques enable co-location of potentially hundreds of systems, and bit rates are currently claimed to be up to 60Mbs. According to their proponents, new generation UWB devices are emerging which have the potential to end spectrum shortage and to revolutionise many aspects of military and civil communications. The systems are likely to be used by the medical, automotive, radar and communications industries, with potential applications including ground-probing radar, secure communications, wireless home networking, a range of public safety applications, broadband internet access, and location, positioning and tracking. Despite the very low average power, the wide bandwidth associated with UWB raises the issue of compatibility with a vast range of co-located conventional narrow band services, which regulators in the UK and the USA are currently assessing.

[1] For example, a typical UWB communications system has a centre frequency of 2 GHz, a bandwidth of 1.6 GHz, and a range of 1km.

Supply creates its own demand ...

2.11 New technology not only allows refinements of existing services, it also encourages the invention and development of entirely new applications. In effect, supply creates its own demand, but in ways which cannot be readily foreseen. The Global Positioning System (GPS), originally developed for defence purposes, is an instance of this, as it is now employed in civilian applications, e.g. the location and administration of public transport and other vehicles.

2.12 There are also examples of this in the public sector, where new technologies enable organisations to operate more effectively. At least one UK ambulance service in the near future will be able to take advantage of real time data-rich digital information. Not only will the ambulances be able to contact hospitals and communicate by voice, they will also be able to receive and transmit data in real time. This facility will allow a patient's condition to be monitored immediately and enable other life-saving options to be employed as necessary.

New technologies succeed (and fail) quicker ...

2.13 Mobile phone use began slowly but then rapidly accelerated. In part, this acceleration was because of increasing competition in the market. The other cause, though, was a network effect: a mobile phone becomes more valuable the greater the number of one's family, friends and acquaintances who possess one. Network effects are ubiquitous in communications markets precisely because the very act of communication connects networks of individuals. Network effects mean that some new technologies can reach critical mass and then rapidly become near-universal. But network effects can also work the other way around. If a new technology does not reach critical mass then it is often destined for failure.

2.14 Governments can, and do, try to predict what sorts of technology will succeed (as highlighted below). But the pace of technological change and the change in consumer demands mean that such forecasts and scenario planning need to be continually updated to reflect new information if they are to be useful guides to policy formation.

Convergence scenarios

Convergence is a term used to describe the combining of personal computers, telecommunications and television[2]. It means that providers of communication systems can deliver products and services that compete with products and services now delivered by other networks. Convergence is not just a technology issue, but also an issue of culture and life style. For the end user, this can mean increasing choice in the equipment that can be used to carry out a particular task. For instance, an internet TV can combine some of the functions of a radio, TV, PC and phone.

The RA has attempted to map the future of digital convergence[3]. This is an ongoing programme where computing, telecommunications and broadcasting developments are considered and then regularly reconsidered under the technique of scenario planning. These scenarios are not predictions, nor do they represent fixed choices or options from which the Government must choose. They offer a range of alternative visions or versions of the future, which can be used as a strategic planning tool. The four scenarios outlined by the RA's study are:

Internet Convergence

Telecommunications, computing, entertainment and information are delivered over the internet, which is part of the fabric of everyday life and the basis for interactive television. Strong brands are highly prized. Value chains are shaken up. Choice and customising abound.

Digital Islands

Diversity continues but in closed community networks. Consumers reject 'excessive' choice on the internet, which is seen as the option of last resort, and are attracted instead to the security and convenience of 'walled gardens', which are entered through trusted portals and interactive digital television.

Total Mobility

Everything is untethered. Lifestyle and working habits mean users value the convenience and personalisation of mobile communications. Mobile phones rather than PCs are the way people access the internet. There is a wide range of service providers, some virtual (i.e. provided over someone else's physical infrastructure).

Broadband Revolution

Wireline speeds and capacity revolutionise broadband communications and entertainment. Only optical fibre, supplemented by fixed wireless access radio applications, can meet ever-increasing demand for bandwidth for communication and entertainment, for example virtual reality and networked interactive games. Environmental and health concerns could constrain mobile networks and service development and encourage telecommuting from broadband-enabled homes.

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[2] Definition from *A New Future for Communications*, DTI/DCMS White Paper, December 2000.

[3] *Mapping the Future of Convergence and Spectrum Management*, Report for RA by NerveWire, Inc., Indepen Consulting, and Intercai Mondiale, 2000, updated by a workshop of industry, academic and RA personnel, January 2001.

Implications for spectrum managers

2.15 The changes discussed above mean that spectrum demand continues to grow, but in unpredictable ways. In the past it has been possible for spectrum managers to keep pace with the rising demand. Technological advances have both increased the intensity with which existing frequencies are used and opened up new frequency bands, thereby increasing supply. But in recent years technological changes have brought about a sharp increase in demand as more spectrum is wanted both for existing services, and for entirely new services. This has meant that there is no longer enough spectrum to accommodate all those wishing to use it. As the RA has highlighted in its latest strategy report[4]: 'The proliferation of services and uses is such that there is now no part of the spectrum which is unallocated at the international level below 275 GHz and, in the UK, the spectrum is fully occupied, or at least committed, up to around 60 GHz'.

Conclusion

2.16 Demand for spectrum is driven ultimately by demand for the myriad services which use it. Technological developments can make new, innovative services possible, but unless individual and business consumers find the services appealing, they will not succeed in the marketplace. These commercial demands for spectrum sit alongside those from public services, driven by parallel operational pressures for greater mobile communications. The following chapters highlight the current and possible future approaches for meeting these demands, to the benefit of the UK as a whole.

[4] *(Draft) Strategy for the Future Use of the Radio Spectrum in the UK*, Radiocommunications Agency, November 2001.

3 ENABLING PRODUCTIVE AND INNOVATIVE SPECTRUM USE

Challenges facing spectrum management

3.1 The first transatlantic radio signals were successfully transmitted and received by Guglielmo Marconi and his team in December 1901. It was recognised very soon thereafter that effective use of radio would require national and international regulation. By 1904, the UK Government had introduced a system of licensing of wireless telegraphy apparatus, and by 1906 the international community had agreed on the first global convention for co-ordinating spectrum use to reduce harmful interference.

3.2 The fundamental building blocks of regulating access to radio spectrum have remained essentially the same during the history of radio. Spectrum blocks are **allocated**, through international agreement, to broadly defined services. National regulatory authorities then **assign** licences for use of specific frequencies within these allocations within their jurisdictions. The current UK primary legislation for spectrum management, the Wireless Telegraphy Act 1949, is largely based on the Wireless Telegraphy Act 1904.

3.3 This regulatory task involves an inherently complex balancing act in a range of dimensions, in each of which there are many conflicting considerations. Key factors include:

- **Interference.** Transmissions interfere unless sufficiently separated in terms of frequency, geography or time. Regulators must strike a balance between reducing the extent of harmful interference, through careful planning, and enabling new and potentially valuable new services to enter the market.
- **International co-ordination.** The effective use of radio spectrum in the UK will typically require careful co-ordination with neighbouring countries, to mitigate the extent of harmful interference. The Government must weigh up the benefits of co-ordinated and harmonised use of spectrum across Europe against the constraints which this imposes on spectrum management in the UK.
- **Investment in equipment.** Most radio equipment can operate over only a limited range of frequencies, and so relies on predictable access over time to defined frequency bands. Stability in spectrum assignments to encourage investment in equipment can slow the pace of spectrum re-use. Increasingly, technical specifications are determined internationally to reap economies of scale in production. National regulators need to balance stability and international harmonisation with responsiveness to new technologies.

3.4 Developments in technology over the last century have opened up the range of useable radio spectrum, so enabling ever-greater access to new allocations and assignments. While demand from consumers, businesses and public services for wireless communications kept pace with this increased supply over much of the twentieth century, the regulatory regime proved sufficiently flexible to cope. But with a sharp acceleration in demand in recent years, change in the market place is outpacing the ability of the national and international regulatory regime to respond.

3.5 Fundamentally, the spectrum manager is called upon to devise procedures to ration current and future demand for radio spectrum between competing commercial and public service users. To do so centrally would require a detailed knowledge of supply and demand trends, technology developments, and the relative value to society of alternative services. This represents a formidable central planning task, which is now growing beyond the scope of any regulatory body, no matter how well staffed and managed. The central regulator is becoming less able to accumulate and assimilate sufficient information to make a correct assignment of spectrum to optimise use over time.

3.6 Instead, spectrum managers will tend, inevitably, to bias decisions in favour of the status quo for a variety of reasons:

- **Demand for spectrum.** Incumbent users, facing few if any continuous incentives to economise on spectrum use, will tend to 'over occupy' spectrum, making wasteful use of it and reducing the amount which can be assigned to new users.
- **Interference management.** Current users have, by definition, been accommodated within a system which minimises harmful interference between users. New services could potentially create additional interference to the detriment of incumbent operators. Technical studies can clarify the potential extent of interference, but judgements about results will tend to favour incumbents' interests.
- **Demand for services.** New services will be based upon uncertain projections of future demand, against data on actual usage for current operators. The weight of regulatory evidence is likely to be in favour of the latter, particularly where new services will compete with existing ones.

3.7 This inherent drawback of a central planning approach does not detract from the significant steps which the RA has taken in recent years to help meet demands for spectrum from new services. Measures taken include:

- promoting the use of more efficient trunked radio services;
- making spectrum available for the early licensing of competing cellular mobile telephony services, and the recent licensing of 3G mobile services;

- moving users of fixed radio links to less congested higher frequencies; and
- enabling the introduction of more spectrally efficient digital technologies in mobile radio and broadcasting.

3.8 This does, however, highlight the need to complement the regulatory regime with other approaches to managing access to radio spectrum, in order to enable continued growth of radio-using services in the UK. The DTI itself identified in the mid-1990s the weaknesses and limits of the traditional approach to spectrum management in proposing the addition of market-based tools to the RA's 'toolkit'[1]:

- **Regulatory burden.** Attempting to tackle 'hoarding'[2] by increased regulation alone would be excessively burdensome and intrusive, as well as requiring substantial additional resources.
- **Inefficiency.** Regulation is inherently inflexible and reduces choice. It does not allow those affected the freedom to make their own decisions based on their individual circumstances and needs. Users have to meet the regulatory requirements irrespective of whether or not this is economically desirable. They have less scope to acquire additional spectrum for potentially valuable applications or to adopt cheaper technical alternatives; and little incentive to increase spectrum efficiency beyond the required minimum. By itself, regulation results in an economically sub-optimal outcome. Market forces, on the other hand, can help distribute spectrum to the most productive users at less cost to the economy as a whole.
- **Ineffectiveness.** Relying on regulation alone would involve the RA in attempting to predict which technology and users would be most likely to be successful and rationing spectrum accordingly. Given the rapid pace of change, technical and otherwise, it is likely that this approach would not achieve the optimal distribution of spectrum and would discourage innovation.

3.9 The net result is that a narrow regulatory approach can reduce the ability of spectrum users to respond adequately to changing demands and technologies. The increasing pace of change in both consumer tastes and technologies accentuates the drawbacks of the current regime. The growing role of radio-based services in the UK economy, including the provision of public services, means that undue reliance on regulation is likely to become an increasing brake on economic growth.

[1] *Spectrum Management: into the 21st Century*, DTI White Paper, June 1996.

[2] 'Hoarding' can be defined as demand in excess of current need, a rational response if spectrum access is under-priced, future needs are likely to rise, and incumbents are conferred rights.

Enabling productive and innovative use

3.10 Spectrum is a finite but non-exhaustible resource which is a vital input into an ever widening range of services. The utility of the resource depends crucially on the management of interference from competing users. This has been, and will continue to be, the primary role of the UK's national spectrum management authority. But the value derived from the economy's use of radio spectrum also depends on the ability of the system to accommodate shifting demands for spectrum use driven by market changes in technology and consumer preferences. Finally, UK society derives unquantified value from spectrum use by a wide range of public services, from defence to broadcasting, whose reasonable demands for spectrum have to be accommodated within any spectrum allocation regime.

3.11 These competing objectives of spectrum management can be expanded under three headings[3]:

Spectrum management objectives

Economic efficiency

- Market allocation of spectrum to users, and to uses, that derive higher value from the resource.
- Provide for responsiveness and flexibility to changes in markets and technologies, accommodating new services as these become technically and commercially feasible.
- Transactions costs, entry barriers and other constraints on a competitive efficient market should be minimised.

Technical efficiency

- Intensive use of scarce spectrum consistent with adherence to technical interference limits.
- Promote development and introduction of new spectrum-saving technologies where the cost of such technologies is justified by the value of the spectrum saved.

Public policy

- Consistent with Government policy towards broadcasting, competition in the telecoms market, and consumer choice.
- Safeguard interests of spectrum use for efficient functioning of defence, emergency and other public services.
- Changes to UK spectrum use should remain consistent with the UK's international and European obligations.

[3] This table is derived in part from *Deregulation of the Radio Spectrum in the UK*, a report for DTI by CSP International, March 1987. The fact that, 15 years later, Government is reviewing again the balance between these objectives highlights the political and economic challenge of the spectrum management task.

3.12 In some cases, the technically efficient solution may not be the same as the economically efficient solution. For instance, a user of spectrum may place a high value on a particular method of establishing a telecoms link between two sites even though that method happened to use more spectrum than other ways of establishing the same link. If the value it attached to the extra spectrum were higher than any other potential user then the technically less efficient solution would be the most economically efficient, i.e. it would maximise the benefits to the UK economy from spectrum use.

3.13 The RA has taken significant steps in recent years to shift its emphasis towards enabling greater economic efficiency in spectrum management. Having assessed the challenges facing spectrum management in the coming years, the review considers that there is an opportunity, and an economic imperative, to move significantly further in this direction. The evidence to date, and prospectively from analysis commissioned by the review[4], suggests that such a move can be made consistently with maintaining standards of technical efficiency in spectrum use, and with the delivery of a range of public policies which depend upon spectrum as an input.

3.14 The fundamental mechanism by which the spectrum management regime could contribute to economic growth is through ensuring that users face continuing incentives towards more productive use of this resource. The review considers that these incentives should be financial and based on the opportunity cost of spectrum use[5]. In this way, spectrum would be costed as any other input into the production process. Price signals about the cost of using spectrum would be disseminated throughout the economy. This information should enable dispersed economic agents to make their own judgements about their use of spectrum and the alternatives open to them to meet their organisational goals.

3.15 As with many other input markets, the operation of market mechanisms for spectrum will continue to take place within a framework set by regulation. The intangible nature of radio spectrum and the adverse impacts of unconstrained transmissions on others mean that a considerable degree of regulation will continue to define specific rights to spectrum use. But the review considers that there is considerable scope:

- to increase the range of spectrum users subject to financial incentives;
- to move such incentives closer to levels at which they reflect the cost to the economy of the spectrum occupied; and
- to increase the flexibility which spectrum users have to respond to these financial incentives.

[4] *Implications of international regulation and technical considerations on market mechanisms in spectrum management*, Aegis Systems and Indepen Consulting, November 2001.

[5] Opportunity cost is the value of an asset or resource in the next best alternative that is foregone by virtue of its actual use.

3.16 The application of incentives towards economically efficient spectrum use will vary sector by sector, but can be encompassed by the review's overarching vision:

Driver	Regulatory response
Rapidly changing environment	***Maximum flexibility*** Generic allocations, trading of licences, facilitating more rapid 'refarming' from one use to another, within a transparent and predictable regulatory framework
Maximising economic benefits	***Market mechanisms*** Auctions and trading of licences where feasible, administratively set spectrum pricing elsewhere
Protecting social priorities	***Reserved allocations*** Make sufficient spectrum available by regulatory rationing for delivery of public services, apply spectrum pricing and positive incentives to share and/or release spectrum into the private sector.

3.17 The net result of the proposed regime should be to place more information in the hands of spectrum users about the costs of the spectrum they occupy, and more freedom to respond to this information in the choices they make about delivery of their organisational objectives. The aim is to move spectrum as far as possible towards a comprehensive competitive input market, where continuing incentives to economise drive spectrum users towards more innovative and productive use over time.

3.18 The benefits of this approach, building on the progress already made in this direction by the RA, will take time to emerge fully. Spectrum use is intimately tied to investment in specific technologies, and major gains in spectrum productivity and innovation are often only possible at step changes in the re-equipment cycle. Lead times between international policy decisions on allocations for new services and the development of commercially viable businesses and technologies can run to decades. Nevertheless, a consistent and comprehensive programme of reforms by the UK should start to bring tangible economic benefits over the next decade. The review sets out an indicative plan for these actions in Chapter 15.

3.19 The rest of the review's report analyses how the overall approach advocated can be incorporated within international and national policy spectrum management frameworks. It identifies the opportunities and constraints presented by frequency co-ordination and spectrum harmonisation at the European level. It sets out proposals for the greater application of market mechanisms in assigning spectrum to uses according to its economic value. Finally, where spectrum has been reserved for the delivery of public services, the report identifies means of increasing the financial incentives on the efficient use of such spectrum.

4 INTERNATIONAL REGULATORY FRAMEWORK

Introduction

4.1 Earlier chapters have outlined the escalating pace of developments in radio communications, which have brought revolutionary changes to the sector in the last ten years. This dynamic environment has in turn been created by changes in regulation, technology and society. The 'digitalisation' of radio technology has resulted in a blurring of some of the previously well defined radio systems and the services they provide. This makes the task of national and international regulatory authorities in managing the spectrum very difficult. In particular, the strategic decision-making relating to which future services should be allowed in which frequency bands is becoming increasingly complex. This in turn increases the possibility of regulators collectively making economically non-optimal decisions. Facing this growing challenge, one of the review's key themes is how the regulatory framework could be made more flexible to respond to changing technologies and demands.

4.2 The very nature of radio spectrum, the pervasive and trans-national nature of radio signals, demands that, in the first instance, its use be considered at an international level. The regulation of radio spectrum has evolved within an increasingly involved international framework, operating on several multilateral and bilateral dimensions. This chapter examines the constraints and opportunities presented by the international framework for evolving a national regulatory regime which increases flexibility in spectrum through greater use of market mechanisms.

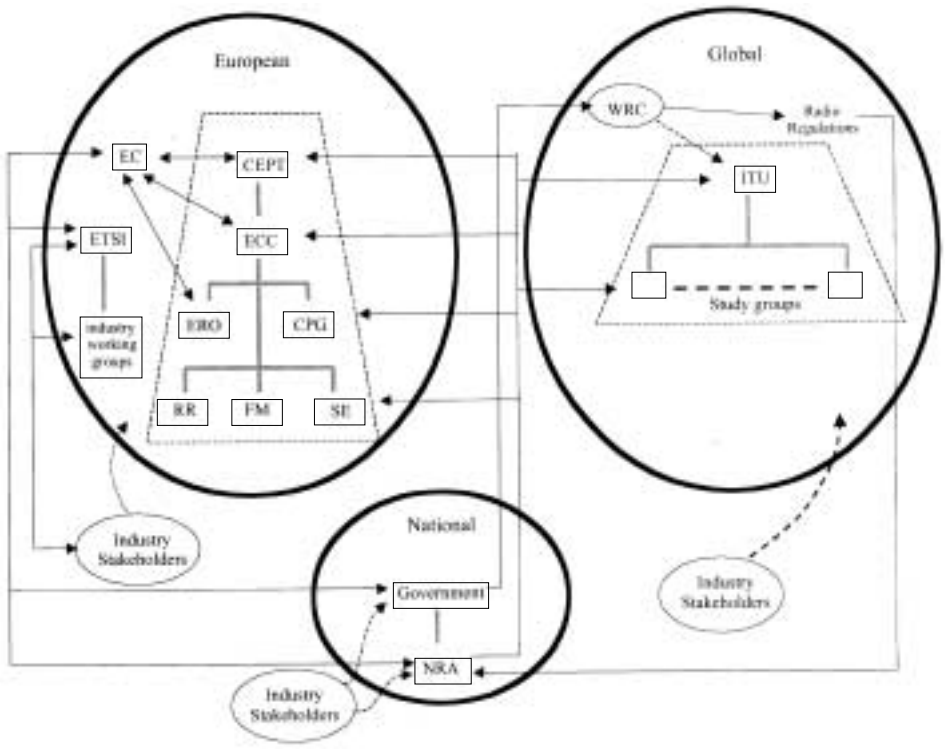
Global and regional regulatory framework

4.3 The global regulatory framework is provided by the International Telecommunication Union (ITU). For the UK, there is also a significant European dimension to this international framework. The Electronic Communications Committee (ECC)[1] of the European Conference of Postal and Telecommunications Administrations (CEPT) provides the regulatory framework, which in many ways reflects the role of the ITU. Within the European Union, the European Commission also has an increasingly significant regulatory influence. In addition to governmental organisations, the European Telecommunications Standards Institute (ETSI), an industry-led organisation, plays an important role in developing European standards for telecommunications (including radio) services and equipment. Figure 4.1 illustrates the inter-relationships of these organisations at the global, European and national levels. **Annex B** provides further background information on the global and European regulatory framework and the constraints this places on UK policy, based upon a study commissioned by the review[2].

[1] The ECC has recently been formed through the merger of the European Radiocommunications Committee and the European Committee for Telecommunications Regulatory Affairs.

[2] *Implications of international regulation and technical considerations on market mechanisms in spectrum management*, Aegis Systems and Indepen Consulting, November 2001.

Figure 4.1 International regulatory framework inter-relationships



Key:

CPG	(WRC) Conference Preparatory Group
ERO	European Radiocommunications Office
FM	Working Group, Frequency Management
NRA	National Regulatory Authorities
RR	Working Group, Radio Regulations
SE	Working Group, Spectrum Engineering
WRC	Word Radio Conference

Industry Stakeholders include companies, consultants, industry groups, international agencies.

4.4 The main priorities of the ITU's regulation of radio spectrum are:

- to protect against harmful interference;
- to allocate radio services to the various radio frequency bands in the radio spectrum (including globally harmonised allocations for systems used in international air and sea travel), taking account of sharing and compatibility studies; and
- to promote the effective use of the spectrum and the geostationary orbit.

4.5 An important way in which the ITU facilitates the avoidance of harmful interference between countries is by a system of registration and co-ordination for notified stations and/or radio systems by member states. Adoption of greater market mechanisms such as spectrum trading would need to be compatible with the UK's international co-ordination obligations under this system. These implications and possible means of addressing them are dealt with in Chapter 5.

4.6 The radio spectrum is used for a variety of radio communications applications. It is used for terrestrial based services as well as satellite applications. These involve a variety of configurations: for example, point to area configurations such as mobile, fixed wireless access and broadcasting, and point to point configurations such as radio relay and fixed satellite systems. Some of these systems are constrained to certain parts of the spectrum, because of the different propagation characteristics of signals at different parts of the spectrum. For example, land mobile applications at present are best suited to the spectrum below around 3 GHz.

4.7 In carrying out its remit, the ITU has, over a number of decades, developed:

- definitions of various discrete radio communications services, such as mobile, fixed, fixed-satellite, mobile-satellite;
- a table of allocations identifying one or more radio services (typically two to four) to each frequency band; and
- regulations and recommendations outlining the broad conditions under which national regulatory authorities (NRAs) should plan the deployments of these services in their jurisdictions.

4.8 Services are allocated on a primary or secondary basis, which in turn confers a certain hierarchy. Current systems in a primary service will be protected from interference from subsequently implemented (registered) systems using primary allocations. Systems operating in a secondary allocation must not cause interference to, and will not be protected from, interference from, current or future primary services, but can claim protection from future secondary services. The table below illustrates the ITU, European and UK allocations in an example frequency band, with primary allocations highlighted in upper case. In the example, the service allocations are identical in each of the three ITU regions[3]. In other bands it is common to have variations in the allocations to each region in a given band. Although allocations at the ITU and European level are, in this example, ostensibly very similar, the detailed notes to the European Common Allocations often define more precisely a range of specified uses within Europe for a given band.

[3] The ITU segments the world into 3 regions: Region 1 is composed of Europe and Africa. The Americas are designated Region 2 and the Far East and Australasia are designated Region 3.

Table 4.1

Frequency band	ITU Region 1 allocation and relevant footnotes	European Common Allocations		UK Peacetime Frequency Allocations	
		Allocation	Major Uses	Allocation	Comments
10-10.15 GHz	FIXED MOBILE RADIO-LOCATION Amateur S5.479	FIXED MOBILE RADIO-LOCATION Amateur S5.479	Non civil ENG/OB envisaged	MOBILE RADIO-LOCATION Amateur (10-10.125 GHz)	10-10.5 GHz – MOD 9.5-10.25 GHz – low power level and flow detection systems 10.125-10.225 GHz radio fixed access, point to multi point
10.15-10.30 GHz		FIXED MOBILE RADIO-LOCATION	Fixed includes point to multipoint ENG/OB is envisaged Civil and non civil (low power) radar in certain sub bands	FIXED MOBILE LOCATION (10.125-10.225 GHz)	

4.9 This example illustrates the general observation that, within the general international allocation framework, NRAs have a reasonable degree of flexibility in choosing services and applications in a given band. (The impact of specific European harmonisation proposals is discussed further below.) Furthermore, each of the services represents a broad range of applications. For example, the fixed service allocation encompasses fixed point to point radio relay applications (commonly used to form the infrastructure networks for many communications systems) and fixed wireless access applications which provide broadband services directly to personal and business customers. As such, these broad categorisations offer NRAs considerable flexibility in terms of candidate applications for licensing. However, once an administration has chosen a particular service for licensing within a band, e.g. FWA, the other option is often excluded in their territory due to co-ordination issues.

European regulatory framework

4.10 Members of the European Union are subject to mandatory EC legislation, and to the optional regulation of the CEPT[4]. The ramifications of the legislation are set out in Annex B. This section summarises some of the key opportunities and constraints arising from current and proposed EU legislation.

4.11 Within Europe, CEPT provides detailed guidance to NRAs on frequency allocations, regulations (including harmonisation) and technical criteria, such as parameters for systems to share bands. CEPT publishes the European

[4] Although the requirements of CEPT (ECC) Decisions become mandatory once Decisions are adopted by Member States, such adoption itself is voluntary.

Common Allocation Table (ECA) which lists, against each frequency band, the various services recognised in Europe. The ECA is an attempt to harmonise use in the region. However, because of the historical diversity of frequency uses throughout Europe, the array of services identified in the ITU Table of Allocations has more or less been faithfully replicated in the ECA, albeit with some further clarification as to precise applications as well as military / non-military usage. As a result, the CEPT allocations confirm much of the same flexibility and choices open to NRAs in the various bands.

4.12 In addition to the administrative flexibility inherent within the international and European allocations, the 'digitalisation' of radio transmissions also means that a given technology can be used to deliver a variety of services to customers.

'Blurring' of services

Traditionally, the various radio communications services served discrete markets and functions. For example, broadcasting systems were essentially one way point to area transmissions of TV and radio programme content to receive-only terminals. Mobile services were purely used to provide voice and basic data services to customers on the move. Social trends are such that people want an increasing variety of services and flexibility in the manner in which they access them. Current technology can permit this. For example:

Broadcasting and data services
In the 'digital world' it is feasible for a system primarily intended for a broadcasting purpose to transmit data services, in addition to or complementing its broadcasting services. Such additional applications delivered within the same overall spectrum allocation have the potential to improve the efficiency of spectrum utilisation and bring economic benefits.

Third Generation mobile services and broadband access
Third Generation systems are potentially capable of transmitting data rates of up to 2 Megabits per second. Such data rates overlap with the capabilities of broadband fixed wireless access. Operators deploying the Third Generation mobile networks may therefore have the technical capacity to address the fixed wireless access market, particularly in rural areas where their core network may be under-utilised.

4.13 The delivery of different digital services within the same internationally defined frequency allocation provides an opportunity for spectrum use in the UK to respond to market signals. The classification of services within administrative definitions does not affect the practical issue of interference management between different types of transmission, i.e. datacasting using broadcasting technology and network planning can be compatible with existing traditional broadcasting services. This flexibility could therefore be achieved without prejudice to the achievement of the interference management objectives of international regulations. It is also in line with the review's general stance towards devolving as much freedom as possible to operators to respond to market pressures in spectrum use.

Recommendation 4.1

The Government should, wherever technically and operationally feasible, facilitate greater flexibility in the use of a given frequency band. This can be achieved by a broader interpretation of the internationally-agreed radio communications service definitions, or by adding additional services to a given frequency band through negotiations at ITU and CEPT level.

Spectrum harmonisation

4.14 Spectrum harmonisation within the European Community has three inter-related strands: the ITU-R, CEPT and the EU. Within the EU the issue is addressed in service-specific Directives and Decisions (addressing areas such as GSM, UMTS and ERMES) and within the proposed Framework Directive and Spectrum Policy Decision. European legislation, driven by the desire to maximise the benefits from inter-operability and interference mitigation across borders within the European Community, offers both opportunities and constraints.

4.15 There are three key factors behind European policy towards spectrum harmonisation:

- technical spectrum efficiency: e.g. satellite broadcasting with regional footprints, requiring some degree of co-ordination across the EU;
- single market in services: e.g. to enable international roaming for mobile telephones, it may be necessary to harmonise spectrum and technology; and
- single market in goods: e.g. to support economies of scale, particularly in markets with high research and development costs and potentially high volume manufacture.

4.16 Historically, harmonisation has been achieved under the auspices of the CEPT. However, adoption of CEPT recommendations, and indeed ECC Decisions in the first instance, is a voluntary matter for each NRA. Whilst common interests and peer pressure have often made this an acceptable approach, the European Commission has argued that such an approach is no longer sufficient. Citing the need for greater certainty on the part of major investors, the recently agreed Spectrum Policy Decision[5] states that: 'where policy agreement is reached to harmonise the use of radio spectrum necessary to implement relevant Community policies, legal provisions should ensure the appropriate implementation of measures by the Member States'. It proposes that harmonisation issues continue to be addressed at a technical level by the CEPT, with the Commission subsequently mandating that the Member States implement them.

[5] Regulatory framework for radio spectrum policy in the EC (COM(2000)407).

4.17 International trade agreements are increasingly a constraint on the EU mandating specific technology **standards**. But they do not necessarily prevent the mandating of specific **services**. For example, following WTO intervention the EU was prevented from mandating use of the European UMTS standard for provision of 3G mobile services, beyond the extent required to cater for international roaming (i.e. at least one UMTS network in each country). ERC Decision (00)01 relating to 3G mobile spectrum, which the UK is committed to implement, explicitly requires all the core 3G mobile spectrum to be made available for 'terrestrial UMTS and other terrestrial systems included in the IMT-2000 family, in order to enable a competitive market for third generation mobile services'.

4.18 Where harmonisation of spectrum use is justified on the basis of promoting a competitive market, this is likely to limit national flexibility to change the use of spectrum, though application of market mechanisms such as auctions or spectrum trading which do not involve change of use would be unaffected. The ERC Decision (00)01 also contains the proviso that the making available of spectrum by the specified date is 'subject to geographically spread market demand', implying that flexibility would be possible where such demand could be demonstrated not to exist. The inclusion of a similar proviso in future harmonisation measures would support flexibility to respond to dynamic and regionally varying market conditions, whilst supporting the development of a competitive international market where demand for such a market genuinely exists.

4.19 Harmonisation of spectrum use does not in itself prevent the introduction of alternative services, so long as these do not impinge on the objectives of the harmonisation measure. For example, it is not necessary in practice for all the spectrum allocated to GSM or 3G mobile to be used for the purpose of mobile communications, so long as sufficient spectrum is available to cater for geographically spread market demand for the harmonised service. This means that in areas where geographic demand does not require the use of all the available spectrum, it could be used for other applications, so long as harmful interference does not occur as a result. For example, in the UK, 3G operators have flexibility under their licence terms to use excess spectrum capacity to deploy fixed wireless access in place of a mobile service.

4.20 There has always been a trade-off between standardisation and market-based innovation in industries, such as radio communications, which involve large upfront investments. An additional factor for manufacturers and operators in this sector, however, is the potential uncertainty relating to the future availability of spectrum. This factor has resulted in regulators becoming involved in the standards-making process, with a view to ensuring the efficient use of the spectrum. The evolving approach to identifying and harmonising spectrum and the standardisation of systems and technology for the mobile communications systems is well illustrated by the following case study[6].

[6] This section is based on analysis in *Market- and committee-based mechanisms in the creation and diffusion of global industry standards: the case of mobile communication*, J L Funk and D T Methe, Research Policy 30(2001).

Evolution of standardisation and harmonisation in mobile communications

The development of what is now known as First Generation analogue mobile telephone systems was strongly influenced by developments in the USA, the UK and Scandinavia. The AMPS (USA), TACS (UK) and the NMT (Scandinavian) systems proved very successful not only in their own countries but also in a number of other (neutral) countries. This was because, although these early First Generation standards tended to be developed around a particular technology, the standards were open and non-proprietary. This allowed neutral manufacturers to adopt them and thus create a bandwagon effect. The national systems in Japan, Germany and France proved less successful because their proprietary standards were intended to favour the national manufacturers. As a result other neutral manufacturers and countries failed to adopt them. There was little co-ordinated multinational effort to harmonise in terms of spectrum. However, the frequency bands inferred by the above successful standards (e.g. 450 MHz for NMTS and 900 MHz for TACS) gained a near-harmonised status.

The emergence of a Second Generation mobile system coincided with an interesting period in European technology policy. CEPT having started work on what became the 2G standard, ETSI had been established to take forward such standards making, and the European Community's desire for a single market came to prominence. ETSI is in many ways an ideal open industry-regulators forum. These conditions helped to create the GSM standard which has proven so successful. The creation of this standard was followed by the European Union mandating the availability of a harmonised core allocation at around 900 MHz in all Member States. This almost automatically led to a substantial early installed base which created an even bigger bandwagon in other countries worldwide. In the USA, the policy of not adopting a common standard or frequency led to a fragmented mobile communications base, and failed to encourage demand in other countries. As a result the GSM's TDMA technology proved more successful globally than the comparably performing IS 95 CDMA, developed in the USA.

Learning from the lessons of the Second Generation developments, a key priority in developing the framework for a Third Generation mobile system was global roaming. European manufacturers were keen to promote an enhanced GSM (TDMA) version, whilst US and Japanese manufacturers were keen on CDMA systems. The WTO, concerned about the use of technology to create unfair barriers to trade, encouraged a technology-neutral approach. Thus, a compromise was reached which resulted in a suite of standards and technologies being possible. This left the way open for manufacturers to form alliances relating to suitable combinations of technologies. Again, as regards spectrum allocation, a core amount of spectrum was set aside (at around 2 GHz) which regulators then licensed in various ways, including the well publicised auctions across many European countries.

In summary, the developments from First Generation to Third Generation suggest a trend for increasing international harmonisation for these mobile services. This has the benefit of providing certainty for the investors as well as facilitating international roaming, which is a priority for European policy makers. However, at the same time, there has also been a trend to be more technology-neutral, in the interests of competition. The result of this competition, in the universal adoption of UMTS across Europe, highlights the benefits of economies of scale and technical compatibility to operators.

4.21 However, not all European harmonisation initiatives achieve the theoretical success predicted at the outset. One such example, ERMES is outlined below.

Enhanced Radio Messaging System (ERMES)

In the footsteps of GSM, the Enhanced Radio Messaging System (ERMES) was an initiative to create a Europe-wide mobile messaging system. The ETSI Standard for ERMES was first agreed in 1992. Two years later the band, 169.4125 – 169.8125 MHz, was harmonised for the application in 1994, via the CEPT/ERC Decision (94)02. However, in contrast to GSM's phenomenal success, there has been no notable implementation of ERMES. As a result, CEPT is now in the process of carrying out a review among member states to assess the merits (or not) of retaining the harmonisation arrangements for ERMES. The RA, which played a key role in initiating this review, is also carrying out a consultation to seek UK industry views as to the best future use of the ERMES spectrum.

Flexibility within international regulation

4.22 The review's consultation paper raised the important question of how far the introduction of market incentives on spectrum use at a national level would be consistent with the UK's international obligations towards spectrum management. There are major potential gains to the UK economy from increasing flexibility in spectrum use, in general, but also benefits in certain circumstances from harmonising UK with European policy. This section assesses how the UK's interests can best be served through national and international policy actions.

4.23 Spectrum allocations and assignments have historically been the result of administrative and political processes that make gradual changes in spectrum use. These changes are often the result of a compromise amongst numerous competing interests. It would be surprising if the resulting allocations were optimal in the sense that the application of an opportunity cost approach caused no user to change their spectrum use. It therefore seems reasonable to assume that application of the market-based approach would lead to demands to change allocations (and assignments) in the UK. These changes may not be consistent with allocations elsewhere in Europe. This could happen, for example, if:

- the timing of demand for new services in UK is different from elsewhere (e.g. digital TV);
- national priorities differ (e.g. retention in France of some GSM1800 spectrum for military applications);
- the size of market required to support equipment manufacture is not large (i.e. UK is sufficient) and/or equipment is adaptable across a number of bands (e.g. FWA);
- the technology used has been developed for US or Japanese markets (e.g. MMDS in Ireland); or
- the application is not truly international by nature. This is the case for most services, except, most obviously, air and maritime radio-navigation and communications (although mobile services such as GSM with a roaming capability are increasingly global in nature, and 3G has been designed from the outset to be a global system).

4.24 To assess whether the international regulatory framework could constrain application of the opportunity cost approach, it is necessary to consider the impact of ITU, EC, CEPT (ECC) and bilateral agreements and regulations. Of these, EC legislation and bilateral agreements are likely to be the most binding constraints.

4.25 If the band in question is subject to an EC Directive or is judged to be harmonised under the proposed Spectrum Decision, then the new use must be compliant with these regulations. This is an absolute constraint until the band(s) in question is removed from the list of harmonised bands. This seems most likely if the services in question are a commercial failure (e.g. ERMES), or become obsolete (e.g. analogue technology replaced by digital). CEPT (ECC) Decisions become mandatory once signed by administrations (although signing itself is optional).

4.26 The situation with regard to ITU regulations is as follows:

- **Primary:** if the new use falls within the definition of the primary use of the band then it can be deployed, subject to co-ordination with incumbent primary services in neighbouring countries.
- **Secondary:** if the new use falls within the definition of the secondary use of the band then the user is not entitled to interference protection from current or future primary services.
- **Unallocated:** if the new use falls outside both the primary and secondary use definitions, then implementation is still possible but the user must not cause harmful interference and it has no right to protection from harmful interference from either primary or secondary services. If interference protection is desired or interference may be caused to other users, it may be possible (in principle) to effect a change by adding a footnote to the ITU Radio Regulations. This could take at least three years to achieve and may be blocked by neighbouring countries not wishing to change existing bilateral agreements in ways that would either restrict their own use or protect the new use from harmful interference.

4.27 Bilateral agreements may constrain what actually happens in practice, assuming the UK's neighbours do not wish to make similar changes in their spectrum use. Bilateral agreements are generally framed in terms of the division of preferred frequencies or codes used in border areas and the level of permitted emissions in preferred/non-preferred frequencies across the band and out of band. If the bandwidth of new services differs from that of existing services, then the agreed sharing pattern may not apply and the new use may face harsh emission constraints. This may prevent service deployment in border areas.

4.28 Studies for the review[7] estimate that, in frequencies around 900 MHz and above, up to 5 per cent of the UK population resides within areas where co-ordination is likely to be required for most services. The extent to which this would impact on the value of the spectrum would depend on the application and whether additional, unconstrained, spectrum were available to support the service. For example, the four UK GSM operators all claim at least 98 per cent population coverage, hence a new entrant who relied exclusively on spectrum that may not be useable by up to 5 per cent of the population could be at a disadvantage. On the other hand, a national broadcaster or fixed wireless access operator could achieve a viable service with a much lower coverage and would be relatively unaffected by such a constraint, as would a mobile operator which used the spectrum to complement its existing GSM or 3G mobile assignment. The effect of bilateral constraints is likely to affect the UK less than some other European countries which have multiple land borders and/or significant proportions of their populations lying within co-ordination zones.

4.29 In summary, the harmonisation of spectrum use under an EC Directive or Decision and bilateral agreements will permit the application of the market-based approach, including secondary trading of spectrum licences, where this does not lead to a major change of use. Where the allocated use of a band would change as a result of applying an opportunity cost approach (e.g. trading, auctions) then the situation is less clear. In some cases, EC Directives could effectively prevent a change of use. EC Directives currently prescribe use in only a relatively small fraction of the total radio spectrum (about 20 per cent of the bandwidth between 900 MHz and 2200 MHz). However, it can be expected that over time the list of harmonised bands will grow (though whether these will be mandated by way of EC Directives or ECC Decisions remains to be seen). Bilateral agreements place a stronger constraint in lower as compared with higher frequency bands. ITU and ECC regulations *per se* are generally a weaker constraint.

4.30 So within the current framework of international agreements, the review considers that the UK has significant freedom of action to implement a more market-based approach to spectrum management. The review's analysis of particular market mechanisms and their application to particular radio services identifies in more detail the limits of this room for manoeuvre.

Spectrum harmonisation

4.31 The review has also considered the UK policy stance towards the multilateral harmonisation of spectrum for specific uses and/or technologies. This process relies on a complex interplay between technology development, industry business planning, and national regulators. The review's general approach here, as elsewhere, is to emphasise the role of firms (operators and manufacturers) in delivering the benefits of timely and effective harmonisation, within a framework set by the regulators.

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[7] *Implications of international regulation and technical considerations on market mechanisms in spectrum management*, Aegis Systems and Indepen Consulting, November 2001.

4.32 The review recognises that, for many services, there are enduring benefits from global or regional co-ordination of spectrum use for a variety of overlapping reasons:

- Cross-border movement of transmitters (e.g. maritime, aviation and increasingly personal mobile phones) requires that equipment operate in harmonised channels internationally.
- Significant propagation of signals across regions (e.g. satellite services, broadcasting) and neighbouring countries require some co-ordination of transmissions.
- Allocation of bands across regions to particular services or technologies enables manufacturers to achieve economies of scale in the production of equipment, enabling more rapid and economical rollout of new services.

But within this generally accepted framework, there remain many decisions about the level at which this co-ordination takes place, and how tightly it constrains individual countries.

4.33 The review's consultation revealed strong support, particularly among telecoms operators and equipment manufacturers, for spectrum to be harmonised to particular technologies. The global open technology standards identified with specific frequency bands enable manufacturers to focus their research and development effort, thus reducing time to market. Economies of scale from producing for multinational markets and competition between manufacturers for standardised equipment can help deliver better quality and value for end users.

4.34 These arguments are compelling for a wide range of wireless terminal product categories. There remain though two major policy choices:

- Where do the costs of harmonisation, in terms of reduced innovation, regulatory delay and constraints on alternative uses, start to outweigh the potential consumer benefits of regionally standardised technology and spectrum?
- Where harmonisation of frequency bands is economically desirable, to what extent do national governments need to mandate this approach through international regulations?

4.35 Both questions can only be answered definitively in specific cases by an empirical examination of the facts. But the review considers that there are generic steps which the UK Government and regulator could take to help ensure that harmonisation proposals deliver economic benefits.

4.36 First, the merits and demerits of harmonisation involving regulatory intervention should be carefully assessed whenever such proposals arise at the European level. With changing technology, including developments such as software-defined radio, traditional arguments for harmonisation on grounds

of production economies of scale may become less relevant in particular cases. In some circumstances, it may be advantageous to delay harmonisation between competing emerging technologies until it is evident which have market backing.

Recommendation 4.2

Where proposals are made for harmonisation at the European Community level, the UK should encourage the Commission and Member States to assess carefully the economic costs and benefits of this approach. Proposals should be tested against the European Commission's technical and single market criteria for harmonisation.

4.37 Wireless technology working in specified harmonised bands may have wide applications across a range of commercial services, so European regulations should enable market operators to decide where and how to deploy such technology.

Recommendation 4.3

Where the UK agrees with a collective European decision to harmonise spectrum to a particular service and/or technology standard, it should seek to ensure that harmonisation constrains the minimum number of parameters necessary to achieve the policy goals of economic and technical efficiency. In the medium term, this implies moving towards harmonisation of broad service categories (e.g. mobile, fixed wireless access, etc) within defined bands, rather than specific technology descriptions (such as DECT, UMTS, etc). This should provide the future spectrum certainty necessary for large-scale research and development investments, while allowing scope for technology competition and innovation.

Recommendation 4.4

Harmonisation should be time limited. Once it has achieved its goal of enabling manufacturers and operators to deliver a cost-effective service to the European market, other developing services and technologies should be able to contest for access to the spectrum. If, on the other hand, harmonisation fails to stimulate the development of a commercially viable market, or the market has plateaued without requiring the full anticipated spectrum allocation, then the regulatory constraint on use of the spectrum should be freed.

4.38 While harmonisation can often bring consumer benefits, there is also the risk that the narrowing of choice about technology, services and the spectrum in which they are to operate may stifle innovation and subdue competition, to the long term detriment on consumers and business. Governments have an important role to play in this process through the linkages and interfaces between spectrum harmonisation decisions and the associated technology standards. The UK Government stance towards particular harmonisation proposals should be focused primarily on achieving consumer benefits

through competition on price and quality. Open standards that permit a family of related specifications can facilitate such competition. This approach would act as a countervailing weight to pressures from individual industrial players to use harmonisation processes to restrict competition.

Recommendation 4.5

Where harmonisation is proposed, the technology standards developed for specified bands should be open and led by industry bodies. This should support innovation and competition in technology throughout the harmonisation process, and enhance competition in production of equipment.

4.39 There has been considerable debate within Europe, following the licensing in all Member States of spectrum for 3G mobile services, of the different mechanisms for assigning licences. In particular, discussion has focused on:

- the choice between auctions and comparative selection other than by reference to a competitive monetary bid; and
- the synchronisation of licensing by Member States.

4.40 As elsewhere in this chapter, the review's starting point is to seek maximum flexibility for UK operators and regulator to respond to market pressures on spectrum. This implies retaining national discretion to implement market-based licensing policy and practice, in order to respond to UK-specific spectrum priorities and shifts in demand. But it also implies being able and willing to co-ordinate with other Member States in circumstances where a harmonised approach would provide demonstrable benefits to European consumers, for example, by enabling consumers to gain early access to Europe-wide roaming on mobile networks.

Recommendation 4.6

Any proposals for harmonisation within Europe of licensing procedures should be subject to a clear demonstration of the benefits this will bring to the single European market. Otherwise, the UK should retain autonomy over the manner in which it assigns spectrum to particular users, which will need to take account of the balance of supply and demand for particular frequencies and the state of competition in the relevant markets.

5 INTERFERENCE MANAGEMENT

Introduction

5.1 One of the main themes throughout the review's report is that, in a rapidly changing business and technology environment, the regulatory framework needs to become more flexible and customer-led. The review explores elsewhere the potential benefits in this regard of market mechanisms such as auctions, trading and leasing of licences, including the facility to change the use to which spectrum is put. These tools could introduce the flexibility required to enable spectrum to be deployed and redeployed quickly. However, such flexible approaches bring significant implications for the regulation of transmissions to ensure that unwanted signal interference is within acceptable limits (referred to here as the interference management regime). This chapter highlights some of the key interference issues in developing a more flexible spectrum management regime. **Annex C** provides further background material on technical considerations in interference management, based on studies commissioned by the review[1].

Interference considerations

5.2 The defining feature of radio-based communications systems is that, unlike wired communications, signals being transmitted and received travel at least a significant portion of their path in free space. This is clearly an essential characteristic in certain applications such as mobile phones, satellite communications, broadcasting and radionavigation. In other applications such as fixed links and fixed wireless access (FWA), it provides a key advantage - the avoidance of upfront costs of laying transmission lines. The main disadvantage however is that transmission over free space means that stray signals from one radio communications system can easily interfere with the proper reception of another.

5.3 Interference is unavoidable and ever present. The impact of excessive interference ranges from simple inconvenience to individual users to, on occasions, the undermining of the commercial viability of networks suffering interference. At the very extreme, it can have 'safety of life' implications, for example where radio systems used by the emergency services suffer interference. Furthermore radio signals do not respect national borders. Thus, if not properly managed, signals emanating from one country can unduly interfere with systems in other countries.

5.4 This propensity to interfere, locally and regionally, is the key factor rendering the radio spectrum a scarce resource. National regulatory authorities (NRAs) throughout the world have therefore regarded it as one of their central duties to ensure both an acceptable interference environment as well as maximising the (technically) efficient use of the available spectrum. This has resulted in

[1] *Implications of international regulation and technical considerations on market mechanisms in spectrum management*, Aegis Systems and Indepen Consulting, November 2001.

a significantly regulated environment in radiocommunications, with the vast majority of NRAs in the world retaining close control on deciding both the type of permitted services and which organisations should be licensed to operate in a given tranche of spectrum. While this has undoubtedly resulted in a well managed environment, the drawback is a general lack of speed in the licensing of systems and refarming of spectrum from one use to another. Thus it could be argued that some of the technical efficiencies gained in spectrum utilisation as a result of careful and lengthy planning are offset by the economic costs of 'downtime' in the planning process.

5.5 It is the job of radio planners, both at the regulatory and individual operator level, to ensure that the radio systems are properly planned so that the interference levels are within acceptable limits. In simple terms, interference management entails ensuring that the received signal strength from the wanted transmitter exceeds the aggregate of the incident interfering signal strength from other transmitters and noise, by at least a predefined margin. This can be achieved by separating the system in question from other potentially interfering systems. This separation can be achieved in one or more dimensions: frequency, spatial, time and signal separation.

5.6 The review considers that the advocated approach of increasing the flexibility and market orientation of spectrum management would be well served by shifting the balance of the responsibilities for interference management further towards operators. In achieving this, there are three important prerequisites:

- public availability of a core set of technical and locational information about all other systems sharing a given frequency band;
- a common understanding, or set of criteria, relating to interference thresholds (acceptable levels of interference) and the calculation of interference; and
- a system for resolving interference problems, which includes monitoring and enforcement arrangements.

This chapter discusses the nature of interference considerations, and provides an overview of current interference management arrangements. Finally, some possible approaches for achieving the above prerequisite elements of a more flexible regime are discussed.

5.7 The impact of interference in a given system depends on the relative signal strength of the wanted signal and the effective aggregate of the unwanted signals and noise strengths (called effective noise) detected by the receiver. This is in turn dependent on the following aspects:

- the transmitted characteristics of the wanted signal source (including the transmitter power level, bandwidth, modulation characteristics, height and directionality of the antenna, and location);
- the transmitted characteristics the interference signals;

- the propagation behaviour of the wanted and interfering signals along their respective transmission paths to the receiver (bearing in mind that this is not necessarily line-of-sight and may be subject to anomalous propagation conditions) including terrain/clutter and climatic conditions; and finally, and crucially,

- the characteristics of the receiver (e.g. receiver bandwidth, modulation characteristics, frequency offset between interfering and wanted signals), which determine the necessary margin between the wanted and unwanted signals required to achieve a certain performance.

