Spectrum Framework Review

A consultation on Ofcom's views as to how radio spectrum should be managed

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Section 1

Executive summary

1.1 Introduction

One of Ofcom's key statutory duties is to ensure the optimal use of the radio spectrum under its management[1]. Radio spectrum is a major asset to the UK, contributing some £24bn to the economy each year and underlying many aspects of our lives. Radio communications is critical to areas such as air travel, emergency services, cellular telephony, sound and television broadcasting, defence and our utilities. Ofcom has been considering carefully its management of this vital resource and is now publishing this "Spectrum Framework Review", a key document setting out its plans for radio spectrum in the medium and long term. This review applies only to spectrum under Ofcom's management.

1.2 The reasons for regulating spectrum

If access to the spectrum was completely unregulated there would likely be intolerable interference in many areas. For example, some broadcasters might set up transmitters on the same frequencies and engage in 'power races' where each would try to drown out its competitors, resulting for the most part in nobody being able to receive a signal. Indeed, this is exactly what happened in the US in the 1920s.

The role of the spectrum manager in outline is to ensure that no two users transmit on the same frequency at the same time and sufficiently close together that they interfere with each other. To do this, the spectrum manager does not give out "spectrum" but instead provides the right to transmit on a particular frequency over a particular geographical area. Such a transmission right is sometimes referred to as "access to the spectrum" and users will sometimes refer to having bought "spectrum at auction". There is often an international dimension to this as radio signals do not stop at international borders.

Spectrum has been managed in the UK for around 100 years. The general approach adopted world-wide during this period has been for the spectrum manager to decide, often in accordance with an agreed international framework, on both the use of a particular band and which users are allowed to transmit in the band. This approach was appropriate while there were relatively few uses and users and the spectrum manager could have as good an understanding of the best use of spectrum as the market itself and hence could sensibly control all aspects of spectrum usage.

However, in recent years, as demand has started to exceed supply in some areas, this centrally managed approach to spectrum, sometimes termed "command & control", has started to become problematic. Where spectrum is scarce the use of "beauty contests" meant that Government had to choose between competing would-be service providers. In the US, such decisions were increasingly subject to legal challenge leading initially to the use of lotteries to overcome this problem and then eventually to the use of auctions. Other countries have followed the US lead. Auctions are useful tools in deciding who can use the spectrum, but they need to be

[1] Ofcom does not manage the entire spectrum. Some is managed by organisations such as the MoD.

combined with the ability to change use, which we term "liberalisation" to help decide the use that spectrum can be put to.

1.3 Proposed changes to spectrum management

In outline, there are three different ways to manage the radio spectrum in order to determine what use it should be put to:

1. The regulator manages the radio spectrum in a similar fashion to the way it has been managed for the last 100 years. This is often known as “command & control” and until recently has been used for around 95 per cent of the spectrum;

2. The market manages the radio spectrum within the boundaries of terms in the licences as set by Ofcom. This is known as “market mechanisms” and was strongly recommended in the Review of Radio Spectrum Management (the "Cave Report") that the Government commissioned on spectrum management in 2001. It is currently being introduced in the UK;

3. Nobody controls who uses the spectrum, but power constraints or other mechanisms restrict usage to reduce the probability of interference. This is known as “licence-exempt use” or sometimes “spectrum commons”. Around 5 per cent of the spectrum in the UK is currently set aside for licence-exempt use.

A key decision for Ofcom to make is the balance between these different approaches. We are setting in place mechanisms that will change this balance over the next five years as shown in Figure 1.1 in simplified and illustrative form.

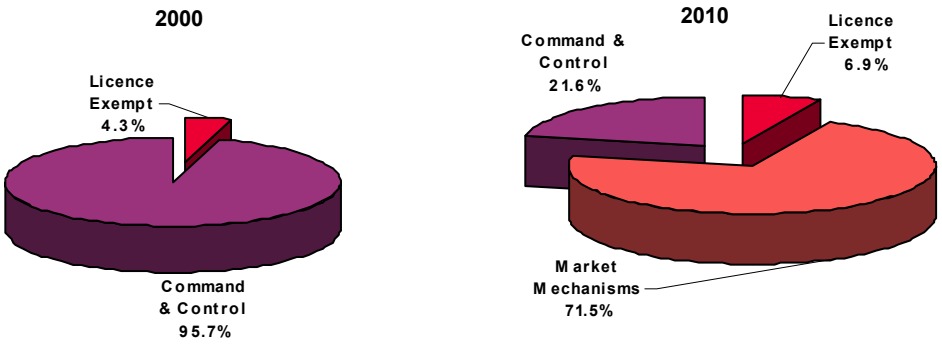


Figure 1.1: Current and future balance of spectrum use

As a light-touch regulator our preference is to move away from central management, allowing market forces to prevail and increasing the use of licence-exemption. We have considered carefully the role for licence-exemption. This is a key area for innovation and growth, with recent examples including WiFi and BlueTooth. However, in order to avoid interference in this unmanaged area, transmit power levels need to be kept low, normally restricting services to ranges of less than around 100m. Our calculations show that if there were 800MHz of spectrum available for licence-exempt use then every person could have 100Mbits/s short range services – more than enough to allow simultaneous high definition TV, browsing and on-line gaming. With around 600MHz of spectrum already available for licence-exempt use, of which over 400MHz has only very recently been made available, a small additional expansion is all that is needed to create significant benefits, although we have not

identified specific frequencies yet. Expanding beyond this would result in unused spectrum. This is an area we need to keep under careful review as applications and demand grows.

We believe that market forces should be allowed to prevail where this is in the best interests of citizens and consumers. This is based on the belief that 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 increased reliance on market forces is a trend across many areas such as fishing quotas and even pollution rights. It has been strongly advocated in spectrum by Professor Martin Cave and others, and successfully implemented to varying degrees in Australia, New Zealand and recently in the US. Allowing the users of the radio spectrum to decide on the best use for it will result in the spectrum being used for the most valuable purposes, and will make it much simple, cheaper and quicker for new applications and technologies to emerge. In a recent report for the EC, Analysys consultants suggested that the benefits in the EU of trading and liberalisation could be €9bn per year.

We believe that when there is sufficient spectrum available for licence-exempt use, market forces should be allowed to prevail where possible through the introduction of appropriate market mechanisms. The areas where there are difficulties in the full application of market mechanisms are:

- Where signals cross international boundaries, in particular satellite transmissions and low frequency signals;
- Where international mobility is critical, for example maritime and aeronautical applications including communications and radar; and
- Where there are legally binding EU harmonisation measures in force.

These areas will continue to require some degree of management for the foreseeable future. However, we will aim wherever possible to deregulate and release market pressure. We are also considering the possibilities of removing the need to have a licence in areas such as amateur and maritime although technology and usage restrictions will continue to apply.

1.4 The role of trading and liberalisation

As set out above, the key change that we propose is to increasingly allow market forces to prevail wherever this is judged to be in the best interests of the citizen-consumer. The key mechanisms we will use to achieve this are:

- Trading of spectrum between users so that they can buy, sell, aggregate and disaggregate spectrum holdings; and
- Liberalisation of spectrum use, so that increasingly users can change the technology or type of use that they make of the spectrum they hold.

Our proposals for trading are now well advanced. We are on track to allow trading in some licence classes before the end of 2004. We plan to progressively extend trading to almost all suitable licence classes by the end of 2007.

We have also recently published a consultative document on spectrum liberalisation. This is a more complex issue than trading - spectrum users have been packed in tightly by spectrum managers over the years, with many users sharing spectrum, and inappropriate liberalisation could cause intolerable interference. Some restrictions on the use of spectrum are therefore essential. There are two mechanisms by which Ofcom can implement liberalisation:

- The first relies upon licence variation to implement changes requested by users. Ofcom will consider all such requests in the light of its statutory duties, in particular we will consider whether the request can be granted without resulting in unacceptable interference to other users.

- The second mechanism involves Ofcom varying existing licences to make them less usage and technology specific. This would allow licensees to make certain types of change to their use of spectrum without needing the prior consent of Ofcom. Ofcom has already identified a number of such changes that are likely to be possible in 2005. However, the more general use of this approach raises some challenging technical questions, which are discussed in this document.

1.5 Technologies which might co-exist with licensed use

In general, Ofcom will make every effort to encourage the emergence of new technologies as long as they help achieve the objective of optimal spectrum usage.

A new technology, ultra-wideband (UWB), has been proposed and allowed in the US. UWB transmits at low power levels but across a wide bandwidth. It can be used to provide a range of potentially valuable services, such as in-home wireless entertainment systems. We are issuing a separate consultation on UWB in parallel with this Review.

A different type of co-existence is cognitive radio. A cognitive radio looks for momentarily unused parts of the spectrum, makes use of the spectrum and then vacates it before the licence holder wishes to use it. We see many technical and commercial problems with cognitive radio which might result in interference and so do not propose to make it licence exempt. However, under trading legislation we will allow licence holders to agree cognitive access with third parties if they wish to do so.

Technologies like UWB raise the question as to whether spectrum should be divided differently. At present, spectrum is divided by frequency. However, UWB might be simpler to introduce if spectrum was divided by power. We have examined different methods of dividing the spectrum and concluded that it is most appropriate for the regulator to continue to divide by frequency, but with more generic allocations. Users, or band managers, can then sub-divide using other methods as appropriate.

1.6 Many users of the radio spectrum will be affected

The proposed changes represent a significant change in the way that radio spectrum is managed. Users, particularly of fixed and mobile systems, will have new opportunities opened up for them. Equally, this will be a significant change for those already using spectrum and there needs to be appropriate transitional arrangements to recognise existing investments. Increasing use of trading and liberalisation could lead to major changes in the services delivered using radio spectrum. It is not Ofcom's role to predict possible developments, but by way of illustration, here are some of the things that might happen:

- An operator acquires some spectrum previously used for fixed applications and deploys a WiMax mobile data service, providing multi Mbits/s mobile laptop coverage across major parts of the country;

- Cellular operators gain more spectrum, enabling a raft of new applications like interactive gaming and personal broadcast services at low cost;

- Emergency services gain temporary access to spectrum when they need it to enable video from the helmet of fire-fighters and emergency medical workers, resulting in many lives saved; and

- Consolidation occurs in the private mobile radio market, resulting in a low-cost but higher capacity service, reducing operating costs for taxi companies, despatch riders and many others.

What actually happens may be very different from this. Importantly, changes will be based on real market need rather than the regulator's assumptions.

1.7 Our vision for spectrum management

Our vision for spectrum where market forces can be applied can be summarised as:

The Ofcom Spectrum Vision

1. Spectrum should be free of technology and usage constraints as far as possible. Policy constraints should only be used where they can be justified;

2. It should be simple and transparent for licence holders to change the ownership and use of spectrum; and

3. Rights of spectrum users should be clearly defined and users should feel comfortable that they will not be changed without good cause.

We will achieve this by:

- Providing spectrum for licence-exempt use as needed, but our current estimates are that little additional spectrum will be needed in the foreseeable future, growing to 7 per cent of the total spectrum;

- Allowing market forces to prevail through the implementation of trading and liberalisation where possible. We believe we can fully implement these policies in around 72 per cent of the spectrum; and

- Continuing to manage the remaining 21 per cent of the spectrum using current approaches.

Inevitably, there will be circumstances when we cannot fully achieve this vision. In these cases we will explicitly explain why we have departed from it.

1.8 Key points for consultation

The key points we wish to gather opinion on are:

1. What will limit the extent to which the market can be relied upon to deliver our objectives?

2. How much spectrum should be set aside for licence exempt use?

3. Should Ofcom allow licence holders to permit cognitive access if they wish but not mandate this?

4. Should Ofcom pursue a more flexible approach to harmonisation? Could industry and the standards bodies arrange detailed harmonisation where necessary, within a broad framework of international rules?

Q1: Are there any other major medium- to long-term spectrum management issues that this review should be considering? Are there any other significant technological or market developments that this review should be aware of when developing its thinking?

1.9 Linkage with other publications

This Consultation Document is part of a series of publications from Ofcom. We will shortly be publishing two directly related consultation documents:

- A consultation on UWB, a topic mentioned briefly in this document but deferred to a separate consultation document in order to provide an appropriate level of detail; and

- The Spectrum Framework Review Implementation Plan, setting out our proposals on how we will move from the current position to the end point set out in this document.

In addition, we continue to publish a series of documents relating to trading and liberalisation, one of the key parts of our overall spectrum strategy.

Section 2

How spectrum is currently managed and used

2.1 Understanding spectrum

When electrical signals are applied to an antenna they result in electro-magnetic waves which radiate outwards. It is this property that is at the heart of wireless communications. These waves can be received some distance away from the transmitter using appropriate antennas and receiving equipment. They can be transmitted at different frequencies depending on the frequency of the waveform applied to the transmitting antenna. The distance they propagate depends on the frequency – the higher the frequency the lower the propagation distance – and on the transmitter power – the higher the power the higher the propagation distance.
A particularly important property of these electro-magnetic signals is that signals transmitted on different frequencies do not interfere with each other, even if they are transmitted in the same place. Using a filter in a receiver it is possible in most cases to remove the unwanted frequencies, leaving just those that the receiver wishes to decode.

The set of usable frequencies is often termed the “radio spectrum”. As technology progresses, the boundaries of useful frequencies are continually extended. At present the lowest useful frequency is around 9kHz and the highest around 100GHz.

2.2 Why spectrum needs to be managed

If access to the spectrum was completely unregulated there would likely be intolerable interference in many areas. For example, some broadcasters might set up transmitters on the same frequencies and engage in “power races” where each would try to drown out its competitors, resulting for the most part in nobody being able to receive a signal. Indeed, this is exactly what happened in the US in the 1920s.

The role of the spectrum manager in outline is to ensure that no two users transmit on the same frequency at the same time and sufficiently close to each other that they interfere[2].

To do this, the spectrum manager does not give out “spectrum” but instead provides the right to transmit on a particular frequency over a particular area. Such a transmission right is sometimes referred to as “access to the spectrum” and users will sometimes refer to having bought “spectrum at auction”.

It has also become apparent over time that there are benefits in deciding what use should be made of each piece of spectrum. For example, collecting all sound broadcasting together in the same band of frequencies allows lower cost receivers.

[2] There are technologies that do allow simultaneous transmissions, but only under very tightly co-ordinated mechanisms such as the allocation of orthogonal codes. These are not considered in this introductory section for simplicity. Note also that "sufficiently close" in some cases might be many thousands of miles apart and a much greater distance than that over which a reliable service can be provided.

Further, because like signals interfere less with each other than unlike signals, it allows the users to be grouped more tightly together resulting in more capacity – in this example, a greater number of radio stations.

2.3 The reasons for the current management mechanisms

Spectrum has been managed in the UK for around 100 years. The general approach adopted world-wide during this period has been for the spectrum manager to decide on both the use of a particular band and which users are allowed to transmit in the band. This approach was appropriate when much of the use of the spectrum was used by the Government for purposes such as defence, public safety, aeronautical and maritime communications and broadcasting. While there were relatively few uses and users, the spectrum manager could also reasonably have as good an understanding of the best use of spectrum as the market itself and hence could sensibly control all aspects of spectrum usage.

However, in recent years, as demand has started to exceed supply in some areas, this "command & control" approach to spectrum management has become problematic. Where spectrum is scarce the use of "beauty contests" meant that Government had to choose between competing would-be service providers. In the US, such command & control decisions were increasingly subject to legal challenge leading initially to the use of lotteries to overcome this problem and then eventually to the use of auctions. In the UK, as in other European countries, there were few contenders for the original cellular licences in 1982, allowing a beauty contest approach to be simply applied. However, by the time the 3G licences were auctioned in 2000, there was an international field of 13 applicants. A fair and transparent beauty contest would have been virtually impossible in these circumstances.

In parallel with these developments, economists have long argued that market mechanisms should be applied to radio spectrum. Seminal papers in this area start with Coase in 1959[3]. The combination of a growing body of theory pointing to the role of market mechanisms, particularly auctions, and the increasing demand for the radio spectrum, led to the widespread use of auctions around the world during the 1990s. Auctions are now used as the preferred competitive means for assigning spectrum in many countries. Auctions solved the most pressing problems for many of the regulators – they allowed spectrum to be assigned where demand significantly exceeded supply in a way that is demonstrably transparent and far less prone to legal challenge than the alternatives. However, auctions without liberalisation cannot let the market decide on the most appropriate use for spectrum.

Any potential problems with the current approach of the regulator deciding the best use for the spectrum are far less visible. The tendency of central command approaches is to be slower than approaches such as trading and liberalisation in enabling new applications. The lack of emergence of an application is difficult to observe. However, there are a number of pointers to potential problems. Some European harmonised allocations have not resulted in successful use of the spectrum. Examples include the terrestrial flight telephone system (TFTS), the European radio messaging system (ERMES) and to some degree the digital PMR Terrestrial Trunked Radio (TETRA) which has not fully met expectations. In environments where innovation can be applied more quickly, such as the US, new applications such as Wi-Fi, WiMax and UWB have emerged many years before the UK. Finally, convergence in areas such as broadcasting and telecommunications could render problematic the allocation of some spectrum to broadcasting and other

[3] R. H. Coase, *The Federal Communications Commission*, 2 J.L. & ECON. 1 (1959).

spectrum to telecommunications in the case where, say, a telecommunications operator provided a form of broadcasting over their system.

As these problems have been growing, so the body of theory and experience in techniques such as trading and administrative incentive pricing (AIP) have been improving to the extent that the most practitioners would now agree that market mechanisms should be used to determine the best use of the spectrum, although there is still some disagreement over the details. In a key report commissioned by the Government, Professor Martin Cave strongly recommended implementing trading in order to introduce market mechanisms into the management of radio spectrum. In the same manner that in the early 1990s the regulator was on brink of changing from beauty contests to auctions, so in the early 2000s the regulator is faced with a similar change in the area of allocation. The most appropriate response to these opportunities and difficulties forms a major part of this document.

2.4 Current usage of spectrum

The usable spectrum currently ranges from 9kHz to around 100GHz (the upper limit has risen over the years as technological progress has allowed higher frequencies to be exploited). Within this very wide range, different frequency bands have very different characteristics.

At the lowest frequencies radio signals are capable of travelling very long distances but can carry relatively little data. At the highest frequencies they are capable of carrying large amounts of information but can only travel short distances and can be impeded by trees and buildings, or even rain at the very highest frequencies.

Intermediate frequencies offer different mixes of distance and information carrying capacity. The “prime” spectrum for communications services is sometimes considered to be between 100MHz and 3GHz as this offers the optimum combination of distance and information carrying capacity.

Figure 2.1 shows the weighted[4] use of the spectrum. Defence and fixed services dominate the overall usage.

