Implications of international regulation and technical considerations on market mechanisms in spectrum management

Report to the Independent Spectrum Review

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1 INTRODUCTION

1.1 Purpose of the Study

This report has been prepared by Aegis Systems Ltd and Indepen Consulting Ltd on behalf of the Independent Spectrum Review, to assist in its work on principles for spectrum management, approaches to promoting efficient use of spectrum and the application of market based spectrum management tools such as spectrum valuation, trading and pricing. The report addresses two specific areas that are likely to have a significant bearing on the implementation of market based spectrum management in the UK, namely the international regulatory framework and the interference management framework.

We were asked to advise on the impact of the international regulatory framework and constraints caused by the need for interference management on:

- The application of opportunity cost and other economic principles
- The use of spectrum trading and auctions
- The use of overlay licences[1]
- Achieving greater autonomy in domestic spectrum policy, including the implementation of a more general (service independent) licensing regime.

We were also asked to advise on the ways in which technology developments may promote market based spectrum management, how the international framework might be changed to facilitate greater use of market mechanisms and how e-commerce and e-government could be used to assist in the application of market mechanisms.

1.2 Current situation

The UK has in recent years made significant progress towards introducing market based mechanisms for spectrum management. The 1998 Wireless Telegraphy Act represented the first major overhaul of the licensing and pricing of radio spectrum for almost 50 years, and made specific provision for auctions of wireless telegraphy licences and the application of administrative pricing to existing licence holders. Subsequent to the passing of this legislation, auctions have been held for third generation (3G) mobile and fixed wireless access (FWA) services and further similar auctions are planned.

The Radiocommunications Agency (RA) consulted on options for spectrum trading in 1998[2] and, following the positive response to this consultation, the Government

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1 Overlay licences are licences that are encumbered by "sitting tenants" with defined rights for both the newly licensed users and incumbents.

2 Managing the Spectrum through the Market, Radiocommunications Agency 1998.

has indicated that it will introduce trading once the relevant EC law has been amended to allow it[3]. The details of the trading regime to be employed have still to be worked out. Possible approaches are likely to draw on experience from those few countries that have implemented such policies, including Australia, New Zealand and the US.

Scenario analysis undertaken for the RA has suggested that convergence of technologies for delivering information, communication and entertainment services will need a more flexible approach to spectrum management, including the use of more flexible allocation and licensing policies. It will also lead to more demand for spectrum for short range mobile and/or untethered applications[4]. Administrations in North America in particular have started implementing more flexible allocation and licensing policies in recognition of these developments.

The introduction of market approaches to spectrum management has been slower in Europe as compared with elsewhere in the Western world. Rather the main focus of spectrum policy has been on achieving fair and transparent licensing procedures and harmonised spectrum allocations. Harmonisation is intended to promote the development of pan-European services and provide a market that is large enough to support the development of new services and equipment. Nevertheless, eight of the thirteen EU countries that have licensed 3G mobile services to date used auctions[5], and three of these have also used auctions to license fixed wireless access (FWA) services[6].

It is often argued that the close proximity of European countries to each other and harmonisation objectives constrain the extent to which the UK and other European countries may adopt the kinds of policies seen in North America and Australasia. Furthermore, the maturity of the European markets, together with the intensity of spectrum use within Europe, particularly in the lower bands, may make it a more complex task to introduce market mechanisms. Aspects of these arguments are explored in this report.

1.3 Report Structure

The report includes a substantial level of detail in a number of areas. Each area is likely to be of particular interest to a different readership. Reflecting this, the report has been structured in two parts. The first part is aimed at all readers, summarising the findings of the study and our conclusions. The second part comprises annexes giving detailed information that supports the findings, but which is likely to be of

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3 A New Future for Communications, DTI and DCMS, December 2000, Cm 5010

4 Mapping the Future.. Convergence and Spectrum Management, Nervewire, Indepen and Intercai Mondiale for the UK Radiocommunications Agency, May 2000.

5 Austria, Belgium, Denmark, Germany, Greece, Italy, the Netherlands and the UK

6 Austria, Greece and the UK

interest to specific readers. The report cross references the annexes as appropriate.

Use of market mechanisms in spectrum management is not a new idea, indeed a number of countries have considerable experience in the area. The lessons that can be learned from these countries are discussed in section 2. Section 3 considers specific European regulatory issues that may constrain the RA's activities. Technical constraints and opportunities are then examined in section 4 and our conclusions are presented in section 5.

In many cases it is not possible to draw hard and fast conclusions that apply across the radio spectrum. Rather what is possible for some services and frequency bands may not be possible for others. We have therefore illustrated our arguments with findings from the analysis of five case studies, namely:

i. Migration of existing GSM bands to IMT-2000

ii. Co-existence of IMT-2000 (3G mobile) and non-mobile services around 2.6 GHz

iii. Migration of analogue TV spectrum to non-broadcast services

iv. Implementation of broadband multimedia wireless systems at 28 GHz and 40 GHz

v. Co-existence between public and private systems in deregulated bands (2.4 GHz and 5 GHz)

The annexes are structured as follows:

- The international regulatory framework for spectrum management is described in Annexes A and F
- International experience with market approaches to spectrum management is reviewed in Annex B
- The ways in which technical factors, and in particular interference management considerations, may constrain the use of market approaches to spectrum management are discussed in Annex C.
- Details of the case studies are given in Annex D.
- Issues associated with the application of e-commerce to support market approaches are explored in Annex E.
- A table summarising constraints and market implications relating to the case studies is attached as Annex G.
- A glossary is provided as Annex H.

2 LESSONS FROM OVERSEAS

Market mechanisms have already been successfully introduced in a number of countries, and as part of the study the experience of Australia, Canada, New Zealand and the USA, was examined in detail (see Annex B). A number of lessons can be learnt, though it should be borne in mind that none of these countries are subject to the regional layer of regulatory constraints that arise from the UK's membership of CEPT and the EU. Hence compliance with ITU regulations and (in the case of Canada and the US) bilateral agreements are sufficient. In summary, we conclude that:

i) Secondary markets can be introduced within the bounds of international constraints and with a relatively flexible approach to services and technologies. However, the benefits from having these different forms of flexibility are likely to be less in geographically small countries, with a high population density and many close neighbours, as compared with countries that are large, have a low population density and have no nearby neighbours. This is because the former countries may sacrifice a considerable proportion of their overall national spectrum resource when their spectrum use differs from that of their neighbours, particularly at lower frequencies where the reach is greater. In the case of Canada and the US, co-ordination for mobile services extends to 150 km from the border, a distance which encompasses almost a third of the Canadian population. Hence the constraints arising from the need to co-ordinate are likely to be somewhat greater in Canada than in the US, where a relatively small proportion of the total population resides in the border area. Nevertheless, differences in spectrum use do exist between the two countries (see section B.2.1), implying that a degree of flexibility can be accommodated even in populated border areas, subject to co-operation between the neighbouring administrations.

ii) Overlay licences have been tendered successfully. These licences generally involve incumbents having time limited rights to stay of up to 5 years. The new entrant has the right to move the incumbent without compensation once the time limit has expired.

iii) Interference management obligations are delegated to licensees where secondary markets have been implemented. The NRA may set the initial values for interference parameters (NZ, Australia, US) or they may be set by industry with NRA oversight (Canada). These parameters may be subsequently changed through negotiation (Canada, NZ) or in the case of Australia with the approval of the NRA. The NRA may specify a process for dispute resolution that requires the parties to seek arbitration in the event of no agreement. The NRA may be the arbitrator.

iv) Provision of a publicly available on-line database(s) of information on licensees and their spectrum use is essential for the efficient functioning of secondary markets. Such databases have been implemented in NZ and Australia and in more limited form in the US and Canada.

All of the countries under review must comply with the ITU Radio Regulations. However, these regulations allow a considerable degree of flexibility, allowing NRAs to make their own decisions regarding actual spectrum use, subject to remaining within the overall framework provided by the Radio Regulations. This flexibility is not currently exploited within the UK as fully as might in theory be possible. The flexibility achieved in Canada and the US is within the constraints posed by the need for bi-lateral co-ordination. The fact that Canada tends to follow the US in its spectrum use makes this co-ordination easier to achieve than would otherwise be the case (there are of course also fewer parties involved than in the UK / European case). Nevertheless differences in use do occur. In these circumstances each NRA must make a trade-off between the spectrum efficiency and equipment cost/availability advantages of harmonisation and the economic and social advantages of supplying non-harmonised services that are more highly valued in its own country than in the neighbour.

The UK will also have to make these trade-offs when deciding the degree of flexibility to be offered to licensees. The spectrum efficiency cost tends to be lower the higher the frequency range in question. The economic costs however depend more on the distribution of population near borders and coastlines.

Experience elsewhere in the world therefore tends to suggest that market mechanisms can indeed be a valuable tool in developing a dynamic market exploiting radio frequencies. However, whilst all nations are subject to the guidance of the ITU, European nations are subject to a further level of regulation that may affect this conclusion. The impact of European regulation is considered in the next section.

3 EUROPEAN REGULATORY ISSUES

Members of the European Union are subject to the mandatory regulation of the European Commission, and to the optional regulation of the CEPT[7]. This secondary layer of regulation both offers opportunities and imposes constraints on Member States. The ramifications of the legislation are discussed in Annex A, whilst a detailed examination of the key instruments is provided in Annex F. This section summarises some of the key opportunities and constraints arising from current and proposed EU legislation.

[7] Although the requirements of CEPT / ERC Decisions become mandatory once Decisions are adopted by Member States, such adoption itself is voluntary

It refers to the following instruments:

- The proposed Framework Directive (EC document 10420/1/01, rev.1[8])
- The proposed Authorisation Directive (EC Document 10419/1/01, rev. 1[9])
- The Competition Directive (as amended) (96/19/EC)
- The proposed Radio Spectrum Policy Decision (EC Document COM/2000/0407)
- The R&TTE Directive (1999/5/EC)

Service specific Directives and Decisions also apply (for example the GSM Directive (87/372/EEC), the DECT Directive (91/287/EEC) Satellite PCS Decision (710/97/EC) (amended 1215/2000/EC) and the UMTS Decision (128/1999/EC)).

3.1.1 Technology standards

Technology to be used within Europe must adhere to the "essential requirements" of the R&TTE Directive, namely that equipment must meet:

> *"(a) the protection of the health and the safety of the user and any other person, including the objectives with respect to safety requirements contained in Directive 73/23/EEC, but with no voltage limit applying;*
> *(b) the protection requirements with respect to electromagnetic compatibility contained in Directive 89/336/EEC.*
> *In addition, radio equipment shall be so constructed that it effectively uses the spectrum allocated to terrestrial/space radio communication and orbital resources so as to avoid harmful interference."*

The primary drivers for this Directive were

- Free circulation in furtherance of the single market
- Deregulation, by putting the onus on manufacturers and suppliers to conform, and provisions for liability if they cause problems

Member States may make limitations through their published interface requirements which link conditions to specific licences or exemptions.

A variety of ETSI standards have been developed that provide blueprints for such technology for services such as IMT-2000 (UMTS), DECT and of course GSM.

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8 Common Position adopted by the Council on 17 September 2001 with a view to the adoption of a Directive of the European Parliament and of the Council on a common regulatory framework for electronic communications networks and services (Framework Directive), available on the web at http://europa.eu.int/information_society/topics/telecoms/regulatory/new_rf/fwork_compos_10420-01rev1en.pdf

9 Common Position adopted by the Council on 17 September 2001 with a view to the adoption of a Directive of the European Parliament and of the Council on the authorisation of electronic communications networks and services (Authorisation Directive), available on the web at http://europa.eu.int/information_society/topics/telecoms/regulatory/new_rf/authn_compos_10419-01rev1en.pdf

Whilst the Commission seeks to encourage adherence to ETSI standards where available, both the R&TTE Directive and the WTO rules indicate that Member states cannot specify that a single technology be used at a given frequency, unless it is possible to demonstrate that use of multiple technologies will cause harmful interference. "Harmful interference" is not however quantified, but is defined qualitatively in the R&TTE Directive as being interference which:

> *"endangers the functioning of a radionavigation service or of other safety services or which otherwise seriously degrades, obstructs or repeatedly interrupts a radiocommunications service operating in accordance with the applicable Community or national regulations."*

On the one hand, the constraint on the European Union not to mandate a single standard for a given technology runs the risk that incompatibility between systems will arise, thereby hindering the development of a truly pan-European market for services and equipment. In practice, the development of multi-mode terminals (such as already exist in the US to provide roaming between digital and analogue cellular services) may largely overcome the difficulties arising from a multiple standard environment. Conversely however, the flexibility of the 'essential requirements' approach may enable innovative and "polite" technologies to be introduced to minimise any interference issues that might present a barrier to change of spectrum use. Such technologies have, for example, enabled the successful introduction of wireless LAN and FWA systems in the 2.4 GHz band, along with a variety of other specialised applications, despite the presence of other users such as outside broadcast systems and microwave ovens that would have made parts of the band unusable for conventional technologies.

3.1.2 Spectrum harmonisation

Spectrum harmonisation within the European Community is underpinned by regulations and recommendations arising from three main bodies: ITU-R, CEPT and EU. Within the EU the issue is addressed in service specific Directives and Decisions (addressing areas such as GSM, S-PCS, UMTS and ERMES) and within the proposed Framework Directive and Spectrum Policy Decision.

As with technology detailed above, European legislation offers both opportunities and constraints, driven by the desire to maximise the extent to which interoperability and interference free systems can be achieved within the Community.

Historically, harmonisation has been achieved under the auspices of the CEPT. However, adherence to CEPT recommendations, and indeed ERC Decisions in the first instance, is a voluntary matter for each NRA. Whilst common interests and peer pressure, have often made this an acceptable approach, the Commission feel that such a situation is no longer sufficient. Citing the need for greater certainty on the part of major investors, the proposed Spectrum Policy Decision (SPD) states that *"where policy agreement is reached to harmonise the use of radio spectrum necessary to implement relevant Community policies, legal provisions should ensure the appropriate implementation of measures by the Member States."* It proposes that harmonisation issues continue to be addressed at a technical level by the CEPT, with the Commission subsequently mandating that (where the results generated by CEPT are acceptable) the Member States implement them.

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

Where harmonisation of spectrum use is justified on the basis of promoting a competitive market, this is likely to limit national flexibility to change the use of spectrum, though application of market mechanisms such as auctions or spectrum trading which do not involve change of use would be unaffected. Note however that Decision (00)01 also contains the proviso that the making available of spectrum by the specified date is “subject to geographically spread market demand”, implying that flexibility would be possible where such demand could be demonstrated not to exist (unlikely in the case of 3G mobile but more feasible in the case of market failures such as the ERMES paging service). The inclusion of a similar proviso in future harmonisation measures would support flexibility to respond to uncertain and dynamic market conditions, whilst supporting the development of a competitive international market where demand for such a market genuinely exists.

Harmonisation of spectrum use does not in itself prevent the introduction of alternative services, so long as these do not impinge on the objectives of the harmonisation measure. For example, it is not necessary in practice for all the spectrum allocated to GSM or 3G mobile to be used for the purpose of mobile communications, so long as sufficient spectrum is available to cater for geographically spread market demand for the harmonised service. This means that in areas where geographic demand does not require the use of all the available spectrum, it could be used for other applications, so long as harmful interference does not occur as a result. A number of European countries currently license GSM 1800 on a geographically limited basis, typically covering major cities, and there may well be a case for allowing the use of GSM or 3G mobile technology to provide FWA services in remote areas where demand for mobility is limited.

An exception to this is spectrum covered by existing service-specific Directives. For example, under the 1987 GSM Directive, Member States were required to reserve the bands 905 – 914 and 950 – 959 MHz (2 x 9MHz) for the *exclusive* use of GSM by 1 January 1991. The remaining parts of the bands 890 – 915 and 935 – 960 MHz (a total of a further 2 x 16MHz) were to be allocated for GSM use in accordance with “commercial demand”. This would seem therefore to leave the allocation of this latter 2 x 16MHz to the discretion of the NRA. As the Directive does not have an expiry date, it may be reasonable to assume that over time the 2 x 16MHz will indeed be better used by new applications, particularly in geographic areas where demand for GSM mobile services is limited. The core 2 x 9 MHz is however constrained to use by GSM services only.

Whether alternative, non-mobile, applications using GSM technology might legitimately occupy the band remains moot. The Directive defines the term public pan-European cellular digital land-based mobile communications services as being “a public cellular radio service provided in each of the Member States to a common specification which includes the feature that all voice signals are encoded into binary digits prior to radio transmission”. Whether the absence of the word mobile from this definition, as against its clear and repeated use throughout the remainder of the Directive would open the door to use of the allocation by fixed systems must be in some doubt.

It is worth noting that NRAs are encouraged to contribute to the promotion of cultural and linguistic diversity, together with media pluralism – perhaps thereby allowing the same (non-harmonised) frequencies to be licensed for different applications in each of the home nations (England, Scotland, Northern Ireland and Wales) dependent upon cultural and linguistic needs.

3.1.3 Licensing

The use of auctions has become well established in several European countries. Secondary trading however, has yet to be introduced on an operational basis (other than straightforward transfer of licensed undertakings).

Under the Framework Directive a degree of secondary trading will be permitted, on condition that licensees keep the NRA informed of changes in the ownership of rights, and that the trading does not distort competition. However, where spectrum use has been harmonised through Decision COM(2000)407 (on a regulatory framework for radio spectrum policy in the EC) the transfer cannot result in a change of use. The term “change of use” is not defined, although the recital relates it to there being “sufficient safeguards in place to protect the public interest” thus any decision should be justified in these terms.

In passing it may be noted that the proposed Framework Directive may introduce another constraint on the Agency, by limiting the extent to which the Agency might encourage innovation within UK based industry by allowing preferential access to the spectrum. All States are required to "ensure that the allocation and assignment of radio spectrum by national regulatory authorities is based on objective, transparent, non-discriminatory and proportionate criteria". As a consequence “Pioneer preference” licences that might be seen to offer UK based companies short-term access to the spectrum on more favourable terms than those offered to companies from other Member States, would not be permissible. This issue should not however affect existing Test and Development (T&D) licences, where the key issue is obtaining agreement from incumbents, particularly those who have paid for licences at auction, to allow temporary and limited access to bands for T&D licensees.

4 TECHNICAL CONSIDERATIONS

The following conclusions are largely based on considerations relating to the management of interference between co-frequency operations in geographically adjacent blocks (national) and between countries (international).

- In general homogeneous systems offer the greatest spectral efficiency and the least problems at boundaries
- High availability systems impose greater sharing constraints because of their need for greater protection due to interference arising from anomalous (short term) propagation conditions. In extreme cases where point-to-point systems operate in the same frequency band in adjacent areas, co-ordination distances of 200 km could be required.
- It is possible to set boundary conditions, both geographic and adjacent band, for spectrum blocks. However setting the boundary conditions at levels that prevent interference under all conditions is impractical (i.e. too constraining). Setting the conditions at levels higher than this leads to a potential for interference. Negotiation / co-ordination is therefore required in order to allow for satisfactory co-existence.
- A similar problem exists for the setting of boundary conditions with respect to other countries. The result is either highly constrained operations in border areas (when the boundary conditions are stringent) or the need to co-ordinate with other administrations (when the boundary conditions are more relaxed). The need to co-ordinate with other administrations, which in any event can be lengthy, is potentially more difficult in the case where UK usage is out of line with international agreements.
- Highly directional antennas can lead to significantly higher potential interference in the worst case, although the probability of this arising is correspondingly much lower because of the narrow beam widths involved. However, where the coverage of the other service using the same frequency is meant to be ubiquitous (e.g. a mobile service) the small probability becomes significant.
- Co-frequency point-to-area systems of similar power levels are more suited to operating in adjacent geographic blocks of spectrum although even here there still remains the potential for interference at boundaries.
- There is no reason from a technical point of view to prevent a change in use providing any agreed changes to boundary conditions are formally recorded. Agreements of this nature can be relatively easy to implement domestically (i.e. between spectrum blocks) but more difficult to implement with respect to other

administrations especially when the change of use falls outside the international framework, as noted above.

- If agreements regarding changed boundary conditions are to be made, they should be made on the basis of common technical data and the availability of common calculation tools, with the recognition that measured power levels may not always correspond with those calculated

- Technologies are available to reduce the impact of the interference environment. It is not immediately clear that the low power density methods (e.g. spread spectrum and ultra wide band systems)[10] offer great benefit other than potentially in the short term (i.e. low numbers of users). Frequency agility and adaptive antennas offer greater potential. Where these are used to enable operation in an anarchic environment (i.e. licence-exempt bands) or where an operator achieves more dynamic frequency planning in its own frequency band there are significant benefits. It might also be thought that they could improve the co-existence situation at boundaries. However, as most of these techniques effectively operate on a "first-come, first-served" basis, there is a danger that an operator on one side of a boundary will effectively (and invisibly) change the boundary conditions in their favour.

It is therefore concluded that it is not possible to isolate either a geographic spectrum block or a country merely by imposing a power flux density / field strength limit at the boundary or generic power limits. Such limits would be too constraining near the boundary and would lead to inefficient use of the spectrum.

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

In general the market can be expected to arrive at the most beneficial apportionment of spectrum to different users through trading. However there is a danger that the spectrum could become fragmented the more it is traded. One result could be that spectrum efficiency suffers due to the need for an increasing

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[10] Such techniques attempt to reduce the likelihood of interference by "spreading" the signal over a bandwidth much wider than that of victim systems, so that only a small proportion of the interfering power lies within the bandwidth of the victim receiver. However, because of the wider bandwidth, many more interfering systems are likely to operate on the same frequency hence as the market for such technologies grows the level of interference (which is cumulative) may once again become problematic.

number of guard bands. In addition fragmentation could lead to more and more complex negotiations between users and the potential for self-correcting market mechanisms to be disrupted by commercial positions adopted by one or more operators. It is therefore important that the ground rules for trading allow for arbitration by the regulatory authority in the event that an unsatisfactory fragmentation arises.

5 CONCLUSIONS

The Independent Review's consultation paper proposes that:

- Spectrum users face the opportunity cost of spectrum
- For commercial users, opportunity cost can be revealed through market mechanisms such as auctions and spectrum trading
- The UK seeks to adopt a more flexible approach to spectrum management, involving greater autonomy in spectrum use and adoption of a less service dependent licensing approach, within the constraints of its current international commitments

This study has addressed the ways in which international regulation and technical factors may constrain or enable implementation of these proposals. This section summarises our conclusions and then goes on to discuss a number of practical issues.

5.1 Opportunity cost of spectrum

The opportunity cost of a particular block of spectrum is the cost of denying use of the spectrum to any other use or user. If the value of the spectrum to the incumbent use/user is less than the opportunity cost, then the distribution of spectrum can be said to be sub-optimal in the sense that more value would be created by reallocating the spectrum. If users are faced with the opportunity cost of spectrum, they will have incentives to increase/decrease their use if they value spectrum more/less than the opportunity cost.

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

- The timing of demand for new services in UK is different from elsewhere (e.g. digital TV)

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

To assess whether the international regulatory framework could constrain application of the opportunity cost approach, it is necessary to consider the impact of ITU, EC, ERC and bilateral agreements and regulations. Of these, EC regulations and bi-lateral agreements are likely to be the most binding constraints.