5.8 These basics apply to the situation where co-frequency operation is being considered. However, the 'spill-over' effects of the transmitted signal and the receiving equipment, means that interference effects from signals in adjacent channels also need to be considered.

5.9 The signal levels of the wanted and unwanted signals, at the receiver, vary as a result of changes in the atmospheric conditions (e.g. air density, humidity) along the propagation paths. Thus interference considerations require in addition a statistical evaluation with a view to ensuring a minimum availability of the system. These requirements often translate into long term and short term levels of permissible interference, where the latter is due to anomalous propagation or the dynamic behaviour of one or other system. In cases where the interference is due to multiple sources it is necessary to aggregate the interfering power.

5.10 All these factors are critical and interrelated in determining the impact of interference and the efficiency of spectrum utilisation. In recent years, the importance of receiver performance, however, has been sometimes underestimated, particularly in some European regulations[2] which have tended to relegate receiver aspects to a secondary and non-essential status.

5.11 In planning systems and assessing interference, regulators and operators tend to consider the potential interference from all other systems occupying the band within a certain 'co-ordination area'. This area can vary from a few to several hundred square kilometres, depending on the frequency band and the types of systems involved. In general, the lower the frequency the higher is the area. The higher the directivity of the antennas, the more elongated the co-ordination zone albeit with a smaller area within it. The spillover effects of transmitters and receivers mean that co-ordination is needed between systems using the same frequency but also nearby frequencies. However, as suggested above, the greater the frequency separation the smaller is the required geographical separation i.e. shorter co-ordination distances.

5.12 The availability of detailed information about all the systems within the co-ordination area enables the most spectrally efficient planning of the band, by facilitating detailed calculations. Such an approach however is impractical in

[2] Such as the Radio equipment and Telecommunications Terminal Equipment (RTTE) Directive (1999/5/EC).

the majority of cases because obtaining the exact system details will be time consuming and lead to large delays in implementation of new systems. Thus regulators and system planners often tend to use generic performance details about systems and equipment in order to make tractable decisions about the use of spectrum. This increased flexibility and speed, however, necessarily involves a trade-off in terms of spectrum efficiency in regulatory decisions about frequency allocation and operators' decisions about deployment of equipment.

5.13 Because the above co-ordination areas can often exceed geographic licence blocks, it is difficult, in interference management terms, to isolate neighbouring licence blocks. The absence of detailed and generally available technical information about all relevant systems and very complex planning tools lead to the general practical conclusion currently that systems with similar characteristics present easier opportunities to share frequencies. Prospectively, the introduction of public on-line frequency assignment/technical information should change this conclusion and facilitate the review's proposals for a flexible and market-led spectrum management environment.

Current arrangements

5.14 Frequency co-ordination involves three aspects: intra-service co-ordinations, inter-service co-ordinations, and international co-ordinations. These are briefly discussed below.

Intra-service co-ordination

5.15 Intra-service co-ordinations involve the planning of different systems in the same service category sharing frequencies in the same band. NRAs tend to use a combination of two basic approaches in their frequency assignment and licensing activities: central management, and self-management by operators.

5.16 The **central management** approach involves the NRA directly managing a central pool of spectrum. Various operators are then able to apply to the NRA for a frequency assignment and licence on a case by case, geographical and 'first come, first served' bases. This method of management is common for certain types of radio systems (e.g. fixed links, fixed satellite earth stations). It has the advantage that a central body is able to facilitate the re-use of frequency channels by licensing individual channels to multiple operators, by careful central planning of the spectrum resource. However, disadvantages include the loss in spectral efficiency due to the need to use generic technical information which is applicable to all users, and the rigidities inherent in any central regulatory system.

5.17 Under the **self-management** approach, the NRA packages a number of frequency tranches by detailed pre-planning of the overall frequency band. These frequency blocks are then offered to potential operators, historically via a method of comparative selection ('beauty contests') by the NRA, but

increasingly via auctions. This approach is often adopted for services which entail area coverage (e.g. cellular and broadcasting systems). NRAs may sacrifice some spectrum efficiency, initially in their pre-planning work (due to the need for planning margins). However, this method allows operators to maximise the utilisation of their individual licensed spectrum by using equipment-specific information from their own suppliers. Also, managing their own spectrum offers operators the advantage of speedy rollout of networks. It is worth noting that self-management of spectrum by operators does not necessarily circumvent the need for the inter-service and international co-ordination, discussed below.

Inter-service co-ordination

5.18 Often, operators are licensed in frequencies which are shared with other services. For example, fixed services (e.g. fixed point to point links and fixed wireless access) often share spectrum with fixed satellite services. Furthermore, organisations such as the Ministry of Defence, Home Office and the Civil Aviation Authority have an interest in other radio-based systems being implemented in frequency bands adjacent to their own, with a view to minimising harmful interference to their own systems.

5.19 Such inter-service co-ordination is expedited by two approaches. Where the spectrum for both services requiring co-ordination is managed by the RA, the necessary work is carried out internally. Where one of the services is managed by an external body, co-ordination is carried out via a formal site clearance and frequency clearance procedure, a statutory arrangement organised by the RA. It is worth noting also that less formal bilateral co-ordinations between third parties also occur which often help to speed up proceedings at the formal process.

International co-ordination

5.20 Interference management between systems in different countries is handled via two related routes: ITU initiated co-ordination and direct bilateral (or multilateral) co-ordination between countries.

5.21 The ITU route entails a procedure whereby all NRAs register the details of the systems they have licensed with the Bureau of the ITU's radio sector. The Bureau collates these details and, following a simple sift, circulates the details to all the other NRAs who may be affected. It is the duty of the individual NRAs to examine these details and submit a request to co-ordinate with any other NRAs which have submitted systems which are likely to interfere with any of their own currently licensed systems.

5.22 Such a request to co-ordinate leads to bilateral (or multi-lateral) co-ordinations between the interested parties. At this stage, it is customary for the NRAs to involve the individual operators in their jurisdiction who will participate in detailed technical negotiations with their foreign counterparts. It is also possible for individual NRAs to engage in direct bilateral discussions prior to the registration procedure with the ITU.

5.23 In performing interference calculations, in any of the above scenarios, planners should endeavour to use system-specific technical information whenever this is available. This invariably produces the most spectrally efficient solution. Where this is not possible, however, more generic information is used. In Europe, performance limits specified in ETSI standards often tend to be used for this purpose. These standards are however a trade-off between spectral efficiency/technical interests, which favour higher performance specifications, and commercial/economic considerations which may imply the reverse. Insufficient consideration to either priority, on the part of standards-making organisations, will undermine the careful balance on which many of the decisions of NRAs are made. The review considers that, in an era of rising and competing spectrum demands, standards-making organisations should take due consideration of the impact on frequency sharing and spectrum efficiency when considering the appropriate equipment performance limits.

UK approach

5.24 The RA is widely regarded as one of the most progressive NRAs in the world with a reputation for implementing innovative new techniques in spectrum management. These policies have helped to create one of the most competitive and productive radiocommunications markets. Coupled with its geographic size, this results in the UK's utilisation of radio being one of the most intensive in the world. This poses particular challenges for the RA in further improving the efficiency of spectrum use, and the rapidity and responsiveness in facilitating access to spectrum.

5.25 As highlighted earlier, these two priorities are often mutually contradictory. Maximising spectrum efficiency requires access to detailed information about all the systems being deployed. Improving flexibility and responsiveness necessitates making compromises about the level of detail being used, and transferring the locus of decision-making from the NRA more towards the users. The solution involves striking a suitable balance between these two priorities. The RA currently employs both central management and exclusive self-managed allocations for managing the civil radiocommunications spectrum.

Contrasting methods of interference management

Central management by NRA or spectrum management organisation

Fixed links are a good example of how spectrum can be managed centrally for certain types of systems. In the UK, the RA has allocated a number of frequency bands from 1.4 GHz to 58 GHz for fixed links. Operators wishing to implement new fixed links request channel assignments and licences, via a paper or electronic application form. The applicant provides the necessary information such as location and performance requirements and the preferred frequency band. The RA enters these details into its technical assignment and licensing software tool. This tool contains a number of complex databases including details of all previously licensed links in each band, UK terrain, rain statistics for UK locations, and performance characteristics of transmission equipment and antennae. The software tool also contains a complex frequency-planning module, the technical criteria for which are agreed via RA consultation with industry. The planning tool then endeavours to find a suitable channel (i.e. where the interference to and from the proposed new link is within acceptable limits). In the vast majority of cases, a suitable channel is identified and the new link is added to the schedule of the operator's licence. If a channel is not immediately found, the RA liaises with the operator to amend the original application to

find a technically acceptable solution. The main advantage of this method is that it enables a large number of operators[3] to have access to a limited pool of channels. In response to demands for improved responsiveness, the RA has been moving to enabling e-business solutions for licensing applications; this can significantly reduce complex data entry and speed up link planning.

Self-management

This is the approach adopted by RA in facilitating access to new spectrum for use by cellular-based services such mobile or fixed wireless access. Having identified such spectrum for licensing, the RA carries out initial technical sharing studies to evaluate the ability of any incumbent systems to co-exist with the proposed new service. If this appears to be problematic, RA endeavours, via negotiation with the incumbent operators a timescale for relocating their services, e.g. by transferring to an alternative band. At the same time technical and economic studies are also carried out to establish the number of licensees (of the new service) which the band and the market can support. In contrast to the approach with fixed links, for mobile and FWA services the RA assigns to the operators a number of channels within which they plan out their own networks, on a self-managed basis. Guard channels are created by the RA at the outset, which, together with site surveys during network planning, are the key tools for interference management between operators.

Spectrum licences

A number of countries (mainly Australia, New Zealand, USA and Canada) have begun to trial new forms of licensing designed to allow greater flexibility both in terms of use and trading. In Australia, spectrum licensing[4] has been introduced since 1998. This differs from apparatus licensing, which has hitherto been the predominant form of radiocommunications licence in Australia and elsewhere. In contrast, by carefully defining the rights and obligations of accessing and using a given 'parcel' of spectrum, spectrum licences allow operators significant flexibility in the types of services they can provide (e.g. point to point, point to multipoint or mobile) along with the possibility of selling or leasing their spectrum in total or in part. The geographic dimensions of the standard units of spectrum licences are based on latitude and longitude co-ordinates. In high population density areas these may be as small as 7-9 km (5 minutes of arc), but in other areas may be as much as 200 km (3 degrees). The basic frequency dimension depends on the frequency band. For example, in the 500 MHz band this is 12.5 kHz. Licences are then created by aggregating units acquired by individual operators.

Spectrum licences place the main responsibility of interference management in the hands of the licensee, thus reducing the administrative burden on government. The regulator defines an interference management framework with technical criteria which operators can use to design their respective systems. Where necessary, operators can bilaterally negotiate adjustments to the conditions of the framework, thereby minimising the need for litigation. The framework is an innovative variation on conventional interference management techniques and divides interference into two kinds: in-band and out-of-band. In-band interference management entails ensuring that signals from one licence area do not cause undue interference in another area. This is achieved by ensuring that the 'device boundary' lies within its own licence area. The device boundary is defined as the boundary at which the signal strength from one licence area falls below a benchmark level for protecting receivers in neighbouring areas. Out-of-band interference which can be particularly significant between operators with overlapping licence areas is managed by defining reduced power thresholds for the out-of-band components of signals.

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[3] There over 300 different operators of fixed links in the UK.

[4] *Establishing and Interference Management Framework for Spectrum Licensing in Australia*, M Whittaker (Australian Communications Authority), IEEE Communications Magazine, April 1998.

5.26 The RA recently implemented the on-line 'sitefinder'[5] database which enables the public to log on and find out about the location and the operator of all public mobile phone base stations in any part of the UK. In a similar fashion, for the future, an on-line frequency register containing additional technical information relating to as many other radio services as possible is under consideration. The RA has recently launched a public consultation on the disclosure of WT Act licence information, in which it proposes the publication of frequency assignments and base station and mast locations. Such a comprehensive on-line database offers the possibility of transferring the locus of control more towards operators without the need to sacrifice spectrum efficiency.

Implications of review proposals

5.27 In pursuing the objective of achieving a market-led approach to spectrum management, the review has made a series of recommendations which would devolve to operators considerably more freedom and flexibility over the use of licensed spectrum. But increased rights over spectrum use would need to be balanced by greater responsibility on the part of operators to participate actively in interference management, given the spillovers between transmissions in adjacent frequencies or areas. Studies for the review[6] conclude strongly that it is not possible to isolate a geographic spectrum block or a country merely by imposing a power flux density or field strength limit at the boundary, or generic power limits. Such limits would be too constraining near the boundary and would lead to technically inefficient use of the spectrum.

5.28 The spectrum management regime has to allow for the negotiation of boundary conditions between spectrum blocks and for co-ordination between administrations. The negotiation of boundary conditions between operators can be undertaken by the operators themselves, providing that common technical data and supporting tools are available. Responsibility for international co-ordination should remain with administrations. As noted in Chapter 4, any change of use in the UK falling outside internationally agreed allocations, and which potentially has an impact on operations in adjacent countries, could cause a complex co-ordination problem unless the other administration is also pursuing a similar, flexible approach to spectrum management.

[5] www.sitefinder.radio.gov.uk

[6] *Implications of international regulation and technical considerations on market mechanisms in spectrum management*, Aegis Systems and Indepen Consulting, November 2001.

5.29 The key elements that need to be in place in order to allow interference management to take place in a spectrum trading regime include:

- a power flux density/field strength level at a border that will trigger negotiation/co-ordination, where the responsibility for setting this level would reside with the regulator;
- the availability of common analysis tools to determine interference power levels, where these tools are approved by the regulator (noting that there is no guarantee as to the absolute accuracy of the tools provided) and used by the operators in the case of national negotiation; and
- a database of deployed systems and their technical parameters, and agreed changes to boundary conditions.

The regulator would remain responsible for international co-ordination.

5.30 If these key elements are in place it should be possible for licensees to undertake the negotiations amongst themselves with no direct involvement of the regulator (except in the case of cross-border situations). At the same time, recording deployed transmitters and changes to boundary conditions in a common database would provide complete transparency. Without this transparency, use of the spectrum would rapidly become static or the interference environment would degenerate, and the benefits of market mechanisms in terms of spectrum and economic efficiency lost.

5.31 This chapter has highlighted some of the main issues involved in establishing an effective interference management regime, notably the respective responsibilities of the central spectrum regulator and spectrum-using operators. It is beyond the scope of this review to consider fully the technical issues in individual bands. These should be considered by the RA as it develops spectrum access licensing (discussed further in Chapter 6) and market-based spectrum management tools, particularly spectrum trading (discussed in Chapter 7).

Recommendation 5.1

The RA should explore fully the scope for, and means of, transferring more responsibility to operators for interference management, in support of wider moves towards using market mechanisms for spectrum management.

5.32 One key element which has the potential to bring considerable benefits is the availability of an on-line frequency register. This should allow operators to undertake more detailed calculations, leading to greater spectrum efficiency, which previously would have been impractical. It would also provide the information foundation for the development of spectrum trading.

Recommendation 5.2

The RA should seek to implement an on-line frequency register covering all the civil radiocommunications bands and the radio systems utilising them. The frequency register should contain a core set of technical and location-based information which would form the basis for operators to carry out the necessary interference co-ordinations associated with any proposed change of use and/or trade within a given band. As an important prerequisite, the RA should, in conjunction with industry, agree a common understanding of the technical criteria for calculating interference levels.

5.33 The above recommendation deals with the calculation of interference, essentially a predictive technique. The other *ex post* aspect of interference management is the means for effective monitoring of actual interference, and enforcing penalties against breach of licence terms. Monitoring and enforcement play an essential complementary role to *ex ante* interference calculations by investigating and identifying actual cases of interference. Monitoring can be used to enable the early cessation of undue or unauthorised interference before events accelerate towards litigation between operators and the RA. As a result of the transnational nature of radio propagation, an important aspect of monitoring is in the management of cross border interference cases. In addition, actual measurement information from the monitoring functions can be used to enhance the accuracy of the interference calculations discussed earlier. The RA has considerable experience in performing all these functions. A number of respondents to the review's consultation highlighted the growing importance of monitoring and enforcement and the need to maintain a credible and impartial service alongside moves to extend market mechanisms for spectrum management.

6 LEGISLATIVE FRAMEWORK

Introduction

6.1 Spectrum management in the UK is shaped significantly by the legislation defining the powers, duties, functions and organisation of this activity. The Government has already committed to re-organise the regulation of communications (including spectrum management) under a new Office of Communications (Ofcom). The forthcoming Communications Bill, which will establish Ofcom's mission and powers, will provide an opportunity to redefine the statutory framework for spectrum management. This chapter examines how this proposed legislation might best provide the right incentives and constraints on Ofcom and Government as a whole to deliver the full benefits of spectrum use to the UK economy and society. It also examines the spectrum licensing tools at Ofcom's disposal.

Objectives for UK spectrum management

Current regime

6.2 There is little guidance in the primary legislation on spectrum management, the Wireless Telegraphy Act 1949, on the objectives which should condition the regulation of spectrum use in the UK. The Act forbids the use of 'wireless telegraphy' apparatus unless licensed by the Secretary of State or subject to an order exempting defined classes of radio use. Licences 'may be issued subject to such terms, provisions and limitations as the Secretary of State may think fit'[1]. Only with regard to apparatus licences for providing a telecommunications service does the Act include any specific reference to the efficiency of spectrum use:

> 'The Secretary of State shall give a notice of any proposals he may have to limit the number of licences he grants, for the purpose of ensuring the efficient use and management of the electro-magnetic spectrum.'[2]

6.3 With the introduction of more market-based tools for spectrum management under the Wireless Telegraphy Act 1998, legislation began to provide more guidance and direction to Ministers in exercising their regulatory powers. This Act requires the Secretary of State to 'have regard, in particular' to the following matters in setting fees for licences:

'(a) the extent of the part of the electro-magnetic spectrum available for use under licences of that description,

(b) the demand and likely future demand for the use of the part of the electro-magnetic spectrum to be used under licences of that description, and

[1] S1(2), WT Act 1949.

[2] S1D(7), WT Act 1949.

(c) the desirability of promoting–

(i) the efficient use and management of the electro-magnetic spectrum,

(ii) any economic benefits arising from the use of wireless telegraphy,

(iii) the development of innovative services, and

(iv) competition in the provision of telecommunication services.'[3]

6.4 Ministers exercise their powers under the Wireless Telegraphy Acts via the Radiocommunications Agency, an executive agency of the Department of Trade and Industry. The RA, in carrying out its statutory functions as an agent of the Secretary of State, is guided by the DTI's own non-statutory departmental objectives. Those relevant to the conduct of spectrum management include:

'Objective I: to promote enterprise, innovation and increased productivity, [and]

Objective III: to develop strong, competitive markets within a regulatory framework which promotes fairness and sustainability.'[4]

6.5 The Agency's own organisational objectives, operating in support of the DTI's wider goals, offer more specific guidance on the aims and objectives of spectrum management. The primary objective of the RA is:

'To support Departmental objectives by managing spectrum in accordance with a clear strategic plan, which:

- promotes enterprise, innovation and competitiveness;
- makes full and appropriate use of all available spectrum management tools, including regulation, administrative spectrum pricing and, where suitable, auctions in order to promote the best economic use of the radio spectrum; and
- carries forward innovative and progressive approaches to spectrum management.'

6.6 In addition to UK statute, the Government is bound by the Radio Regulations of the ITU. These require that in using radio spectrum, Member States:

- endeavour to limit the number of frequencies and the spectrum used to the minimum essential to provide the necessary services and to apply the latest technical advances as soon as possible; and
- bear in mind that spectrum and orbit resources are limited and that they must be used rationally, efficiently and economically in conformity with the Regulations so that countries may have equitable access to said resources.

[3] S2(1), WT Act 1998.

[4] DTI Aims and Objectives, 2000-01.

6.7 At the European level, the 1997 Licensing Directive[5] also conditions the way in which spectrum is assigned to users in the UK. While this Directive does not alter the powers of the Secretary of State to issue licences or exemptions, it has formally required the RA to act fairly, proportionately and transparently in taking licensing decisions. This European legislation has added further impetus to the RA's own steps to increase the visibility of its spectrum management processes. It does not, however, give any steer as to the direction or objectives to guide national regulatory authorities in their spectrum management.

6.8 In sum, therefore, the current UK, European and international legislation provides little indication as to the purpose of spectrum management and the objectives which the Government is seeking to achieve in regulating access to radio spectrum. There is a general statutory presumption in favour of a parsimonious approach to spectrum licensing, releasing only those frequencies which the regulator deems necessary for the licensee to deliver their proposed service.

6.9 In practice, the RA has chosen to set out, as part of its Agency corporate plan, a more precise purpose against which its actions can be judged. As a part of the DTI, though, the RA's objectives inevitably reflect the DTI's wider goals, and do not explicitly recognise the tension between commercial and non-commercial uses of spectrum. This imbalance is redressed in part by the RA's strategic plans for the future use of radio spectrum in the UK, which provide more detailed information on the intended management of spectrum by both the RA and other public sector spectrum managers, notably the Ministry of Defence.

6.10 In assessing the current and future statutory objectives for spectrum management in the UK, it is illustrative to consider the legal frameworks adopted in other countries to define the objectives of spectrum management. The following section examines the situation in the USA, Australia and New Zealand.

[5] 97/13/EC.

USA

The 1934 Communications Act establishes the Federal Communications Commission as an agency independent from the executive branch, to manage all non-federal government spectrum (including commercial, state and local government use). The Department of Commerce's National Telecommunications and Information Administration is charged with managing all spectrum used by the federal government. The 1934 Act authorises the FCC to grant licences for radio frequency bands, but provides few details other than requiring that FCC rulings be consistent with the 'public interest, convenience, and necessity'. The Act authorises the FCC to regulate 'so as to make available ... a rapid, efficient, nationwide, and worldwide wire and radio communication service with adequate facilities at reasonable charges, for the purpose of national defense, and for the purpose of promoting safety of life and property'.

In practice, the FCC, under current Chairman Powell, is moving towards a more market-oriented spectrum allocation policy, as the following extract from a recent policy statement indicates[6]:

'Market-oriented Allocation Policy.
It is important that the Commission move from its traditional spectrum management paradigm of "command and control" to a paradigm of market-oriented allocation policy to provide more flexible allocations that allow multiple uses so that spectrum can be put to its highest and best use.

Interference Protection.
In moving toward a market-oriented allocation policy, it is vital that we carefully consider technological boundaries and that we clearly define spectrum interference limits and usage rights. It is imperative to carefully consider where best to set limits: transmitters, receivers, or both.

Aggressively Promote Spectral Efficiency.
We must aggressively promote spectral efficiency to ensure that we maximize the use of available spectrum to the extent technically possible. Through this, we must continue to highlight and advance new spectrum efficient technologies and explore the possibility of expanding use of experimental licensing. We must play a key role in supporting spectrally efficient technologies and explore new solutions such as spectrum leasing.

Reserve and protect spectrum for public safety.
It is paramount that we keep the increasing needs of the public safety community at the forefront of any new thinking in spectrum allocation policy.'

Australia

By contrast with the USA, the Australian national spectrum regulator, the Australian Communications Authority (ACA), operates under a very explicit set of statutory objectives. The ACA is an independent regulator, appointed by government to implement legislative powers over spectrum and telecommunications regulation. The object of the spectrum legislation[7] is to provide for the management of the radiofrequency spectrum in order to:

- maximise, by ensuring the efficient allocation and use of the spectrum, the overall public benefit derived from using radiofrequency spectrum;
- make adequate provision of the spectrum for use by public or community services;

[6] remarks by Michael K Powell, Chairman, FCC, at press conference on Digital Broadband Migration, 23 October 2001.
[7] Radiocommunications Act 1992.

- provide a responsive and flexible approach to meeting the needs of users of the spectrum;
- encourage the use of efficient radiocommunication technologies so that a wide range of services of an adequate quality can be provided;
- provide an efficient, equitable and transparent system of charging for the use of spectrum, taking account of the value of both commercial and non-commercial use of spectrum;
- support the communications policy objectives of the Commonwealth Government;
- provide a regulatory environment that maximises opportunities for the Australian communications industry in domestic and international markets; and
- promote Australia's interests concerning international agreements, treaties and conventions in relating to radiocommunications or the radiofrequency spectrum.

The Australian Productivity Commission is currently reviewing the Radiocommunications Act and the role of the ACA[8]. The ACA's experience of operating under these objectives is positive[9]: the ACA considers that their statutory objectives adequately describe at least the social and economic concerns involved in spectrum management. While there are inevitably trade-offs between competing objectives, the Act establishes an appropriate structure for these decisions by having as its first objective the maximisation of the overall public benefit derived from use of the spectrum.

New Zealand

The New Zealand Ministry of Economic Development is the national spectrum manager, operating under the Radiocommunications Act 1989. The prime objective of this Act, and of spectrum management generally, is to maximise the value of spectrum to New Zealand society. In order to achieve this objective, the New Zealand government has set the following sub-objectives:

- ensure that spectrum is allocated to the uses that New Zealand society values the most;
- provide sufficient exclusivity of use to enhance the value of particular parts of the spectrum;
- provide for security of tenure to encourage spectrum-related investment;
- provide a reliable means to resolve interference problems that minimises transaction costs, both within and outside New Zealand's legal jurisdiction; and
- ensure that the concentration of control of the spectrum does not unnecessarily inhibit competition.

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[8] see www.pc.gov.au for further information on this review, due to report in July 2002.
[9] ACA response to the Productivity Commission review, 2001.

Statutory objectives for Ofcom

6.11 With the creation of Ofcom and the devolution to this independent regulator of Ministerial powers over spectrum use, the review considers that there will need to be significantly greater clarity about the statutory objectives guiding Ofcom's spectrum management functions. This is necessary for two reasons.

6.12 First, the scope of spectrum regulation extends widely across the public and private sectors, far beyond the telecommunications and broadcast industries. So Ofcom should face an enduring duty to regulate use of radio spectrum with all users in mind. This goes some way beyond the remit of Ofcom's other functions, which are concerned with improving the quality and price of communications services.

6.13 Second, the very range of Ofcom's spectrum users (from radio astronomers to taxi firms), the admixture of public and private sector users, and the rising demands for spectrum use from many services mean that certain aspects of spectrum regulation have an inevitable political dimension. With the RA as an executive agency of the DTI, the Secretary of State is clearly accountable for the political consequences of spectrum-related decisions. With the creation of Ofcom as a regulator independent of the Government, it will be important to set out the spectrum objective against which Ofcom can be judged and held accountable. It will also be important to define the boundary between Ofcom's independent actions and those where it is operating under direction from Ministers.

6.14 Ofcom will assume the functions of the four pre-commencement regulators[10] and of the Secretary of State (operating through the RA) with regard to spectrum management. The overall tenor of Ofcom will be determined primarily by the interplay of the statutory duties placed on the organisation in carrying out its statutory functions.

6.15 As noted already, the statutory functions of the Secretary of State with regard to spectrum management are very broadly defined and give little guide as to the purpose of the regulatory function. The Communications Bill creates an opportunity to define spectrum management more clearly and to embed it into the economic regulatory functions of Ofcom. The most effective legal mechanism for doing so is likely to be the definition of Ofcom's duties.

6.16 The duties are defined to some extent by the policy aims for Ofcom, which are mapped out in the Communications White Paper[11]. This describes the economic regulation of communications networks and services and the content regulation of broadcasting to be carried out by Ofcom by reference to the following high-level duties:

- **Consumer benefits:** to further the interests of consumers of services and facilities in relation to which Ofcom has functions, in particular, their interests in respect of choice, price, quality of service and value for money;

[10] Broadcasting Standards Commission, Independent Television Commission, Office of Telecommunications, Radio Authority.

[11] *A New Future for Communications*, DTI/DCMS White Paper, December 2000

- **Competition:** to encourage the establishment and development of dynamic and competitive markets in the United Kingdom in those services and facilities;
- **Broadcasting quality:** to secure that access is available to broadcasting services with high quality content, satisfying a variety of tastes and interests and comprising a wide range of services and a plurality of opinions and viewpoints;
- **Broadcasting decency:** to apply standards to provide adequate protection for members of the public from offensive and harmful material in broadcasting services, and from unwarranted infringements of privacy.

6.17 In addition to these duties covering specific aspects of Ofcom's remit, it is likely that the regulator will be operating under generic duties:

- to deliver best regulatory practice by applying principles of transparency, accountability, proportionality and consistency; and
- to minimise the burden of regulation.

These are consistent with the Government's wider aims of improving the outputs of regulation in the UK economy and reducing the adverse impacts of the regulatory process.

6.18 Against this background, the review considers that Ofcom should operate under a statutory spectrum management duty, which would have equal status with its other duties. It would be up to Ofcom to decide how to resolve any conflicts between them. From the viewpoint of economic efficiency, it could be argued that there should simply be a primary duty to promote competition as this is likely to be the most robust means, in the long term, of delivering continuing improvements in consumer benefits, including through services delivered via radio spectrum. However, given the extensive uses of spectrum for non-marketed public services, any particular emphasis on competition would need to be balanced by a remit towards the beneficiaries of such public services, as their needs are not expressed through transactions in a competitive market.

6.19 Furthermore, the principles which should guide Ofcom in the exercise of its duties place strong emphasis on reducing regulation where it proves to be unnecessary. This, by implication, encourages reliance on market mechanisms as far as possible. To support these principles, there is a requirement placed on Ofcom, in carrying out its functions, to reduce the burden of regulation.

6.20 There is a tension within discussions about the goals of spectrum management between achieving a technically efficient or economically efficient outcome. The former optimises the use of radio spectrum from an engineering viewpoint, maximising the capacity of the spectrum to carry a diverse range of systems across frequency bands while minimising the adverse impact of interference. The latter builds on the concept of technical efficiency, by seeking to select policies, from a range of technically feasible outcomes, which

maximise the value to the economy as a whole derived from spectrum use. There are also tensions between 'parsimonious' approaches to spectrum management, as embodied in the ITU's Radio Regulations, versus a more 'promotional' approach, as embodied in the RA's own corporate objectives, which seeks to encourage innovative and entrepreneurial uses of radio spectrum.

6.21 The review welcomes the approach taken by the RA in recent years to embed its own objectives explicitly within the overall DTI goals of improving productivity, innovation and enterprise within the UK economy. This emphasises the importance of enabling economic activity through the use of radio spectrum. It also encourages a more quantitative approach to assessing the competing claims for spectrum use, through assessing the value to the UK economy of different radio services, and weighing these quantified benefits against some of the unquantified social gains from spectrum use.

6.22 Without this economic framework, spectrum management could become a 'satisficing' task in which the regulator attempts to licence users according simply to technical criteria about minimising interference. Under this scenario, there would be no metric to judge the value of introducing a new radio system against the potential interference concerns of incumbent operators. There is the risk that incumbents' concerns could dominate the regulators' analysis and judgement, at the expense of new entrants and innovation in use of spectrum which could bring wider benefits to the economy as a whole.

Recommendation 6.1

Ofcom should operate under a distinct spectrum management duty, which should provide an ongoing requirement on the regulator to maximise the value of benefits derived by UK society from spectrum use. One potential formulation for such a duty would be: 'to maximise, by ensuring the efficient allocation and use of the spectrum, the overall value derived by society from using the radiofrequency spectrum'.

Ministerial direction over Ofcom

6.23 In addition to clarifying the objectives of Ofcom with regard to spectrum management, the Communications Bill should also establish clearly the dividing line between Ofcom's independence in spectrum matters and the continuing role for Ministers in giving Ofcom political direction.

6.24 Many of the fundamental decisions about the allocation of spectrum across public and private sector uses are best made at the political level. Such decisions affect UK citizens in general as well as consumers of telecommunications and broadcasting services, who are the core constituency of Ofcom. Ministers are better placed than Ofcom to weigh up the competing interests of different sectors to reflect the interests of UK society as a whole.

6.25 As now, the balance between defence and civil, public and private sector uses should continue to be set by the Government as a whole, operating through and advised by a Cabinet committee of officials, the UK Spectrum Strategy Committee. With the creation of Ofcom, the strategic spectrum policy role currently performed by the RA acting for DTI Ministers would transfer to the independent regulator. This transfer of skills and experience from Government to the regulator could alter the balance of interests on the UKSSC. Ofcom would need to ensure that it could resolve potential conflicts between its roles as independent regulator and, as co-chair of the UKSSC, adviser to Ministers on spectrum policy. The constitution and resourcing for this central Governmental spectrum policy group should be reviewed to ensure that it remains an effective forum within Government for balancing the competing societal demands on radio spectrum. One option may be to retain within central Government a small national spectrum policy executive, working to Ministers, to co-ordinate competing UK policy interests and to formulate the UK's international spectrum policy.

Recommendation 6.2

With the transfer of spectrum management functions from the RA to Ofcom, the constitution and resourcing of the Cabinet Office UK Spectrum Strategy Committee should be reviewed to ensure that it can continue to balance the competing requirements of civil and military, public and private sector spectrum users.

6.26 There will also be cases where decisions which are reached by Ofcom on its own, delivering its functions according to its guiding duties and principles, could run counter to the wider interests of the Government as a whole. For example, the UK Government may become subject to obligations under European legislation which would require specific actions by Ofcom to comply with them. To cater for such eventualities, the Bill should provide for the Secretary of State to direct Ofcom for a limited range of purposes, covering national security, public safety and international relations.

6.27 In the context of spectrum management, this power could potentially be used to reserve spectrum for the purposes of non-commercial services. It would not, however, provide the vires for Ministers to direct Ofcom with regard to broadcasting or commercial telecommunications, except where relevant to meeting international, security or public safety objectives. There would therefore need to be an additional power of direction for Ministers over Ofcom for the Government to set the strategic allocation of spectrum access between public and private sector. Within this framework, Ofcom would then be enjoined to apply such regulations (including licensing) as were necessary to maximise the overall societal benefit derived from spectrum use. The exercise of this Ministerial power would require some degree of Parliamentary scrutiny. The transparency associated with this may in itself bring some benefits in clarifying the boundaries of Governmental strategic interest in spectrum allocation, on the one hand, and Ofcom's regulatory independence on the other.

6.28 The RA's position as an executive agency of the DTI has, to date, required Ministers to become extensively involved in the detailed decisions involved in regulating spectrum use. The review considers that the creation of Ofcom provides an opportunity for Ministers to remove themselves from this management of the licensing process. By providing Ofcom with clear objectives and sufficient independence for it to become a credible regulator, accountable for its own decisions, the review considers that Government is more likely to be able to achieve its ultimate goal of delivering benefits to consumers and citizens from communications.

6.29 An alternative approach, whereby Ministers would retain additional powers over spectrum management in order to direct Ofcom's licensing decisions, would risk the delivery of effective regulation. Ofcom's regulatory independence could be significantly undermined by exercise, or perceived threat of exercise, of such a Ministerial power. This could hinder the development of a consistent, credible and transparent approach to spectrum management and licensing, which should in itself bring economic benefits by reducing the cost of uncertainty borne by private sector spectrum users. There is also a risk that Ministerial intervention on specific licensing decisions could attract political lobbying from powerful incumbents, tilting decisions against the development of competitive markets.

6.30 The review would also have concerns were Ministerial directions on spectrum management to be used as an active lever of industrial policy. Such a policy lever would not have an explicit cost attached to it, and would not require the DTI to seek public spending resources from the Treasury, nor the Government as a whole to seek expenditure from Parliament. Achieving industrial policy outcomes is a legitimate goal of Government, and indeed it is implicit in the current structure in which the RA takes direction from the Secretary of State. But it is contrary to the Government's stated aim of creating 'a new, independent statutory regulatory body, Ofcom, responsible for economic regulation of communications, content regulation and spectrum management'.

6.31 Any putative powers of intervention for Ministers in spectrum management would also go against the trend in other areas of regulation. The Government's generic approach here has been to define clearly in statute the objectives, functions and accountabilities of the regulator, and then to devolve considerable operational independence to the regulator. For example:

- **Competition policy:** the Government has, over recent years, introduced a series of reforms, with aim of giving greater effective powers to the competition authorities to pursue transparent pro-competition objectives. The latest White Paper[12] includes a commitment that 'The Government will: respect the absolute independence of our competition authorities; not interfere in cases which are under investigation; adopt remedies recommended by the Competition Commission except where there are exceptional public interest grounds not to do so ...'

[12] *A World Class Competition Regime*, DTI White Paper, July 2001

- **Monetary policy:** the Government's first step in 1997 was to establish independence for the Bank of England with regard to interest rate policy formation. The Bank of England Act 1998 gives the Chancellor of the Exchequer reserve powers to direct the Bank in monetary policy matters only in extreme economic circumstances.
- **Financial services:** the Government has established the Financial Services Authority as a strong independent regulator, operating under statutory objectives, and accountable to the Treasury and Parliament. Treasury Ministers are limited to directing the FSA to examine particularly serious regulatory issues, and not to directing a particular regulatory outcome.
- **Energy sector:** the Utilities Act 2000 provides for the Secretary of State and the Office of Gas and Electricity Markets (Ofgem) to share the functions of regulating the energy markets in a complementary manner. Strategic decisions are reserved to Ministers, while Ofgem has operational independence over licensing of regulated activities. There is no power of direction over Ofgem, although Ministers can issue guidance on social and environmental matters, to which Ofgem shall have regard.

6.32 In summary, the review considers that there are substantial economic and longer term political benefits from establishing a distinct remit for Ofcom's spectrum management role. This should be guided at a strategic level by political direction from Government, but insulated from Ministerial intervention at the operational level.

Recommendation 6.3

The Government should limit its powers to intervene in the details of spectrum licensing. Ministers should retain powers to intervene with Ofcom over the distribution of radio spectrum, in order to make essentially political judgements about: the allocation of spectrum between different classes of use; and the reservation of spectrum for specified uses (such as defence) or for specified users (such as the BBC to enable it to meet its current universal terrestrial coverage requirement). Ministers should also retain a power to specify other public policy objectives and criteria which Ofcom should take into account in regulating spectrum access. Such powers should be clearly defined, transparent and limited in scope, in order not to compromise Ofcom's responsibilities for efficient spectrum management. Ministers should refrain from taking powers to direct Ofcom in the specifics of spectrum management tools, such as assignment methods, auction design, administrative incentive pricing, and exemptions from licensing.

New approaches to spectrum licensing

Current regime

6.33 The WT Act 1949 provides the legal basis for regulating use of radio frequencies via licensing of apparatus for the transmission or reception of wireless telegraphy signals. The WT Act prohibits any person establishing or

using any station for wireless telegraphy or installing or using any apparatus except under the authority of a licence, unless the apparatus has been exempted by regulation made by the Secretary of. Licences which are granted under the WT Act may give permission to transmit, provided the licence holder adheres to the conditions of the licence. There are also reciprocal arrangements in place between countries to allow the licensing of radio use on agreed frequencies for services such as shipping and aircraft.

6.34 Some types of radio equipment (depending upon use) have been exempted from the requirement for a licence by regulations made under section 1 of the WT Act. Such licence-exempt spectrum use is discussed in more detail in Chapter 8 in the context of public telecommunications services.

6.35 For some services using radio, other licences are also required in addition to WT Act licences. For example telecommunications services are also subject to the Telecommunications Act 1984, and operators of such services need to be covered by a licence under that Act. Similarly, independent broadcasting services transmitted under authority of a WT Act licence also need a licence under the Broadcasting Acts of both 1990 and 1996.

6.36 There are three levels of regulation embodied within licences, depending on whether the RA has to:

- assign a specific frequency (as opposed to allowing operation within a band);
- clear the use of the frequencies concerned at a particular site; and/or
- co-ordinate the licensed service internationally to mitigate risk of interference.

6.37 Certain terms and conditions (such as frequency allocated) are unique to certain individual licences. For example, the frequency allocated to an individual private mobile radio licence holder would not be the same as that allocated to another PMR licence holder in close proximity, as this may cause interference. There may also be other conditions such as antenna height, power output, etc, which would differ between licences. These individual terms and conditions are set out in technical schedules which are attached to the licences. Individual conditions may also apply in relation to persons authorised to use the equipment.

6.38 There are three broad types of WT Act licence which the RA currently issues:

- **Pre-packaged Licences:** these include standardised conditions of use, with pre-determined frequencies or power output. Examples include ship or aircraft radio licence classes where there is no customised frequency assignment.
- **Customised Licences:** these types of licence apply where applicants have a specific requirement which they have determined is unique to their business, e.g. they may need sole access to a channel within a defined geographical area (local, regional or nationwide). In these cases, detailed technical processing is required to tailor the frequency concerned so that it does not interfere with other users. These licences may also need site or frequency clearance.

- **Spectrum Licence:** this licence type may be awarded as a result of a competition, or by detailed negotiations with RA. These are licences where a block of spectrum or set of pre-defined channels are agreed before the licence is issued. The licence holder then has responsibility for how that spectrum is used within agreed terms and conditions (for example, they may have to use specified equipment). Generally the licence holder will have exclusive use of this channel or frequency within a defined geographical area, or for national use.

Additional form of licensing: spectrum access

6.39 The current licensing regime provides significant flexibilities to cater for a wide range of licence types, with varying degrees of freedom for the licensee to plan the use of radio equipment within the terms of the licence. Some licences in practice give operators wide discretion over the nature and location of the radio equipment which they operate under the licence. For example, in the licences for the 28 GHz broadband fixed wireless access spectrum[13], the licensee is simply required to deploy sufficient radio equipment to install a BFWA network which has the capacity to reach 10 per cent of business units in the licence's region within 18 months of licence award. The licensee has discretion over the location of equipment and the type of technology used, and has simply to report to the RA on the deployment of 'access point transceivers'.

6.40 Basing spectrum regulation on licensing of particular apparatus for particular services is a practicable proxy in many cases for a more neutral approach of regulating radio emissions. By defining the service and narrowing the range of equipment used and the way it is deployed, the task of the regulator in planning multiple frequency assignments in a crowded spectrum space is made more tractable. Also, where there are over-riding public policy reasons to mandate a particular use in certain bands (e.g. defence, aeronautical radar, public service broadcasting), then there may have been little to gain from providing for greater flexibility in spectrum licence terms.

6.41 So, historically in the UK and elsewhere, there has been little pressure to move away from apparatus licensing as the primary means of regulating spectrum access. Also, the RA has enabled some considerable flexibility, under the terms of the WT Act, to allow licensees in some bands to determine the assignment of channels and the location of transmission sites within the spectrum licensed to them. In many cases, the remaining technical restrictions within licences[14] result from wider Government policies towards competition in the telephony market and the provision across the UK of widely available broadband communications services.

6.42 The current licensing approach has proved remarkably robust and flexible in the face of technological and market developments over recent decades. There are, however, two areas where a different form of licensing could enable the RA to achieve its regulatory objectives more effectively.

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[13] Auctioned initially in autumn 2000, with the remaining licences on sale from October 2001.

[14] E.g. the requirement in the licences for 28 GHz auctioned in 2000 in the UK for licensees to roll out a broadband fixed wireless access service, rather than use the frequencies for, say, fixed links telecoms infrastructure.

6.43 First, the emphasis on **apparatus** licensing can reinforce a tendency towards specifying technology and services to be deployed under particular licences. At heart, the purpose of spectrum management by a government regulator is to maximise the value derived from spectrum use by reducing the extent of harmful interference. This aim could be pursued by focusing regulation on the nature of the radio signals, independent of the equipment used and service provided in particular bands. By defining the licence in terms of the geographical, time and frequency dimensions of the radio signals which can be transmitted under the licence, the regulator can step back from decisions which commercial operators are better placed to take about the choice of equipment and service to deploy.

6.44 There was support from a wide range of respondents to the review in favour of moving towards the licensing of rights to access spectrum in place of the current apparatus licensing. This applied particularly for commercial communications, where flexible spectrum access licensing could support the introduction of spectrum trading, by creating a framework for operators to alter the configuration of their spectrum as technology and market demands evolved. This approach may also have application in defining access to spectrum for public service users, and enabling them subsequently to lease access to their spectrum blocks to others. As later chapters of this report discuss, in future, with greater financial incentives to economise on spectrum used for public services, such flexibility in licensing to accommodate changing uses could become more important.

6.45 Second, the use of spectrum for transmissions **from** satellites **to** UK-based receivers is not subject to WT Act licensing at present. (Other terrestrial transmission elements of satellite communications systems are subject to UK licensing.) By using spectrum access licensing, the RA could help to resolve the respective rights of terrestrial and satellite systems to transmit and receive signals, particularly where bands are shared and thus potentially subject to congestion and interference in the UK. Chapter 8 discusses satellite systems in more detail.

6.46 A number of other national regulatory authorities, including Australia, Canada, New Zealand, and the USA, have begun to introduce a more generic approach to licensing access to radio spectrum, motivated by the desire to enable flexibility and innovation in spectrum use. Of these, the Australian approach is the most fundamental reform of traditional spectrum management methods.

Australian approach to spectrum licensing

Spectrum licensing is a form of licensing introduced in Australia by the Radiocommunications Act 1992 and implemented by the Australian Communications Authority (ACA)[15]. Spectrum licences were awarded for the first time in 1997, following the auction of the 500 MHz band. Spectrum licences are a tradeable, technology neutral spectrum access right for a fixed non-renewable term. Instead of authorising the use of a specific device, spectrum licences authorise the use of spectrum space, and give licensees the freedom to deploy any device from any site within their spectrum space, provided that the device is compatible with the core conditions of the licence and the technical framework for the bands.

Spectrum licences offer a new way of managing the radiofrequency spectrum. Licensees have the flexibility to plan and deploy devices within their spectrum space. Licences are for a fixed term of up to fifteen years. Within the bounds of spectrum space and the technical co-ordination framework, licensees are free to operate whatever type of communications service they choose, and are able to change that service in response to technical improvements or changes in consumer demand. The only requirement is that some types of device must be registered with the ACA before they can be operated. Spectrum licences are tradeable. Licensees can negotiate with others to buy and sell spectrum space in the open market as the need arises, or authorise others to use their spectrum space. Spectrum licences can be aggregated or sub-divided to form new licences, based upon finite indivisible units of spectrum space called standard trading units, or STUs. The frequency bandwidth of STUs may vary in size depending on the spectrum band in which licences are being issued, but the area grid will be constant for all bands.

The ACA has applied the spectrum licensing approach selectively in the following bands to date: 500 MHz, 800 MHz, 1.8 GHz, 2 GHz, 2.3 GHz, 3.4 GHz, 27 GHz, 28 GHz and 31 GHz. These bands were selected on the basis that there is a choice of technologies and services which operators could practically deploy in these frequencies, and so take advantage of the flexibilities offered by spectrum licensing. These bands were also by and large clear of incumbent users when licensed, so the new licensee is relatively unconstrained by existing services in deciding how best to utilise the spectrum. In all other bands, the ACA continues to issue apparatus licences (very much akin to the UK WT Act licences), which are more specific as to technology and service to be provided by the licensee.

[15] This section is based on material from the ACA website.

6.47 The review considers that the Communications Bill provides an excellent opportunity for the Government to equip Ofcom with a new mode of licensing based upon spectrum access, rather than use of particular apparatus. This would facilitate the introduction of spectrum trading. It would also enable moves towards allowing more flexible use of spectrum by licensees in certain bands. Finally, given that the licence would apply to the transmission of signals though UK-managed spectrum, rather than to the operation of UK-based apparatus, it would enable Ofcom to provide greater legal clarity about the use of spectrum by transmissions into the UK from satellite.

Recommendation 6.4

The Government should introduce, in the Communications Bill, a power for Ofcom to regulate spectrum use via a complementary form of spectrum access licensing, which could be applied as an alternative to a traditional apparatus licence for certain frequency bands. This new form of licence should grant the licensee some exclusivity and protection from interference for transmission and/or reception of radio signals within specified frequencies and geographical areas. Spectrum access licences should be capable of being cast in neutral terms with respect to the type and coverage of the service deployed in the band and the technology used.

7 MARKET MECHANISMS FOR MANAGING SPECTRUM

Introduction

7.1 This chapter considers how market-based spectrum management tools can be used to maximise benefits for the UK from the use of spectrum. As discussed in chapters 2 and 3, such tools need to be used in order that the spectrum management system keeps pace with the rising and increasingly unpredictable demand for spectrum. The chapter also considers the benefits of removing restrictions on how spectrum is employed, to allow it to flow to the use which brings the greatest benefit to the UK economy and society.

Changing demands for spectrum

7.2 As discussed in Chapter 2, the demand for spectrum has both altered and increased in recent years. The RA has responded to these changes by changing the way in which it assigns spectrum. Indeed, the RA has been in the vanguard among national spectrum authorities in introducing spectrum management tools such as spectrum pricing and auctions.

7.3 This receptiveness to change is evident in the proposals contained within the RA's *Future Management of the Radio Spectrum*, published in 1994, and in *Spectrum Management: into the 21st Century*[1], published by the DTI in 1996. The proposed changes were enacted in the Wireless Telegraphy Act 1998 (WT Act 1998). Before this Act was enacted the fees paid for wireless telegraphy licences were set at a level which enabled the RA to recover its costs, sector by sector. The WT Act 1998 introduced two new forms of charging for spectrum:

- auctions, in which fees are set directly by the market; and
- administrative pricing, in which fees are set by regulation (referred to alternatively here as spectrum pricing or incentive pricing, since the objective is to create incentives to use spectrum efficiently and economically by varying prices with the amount of congestion that exists in a particular spectrum space).

7.4 The RA has adopted an open and consultative approach over a period of years in order to secure consensus for the shift from cost-based spectrum licence fees to incentive pricing. This work included commissioning an analysis of the application of spectrum pricing, and proposed methodology for setting incentive prices, *Study into the use of spectrum pricing*, by NERA and Smith System Engineering Ltd[2], (Smith-NERA report).

[1] *Spectrum Management: into the 21st Century*, DTI White Paper, June 1996.

[2] *Study into the Use of Spectrum Pricing*, by NERA and Smith System Engineering Ltd, published by the Radiocommunications Agency, June 1996.

7.5 In April 2000, the RA was the first administration to hold an auction for Third Generation mobile spectrum. It has also held an auction for broadband fixed wireless access spectrum at 28 GHz.

7.6 In 1998, the RA also issued a consultation paper[3], *Managing spectrum through the market*, part of which discussed spectrum trading, which would allow holders of rights to use spectrum the ability to buy and sell these rights without approaching the RA. The proposal to introduce spectrum trading was well received and served as a platform to seek regulatory changes at an EC level, and thereby allow spectrum trading in the UK.

7.7 The aim of this chapter is to consider ways of building on the considerable achievements to date. The chapter makes broad recommendations for how each of the main market-based spectrum management tools – trading, auctions, and pricing – should be applied, and later chapters discuss implementation in particular sectors.