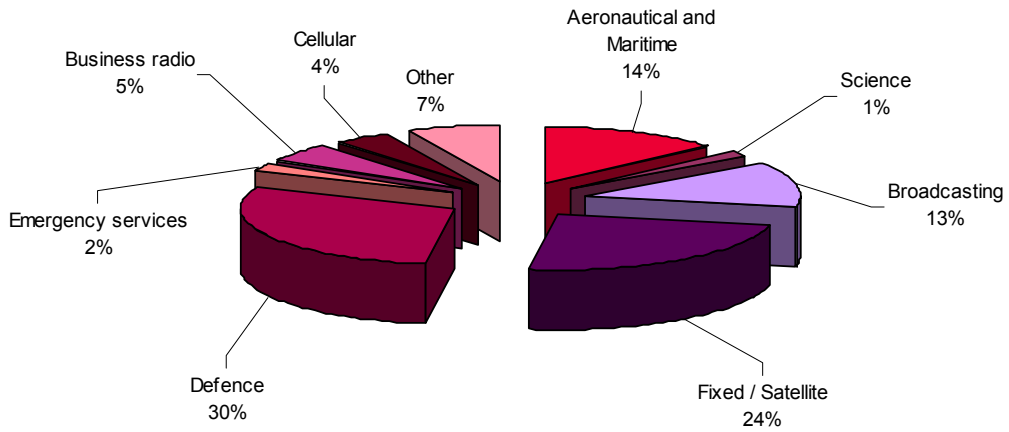


Figure 2.1: Current distribution of the radio spectrum (weighted)

[4] This has been weighted such that a 1MHz allocation at 100MHz is given equal weighting to a 10MHz allocation at 1GHz.

An alternative way of looking at the allocation is shown in Table 2.1. This shows the unweighted distribution across the different spectrum bands.

	0-300MHz	300MHz-3GHz	3-10GHz	10-30GHz	30-60GHz	Total
Defence	33	21	48	21	28	28
Broadcasting	16	14	0	4	0	2
Mobile	28	20	1	0	0	2
Fixed / Satellite	0	4	33	68	54	53
Aeronautical and Maritime	16	22	16	2	0	3
Science Services	0	2	0	3	11	6
Others	7	17	2	2	7	6
Totals	100	100	100	100	100	100

Table 2.1: Current allocation of the radio spectrum (%)

Note that in this table the totals for the different services are not the same as in the pie chart due to the weighting used in the latter. A few points of note are that:

- In the band of 300MHz to 3GHz, where demand is typically highest, the spectrum is fairly evenly distributed across the major services;
- At lower frequencies broadcasting and mobile have large allocations whereas at higher frequencies fixed has the largest allocations;
- Defence usage, which covers a number of different services, has a significant amount of spectrum across the whole band.

2.5 International obligations

2.5.1 Global – the ITU

The radio spectrum is planned at the global level through the International Telecommunication Union (ITU), a specialised agency of the United Nations. The ITU's International Radio Regulations, which have treaty status, include a frequency table which allocates the spectrum, from 9 kHz to over 275 GHz, to a multiplicity of defined radio services. The remainder of the Radio Regulations include a wide range of regulatory, operational and technical provisions designed to ensure that radio services, whether terrestrial or satellite, operate in such a way as to achieve compatibility and freedom from harmful interference between countries. These provisions include the criteria for inter-country frequency notification, coordination and registration which provide a framework for new assignments to be agreed by any other country that may be affected (in the case of HF or satellite services, these may extend across the whole world) and, once agreed, to protect those new assignments from harmful interference from other countries. It is important to stress that while the ITU's remit is to ensure such inter-country cooperation; nothing in the regulations can constrain each country's freedom to regulate as it wishes, as long as the impact on other countries is minimal and it is willing to accept the risk of interference.

The ITU's framework has provided the mechanism for global, and in some cases regional, harmonisation of radio services to develop. The clearest and most historic examples are in maritime communications and broadcasting, but they have extended over time to embrace navigation, aeronautical communications, all forms of satellite services (whether used for communications, navigation, scientific or environmental purposes), the amateur service and scientific services such as radio astronomy. For most of these applications there is a clear operational, or in some cases technical, requirement for some element of harmonisation at the global level.

Allocations in the International Frequency Table do not normally specify any particular application or technology, particularly for the terrestrial fixed and mobile services which often share allocations. For example, allocations are made to the *mobile* service, not to paging, public mobile, private mobile, etc. Indeed, in the ITU terminology, *mobile* includes not only land mobile but also maritime and aeronautical mobile services. Similarly allocations to *broadcasting* do not specify whether it is sound or television, or analogue or digital, although general practice and other ITU agreements (such as regional plans) do constrain choice. The ITU has tended to move to more generic allocations, albeit over a very long timescale. For example previously separate allocations for the land, aeronautical and maritime variants of the mobile-satellite service have been combined into a generic mobile-satellite service allocation.

There are exceptions, where it has been considered desirable to identify allocations at the global level, for example where spectrum is identified for 3G mobile services (IMT-2000 in ITU parlance). However, even then the frequency bands in question are not exclusively allocated to this particular application and may be used by other mobile systems (or indeed by non-mobile systems, subject to not causing interference to, or being protected from, mobile users outside the UK).

The ITU framework provides a considerable degree of harmonisation in both frequency allocations and regulations for those applications which need such an approach but leaves much flexibility at the national level. The only underlying constraint is that any assignment in one country must protect assignments in another country, if the latter operates in accordance with the international regulations, and must accept interference caused by the other country.

2.5.2 Europe – CEPT

More detailed planning of the spectrum is carried out by the CEPT, an organisation of 46 countries established for cooperation in the field of telecommunications and postal matters. CEPT has for many years produced recommendations and non-binding decisions on spectrum harmonisation, usually at a more detailed level than the ITU and for well over 10 years, CEPT has adopted Decisions which have a formal but non-binding commitment. Such Decisions may designate frequency bands for specific applications (eg mobile communications for the railways) and for specific technology (eg GSM). However despite their more formal status, each country can select whether to implement a Decision. Furthermore, Decisions on the harmonised use of spectrum usually leave a degree of flexibility. For example, the CEPT Decision on harmonised spectrum for the TETRA digital mobile radio technology does not exclude the use of other technologies, even for those countries committed to the Decision.

CEPT has also developed a European Common frequency allocation table (the ECA) in an attempt to minimise cross-border problems, provide a larger market for

equipment and allow for free circulation of equipment where appropriate. The ECA contains considerably more detail than the ITU's table of frequency allocations, often selecting a single radio service where the ITU allocations are shared and specifying the particular application within a more general allocation (eg, specifying public mobile services using GSM technology within a general mobile service band).

Although there are merits in this harmonised approach, the CEPT agreements do not impose binding constraints on countries and there is considerable freedom to act, especially where the new application will not cause, or suffer, undue interference from other countries.

2.5.3 NATO

The NATO countries have reached agreement on frequency allocations for defence use. This agreement is reflected in the ECA and by the Member States. It results in a fairly rigid division of spectrum, with many bands set aside exclusively for defence use throughout NATO. However, there is a regular dialogue between the civil and defence administrations at both national and European level and this has resulted in some adjustments over the years. For example, some of the spectrum used for terrestrial digital sound broadcasting in the UK, and the spectrum assigned to Airwave for the police and other emergency communications, was released from previously exclusive NATO spectrum.

2.5.4 European Union

The EU's interest and role in spectrum management has gradually increased over the past 15 years. There are three binding EU Directives on spectrum harmonisation (for GSM, DECT and ERMES). The first in particular was spectacularly successful but the ERMES Directive was not and this has demonstrated the rigidity and inflexibility of this approach to spectrum management. More recent harmonisation measures have been via EU Decisions, such as that adopted for UMTS (3G services). The current practice is for the EU, via its new Radio Spectrum Committee, to mandate the CEPT to carry out the detailed planning work necessary for a new harmonised allocation and for the Committee to subsequently adopt a Decision which is binding on Member States. The first such Decision to be adopted was in July 2004 on spectrum at 79GHz for wide-band vehicle radars.

The EU's harmonisation measures, although binding, are limited to those applications for which there is a strong requirement for pan-European harmonisation. There are signs that a less prescriptive approach might be taken in future, especially in respect of selecting particular technologies. For example, the EU recently commissioned a study from Analysys looking at the potential benefits of allowing trading and liberalisation across Europe. The European Commission has sought an Opinion from the EU's Radio Spectrum Policy Group on adopting a more technology-neutral approach.

2.5.5 Bilateral agreements

A number of bilateral agreements exist for certain parts of the spectrum and specific applications. For example the use of VHF Band III for mobile services in the UK is subject to an agreement with France, which uses the band mainly for television services. Such agreements are generally very specific to the application and the technology.

2.6 Health concerns

The use of mobile phones in particular, and electro-magnetic emissions in general has raised many concerns about health. It is not Ofcom's role to comment on health impacts - a number of national and international bodies such as the National Radiological Protection Board (NRPB) and the International Commission on Non-Ionising Radiation Protection (ICNIRP) produce guidance in this area. As a result, health issues are not discussed further in this document. However, Ofcom recognises health concerns as important and contributes to a study conducted by the Department of Health on the impact of electro-magnetic radiation.

2.7 Summary

In this chapter we have discussed the current approach to spectrum management and the reasons why there are benefits in changing this approach. Details of the current usage of the spectrum were provided. We noted that:

- A key role of the regulator is to prevent interference;
- When there were relatively few users of the spectrum, the regulator could achieve this goal by deciding upon the most appropriate use and user of each frequency band;
- As the number of users and uses have grown, centralised methods have become increasingly unworkable and unjustifiable; and
- There are some international obligations which restrict freedom within the UK, but for the most part these still allow a substantial degree of flexibility.

In the next chapter we look at the rationale for publishing this Spectrum Framework Review.

Section 3

The objectives and positioning of this Review

3.1 The Spectrum Framework Review is one of the three major reviews

In its annual plan for 04/05 Ofcom set out its intentions to publish three major reviews:

- The Public Service Broadcasting Review to look at the most appropriate structure for public service broadcasting in the future;
- The Telecommunications Review to look at the best means to regulate the telecoms industry; and
- The Spectrum Framework Review to set out Ofcom's long term strategy for managing the radio spectrum.

These three reviews broadly cover the three major areas where Ofcom regulates – broadcasting, telecoms and spectrum. There is also some degree of overlap between them – spectrum is one of the inputs required for broadcasting and for some of the telecoms services. Decisions made in this Spectrum Framework Review will have an impact on how any digital dividend from broadcasting switchover is released and might impact the likelihood of the emergence of fixed wireless providers to compete with BT in the last mile. Key consultation documents are being published on all these reviews across the last quarter of 2004 to allow them to be considered together, while at the same time avoiding the consultative load that would have resulted from simultaneous publication.

3.2 Rationale for publishing a spectrum strategy

Ofcom believes that publishing a medium to long term strategy for spectrum will be advantageous to users of the radio spectrum. Having a spectrum strategy will allow Ofcom to pursue a coherent long-term policy, and to ensure that short and medium term decisions fit within the framework of an overall objective. By short, medium and long term, Ofcom means periods of around 2, 5 and 10 years, respectively. Publishing the Spectrum Framework Review allows:

- Consultation and discussion around the key strategic decisions;
- Users making long term decisions to do so on the basis of the best information available; and
- Those engaging in market-related activities such as trading to have increased certainty about the future availability of spectrum.

Ofcom will revise this document according to feedback received during the consultation process and reissue.

3.3 Previous 'spectrum strategy' documents

Prior to the formation of Ofcom, the Radiocommunications Agency (RA) published a spectrum strategy document on a near-annual basis. This document was last published in April 2002[5].

The RA Spectrum Strategy document tended to concentrate predominantly on the changes foreseen for each particular frequency band or user group. Only in recent years had it started to discuss higher level strategic issues.

Ofcom believes that providing a "compendium" of information about issues and changes for each band or user group, including an annotated frequency table, remains a useful exercise and plans to continue publishing this information. By taking the Spectrum Framework Review and the Compendium together a user of radio spectrum will be able to understand detailed planned changes and longer term direction for spectrum management. Together they ensure that there will be no surprises for spectrum users over the foreseeable future. Our current plan is to publish such a compendium in summer 2005.

Q2: Do you believe it is useful to publish a compendium of issues? How frequently should it be published? What information should be included?

3.4 Ofcom's spectrum management strategy

In line with its principal statutory duties, Ofcom seeks to further the interests of citizens in relation to communication matters and to further the interest of consumers in relevant markets, where appropriate, by promoting competition. In relation to spectrum management Ofcom is required to secure the optimal use of the spectrum. Ofcom does not manage all the spectrum - some is managed by the Government for defence and other purposes. This Review applies only to the spectrum under Ofcom management.

In carrying out its spectrum management duties Ofcom must have particular regard to

- Availability of spectrum; and
- Current and future demand for spectrum.

And to the desirability of promoting

- Efficient management and use of the spectrum;
- Economic and other benefits arising from its use;
- Development of innovative services; and
- Competition in electronic communications services.

Ofcom has also made it clear that It aims to adopt an approach of light touch regulation, deregulating or simplifying regulation wherever possible.
In addition, Ofcom proposes to build on a number of important developments in recent years, set in place by previous decisions taken by the RA, by publications from Ofcom, and reinforced by the findings of the Cave Report. These include :

[5] http://www.ofcom.org.uk/static/archive/ra/rahome.htm

- The use of auctions as the primary mechanism to assign cleared radio spectrum for new services;

- The continued use of administrative incentive pricing (AIP) as a mechanism to inject market forces into spectrum usage, with prices set across many areas of use and reviewed periodically; and

- The progressive introduction of spectrum trading and liberalisation between 2004 and 2007.

These strategies form the starting point for the discussion of strategic issues in this document.

3.5 Summary

In this chapter we have set out the positioning and the purpose of this Review. In summary:

- This Review is one of the three major reviews being performed by Ofcom in the 04/05 year;

- The intention of the Review is to provide users of spectrum with a clear framework within which spectrum management decisions will be taken so that the future framework of regulatory policy is clear;

- This document differs from previous spectrum strategy publications from the RA in being focussed more on strategy and less on band-by-band discussion; and

- The strategy we propose will build upon previous statements and publications such as the Cave Review.

In the next chapter we examine the different models for spectrum management and set out our thoughts on the correct balance between these.

Section 4

Balancing the different models of spectrum management

4.1 The possible boundaries of spectrum management

In the absence of constraints, there are three potential approaches to managing the spectrum:

1. The regulator manages the radio spectrum (in a similar fashion to the way it has been managed for the last 100 years);

2. Nobody manages the spectrum, but usage is restricted by the regulator setting technical parameters to reduce the probability of interference; and

3. The users manage the radio spectrum through the market according to a set of rules laid out by the regulator.

However, there are legal constraints which do limit options. Taking these into account these three options can be expanded as follows:

1. **Command & control**. This is the historical approach where the regulator decides how much spectrum each application should have and allocates and assigns[6] the spectrum accordingly. It is still the predominant method of managing spectrum;

2. **Spectrum available for licence-exempt use**. This is also known as "spectrum commons" and "unlicensed access"[7]. The regulator allows free access to the spectrum, although normally with restrictions on power levels, making it most suitable for short-range devices; and

3. **Market mechanisms**[8]. This is broadly the use of auctions and trading with liberalisation, to allow the market to modify historical allocations towards those more likely to maximise economic efficiency. Spectrum pricing can also inject some market disciplines into the allocation and assignment process.

[6] *Allocation* is the process of deciding which use the spectrum should be put to. *Assignment* is the process of deciding which users should gain a licence to use the spectrum within the agreed allocation. However, note that there are varying degrees of allocation depending on the level of international agreement and the degree of specification. The term allocation is used here to refer to national decisions on the best use for the spectrum.

[7] Some commentators make a differentiation between spectrum available for licence-exempt use, where all are allowed access, and spectrum commons where users must agree to the rules of the commons prior to entering. Such rules might include equipment able to download operating parameters. This distinction is not drawn in this document, where restricted rules of entry are considered part of the possible parameter set for licence-exempt spectrum.

[8] Note that the term "market mechanisms" is used in this document to indicate market-based spectrum management tools. To be specific, Ofcom will continue to manage the spectrum but market mechanisms can change allocation decisions.

Allowing the market to play an increasing role in allocation decisions will change the manner in which international harmonisation is performed, since the market may change the use away from a harmonised approach, or may provide harmonisation itself. A discussion on harmonisation is provided at the end of this section.

Another major policy issue, which to some extent overlaps with the decision regarding the balance between the three key modes of spectrum management, is the entitlement to transmit in spectrum for which a third party has been granted a licence. With the exception of unwanted emissions from non-communications devices, such transmissions are not currently allowed in the UK. Two types of entitlement have been proposed, namely:

1. **Entitlement in time**. This is the entitlement to transmit in a third party's spectrum if that third party is not currently using it. This may be done by agreement between users or through the use of technology which seeks out currently unused frequency bands. In the later case, it is known as "cognitive radio" or, somewhat erroneously, "software defined radio" (SDR); and

2. **Entitlement in power**. This is the entitlement to transmit in a frequency band used by existing services at very low power levels such that their use of the spectrum will not be materially affected. The technology that enables this is ultra-wideband (UWB).

Such entitlements only apply for command & control and market led forms of spectrum management since there are few restrictions on transmitting in spectrum set aside for licence-exempt use.

This document does not discuss policy issues relating to specific services or bands. However, there are some issues which are of such significance that they could impact high level spectrum strategy. Ofcom judges these to be:

- Digital TV switchover and the subsequent use for the band;

- Potential for release / refarming of significant holdings of spectrum such as military and radar usage;

- A range of issues related to the extension of trading and liberalisation to 2G and 3G services; and

- Broadband fixed wireless access.

In Section 6 the timetable and proposed approach to consulting on these issues is discussed.

Q3: Are there any other issues of sufficient significance to merit mention in this document?

4.2 Current direction

Historically almost all spectrum was managed using the approach that we have termed "command & control". In the last few years this has been relaxed somewhat by:

- Using auctions to assign spectrum. However, this has not changed allocation decisions so there is still a large element of central control;

- The proposals for spectrum trading which will allow some change of ownership; and
- New allocations set aside for licence-exempt use, for example at 5GHz.

The relative amounts of spectrum managed under these three different approaches is shown in Figures 4.1 to 4.3 for the years 1995, 2000 and a prediction for 2005 based on existing Ofcom policies[9].