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

ERC Decisions become mandatory once signed by administrations (although signing itself is optional). The situation with ITU regulations is as follows:

- If the new use falls within the definition of the primary use of the band there is no problem;
- If the new use falls within the definition of the secondary use of the band then the user is not entitled to interference protection from current or future primary services;
- If the new use falls outside both the primary and secondary use definitions, then implementation is still possible but the user must not cause harmful interference and it has no right to protection from harmful interference from either primary or secondary services. If interference protection is desired or interference may be caused to other users, it may be possible (in principle) to effect a change by adding a footnote to the ITU-R Radio Regulations. This could take at least 3 years to achieve and may be blocked by neighbouring countries not wishing to change existing bilateral agreements in ways that would either restrict their own use or protect the new use from harmful interference.

Bilateral agreements may constrain what actually happens in practice assuming the UK’s neighbours do not wish to make similar changes in their spectrum use.

Bilateral agreements are generally framed in terms of the division of frequencies used in border areas and the level of permitted emissions in preferred/non-preferred frequencies across the band and out of band. If the bandwidth of new services differs from that of existing services, then the agreed sharing pattern may not apply and the new use may face harsh emission constraints. This may prevent service deployment in border areas.

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

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

The above discussion is framed in terms of change of use. The issue of change of technologies also applies. Here it is only the European regulation and bilateral agreements that may constrain a liberal approach. Against this, the WTO agreement and R&TTE Directive do not allow member states to restrict the technology used except on grounds of harmful interference. This may neutralise the effect of any technology specific European regulations, but it does not deal with the issue of bilateral agreements as these are driven by interference considerations. As discussed above, bilateral agreements may constrain the area over which a new technology or service may operate and in some cases this may mean it is not worthwhile deploying the service/technology in question. As illustrated by the case studies, the outcome largely depends on the frequency band and nature of technologies deployed on each side of the border.

5.2 Market Mechanisms

5.2.1 Trading and Auctions

Secondary trading and spectrum auctions will both be permitted under EC legislation once the Framework Directive and Spectrum Decision have been passed. The only real constraint imposed by this legislation is that trading may not result in the change of use in a band harmonised under either a specific directive or the Spectrum Decision.

As discussed above, changes in use may be problematic in some cases because of the constraints imposed by bilateral agreements.

5.2.2 Aspects of Secondary Trading

In this section we address the following issues:

- Methods for interference management under secondary trading
- Ways of dividing spectrum rights for auction and trade
- The definition of overlay rights

5.2.2.1 Interference Management

It is technically possible to set a power flux density / field strength limit either around a geographic spectrum block or around a country, such that adjoining blocks or countries are unaffected. This however is not a practical proposition in the case of the UK for two reasons:

- The level would have to be so low that operations would be seriously constrained near the boundary
- At the boundary there is always the possibility of interference whatever the level that has been set as a limit

Such an approach would only work if it is accepted that areas near to boundaries, be they internal or international, are effectively unusable.

The consequence of this situation is that the most efficient use of the spectrum can only be entertained when there is some form of mutual agreement that allows for the existence of systems close to one another on either side of the boundary. In terms of interference management the fundamental requirement is for a system that allows for negotiation / co-ordination to take place. If this is accepted and the necessary processes are put into place then there is no constraint on the trading of spectrum, however it is packaged.

The key elements that need to be in place in order to allow interference management to take place in a spectrum trading regime are as follows:

- a power flux density / field strength level at a border that will trigger negotiation / co-ordination, where the responsibility for setting this level would reside with the regulator.

- the availability of common analysis tools to determine interference power levels, where these tools are approved by the regulator (noting that there is no guarantee as to the absolute accuracy of the tools provided) and used by the operators in the case of national negotiation.
- a database of deployed systems and their technical parameters, and agreed changes to boundary conditions.
- the regulator would remain responsible for international co-ordination.

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

It is considered that the main cause of any dispute is likely to be the reception of unacceptable interference. This could be due to an unknown and unauthorised source, authorised equipment performing outside specification, or real field strengths exceeding those calculated using the common tools made available to all parties. The first two of these are similar in that they both involve unauthorised emissions of one sort or another. The enforcement activity required to control these should be undertaken by the regulator. The third example is more difficult.

The use of common data and tools to support the negotiation about boundary conditions between operators has been proposed in order to reduce the likelihood of disagreement at the negotiation stage. However once the systems are in place and operational there is always the small possibility that received signal strengths differ from those predicted by the models used. This applies to interference as much as it does to the wanted signals. This situation is true under the present regime as much as it would be under any new regime that involves spectrum trading. It is essential that operators be made aware that the models used do not guarantee complete interference-free operation and that in the event of this situation occurring arbitration will be required.

5.2.2.2 Division of Spectrum

Two different approaches to defining the blocks of spectrum that are auctioned and traded have been adopted in other countries. These are:

- Building block approach. This is used in Canada and Australia. It involves defining basic building blocks or units of spectrum that cannot be divided but can be aggregated and traded. The units are defined in terms of geographic coverage, time, frequency band and bandwidth.

- Tailored licence approach. This is used in New Zealand and the US, and was used in the UK for the recent 3G mobile and BFWA auctions. Spectrum licences are defined in terms of the spectrum package that the regulator considers to be most appropriate for the service concerned. These packages are auctioned and, in New Zealand and the USA can be aggregated or divided after the auction. The user decides the level of aggregation/disaggregation that best meets its needs.

The pros and cons of the two approaches are summarised below:

Pros and cons of the building block approach versus the tailored licence approach
Pros
The building block approach allows users to acquire small or large spectrum blocks in auction – what ever suits their commercial purposes.
Government does not pre-define the shape of licences based on imperfect information as may be the case with a tailored licence approach. Rather it is left to the market to define the size of licences.
Cons
The building block approach involves higher transaction costs and risks for bidders in the auction as they have to piece together small parcels of spectrum to get the coverage and bandwidth they require. There is a risk that bidders may finish up with total packages that are insufficient to provide a viable service(as happened in the Dutch 2G auction[11]).
The building block approach predefines the way in which spectrum may be disaggregated and it is possible that this may not meet all future needs. In the tailored licence approach users define the appropriate level of disaggregation if the spectrum is subsequently traded.
There are administrative costs in setting up the system of basic trading units, and to meet competition objectives it is likely to be necessary to place caps on the total spectrum package that can be acquired.

In summary, the building block approach involves greater use of market information on the part of bidders to determine their initial spectrum requirement, while the tailored approach possibly allows greater market involvement in any later reformulation of licences. Initial transaction and set up costs are higher under the building block approach, but transaction costs post-auction may be higher under the tailored licence approach if Government has not designed licences in a way that meets market requirements.

Experience in the four countries we surveyed does not obviously show one system to be superior to the other, and it is not clear where the balance lies in the UK case. It is likely to depend on the band in question, the nature of the application and whether other policy factors (e.g. competition issues) dictate a particular configuration for the spectrum.

5.2.2.3 Overlay rights

Overlay licences are licences for a block of spectrum which are encumbered by existing licensees who have apparatus licences (i.e. site specific licences). The issues that need to be considered in granting overlay licences are:

- The rights of incumbents to interference protection

11 The Dutch Government auctioned 18 lots of mobile radio frequencies. Two lots comprised 15 MHz of DCS1800 spectrum and 5MHz of extended GSM spectrum, while the remainder variously had bandwidths of 2.4 MHz and 2.6 MHz. Orange / Veba won only two of these smaller lots which was not sufficient to offer a service. The lots could only be resold with the permission of the State.

- The duration of incumbents' licences
- The new entrants' rights to interference protection
- The grounds on which the new entrant may ask the incumbent to vacate the spectrum

Economic analysis suggests that giving new entrants a right to move incumbents with compensation, and/or giving incumbents a time limited right to stay is more efficient than simply giving incumbents a perpetual right to stay. This means the new entrant is faced with the cost of relocation but is not held up to indefinite negotiations with incumbents trying to extract the full value of the spectrum.[12]

Overlay licences have been created in all four countries reviewed. They have the following common features:

- Incumbents' rights are time limited (2-5 years)
- Incumbents have a right to compensation from the new entrant if asked to leave before their licences have expired
- New entrants must offer incumbents the same interference protection as they had originally
- New entrants are similarly given the same level of protection from interference as other site licensees in the band

The creation and auction of overlay rights is clearly feasible and provides a pragmatic response to the issue of migrating incumbents. Encumbered spectrum is likely to be valued less than unencumbered spectrum, but the discount can be limited by giving incumbents time limited rights.

5.3 Case studies

A number of case studies have been examined with regard to the main objectives of the work undertaken and reported here. The following table summarises the main conclusions of those case studies, further details on which can be found in Annex D:

Case Study	Boundary conditions	International regulations	Market issues
1 - Migration of existing GSM bands to IMT-2000.	Some international problems - borders with France and Ireland. Micro and pico cells may only be possible here.	EC Directives constrain part of the 900 MHz GSM band but no such constraint on DCS1800. Existing bi-lateral agreements may need to be renegotiated.	Auction and trading of GSM spectrum for IMT-2000 use possible but value may be reduced because of border problems.

12 Efficient Relocation of Incumbents, P Cramton, E Kwerel, J Williams; University of Maryland and the FCC. October 1996.

2 - Co-existence of IMT-2000 and non-mobile services around 2.6 GHz.	Potential problems at international borders - directional antennas in Ireland and France.	Although already identified for use by IMT-2000 at an international level, not yet harmonised for such use in Europe.	Impact on French fixed links and Irish MMDS services needs to be addressed. Could be achieved through financial pay-off and/or government intervention.
3 - Migration of analogue TV spectrum.	Based on a Mobile system example, micro and pico cells may only be possible near international borders.	Part of the spectrum allocated to Fixed already - no general allocation to Mobile. Stockholm and Chester broadcast plans dominate but CEPT states that the bands are to be reviewed for possible future applications after the introduction of DVB-T.	Take-up of digital TV can be accelerated by financial incentives achieved through market mechanisms but this could be difficult. The use of released spectrum will also be difficult near borders because of interference problems.
4 - Wideband systems at 28 GHz and 40 GHz.	Small impact on point-to-point operations in other countries. Particular (bad) cases can be dealt with on a case by case basis.	P-P and P-MP allowed to operate under ITU-R allocations. European usage not completely harmonised.	Viability of proposed services questionable. Could make use more flexible by auctioning and trading blocks with general boundary limits.
5 - Licence-exempt systems.	Condition of licence-exempt operation is generally "no protection, no interference". Can be appropriate to mandate interference mitigation technologies in order to protect authorised primary services.	2.4 GHz ISM band now used on a global basis (forced by prospect of Bluetooth). 5 GHz less harmonised globally. Europe promoting the opening of this band on the basis of mandated interference mitigation techniques.	Strong demand for global harmonisation, especially at 5 GHz.

5.4 E-commerce

In line with the Government's overall policy on increased use of the internet for delivery of public services, as detailed in the Cabinet Office document "e-government: a strategic framework for public services in the Information Age", the Agency is considering how e-commerce and e-government may help dynamic spectrum management.

The experience of Australia, Canada, New Zealand and the USA suggest that the introduction of more automated, on-line licensing procedures and licence information is essential to the development of secondary trading and offers administrative benefits both to the Agency and to the market. By removing the need for Agency staff to become involved in the licensing process until a much later stage, the Agency would be able to free staff to work on other issues, and applicants should benefit from a faster, more transparent decision process. The benefits seem likely to be maximised if a suite of support services is introduced providing the information and tools needed to assess the viability of a licence application before actual submission. This is likely to be of particular value to new market entrants (e.g. non-2G licensees), who do not have experience or detailed knowledge of the UK market and licensing procedures, and may therefore help to further stimulate the market. Security issues, both commercial and national, are clearly an area which will require considerable thought. However, these issues have not proved insurmountable in any of the countries which have to date ‘gone on line’.

The Agency has recently launched a publicly accessible database that provides locational and other details (for example emissions and operator) for all operating cellular base stations. This is in response to the recommendations of the Independent Expert Group on Mobile Phones report chaired by Professor Sir William Stewart. In addition, the MSC sub group is considering development of a database to aid spectrum trading, mast sharing, and interference issues and to facilitate engineering/assignments. The Agency is also looking more widely at databases concerning licences, frequencies and assignments and at the business issues arising of how to provide comprehensive or “snapshot” information, and at industry and citizen access issues.

These two work strands may provide a good spring board from which to develop a more comprehensive set of public domain databases. However, the longer term objective, of providing all the services and information needed to allow on-line licensing, might usefully be fed into the current design and development process to ensure longer term compatibility between the various databases and licensing tools.

A strong case can be made for the introduction of a standardised set of modelling tools (or at a minimum a standardised set of functions and interfaces). It is likely that such standardisation will be essential as part of a secondary trading regime, to ensure that problems such as those experienced during the Swedish 3G auction do not occur[13].

In summary, use of the internet for on-line licensing appears to offer significant benefits. A number of levels of service provision can be envisaged, from the simple return of forms on-line, through to provision of a comprehensive suite of support tools. It is likely that further work into the costs / benefits of service provision will need to be undertaken before a final recommendation can be made as to where along the continuum the Agency should seek to operate.

5.5 Greater Flexibility

We were asked to advise on:

- The scope for greater autonomy in domestic spectrum policy e.g. generic licences not related to a particular service or technology. An example would be to reclassify licences as being either point to point or point to area.
- Technical factors which might constrain the introduction of service independent licensing

[13] During the Swedish auction different coverage modelling assumptions on the part of some bidders and the NRA led to legal challenge of the auction outcome, which was partly based on assessment of coverage projections

- Ways in which new technology developments might promote a more market based system of spectrum management

Each issue will now be considered.

5.5.1 Greater Autonomy in Domestic Spectrum Policy

Greater autonomy in domestic spectrum policy might be achieved by

- Implementing new technologies/services unilaterally rather than trying to get a harmonised allocation in Europe
- Applying generic service categories to the extent that this is compatible with ITU regulations and EU Directives
- Following a technology neutral approach, to the extent that this is compatible with EU Directives and interference constraints
- Permitting use of spectrum earmarked for future harmonisation on an interim basis by other services, perhaps including time-limited incumbency rights.

There is potentially scope to move ahead on all of the above for some services. As we have already discussed, in many cases the main constraint is the practical one of needing to conform to existing bilateral co-ordination agreements. For some services (e.g. public mobile services, satellite services), the limitations on implementing new technologies/services on just a domestic basis are economic rather than regulatory.

Adoption of a technology neutral approach to spectrum allocation in Europe would be consistent with WTO requirements but could conflict with the Commission policy with regard to the development of pan-European markets, free circulation and international roaming.

Permitting the interim use of spectrum earmarked for future harmonisation may involve either provision for temporary requirements (e.g. use of MMDS to provide access to multi-channel TV pending the roll-out of cable infrastructure), or the introduction of new services which may in the future be compatible with, or capable of migration to, the proposed harmonised service (such an approach would involve an element of risk on the part of the bidder that their service / technology may not subsequently be compatible, but that could be reflected in the price bid).

5.5.2 Service independent licensing

Some of the technical factors that need to be considered with regard to service independent licensing are:

- Some applications (e.g. certain satellite services) and modulations (e.g. analogue TV) are more sensitive to interference than others
- Particular characteristics of a system make it more sensitive to interference e.g. highly directional receive antennas (although the probability of the worst case geometrical alignment is not great)

- Any imbalance in power levels required to support a system (i.e. homogeneity is good)

Overall though, if there is to be spectrum management based on spectrum blocks of one sort or another, and there is to be negotiation regarding the boundary conditions associated with these blocks, there is no technical reason (from a national point of view) why service independent licensing cannot be introduced. However there will be overall spectrum inefficiencies that will naturally arise when very different types of system are used in the same frequency band.

The main difficulty with service independent licensing will arise from the need to observe international obligations. Co-ordination at international borders may be difficult if a particular application falls outside the service allocations of the ITU-R or CEPT.

In general a broad distinction can be made between point to point systems involving highly directional antennas and high availability requirements, and point to area systems such as mobile, broadcast and FWA services. However, it is also necessary to differentiate between broadcast services, which tend to involve high power transmissions serving large areas with limited frequency re-use, and mobile or FWA services which employ cellular technology with relatively small transmitter coverage areas and intensive frequency re-use. This means that co-ordination distances for broadcasting systems must inevitably be greater than for mobile and FWA, even in the same frequency bands.

It could be argued that adoption of cellular techniques for broadcasting would overcome this problem, however consideration of the different economics of one-to-one (telecommunications) and one-to-many (broadcast) services tends to rule this out. Broadcasters generally require the ability to deliver the same material simultaneously to the maximum number of recipients (to compete with alternative platforms like satellite or cable and maximise their advertising revenue), whilst mobile or FWA operators need to maximise capacity (and hence revenue) on their networks. Hence the difference in approach to the delivery of broadcast and wireless telecommunication services, outlined above. Whilst some degree of convergence between broadcast and telecommunications services is anticipated, this fundamental difference in the approach to delivering “one-to-many” and “one-to-one” services is likely to remain for the foreseeable future.

5.5.3 New technology developments

Several new technology developments have been introduced in order to make better use of the spectrum when the interference environment is hostile, whether it be created by similar systems or other services operating in the same band. These developments are often market driven and have been developed by manufacturers / operators in order to gain access to the spectrum and / or make more efficient use of the spectrum. Sometimes the requirement for a particular technique is mandated by regulators to prevent interference to other services.

While some of these techniques work well in an uncontrolled environment (e.g. licence-exempt bands) or with respect to other devices within a single system, there are some dangers when used across systems deployed by different operators. This is particularly the case where operators are working within a well defined and agreed boundary. In this instance systems using some sort of automatic frequency selection could make an "invisible" incursion into the territory owned by another operator on the other side of the agreed boundary.

In the case of harmonised bands, new technologies can be introduced, where these do not entail a change of use or a change to the agreed bilateral co-ordination criteria. An example would be the introduction of the EDGE (Enhanced Data rates in a GSM environment) by GSM operators, which utilises a different modulation scheme but retains the same channel plan and emission limits as standard GSM technology. The introduction of more radical changes, such as the adoption of the UMTS standard in the GSM bands, would be more problematic due to the very different channel plan, which would prevent the continued use of the “preferred channel” co-ordination procedure. This is addressed in more detail in the case studies (see appendix D.1).

5.6 Changes to the International Framework

There may be scope for the UK to seek changes to the international regulatory framework, or to seek to influence future developments, that would facilitate greater flexibility in national spectrum management. This could for example include the removal, or at least revision, of older service specific Directives that have outlived their purpose, e.g. GSM, ERMES, and DECT and support for the adoption throughout Europe of a more technology neutral/less service specific approach to licensing and spectrum management, building on the new Framework package. It is particularly important for the UK to play an active role in European fora such as the CEPT ERC Radio Regulatory Working Group, which are actively addressing spectrum trading and refarming issues.

It should be noted that case studies indicate that even if these changes are made, differences in bandwidth and the way spectrum is used by different services mean that bilateral co-ordination close to borders will continue to be required in most cases and that this may limit the scope for introducing much greater flexibility in use. The situation is easier for low power services and at for services operating at higher frequencies. Also, where spectrum is additional to other spectrum, the constrained spectrum may only be required where traffic demand is highest, e.g. in major conurbations away from border areas, largely negating the need for co-ordination.

Note that some limited change of use can already be accommodated within the existing international framework. For example, the use of 3G mobile spectrum for fixed services in areas where there is limited demand for mobile, would be compatible with ERC Decision (00)01, which allows for variations in regional market demand to be taken into account. Such provision would also be compatible with the co-primary ITU allocation of the spectrum to fixed and mobile services. Note however that any bilateral agreements would still need to be met and that this might constrain such use in areas near the channel coast or the Irish border.

A THE INTERNATIONAL REGULATORY FRAMEWORK

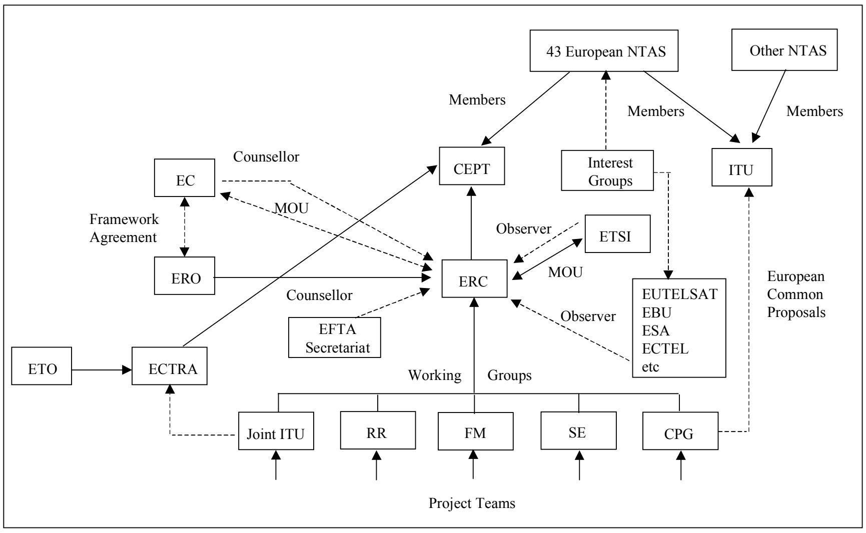
A.1 Introduction

The very nature of the radio spectrum demands that its use is, in the first instance, considered at an international level. The national regulatory authority (NRA) must often comply with international / regional regulation (particularly if it has agreed to the relevant regulatory instrument), and is well advised to take account of the possible impact that any changes it proposes in the use of spectrum may have upon neighbouring states. Typically this involves the setting up of specific memoranda of understanding to protect services in neighbouring countries, such as that reached between the UK, France and Belgium to facilitate the replacement of UK Band III TV broadcasts by public access mobile radio, or those relating to GSM cellular services.

Management and use of the radio spectrum is subject to regulation (be that mandatory or advisory) by five major international bodies:

- ITU-R and CEPT have pioneered development of spectrum regulation through technical means, whilst the work of ETSI and other standards bodies has helped make possible the standardisation and harmonisation of spectrum use
- EU and WTO have focussed on trade / market mechanisms by which to achieve fully efficient use of the spectrum[14]

The relationships between many of these bodies are shown in the following diagram. This illustrates the complexity of these associations.



The complexities of international regulatory relationships

14 It may of course be noted that the EU is taking an increasingly active role in the technical management of spectrum

The detailed responsibilities of the key organisations, and the manner in which they are likely to affect the UK's approach to spectrum management, are discussed in the following sections.

A.2 Global considerations

A.2.1 Introduction

The international framework for radio regulation exists primarily to protect against harmful interference. Also for services of an international nature, such as satellite, maritime and aeronautical services, international harmonisation of allocations is necessary to allow users to operate safely and effectively (e.g. international air travel, merchant navies etc). Supporting these objectives, the International Telecommunications Union Radiocommunications Sector (ITU-R) provides the overall, global, framework for spectrum use, in the form of the International Frequency Allocation Table (Article S5 of the Radio Regulations), which allocates spectrum to broad categories of service such as fixed, mobile, broadcasting or radionavigation. Services are allocated on a primary or secondary basis. Current systems operating in a primary allocation are protected from interference from all future systems. Future systems operating in a primary allocation are protected from subsequently introduced primary systems and from systems operating in a secondary allocation, but not from current primary systems. Systems operating in a secondary allocation must not cause interference to, and will not be protected from interference from, current or future primary services, but can claim protection from future secondary services.