Economic principles of spectrum management

7.8 The review's goal is to implement mechanisms which ensure spectrum is used efficiently. The review believes that the key means of achieving this goal is to ensure that spectrum users face an appropriate charge, explicit or implicit, which reflects the opportunity cost of their spectrum use.

7.9 Because spectrum is a scarce and finite resource, its use involves an opportunity cost. This opportunity cost is the value of output foregone when a block of spectrum is employed for one particular use rather than the next best alternative. If the value of spectrum to a particular user is less than the opportunity cost, then the spectrum is, by definition, valued more by someone else. If it were to be reassigned to that alternative potential user then there would be a gain in economic efficiency.

7.10 It follows therefore that a spectrum user will have incentives to alter spectrum usage if it faces a charge for the spectrum equivalent to the opportunity cost **and** if the value it attaches to the spectrum differs from the opportunity cost.

7.11 The incentives for operators to use spectrum more efficiently include those:

- to examine their spectrum needs, and release unused spectrum;
- to use spectrum to provide alternative services;
- to use less congested parts of the spectrum; and
- to implement more spectrally efficient technologies, e.g. introducing new systems which use less spectrum, but require higher investment.

7.12 The changes to spectrum usage need not necessarily be possible immediately. In some cases, for instance, there may need to be significant investment in new equipment. But even if the changes are slow to occur, mechanisms which

[3] *Managing spectrum through the market*, Radiocommuncations Agency, 1998.

oblige the user to take into account the opportunity cost are still likely to be worthwhile; without them, the changes leading to improvements in spectrum efficiency will never commence.

7.13 If the right incentives to use spectrum efficiently are not in place, then, as the Government recognised when it proposed implementing market mechanisms for managing spectrum[4] 'a self-perpetuating vicious circle of hoarding and shortage can develop'. This will lead to a misallocation of resources in the economy, with consequent damage to economic efficiency, productivity and output.

7.14 If however the right incentives are in place, then the economy will benefit as individual users economise on their use of spectrum. The gains will partly come from the fact that spectrum is not wasted. But the most significant gains will come from added dynamic efficiency, i.e. more innovation and greater competition in the markets in which spectrum is used, as new entrants and new technologies win access to spectrum.

Recommendation 7.1

All classes of users should face incentives to economise on the spectrum they occupy. For the majority of frequency bands, where demand exceeds supply, this will entail paying a positive price to obtain access to spectrum, provided there are potential alternative users or uses of a block of spectrum (i.e. the opportunity cost is greater than zero).

7.15 This principle of opportunity cost charging can be applied in a number of different ways: trading, auctions and pricing. Each of these is considered later in the chapter after some recommendations on general restrictions in spectrum licences have been set out. Later chapters set out how different charging mechanisms might be applied in particular areas of spectrum use. The review's aim is not to identify precisely how spectrum is used inefficiently at present. Indeed, doing so is extremely problematical since spectrum managers will find it difficult – and, in many cases, impossible – to acquire all the information required, e.g. the value numerous individual spectrum holders attach to its use. Instead, the review believes that if the principle of opportunity cost charging is not applied then the inevitable and inexorable consequence will be inefficient use of spectrum and a loss to the UK economy.

Restrictions on spectrum licences

7.16 One of the themes of the review is that users of spectrum should have as much flexibility as possible to arrange their use of spectrum, since this would allow them to be much more responsive to changes in demands for spectrum. Some existing licences, however, impose restrictions on how spectrum is used; these restrictions include coverage requirements and service restrictions.

[4] *Spectrum Management: into the 21st Century*, DTI White Paper, 1996.

Coverage restrictions

7.17 Some licences which give rights to use spectrum include rollout requirements, and/or requirements for holders of spectrum to use spectrum or else return it to the spectrum manager ('use it or lose it' clauses).

7.18 'Use it or lose it' clauses seem designed to ensure that spectrum which is assigned to an operator is used in practice (although it is questionable whether such clauses can, in practice, be invoked when spectrum is left idle). Rollout clauses meanwhile seem designed to ensure that operators using spectrum provide their services to a proportion of the country which is defined by the Government (acting through the RA).

7.19 But where users of spectrum have faced the opportunity cost of spectrum, they are likely to have the incentive to deploy services in order to make a commercial return. Obliging holders of spectrum to take account of the opportunity cost of the spectrum, through auctions, incentive pricing or trading, would therefore make rollout and 'use it or lose it' clauses redundant.

7.20 If, on the other hand, such clauses force an operator to deploy services faster than commercial imperatives alone would have done, then this could cause problems for the company concerned. New entrants into a market are often short of positive cashflows at a time when they are investing heavily in infrastructure to provide services to consumers. Obliging an operator to invest in infrastructure to meet a 'use it or lose it' or rollout clause at such a time could cause it financial difficulties.

7.21 Obliging holders of spectrum to use it may also prevent useful economic functions. In some cases, for instance, a purchaser of spectrum may hold spectrum for which it does not currently have a use in expectation of a future technological or market development. Forcing the purchaser to use spectrum may prevent such developments from gaining access to spectrum. 'Use it or lose it' clauses have also been proposed as a means of preventing 'speculation' once trading has been introduced. But speculators may contribute to the functioning of the market by, for instance, purchasing spectrum which they expect to rise in value. This can provide useful liquidity by allowing spectrum to be made available to other potential users.

Service restrictions

7.22 Another type of restriction which is sometimes imposed limits the type of service or technology which can be deployed in a particular band – even where this is not necessary to meet international and/or interference management obligations. The limits seem designed to ensure that the services which are provided using the spectrum assigned are the ones which the Government has decided should be provided. But such restrictions are becoming increasingly anachronistic as a result of digitalisation of systems and convergence of services. Growing integration between broadcasting, telecommunications and information technology industries is making it

possible to provide new innovative services using spectrum. As the RA has put it[5]: 'convergence in digital communications is giving rise to changes that are not only rapid but also highly unpredictable.'

7.23 Given this unpredictability, it seems preferable to devolve decisions on which services are deployed in which bands to the market players who have the best available information, and who can respond fastest to shifting patterns in consumer demands. Information about which services consumers find most appealing at any one particular point in time is more likely to be available to operators than to the Government. Second-guessing by Government on which parts of the radio spectrum are devoted to which services seems unlikely to serve consumers' best interests.

7.24 Removing restrictions on the apparatus deployed in particular blocks of spectrum would also have advantages since it would allow operators the flexibility to decide which technology to use. Users of spectrum are best placed to balance the extra costs associated with using more spectrum against the extra costs associated with engineering their systems to offer the same capacity with less spectrum.

7.25 In recommending the removal of unnecessary restrictions on coverage and services deployed, the review agrees with the Government which has stated[6] that 'regulation is inherently inflexible and reduces choice. It does not allow those affected the freedom to make their own decisions based on their individual circumstances and needs. Users have to meet the regulatory requirements irrespective of whether or not this is economically desirable.'

Recommendation 7.2

The RA should aim to minimise the licence conditions to those necessary for efficient spectrum use. Existing licences should be amended to remove restrictions which are not needed for reasons of international co-ordination or interference management, and new licences should be issued with the minimum number of restrictions possible.

Spectrum trading

7.26 One way of exposing users to the opportunity cost of their spectrum use is through the introduction of spectrum trading. This gives users of spectrum the ability to sell on the rights to use spectrum, without approaching a spectrum manager. If it is possible to trade spectrum then each user will have to consider whether it is worth retaining these rights to use spectrum, or alternatively whether it should sell them. Trades will take place when the spectrum is worth more to another user than it is to the existing user, i.e. when the opportunity cost is greater than the value of the spectrum to the incumbent holder.

[5] *(Draft) Strategy for the Future Use of the Radio Spectrum in the UK*, Radiocommunications Agency, November 2001.

[6] *Spectrum Management: into the 21st Century*, DTI White Paper, 1996.

7.27 The review considers therefore, that spectrum trading is a crucial addition to the spectrum management system. Trading would allow each block of spectrum to be transferred to the user which valued it most. Over time, this should ensure that far more spectrum is employed in the use, and by the user, which brings the greatest benefit to the economy. Perhaps more significantly, spectrum trading should also bring dynamic benefits to the economy through greater competition and faster innovation. Because the ready availability of spectrum would make it easier to enter communications markets, incumbent operators would find it more difficult to exert market power. The threat of new entry will help constrain prices and encourage incumbent operators to invest in providing new services to consumers. Trading will also help ensure that firms with pioneering new ideas are not restricted through a lack of available spectrum.

Greater competition through spectrum trading

During the 1980s and 1990s, a US firm, Nextel, acquired a number of specialised mobile radio (SMR) licences through a combination of purchases in the secondary market and applications to the FCC. SMR services were supplied to businesses such as taxi companies and food delivery firms. Individually, the licences provided local coverage but collectively they gave Nextel a nationwide reach. The firm sought permission from the FCC to use the spectrum for mobile telephony. Incumbent mobile network operators were opposed. Despite this opposition, Nextel won the necessary permission – albeit after a prolonged process – and began offering mobile telephony from 1991 onwards. Commenting on the case, a leading US regulatory economist said[7] 'bringing radio spectrum out of an unproductive employment should not be such tricky business'. Spectrum trading, with some change of use allowed, would make it more straightforward.

[7] *The Wireless Craze, the Unlimited Bandwidth Myth, the Spectrum Auction Faux Pas, and the Punchline to Ronald Coase's 'Big Joke'*, T W Hazlett, January 2001.

7.28 The Government committed itself to introducing spectrum trading in the Communications White Paper[8]. The benefits of trading have also become more widely realised among other national regulatory authorities. Spectrum trading, with varying degrees of flexibility, has been introduced in Australia, New Zealand, Canada and the USA. The EC has also recognised the benefits of spectrum trading. Rules concerning licensing imposed through existing EC Directives currently prevent the transfer of rights to use spectrum. But spectrum trading will be allowed once the directives resulting from the current review of EC communications legislation have been implemented in the UK. The RA has anticipated the likely changes and will be consulting this year on proposals to introduce spectrum trading. Due in large part to the foresight of the RA, therefore, the opportunity exists for Britain to become a pioneer in the area of spectrum trading in Europe.

[8] *A New Future for Communications*, DCMS/DTI White Paper, December 2000.

EC legislation on spectrum trading

Spectrum trading rules will need to comply with the requirements of the EC Framework Directive[9], which was approved by the European Parliament in December 2001. The Directive permits Member States to introduce spectrum trading provided that spectrum trades are notified to the relevant national regulator, are made public and do not distort competition or result in change of use of spectrum which is harmonised by the EC. The Directive is expected to be implemented in the UK in 2003, and the UK national regulatory authority for spectrum will have to take its requirements into account when designing a spectrum trading regime.

[9] Directive on a common regulatory framework for electronic communications networks and services (see OJ C 337/34).

7.29 The principle of spectrum trading was also welcomed by respondents during the review's consultation process. But some respondents felt that the success of a trading regime would very much depend on the detailed mechanisms at work. The review agrees that the professed benefits of spectrum trading will only materialise in practice if the trading regime is designed properly.

7.30 The experience of spectrum trading in other countries suggests that spectrum trading is hindered when transactions costs are too high. For instance, in the USA, where prior approval from the FCC is necessary before a trade can take place, trading has been limited because of the added risks involved. The FCC has made efforts[10] to promote spectrum trading in general, and leasing in particular, by removing or modifying its rules and procedures 'to eliminate unnecessary barriers to the operation of secondary market processes and to promote flexibility'.

7.31 It is important therefore that the process by which spectrum is traded is as simple, transparent and cost-free as possible. Also, it is important that there is as much flexibility as possible for operators to change the use of spectrum; without such leeway it will be impossible to achieve the goal of ensuring that spectrum is transferred to the most efficient use and user. In some cases, change of use may not be possible as a result of international harmonisation measures, but the review considers that within these limits, spectrum trading coupled with change of use should be allowed.

[10] *Principles for Promoting the Efficient Use of Spectrum by Encouraging the Development of Secondary Markets*, FCC, December 2000.

International restrictions on changes of use

The existence of international allocations of spectrum provides some constraints on the extent to which the use of spectrum can be changed[11]. Constraints such as the ITU Radio Regulations exist primarily because of the potential for harmful interference across national boundaries. Within the constraints, however, there is a considerable degree of scope to change the use of spectrum.

In many cases there is scope to use spectrum within a given allocation for alternative uses, e.g. spectrum allocated to TV broadcasting can be used to provide data services provided the internationally mandated technology (DVB-T) is used. Over time, there should be scope to relax these constraints – especially given the fact that convergence is making many of the definitions of services increasingly redundant.

The use of some spectrum, e.g. for 3G mobile telephony, has been harmonised at an EC level. Where this is the case there is still scope for allowing spectrum trading within the harmonised bands. Allowing this would also contribute to spectrum efficiency as operators could buy and sell unused spectrum between each other. Bilateral agreements to control interference may also limit the ability to change the use of spectrum – particularly in the lower frequency bands – but again these agreements need not prevent change of use. Chapter 4 discusses the constraints and opportunities created by the international regulatory framework.

[11] See also *Implications of international regulation and technical considerations on market mechanisms in spectrum management*, Aegis Systems and Indepen Consulting, November 2001

Recommendation 7.3

Spectrum trading should be implemented in the UK as soon as possible. The trading regime should be designed to minimise the transactions costs of trading, and it should allow operators to change the use of traded spectrum within international allocations and the national interference management framework.

Types of trading

7.32 There are different varieties of spectrum trading:

- Outright sale of a block of spectrum or an apparatus licence would involve complete transfer of all the rights and obligations covered by a licence to another party.
- Leasing of a block of spectrum for a fixed time (or other condition) would mean that current apparatus licences were modified to allow licensees to lease some or all of the assigned spectrum. The length of the lease would be up to the time included within the original apparatus licence. The lessee would be able to use the spectrum for any purpose it chose within the relevant international allocation provided that it ensured that all the conditions included within the original licence were not breached. Although all such trades would be notified to the RA/Ofcom, this would be a relatively simple process which achieved flexibility without extensive intervention on the part of the regulator.

- Partition of current apparatus licences by geography, frequency or other means, so that individual parts could then be leased. If an operator decided that it no longer wished to use part of its assigned spectrum, it could return it to the RA for reassignment.

7.33 The review considers that there is scope to implement some or all of these different types of trading arrangements in different areas of spectrum use (later chapters describe how they might be applied in individual sectors). Allowing flexibility to holders of spectrum to decide how they should trade would boost the amount of spectrum which is traded, which in turn would boost the overall benefits to the economy. For example, a licensee may wish to lease a frequency in a particular location, but use the same frequency itself elsewhere. Or a spectrum holder may wish to lease its spectrum until it is able to complete an infrastructure network capable of using the spectrum. Such arrangements can bring into use spectrum which might otherwise lie idle.

7.34 In order to facilitate flexible trading arrangements it will be necessary to define the rights and responsibilities of licensees. Spectrum access licensing could be used to achieve this. The role of Ofcom in such a regime would be to define the initial parameters of the licence including interference requirements, and then assign the licence (usually through auction). After the licence has been issued, Ofcom would be responsible for ensuring compliance with licence conditions and for administering the trading arrangements.

Spectrum access licensing

As discussed in Chapter 6, it may also be possible to use spectrum access licensing as a partial replacement for the current system of apparatus licensing. This would allow the spectrum manager to define basic building blocks of spectrum and then allow bidders in an auction to aggregate them as they wished. Once it was possible to trade spectrum, individual licensees could change the amount of spectrum used by buying and selling as necessary.

Such licences would be defined by the following elements:

- a geographic area/volume;
- a frequency range of use;
- the emission limit at which negotiations with licensees of neighbouring spectrum blocks would be triggered;
- the name of the owner of the legal title that is lodged in a central register administered by or on behalf of Ofcom;
- a general proviso not to breach international treaties to which the UK is bound;
- provisos to cease transmission if safety of life or national security issues are raised (with compensation if the user is operating within the terms of their licence); and
- the time limit, including a condition which allowed Ofcom, in defined circumstances, to revoke the licence or to make a compulsory purchase.

7.35 Spectrum holders may also delegate their rights to use spectrum. For example, a licensee may permit another party to exercise the licensee's rights under the terms of the licence. Since there would be no transfer of the actual licence and the licensee would remain responsible for observing all the obligations under the licence, this need not be considered as trading of spectrum.

Costs of trading

7.36 The review agrees with many of the respondents who commented that the success of any trading regime would very much depend on its details. If the procedures for trading are too onerous then trading will be hindered. Any trading regime would have to have mechanisms in place which ensured that it effectively dealt with matters relating to interference. It would also have to be designed in such a way as to meet any obligations arising from relevant EC Directives. Some recommendations on how such concerns might be taken into consideration are set out below.

Interference

7.37 Any trading regime would have to ensure that once rights to use spectrum were transferred, the new licensee met the interference limits contained within the original licences. In some cases, e.g. the transfer of apparatus licences, which specify to some degree the equipment deployed, this need not cause undue difficulties. But detailed consideration would have to be given to situations where the use of spectrum was changed substantially, or where licences were partitioned.

7.38 One possible means of doing this would be to incorporate the extent to which the licence holder is allowed to interfere with neighbouring blocks within the terms of the tradable spectrum licences. The licence holder could then deploy any service within the block as long as it did not breach the interference limit. If it did, then it would be obliged to cease the activity causing the excessive interference, or alternatively to negotiate with holders of the spectrum which was subject to the interference. This could result in changes to licence boundary conditions, with one licensee compensating the other. The spectrum regulator would arbitrate any disputes. This form of spectrum access licensing would allow trading to take place alongside change of use within international restrictions.

7.39 Studies[12] for the review considered the extent to which trading could take place within the limits on interference between neighbouring parts of the spectrum. They considered that there is no reason from a technical point of view to prevent a change of use providing any agreed changes to boundary conditions are formally recorded. Chapter 5 discusses the implications for interference management of spectrum trading and greater flexibility in spectrum use.

[12] *Implications of international regulation and technical considerations on market mechanisms in spectrum management*, Aegis Systems and Indepen Consulting, November 2001.

7.40 Where negotiation between licensees results in changes to boundary conditions, the new licences could be subject to the technical approval of the RA. This could, however, delay and restrict the trading process. In the USA, the requirement to seek prior approval of trades has been found to inhibit spectrum trading; as a result, the FCC is considering ways of reducing the need for this intervention[13]. The review's preference is for a system of self-certification, as introduced in Australia, whereby the parties involved would certify that the particular trade did not violate the licence conditions. Sanctions could be used to enforce such conditions, including suspending the licensee's right to transmit until it was compliant; ultimately, the licence could be repossessed.

Competition

7.41 There is a possibility that spectrum trading could prevent the achievement of effective competition in the markets in which spectrum is used. For instance, it could allow firms to foreclose competition in relevant consumer markets by purchasing spectrum and preventing others from using it. Any trading regime would need to have mechanisms in place to prevent such problems from occurring. Indeed it is a requirement of the proposed EC Framework Directive[14] that Member States ensure that competition is not distorted as a result of spectrum trading.

7.42 The review believes that the incidence of such problems should not be over-estimated – not least because the advent of trading itself makes it more difficult to foreclose competition in end user markets. Allowing trading and change of use across a broad swathe of spectrum means that operators would need to purchase spectrum across a wide range of frequencies if they were to try to exclude competitors.

7.43 Also, it should be remembered that only operators with existing or prospective market power in the consumer/end user markets could afford to pay above the competitive level for the spectrum. If an operator did not have such market power then it could not hope to recover the price it had paid for spectrum through higher prices to consumers.

7.44 Where operators did possess market power, it would be possible to use the provisions of the Competition Act 1998 to prevent any harmful effects to consumers arising from spectrum trading. Section 18 of the Act (the Chapter II prohibition) prohibits the abuse of a dominant position held by one or more undertakings. The concept of 'abuse' is broad. In Hoffman-La Roche[15], the European Commission held that 'abuse' is an 'objective concept relating to the behaviour of an undertaking in a dominant position which is such as to influence the structure of a market where, as a result of the very presence of the undertaking in question, the degree of competition is weakened'.

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[13] *Principles for Promoting the Efficient Use of Spectrum by Encouraging the Development of Secondary Markets*, FCC, December 2000.

[14] Directive on a common regulatory framework for electronic communications networks and services (see OJ C 337/34).

[15] Case 85/76 [1979] 3 CMLR 211 (para 91).

7.45 Under the proposals contained within the Communications White Paper, Ofcom would have concurrent powers to apply the Competition Act 1998. It would also be possible for complex and scale monopolies in relevant markets to be referred to the Competition Commission for investigation under the terms of the Fair Trading Act 1973. It seems sensible therefore to consider using these general competition powers, rather than potentially onerous *ex ante* measures, to prevent distortions to competition when spectrum is traded. Some other potential ways of preventing distortions to competition, such as thresholds on the amount of spectrum which can be held by an operator (so-called 'spectrum caps'), have the inherent weakness of failing to evaluate the level of market power which is a pre-requisite to considering possible anti-competitive behaviour. Such spectrum caps can also limit expansion by efficient suppliers, and restrict the ability to migrate existing customers to new services (e.g. migration from GSM to 3G mobile telephony). In the USA, the FCC has recently announced its intention to eliminate its spectrum caps which apply to Commercial Mobile Radio Services.[16]

7.46 One respondent suggested that when considering whether a trade should be allowed, the RA or Ofcom should consider whether the trade created or strengthened a dominant position. This is the similar to the test which applies under the EC Merger Regulation[17]. The review believes such a test may be unnecessarily restrictive in that it may prevent a dominant firm from increasing the amount of spectrum it possesses. Nor is the review convinced that it is necessary to treat the purchase of spectrum – an input into a final product market whose purchase **may** allow an increase in market share – in exactly the same way as a merger which directly raises market share. To do so would seem disproportionate.

7.47 The review's preference therefore is to use general competition law to prevent distortions to competition through spectrum trading. Where spectrum is an input into a market which is subject to sector-specific regulation, however, Ofcom may prefer to advance the objectives of the regulatory regime by a more interventionist approach towards spectrum trading, including ex ante approval of specific trades. One possible approach is to prevent the acquisition of spectrum by an operator which is designated as possessing 'significant market power' under the relevant EC Directives. The review believes that this too could be disproportionately onerous as it may prevent firms with such power from expanding their operations. It should also be remembered that the EC Communications Directives only cover some of the markets in which spectrum is used. The review's preference in such situations therefore would be to assess whether a particular trade is regarded as likely to lead to a substantial lessening of competition.

[16] *2000 Biennial Regulatory Review Spectrum Aggregation Limits For Commercial Mobile Radio Services*, FCC, November 2001.

[17] *Regulation 4064/89 on the control of concentrations between undertakings*, OJ L257/13, 1990.

7.48 In cases where rules on spectrum trading are not necessary to support sector-specific regulation, the review considers that distortions to competition can be prevented by using general competition law since this focuses on the aspect which should be central: using spectrum in an anti-competitive way.

Recommendation 7.4

The general competition regime, relying on an *ex post* analysis of the impact of spectrum trading in defined markets, should be the primary safeguard against any anti-competitive behaviour. Where spectrum is an input into a market which is subject to sector-specific regulation, then the objectives of this regulatory regime may be furthered by a more interventionist approach towards spectrum trading, such as *ex ante* approval of specific trades. In all cases, Ofcom will need to monitor and register trades.

7.49 The review has also considered whether it is necessary to intervene in the spectrum trading market to protect particular groups of users. One example put forward was a possible need for regulators to prevent private mobile operators from selling their spectrum to public mobile operators if this depleted competition between the two kinds of network. The review believes that beyond the application of normal competition law, it is, in general, unnecessary to impose constraints in the spectrum market in order protect competition in downstream markets. Assuming, for example, that private mobile radio does provide a competitive constraint to public mobile operators (which is not necessarily the case in practice), and that measures to ensure effective competition are necessary, then the best means of achieving a competitive dynamic between public and private mobile radio would be through regulatory measures in the relevant end user market. Far from securing benefits for consumers, intervention in the spectrum market runs the risk of preventing spectrum becoming available for services which consumers find valuable.

Length of licences

7.50 Spectrum managers occasionally need to be able to take possession of spectrum in order to reorganise use of spectrum (refarming). There are two types of conditions which could be used to achieve this – both of which could be used. One is through the inclusion of a licence term which allows compulsory purchase; the other is through a licence term which has a rolling period of notice attached (once an initial period had passed). The review believes that long licences would provide more clarity for spectrum users who may, for instance, need to invest in expensive infrastructure, and would also allow licensees to offer long leases to lessees. Uncertainty about the length of licences is also likely to inhibit trading.

Recommendation 7.5

There should be greater legal clarity than at present about the tenure of incumbent licensees. Ofcom should consider, band by band, how best to provide some certainty for licensees to engage in trading, together with some ability for Ofcom to retrieve spectrum where necessary for any future strategic replanning of frequency bands. Options include converting the terms of licences to a rolling five to ten year period, or to perpetual licences with a compulsory purchase provision for Ofcom.

Information

7.51 The review believes it would be useful for Ofcom to be notified when trades take place and to maintain a public on-line register of the assignment of each block of spectrum. Such a register can assist spectrum trading by helping to inform market players about spectrum ownership. It would also allow the RA to detect sources of interference and enforce any conditions attached to the licences. Provided Ofcom publishes a comprehensive register of frequency assignments, enabling the market to identify changes in licensee, further reporting requirements, such as publication of transaction prices, may be unnecessary. Evidence from spectrum trading elsewhere suggests that specialist brokers can rapidly fill any information gaps. It would not be necessary for the RA/Ofcom to approve each and every trade in advance. The experience of spectrum trading in the USA suggests that such a requirement can unnecessarily hinder trading.

Trading and other management tools

7.52 Some respondents suggested that once spectrum trading was allowed in a particular sector, spectrum pricing in that sector could be abolished. It has also been suggested that trading should be restricted to areas where a full price for the spectrum has been paid through an auction. The review believes it is worthwhile distinguishing two separate arguments for retaining spectrum pricing after the introduction of trading, or for allowing trading only in areas where the spectrum had been originally allocated through auctions. One argument involves economic efficiency; the other, equity.

7.53 As discussed earlier, pricing, auctions and trading all oblige the holder of spectrum to take into account the opportunity cost of spectrum use. Auctions and spectrum pricing impose a direct charge for spectrum; trading imposes an indirect charge. If it is possible to trade spectrum the user will have to consider whether it is worth retaining the spectrum, or alternatively whether it should raise revenue by selling or leasing it to another potential user.

7.54 The review considers that operators in the commercial sector (where profit-maximisation is the key goal) are likely to make no distinction between the revenue foregone by not trading spectrum, and incentive pricing which charges for the spectrum used. As stated in the Smith-NERA report 'active spectrum pricing will not assist in achieving greater economic efficiency in a traded market.'

7.55 While a spectrum trading market is nascent, however, it may be useful to maintain pricing since it would provide information to market players about the level of prices at which spectrum might be traded. Once the market for tradable spectrum is well established, the need for pricing for efficiency reasons would disappear.

7.56 Another possible argument in favour of retaining spectrum pricing after the introduction of trading is to prevent windfall gains. If there were a difference between the price paid by a user for spectrum and the price at which it is later sold, and the gain in price is not caused by value added by the user, then the seller will make a windfall gain.

7.57 Any such windfalls are, in economic terms, simply a transfer payment and do not affect the efficiency with which spectrum is used. What would affect the efficiency with which spectrum is used, however, would be any limitations which dictated that spectrum could not be traded unless windfall gains had been entirely eliminated through auctions or spectrum pricing. The gains from trading spectrum, in terms of increased efficiency, should benefit the entire UK economy. Unnecessary restrictions which reduce the amount of traded spectrum would threaten the achievement of these efficiencies.

7.58 It should also be noted that the size of any windfalls could well, in practice, be limited. The review's recommendations on spectrum pricing and trading, coupled with the granting of increased flexibility over its use, would encourage and enable users to release spectrum onto the tradable market when they do not need it for their own uses. This increased supply should ease scarcity of spectrum and help restrain prices for traded spectrum, and hence the size of any windfalls.

7.59 Although not directly related to spectrum management, therefore, the Government may regard it as necessary to limit windfall gains, particularly in the early years of spectrum trading, where trading rights are granted to licensees which had not purchased their spectrum via auction. One way of addressing such concerns may be to levy a trading duty based on a proportion of the net gain from a particular spectrum trade. This, however, could involve Ofcom in complex assessments of individual transactions, and may distort the market by inducing incumbent users towards leasing spectrum rather than selling it outright. A less direct, but simpler approach, could be to maintain administrative pricing until licences are re-assigned via auction. As market prices and administrative prices converge, this should in itself reduce the scope for windfall gains. Perhaps the simplest approach however would be to tax windfall gains through the general tax system.

Recommendation 7.6

Trading rights should be extended to extant commercial licences regardless of the method of original assignment (auction, comparative selection, or 'first come, first served'). These rights should be granted for free. The Government should assess the case for levying a duty on net gains from spectrum trades and/or continuing with spectrum pricing for tradable licences, against its objectives of encouraging efficient use of spectrum and achieving full economic value for consumers, industry and the taxpayer.

7.60 The table below briefly sets out how a trading regime might work in practice:

Rights to trade spectrum

Nature of rights	Tradable spectrum access licences defined in terms of frequency, geography, emissions. Change of use within ITU allocation. Apparatus licences can also be sold in their entirety, or sub-divided where they cover an area and frequencies exclusively. Licensees have right to lease the spectrum within the licence.
Type of licence	Spectrum access licence of which partitioning/aggregation is allowed. Tradable apparatus licence.
Transfer of control	Registered with RA/Ofcom subject to new licensee agreeing to meet all the conditions within the original licence.
Aggregation/partitioning	Permitted, except where tradable apparatus licence is not exclusive to band or frequency.
Duration	Duration specified in licence terms when auctioned. Rolling period of notice for non-auctioned bands. Duration of traded spectrum is up to time remaining on original licence.
Technical parameters	Boundaries set for point at which negotiations between neighbours are triggered.
Method of changing interference parameters	Negotiations between the parties, subject to RA/Ofcom discussion/arbitration.
Service/technology constraints	Change of use allowed within ITU allocation.
Compliance with licence conditions	Licensee responsible for ensuring it and/or lessee complies with conditions.
Process for enforcing interference conditions	Licensees negotiate with each other. RA/Ofcom can take action and ultimately revoke licence if conditions breached.
Process for dealing with disputes between licensees	RA/Ofcom can intervene to arbitrate prolonged disputes Otherwise licensees resolve problems.

Method for dealing with international obligations	Licences have proviso that licensees must meet international obligations.
Licence variation/ cancellation	RA/Ofcom can revoke licences and make compulsory purchases.
Approvals process	No prior approval necessary. Only notification to RA/Ofcom certifying that conditions within licence will be met by new licensee.
Publicly available information	Public on-line database of assignments.

Role of a spectrum manager under trading

7.61 The review believes that the transition to spectrum trading will be complex, and therefore requires considered planning and progressive implementation over a number of years. But the movement to spectrum trading is essential. Spectrum trading leads to more efficient use of spectrum because it utilises the dispersed information and varying judgements held by a wide variety of current and potential users about the economic value of spectrum. As trading becomes more common, it could supplant to some extent the central planning role of the RA. Spectrum management organisations (SMOs), or band managers, (discussed in the box below) could play a greater role in assigning spectrum to individual users. There may then be a gradual shift in emphasis in the RA's approach to spectrum management, away from specific detailed assignments and towards more generic allocation policies, definition of tradable spectrum units with associated rights and responsibilities, and policing the operation of the secondary markets in spectrum usage. In particular, as trading becomes more common the role of RA, and later Ofcom, will focus increasingly on the following:

- issuing spectrum licences and tradable licences;
- enforcing licence conditions;
- ensuring access to spectrum is available to fulfil public policy goals;
- ensuring spectrum is not used to prevent effective competition;
- planning the use of spectrum over the longer term; and
- negotiating and giving effect to international obligations.

Chapter 15, on implementation of the review's advocated approach, discusses further the implications of spectrum trading for RA/Ofcom activities.

Spectrum management organisations

Spectrum management organisations already serve a number of different spectrum user groups. For example, the Joint Radio Committee (JRC) assigns spectrum for the fuel and power industries and the Joint Frequency Management Group (JFMG) assigns spectrum for programme-making and special events. In these areas, spectrum users obtain spectrum from the SMO rather than from the RA, although the RA determines the prices which should be paid, and the use to which the spectrum can be put.

A number of *de facto* SMOs may emerge as a result of spectrum trading since spectrum holders would then be able to sell or lease access to frequencies to others. But it may also be advantageous to take positive steps to create the conditions for more SMOs to emerge (for example by auctioning blocks of spectrum which licensees could then sub-assign for individual fixed links or private mobile radio use). There may also be benefits in lifting restrictions on existing SMOs, so they could purchase more spectrum and then lease it to any user, and for any use within international and technical constraints.

SMOs could lead to a number of advantages for users of spectrum, as well as increasing the efficiency with which spectrum is used. SMOs may for instance provide additional services alongside spectrum, e.g. network planning, or leasing equipment. SMOs would also have detailed knowledge of the needs of their users. This would provide them with the ability to assign spectrum in a way which increased the number of users within each block of spectrum, thereby helping to relieve congestion. The prices which SMOs had paid for spectrum would provide added incentives in this direction.

There would also be advantages for the RA/Ofcom in that they could leave many of the detailed assignment procedures to SMOs, and focus instead on more strategic goals, and on ensuring that competition was not distorted as a result of trading. Later chapters discuss how the use of SMOs may be extended in individual sectors.

Auctions

7.62 The auctioning of spectrum licences is now a well established practice among many national regulatory authorities. In the UK, as well as the auction for 3G mobile licences, spectrum at 28 GHz (designated for use by broadband fixed wireless access operators) has been sold by auction. Broadcasting regulators have also auctioned franchises for analogue commercial TV, and national radio stations; spectrum is one of the major and valuable assets bundled within the rights and obligations associated with each franchise.

7.63 Some respondents to the consultation document argued that auctions should be the preferred method of allocating spectrum. But others argued that auctions caused bidders to overpay for licences and should consequently be avoided; the example of the 3G auction was quoted a number of times. The review rejects claims that auctions raise prices to consumers and delay deployment of services. The review also considers that its recommendations, especially those concerning the introduction of spectrum trading and those which allow more flexible spectrum use, should lead to a more fluid market in spectrum which, in turn, would mean that any one particular auction for spectrum would be less critical to operators.

The 3G mobile auction

The recent travails of the telecoms sector, which followed auctions of 3G licences in the UK and other EU countries, have led some commentators to suggest that auctions have a number of negative effects including the raising of prices to consumers, and the delay of deployment of services.

The recent National Audit Office (NAO) report[18], considered these arguments. The report concluded that it was not evident 'that the cost of the licences will increase the price of 3G services to UK consumers', and pointed out that 'mobile telephone services in the UK are habitually priced according to market conditions, as opposed to simply passing on costs'. The NAO indicated that the cost of the 3G licences would be borne by the companies involved. The report stated that the mobile network operators 'will suffer to the extent that they have paid for spectrum, which in previous generations of telephony the government allocated to them at negligible cost. Their rates of return on their investments, and the value of their businesses, will be lower than they would otherwise have been.'

On the argument that the auction would delay the introduction of 3G services in the UK, the NAO said that 'although most major telecommunication companies, including the 3G licensees in the UK, have experienced greater difficulty in raising finance, Hutchison, One2One, Vodafone and Orange have already arranged funding for their new UK networks. Vodafone and Hutchison told us the high cost of their licence gave them an added commercial incentive to roll out 3G services more quickly than if the spectrum had been given away. Difficulties that remain to be overcome for roll-out to proceed are mainly technical, for example the development of suitable base station and hand-set equipment.'

Overall, the NAO said that they had not found 'strong evidence that the level of proceeds of the auction will have a negative impact on the wider economic benefit of 3G in terms of taxation and employment in the UK.' Also, the NAO noted that 'it was the bidders, not Government, who decided the price that was paid.'

[18] *The Auction of Radio Spectrum for the Third Generation of Mobile Telephones: Report by the Comptroller and Auditor General,* HC233 Session 2001-2002: 19 October 2001.

7.64 The review considers that auctions have significant advantages over other methods of assigning spectrum. The chief advantage is that they assign spectrum to the user who values it the most. This in turn serves as a proxy for judging which particular user will contribute most to overall economic welfare. As well as allowing spectrum to go the **user** which brings the most overall benefit to the economy, auctions can also ensure that spectrum is employed in the best possible **use** – provided there are no unnecessary restrictions on usage.

7.65 Auctions also have the advantage of creating a clear and objective process by which to allocate assets for which demand exceeds supply. Comparative selection or 'beauty contests' inevitably involve a degree of subjective judgement – even if the criteria against which bids are assessed are entirely clear – which can mean that spectrum is not assigned to the user who can most benefit the economy.

7.66 The review therefore agrees with the National Audit Office which recommended in its report on the UK 3G mobile auction[19] that the Government should recognise that 'auctions are a useful mechanism for allocating resources in many situations, particularly where demand for items outstrips supply; where there are likely to be more bidders than lots; and little information exists about their worth, though they are capable of being independently valued. Compared to other methods of allocation auctions can be more transparent, objective and relatively cheap to administer, and how bidders become winners is easier to understand. However, each economic environment requires an auction design and associated policy framework that is tailored to that environment – one size does not fit all.'

7.67 Auctions may not, however, be appropriate in areas where there are currently many different users of spectrum, who effectively share frequencies within a given area (such as private mobile radio and fixed links bands). It is envisaged that spectrum pricing would continue to be used for such areas, at least initially, although it may be worth considering the auctioning of overlay rights as a means of improving spectrum efficiency. Where auctions are used to assign spectrum there would be no need to impose administrative pricing as well since the opportunity cost of the spectrum would already have been paid through the auction process.

Overlay auctions

One particular use of auctions is to assign overlay licences. These involve auctions for blocks of spectrum which are encumbered by existing licensees which typically have apparatus licences (i.e. site- specific licences such as fixed links or broadcast transmitters).

Auctioning overlay rights can be useful when there is a need to clear spectrum of existing users, or when it is regarded as useful to create alternative arrangements for managing spectrum. In the first case, the purchaser of overlay rights would negotiate with users of spectrum to determine when and how it should be vacated. In the second case, particular bands encumbered with users would be auctioned, with the purchaser (a band manager or spectrum management organisation) then able to manage usage of the spectrum. Also, spectrum trading would allow *de facto* band managers to arise without auctions.

Studies[20] for the review considered the use of overlay rights in several countries, including the USA, Australia and New Zealand. The issues identified for consideration in granting overlay licences were:

- the rights of incumbents to interference protection;
- the new entrants' rights to interference protection; and
- the grounds on which the new entrant may ask the incumbent to vacate the spectrum.

[20] *Implications of international regulation and technical considerations on market mechanisms in spectrum management,* Aegis Systems and Indepen Consulting, November 2001.

[19] *The Auction of Radio Spectrum for the Third Generation of Mobile Telephones: Report by the Comptroller and Auditor General,* HC233 Session 2001-2002: 19 October 2001.

It was also suggested that in attempting to clear spectrum, overlay rights are most likely to achieve success when:

- incumbents' rights are time limited (two to five years);
- incumbents are paid compensation to vacate the spectrum before their licences have expired;
- new entrants offer incumbents the same interference protection as they had originally whilst they remain within the spectrum; and
- new entrants are similarly given the same level of protection from interference as would other site licensees in the band.

Recommendation 7.7

Auctions should become the default means of assigning spectrum licences between competing users, to achieve an efficient market-driven outcome.

Recommendation 7.8

Where licensees are currently granted tailored access to shared spectrum which is managed by the RA, such as in fixed links and certain private mobile radio bands, the RA should move progressively to converting the spectrum to auctionable geographic licence blocks. Competing commercial licensees would then manage access for their own and/or third party use of this spectrum.

Spectrum pricing

7.68 The introduction of auctions and spectrum trading will allow the development of a fully fledged market in spectrum. In some cases, however this will not be possible. For instance, some spectrum may not be suitable for trading, or spectrum may need to be reserved for public service users. Spectrum pricing is another means by which spectrum users can factor in the opportunity cost of spectrum into their decisions on usage. Under the WT Act 1998, the Secretary of State (acting through the RA) is required in setting spectrum licence fees to have regard to various spectrum management factors. These are:

- the balance between spectrum availability and current and expected future demand; and
- the desirability of promoting:
- efficient spectrum use and management;
- economic benefits;
- development of innovative services;
- competition.

7.69 Since enactment of the WT Act 1998, the RA has progressively introduced pricing across a wide range of spectrum-using sectors. Implementation has been staged, with pricing applied first to those sectors judged to be most congested and then progressively extended to others. Within each sector, transition from cost-recovery to incentive pricing has generally been phased-in over a four year period in order to allow users time to adjust. The Government decided that only half the amount of the increases implied by the methodology contained within the original Smith-NERA report on spectrum pricing should be implemented in this first phase[21]. This was in order that the rise in fees could be minimised and the effects of pricing monitored to see whether there was a spectrum management need for additional increases.

Phased implementation of spectrum pricing

In order to give users an opportunity to adjust, spectrum pricing was implemented in stages to different areas of use, and prices in each area have been increased gradually. The first stage began in July 1998, and applied spectrum pricing to public mobile telephony networks and reduced licence fees for users of on-site private mobile radio. The second stage, which began in July 1999, extended spectrum pricing to other mobile radio users and point-to-point fixed links. The third stage, which started in July 2000, extended spectrum pricing in the private mobile radio sector. Fees for national telecoms networks and point-to-point fixed links increased. Users of shared spectrum continued to benefit from fee reductions. The fourth stage, which started in July 2001, extended spectrum pricing principles to some earth stations and to some areas of the programme-making and special events sector. Fees for national telecoms networks, common base stations and fixed links increased for congested or national channels, while fees in non-congested areas continued to decrease.

7.70 There are a number of different ways in which the opportunity cost of spectrum use can be derived. The review considers that the methodology set out in the original Smith-NERA report currently remains the most appropriate for the purpose of establishing administratively set spectrum prices.

Smith-NERA methodology

The Smith-NERA approach to spectrum pricing involves calculating the marginal value of the spectrum to the user. The rationale for this is that ideally, administrative pricing would result in fees equal to market clearing rates that balanced supply and demand for spectrum. In practice, it is extremely difficult to estimate this rate. One possible method is to assess the marginal value to the user on the basis of the additional cost of the least-cost practicable alternative to the present assignment. This is a measure of the worth of the assignment since it reflects the amount that the user would have to pay if deprived of it.

For example, for a user of a point-to-point fixed links band the most cost-effective alternative was regarded as being the installation of narrow bandwidth equipment or moving to higher frequency links. The costs involved gave the marginal value of the

[21] *Spectrum Management: into the 21st Century,* DTI White Paper, June 1996.

spectrum. For a private mobile radio user, the marginal value of the spectrum was regarded as being equivalent to the additional cost involved in using a public access mobile radio band. The Smith-NERA report proposed that the marginal values should be based on the least-cost practicable option for enhancing spectrum efficiency. The actual prices charged should vary according to factors such as bandwidth, coverage, degree of sharing, and geographical location.

7.71 The Smith-NERA methodology allows prices to be set at levels which take into account the degree of congestion in a particular band and/or in a particular locality. The Smith-NERA report suggests that lower prices are set in areas or bands where congestion is currently not severe. This is the practice of the RA at the moment and the review recommends that it continues so spectrum prices are set at levels which take into account the regional variations in the demand for spectrum. The review welcomes the RA's work in monitoring the degree of congestion in different bands and localities. The review's recommendations entail the extension of spectrum pricing across a wider range of services, as well as the raising of prices in areas where spectrum pricing has already been applied. This will necessarily involve more detailed work for the RA on the definition of congested and non-congested areas.

7.72 Because of the relatively recent launch of incentive pricing, and because price increases have been phased in over time, with prices not yet reaching the full opportunity cost level, any conclusions on the impact of spectrum pricing so far are necessarily tentative. The RA is currently conducting further studies on the impact of spectrum pricing to date and the review welcomes this valuable work. Nevertheless, there is some evidence that the extent of pricing leaves further scope for adjustment. For instance, at the current levels of incentive prices there have only been a few instances of the return of spectrum to the RA following the introduction of incentive pricing, and congestion in a number of different bands does not appear to have been materially affected. This is not surprising given that pricing is only likely to influence decisions on spectrum usage when it is set at the full opportunity cost level.

7.73 The review considers therefore that in light of continuing and prospective spectrum congestion, further price increases should be introduced. This would necessarily involve recalculating the full opportunity cost price levels to take into account developments since they were last revised in 1998, using the methodology contained in the Smith-NERA report. The actual prices set should reflect the main factors affecting spectrum consumption, and thus the degree of congestion, including bandwidth, coverage area and the degree of sharing. Secondary factors, such as competition, choice and diversity, quality of service and spectrum usage constraints, are not as relevant.

7.74 Companies will, however, require a degree of certainty about the price at which they are being charged for spectrum and no major changes within this time period. For this reason, the review considers that where spectrum pricing has started to be phased-in, the first phase should be completed before subsequent increases in prices to full opportunity cost levels are introduced.

7.75 The Smith-NERA report makes clear the importance of monitoring market developments and modifying spectrum charges in the light of changes in technology, equipment costs and demand for spectrum. This may mean that there is a potential reduction in prices in non-congested areas. Prices paid for spectrum on the traded market could also be monitored so that administratively set prices and market-determined prices could converge over time where competitive market prices provided useful information about the revealed opportunity cost of spectrum. On the other hand, there is a need to provide some degree of stability to spectrum users. The review believes therefore that the RA should continue to monitor the effects of pricing, and change prices where there is evidence of congestion, but commit itself to a certain time period during which prices would not be altered.

Recommendation *7.9*

Spectrum pricing should be applied at more realistic levels and more comprehensively across spectrum uses. Where spectrum pricing has already been implemented, and where there is evidence of continuing shortage of spectrum, then incentive prices should be set at the full opportunity cost level, rather than at the current 50 per cent of the levels derived from pricing models, which should themselves be subject to regular review.

7.76 Later chapters discuss the application of this recommendation to individual areas of spectrum use. It is worth considering here, however, two possible arguments against spectrum pricing which have been raised during the consultation process.

7.77 First, some users of spectrum pointed out that they generate externalities through their use of spectrum, i.e. that the social value of their spectrum use differs from the value to the user itself. The review acknowledges that in such situations, spectrum pricing could potentially result in inefficient outcomes since it could result in too little of the socially beneficial activity being provided. But this could be avoided if the necessary funding was made available to the spectrum user to pay for the reserved spectrum required. This would enable the service in question to be provided, whilst also ensuring that spectrum was used in the most efficient way possible.

7.78 Another possible argument against spectrum pricing, particularly amongst public sector users, is that spectrum pricing would simply lead to a recycling of funds between different branches of government. But the review considers that even if the public sector user were to be fully compensated for their spectrum use, then it would still have incentives to reduce usage of spectrum and use the funds made available for other purposes. This should prove of benefit to other users, and the overall economy, by releasing spectrum.

Spectrum pricing and other tools

7.79 The RA is responsible for setting the prices for spectrum in line with its statutory responsibilities under the WT Act 1998. In the industries in which spectrum is being used, factors relevant to determining the opportunity cost of spectrum use change all the time as consumer demands shift and as it becomes possible to supply new services. It is difficult, however, for the body responsible for valuing spectrum to keep pace and to gather all the information necessary to price spectrum properly. In order to respond to the rapidly changing demands for spectrum, it would be necessary to update administratively set prices on a regular basis to reflect new information about current valuations of spectrum use, e.g. from relevant auctions. At the same time, however, spectrum users will require a degree of certainty about the level of spectrum fees they pay. The resulting lack of flexibility and responsiveness is an inherent flaw within any system of spectrum pricing.

7.80 Unless other tools – especially spectrum trading – are used therefore there is a danger that the spectrum management system would lack the necessary flexibility to keep pace with shifting demands. The review believes therefore that whilst incentive pricing has benefits, its use should be focused on those areas where other tools are not, in themselves, sufficient to ensure efficient use of spectrum. This would mean for instance that incentive pricing would be unnecessary where spectrum had been auctioned. Where spectrum becomes tradable, spectrum pricing may be necessary in the short to medium term whilst the market is nascent or where there are concerns about windfall gains, but would not be necessary in the longer term.

Conclusions

7.81 This chapter has set out broad recommendations for how the spectrum management system should change to cope with the rising and increasingly unpredictable demand for spectrum. Wherever it is possible to remove restrictions on how spectrum is used, this should happen. Exposing spectrum users to the whole opportunity cost of their use is also vital. Opportunity cost charging may be regarded as an esoteric economic concept, but the purpose of it is simple enough: to create full and proper incentives to use spectrum efficiently. Unless this is done, there will be a substantial loss to the UK economy, one which will increase over time as communications services become more crucial to generating economic growth.

7.82 In summary, the recommendations made in this chapter would entail the following:

- existing WT Act and other relevant licences (e.g. Broadcasting Act) should be modified to allow spectrum to be used for a wider range of different purposes, within ITU allocations. New licences should be issued with minimal restrictions on the type of service which can be deployed in a particular band and coverage;
- auctions should become the primary means of assigning spectrum initially between different uses and users;
- prices should be increased to the full opportunity cost level implied by the currently applied Smith-NERA methodology; and
- once trading is allowed by EC and UK legislation, existing licences should be altered to enable spectrum trading.

Later chapters describe how the recommendations set out in this chapter apply in particular areas of spectrum use.

8 COMMERCIAL SERVICES

Introduction

8.1 Demand for spectrum for commercial uses has grown considerably in recent years, particularly in the telecoms sector. Growing use of mobile phones, for instance, has led to both a direct increase in the demand for spectrum, and an indirect increase through rising demand for support infrastructure, e.g. fixed terrestrial links, which use spectrum. The technological changes outlined in Chapter 2 meanwhile have meant that many telecoms operators are able to offer services which were beyond their capabilities only a few years ago, e.g. internet access over mobile phones. Such changes are likely to accelerate in the next few years, further increasing the demand for spectrum.

8.2 The extension of market-based spectrum management tools in the commercial bands should help improve the efficiency of spectrum utilisation. In particular, the review considers that:

- operators should have greater flexibility to decide which services they offer to consumers;
- spectrum trading should be introduced once legislative changes make it possible;
- auctions should be used to assign spectrum between competing users; and
- administratively set prices should be raised to the full opportunity cost level.

The rest of this chapter describes how these broad recommendations, developed in Chapter 7, can be applied in particular segments of commercial spectrum use.

Public mobile telecoms

Flexibility over usage

8.3 Public mobile telecoms include both voice and data services delivered via public paging and mobile phone networks. The majority of spectrum for public mobile telephony is subject to EU or CEPT decisions harmonising the use of particular frequencies to specific technologies. For example, spectrum for Second Generation mobile phones has to employ GSM-standard equipment. More recently, the spectrum identified for 3G mobile systems is required to deploy apparatus using IMT-2000 standard radio interfaces, which offer more choice in the technology used.