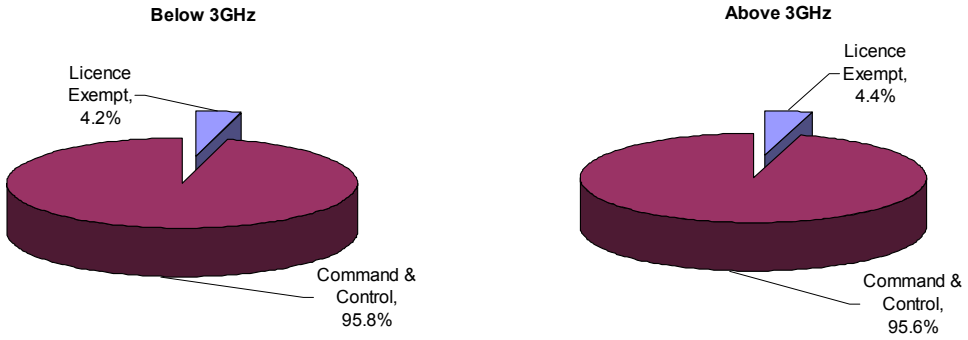


Figure 4.1: Relative amounts of spectrum under different management methods in 1995 (Illustrative)

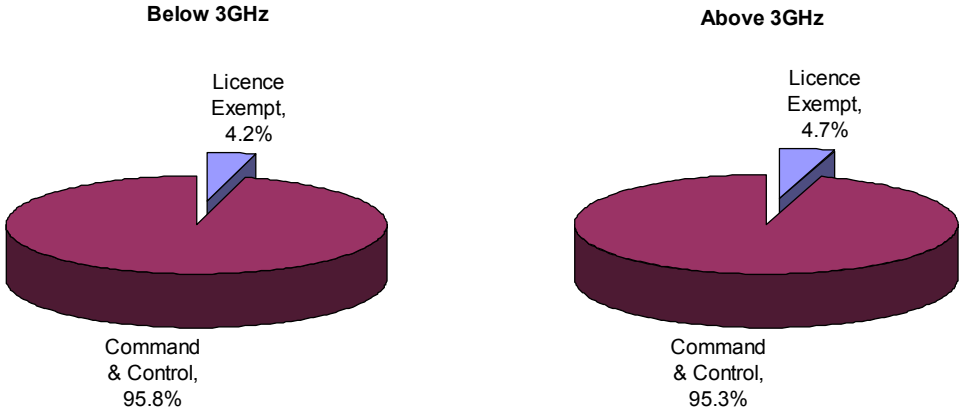


Figure 4.2: Relative amounts of spectrum under different management methods in 2000 (Illustrative)

[9] These charts exclude defence spectrum and are percentages of amounts of spectrum relative to the band centre frequency, rather than absolute amounts. Note that compiling these charts is somewhat complicated by the fact that many bands are shared. We have taken the approach of counting the use of a band as subject to market forces if at least one of the shared applications will be tradable. Also note that the distinction between market forces and command & control is often not clear-cut. For these reason all the pie charts in this section should be taken as illustrative.

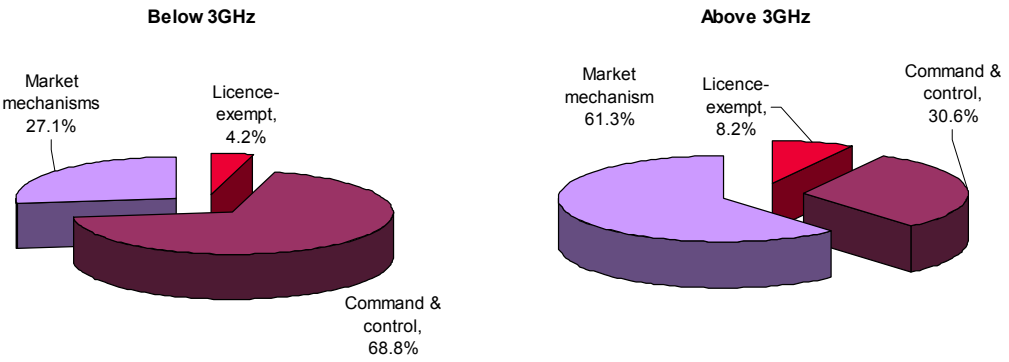


Figure 4.3: Relative amounts of spectrum under different management methods in 2005 (Illustrative)

The figures show that there was no appreciable change between 1995 and 2000 but that by 2005 there will have been a significant increase in the role of the market in managing spectrum. However, even by 2005, about half of the spectrum will still be managed in a centralised fashion. Above 3GHz, the increase in spectrum for licence-exempt usage between 2000 and 2005 is clear. This is due to the availability of a significant amount of new spectrum at 5GHz.

Over the last few years there has been considerable literature discussing possible new spectrum management models. A more detailed summary of this literature is provided in Annex F. In summary:

- **Cave Report**: The general direction of the Cave report as it relates to this review is to encourage the use of market mechanisms predominantly through the implementation of spectrum trading in as flexible and simple a manner as possible; and

- **Licensed versus licence exempt**: There is a wide divergence of views. Some suggest that if all spectrum were set aside for licence exempt use and devices were intelligent then there would be more than enough spectrum and no further regulation would be needed. Others suggest all spectrum be licensed but licence holders be able to grant access to others, who might not have a licence. Many compromises are also put forward. It is difficult to establish a consensus from this literature.

There is also some experience in implementing new spectrum management models in other countries. A more detailed account of this is provided in Annex G. In summary, a few countries have implemented spectrum trading. These include New Zealand, Australia, Guatemala, El Salvador and the US. The scope of these implementations has varied as has the degree of change of use allowed. Although there are important lessons to learn from each, none provides the degree of flexibility that would ideally characterise a spectrum trading environment.

Q4: Are there important lessons to be learnt from experience in other countries that is not addressed here?

4.3 Longer term use of command & control

Ofcom is a light touch regulator. This will incline it towards an approach of minimal regulation, as far as possible. As a result, it believes that spectrum access should be deregulated where appropriate with market mechanisms being applied to the

maximum extent possible where deregulation cannot be applied. The key rationale for allowing the market to make allocation and assignment decisions is that 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. This approach is almost unanimously advocated by commentators, and also one of the key recommendations of the Cave report[10]. In many other areas there has been a move away from central planning to market forces including:

- Electricity markets in many countries; and
- Markets in various newly created environmental property rights such as sulphur dioxide emission trading.

In each case, there were many who doubted whether the application of market forces was appropriate, and there have been initial problems. However, for each of these examples there is now some evidence that the outcome is better than would likely have been achieved under the command & control approach that was previously adopted.

As discussed in Annex G, trading and liberalisation of spectrum has been introduced to varying degrees in other countries. Although early days, the outcomes appear generally favourable in that trading and change of use has occurred, while there does not appear to have been any unexpected problems.
Taking into account:

- the general belief in the superiority of the market to central control;
- the positive experience in the few other countries that have implemented trading; and
- the generally positive experience in other sectors.

then we believe that there is a strong case for allowing the market to operate feely, where this is in the best interests of the citizen-consumer.

We are seeking input on how far it is possible to implement trading and liberalisation. We believe that there will remain some areas for which market mechanisms cannot be fully applied, particularly in making allocation decisions, although measures such as recognised spectrum access (RSA) may allow market forces to play a greater role in some cases. The areas where trading and liberalisation cannot be fully applied might be:

- Spectrum where there are unavoidable, important or valuable international issues. For example, spectrum assigned to satellite operation is generally covered by international obligations and there may be valid economic reasons why the UK would like to see these continue;
- Spectrum which relates to a broader social objective. Ofcom is generally not in favour of spectrum allocation and assignment being used as a mechanism to achieve social policy. However, there are some current licences where policy conditions are, or will be attached and it will not be possible to remove

[10] For example, see paragraph 67 in the Executive Summary

them. This applies to broadcasting spectrum and to some of the emergency services; and

- Spectrum where it is important to maintain international harmonisation for operational reasons, eg aeronautical and maritime where the use of common frequencies world-wide is essential.

In summary, the areas where in our view trading and liberalisation cannot be fully applied are as follows:

Services	Usage and comment
Satellite	The international nature of satellite services and the fact that the frequencies are harmonised internationally limit the scope for allowing change of use in the UK. However, some earth stations use shared bands and there could be advantage in permitting some flexibility.
EC harmonised bands	EC regulation prohibits reductions of the restrictions on permitted use in these bands.
Maritime and aviation bands.	The international nature of these bands and the treaties associated with them will prevent reductions of restrictions on permitted use. However there are also some commercial bands (e.g. maritime business radio) which offer some flexibility.
Services operating below 30MHz	Propagation at these frequencies is such that almost all usage will need international coordination.
All analogue broadcasting	Analogue broadcasting is governed by both national broadcasting legislation and a number of international agreements. Technical constraints around broadcasting parameters are also problematic.
Radio astronomy	Radio astronomers need access to particular protected frequencies and work on an international basis.
Radio amateurs	This is a use of the spectrum where there is an operational need for harmonisation on an international basis.

Table 4.1: Frequency bands where trading and liberalisation cannot be fully applied due to international issues

Q5: Do you agree with Ofcom's intent to maximise the use of trading and liberalisation?

Q6: Are there other areas, apart from those identified above, where trading and liberalisation should be restricted? Are there areas identified above where you believe the trading and liberalisation could be fully implemented?

4.4 Longer term availability of spectrum for licence-exempt use

Ofcom's light-touch philosophy biases it towards deregulating access to spectrum where possible and appropriate.

The legal basis for licence exemption is as follows. Under section 1 of the Wireless Telegraphy Act 1949 (the "1949 Act") it is a criminal offence to establish or use

equipment for wireless telegraphy (transmission) except under the authority of a wireless telegraphy licence granted by Ofcom. An exception from the requirement to hold a wireless telegraphy licence exists where Ofcom has exempted the use of particular equipment by including that equipment in a Statutory Instrument[11]. Where the use of any particular equipment for wireless telegraphy is not likely to involve undue (harmful) interference, Ofcom must exempt the use of that equipment from the requirement to hold a wireless telegraphy licence[12].

Under this legislation there is not actually any licence-exempt spectrum. Instead there is spectrum that Ofcom has chosen to set aside solely for licence-exempt devices using a particular technology or range of technologies. We will refer to this as "spectrum available for licence-exempt use" in this document. Additionally some apparatus is exempted for use on licensed bands (e.g. handsets for mobile telephony where the network is licensed to the operator).

There is a range of different types of spectrum available for licence-exempt use, depending on the degree of technology neutrality allowed.

- **Specific technology or usage**: In some case, such as amateurs and maritime radio, the usage and technology is tightly constrained but it might be possible to remove the need for a licence to transmit. This type of usage is discussed in more detail below but not otherwise considered in the further discussion of spectrum available for licence-exempt use; and

- **Power limit only**: The least degree of constraint is where the only restriction placed on the usage is a maximum power. Typically, it is not possible to remove the restriction on maximum power because of the risk of interference.

Some of the more extreme views on spectrum commons suggest that if all the spectrum were set aside for licence exempt use that there would be less congestion than is currently the case[13]. This is often predicated on limited measurements that appear to show there is little actual use of radio spectrum at any particular time and place.

Ofcom does not concur with the view that all access should be licence-exempt. We believe that were all access deregulated there would be significant interference between, for example, broadcasters. The economics of spectrum management[14] show that where congestion is expected that a licensed approach should be followed. In general, longer range communications rapidly increase the probability for interference and hence congestion. The exceptions to this are in rural areas or relatively under-utilised bands. However, we do agree that advanced technology using "politeness protocols" can result in more efficient licence-exempt use and should be encouraged through the appropriate standards bodies.

[11] The current Statutory Instrument is the Wireless Telegraphy (Exemption) Regulations 2002.

[12] This requirement is imposed by both EU and UK law (Article 5(1) of the Authorisation Directive and Section 1AA of the 1949 Act).

[13] This is sometimes referred to as the “supercommons”. For example, see Werbach, “Supercommons: Towards a unified theory of wireless communications”, TPRC 31, September 2003.

[14] See http://users.wbs.warwick.ac.uk/group/cmur/publications/spectrum2 “Spectrum licensing and spectrum commons – where to draw the line”.

We are seeking input on the likelihood of congestion occurring in spectrum set aside for licence exempt use. We believe we can determine the relative probability for interference given a maximum range and likely user density, but cannot be certain that congestion will never occur. Hence, we believe that the regulator needs to work on the balance of probability and with an action plan to ease congestion should it arise. In the 2.4GHz band we are now seeing early reports of interference, predominantly between Wi-Fi nodes. These have a typical maximum range of around 200m and hence we believe that this should generally be the upper limit for licence exempt devices in urban areas. Indeed, given that some congestion is now starting to occur, it could be argued that the maximum range should be less than 200m.
If it were possible we would ideally like to allocate spectrum for licence-exempt use through a market mechanism. To date, the view has been that market mechanisms are unlikely to be able to allocate spectrum for licence-exempt uses because it is difficult for multiple licence exempt users to join together to buy spectrum at auction. The business case for a band manager buying spectrum and turning it into a "private commons" is not clear. If this is true, despite the desire to make use of market mechanisms, regulators will need to decide on the appropriate amount of spectrum for licence-exempt use. At present, there are no widely accepted mechanisms available to do this. Approaches which have been advocated include:

- Assessment on a block-by-block basis to understand the likelihood of congestion, making the spectrum available for licence exempt use if this likelihood appears low;

- Prediction of the amount of spectrum needed for short-range communications and setting this as the upper limit of the amount of spectrum for licence-exempt use; and

- Taking the view that it is not possible to determine how much spectrum should be provided, but that it is likely to be more than is currently provided[15].

Ofcom is keen to understand whether there might be other approaches and which of these approaches it should adopt. At present, we are minded to use a combination of the first two of these approaches. Having some understanding of the demand for short range communications would allow us to place an upper limit on the amount of spectrum available for licence-exempt use. By restricting spectrum for licence-exempt use to short-range applications, the likely demand, at least over the short to medium term can be determined.

After the likely demand has been estimated it is still necessary to determine whether it would be in the economic interests of the UK to make the spectrum available for licence exempt use and that it is in line with Ofcom's other statutory duties. This analysis is difficult to perform with certainty because it relies on forward-looking assumptions about what each frequency band would be used for under licensed and licence-exempt scenarios, but can provide some measure of guidance.

Estimating the total amount needed for short range communications would be based on the maximum likely data rates needed in the local area – for example SMAG[16] has suggested that 100Mbits/s should be sufficient for the applications that can be

[15] FCC, OSP Working Paper Series, No 39, "Unlicensed and unshackled", May 2003. www.fcc.gov/osp/workingp.html .

[16] The Spectrum Management Advisory Group (SMAG) is the predecessor to the Ofcom Spectrum Advisory Board (OSAB).

foreseen over the next 5–10 years. By understanding the reuse factors needed in urban environments, a ceiling on the amount of spectrum needed for licence-exempt use can be reached[17]. Ofcom's initial view is that around 800MHz of spectrum might be sufficient if user data rates of 100Mbits/s are required. Ofcom has already made 535MHz available in the 2.4GHz and 5GHz bands (excluding band C which is subject to light touch licensing). As a maximum, then, an additional 250MHz or so of spectrum might be needed for licence-exempt use. Given the technologies will generally work better with contiguous spectrum, this might best be allocated close to the existing 5GHz band, although no specific frequencies have been identified at this point. While 250MHz may seem like a small increment it should be remembered that a very large amount of spectrum has been recently reserved for licence-exempt use in the 5GHz band which is broadly unused at present.

The next stage is to consider whether making this spectrum available for licence exempt use would be in the best economic interests of the UK. To do this, Ofcom would need to compare the economic benefits of licence exempt usage with the benefits of licensed usage. As mentioned above, this is a difficult comparison as it requires forward-looking assessments of the best use of the spectrum. However, since at present, the existing part of the 5GHz band set aside for licence exempt use is little used, it seems unlikely that immediately providing additional spectrum will be economically sensible. Therefore, instead, Ofcom proposes to monitor the usage of the 5GHz band[18] in order to predict when demand in the band might exceed capacity.

Once it is clear that this is likely to happen at some point in the future, Ofcom will conduct an economic study to assess whether more spectrum should be made available for licence-exempt use and will act accordingly. Ofcom might also periodically assess whether its calculations as to the maximum amount of spectrum needed for licence-exempt use are still correct by re-examining wireless applications and the models used to estimate the amount of spectrum needed.

In rural areas where less demand is predicted, we believe that we can allow an increased range for licence-exempt use to reflect the lower probability of interference. We would welcome views on this. For example, the coverage area might be scaled in inverse proportion to the relative population density. We will consult on the most appropriate mechanisms to define areas where higher powers are permitted and to monitor and enforce correct operation.

In the frequency bands below 1GHz there are a number of small bands set aside for licence exempt use. These have proved very popular for applications such as telemetry. Ofcom will continue to monitor the usage of these bands and will introduce further relatively small allocations where appropriate.

[17] Ofcom has conducted some preliminary studies using ITU methodology ITU-R M1651. These suggest that around 800MHz of unlicensed spectrum would allow all users in an office or home environment to have access to 100Mbits/s transmissions under most normal situations.

[18] This will be an inexact process because the short range of the devices would require many thousands of measurements across a city, each of a significant duration, in order to fully characterise the utilisation. Ofcom would welcome suggestions on approaches to measuring occupancy.

Measuring spectrum usage

Making measurements to determine how well spectrum is used is not straightforward. There are many potential reasons why spectrum may appear vacant:

- It is momentarily unused – for example a taxi company might not be making transmissions at that point;
- Signals are not reaching the measurement receiver. There might be a mobile behind a nearby building making a transmission but this signal may be blocked to the measurement receiver;
- It is reserved for particular, critical, applications which are not currently transmitting – for example military and emergency service spectrum often fall into this category;
- The frequency is left as a guard band, either between two frequencies or between the use of this frequency in nearby cells. In this case, if it were used it might result in interference to other existing users; and
- Signals may be hard to detect – for example CDMA signals are often transmitted near the noise floor and can be difficult to detect with a conventional measurement receiver.

For all these reasons, making measurements of spectrum usage is likely to under-represent the actual usage of the spectrum. Nevertheless, it is clear that spectrum is not 100 per cent utilised. Annex I presents the results of some measurements that Ofcom has conducted in the bands below 1GHz where there appears to be relatively little usage, although the issues listed above must be taken into account when considering utilisation. Ofcom's view is that greater utilisation can be more readily gained from using market forces rather than opening access to the spectrum on an licence exempt basis.

Q7: Do you agree with Ofcom's approach to providing spectrum for licence-exempt use?

Q8: Is Ofcom's proposed methodology to estimate the amount of spectrum needed likely to deliver the right results?

Q9: What is the appropriate timing and frequency bands for making available any additional spectrum for licence-exempt use that might be needed?