A.2.2 The ITU Radio Regulations

The ITU issues Radio Regulations (RR) which have the status of treaties, once ratified by individual Member states. These are agreed at World Radio Conferences and Member states that do not abide by the RR cannot expect any protection from interference. Clearly it is potentially less damaging for countries that are remote islands (e.g. New Zealand and Australia) to violate the ITU regulations than it is for countries which are proximate to many others (e.g. the UK and the rest of Western Europe).

In using the radio frequency spectrum Member States of the ITU are required:

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

It is further required that all stations must be operated in such a manner as not to cause harmful interference to the authorised radio services of other Member States which operate in accordance with the Regulations.

The Regulations therefore set out to:

- facilitate equitable access to and rational use of spectrum and orbit resources
- ensure the availability and protection from harmful interference of frequencies provided for distress and safety purposes
- assist in the prevention and resolution of cases of harmful interference between the radio services of different administrations
- facilitate the efficient and effective operation of all radiocommunication services
- to provide for, and where necessary, regulate new applications of radiocommunications technology

It is difficult to summarise the contents of the Radio Regulations and in any event it is not necessary for the purposes of this report to present the detail. It is however useful to have an overview of the issues that the Regulations address. The main body of the text is made up of several Articles supported by Appendices, Resolutions and Recommendations, the latter not to be confused with ITU-R Recommendations. The most important parts of the Regulations are those that:

- define the different radio services and many other important terms (Articles S1 to S3)
- outline the conditions for frequency assignment including the Table of Frequency Allocations (Articles S4 to S6)
- specify the procedures relating to frequency co-ordination and notification (Articles S7 to S14)
- describe provisions relating to interference and administrative issues (Articles S15 to S20)
- specify the technical, operational and administrative constraints associated with various radiocommunication services (Articles S21 to S29)
- outline provisions specifically associated with distress and safety communications (Articles S30 to S34)
- outline provisions specifically associated with aeronautical services (Articles S35 to S45)
- outline provisions specifically associated with maritime services (Articles S46 to S59)

It is important to appreciate that the Radio Regulations only provide a high level framework within which administrations operate. Using the technical characteristics specified in the Regulations for various types of radiocommunication station does not mean that different systems will be able to coexist. In the interests of flexibility, efficiency and the desire of nation states to exercise control, the Regulations only assist in arriving at a situation where coexistence might be achieved.

From the point of view of this study perhaps the most important provision is S4.4 which requires that:

> *Administrations of the Member States shall not assign to a station any frequency in derogation of either the Table of Frequency Allocations in this Chapter or the other provisions of these Regulations, except on the express condition that such a station, when using such a frequency assignment, shall not cause harmful interference to, and shall not claim protection from harmful interference caused by, a station operating in accordance with the provisions of the Constitution, the Convention and these Regulations.*

In fact using harmful interference as the yardstick gives significant latitude as its definition is vague and less stringent than other measures of interference, although it is the one definition of interference contained in the Constitution of the ITU.

> *Permissible interference – Observed or predicted interference which complies with quantitative interference and sharing criteria contained in these Regulations or in ITU-Recommendations or in special agreements as provided for in these Regulations.*
>
> *Accepted interference – Interference at a higher level than that defined as permissible interference and which has been agreed upon between two or more administrations without prejudice to other administrations.*
>
> *Harmful interference – Interference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with Radio Regulations.*

In addition to the types of interference level defined above there are also a number of "trigger" levels which are specified with a view to determining whether co-ordination is required or not. Most of the "trigger" levels in the Radio Regulations are related to satellite services as these are of a more global nature. However, co-ordination "trigger" levels are often agreed between administrations having territorial boundaries. These bilateral "trigger" levels are often based on ITU-R Recommendations.

All of these interference levels, the co-ordination "trigger" level, the permissible interference level and the accepted interference level (once agreed between administrations) are quantified. The most fundamental of them all, namely harmful interference, however is not. In terms of international obligation therefore it is difficult to know exactly what should be met without stepping back and taking account of the other interference levels that are defined. In any event other administrations are not likely to accept an interference level that falls just below the harmful interference level (if this can be agreed) but above the permissible interference level even if the legal situation deems this as satisfactory.

The main question that arises from the key parts of the framework of the Radio Regulations as identified above is "How, and under what circumstances, can you define radio operations within your own territory so that they do not cause (harmful) interference to systems managed by other administrations?” This is the question addressed in annex C.

A.2.3 ITU-R Recommendations

ITU-R Recommendations, as their name implies, do not have the same legal status as the Radio Regulations. They are intended to be advisory rather than mandatory. However it can be noted that most Administrations take them sufficiently seriously that they are widely acknowledged and implemented in practice.

There are some special cases in the Radio Regulations where specific ITU-R Recommendations are incorporated by reference. In these instances the ITU-R Recommendations concerned will have a higher legal status and will be binding in the same way that the Radio Regulations are.

As noted earlier the fundamental requirement not to cause harmful interference is not quantified and therefore difficult to assess. It is probable that any dispute regarding interference would revert to criteria that have been quantified, namely permissible interference and accepted interference. Values associated with these criteria are likely to be based on ITU-R Recommendations. Under these circumstances it can be seen that ITU-Recommendations take on a level of importance not immediately obvious from their legal status.

A summary of relevant ITU-R Recommendations, covering the bands and services addressed by the case studies, are presented in the matrix in Annex G.

A.2.4 World Trade Organisation

The WTO Agreements focus on the desirability of a market that is as free from restriction as is possible. Thus the General Agreement on Trade in Services (GATS) requires that any member / group (e.g. CEPT) operating under the auspices of the GATS ensure that procedures for the allocation and use of frequencies should be carried out in an objective, timely, transparent and non-discriminatory manner.

One interpretation of this, in terms of the deployment of radio equipment, is that it is not acceptable to specify a national / regional equipment or interface standard to the exclusion of other standards unless it can be demonstrated that another standard will cause harmful interference.

This situation is effectively reflected in the EC's R&TTE Directive that specifies essential requirements for the placement of equipment on the market at a qualitative level, rather than in a quantitative manner as is generally the case in a technical standard.

A.2.5 Other sector-specific bodies

There are a number of other organisations that represent the interests of specific user groups, such as the International Maritime Organisation and the International Civil Aviation Organisation. These bodies represent their user communities in ITU fora and co-ordinate spectrum usage in accordance with the Radio Regulations and relevant ITU recommendations, but are not directly involved in the frequency allocation process.

A.3 Regional (European) considerations

A.3.1 Introduction

Within Europe, the European Conference of Posts and Telecommunications Administrations (CEPT) provides detailed guidance to NRAs, operators and vendors, seeking to achieve harmonisation throughout the region, an objective mandated by the European Union (EU). Within CEPT the European Radiocommunications Committee (ERC) undertakes spectrum harmonisation activities. The main instrument for the harmonisation of frequency allocations in Europe is the ERC Decision. ERC Decisions often specify the service and the technical standards to be used. ERC Decisions are agreed by consensus and the intention to conform to a Decision is signalled by signing the Decision, an act which is strictly optional. However, if EU member states do not support measures which the European Commission (EC) would like to see implemented it is possible that the EC would seek to have the measures implemented through EC legislation.

The European Telecommunications Standards Institute (ETSI) develops the harmonised equipment standards that help systems to operate freely across the continent, and indeed beyond.

A.3.2 Constraints arising from European Commission regulatory activities

As noted in the preceding section, there are a variety of European legislative measures, both proposed and in force that have the potential to constrain UK spectrum management activities. Amongst the Directives and Decisions most likely to affect spectrum use are[15]:

- the proposed Framework Directive (EC document 10420/1/01, rev.1)
- the proposed Authorisation Directive (EC Document 10419/1/01, rev. 1)
- the Competition Directive (as amended) (96/19/EC)
- the proposed Radio Spectrum Policy Decision (EC Document COM/2000/0407)
- the R&TTE Directive (1999/5/EC)

In addition there are a number of existing service-specific Directives and Decisions which place constraints on specific frequency bands, namely:

- the GSM Directive (87/372/EEC)

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15 A *Directive* binds Member States concerning the objectives to be achieved by a given date, leaving the national authorities the choice of form and means to be used. Directives have to be implemented in national legislation in accordance with the procedures of the individual Member States.

A *Decision* binds those to whom it is addressed. A decision does not require national implementing legislation. A decision may be addressed to any or all Member States, to enterprises or to individuals.

- the ERMES Directive (90/544/EEC)
- the DECT Directive (91/287/EEC)
- the Satellite PCS Decision (710/97/EC) (amended 1215/2000/EC)
- the UMTS Decision (128/1999/EC)

It may also be noted that some pressures on spectrum management are likely to arise from the proposed Access & Interconnection Directive and from the Users Rights & Universal Services Directive.

The service specific measures are likely to continue in force under the new regulatory framework, which is expected to come into force during between April and September 2003 and any moves towards furthering the use of market based spectrum management should take account in particular of the provisions in the proposed Authorisation Directive and the Spectrum Decision.

The Decisions and Directives are examined in detail in Annex F, whilst the possible impact of the legislation is addressed in the next section.

A.3.2.1 Implications of European jurisdiction

The primacy of European legislation over national legislation produces both opportunities, such as those offered by European harmonisation, and constraints for each Member State. This section looks at three specific issues, namely:

i) The feasibility and implications for the EU market and industrial development policy, of the UK adopting non-European standards or technologies

ii) The importance of future European harmonisation plans

iii) Band specific constraints arising from service specific Directives and Decisions

It is worth noting that the European Directives and Decisions are on occasion ambiguous and are subject to interpretation, and that the proposed new Directives are not yet finalised. Furthermore, as in the case of UMTS for example, even where an action is mandated (provision of a system adhering to the ETSI UMTS standard) this need not prevent an NRA from taking actions which may perhaps go against the spirit, if not the letter, of the relevant text. Thus once the NRA has licensed a UMTS conformant system, it might choose also to license a non-UMTS conformant system. The following sections seek to identify some of the constraints which arise from actual and proposed European legislation, and to determine whether other courses of action may yet be legitimate.

i) The potential for non-European standards

Development, adoption and use of standards within the Community are addressed in, amongst others, the R&TTE Directive and proposed new Framework Directive.

In broad terms, the R&TTE Directive seeks to encourage the introduction of innovative technologies, through: "fast track" procedures such as the use of self-declarations of conformance; a shift from the use of standards as an end in themselves to a support for legal requirements defined within the Directive; simplification of the conformance process by introduction of Europe wide standards, rather than national standards, some of which are equivalent and some of which are not. Crucially, it also permits operation of apparatus that does not conform to a European standard, but does meet "essential requirements" as defined in Article 3. These essential requirements demand that all equipment:

- meets the health and the safety requirements contained in Directive 73/23/EEC;
- meets the protection requirements with respect to electromagnetic compatibility contained in Directive 89/336/EEC,
- and, in the case of radio equipment, uses the spectrum allocated to terrestrial/space radio communication and orbital resources so as to avoid harmful interference.

The Framework Directive seems to support this liberal stance, stating that all regulation should be technologically neutral, indeed the latest Commission Proposal is "to give preference to technically neutral standards". Yet the underlying intention of the FD is clear: that all Member States should adopt the same standards in order to maximise the possibility of pan-European operation and the development of pan-European markets. Following the WTO ruling on free trade, the Community now "encourages" rather than mandates adherence to specific standards, thus the path is broadly clear for the introduction of alternative technologies, particularly where that technology is intended solely for use within a single Member State and where issues such as cross border interference will not arise.

Thus alternative technologies can in theory function within the European market. However, failure to conform fully and precisely to a European standard may lead to significant problems should any Member State wish to challenge the entry of a new service or technology into its own national market, making it more difficult, or even impossible, to achieve a pan-European market without the use of a European standard.

A Member State is at liberty to refuse to allow a technology which it believes fails to meet the provisions of the R&TTE to operate within their boundaries (Article 9 of the R&TTE Directive). Grounds for refusal include:

(a) incorrect application of the harmonised standards

(b) shortcomings in the harmonised standards;

(c) failure to satisfy the "essential requirements" referred to in Article 3 of the R&TTE Directive (despite having adhered to an equivalent standard for example)

Furthermore, Member States can bar from their markets equipment that falls outside the provisions of the R&TTE Directive as a consequence of Article 30 of the EC Treaty. This article allows nations to restrict the free movement of goods on the grounds of public order, public security or protection of health.

Member States are urged to take measures to withdraw apparatus that fails to meet the requirements of the Directive from the market or from service, prohibit its sale or use and restrict its free movement. Under article 8.2 of the R&TTE Directive, all Member States are obliged to allow non-conformant apparatus to be displayed at exhibitions, demonstrations etc, but the apparatus must be clearly signed as being non-compliant with the Directive, and therefore not permitted to be marketed or to operate. This would be of slight benefit whilst determining whether a Member State was justified in rejecting the technology.

Developing and improving European standards

Introducing a technology that does not adhere to a European standard can therefore be seen to have certain pitfalls associated with it. One possible reason for using non-European standards and technology would be the inadequacy of, or restrictions imposed by, existing European standards in the area of interest. This possibility is addressed by both the R&TTE and Framework Directives. A process for continuous improvement is outlined in Article 15 of the FD, which may be summarised thus:

1. The Commission will develop a list of standards (produced by ETSI, CENELEC, or CEN) which Member States shall encourage organisations to use. The objective of this set of standards will be to ensure interoperability and extend freedom of choice. The Commission may make use of certain standards compulsory if voluntary use is failing to achieve interoperability / freedom of choice, and conversely may remove a standard if it is deemed to hamper innovation or no longer to achieve its purpose.
2. Where a service is not addressed by a standard from the Commission list, Member States are to encourage the use of standards from ITU, ISO or IEC.
3. The European Standards Organisations will then be encouraged to develop appropriate European standards, based on the International standards, which may then be published as part of an increasingly comprehensive Commission list.

Beyond conformance

Conformance to a European standard does not guarantee success within the European market however. Although by default conformance demands pan-European acceptance, Member States retain a number of grounds upon which they can decline to accept even conformant technology. For example, under A 7.2 R&TTE, Member States may restrict use of radio equipment on grounds related to the effective and appropriate use of the radio spectrum, avoidance of harmful interference or matters relating to public health. If a Member State considers that apparently compliant apparatus would cause serious damage to a network or harmful radio interference the operator may be authorised to refuse connection, to disconnect such apparatus or to withdraw it from service.

In summary, the situation with regard to use of technology which does not adhere to a European standard depends to some extent upon interpretation of the applicable Directives. Where the technology is to be used exclusively within the boundaries of a Member State the opportunities do exist for successful introduction. However, if, as is probably more likely, the owner of the technology wishes to introduce it into one Member State as a point of entry to the wider European market, the obstacles and associated risks are considerably greater, though not necessarily insurmountable.

ii) Ramifications of spectrum harmonisation

Harmonisation within the Community comprises two main strands; equipment harmonisation, as touched upon in the preceding section, and spectrum harmonisation.

Spectrum harmonisation within the Community is underpinned by regulations and recommendations arising from three main bodies: ITU-R, CEPT and EU. Within the EU the issue is addressed both in the service specific Directives and Decisions (see next section) and within the Framework Directive. As with equipment harmonisation, European legislation offers both opportunities and constraints, driven by the desire to maximise the extent to which interoperability and interference free systems can be achieved within the Community.

Historically, harmonisation has been achieved under the auspices of the CEPT. However, adherence to CEPT recommendations, and indeed ERC Decisions in the first instance, is a voluntary matter for each NRA. Whilst common interests and peer pressure have often made this an acceptable approach, the Commission consider that such a situation is no longer sufficient or acceptable. Citing the need for greater certainty on the part of major investors, the Spectrum Policy Decision (SPD) states that *“where policy agreement is reached to harmonise the use of radio spectrum necessary to implement relevant Community policies, legal provisions should ensure the appropriate implementation of measures by the Member States.”* It proposes that harmonisation issues continue to be addressed at a technical level by the CEPT, with the Commission subsequently mandating that (where the results generated by CEPT are acceptable) the Member States implement them (A6 – SPD). The issues to be addressed will be determined by the Senior Official Radio Spectrum Policy Group (created by the SPD) and may cover harmonisation of: the use of spectrum, assignment methods, conditions for use, and availability of information related to spectrum use.

The Group is constrained in its choice of bands for harmonisation by the Framework Directive which indicates that Member States shall promote the harmonisation of spectrum use “consistent with the need to ensure effective and efficient use thereof” (A8 - FD). As noted earlier, the Article goes on to permit the transfer of rights to spectrum use – but specifically requires that harmonised spectrum does not change use.

It is worth noting that some flexibility is provided for in A7.1 – FD, which enables NRAs to contribute to the promotion of cultural and linguistic diversity, together with media pluralism – perhaps thereby allowing the same (non-harmonised) frequencies to be licensed for different applications in each of the home nations (England, Scotland, Northern Ireland and Wales) dependent upon cultural and linguistic needs.

iii) Implications for specific bands

The service specific Directives impose some quite clear constraints on the use of certain parts of the spectrum. Given that each Directive has the force of law in the UK, these constraints may be considered immutable. However, the Directives all arise from a desire to maximise the choice, quality and value of services available to European citizens. Where markets are in decline, or have reached a plateau without requiring their full anticipated spectrum requirements, as for example in the case of ERMES, spectrum may perhaps be made available for alternative services. As with other Directives, some aspects are less clear cut and allow some room for interpretation.

1880 – 1900 MHz: DECT

The DECT Directive constrains use of the band, providing as it does for primacy of DECT systems over all others. Furthermore, although pre-existing services are permitted to keep operating on a non-interference basis, the Directive does not allow for new services to enter the band, thereby reducing the flexibility available to the Agency. Any system wishing to make use of the privileges associated with the DECT Directive must conform to the European Telecommunications Standard for digital cordless telecommunication systems. Given the deregulated nature of DECT services and its widespread adoption in the consumer market it would in any case be difficult to accommodate other services or technologies within this spectrum

169.4 – 169.8 MHz: ERMES

The ERMES Directive identifies four channels as being of particular importance (as noted previously), with the remainder of the band needing only to be allocated to paging should commercial demand so require. Although the Directive cites preferred channels, these are not mandated; references to the need for co-ordination between Member States suggests that some flexibility may be allowed. In view of the limited market success of ERMES, the European Commission has subsequently announced that administrations may allocate channels for paging services other than ERMES. The Commission is re-examining the ERMES Directive as part of the 1999 review of the telecommunications regulatory framework.

890 – 915 MHz and 935 – 960 MHz: GSM

The introduction of GSM services to Europe is often cited as an example of good practice in regional regulation. The Directive foresees a market that reaches its peak within ten years of the service coming into operation – i.e. by 2001, requiring that the full allocation, 890 – 915 MHz and 935 – 960 MHz be made exclusively available to GSM systems. In fact this full allocation was required some years ago in many EU Member States, due to the success of GSM. It is hard to envisage any part of the current allocation being relinquished by the GSM community, unless and until third generation systems become as widespread and as commercially successful as the second generation. Even then it is likely that GSM spectrum, which has been earmarked internationally for the expansion of IMT-2000, will be required to facilitate migration from 2G to 3G services . On a different tack, it is interesting to note that the GSM Directive addresses spectrum that was, at the time the legislation was passed, occupied by a variety of systems in different Member States. The GSM approach, including wide consultation, early notification and phased introduction enabled most Member States to refarm in a timely and effective fashion (though the continuing presence of tactical fixed links in the GSM 1800 band has arguably hindered the development of GSM in France).

2 GHz: IMT-2000

The UMTS Decision mandates Member States to ensure that UMTS operates in the frequency bands harmonised by CEPT, namely: 1900 – 1980 MHz, 2010 – 2025 MHz, 2110 – 2170 MHz (terrestrial), and 1980 – 2010, 2170 – 2200 MHz (satellite).

NRAs are required to ensure that UMTS is organised “pursuant to European standards for UMTS, approved or developed by ETSI, where available”, and that licences allow trans-national roaming within the Community. However, within the preamble, the Decision recognises that the voluntary application of standards remains the default, with specific standards being mandated only when necessary to ensure interoperability and to facilitate international roaming.

Both the R&TTE Directive and the WTO rules indicate that Member states cannot specify that a single technology be used at a given frequency, unless it is possible to demonstrate that use of multiple technologies will cause harmful interference. “Harmful interference” is not however defined in quantified fashion.

1.6 / 2.4 GHz and 1.9 / 2.1 GHz: S-PCS

Satellite Personal Communication Systems (S-PCS) are another relatively recent development within the telecommunications markets, a fact that is reflected in the 1997 Decision[16] affecting their introduction and use. By the time of this Decision,

16 Extended, but unchanged by: Decision No 1215/2000/EC of the European Parliament and of the Council of 16 May 2000 extending Decision No 710/97/EC on a co-ordinated authorisation approach in the field of satellite personal

the paradigm shift that moved spectrum management away from being an exclusively engineering preserve into one in which engineering and economics work hand in hand, was well underway. This Decision therefore touches upon matters that were not addressed by the earlier Directives. For example, when considering licensing procedures, an extended time frame is allowed for NRAs using comparative bidding procedures.

The S-PCS Decision requires that, where spectrum scarcity limits the number of systems that can viably operate, Member States co-ordinate amongst themselves to ensure that common systems operate across the Community. A new feature within the Decision is the "one stop shopping" procedure outlined in the next section and Annex F. In short, this results in applications / notifications being made to a European body, from which the application / notification is forwarded to the NRA. Arguably, this greater distance between the NRA and the applicant, may have a detrimental impact on the relationship between the two.

The Directive expires on 31 December 2003.