8.4 The review believes that consumer interests are best served if the users of spectrum have maximum flexibility to decide how they use spectrum. In order to achieve this, new licences which are assigned to public mobile users should have minimal restrictions on the technology which can be used within the

bands, on the services which can be provided, and on the pace with which services are deployed. Existing licences should also be modified to allow greater flexibility for operators in each of these areas.

8.5 Harmonisation decisions taken at the European level may, on occasions, unnecessarily limit the technology which can be deployed within some bands. The review believes that the UK should seek early retirement of harmonisation decisions which have outlived their usefulness, such as the ERMES public paging directive. The GSM harmonisation directive, which has now served its purpose, should also be phased out. This would provide operators more flexibility in the range of technologies and services which can be deployed, allowing them, for example, to decide whether and when they wished to use 2G spectrum to provide 3G services. Any alterations to extant licences should clearly be subject to the commitments given by the RA at the time of the 3G spectrum auction. The review considers that the mobile network operators are in the best position to decide whether or not their customers should continue to use 2G spectrum, or alternatively migrate to 3G services.

Spectrum trading

8.6 The review recommends that spectrum trading be introduced as soon as practicable for all public mobile telecoms spectrum. Trading could bring significant benefits by allowing operators to tailor their spectrum licences to their specific needs, and enabling new entrants to obtain spectrum for innovative services using compatible technology.

8.7 Where licences had previously been assigned by comparative selection and are now subject to spectrum pricing, licences should be converted to tradable form. Ofcom could continue to impose spectrum prices in the early years following the introduction of trading to provide ongoing financial incentives, or to address concerns about windfall gains accruing to licensees.

Auctions

8.8 Five licences for 3G mobile telecommunications services were assigned by auction in early 2000. Four network operators meanwhile use the spectrum licences for 2G mobile services which were assigned through comparative selection, and which are now subject to incentive pricing. As well as ensuring that the 3G licences went to the users who could deliver most value from them, the auction process is also likely to spur faster rollout of services as holders of licences strive to maximise returns before their licences expire at the end of 2021. The review endorses the view of the National Audit Office which stated in its report on the 3G auction[1] that compared with other methods of assignment, auctions 'can be more transparent, objective and relatively cheap to administer'.

[1] *The Auction of Radio Spectrum for the Third Generation of Mobile Telephones,* Report by the Comptroller and Auditor General, HC 233 Session 2001-2002, October 2001.

8.9 The review considers, therefore, that auctions should be used to assign any new spectrum identified for commercial mobile services. Additional spectrum may be available for 3G use in the future. Some of this (the so called 3G expansion bands) is located at 2.5 GHz, and is currently used for broadcast programme-making. The possibility of relocating the current users of the bands is being explored by the RA. If this is done, the review recommends that the spectrum licences be sold through a competitive auction with no restrictions on use other than those necessary to meet international and technical constraints. The existing 3G operators would then have an opportunity to bid for it, as would potential new entrants.

Pricing

8.10 Incentive pricing has been applied in the public mobile telecoms sector, but some signs of congestion remain[2]. Some areas are more congested than others, but in all cases, the review considers that users of spectrum should pay the full opportunity cost price, which would vary by location.

8.11 The review recommends, therefore, that following implementation of the current phase of incentive pricing, prices for public telecoms operators should be raised to the full opportunity cost level over a period of two to three years, following a re-evaluation of the price levels implied by the Smith-Nera methodology.

Recommendation 8.1

Auctions should be used to assign spectrum available for public telecoms use. Where spectrum pricing is currently used, prices should be raised to the full opportunity cost levels. Once spectrum trading is introduced, public telecoms operators should be able to trade spectrum subject to international constraints.

Licence-exempt spectrum use

8.12 Some types of radio equipment have been exempted from the requirement for individual licence under the WT Act, by Regulations made under Section 1 of the Act. Use of specified types of device without a licence is on the understanding that the equipment shall not be provided with the same protection from interference that would otherwise be available to licensed services. Factors involved in determining exemptions include:

- the particular frequency allocated for transmission;
- the power of transmission;
- the use to which equipment is put;
- the compliance of equipment with agreed national or international standards; and
- the need for the equipment to be protected from interference from other authorised users.

[2] *(Draft) Strategy for the Future Use of the Radio Spectrum in the UK,* Radiocommunications Agency, November 2001.

8.13 Many users of spectrum are thus exempt from individual licensing. In the case of user terminals (such as mobile telephones or televisions), this is because spectrum use is controlled by the licence granted to the system operator. The other broad category of licence-exempt spectrum uses are those where the propagation of radio signals (defined by the permitted power levels and technology standards for the band) is judged to be so localised that they do not materially interfere with other spectrum users. In other words, the costs of regulating via licensing outweigh the potential benefits. These uses are typically confined to bands which are dedicated to licence-exempt use, often those which had originally been designated for industrial, scientific and medical uses.

8.14 Use of licence-exempt spectrum is on a non-interference, non-protected basis. Users of such deregulated spectrum must not cause interference to other authorised spectrum users, nor can they claim protection from interference from such services. With short-range propagation and few devices in any given location, the risk of interference caused by such low power licence-exempt spectrum use has historically been relatively low. At the same time, the absence of regulations covering receive-only equipment has meant that in some cases equipment can be very vulnerable to interference from other services. Technology now offers the prospect of increasing the intensity of spectrum use in these unregulated bands through the use of systems which are automatically self-protecting and 'polite'. By dynamically selecting channels, these avoid interference coming into the band and minimise transmitting over other signals within the band.

8.15 Licence-exempt spectrum provides an alternative paradigm to regulating for economically efficient spectrum use. Instead of minimising harmful interference through exclusive access to spectrum, the regulator enables multiple re-use of the same spectrum space by limiting the geographical coverage of transmissions. This provides significant flexibility for users, which in turn creates demand for innovative applications of radio technology within these bands. Technology developments are increasingly enabling more valuable broadband applications to be delivered across licence-exempt spectrum.

8.16 At present in the UK, use of licence-exempt spectrum for the provision of public access communications systems is prohibited under WT Act regulations. Recent studies for the RA[3] (summarised below) have assessed the impact of alternative regulatory strategies in this area.

[3] *Spectrum Management Strategies for Licence-Exempt Spectrum,* report for the RA by Mason Communications Ltd and DotEcon Ltd, November 2001.

Deregulation of licence-exempt spectrum

Technical analysis

Both public and private use of radio local area networks (RLANs) in the 2.4 and 5 GHz bands is feasible from a technical perspective. The use of mesh FWA systems in the 5 GHz bands appears feasible if geographic limitations, to rural and suburban environments, can be ensured. The lack of progress on standardisation means that no conclusions can be drawn for the 3G licence-exempt band from 2010 - 2025 MHz. The use of the 1.9 GHz DECT spectrum to offer licence-exempt public and private services appears technically feasible, assuming systems conforming to the current DECT specifications are employed. Use of higher gain antennas to deploy wireless local loop services in this band would cause potential problems to current and future users of DECT for telephony. Overall, if systems with homogeneous operating characteristics (i.e. with similar bandwidths, EIRPs, etc) using 'polite' technologies are employed, then generally more benign sharing situations will result.

Economic analysis

Given reasonable take-up and pricing assumptions, it is considered that allowing the introduction of RLANs would generate a very substantial consumer surplus in the order of £500 million per annum for the UK. The overall impact on economic welfare is likely to be of a similar order to this, regardless of whether market conditions are effectively competitive or not. The technical analysis suggests that allowing public access use of the 2.4 and 5GHz bands is likely to generate minimal additional interference costs for existing users. In particular any such costs (including possible costs for existing users of SRDs) are very unlikely to exceed these benefits. Overall, this strongly suggests that allowing public access systems to use licence-exempt spectrum is likely to be beneficial, but that certain conditions ought to be put in place in order to make sure that congestion and interference are minimised. Where there may be difficulties in accommodating all possible uses of unlicensed spectrum, priority should be given to services meeting new demands rather than those substituting for similar existing services supplied by other means. This may imply giving greater priority to RLANs than FWA systems to the extent that the demands they make on unlicensed spectrum conflict.

8.17 The review agrees with the conclusions of this study that there are significant consumer benefits which this highly innovative and ubiquitous use of spectrum can bring. The potential drawbacks of this regulatory approach are that the quality of transmissions cannot be guaranteed, and the utility of the spectrum may ultimately be degraded through excessive use. The review considers, though, that a combination of market forces and regulation is capable of resolving these challenges:

- users will decide between licence-exempt and licensed spectrum use, depending on the quality of service they require;
- interference from local congestion is often internal to a user's premises and can therefore be regulated by that user; and
- ultimately, if particular bands show signs of becoming congested, then manufacturers can improve the resilience of radio equipment to interference and regulators can restrict the propagation of signals through power limits.

8.18 The review therefore considers that further liberalisation of use of licence-exempt bands, by opening up such spectrum to a range of technologies and services, is likely to deliver significant consumer benefits.

Recommendation 8.2

The current constraint on the use of licence-exempt bands for the provision of public access communications services should be removed as soon as possible.

8.19 Finally, the review believes that there is also significant future potential for some of these licence-exempt services at frequencies above 50 GHz, due to the associated propagation characteristics of that spectrum (i.e. high levels of attenuation which limit interference to very localised areas). Up to now technological constraints have been a limitation. These propagation characteristics also render this spectrum valuable for other services, such as space science and fixed services.

Private mobile radio

8.20 Private mobile radio (PMR) is a broad term which covers a wide range of different services including voice, paging and data services which are provided to a closed-user group. Private mobile radio is a complex licence sector, with over 55,000 licensees across the UK including a large number of emergency service and other public safety operators. The services use spectrum in a selection of bands from 26 MHz to 5.8 GHz.

8.21 The RA currently issues a wide variety of licences tailored to the spectrum use defined under the licence. Frequency planning is primarily managed by the RA, to enable a large number of localised users to share a given national channel. Demand for spectrum in this sector is rationed by the RA, through the application of spectrum prices and the careful assignment of licences. For some bands, spectrum management is devolved to organisations catering for the radio needs of defined groups (such as the utilities). Although some PMR users have begun to start using public telecoms systems, many prefer to remain within the PMR bands because of cost advantages and the availability of added functionality.

8.22 The use of PMR remains high and congestion continues to exist in a number of different PMR bands. The RA has stated that it is seeking to make available more spectrum for PMR use, including spectrum used for military purposes in the 410-430 MHz band, and spectrum at 450-470 MHz currently used by emergency services. But it is not yet clear when such spectrum might be made available.

8.23 One measure which could help relieve congestion in the shorter term is to encourage PMR users to move to more spectrally efficient technologies such as digital equipment. Such equipment may also allow PMR users to roam onto public mobile systems which would create much more flexibility for the users. The review considers that such moves could be supported through the application of market-based spectrum management tools in the PMR sector.

8.24 Although spectrum pricing for PMR users was introduced in July 1998, prices have not yet reached the full opportunity cost levels. The review recommends, therefore, that given the continuing congestion in certain areas, administrative prices for PMR users should be raised to the full opportunity cost levels (see Chapter 7).

8.25 The review also considers that licensees should be given the ability to use the spectrum within their licences for a wider range of purposes than hitherto. It is recommended, therefore, that restrictions in licences unrelated to interference management be removed. Trading would also help in creating more efficient usage and the review recommends therefore that once trading is made possible, PMR licences should be converted to tradable form. With the publication of a frequency assignment database, these steps should enable a market to develop in spectrum currently allocated to private mobile radio.

8.26 The introduction of spectrum trading will allow PMR users to sell their licences if they wish. Trading would also enable the emergence of band managers for PMR spectrum, if that were supported by market demand. As discussed in Chapter 7, these band managers could create greater flexibility over spectrum use and encourage more efficient use. Band managers for PMR spectrum could emerge by purchasing spectrum from a number of different users to create a broader licence. The band managers would be able to charge a fee for the right to use the spectrum to the current licensees, who could retain their existing rights to spectrum use and effectively become lessees of the commercial band manager. The band manager could then use or lease any additional spectrum included within the licence.

8.27 Another means of creating competing national band managers for a range of PMR bands would be to auction spectrum in these bands. The review believes it would be useful for the RA to conduct an early experiment along these lines in one or more PMR bands. If successful in enabling innovative and intensive use of spectrum, this approach could ultimately be extended across the majority of PMR spectrum.

8.28 The review considers that there would be significant benefits for PMR users if they were given greater flexibility over how they obtain spectrum. As well as being able to choose between using a public telecoms network or PMR spectrum from the RA, the introduction of spectrum trading would allow PMR users to obtain spectrum from other PMR users, or from a number of competing band managers who may choose to offer equipment and/or added value services. Also, there would be efficiency gains for the broader economy as there would be greater flexibility over how spectrum could be used.

Recommendation 8.3

Current restrictions on the use of PMR bands should be removed, and PMR licences should be made tradable. Area licences should be auctioned in a number of different bands. This approach could, if successful, be extended across the majority of PMR spectrum.

Fixed terrestrial services

8.29 Another major use of spectrum is in the provision of fixed terrestrial services for infrastructure and access networks for telecommunications and broadcasting systems. The ITU has allocated a large number of frequency bands for such use, within the broad category of fixed services. In the UK, the RA licenses a number of these bands, ranging from around 1.4 GHz to 58 GHz, for fixed terrestrial services. Some of the spectrum is used to provide point-to-point fixed links, whilst another use is to provide fixed wireless telecoms services to homes and businesses. The RA currently makes individual assignments for fixed links licences, and assigns exclusive geographical area licences for fixed wireless access, such as the ongoing auction for regional 28 GHz licences for broadband services.

Flexibility over use

8.30 The spectrum in each of the bands used for fixed terrestrial services has its own particular characteristics (e.g. bandwidth, propagation distances). This means that some bands can be used for certain purposes (e.g. broadband services) while others cannot. Nevertheless, the international allocations for fixed services offer some scope in terms of the types of systems which can be deployed. For example, the bands can be used to deploy either fixed point-to-point links or point-to-multipoint fixed wireless access services.

8.31 At present, however, the RA imposes limits beyond international restrictions on the use some of the bands. For example, spectrum at 28 GHz has been allocated by the RA for broadband fixed wireless access (BFWA) only. This means that licensees are prevented from deploying fixed links for purposes other than their own infrastructure network. Some regional licences in the band were assigned following an auction in November 2000, but most remain unsold, despite being made available in a further award process which began in October 2001. The inability to date to sell all the licences is partly due to the downturn in the telecoms sector. But it also demonstrates that it is impossible to create a consumer demand for a service (in this case, broadband services) simply by reserving spectrum for it. Reserving spectrum for a particular service where demand for that service is either unproven or limited means that the spectrum cannot be used for anything else, and hence potentially lies fallow.

8.32 If greater flexibility were allowed, operators could decide whether they wished to deploy BFWA services within some of the licence area, and fixed links within the rest. Alternatively, operators may decide to use all the spectrum for fixed links, unless and until a proven demand for BFWA services emerged. It may also be the case that in some parts of the country, the best commercial option is to use the spectrum for BFWA, whilst in others the commercially viable option is to use the spectrum for fixed links. Designating spectrum for only a subset of the possible services, therefore, risks hindering the development and deployment of new kinds of services - something which is clearly not in the interests of consumers. The review believes that providing

operators with extra flexibility in use and trading of the spectrum will encourage the deployment of a range of complementary broadband access and other fixed wireless technologies. This approach will enable operators to respond directly to the changing market demands for broadband and other telecoms services.

8.33 The review considers therefore that the existing assigned and unassigned licences for the 28 GHz spectrum should be modified to allow the commercial deployment of fixed services other than BFWA, within the geographic and frequency bounds of the licences. Interference management within and at the boundaries of the licence would remain the responsibility of the licensee, subject to co-ordination requirements embedded within the licence terms. Licensees in other bands used for fixed wireless access should also have their licences modified to allow the deployment of other fixed systems, taking into account international obligations and technical considerations.

Trading

8.34 Once spectrum trading has been introduced, licences for fixed services should be varied to allow it. This will create greater flexibility over the usage of spectrum. Possibilities for trading fixed links are limited since individual fixed links are, by definition, specific to two defined end points, both of which are often owned by the link operator. It should be possible, however, to trade individual links, which would allow operators to reconfigure their networks.

8.35 One way of increasing flexibility, however, may be to assign area licences for operators to use spectrum for fixed services. The holders of these licences could then deploy a variety of fixed wireless infrastructure links or broadband access systems, or trade or lease access to others to do so within the limits of the licence. In effect, the holders of the licences would become spectrum management organisations (see Chapter 7). This approach has been adopted in USA with the auction of spectrum at 39 GHz for microwave services and at 4.7 GHz for so called General Wireless Communications Services. Such a mechanism increases the efficiency of spectrum use because it grants operators greater scope to make intensive economic use of the spectrum. This could best be trialled in the UK by auctioning a number of national licences in spectrum which has yet to be assigned (such as at 32 GHz).

Auctions

8.36 As discussed above, auctions have already been used to assign spectrum for fixed terrestrial services in the 28 GHz band. The review believes that auctions should be used to award other spectrum which is made available for fixed systems.

8.37 One such band, at 40 GHz, has been allocated at an international level for high capacity broadband services, in particular for converged Multimedia Wireless Systems (MWS). The definition of this service is quite broad, in that it allows the deployment of fixed wireless access direct to the end user for multimedia services. These multimedia services include more than simply

broadband internet access; in theory, broadcasting could be provided. As well as MWS, other services, including high-density fixed services and satellite downlinks can also operate in the 40 GHz band. The review considers that the broad range of services which can be offered using the 40 GHz band makes it a suitable place to introduce spectrum access licensing (described in Chapter 6). The review recommends that area licences for spectrum at 40 GHz should be auctioned, with minimal conditions attached to the service deployed in the band. Once spectrum trading is permitted, operators will be allowed to trade these blocks.

Pricing

8.38 Spectrum pricing was introduced to fixed links bands in 1998. Since then prices have been gradually increased, and the initial phase of price increases (to half the full opportunity cost level) will be completed in July 2002. Nevertheless, signs of congestion remain in fixed links bands. As the RA has highlighted[4], there has been a significant increase in demand for fixed links over the past few years, particularly in the higher frequency bands such as 23, 25 and 38 GHz. In order to help relieve this congestion, the review considers that the full opportunity cost level of prices in all fixed links bands should be reassessed, and prices then raised to the full opportunity cost level.

Recommendation 8.4

Current restrictions on the use of fixed wireless access bands should be removed so as to allow the deployment of any fixed service. Licences should also be converted to allow spectrum trading. The RA should begin to auction area licences in fixed bands which would allow the licensees to deploy any fixed service, or trade the rights to do so

Programme-making and special events

8.39 Broadcasters, independent production companies, theatres and organisers of special events (e.g the British Grand Prix) all use spectrum as part of their output. The demand for this spectrum from the programme-making and special events (PMSE) sector is growing rapidly as the number of programmes, the amount of broadcasting from outside broadcasts, and the quantity of cameras and other radio devices (such as radio microphones for theatres) deployed at such events have all increased.

8.40 For these uses, the RA makes available a number of different frequencies in a wide range, from 47.55 MHz to 48.5 GHz. Many of the frequencies are shared with other users (e.g. radio microphones share spectrum with TV broadcasting), or make occasional use of spectrum assigned to others, e.g. the Ministry of Defence.

[4] *(Draft) Strategy for the Future Use of the Radio Spectrum in the UK,* Radiocommunications Agency, November 2001

8.41 The Joint Frequency Management Group (JFMG), a commercial company owned by major PMSE stakeholders, has been contracted to manage and license the radio spectrum used for programme making and special events. The fees for the relevant licences are set by the RA.

8.42 The JFMG therefore acts as a contractor for the process of managing spectrum and assigning it between users. Although it has incentives, as a profit-oriented company, to conduct this process as cheaply and effectively as possible, it does not have the ability to vary prices to relieve congestion, nor to encourage the move to more spectrum efficient equipment. Also, there are currently limits which restrict the ability of the JFMG to offer spectrum to users other than programme-makers or special events, e.g. the JFMG can license spectrum for use by microphones at a concert, but it cannot license use of similar spectrum by security or catering services at that concert.

8.43 In line with the review's general principles of creating greater flexibility, the review considers that these limits should be removed as soon as possible, and the JFMG should be able to assign its spectrum to any use within international and technical constraints. This would mean, for example, that the JFMG would be able to provide spectrum for private mobile radio use on the same terms as it does for PMSE users. Once spectrum trading is introduced, other holders of spectrum would be able to offer their spectrum to the PMSE sector. The review also considers that in order to ensure efficient usage, the price charged by the RA for PMSE spectrum should be raised to the full opportunity cost level, which the JFMG would, in turn, pass onto users.

8.44 The review also suggests that the option of auctioning spectrum for PMSE users be explored further as a means of ensuring efficient use of spectrum. There may be limited amounts of spectrum in such bands and it will not necessarily be possible to have more than one spectrum management organisation for these PMSE users. This could lead to competition problems in the provision of such spectrum. Such problems are unlikely where users within the PMSE sector can use spectrum in other bands, but where users have dedicated equipment designed for particular bands there could be a danger that any spectrum management organisation would price excessively. If such competition problems are likely, it may be necessary to have some form of *ex ante* regulation of the spectrum management organisation's prices.

Satellite services

8.45 Satellite services play an increasingly important role in communications. Satellite-based systems mirror the range of applications provided by terrestrial systems, e.g. mobile, broadcasting, fixed, radionavigation etc. The Government's latest UK online report[5] recognises the role of satellite technology in helping to introduce broadband communications and digital TV in the UK.

[5] *The UK online annual report 2001,* DTI/Office of the e-Envoy, November 2001.

8.46 A variety of satellite services exist including:

- Mobile Satellite Systems (MSS) involve a communication system between mobile earth stations or terminals and one or more space stations.
- Fixed Satellite Systems (FSS) involve earth stations in given fixed points on the ground (including transportable terminals) and one or more space stations.
- Broadcasting Satellite Systems (BSS) involve a radiocommunications service transmitted by a space station which is intended for direct reception by the general public.
- Other categories include radiolocation satellite services, inter-satellite services and space science services.

8.47 Because of their location in orbit, transmissions from satellite transmitters can have large coverage areas, or footprints. Depending on the satellite's orbital height and the antenna beamwidth, the size of the footprint can range from parts of a country to entire continents. Although the development and launch of satellite systems entail a significant initial expense, they allow satellite operators to access directly large numbers of customers without the need to build extensive terrestrial infrastructure.

Licensing of satellite services

8.48 Some satellite systems are currently subject to UK licensing. Satellite transceivers in the Inmarsat, Eutelsat, Intelsat, Iridium, ICO, Globalstar land mobile satellite services are exempted from individual licensing by a class licence, and receive-only satellite dishes are exempted from WT Act licensing by statutory instrument under the Act. Other customer-based satellite transceivers are licensed collectively by the system operator. Also, transmissions to satellites from fixed sites in the UK are licensed under the WT Act (and subject to administrative pricing for use of these bands reflecting the amount of spectrum occupied and based on charges for terrestrial fixed links which share the bands).

8.49 The use of spectrum for transmissions **from** satellite space stations **to** UK-based receivers is not, however, subject to WT Act licensing at present. This means that the users of the spectrum could face some uncertainty that their services would be protected from interference if they share bands with other (usually terrestrially-based) services. Spectrum access licences could be introduced as a way of providing such certainty. Instead of authorising the use of a specific device, spectrum access licences would authorise the use of spectrum space, and give licensees the freedom to deploy any device which transmitted through their spectrum space, provided that the device is compatible with the core conditions of the licence and the technical framework for the bands. This form of licensing would have the advantage of defining the interference protection afforded to satellite and terrestrial systems operating in the same or neighbouring bands. It would also provide greater clarity to operators of satellite systems as to the spectrum they could use.

8.50 Access to spectrum for transmissions to and from satellites is subject to extensive international planning and co-ordination. In particular, some frequencies are tied to specific satellite systems, often for the delivery of international services. Trading of such frequencies within the UK's jurisdiction is therefore unlikely to be feasible. The use of auctions would also be difficult where satellite transmissions extended across a number of different countries. Auctions and trading may, however, be facilitated by creating a system of area licences whereby licensees could use spectrum for transmissions to and from satellites, but could also use the spectrum for entirely terrestrial use, or a mix between terrestrial and satellite services. Such licences could be auctioned.

8.51 There may also be scope to use spectrum pricing to ensure that satellite operators face the opportunity cost of the UK spectrum which they occupy. Any such pricing regime should, however, take account of the fact that in many cases, spectrum used by satellite operators has no opportunity cost. Some spectrum for instance is internationally allocated to satellite use on an exclusive basis, and does not constrain any other terrestrial or satellite service. For example, the same bands can be re-used for downlinks to the UK from multiple satellites; the scarce resources in this case are slots in the geostationary orbit, access to which is regulated at the ITU level. If, however, spectrum used by satellite operators can be used for other purposes then there will be an opportunity cost, e.g. where frequencies are internationally allocated to satellite and terrestrial services on a co-primary basis.

8.52 The opportunity cost will arise to the extent that satellite services can cause, or be susceptible to, interference from these other services. The possibilities for interference can be broadly categorised as follows:

Interference scenarios between satellite and terrestrial systems

A: Interference to terrestrial systems from satellite space stations

In this scenario, the transmitted signal from the satellite (downlink) interferes with receivers of other terrestrial services which share the same or similar frequencies. The degree of interference depends on the extent of frequency overlap, the power level and position of the satellite. Any interference which occurs will, to some degree, constrain the deployment of terrestrial services, although the permitted maximum power level received on the ground from satellite transmissions tends to be defined internationally by the ITU.

B: Interference to satellite space stations from terrestrial systems

In some cases, it becomes necessary to place limitations on terrestrial systems to protect the receivers on satellites. The usual mechanism, where this scenario applies, is to limit the power of the signal from the terrestrial interfering system in the direction of the satellite

C: Interference to other terrestrial systems from transmissions (uplinks) from satellite earth stations

Since both the source of interference and victim of it are on the ground, and possibly close together, the interference in such cases could be significant. Where two services share frequencies and a common coverage area, one service or system is likely to constrain the other. Interference management in such cases involves either separating the two systems in terms of distance and/or angle, or allocating different parts of a frequency band for the satellite and terrestrial service.

D: Interference to satellite (receiving) earth stations from other terrestrial systems

As in scenario C, both the source of interference and the potential victim are terrestrially-based and therefore possibly in close proximity. Again, one service potentially constrains the other. Interference management in such cases could involve physical or frequency separation.

8.53 The first of these scenarios (scenario A), although uncommon in the past, is becoming increasingly relevant with the advent of non-geostationary orbit (NGSO) satellite systems. Scenario B has also been rare and managed by restricting the power level of earth-based transmitters whose main beams face the satellite. However, the NGSO systems and the increasing numbers of terrestrial cellular systems make this scenario also worthy of consideration.

8.54 The fact that satellite uplinks constrain the deployment of other terrestrially-based services (scenario C) is already acknowledged by the UK spectrum management regime, since transmitting earth stations are licensed under the WT Act. The earth stations are also subject to administrative pricing for their use of spectrum, with the prices reflecting the amount of spectrum occupied, and based on the charges for terrestrial fixed links which share the bands. In the past, satellite uplinking has been conducted solely through a relatively small number of permanent earth stations. But there is now increasing demand for spectrum for earth-to-satellite transmitters (so called satellite interactive and user terminals). In order to encourage more efficient spectrum use, the review recommends that these transmitters are also licensed in the least onerous way possible and charged the appropriate opportunity cost for the spectrum they use.

8.55 Where protecting the reception of satellite downlinks constrains the deployment of other fixed services (scenario D), there is currently no mechanism by which the satellite operator can be obliged to take into account any opportunity cost of spectrum use, since satellite space stations transmitting to earth are not currently subject to licensing. The introduction of spectrum access licensing would allow an opportunity cost-based price to be applied. Before this is done, however, the review believes it would be useful for RA/Ofcom to clarify the extent to which scenario D is likely, and in particular to identify the particular bands where satellite services could constrain the deployment of other fixed services.

8.56 If spectrum access licensing is introduced, spectrum pricing could be applied to both satellite downlinks and uplinks wherever there was an opportunity cost arising from the use of spectrum. This is consistent with the review's proposals in other areas. Such charges would encourage satellite operators to consider ways of economising on their use of spectrum. Improvements in spectrum efficiency resulting from spectrum pricing may not be possible immediately. The review believes, however, that this should not preclude the introduction of spectrum pricing because such improvements are possible in the longer-term, e.g. more spectrally efficient technology may be deployed, different services might be deployed within the bands, or there might be a move to exclusive satellite bands which do not involve an opportunity cost, thus releasing shared bands for terrestrial uses.

8.57 Some respondents to the review suggested that the introduction of opportunity cost based charging for spectrum use by satellite operators would damage the industry. The review believes that the arguments which apply to other commercial users of spectrum also apply to satellite operators, i.e. charging the opportunity cost of spectrum use does not lead to higher prices to consumers, or slow the deployment of new services.

8.58 The review also recognises the inherently international nature of the satellite industry and the need for international harmonisation in its spectrum allocation. Where this leads to allocations exclusively to satellite services, the review believes, as stated earlier, that the opportunity cost is minimal. However, where spectrum is shared with fixed services, there is potential for one service to constrain the other and, consequently, an opportunity cost; this cost should be taken into account by satellite operators. The resulting efficiency gain in spectrum use will provide benefits for the entire economy.

Recommendation 8.5

Opportunity cost pricing should be applied to satellite systems' use of spectrum where such use shares with, and constrains, the deployment of UK-based terrestrial services. Spectrum pricing should continue to apply to permanent earth stations but at full opportunity cost levels. Transmissions from user/interactive terminals should also be licensed with an appropriate spectrum charge. Spectrum access licensing could be used to clarify the rights and responsibilities of satellite transmissions into the UK and, where appropriate, to apply opportunity cost pricing to such spectrum use.

9 PUBLIC SERVICES

9.1 Public services consume significant swathes of valuable spectrum. For example, terrestrial TV broadcasting occupies 40 per cent of the spectrum below 1 GHz, while defence users are allocated nearly 50 per cent of bands in the range 3-10 GHz as well as extensive frequencies elsewhere. It is vital for the productivity of the economy as a whole that such public services face strong and enduring incentives to economise on the spectrum needed to deliver their public service outputs. Without such incentives, there is a growing risk that excessive spectrum retention by the public sector will constrain the growth of private enterprise.

9.2 The review recognises that there will remain a number of public services for which spectrum is a vital input and for which, in the absence of a fully fledged spectrum market, the current regime of reserving sufficient frequency bands for the delivery of these services should continue through the medium term. In the longer term, as spectrum trading develops, the Government should look to expose more public services' spectrum use to this market mechanism. In the interim, therefore, the primary means of encouraging spectrum efficiency should be administratively set spectrum pricing, based on the opportunity cost of spectrum occupied. The review recommends that all public services should be subject to this regime.

9.3 However, for any public service spectrum use, it is inherently difficult for any central manager to identify in advance precisely how much spectrum should be allocated to a particular service. Even in the face of ongoing financial incentives from spectrum pricing, it is likely that there will arise gaps between the bandwidth allocated to a particular public service and the actual use made of these frequencies. These gaps may occur in time, geography and/or frequency domains.

9.4 To encourage full utilisation of radio spectrum, the review advocates increasing the scope for public services to lease access to their allocated spectrum for commercial uses. Spectrum pricing should, of itself, encourage public service users to identify opportunities for such 'trading at the margins'. But spectrum leasing would provide a further positive financial incentive on these users to explore ways of accommodating other users and/or uses, consistent with the delivery of the public services for which the spectrum was originally reserved. The review outlines options for granting greater legal and operational flexibility in the use of reserved public service spectrum, which vary sector by sector and according to the public or private sector nature of the spectrum-using organisation.

9.5 Over time, the wider application of spectrum pricing and greater opportunities to share or lease spectrum access is likely to lead to a material shift towards the commercial use of radio spectrum. This shift would be consistent with the continued delivery of public services through spectrum and/or other media. The spectrum resources thus released would represent

a significant productivity gain for the rest of the economy. Releasing these gains will not be an easy or costless exercise. Spectrum sharing and leasing may require investment in new planning tools, re-engineering of radio sites, or full scale re-equipment by public service users to move to more spectrally efficient systems. But the review considers that a commitment now to the approach advocated, and consistent application in the coming years, should yield substantial benefits to the UK economy.

9.6 Some respondents to the review argued for a much more thorough exposure of public service spectrum usage to market discipline. In particular, they advocated moving in the near term to a comprehensive application of spectrum trading for all public service requirements. The review agrees with the objectives of such an approach: that all users should be subject to meaningful incentives towards economically efficient use of spectrum as an input in delivering their public service outputs. But it considers that it would be premature to make such a move before the commercial market in spectrum access has developed to the point that Government could credibly remove the 'safety net' of reserved spectrum for public services.

9.7 In the short to medium term, most of the practical benefits of greater spectrum efficiency and flexible use (within the constraints imposed by public service delivery) would be realised by the review's approach of using pricing and trading/leasing at the margin. Other gains may be realised through the contracting out of radio services from public sector users to commercial service providers, so that public services were delivered via spectrum licensed and managed for commercial purposes. In the longer term, as spectrum trading develops, it should be possible to reduce gradually the extent of reservation of spectrum for public services and open up a wider market for a variety of uses. To prevent a stark bifurcation of spectrum use between public and private sectors, though, Ofcom should ensure that administratively set spectrum pricing incorporates information arising over time from transactions in the commercial spectrum market.

10 DEFENCE

Introduction

10.1 The Ministry of Defence is the largest single user of radio spectrum in the UK. Given its particular responsibilities, it is accorded a distinct and privileged position in the UK spectrum management system, managing for its own purposes large tracts of spectrum which have been allocated for military use. The MOD faces strong internal pressures to make more intensive use of its frequency bands, as a result of rising demands from operational and support functions for communications and data services. It also faces external pressures from civil users to make more spectrum available for a range of commercial and public services. This chapter outlines the review's assessment of the current mechanisms designed to resolve these conflicting pressures, and makes recommendations designed to sharpen the financial incentives facing MOD spectrum use.

Military spectrum requirements

10.2 The highly mobile nature of military operations and their logistic support requires extensive use of high speed, high capacity communications for voice, data, video conferencing and imagery. Many of these requirements can only be met by the use of radio or satellite links. Similarly, target acquisition and surveillance systems using radar technology and radionavigation play a vital role in many military systems. Military communications, sensor and navigation equipment enhance the capability of fighting systems and multiply the effectiveness of forces. The extensive use of the radio spectrum is therefore a pre-requisite for successful military operations.[1]

10.3 The move towards more flexible, highly mobile joint task forces, together with the rapidly expanding demands for more accurate and timely information in both the front line and within headquarters, is causing considerable growth in the need for bandwidth and thus spectrum. Another factor is that training previously carried out abroad now needs to be done at home. This growth in the military need for spectrum is expected to continue for the foreseeable future and will need careful management if military access to spectrum for both current and future UK defence needs is to be assured.

10.4 The MOD has extensive access to designated spectrum allocations across the full range of frequencies, from the very lowest to the highest. The following table highlights military allocation and use by band:

[1] Further detailed information is provided in Chapter 3 of the *(Draft) Strategy for the Future Use of the Radio Spectrum in the UK,* Radiocommunications Agency, November 2001.

Spectrum band	% allocated to defence	Summary of use
0-1 GHz	22	long range communications, tactical radio, main NATO-managed band at 225-400 MHz, radionavigation
1-3 GHz	17	radio relays, tactical radar
3-10 GHz	48	radars, fixed telecoms networks, fixed satellite links
10-30 GHz	21	fixed and fixed satellite links, radionavigation and radiolocation radar
30-60 GHz	28	tracking radars, planned for future use of satellite, fixed and mobile

Military spectrum management

10.5 The allocation of UK spectrum is governed, at the highest level, by the UK Spectrum Strategy Committee (UKSSC), an inter-departmental Cabinet Office committee, which ultimately takes authority from the Cabinet itself. This Committee is co-chaired by the Chief Executive of the RA and a senior official from MOD Communications Policy Directorate. It decides the division of spectrum between military and civil uses, which is then codified in the UK Peacetime Frequency Allocation Table (PFAT). The management of the allocated civil spectrum is the responsibility of the RA, while the MOD manages allocated military spectrum. The UKSSC is also the forum for agreeing the collective UK stance towards international spectrum planning conferences.

10.6 The Defence Spectrum Management organisation is responsible within MOD for implementing the UK military spectrum strategy. It works closely with other branches of the MOD, the Defence Procurement Agency and military headquarters staffs, with the aim of matching demands for radio spectrum for military tasks with available supply.

10.7 A broad distinction can be made between the spectrum needs of military systems that are principally intended for warfighting, and those that provide support. In general, these occupy different bands and can be considered separately, although the dividing line between the two can vary. The bulk of MOD's spectrum needs falls into the first category.

10.8 In the first category, the spectrum supports the MOD's operational requirements for the defence of the UK and its overseas interests. In addition, this spectrum supports realistic training of combat forces to maintain a high level of competence and readiness. In its response to the review, the MOD argued that it should retain primacy in these bands, in order to plan the use of spectrum for warfighting and to integrate access to spectrum with the long term equipment procurement process.

10.9 Facing rising demands from a range of military users for greater mobility and greater bandwidth, there is a growing awareness that the aspirations of those who specify future systems cannot be satisfied in full from the available spectrum allocated for military use. The MOD is seeking now to narrow this gap between defence policy objectives and available spectrum, in part through ensuring that specification of spectrum access features more strongly in future equipment procurement decisions. But where equipment is purchased 'off the shelf' or as a result of a multinational procurement exercise, the UK's ability to factor spectrum access into specification decisions may be more limited.

10.10 The MOD also faces greater pressure on the use of warfighting spectrum within geographical areas used for major training exercises or operations. In such a crowded and potentially hostile radio environment, defence planners increasingly face spectrum congestion constraints on the deployment of multiple systems within a given battlespace. The MOD is in the process of procuring spectrum management tools to enable the near real time management of frequencies in the battlespace. The technical problems which such software tools could solve are similar to those arising from the challenge of maximising use of defence spectrum in the UK through sharing with civil applications. It may be technically feasible to apply this capability to the peacetime situation in the UK to facilitate civil access to MOD spectrum at times it is under-utilised by military users.

10.11 In the second category, the spectrum provides communications for support and logistics functions, such as management radio, airborne telemetry and range facilities. The requirements for dedicated prime access are less onerous here than for operational spectrum. Since the equipment used here is not subject to the rigours of combat (such as radio congestion or electronic attack), there may be more scope for economising on spectrum. Also, for some MOD business management and logistics functions, there are more likely to be closely equivalent commercial technologies which could be more compatible with military systems. All of these factors suggest, as acknowledged by the MOD in its response to the review, that there may be greater scope for the transfer or sharing of military spectrum in these bands.

Private financing and contracting of military services

A further factor affecting demand for dedicated military spectrum is the MOD-wide trend towards contracting out of services which can be delivered more economically in the private sector. Examples of this in the communications field include:

- Defence Fixed Telecommunications Service. Under this Private Finance Initiative contract placed with a BT-led consortium in 1997, MOD and all three Services obtain access to common telecommunications platforms within the UK, including a digital-based telephone system and wide area data networks;
- proposed Private Finance Initiative (PFI) contract for the delivery of satellite communications via the SKYNET 5 system; and
- procurement via PFI contract from Inmarsat of commercial satellite communications services for Royal Navy ships.

10.12 These developments could enable MOD in future to access a wider range of its communications services, particularly those for the support and logistics functions, from commercial operators. Such service providers would be using either commercial spectrum obtained through civil regulatory procedures (as in the case of Inmarsat), or defence spectrum which had been made available to the service provider, with some freedom to use spare capacity to carry commercial traffic (as in the proposed SKYNET contract). In either case, the contracting out of military communications services offers the prospect of deriving much greater value from the spectrum by increasing its utilisation.

10.13 There is a close ongoing dialogue between the RA and MOD about the current and future demands for military spectrum, and the interface between military and civil spectrum use. The MOD views active engagement in this co-operative activity as an important contributor to the development and implementation of the national spectrum strategy. It also creates some degree of shared understanding between the RA and MOD about military spectrum needs, which MOD considers helpful in protecting its own interests in national and international spectrum policy fora.

10.14 A key challenge facing RA and MOD jointly is to reconcile the increasing demands for both civil and military spectrum. There are three principal means of doing so:

Civil-military spectrum sharing

Permanent transfer

Where military needs for a particular band fall away entirely, then such spectrum can be permanently reallocated to civil uses and returned to the RA for licensing for civil purposes. The MOD retains no further involvement in the management of such bands, nor any claims about future access to the spectrum. Examples of this approach include spectrum for the deployment of the new digital public safety radio communications system at 380-385 MHz and 390-395 MHz.

Long term lease

Where MOD has no current or medium term use of particular bands, but has a possible future requirement (based, for example, on a long term equipment programme), then spectrum may be returned to the RA for civil licensing in the interim period. An example of this approach is the 3.4 GHz band which has been released by MOD for licensing by the RA for commercial fixed wireless access for 15 years. MOD retains the possibility to negotiate with the RA for future access to the band at the end of the civil licence period. The strength of this negotiating right has yet to be tested.

Shared use

In these cases, MOD may continue to deploy radio systems while enabling civilian services to co-exist. To date, this has been achieved by MOD agreeing with the RA the co-ordination requirements to protect incumbent military systems, and then the RA licensing services within these co-ordination restrictions. There are two dimensions to sharing: geographic sharing, and pre-emptive, where MOD have defined rights to increase their use of shared bands leading to a degradation of the commercial services. Examples of shared use include the spectrum formerly used for First Generation analogue mobile phones services at 870-888 MHz and 915-933 MHz, and spectrum assigned for TETRA business radio within 410-430 MHz.

10.15 The MOD noted in its response to the review that sharing spectrum access between military and civil users can cause spectrum management challenges arising from the differing patterns of demand and deployed equipment. Commercial users, particularly if supplying a service to third parties, may require a well defined level of geographical, time and frequency coverage. This may not be compatible with military requirements to deploy systems flexibly to meeting training and operational needs. Differing technical standards between commercial and military equipment can also work against spectrum sharing. These factors suggest that spectrum sharing can be a resource-intensive exercise for both sides. But given the value of the spectrum access concerned, there are strong grounds for enabling and encouraging both sides to explore the scope for sharing spectrum access.

Application of market-based spectrum management tools

10.16 Following the passage of the WT Act 1998, the Government decided to include certain MOD bands within the scope of spectrum pricing introduced under the Act with the aim of incentivising efficient spectrum use. Pricing was introduced in 1999, and MOD spectrum is now subject to pricing in all bands except:

- where RA has no alternative use that is in accordance with the international and UK allocation tables, mostly in some radiolocation bands and bands above 16 GHz;
- the 225-400 MHz band which is managed by NATO on behalf of national military forces and where there is as a result limited freedom of action for the MOD to release spectrum for civil use or to share it; and/or
- where pricing has yet to apply in the civil sector, most notably in aeronautical and maritime spectrum.

10.17 Spectrum pricing was phased in over three years and has now plateaued at around £23m per year, based upon the standard tariff units applied to civil mobile and fixed links operators. In practice, there remain large swathes of MOD spectrum which are not subject to pricing incentives. The following table provides an approximate summary of MOD occupancy of spectrum, band by band, and the extent of the application of spectrum pricing:

Band	Percentage allocated to defence	of which, percentage subject to spectrum pricing
0-1 GHz	22	26
1-3 GHz	17	59
3-10 GHz	48	80
10-30 GHz	21	29
30-60 GHz	28	0
Overall		
0-60 GHz	28	21

In the lower frequency block (0-1 GHz), the percentage of spectrum subject to charging is reduced by the exclusion of the NATO communications band. In the higher frequency blocks, the pricing percentage is reduced as a result of the zero-rating of radar and satellite spectrum bands.

10.18 In the bands which have been subject to pricing, there is limited and mixed evidence on the impact to date. The MOD finance system has cascaded the RA spectrum charge outwards from the Defence Spectrum Management organisation to the units responsible for the deployment of the relevant radio systems. There is anecdotal evidence that in some cases the introduction of this financial signal may have triggered a local review of channel utilisation by those responsible for communications within a particular unit. This in turn has led to units relinquishing some channels back to DSM for re-assignment, thus generating some marginal improvement in efficient spectrum use.

10.19 At the wider level, there is no evidence yet that the introduction of spectrum pricing has started to influence MOD's strategic decisions about spectrum allocation. The MOD, in its response to the review, noted that there have been no significant releases of spectrum from military to civil uses since the introduction of spectrum pricing which could be attributed to pricing. The MOD argue that the main driver to the release of spectrum continues, as before the WT Act 1998, to be MOD's 'enlightened self-interest' in co-operating with the development of the national spectrum strategy, in the wider interests of the UK.

10.20 The main constraint on the MOD's ability to respond to financial incentives on spectrum use is the continuing requirement for a given military capability (operational or support) with a given capital stock. Over the procurement cycle, the financial cost of spectrum use should feature, along with other 'through life costs' of equipment, in decisions about the specification and affordability of new and replacement systems. But MOD have argued that at current levels and scope, spectrum pricing is too low to make a material impact on equipment specification. Of greater concern to MOD spectrum managers is the rising demand for mobility and bandwidth from those specifying future systems, and the increasing difficulty of accommodating such demands within MOD's allocated bands.

Assessment

10.21 The review's aim in considering military use of spectrum is to identify mechanisms through which MOD can continue to access the spectrum required for operational and support functions, while facing comprehensive and effective incentives to economise on spectrum use over time. This review, unlike some previous exercises[2], has not been tasked with making a quantitative and qualitative assessment of the MOD's current and future demands for spectrum and the parallel demands from the civil sector. But it starts from the uncontroversial premise, corroborated by responses to the

[2] For example, *Report of the Independent Review of Defence Radio Frequency Spectrum (470 MHz to 3400 MHz) (Corfield review),* March 1998.

review, that rapidly rising demands for spectrum from both civil and military sectors will place growing strains on current mechanisms for reconciling this conflict. Unless these mechanisms are made more responsive to the economic value of the spectrum allocated to the military, then productivity and innovation in spectrum use is likely to be held back, at a growing cost to the UK economy.

10.22 The review has assessed spectrum management mechanisms applying to military spectrum under three broad headings:

- organisation and information;
- pricing; and
- incentives and mechanisms for spectrum release.

These three aspects are clearly linked, and the review considers that reforms in all areas should, collectively, improve the responsiveness of the spectrum management regime to changes in civil and military demands.

Organisation and information

10.23 The MOD occupies a privileged position in the UK spectrum management system. Through historical allocation decisions it has strong incumbency rights on around 28 per cent of the currently useable spectrum, including significant usage of the most commercially attractive spectrum in the UHF band (300-3000 MHz). It also co-chairs, with the RA, the UK Spectrum Strategy Committee. The MOD has, in recent years, recognised its wider responsibility stemming from this privilege to co-operate with other Government departments in developing a national spectrum strategy. Over the last decade, following a series of previous reviews of military and civil spectrum use, the MOD has started to put more information into the public domain about its own spectrum usage and strategy.

10.24 With the creation of Ofcom, including the RA, the balance of power on the UKSSC could shift, potentially significantly. At present, the RA derives legal authority as co-chair directly from the Secretary of State for Trade and Industry, with the MOD representative similarly deriving authority from the Secretary of State for Defence. In practice, the RA's central role in shaping the UK's spectrum strategy originates from its expertise and scope of activities in commercial and non-commercial spectrum management.

10.25 This experience and range of functions is expected to transfer to Ofcom in future. But Ofcom, as an independent regulator, will be accountable to Ministers and Parliament for the delivery of statutory functions and objectives, yet at the same time subject to Ministerial directions for the achievement of public policy goals which extend beyond Ofcom's remit. Ofcom's formal role and informal influence on the UKSSC may therefore be somewhat different from that of the RA. As discussed in Chapter 6, the review recommends that the constitution and resourcing of the UKSSC should be reviewed as spectrum management passes from the RA to Ofcom, to ensure that the UKSSC can

continue to balance the competing requirements of civil and military, public and private sector spectrum users.

10.26 MOD should face similar pressures to other public sector spectrum users to justify and account for its spectrum allocations. To assist this move towards greater accountability, the review considers that MOD should improve the information flow about its spectrum use. There are three aspects of information flow which should be improved:

- intra-MOD;
- MOD disclosure to RA/Ofcom; and
- MOD disclosure publicly.

10.27 On the first, the review is concerned that insufficient resources are devoted within MOD to tracking and analysing its own current and prospective future uses of radio spectrum. The Defence Spectrum Management organisation is very tightly staffed and has as a result focussed on the essentials of the task to meet MOD's ongoing needs for frequency assignments. MOD does not strictly follow a licensing process in assigning frequencies to stations so, unlike the RA, does not have a comprehensive and accurate database of current assignments for assessing spectrum usage and planning future systems. This has lead to DSM losing visibility of some assignments which may no longer be needed, with the potential for inefficient spectrum utilisation.

10.28 On the second, lack of resources in spectrum management can also hinder the commercial use of spectrum. Where civil users have to co-ordinate deployment of their systems with MOD usage in the same or adjacent bands, then any substantial delay imposed by consultation via the RA with MOD has an economic cost. Gaps in MOD's own understanding about the intensity of spectrum use by its own systems and their tolerance of interference can also inhibit joint analysis by RA and MOD of the scope for band sharing and reallocation of spectrum from military to civil usage.

10.29 On the third aspect, the review welcomes moves in recent years towards greater disclosure by MOD of its spectrum use including publication of a military spectrum strategy, as part of the UK-wide spectrum strategy. But the review is concerned that this summary information provides insufficient detail to prospective commercial operators to identify opportunities for spectrum sharing with incumbent military systems. In particular, it gives little insight into the pattern of spectrum usage by geography and time in the UK, which is vital in identifying the scope for sharing.

10.30 The need for greater disclosure to commercial operators has long been recognised. The Corfield defence spectrum review[3] in 1988 recommended that:

[3] *Report of the Independent Review of Defence Radio Frequency Spectrum (470 MHz to 3400 MHz),* March 1988.

'Without prejudice to security, the MOD users should make every effort to present to responsible commercial users a description of their broad pattern of usage in order to promote a better understanding of MOD needs, typically by conferences arranged to inform and answer questions ....

'To make [sharing of bands with commercial users] possible, allocations, and in particular assignments, need to be considered not only on the basis of frequency ... but also on the basis of time and location.'

Given the greater degree of openness now possible, advances in technology to enable dynamic spectrum sharing, and the rise in demand for spectrum, these recommendations have stronger force today than they did in the late 1980s.