4.4.1 Removing the need for a licence in constrained bands

It remains illegal in the UK to install or operate radio without a licence except where Ofcom makes regulations to exempt the need for specific licences. In line with new European requirements, Ofcom now has a statutory duty to consider exemption if Ofcom is satisfied that no undue interference will result to other Wireless Telegraphy networks and services, or that there is some national interest safeguard or international treaty arrangement (such as the use of Aeronautical radio for safe fight control).

In this new framework, Ofcom is re-examining its need for individual licences, and is actively looking at ways where national interest safeguards can still be met through general authorisation arrangements. A number of currently licensed blocks of spectrum are issued to users with an individual licence as detailed below. However, we believe that the need for a licence is not primarily driven by the prevention of interference between individual users. We are therefore considering the feasibility of removing the requirement for an individual licence. In many areas the requirements for use of the bands will be very similar to that which is required under the current licensing regime, but the need for an individual licence may be removed. Where it is not possible to remove the need for individual licences, Ofcom is considering making them easily available via its website for local downloading.

These changes bring with them a number of legal and procedural issues and we also need to ensure that the interests of other regulators, especially for maritime and aeronautical licences are accommodated in the new arrangements. The final outcome of this initiative will depend on what is feasible and practical.

There are four areas which we are considering for this approach at present

- **Aeronautical and Maritime Licences for Onboard Equipment.** Spectrum for onboard aeronautical and maritime use is internationally harmonised and the technology which can be used is specified by a series of interface requirements (IR). The International Telecommunications Union requires that licence be issued to users along with a unique call sign being allocated and registered. The call sign is a crucial identifier both in general communications but also in safety of life situations and so must be retained in any changes we make to licensing arrangements. Ofcom is working closely with the sector regulators, the Maritime and Coastguard Agency (MCA) and the Civil Aviation Agency (CAA) to devise ways of eliminating or radically simplifying the licence process;

- **Amateur Licences.** Radio amateurs can use a range of bands across the spectrum for hobby and voluntary activities. At present there are 3 levels of licences: Foundation, Intermediate and Full Licences. Each level gives amateurs access to a wider range of bands and enables the use of higher power. Each level is accessed via a training course and an examination of competence. The use of high power sometimes over long distances makes this type of use a real challenge for a general authorisation through exemption or some lighter form of licensing requirement. Ofcom is initiating a project to consider the options for moving to a general authorisation or radically simplifying access to amateur licences;

- **On-site Business Radio.** Some types of business radio licences are geographically limited and operate at low power. We are exploring the scope for possible exemption or lighter licensing over the next year or so; and

- **Citizens Band Radio.** There are no spectrum management issues associated with the current CB use of the band. The number of users is declining and although the equipment is high powered, given the level of use, interference is unlikely to occur. At present we plan to trial the use of the UK bands for a new service, Community Audio Distribution System. This is intended to allow religious organisations to transmit their services to the elderly and housebound. The evaluation of the trial will consider the degree to

which conventional CB can co-exist alongside this service and after the trial we will review the option of full exemption once again.

4.5 Longer term use of market mechanisms

In bands which are not set aside for licence exempt use and where there are no international restrictions, or other issues as set out earlier, Ofcom plans to make use of auctions, trading and liberalisation to provide market-led management of the spectrum.

Auctions

Ofcom is already following a strategy of using auctions as the most appropriate means to distribute spectrum that is not currently assigned or has been "returned".

There are two key sets of decisions to be made in auctioning spectrum:

- The logistics of the auction in terms of timing and type of auction; and
- The specification of the spectrum to be auctioned in terms of size of bands, spectrum masks, geographical division, etc.

The logistics will depend on the circumstances of each band. For example, with bands that are to be cleared at some point in the future, early auctions, perhaps with overlay rights, might be considered as an option. In any case, Ofcom will seek to auction spectrum as soon as possible so that it can be put to use with the minimum delay. Where there are multiple bands to be auctioned simultaneously, perhaps because they are close substitutes for each other, more complex auction types such as multiple-round ascending auctions might be used whereas for simpler auctions sealed-bid or Vickrey auctions might be preferred. Ofcom will seek to use the most appropriate type of auction for each situation.

In specifying the details of the spectrum there is some tension between Ofcom's desire for technology and usage-neutrality and the practicalities of designing an auction and minimising the subsequent effort required by bidders to reformulate the spectrum into a package most useful for them. Spectrum must be auctioned in "packages" with each package having a lower and upper frequency, and hence a bandwidth. Small packages allow greater flexibility in that bidders can assemble as many as they need but might result in fragmentation and hold-outs. Larger packages require less effort from bidders but make it difficult for those who only want small packages to bid. Because we will normally allow aggregation and dis-aggregation of spectrum by the market, it will be possible for the market to correct any errors made in the original packaging design, but this will require effort on behalf of the licence holders.

The approach we will follow is to determine, for any given band, what the most likely use of the spectrum is. To do this we might conduct a market study or consult industry. We will then design the auction package so that it reflects the best information available on the most likely use, but will retain as much flexibility as possible such that if it subsequently transpires that a different use is optimal then the market can move to this use. The details of the auction package that we will set in this manner will include the bandwidth and the spectrum mask. Based on our view as to the most likely use we will also decide whether to auction national or regional licences. In general, our preference will be for national licences unless there is a

strong indication that the market would prefer regional licences. As with bandwidth, we will generally allow geographical disaggregation.

By this approach we aim to minimise the effort required by bidders in formatting the spectrum as they prefer, while retaining market flexibility to correct any errors in our assumptions as to the preferred usage. The mechanisms for market flexibility are described below.

Trading and Liberalisation

In December 2003 Ofcom issued a consultative document on spectrum trading. This proposed that trading be implemented across much of the prime spectrum. The spectrum trading proposals were broadly welcomed in the responses to the consultation exercise although many responded that Ofcom should move forward slowly and cautiously. Ofcom subsequently issued a statement on spectrum trading in August this year.

In September 2004, Ofcom published a consultation on spectrum liberalisation. This proposed a twin-track approach of varying licences individually following assessment of the interference risk on a case-by-case basis and making licences more inherently flexible by removing unnecessary or disproportionate restrictions so users could change use or technology without applying to Ofcom. The former approach gives users less certainty and is also more burdensome administratively. The second approach offers greater certainty and is less burdensome but is more challenging technically because of the complexity of defining licences to be flexible and technology-neutral while retaining sufficient safeguards against interference. Beyond the trading and liberalisation mechanisms already proposed by Ofcom, the key aspect to increasing the scope for allowing spectrum to be managed through the market is liberalise licence terms such that licence holders can change the use to which they put spectrum in the simplest manner.

Ofcom would like to increasingly liberalise licence terms as lessons are learnt from early applications of spectrum trading. Liberalising to a sufficient degree that simple change of use is possible will require:

- *Better definition of spectrum usage rights*. One of the major blocks to widespread trading in Australia has been identified as spectrum usage rights that are tailored to particular applications, making change of use difficult; and

- *Modelling of the effect of different uses*. Modelling may be needed to understand the impact of a range of possible new uses in existing bands.

Ofcom sees the definition of a system of spectrum usage rights as a highly complex problem. This is because they would need to be both sufficiently flexible to allow widespread change of use, while being sufficiently robust to protect existing users of spectrum from excessive interference. Some of the key issues to resolve in defining a workable set of spectrum usage rights are:

- The definition of limits around geographical borders. Should these be set by measurement, prediction or by the regulator approving the deployment of nearby sites?

- An understanding of how restrictive spectrum usage rights would need to be in order to avoid interference to existing users;

- The manner in which in-band and out-of-band limits are specified and measured including a range of factors such as height above the ground and measurement bandwidth;

- A means whereby the density of deployment of base stations can be taken into account when defining spectrum usage rights; and

- A decision on whether an indicative "noise floor" should be included in the licence and if so how it should be calculated and what value it would have.

We would welcome views on the best way to resolve these issues. One possible approach is summarised below and are set out in detail in Annex H and we are seeking input on whether this approach is workable.

One approach to spectrum usage rights is to have *two* sets of spectrum usage rights for each licence:

- The "specific" spectrum usage rights which correspond to the current usage (for example, for 3G operators they would be the in-band and out-of-band limits set out in the 3GPP specifications); and

- The "restrictive" spectrum usage rights.

The specific spectrum usage rights would vary across different current uses of the spectrum, however, the restrictive spectrum usage rights would be the same for all. Licence holders would abide by their specific spectrum usage rights unless they changed the use of the spectrum. A definition of the existing usage would be provided in the specific spectrum usage rights so that it would be clear when a change of use had occurred. Once a change of use occurs the licence holder must abide by the restrictive spectrum usage rights. They can generate a new set of specific spectrum usage rights but only with the agreement of neighbouring users.

The logic behind this approach is set out in Annex H. An example, already set out in the Analysys report on trading, is provided here to illustrate how it might work. Imagine that a broadcaster in the UHF band decides to trade some spectrum to a 3G operator. The 3G operator might wish to deploy a system conforming to the 3GPP specifications, however, this risks serious interference to the neighbouring broadcasters in cases such as a cellular base station being very close to a house with a TV antenna. In this case, because a change of use is proposed, the 3G operator would have to abide by the restrictive spectrum usage rights. These require much lower transmission levels than the specific rights and will provide sufficient protection to broadcasters. However, the restrictive rights are likely to be too restrictive for the 3G operator to provide a viable service. As a result, the operator might try to construct some specific spectrum usage rights. To do this he would negotiate with the neighbouring broadcasters. Perhaps, by agreeing to co-site base stations for example, the broadcasters might agree that higher transmit powers could be used.

By this approach complete technology-neutrality and total change of use would be enabled. Further, the existing users of the spectrum have been completely protected against any increase in interference that they did not explicitly agree with.
We would welcome comment on this approach to spectrum usage rights or alternative suggestions. Further documents will be published once the consultation on this document is complete, providing an indication of the possible timescales.

A variation on market mechanisms is the use of band managers. In theory, companies may emerge who make it their business to buy spectrum and then sell or lease it onto end users. This can be particularly beneficial where the end users have needs that make it less appropriate for them to hold the spectrum directly – for example they have short term and unpredictable requirements for spectrum. It can also be useful where spectrum is being sold in relatively large blocks, but individual users for some applications only require small blocks. Band managers can purchase the large block on behalf of the community of users who require small blocks and then divide the spectrum accordingly. Band managers can also facilitate overlay auctions, where spectrum is auctioned with incumbents and the band manager facilitates the removal, or accommodation of the incumbent and the subsequent re-packaging and reuse of spectrum.

At present, there is little evidence from countries where trading has been implemented that band managers will emerge. As a result, Ofcom is unsure as to the viability of commercial band managers and does not wish to rely on band management as a mechanism for facilitating the introduction of market mechanisms. Equally, if there was a sensible role for band managers, Ofcom would not wish to do anything to prevent their emergence. As a result, Ofcom will structure the licence conditions in such a way as to ensure band managers can emerge but will not rely upon their emergence as part of its strategy.

Q10: Do you agree with Ofcom's longer term proposals for market-based spectrum management methods?

Q11: Is the approach set out here, and in Annex H, for developing technology-neutral spectrum usage rights appropriate? Are there alternatives?

4.6 Preferred balance between the different modes

In overview, our preference is to set aside spectrum for licence exempt use where possible, and where not possible to continue to increase the use of trading and liberalisation, steadily withdrawing from making allocation decisions. If this approach were followed, the figure below simplistically shows Ofcom's expectation as to the relative amounts of spectrum managed under the three different types of management system by 2010[19] while the tables show the progression of different methods between 1995 and 2010.

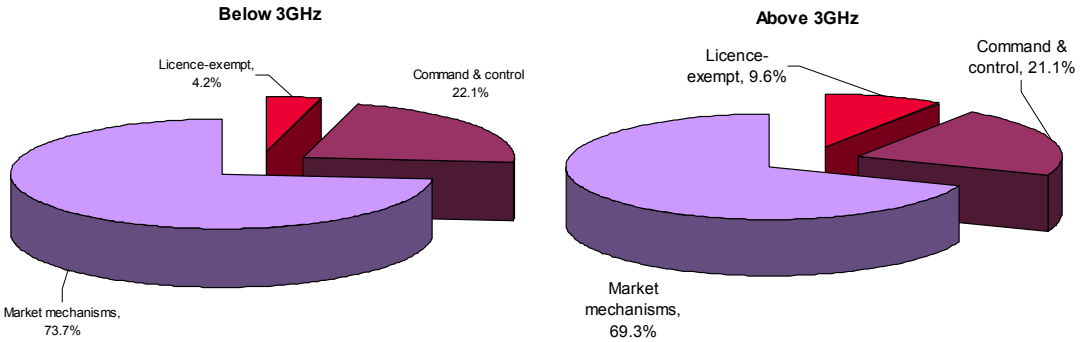


Figure 4.4: Relative amounts of spectrum under different management methods in 2010 (Illustrative)

[19] Note that for the purposes of simplicity we have drawn a hard distinction between command & control and market forces. In practice, there will be areas where some degree of both will apply.

	Command & Control	The Market	Licence Exempt
1995	95.8%	0.0%	4.2%
2000	95.8%	0.0%	4.2%
2005	68.8%	27.1%	4.2%
2010	22.1%	73.7%	4.2%

Table 4.1: Change in values for spectrum below 3GHz

	Command & Control	The Market	Licence Exempt
1995	95.6%	0.0%	4.4%
2000	95.3%	0.0%	4.7%
2005	30.6%	61.3%	8.2%
2010	21.1%	69.3%	9.6%

Table 4.2: Change in value for spectrum between 3GHz and 60GHz

Compared to the position in 2005, the amount of spectrum where trading and liberalisation allows the market to make assignment and allocation decisions is predicted to grow massively below 3GHz, but minimally above 3GHz. The remaining command & control spectrum represents a core few areas where it will be difficult to fully apply trading and liberalisation in the foreseeable future. Hence little further change might be expected. The further increase shown in licence-exempt spectrum above 3GHz is based on the assumption that the additional 200MHz or so identified earlier might be needed by 2010.

4.7 Additional roles for a spectrum manager

4.7.1 Interference Management

Whatever the spectrum management method employed, one of the roles of the spectrum manager will always remain the resolution of interference issues. As indicated in the Spectrum Trading Consultation Document, Ofcom fully intends to remain responsible for investigating interference complaints that cannot be dealt with directly by the affected parties.

Ofcom intends to work to resolve interference in two manners:

- **Proactive**. Ofcom is considering deploying a dense network of unattended monitoring stations across the country which would seek out unusual activity across the spectrum and in most cases be able to pin-point the location of the signal and the type of the signal. If this appears to be illegal interference, Ofcom will launch an investigation, even if a complaint of interference has not yet been received; and

- **Reactive**. If a licence holder has a case of interference that they are unable to resolve themselves, Ofcom will work to identify the cause of the interference and be the final arbiter as to who is at fault.

Interference could arise across each of the three differently managed types of spectrum. Even in spectrum available for licence-exempt use there might be interference, for example, if someone is transmitting at an illegally high power.

Q12: Should Ofcom do more to resolve interference?

4.7.2 Managing for innovation

One of Ofcom's duties in relation to management of the radio spectrum is to stimulate innovation. Ofcom believes that this is best achieved through a combination of market mechanisms and making spectrum available for licence-exempt use. With market mechanisms, those with innovative new technologies or ideas can acquire spectrum rapidly in the marketplace and can change the use of the spectrum, subject to interference considerations, to reflect their new ideas. This will allow a much more rapid and certain deployment of new ideas than has been possible under the command & control approach. With spectrum for licence-exempt use new low-power systems can be deployed without any need for a licence, as we have already seen, for example, with Wi-Fi.

However, some have noted that even where market mechanisms are used to manage the spectrum there may be barriers to entry. For example, at 10GHz, national licences to provide fixed wireless access systems were auctioned. Little equipment has been deployed. Some companies would like access to this spectrum in certain towns to deploy a selective fixed wireless access solution but claim to have been unable to access the spectrum. Their view is that their activity is too small to interest the large players who tend to hold the spectrum, but that spectrum is generally seen as sufficiently valuable that the large players do not wish to relinquish the spectrum, even if they are not making use of it.

Ofcom could potentially provide spectrum for "innovative applications", perhaps in the form of an extended test and development (T&D) licence. Alternatively, it could seek powers to intervene in the market by promoting the emergence of intermediaries who could sit between the large and small players. With our bias towards light touch regulation, our preference is to help the market find a solution rather than to intervene directly. However, we are interested in hearing the views of those in the market as to the kind of intervention they see as most appropriate.

Q13: To what extent should Ofcom intervene in promoting innovation?

4.7.3 Managing Shared Bands

Many spectrum bands are shared between different types of users – for example between fixed links and satellite systems. Where possible, Ofcom will identify spectrum usage rights that reflect the shared nature of the band and then allow trading. Where this is overly complicated, Ofcom will, on a case-by-case basis, consider different approaches such as overlay auctions, band managers or retaining control of the band itself. It is possible, as a result, that some bands might stay shared for the foreseeable future.

4.8 Harmonisation

The ITU, ERC and more recently the European Commission have been working for many years to achieve increasing harmonisation of use of spectrum both at a European and Global level. Harmonisation can bring a number of benefits such as reduced interference, lower cost equipment through economies of scale, increased certainty for manufacturers and international roaming. GSM is often quoted as a

prime example of a successful application of harmonisation[20]. For some internationally mobile services in the aeronautical and maritime area, harmonisation is an operational necessity and for satellite services which normally span many countries it is a practical requirement.

Equally, as a recent study commissioned by Ofcom[21] has shown, there are cases where harmonisation has provided little benefit, or has actually reduced the value of the spectrum by reserving spectrum for a technology that did not become commercially deployed. On balance, the value gained in the cases where harmonisation has worked would appear to be greater than the sum of the value lost in areas where harmonisation was not effective, although this depends on how much of the value, for example from the successful deployment of GSM, is attributed to harmonisation. A further study completed for Ofcom[22] has assessed whether, if the UK allowed different uses than those harmonised across Europe, this would significantly curtail use of the bands. The study broadly concluded that in most cases, particularly in the areas of fixed and mobile services, the UK could adopt a different use with minimal interference. This is aided by the geographical separation around much of the UK's border areas and is not true for all countries.

For new standards and technologies, it would be possible to allow the market to perform the harmonisation, rather than the regulator. For example, interested manufacturers and operators, working within a body like ETSI, might propose a frequency band for their new standard. Then, subject to studies confirming interference issues, Ofcom and other regulators could ensure that the licence terms were sufficiently flexible for the spectrum to be used for the new application proposed by the market. Users of spectrum would then be free to acquire the newly harmonised spectrum through trading and change its use. This approach would ensure that spectrum would not remain unutilised in the case that an inappropriate standard has been harmonised since in this case it is likely that the spectrum will not be acquired by new users, but left with the existing users.