A.3.3 Summary of relevant Directives and Decisions

The preceding sections have addressed the core Directives and Decisions affecting spectrum management and regulation. However, a wider range of legislation / proposed legislation exists, much of which is cross referenced within the texts addressed above and in Annex F. For completeness the following table, showing Directives then Decisions in chronological order, is provided.

communications services in the Community
Official Journal L 139 , 10/06/2000 P. 0001 - 0001

Directives	
87/372/EEC OJ No. L 196 17/07/87 pg.85	Council Directive 87/372/EEC of 25 June 1987 on the frequency bands to be reserved for the co-ordinated introduction of public pan-European cellular digital land-based mobile communications in the Community (GSM Directive)
89/336/EEC OJ No. L 139 23/05/1989 pg.19	Council Directive 89/336/EEC of 3 May 1989 on the approximation of the laws of the Member States relating to electromagnetic compatibility (The EMC Directive)
90/388/EEC OJ No L 192 24/07/1990, pg 10	Commission Directive 90/388/EEC of 28 June 1990 on competition in the markets for telecommunications services (amended by Directive 96/19/EC)
90/544/EEC OJ No. L 310 09/11/90 pg.28	Council Directive 90/544/EEC of 9 October 1990 on the frequency bands designated for the co-ordinated introduction of pan-European land-based public radio paging in the Community (The ERMES Directive)
91/287/EEC OJ No. L 144 08/06/91 pg.45	Council Directive 91/287/EEC of 3 June 1991 on the frequency band to be designated for the co-ordinated introduction of digital European cordless telecommunications (DECT) into the Community (The DECT Directive)
94/46/EC OJ No L 268, 19/10/1994, pg 15	Commission Directive 94/46/EC of 13 October 1994 amending Directive 88/301/EEC and Directive 90/388/EEC in particular with regard to satellite communications (The Satcoms Directive)
95/62/EC OJ No L 321, 30/12/1995, pg. 6	Directive 95/62/EC of the European Parliament and of the Council of 13 December 1995 on the application of the principles of open network provision (ONP) to voice telephony (The ONP Directive)
98/61/EC OJ No. L268 03/10/1998	Directive of the European Parliament and of the Council on interconnection in telecommunications with regard to ensuring universal service and interoperability through application of the principles of open network provision (ONP) (The Interconnection Directive – (97/33/EC amended)
96/2/EC OJ No. L 020 26/01/1996 pg 59	Commission Directive 96/2/EC of 16 January 1996 amending Directive 90/388/EEC with regard to mobile and personal communications (The Mobile Directive)
96/19/EC OJ No. L074 22/03/96 pg13	Commission Directive 96/19/EC of 13 March 1996 amending Directive 90/388/EEC with regard to the implementation of full competition in telecommunications markets (The Competition Directive)
97/66/EC OJ No. L 024 30/01/1998 pg1	Directive 97/66/EC of the European Parliament and of the Council of 15 December 1997 concerning the processing of personal data and the protection of privacy in the telecommunications sector
98/34/EC OJ No. L 204 210/07/1998 pg 37	Procedure for information in the field of technical standards and requirements in the Information Society (amended by 98/48/EC)
98/48/EC OJ No. L 217 05/08/1998 pg 18	Directive 98/48/EC of the European Parliament and of the Council of 20 July 1998 amending Directive 98/34/EC laying down a procedure for the provision of information in the field of technical standards and regulations
98/84/EC OJ No. L 320 28/11/1998 pg 54	Directive 98/84/EC of the European Parliament and of the Council of 20 November 1998 on the legal protection of services based on, or consisting of, conditional access.
1999/5/EC OJ No. L 091 07/04/99 pg.10	Directive 1999/5/EC of the European Parliament and of the Council of 9 March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity (The R&TTE Directive)
DECISIONS	
710/97/EC OJ No L 105 23/04/97 p.4	Decision No 710/97/EC of the European Parliament and of the Council of 24 March 1997 on a co-ordinated authorisation approach in the field of satellite personal-communication services in the Community (amended 1215/2000/EC)
128/1999/EC OJ No L 017 22/01/1999 pg 1	Decision No 128/1999/EC of the European Parliament and of the Council of 14 December 1998 on the co-ordinated introduction of a third-generation mobile and wireless communications system (UMTS) in the Community

A.3.4 Constraints from CEPT regulatory activities

A.3.4.1 Introduction

The UK plays an active role in CEPT, participating in all three of the principal ERC Working Groups and many of the subsidiary project teams. The UK has committed to implementing most ERC Decisions and follows many of its Recommendations, for example relating to channel plans for fixed links and mobile services.

A.3.4.2 Impact of CEPT Decisions and Recommendations

Before considering CEPT Decisions and Recommendations in detail, it is helpful firstly to clarify the nature of the two instruments. Unlike EU Directives, CEPT Decisions and Recommendations (commonly referred to as ERC Decisions and CEPT Recommendations) are not mandatory. However, when an Administration agrees to implement an ERC Decision, the requirements of that Decision then become mandatory in the Administration concerned as an International Obligation. Recommendations are at all times for guidance only, although their adoption in practice can lead to *de facto* constraints, particularly with regard to national frequency allocations or channel plans. Whilst the EU has in recent years tended to delegate significant aspects of frequency management to the CEPT, it should be noted that, as identified earlier, this approach is based on an assumption that the implementation of ERC Decisions will be on a sufficiently ubiquitous basis to facilitate the EU's harmonisation objectives. Excessive delay in adopting Decisions, or the failure of these to be adopted on a sufficiently widespread basis, may lead to the EU taking a more direct interventionist approach in spectrum management, as it has already done in the case of 3G mobile and as presaged by the draft new Spectrum Decision.

What then is the likely impact of these Decisions and Recommendations?

Spectrum pricing

The ERC's Radio Regulatory Working Group (WGRR) has been addressing spectrum pricing as part of its remit. Project team RR8 was first established to address Fees and Charges. It issued a report on using spectrum pricing as a spectrum management tool and has subsequently started developing a draft ERC Report on refarming and secondary trading issues and other related topics as indicated in the EU’s package of new directives. A draft document on the subject was circulated at the WGRR plenary meeting in July 2000. It has also issued a report on PMR pricing (early in 2001) and has recently issued a first draft on satellite pricing. The UK has been closely involved in each of these pieces of work.

Refarming and spectrum trading

ERC has decided that secondary trading should be one of the issues it considers in the context of spectrum refarming, and a draft report is currently being developed by

WGRR[17]. The ERC work will take into account developments in non-European countries such as the USA and Canada, along with the potential interest in spectrum trading among CEPT members. The draft report identifies spectrum trading as one measure that might be used in refarming frequency bands (i.e. recovery of spectrum from existing users for re-assignment either for new uses or new, spectrally efficient technologies). It also notes that trading more generally facilitates more efficient use of spectrum, by providing incentives for incumbents to relinquish spectrum they do not require in favour of a new entrant who can make more effective use of it.

However, the report also flags up potential constraints which might prevent a completely free hand in a trading environment, in particular the international and technical factors assessed by the current study.

Dialogue with other European NRAs suggests that the UK is considerably more advanced than other EU Member States in its thinking on spectrum trading. For example, a number of Administrations have expressed the view that they would not envisage change of use in a trading environment. There would seem to be a strong case therefore for the UK to play an active role in the development of policy with ERC at this formative stage, to ensure that its future options are not constrained by adoption of excessively conservative approaches to European policy in this area.

ETO One stop shop facility

In 1996, the European Telecommunications Office (ETO) an administrative arm of the CEPT, established a "One-stop-shop" facility to process licensing for satellite and other liberalised telecommunications services on a pan-European basis. Where adopted by individual NRAs, the OSS procedure provides licence applicants with the following facilities:

- A single point of contact (ETO) for services providers wishing to provide telecommunications services in different European countries.
- Information on licensing procedures in the different CEPT countries
- A single application form in English, common to all countries.
- A single document summarising the results of the procedure, with any licences granted by different NRAs (National Regulatory Authorities) attached.
- A procedure where an answer is given to the service provider in no more than 9 weeks.

In practice, it is unlikely that the OSS would constrain flexibility in spectrum licensing, since spectrum is subject to individual licensing, typically involving selection on the basis of financial (auctions) or other (beauty contest) criteria. The OSS could facilitate the trading process by providing a simplified and centralised approach to telecommunications service licensing where this is required to utilise

17 "Draft ERC Report on Refarming and Secondary Trading in a converging world", Doc CEPT/ERC/RR(01)071 Annex 2

the spectrum which is being purchased. The UK joined the OSS procedure at the end of March 2001.

A.3.5 Bilateral considerations

Radio signals do not respect national boundaries and it is therefore necessary for the UK to co-ordinate its usage of the radio spectrum with its immediate continental neighbours. In the case of some satellite and low frequency services, co-ordination with countries further afield may also be required. However for terrestrial services above 100 MHz, with which this study is principally concerned, co-ordination is potentially required with the Belgian, Dutch, French and Irish administrations. The UK has already entered into bilateral agreements with these countries for a number of services, notably mobile services such as GSM, and the Band 3 analogue trunked radio services. Similar bilateral agreements are also being negotiated for the core IMT-2000 bands. Three different approaches have been taken, depending on the nature of the services and spectrum being co-ordinated: these are considered below:

i) Co-ordination between mobile and broadcasting services in Band III (174 - 225 MHz)

When the 405-line TV services was discontinued in the 1980's, the UK decided to introduce a new public access mobile radio (PAMR) service in the spectrum that was vacated (Band III). Belgium, France and Ireland continued to operate analogue TV services in this band however, and indeed still do so today. It was therefore necessary for the UK administration to reach agreement with its neighbours on the protection of these services. The approach taken to protecting the broadcasting service in neighbouring countries was based on the determination of a cumulative "nuisance field" determined using statistical methods developed by the CCIR (forerunner of ITU-R). This cumulative figure would take account of all UK mobile base station transmitters within up to 300 km of the neighbouring coastline or border, although in practice interference would be dominated by the closest transmitters.

The situation in Band III was further complicated by the fact that narrow band (12.5 kHz) mobile radio channels were being co-ordinated with broadband (6 - 8 MHz) television channels, and that the protection requirements of the TV channels were not constant over the channel bandwidth but varied by almost 20 dB depending on proximity to the sound and vision carriers. Furthermore, each of the neighbouring countries operated different TV standards, with different sound and vision carrier frequencies. By careful partitioning of the band, so that base station transmit sub-bands avoided as far as possible the most sensitive vision carrier frequencies, the UK was able to maximise the use of the band for mobile services but nevertheless the need to protect broadcast services in France, Belgium and the Netherlands severely constrained PAMR network capacity in the South East and arguably may have contributed to the difficulties experienced by the operators, several of whom had to cease operations or merge with competitors over the years.

The Band III experience is an interesting one as it is likely to have parallels with any attempt to refarm unilaterally the UHF broadcasting bands. This will be considered in more detail in the corresponding case study.

ii) Co-ordination between GSM services in the 900 MHz and 1800 MHz bands

Because the GSM bands are largely common throughout Europe (notwithstanding some outstanding non-GSM operations in the E-GSM and 1800 MHz bands) and common standards are involved, the co-ordination process is greatly simplified. The approach is defined in ERC Recommendations T/R 20-08 (for the 900 MHz band) and T/R 22-07 (for the 1800 MHz band) and involves the agreed apportionment of preferred channels or blocks of channels between the co-ordinating countries. Field strength limits are defined which, for preferred channels, must not be exceeded 15 km inside the neighbouring country's territory and, for non-preferred channels, must not be exceeded at the border. In coastal areas, the co-ordination is based around a line midway between the two neighbouring countries. In practice, variations on this approach (e.g. agreement of alternative field strength limits) may be made. In the UK case, co-ordination typically involves preferred and non-preferred blocks of 1 - 3 MHz. Co-ordination is also required between GSM and other services, notably in the UK case between parts of the GSM 1800 band and transportable fixed stations in France. These are conducted on a bilateral basis taking account of the characteristics of each service (specific details are confidential).

International co-ordination of GSM services is not in practice a major constraint on the use of the GSM bands, since an increasingly large proportion of transmitters serve micro or picocells, which by their nature cover small areas and operate at relatively low power levels. Cellular planning requires intensive frequency re-use over relatively short distances, hence techniques such as antenna downtilt are generally employed, which further reduces the interference exported to neighbouring countries. Optimum use of the available spectrum can be made by operating macrocells on preferred channels and micro or picocells on non-preferred channels. However, this approach may not be feasible if the GSM bands are migrated unilaterally to 3G technologies such as wideband CDMA, since the 5 MHz channel used for the macro layer may encompass both preferred and non-preferred GSM blocks. This is considered in more detail in the case study.

iii) Co-ordination between 3G mobile services

3G mobile differs from GSM in that the radio frequency channels have much greater bandwidth (5 MHz compared to 200 kHz) and the same radio channel is used in each cell, relying on code division multiple access (CDMA) to differentiate between different users. In practice, more than one radio channel is deployed (UK networks have between three and four), but these are distributed between cellular layers rather than between individual cells. In other words, if an operator has 3 radio channels, it is likely to use one exclusively for all its macro cells, one for all its micro cells and one for all its pico cells. It is therefore not practical to co-ordinate on the basis of preferred channels alone, and co-ordination on the basis of CDMA codes is therefore proposed.

The approach is defined in ERC recommendation ERC/REC 01/01. This defines field strengths above which co-ordination on the basis of CDMA codes is required, and also allows for the possibility of preferred frequencies to be designated. This might, for example, allow for agreement that a frequency used for macrocell coverage be used for picocell coverage in a neighbouring administration, and vice-versa. This would tend to minimise the likelihood of interference arising between the two. Decision 01/01 also defines a "blanket" field strength level below which non-CDMA systems may be operated without co-ordination. The field strength is defined as anywhere within the neighbouring country.

As with GSM, the Recommendation allows for administrations to reach bilateral agreements which differ from the criteria specified. Indeed it is noted in the Recommendation that such bilateral agreements might typically lead to permissible field strengths up to 15 - 20 dB higher than those specified.

The following table summarises the current use of the main bands of interest in the UK and neighbouring countries. It can be seen that in most bands there has been good progress towards alignment with the European Common Allocation Table (ECAT).

However, significant differences exist in the use of some of the bands, for example Band III which is used for broadcasting in all neighbouring countries, and the 28 GHz band which is used for FWA in the UK but for fixed links in neighbouring countries. The migration from analogue to digital television is likely to take place at different times in the different countries and may lead to different services being deployed in Bands IV / V following the cessation of analogue TV transmission in one or more countries. The introduction of new services in the bands is noted in the ECAT and there would seem to be a good opportunity to initiate dialogue within CEPT on how this band might be used in the most flexible manner, whilst protecting the incumbent TV services. Clearly a co-ordinated approach to refarming part of the band, in a similar fashion to that being pursued in the US would be beneficial.

Band	Sub-band (MHz)	Current UK use	CEPT allocation	F usage	B usage	IRL usage	Comments
Band III (PMR/ PAMR)	174 - 216	Mobile (PMR & PAMR)	BROADCASTING MOBILE	TV Broadcasting	TV Broadcasting, DAB (blocks 6C, 6D, 9C	TV Broadcasting	Bilateral agreements exist with Belgium, France and the Netherlands for UK operation of analogue PMR / PAMR. These will need to be revised if new services are introduced into the band.
Bands IV / V TV B'cast	470 - 590	TV Broadcasting (channels 21-35) Some SAB use	BROADCASTING Mobile (SAB only)	TV Broadcasting	TV Broadcasting	TV Broadcasting	Use of band to be reviewed in ERC for possible future applications after introduction of DTB
	590-598	Airport Radars Also used in some geographic areas for TV Broadcasting (Channel 36)	BROADCASTING Mobile (SAB only)	TV Broadcasting	TV Broadcasting SAB	TV Broadcasting SAB	Radar use only in the UK, allowed under RR footnote S5.302, which requires all new assignments to be co-ordinated with Germany, Belgium, Denmark, Spain, France, Ireland, Luxembourg, Morocco, Norway and the Netherlands.
	598-606	TV Broadcasting (channel 37)	BROADCASTING Mobile (SAB only)	TV Broadcasting	TV Broadcasting SAB	TV Broadcasting SAB	
	606-614	Radioastronomy	BROADCASTING Radioastronomy Mobile	TV Broadcasting	TV Broadcasting Radioastronomy	TV Broadcasting	Although there is currently no TV broadcasting on this channel in the UK, there are high power transmitters in neighbouring countries (e.g. Lille, 300 kW),
	614 - 854	TV Broadcasting (channels 39 - 68) Some SAB use	BROADCASTING Mobile (SAB only)	TV Broadcasting	TV Broadcasting SAB	TV Broadcasting SAB	CEPT co-primary allocation to MOBILE above 838 MHz, but limited to tactical radio relay systems.
	854 - 862	SAB	BROADCASTING Mobile (SAB only)				CEPT co-primary allocation to MOBILE, but limited to tactical radio relay systems
GSM	880-890 / 917 - 925	E-GSM Band (some residual TACS use)	MOBILE	Defence systems ?	Tactical and transportable Radio Relays (defence); Assigned to GSM operators but not yet taken up used	To be assigned to GSM or 3G mobile operators	Identified at WRC-00 as expansion spectrum for IMT-2000
	890 - 915 / 925 - 960	GSM core band - fully utilised	MOBILE Radiolocation	GSM	GSM	GSM	Harmonised pan-European band. Identified at WRC-00 as expansion spectrum for IMT-2000
	1710-1785/ 1805-1880	GSM 1800 band - fully utilised except for top 3.5 MHz (DECT guard band)	FIXED MOBILE	GSM (upper part) Defence Systems (tactical radio relay)	GSM	GSM	Identified at WRC-00 as expansion spectrum for IMT-2000
IMT-2000	1900-1980/ 2010-2025/ 2110-2170	IMT-2000	FIXED MOBILE	IMT-2000 Some residual defence use	IMT-2000	IMT-2000	Harmonised pan-European band.

Band	Sub-band (MHz)	Current UK use	CEPT allocation	F usage	B usage	IRL usage	Comments
2.6 GHz	2520-2670	SAB Trans-Horizon links	FIXED MOBILE exc aero	SAB (video links)	Fixed Links (ITU-R rec 283 Helicopter links	TV Retransmission Systems (MMDS)	Designated as expansion spectrum for IMT-2000 at WRC-2000
3.5 GHz FWA bands	3400-3600	FWA: 3425 – 3422 paired with 3475 - 3492 MHz -	FIXED FIXED-SATELLITE (S-E) MOBILE Major use Fixed Links and FWA Systems	FWA: 3465-3495 (subs) paired with 3565-3595 (base)	FWA: 3450-3500 paired with 3550-3600 MHz. Remainder defence systems and helicopter links	FWA: 3410 - 3435 paired with 3510 - 3535, and 3475 - 3490 paired with 3575 - 3600 MHz. Remainder fixed links (RTE)	
5 GHz band	5150 - 5350	Aero Radionavig HIPERLAN MSS Feeder Links	MOBILE FIXED-SATELLITE (E-S) Major use HIPERLAN	HIPERLAN MSS Feeder Links	HIPERLANs	HIPERLANs	200 mW EIRP limit, intended for indoor use only
	5470 - 5650	SAB HIPERLAN planned	MARITIME RADIO-NAVIGATION Radiolocation	Defence systems	Ground based weather radars	HIPERLANs	Planned for HIPERLANs - 1W limit, indoor / outdoor use
	5650 - 5725	SAB HIPERLANs planned	RADIOLOCATION Amateur	Amateur	Amateur	HIPERLANs	Planned for HIPERLANs - 1W limit, indoor / outdoor use
	5725 - 5875	Radars ISM	FIXED-SATELLITE (E-S) RADIOLOCATION Amateur, Mobile	Amateur SRDs Traffic info systems	ISM Amateur Traffic Info systems	ISM SRDs Traffic Info Systems Amateur	Possible future FWA band?
28 GHz band	27500 - 29500	Broadband FWA	FIXED FIXED-SATELLITE (E-S) Major use: fixed links	Fixed service (type unspecified)	Planned for fixed links and FWA	Planned for fixed links	
40 GHz band	40500 - 43500	Planned for MWS	BROADCASTING BROADCASTING-SATELLITE FIXED Major use: MVDS		Planned for MWS	MWS and MVDS under consideration	Proposed harmonised band for MWS services.

B MARKET BASED SPECTRUM MANAGEMENT IN NORTH AMERICA & AUSTRALASIA

B.1 Introduction

This section draws out lessons for the UK from experience in the US, Canada, New Zealand and Australia with respect to market approaches to spectrum management. The specific questions addressed are

i) How does each country deal with requirements to comply with international regulations and bi-lateral co-ordination of spectrum use in cases where users have been given considerable flexibility in the services and technologies that may be used in different bands?

ii) What approaches have been used to define overlay rights?

iii) What information on assignments is publicly provided and how is this information accessed?

iv) How is interference managed for tradable licences?

A description of the approaches to spectrum trading used in the different countries is provided later in this section.

B.2 Constraints from international co-ordination & service / technology flexibility

B.2.1 International Constraints

For the countries under consideration there are two levels of international constraint that apply, namely the ITU Radio Regulations and requirements for bi-lateral co-ordination. There are no mandatory or even voluntary harmonisation arrangements that are comparable to those that apply in Europe through CEPT and the EU. The table below summarises the situation in each of the four countries with respect to international constraints on spectrum use. In all cases legislation concerning radiocommunications gives the respective governments powers to enforce compliance with the ITU RR. In New Zealand this was not made clear in the initial legislation setting up the system of property rights in spectrum, but has since been clarified in amendments to the legislation.

Methods for Dealing with International Constraints

	ITU RR	Bi-lateral Co-ordination
US	Government retains administrative rights over spectrum and has powers to reallocate in line with ITU RR	Co-ordination required along north and south borders.
Canada	Government retains sovereign rights over spectrum. Has powers to reallocate in line with ITU RR	Co-ordination with US required
Australia	Provisions in legislation for cancelling licences and compliance with National Plan and ITU RR	Only for very low frequencies (e.g. HF broadcasting) and satellites
New Zealand	Provisions in legislation for cancelling licences and requiring compliance with ITU RR	Only for very low frequencies (e.g. below 30MHz) and satellites

Bi-lateral co-ordination does not come into play for Australia and New Zealand for terrestrial services above 30 MHz, due their relative geographic isolation.

The US and Canada have co-ordination arrangements that involve one or both of the following approaches

i) Block & Zone. This refers to the situation where within a predefined sharing zone (typically 120km on each side of the border for the land mobile service) spectrum blocks are identified for exclusive use of each country. The size of the spectrum block allocated to each country is normally 50% of the total spectrum everywhere except where demographic considerations (i.e. relative populations) dictate differently.

ii) Power flux density (PFD) limit at the border.

In each case, the underlying principles in developing sharing agreements are the same, namely:

1. to maximum the use of spectrum in each country,
2. to minimise possibility of interference,
3. to minimise burden of co-ordination on each regulatory agency,
4. where a limited number of operators provide service (e.g. Cellular/PCS), to provide a general framework for spectrum sharing to the operators leaving the responsibility of detailed co-ordination with the operators. The Government Agencies (i.e. Industry Canada & FCC) provide for the resolution of any disputes between the operators.

As in Europe, not all North American spectrum allocations are harmonised. For example, in the US, the 220-222 MHz band is identified for mobile use and in Canada it is used by amateurs. The frequency band 3400-3700 MHz is identified for fixed wireless access (FWA) in Canada, shared in parts with radars, whereas it is used solely for radars by the US Government. In the first case the Block and Zone approach is used, whereas in the second case the sharing is technically complex and requires use of interference mitigation techniques to share the spectrum between FWA and the radars. Even within the US, sharing between Government / Military systems and commercial networks has proved particularly difficult, and is continuing to delay the licensing of 3G mobile systems in the IMT-2000 bands.

Use of the broadcasting bands is also not the same in the two countries. For example, in the US, spectrum for TV channels 13-20 (470-512 MHz) has been available for use by mobile services in 13 major cities. These channels are protected in the US/Canada border area for broadcasting use. Further, the US has identified use of TV channels 60-69 for public safety and commercial mobile services subject to transition of DTV. The Canadians appear to be following the US approach in these bands[18].

B.2.2 Service and Technology Flexibility

The trend is to provide flexibility in services and use of technologies in all the countries reviewed. The absence of bilateral co-ordination constraints makes this easier to achieve in New Zealand and Australia, although the small size of both these markets means that services tend to be introduced after world market leaders and they invariably adopt technologies developed elsewhere – particularly in the US and Europe (Australia has both GSM and CDMA cellular networks, for example). This also occurs the case in other small countries, such as Hong Kong, that are more constrained by bi-lateral co-ordination requirements[19].

However, in both Australia and New Zealand potential flexibility is constrained by the way spectrum is packaged for auction. This is done so as to facilitate the most likely use or uses of the band under consideration and so does not result in a technologically neutral outcome. Likely use is judged by the availability of equipment and typical international use of the band. In Australia, "Standard Trading Units" of spectrum are defined which are intended to accommodate all likely uses, whereas in New Zealand larger packages of spectrum that are thought likely to have immediate utility are put out to tender (e.g. TV channels in UHF broadcast bands, blocks of cellular go/return channels in 800/900 MHz bands).