10.31 The review therefore recommends a number of steps to be taken by the MOD to improve internal and external understanding of its spectrum use.

Recommendation 10.1

The RA should publish the (unclassified) UK Peacetime Frequency Allocation Table, identifying which bands are under MOD management.

Recommendation 10.2

MOD should invest in a comprehensive audit of all frequency assignments, including patterns of usage by time and location, in order to inform its own tactical and strategic management of the military spectrum asset. This data should be periodically updated, and should be disclosed to RA to improve RA's own visibility and understanding of military spectrum use. MOD should combine this data capture with investment in new frequency management tools, to enable more sophisticated sharing of military frequencies by time and location.

Recommendation 10.3

MOD should, without prejudice to security, disclose to industry those bands where spectrum sharing may be feasible as a result of the patterns of military usage. MOD should identify the pre-emption terms and interference management requirements for military systems, to enable commercial operators to judge the viability of sharing such spectrum on a subordinate basis.

10.32 There should be some complementarity between the latter two of these recommendations: the significant studies undertaken for an internal audit of spectrum use could form the basis for disclosed information on the scope for spectrum sharing. It is likely that both recommendations would require MOD to commission significant technical studies, either from 'in-house' technology advisers or from trusted external consultants, as the these tasks extend beyond the current scope of the Defence Spectrum Management organisation.

Spectrum pricing

10.33 The review has argued elsewhere (in Chapter 7) that, in the absence of a fully-fledged primary and secondary market in spectrum access, pricing provides a valuable additional pressure on spectrum users to economise on their spectrum use over time. It has also argued (in Chapter 9) that pricing should be applied more comprehensively to a wider range of spectrum users, particularly those in the public sector or those involved in the delivery of public policy objectives. Both of these arguments apply with some force to the MOD.

10.34 The MOD is in a privileged position among UK spectrum users in having management control over very significant bandwidth, and over a substantial procurement budget for the equipment which will utilise these bands. So, in principle, MOD should be well placed to make efficient trade-offs within its overall budget between spectrum use, equipment and operational capability. In practice, though, the level of spectrum pricing is at present too low, and its scope too narrow, to provide a material input into long term decision making affecting military spectrum use. In addition, the organisational linkage between spectrum pricing and availability, on the one hand, and decisions on equipment procurement and deployment, on the other, could be strengthened.

10.35 On the level of spectrum pricing, the review considers that MOD's current charges for the use of fixed and mobile bands should be revised in light of the proposed revalidation and full application of the opportunity cost approach[4]. This would most probably lead to a significant increase in the annual spectrum charge for MOD of £23m, as the current prices have been set at only 50 per cent of the level originally recommended by consultants.

10.36 On the scope of pricing, the review acknowledges the pragmatic approach taken so far that spectrum pricing should not apply where frequencies are managed by NATO, rather than MOD. The rationale for this is that decisions about spectrum use here reside largely outside the UK and would be little affected in the short term by UK-based pricing[5]. But this leaves a major lacuna in the financial incentives on MOD to economise on spectrum: the NATO-managed bands occupy some 175 MHz of 'prime' mobile spectrum, which would incur annual charges of some £40-60m under the current spectrum pricing tariffs. While much of this spectrum is core to MOD's and NATO's operations, some of these bands have been released in recent years. The value of this spectrum to the civil sector should be taken into account by MOD in international discussions with other national military authorities about civil access to these bands.

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[4] As proposed in the original study of RA, *Study into the Use of Spectrum Pricing,* by NERA and Smith System Engineering Ltd, published by the RA, June 1996.

[5] This argument also extends to the use of UK spectrum by US military based here, and by visiting overseas forces.

Recommendation 10.4

The value of UK spectrum effectively given over to NATO for management should be more clearly and publicly identified, through disclosure of an annual 'shadow' charge which would apply if the bands were MOD-managed.

10.37 The review does not support the current exemption of military radiolocation spectrum from the pricing regime. As argued in Chapter 12, the review considers that the introduction of pricing for spectrum use by UK ground-based aeronautical and maritime radar could provide helpful incentives towards spectrum efficiency in the long term.

10.38 Currently, some 5 GHz of MOD spectrum is subject to spectrum pricing. In addition, MOD manages around 3 GHz of radar spectrum, with CAA managing a further 1 GHz. For the civil use of this spectrum, the review has recommended that only UK ground-based radar be subject to spectrum pricing, since the use of spectrum by on-board secondary radar is subject to harmonisation on a global basis and would be virtually immune to a UK pricing regime. This argument does not hold, though, for MOD's use of radar spectrum, since the department has control over the deployment of radars in the UK and on board aircraft and ships. It thus has the ability to make trade-offs between spectrum use, equipment design and operational capability. So spectrum pricing should apply to the whole of MOD's radar usage.

Recommendation 10.5

MOD should bear the full opportunity cost of spectrum which is currently subject to incentive pricing (fixed and mobile bands subject to MOD management), with comparable tariffs applying to comparable civil and military uses. MOD should also be subject to a spectrum charge for all of its radar bands, with the tariff unit equal to that applied to civil aeronautical and maritime radar usage. New spectrum charges should be introduced for MOD as soon as practically possible after the preparatory technical studies to determine the standard tariff units.

10.39 This recommendation could have a material impact on the level of spectrum fees borne by MOD. Applying the full opportunity cost approach to fixed and mobile spectrum already subject to pricing could double fees to around £50m (abstracting from any technological developments since the original 1996 study which could reduce the cost). It is difficult to estimate the likely level of charging which would apply to MOD radar usage, in advance of currently ongoing technical studies for the RA about the spectrum efficiency of civil radars. An alternative approach to charging would be to 'import' the fee level applying to neighbouring bands, in this case the fixed standard tariff unit. This could entail an annual charge for MOD radar spectrum in excess of £50m.

10.40 With the prospect of the total annual spectrum charge reaching £100m or more, four times greater than current levels, spectrum pricing would start to have a material impact on MOD's budgetary process. This is a desirable outcome of spectrum pricing. But it also raises questions about the impact of spectrum pricing on MOD's ability to finance its defence outputs. It may therefore be desirable to neutralise the impact of significantly higher and more comprehensive spectrum charges on MOD's budget, while providing ongoing medium term incentives on the department to minimise such fees through spectrum efficiency.

Recommendation 10.6

Decisions on MOD's departmental budget should be made consistent with the maintenance of credible and enduring incentives on MOD from spectrum pricing and leasing, to provide positive financial benefit to MOD from efficient spectrum use over time.

10.41 The review does not make any specific recommendations about how MOD should treat spectrum charges within its budgetary system. It should be in the MOD's own interests to ensure that the information from the spectrum pricing regime feeds through to the relevant decision takers, themselves operating under a general budget constraint, to influence MOD's spectrum usage in the short, medium and long term. In particular, the review would expect MOD to develop of its own accord mechanisms to link more closely information on the availability and cost of military radio spectrum into the equipment procurement process.

Incentives and mechanisms for spectrum release

10.42 The review's recommendations concerning transparency should help to inform the RA and industry better about the scope for the release of radio spectrum from military use for exclusive or shared use by the civil sector. The recommendations concerning spectrum pricing should place a stronger and broader-based incentive on MOD to release under-utilised spectrum and to make procurement decisions in light of the spectrum implications. In addition, the review considers that MOD should be subject to further positive financial incentives towards spectrum release.

10.43 As in other fields of spectrum use, major improvements in military spectrum efficiency are often only feasible with a switch to a new generation of technology (such as the switch from analogue to digital transmission in mobile radio). Defence procurement cycles, though, can typically run to decades. Delays in deployment of new equipment can therefore seriously hinder MOD's ability to make meaningful economies in spectrum use in certain bands. This cost to the economy may not be fully captured by the spectrum pricing incentive on military spectrum use. There could thus be a

net gain to the UK as a whole, as well as benefits for MOD's ability to meet its operational objectives, from an acceleration in certain procurement programmes, which would enable spectrum to be released to, or shared with, civil users.

10.44 Proposals for release of military spectrum could also be accelerated by enabling the incoming commercial licensees to contract with incumbent military users on timetables for vacating identified bands. Licensees would be issued so called overlay licences (discussed further in Chapter 7), which have the following features:

- incumbents' rights are time limited (typically two to five years);
- incumbents must be paid compensation to vacate the spectrum before their licences have expired;
- new entrants must offer incumbents the same interference protection as they had originally whilst they remain in the spectrum; and
- new entrants are similarly given the same level of protection from interference as would other licensees in the band.

10.45 The advantages of this approach are that migration out of a specific band acceptable to MOD would be protected by the 'baseline' timetable built into the overlay licence. At the same time, there is scope for gain to both MOD and the incoming commercial licensee if they voluntarily agree an acceleration of this timetable in return for financial compensation for MOD.

10.46 The US administration is currently developing an extension of this policy under which **all** relocation costs for military (and other Federal government) systems vacating spectrum for licensing by the FCC are to be borne by incoming commercial licensees. The US National Telecommunications and Information Administration is devising rules for the timely disclosure of estimates of relocation costs from Federal incumbents to the FCC. Evidence from public consultations suggests strongly that commercial operators are most unlikely to be willing to bid for spectrum which is encumbered with an unknown and open-ended cost liability, as currently proposed. Federal incumbents, on the other hand, are unwilling to accept capped relocation costs.

10.47 The review has considered but rejected this approach for the UK. This proposal could hinder the 'refarming' of spectrum from military to civil commercial use, by providing a means for military spectrum users to extract significant commercial rents by enhancing claims for compensation, in excess of reasonable re-equipment costs. Given the existing and proposed financial incentives on MOD spectrum use, the review is not attracted to an additional incentive, along the lines being developed in the US, of full compensation for military spectrum users for the re-equipment cost of vacating bands.

Recommendation 10.7

The MOD should consider making specific proposals to Treasury for bringing forward budgeted equipment spending which would enable re-equipment and thus an earlier opening of identified military spectrum for release to, or sharing with, the civil sector. Where MOD has agreed to vacate spectrum for commercial licensing, RA should enable rapid refarming through assigning overlay licences which provide for new licensees to compensate MOD for early departure from the bands.

10.48 Hitherto, all cases of spectrum sharing have involved MOD relinquishing licensing of the band to the RA, having defined the residual military requirements for access to the relevant spectrum, and the technical parameters for co-ordination between military and civil users. This approach has worked well where military and civil users could be clearly separated in time or location. It is likely to be less effective, though, where military and potential civil users are more closely intertwined. The MOD noted in its response to the review that there is the prospect here of opportunities for a more dynamic approach to frequency assignment. This may require additional expenditure on both military and civil systems or on the means to provide assignments via a more sophisticated spectrum management tool.

10.49 The review considers that MOD should be placed under positive financial incentives to explore the scope for such dynamic spectrum sharing by civil users on spectrum which remains under active MOD management. Effectively, MOD could lease spectrum access to civil users where:

- it continued to require the frequencies for operational and/or support functions;
- the spectrum is not fully utilised in peacetime; and
- continued presence of MOD systems within the band precluded the standard approach to spectrum release or sharing.

10.50 These conditions attaching to spectrum leasing are important, and should be rigorously policed by the RA and the over-arching UK Spectrum Strategy Committee. The priority should continue to be for MOD to release spectrum back to RA/Ofcom permanently or on a long term lease, with geographical or interference co-ordination constraints where necessary. In this way, the RA can incorporate the released spectrum within its wider UK spectrum strategy. Only where MOD's use of a band is sufficiently intense or complex to preclude release of spectrum to the RA for management should leasing be considered an option.

10.51 Such an approach to leasing would be consistent with the MOD's general policy of making more intensive and cost-effective use of assets it retains through commercialising access to such assets, under the Defence Wider Markets Initiative. As with previous proposals for audit and some disclosure of military spectrum use, the introduction of leasing on MOD spectrum is likely to require specialist technical and financial skills outside the current scope of Defence Spectrum Management organisation. In particular, the MOD's Public Private Partnership Unit could become engaged in advising on the structuring of income-generating spectrum leasing contracts, as they have done with other innovative proposed PPPs.

10.52 In line with the Treasury's general principle for the Wider Markets Initiative[6], the review considers that MOD should have an automatic right to benefit from income generation. Without such a credible medium term assurance, the financial incentives on MOD to invest management time and resources into exploring spectrum leasing opportunities would be muted.

10.53 At present MOD, as a Crown body, is not licensed under the WT Act to operate wireless apparatus. To allow lessees to use MOD-managed spectrum legally, RA/Ofcom would probably need to provide some form of licensing. This might take the form of a class licence for lessees on MOD spectrum. Alternatively, MOD could be granted a new spectrum access licence, defining a spectrum 'space' within which MOD could allow commercial operators to lease access. In either case, Ofcom as the UK national spectrum regulator would have a duty, under the terms of the EU Licensing Directive[7], to act fairly, proportionately and transparently. This duty may also condition MOD's approach to spectrum leasing, but is unlikely to constrain it significantly.

Recommendation 10.8

MOD should have the ability to retain income generated from arrangements to lease access to spectrum which remains under active MOD management. Such spectrum should continue to bear the full spectrum charge, to be paid by MOD to RA/Ofcom.

Annex

The following table summarises the MOD's use of radio spectrum band by band. It is derived from the Military Spectrum Strategy chapter of the UK Spectrum Strategy 2001.

[6] The Government's policy on selling Government services into wider markets. The policy, launched in July 1998, is intended to make better use of existing Government assets.

[7] 97/13/EC.

Band	Summary of spectrum use
VLF: 3-30 kHz	sub-surface long range broadcasts
LF: 30-300 kHz	navigational beacons, long range maritime comms
MF: 300-3000 kHz	naval and air navigational beacons
HF: 3-30 MHz	long range strategic and short range tactical communications
VHF: 30-300 MHz	tactical radio relay, local radio nets, fixed comms, some NATO aircraft channels
UHF: 300-3000 MHz	
225-400 MHz	main NATO-managed command, control and comms band
400-450 MHz	meteorological services, land mobile, land radar
590-598 MHz	aeronautical radars
856-933 MHz	tactical training radio relay
960-1215 MHz	tactical navigation, identification friend or foe, joint tactical information distribution system
1215-1350 MHz	long range surveillance radars
1375-1452 MHz	tactical training radio relay, wideband security surveillance
1559-2450 MHz	aero navigation, met sondes, satellite command, telemetry, tactical radio relay, fixed, telemetry, mobile
2700-3600 MHz	aero and maritime surveillance and traffic control radars
SHF: 3-30 GHz	
4.2-4.4 GHz	radar altimeters
4.4-5 GHz	fixed and mobile
5-5.15 GHz	microwave landing system
5.25-5.85 GHz	tactical radars
7.35-8.4 GHz	UK SKYNET satellite links
8.5-10.125 GHz	radiolocation and radionavigation radars
10.125-10.5 GHz	radars and data links
13.25-14 GHz	aero radionavigation and radiolocation
14.62-15.23 GHz	fixed, mobile, airborne data links, short-range radio relay and fixed links
15.7-17.3 GHz	wideband data, command links, airfield radars
20.2-21.2 GHz	mobile military satellite downlinks
26.5-27.5 GHz	planned for wideband fixed and mobile
EHF: >30 GHz	
30-31 GHz	mobile military satellite systems
33.4-36.0 GHz	tracking radars
59-64 GHz	mobile and radiolocation

11 BROADCASTING

Issues considered by the review

11.1 Broadcasting in general, and terrestrial TV in particular, is a major user of radio spectrum. Terrestrial TV transmissions occupy 40 per cent of the spectrum below 1 GHz. Sound broadcasting (referred to as radio in the rest of this particular chapter) uses spectrum in the long wave, medium wave, short wave and FM bands. Digital radio uses spectrum in the VHF bands. Analogue TV and digital terrestrial TV (DTT) share the same block of UHF spectrum using 'interleaved' frequencies.

11.2 Spectrum management for the broadcasting sector has traditionally been affected by – and sometimes dictated by – other policy considerations. For example, the main public service analogue broadcasters are subject to a universal coverage requirement which has led to their services being available to 99.4 per cent of households.

11.3 One of the aims of this review is to consider ways in which the efficient use of spectrum might be secured alongside these broadcasting policy objectives. The review has not considered those areas of policy which it considers to lie solely within the bounds of broadcasting policy. But where broadcasting policy has implications for spectrum management, the review has considered how spectrum efficiency can be secured alongside the objectives of broadcasting policy.

Interleaving

Analogue and digital terrestrial TV transmissions use 368 MHz of spectrum within the band 470-854 MHz. The spectrum is split into 46 frequency channels, each composed of 8 MHz of spectrum. The following bands are used:

- 470 to 590 MHz (channels 21 to 35);
- 598 to 606 MHz (channel 37);
- 614 to 854 MHz (channels 39 to 68).

Each channel can be used to broadcast either one analogue TV service, or one digital multiplex - carrying six or more separate TV services - from a given transmission site. The table below shows (in black) the channels which are used for analogue transmissions, and (in white) the channels used for DTT transmissions from the Crystal Palace transmitter.

21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37

There is thus a maximum of 11 channels used at a transmission site (five for analogue TV channels, and six for DTT multiplexes). At such sites there are still seemingly 35 frequencies (46 minus 11) lying idle (in the above example, channels 21, 24, 27, 31, 35 and channels 39-68). These empty frequencies are interleaved with the frequencies used for the analogue and DTT services. Some of the empty interleaved frequencies channels cannot be used because they would cause interference with the channels which are used or with adjacent transmitters; some, however, could be made available to broadcasters or other users.

11.4 The constraints placed on broadcasters limit their ability to release spectrum for other uses. Some improvements in spectrum efficiency are however possible within the existing constraints. The review has considered how spectrum management tools can be used to ensure that these improvements happen.

11.5 The chief means of improving spectrum efficiency in the broadcasting sector will be to move from analogue transmission to digital. Digital transmission allows more information to be squeezed into any given amount of spectrum, e.g. six or more digital TV services can be housed in the spectrum used by one of its analogue equivalents. Spectrum released by digital switchover can be used to provide valuable new services which technological change is making possible. The Government is committed[1] to ensuring that analogue terrestrial broadcasting is maintained until:

- everyone who can currently get the main public service broadcasting channels in analogue form can receive them on digital systems;
- switching to digital is an affordable option for the vast majority of people; and
- as a target indicator of affordability, 95 per cent of consumers have access to digital equipment.

11.6 The review has considered how spectrum management tools could be used to achieve these switchover targets. Whilst the strategic decisions on when and how to make the switchover from analogue to digital terrestrial TV transmission will clearly remain with Government, the review has considered how spectrum management tools could be used to incentivise broadcasters to create the conditions for this move. The Digital Television Action Plan[2] set out by the Government identifies a wide range of spectrum planning and market preparation activities involving broadcasters for the coming years. The review has also considered how the spectrum currently used for broadcasting might be used after switchover.

11.7 Another means for improving spectrum efficiency involves using other delivery mechanisms for supplying digital TV services. These alternative platforms include satellite and cable, or terrestrial transmissions in less congested frequencies in higher reaches of the radio spectrum where there is scope to accommodate high bandwidth services such as TV as a supplement to, or instead of, UHF spectrum. In many ways, these platforms are more efficient delivery mechanisms, particularly for fixed reception, but may be less flexible than the UHF spectrum, e.g. for reception by portable TVs within homes. The review has considered how spectrum management tools could be used to ensure that broadcasting services are delivered using the most efficient means available.

[1] *A New Future for Communications,* DTI/DCMS White Paper, December 2000

[2] *Digital Television Action Plan,* DTI/DCMS, October 2001, at www.digitaltelevision.gov.uk

11.8 In devising its conclusions, the review has kept in mind the fact that broadcasting is only one possible use for radio spectrum. By establishing Ofcom, the Government has acknowledged that policies for the broadcasting sector which are separated and insulated from the rest of the communications market are becoming increasingly unsustainable. The review believes this also applies to spectrum management policies. It has considered, therefore, how spectrum management policies for broadcasting could be more closely integrated with the Government's wider stance towards spectrum management in general.

11.9 The review has therefore considered how spectrum management tools can be used to ensure that:

- broadcasters explore methods of releasing spectrum when they do not need it;
- broadcasters, over time, use more spectrally efficient transmission mechanisms; and
- broadcasting policy is determined with a full consideration of the impact on spectrum management.

Incentives to use spectrum efficiently

11.10 Broadcasters currently face some incentives to utilise spectrum efficiently. Using more spectrum may increase a broadcaster's transmission costs; the need to minimise these costs may cause it to economise on spectrum use. A particular broadcaster may also have some incentives to limit the amount of spectrum it uses for its main channels in order to free spectrum in which it can launch new services. Finally, broadcasting spectrum is currently planned through co-operation between the BBC, the ITC, Radio Authority and the RA. This regulatory process, in which each organisation 'peer reviews' the other's claims for spectrum may work to ensure that each broadcaster uses no more spectrum than it needs to meet its coverage requirements.

11.11 Crucially, however, broadcasting is an area where the provisions of the WT Act 1998, specifically aimed at ensuring efficient use of spectrum, have not been generally applied. Instead, fees for broadcasting spectrum are set at a level to recover administrative costs; price levels are not designed to encourage more efficient use of spectrum. Where broadcasters do not pay for spectrum, the opportunity cost of their usage is borne by the Government (and therefore ultimately by UK citizens). As discussed in Chapter 7, if spectrum users are not exposed to the opportunity cost of their use of spectrum, then inefficiencies in usage will result. If, however, users were exposed to the opportunity cost of spectrum use then there would be greater incentives for them to:

- examine spectrum needs, and release unused spectrum;
- use spectrum to provide alternative services;
- use less congested parts of the spectrum; and
- implement more spectrally efficient technologies.

11.12 During the consultation process, some broadcasters suggested that their public service obligations (such as the universal coverage requirements) controlled how they used spectrum, and that, as a result, spectrum management tools would not, in practice, have these positive effects.

11.13 The review acknowledges that requirements from Government limit the room for manoeuvre for public service broadcasters, since they have to use enough spectrum to meet their public service obligations. Nevertheless, the review considers that there is scope for all broadcasters to economise on spectrum use, e.g. by exploring all means of meeting their universal coverage targets whilst using reduced amounts of spectrum. In this regard, it is worth noting that the BBC, in its response to the review, suggested that it would welcome the opportunity to be able to sub-lease under-used spectrum – suggesting that it has spectrum available beyond the amount necessary to meet its public service broadcasting requirements.

11.14 Exposing broadcasters to the opportunity cost of spectrum use could also bring about a number of other improvements. It could, for instance, encourage broadcasters to explore trade-offs between using spectrum and other expenditures, e.g. introducing more spectrally efficient transmission systems. Broadcasters could also be encouraged to consider the extent to which current spectrum planning standards are still relevant (subject to international constraints). For example, the RA has recently stated[3] that it may be possible to free spectrum in the FM band 'if a more relaxed approach is taken to planning standards'.

11.15 Market-based spectrum management tools can also encourage broadcasters to adjust the balance between transmitting radio or TV, and transmitting data services. Allowing the operators the flexibility to decide which service to provide can ensure that spectrum is used for the service most valuable to consumers. Broadcasters also have leeway to decide the times at which they use spectrum (e.g. whether they broadcast during the night). Incentives could be put in place which lead them to consider whether they wished to broadcast 24 hours a day, or whether spectrum should be used at certain times of the day for other services (e.g. commercial datacasting).

11.16 Market mechanisms can also be used to incentivise broadcasters to create the conditions by which their services could be shifted to more efficient transmission mechanisms. In particular, it may be possible to use spectrum pricing to hasten achievement of the Government's targets for switchover from analogue to digital terrestrial TV transmission.

11.17 If the right incentives are in place, spectrum which is currently in the hands of existing broadcasters could be released and used to provide valuable new services, while maintaining the core output and coverage of public service broadcasting which is mandated by Government. New national, local and community radio and TV stations could be launched. Some of the existing

[3] *(Draft) Strategy for the Future Use of the Radio Spectrum in the UK,* Radiocommunications Agency, November 2001

terrestrial TV spectrum could also be used to supply innovative new services to consumers, e.g. mobile multimedia applications. One respondent suggested that broadcasting frequencies could also be used to provide targeted internet-style data services, to homes or businesses, through existing TV antennas.

11.18 Within the constraints of their public service broadcasting obligations therefore, the review considers that broadcasters have the ability to:

- fit current services into less spectrum;
- release spectrum by replanning its use;
- share spectrum with non-broadcasting users; and
- assist in achieving digital switchover.

11.19 The review considers that the potential gains from increased spectrum efficiency, in terms of new services and added competition, make it worthwhile to extend the application of market-based spectrum management tools in the broadcasting sector.

Recommendation 11.1

Market-based spectrum management tools should be applied to the broadcasting sector so that usage of spectrum by all broadcasters is exposed to the full opportunity cost of spectrum use.

Leasing

11.20 One way of exposing broadcasters to the opportunity cost of their use of spectrum would be to allow them to trade spectrum. Because spectrum is usually awarded alongside fixed-term Broadcasting Act licences, leasing of spectrum within these fixed terms, rather than outright sale, would be the appropriate trading mechanism. Chapter 7 includes a full discussion of different trading arrangements. The ability to lease spectrum would be subject to the lessor meeting other obligations such as universal coverage, delivery of public service broadcasting requirements, and maintaining standards of picture and sound quality.

11.21 The decision as to whether or not to lease spectrum should be left in the hands of each particular broadcaster since it will be in a position to know exactly how much spectrum is needed to meet its commercial objectives and/or public service obligations. The lessee would then be responsible for obtaining any relevant licence from regulators to deploy services in the spectrum.

11.22 The correct financial incentives clearly need to be in place to ensure that any spare spectrum is actually released. The review believes therefore that broadcasters who lease spectrum should be able to keep all the proceeds. Arrangements to allow the leasing of spectrum will need to take into account

the particular circumstances of the BBC. The review recommends that the Government clarifies the ability of the BBC, under its Charter and Agreement, to use spectrum to generate commercial revenues from transmitting data other than its public service programming, provided it can continue to demonstrate that it is meeting its public service remit. This approach was supported by the BBC which advocated, in its response to the review, greater flexibility to encourage public service broadcasters to share capacity on their spectrum with commercial operators where this does not compromise the delivery of public services, and to enable them to reinvest any financial proceeds from such arrangements back into those public services.

Recommendation 11.2

Broadcasters should be given the ability to lease spectrum to other uses and/or users, once they have met their public service broadcasting commitments and other obligations. Broadcasters leasing spectrum would be able to keep the resulting revenues.

Spectrum pricing

11.23 The Government has considered the use of spectrum pricing in the broadcasting sector. In the Communications White Paper, the Government stated[4] that:

'Broadcasters, like other major users of spectrum, must use spectrum efficiently, and there should be effective mechanisms to ensure this, which might include regulation or spectrum pricing. The Government has therefore decided that spectrum used by broadcasters should be valued. However, the extent to which payment is required for use of this spectrum will need to take account of the particular circumstances of broadcasting. These include the substantial payments already made under the Broadcasting Acts by commercial broadcasters; the level of public service obligations undertaken by the broadcasters; and the forthcoming switchover to digital broadcasting.'

11.24 The review welcomes this statement as an explicit recognition that the spectrum used by all broadcasters (including public service broadcasters) has an opportunity cost. The review considers that valuation is the first step in helping to secure better use of spectrum by broadcasters.

Recommendation 11.3

The spectrum used for broadcasting should be valued and the valuations released into the public domain. From the overall valuation, a value for each national analogue channel and digital multiplex should be derived, based upon relevant factors such as geographical coverage and bandwidth used.

[4] *A New Future for Communications,* DTI/DCMS White Paper, December 2000

11.25 Although valuation will be a useful first step to ensuring more efficient use of spectrum, more can, and should, be done to help achieve this objective. Charging broadcasters for their use of spectrum would, the review considers, provide incentives to use spectrum more efficiently, and in particular could contribute to the achievement of digital TV switchover. This approach is consistent with the review's conclusions in respect of other sectors that involve public service elements including defence, transport safety and the emergency services.

11.26 Some public service broadcasters (PSBs) have argued strenuously that their demands for spectrum are determined by the universal coverage requirements imposed by the Government. The suggestion is that PSBs have no discretion on the amount of spectrum which they use; as a consequence, there would be no efficiency benefit from imposing a spectrum charge on them. It was also suggested that the ability to lease spectrum would provide sufficient incentive to release any spectrum which was excess to their public service broadcasting requirements; spectrum pricing would be an unnecessary additional regulatory burden.

11.27 The review has considered these arguments in respect of broadcasters – as indeed it has done with all other users of spectrum. But it considers, on balance, that incentive pricing can play a useful additional role in helping to secure efficient use of spectrum by broadcasters, incentivising them to take a range of actions towards this end.

11.28 Although the ability to lease spectrum may encourage broadcasters to release spectrum when they do not need it to fulfil any public service broadcasting commitments, it may not, in itself, encourage broadcasters to examine comprehensively whether their spectrum could be used by others to provide services other than TV or radio, e.g. whether DTT multiplex capacity might be used to transmit data. This is particularly the case with BBC and Channel 4, which are not subject to shareholder pressure to maximise profits. The review judges that these broadcasters are more likely to respond to the explicit price signal resulting from a direct charge for spectrum than they are to an implicit revenue signal resulting from a potential spectrum leasing arrangement.

11.29 Spectrum pricing can also encourage broadcasters to consider measures such as replanning the use of spectrum on changed technical assumptions. The interleaved nature of broadcasting spectrum means that the spectrum released by such replanning may then become available for reassignment by the RA rather then being available for leasing by the broadcaster. If this were the case, then leasing on its own would not encourage the broadcaster to give up spectrum but pricing would.

11.30 Charging for spectrum can also stimulate broadcasters to invest in more spectrally efficient technology or alter the services supplied. Experience suggests that broadcasters, including public sector/service broadcasters, can respond to price signals in deciding how they use spectrum. For example,

the BBC has declined to lease multiplex capacity which would allow it to transmit one of its channels (BBC Parliament) in video form on the DTT platform, whereas it was willing to do this for one of its other channels (BBC Knowledge). It does however supply BBC Parliament in video form on cable and satellite networks where shortage of spectrum is not a concern. The review has also noted that the BBC has recently introduced technology which allows it to transmit more services on its DTT multiplex. This investment was made so the BBC itself could provide additional services to viewers. Spectrum pricing would fully incentivise broadcasters to make such investments even if they were not able to use the additional capacity for their own services.

11.31 Perhaps most importantly, pricing and leasing together would fully encourage broadcasters to move to alternative ways of transmitting their services which use less spectrum or to use less congested parts of the spectrum. This combination of incentives should encourage broadcasters to create the conditions by which their services could be shifted to digital transmission, and thus enable digital switchover.

11.32 The review further considers that many users of spectrum for public services are constrained, at least in the short to medium term, by a combination of their past investment decisions and their obligation to provide services. In the longer term, it is likely that these constraints will either be relaxed or changed. In order to gain efficiency benefits in the future, it is essential that decisions begin to be taken now on the expectation of future spectrum charges.

11.33 The review believes therefore that incentive pricing can encourage more efficient use of spectrum above and beyond the efficiency benefits produced by leasing. This has already been recognised by the Spectrum Management Advisory Group[5] when it recently stated[6] that 'spectrum pricing must be used as an incentive to encourage the switch to digital broadcasting'.

11.34 The review considers therefore that spectrum pricing should be applied to all broadcasters. The timing of introduction should take account of extant regulatory agreements between broadcasters and the Government. The timing and form of payments should also be consistent with the goal of promoting and supporting the take-up of digital TV and radio. For example, some abatement of pricing could be applied to digital broadcasting spectrum up to the point of switchover.

BBC and Channel 4

11.35 The Government currently has an Agreement with the BBC which expires in 2006. Channel 4 has a Broadcasting Act licence which runs until 2003. After the expiry of these commitments the Government could apply a price for the spectrum used, but as noted above, the timing of introducing spectrum pricing should take into account the wider goal of achieving digital TV switchover.

[5] A non-departmental public body which provides independent strategic advice to the UK Government on spectrum matters

[6] *Third Annual Review,* Spectrum Management Advisory Group, November 2001

11.36 In the longer term, the review believes that greater freedom over how to achieve the Government's requirements for the coverage of TV reception should be delegated to the broadcasters themselves, acting under the incentive of spectrum charges. This is discussed further below.

Channel 3 and Channel 5

11.37 Channel 3 licensees and Channel 5 originally won their Broadcasting Act licences in a competitive auction, and pay an ongoing price on renewal of the licences. The amounts paid include an implicit sum for spectrum, but also include an implicit subsidy for the public service obligations which the licensees are subject to, and a payment for a 'must carry' obligation on cable operators. Most importantly, the sum paid also incorporates a payment for the exclusive right to broadcast in a particular locality. As the ITC has said[7] 'these additional payments are charged on the grounds that it is by the use of a scarce resource (the broadcasting spectrum) that monopoly profits accrue to the licensees who are granted the sole right to broadcast in their area'.

11.38 In order to provide more tangible incentives to use spectrum efficiently, the review believes that spectrum should be charged for separately from the other elements associated with a Broadcasting Act licence. Once the current licences of Channel 3 licensees and Channel 5 expire, therefore, payment of an explicit charge should become a pre-condition for licence renewal. The level of spectrum prices would be set by Ofcom in light of studies which determined the opportunity cost of usage. Where new broadcasting licences are auctioned or awarded by beauty contest, the spectrum charge applying to the licence would be made known before the contest begins. The ITC could continue to apply additional charges for elements other than spectrum. In the meantime, Channel 3 licensees will continue to benefit from the so called 'digital dividend', the mechanism which reduces their broadcasting franchise fees in line with the rise in digital take-up.

DTT multiplexes

11.39 The BBC's DTT multiplex operates under its Charter, due for renewal in 2006. After that point, a spectrum price could be applied to this multiplex, taking account of the Government's wider approach to promoting digital take-up. The five non-BBC DTT multiplexes operate under ITC licences awarded for a 12 year period in 1997 or 1998, with an option to renew for a further 12 years. At the time of the award, the Government stated that it would not charge a licence fee under the Broadcasting Act 1996 for the commercial multiplexes for the initial 12 years in order to stimulate the development of DTT. The review recognises that this approach to DTT in the early years of its development has encouraged investment in the platform, which could lead to substantial spectrum efficiencies to the benefit of the whole economy.

[7] *ITC Note No. 4: Commercial television: revenues and payments,* Independent Television Commission, July 2001

But in the longer term, the review considers that the benefit to the overall economy is maximised if DTT multiplex holders face ongoing financial incentives to spectrum efficiency.

11.40 The review therefore recommends that commercial DTT multiplex holders should pay a spectrum price from the date of renewal of their licences in 2009 or 2010. This timing is consistent with the current plans for digital switchover. Commitment now to future pricing should help broadcasters and their transmission operators to respond in an informed manner to the Government's current consultation on the principles for DTT spectrum planning[8].

Analogue and digital radio

11.41 Spectrum pricing should also be applied to radio broadcasting in order to increase spectrum efficiency. The BBC's analogue radio frequencies could thus have a charge based on the opportunity cost of spectrum use applied from 2006 onwards. Commercial analogue radio licensees could also be charged for spectrum after the expiry of their current Broadcasting Act licences. New licensees would also be charged an explicit fee for the opportunity cost of the spectrum used. In areas where demand for broadcasting spectrum was limited in relation to supply, the opportunity cost (and therefore the spectrum charge) would be commensurately low. The timing and level of prices for digital radio multiplexes would need to take into account the objective of encouraging the platform. But in the longer term, as for TV, the review considers that the benefit to the overall economy is maximised if holders of digital radio multiplexes face ongoing financial incentives to spectrum efficiency.

Encouraging digital TV switchover

11.42 The review considers that the form of spectrum pricing could be designed in a way which encourages broadcasters to stimulate consumer take-up of digital receivers. For example, spectrum prices could be adjusted to give broadcasters targeted incentives to encourage digital take-up. A version of this already applies with respect to the franchise fees for Channel 3 companies. The terms of the current regulatory regime mean that Channel 3 licensees receive the benefit of reduced licence payments for every household in which their services are received in digital form.

11.43 A similar system could be applied to other radio and TV broadcasters, with spectrum fees varying with the extent of digital take-up. Alternatively, a more targeted system could apply to all broadcasters whereby actions on the part of broadcasters which measurably increased digital radio and TV take-up were rewarded with reduced spectrum fees.

[8] *Digital Television: The Principles for Spectrum Planning*, DTI/DCMS, December 2001

11.44 Alternatively, the Government has powers under the WT Act 1998 to award selective grants to promote spectrum efficiency. No grants have been made through this mechanism so far, but if spectrum pricing were applied to broadcasters more widely, then there may be greater scope for using spectrum efficiency grants to boost the adoption of digital radio and TV. Possible uses for such spectrum efficiency grants in the broadcasting sector could include research and development into cheap analogue-to-digital converters. Overlay auctions could also be used to hasten digital switchover.

Switchover through overlay auctions

Another spectrum management mechanism which could be used to achieve digital switchover is the use of overlay auctions (described in Chapter 7). Once the Government's switchover targets are close to being achieved, the analogue TV spectrum could be auctioned, with the purchasers being obliged to maintain analogue TV transmissions until the Government's switchover targets had been achieved. The purchaser of the spectrum would then have the incentive to achieve the switchover targets as cheaply and quickly as possible. This mechanism could help achieve digital switchover at the least possible cost. Such overlay licences have been used in the USA by the Federal Communications Commission as a means of clearing analogue TV spectrum[9].

[9] *Third report and order – service rules for the 746-764 and 776-794 MHz bands and revision to part 27 of the Commission's rules*, FCC, January 2001.

Spectrum pricing and public service broadcasting

11.45 One argument against pricing which was put forward was that broadcasters effectively pay for their spectrum through the public service broadcasting commitments they make. The review acknowledges that spectrum pricing can potentially result in inefficient outcomes if the private or commercial value of spectrum usage differs from its wider social value. But the review considers that the same principle should apply to broadcasters as to other public services, i.e. the goal of overall economic efficiency is best served if broadcasters are given incentives to use spectrum efficiently. The Government can then make available any funds it finds necessary to compensate public sector broadcasters for any charge for spectrum, with the compensation mechanism designed to be consistent with other objectives such as independence of broadcasters from Government.

11.46 This approach also helps create greater transparency about the true costs of public service broadcasting. Although the Government is currently paying the opportunity cost of broadcasters' spectrum use, the Government, Parliament and the public at large do not know the size of this opportunity cost. They cannot therefore compare it to the wider benefits. Charging broadcasters for their spectrum use overcomes the problem of evaluating the precise economic and social value of that broadcaster's public service broadcasting output. Over time, the greater visibility about the full economic

cost of public service broadcasting created by spectrum pricing should (as with other economic information) start to influence debates about policy choices, e.g. the extent of public service broadcasting obligations.

Recommendation 11.4

Spectrum pricing should be applied to all broadcasters. The timing of the introduction of spectrum pricing should take account of extant regulatory agreements between broadcasters and the Government (including commercial broadcasters' current franchise fees, which encompass access to spectrum). It should also take into account the Government's commitment to promote and support the take-up of digital TV.

Recommendation 11.5

The Government, its agencies and broadcasting regulators should explore options for using variable spectrum pricing and/or spectrum efficiency grants to contribute to the Government's aim of promoting and supporting the take-up of digital TV. The Government should also consider using overlay licences as a mechanism for achieving digital switchover.

Licensing

11.47 In order to create the proper incentives to lease spare spectrum, there may need to be changes to the way in which spectrum is currently assigned to users. The current complex system for licensing spectrum use by broadcasters is summarised below.

Licensing spectrum use by broadcasters

The arrangements which assign rights to use spectrum for broadcasting involve the Government (including the RA), the independent broadcasting regulators, the BBC, commercial broadcasters, and transmission providers (such as ntl and Crown Castle). The Government, led by RA/DTI, first determines the amount of spectrum to devote to the various radiocommunications services (broadcasting, fixed, mobile etc). After the spectrum allocated to broadcasting is split between TV and radio, the Government determines how it is shared between the BBC, for the delivery of the Corporation's services under the terms of its Charter and Agreement, and the Radio Authority and Independent Television Commission, for the delivery of independent broadcasting according to the requirements of the Broadcasting Acts 1990 and 1996. The Government can also specify how spectrum should be divided between different users (e.g. it specified that the DTT multiplexes with the widest coverage should be used to provide BBC, ITV and Channel 4).

Spectrum is made available to the ITC and Radio Authority by the Secretary of State (acting through the RA) in line with the relevant provisions in the Broadcasting Acts. The ITC and Radio Authority consult with the BBC on spectrum issues, but the BBC is responsible for planning the spectrum for its UK-based TV and radio transmissions.

The Radio Authority is given spectrum to enable it to fulfil its functions to regulate the provision of sound broadcasting services under the terms of the 1990 and 1996

Broadcasting Acts. The RA, on behalf of the Government, issues a notice which specifies the frequency bands which can be used for different services. The Radio Authority then plans individual frequency assignments for national, local and restricted service analogue radio services, and for national and local digital radio multiplexes. Competitions are then held by the Radio Authority to determine who gains analogue radio and digital radio multiplex licences (broadcasters providing services on the digital radio multiplexes are separately licensed under the Broadcasting Act 1996). National analogue commercial radio licences are auctioned, but other radio licences are awarded through a beauty contest.

The winners of analogue radio and digital radio multiplex licences then have guaranteed access to the frequency assignments planned by the Radio Authority subject to the provision of licences under the Telecommunications Act and the WT Act 1949. The Broadcasting Act licensee decides whether it should be responsible for the WT Act licence, or whether the WT Act licence should be held by a third party (e.g. a transmission provider such as ntl or Crown Castle). The RA then issues the WT Act licence to the relevant party incorporating a clause that makes a linkage to the holding of the Broadcasting Act licence.

The situation for TV is similar to that for radio. The BBC and ITC plan the use of spectrum in order to share it effectively, and minimise interference. The ITC holds competitions under the terms of the Broadcasting Acts for licences for Channel 3, Channel 5 and DTT multiplexes. Channel 4 is licensed without a competition. The Broadcasting Act licensees then have guaranteed access to the frequencies planned by the ITC (subject to the award of licences under the Telecommunications Act and the WT Act 1949). Individual services that use capacity on DTT multiplexes are also separately licensed under the Broadcasting Act 1996. The two transmission providers for TV, ntl and Crown Castle, hold the WT Act licences and the RA charges for these licences on cost-based terms.

11.48 Broadcasters are currently given the right to use spectrum by the Government or by the relevant regulator, but, in most cases, they do not hold the relevant WT Act licences. The review recommends that the system of licensing is altered so that the WT Act licences, and the associated rights to use spectrum, are held by the broadcasters who could then decide whether they wish to disaggregate the spectrum, and lease some of it, once they have met any public service requirements or other obligations. The broadcasters could also delegate the right to deploy wireless telegraphy equipment to transmission providers.

Limits on usage

11.49 The benefits of leasing are far more likely to emerge if it is possible to use spectrum for purposes other than conventional broadcasting. International constraints will limit the extent to which this is possible, although within the broad category of 'broadcasting' it is possible to provide mobile services or datacasting using the internationally harmonised broadcast technology (known as DVB-T). In any case, some of the existing limits may be removed after the relevant international spectrum planning conferences have taken place in 2004 and 2005. The review considers that within these constraints, and any interference limits that apply, operators should be allowed to use the spectrum currently allocated to broadcasting for other purposes.

International constraints on use of broadcasting spectrum[10]

The current constraints imposed at an international level prevent the release of broadcasting spectrum to other uses such as mobile, although it is possible to use broadcasting spectrum to provide other mobile and fixed services if the appropriate technology (DVB-T) is used.

ITU-R

The Radio Regulations (Region 1) allocate spectrum at 470-862 MHz to broadcasting only (470-790 MHz) and broadcast sharing with fixed services on a co-primary basis (790-862 MHz). Applications such as 3G telecoms are not therefore permitted at present. If these regulations are relaxed then it would be possible to use broadcasting spectrum for alternative users.

EU and CEPT

The Stockholm (1961) and Chester (1997) plans detail the use of spectrum by analogue and digital TV. However, whilst at present broadcasters enjoy largely exclusive use of this spectrum, secondary services occur in the band 470-838 MHz, whilst a primary fixed allocation exists in the band 838-862 MHz. The European Common Frequency Allocation Table states that these bands are to be reviewed for possible future applications after the introduction of DVB-T. Administrations are urged to clear the bands of aeronautical radionavigation services by 2008. No comment is made regarding the future of the tactical radio relay systems operating from 790-862 MHz.

Technical considerations will also have an impact on the use of the spectrum. Opportunities to use any spectrum released for mobile services will be constrained by interference considerations – both interference caused to French and Irish TV, and even more importantly interference to the mobile service from TV in France and Ireland.

[10] From *Implications of international regulation and technical considerations on market mechanisms in spectrum management,* Aegis Systems Ltd and Indepen Consulting Ltd, November 2001

11.50 Such a relaxation of restrictions on usage would require changes to the operating licences for both analogue and digital broadcasters. Under the terms of the Broadcasting Act 1996, there are currently limits on the proportion of digital TV and radio multiplex capacity which can be used for non-programme related data broadcasts on most digital TV and digital radio multiplexes. The limits are currently set at 10 per cent for DTT multiplexes and 20 per cent for digital radio multiplexes, but can be varied through secondary legislation.

11.51 The accelerating pace of convergence means such limits are becoming increasingly anachronistic. Removing them would allow operators – and not regulators – to decide what mix of data and broadcasting services consumers would find most appealing. The desirability of attaining effective competition should also be a consideration. As discussed in Chapter 7, removing restrictions on the ability to use a particular piece of spectrum for different purposes, makes it easier to achieve effective competition in the various end user markets for which spectrum is employed.

11.52 The review considers, therefore, that the interests of consumers are best served if limits on spectrum use are removed. This would mean that digital broadcasting multiplexes could be used for more than just TV and radio broadcasts. This would not, of course, mean that none of the digital multiplex capacity would be used for programmes and programme-related services. As long as consumers find these services valuable, operators will continue to offer them. Most importantly, the Government has powers to ensure that all current and future public service broadcasting channels remain available to all households, if necessary, by reserving digital multiplex capacity for them.

11.53 The removal of limits on usage should also apply to new spectrum that is potentially available to broadcasting. For example, there are 23 blocks of spectrum available at 1.4 GHz ('L-Band'), each of 1.5 MHz bandwidth. This spectrum has been identified for future use for digital radio multiplexes, but could also be used to provide other kinds of services. The review considers that none of these blocks should be earmarked purely for broadcasting use, and instead should be made available through an auction to any use or user.

Recommendation 11.6

Limits on the proportion of digital broadcasting multiplex capacity which can be used for non-programme related data services should be relaxed as soon as possible, and ultimately eliminated. Spectrum released in the future which can potentially be employed for broadcasting should not be confined to broadcasting use alone, but should be made available for other uses through a competitive auction.

Spectrum planning

11.54 The amount of spectrum that is used by a broadcaster is determined by certain planning standards including international arrangements for ensuring equitable shares of spectrum across national boundaries. These standards cover issues such as power levels of transmitters, and have an important impact on the amount of spectrum which is used (e.g. using high-powered transmitters to broadcast in a particular frequency makes it impossible to reuse that frequency until a great distance away). Many of these planning and spectrum sharing requirements were decided over 40 years ago through the Stockholm 1961 conference.

11.55 The UK will be negotiating with other countries at the next re-planning conferences, which are scheduled for 2004 and 2005. The review believes that the UK should adopt a position which allows maximum flexibility over use of the VHF and UHF spectrum. For example, the UK should seek to ensure that mobile telecoms technologies, as well as mobile variants of broadcasting technology, may access the bands. It may also be desirable for the UK to ensure planning arrangements which allow the fullest flexibility in the use of broadcasting technology for the effective deployment of mobile services (TV, sound or data), as well as fixed and portable services, in the broadcast spectrum.

11.56 The review also considers that the RA, in conjunction with broadcasters, transmission providers, and the ITC and Radio Authority, should update plans for the use of spectrum. These plans are based on certain technical assumptions, e.g. on the capability of TVs and radios to receive broadcasts. Since the plans were originally formulated there has been a significant improvement in the quality of reception equipment. This could make it possible for broadcasters to fulfil their universal coverage requirements using less spectrum. Spectrum pricing would incentivise broadcasters to weigh planning requirements against the costs of spectrum during this replanning process.

Interleaved spectrum

11.57 The review considers that currently under-utilised spectrum which is interleaved with terrestrial transmissions should be made available for other uses. At present, though, it may not be possible to guarantee that the same frequencies would continue to be available for use after digital switchover. The situation will become clearer, however, once the Government has finalised its post-switchover spectrum plans. After the plans have been completed, the review considers that the interleaved spectrum should be licensed for use (possibly on short-term licences until switchover and/or pending changes in service allocation decisions). In line with the review's general conclusions about allowing more flexibility over spectrum use, this spectrum should not be restricted to DTT alone, but should instead be auctioned for all possible users within international and technical constraints.

Broadcasting spectrum after switchover

11.58 Once the switchover from analogue to digital TV transmission is completed, it will be possible to use the spectrum thus released for other purposes, subject to international and technical constraints. For instance, the spectrum could be used to meet the pressure of demand from services where spectrum needs are increasing such as various mobile technologies, including mobile telecoms and TV. Clearly, there is a balance to be struck between retaining enough spectrum to provide digital TV for fixed and portable reception and releasing as much as possible for use in as many other ways as technology and international arrangements permit.

11.59 The Government is currently considering how much spectrum should be released following the switchover from analogue to digital TV and has issued a consultation document focused on how spectrum should be planned after switchover[11]. The document considers questions such as:

- How much spectrum should be allocated to DTT for fixed reception?
- How much of this spectrum should be allocated to public service broadcasting and how much to pay TV?
- What level of coverage is required by DTT for public service broadcasting and for pay TV services?
- Which spectrum should be cleared for reuse?

[11] *Digital Television: The Principles for Spectrum Planning*, DTI/DCMS, December 2001

11.60 The review believes that these questions should be examined with a full and proper consideration of the costs and benefits involved. Such an analysis would consider, amongst other matters, the benefits of DTT as a means for delivering public service broadcasting, and pay TV, compared with other platforms, and the costs (in terms of consumer and producer benefits foregone) of using spectrum for DTT rather than for other uses. The review considers that the Government should take into account the conclusions of such an analysis, and a full consideration of all the potential services that could prospectively use the spectrum, before deciding how spectrum should be used following switchover. Unless this is done, there is the danger that too much spectrum would be consumed by DTT, which in turn would mean that the UK would be deprived of potentially useful new technologies such as mobile multimedia services.