There are potential problems with the market-led approach:

- The chicken and egg problem – operators may be unwilling to buy the spectrum until equipment is available and manufacturers may be unwilling to make equipment until users have the spectrum. This might be overcome using tools such as MoUs; and

- The holdout problem – a user retains a small but critical holding in the centre of the band and holds the new operator to "ransom" for the entire value of the band. This might be overcome with simultaneous purchase across the band of interest.

Where the conventional approach to harmonisation is used there are mechanisms that might improve its success such as:

[20] Although other factors, such as the technical design and the MoU signed by the operators, also contributed to its success.

[21] http://www.ofcom.org.uk/research/industry_market_research/m_i_index/spectrum_research/framework/harmonisation/

[22] http://www.ofcom.org.uk/research/industry_market_research/m_i_index/spectrum_research/framework/autonomy/?a=87101

- Technology-neutrality and flexibility so as not to preclude other uses in the band in question, provided that they are technically compatible and can operate without interfering with the harmonised application;

- Use of periodic review to assess the state of development of the harmonised service so that, if it appears that the service is unlikely to be successful commercially or that progress towards commercial exploitation is too slow, the spectrum can be opened to other innovative services;

- Use of 'sunset provisions' so that harmonisation ceases after a specified period. If a harmonised service is successful commercially, there is no need to maintain mandatory harmonisation since market forces will achieve this. If the service is not successful, it is even more desirable that the harmonisation should be rescinded. Sunset clauses provide a long-stop for the review process advocated above; and

- Use of a cost-benefit analysis in the cases where harmonisation is proposed to demonstrate its justification.

Ofcom is leading and supporting moves in CEPT and the European Commission to make harmonisation more flexible, technology-neutral and dynamic.

Subject to further discussion around these issues, and due consideration of international obligations, our current thinking is that we would not mandate harmonisation once a band has been opened up for trading, but would instead aim to reduce licence restrictions, where needed, such that the spectrum could be used for the new application. In bands where trading has not yet been applied, Ofcom would harmonise in the same manner that it has done in the past but with the addition of sunset clauses.

Q14: Do you agree with Ofcom's proposed approach to harmonisation?

Q15: Can you foresee any problems with the proposed approach to harmonisation other than those listed above?

4.9 Summary

In this chapter we have:

- Discussed the three approaches to managing radio spectrum – command & control, market mechanisms and licence exemption;

- Noted that while command & control is currently the predominant spectrum management method, the introduction of trading and liberalisation will increasingly allow the market to control spectrum allocation and assignment over the next few years;

- Suggested that the areas where trading and liberalisation are not fully applied should be minimised to around 20 per cent of the spectrum and detailed which areas these are;

- Provided an argument which indicates that there is limited need for an expansion in the amount of spectrum available for licence-exempt use;

- Discussed the longer term possibilities of liberalisation and set out a mechanism for delivering technology-neutral spectrum usage rights;

- Noted that Ofcom will, in any case, remain active in managing interference; and

- Shown that a move to market-led allocation will require a new approach to harmonisation and suggested that as a result we should gradually withdraw from harmonisation activities.

In the following chapter we consider how entitlements to transmit in spectrum owned by others would fit into the spectrum management approach proposed and indeed, whether a more fundamental change to spectrum management is required.

Section 5

Alternative approaches to dividing spectrum

5.1 The historical approach

Spectrum management can be traced back as far as the original Wireless Telegraphy Act in 1904. Since that date, the means of division of the spectrum has broadly been via frequency. That is, the spectrum is divided into discrete frequency bands and different uses/users are given different bands.

Other methods of division are sometimes operated within these bands. For example, fixed links within a particular band may be assigned on a geographical basis, or even an angular basis[23]. PMR assignments are sometimes made on a time basis but still within a specified frequency by assuming that a typical user will not transmit all the time.

Despite this, division by frequency remains the underlying approach to spectrum management adopted around the world to date.

It should also be noted that Ofcom does not have management responsibility for the spectrum used by the MoD. Essentially, the division of spectrum management responsibility is on a frequency basis, although there is some geographical sharing. This arrangement is unlikely to change in the foreseeable future and places some restrictions on the ability of Ofcom to change the means of dividing spectrum.

5.2 Other methods of dividing the spectrum

The advent of UWB has raised questions about the manner in which spectrum is partitioned. Some consider UWB to be a mechanism whereby spectrum can be divided in terms of power rather than frequency. Ofcom does not believe this to be the case. It is not possible with UWB to assign power levels 1-5 to one user and 6-10 to a different user. In practice, the higher powered user would cause excessive interference to the lower powered user, significantly reducing the data rates that they could transmit[24]. If all spectrum was reserved for UWB with all users having similar power levels then this would be an equivalent approach to having spectrum available for licence-exempt use.

Division by time, angle, polarisation or other attribute remains sensible in some cases. However, this can be done after division by frequency. That is, a frequency band is set aside for a particular application and within that band there is further

[23] That is, one operator may be assigned a fixed link starting from a particular mast and pointing, say North. Another operator might be assigned a link from the same mast but pointing East.

[24] The body of theory that surrounds the use of CDMA technology has shown that capacity is maximised when the transmissions from all interfering users are received with equal power levels. This prevents one user “drowning out” multiple other users. Maintaining this equal power is an important part of a cellular CDMA technology. To divide the spectrum in such a way that users had different powers would be technically inefficient.

sub-division according to one of these other parameters. In general, Ofcom believes that this subdivision can be better done by the users, or a third party band manager, than it can by the regulator. This is because the third party will typically be more focussed and responsive to the user's needs than a regulator could be. Indeed, there are many example of this happening already.

We are seeking views on the most appropriate way to divide spectrum. Following from the discussion above, it appears to us that division by frequency should remain the primary mechanism for allocating and assigning spectrum.

Q16: Do you agree with Ofcom's proposal to continue with division by frequency as the primary method of dividing the spectrum?

5.3 Entitlements to transmit in spectrum licensed to other parties

5.3.1 Entitlements are already provided

De-facto entitlements to transmit in spectrum licensed to others already exist – for example many items of electrical equipment such as hairdryers transmit unwanted interference into a wide range of frequency bands. Those who own such equipment have effectively been given an entitlement under the EMC policy to transmit into spectrum licensed to others. In practice, this is rarely noted because the entitlement is provided as part of the CE-marking process and the power levels transmitted are normally so small that they have little noticeable impact on use of the radio spectrum. Discussion around UWB and frequency agile radios has raised the possibility of two forms of entitlement:

- Entitlements in time whereby third parties can hop onto a temporarily unused frequency, transmit briefly and leave the frequency before the person to who it has been licensed needs to use it; and

- Entitlements in power where low power technologies such as UWB can transmit across multiple bands licensed to others but at such a low power level there is no significant degradation in performance.

Such entitlements can act across a wide range of spectrum bands which might contain some spectrum which is licensed and some which is set aside for licence exempt use. In general, we are less concerned where the spectrum is set aside for licence exempt use. In this case, if the transmission is low power it would typically already be allowed. If it is a higher power transmission, it would need to remain within the overall power limits for the licence exempt equipment. The discussion that follows is focussed on entitlements in licensed spectrum.

5.3.2 Entitlement in time ('cognitive radio')

Radios can now be implemented which can scan multiple frequency bands, spot an unused band, transmit on this band and then move to a different band. Such radios have been termed software-defined radios (SDR) or cognitive radios. Strictly they only need be frequency agile radios. For simplicity the term cognitive radio will be used here to describe a radio with the behaviour set out above.

Entitlements in time suffer from the 'hidden terminal problem' as shown in Figure 5.1. A cognitive radio user might make a measurement and not spot any activity on a piece of spectrum. However, there might be a legitimate user of that spectrum behind the next building, transmitting to a tower on the hill. Because the building is between

the users, the cognitive radio user does not receive the legitimate signal and so concludes the spectrum is unoccupied. But because both users are visible to the tower on the hill, when the cognitive radio user transmits its signal it is received as interference at the tower.

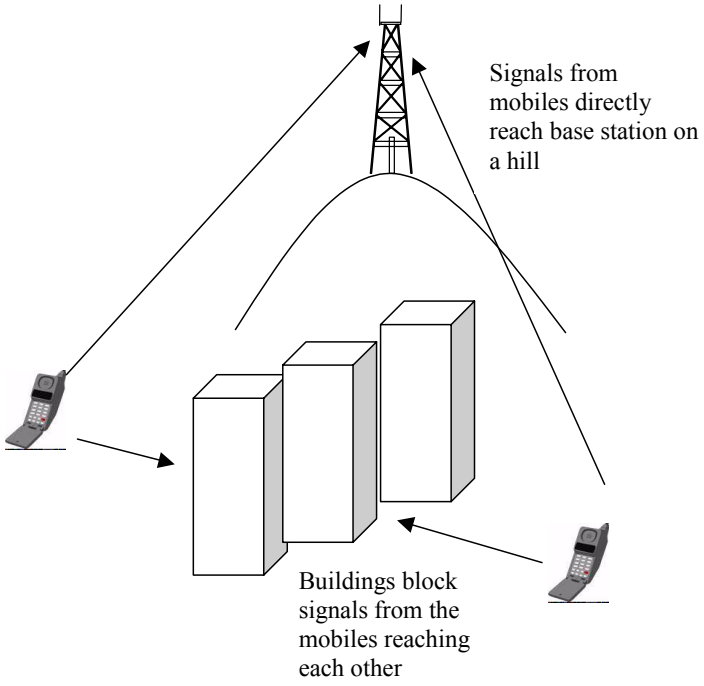


Figure 5.1: The 'hidden terminal' problem

This problem is solved by the tower on the hill transmitting a signal indicating whether the spectrum is free. A terminal then requests usage of the spectrum, and if granted, the tower indicates that the spectrum is busy. Such an approach works well but it requires central management by the owner of the band. Hence, it becomes a choice of the owner of the spectrum as to whether they wish to allow this kind of access and if so under what conditions. In this case it seems appropriate for Ofcom to allow licence holders to enable opportunistic access if they wish to do so as part of the general trading regime. Clearly this is complicated in bands where multiple users share the same spectrum.

There may be other technical approaches which solve this problem. For example, there have been suggestions that all terminals could monitor a band and periodically all transmit on those bands they consider occupied. This would give a mobile greater certainty that there was not a hidden terminal as it would be likely that it could receive a signal from a mobile which in turn could see the hidden mobile. Ofcom is unclear as to whether this approach overcomes existing problems, does not introduce problems of its own, and requires regulatory intervention. Ofcom would welcome further views on this issue.

If cognitive access is left to licence holders then to ensure that the market is well-informed, Ofcom could indicate which bands it considered to be well-suited to cognitive radio and the technologies and implications of allowing cognitive radio access. *Prima facie*, Ofcom expects these to be bands with single owners, and in

particular bands which have a high peak-to-average usage such as some emergency service bands.

We are seeking views on whether our proposed approach of not making entitlements in time licence-exempt is appropriate.

Q17: Is Ofcom's approach of not Intervening to mandate entitlements in time appropriate?

US proposals for cognitive radio

The concepts of cognitive radios has found much favour in the US. In June 2004, the Federal Communications Commission (FCC) issued a consultative document suggesting the possibility of cognitive access in the UHF broadcasting spectrum. However, much of the US thinking on cognitive radios is predicated on a different existing licensing structure than the UK. In the US, TV transmitters have been assigned local licences, typically relating to a city. As a result there is often "white space" between assignments where there are no significant transmissions. This white space is most prevalent outside of urban areas, but even in urban areas many TV channels are unused to prevent interference to those channels that are used. The FCC contend that this white space could be used, particularly by lower-power transmitters, with minimal risk of interference to existing TV transmissions. They further contend that the white space represents unlicensed spectrum and that therefore it is for the FCC to make a decision as to how best that spectrum should be used. Both of these contentions are currently being challenged by the US broadcasting community.

The situation in the UK is different and so the approach being proposed in the US may not be appropriate. The major analogue and digital TV networks are planned on a national basis with the broadcasters having near-universal coverage objectives and much of the white space is licensed for low powered programme-making uses on a non-interference-to-TV basis. The planning and co-ordination processes for the six current digital TV networks, particularly after switchover, will identify not only the channels to be released on a national basis but also, within each location, which channels set aside for the digital networks are also available for additional use. The interleaved spectrum could be made available to users, through a market-based approach, in the same way as the 14 nationally cleared channels.

Because of these differences, the approach being proposed in the US would not be appropriate in the UK.

5.3.3 Entitlements in power ('UWB')

Ultra-wideband (UWB) is a technology which spreads a data signal across a broad bandwidth. By using increased bandwidth, very low power levels can be used but the transmissions spread across broad swathes of spectrum where there may be hundreds of licence holders. UWB might have a wide range of uses including in-home networks, car radars and board-to-board communications within racks of equipment. Because it is difficult for a UWB transmitter to negotiate with hundreds of licence holders for permission to transmit, the decision as to whether to enable UWB is an issue for the regulator.

The proponents of UWB argue that the power their devices transmit is so small that it will not significantly change the overall interference levels experienced by the owners of spectrum. Opponents argue that while this may be true for a single device, when there are multiple devices in the same area their combined power will have a significant impact.

UWB has been permitted in the US. The FCC has undertaken substantial research in deciding which bands and power levels would result in minimal interference, considers its current limits to be extremely cautious and has indicated that it might allow higher power UWB transmissions in the future. It is possible that UWB equipment will end up in illegal use in the UK if nothing further is done from a regulatory viewpoint.

The European Commission is addressing the question as to whether there should be any harmonisation of UWB across Europe. As part of this process it has issued a mandate to CEPT to carry out an in–depth examination of the implications of UWB co-existing with other services with a view to identifying the most appropriate mask for UWB operation. The target date for the final report from CEPT is March 2005. Deciding whether to allow UWB, and if so under what conditions, is an important and complex policy decision. Separate to this Review we are publishing a consultation on UWB.

5.4 New technologies

Consideration of technologies such as UWB and cognitive radio raise questions as to what Ofcom's response would be in the advent of other new technologies arising. It is difficult to provide a detailed answer for technologies that do not yet exist. A new technology will fall into one of the two following generic categories:

- **Fitting within existing spectrum management approaches**. If the technology can be deployed without any change of overall spectrum management then Ofcom does not need to intervene. Using trading, with change of use if needed, the new technology can be introduced in tradable spectrum, or potentially within spectrum available for licence-exempt use, if the power requirements are low; and

- **Not fitting into the existing spectrum management approach**. In this case, Ofcom would have to give due consideration to the new technology in the same manner as it has with UWB. Ofcom will generally seek to perform cost-benefit assessments to understand the merit of introducing the new technology. Like UWB, there may also be international dimensions to consider.

5.5 Summary

In this chapter we have:

- Discussed other methods of dividing the spectrum but concluded that division by frequency should remain the primary mechanism used by Ofcom;

- Concluded that cognitive radio might best be enabled by providing licence holders with the freedom to allow cognitive access if they wish;

- Noted that we will be consulting separately on UWB; and

- Noted that other new technologies may arise in the future which do not fit within the existing framework and will require careful consideration.

This concludes our high-level look at the overall spectrum framework. In the final chapter we indicate some of the implications of applying this framework to key forthcoming decisions.

Section 6

Forthcoming important decisions

6.1 Introduction

There are a number of major decisions to be taken in the management of radio spectrum. Each of these will likely be subject to a consultation document in its own right. They are mentioned here to clarify Ofcom's timetable for resolving the issues and illustrate, at a high level, how this framework strategy will be applied.

6.2 Digital TV switchover

With a steadily increasing number of viewers moving to cable, satellite or digital terrestrial broadcast reception, there is a clear possibility that analogue terrestrial broadcasting will eventually be switched off. Indeed, the Government recently indicated a target date for switch off of 2012.

The move to digital broadcasting will make spectrum available for other purposes as digital technologies will permit existing services to be provided in less spectrum. Switching off analogue broadcasting will release 14 channels, or 112MHz of spectrum. There are many potential uses for this spectrum including cellular radio, more broadcasting and private radio systems.

This spectrum framework review has recommended the use of market mechanisms wherever possible to allocate and assign spectrum. On this basis, the preference of Ofcom would be a technology-neutral auction process. However, Ofcom will take into account any relevant public policy issues before reaching a decision.

Given that switchover has not yet been agreed, is still some time away, and any policy issues remain unclear, Ofcom is unable to provide a definite time-plan for any consultation on these frequencies. As timing becomes clearer Ofcom will communicate a time-plan. In any case, we would await the outcome of the Regional Radio Conference in 2006 before seeking to reach a decision on how this spectrum might be released into the market.

6.3 Mobile issues

There are a number of inter -related issues that Ofcom needs to address in relation to spectrum used for 2G and 3G mobile services. These include the extension of trading and liberalisation to existing 2G and 3G bands, and the timing of future awards of spectrum in frequencies up to 4GHz.

Ofcom's preference in this area is to follow a market-led approach. As discussed in Section 4.4 we believe that we will not be significantly expanding the spectrum available for licence-exempt use, therefore, in the case of mobile, our preference will be to use trading and auctions. We would like to reach a situation where:

- There are no constraints on "fixed" spectrum being used for "mobile" or vice versa, except in those situations where this may cause interference to other shared users of the band;

- There are no technological constraints – any technology can be used in any band subject to basic technological limits necessary to prevent interference; and

- Spectrum that has been freed up is generally auctioned without policy constraints, unless they can be justified, in a technologically neutral manner and in a way that allows the market to aggregate or disaggregate both geographically and in spectrum terms.

Our end point is relatively simple. We would like to see spectrum available for any application, whether fixed, mobile, broadcast or some convergence of these. We would like there to be no technological constraints, beyond those necessary to avoid interference (for example, as set out in Annex H where we deal with spectrum usage rights). We would like there to be as little use as possible of policy goals such as coverage obligations or the biasing of the auction process towards new entrants.

There are however a number of important issues to be addressed about the transition between the status quo and the end point described above. The Implementation Plan to be published shortly after this document will address these issues in more depth.

6.4 Release of spectrum from Government and other organisations

The division of the spectrum on a national basis between Ofcom, the Ministry of Defence (MOD) and other major users such as aeronautical which is co-ordinated and assigned on Ofcom's behalf by the Civil Aviation Authority (CAA) is determined through an interdepartmental committee, the UK Spectrum Strategy Committee. Changes to the distribution of spectrum are usually negotiated informally between the relevant parties before formal agreement is sought through the committee structure. Historically, the MOD has been responsible for a very large part of the spectrum but the proportion has decreased over the years as spectrum has been released for civil use, usually on a shared basis but sometimes for the exclusive management of the civil regulator. The MOD allocation is currently about 28 per cent of the spectrum, a considerably lower figure than in many other European countries. In the last decade, over 250MHz of defence spectrum in the particularly valuable range below 3GHz has become available for civil use. Ofcom intends to continue to work closely with MOD with a view to securing the release of further spectrum. The continued application of administrative incentive pricing at a comparable rate to commercial users, will facilitate this process. However it is thought that the scope for further releases below 3GHz is rather limited.