In the US and Canada decisions concerning the degree of service and technology flexibility that may be offered are generally taken on a case by case basis. This allows consideration of factors such as compatibility among the services allowed within the band, availability of equipment, impact on other services in adjacent

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18 Proposal to introduce mobile service on a co-primary basis with the broadcasting service in the frequency band 746-806 MHz, Industry Canada. Protection criteria have been developed between Canada and the US and are given in section 13 of the "Letter of Understanding Between the FCC and Industry Canada related to the Use of the 54-72 MHz, 76-88 MHz, 174-216 MHz and 470-806 MHz Bands for the Digital Television Broadcasting Service along the Common Border". See www.strategis.ic.gc.ca/SSG/sf05374e.html.

19 In Hong Kong the regulator takes a technology neutral approach to licensing. For example, US and European systems have been deployed for 2G and Japanese and European cordless telephone technologies are used.

bands, co-ordination requirements etc. when deciding how much flexibility can be offered to licensees.

As mentioned above, these considerations have resulted in some differences between the US and Canada in the use of a number of bands. However, it would appear that more often the development of services and equipment for particular bands in the US results in demand for similar spectrum allocations in Canada.

B.2.3 Example: Canadian 24 and 38 GHz fixed service bands

Flexible, tradable and divisible licences to provide services in the 24 and 38 GHz bands have been auctioned. The services provided must be fixed terrestrial services, however services may be point to point or point to multi-point. There are no restrictions on the type of service that may be provided or the technology that could be deployed. Block licences were assigned (i.e. exclusive assignments of blocks of spectrum within a defined geographic area). Boundary conditions for interference protection were applied at the edges of licensed areas and emission limits at the channel block edges. Individual transmitters need not be licensed but technical and site information must be submitted to the NRA for international co-ordination purposes.

Licensees were expected to use the spectrum to provide broadband fixed services and so the frequency band structure was designed to accommodate this and the use of equipment developed (or in some cases being developed) for the US market. However, licensees have the flexibility to trade spectrum should market and technology developments demand a different frequency configuration.

The bands are co-ordinated with the US where there is similar use of the bands. The sharing zone is about 50km either side of the border.

B.2.4 Conclusions

All of the countries under review must comply with the ITU Radio Regulations. However, these regulations allow a considerable degree of flexibility – far more than is currently the case in the UK. The flexibility achieved in Canada and the US is within the constraints posed by the need for bi-lateral co-ordination. The fact that Canada tends to follow the US in its spectrum use makes this co-ordination easier to achieve than would otherwise be the case (there are also fewer parties involved than in the UK / European case). Nevertheless differences in use do occur. In these circumstances each NRA must make a trade-off between the spectrum efficiency and equipment cost/availability advantages of harmonisation and the economic and social advantages of supplying non-harmonised services that are more highly valued in its own country than in the neighbour.

The UK will also have to make these trade-offs when deciding the degree of flexibility to be offered to licensees. The spectrum efficiency cost tends to be lower the higher the frequency range in question. The economic costs however depend more on the distribution of population near borders and coastlines.

B.3 Overlay Licences

B.3.1 Introduction

Overlay licences are licences for a block of spectrum which are encumbered by existing licensees which typically have apparatus licences (i.e. site specific licences such as fixed links or broadcast transmitters). The issues that need to be considered in granting overlay licences are

i) The rights of incumbents to interference protection

ii) The duration of incumbents' licences

iii) The new entrants rights to interference protection

iv) The grounds on which the new entrant may ask the incumbent to vacate the spectrum

Analysis suggests that giving new entrants a right to move incumbents with compensation, and/or giving incumbents a time limited right to stay is more efficient than simply giving incumbents a right to stay. This means the new entrant may be faced with the cost of relocation but is not held up to indefinite negotiations with incumbents trying to extract the full value of the spectrum.[20]

Overlay licences have been awarded in all four countries reviewed. The arrangements in each case are described below. They have the following common features

- Incumbents' rights are time limited (2-5 years)
- Incumbents must be paid compensation to vacate the spectrum before their licences have expired
- New entrants must offer incumbents the same interference protection as they had originally whilst they remain within the spectrum
- New entrants are similarly given the same level of protection from interference as would other site licensees in the band

B.3.2 US approach to overlay licences

The FCC is moving from site-by-site to geographic area licensing via overlay rights. This in part this reflects a change of use from radio relay services, licensed on a link-by-link basis, to area exclusive services such as PCS and FWA. Overlay geographic licensees must protect adjacent area licensees and incumbent site-by-site licensees from interference. Site-by-site licensees must protect other site-by-site licensees and overlay geographic licensees. Both overlay and site by site licensees must comply with service specific rules. Incumbents may not expand existing site-by-site service beyond existing interference contours.

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20 Efficient Relocation of Incumbents, P Cramton, E Kwerel, J Williams; University of Maryland and the FCC. October 1996.

Incumbents' rights to stay have typically been time limited. For example, incumbent microwave link users were given 3 years to stay in the case of broadband PCS extended to 5 years for public safety incumbents. Negotiation was voluntary initially and mandatory in the final year. Perhaps not surprisingly some public safety users were able to negotiate very favourable arrangements for moving.

B.3.3 Australian approach to overlay licences

Overlay rights have been created in bands where new allocations have been made. By law incumbents have a minimum of 2 years notice to vacate the spectrum, but have no right to compensation. During this two years the NRA works with the incumbents to find suitable new spectrum, or the new entrant may buy them out. Although the NRA expects new entrants to try and accommodate incumbents, in practice most prefer to buy them out.

B.3.4 New Zealand approach to overlay licences

Management rights were created which allowed users to manage blocks of spectrum. Any incumbents in these blocks were given "incumbency" rights, i.e. the right to retain a licence under the new management right if they had an apparatus licence at the time the management right was created and in some cases if they had a licence before 1st July 1989. For TV, radio and mobile telephony spectrum these incumbency rights are 20 years in duration and are subject to payment of a "resource rent". Otherwise incumbency rights are 5 years duration and no rental is paid.

B.3.5 Canadian approach to overlay licences

Industry Canada's Spectrum Transition Policy recognises the need to provide a "reasonable period of notification" for the displacement of incumbents. The notification period is a minimum of two years. In the case of PCS licences which were auctioned with incumbent fixed link users, incumbents that had been operating for less than 10 years were given a 4 year notification period, while others had a two year notification period. New entrants were allowed to negotiate with incumbents to move before the end of the notification period.

B.4 Public availability of information on spectrum licensing

In Australia and New Zealand there are publicly available on-line databases of assignment information for spectrum and apparatus licences[21]. These facilitate trading and the registration of legal entitlements to use spectrum. In Canada there is a publicly available database of licences auctioned and corresponding licensees. A similar situation applies in the US. With the advent of spectrum leasing the FCC recognises the need for more detailed databases containing assignment information, and has proposed that this should be managed by the private sector.

21 In Australia the database may be purchased on CD-ROM.

B.5 Interference management

The management of interference for tradable spectrum licences in the countries under consideration involves specification of the following:

- Boundary conditions – frequency and geographic
- Conditions that apply to devices / equipment and their location
- The approach to ensuring compliance with interference and equipment requirements
- Allocation of responsibilities for compliance
- The approach to handling and resolving disputes

Some information is given in the table towards the close of this section. One point to note is that in Australia and Canada the approach is based on building up from geographic and (only in the case of Australia) frequency blocks, whereas in the US and New Zealand such standard "building blocks" are not specified. Rather area and frequency parameters are defined on a case-by-case basis for lots auctioned and then licensees have freedom to partition/disaggregate spectrum as they wish subject to meeting specified overall interference constraints.

Concerning the allocation of responsibilities for interference management, in all cases licensees are expected to resolve disputes but if this is not possible then some form of arbitration applies. Resolution of disputes through the courts was tried and found not to work in New Zealand.

B.6 Approaches to Spectrum Trading and Secondary Markets

B.6.1 USA

Since 1996 the FCC has been introducing measures to encourage secondary markets in spectrum as a way of promoting more efficient use of spectrum. The first set of measures comes under the general heading of partitioning and disaggregation rules. The second broad set of measures comes under the heading of spectrum leasing.

Partitioning and Disaggregation

Partitioning and disaggregation rules allow licensees to divide their licences by geography and frequency respectively. They apply in the following services: cellular, PCS, MDS, 800 and 900 MHz specialised mobile radio (SMR), 39 GHz fixed link services, wireless communications services and general wireless communications services (GWCS).

The level of activity promoted by these rules so far is not great. C Bennet, counsel to the Rural Telecommunications Group (RTG), notes that “less than one-tenth of one percent of licences auctioned by the FCC have been through the partitioning or the disaggregation process".[22] She suggests there is no incentive on licensees to partition or disaggregate their spectrum. Three main reasons are given:

- Carving up the spectrum devalues the asset (and licensees may have a view to later sale)
- Licensees may want to serve the area in the future
- Even if they are interested in trading, transaction costs are often too high

R Shiver of Securicor also notes that partitioning and disaggregation are an imperfect substitute for spectrum leasing. He makes the point about devaluing his company's assets by breaking them up. Attempts to extend coverage through management agreements between the licensee and local providers also have high transaction costs. This is partly due to the rules laid down under the FCC's "Intermountain Decision" concerning what is and what is not a transfer of control. The current process takes a minimum of 3 months. The steps involved are

i) File an application for transfer of control for part of whole of a licence holding

ii) There is a 30 day public notice period during which objections may be lodged

iii) If there are no objections, consent will be granted in 90 days

iv) If there are objections the process could take from 6-12 months and even longer.

The FCC is now proposing to modify the rules. Nevertheless, it is thought that disaggregation/partitioning policy has not worked as well as intended and that other ways of stimulating secondary markets are required.

Spectrum Leasing

The FCC has made proposals for spectrum leasing which it is currently consulting on. The final shape of the regime will not be known until the end of 2001. In broad terms the proposals envisage the creation of flexible arrangements for spectrum leasing which leave most but not necessarily all responsibility for compliance with interference, service and technical regulations with the licensee. In order to realise this enhanced flexibility the FCC proposes to relax a range of technical and service rules. The proposals are summarised in the table that follows.

There are many issues for which answers are required, including the balance of rights and obligations between the licensee and the lessee and the extent to which the FCC should have a role in approving transactions. Some respondents have argued that lessees should be responsible for interference and other obligations in those cases where they are running systems. While the 1934 Communications Act envisages the FCC playing a considerable role in ensuring the spectrum is well

22 Transcript of the Public forum on Secondary markets in Radio Spectrum, May 23, 2000

managed, this is at odds with current policy aimed at facilitating market arrangements with low transaction costs.

The FCC has not proposed a system of property rights mainly because users prefer a leasing approach and also partly because a property rights approach would not be feasible under Section 301 of the 1934 Communications Act. The purpose of the Act is to “maintain the control of the United States over all the channels of radio transmission” and “to provide for use but not the ownership thereof”. Licensees must therefore waive claims to use any frequency as against the regulatory power of the US.

Nevertheless, it should be noted that licensees providing public services in effect have their licences in perpetuity. Ten year licences are auctioned but then can be renewed repeatedly for 10 year periods. Licensees would only be displaced if the service was discontinued (e.g. as with analogue mobile and TV services).

B.6.2 Canada

In Canada, licences assigned through auctions have what are called enhanced privileges. These include rights to divide and transfer licences if certain conditions are met. The conditions are:

- All eligibility criteria and licence conditions that apply to the licence, including those related to interference management, will continue to apply if the licence is transferred
- Compliance with any spectrum caps imposed by the NRA
- Duration of new licences is that time remaining on the original licence
- Written notification of transfers and documentation attesting that the above conditions have been met must be submitted to Industry Canada

There are no plans to extend these privileges to other licensees who generally have apparatus and not spectrum licences.

Auctioned licences offer the maximum service and technical flexibility possible within the Canadian spectrum plan. Boundary conditions define interference that may be caused and received, though users are encouraged to augment these conditions so as to maximise their use of spectrum. Industry Canada (IC) maintains a publicly accessible database listing all auctioned licences and the current licensees.

The Canadian government retains sovereign rights over the spectrum and can, under Section 40 of the Radiocommunications Act, implement any reallocation required under international regulations (or to meet national security concerns). Government has committed to renew licences (which have a 10 year duration) unless they are breached, a reallocation is required under ITU regulations or there are overriding policy factors (e.g. national security requirements for the spectrum). IC will start consultations on renewal no later than 2 years before the end of the licence term.

B.6.3 Australia

Australia has adopted a property rights approach to secondary trading in bands where spectrum has been auctioned. Spectrum blocks are built up from fundamental trading units called Standard Trading Units (STUs). The size of an STU varies by band and depends on the services likely to be provided. A technology neutral approach to spectrum licensing is adopted. A mix of US and European technologies are used, for example, for cellular services.

Third party use of spectrum held by a licensee is permitted. Apparatus licences, which are issued on a first come first served basis, are also tradable. The Government retains the right to vary or cancel licences (in some cases with compensation) and this ensures that ITU obligations can be met if this is not already the case. In practice, there has been relatively little trading to date. This is not surprising given the abundance of spectrum for both existing and new services.

B.6.4 New Zealand

A property rights regime has been adopted involving two tiers of rights – management rights and licences. Third party use of licensed spectrum is also permitted. Most of the management rights are still held by the Crown, which also owns the frequencies. Requirements for compliance with ITU regulations are made explicit in legislation and licences. There has been very little trading between users and no shifts between uses, probably for the same reason as in Australia.

Approaches to Secondary Trading in Australia, Canada, New Zealand and the US

	USA	Canada	Australia	NZ
Nature of rights	Spectrum usage rights which may be leased in whole or part without prior Commission approval. Control stays with original licensee. Ultimate administrative right rests with US gvt - para 304 of Act. Swaps and cross leasing might be permitted. Band manager licensing introduced where leasing is core function.	Exclusive transferable and divisible licences are assigned for blocks of spectrum. Licences divisible in the geographic dimension in terms of Spectrum Grid cells specified by Industry Canada.	Mutually exclusive spectrum access rights. Spectrum licences defined in terms of - frequency bandwidth, longitude, latitude, time. Sharing managed by the access right holder. Standard trading units created by the NRA that are divisible (e.g. in time) and can be aggregated. Licensees do own planning. and planners are accredited.	Property rights regime. Management rights - exclusive right to manage a national band of frequencies. Created by the Minister. Tradable licence issued by manager to transmit radio waves Administrative licence i.e. apparatus licence. Provision to allow licensing of frequencies rather than apparatus
Type of licence	Exclusive authority, spectrum (area) and apparatus (site by site) licence. Moving to greater use of area-wide licences via overlay rights. Excludes public safety radio, amateur radio, personal radio and maritime and aviation services. Also assume gvt use under NTIA is out??	Spectrum licence. No change to the traditional apparatus licence regime.	Spectrum licences – exclusive built up from STUs. Third party operation permitted. Tradable apparatus licences. Third party operation of devices permitted with necessary authorisation.	Management rights defined in terms of certain emission parameters for the given frequency band - emission mask and power levels. Crown is owner of frequencies to which management right relates. Manager has sole right to grant licence in bands for which it has rights. Licences are registered if they comply with general requirements. Third party use allowed.
Transfer of control	Transfer of de facto and de jure control is subject to FCC approval. Control relates to control of spectrum not facilities. FCC to propose essential rights and obligations that licensees must retain as part of lease agreement.	Written notification of transfers must be submitted to IC. Documentation certifying that the transfer is compliant with licence conditions and ownership constraints must be submitted. Once transfers are registered the original licence is amended and a new licence issued.	Permitted through the secondary market with no NRA intervention. Trade must be registered with and trading form approved by NRA. Apparatus licences may be traded subject to ACA approval. There is a right of appeal against ACA decisions.	Through registration
Aggregation/ Partitioning	Leasing allows partitioning/disaggregation. Aggregation could happen by being a multiple lessor.	Yes permitted.	Licensee can do this - all planning within a holding of rights is the licensees responsibility	Can do for management rights and tradable licences.
Duration	Auctioned licences 10 years duration. They are renewable. For leases duration must be less than or equal to the duration of the lessor licence. Contingent renewal beyond duration permitted.	Auctioned licences are for 10 years with strong expected of renewal for a further 10 years. Duration of transferred licences is time remaining on original licence.	Up to 15 years after which spectrum licences reallocated and no guaranteed right of renewal Apparatus licences up to 5 years and may be renewed	Initially up to 20 years. Now could be perpetual for management rights/licences. Apparatus licences – annual

Technical parameters	As in the lessor licence (e.g. tower height, power, equipment, emission masks etc). FCC asks whether need to have due diligence by licensee, lessee certification etc. to ensure compliance. In last 5-6 years FCC has reduced technical constraints so that they are now very general emission limits and the like.	Boundary conditions and radio interference management rules are to be developed on a case by case basis (under the auspices of the Radio Advisory Board of Canada) in response to a pre-auction consultation. Outbound signals at licence area boundary should fall below a given level. Conditions on the inbound signal (e.g. antenna height, characteristics and transmit power constraints) will also apply. Out of band emission limits will apply.	Emission limits set. In band emissions regulated by devices having emissions of given strength within the spectrum space, taking account of topography. Out of band emissions - and intermodulation interference based on maximum radiated power, location of transmitter/receiver. Max power levels set for out of band interference. Devices must be registered and licensees self-certify that will not cause unacceptable interference. Apparatus - usual constraints	Various limits for management rights and licences, and administered licences. When management rights registered must have certificate confirming will not endanger various services. Likewise for licences.
Method of changing technical/interference parameters	Uncertain as to whether licensee or lessee to negotiate changes and co-ordination and otherwise resolve interference matters. FCC seeking ways of making technical rules more flexible so spectrum becomes more fungible.	Technical parameters set are trigger values set conservatively to minimise the potential for interference. Communications between licensees to change the parameters can be triggered when changes to distance or pfd parameters are requested.	Licensee may propose changes to NRA who will incorporate if demonstrated workable	For management rights – need Secretary of State approval, consent of the neighbour and certification. Changes to licence parameters .(emission limits and frequencies) can be made with agreement of the manager and certification re effects.
Service/technology constraints	As in the lessor licence. Options - either apply to lessee, and perhaps require licensee to undertake due diligence, apply to both or apply less onerous rules to the lessee. (Eligible licensees, roll-out requirements, private/public services, international treaty obligations, spectrum caps, roll-out obligations, USOs, emergency calls etc). FCC relaxing its rules to allow more services to co-exist on a case by case basis. May allow lessees to operate completely different services. For example, allow non-interfering new services/technologies.	Spectrum licences made as flexible as possible within the constraints of the Canada Spectrum Allocation Table. Apparatus licences are service specific.	None in spectrum licences - competition issues dealt with by ACCC Apparatus licences are service specific - usually site based	In theory none, though channel plans tend to dictate the services and technologies that can use the spectrum Administered licences are service specific
Compliance	With licensee, though have proposals to make lessee also liable/accept FCC oversight and require certain actions by lessee to show it is compliant.	With licensees	With licensee.	With rights holders
Process for enforcing interference condns	Licensee is responsible. Normal FCC processes then apply.	With licensees to sort out if they can.	Licensees to sort it out if they can.	Manager can revoke licence if breached.

Process for dealing with disputes between licensees	Courts, arbitration, conciliation	Arbitration by IC in cases where disputes cannot be resolved.	Licensees expected to work out problems. If they cannot agree NRA may intervene and appoint an independent conciliator. Civil actions for damages possible.	Dispute resolution procedure finally ending in compulsory arbitration if agreement cannot be reached
Method for dealing with international obligns/co-ordination	Licences must comply with ITU RR. Co-ordination on borders required.	Licences issued are compliant with Allocation Table. Section 40 of the Radiocommunications Act gives government right to reallocate spectrum to meet international obligations	All licences must be compliant with national spectrum plan.	Licences must be compliant with IRRs at time of issue and as they change.
Licence variation/cancellation	Under Communications Act Government has power to change/cancel licences.	See above plus non-renewal of licences only decided after consultation.	All licences can be varied by NRA without agreement or compensation. Cancellation of spectrum licences requires Ministerial approval and compensation. Cancellation of apparatus licences possible by NRA without compensation.	Managers can determine circumstances in which licences may be cancelled (e.g. as a result of changes in international obligns). Usual arrangements with apparatus licences.
Process for making a trade – approvals etc	Now looking to put in place arrangements that do not require FCC approvals.	Register the trade	Register the trade	Register the trade - certification that will not contravene the Act, cause undue interference etc.
Information publicly available	Have a no of databases with licences and licensees on them but little about actual spectrum use. Think private sector should develop and maintain databases e.g. band managers. FCC may encourage private information clearinghouses.	On-line database of licences and licensees	Public database of assignments - holds STU information and apparatus licence info	Register records management rights, licences, and particulars of transfers. This establishes legal title. Registered licences require a certificate from an approved engineer that exercise of rights will not cause harmful interference. Register has details of all licences – apparatus and spectrum.

C TECHNICAL FACTORS AFFECTING SPECTRUM MANAGEMENT

C.1 Introduction

The most important tenet of the Radio Regulations is that the spectrum, being a limited resource, should be used efficiently and equitably. In order to achieve this the main technical consideration concerns the interference environment and its relationship with the technology employed.

Use of the radio spectrum is dependent on frequency, spatial location, time and signal separation. Sharing is accomplished when one or more of these dimensions provides sufficient isolation. The following table shows some of the methods which can be used to facilitate sharing, a number of which have been formally recognised by the ITU (ITU-R Recommendation SM.1132-1, "General principles and methods for sharing between radiocommunication services or between radio stations").

Methods to facilitate sharing

Frequency separation	Spatial separation	Time separation	Signal separation
Channelling plans Band segmentation Frequency agile systems Dynamic sharing: ▪ dynamic channel assignment (1) Frequency division multiple access (FDMA) Control of emission spectrum characteristics Dynamic variable partitioning Frequency tolerance limitation	Geographically partitioned allocations Minimum site separation for co-channel systems Antenna system characteristics: ▪ adaptive antenna and polarisation discrimination ▪ antenna pattern discrimination Spatial division multiple access (SDMA) Physical barriers and site shielding	Duty cycle control Dynamic channel assignment (1) Time Division Multiple Access (TDMA) Synchronisation of co-frequency TDMA systems Collision avoidance protocols ("listen before transmit")	Signal coding (2) and processing FEC Interference rejection Code Division Multiple Access (CDMA) Spread spectrum: ▪ direct sequence ▪ frequency hopping ▪ pulsed FM Interference power / bandwidth adjustments: ▪ co-channel ▪ dynamic transmitter level control ▪ PFD limitation and power spectral density (PSD) limitation (energy dispersal) Antenna polarisation

(1) Dynamic real-time frequency assignment facilitates sharing by simultaneously using frequency and time domains. Therefore, this method is shown in both columns.

(2) Coding techniques may also be applied to frequency, spatial and time separation technology.

Spectrum management aims to provide an acceptable interference environment and at the same time ensure that the spectrum is used efficiently. From a purely technical point of view spectrum utilisation (for an application) can be defined in terms of the bandwidth used, the space (area or volume) taken up[23] and the time for which it is used. The spectrum efficiency is then the amount of information conveyed over a distance related to the spectrum utilised.