11.61 The review's general approach towards flexibility in spectrum use would suggest that, taking into account the results of the relevant cost-benefit analysis, the Government should seek to maximise the amount of contiguous spectrum available for re-use following switchover (if necessary, by reducing the number of multiplexes reserved purely for regulated DTT broadcasting). This maximises the possibility of using the spectrum for a range of mobile, fixed and portable services employing mobile technologies (such as UMTS) and/or mobile/fixed technologies (such as DVB-T). As a corollary, it should, subject to an assessment of economic and social costs and benefits, minimise the spectrum reserved for the delivery of defined public service broadcasting outputs. The review also considers that the spectrum released after digital switchover should be available through an auction to all possible users, and not simply to broadcasters (subject of course to international agreements and interference limitations).

11.62 After switchover, some interleaved spectrum within the block used for DTT will continue be available for other uses at each transmission site. This could be used to provide digital TV services with limited coverage, but it could also be used for other uses including mobile TV or data services. The review believes that this interleaved spectrum too should be auctioned and available to uses other than TV transmissions.

The role of Government

11.63 As this chapter has made clear, the Government, including the RA, plays a pivotal role in determining the way in which spectrum is used by the broadcasting sector, in particular by:

- granting a specific amount of spectrum to broadcasting;
- deciding the distribution of spectrum between the BBC and commercial broadcasters and resolving any spectrum policy issues that arise in the sharing of spectrum;
- determining the priorities for using the spectrum between different services, e.g. deciding which broadcaster should have the 'best' multiplex frequencies;

- setting out conditions (including PSB requirements) for the way in which spectrum may be used by the BBC and independent broadcasters;
- setting out rules for deciding allocation, duration and cost of broadcasting licences; and
- setting spectrum prices under the WT Act 1998;

11.64 Once Ofcom is established, the Government could leave spectrum management tasks to the independent regulator which will be in a much better position to consider the issues involved, and which will have statutory responsibilities to be independent and accountable.

Recommendation 11.7

Once Ofcom is established, the Government should devolve detailed spectrum planning to the independent regulator, subject to Ministerial direction where necessary in particular circumstances, e.g. to reserve spectrum for BBC services. In order to ensure that the entire volume of spectrum is used in the most efficient way, Ofcom should be given responsibility to plan all the broadcasting spectrum, including that currently used by the BBC.

11.65 The review also believes that in formulating its broadcasting policy the Government should be aware of, and take into account, the implications for spectrum management. This process has already started in the Government's initial consultation exercise on digital TV spectrum planning[12], but the review believes it should go further. For instance, before deciding how many DTT multiplexes should be reserved for PSBs, the Government should explicitly consider the costs in terms of extra spectrum used and other services foregone. In the interests of full transparency, the size of these costs should be in the public domain so they can be weighed against the benefits. Valuing the spectrum used for broadcasting will help achieve this because it will allow the Government to measure the full costs – including those of spectrum use – of achieving its broadcasting policy goals.

11.66 In the longer term the review believes it would be desirable for the Government to separate entirely its broadcasting policy from the management of spectrum used for broadcasting. The Government would then set coverage and content requirements for public service broadcasters who would then obtain access to as many separate communications platforms as were necessary to meet these targets.

[12] *Digital Television: The Principles for Spectrum Planning*, DTI/DCMS, December 2001

11.67 Spectrum for communications services would be auctioned, tradable and freed of restrictions on the type of services which could be offered to consumers. This would mean that regulators avoided reserving spectrum for one particular converged service (e.g. TV) rather than another (e.g. internet), since they are not in a position to know which particular service is most valued by consumers. The precise mix and type of audio-visual content, datacasting and telecoms services which was offered using spectrum would thus be decided by consumer preferences rather than the Government. Some of the resulting benefits could be obtained in the shorter term by lifting current restrictions on the use of broadcasting spectrum.

11.68 Adopting a more liberal approach to regulation in the way suggested would mean less control by the Government. But the benefits of public service broadcasting would be preserved, whilst there would be added gains for the economy through greater innovation, inventiveness, and investment.

Conclusions

11.69 The switchover from analogue to digital broadcasting offers the UK the biggest potential efficiency gain in spectrum use in the next decade. The review's proposals would make it easier to achieve digital switchover. The review's recommendations on the use of analogue TV spectrum after switchover would ensure that this spectrum would be used in the way which proved to be most valuable to consumers.

11.70 The review believes that even before switchover it is possible to improve the efficiency with which spectrum is used by broadcasters. Spectrum pricing, and the ability to lease, would encourage broadcasters to give up spectrum where they do not need it to fulfil their public service broadcasting and/or commercial goals. This would help fulfil the review's broader objective of ensuring that spectrum is employed in the use, and by the user, who brings the greatest benefits to the overall economy.

11.71 The review believes that some of the scenarios which respondents have suggested would result from implementation of these recommendations are unnecessarily fearful. Charging for spectrum would not be a 'tax' on viewers or licence fee payers, just as charging for any other input into broadcasting does not constitute a tax. Instead, the changes suggested will allow the Government to fulfil its broadcasting policy goals whilst simultaneously ensuring spectrum is used efficiently. This will benefit consumers, broadcasters, and the economy as a whole.

12 AERONAUTICAL AND MARITIME

Introduction

12.1 The aeronautical and maritime sectors are significant users of radio spectrum. Spectrum is a key input for a variety of radio-based systems which provide communications, navigation and surveillance functions. These systems often play an invaluable role in ensuring the safe passage of aircraft and maritime vessels. They are also used by land-based organisations such as air traffic control and coastguard to manage airspace and sea lanes. As such, most of the spectrum usage by the aeronautical and maritime community has a significant public safety, and thus a public policy, dimension.

12.2 By their nature, both sectors are highly international. Thus many of the communications and navigation systems used, particularly the on-board equipment, need to be inter-operable and compatible with ground-based systems globally. As such, the spectrum used tends to be allocated exclusively on an international basis at the ITU level.

12.3 Within these constraints of public safety policy and international harmonisation of spectrum, the review considers the scope for encouraging greater efficiency in spectrum use through the introduction of financial incentives.

Spectrum management in the aeronautical sector

12.4 Spectrum for aeronautical use, in common with all other spectrum use, is allocated by the ITU. However, in order to achieve global inter-operability, equipment standards and frequency planning criteria are further harmonised through the International Civil Aviation Organisation (ICAO), which requires compliance with published Standards and Recommended Practices (SARPs). In addition, in Europe, the European Organisation for the Safety of Air Navigation, Eurocontrol, provides the institutional and support framework within which the spectrum and frequency management processes are co-ordinated in conjunction with ICAO.

12.5 The overall aim is to ensure that the communications, navigation and surveillance strategies in support of aviation in Europe can be achieved. However, the overall responsibility for spectrum and frequency management remains a matter for national Governments. Nevertheless, there is further political oversight of activities on a regional basis by the European Civil Aviation Conference (ECAC) which is attended by Ministers of Transport. This body, which meets every two years, maintains a keen interest in ensuring that Eurocontrol, ICAO (on a regional basis), and the Member States deliver the necessary services, including spectrum and frequency management.

12.6 Within the UK, the Directorate of Airspace Policy (DAP) of the Civil Aviation Authority (CAA), the specialist aviation regulator, is responsible to the Department of Transport, Local Government and the Regions (DTLR) for spectrum and frequency management. DAP's Surveillance and Spectrum Management Section works closely with the RA to address aviation spectrum issues. In addition, DAP is responsible for frequency assignment within the aeronautical bands.

12.7 Close liaison is maintained with all user groups through a formal consultation process and regular informal contacts. This is particularly important with organisations such as MOD and National Air Traffic Services Ltd (NATS). NATS, which was part of CAA until April 2001, provides air traffic control and air traffic management services on a commercial basis and therefore has a major interest in spectrum and frequency management issues.

12.8 The RA has recently appointed the CAA as its agent to distribute aeronautical radio licences on its behalf. The Directorate of Airspace Policy took over the distribution of aeronautical radio licensing on a contractual basis with effect from January 2002. The RA retains responsibility for setting the WT Act licence fees.

Spectrum management in the maritime sector

12.9 Spectrum use by the maritime sector is similarly largely determined by both the ITU and the global sectoral regulator, in this case the International Maritime Organisation and its specialist radio communications sub-committees. Within the UK, the Maritime and Coastguard Agency (MCA), an agency of the DTLR, manages use of the spectrum for H M Coastguard operational communications. MCA is also the national administration with responsibility for maritime radiocommunications (specifically the Global Maritime Distress and Safety System (GMDSS)), and maritime radiodetermination (specifically radionavigation). The RA remains the issuing authority for ship and coastal station radio licences, but is currently considering transferring the processing of these licences to the MCA.

Spectrum use in the aeronautical sector

12.10 Aeronautical use of radio spectrum encompasses a variety of communications and radar systems:

Aeronautical sector

Total spectrum allocation of 2440 MHz, of which:		percentage
Primary radar	radio beacon	11
	radar	61
Secondary radar and radar altimeters		19
Communications (including satellite)		7
Satellite global positioning system		2

12.11 Surveillance requirements continue to be met through extensive use of primary radar, which does not rely on co-operative aircraft systems, thereby providing reliable independent surveillance. This is increasingly complemented by the use of secondary surveillance radar (SSR), which does require the carriage and operation of transponders on the aircraft. In addition to meeting Air Traffic Service provision needs, SSR also forms the basis for Airborne Collision Avoidance Systems (ACAS).

12.12 Navigational requirements are based on Distance Measuring Equipment (DME), Instrument Landing Systems (ILS), VHF Omni-Directional Range (VOR) and Non-Directional Beacon (NDB). Although within Europe there are plans to reduce reliance on these traditional systems to support en-route navigation for commercial aviation, they will be required for many years by general aviation and for airport approach procedures. In respect of Microwave Landing Systems (MLS), plans for implementation are being developed at 11 civil airports and 29 military airfields from 2002 onwards.

12.13 Air-Ground voice communications are primarily met by VHF, which is in high demand and therefore under acute pressure. However, the introduction of narrower channel spacing (8.33 kHz), requiring on-board re-equipment, and in time the increased use of datalinks, will enable increasing demand to be managed more effectively. In addition, UHF and HF continue to be used to support certain voice communication applications.

Radars

Radars play an essential role in both sectors, and are the most significant consumer of spectrum in both sectors. Radars are used for:

- surveillance (radiolocation) applications - such as use by air traffic control, coast guard and ports to monitor and guide aircraft and ships; and
- navigation (radionavigation) applications - such as the instruments on board vessels and aircraft to help them negotiate their route safely.

Radar transmitters send out high power bursts (pulses) of microwave frequency signals, usually via a rotating antenna. These signals will be reflected by any objects upon which they are incident. A fraction of the reflected signals returns to and is detected by the radar receiver. Electronically comparing the received pulses with the transmitted pulses gives information about the target's position (range and angular position) relative to the receiver. This position is usually displayed on electronic visual displays or charts.

The radar detection range is proportional to signal power, antenna size and angular coverage of pulses. Because of their application, radars are required to provide a certain performance level, relating to the target sensitivity (size and speed) and detection range. To achieve the range, radar designers trade off power and antenna size (with consequences for cost and weight of equipment). Radar sensitivity tends to be proportional to the bandwidth used, as wide frequencies are needed to create the sharp rise and fall of radar pulses, which in turn help the receiver discriminate between targets.

Modern solid-state technology and advanced signal processing offer opportunities to reduce somewhat the power and bandwidth requirements of radar. Solid-state devices'

receiver components, with excellent noise figure performance, allow the radar receiver to detect very low level signals - thus offering scope for reducing the power while maintaining a given detection range. Also, advanced signal processing enables improvements in sensitivity performance for less bandwidth.

In recognition of the significant amount of spectrum used by civil aeronautical and maritime radar systems, the UKSSC commissioned in 2001 an investigation into the characteristics, operation and protection requirements of these systems operating up to 16 GHz. This will allow investigation into possible rationalisation of existing radar frequency allocations and enable sharing studies to be conducted. The study is being carried out by the RA, in consultation with the MCA and CAA. It will cover, but is not limited to:

- an audit of the present use of radar;
- an investigation into the wanted transmission characteristics and operational parameters of existing and state-of-the-art civil radar systems;
- an investigation into the measured unwanted emission levels from 30 MHz to 30 GHz. Systems to be studied include existing and state-of-the-art civil radar systems operating in all civil frequency bands;
- a study of mitigation options which could be taken into consideration in the design and implementation of radar systems to reduce unwanted emissions and/or occupied bandwidth; and
- an investigation into the radar receiver characteristics and protection criteria required for the protection of radar services.

This study is expected to report during 2002.

New satellite based technology, such as the Global Navigational Satellite System, offer the potential in the future to reduce reliance on radar. However, there are currently frequency protection concerns about relying solely on satellite networks in place of radionavigation and radiolocation. Thus conventional radar is likely to be needed for the foreseeable future.

Spectrum use in the maritime sector

12.14 As in aeronautical services, radars represent a significant part of the maritime consumption of spectrum. It is used in coastal installations for surveillance purposes and for navigational use in on-board equipment. Vessel Traffic Monitoring Systems are used in and around ports to monitor the movements and identities of vessels, using radar, video surveillance, and VHF data links. In the case of coastal radar, the beam is only active over angles facing the sea: i.e. the signal is blanked for inland angles. This offers scope for minimising the area affected by radars and may offer possibilities for other services to utilise the corresponding frequencies. Most ships, including many smaller vessels also use on-board marine navigation radar systems. Finally, racon beacons are radar transponders, located in fixed positions, which positively identify a navigational feature (e.g. a buoy or lighthouse) on a vessel's radar display.

12.15 In addition to radar, maritime spectrum use encompasses many frequencies allocated both nationally and internationally for distress and safety, search and rescue and emergencies. The key usage is for the Global Maritime Distress and Safety System (GMDSS), an internationally mandated system which enables shore-based co-ordination of maritime search and rescue. There are additional frequencies specifically used by H M Coastguard and other UK agencies in search and rescue operations. In addition to the navigation and safety communications systems carried, there is an increasing demand for on-board access to business communications facilities, such as private mobile radio, the internet and other broadband services.

Assessment

12.16 Spectrum use in the aeronautical and maritime sectors is subject to significant constraints arising from public safety policies, international harmonisation of spectrum allocations and associated technologies, and the global nature of aircraft and vessels using UK-managed aeronautical and maritime spectrum. In the review's view, these factors limit but do not exclude the application in the UK of economic incentives to encourage greater efficiency in spectrum use.

12.17 At the same time, there are increasing requirements for spectrum originating from commercial aviation and maritime users and, in particular, from non-transport commercial interests to share or acquire aeronautical/maritime allocations. These pressures have caused the sectoral regulators to reassess the national and international approach to spectrum management and frequency assignment, with the aim of identifying more efficient practices. There is recognition by both the CAA and MCA that the aeronautical and maritime sectors need to demonstrate more clearly than hitherto that they have effective mechanisms in place for delivering efficient spectrum usage. Both the CAA and MCA acknowledge in their responses to the review that an appropriate spectrum pricing regime would help complement current regulatory efforts in this arena.

12.18 The review agrees with the majority of interested parties who responded on this issue, that those radio frequencies used directly for the safe operation of aeronautical and maritime services should have guaranteed access to the required spectrum. Thus auctions and trading are not an appropriate mechanism for assigning this core spectrum. As with other public services, the review recommends continued reservation of spectrum, largely based on internationally agreed allocations.

On-board systems

12.19 For communications spectrum and other bands used by on-board systems, including airborne secondary radar, UK spectrum space is effectively part of a wider international common resource. Any aircraft or vessel entering UK territory has the right, by international convention, to communicate for navigation and safety purposes on given channels using harmonised protocols. In most cases, the spectrum efficiency of these transmissions is dictated by internationally mandated technology standards.

12.20 In these circumstances, the opportunity cost to individual users is effectively zero. There is no defined amount of spectrum which if given up by one user could be assigned to another user or another alternative use, and users have no means of responding to spectrum pricing by switching to more efficient technology. There is therefore no case in principle or in practice for UK-based spectrum pricing.

12.21 However, there are some communications uses of spectrum where there is greater scope to incentivise spectrum efficiency over time. At present, where new equipment standards are introduced which improve spectrum efficiency, the sectoral regulators (CAA and MCA respectively) give several years notice for implementation (seven in the case of the CAA). In some cases, these changes are only advisory, not mandatory, giving individual users discretion over when to adopt the new standards. Slow adoption by users hinders the spectrum managers' ability to increase the capacity utilisation of a given band, and so hinders overall spectrum efficiency.

12.22 This is particularly an issue with general aviation users (e.g. light aircraft with limited access to UK airspace), which are subject to less stringent communications standards since they operate in less congested airspace and so have some leeway about when to re-equip. Examples here include:

- the proposed move to narrower 8.33 kHz channel spacing, which should eventually deliver efficiencies in the use of spectrum and airspace management; and
- the opening of higher VHF communications frequencies (up to 136-137 MHz), which are currently under-utilised because many general aviation users have retained equipment tied to lower frequencies.

12.23 In these situations, there is a strong case on spectrum efficiency grounds for applying an additional proportionate levy on top of the WT Act licence fee for those aeronautical and maritime users which have yet to migrate to the latest spectrally efficient standard.

Recommendation 12.1

For spectrum reserved for on-board navigation and communications systems, the opportunity cost to individual users is, in most cases, effectively zero, since use of this spectrum is mandated internationally, and users are required to adopt specific technologies. But where UK-based users face some technology choice for their on-board systems, then the RA, working with the CAA and MCA, should apply differential licence fees to encourage moves to more spectrally efficient equipment, thus easing congestion over time.

12.24 In addition to these spectrum uses which serve a public safety objective, there are also purely commercial applications in both sectors, such as the use of coastal radio by commercial shipping fleets and on-board telephones in aircraft. These applications of radio spectrum should be subject to the same market-based spectrum management tools (pricing and trading) as the review advocates for their terrestrial equivalent private mobile radio.

Ground-based radars

12.25 Following the reasoning applied above, there is a stronger case in principle and practice for applying administratively-set spectrum pricing to the use of spectrum by UK ground-based aeronautical and maritime radars.

12.26 Radars use considerable amounts of bandwidth across much of the UK. Operators based here are clearly under the jurisdiction of the RA and CAA or MCA, and so UK-based spectrum efficiency incentives could have a direct and comprehensive impact on spectrum usage here. Regulatory measures alone appear not to have been fully effective to date in ensuring that spectrally efficient equipment and systems are comprehensively deployed. As evidenced by the Government's commissioning of a major audit of civil radar usage and of the options for reducing bandwidth consumption, there is latent concern within the UK regulatory community about the scope for greater spectrum efficiency in this area.

12.27 The sectoral regulators' responses to the review recognised the need for greater application of economic incentives to push users in the direction of more efficient radar technology. They both supported the introduction of spectrum pricing which should encourage such a move over time as radar operators progressively re-equip. There are two main practical issues, though, to address in implementing this approach.

12.28 First, the scope for greater spectrum efficiency would need to be studied in some further detail before arriving at an appropriate metric for spectrum pricing. There are several means of improving efficiency in this area:

- re-equipment of specific radars (e.g. better signal processing within the receiver);
- redeployment of radars geographically;
- sharing of radar-derived data between different operators; and/or
- sharing of bands with non-radar users.

The RA's current study of civil radar usage should help provide the technical basis for deriving spectrum tariff units based upon the least cost technical options for reducing, at the margin, spectrum consumption of a given radar system.

12.29 Second, the introduction of a new spectrum pricing regime for radar should recognise the extended notice periods which the regulators in this sector typically provide for operators. This is in recognition of the substantial and long term investments which stem from regulatory decisions; the working life of radar equipment can exceed 20 years. The pricing regime should also recognise the fact that, in the aeronautical sector, the spectrum charge (which is likely to be insignificant relative to total aviation costs) would be borne mainly by NATS and the major airport operators, such as BAA. Both NATS and BAA are subject to economic regulation by the CAA. These factors suggest a phased introduction of spectrum pricing around the middle of the decade, taking account of the CAA's periodic reviews of regulation on BAA and NATS.

Recommendation 12.2

In light of the current study for RA of the UK's civil radar deployment and the technical scope for reducing spectrum consumption, the RA should develop a pricing regime, in conjunction with CAA and MCA, for the spectrum used by UK-based radionavigation and radiolocation equipment. This should be phased in over the next five to seven years, consistent with outstanding economic regulation agreements in the aviation sector between companies and the CAA.

13 PUBLIC SAFETY SERVICES

Introduction

13.1 A wide range of emergency and public safety services require robust and effective mobile communications, to manage operations within their service, between each service, and to and from the outside world. The co-ordination of disparate safety services responding to a particular incident places a premium on the ability to communicate across services. Radio spectrum is an important resource essential to the work of these services. Management of this resource is a complex task given the interaction between the diverse operational requirements of a wide group of public safety users, the obligation to make spectrum available to them, and the impact on efficient spectrum use.

Public safety spectrum management

13.2 Most of the spectrum use by the emergency services has historically been overseen by the Home Office, which also makes spectrum assignments to specialist covert units in other agencies (e.g. H M Customs & Excise, Inland Revenue) which require facility for joint operations with the police. Spectrum usage covers a wide range of applications including personal and mobile radio; secure voice, data and video links; location devices; and telemetry links. Spectrum is planned to a high standard to reduce probability of co-channel interference. Many assignments are national to allow for inter-operability and movement of officers around the UK. Ambulance services' spectrum requirements have been managed by the RA.

13.3 Although police forces and fire brigades are independent and have responsibility for their own procurement, the growing demands for inter-operability have led to commonality in the type of systems deployed. This process is being taken forward with the introduction over the next few years of a major new national trunked radio system, the Public Safety Radio Communications Service (PSRCS), now branded Airwave. This service, procured by the Home Office under a private finance initiative contract, will allow significant rationalisation of spectrum allocated to the Home Office, and access to an integrated digital system for a wide range of public safety users.

Airwave

Airwave (formerly known as the Public Safety Radio Communications Service) is set to be the first digital national radio communication service designed for the police forces of England, Wales and Scotland. It will also be marketable to the wider emergency service community. The 19 year contract to provide Airwave was awarded to BT (now mmO2) under the terms of a framework agreement signed in February 2000 by the Police Information Technology Organisation, a non-departmental public body financed by the Home Office. Airwave is built to the TErrestrial Trunked RAdio standard (TETRA). The new service will replace the current analogue police radio communications network, enabling the Home Office to release the majority of its allocations between 450-470 MHz by 2005-07 on satisfactory completion of migration of police forces to the Airwave service.

TErrestrial Trunked RAdio (TETRA)

TETRA is a digital professional two-way radio standard developed by the European Telecommunications Standards Institute (ETSI) which provides significant improvements in spectrum efficiency for larger Public Access Mobile Radio (PAMR) networks. It also has the potential to enhance the variety and quality of services to the use, including advanced speech and data facilities, wide area coverage and greater immunity from interference and eavesdropping. Specific frequency bands have been identified for TETRA at a European level and the RA has been working to release spectrum for commercial and other civil users.

13.4 The development of the PSRCS has been enabled by the transfer from NATO use of 10 MHz (2x5) of 'prime' spectrum between 380-400 MHz. In recognition of the need for coherent national and international emergency communications across Europe, the European Radiocommunications Committee designated the 380-385 MHz and 390-395 MHz frequency bands for the introduction of 'Digital Land Mobile Systems for the Emergency Services'. The UK Government signed up to this Decision[1] and has provisionally allocated the spectrum to meet all the mobile communication needs of agencies and organisations whose primary role is the provision of emergency and public safety services.

13.5 These Public Safety Mobile Bands (PSMB) have, since July 2000, been jointly managed by the RA, DTI, Scottish Executive, and the Home Office. Allocations and assignments from these frequencies are granted on the recommendation of the Public Safety Spectrum Management Group (PSSMG), a standing committee of officials from these departments, with an independent chair, which itself is responsible to the UK National Frequency Planning Group (NFPG). The PSSMG remit is to ensure that designated frequencies provide sufficient spectrum for public safety needs of England, Wales and Scotland, with devolved but co-ordinated arrangements for other parts of the UK and the Islands[2]. Detailed spectrum management is carried out by technical staff of the departments represented on PSSMG.

13.6 The Airwave service has been granted an initial allocation of 6 MHz (2x3) within PSMB to meet the needs of police in England, Wales and Scotland. PSSMG will consider reasonable and justified applications from the service provider to extend this initial allocation to meet increased traffic demands resulting from:

- expansion of the service to eligible non-police users;
- expansion of services offered to existing users; and
- introduction of new Airwave-based applications.

[1] ERC/DEC/(96)01 of 7 March 1996

[2] PSSMG terms of reference are at www.pssmg.radio.gov.uk/

13.7 The reserved spectrum is also designed to cater for independent applications for frequencies from eligible organisations that wish to operate outside of Airwave but within its coverage area. PSSMG will seek to ensure that the business benefits of adopting an alternative to Airwave have been stated and agreed.

Emergency and public safety services

In addition to the main 'blue light' emergency services (fire, police and ambulance), a number of other organisations involved in public safety are also defined as approved emergency and public safety services for the Airwave service by the DTI under the Telecoms Act licence. Only approved services that, in general, need to inter-operate with the 'blue light' emergency services are eligible to become 'sharers' of Airwave. Having been approved, such services are also eligible to apply for independent assignments of spectrum within the Public Safety Mobile Bands for deploying their own non-Airwave radio systems under stringent co-ordination requirements. Claims by organisations to become approved users are judged against four criteria:

- the extent to which they need to respond to emergencies;
- proportionality;
- whether they are civilian organisations; and
- the extent to which there would be interaction with those who respond to emergencies (only if the main purpose of using Airwave is interaction with the Emergency Services and if the proposed user requires instant connection with the Emergency Services).

At present, there are around 90 separately identified approved emergency and public safety services, including a wide range of military security and safety services. The DTI has recently consulted on the procedures for adding to the list of approved public safety sharers.

13.8 All spectrum used by public safety services is subject to administratively set spectrum pricing, determined by the RA on the same basis as the prices charged for comparable private mobile radio users. However, these fees are subject to apportionment on the basis of population coverage.

Assessment

13.9 As for other public services which rely on radio spectrum to deliver their objectives, the review agrees that the Government should continue to reserve sufficient spectrum to meet the communications needs of emergency and public safety services. The nature of these radio services (robust to peak demands at emergency locations, wide area coverage, inter-operability, and security) means that public safety needs will continue to be distinct from business radio, and thus not fully met by commercial public or private mobile radio systems. With the development of a market in spectrum and greater flexibility over use of spectrum, the gap between public safety communications demands and commercial supply of services, based on generic mobile radio spectrum, should narrow. Until then, though, public safety policies require access to dedicated spectrum.

13.10 But these services, like other business users, face choices about the technology and spectrum requirements of their communications systems. The application of administratively set spectrum pricing, set at realistic levels reflecting the trade-off between spectrum and hardware in delivering a defined radio services, should provide an ongoing incentive to spectrum efficiency.

Recommendation 13.1

Public safety users should continue to benefit from guaranteed access to radio spectrum, subject to full spectrum pricing applicable to comparable private mobile radio systems.

13.11 It is possible to co-ordinate additional eligible services alongside Airwave where there is spare capacity. The current arrangements for managing spectrum for public safety services are, however, generally a hybrid between two very different approaches. On the one hand, service providers (notably mmO2, providing Airwave in England, Wales and Scotland) have been allocated a block of spectrum which is self-managed within an agreed geographic area. The regulatory framework defines the user base, the interference environment within which services must operate and permitted levels of exported interference outside the agreed operational area. On the other hand, safety services continue to have access to individual frequency assignments within neighbouring spectrum blocks for localised and dedicated radio systems.

13.12 There are clear benefits from establishing a single nationally co-ordinated network for the provision of public safety mobile communications:

- operational benefits from inter-operability;
- spectrum efficiency savings from a fully integrated infrastructure planned to common standards; and
- financial benefits from economy of scale.

13.13 There are also drawbacks, however. The adoption of one network (with a single technology standard) across all the allocated bands would create a monopoly, preventing other providers from competing in this market. It is also very unlikely that the Airwave service would be universally adopted by all those services which are eligible to use it. The resources and needs of the other safety services are not the same as those of the police, and so they may not procure identical applications. The ability to choose an alternative service provider can allow greater flexibility with the benefits of real choice, notably:

- customised services and the provision of bespoke applications;
- reduced outlay costs from choosing ‘off the shelf’ technologies; and
- stimulation of competition leading to value for money.

13.14 However, different systems must be carefully managed to minimise:

- difficulties in inter-operability or interconnection with the other public safety services;
- an inefficient use of the spectrum where disparate technologies need to be separated by guard-bands, thus reducing the amount of usable spectrum; and
- an inefficient use of the spectrum through fragmentation of systems, particularly when adopting a regional rather than a nationally co-ordinated approach.

13.15 The current management by PSSMG of reserved public safety bands therefore requires careful stewardship. Demand for these frequencies is great and is expected to increase. As the police complete their adoption of the Airwave service across the UK and as more applications and capabilities are demanded, the pressure for an expansion in the spectrum allocated to Airwave will rise. Frequency planning for police TETRA services, falling within discrete geographical boundaries in contiguous areas, will be followed by more complex planning if and when other approved users take up their options of an Airwave service. The prospective expansion of the list of approved users would place greater demands on spectrum planning and capacity management.

13.16 A further allocation of closely managed spectrum to the public safety services could help resolve the divergent demands of a widening group of public safety users and provide effective competition for the Airwave service. It could also enable faster migration of non-police emergency services from their current analogue systems to digital technologies. One means of achieving this further allocation could be to create a nationally co-ordinated band from the release and realignment of the relevant analogue frequencies after they are freed by the migration of various public safety services to the use of digital systems.

13.17 Wherever possible, a range of technologies should be allowed to be deployed in these expanded bands and the original PSMB. This would allow competitive tendering by a range of suppliers and systems, with users defining the degree of inter-operability they require with other public safety services and systems. However, close management of the bands, seeking spectrum efficiencies and best co-ordination wherever possible, may at times necessitate a narrowing of this technology-neutral approach.

Recommendation 13.2

The RA should rationalise existing disparate assignments and widen the pool of spectrum reserved specifically for the delivery of public safety services, under the management of the Public Safety Spectrum Management Group. Wherever possible, a technology neutral approach should be taken to the systems adopted for use to allow for competition.

13.18 Given a wider remit over more reserved spectrum, there is a case for expanding the group of users eligible to access these bands. There are two main directions in which access could be expanded:

- commercial and local government organisations with a public safety remit (for example, emergency response engineers from power utilities); and
- specialist users whose spectrum needs are currently met from within Home Office managed bands.

13.19 On the former, the DTI has recently consulted on the procedures for adding to the list of approved public safety sharers. Given the wide range of civil and military safety services already able to access public safety spectrum, and the benefits of inter-operability in handling incidents, there is a case for examining favourably applications for new users that meet the emergency and public safety criteria. In doing so, it may be necessary to restrict prioritised access to sub-groups within commercial/local government organisations which have a clearly defined role in responding to public safety incidents.

13.20 On the latter, the Home Office has indicated (in its response to the review) that a small requirement for access to spectrum outside the 380-400 MHz public safety bands will remain once police forces have migrated to Airwave. This is in order to support emergency services' specialist applications and the requirements of services that are unable, for a combination of technical, operational or financial reasons, to subscribe to Airwave. In most cases, the residual users will be subject to band alignment and frequency change.

13.21 With a reduced spectrum management activity following transfer of police radio to Airwave, there are likely to be spectrum management efficiencies from incorporating these residual Home Office spectrum requirements, and the residual Home Office bands, under the management of the PSSMG. Non-police Home Office users would gain access to a wider pool of public safety spectrum open to non-Airwave services. The PSSMG would gain access to bands previously managed exclusively by the Home Office, with the potential to improve on spectrum utilisation over time, while respecting the rights of incumbent users.

13.22 The organisation of the spectrum management activity under the oversight of the PSSMG could evolve over time. This might entail devolving the functions to a specialist band management group within Ofcom, or placing a contract for this service with an external specialist organisation.

Recommendation 13.3

The remit of the Public Safety Spectrum Management Group should be broadened to encompass an expanded group of approved users, including: commercial and local government organisations with a public safety remit; and specialist users whose spectrum needs are currently met from within Home Office managed bands. Bands currently managed by the Home Office which provide access for users not migrating to Airwave should be placed under the control of PSSMG.

14 SCIENCE SERVICES

Introduction

14.1 The two main areas of spectrum use within the science services sector are earth-based radio astronomy and space-based earth exploration. Other uses include meteorological aids[1] and standard time signals. This chapter focuses on radio astronomy, which makes significant use of a range of frequency bands and where there is some scope for action at a national level to optimise spectrum use. The continued expansion of commercial communications networks is putting increased pressure on spectrum used by science services in the UK, particularly passive services which are vulnerable to man-made interference. This UK experience is set against a trend towards global scientific collaboration in scientific research, particularly in fields such as radio astronomy which bring universal benefit.

Spectrum use by radio astronomy

14.2 The ITU has allocated some 2 per cent of spectrum below 50 GHz to radio astronomy for passive observation of cosmic emissions. Around one third of these frequency allocations are harmonised globally purely for passive use, and are shared with other passive systems such as remote sensing and earth observation. The remaining two thirds of bands are shared with active services which transmit, typically fixed terrestrial and mobile services. These services have the potential to interfere with radio astronomy's passive use of the spectrum. Conversely, the degree of protection afforded by the RA to specific astronomy sites in particular bands can significantly constrain the deployment of alternative services.

14.3 The Particle Physics and Astronomy Research Council (PPARC) spends around £6m annually on the operation of six UK ground-based observatories[2], in Cambridge, Cheshire, and Worcestershire. At each site and for each frequency band, the RA provides PPARC a defined category of protection from interference:

[1] Meteorological use of spectrum is covered in the chapter on military spectrum use, as the Met Office is an Agency of the Ministry of Defence and subject to the same spectrum management regime, including pricing.

[2] PPARC devotes a further £2m to the operation of a Hawaii-based radio astronomy site, out of a total annual budget of some £210m (of which around half is dedicated to the UK's contribution to major international research activities).

Category	Protection	% of UK radio astronomy bandwidth
A	The full protection afforded a primary or exclusive radiocommunication allocation.	17
B	Full protection within a stated limit will be provided for a named observatory.	3
C	All practicable measures will be taken to protect the radio astronomy service from harmful interference when planning assignments within the band.	19
D	No protection can be afforded to the radio astronomy service in this band.	62

14.4 In practice, these levels of protection equate to exclusion zones of varying size around the astronomy sites using the bands. Protection category A can effectively result in an exclusive national allocation, with no other spectrum user having transmission rights within the band which could interfere with radio astronomy use. Protection category B and C equate to regional and local exclusion zones respectively, which vary in size according to the frequency band and the intensity of use by commercial services sharing the band. Typically, though protection category B may require the RA to limit significantly deployment of any service within a 50-100km radius of an astronomy site.

14.5 The RA currently charges some £0.3m annually to PPARC for interference protection services and representation of radio astronomy interests in international spectrum fora.

Assessment

14.6 The continued protection from interference of large and valuable blocks of spectrum for the purposes of UK-based radio astronomy imposes a cost on the rest of the UK economy, and one which is likely to increase as commercial demands on spectrum rise. At present, this cost is invisible to science policy makers and spectrum managers, and so cannot readily influence decisions about where and how basic scientific research is best conducted. Such decisions might include the continued use, with perhaps varying levels protection from interference, for bands particularly important to PPARC's research agenda. They could also encompass choices about the use of alternative UK or overseas facilities to obtain research data. In the long run, there may also be choices about the location within the UK of radio telescopes.

14.7 As with other public service spectrum users which face some choice over time about their spectrum consumption, the review advocates the application to radio astronomy of financial incentives to influence these choices.

Recommendation 14.1

UK-based radio astronomy sites should be subject to an administratively set spectrum charge for those bands where the UK has scope, under ITU regulations, to deploy other actively transmitting radio services on a co-primary basis in the band. The charge should be directly related, as elsewhere, to the geographic area and bandwidth sterilised, and should be based on the spectrum pricing which would apply to the active use of the band in that region. Where radio astronomers allow other services to deploy within their defined spectrum access, they should be compensated, for example, by the RA passing on the spectrum fee levied on fixed links which it assigns within the protection zones around observatories.

14.8 Based on an application of the current administrative pricing for fixed links and mobile, the resulting spectrum charge could amount to several million pounds. This could have a material impact on PPARC's overall radio astronomy budget. DTI could therefore consider neutralising the impact of significantly increased spectrum prices on PPARC's budget, while retaining incentives for economising on use of spectrum for radio astronomy. One means of doing so would be to agree a baseline level of spectrum fees, based upon current spectrum use and the comprehensive application of spectrum pricing, which would be funded within the PPARC budget for at least a five year period. PPARC would then gain from any economies in spectrum use over the period through retention of the spectrum fee.

15 IMPLEMENTATION

Introduction

15.1 Reform of spectrum management in the UK is a major undertaking: substantial long term benefits will only be realised through thoroughly prepared and carefully managed implementation. The RA has been actively engaged in a series of linked reforms in recent years, starting with the first public consultation in 1994 on market-based spectrum management, followed by a White Paper in 1996, new legislation in 1998, the phased implementation of spectrum pricing from 1998, and the first auction in 2000.

15.2 This review has identified a wide range of actions which build on the steps taken to date. These entail a comprehensive series of reforms, requiring action by the UK Government at all levels: international and European spectrum management policy, national legislation, domestic regulatory policy and practice. These reforms will have widespread impact across the full range of commercial and public sector spectrum users. They will need to be implemented in a manner which supports the development of competition in the private sector, and maintains wireless-delivered public services provided by public sector bodies and sectoral regulation of commercial bodies. This chapter sets out some pointers to the potential timescales for reform of spectrum management and the possible implications for the central UK spectrum regulator.

Potential timetable

15.3 To help clarify the sequencing of events and the shape of the resulting spectrum management framework, the review has identified a potential implementation timetable. This provides an overview of the main recommended steps which could be taken by the RA, Ofcom and other Government agencies over the coming decade, were the Government to commit to the programme of reforms advocated by the review.

2002

- **Ofcom:** creation of corporate entity and publication of Communications Bill.

- **Spectrum pricing:**
  - RA commissions evaluation of technical parameters for fixed links and mobile spectrum pricing, as prelude to full implementation of administratively set opportunity cost pricing;
  - Government commits to opportunity cost pricing for sectors to be exposed to pricing (terrestrial broadcasting, UK-based aeronautical and maritime radar, satellite transmissions, and radio astronomy) and RA commissions study on pricing models.

- **Spectrum trading:** RA consults on proposals for the introduction of spectrum trading.

- **Auctions:** ongoing auction of broadband wireless access licences at 28 GHz; further auctions of fixed terrestrial services spectrum at 3.4 GHz, and possibly 10 GHz and 40 GHz, with future trading ability built into licences.

- **Spectrum licensing:**
  - licence-exempt spectrum opened up for the deployment of public telecoms services;
  - consult market on using flexibility under WT Act to reduce restrictions on commercial licences.

2003

- **Ofcom:**
  - Passage of Communications Act and transfer of regulatory powers to Ofcom.

- **European legislation:** implementation of the Framework and Authorisation Directives and establishment of the Spectrum Policy Group.

- **Spectrum planning:**
  - Broadcasting:
    - Cost-benefit analysis of options and timing for achieving digital switchover for terrestrial free-to-air TV, and decisions on amount and location of released spectrum;
    - Channel 4's analogue Broadcasting Act licence due to be renewed.
  - World Radio Conference: advocate wider co-primary use of spectrum allocated to TV broadcasting.

- **Spectrum pricing:**
  - Users currently subject to spectrum pricing: first year of two year transition to full opportunity cost prices for licensees already subject to spectrum pricing;
  - Aeronautical and maritime: RA to set out basis for spectrum pricing and timetable for implementation, taking into account extant economic regulatory agreements between CAA, airport operators and NATS;
  - Defence: introduction of higher (mobile and fixed links) and more comprehensive (radar) spectrum pricing;
  - Radio astronomy: phased introduction of spectrum pricing.

- **Spectrum trading:**
  - Start of phased band by band conversion of extant and newly issued commercial licences to tradeable form;
  - Publication of spectrum assignment database;

- Broadcasting: introduce greater flexibility for public sector and commercial broadcasters to lease access to broadcasting spectrum for datacasting.

- **Auctions:** further auctions of higher frequency fixed services bands, with ability for licensees to trade/lease spectrum and/or operate as commercial band managers.

2004

- **Spectrum planning:** ITU planning conference for European TV broadcasting spectrum.

- **Spectrum pricing:** second year of two-year phased implementation of full opportunity cost pricing in fixed and mobile bands.

- **Spectrum trading:** continued conversion of bands to tradeable form.

2005

- **Spectrum planning:** ITU planning conference for European TV broadcasting spectrum.

- **Spectrum trading:** private mobile radio: the release of spectrum from the migration of emergency services to the digital Airwave service and the subsequent PMR band alignment assisted by spectrum trading.

2006

- **Spectrum planning:** World Radio Conference.

- **Regulation:**
  - Broadcasting: BBC Charter review completed;
  - Aeronautical: quinquennial review of NATS price cap regulation;

- **Auctions:** assignment of spectrum at L Band for sound broadcasting digital multiplexes and/or general use.

2007

- **Auctions:** possible licensing of additional spectrum for 3G mobile services.

2008

- **Auctions:** possible licensing of contiguous spectrum block(s) to be released from terrestrial analogue broadcasting as a result of digital TV switchover, and spare channels interleaved within TV spectrum block.

2010 onwards

- **Broadcasting:**
  - Anticipated end-point by which switchover to digital terrestrial TV and ending of analogue transmission will have been completed;
  - Full application of pricing to all spectrum reserved for delivery of DTT when digital multiplex licences are renewed.

Potential impact on RA organisation

15.4 The review's recommendations entail a shift, over time, from Government to the market, of responsibility for managing use of spectrum. There will remain large areas of spectrum reserved for delivery of public services, with continuing requirement for regulatory control. But in commercial spectrum, the operators themselves will increasingly determine the planning of assignments and uses within spectrum blocks to which they have access. The regulator's role will move away from 'retailing' spectrum towards 'wholesaling', with greater emphasis on defining the rules of engagement within which operators decide what spectrum to acquire and what services to deploy.

15.5 This section explores the **potential** impact of this shift on the organisation of the RA and, prospectively, the spectrum management groups within Ofcom. It is not part of the review's remit to assess in detail the organisational implications for RA, Ofcom and other Government bodies. Accordingly, this section aims to highlight the type of spectrum management activities which might continue or change as a result of the review's recommended approach, without analysing the level of resourcing and internal structuring of such activities.

15.6 As part of the preparatory work for the creation of Ofcom, the regulators which will form Ofcom have already begun considering the range of activities to be carried out by the new organisation. The box below highlights the conclusions of the initial scoping report by consultants[1] for the Ofcom regulators' steering group.

[1] *OFCOM SCOPING PROJECT,* Towers Perrin report to Regulators' Steering Group, October 2001.

Activity	Impact[2]	Uncertainty
Examples of spectrum management activities expected to stop under OFCOM		
Long-run move to spectrum trading leading to reduction in work associated with designing, pricing and monitoring some spectrum licences	L but H in long run	H
Examples of activities expected to start under OFCOM		
Competition work associated with spectrum trading operations	H	H
Introduction of spectrum trading legislation and operations	H	H
Examples of activities expected to continue differently under OFCOM		
Management of internal policy trade-offs between spectrum management, economic regulation and content regulation	H	L
More pre- and post-spectrum auction competition work (3G, broadband, etc)	M	L
E-enablement of less complex spectrum licensing work	M	M
Greater emphasis on spectrum refarming work, eg relating to analogue broadcasting	M	H
More interference resolution and enforcement work in high value radio bands	M	M
Increasing international spectrum negotiation work	M/L	L

[2] Key: L – low, M – medium, H – high

Continuing functions

15.7 The two key functions of strategic spectrum policy and international representation will continue for the foreseeable future to require a cohesive group of spectrum expertise in a central national regulatory body. The linkages between the UK's national spectrum strategy and the UK's position towards international spectrum co-ordination are so strong that both activities should be carried out by the same body. This suggests that the activities currently carried out within the RA's Chief Executive Group and Spectrum Policy Executive should remain together.

15.8 The conduct of this high-level spectrum policy will need to be increasingly informed by specialist economic advice, and strong commercial legal expertise to judge the implications of spectrum policy on the communications market. The growing involvement of the European Commission in spectrum policy suggests that European policy and legal capacity should be strengthened. The spectrum engineering capacity within the RA's Spectrum Policy Executive could be focused on defining the interference management framework for a spectrum access licensing regime.

15.9 The interference management and enforcement activities of the RA's Customer Services Executive would continue to be needed, and could become more important where operators have greater flexibility over their use of spectrum. Some operators will increasingly take on the task of determining access to their own spectrum blocks and negotiating boundary and other interference disputes with neighbours. The provision of detailed assignment information and planning criteria by the RA will help this process. But an impartial non-commercial spectrum 'police force', with full powers (as now) to tackle damaging interference problems, is likely to remain an efficient and effective means of keeping the spectrum clean for productive use. Indeed, with fewer restrictions on what operators can do with their licensed spectrum and a greater premium on generating a commercial return from particular bands, the number and intensity of disputes between licensees and with the regulator are likely to increase.

15.10 The RA's Spectrum Service Executive currently consists of a mixture of high level spectrum policy experts, particularly in the fields of telecoms and broadcasting, and a large number of staff engaged in licensing policy and practice. With the introduction of auctions and spectrum pricing, the RA has already devoted more resources to economic analyses of spectrum use and the impact of assignment processes on competition. The introduction of spectrum trading will accentuate the need for high quality policy teams, incorporating engineering, legal, corporate finance and economic expertise.

Devolved functions

15.11 The RA already contracts out frequency assignment and licensing tasks to a number of specialised agencies; much of the routine licensing work in particular is outsourced (around 70 per cent by volume). The RA's licensing/assignment agencies typically serve a single defined group of users who share similar spectrum demands, for example JFMG serving broadcast programme makers, and the JRC serving the power utilities.

15.12 The implications of developing spectrum trading and flexible use of spectrum are that more bands which are currently closely managed by the RA would become effectively managed by commercial operators. This could occur through a number of mechanisms:

- greater use of frequency co-ordinators and/or licensing sub-contractors operating on agency basis, an extension of the current approach adopted with JFMG, JRC, etc;
- auctioning of national and/or regional licences which are explicitly designed for spectrum management organisations, for example through requirements on the extent of third party use of a band; or
- auctioning of spectrum blocks with no restrictions (other than interference management and international harmonisation) on the deployment of third party or the operator's own systems within the band.

The availability of a public on-line database and increasing use of e-business may well also bring new dynamic and direct ways of managing the spectrum, with implications for resourcing of the central spectrum regulator.

15.13 The implications of this are most relevant for the staffing and organisation of RA HQ and regional teams involved in private mobile radio, and HQ teams in the Spectrum Service Executive involved in fixed links licensing. Altogether, some 210 full time equivalent RA staff are engaged in licensing activities, against 140 in policy and 130 in compliance. This analysis highlights that substantial numbers of in-house staff are engaged in servicing the licensing needs of the Agency's 220,000 licensees. Some of the policy work which currently supports assignment decisions may also fall away as those decisions are devolved from the RA to the licensee controlling access to specific spectrum bands.

15.14 With regard to interference management, some of the policing issues which currently arise will become internalised within the operations of commercial band managers. For example, in-band interference between two different business users, currently resolved by the RA, would become a contractual matter for a band manager to resolve between two customers. However, where licensees have greater freedom about the services and technologies they deploy, there could be greater pressure to make full use of the spectrum up to the limits of the licence. In these situations, there could be an increase in the demand for the RA's role in enforcing licensees' rights and obligations and keeping spectrum 'clean' for those who are authorised to use it.

Conclusion

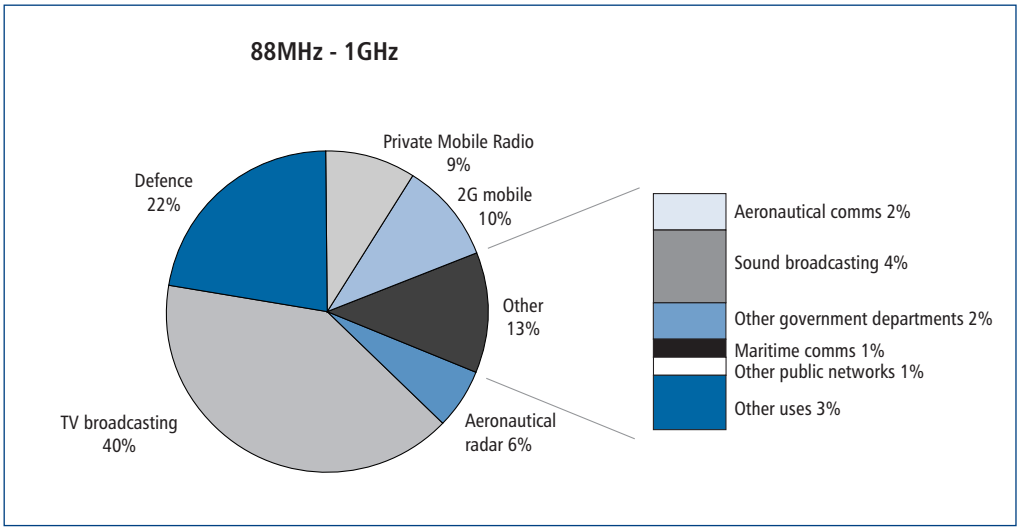
15.15 As the Ofcom Regulators' Steering Group has already identified, in the long run the move to market-based spectrum management would lead to a reduction in work associated with designing, pricing and monitoring some spectrum licences. Some new work, particularly the introduction of spectrum trading, is likely to lead to an increase in activity in the short to medium term. The implementation of the review's recommended approach to spectrum management would amplify these conclusions.