Where spectrum is shared between the MOD and commercial users, the constraints imposed can severely limit civil operations and potentially will hamper spectrum trading. Where it is intended that such bands should be auctioned, it will be imperative for potential bidders to know the extent of the constraints in some detail. Ofcom is therefore conducting a review of constraints in bands shared with the MOD with a view to removing the constraints wherever possible or at least minimising them and defining the constraints more explicitly.

Other major users which historically have held large amounts of spectrum include the radar community (aeronautical and maritime, civil and military) and telecommunications networks (for fixed radio links). Ofcom intends to explore the scope for releasing spectrum from major spectrum holdings to other uses. We are also conducting research to seek more spectrally efficient approaches to radar and other major uses of spectrum.

6.5 Broadband fixed wireless

Broadband fixed wireless access (BFWA) is a technology that might enable competition in the last mile, or potentially might enable higher data rates to the home than can currently be achieved with traditional wireline technologies. BWFA has had a difficult past, with very few BFWA operators generating profit, and most closing down. However, with ever-improving technology it is possible that BWFA might be more successful in the future. Ofcom considers the likely role of BFWA in more detail in the Telecoms Strategic Review.

In line with its goals for light touch regulation and the use of market mechanisms, Ofcom does not believe that it is appropriate to regulate spectrum in such a manner as to favour BFWA over other uses. Instead, Ofcom believes that it should make spectrum available for a range of uses such that BFWA operators have as wide a choice as possible of the spectrum they might employ for their service. However, they will need to compete with other potential users of the spectrum.

Those with an interest in BFWA are represented in the UK by the Broadband Stakeholders Group (BSG). The BSG has made four recommendations regarding fixed wireless which specifically mention Ofcom. They are:

1. Ofcom should introduce geographically differentiated regulation to increase the EIRP level at 2.4GHz to enable the use of directional antennas in rural areas to achieve greater range;

2. Ofcom should consult on options for allocating further spectrum in the short term. The allocation of further spectrum bands below 10GHz, particularly around 2GHz, could encourage the introduction of technologies used in other parts of the world, such as plug and play portable wireless DSL systems. Ofcom should consult on the options for allocating spectrum;

3. Ofcom should undertake an urgent review of the spectrum requirements for wireless broadband services and set out a strategic plan for wireless broadband; and

4. Ofcom should undertake a major review of spectrum management on the model of the FCC's Spectrum Policy Task Force.

In line with our overall strategy and the comments above, Ofcom's comments in response to these points are that:

1. The first item relates to the regulation surrounding spectrum available for licence-exempt use. As discussed earlier, spectrum should be made available for licence-exempt use where there is a low probability of congestion. The probability of congestion increases with range but decreases with lower device density. Hence, it is appropriate that increased range be allowed in less dense areas so long as the combination of range and density are such that probability of congestion remains small. Theoretically, the range could be based on the local population density, so that there would be a smooth increase in range into more rural areas. Practically, it may prove simpler to have two or more maximum transmit levels relating to different population densities. The difficulties are in the areas of ensuring proposals are simple, enforceable and yet meet the needs of industry. Ofcom is concluding its

examination of the possibility of allowing higher power in the 2.4 GHz licence exempt band and will be publishing its conclusions in due course;

2. The second item suggests that Ofcom should consult with the objective of identifying additional spectrum for fixed wireless. This suggestion is somewhat at odds with the views set out in this document that market mechanisms should be used to allocate spectrum where appropriate. These have already been used in the area of fixed wireless and Ofcom expects this process to continue. Ofcom would expect to work towards allowing change of use in as much of the identified band (2GHz–10GHz) as possible, with fixed wireless being one of the possible uses. This strategy would not be compatible with a consultation on the most appropriate bands for fixed wireless. In the Spectrum Framework Review Implementation Plan that Ofcom intends to publish in December it will set out proposals for awarding spectrum, some of which will be in bands between 2 GHz and 10 GHz;

3. The third item suggests an urgent review of the spectrum needs for fixed wireless and a resulting plan. Ofcom's response to this is essentially the same as to the second item. Since it will be up to the market to decide on the optimal use for spectrum then it is not appropriate for Ofcom to review the needs or issue a plan; and

4. The fourth item recommends that Ofcom undertake a major review of spectrum management. Ofcom agrees with this recommendation and considers the publication of this consultative document to be such a review.

In overall terms, Ofcom does not consider that there should be any regulation specifically aimed at providing an advantage for broadband fixed wireless over other uses of spectrum. Instead, through trading and change of use, Ofcom will allow potential broadband fixed wireless operators to have access to the widest possible range of frequency bands and technologies.

6.6 Summary

In this chapter we have commented on the application of the proposed framework to some forthcoming major decisions. The key conclusions were:

- Digital switchover is still too far off to have a detailed plan, but we would likely prefer a technology-neutral auction to distribute the spectrum;

- Mobile issues are complex, but in outline we would like to remove distinctions between fixed and mobile, and indeed within the mobile category as well as making licences technology-neutral;

- Releasing spectrum from Government and other large users continues to be an important activity and we will undertake a review of all major spectrum holdings; and

- Broadband fixed wireless will be best served by making spectrum widely available and allowing operators to select the most appropriate bands, trade them and change their use as needed, but not by setting aside spectrum for this application.

The following chapter provides a summary of our vision for spectrum.

Section 7

The Ofcom vision for spectrum

Ofcom wishes to optimise the use of the spectrum and to encourage the emergence of dynamic and innovative services and organisations. Based on the discussion within this document, and subject to consultation, in summary the way will do this is as follows:

- Providing spectrum for licence-exempt use as needed, but our current estimates are that little additional spectrum will be needed in the foreseeable future, growing to just under 7 per cent of the total spectrum;

- Allowing the market to operate freely through the implementation of trading and liberalisation where possible. We believe we can fully implement these policies in around 72 per cent of the spectrum; and

- Continuing to managing the remaining 21 per cent of the spectrum using current approaches.

Where spectrum is returned to the regulator it will normally be auctioned. In general, with auctioned spectrum we will seek to:

- Minimise the number of constraints on its use. Ideally, we would not apply any technology or usage constraints, but instead rely on a spectrum mask;

- Avoid using the spectrum as a means to achieve policy goals, for example, avoiding applying coverage obligations or structuring the auction to favour new entrants, unless clearly justifiable; and

- Make the spectrum available as rapidly as possible.

For most spectrum we will allow trading with the minimum of restrictions, having the long term aim of:

- Allowing simple and rapid change of ownership; and

- Allowing change of use of spectrum without any intervention from Ofcom and with no specific restrictions, although possible usage will be limited through the use of a spectrum mask.

We are sceptical that mandatory harmonisation of technology or type of use will be appropriate in areas where liberalisation applies or is planned. In other areas, a more prescriptive approach internationally may be necessary, but individual harmonisation measures should still be justified by reference to the costs and benefits.

Simplistically, our vision for areas of the spectrum where we can fully apply trading and liberalisation can be summarised as:

The Ofcom Spectrum Vision

1. Spectrum should be free of technology and usage constraints as far as possible. Policy constraints should only be used where they can be justified;

2. It should be should be simple and transparent for licence holders to change the ownership and use of spectrum; and

3. Rights of spectrum users should be clearly defined and users should feel comfortable that they will not be changed without good cause.

In the medium to longer term we expect the effect of this to be that Ofcom increasingly withdraws from managing the radio spectrum.

Inevitably, there will be circumstances when we cannot fully achieve this vision. In these cases we will explicitly explain why we have not done so.

Annex A

Responding to this consultation

A.1 How to respond

Ofcom invites written views and comments on the issues raised in this document, to be made by **5pm on 15 February 2005**.

Ofcom strongly prefers to receive responses as e-mail attachments, in Microsoft Word format, as this helps us to process the responses quickly and efficiently. We would also be grateful if you could assist us by completing a response cover sheet (see Annex 2), among other things to indicate whether or not there are confidentiality issues. The cover sheet can be downloaded from the 'Consultations' section of our website.

Please can you send your response to **william.webb@ofcom.org.uk**

Responses may alternatively be posted or faxed to the address below, marked with the title of the consultation.

Professor William Webb
Ofcom
Riverside House
2a Southwark Bridge Road
London SE1 9HA

Fax: 020 7981 3333

Please note that we do not need a hard copy in addition to an electronic version. Also note that Ofcom will not routinely acknowledge receipt of responses.

It would be helpful if your response could include direct answers to the questions asked in this document, which are listed together at Annex 3. It would also help if you can explain why you hold your views, and how Ofcom's proposals would impact on you.

A.2 Further information

If you have any want to discuss the issues and questions raised in this consultation, or need advice on the appropriate form of response, please contact William Webb on 020 7891 3770.

A.3 Confidentiality

Ofcom thinks it is important for everyone interested in an issue to see the views expressed by consultation respondents. We will therefore usually publish all responses on our website, www.ofcom.org.uk, ideally on receipt (when respondents confirm on their response cover sheer that this is acceptable).

All comments will be treated as non-confidential unless respondents specify that part or all of the response is confidential and should not be disclosed. Please place any

confidential parts of a response in a separate annex, so that non-confidential parts may be published along with the respondent's identity.
Ofcom reserves its power to disclose certain confidential information where this is necessary to fulfil its functions, although in practice it would do so only in limited circumstances.

Please also note that copyright and all other intellectual property in responses will be assumed to be assigned to Ofcom unless specifically retained.

A.4 Next steps

Following the end of the consultation period, Ofcom intends to publish a statement in Spring or Summer 2005.

Please note that you can register to get automatic notifications of when Ofcom documents are published, at http://www.ofcom.org.uk/static/subscribe/select_list.htm.

A.5 Ofcom's consultation processes

Ofcom is keen to make responding to consultations easy, and has published some consultation principles (see Annex 1) which it seeks to follow, including on the length of consultations.

If you have any comments or suggestions on how Ofcom conducts its consultations, please call our consultation helpdesk on 020 7981 3003 or e-mail us at consult@ofcom.org.uk. We would particularly welcome thoughts on how Ofcom could more effectively seek the views of those groups or individuals, such as small businesses or particular types of residential consumers, whose views are less likely to be obtained in a formal consultation.

If you would like to discuss these issues, or Ofcom's consultation processes more generally, you can alternatively contact Philip Rutnam, Partner, Competition and Strategic Resources, who is Ofcom's consultation champion:

Philip Rutnam
Partner
Ofcom
Riverside House
2a Southwark Bridge Road
London SE1 9HA

Tel: 020 7981 3585
Fax: 020 7981 3333
E-mail: philip.rutnam@ofcom.org.uk

Annex B

Ofcom's consultation principles

Ofcom has published the following seven principles that it will follow for each public written consultation:

B.1 Before the consultation

Where possible, we will hold informal talks with people and organisations before announcing a big consultation to find out whether we are thinking in the right direction. If we do not have enough time to do this, we will hold an open meeting to explain our proposals shortly after announcing the consultation.

B2 During the consultation

We will be clear about who we are consulting, why, on what questions and for how long.

We will make the consultation document as short and simple as possible with a summary of no more than two pages. We will try to make it as easy as possible to give us a written response. If the consultation is complicated, we may provide a shortened version for smaller organisations or individuals who would otherwise not be able to spare the time to share their views.

We will normally allow ten weeks for responses to consultations on issues of general interest.

There will be a person within Ofcom who will be in charge of making sure we follow our own guidelines and reach out to the largest number of people and organisations interested in the outcome of our decisions. This individual (who we call the consultation champion) will also be the main person to contact with views on the way we run our consultations.

If we are not able to follow one of these principles, we will explain why. This may be because a particular issue is urgent. If we need to reduce the amount of time we have set aside for a consultation, we will let those concerned know beforehand that this is a 'red flag consultation' which needs their urgent attention.

B.3 After the consultation

We will look at each response carefully and with an open mind. We will give reasons for our decisions and will give an account of how the views of those concerned helped shape those decisions.

Annex C

Consultation response cover sheet

In the interests of transparency, we will publish all consultation responses in full on our website, www.ofcom.org.uk, unless a respondent specifies that all or part of their response is confidential. We will also refer to the contents of a response when explaining our decision, unless we are asked not to.

We have produced a cover sheet for responses (see below) and would be very grateful if you could send one with your response. This will speed up our processing of responses, and help to maintain confidentiality by allowing you to state very clearly what you don't want to be published. We will keep your completed cover sheets confidential.

The quality of consultation can be enhanced by publishing responses before the consultation period closes. In particular, this can help those individuals and organisations with limited resources or familiarity with the issues to respond in a more informed way. Therefore Ofcom would encourage respondents to confirm on the response cover sheet that Ofcom can publish their responses upon receipt. We strongly prefer to receive responses in the form of a Microsoft Word attachment to an email. Our website therefore includes an electronic copy of this cover sheet, which you can download from the 'Consultations' section of our website.

Please put any confidential parts of your response in a separate annex to your response, so that they are clearly identified. This can include information such as your personal background and experience. If you want your name, contact details, or job title to remain confidential, please provide them in your cover sheet only so that we don't have to edit your response.

Cover sheet for response to an Ofcom consultation

BASIC DETAILS

Consultation title:

To (Ofcom contact):

Name of respondent:

Representing (self or organisation/s):

Address (if not received by email):

CONFIDENTIALITY

What do you want Ofcom to keep confidential?

Nothing	☐	Name/contact details/ job title	☐
Whole response	☐	Organisation	☐
Part of the response	☐	If there is no separate annex, which parts?	

If you want part of your response, your name or your organisation to be confidential, can Ofcom still publish a reference to the contents of your response (including, for any confidential parts, a general summary that does not disclose the specific information or enable you to be identified)?

Yes	☐	No	☐

DECLARATION

I confirm that the correspondence supplied with this cover sheet is a formal consultation response. It can be published in full on Ofcom's website, unless otherwise specified on this cover sheet, and all intellectual property rights in the response vest with Ofcom. If I have sent my response by email, Ofcom can disregard any standard email text about not disclosing email contents and attachments.

Ofcom can publish my response: on receipt ☐ once the consultation ends ☐

Name Signed (if hard copy)

Annex D

Consultation questions

Q1: Are there any other major medium- to long-term spectrum management issues that this review should be considering? Are there any other significant technological or market developments that this review should be aware of when developing its thinking?

Q2: Do you believe it is useful to publish a compendium of issues? How frequently should it be published? What information should be included?

Q3: Are there any other issues of sufficient significance to merit mention in this document?

Q4: Are there important lessons to be learnt from experience in other countries that is not addressed here?

Q5: Do you agree with Ofcom's intent to maximise the use of trading and liberalisation?

Q6: Are there other areas, apart from those identified above, where trading and liberalisation should be restricted? Are there areas identified above where you believe the trading and liberalisation could be fully implemented?

Q7: Do you agree with Ofcom's approach to providing spectrum for licence-exempt use?

Q8: Is Ofcom's proposed methodology to estimate the amount of spectrum provided for licence-exempt use likely to deliver the right results?

Q9: What is the appropriate timing and frequency bands for making available any additional spectrum needed for licence-exempt use?

Q10: Do you agree with Ofcom's longer term proposals for spectrum trading?

Q11: Is the approach set out here, and in Annex H, for developing technology-neutral spectrum usage rights appropriate? Are there alternatives?

Q12: Should Ofcom do more to resolve interference?

Q13: To what extent should Ofcom intervene in promoting innovation?

Q14: Do you agree with Ofcom's proposed approach to harmonisation?

Q15: Can you foresee any problems with the proposed approach to harmonisation other than those listed above?

Q16: Do you agree with Ofcom's proposal to continue with division by frequency as the primary method of dividing the spectrum?

Q17: Is Ofcom's approach of not Intervening to mandate entitlements in time appropriate?

Q18: Do you agree with the RIA?

Annex E

Regulatory Impact Assessment

E.1 Policy Objective

This regulatory impact assessment (RIA) estimates the costs and benefits of the proposed spectrum framework. Overall, the proposed changes will reduce the amount of regulation.

Ofcom's objectives for the spectrum framework are to maximise the value created by use of the radio spectrum while at the same time protecting existing users. Value will be maximised by allowing the spectrum to pass to the most economically efficient use, by encouraging innovation, by removing barriers to entry for new companies or technologies and by minimising the time that spectrum sits unused.

E.2 Options

Ofcom has identified that the three main spectrum management mechanisms are:

- Command & control;
- Licence exemption; and
- Market mechanisms.

The options open to Ofcom are the relative amount of spectrum managed by each of these methods. In outline, we have concluded that the spectrum set aside for licence exempt use should grow slightly to around 7%, that command & control should fall from 95% to 21% and that market mechanisms should grow from 0% to 72%.

There is an infinite range of alternative options having different distributions of each of these management mechanisms. At their extreme, the alternative options could be for 100% of the spectrum to be managed by any one of these methods.

As a result of the use of market forces, we have identified the fact that harmonisation may need to change. The options here are:

- To continue to harmonise as in the past;
- To withdraw from all harmonisation; and
- To harmonise selectively in those areas where market mechanisms cannot be used.

Our preference is to harmonise selectively where market mechanisms cannot be used.

E.3 Risks

The risk of doing nothing is substantial. In a recent study for the EC, Analysys have estimated that the benefits to Europe of introducing trading and liberalisation are in the region of €9bn per year. This study assumes the implementation of market forces

broadly in line with our proposals. If we continue to manage spectrum using command & control it is likely that very substantial benefits to the UK economy will be lost through inefficient use of the radio spectrum. The risk of largely increasing the amount of spectrum set aside for licence-exempt use is also significant. Additional spectrum available for licence-exempt use will prevent licensed use with resulting loss in value. Although there are no published studies providing evidence we believe that as increasing amounts of spectrum are provided for licence-exempt use, the value of each additional MHz of spectrum will fall, while the loss of revenue from licensed applications will grow.

However, the approach proposed is not risk-free. With such wide-ranging and high level proposals there are many potential risks. Here we address the key ones.