C.2 Interference considerations

The effect of interference of one system on another is determined by:

- the transmit characteristics of the interfering source (including the transmitter power level, bandwidth, modulation characteristics, height / directionality of the antenna and location)
- the propagation behaviour of the transmission path along which the interfering signal travels (bearing in mind that this is not necessarily line-of-sight and maybe due to anomalous propagation conditions) including terrain / clutter and climatic conditions
- the characteristics of the receiver experiencing the interfering signal (including the level of the wanted signal received from its associated transmitter[24], the noise floor of the receiver, the receiver bandwidth and the modulation characteristics being used, height / directionality of the antenna and location)
- the availability requirements of the wanted link and how these are related to the demodulator behaviour in the presence of noise and interference – these requirements often translate into long term and short term levels of permissible interference, where the latter is due to anomalous propagation or the dynamic behaviour of one or other system.

The above fundamentals relate to single entry interference. In the case where the interference is due to multiple sources it is necessary to aggregate the interfering power. In addition it is not necessarily the case that the situation is static. Other factors that therefore need to be considered include the mobility of sources and victims, their density and distribution.

These basics apply to the situation where co-frequency operation is being considered (including the case where the transmit channel of the interfering source overlaps with the receiver channel). The situation also applies with respect to adjacent channel and dual polar operations where the transmit and/or receive out-of-band and cross-polar behaviour needs to be known.

Consideration of the complete situation can lead to a very technically efficient use of the spectrum if all relevant parameter values are known and can be manipulated (controlled). This however is at the expense of flexibility and economic cost amongst others.

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23 Space within which other users are not able to share.

24 Noting that this will be influenced by the propagation characteristics on the wanted path.

Homogeneity of characteristics is known to lead in nearly all cases to the most efficient use of the spectrum – but this is a counsel of perfection. What are the options in terms of defining service constraints, particularly in terms of the transmitter as it is easier to control the parameters through licensing compared to the receiver[25].

Various options for defining limits on systems in order to control the interference environment include:

- Specification of the maximum transmitter spectral power density only. This is appropriate for those applications where omnidirectional antennas are used. It is also appropriate where the interference into a system is due to the aggregation of interference power from multiple sources where these sources are using directional antennas and no one source dominates due to proximity to the victim or due to high directionality. In this case the aggregate interference averages according to the transmitter power and not the EIRP. It is therefore appropriate to specify a maximum transmitter spectral power density rather than a maximum EIRP spectral power density in this case.

  This approach does not allow for the frequency reuse advantages afforded by directional antennas which may be employed both at the transmit and the receive ends of the interfering path. In addition assumptions (most likely worst case) have to be made about other system characteristics of the victim receiver.

- Specification of the maximum transmit EIRP spectral power density only. In the case of highly directional systems, and in particular those which might individually (rather than as an aggregate) cause an interference problem to other services sharing the same frequency allocation, it is necessary to limit the maximum EIRP spectral power density. Frequency reuse may be possible depending on actual deployment. However, this limit in itself does not prevent omnidirectional transmitters operating at the maximum EIRP spectral power density. In this instance the interference may well be controlled to acceptable levels but the possibility of frequency reuse is substantially diminished.

- Specification of the maximum transmitter spectral power density and antenna pattern. In effect this defines the maximum transmit EIRP spectral power density in all directions. Where maximum efficiency is required and it is not necessary to allow extensive flexibility for the systems deployed, this controls the interference environment to the maximum extent possible.

- Specification of a power flux density (or field strength) limit along a boundary (where the PFD is considered to be orthogonal to that boundary), whether between adjacent national "spectrum blocks" or between countries. Insofar as a victim receiver is concerned in most cases there is no real concern about how

25 It can also be noted that the essential requirements of the R&TTE Directive do not allow for receiver characteristics to be specified

interference sources are deployed or operate providing the interference environment is controlled to a level related to the receiver's noise floor. This can be achieved by specifying an absolute power flux density or field strength limit at the receiver. While this method protects the receiver and at the same time allows flexibility to interfering systems it is important to note that it can also sacrifice spectrum efficiency as any discrimination at the receiver due to receive antenna directionality cannot be taken into account. Furthermore, account may not then be taken of the margins available in the various systems.

- Specification of a PFD "trigger[26]" along a boundary. As implied in the previous option the setting of a PFD level has to make an assumption about the characteristics of the receiver. As this knowledge is not known in advance a worst case assumption would have to be made if unacceptable interference is to be avoided. As an alternative it would be possible to specify the PFD level as a trigger level that would be allowed to increase as the result of an agreement between the parties operating on either side of the boundary once the real characteristics of the systems had been taken into account.
- Specification of relevant equipment parameter values (i.e. transmitter power, antennas, modulation / coding, protocols). In general this has the potential to provide the best efficiency in use of the spectrum because more tightly defined characteristics provide a greater control over the interference environment. However this is mainly in the situation where there is still control on the licensing of devices in terms of their location. In the case where devices are licence-exempt and therefore uncontrolled in terms of their location some of this benefit is lost. Clearly the flexibility available to the user is extremely limited, but in the case of global harmonisation, for example, this loss of flexibility might be considered to be an advantage in terms of a more economically efficient market.

It should be noted that all of the above methods take no account of the technical characteristics of the receive system. If there is no a priori knowledge of the receive characteristics it is inevitable that one or more assumptions have to be made in arriving at the limiting values associated with the particular parameters of each method. In the case of the "trigger" PFD level there is at least some flexibility that would allow a relatively efficient use of the spectrum to be achieved. It allows for the PFD level at the boundary to be changed with the agreement of operators on both sides of the boundary.

It is clear from this that there is no single method that will allow for complete flexibility and spectrum efficiency regardless of the types of system being deployed. Complete flexibility is attainable by making few or no assumptions about the characteristics of interfering transmitters and victim receivers but at the expense of spectrum efficiency. On the other hand absolute knowledge of the characteristics of interfering transmitters and victim receivers allows for maximum efficiency in

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[26] A PFD threshold that triggers co-ordination between parties on either side of the boundary.

spectrum utilisation. Even in the case where two systems are not particularly compatible, complete knowledge of their characteristics will allow for the most efficient use of the spectrum under those circumstances. It is this conclusion that has led to the current approach of co-ordination, whereby some knowledge of the equipment to be used along with some worst case assumptions allows for an assessment to be made as to whether the situation needs to be considered in more detail.

The preceding discussion mainly relates to the packaging of spectrum for terrestrial services. In the case of satellite services where very wide area coverage is the norm it is difficult to see how some of the principles of PFD limits at boundaries could be applied other than at a macro level.

The importance of the possible limits described above depends on the circumstances under which spectrum to be licensed is packaged. This then determines the most suitable balance between overall efficiency of spectrum use and the flexibility available to the licensee.

C.3 Propagation considerations

The importance of the behaviour of propagation is directly related to availability requirements

- Some applications require high availability - hence there is a need to satisfy long term and short term interference requirements. In this case anomalous propagation conditions are of importance.
- Some applications where the availability requirement is not so high may be able to accept the effect of interference due to anomalous propagation behaviour. In this case the long term interference is the important consideration.
- More recently there are applications where the availability requirement is determined by a greater user acceptance of the unreliability of communications channels. In this instance, especially where related to the Internet, it is possible to offer a service based on so called “best endeavours”. Under these circumstances the interference environment does not have to be so carefully controlled. Operation in this sort of environment generally relies on adaptive technologies that, as the name implies, are able to move away (in frequency) from interference or wait and try again when the interference changes with time.

Depending on the availability requirements of the application, it can be seen that the degree of control of the interference environment, which is significantly influenced by propagation behaviour, differs. In the case of high availability applications the impact of an interferer is enhanced by anomalous propagation and the consequently the separation distance required between victim and interferer to reduce the interference to acceptable levels can be significant. At the other extreme, where adaptive technologies are available, the interference on a given channel and/or from a particular direction can be very severe. Operation is not prevented, however, as the adaptive technology changes the victim system configuration to avoid the interference thereby allowing operation in a more benign environment.

Examples of links requiring high availability are earth / space links supported by FSS satellite earth stations and fixed point-to-point links supporting trunk telephony traffic. In both cases a required availability of 99.99% or more is common and the resulting short term interference that can be tolerated is often the deciding factor in determining separation distances.

Applications where the availability requirement is not so great include mobile systems. It this case it is more difficult to sustain a highly reliable link anyway and therefore short term interference is of less importance. It can be noted, for example, that when deciding whether two mobile systems need to be co-ordinated, the criterion used is based on the presence (or otherwise) of a specified interfering field strength that is exceeded at 50% of the locations (within any area of approximately 200 m by 200 m) for 10% of the time. It can be seen from these figures that longer term interference is the issue and short term anomalous propagation effects giving rise to interference from other systems are not of great significance.

There has been increasing pressure from Internet Service Providers (ISPs) to use spectrum for wireless Internet access, for both fixed and mobile subscribers. For fixed subscribers there is the more traditional route of using the various parts of the spectrum designated for fixed wireless access. However there has been significant interest in the use of licence-exempt bands even though it is not currently permitted in the UK to use licence-exempt bands for the provision of public services. The attraction of licence-exempt bands is the absence of any fees for their use, combined with the ready availability and relatively low cost of equipment. However the point of interest here is that ISPs consider it feasible to offer a service that would be acceptable to users in a relatively[27] uncontrolled interference environment.

Depending on the nature of this uncontrolled interference environment the techniques used to overcome its effects include frequency hopping (both at a micro {FHSS} and a macro {DFS} level) and network protocols that request repeat transmissions in the event of error. In the event that the utilisation of the frequency band by other services is very intense, both from a geographic and a traffic point of view, the efficacy of these techniques is likely to be reduced.

It can also be noted that some of these techniques are useful in opening up the spectrum to a new service where there is an incumbent service giving rise to an interference environment that is more controlled (i.e. not licence-exempt).

27 Note that there is some control of the interference environment as significant operating parameters (e.g. transmitted power) are constrained.

C.4 Implications of changing the PFD level at a boundary

C.4.1 The scenario

The starting point is that Operator A is permitted to establish a system on one side of a boundary and Operator B is permitted to establish a system on the other side of the boundary. At the boundary an initial PFD level is set.

In order to establish his system Operator A needs to be allowed to create a higher PFD level at the boundary. Operator B agrees to this higher PFD level on the basis that his system, as implemented or planned, provides sufficient discrimination to operate successfully under the new circumstances.

Operator A pays for this arrangement and the value of his spectrum increases whereas the value of Operator B's spectrum decreases.

If Operator B or a subsequent "owner" of Operator B's spectrum decides that the higher PFD level is a constraint on their system development then there is an opportunity to negotiate with Operator A to reduce the PFD level. If successful there would be financial consideration in the opposite direction and the value of the spectrum blocks would change accordingly.

How then should the PFD level be set, and what are the implications of changing it?

C.4.2 Inter-system and inter-service co-ordination

In the first instance it might reasonably be assumed that the operators on either side of a boundary will want to operate up to the boundary itself. Generally, whatever level is set for the PFD at the boundary a transmitter will have to be located some distance away from the boundary in order to satisfy the limit (although in some cases shielding and / or pointing the antenna away from the boundary may be sufficient).

In the case where victim receivers use omni- or near omnidirectional antennas it would be sensible to set the effectively interfering PFD level relative to and some way below the noise floor of the receiver. This might be overly conservative if significant margins are available in the victim system.

In the case where victim receivers use directional antennas it is more difficult to set a PFD level as it is not known a priori whether the directional antennas are pointing towards the boundary or not. If it is assumed that the antennas are pointing away from the boundary then the residual gain towards the boundary will be 0 dBi or less. In this instance it would be appropriate to set the PFD level at the boundary in a similar way to the omnidirectional case (see above) i.e. at a level relative to and some way below the noise floor of the receiver. If however it is assumed that the antenna of the victim receiver points towards the boundary then it will be necessary to lower the PFD level significantly in order to reflect the boresight gain. In this situation the PFD level would arguably be set at a level that constrains the development of the interfering system in order to protect the victim system. However it should be remembered that the situation is two-way: the victim system also acts as an interfering system in the opposite direction. It is therefore in the interests of both systems to negotiate a mutually agreeable PFD level, although there may be commercial reasons for not doing so. This begs the question as to whether there should be two PFD levels at the boundary reflecting susceptibility to the interference environment in the two different directions.

The question also arises as to whether the negotiated PFD level extends along the whole length of the boundary or whether some parts of the boundary can withstand higher PFD levels than others. As soon as one takes account of actual equipment (its location and pointing for example) and the local terrain / clutter rather than the general case, which inevitably has to make worst case assumptions if interference is to be completely avoided, the derived PFD level will reflect the local circumstances. It would not then be appropriate to apply the same value along the whole boundary. After agreement has been reached by the two parties on either side of the boundary, it will be necessary to specify how the PFD level is allowed to vary along the boundary.

C.5 Feasibility of broader service categories

It is considered by some parties that the multitude of narrowly defined radio services that are allocated spectrum restricts flexibility and limits spectrum utilisation. There have been moves to arrive at a set of more broadly defined services based on consideration of technical and operational factors. It is felt that services could be merged if as many as possible of the following conditions are satisfied:

- Compatible RF power level / service area
- Similar or related bandwidth
- Similar protection requirements
- Similar potential for causing interference
- Compatible operation or technical means to overcome incompatibility
- Similar performance requirements

This is much in line with the general rule of thumb that the best spectrum efficiency is obtained when services or systems with homogeneous characteristics share an allocation.

Using more broadly defined services can be considered to be one alternative allocation method. Other allocation methods can also be envisaged. For example, it may be possible to allocate on the basis of spatial characteristics. For terrestrial systems the categories would include point-to-point, point-to-area and possibly other combinations such as area-to-area. For satellite systems the obvious categories are space-to-Earth, Earth-to-space and space-to-space, and possibly geostationary and non-geostationary. While potentially offering great flexibility it is not immediately obvious that most efficient use of the spectrum would be made as the technical homogeneity of the systems operating in the same spatial allocation would not necessarily be there. In the case of satellite systems, for example, the technical characteristics of fixed satellite systems and mobile satellite systems are very different. Sharing the same spatial allocation would lead to severe inefficiencies.

Consideration of more flexible allocation methods is a prelude to investigating the technical implications of introducing various market mechanisms to spectrum management. Several of the proposals in the past relating to spectrum trading have involved little or no change in use from a technical point of view. Under these circumstances there is little or no change to the interference environment and technical issues do not arise.

If market mechanisms are to allow changes in use then the interference implications are potentially very significant. There will be implications for other co-frequency users and adjacent channel (or band) users.

It has been noted that Australia has implemented spectrum trading on the basis of a standard trading unit which is defined in four dimensions: parallels of latitude, meridians of longitude, a standard bandwidth in frequency and time. Most importantly from the technical point of view interference levels have been set at the geographic boundaries of each block. While this approach offers great flexibility and allows for the relatively easy introduction of spectrum trading, it may be inefficient from a spectrum utilisation point of view (not with respect to individual users necessarily but taken as a whole across all users) unless negotiations are allowed to take place in order to vary the interference level at a given boundary such that it reflects the systems being deployed.

One alternative to setting boundary conditions is to require co-ordination to take place between new and existing users in much the same way as the RA undertakes this activity at present. This would however require the public availability of the technical characteristics of existing systems. This approach avoids the lack of efficiency inherent in the more general approach above but at the expense of simplicity.

Similar technical problems arise both within UK (i.e. between different systems operating in geographic/frequency blocks) and between UK and adjacent countries, although in the former case it all remains in the sole jurisdiction of the UK.

C.6 Adjacent channel considerations

While the previous discussion has concentrated on the boundary between two geographic areas where the same frequency band is being used, there is also the boundary between adjacent frequency bands to consider.

In many ways the arguments are similar here. It would be possible to define out-of-band emission limits in absolute terms such that the possibility of interference is avoided. However, as before, such a level would lead to inefficient use of the spectrum in terms of preventing many systems from being implemented and / or requiring the use of extensive guard bands.

As in the case of the in band interference across geographic boundaries, it is appropriate to set a less stringent level that will still lead to guard bands being required but allow operators in adjacent bands to negotiate rights to higher or lower levels of out-of-band emissions.

Out of band emissions may be a particular problem where consumer equipment (e.g. domestic TV receivers) are concerned, as these may have poorer frequency selectivity compared to professional equipment. For example, there have in the past been isolated cases of interference to reception of TV broadcasts on channel 21 due to co-sited paging transmissions in the nearby 466 MHz frequency band. Similarly, localised interference to, or blocking of, mobile terminals may arise if very high power broadcast transmitters are operating in adjacent bands. Care should be taken to ensure sufficient guard bands are provided, for example if migrating parts of the TV broadcast band to mobile services.

C.7 Implications of service characteristics for co-ordination

C.7.1 Point-to-point systems

The significant co-ordination distances that can generally be expected between point-to-point systems arise because of two factors. In the first instance these systems often support high availability links and short term anomalous propagation events therefore have to be taken into account. In addition, particularly for longer links, highly directional antennas are used at both ends of the link and high transmitted EIRPs are used. The longer links are usually established in the lower frequency bands e.g. 4 GHz where a 40 km link would have a co-ordination distance of 200 km or more. At higher frequencies links are shorter as are co-ordination distances, although the latter can still be significant for high availability links. For example, at 38 GHz links are generally no more than around 8 km but the co-ordination range with other point to point links may still be as high as 100 km. It should be remembered however that the probability of interference problems arising within these co-ordination distances is generally small because of the highly directional nature of the antennas used at both ends of this type of link (and therefore at both ends of the interfering path).

Co-ordination between a point-to-point system and a point-to-area system will not be looking for the most serious geometrical alignment mentioned above (i.e. a highly directional antenna at both ends of the interfering path), and may also be able to take advantage of other benign characteristics of point to area systems, such as the use of downtilted antennas at FWA base stations. However, there will still be the case that a highly directional antenna in the point-to-point system can point at the transmitters or receivers in a point-to-area system[28].

[28] The high EIRP of a point-to-point transmitter can be directed towards a victim receiver in a point-to-area system. Alternatively, a receiver (using a highly directional antenna) in a point-to-point system can be pointed at a transmitter in a point-to-area system.

C.7.2 Point-to-area systems

There are three types of point-to-area system - broadcast, mobile and fixed wireless access. Although they fall into this one category they do have their own distinct characteristics that makes it difficult to generalise about the co-ordination of point-to-area systems.

Broadcast - Audio and TV broadcast systems (analogue and digital) operating on a traditional basis employ high power omnidirectional (or wide area) transmitters providing coverage from tall masts and/or hilltops. When planning these systems only a small amount of discrimination is assumed, except in the case of DAB where no discrimination is assumed. These systems are essentially one-way i.e. the user terminal is solely a receiver and does not therefore support a return path over a radio link. Because these systems use high powers to cover extensive areas the rate of fall-off in signal strength beyond the coverage area is slow (in terms of dB/km) when compared to more local systems. Co-ordination distances relating to these systems will therefore be great - of the order of hundreds of kilometres – except in the case of lower power relay stations.

Mobile – Cellular mobile systems tend to operate either side of 1 GHz generally in the range 400 MHz to 3 GHz. Base stations are configured to support macro, micro or picocells using omnidirectional or sectored antennas. Handsets use substantially omni-directional antennas and have to transmit at relatively low power levels mainly for safety reasons but also because they are constrained by battery power (for the same reason they also use ATPC which results in typical transmitted powers 10 – 20 dB below the maximum). In addition, as cellular networks by their nature require intensive re-use of frequencies in adjacent cell clusters, coverage areas supported by base stations tend to be significantly less than broadcast coverage areas and the rate of fall-off in signal strength beyond the coverage area is therefore relatively quicker. The co-ordination distance between two geographically adjacent cellular networks is likely to be similar to the minimum separation distance between cells within a cellular network. This is defined in terms of the cellular re-use factor (i.e. number of cells in a re-use pattern, K) and the cell radius (R), using the formula $D/R = \sqrt{(3*K)}$. In typical high density GSM networks, the value of K is 4, and the maximum radius of a macro cell (determined by the TDMA timing constraints) is 35 km. Thus the co-ordination distance between two GSM networks would be of the order of ($\sqrt{12}$ * 35) = 121 km. In practice, a smaller co-ordination distance may be feasible, depending upon the actual cell radii deployed in the adjacent networks, however this figure is likely to be a realistic starting point if flexibility of spectrum use within a GSM network is to be retained. A similar distance is likely to apply for other types of point to area system using the GSM bands, however for FWA services using higher frequency bands the maximum cell size becomes much smaller (e.g. at 28 GHz this is likely to be < 10 km) and the co-ordination distance correspondingly so – see below).

Fixed Wireless Access - These systems can operate across a wide range of frequencies from 2.4 GHz up to 40 GHz and potentially beyond. The lower frequencies provide relatively narrowband connections to the PSTN over wide areas whereas the higher frequencies support broadband connections over more local areas. Current networks operate in a similar way to mobile systems, in that the links are established through base stations generally using sectored antennas. In this case the user terminals also have a degree of directionality, which can be significant at the higher frequencies. Co-ordination distances for FWA operators corresponding to boundary trigger PFD levels recommended in previous work are 18 km from the boundary at 42 GHz and 27.5 km at 28 GHz for base stations and 10 km at 42 GHz / 16 km at 28 GHz for subscriber terminals. “Mesh” FWA networks have also been proposed which dispense with base stations and use the subscriber stations as repeater “nodes”, in which case only the subscriber co-ordination requirement applies.

C.7.3 Implications

The co-ordination that would be required between the above systems will differ depending on the combination of systems. However it is possible to make some observations on the implications for co-ordination between different systems.

1. Fixed Wireless Access systems offer the greatest possibilities for spectrum efficiency when co-ordinating as they are based on directional antennas both at the base station and the user terminal - although the directionality will not be as great at lower frequencies and the advantage will be diminished.

2. The core of a traditional broadcast system is based on a small number of high power transmitters each of which is designed to provide service to a large area. Signal strength fall-off outside the coverage area is relatively slow (because of the large coverage area) and the interference potential is therefore significant. It is important therefore that any other system sharing the same frequency in an adjacent area is able to provide a high degree of discrimination.

3. The omni-directional nature of mobile terminals provides nothing in the way of discrimination with respect to other systems using the same frequency band. Furthermore the fact that these terminals are mobile means that there is no fixed relationship between an interfering source and a victim receiver. This potentially increases the possibility of unintentional interference unless conservative assumptions are made when establishing sharing conditions and/or control techniques are in place to ensure unintentional or unauthorised transmissions are prevented.

4. The height of antennas will determine whether clutter has a significant impact on the signal. The siting of antennas to take advantage of clutter / local shielding to reduce the impact of interference should be encouraged.

5. Finally, the different economic characteristics of broadcast and telecommunications networks, and their implications for the technical and physical network characteristics, need to be considered. Cellular networks require relatively small cells with intensive frequency re-use to maximise capacity and revenue on the network. A national or regional broadcaster, on the other hand, requires an economic means to deliver simultaneously the same material to the maximum potential audience (an objective that is likely to increase in importance as more competing channels and delivery platforms become available). This implies relatively large transmitter service areas with much more limited frequency re-use, and consequently larger co-ordination zones. Whilst some degree of convergence between broadcast and telecommunications services is anticipated, this fundamental difference in the approach to delivering “one-to-many” and “one-to-one” services is likely to remain for the foreseeable future.

C.8 Point-to-point and Point-to-multipoint sharing

A specific example of the problems inherent in frequency sharing between systems with different technical characteristics is the case of point to point fixed links sharing spectrum with point-to-multipoint systems. There are two distinct scenarios to consider here, namely co-existence of FWA networks deploying these two technologies and co-existence between FWA networks and conventional radio relay systems.