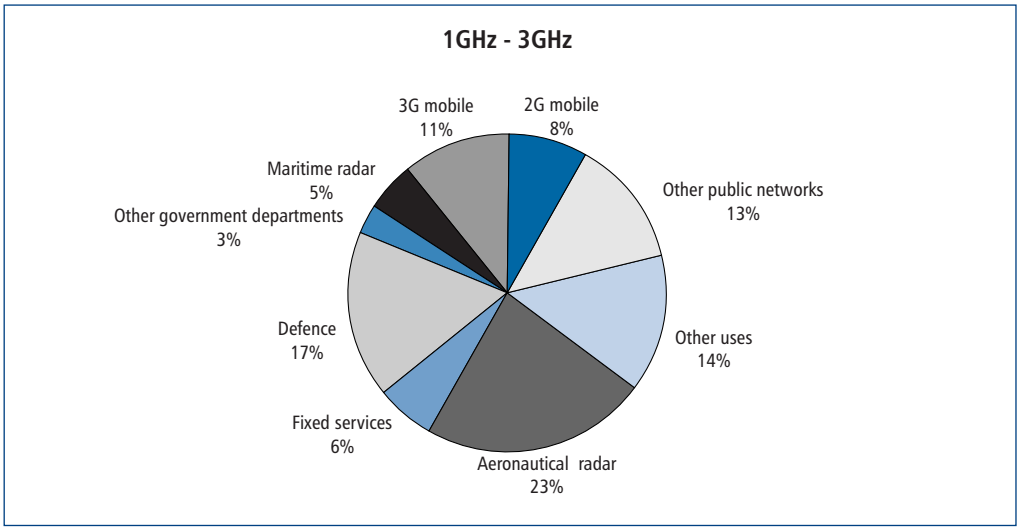
15.16 It is difficult at this stage to judge the consequences of the long term decline in work for the regulator in terms of the reduction in staff employed on spectrum management policy and implementation. Net reductions in staffing might be achieved during the second half of this decade, after the licensing of 3G expansion bands, the realignment of private mobile radio bands, progress towards digital TV switchover, and early experience of spectrum trading.

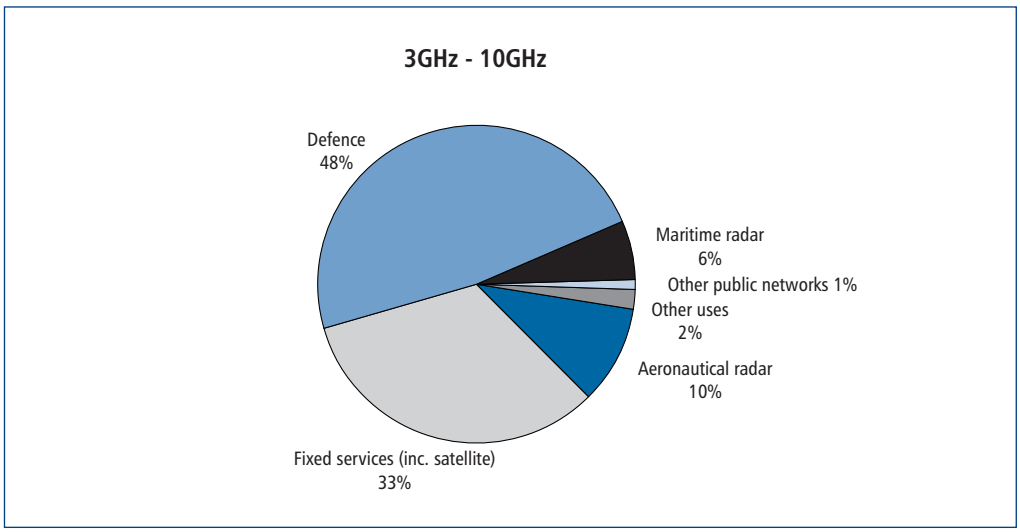
ANNEX A

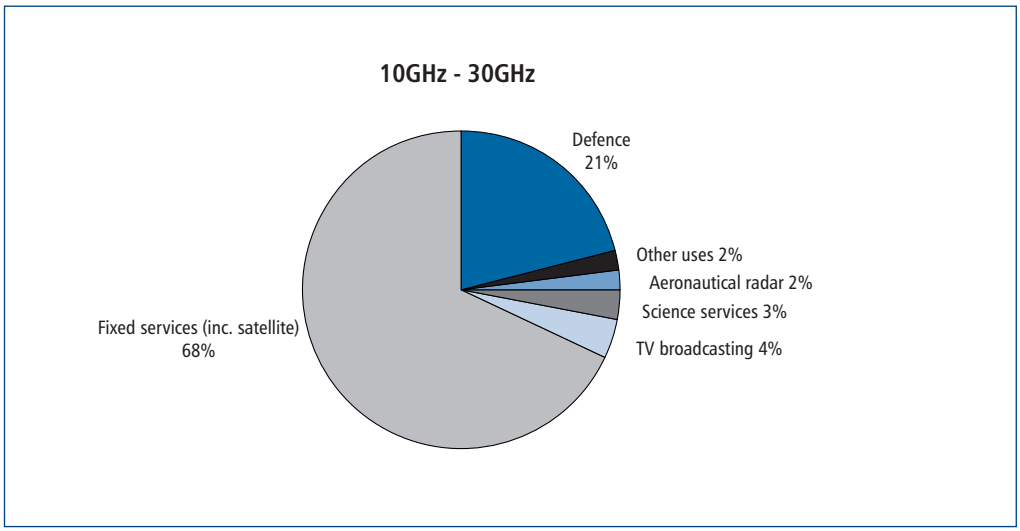
Spectrum allocations

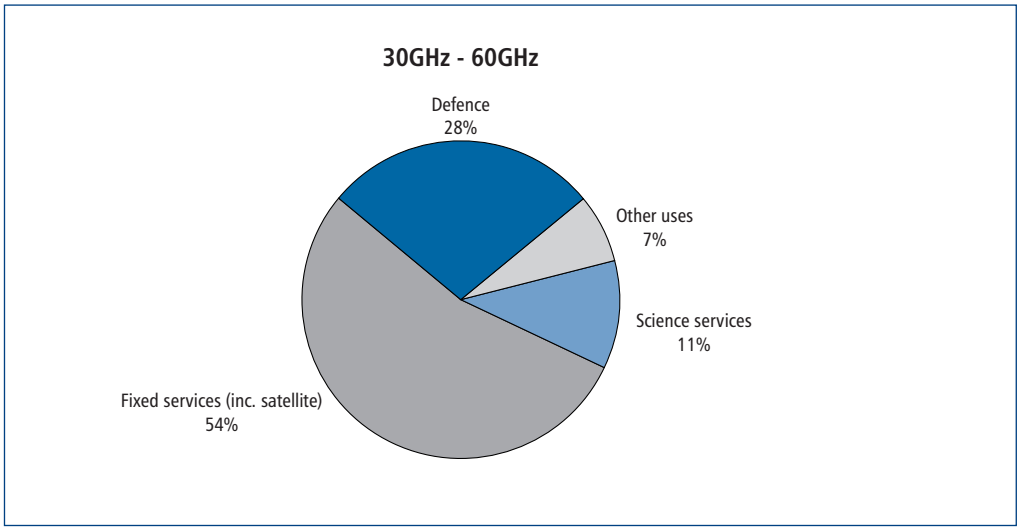
The following charts highlight the broad allocation of spectrum in the UK by various categories of use. This data was provided by the Radiocommunications Agency for illustrative purposes, based on an analysis of the detailed spectrum allocation table for the UK. Where spectrum is shared between different user categories, assumptions have been made about the amount of spectrum to be shown against each category. As the information is based on allocation table data rather than licensing records, there may be some disparities between the amount of spectrum shown and the amount of spectrum actually issued under licence.






3GHz - 10GHz
Defence
48%
Maritime radar
6%
Other public networks 1%
Other uses
2%
Aeronautical radar
10%
Fixed services (inc. satellite)
33%


10GHz - 30GHz
Defence
21%
Other uses 2%
Aeronautical radar 2%
Science services 3%
TV broadcasting 4%
Fixed services (inc. satellite)
68%


30GHz - 60GHz
Defence
28%
Other uses
7%
Science services
11%
Fixed services (inc. satellite)
54%

ANNEX B

International regulatory framework: background

This Annex presents an excerpt from the final report of a study carried out for the review by Aegis Systems Ltd and Indepen Consulting Ltd on *Implications of International Regulation and Technical Considerations on Market Mechanisms in Spectrum Management*. The full report was published at the review's website (www.spectrumreview.radio.gov.uk).

B.1 Introduction

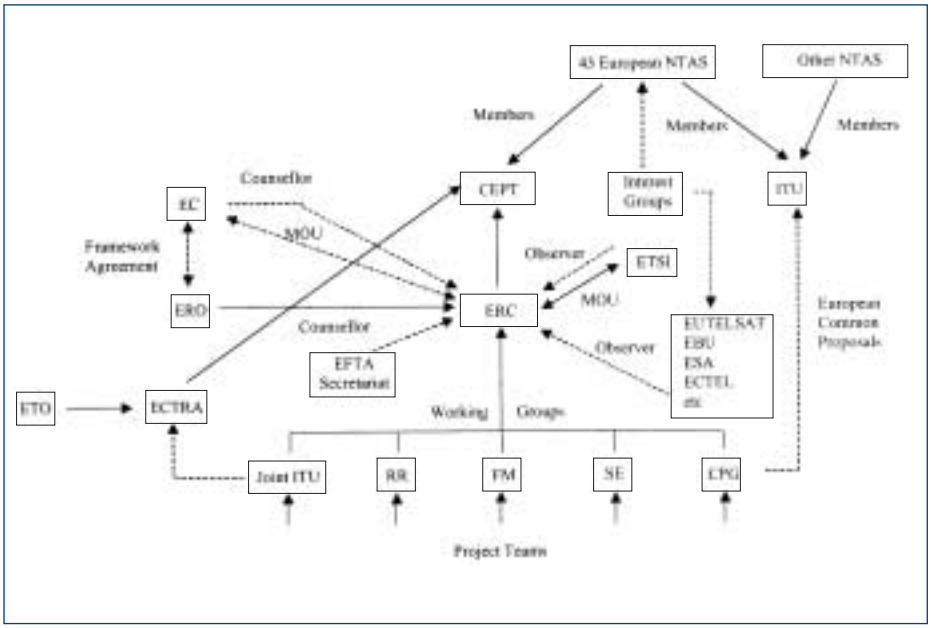
The very nature of the radio spectrum demands that its use is, in the first instance, considered at an international level. The national regulatory authority (NRA) must often comply with international / regional regulation (particularly if it has agreed to the relevant regulatory instrument), and is well advised to take account of the possible impact that any changes it proposes in the use of spectrum may have upon neighbouring states. Typically this involves the setting up of specific memoranda of understanding to protect services in neighbouring countries, such as that reached between the UK, France and Belgium to facilitate the replacement of UK Band III TV broadcasts by public access mobile radio, or those relating to GSM cellular services.

Management and use of the radio spectrum is subject to regulation (be that mandatory or advisory) by five major international bodies:

- ITU-R and CEPT have pioneered development of spectrum regulation through technical means, whilst the work of ETSI and other standards bodies has helped make possible the standardisation and harmonisation of spectrum use;
- EU and WTO have focussed on trade / market mechanisms by which to achieve fully efficient use of the spectrum[1].

The relationships between many of these bodies are shown in the following diagram. This illustrates the complexity of these associations.

[1] It may of course be noted that the EU is taking an increasingly active role in the technical management of spectrum.



The complexities of international regulatory relationships

The detailed responsibilities of the key organisations, and the manner in which they are likely to affect the UK's approach to spectrum management, are discussed in the following sections.

B.2 Global considerations

B.2.1 Introduction

The international framework for radio regulation exists primarily to protect against harmful interference. Also for services of an international nature, such as satellite, maritime and aeronautical services, international harmonisation of allocations is necessary to allow users to operate safely and effectively (e.g. international air travel, merchant navies etc). Supporting these objectives, the International Telecommunications Union Radiocommunications Sector (ITU-R) provides the overall, global, framework for spectrum use, in the form of the International Frequency Allocation Table (Article S5 of the Radio Regulations), which allocates spectrum to broad categories of service such as fixed, mobile, broadcasting or radionavigation. Services are allocated on a primary or secondary basis. Current systems operating in a primary allocation are protected from interference from all future systems. Future systems operating in a primary allocation are protected from subsequently introduced primary systems and from systems operating in a secondary allocation, but not from current primary systems. Systems operating in a secondary allocation must not cause interference to, and will not be protected from interference from, current or future primary services, but can claim protection from future secondary services.

B.2.2 The ITU Radio Regulations

The ITU issues Radio Regulations (RR) which have the status of treaties, once ratified by individual Member states. These are agreed at World Radio Conferences and Member states that do not abide by the RR cannot expect

any protection from interference. Clearly it is potentially less damaging for countries that are remote islands (e.g. New Zealand and Australia) to violate the ITU regulations than it is for countries which are proximate to many others (e.g. the UK and the rest of Western Europe).

In using the radio frequency spectrum Member States of the ITU are required:

- to endeavour to limit the number of frequencies and the spectrum used to the minimum essential to provide the necessary services and to apply the latest technical advances as soon as possible;
- to bear in mind that spectrum and orbit resources are limited and that they must be used rationally, efficiently and economically in conformity with the Regulations so that countries may have equitable access to said resources.

It is further required that all stations must be operated in such a manner as not to cause harmful interference to the authorised radio services of other Member States which operate in accordance with the Regulations.

The Regulations therefore set out to:

- facilitate equitable access to and rational use of spectrum and orbit resources;
- ensure the availability and protection from harmful interference of frequencies provided for distress and safety purposes;
- assist in the prevention and resolution of cases of harmful interference between the radio services of different administrations;
- facilitate the efficient and effective operation of all radiocommunication services;
- to provide for, and where necessary, regulate new applications of radiocommunications technology.

It is difficult to summarise the contents of the Radio Regulations and in any event it is not necessary for the purposes of this report to present the detail. It is however useful to have an overview of the issues that the Regulations address. The main body of the text is made up of several Articles supported by Appendices, Resolutions and Recommendations, the latter not to be confused with ITU-R Recommendations. The most important parts of the Regulations are those that:

- define the different radio services and many other important terms (Articles S1 to S3);
- outline the conditions for frequency assignment including the Table of Frequency Allocations (Articles S4 to S6);
- specify the procedures relating to frequency co-ordination and notification (Articles S7 to S14);

- describe provisions relating to interference and administrative issues (Articles S15 to S20);
- specify the technical, operational and administrative constraints associated with various radiocommunication services (Articles S21 to S29);
- outline provisions specifically associated with distress and safety communications (Articles S30 to S34);
- outline provisions specifically associated with aeronautical services (Articles S35 to S45);
- outline provisions specifically associated with maritime services (Articles S46 to S59).

It is important to appreciate that the Radio Regulations only provide a high level framework within which administrations operate. Using the technical characteristics specified in the Regulations for various types of radiocommunication station does not mean that different systems will be able to coexist. In the interests of flexibility, efficiency and the desire of nation states to exercise control, the Regulations only assist in arriving at a situation where coexistence might be achieved.

From the point of view of this study perhaps the most important provision is S4.4 which requires that:

Administrations of the Member States shall not assign to a station any frequency in derogation of either the Table of Frequency Allocations in this Chapter or the other provisions of these Regulations, except on the express condition that such a station, when using such a frequency assignment, shall not cause harmful interference to, and shall not claim protection from harmful interference caused by, a station operating in accordance with the provisions of the Constitution, the Convention and these Regulations.

In fact using harmful interference as the yardstick gives significant latitude as its definition is vague and less stringent than other measures of interference, although it is the one definition of interference contained in the Constitution of the ITU.

Permissible interference – Observed or predicted interference which complies with quantitative interference and sharing criteria contained in these Regulations or in ITU-Recommendations or in special agreements as provided for in these Regulations.

Accepted interference – Interference at a higher level than that defined as permissible interference and which has been agreed upon between two or more administrations without prejudice to other administrations.

Harmful interference – Interference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with Radio Regulations.

In addition to the types of interference level defined above there are also a number of "trigger" levels which are specified with a view to determining whether co-ordination is required or not. Most of the "trigger" levels in the Radio Regulations are related to satellite services as these are of a more global nature. However, co-ordination "trigger" levels are often agreed between administrations having territorial boundaries. These bilateral "trigger" levels are often based on ITU-R Recommendations.

All of these interference levels, the co-ordination "trigger" level, the permissible interference level and the accepted interference level (once agreed between administrations) are quantified. The most fundamental of them all, namely harmful interference, however is not. In terms of international obligation therefore it is difficult to know exactly what should be met without stepping back and taking account of the other interference levels that are defined. In any event other administrations are not likely to accept an interference level that falls just below the harmful interference level (if this can be agreed) but above the permissible interference level even if the legal situation deems this as satisfactory.

The main question that arises from the key parts of the framework of the Radio Regulations as identified above is "How, and under what circumstances, can you define radio operations within your own territory so that they do not cause (harmful) interference to systems managed by other administrations?" This is the question addressed in annex C.

B.2.3 ITU-R Recommendations

ITU-R Recommendations, as their name implies, do not have the same legal status as the Radio Regulations. They are intended to be advisory rather than mandatory. However it can be noted that most Administrations take them sufficiently seriously that they are widely acknowledged and implemented in practice.

There are some special cases in the Radio Regulations where specific ITU-R Recommendations are incorporated by reference. In these instances the ITU-R Recommendations concerned will have a higher legal status and will be binding in the same way that the Radio Regulations are.

As noted earlier the fundamental requirement not to cause harmful interference is not quantified and therefore difficult to assess. It is probable that any dispute regarding interference would revert to criteria that have been quantified, namely permissible interference and accepted interference. Values associated with these criteria are likely to be based on ITU-R Recommendations. Under these circumstances it can be seen that ITU-Recommendations take on a level of importance not immediately obvious from their legal status.

B.2.4 World Trade Organisation

The WTO Agreements focus on the desirability of a market that is as free from restriction as is possible. Thus the General Agreement on Trade in Services (GATS) requires that any member / group (e.g. CEPT) operating under the auspices of the GATS ensure that procedures for the allocation and use of frequencies should be carried out in an objective, timely, transparent and non-discriminatory manner.

One interpretation of this, in terms of the deployment of radio equipment, is that it is not acceptable to specify a national / regional equipment or interface standard to the exclusion of other standards unless it can be demonstrated that another standard will cause harmful interference.

This situation is effectively reflected in the EC's R&TTE Directive that specifies essential requirements for the placement of equipment on the market at a qualitative level, rather than in a quantitative manner as is generally the case in a technical standard.

B.2.5 Other sector-specific bodies

There are a number of other organisations that represent the interests of specific user groups, such as the International Maritime Organisation and the International Civil Aviation Organisation. These bodies represent their user communities in ITU fora and co-ordinate spectrum usage in accordance with the Radio Regulations and relevant ITU recommendations, but are not directly involved in the frequency allocation process.

B.3 Regional (European) considerations

B.3.1 Introduction

Within Europe, the European Conference of Posts and Telecommunications Administrations (CEPT) provides detailed guidance to NRAs, operators and vendors, seeking to achieve harmonisation throughout the region, an objective mandated by the European Union (EU). Within CEPT the European Radiocommunications Committee (ERC) undertakes spectrum harmonisation activities. [N.B. The ERC has now been subsumed within the Electronic Communications Committee (ECC) of the CEPT.] The main instrument for the harmonisation of frequency allocations in Europe is the ERC Decision. ERC Decisions often specify the service and the technical standards to be used. ERC Decisions are agreed by consensus and the intention to conform to a Decision is signalled by signing the Decision, an act which is strictly optional. However, if EU member states do not support measures which the European Commission (EC) would like to see implemented it is possible that the EC would seek to have the measures implemented through EC legislation.

The European Telecommunications Standards Institute (ETSI) develops the harmonised equipment standards that help systems to operate freely across the continent, and indeed beyond.

B.3.2 Constraints arising from European Commission regulatory activities

As noted in the preceding section, there are a variety of European legislative measures, both proposed and in force that have the potential to constrain UK spectrum management activities. Amongst the Directives and Decisions most likely to affect spectrum use are[2]:

- the proposed Framework Directive (EC document 10420/1/01, rev.1);
- the proposed Authorisation Directive (EC Document 10419/1/01, rev. 1);
- the Competition Directive (as amended) (96/19/EC);
- the proposed Radio Spectrum Policy Decision (EC Document COM/2000/0407);
- the R&TTE Directive (1999/5/EC).

In addition there are a number of existing service-specific Directives and Decisions which place constraints on specific frequency bands, namely:

- the GSM Directive (87/372/EEC);
- the ERMES Directive (90/544/EEC);
- the DECT Directive (91/287/EEC);
- the Satellite PCS Decision (710/97/EC) (amended 1215/2000/EC);
- the UMTS Decision (128/1999/EC).

It may also be noted that some pressures on spectrum management are likely to arise from the proposed Access & Interconnection Directive and from the Users Rights & Universal Services Directive.

The service specific measures are likely to continue in force under the new regulatory framework, which is expected to come into force during between April and September 2003 and any moves towards furthering the use of market based spectrum management should take account in particular of the provisions in the proposed Authorisation Directive and the Spectrum Decision.

The possible impact of the legislation is addressed in the next section.

B.3.2.1 Implications of European jurisdiction

The primacy of European legislation over national legislation produces both opportunities, such as those offered by European harmonisation, and constraints for each Member State. This section looks at three specific issues, namely:

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[2] A *Directive* binds Member States concerning the objectives to be achieved by a given date, leaving the national authorities the choice of form and means to be used. Directives have to be implemented in national legislation in accordance with the procedures of the individual Member States.
A *Decision* binds those to whom it is addressed. A decision does not require national implementing legislation. A decision may be addressed to any or all Member States, to enterprises or to individuals.

i) The feasibility and implications for the EU market and industrial development policy, of the UK adopting non-European standards or technologies;

ii) The importance of future European harmonisation plans;

iii) Band specific constraints arising from service specific Directives and Decisions.

It is worth noting that the European Directives and Decisions are on occasion ambiguous and are subject to interpretation, and that the proposed new Directives are not yet finalised. Furthermore, as in the case of UMTS for example, even where an action is mandated (provision of a system adhering to the ETSI UMTS standard) this need not prevent an NRA from taking actions which may perhaps go against the spirit, if not the letter, of the relevant text. Thus once the NRA has licensed a UMTS conformant system, it might choose also to license a non-UMTS conformant system. The following sections seek to identify some of the constraints which arise from actual and proposed European legislation, and to determine whether other courses of action may yet be legitimate.

The potential for non-European standards

Development, adoption and use of standards within the Community are addressed in, amongst others, the R&TTE Directive and proposed new Framework Directive.

In broad terms, the R&TTE Directive seeks to encourage the introduction of innovative technologies, through: "fast track" procedures such as the use of self-declarations of conformance; a shift from the use of standards as an end in themselves to a support for legal requirements defined within the Directive; simplification of the conformance process by introduction of Europe wide standards, rather than national standards, some of which are equivalent and some of which are not. Crucially, it also permits operation of apparatus that does not conform to a European standard, but does meet "essential requirements" as defined in Article 3. These essential requirements demand that all equipment:

- meets the health and the safety requirements contained in Directive 73/23/EEC;
- meets the protection requirements with respect to electromagnetic compatibility contained in Directive 89/336/EEC;
- and, in the case of radio equipment, uses the spectrum allocated to terrestrial/space radio communication and orbital resources so as to avoid harmful interference.

The Framework Directive seems to support this liberal stance, stating that all regulation should be technologically neutral, indeed the latest Commission Proposal is "to give preference to technically neutral standards". Yet the underlying intention of the FD is clear: that all Member States should adopt

the same standards in order to maximise the possibility of pan-European operation and the development of pan-European markets. Following the WTO ruling on free trade, the Community now "encourages" rather than mandates adherence to specific standards, thus the path is broadly clear for the introduction of alternative technologies, particularly where that technology is intended solely for use within a single Member State and where issues such as cross border interference will not arise.

Thus alternative technologies can in theory function within the European market. However, failure to conform fully and precisely to a European standard may lead to significant problems should any Member State wish to challenge the entry of a new service or technology into its own national market, making it more difficult, or even impossible, to achieve a pan-European market without the use of a European standard.

A Member State is at liberty to refuse to allow a technology which it believes fails to meet the provisions of the R&TTE to operate within their boundaries (Article 9 of the R&TTE Directive). Grounds for refusal include:

(a) incorrect application of the harmonised standards;

(b) shortcomings in the harmonised standards;

(c) failure to satisfy the "essential requirements" referred to in Article 3 of the R&TTE Directive (despite having adhered to an equivalent standard for example).

Furthermore, Member States can bar from their markets equipment that falls outside the provisions of the R&TTE Directive as a consequence of Article 30 of the EC Treaty. This article allows nations to restrict the free movement of goods on the grounds of public order, public security or protection of health.

Member States are urged to take measures to withdraw apparatus that fails to meet the requirements of the Directive from the market or from service, prohibit its sale or use and restrict its free movement. Under article 8.2 of the R&TTE Directive, all Member States are obliged to allow non-conformant apparatus to be displayed at exhibitions, demonstrations etc, but the apparatus must be clearly signed as being non-compliant with the Directive, and therefore not permitted to be marketed or to operate. This would be of slight benefit whilst determining whether a Member State was justified in rejecting the technology.

Developing and improving European standards

Introducing a technology that does not adhere to a European standard can therefore be seen to have certain pitfalls associated with it. One possible reason for using non-European standards and technology would be the inadequacy of, or restrictions imposed by, existing European standards in the area of interest. This possibility is addressed by both the R&TTE and Framework Directives. A process for continuous improvement is outlined in Article 17 of the FD, which may be summarised thus:

1. The Commission will develop a list of standards (produced by ETSI, CENELEC, or CEN) which Member States shall encourage organisations to use. The objective of this set of standards will be to ensure interoperability and extend freedom of choice. The Commission may make use of certain standards compulsory if voluntary use is failing to achieve interoperability / freedom of choice, and conversely may remove a standard if it is deemed to hamper innovation or no longer to achieve its purpose.

2. Where a service is not addressed by a standard from the Commission list, Member States are to encourage the use of standards from ITU, ISO or IEC.

3. The European Standards Organisations will then be encouraged to develop appropriate European standards, based on the International standards, which may then be published as part of an increasingly comprehensive Commission list.

Beyond conformance

Conformance to a European standard does not guarantee success within the European market however. Although by default conformance demands pan-European acceptance, Member States retain a number of grounds upon which they can decline to accept even conformant technology. For example, under A 7.2 R&TTE, Member States may restrict use of radio equipment on grounds related to the effective and appropriate use of the radio spectrum, avoidance of harmful interference or matters relating to public health. If a Member State considers that apparently compliant apparatus would cause serious damage to a network or harmful radio interference the operator may be authorised to refuse connection, to disconnect such apparatus or to withdraw it from service.

In summary, the situation with regard to use of technology which does not adhere to a European standard depends to some extent upon interpretation of the applicable Directives. Where the technology is to be used exclusively within the boundaries of a Member State the opportunities do exist for successful introduction. However, if, as is probably more likely, the owner of the technology wishes to introduce it into one Member State as a point of entry to the wider European market, the obstacles and associated risks are considerably greater, though not necessarily insurmountable.

Ramifications of spectrum harmonisation

Harmonisation within the Community comprises two main strands; equipment harmonisation, as touched upon in the preceding section, and spectrum harmonisation.

Spectrum harmonisation within the Community is underpinned by regulations and recommendations arising from three main bodies: ITU-R, CEPT and EU. Within the EU the issue is addressed both in the service specific Directives and Decisions (see next section) and within the Framework

Directive. As with equipment harmonisation, European legislation offers both opportunities and constraints, driven by the desire to maximise the extent to which interoperability and interference free systems can be achieved within the Community.

Historically, harmonisation has been achieved under the auspices of the CEPT. However, adherence to CEPT recommendations, and indeed ERC Decisions in the first instance, is a voluntary matter for each NRA. Whilst common interests and peer pressure have often made this an acceptable approach, the Commission consider that such a situation is no longer sufficient or acceptable. Citing the need for greater certainty on the part of major investors, the Spectrum Policy Decision (SPD) states that *"where policy agreement is reached to harmonise the use of radio spectrum necessary to implement relevant Community policies, legal provisions should ensure the appropriate implementation of measures by the Member States."* It proposes that harmonisation issues continue to be addressed at a technical level by the CEPT, with the Commission subsequently mandating that (where the results generated by CEPT are acceptable) the Member States implement them (A4 – SPD). The issues to be addressed will be determined by the Senior Official Radio Spectrum Policy Group (created by the SPD) and may cover harmonisation of: the use of spectrum, assignment methods, conditions for use, and availability of information related to spectrum use.

The Group is constrained in its choice of bands for harmonisation by the Framework Directive which indicates that Member States shall promote the harmonisation of spectrum use "consistent with the need to ensure effective and efficient use thereof" (A9 – FD). As noted earlier, the Article goes on to permit the transfer of rights to spectrum use – but specifically requires that harmonised spectrum does not change use.

It is worth noting that some flexibility is provided for in A8.1 – FD, which enables NRAs to contribute to the promotion of cultural and linguistic diversity, together with media pluralism – perhaps thereby allowing the same (non-harmonised) frequencies to be licensed for different applications in each of the home nations (England, Scotland, Northern Ireland and Wales) dependent upon cultural and linguistic needs.

Implications for specific bands

The service specific Directives impose some quite clear constraints on the use of certain parts of the spectrum. Given that each Directive has the force of law in the UK, these constraints may be considered immutable. However, the Directives all arise from a desire to maximise the choice, quality and value of services available to European citizens. Where markets are in decline, or have reached a plateau without requiring their full anticipated spectrum requirements, as for example in the case of ERMES, spectrum may perhaps be made available for alternative services. As with other Directives, some aspects are less clear cut and allow some room for interpretation.

1880 – 1900 MHz: DECT

The DECT Directive constrains use of the band, providing as it does for primacy of DECT systems over all others. Furthermore, although pre-existing services are permitted to keep operating on a non-interference basis, the Directive does not allow for new services to enter the band, thereby reducing the flexibility available to the Agency. Any system wishing to make use of the privileges associated with the DECT Directive must conform to the European Telecommunications Standard for digital cordless telecommunication systems. Given the deregulated nature of DECT services and its widespread adoption in the consumer market it would in any case be difficult to accommodate other services or technologies within this spectrum

169.4 – 169.8 MHz: ERMES

The ERMES Directive identifies four channels as being of particular importance (as noted previously), with the remainder of the band needing only to be allocated to paging should commercial demand so require. Although the Directive cites preferred channels, these are not mandated; references to the need for co-ordination between Member States suggests that some flexibility may be allowed. In view of the limited market success of ERMES, the European Commission has subsequently announced that administrations may allocate channels for paging services other than ERMES. The Commission is re-examining the ERMES Directive as part of the 1999 review of the telecommunications regulatory framework.

890 – 915 MHz and 935 – 960 MHz: GSM

The introduction of GSM services to Europe is often cited as an example of good practice in regional regulation. The Directive foresees a market that reaches its peak within ten years of the service coming into operation – i.e. by 2001, requiring that the full allocation, 890 – 915 MHz and 935 – 960 MHz be made exclusively available to GSM systems. In fact this full allocation was required some years ago in many EU Member States, due to the success of GSM. It is hard to envisage any part of the current allocation being relinquished by the GSM community, unless and until third generation systems become as widespread and as commercially successful as the second generation. Even then it is likely that GSM spectrum, which has been earmarked internationally for the expansion of IMT-2000, will be required to facilitate migration from 2G to 3G services. On a different tack, it is interesting to note that the GSM Directive addresses spectrum that was, at the time the legislation was passed, occupied by a variety of systems in different Member States. The GSM approach, including wide consultation, early notification and phased introduction enabled most Member States to refarm in a timely and effective fashion (though the continuing presence of tactical fixed links in the GSM 1800 band has arguably hindered the development of GSM in France).

2 GHz: IMT-2000

The UMTS Decision mandates Member States to ensure that UMTS operates in the frequency bands harmonised by CEPT, namely: 1900 – 1980 MHz, 2010 – 2025 MHz, 2110 – 2170 MHz (terrestrial), and 1980 – 2010, 2170 – 2200 MHz (satellite).

NRAs are required to ensure that UMTS is organised "pursuant to European standards for UMTS, approved or developed by ETSI, where available", and that licences allow trans-national roaming within the Community. However, within the preamble, the Decision recognises that the voluntary application of standards remains the default, with specific standards being mandated only when necessary to ensure interoperability and to facilitate international roaming.

Both the R&TTE Directive and the WTO rules indicate that Member states cannot specify that a single technology be used at a given frequency, unless it is possible to demonstrate that use of multiple technologies will cause harmful interference. "Harmful interference" is not however defined in quantified fashion.

1.6/2.4 GHz and 1.9/2.1 GHz: S-PCS

Satellite Personal Communication Systems (S-PCS) are another relatively recent development within the telecommunications markets, a fact that is reflected in the 1997 Decision[3] affecting their introduction and use. By the time of this Decision, the paradigm shift that moved spectrum management away from being an exclusively engineering preserve into one in which engineering and economics work hand in hand, was well underway. This Decision therefore touches upon matters that were not addressed by the earlier Directives. For example, when considering licensing procedures, an extended time frame is allowed for NRAs using comparative bidding procedures.

The S-PCS Decision requires that, where spectrum scarcity limits the number of systems that can viably operate, Member States co-ordinate amongst themselves to ensure that common systems operate across the Community. A new feature within the Decision is the "one stop shopping" procedure outlined in the next section. In short, this results in applications/notifications being made to a European body, from which the application/notification is forwarded to the NRA. Arguably, this greater distance between the NRA and the applicant, may have a detrimental impact on the relationship between the two.

The Directive expires on 31 December 2003.

[3] Extended, but unchanged by: Decision No 1215/2000/EC of the European Parliament and of the Council of 16 May 2000 extending No 710/97/EC on a co-ordinated authorisation approach in the field of satellite personal communications services in the Community *Official Journal L 139, 10/06/2000 P. 0001-0001.*

B.3.3 Summary of relevant Directives and Decisions

The preceding sections have addressed the core Directives and Decisions affecting spectrum management and regulation. However, a wider range of legislation/proposed legislation exists, much of which is cross referenced within the texts addressed above. For completeness the following table, showing Directives then Decisions in chronological order, is provided.

Directives

87/372/EEC OJ No. L 196 17/07/87 pg. 85	Council Directive 87/372/EEC of 25 June 1987 on the frequency bands to be reserved for the co-ordinated introduction of public pan-European cellular digital land-based mobile communications in the Community (GSM Directive)
89/336/EEC OJ No. L 139 23/05/1989 pg.19	Council Directive 89/336/EEC of 3 May 1989 on the approximation of the laws of the Member States relating to electromagnetic compatibility (The EMC Directive)
90/388/EEC OJ No L 192 24/07/1990, pg.10	Commission Directive 90/388/EEC of 28 June 1990 on competition in the markets for telecommunications services (amended by Directive 96/19/EC)
90/544/EEC OJ No. L 310 09/11/90 pg. 28	Council Directive 90/544/EEC of 9 October 1990 on on the frequency bands designated for the co-ordinated introduction of pan-European land-based public radio paging in the Community (The ERMES Directive)
91/287/EEC OJ No. L 144 08/06/91 pg. 45	Council Directive 91/287/EEC of 3 June 1991 on the frequency band to be designated for the co-ordinated introduction of digital European cordless telecommunications (DECT) into the Community (The DECT Directive)
94/46/EC OJ No L 268, 19/10/1994, pg.15	Commission Directive 94/46/EC of 13 October 1994 amending Directive 88/301/EEC and Directive 90/388/EEC in particular with regard to satellite communications (The Satcoms Directive)
95/62/EC OJ No L 321, 30/12/1995, pg. 6	Directive 95/62/EC of the European Parliament and of the Council of 13 December 1995 on the application of the principles of open network provision (ONP) to voice telephony (The ONP Directive)
98/61/EC OJ No. L268 03/10/1998	Directive of the European Parliament and of the Council on interconnection in telecommunications with regard to ensuring universal service and interoperability through application of the principles of open network provision (ONP) (The Interconnection Directive – (97/33/EC amended)

96/2/EC OJ No. L 020 26/01/1996 pg. 59	Commission Directive 96/2/EC of 16 January 1996 amending Directive 90/388/EEC with regard to mobile and personal communications (The Mobile Directive)
96/19/EC OJ No. L074 22/03/96 pg.13	Commission Directive 96/19/EC of 13 March 1996 amending Directive 90/388/EEC with regard to the implementation of full competition in telecommunications markets (The Competition Directive)
97/66/EC OJ No. L 024 30/01/1998 pg.1	Directive 97/66/EC of the European Parliament and of the Council of 15 December 1997 concerning the processing of personal data and the protection of privacy in the telecommunications sector
98/34/EC OJ No. L 204 210/07/1998 pg. 37	Procedure for information in the field of technical technical standards and requirements in the Information Society (amended by 98/48/EC)
98/48/EC OJ No. L 217 05/08/1998 pg.18	Directive 98/48/EC of the European Parliament and of the Council of 20 July 1998 amending Directive 98/34/EC laying down a procedure for the provision of information in the field of technical standards and regulations
98/84/EC OJ No. L 320 28/11/1998 pg. 54	Directive 98/84/EC of the European Parliament and of the Council of 20 November 1998 on the legal protection of services based on, or consisting of, conditional access.
1999/5/EC OJ No. L 091 07/04/99 pg.10	Directive 1999/5/EC of the European Parliament and of the Council of 9 March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity (The R&TTE Directive)
DECISIONS	
710/97/EC OJ No L 105 23/04/97 p. 4	Decision No 710/97/EC of the European Parliament and of the Council of 24 March 1997 on a co-ordinated authorisation approach in the field of satellite personal-communication services in the Community (amended 1215/2000/EC)
128/1999/EC OJ No L 017 22/01/1999 pg.1	Decision No 128/1999/EC of the European Parliament and of the Council of 14 December 1998 on the co-ordinated introduction of a third-generation mobile and wireless communications system (UMTS) in the Community

B.3.4 Constraints from CEPT regulatory activities

B.3.4.1 Introduction

The UK plays an active role in CEPT, participating in all three of the principal ERC Working Groups and many of the subsidiary project teams. The UK has committed to implementing most ERC Decisions and follows many of its Recommendations, for example relating to channel plans for fixed links and mobile services.

B.3.4.2 Impact of CEPT Decisions and Recommendations

Before considering CEPT Decisions and Recommendations in detail, it is helpful firstly to clarify the nature of the two instruments. Unlike EU Directives, CEPT Decisions and Recommendations (commonly referred to as ERC Decisions and CEPT Recommendations) are not mandatory. However, when an Administration agrees to implement an ERC Decision, the requirements of that Decision then become mandatory in the Administration concerned as an International Obligation. Recommendations are at all times for guidance only, although their adoption in practice can lead to de facto constraints, particularly with regard to national frequency allocations or channel plans. Whilst the EU has in recent years tended to delegate significant aspects of frequency management to the CEPT, it should be noted that, as identified earlier, this approach is based on an assumption that the implementation of ERC Decisions will be on a sufficiently ubiquitous basis to facilitate the EU's harmonisation objectives. Excessive delay in adopting Decisions, or the failure of these to be adopted on a sufficiently widespread basis, may lead to the EU taking a more direct interventionist approach in spectrum management, as it has already done in the case of 3G mobile and as presaged by the draft new Spectrum Decision.

What then is the likely impact of these Decisions and Recommendations?

Spectrum pricing

The ERC's Radio Regulatory Working Group (WGRR) has been addressing spectrum pricing as part of its remit. Project team RR8 was first established to address Fees and Charges. It issued a report on using spectrum pricing as a spectrum management tool and has subsequently started developing a draft ERC Report on refarming and secondary trading issues and other related topics as indicated in the EU's package of new directives. A draft document on the subject was circulated at the WGRR plenary meeting in July 2000. It has also issued a report on PMR pricing (early in 2001) and has recently issued a first draft on satellite pricing. The UK has been closely involved in each of these pieces of work.

Refarming and spectrum trading

ERC has decided that secondary trading should be one of the issues it considers in the context of spectrum refarming, and a draft report is currently

being developed by WGRR[4]. The ERC work will take into account developments in non-European countries such as the USA and Canada, along with the potential interest in spectrum trading among CEPT members. The draft report identifies spectrum trading as one measure that might be used in reframing frequency bands (i.e. recovery of spectrum from existing users for re-assignment either for new uses or new, spectrally efficient technologies). It also notes that trading more generally facilitates more efficient use of spectrum, by providing incentives for incumbents to relinquish spectrum they do not require in favour of a new entrant who can make more effective use of it.

However, the report also flags up potential constraints which might prevent a completely free hand in a trading environment, in particular the international and technical factors assessed by the current study.

Dialogue with other European NRAs suggests that the UK is considerably more advanced than other EU Member States in its thinking on spectrum trading. For example, a number of Administrations have expressed the view that they would not envisage change of use in a trading environment. There would seem to be a strong case therefore for the UK to play an active role in the development of policy with ERC at this formative stage, to ensure that its future options are not constrained by adoption of excessively conservative approaches to European policy in this area.

ETO One stop shop facility

In 1996, the European Telecommunications Office (ETO) an administrative arm of the CEPT, established a "One-stop-shop" facility to process licensing for satellite and other liberalised telecommunications services on a pan-European basis. Where adopted by individual NRAs, the OSS procedure provides licence applicants with the following facilities:

- A single point of contact (ETO) for services providers wishing to provide telecommunications services in different European countries.
- Information on licensing procedures in the different CEPT countries.
- A single application form in English, common to all countries.
- A single document summarising the results of the procedure, with any licences granted by different NRAs (National Regulatory Authorities) attached.
- A procedure where an answer is given to the service provider in no more than 9 weeks.

In practice, it is unlikely that the OSS would constrain flexibility in spectrum licensing, since spectrum is subject to individual licensing, typically involving selection on the basis of financial (auctions) or other (beauty contest) criteria. The OSS could facilitate the trading process by providing a simplified and

[4] *Draft ERC Report on Refarming and Secondary Trading in a converging world*, Doc CEPT/ERC/RR(01)071 Annex 2

centralised approach to telecommunications service licensing where this is required to utilise the spectrum which is being purchased. The UK joined the OSS procedure at the end of March 2001.

B.3.5 Bilateral considerations

Radio signals do not respect national boundaries and it is therefore necessary for the UK to co-ordinate its usage of the radio spectrum with its immediate continental neighbours. In the case of some satellite and low frequency services, co-ordination with countries further afield may also be required. However for terrestrial services above 100 MHz, with which this study is principally concerned, co-ordination is potentially required with the Belgian, Dutch, French and Irish administrations. The UK has already entered into bilateral agreements with these countries for a number of services, notably mobile services such as GSM, and the Band 3 analogue trunked radio services. Similar bilateral agreements are also being negotiated for the core IMT-2000 bands. Three different approaches have been taken, depending on the nature of the services and spectrum being co-ordinated: these are considered below:

Co-ordination between mobile and broadcasting services in Band III (174 – 225 MHz)

When the 405-line TV services was discontinued in the 1980's, the UK decided to introduce a new public access mobile radio (PAMR) service in the spectrum that was vacated (Band III). Belgium, France and Ireland continued to operate analogue TV services in this band however, and indeed still do so today. It was therefore necessary for the UK administration to reach agreement with its neighbours on the protection of these services. The approach taken to protecting the broadcasting service in neighbouring countries was based on the determination of a cumulative "nuisance field" determined using statistical methods developed by the CCIR (forerunner of ITU-R). This cumulative figure would take account of all UK mobile base station transmitters within up to 300 km of the neighbouring coastline or border, although in practice interference would be dominated by the closest transmitters.

The situation in Band III was further complicated by the fact that narrow band (12.5 kHz) mobile radio channels were being co-ordinated with broadband (6 – 8 MHz) television channels, and that the protection requirements of the TV channels were not constant over the channel bandwidth but varied by almost 20 dB depending on proximity to the sound and vision carriers. Furthermore, each of the neighbouring countries operated different TV standards, with different sound and vision carrier frequencies. By careful partitioning of the band, so that base station transmit sub-bands avoided as far as possible the most sensitive vision carrier frequencies, the UK was able to maximise the use of the band for mobile services but nevertheless the need to protect broadcast services in France, Belgium and the Netherlands severely constrained PAMR network capacity in the South East and arguably may have contributed to the difficulties experienced by the operators, several of whom had to cease operations or merge with competitors over the years.

The Band III experience is an interesting one as it is likely to have parallels with any attempt to refarm unilaterally the UHF broadcasting bands. This will be considered in more detail in the corresponding case study.

Co-ordination between GSM services in the 900 MHz and 1800 MHz bands

Because the GSM bands are largely common throughout Europe (notwithstanding some outstanding non-GSM operations in the E-GSM and 1800 MHz bands) and common standards are involved, the co-ordination process is greatly simplified. The approach is defined in ERC Recommendations T/R 20-08 (for the 900 MHz band) and T/R 22-07 (for the 1800 MHz band) and involves the agreed apportionment of preferred channels or blocks of channels between the co-ordinating countries. Field strength limits are defined which, for preferred channels, must not be exceeded 15 km inside the neighbouring country's territory and, for non-preferred channels, must not be exceeded at the border. In coastal areas, the co-ordination is based around a line midway between the two neighbouring countries. In practice, variations on this approach (e.g. agreement of alternative field strength limits) may be made. In the UK case, co-ordination typically involves preferred and non-preferred blocks of 1 – 3 MHz. Co-ordination is also required between GSM and other services, notably in the UK case between parts of the GSM 1800 band and transportable fixed stations in France. These are conducted on a bilateral basis taking account of the characteristics of each service (specific details are confidential).

International co-ordination of GSM services is not in practice a major constraint on the use of the GSM bands, since an increasingly large proportion of transmitters serve micro or picocells, which by their nature cover small areas and operate at relatively low power levels. Cellular planning requires intensive frequency re-use over relatively short distances, hence techniques such as antenna downtilt are generally employed, which further reduces the interference exported to neighbouring countries. Optimum use of the available spectrum can be made by operating macrocells on preferred channels and micro or picocells on non-preferred channels. However, this approach may not be feasible if the GSM bands are migrated unilaterally to 3G technologies such as wideband CDMA, since the 5 MHz channel used for the macro layer may encompass both preferred and non-preferred GSM blocks. This is considered in more detail in the case study.

Co-ordination between 3G mobile services

3G mobile differs from GSM in that the radio frequency channels have much greater bandwidth (5 MHz compared to 200 kHz) and the same radio channel is used in each cell, relying on code division multiple access (CDMA) to differentiate between different users. In practice, more than one radio channel is deployed (UK networks have between three and four), but these are distributed between cellular layers rather than between individual cells. In other words, if an operator has 3 radio channels, it is likely to use one exclusively for all its macro cells, one for all its micro cells and one for all

its pico cells. It is therefore not practical to co-ordinate on the basis of preferred channels alone, and co-ordination on the basis of CDMA codes is therefore proposed.

The approach is defined in ERC recommendation ERC/REC 01/01. This defines field strengths above which co-ordination on the basis of CDMA codes is required, and also allows for the possibility of preferred frequencies to be designated. This might, for example, allow for agreement that a frequency used for macrocell coverage be used for picocell coverage in a neighbouring administration, and vice-versa. This would tend to minimise the likelihood of interference arising between the two. Decision 01/01 also defines a "blanket" field strength level below which non-CDMA systems may be operated without co-ordination. The field strength is defined as anywhere within the neighbouring country.

As with GSM, the Recommendation allows for administrations to reach bilateral agreements which differ from the criteria specified. Indeed it is noted in the Recommendation that such bilateral agreements might typically lead to permissible field strengths up to 15 – 20 dB higher than those specified.

The following table summarises the current use of the main bands of interest in the UK and neighbouring countries. It can be seen that in most bands there has been good progress towards alignment with the European Common Allocation Table (ECAT).

However, significant differences exist in the use of some of the bands, for example Band III which is used for broadcasting in all neighbouring countries, and the 28 GHz band which is used for FWA in the UK but for fixed links in neighbouring countries. The migration from analogue to digital television is likely to take place at different times in the different countries and may lead to different services being deployed in Bands IV/V following the cessation of analogue TV transmission in one or more countries. The introduction of new services in the bands is noted in the ECAT and there would seem to be a good opportunity to initiate dialogue within CEPT on how this band might be used in the most flexible manner, whilst protecting the incumbent TV services. Clearly a co-ordinated approach to refarming part of the band, in a similar fashion to that being pursued in the US would be beneficial.

Band	Sub-band (MHz)	Current UK use	CEPT allocation	F usage	B usage	IRL usage	Comments
Band III	174-216	Mobile (PMR & PAMR)	BROADCASTING MOBILE	TV Broadcasting	TV Broadcasting, DAB (blocks 6C, 6D, 9C	TV Broadcasting	Bilateral agreements exist with Belgium, France and the Netherlands for UK operation of analogue PMR / PAMR. These will need to be revised if new services are introduced into the band.
Bands IV/ V TV B'cast	470-590	TV Broadcasting (channels 21-35) Some SAB use	BROADCASTING Mobile (SAB only)	TV Broadcasting	TV Broadcasting	TV Broadcasting	Use of band to be reviewed in ERC for possible future applications after introduction of DTB
	590-598	Airport Radars Also used in some	BROADCASTING Mobile (SAB only)	TV Broadcasting	TV Broadcasting SAB	TV Broadcasting SAB	Radar use only in the UK, allowed under RR footnote S5.302, which requires all new assignments to be co-ordinated with Germany, Belgium, Denmark, Spain, France, Ireland, Luxembourg, Morocco, Norway and the Netherlands.
	598-606 (channel 37)	TV Broadcasting Mobile (SAB only)	BROADCASTING	TV Broadcasting	TV Broadcasting SAB	TV Broadcasting SAB	
	606-614	Radioastronomy	BROADCASTING Radioastronomy Mobile	TV Broadcasting	TV Broadcasting Radioastronomy	TV Broadcasting	Although there is currently no TV broadcasting on this channel in the UK, there are high power transmitters in neighbouring countries (e.g. Lille, 300 kW),
	614-854	TV Broadcasting (channels 39-68) Some SAB use	BROADCASTING Mobile (SAB only)	TV Broadcasting	TV Broadcasting SAB	TV Broadcasting SAB	CEPT co-primary allocation to MOBILE above 838 MHz, but limited to tactical radio relay systems.