Area of risk	*Possible effects*	*Mitigation*
Market mechanisms applied too widely	◦ Subsequent change of use breaches international agreements. ◦ Increased interference results.	◦ Ofcom will carefully check on international agreements before making licences tradable. ◦ Careful introduction of liberalisation to allow the interference risk to be assessed.
Market mechanisms not applied widely enough	◦ Potential benefits of trading not fully achieved. ◦ Distortion of competition in the case that competing providers have differing abilities to trade.	◦ Ofcom will make trading as widely available as possible. ◦ Ofcom will consider all potentially competing users of spectrum and ensure a level playing field as far as possible.
Insufficient spectrum available for licence-exempt use	◦ Congestion in existing spectrum, reducing benefits to users. ◦ Lack of innovation.	◦ Careful and periodic monitoring of spectrum available for licence-exempt use to understand how usage is growing.
Excessive spectrum available for licence-exempt use	◦ Spectrum unused or little used with resulting loss in potential economic value.	◦ Release spectrum available for licence-exempt use carefully and in stages to avoid excessive supply.
Changes to harmonisation	◦ UK moves out of line with other countries. ◦ Valuable services not launched because of inability to harmonise.	◦ Monitor international harmonisation and any UK differences and evaluate whether they require corrective action.
Disruption to customers	◦ As spectrum is traded some services may be withdrawn with subsequent disruption.	◦ Limited action from Ofcom – this is part of a standard market and would not normally require intervention.

We are seeking comments on whether there are other important risks that we have not covered here.

E.4 Costs and benefits

For the approach proposed for spectrum management, the only costs imposed on licence holders are voluntary. Any licence holder can choose not to trade and hence to continue their use of spectrum unchanged. If licence holders wish to trade then there may be costs associated with the trade, but it is likely that licence holders would not incur these costs unless they expected the benefits to be greater.

The benefits are difficult to quantify since they will depend on the uses to which the spectrum is put and subsequent technical developments. Based on the Analysys report and assuming that the benefits to the UK equate to approximately 1/6th of the benefits to all of Europe, we estimate that the benefits across all of the economy including licence holders, consumers, etc, might be in the region of £1bn per year. This estimate is highly speculative.

Regarding harmonisation, in general we do not believe there will be significant costs to our proposals as we believe the market will deliver any worthwhile harmonisation. There will likely be benefits associated with the avoidance of inappropriate harmonisation and the subsequent sterilisation of the spectrum. A recent report we commissioned[25] suggests that the costs of inappropriate harmonisation could run into the billions although it was difficult to quantify exactly.

We welcome comments on our calculation of the costs and benefits.

E.5 Summary and recommendations

In summary:

- We plan to significantly increase the role of market mechanisms in the management of spectrum and to steadily withdraw from harmonisation;
- There are risks involved in such an approach but in most cases there are mechanisms whereby the impact can be reviewed and our approach modified if problems appear to be emerging; and
- Because most of our proposals reduce regulation, there is little cost for users. Benefits are difficult to quantify and necessarily speculative, but could be in excess of £1bn per year.

[25] http://www.ofcom.org.uk/research/industry_market_research/m_i_index/spectrum_research/framework/harmonisation/

Annex F

Literature

F.1 The independent review of spectrum management

In March 2002 the "Review of Radio Spectrum Management" by Professor Martin Cave was published. This extensive review set out recommendations for future management of the radio spectrum. Many of these have now been implemented, or are in the process of being implemented. Equally, some of the discussion and recommendations are pertinent to this spectrum framework review. These are repeated below.

Paragraph 14 : 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.

Paragraph 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.

Paragraph 67: 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.

Paragraph 71: The review strongly advocates the earliest and widest application of spectrum trading possible. Once the necessary liberalising European legislation 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.

*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.

*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.

Paragraph 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.

*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. In summary, the general direction of the Cave report as it relates to this review is to encourage the use of market forces predominantly through the implementation of spectrum trading in as flexible and simple a manner as possible. These recommendations form a core part of this review.

F.2 Other literature

There is a substantial body of literature, most of it from the US, discussing the balance between these three spectrum management methods. There is general agreement that the “command and control” approach should be used as little as possible, mainly in cases such as for public safety or military usage where market structures might not generate an appropriate result. However, there is little agreement as to the relative amount of spectrum assigned to trading and unlicensed usage. There are also many hybrid suggestions. For example, Noam[26] has suggested that spectrum be unlicensed but users have to pay a fee to access it depending on the current level of congestion. Alternatively, Faulhaber[27] has suggested that all spectrum be licensed but that licence holders be able to create “private commons” allowing a form of unlicensed access which they charge for in some form.

[26] Noam, “The fourth way for spectrum”, FT, 29 May 2003

[27] Faulhaber and Farber, “Spectrum management: Property rights, markets and the commons”, http://rider.wharton.upenn.edu/~faulhabe/SPECTRUM_MANAGEMENTv51.pdf

It should be noted that some of the suggestions put forward would not be feasible within the current legislative framework that Ofcom operates under. For example, Ofcom could not collect fees for licence-exempt use as is suggested by Noam without a change to its legislation.
Some of the key recent literature in this area includes:

- Faulhaber and Farber suggest that the spectrum be licensed with spectrum usage rights but that entitlements for others to transmit either be written into the licence or that UWB and cognitive access be negotiated with the owners of the spectrum;

- Carter et al[28] produced a detailed paper on the history and current usage of unlicensed spectrum in the US. This also notes that the Spectrum Policy Taskforce within the FCC has looked at the question of unlicensed spectrum and concluded that it is not possible to determine how much more unlicensed spectrum is needed, but it would appear that more is needed;

- Noam advocates a mixed approach where unlicensed users also pay for access to the spectrum, but are able to access licensed spectrum if temporarily unused;

- Horne[29] categorises spectrum into different dimensions such as polarisation and angle of arrival and suggests that there may be many other ways to define access to the spectrum than frequency and power;

- Peah[30] notes that a licence holder could dynamically grant access to someone else, but would only do so if the availability criteria of both parties could be met by doing so. This would be a licensed regime where unlicensed access was agreed with the licence holder; and

- Raja[31] proposes that a widespread commons approach will work. He suggests the use of unlicensed spectrum until it gets congested when users will then need to be moved to licensed spectrum.

No consensus appears to have been reached as to which of these routes should be preferred.

[28] Carter, Lahjouji and McNeil, "Unlicensed and unshackled: A joint OSP-OET white paper on unlicensed devices and their regulatory issues", http://www.fcc.gov/osp/workingp.html

[29] W Horne, "Adaptive spectrum access: Using the full spectrum space", Proceedings of TPRC 2003.

[30] J Peah, "Real time secondary markets for spectrum", ibid.

[31] S Raja and F Bar, "Transition paths in a spectrum commons regime", *ibid*.

Annex G

Positions taken by other spectrum regulators

A few countries have implemented spectrum trading. These include New Zealand, Australia, Guatemala, El Salvador and the US. Some of the relevant experiences from these countries is detailed below. Note that the following material is taken from an ITU Report[32].

G.1 Spectrum management in New Zealand[33]

New Zealand has shown that it is feasible to create tradable spectrum rights and to auction these rights despite the presence of incumbents in the bands. This was largely accomplished through a three-tier system of rights:

- **Management rights** bestow the exclusive right to the management of a nationwide band of frequencies for a period of up to 20 years. Within this band, the manager can issue licences. They are not constrained as to the uses for which licences are issued;

- **Licence rights** are derived from spectrum licences that are issued by the management rights holder which allow licensees the right to use frequencies within their bands. Licences are use specific and defined in terms of transmitter sites. The management rights holder can issue licences to itself; and

- In blocks of spectrum where management rights have not been created, the legacy regime of non-tradable **apparatus licences** continues.

The Government favoured a progressive conversion of licences to a spectrum rights regime. As the initial owner of all management rights, the Government has used auctions to make primary assignments of tradable management rights. There were 91 management rights as at February 2004, with the New Zealand Government retaining ownership of 15 of these rights, predominantly over spectrum used to provide public services.

It is left to the ensuing management rights holders whether or not to trade their rights. There are no restrictions on the activities of the operators, the number of entrants into the markets or specialised licensing requirements.

[32] ITU, "Spectrum Management For A Converging World", http://www.itu.int/osg/spu/ni/spectrum/RSM-BG.doc

[33] *Source:* Ministry of Economic Development at http://www.med.govt.nz/rsm/ and http://spectrumonline.med.govt.nz/.

G.2 Spectrum leasing in the United States[34]

In May 2003, the Federal Communications Commission (FCC) adopted a "landmark" order on spectrum leasing that authorised most wireless radio licensees with exclusive rights to their assigned spectrum to enter into spectrum leasing arrangements.

Under the leasing rules adopted, licensees in certain services are allowed to lease some or all of their spectrum usage rights to third parties for any amount of spectrum and in any geographic area encompassed by the licence, and for any time within the term of the licence.

The order also creates two different mechanisms for spectrum leasing depending on the scope and responsibilities to be assumed by the lessee:

The first leasing option – 'spectrum manager' leasing – enables parties to enter into spectrum leasing arrangements without obtaining prior FCC approval so long as the licensee retains both *de jure* control of the licence and *de facto* control over the leased spectrum. The licensee must maintain an oversight role to ensure lessee compliance with the Communications Act and all spectrum related FCC rules. In enforcing the rules, the FCC will look primarily at the licensee on compliance issues but lessees are potentially accountable as well.

The second option – *de facto* transfer leasing – permits parties to enter into leasing arrangements, with prior approval of the FCC, whereby the licensee retains *de jure* control of the licence while *de facto* control is transferred to the lessee for the term of the lease. Lessees are directly and primarily responsible for ensuring compliance with all FCC rules. For enforcement purposes the FCC will look primarily to the lessee for compliance, and lessees will be subject to enforcement action as appropriate. Licensees will be responsible for lessee compliance in so far as they have constructive knowledge of the lessee's failure to comply or violation.

G.3 Spectrum as commodity: Australia and the standard trading unit (STU)

In Australia spectrum blocks owned by licensees are represented in units called standard trading units (STUs). An STU covers a predetermined geographic area and frequency band. STUs can be combined vertically to provide increased bandwidth or horizontally to cover a larger area. An STU is the smallest spectrum unit recognized by the ACA and its bandwidth and geographic dimensions cannot be further divided. The minimum frequency band for any spectrum licence would have a width of one STU bandwidth. In some bands this bandwidth is as small as 0.0125 MHz. The minimum geographic area for an STU is a single cell of a Spectrum Map Grid. The Spectrum Grid covering Australia consists of cells of various sizes depending on their location.

Different cell sizes are used depending on the levels of population. Larger cells are defined in rural areas. Small cells are defined in population density areas, such as cities, towns and their suburban areas.

[34] *Source:* Report and Order and Further Notice of Proposed Rulemaking (FCC 03-113), Federal Communications Commission.

Auction lots of spectrum space are then defined for sale. An auction-lot area is defined by reference to the spectrum map grid. The auction-lot areas are defined to cover the total area available from each band release and with no overlap of areas. Auction-lot areas are created by a process that aggregates map grid cells. The process takes account of the value of populated areas, the incumbent services and the requirements of technical framework itself, for example, the size of the emission buffer zone.

G.4 Fragmenting spectrum in Guatemala[35]

Spectrum rights in Guatemala are granted in fully transferable and fragmentable frequency usage titles (*Titulos de Uso de Frecuencias* or 'TUF's), which have technical limitations to protect against interference but which have no service limitations. Under the system, all spectrum that is not assigned can be requested. Following a request, the regulatory administration determines whether the request would infringe upon any other person's rights and if it does not, it opens up a period where other parties may object to the granting of the right, which must be based on a violation of the protesting party's existing right, and where other parties may seek a portion of that requested spectrum. In the latter case, the administration is obliged to start an auction. In cases where fragmentation would promote competition, the law requests from the administration that it auctions the requested spectrum in a fragmented fashion.

The first TUF auction in Guatemala was launched on 4 June 1997. It comprised 20.8MHz of nationwide spectrum in the 800MHz range, which was used for trunking or specialized mobile radio (SMR). There were initially 11 bidders, including the incumbent GUATEL. It was decided to fragment the 20.8MHz of spectrum was into 19 pairs of outbound and inbound bands: seven band pairs of 1 MHz each, and 12 bands of 200kHz each. The auction ended after two weeks of intense biding, with total payments of about USD 3 million. Out of the initial 11 bidders, seven won at least one lot.

G.5 Spectrum pricing in Australia[36]

The Australian spectrum pricing system is conceived on the assumption that charges to the users of spectrum should serve two objectives:

- act as a rationing device and set in a manner that encourages efficient use of spectrum; and

- deliver a fair return to the community for the private use of a community resource.

The radiocommunication licence taxes (for transmitters and receivers) are based on a formula that takes into account:

- the spectrum location authorised by a licence (some spectrum bands are in higher demand and are therefore more congested than other bands);

[35] *Source:* Pablo T. Spiller and Carlo Cardilli, Towards a Property Rights Approach to Communications Spectrum (1999), Yale Journal of Regulation, Vol. 16, No.1.

[36] *Source:* ITU Country Case Study, Radiospectrum Management for a Converging World: Australia.

- the amount of spectrum (bandwidth) used by a licensee;
- the geographic coverage authorised by the licence; and
- the power of the transmitter (transmitters operating a low power will attract a discount).

ACA acknowledges that, in the interests of simplicity and accessibility to spectrum users, the fee formula incorporates some compromises and a degree of crudeness in the manner in which different factors are measured and charged. Since introducing the fee formula in 1995, the ACA has continued to monitor and adjust the fees. The ACA has a programme to review fee levels, in particular in bands, which are experiencing congestion and in which there is arguably a case for increasing fees. Ideally, in spectrum bands and geographic locations where there is scarcity and congestion, fees should be set at 'market' levels. However, the task of establishing those market levels is very difficult. Methods by which values might be established that would match supply with demand include:

- shadow pricing against auction outcomes;
- shadow pricing against alternative (non-wireless) service delivery mechanisms;
- gathering evidence of market values from observing trading in the secondary market; and
- where there is evidence of congestion (excess demand) in a band or location, gradually increasing annual spectrum charges to the level which causes an easing of that congestion.

In addition to commercial services, the ACA levies spectrum pricing on a number of public users of spectrum. For example, the Department of Defence pays around A$ 8.4 million each year for spectrum reserved in the defence bands. It pays a further A$ 979 000 for spectrum it uses outside the defence bands and A$ 245 000 for classified assignments. Although it may be difficult to make judgements about opportunity costs in the defence environment, for example security reasons may prevent full disclosure of the purpose for which spectrum is used, the ACA nevertheless believes that charges for defence spectrum should continue to be made on the same basis as for other users. This provides the best assurance that there will be an incentive for the Department of Defence to make efficient use of spectrum, including surrendering spectrum that it no longer requires. It should be noted that there have been several examples where the Department of Defence has been willing to give up or share spectrum.

G.6 Summary

In general, the case studies show that spectrum trading has been implemented in a small number of countries around the world. The scope of these implementations has varied as has the degree of change of use allowed. Although there are important lessons to learn from each, none provides the degree of flexibility that would ideally characterise a spectrum trading environment.

Annex H

The definition of technology-neutral spectrum usage rights

H.1 The general form of a technology neutral spectrum usage right

Ofcom believes that the best mechanism for implementing change of use is through technology-neutral spectrum usage rights. These will allow users to understand their ability to change their technology or usage without needing prior approval from Ofcom or expensive interference studies.

The key challenge in defining technology-neutral rights is to allow maximum flexibility to change technology or usage while at the same time neither reducing the efficiency with which spectrum is used or the interference suffered by others. An introduction is provided by Cave et al[37] in their paper on spectrum usage rights. This paper forms the starting point for the discussion in this annex.

Ofcom believes that a single set of spectrum usage rights will not provide the flexibility it seeks. In countries where single sets of spectrum usage rights have been used there is a recognition that true technology neutrality has not been achieved because the spectrum usage rights tend to favour particular technologies or applications. Further, if spectrum usage rights are set to current de-facto levels then in many cases a change of use would result in interference. For example, if a 3G operator purchased a UHF channel previously used for broadcasting and operated within the spectrum usage rights of a broadcaster they would likely generate interference to neighbouring broadcasters. However, if spectrum usage rights are set to levels where interference would be unlikely to occur they would be much more restrictive than current rights and as a result likely to reduce the economic value of the spectrum.

To overcome these issues, Ofcom believes that for any licence there should be *two* sets of spectrum usage rights:

- The ‘specific’ spectrum usage rights which correspond to the current usage (for example, for 3G operators they would be the in-band and out-of-band limits set out in the 3GPP specifications); and

- The ‘restrictive’ spectrum usage rights.

The specific spectrum usage rights would vary across different users of the spectrum, however, the restrictive spectrum usage rights would be the same for all. Licence holders would abide by their specific spectrum usage rights unless they changed the use of the spectrum. A definition of the existing usage would be provided in the specific spectrum usage right so that it would be clear when a change of use had occurred. Once a change of use occurs the licence holder must abide by the restrictive spectrum usage rights. However, they can generate a new set of specific spectrum usage rights with the agreement of neighbouring users. Indeed, at

[37] See http://users.wbs.warwick.ac.uk/group/cmur/publications/spectrum2 “Designing property rights for the operation of spectrum markets”, by Cave and Webb.

any time, any licence holder can seek to modify their specific spectrum usage rights through negotiation.

This is how we envisage such an approach might work in practice, taking the example of a cellular operator acquiring UHF broadcasting spectrum.

- Broadcaster A indicates to a 3G operator that they would be willing to trade part of their spectrum. Were this to happen, the 3G operator would only be able to use the restrictive spectrum usage rights. These would be too restrictive to allow the 3G operator to provide a viable service;

- Before entering into detailed negotiation with the seller, the 3G operator consults with the owners of the neighbouring channels, who are broadcasters. The 3G operator reaches an agreement in principle with them that were it to buy broadcaster A's spectrum it would abide by certain restrictions on siting base stations and make compensatory payments of an agreed amount to the other broadcasters. In return, the other broadcasters would agree on a new specific property right which would be close to the 3GPP specification;

- The 3G operator builds a business case based on the new specific spectrum usage rights and compensation payments and decides on the maximum it will pay broadcaster A for its spectrum. It then re-enters negotiation with broadcaster A; and

- If the business case is viable, the trade proceeds.

The restrictive licences should be such that whatever the original and new uses are, the neighbours to the spectrum being traded should not suffer any additional interference. We believe that the only way to calculate these restrictive rights is to examine the set of possible changes of use most likely to lead to interference and calculate the necessary restrictive rights in each of these cases, then take the most restrictive set.

We have made a start in this process. The restrictive rights set out below would apply in the case of a UHF TV broadcast channel being changed to a 3G channel. Because of the differences in power levels, in uplinks and downlinks and in deployment types, we believe that this will be the worst case. We will continue to investigate other cases and would welcome support in this undertaking. In particular, we would like suggestions as to cases that might be worse than this.