In the first scenario, the characteristics of the two systems do not differ wildly, since relative low gain directional antennas are involved and the EIRP levels are modest, reflecting the short distances involved. Previous work conducted by Aegis Systems on behalf of the RA[29] demonstrated the feasibility of "mesh" type FWA networks, comprising high density point-to-point links connecting individual subscriber stations, co-existing with conventional point to multipoint systems.

However, the second scenario, involving very high gain antennas (typically 40 dBi or greater) and typically trunk radio relay networks requiring very high availabilities (99.99% or more) may be more problematic. Work carried out for Industry Canada in 1999 suggested that, in the 38 GHz band, the PFD limit required to provide adequate protection for point to point links would be 6 dB lower than that required for PMP subscriber stations, and 30 dB lower than for PMP base stations. The problem is compounded by the fact that radio relay stations are more likely to be located at high sites, hence less likely to be shielded from co-channel interference than FWA subscriber stations.

However, the use of interference mitigation techniques, such as ensuring antennas are oriented away from the neighbouring country in border or coastal areas and that FWA base station antennas deploy downtilt, should enable co-existence to take place in most cases. An analysis of the potential interference scenario in the 28

29 "Co-ordination between Broadband Fixed Wireless Access systems in the 28 and 42 GHz bands", Final report prepared by Aegis Systems Ltd for the Radiocommunications Agency, January 2000.

GHz band if point to point links and FWA systems are deployed either side of the channel or Irish border is considered in one of the case studies (see Appendix D.4).

C.9 Implications of "change of use"

A number of options can be addressed when considering what happens when the use of a block of spectrum changes from one operator to another. The implications of these options from a technical point of view are outlined below.

C.9.1 Change of licence only

If the technical characteristics of the system or systems deployed or being deployed stay the same, or at least within the technical characteristics defined by the licence, the nature of the interference environment would not be expected to change, except in the case where the density of use changes significantly.

As a consequence, the co-ordination required across boundaries, international or domestic (i.e. between spectrum trading blocks), geographic or adjacent band, would also not be expected to change in its nature. However, there could be an increased amount of co-ordination across boundaries if operators acquiring an existing licence chose to modify the technical characteristics of the system, albeit within the constraints of the licence, or if the density of use changes significantly.

C.9.2 Partitioning or aggregation of spectrum and/or geographic areas

As in the case above, no change to the system technical characteristics means that there will be no change to the type of interference environment generated and / or experienced. Also, and similarly to the above case, there could be an increased level of co-ordination between blocks (spectrum and / or geographic) not only because of possible modifications to system technical characteristics as licences change hands (as above) but also because of the more fragmented nature of the blocks and hence an increased number of boundaries (when "disaggregation" dominates). However, in the case where spectrum and / or geographic blocks are aggregated less co-ordination activity can be expected.

C.9.3 Change of use

In this case change of use implies that the technical characteristics of a system could change significantly.

If the only boundary condition is specified in absolute terms then there is no technical impact as any changed characteristics will still have to fall within this boundary condition. However, an absolute boundary condition implies that it has been set at a level that avoids the possibility of interference. This is potentially very inefficient .

If the boundary condition represents a trigger level for negotiation then co-ordination activity will be required. The nature of this activity will depend on the characterisation of the systems involved. When systems on either side of the boundary are relatively similar the negotiation will involve a few terminals on either side of the boundary. When inhomogeneous systems are involved negotiation could extend to systems well within, or beyond, a spectrum block. Depending on the granularity of the spectrum blocks at the time, it may be the case, for example with a highly directional antenna, that the potential area affected by interference could stretch not just into the adjacent block but across the adjacent block and into the next block, or across several blocks. It is therefore important that the user of a spectrum block intending to change its use is aware that boundaries other than the immediately adjacent ones may be tested.

It should also be noted that the criteria used for assessing the impact of interference can be both long term and short term in nature, especially where high availability systems are concerned. When setting boundary conditions both should be considered. In some circumstances it would be easy to meet a boundary condition based on a long term interference criterion yet fail to meet the victim's short term interference criterion.

C.9.4 Change of use and partitioning

In general the comments noted against Options B & C above apply here as this option (D) is merely a combination of these.

C.10 Apportioning rights and responsibilities

From a technical point of view there are no difficulties in undertaking a co-ordination exercise in terms of working out a technical accommodation of systems providing all the information and supporting tools are available.

If the starting point is a set of boundary conditions that are negotiable then providing all the technical information is available (i.e. the technical characteristics of actual transmitters) it can readily be established what the interfering power at any point due one or more transmitting terminals is likely to be. If a particular interfering power different to the boundary condition is agreed, a technical record of this agreement needs to be kept.

One of the key questions that has to be resolved at the outset is whether the negotiation is based on calculation or measurement. While the closest to reality is measurement, it is not really practical to adopt this approach. If calculation is to be adopted then it will be essential that common data and common calculation tools are made available. There does however remain the question of what happens if an operator claims to be experiencing, and is able to measure, unacceptable interference even though the calculated interference levels indicate that the situation is satisfactory. It is considered that the likelihood of this is remote as experience tends to show that the engineering calculations used to assess interference are relatively conservative. However there would need to be a clear statement associated with the calculation tools that negotiated agreements reached on the basis of results obtained from the calculation tools do not completely guarantee interference free operation.

On the basis of common data and calculation tools being available it is clear that operators can undertake the negotiation regarding boundary conditions between spectrum blocks themselves. A similar problem exists regarding international boundaries but the situation can be slightly different. If the UK chooses to allow the operation of systems that are not in line with the frequency allocation table of the Radio Regulations, or with harmonised frequency allocations agreed within the CEPT, the situation will be made more difficult and it should be the responsibility of the administrations to agree the conditions under which such operations should be allowed to take place.

It can be concluded that internal negotiation / co-ordination between spectrum blocks can be readily undertaken by the operators themselves providing common procedures and supporting tools are in place. On the other hand co-ordination with other administrations should remain the responsibility of the national regulatory authority.

C.11 Assessment of emerging technologies

Largely in response to the scarcity of spectrum and the adverse effects of the interference environment, technology has been developed to exploit the airwaves more efficiently.

The technologies fall into two categories. Firstly those that operate at low spectral power densities thereby reducing the potential for causing interference[30] and secondly those that seek to avoid interference by one or other means.

C.11.1 Low spectral power density

Low spectral power density systems include spread spectrum and ultra-wideband (UWB) techniques. Spread spectrum is a technique that has been available for some time now. In the past it has often been promoted as the most efficient and resilient modulation / access technique available. While in many instances it is a highly appropriate technique, the rather wider claims that have been made for it in terms of spectrum efficiency do not stand up to scrutiny and this has led to a suspicion about anything that in spectrum terms claims to provide "something for nothing". It is claimed that it is possible to provide efficient and resilient communications based on wideband low spectral power density techniques in exchange for increased overall noise levels. Ultimately noise limits the number of systems that can operate co-frequency co-coverage so it is debatable whether the co-existence of wideband low power spectral density systems with systems using other modulation techniques is any more efficient overall than segmenting the frequency band for different users. It may well be the case that a low number of wideband low spectral power density users will have little or no noticeable impact but as soon as the numbers become significant the preceding argument would apply.

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30 Sometimes these techniques also have the ability to reduce the impact of received interference.

One victim of this attitude is the UWB technology that is currently being promoted for all manner of applications, including ground penetrating radar and radiocommunications. Essentially, UWB communicates by way of short shaped pulses arranged in the time domain. The resulting emitted power in the frequency domain is spread over a very wide bandwidth (e.g. 1 GHz) at a level that is below the spurious emission levels permitted for other equipment. This naturally leads to the claim that as the emitted power level is below spurious emission levels, what can be the problem? This claim is still being assessed by various organisations in the US and Europe, and probably elsewhere. In the meantime, there is clearly some scepticism about the claims that fall into the "something for nothing" category noted above.

C.11.2 Frequency agility

Avoiding interference on a dynamic basis can be undertaken at a macro and a micro level. At a macro level this involves the selection an interference free channel which is then used for an extended period of time, and at a micro level this involves rapid hopping between frequency channels in a sequence.

A good example of the macro approach to frequency agility is the use of two so called "polite technologies", dynamic frequency selection (DFS) and transmitter power control (TPC), by a particular radio application that has been allocated spectrum recently. As their names imply DFS means that the transmitter listens for other users before selecting a channel to use and TPC means that the transmitter uses the lowest power level commensurate with the quality required. Both of these techniques keep the level of interference down. A requirement on High Performance Radio Local Area Networks (HIPERLANs) to implement these technologies has allowed allocations to be made in 5 GHz bands already occupied by other services. Without these techniques the allocation would not have been possible. While a limitation on power level and a restriction to indoor use were important factors in allowing frequency sharing with satellite services, it was the mandatory use of DFS and TPC (particularly the former) that opened up the 5 GHz band to HIPERLAN use.

Another example of the effective use of frequency agility, very similar to the DFS associated with HIPERLANs, is the Autonomous Frequency Assignment (AFA) scheme that is being promoted with respect to the introduction of Broadband Fixed Wireless Access (BFWA) systems using Time Division Duplex (TDD) techniques. In these systems base stations constantly monitor the spectrum and create an air traffic map of the frequency band. When a new hub base station or a new sector is introduced a frequency scan is undertaken across the all the carriers that are allowed to be used, measuring the received interference power for each one. The carrier frequency corresponding to the minimum received interference power would then be the one that is used. This scheme has potential advantages over the use of an *a priori* worst-case predictive plan.

At a micro level the frequency hopping variant of spread spectrum (see low spectral power density techniques above) also has interference avoidance characteristics. Radio Local Area Network (RLAN) devices operating in the 2.4 GHz band where the interference environment is hostile largely because of licence-exempt operations successfully use this technique. Providing the appropriate link protocols are employed, the loss of any of the frequency channels that are visited during the hopping process, due a collision with the transmissions of similar devices or due to another type of interference source, leads to a loss of throughput. This loss is graceful rather than catastrophic and the technique therefore provides a useful approach to dealing with hostile interference environments.

C.11.3 Other techniques

The Direct Sequence variant of spread spectrum has some interference rejection techniques that can be of use in particular circumstances. One of the features of the demodulation process that extracts the wanted signal from the noise like signal through code correlation, is the associated effect that interfering signals are spread. This is much like the original process that spreads the wanted signal before it is transmitted. This is of most benefit when the interfering signal is a relatively high power narrowband signal. Hence the interest of the military establishment in this type of modulation technique when trying to counteract jamming signals.

Adaptive antenna technology is also increasingly being proposed to reduce interference and thereby increase spectrum utilisation. The principle is based on array technology and associated signal processing. On the basis that the direction of an interfering source can be determined it is possible to adjust the overall pattern of the antenna such that a null, or at least some discrimination, is directed towards the interfering source thereby reducing its impact.

C.11.4 Summary

All of the above techniques are able to offer improvements in hostile interference environments although some remain unproven.

It should be noted that some adaptive technologies, especially some of the frequency agile ones, require slack in the system in order to be able to provide effective interference avoidance characteristics. That is to say, more spectrum (i.e. a greater overall bandwidth) is required to function properly than would normally be needed in a benign environment. This requirement runs counter to the traditional approach of spectrum managers which is usually based on providing the minimum amount of bandwidth necessary.

D CASE STUDIES

This section examines a set of five case studies, exploring some of the issues raised in the preceding sections.

The matrix presented at Annex G summarises the key global and regional constraints on spectrum utilisation in the UK in the frequency bands addressed by these case studies, and also summarises some of the key issues that might arise with regards to auctioning and/or trading spectrum in these bands.

D.1 Migration of existing GSM bands to IMT-2000

D.1.1 Scenario

For this case study, we have assumed that the UK permits the migration of spectrum in the GSM 1800 band to IMT-2000 on unilateral basis, whilst the spectrum is still being used for GSM services in France and Ireland. The current approach to bilateral co-ordination in this band involves blocks of spectrum comprising 2 – 3 MHz being defined as preferred or non-preferred in one or other country, and subject to greater or lesser interference protection accordingly. This would no longer be feasible under the case study scenario, due to the 5 MHz IMT-2000 channel width. Since the power spectral density for the IMT-2000 transmissions is substantially constant within the channel bandwidth, it would therefore be necessary to apply the non-preferred channel interference limit to the entire 5 MHz block, substantially restricting the emission levels near the coastline / border.

D.1.2 Boundary conditions

CEPT Recommendation T/R 22-07 (Frequency bands, planning and co-ordination for systems using the DCS 1800 standards) recommends that for non-preferential frequencies (which as noted above must be assumed in this case), co-ordination is required if the field strength produced by a base station exceeds **25 dBμV/m** at a height of 3 m above ground at the border line between two countries. *(Assuming a receiver noise figure of 9 dB this field strength equates to an interference level 4.7 dB below the noise floor when the receiver uses an isotropic antenna).*

In addition it is recommended that frequency planning in coastal areas is based on …… co-ordinated frequencies assuming a middle-line between the countries involved (i.e. in this case midway across the channel).

The technical characteristics associated with the types of base station anticipated for the UMTS system in Europe are as follows (ref - Document 8F/367 25 June 2001):

Type	Transmitter power dBW (W)	Antenna gain dBi	EIRP dBW	EIRP relative to 1 kW ERP propagation curves
Macro	13 dBW (20 W)	15	28	-4 dB
Micro	0 dBW (1 W)	6	6	-26 dB
Pico	-6 dBW (250 mW)	0	-6	-38 dB

D.1.3 Interference at French coastline and midway points

Using the sea path propagation curves contained in CEPT Recommendation T/R 22-07 it is possible to consider the level of interference received in France and at the midway point based on the closest distance to France of 36 km, but also taking account of the more general distances across the channel of 100 to 140 km.

Separation scenario	Distance (km)	Field strength (dBμV/m) due to 1 kW ERP (from propagation curves)	Field strength (dBμV/m) due to macro base station EIRP
Closest	36	55	18
Closest (middle-line)	18	62	25
General 1	100	37	0
General 1 (middle-line)	50	50	13
General 2	140	30	-7
General 2 (middle-line)	70	45	8

Note: The correction factor in moving from the field strength generated by 1 kW ERP to the field strength generated by the macro base station EIRP, and taking account of the requirements of the CEPT Recommendation and the relative characteristics of the interfering and victim systems, is made up of the following elements:

- operation in the 1800 MHz band in relation to the 450 to 1000 MHz curves contained in the CEPT Recommendation = -9 dB
- 3 m receive antenna height in relation to the 10 m curve = -10 dB
- 200 kHz receiver bandwidth GSM / DCS 1800) in relation to a 5 MHz transmit bandwidth (W-CDMA/IMT-2000 = UMTS) = -14 dB
- macro base station EIRP in relation to 1 kW ERP = -4 dB (see right hand column of first table)

It should also be noted that the results in the table above are based on a transmitter height above sea level of 37.5 m. If the transmitter height were to be 10 m above sea level, the interfering field strengths shown above would be approximately 10 dB less.

Comparison of the resulting field strength from a single UMTS macro base station (see right hand column of table above) with the co-ordination field strength trigger of 25 dBμV/m would appear to indicate that there should be no problem even at the middle-line of closest approach to France. However there is one further important characteristic of the W-CDMA UMTS / IMT-2000 system and that concerns its frequency reuse pattern. Unlike GSM FDMA/ TDMA systems, adjacent cells use the same frequency. This means that the aggregation of interference from multiple sources nearby will be more serious. Given that macro base stations in the UMTS systems are expected to use a cell radius in the range 0.5 to 1 km (in urban areas) it can be seen that the interfering field strength in France could easily be 10 dB higher than that from a single base station, and potentially even more than that.

Even though microcell and picocell base stations employ EIRPs 22 dB and 34 dB less that macro cell base stations, it has to be remembered that the cell sizes will be correspondingly smaller and therefore there will be a larger number of interfering sources aggregating to cause the interfering field strength. On the other hand the base station for such cells is likely to be at a much lower height than that assumed for macro cell base stations. This will provide additional isolation. The use of downtilted antennas, which are commonly deployed in cellular networks to reduce intra-network interference, will also have a mitigation effect and may enable base stations to be located nearer to the coastline than would otherwise be the case.

From this general analysis it might reasonably be concluded that:

- macro base stations in Kent could cause a problem to GSM mobile terminals located in North East France
- macro base stations located along the rest of the South coast of England are unlikely to cause a problem to GSM mobile terminals located in France
- microcell and picocell base stations located anywhere along the South coast of England are unlikely to cause a problem to GSM mobile terminals located in France

D.1.4 Interference at Border with Ireland

In the case of the boundary between Northern Ireland and Ireland there is no natural separation like the English Channel. It is therefore necessary to assess what sort of separation would be required.

From the land based curves in CEPT Recommendation T/R 22-07, and taking account of corrections similar to those identified above for the sea path, it can be determined that a single macro base station would have to be located 10 km from the border in order to remain below the co-ordination trigger level 25 dBμV/m.

However, bearing in mind the co-channel nature of CDMA cellular systems noted earlier it is likely that the separation distance required will be greater than 10 km.

It can be concluded that there will be some difficulty in border areas unless macro base stations situated near the border are directed away from the border. Deployment of micro- and pico stations close to the border should be feasible, especially if there is screening in the direction of the border from surrounding terrain or buildings. These mitigation techniques should enable base stations to be situated as close as possible to the border, but will not however solve the problem completely. Bilateral arrangements will continue to be necessary.

It is interesting to note that CEPT Recommendation T/R 22-07 also identifies in more detail the level of interference that can be tolerated by a DCS 1800 system.

The co-channel C/I ratio required with respect to multiple interferers is 9 dB and the minimum field strength to be protected is 42 dBμV/m[31]. Assuming a receiver noise figure of 9 dB, as before, this implies that the total interference that can be tolerated is equivalent to an interfering field strength of 33 dBμV/m, some 8 dB higher than the co-ordination trigger level of 25 dBμV/m, and 3.3 dB higher than the noise floor. This effectively gives additional margin and therefore reduces the probability of there being a problem in practice.

One other aspect that should be noted concerns the potential for interference in the opposite direction. While a straightforward analysis of the potential for interference from GSM systems (France or Ireland) into UMTS systems (UK) is likely to result in similar conclusions regarding necessary separation distances, it has to be remembered that MoUs are already in place regarding GSM operations in France and Ireland. If these MoUs permit power levels higher than those that give rise to the co-ordination trigger level field strength, this may act as a constraint on UMTS operation in the UK.

D.1.5 Impact of international regulations

ITU-R

At the World Radio Conference 2000, resolution (RES[COM5/24]-3) identified the band 1 710 – 1 885 MHz for use by IMT 2000 applications as market demand and other considerations require. This was in line with the CEPT European Common Position, which identified the band as being appropriate for longer term 3G use, though not as "new" spectrum. Thus the longer term intention for this band at an international level would indeed include UMTS, though it may be noted that footnote S5.AAA of the Provisional Final Acts from WRC 2000 that identification of the band "does not preclude [its] use by any application of the services to which they are allocated and does not establish priority in the Radio Regulations".

EU/CEPT

At a Community level the GSM Directive addresses the lower band only, reserving the 905-914 and 950-959 MHz bands for the exclusive use of GSM applications. It does not, unsurprisingly, mention the DCS1800 band, and so should not be an impediment to use by UMTS. Neither should the Mobile Directive, which whilst requiring administrations not to refuse to license GSM services in this band, does not specifically mandate any part of the spectrum for this purpose.

The EU UMTS Decision recognises DCS1800 as a member of the GSM family and identifies the need for inter-working between second and third generation mobile systems. It expressly addresses the core UMTS bands, requiring Member States to

31 This field strength is related to 50% of locations and 50% of time, rather than the 50% of locations and 10% of time used to determine whether co-ordination is required. For short distances (e.g. 20 – 30 km) the correction will be small (a few dB). For longer distances (e.g. 100 km) the impact will be greater (20dB) and will therefore significantly reduce the impact of interference.

use frequency bands harmonised within CEPT for UMTS. However it remains silent with regard to the non-harmonised extension bands. It does however note the importance of a common European position, and requires the Commission to mandate CEPT to investigate additional spectrum.

ERC Decision ERC/DEC/(00)01 extends ERC/DEC/(97)07 in response to the EU mandate LC/10/99 rev.1 recommending that 1900-1980, 2010-2025 and 210-2170 MHz be harmonised. It too remains silent with regard to DCS1800.

In the ERC response to the output of DSI Phase III some members of Working Group FM have expressed serious concerns over the prospect of including DCS1800 into a single channelling solution with the 2.5 GHz band because of legal obligations and existing plans for use of DCS1800 applications for many years to come. It has been recommended that further discussion on this matter should take place in ERC Project Team 1 (PT1).

Bi-lateral

Existing bi-lateral agreements, specifically with France and Ireland, may constrain the practicality of introducing 3G whilst these countries continue with 2G systems. The field strength constraints cited in the bi-lateral agreements can only be amended through a process of negotiation.

D.1.6 Market issues

There are a number of ways migration from GSM to IMT2000 might be achieved

- Existing operators replace some or all of their GSM systems / spectrum with IMT2000.
- GSM spectrum becomes tradable and existing GSM operators trade this with operators who want more spectrum for IMT2000
- Government announces an end date for the provision of GSM services (as happened with analogue cellular services) and auctions the GSM spectrum for general mobile purposes
- Combinations of the above e.g. government reclaiming some spectrum for one or more new operators and letting incumbents keep the remainder.

The GSM Directive does not allow refarming of GSM900 spectrum so the focus would have to be on the 1800 MHz spectrum until the Directive is changed or disbanded. Technical constraints may constrain IMT 2000 deployment around the Irish border (without re-negotiation of the bi-lateral agreement) and in Kent, although as noted above mitigation techniques should help and it should still be possible to operate macro and micro cell base stations at many locations within these areas. None of this directly affects the ability of government to auction spectrum or of users to trade it, though it may slightly reduce the value of the spectrum by constraining network planning in the vicinity of the coastline / border (not that this may not be a problem at all if the spectrum is used to complement an operator's existing spectrum in the core IMT-2000 band, but it may be an issue for a new entrant).

Auctioning the spectrum should be relatively straightforward though attention may need to be given to whether the spectrum is auctioned with or without incumbents and, if the former, the duration of their incumbency and the interference controls that would apply. If national licences are auctioned then no particular interference issues arise beyond those concerning bi-lateral agreements.

If spectrum was auctioned or traded on a regional basis such that a patchwork of GSM and IMT2000 use resulted then additional border problems would arise and it would be necessary for operators to renegotiate interference conditions near licence area boundaries, although again the use of mitigation techniques and avoidance of macro base stations in border regions would largely overcome these.

We expect that operators would be unlikely to trade their spectrum unless this was necessary to gain additional 5 MHz blocks. This is because having more spectrum provides them with competitive advantage and because agreeing the value of the spectrum value may be difficult (as it will be a thin market). If trading is necessary for operators to create additional 5 MHz blocks, then swaps between operators may occur.

D.2 Co-existence of IMT-2000 & non-mobile services around 2.6 GHz

In this case study we have assumed that the UK introduces IMT-2000 services in the 2520 – 2670 MHz band while this band is still being used for other services in neighbouring countries. In the case of France, these are assumed to be point to point links, whereas in Ireland, the band is currently used for MMDS services, which are likely to be operational in some areas for the next decade or so.

D.2.1 Boundary conditions

Previous work undertaken within CEPT (see Report 64, Frequency sharing between UMTS and existing fixed services, May 1999), has looked at the potential for interference between UMTS base stations and fixed link terminals situated in the UK. The work concluded that separation distances of many tens of km are required to allow for satisfactory co-existence, especially in relation to the fixed link boresight.