Band	Sub-band (MHz)	Current UK use	CEPT allocation	F usage	B usage	IRL usage	Comments
	854-862	SAB	BROADCASTING Mobile (SAB only)				CEPT co-primary allocation to MOBILE, but limited to tactical radio relay systems
GSM	880-890 / 917-925	E-GSM Band (some residual	MOBILE TACs use)	Defence systems ?	Tactical and transportable Radio	To be assigned to spectrum for IMT-2000	Identified at WRC-00 as expansion
	890-915 / 925-960	GSM core band – full utilised	MOBILE Radiolocation	GSM	GSM	GSM	Harmonised pan-European band. Identified at WRC-00 as expansion spectrum for IMT-2000
	1710-1785/ 1805-1880	GSM 1800 band – fully utilised except for top 3.5 MHz (DECT guard band)	FIXED MOBILE	GSM (upper part) Defence Systems (tactical radio relay)	GSM	GSM	Identified at WRC-00 as expansion spectrum for IMT-2000
IMT-2000	1900-1980/ 2010-2025/ 2110-2170	IMT-2000	FIXED MOBILE	IMT-2000 Some residual defence use	IMT-2000	IMT-2000	Harmonised pan-European band
2.6 GHz	2520-2670	SAB Trans-Horizon links	FIXED MOBILE exc aero	SAB (video links)	Fixed Links (ITU-R rec 283 Helicopter links	TV Retransmission Systems (MMDS)	Designated as expansion spectrum for IMT-2000 at WRC-2000

Band	Sub-band (MHz)	Current UK use	CEPT allocation	F usage	B usage	IRL usage	Comments
3.5 GHz FWA bands	3400-3600	FWA: 3425-3422 paired with 3475-3492 MHz –	FIXED FIXED SATELLITE (S-E) MOBILE Major use Fixed Links and FWA Systems	FWA: 3465-3495 (subs) paired with 3565-3595 (base)	FWA: 3450-3500 paired with 3550-3600 MHz. Remainder defence systems and helicopter links	FWA: 3410-3435 paired with 3510-3535, and 3475-3490 paired with 3575-3600 MHz. Remainder fixed links (RTE)	
5 GHz band	5150-5350	Aero Radionavig HIPERLAN MSS Feeder Links	MOBILE FIXED-SATELLITE (E-S) Major use HIPERLAN	HIPERLAN MSS Feeder Links	HIPERLANs	HIPERLANs	200 mW EIRP limit, intended for indoor
	5470-5650	SAB HIPERLAN planned	MARITIME RADIO-NAVIGATION Radiolocation	Defence systems	Ground based weather radars	HIPERLANs	Planned for HIPERLANs – 1W limit, indoor/outdoor use
	5650-5725	SAB HIPERLANs planned	RADIOLOCATION Amateur	Amateur	Amateur	HIPERLANs	Planned for HIPERLANs – 1W limit, indoor/outdoor use
	5725-5875	Radars ISM	FIXED-SATELLITE (E-S) RADIOLOCATION Amateur, Mobile	Amateur SRDs Traffic info systems	ISM Amateur Traffic info systems	ISM SRDs Traffic info systems. Amateur	Possible future FWA band?

Band	Sub-band (MHz)	Current UK use	CEPT allocation	F usage	B usage	IRL usage	Comments
28 GHz band	27500-29500	Broadband FWA	FIXED FIXED-SATELLITE (E-S) Major use: fixed links	Fixed service (type unspecified)	Planned for fixed links and FWA	Planned for fixed links	
40 GHz band	40500-43500	Planned for MWS	BROADCASTING BROADCASTING-SATELLITE FIXED Major use: MVDS		Planned for MWS	MWS and MVDS under consideration	Proposed harmonised band for MWS services

ANNEX C

Technical factors affecting spectrum management: background

This Annex presents an excerpt from the final report of a study carried out for the review by Aegis Systems Ltd and Indepen Consulting Ltd on *Implications of International Regulation and Technical Considerations on Market Mechanisms in Spectrum Management*. The full report was published at the review's website (www.spectrumreview.radio.gov.uk).

C.1 Introduction

The most important tenet of the Radio Regulations is that the spectrum, being a limited resource, should be used efficiently and equitably. In order to achieve this the main technical consideration concerns the interference environment and its relationship with the technology employed.

Use of the radio spectrum is dependent on frequency, spatial location, time and signal separation. Sharing is accomplished when one or more of these dimensions provides sufficient isolation. The following table shows some of the methods which can be used to facilitate sharing, a number of which have been formally recognised by the ITU (ITU-R Recommendation SM.1132-1, "General principles and methods for sharing between radiocommunication services or between radio stations").

Spectrum management aims to provide an acceptable interference environment and at the same time ensure that the spectrum is used efficiently. From a purely technical point of view spectrum utilisation (for an application) can be defined in terms of the bandwidth used, the space (area or volume) taken up[1] and the time for which it is used. The spectrum efficiency is then the amount of information conveyed over a distance related to the spectrum utilised.

[1] Space within which other users are not able to share.

Methods to facilitate sharing

Frequency separation

Channelling plans

Band segmentation

Frequency agile systems

Dynamic sharing:

- dynamic channel assignment (1)

Frequency division multiple access (FDMA)

Control of emission

spectrum characteristics

Dynamic variable partitioning

Frequency tolerance limitation

Spatial separation

Geographically partitioned allocations

Minimum site separation for co-channel systems

Antenna system characteristics:

- adaptive antenna and polarisation discrimination
- antenna pattern discrimination

Spatial division multiple access (SDMA)

Physical barriers and site shielding

Time separation

Duty cycle control

Dynamic channel assignment (1)

Time Division Multiple Access (TDMA)

Synchronisation of co-frequency TDMA systems

Collision avoidance protocols ("listen before transmit")

Signal separation

Signal coding (2) and processing

FEC

Interference rejection

Code Division Multiple Access (CDMA)

Spread spectrum:

- direct sequence
- frequency hopping
- pulsed FM

Interference power/bandwidth adjustments:

- co-channel
- dynamic transmitter level control
- PFD limitation and power spectral density (PSD) limitation (energy dispersal)

Antenna polarisation

(1) Dynamic real-time frequency assignment facilitates sharing by simultaneously using frequency and time domains. Therefore, this method is shown in both columns.

(2) Coding techniques may also be applied to frequency, spatial and time separation technology.

C.2 Interference considerations

The effect of interference of one system on another is determined by:

- the transmit characteristics of the interfering source (including the transmitter power level, bandwidth, modulation characteristics, height/directionality of the antenna and location);
- the propagation behaviour of the transmission path along which the interfering signal travels (bearing in mind that this is not necessarily line-of-sight and maybe due to anomalous propagation conditions) including terrain/clutter and climatic conditions;

- the characteristics of the receiver experiencing the interfering signal (including the level of the wanted signal received from its associated transmitter[2], the noise floor of the receiver, the receiver bandwidth and the modulation characteristics being used, height/directionality of the antenna and location); and

- the availability requirements of the wanted link and how these are related to the demodulator behaviour in the presence of noise and interference – these requirements often translate into long term and short term levels of permissible interference, where the latter is due to anomalous propagation or the dynamic behaviour of one or other system.

The above fundamentals relate to single entry interference. In the case where the interference is due to multiple sources it is necessary to aggregate the interfering power. In addition it is not necessarily the case that the situation is static. Other factors that therefore need to be considered include the mobility of sources and victims, their density and distribution.

These basics apply to the situation where co-frequency operation is being considered (including the case where the transmit channel of the interfering source overlaps with the receiver channel). The situation also applies with respect to adjacent channel and dual polar operations where the transmit and/or receive out-of-band and cross-polar behaviour needs to be known.

Consideration of the complete situation can lead to a very technically efficient use of the spectrum if all relevant parameter values are known and can be manipulated (controlled). This however is at the expense of flexibility and economic cost amongst others.

Homogeneity of characteristics is known to lead in nearly all cases to the most efficient use of the spectrum – but this is a counsel of perfection. What are the options in terms of defining service constraints, particularly in terms of the transmitter as it is easier to control the parameters through licensing compared to the receiver[3].

Various options for defining limits on systems in order to control the interference environment include:

- Specification of the maximum transmitter spectral power density only. This is appropriate for those applications where omnidirectional antennas are used. It is also appropriate where the interference into a system is due to the aggregation of interference power from multiple sources where these sources are using directional antennas and no one source dominates due to proximity to the victim or due

[2] Noting that this will be influenced by the propagation characteristics on the wanted path.
[3] It can also be noted that the essential requirements of the R&TTE Directive do not allow for receiver characteristics to be specified.

to high directionality. In this case the aggregate interference averages according to the transmitter power and not the EIRP. It is therefore appropriate to specify a maximum transmitter spectral power density rather than a maximum EIRP spectral power density in this case.

This approach does not allow for the frequency reuse advantages afforded by directional antennas which may be employed both at the transmit and the receive ends of the interfering path. In addition assumptions (most likely worst case) have to be made about other system characteristics of the victim receiver

- Specification of the maximum transmit EIRP spectral power density only. In the case of highly directional systems, and in particular those which might individually (rather than as an aggregate) cause an interference problem to other services sharing the same frequency allocation, it is necessary to limit the maximum EIRP spectral power density. Frequency reuse may be possible depending on actual deployment. However, this limit in itself does not prevent omnidirectional transmitters operating at the maximum EIRP spectral power density. In this instance the interference may well be controlled to acceptable levels but the possibility of frequency reuse is substantially diminished.

- Specification of the maximum transmitter spectral power density and antenna pattern. In effect this defines the maximum transmit EIRP spectral power density in all directions. Where maximum efficiency is required and it is not necessary to allow extensive flexibility for the systems deployed, this controls the interference environment to the maximum extent possible.

- Specification of a power flux density (or field strength) limit along a boundary (where the PFD is considered to be orthogonal to that boundary), whether between adjacent national “spectrum blocks” or between countries. Insofar as a victim receiver is concerned in most cases there is no real concern about how interference sources are deployed or operate providing the interference environment is controlled to a level related to the receiver’s noise floor. This can be achieved by specifying an absolute power flux density or field strength limit at the receiver. While this method protects the receiver and at the same time allows flexibility to interfering systems it is important to note that it can also sacrifice spectrum efficiency as any discrimination at the receiver due to receive antenna directionality cannot be taken into account. Furthermore, account may not then be taken of the margins available in the various systems.

- Specification of a PFD "trigger[4]" along a boundary. As implied in the previous option the setting of a PFD level has to make an assumption about the characteristics of the receiver. As this knowledge is not known in advance a worst case assumption would have to be made if unacceptable interference is to be avoided. As an alternative it would be possible to specify the PFD level as a trigger level that would be allowed to increase as the result of an agreement between the parties operating on either side of the boundary once the real characteristics of the systems had been taken into account.

- Specification of relevant equipment parameter values (i.e. transmitter power, antennas, modulation/coding, protocols). In general this has the potential to provide the best efficiency in use of the spectrum because more tightly defined characteristics provide a greater control over the interference environment. However this is mainly in the situation where there is still control on the licensing of devices in terms of their location. In the case where devices are licence-exempt and therefore uncontrolled in terms of their location some of this benefit is lost. Clearly the flexibility available to the user is extremely limited, but in the case of global harmonisation, for example, this loss of flexibility might be considered to be an advantage in terms of a more economically efficient market.

It should be noted that all of the above methods take no account of the technical characteristics of the receive system. If there is no a priori knowledge of the receive characteristics it is inevitable that one or more assumptions have to be made in arriving at the limiting values associated with the particular parameters of each method. In the case of the "trigger" PFD level there is at least some flexibility that would allow a relatively efficient use of the spectrum to be achieved. It allows for the PFD level at the boundary to be changed with the agreement of operators on both sides of the boundary.

It is clear from this that there is no single method that will allow for complete flexibility and spectrum efficiency regardless of the types of system being deployed. Complete flexibility is attainable by making few or no assumptions about the characteristics of interfering transmitters and victim receivers but at the expense of spectrum efficiency. On the other hand absolute knowledge of the characteristics of interfering transmitters and victim receivers allows for maximum efficiency in spectrum utilisation. Even in the case where two systems are not particularly compatible, complete knowledge of their characteristics will allow for the most efficient use of the spectrum under those circumstances. It is this conclusion that has led to the current approach of co-ordination, whereby some knowledge of the equipment to be used along with some worst case assumptions allows for an assessment to be made as to whether the situation needs to be considered in more detail.

[4] A PFD threshold that triggers co-ordination between parties on either side of the boundary.

The preceding discussion mainly relates to the packaging of spectrum for terrestrial services. In the case of satellite services where very wide area coverage is the norm it is difficult to see how some of the principles of PFD limits at boundaries could be applied other than at a macro level.

The importance of the possible limits described above depends on the circumstances under which spectrum to be licensed is packaged. This then determines the most suitable balance between overall efficiency of spectrum use and the flexibility available to the licensee.

C.3 Propagation considerations

The importance of the behaviour of propagation is directly related to availability requirements.

- Some applications require high availability – hence there is a need to satisfy long term and short term interference requirements. In this case anomalous propagation conditions are of importance.
- Some applications where the availability requirement is not so high may be able to accept the effect of interference due to anomalous propagation behaviour. In this case the long term interference is the important consideration.
- More recently there are applications where the availability requirement is determined by a greater user acceptance of the unreliability of communications channels. In this instance, especially where related to the Internet, it is possible to offer a service based on so called “best endeavours”. Under these circumstances the interference environment does not have to be so carefully controlled. Operation in this sort of environment generally relies on adaptive technologies that, as the name implies, are able to move away (in frequency) from interference or wait and try again when the interference changes with time.

Depending on the availability requirements of the application, it can be seen that the degree of control of the interference environment, which is significantly influenced by propagation behaviour, differs. In the case of high availability applications the impact of an interferer is enhanced by anomalous propagation and the consequently the separation distance required between victim and interferer to reduce the interference to acceptable levels can be significant. At the other extreme, where adaptive technologies are available, the interference on a given channel and/or from a particular direction can be very severe. Operation is not prevented, however, as the adaptive technology changes the victim system configuration to avoid the interference thereby allowing operation in a more benign environment.

Examples of links requiring high availability are earth/space links supported by FSS satellite earth stations and fixed point-to-point links supporting trunk telephony traffic. In both cases a required availability of 99.99% or more is common and the resulting short term interference that can be tolerated is often the deciding factor in determining separation distances.

Applications where the availability requirement is not so great include mobile systems. It this case it is more difficult to sustain a highly reliable link anyway and therefore short term interference is of less importance. It can be noted, for example, that when deciding whether two mobile systems need to be co-ordinated, the criterion used is based on the presence (or otherwise) of a specified interfering field strength that is exceeded at 50% of the locations (within any area of approximately 200 m by 200 m) for 10% of the time. It can be seen from these figures that longer term interference is the issue and short term anomalous propagation effects giving rise to interference from other systems are not of great significance.

There has been increasing pressure from Internet Service Providers (ISPs) to use spectrum for wireless Internet access, for both fixed and mobile subscribers. For fixed subscribers there is the more traditional route of using the various parts of the spectrum designated for fixed wireless access. However there has been significant interest in the use of licence-exempt bands even though it is not currently permitted in the UK to use licence-exempt bands for the provision of public services. The attraction of licence-exempt bands is the absence of any fees for their use, combined with the ready availability and relatively low cost of equipment. However the point of interest here is that ISPs consider it feasible to offer a service that would be acceptable to users in a relatively[5] uncontrolled interference environment.

Depending on the nature of this uncontrolled interference environment the techniques used to overcome its effects include frequency hopping (both at a micro {FHSS} and a macro {DFS} level) and network protocols that request repeat transmissions in the event of error. In the event that the utilisation of the frequency band by other services is very intense, both from a geographic and a traffic point of view, the efficacy of these techniques is likely to be reduced.

It can also be noted that some of these techniques are useful in opening up the spectrum to a new service where there is an incumbent service giving rise to an interference environment that is more controlled (i.e. not licence-exempt).

[5] Note that there is some control of the interference environment as significant operating parameters (e.g. transmitted power) are constrained.

C.4 Implications of changing the PFD level at a boundary

C.4.1 The scenario

The starting point is that Operator A is permitted to establish a system on one side of a boundary and Operator B is permitted to establish a system on the other side of the boundary. At the boundary an initial PFD level is set.

In order to establish his system Operator A needs to be allowed to create a higher PFD level at the boundary. Operator B agrees to this higher PFD level on the basis that his system, as implemented or planned, provides sufficient discrimination to operate successfully under the new circumstances.

Operator A pays for this arrangement and the value of his spectrum increases whereas the value of Operator B's spectrum decreases.

If Operator B or a subsequent "owner" of Operator B's spectrum decides that the higher PFD level is a constraint on their system development then there is an opportunity to negotiate with Operator A to reduce the PFD level. If successful there would be financial consideration in the opposite direction and the value of the spectrum blocks would change accordingly.

How then should the PFD level be set, and what are the implications of changing it?

C.4.2 Inter-system and inter-service co-ordination

In the first instance it might reasonably be assumed that the operators on either side of a boundary will want to operate up to the boundary itself. Generally, whatever level is set for the PFD at the boundary a transmitter will have to be located some distance away from the boundary in order to satisfy the limit (although in some cases shielding and/or pointing the antenna away from the boundary may be sufficient).

In the case where victim receivers use omni- or near omnidirectional antennas it would be sensible to set the effectively interfering PFD level relative to and some way below the noise floor of the receiver. This might be overly conservative if significant margins are available in the victim system.

In the case where victim receivers use directional antennas it is more difficult to set a PFD level as it is not known a priori whether the directional antennas are pointing towards the boundary or not. If it is assumed that the antennas are pointing away from the boundary then the residual gain towards the boundary will be 0 dBi or less. In this instance it would be appropriate to set the PFD level at the boundary in a similar way to the omnidirectional case (see above) i.e. at a level relative to and some way below the noise floor of the receiver. If however it is assumed that the antenna of the victim receiver points towards the boundary then it will be necessary to lower the PFD level significantly in order to reflect the boresight gain. In this situation

the PFD level would arguably be set at a level that constrains the development of the interfering system in order to protect the victim system. However it should be remembered that the situation is two-way: the victim system also acts as an interfering system in the opposite direction. It is therefore in the interests of both systems to negotiate a mutually agreeable PFD level, although there may be commercial reasons for not doing so. This begs the question as to whether there should be two PFD levels at the boundary reflecting susceptibility to the interference environment in the two different directions.

The question also arises as to whether the negotiated PFD level extends along the whole length of the boundary or whether some parts of the boundary can withstand higher PFD levels than others. As soon as one takes account of actual equipment (its location and pointing for example) and the local terrain/clutter rather than the general case, which inevitably has to make worst case assumptions if interference is to be completely avoided, the derived PFD level will reflect the local circumstances. It would not then be appropriate to apply the same value along the whole boundary. After agreement has been reached by the two parties on either side of the boundary, it will be necessary to specify how the PFD level is allowed to vary along the boundary.

C.5 Feasibility of broader service categories

It is considered by some parties that the multitude of narrowly defined radio services that are allocated spectrum restricts flexibility and limits spectrum utilisation. There have been moves to arrive at a set of more broadly defined services based on consideration of technical and operational factors. It is felt that services could be merged if as many as possible of the following conditions are satisfied:

- Compatible RF power level/service area;
- Similar or related bandwidth;
- Similar protection requirements;
- Similar potential for causing interference;
- Compatible operation or technical means to overcome incompatibility; and
- Similar performance requirements.

This is much in line with the general rule of thumb that the best spectrum efficiency is obtained when services or systems with homogeneous characteristics share an allocation.

Using more broadly defined services can be considered to be one alternative allocation method. Other allocation methods can also be envisaged. For example, it may be possible to allocate on the basis of spatial characteristics. For terrestrial systems the categories would include point-to-point, point-to-

area and possibly other combinations such as area-to-area. For satellite systems the obvious categories are space-to-Earth, Earth-to-space and space-to-space, and possibly geostationary and non-geostationary. While potentially offering great flexibility it is not immediately obvious that most efficient use of the spectrum would be made as the technical homogeneity of the systems operating in the same spatial allocation would not necessarily be there. In the case of satellite systems, for example, the technical characteristics of fixed satellite systems and mobile satellite systems are very different. Sharing the same spatial allocation would lead to severe inefficiencies.

Consideration of more flexible allocation methods is a prelude to investigating the technical implications of introducing various market mechanisms to spectrum management. Several of the proposals in the past relating to spectrum trading have involved little or no change in use from a technical point of view. Under these circumstances there is little or no change to the interference environment and technical issues do not arise.

If market mechanisms are to allow changes in use then the interference implications are potentially very significant. There will be implications for other co-frequency users and adjacent channel (or band) users.

It has been noted that Australia has implemented spectrum trading on the basis of a standard trading unit which is defined in four dimensions: parallels of latitude, meridians of longitude, a standard bandwidth in frequency and time. Most importantly from the technical point of view interference levels have been set at the geographic boundaries of each block. While this approach offers great flexibility and allows for the relatively easy introduction of spectrum trading, it may be inefficient from a spectrum utilisation point of view (not with respect to individual users necessarily but taken as a whole across all users) unless negotiations are allowed to take place in order to vary the interference level at a given boundary such that it reflects the systems being deployed.

One alternative to setting boundary conditions is to require co-ordination to take place between new and existing users in much the same way as the RA undertakes this activity at present. This would however require the public availability of the technical characteristics of existing systems. This approach avoids the lack of efficiency inherent in the more general approach above but at the expense of simplicity.

Similar technical problems arise both within UK (i.e. between different systems operating in geographic/frequency blocks) and between UK and adjacent countries, although in the former case it all remains in the sole jurisdiction of the UK.

C.6 Adjacent channel considerations

While the previous discussion has concentrated on the boundary between two geographic areas where the same frequency band is being used, there is also the boundary between adjacent frequency bands to consider.

In many ways the arguments are similar here. It would be possible to define out-of-band emission limits in absolute terms such that the possibility of interference is avoided. However, as before, such a level would lead to inefficient use of the spectrum in terms of preventing many systems from being implemented and/or requiring the use of extensive guard bands.

As in the case of the in band interference across geographic boundaries, it is appropriate to set a less stringent level that will still lead to guard bands being required but allow operators in adjacent bands to negotiate rights to higher or lower levels of out-of-band emissions.

Out of band emissions may be a particular problem where consumer equipment (e.g. domestic TV receivers) are concerned, as these may have poorer frequency selectivity compared to professional equipment. For example, there have in the past been isolated cases of interference to reception of TV broadcasts on channel 21 due to co-sited paging transmissions in the nearby 466 MHz frequency band. Similarly, localised interference to, or blocking of, mobile terminals may arise if very high power broadcast transmitters are operating in adjacent bands. Care should be taken to ensure sufficient guard bands are provided, for example if migrating parts of the TV broadcast band to mobile services.

C.7 Implications of service characteristics for co-ordination

C.7.1 Point-to-point systems

The significant co-ordination distances that can generally be expected between point-to-point systems arise because of two factors. In the first instance these systems often support high availability links and short term anomalous propagation events therefore have to be taken into account. In addition, particularly for longer links, highly directional antennas are used at both ends of the link and high transmitted EIRPs are used. The longer links are usually established in the lower frequency bands e.g. 4 GHz where a 40 km link would have a co-ordination distance of 200 km or more. At higher frequencies links are shorter as are co-ordination distances, although the latter can still be significant for high availability links. For example, at 38 GHz links are generally no more than around 8 km but the co-ordination range with other point to point links may still be as high as 100 km. It should be remembered however that the probability of interference problems arising within these co-ordination distances is generally small because of the highly directional nature of the antennas used at both ends of this type of link (and therefore at both ends of the interfering path).

Co-ordination between a point-to-point system and a point-to-area system will not be looking for the most serious geometrical alignment mentioned above (i.e. a highly directional antenna at both ends of the interfering path), and may also be able to take advantage of other benign characteristics of point to area systems, such as the use of downtilted antennas at FWA base

stations. However, there will still be the case that a highly directional antenna in the point-to-point system can point at the transmitters or receivers in a point-to-area system[6].

C.7.2 Point-to-area systems

There are three types of point-to-area system – broadcast, mobile and fixed wireless access. Although they fall into this one category they do have their own distinct characteristics that makes it difficult to generalise about the co-ordination of point-to-area systems.

Broadcast – Audio and TV broadcast systems (analogue and digital) operating on a traditional basis employ high power omnidirectional (or wide area) transmitters providing coverage from tall masts and/or hilltops. When planning these systems only a small amount of discrimination is assumed, except in the case of DAB where no discrimination is assumed. These systems are essentially one-way i.e. the user terminal is solely a receiver and does not therefore support a return path over a radio link. Because these systems use high powers to cover extensive areas the rate of fall-off in signal strength beyond the coverage area is slow (in terms of dB/km) when compared to more local systems. Co-ordination distances relating to these systems will therefore be great – of the order of hundreds of kilometres – except in the case of lower power relay stations.

Mobile – Cellular mobile systems tend to operate either side of 1 GHz generally in the range 400 MHz to 3 GHz. Base stations are configured to support macro, micro or picocells using omnidirectional or sectored antennas. Handsets use substantially omni-directional antennas and have to transmit at relatively low power levels mainly for safety reasons but also because they are constrained by battery power (for the same reason they also use ATPC which results in typical transmitted powers 10 – 20 dB below the maximum). In addition, as cellular networks by their nature require intensive re-use of frequencies in adjacent cell clusters, coverage areas supported by base stations tend to be significantly less than broadcast coverage areas and the rate of fall-off in signal strength beyond the coverage area is therefore relatively quicker. The co-ordination distance between two geographically adjacent cellular networks is likely to be similar to the minimum separation distance between cells within a cellular network. This is defined in terms of the cellular re-use factor (i.e. number of cells in a re-use pattern, K) and the cell radius (R), using the formula $D/R = (\sqrt{3}*K)$. In typical high density GSM networks, the value of K is 4, and the maximum radius of a macro cell (determined by the TDMA timing constraints) is 35 km. Thus the co-ordination distance between two GSM networks would be of the order of $(\sqrt{12}*35) = 121$ km. In practice, a smaller co-ordination distance may be feasible, depending upon the actual cell radii deployed in the adjacent networks, however this figure is likely to be a realistic starting point if

[6] The high EIRP of a point-to-point transmitter can be directed towards a victim receiver in a point-to-area system. Alternatively, a receiver (using a highly directional antenna) in a point-to-point system can be pointed at a transmitter in a point-to-area system.

flexibility of spectrum use within a GSM network is to be retained. A similar distance is likely to apply for other types of point to area system using the GSM bands, however for FWA services using higher frequency bands the maximum cell size becomes much smaller (e.g. at 28 GHz this is likely to be < 10 km) and the co-ordination distance correspondingly so – see below).

Fixed Wireless Access – These systems can operate across a wide range of frequencies from 2.4 GHz up to 40 GHz and potentially beyond. The lower frequencies provide relatively narrowband connections to the PSTN over wide areas whereas the higher frequencies support broadband connections over more local areas. Current networks operate in a similar way to mobile systems, in that the links are established through base stations generally using sectored antennas. In this case the user terminals also have a degree of directionality, which can be significant at the higher frequencies. Co-ordination distances for FWA operators corresponding to boundary trigger PFD levels recommended in previous work are 18 km from the boundary at 42 GHz and 27.5 km at 28 GHz for base stations and 10 km at 42 GHz/16 km at 28 GHz for subscriber terminals. "Mesh" FWA networks have also been proposed which dispense with base stations and use the subscriber stations as repeater "nodes", in which case only the subscriber co-ordination requirement applies.

C.7.3 Implications

The co-ordination that would be required between the above systems will differ depending on the combination of systems. However it is possible to make some observations on the implications for co-ordination between different systems.

1. Fixed Wireless Access systems offer the greatest possibilities for spectrum efficiency when co-ordinating as they are based on directional antennas both at the base station and the user terminal – although the directionality will not be as great at lower frequencies and the advantage will be diminished.

2. The core of a traditional broadcast system is based on a small number of high power transmitters each of which is designed to provide service to a large area. Signal strength fall-off outside the coverage area is relatively slow (because of the large coverage area) and the interference potential is therefore significant. It is important therefore that any other system sharing the same frequency in an adjacent area is able to provide a high degree of discrimination.

3. The omni-directional nature of mobile terminals provides nothing in the way of discrimination with respect to other systems using the same frequency band. Furthermore the fact that these terminals are mobile means that there is no fixed relationship between an interfering source and a victim receiver. This potentially increases the possibility of unintentional interference unless conservative assumptions are made

when establishing sharing conditions and/or control techniques are in place to ensure unintentional or unauthorised transmissions are prevented.

4. The height of antennas will determine whether clutter has a significant impact on the signal. The siting of antennas to take advantage of clutter/local shielding to reduce the impact of interference should be encouraged.

5. Finally, the different economic characteristics of broadcast and telecommunications networks, and their implications for the technical and physical network characteristics, need to be considered. Cellular networks require relatively small cells with intensive frequency re-use to maximise capacity and revenue on the network. A national or regional broadcaster, on the other hand, requires an economic means to deliver simultaneously the same material to the maximum potential audience (an objective that is likely to increase in importance as more competing channels and delivery platforms become available). This implies relatively large transmitter service areas with much more limited frequency re-use, and consequently larger co-ordination zones. Whilst some degree of convergence between broadcast and telecommunications services is anticipated, this fundamental difference in the approach to delivering "one-to-many" and "one-to-one" services is likely to remain for the foreseeable future.

C.8 Point-to-point and Point-to-multipoint sharing

A specific example of the problems inherent in frequency sharing between systems with different technical characteristics is the case of point to point fixed links sharing spectrum with point-to-multipoint systems. There are two distinct scenarios to consider here, namely co-existence of FWA networks deploying these two technologies and co-existence between FWA networks and conventional radio relay systems.

In the first scenario, the characteristics of the two systems do not differ wildly, since relative low gain directional antennas are involved and the EIRP levels are modest, reflecting the short distances involved. Previous work conducted by Aegis Systems on behalf of the RA[7] demonstrated the feasibility of "mesh" type FWA networks, comprising high density point-to-point links connecting individual subscriber stations, co-existing with conventional point to multipoint systems.

However, the second scenario, involving very high gain antennas (typically 40 dBi or greater) and typically trunk radio relay networks requiring very high availabilities (99.99% or more) may be more problematic. Work carried out for Industry Canada in 1999 suggested that, in the 38 GHz band, the PFD limit required to provide adequate protection for point to point links

[7] "Co-ordination between Broadband Fixed Wireless Access systems in the 28 and 42 GHz bands", Final report prepared by Aegis Systems Ltd for the Radiocommunications Agency, January 2000.

would be 6 dB lower than that required for PMP subscriber stations, and 30 dB lower than for PMP base stations. The problem is compounded by the fact that radio relay stations are more likely to be located at high sites, hence less likely to be shielded from co-channel interference than FWA subscriber stations.

However, the use of interference mitigation techniques, such as ensuring antennas are oriented away from the neighbouring country in border or coastal areas and that FWA base station antennas deploy downtilt, should enable co-existence to take place in most cases.

C.9 Implications of "change of use"

A number of options can be addressed when considering what happens when the use of a block of spectrum changes from one operator to another. The implications of these options from a technical point of view are outlined below.

C.9.1 Change of licence only

If the technical characteristics of the system or systems deployed or being deployed stay the same, or at least within the technical characteristics defined by the licence, the nature of the interference environment would not be expected to change, except in the case where the density of use changes significantly.

As a consequence, the co-ordination required across boundaries, international or domestic (i.e. between spectrum trading blocks), geographic or adjacent band, would also not be expected to change in its nature. However, there could be an increased amount of co-ordination across boundaries if operators acquiring an existing licence chose to modify the technical characteristics of the system, albeit within the constraints of the licence, or if the density of use changes significantly.

C.9.2 Partitioning or aggregation of spectrum and/or geographic areas

As in the case above, no change to the system technical characteristics means that there will be no change to the type of interference environment generated and/or experienced. Also, and similarly to the above case, there could be an increased level of co-ordination between blocks (spectrum and/or geographic) not only because of possible modifications to system technical characteristics as licences change hands (as above) but also because of the more fragmented nature of the blocks and hence an increased number of boundaries (when "disaggregation" dominates). However, in the case where spectrum and/or geographic blocks are aggregated less co-ordination activity can be expected.

C.9.3 Change of use

In this case change of use implies that the technical characteristics of a system could change significantly.

If the only boundary condition is specified in absolute terms then there is no technical impact as any changed characteristics will still have to fall within this boundary condition. However, an absolute boundary condition implies that it has been set at a level that avoids the possibility of interference. This is potentially very inefficient .

If the boundary condition represents a trigger level for negotiation then co-ordination activity will be required. The nature of this activity will depend on the characterisation of the systems involved. When systems on either side of the boundary are relatively similar the negotiation will involve a few terminals on either side of the boundary. When inhomogeneous systems are involved negotiation could extend to systems well within, or beyond, a spectrum block. Depending on the granularity of the spectrum blocks at the time, it may be the case, for example with a highly directional antenna, that the potential area affected by interference could stretch not just into the adjacent block but across the adjacent block and into the next block, or across several blocks. It is therefore important that the user of a spectrum block intending to change its use is aware that boundaries other than the immediately adjacent ones may be tested.

It should also be noted that the criteria used for assessing the impact of interference can be both long term and short term in nature, especially where high availability systems are concerned. When setting boundary conditions both should be considered. In some circumstances it would be easy to meet a boundary condition based on a long term interference criterion yet fail to meet the victim's short term interference criterion.

C.9.4 Change of use and partitioning

In general the comments noted against Options B & C above apply here as this option (D) is merely a combination of these.

C.10 Apportioning rights and responsibilities

From a technical point of view there are no difficulties in undertaking a co-ordination exercise in terms of working out a technical accommodation of systems providing all the information and supporting tools are available.

If the starting point is a set of boundary conditions that are negotiable then providing all the technical information is available (i.e. the technical characteristics of actual transmitters) it can readily be established what the interfering power at any point due one or more transmitting terminals is likely to be. If a particular interfering power different to the boundary condition is agreed, a technical record of this agreement needs to be kept.

One of the key questions that has to be resolved at the outset is whether the negotiation is based on calculation or measurement. While the closest to reality is measurement, it is not really practical to adopt this approach. If calculation is to be adopted then it will be essential that common data and common calculation tools are made available. There does however remain

the question of what happens if an operator claims to be experiencing, and is able to measure, unacceptable interference even though the calculated interference levels indicate that the situation is satisfactory. It is considered that the likelihood of this is remote as experience tends to show that the engineering calculations used to assess interference are relatively conservative. However there would need to be a clear statement associated with the calculation tools that negotiated agreements reached on the basis of results obtained from the calculation tools do not completely guarantee interference free operation.

On the basis of common data and calculation tools being available it is clear that operators can undertake the negotiation regarding boundary conditions between spectrum blocks themselves. A similar problem exists regarding international boundaries but the situation can be slightly different. If the UK chooses to allow the operation of systems that are not in line with the frequency allocation table of the Radio Regulations, or with harmonised frequency allocations agreed within the CEPT, the situation will be made more difficult and it should be the responsibility of the administrations to agree the conditions under which such operations should be allowed to take place.

It can be concluded that internal negotiation/co-ordination between spectrum blocks can be readily undertaken by the operators themselves providing common procedures and supporting tools are in place. On the other hand co-ordination with other administrations should remain the responsibility of the national regulatory authority.

C.11 Assessment of emerging technologies

Largely in response to the scarcity of spectrum and the adverse effects of the interference environment, technology has been developed to exploit the airwaves more efficiently.

The technologies fall into two categories. Firstly those that operate at low spectral power densities thereby reducing the potential for causing interference[8] and secondly those that seek to avoid interference by one or other means.

C.11.1 Low spectral power density

Low spectral power density systems include spread density spectrum and ultra-wideband (UWB) techniques. Spread spectrum is a technique that has been available for some time now. In the past it has often been promoted as the most efficient and resilient modulation/access technique available. While in many instances it is a highly appropriate technique, the rather wider claims that have been made for it in terms of spectrum efficiency do not stand up to scrutiny and this has led to a suspicion about anything that in spectrum terms claims to provide “something for nothing”. It is claimed that it is possible to provide efficient and resilient communications based on

[8] Sometimes these techniques also have the ability to reduce the impact of received interference.

wideband low spectral power density techniques in exchange for increased overall noise levels. Ultimately noise limits the number of systems that can operate co-frequency co-coverage so it is debatable whether the co-existence of wideband low power spectral density systems with systems using other modulation techniques is any more efficient overall than segmenting the frequency band for different users. It may well be the case that a low number of wideband low spectral power density users will have little or no noticeable impact but as soon as the numbers become significant the preceding argument would apply.

One victim of this attitude is the UWB technology that is currently being promoted for all manner of applications, including ground penetrating radar and radiocommunications. Essentially, UWB communicates by way of short shaped pulses arranged in the time domain. The resulting emitted power in the frequency domain is spread over a very wide bandwidth (e.g. 1 GHz) at a level that is below the spurious emission levels permitted for other equipment. This naturally leads to the claim that as the emitted power level is below spurious emission levels, what can be the problem? This claim is still being assessed by various organisations in the US and Europe, and probably elsewhere. In the meantime, there is clearly some scepticism about the claims that fall into the "something for nothing" category noted above.

C.11.2 Frequency agility

Avoiding interference on a dynamic basis can be undertaken at a macro and a micro level. At a macro level this involves the selection an interference free channel which is then used for an extended period of time, and at a micro level this involves rapid hopping between frequency channels in a sequence.

A good example of the macro approach to frequency agility is the use of two so called "polite technologies", dynamic frequency selection (DFS) and transmitter power control (TPC), by a particular radio application that has been allocated spectrum recently. As their names imply DFS means that the transmitter listens for other users before selecting a channel to use and TPC means that the transmitter uses the lowest power level commensurate with the quality required. Both of these techniques keep the level of interference down. A requirement on High Performance Radio Local Area Networks (HIPERLANs) to implement these technologies has allowed allocations to be made in 5 GHz bands already occupied by other services. Without these techniques the allocation would not have been possible. While a limitation on power level and a restriction to indoor use were important factors in allowing frequency sharing with satellite services, it was the mandatory use of DFS and TPC (particularly the former) that opened up the 5 GHz band to HIPERLAN use.

Another example of the effective use of frequency agility, very similar to the DFS associated with HIPERLANs, is the Autonomous Frequency Assignment (AFA) scheme that is being promoted with respect to the introduction of Broadband Fixed Wireless Access (BFWA) systems using Time Division Duplex (TDD) techniques. In these systems base stations constantly monitor the spectrum and create an air traffic map of the frequency band. When a new

hub base station or a new sector is introduced a frequency scan is undertaken across the all the carriers that are allowed to be used, measuring the received interference power for each one. The carrier frequency corresponding to the minimum received interference power would then be the one that is used. This scheme has potential advantages over the use of an a priori worst-case predictive plan.

At a micro level the frequency hopping variant of spread spectrum (see low spectral power density techniques above) also has interference avoidance characteristics. Radio Local Area Network (RLAN) devices operating in the 2.4 GHz band where the interference environment is hostile largely because of licence-exempt operations successfully use this technique. Providing the appropriate link protocols are employed, the loss of any of the frequency channels that are visited during the hopping process, due a collision with the transmissions of similar devices or due to another type of interference source, leads to a loss of throughput. This loss is graceful rather than catastrophic and the technique therefore provides a useful approach to dealing with hostile interference environments.

C.11.3 Other techniques

The Direct Sequence variant of spread spectrum has some interference rejection techniques that can be of use in particular circumstances. One of the features of the demodulation process that extracts the wanted signal from the noise like signal through code correlation, is the associated effect that interfering signals are spread. This is much like the original process that spreads the wanted signal before it is transmitted. This is of most benefit when the interfering signal is a relatively high power narrowband signal. Hence the interest of the military establishment in this type of modulation technique when trying to counteract jamming signals.

Adaptive antenna technology is also increasingly being proposed to reduce interference and thereby increase spectrum utilisation. The principle is based on array technology and associated signal processing. On the basis that the direction of an interfering source can be determined it is possible to adjust the overall pattern of the antenna such that a null, or at least some discrimination, is directed towards the interfering source thereby reducing its impact.

C.11.4 Summary

All of the above techniques are able to offer improvements in hostile interference environments although some remain unproven.

It should be noted that some adaptive technologies, especially some of the frequency agile ones, require slack in the system in order to be able to provide effective interference avoidance characteristics. That is to say, more spectrum (i.e. a greater overall bandwidth) is required to function properly than would normally be needed in a benign environment. This requirement runs counter to the traditional approach of spectrum managers which is usually based on providing the minimum amount of bandwidth necessary.

ANNEX D

Consultation by the review

1. The review published a Consultation Document in June 2001. Full texts of the published responses can be found on the website at www.spectrumreview.radio.gov.uk.

2. **Written responses** were received from:

Aircraft Owners and Pilots Association
Association of Communication Services Providers
Association of European Airlines
Astrium
BAA
BAE SYSTEMS Avionics
British Air Transport Association
British Airline Pilots Association
British Airways
British Broadcasting Corporation
British Helicopter Advisory Board
BT
BT Cellnet/mmO2
Channel 4
Channel 5
Civil Aviation Authority
Cogent
Commercial Radio Companies Association
Community Media Association
Consume Project
Consumers' Association
Crown Castle UK
CSS Spectrum Management Services
Gerald David
Department for Transport, Local Government and Regions
Federation of Communication Services
Federation of the Electronics Industry
Gordon Fraser
Futurepace Solutions
GWR
David Hall
Helicopter Club of Great Britain
Home Office
Hutchison 3G UK
Iberia Airlines International
Independent Television Commission
Inmarsat
Institute of Electrical Engineers

International Air Transport Association
ITV and ITV Digital
Jodrell Bank Observatory
Joint Radio Company
KLM Royal Dutch Airlines
John Larsen
Macquarie Bank
Maritime and Coastguard Agency
Met Office
Ministry of Defence
Motorola
National Air Traffic Services
National Physical Laboratory
Nokia UK
ntl
Office of Telecommunications
One2One
On-Site Communications Association
Orange
Particle Physics and Astronomy Research Council
Philips Research Laboratories and Philips Digital Systems Laboratory
Vincent Porter
Public Voice
Radio Authority
Radio Society of Great Britain
Royal Institute of Navigation
David Rudd
Satellite Action Plan Regulatory Group
Scottish Executive
SES Astra
Siemens Datatrak
Spectrum Management Advisory Group
Suvan Marine Data Services
Thus
Transfinite Systems Limited
Trinity House Lighthouse Service
UK Uplink Providers
Vodafone
Voice of the Listener & Viewer
White Box Solutions
The Wireless Group
Wireless Messaging Association

In addition, there were responses from several organisations which were submitted on a confidential basis.

3. The review has met with the following **UK Government Departments and regulatory bodies:**

Civil Aviation Authority
Department of Culture, Media and Sport
Department of Trade and Industry
H M Treasury
Home Office
Independent Television Commission
Maritime and Coastguard Agency
Ministry of Defence
National Audit Office
No. 10 Policy Unit
Office of Telecommunications
Radio Authority
Radiocommunications Agency

4. The review has consulted with the following **overseas government departments and agencies:**

European Union:
European Commission (DG Information Society)

USA:
Department of Defense
Federal Communications Commission
General Accounting Office
National Telecommunications and Information Administration

Australia:
Australian Communications Authority

New Zealand:
Ministry of Economic Development

5. In addition, the review has met with the following **individuals and organisations:**

Aegis Systems
British Broadcasting Corporation
BSkyB
BT
BT Cellnet/mmO2
Channel 4
Commercial Radio Companies Association
Confederation of British Industry
Convergence Group
Crown Castle UK
Federation of Communication Services
Federation of the Electronics Industry

John Forrest, Chairman, Spectrum Management Advisory Group
ICO Teledesic
Indepen Consulting
Institute of Electrical Engineers
ITV and ITV Digital
Jodrell Bank Observatory
Joint Frequency Management Group
Joint Radio Company
The Media Trust
Motorola
National Air Traffic Services
Nokia UK
Jim Norton
ntl
Brian Oliver, Chairman, Public Safety Spectrum Management Group
One2One
Orange
Oxera
Peter Ramsdale
Re:Think!
SES Astra
Andrew Sleigh, Managing Director, QinetiQ
Spectrum Management Advisory Group
Spectrum Strategy Consultants
Tomasso Valletti, Imperial College and CEPR, London
Vodafone
WS Atkins

ANNEX E

Terms of reference

Remit

1. In the November 2000 Pre-Budget Report, the Government announced an independent review of radio spectrum management.

2. The review's remit[1] is to advise on the principles that should govern spectrum management, and what more needs to be done to ensure that all users, including non-commercial users, are focused on using their spectrum in the most efficient way possible. In doing so, it will consider the use of spectrum management tools such as spectrum valuation, pricing and trading.

3. The review will report to the Chancellor and to the Secretary of State for Trade and Industry.

Context and timing

4. In December 2000 the Government published the Communications White Paper. This sets out the future for regulation in the communications sector, including the transfer of spectrum management functions into the new unified regulator, Ofcom.

5. The purpose of the review is not to revisit these institutional arrangements. However, it may be the case that the review wishes to make recommendations for the implementation of the proposed legislation (the Communications Bill that will define Ofcom's powers and functions).

6. The review will provide a final report to Ministers by January 2002[2].

Process

7. In order to ensure that the review is fully informed and authoritative, it will carry out full consultation with interested parties including from the private sector (such as broadcasters, telecommunications companies, manufacturers, etc), and from relevant Government departments (including, but not necessarily limited to, the Ministry of Defence, the Department of Culture, Media and Sport and the Department for the Environment, Transport and the Regions).

8. The recommendations that the review produces need to be practical as well as desirable. It will consider not only analytical issues but also the incentives facing different users and realistic mechanisms for improving spectrum management.

[1] Set out in HM Treasury press notice, 35/01, 22 March 2001.

[2] Originally December 2001.

ANNEX F

Glossary

3G	Third Generation mobile system
ACA	Australian Communications Authority
AFA	Autonomous Frequency Assignment
BFWA	Broadband Fixed Wireless Access
CAA	Civil Aviation Authority
CDMA	Code Division Multiple Access
CEN	European Standards Committee
CENELEC	European Electrotechnical Standards Committee
CEPT	European Conference of Postal and Telecommunications Administrations
DAB	Digital Audio Broadcast
DAP	Directorate of Airspace Policy
dBW	Decibels relative to one Watt of power
DCS1800	Digital Cellular System 1800 – former term for GSM services operating at 1800 MHz
DECT	Digital Enhanced Cordless Telecommunications
DFS	Dynamic Frequency Selection
DSSS	Direct Sequence Spread Spectrum
DTB	Digital TV Broadcasting
DTI	Department of Trade and Industry
DTT	Digital Terrestrial TV
DTV	Digital TV
DTLR	Department of Transport, Local Government and the Regions
DVB-T	Digital Video Broadcasting – Terrestrial
EC	European Commission
ECC	Electronic Communications Committee
ECAT	European Common (Frequency) Allocation Table
EHF	Extremely High Frequency (30 – 300 GHz)
EIRP	Effective Isotropically Radiated Power
EMC	Electro-Magnetic Compatibility
ENG/OB	Electronic News Gathering/Outside Broadcast
ERC	European Radiocommunications Committee
ERMES	European Radio Messaging System
ERO	European Radiocommunications Office
ERP	Effective Radiated Power

ESO	European Standards Organisations
ETO	European Telecommunications Office
ETSI	European Telecommunications Standards Institute
EU	European Union
FCC	Federal Communications Commission (USA)
FD	Framework Directive
FDMA	Frequency Division Multiple Access
FEC	Forward Error Correction
FHSS	Frequency Hopping Spread Spectrum
FM	Frequency Modulation
FWA	Fixed Wireless Access
GATS	General Agreement on Trade in Services
GHz	GigaHertz – a frequency of one thousand million Hertz (cycles per second)
GMDSS	Mobile Maritime Distress and Safety System
GPRS	General Packet Radio Service
GPS	Global Positioning System – a satellite radionavigation system
GSM	Global System for Mobile Communications
GSO	Geostationary Orbit
GWCS	General Wireless Communications Services
HF	High Frequency (3 – 30 MHz)
HIPERLAN	High Performance Radio Local Area Network
HO	Home Office
ICAO	International Civil Aviation Organisation
IEC	International Electrotechnical Commission
IMT-2000	International Mobile Telecommunications 2000 – family of air interface standards for 3G mobile services
ISM	Industrial, Scientific and Medical
ISO	International Organisation for Standardisation
ITC	Independent Television Commission
ITU	International Telecommunication Union
ITU-R	ITU-Radiocommunications Sector
ITU RR	ITU Radio Regulations
ITV	Independent Television
JFMG	Joint Frequency Management Group
JRC	Joint Radio Company
kHz	kiloHertz – a frequency of one thousand Hertz (cycles per second)
LF	Low Frequency (30 to 300 kHz)
MCA	Maritime and Coastguard Agency

MF	Medium Frequency (300 – 3000 kHz)
MHz	MegaHertz – a frequency of one million Hertz (cycles per second)
MLS	Microwave Landing System
MMDS	Multichannel Multipoint Distribution Service
MOD	Ministry of Defence
MoU	Memorandum of Understanding
MVDS	Multipoint Video Distribution System
MWS	Multimedia Wireless System
NATO	North Atlantic Treaty Organisation
NDPB	Non-Departmental Public Body
NGSO	Non-Geostationary Orbit
NRA	National Regulatory Authority
NTIA	National Telecommunications and Information Administration (USA)
Ofcom	Office of Communications
Ofgem	Office of Gas and Electricity Markets
OFT	Office of Fair Trading
Oftel	Office of Telecommunications
ONP	Open Network Provision
OSS	One Stop Shop
PAMR	Public Access Mobile Radio
PFAT	Peacetime Frequency Allocation Table
PPARC	Particle Physics and Astronomy Research Council
PFD	Power Flux Density
PFI	Private Finance Initiative
P-MP	Point to Multi-Point
PMR	Private Mobile Radio
PMSE	Programme-Making and Special Events
PPP	Private Public Partnership
P-P	Point to Point
PSB	Public Service Broadcasting/Broadcaster
PSMB	Public Safety Mobile Bands
PSRCS	Public Safety Radio Communications Service
PSSMG	Public Safety Spectrum Management Group
RA	Radiocommunications Agency
RF	Radio Frequency
RLAN	Radio Local Area Network
RR	Radio Regulations
R&TTE	Radio & Telecommunications Terminal Equipment

SAB	Services Ancillary to Broadcasting
SARP	Standards and Recommended Practices
SDMA	Spatial Division Multiple Access
SHF	Super High Frequency (3 – 30 GHz)
SMAG	Spectrum Management Advisory Group
SMO	Spectrum Management Organisations/Band Managers
SMR	Specialised Mobile Radio
S-PCS	Satellite Personal Communications System
SPD	Spectrum Policy Decision
SRD	Short Range Device
STU	Standard Trading Unit
TACS	Total Access Communication System – analogue cellular mobile standard
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TETRA	Terrestrial Trunked Radio – ETSI digital trunked radio standard
TETRAPOL	Proprietary digital trunked radio standard
TPC	Transmitter Power Control
UHF	Ultra High Frequency (300 – 3000 MHz)
UKSSC	UK Spectrum Strategy Committee UKSSC
UMTS	Universal Mobile Telecommunications System – 3G mobile standard
U-NII	Unlicensed National Information Infrastructure
USO	Universal Service Obligation
UWB	Ultra Wide Band
VHF	Very High Frequency (30 – 300 MHz)
VLF	Very Low Frequency (3 to 30 kHz)
WAP	Wireless Application Protocol
W-CDMA	Wideband Code Division Multiple Access
WGRR	Radio Regulatory Working Group (CEPT / ECC)
WRC	World Radio Conference
WT Act	Wireless Telegraphy Act (1949 or 1998)
WTO	World Trade Organisation