Based on our initial work, the restrictive spectrum usage rights will be as follows:

Description of parameter	Limits to apply
Frequency band owned	Will vary, eg 1,995MHz – 2,010MHz and 2,060MHz – 2,075MHz
Geographical limits	Will vary, eg UK national boundaries
Downlink Parameters	
Maximum in-band power allowed at >100m from mast site	-41dBm / 1MHz measured at 1.5m AGL
Maximum out of band power allowed at >100m from mast site	-86dBm / 1MHz in bands +/- 5MHz from band edge measured at 1.5m AGL
Indicative noise floor at >100m from a neighbouring mast site	-83dBm / 1MHz measured at 1.5m AGL
Maximum in-band power allowed beyond geographical limits	-86dBm / 1MHz measured at 1.5m AGL
Uplink parameters	
Maximum in-band power allowed at >10m from a mobile	-51dBm / 1MHz measured at 1.5m AGL
Maximum out of band power allowed at >10m from a mobile	-95dBm / 1MHz measured at 1.5m AGL
Indicative noise floor at >10m from neighbouring mobiles	-90dBm / 1MHz measured at 1.5m AGL
Maximum in-band power allowed beyond geographical limits	-95dBm / 1MHz measured at 1.5m AGL

Table H.1 – The restrictive set of spectrum usage rights

The specific licences will have the same set of parameters. However, the actual values will vary according to the current usage.

H.2 Modification of rights and the resulting complexity

Ofcom believes that these restrictive rights are too restrictive to allow efficient use if applied directly. Because most users of similar services and technologies are placed together in neighbouring bands, and because similar technologies are less likely to interfere with each other, far less restrictive rights than these can normally be used in practice. If existing users were forced to adopt the restrictive rights they would likely have to either curtail the service they offered or significantly upgrade their infrastructure.

Ofcom will allow users to modify their rights provided they have agreement with all the affected third parties. For example, a cellular operator might agree with all of those who hold spectrum within ±10MHz of its assignment to modify its rights. This modification might be to those parameters set out in the 3G specifications. Indeed, to facilitate the initial deployment of spectrum usage rights, Ofcom will work with licence holders to assess what their de-facto rights are and modify their licences to these rights during the period that spectrum usage rights are rolled out.

H.3 Point-by-point explanation of the licence parameters

Geographical limits

Geographical limits will be specified either by well understood boundaries lines, such as national borders, or by a sequence of grid references with a straight line boundary between each reference.

Signal strength will be predicted using an agreed modelling tool rather than measured. This is because of the potential difficultly in making measurements outside of a licence holder's coverage area where the interfering signal from geographical neighbours might be stronger than the signal that the licence holder is attempting to measure. Ofcom proposes that we should use ITU-R Recommendation P.1546. However, this is a complex model, and in order to provide a definitive solution Ofcom proposes that it would develop an appropriate modelling tool and make it available on the Internet as the final arbiter.

Where the boundaries are international, the use of the model will need to be agreed with the national regulatory body. Subject to the outcome of this consultation exercise Ofcom will commence discussions with other national regulators and appropriate international bodies to gain agreement for this approach.

Should it transpire that there are significant inaccuracies with the model, Ofcom will consider revision. This would need to be undertaken by the relevant international body such as the ITU.

Maximum in-band power

A maximum in-band power limit is needed to allow designers of equipment intended for neighbouring bands to assess the need for adjacent channel rejection. Maximum in-band power could be specified in terms of EIRP, as it is today, however, this makes it difficult for a neighbouring users to assess whether the level of interference they are receiving is excessive.

Instead, Ofcom intends to provide a maximum signal strength as measured at 1.5m above ground level[38], at a distance of 100m from any base station site. The measurements will be in a bandwidth of 1MHz, except where there is an obvious reason to use a different bandwidth – for example when measuring GSM systems a bandwidth of 200kHz would be more appropriate. Licence holders may agree to modify the measurement height, for example, a higher height might be appropriate for measuring fixed link signal strengths. Since these levels are maximum signal strength, any signal exceeding this level, for however short a period, would qualify as interference.

There may be circumstances where measurements at 100m are inappropriate. It may not be possible to approach as close as 100m to the base station. Or, for an in-building base station it may not be possible to get 100m away from the base station. Alternatively, the height of the base station and vertical beamwidth of the antenna may be such that the signal on the ground at 100m is relatively weak. In this case,

[38] Ground level is taken as approximately the same level as the foot of the mast. In the case where a base station is indoors, ground level is the floor level of the floor on which the base station is mounted. In unusual cases, such as a base station mounted outside of building A, perhaps on the exterior of building B, and illuminating the upper floors of building A, floor level would be the floor in building A where the greatest signal strength was experienced.

those making the measurement should seek to make a measurement in line-of-sight from the base station and assume a decay in signal strength corresponding to free-space propagation. So, for example, a measurement at 1,000m should not exhibit a signal strength more than 20dB below the 100m level.

Because these measurements are made close to the base station and often in a line-of-sight, there should be little temporal variation in the signal. Therefore, it does not seem necessary to specify the signal in statistical terms (eg signal strength should not exceed -80dBm for more than 50 per cent of the time).

Maximum out-of-band power

The issues here are identical to the in-band power issues.

Indicative noise floor

Ofcom believes that giving licence holders an indication of the interference level that they can expect in their band will be helpful. It will allow licence holders to design their system with some certainty and will enable all parties including the regulator, to understand when interference conditions have been breached.

Measuring the interference levels may be a difficult activity as it can typically only be performed after having turned off the wanted transmitter, or indeed multiple transmitters in the area in some cases[39]. Where interference is intermittent it may be difficult to locate. However, where the interference is harmful, it may be necessary to take these steps.

Interference measurements will be in a bandwidth of 1MHz, except where a different bandwidth is clearly more appropriate. Measurements will be averaged over a period of 1 second.[40]

Where there is a case of interference the licence holder will be encouraged in the first instance to discuss the problem with the interferer. If a resolution cannot be reached then Ofcom will step in and determine who is at fault.

It may be that there are cases where nobody is at fault but the terms of the licence conditions given to the various parties are not compatible. In this case, Ofcom will change the licence conditions in what it sees as the most appropriate manner and on a case-by-case basis.

H.4 Changes in the number of base stations

An implication of this definition of spectrum usage rights is that the interference experienced by a neighbour will be dependent on the density of deployment of base stations. This is potentially problematic in that if a network owner designed their network on the basis of their neighbour having a small number of base stations, and then, perhaps through change of use, the number of base stations grows substantially, so might the interference.

[39] For example, in the case of a 3G system where all cells are using the same frequency, it might be necessary to turn of transmissions across tens or even hundreds of cells before making a measurement in order to be sure that the interference is not self-induced.

[40] In the case of signals with repetition rates of less than 1s more detailed investigation and measurement methods may be required. To date, such cases of interference have been very rare.

This might not be a problem in practice since typically as the number of base stations deployed is increased, the power transmitted per base station is reduced. Hence, the higher number of base stations might not result in a greater level of interference, rather a more homogeneous one, which would typically be more beneficial to neighbouring systems.

Another safe-guard is that a significant change in the number of base stations would be most likely if there were a change of use of the spectrum. In this case, the restrictive spectrum usage rights would apply. With their relatively low limits on signal strength these would likely result in less interference, even with more base stations.

The licence conditions could be extended to specify the total number of base stations, or the maximum density of base stations in any given area. Although this would decrease the uncertainty around interference levels it would be restrictive to the licence holder. Ofcom's view is that the effect of this restriction might be more severe than the additional certainty provided to neighbouring licence holders.

As a result, Ofcom has come to the conclusion that although the number of base stations in neighbouring bands will result in some uncertainty in the levels of interference experienced, that in practice this seems unlikely to be a significant problem and no specific measures are needed to address it.

Annex I

Measurement data

The data provided in this section was generated using an Rohde & Schwarz EB200 Miniport receiver complete with a controlling PC and specialist software called ‘Scenerioflex”, which is a complex signal analyst tool allowing the user to control a host of communications, test and measurement equipment via industry standard interfaces. The Scenerioflex controlling software was configured to run the EB200 receiver in Frequency Scan Mode, having a Start frequency of 50MHz and a Stop frequency of 1000MHz. Step frequency was set to 100kHz with a dwell time of 1 (one) millisecond. The receiver's peak detector was used along with the automatic attenuation settings found on this unit.

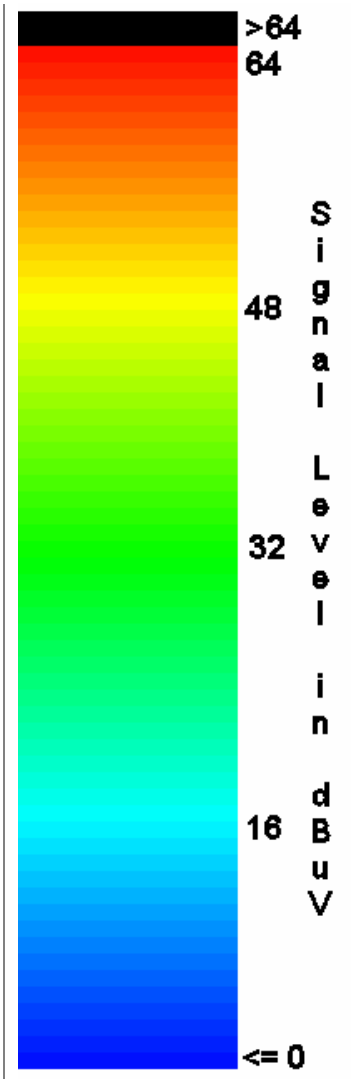
The RF audit system once deployed was scheduled to start at mid-day and run for a period of 24 hours until mid-day the next, resulting in 450 passes for this time period at each location.

At each location a wideband commercial grade discone antenna was used. Due to the nature of this type of antenna vertically polarised signals are the more dominant and therefore low level horizontally polarised signals may be excluded from the audit results. Using a wideband antenna of this sort may result in lower gain in some bands than the specific antennas used by those services and so may result in low-level signals not being measured.

The key and the measured data are presented on the next two pages. A more detailed plot is available from Ofcom. In overview:

- As might be expected, the London measurement (Southwark) shows higher utilisation than the more rural location (Baldock);
- All appear to show large parts of the spectrum that are little used, but it is important to remember the caveats discussed in Section 4.4. For example, (although not clearly visible on these plots), the GSM downlink bands appear occupied while the uplink bands appear less so, but for the most part, for each downlink transmission there is a matching uplink transmission;
- The bands which most consistently appear unused are the MOD bands, however, it might be that these are used in other areas, or for signals which cannot easily be detected; and
- The TV broadcast bands appear somewhat lightly used, but generally, these are channels used elsewhere which cannot be used in this location because of interference.

Key for Spectrograms



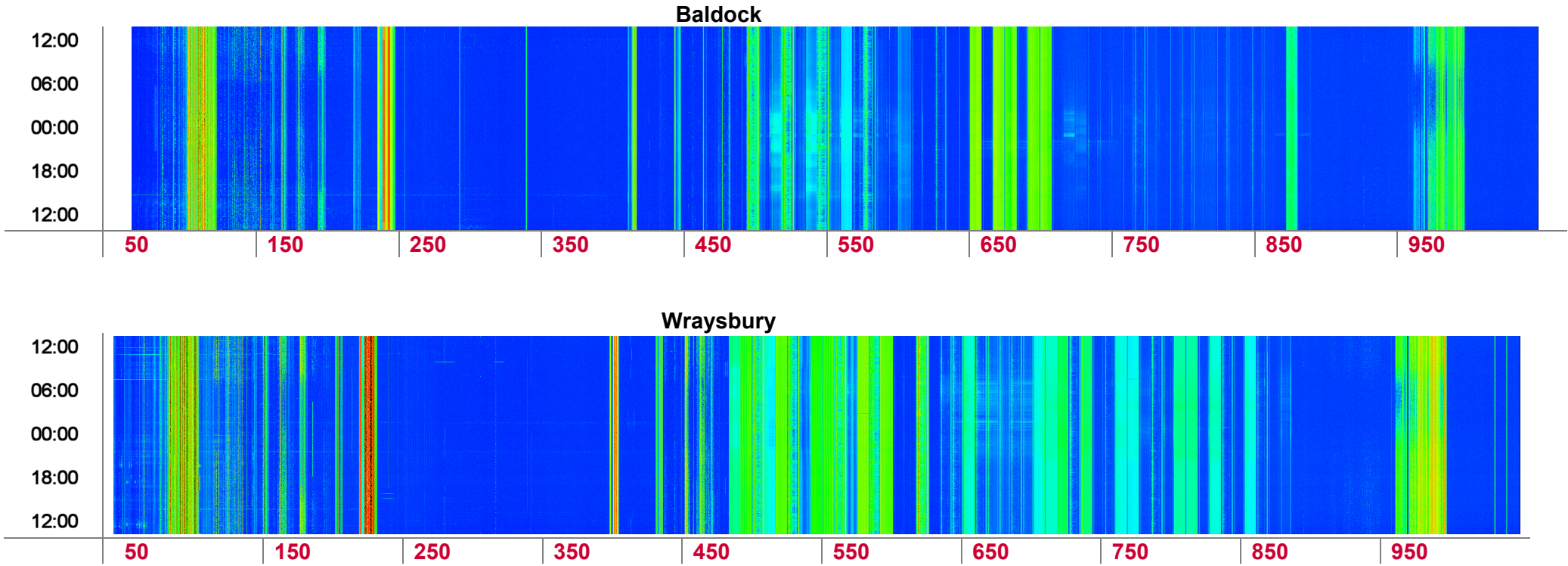
Signal Strength data for the following plots was obtained over a 24 hour period from midday to midday as detailed below. For all plots, the time ascends from the bottom to top of the plot i.e. the earliest time is at the baseline.

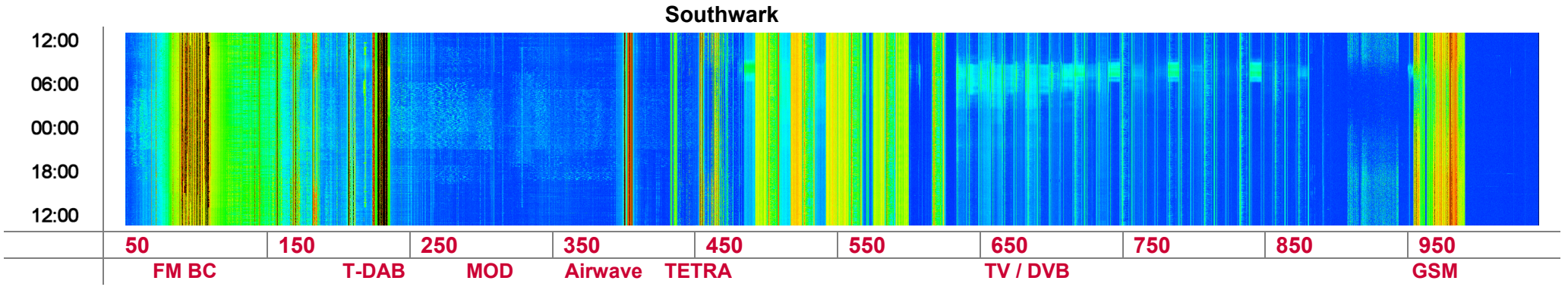
Baldock (Hertfordshire): NGR: TL286356
1200 on 20th July 2004 to 1200 on 21st July 2004

Wraysbury (Heathrow) : NGR: TQ017740
1200 on 26th July 2004 to 1200 on 27th July 2004

Southwark (Riverside House, Central London) : NGR: TQ322805
1200 on 27th July 2004 to 1200 on 28th July 2004

Overview: 50 MHz to 1000 MHz




Southwark
12:00
06:00
00:00
18:00
12:00
50
150
250
350
450
550
650
750
850
950
FM BC
T-DAB
MOD
Airwave
TETRA
TV / DVB
GSM

Annex J

Glossary

3G	The third generation cellular phone system, currently being deployed, which offers higher data rates than previous systems allowing services such as videophones.
AIP	Administrative incentive pricing. A fee charged to users of the spectrum to encourage them to make economically efficient use of their spectrum.
Auction	The use of a standard bidding process to award spectrum licences to those prepared to pay the most for them.
Beauty contest	An approach to deciding who should have a spectrum licence where those who want the licence make a case as to why they should have it and the regulator decides which case is most convincing.
BlueTooth	A standard for short range communications between devices such as cellphones and headsets.
BWFA	Broadband fixed wireless access. A means of connecting to homes and offices using wireless, as opposed to copper or fibre optics.
CEPT	The European Conference of Postal and Telecommunications administrations. A Europe-wide organisation whose aims include harmonised use of the spectrum.
Cognitive radio	A radio which can sense when a piece of spectrum is not being used, adapt itself to fit the spectrum, transmit briefly and then move onto the next free piece of spectrum.
Command & control	A way of managing the radio spectrum where the regulator takes all the key decisions including what spectrum is to be used for and who can use it.
DAB	Digital Audio Broadcasting. A standard for digital radio.
DECT	The Digital European Cordless Telephone. A cordless phone standard widely deployed in homes and offices.
De-regulation	Removing the need to have a licence in order to make a transmission in some specific areas.
EMC	Electro-magnetic compatibility. Regulations that ensure that non-radio devices do not generate interference and are reasonably immune to radio frequency interference.
ERMES	The European radio messaging system, a standard for paging. It was not widely deployed.
GSM	The Global System for Mobile Communications. The existing cellular technology widely deployed around the world.

Interference	Two or more signals on the same frequency resulting in the receiver not being able to distinguish one clearly.
ITU	The International Telecommunication Union. A body that seeks to harmonise telecommunication activities around the world, including access to spectrum.
Liberalisation	Allowing licence holders to change the use to which they put their spectrum, within constraints to prevent interference.
Licence-exempt	Allowing anyone to use the spectrum for any application under certain specified restrictions, but typically with maximum power levels.
Market mechanisms	An approach to managing spectrum where key decisions are made by the licence holders acting to buy and sell spectrum, rather than by the regulator.
Power	The strength of the wireless transmission. The stronger the signal the further it will travel, but this in turn will increase the chances of interference.
Regulation	The management of the radio spectrum.
SDR	Software defined radio. A radio whose characteristics are set by software, not hardware, which as a result can change itself considerably to adapt to situations.
Spectrum	The set of radio frequencies from around 9kHz to 300GHz.
TETRA	The Terrestrial Trunked Radio system. A standard for the type of radios used by emergency services and some business users.
TFTS	Terrestrial flight telephone system. A standard developed to allow phone calls from planes direct to the ground. It was never deployed - current systems use satellites to relay signals.
Trading	The ability of users to buy and sell spectrum licences without prior approval from the regulator.
UWB	Ultra-wideband. A technology that transmits at high data rates over short distances by using low power signals spread across many different parts of the spectrum.
WiFi	Another name for wireless LANs. The technology used to connect computers wirelessly in homes, offices and increasingly in “hotspot” areas such as airports. Also sometimes known as IEEE 802.11.
WiMax	A developing standard for delivering broadband mobile data services within urban areas.

Of 205 (Nov 04)

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