D.2.2 Interference at French coastline

Taking the macro base station characteristics detailed in the previous case study (i.e. an EIRP of 28 dBW) the field strength at the French coast can be derived from the Draft New Recommendation ITU-R P.[BLM] (Method for point-to-area predictions for terrestrial services in the frequency range 30 to 3000 MHz). Based on the propagation curve for 2000 MHz, 50% of locations and a transmitter height above sea level of 37.5 m, the field strengths are:

Distance (km)	Field strength (dBμV/m) for 50% time	Field strength (dBμV/m) for 10% time	Field strength (dBμV/m) for 1% time
36	52	72	76
100	4	50	67
140	-8	41	63

Note: The only correction that has been applied to the values from the propagation curves in the Recommendation concerns the difference between EIRP and ERP, and the relative power level of the base station and the 1 kW reference level used for the derivation of the propagation curves.

No corrections have been made for:

- frequency. The curves from the Recommendation that were used to derive the above values represent propagation behaviour at 2 GHz. The frequency of interest in here is 2.6 GHz. Field strengths at this frequency are likely to be 2 to 3 dB less than the levels indicated in the table, but this has not been taken into account in the tables that follow.
- receive antenna height. The receive antenna height is assumed to be 10 m.
- bandwidth. The bandwidth of the interfering UMTS transmission (i.e. 5 MHz) is assumed to fall within the bandwidth of the fixed link receiver.

The equivalent power received by an isotrope is shown in the table below:

Distance (km)	Power received by isotrope (dBW) for 50% time	Power received by isotrope (dBW) for 10% time	Power received by isotrope (dBW) for 1% time
36	-123.5	-103.5	-99.5
100	-171.5	-125.5	-108.5
140	-183.5	-134.5	-112.5

The equivalent power density received by an isotrope is shown in the table below:

Distance (km)	Power density received by isotrope (dBW/MHz) for 50% time	Power density received by isotrope (dBW/MHz) for 10% time	Power density received by isotrope (dBW/MHz) for 1% time
36	-130.5	-110.5	-106.5
100	-178.5	-132.5	-115.5
140	-190.5	-141.5	-119.5

These figures can be compared with the long term (20%) interference criterion for fixed systems as contained in ITU-R Recommendation 759. The value falls in the range -141 to -146 dBW/MHz. It might reasonably be assumed that the short term interference level (0.01%, say) will be approximately 30 dB less stringent at -111 to -116 dBW/MHz.

The percentage times provided by the propagation curves of Draft New Recommendation ITU-R P.[BLM] do not make it easy to make a direct comparison. However, by visual interpolation and extrapolation it is possible to conclude that the short term interference is going to cause a problem with respect to the whole of the South Coast of England. This is most especially so when one considers that the levels of interference in the table above relate to an isotropic receive antenna. A point-to-point antenna will in reality have a boresight gain of anything between 10 and 35 dBi with a residual gain of -10 dBi through rear sidelobes. It can be seen that if the French point-to-point antenna is pointing away from the English coast then the situation might be satisfactory. However any other alignment, for example parallel or slightly towards the English coast, is likely to give rise to problems.

D.2.3 Interference at Border with Ireland

In the case of the Irish land border, the figures in the table below show the power received by an isotrope on the border when the interfering macro base station is situated 10 km within the border and pointing towards it.

Percentage time	Field strength (dBμV/m)	Power received by isotrope (dBW)	Power density received by isotrope (dBW/MHz)
50%	56	-119.5	-126.5
10%	57	-118.5	-125.5
1%	59	-116.5	-123.5

Comparing the power density figures with the earlier criteria (-141 to -146, long term and -111 to -116) shows that it is the long term criterion that is most important in this situation.

At 10 km separation the long term criterion is not met. The power levels at the border when the macro base station is 20 km inside the border are shown below.

Percentage time	Field strength (dBμV/m)	Power received by isotrope (dBW)	Power density received by isotrope (dBW/MHz)
50%	40	-135.5	-142.5
10%	41	-134.5	-141.5
1%	44	-131.5	-138.5

It can be seen that the long term criterion of -141 to -146 dBW/MHz is just about met, but it should not be forgotten that this is with respect to an isotropic receiver. An MMDS receive antenna will in reality have a boresight gain of anything between 10 and 35 dBi with a residual gain of -10 dBi through rear sidelobes. Any degree of pointing towards the border will therefore cause the interference criterion to be exceeded even when the macro base station is 20 km within the border.

D.2.4 Summary

In summary it appears that co-existence between IMT-2000 macro cell stations might only be possible near the French and Irish borders if both antennas (i.e. the UK macro base station and the French / Irish point-to-point / MMDS antenna) were to be pointing in opposite directions. From a practical point of view this would be difficult to ensure and may put an unacceptable constraint on all systems involved. Deployment of microcell and picocell base stations should be feasible although some bilateral co-ordination will still be required near the coastline / border. Potential interference from mobile terminals may preclude the use of this spectrum at locations very close to the Irish border, depending upon the precise location of victim MMDS receivers.

As a result of these constraints it may be necessary in the early stages of opening this band to restrict use to microcell and picocell coverage, implying that the spectrum would be complementary to other IMT-2000 spectrum (which would be used to provide macro coverage) rather than intended to provide a stand-alone capability.

D.2.5 International regulations

ITU-R

As with the first case, this band was identified for extension UMTS / IMT 2000 services at the World Radio Conference 2000. Again, resolution (RES[COM5/24]-3) identifies 2 500 – 2 690 MHz for use by IMT 2000 applications as market demand and other considerations require, indicating that the band will be available for use by UMTS (with the same sharing and priority caveats previously mentioned). This also reflected the CEPT position which had identified this band as part of a total requirement for 160MHz of new spectrum for 3G.

EU/CEPT

At a Community level the UMTS Decision requires Member States to use frequency bands harmonised within CEPT for UMTS. As noted earlier, it remains silent with regard to the non-harmonised extension bands, but requires the Commission to mandate CEPT to investigate additional spectrum.

D.2.6 Market issues

Fixed links in France and MMDS services in Ireland could constrain use of the IMT2000 band near the UK border. Clearly 3G operators will want to change this situation. One market-like approach to this problem would involve the 3G operators seeking to buy off the fixed / MMDS operators, for example by paying for the necessary re-engineering of their systems. This may need to be facilitated by the respective governments. If the fixed / MMDS operators do not agree then bi-lateral negotiation is the only other solution. In practice the spectrum may nevertheless retain much of its value as it will still be useable without constraints in the major UK conurbations and for microcell and picocell provision even in border areas, subject to co-ordination. The impact will depend on whether the spectrum is the sole means of delivering the service or whether the licensee has other spectrum at its disposal that it can use in affected areas.

D.3 Migration of analogue TV spectrum

In this case study, we have considered the implications of the UK introducing non-broadcast services, such as mobile, into parts of the TV broadcasting bands IV and V, whilst these are still being used for analogue or digital TV in neighbouring countries.

D.3.1 Boundary conditions

ITU-R Recommendation 417 specifies the minimum median field strengths for which protection may be sought in planning a television service. For the bands of interest these are:

- 65 dBμV/m at 10 m above ground level for Band IV
- 70 dBμV/m at 10 m above ground level for Band V

In order to protect these field strengths, assuming that there is no antenna discrimination at the TV receiver (i.e. interferer and victim are in the same direction), it is necessary that the interfering signal strength is significantly below these levels as represented by an appropriate protection ratio.

The sensitivity of an analogue TV carrier to narrowband interference varies across its bandwidth. In the worst case a protection ratio of 50 dB is required. France uses a positively modulated vision signal and a -2dB correction factor has to be applied with respect to a CW interferer. The protection ratio required is therefore 48 dB and the permitted narrowband interfering field strengths then become:

- 17 dBμV/m at 10 m above ground level for Band IV
- 22 dBμV/m at 10 m above ground level for Band V

For a wideband interferer (a bandwidth of 2 MHz or more, say) the protection ratio is less stringent and might reasonably be assumed to be about 30 dB. The permitted wideband interfering field strengths then become:

- 35 dBμV/m at 10 m above ground level for Band IV
- 40 dBμV/m at 10 m above ground level for Band V

In assessing the interfering field strengths it is necessary to consider 1% of time and 50% of locations. This is the case for analogue TV. In the case of digital TV the considerations are different because of the less graceful degradation of digital carriers. However, although there is a more even sensitivity to interference across the carrier bandwidth thereby allowing a lower protection ratio, greater margin has to be in-built in order to avoid the catastrophic failure to which digital carriers are prone. These factors mean that it is likely that any conclusion drawn for analogue TV carriers is likely to be similar for digital TV carriers, at least to a first order.

D.3.2 Interference at French coastline

Using the same coastal separation distances and the appropriate propagation curve (Figure 16a from ITU-R Recommendation 370-7) it is possible to derive the maximum ERP of a transmitter (or the equivalent aggregation of a number of transmitters) that would satisfy the acceptable interfering field strengths identified earlier. The derived ERPs are shown in the table below.

Distance (km)	1kW ERP gives field strength (dBμV/m)	Narrowband ERP (dBW) to satisfy tolerable field strength (Note 1)	Wideband ERP (dBW) to satisfy tolerable field strength (Note 2)
36	64	-17 (Band IV)	1 (Band IV)
36	64	-12 (Band V)	6 (Band V)
100	60	-13 (Band IV)	5 (Band IV)
100	60	-8 (Band V)	10 (Band V)
140	58	-11 (Band IV)	7 (Band IV)
140	58	-6 (Band V)	12 (Band V)

Note 1: 17 dBμV/m (Band IV) and 22 dBμV/m (band V)

Note 2: 35 dBμV/m (Band IV) and 40 dBμV/m (band V)

D.3.3 Interference at border with Ireland

In the absence of a natural separation at the Irish land border the maximum ERP of a transmitter (or the equivalent aggregation of a number of transmitters) that would satisfy the acceptable interfering field strengths identified earlier can be derived for locations 10 and 20 km inside the border. The ERPs shown in the table below are based on Figure 11 from ITU-R Recommendation 370-7.

Distance (km)	1kW ERP gives field strength (dBμV/m)	Narrowband ERP (dBW) to satisfy tolerable field strength (Note 1)	Wideband ERP (dBW) to satisfy tolerable field strength (Note 2)
10	65	-18 (Band IV)	0 (Band IV)
10	65	-13 (Band V)	5 (Band V)
20	52	-5 (Band IV)	13 (Band IV)
20	52	0 (Band V)	18 (Band V)

Note 1: 17 dBμV/m (Band IV) and 22 dBμV/m (band V)

Note 2: 35 dBμV/m (Band IV) and 40 dBμV/m (band V)

One can assess the usefulness of these power levels by looking at the typical EIRP values for macrocell, microcell and picocell base stations outlined earlier in the first case study - 28, 6 and -6 dBW respectively. If it is assumed that the same type of application (including cell size) is to be deployed at the lower frequencies being considered here then the amount of power required will be less because of lower propagation losses. Taking the propagation losses to be proportional to $(\text{frequency})^2$, and making the correction for EIRP to ERP, the macrocell, microcell and picocell ERPs would be approximately 17.5, -4.5, and -16.5 dBW for Band V and 14, -8 and -20 dBW for Band IV.

Bearing in mind the potential aggregation of base station interference, it can be seen by comparing the tolerable ERPs (for a single emitter) contained in the tables above with the ERPs required, it can be concluded that macrocell base stations operating near borders will likely cause unacceptable interference whereas microcell and picocell base stations are not likely so to do.

It should be noted that the power of TV transmissions is likely to cause problems in the opposite direction, depending upon where (geographically) individual TV channels are in use.

D.3.4 Impact of international regulations

ITU-R

The Radio Regulations (Region 1) allocate 470 – 862 MHz to Broadcast only (470 – 790 MHz) and Broadcast sharing with Fixed on a co-primary basis (790 – 862 MHz). A variety of nations also use the bands for land mobile SAB and / or radiolocation on a secondary basis. Applications such as 3G are not therefore permitted at present.

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The Stockholm (1961) and Chester (1997) plans detail the use by analogue and digital TV respectively of bands 4 and 5. However, whilst at present Broadcasters enjoy largely exclusive use of this spectrum, secondary services occur in the band 470 – 838 MHz, whilst a primary Fixed allocation exists in the band 838 – 862MHz. The European Common Frequency Allocation Table states that these bands are to be reviewed for possible future applications after the introduction of DVB-T. Administrations are urged to clear the bands of aeronautical radionavigation services by 2008. No comment is made regarding the future of the tactical radio relay systems operating from 790 – 862 MHz.

D.3.5 Market issues

The migration from analogue to digital TV is currently being achieved through administrative processes, in the sense that broadcasters have been assigned spectrum for digital services either by beauty contest or based on the extent of their analogue services. The issue considered here is whether market approaches could be used to

- Encourage the take-up of digital TV so analogue services can be switched off.
- Reallocate the TV spectrum to new uses

These two issues are interrelated.

At present most consumers adopt digital TV so that they can receive subscription TV services. It is expected that there will be a significant number of consumers who will not want to or will not be able to afford to purchase subscription TV or a non-subsidised digital TV or set top box to receive free-to-air digital services.. Over time, as the price of digital receivers converges with analogue, consumers will purchase digital TVs to replace redundant analogue TVs. This would eventually lead to all consumers being able to receive digital TV but this may not be for 20-30 years if relying purely on set replacement cycles. To achieve transition in shorter timescales, analogue TV consumers will need a financial incentive to switch. Such incentives (e.g. free set top boxes) might be paid for by:

1. potential new users of the analogue spectrum released
2. all users of the TV bands, i.e. including the broadcasters who have already received spectrum for digital services
3. the proceeds of an auction of the spectrum released by the transition

4. incumbent analogue broadcasters, who in turn may receive payments from new users purchasing the spectrum they occupy

Under the first and second options there would need to be a mechanism for sharing the subsidy costs because viewers will almost certainly be receiving analogue services that occupy spectrum assigned to more than one spectrum user[32] i.e. there is not a one to one map from TV viewers to new users of the analogue spectrum.

In options 1 and 2, an auction, or possibly even secondary trading of spectrum currently assigned to incumbent broadcasters, could be used to assign spectrum to new users. Allowing incumbents to trade their spectrum has little merit unless they are required to convert viewers to digital before trading their spectrum. Because multiple broadcasters serve a single TV viewer a co-operative approach would again be required. This may need to be mandated to avoid free rider problems.

The third option requires little comment except to note that in designing the auction consideration would need to be given (amongst other things) to whether the spectrum was cleared in advance or not. This issue is discussed further below.

The fourth option is similar to the approach being adopted by the US Government. The US Government has set a target date of 2006 for the end of analogue transmissions. DTV services are expected to relocate to channels 2-51 and the remaining 108 MHz of analogue spectrum on TV channels 52-69 will be reallocated to mobile services.

60 MHz of the spectrum released by switchover has been reallocated for public safety and new commercial wireless services. The frequencies allocated to commercial use are due to be auctioned soon, though the auction date has still to be determined. Licences for the remaining 48 MHz are due to be auctioned by September 30 2002. In the transition period, new service providers are expected to negotiate voluntary band clearing agreements with broadcasters in channels 52- 69. The FCC has adopted rules and policies designed to facilitate this process for channels 60-69. These are as follows[33]

- Arrangements for sharing the costs of moving incumbents between new entrants are left to voluntary negotiation or private secondary auctions.
- Agreements need to be approved by the FCC. The scope of the FCC's investigations will be limited to weighing up the public interest implications of a loss of broadcast service and the advent of new wireless services on a case-by-case basis.

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32 This is because of the way analogue TV spectrum is interleaved and because small transmitters are fed their signal from large ones.

33 Third report and Order - Service rules for the 746-764 and 776-794 MHz bands and revision to part 27 of the Commission's rules. FCC, January 23 2001.

- Three way agreements between new entrants, TV incumbents in channels 60-69 and TV incumbents in lower bands fall under the rules similar to those for bilateral agreements. Broadcasters may relocate temporarily to channels 52-58.

The FCC has rejected requests for caps on the costs of moving incumbents and mandatory requirements to move in the case of “lone hold-out” by a single broadcaster. Rules for channels 52-59 will be determined in light of experience in channels 60-69.

The FCC is in effect planning to sell overlay rights for TV spectrum with no limits on the duration of incumbents’ rights. We think this is likely to be problematic because of hold out problems and the uncertainty this creates for those bidding for rights to use the spectrum in future. There will be uncertainty over both the sums required to clear incumbents and the timing of spectrum release. The latter is compounded by FCC rules that require continuation of analogue services if 15% or more of households in a market do not have access to digital TV.

In conclusion, there would appear to be some scope for use of market approaches in hastening the transition, in particular auctions of suitably defined overlay rights and possibly trading. However opportunities to use any spectrum released for mobile services will be constrained by interference considerations – both interference caused to French and Irish TV and even more importantly interference to the mobile service from TV in France and Ireland.

International regulations seem unlikely to constrain the use of these market approaches as it seems unlikely that the conditions set by Government for switching off analogue services will be met before 2008.[34] That part of the 700-800 MHz band that is designated as mobile on a secondary basis will not have protection from interference from TV services. Our analysis suggests that interference from TV services could render this spectrum largely unusable.

D.4 Wideband systems at 28 GHz and 40 GHz

This case study considers the implications of co-existence between broadband FWA or MWS services in the UK and both similar services and other services (notably point to point links) in neighbouring countries.

D.4.1 Boundary conditions

Previous work undertaken by Aegis for the Radiocommunications Agency looked at the co-ordination requirements for Broadband Fixed Wireless Access (BFWA) systems operating at 28 and 40 GHz. The work concentrated on co-channel use by different operators in adjacent licence areas. The power flux density and distance

34 The Government has set three pre-conditions for switchover, referred to as the availability test (99.4% of the population must be able to receive free to air services digitally), the take-up test (95% of consumers must have a digital receiver) and the affordability test (the switch must be affordable by people on low or fixed incomes).

co-ordination trigger levels derived during that work are now part of the RA's co-ordination guidelines for BFWA operators.

Typical transmit characteristics of BFWA systems operating at both of these frequencies were considered to be:

Transmit terminal	Antenna gain (dBi)	EIRP (dBW)	EIRP density (dBW/MHz)
Base station	15	15	0.5
Subscriber unit	33	26	11.5

The long term interference criterion associated with the various fixed links operating in these bands ranges from -141 to -149 dBW/MHz (see ITU-R Recommendation 758). Depending on the margins available in these fixed links it might reasonably be expected that the tolerable short term interference level would be some 20 to 30 dB higher than the long term level. This would mean a short term level somewhere around -120 dBW/MHz.

The other important characteristic of these fixed link receive terminals is the gain of the antenna. Since it is possible that point-to-point links are or will be used in France it has to be assumed that the antennas will have significant directionality. ITU-R Recommendation 758 suggests that anything between 36 and 47 dBi would be representative.

D.4.2 Interference at French coastline

Assuming a BFWA subscriber terminal on the UK coast points towards France the following received power levels can be calculated using the ITU-R Recommendation 452 propagation model that is appropriate to interference paths at these frequencies.

Frequency (GHz)	Distance (km)	Percentage time (%)	Loss (dB)	Power received by an isotrope (dBW/MHz)
28	36	50	197.4	-185.9
		0.01	152.0	-140.5
40		50	204.0	-192.5
		0.01	156.3	-144.8
28	100	50	231.7	-220.2
		0.01	172.8	-161.3
40		50	237.6	-226.1
		0.01	180.2	-168.7

The short term levels *(italics)* in the right hand column need to be compared to the criterion of around *-120 dBW/MHz* and the long term levels with -141 to -149 dBW/MHz. However the levels in the right hand column assume that the power received in France is captured by an isotrope and there is the possibility, albeit small, that a highly directional fixed link antenna in France could be pointing directly at the BFWA subscriber terminal on the UK coast.

With respect to the closest approach to France the margin available for an isotrope is around 40 dB (long term interference consideration) and just above 20 dB (short term consideration).

With respect to the more representative distance of 100 km the margin available for an isotrope is more than 70 dB (long term interference consideration) and around 45 dB (short term consideration).

These margins are reduced by the gain of any receive antenna on the coast of France pointing towards the UK, where that gain could be in the range 36 to 47 dBi.

The figure above indicate that the potential for interference across most of the English channel does not exist. However, at the point of closest approach, the figures suggest that short term interference could be a problem by a factor of 16 to 27 dB. The likelihood of this occurring is remote for two reasons:

- the probability of the subscriber station (with directionality of G = 33 dBi) and a fixed point-to-point terminal (with directionality of G = 36 to 47 dBi) pointing directly at each other is very small. The conclusion above is based on this configuration. Any off-pointing by one or other or both antennas is likely to provide the necessary isolation to eliminate the problem
- both terminals are assumed to be on their respective coastlines meaning that the interference path is purely a sea path with the more troublesome short term interference being dominated by ducting effects as would be expected. In practice the terminals will be situated inland somewhat. This will introduce further losses on the interference path which will benefit the situation.

In conclusion therefore it is considered that there will be negligible impact on French point-to-point links from UK BFWA operations in the bands 28 and 40 GHz. There is a small possibility of unacceptable interference occurring across the narrowest parts of the English Channel should a very particular geometrical alignment arise. The possibility of this arising is remote and could be dealt with on a case by case basis. It is not considered that such a situation should determine the overall level of constraint that could be imposed.

D.4.3 Interference at Border with Ireland

Once again he situation with respect to the Irish border is more difficult as there is no natural separation distance as is the case with the English Channel. On the other hand, interference paths will not be dominated by the short term propagation effect of ducting as we are dealing with a ground based path here[35]. The overall situation is therefore very similar to the co-ordination problems that can arise between different operators operating co-channel in adjacent licence areas.

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35 This material refers to the land border between Northern Ireland and Ireland. The sea border between Wales/England/Scotland is analogous to the English/French situation across the English Channel.

In the UK a boundary 28 GHz PFD value has been set at a level (-102.5 dBW/MHz/m^2) which is a balance between minimising the constraints on deployment against the probability of unacceptable interference in a neighbouring area. It is recognised that meeting the PFD trigger level does not in itself guarantee interference free operation in the neighbouring area. However, statistical modelling has demonstrated that when allowance is made for the limited line-of-sight between interferer and victim stations and the realistic deployment of antennas, application of the limit will ensure substantially interference free co-existence. A corresponding value of -98.5 dBW/MHz/m^2 has been calculated for the 40 GHz band.

Similar PFD limits could be applied at the Irish border and if Irish operations in these bands are also BFWA then it can be assumed that the likelihood of interference will be small. If, as seems more likely according to recent announcements by the Irish NRA, more directional point-to-point links are to be deployed in Ireland then there is a potential for the situation to become similar to the French case above. However, the fact that the interfering path is land rather than sea based does improve the situation. In this instance it is likely that the ground clutter will reduce the distances over which interference could occur significantly. Ultimately though, because there is no natural separations distance there will always be the possibility of interference unless the PFD level at the boundary is set so low as constrain use of the frequency unreasonably or a bilateral agreement is reached.

Note that a similar situation applies in the 26 GHz band, where FWA operates in France and Ireland, whilst fixed links operate in the UK.

D.4.4 Impact of International regulations

D.4.4.1 ITU-R

BFWA and Fixed point to point systems enjoy protection as primary status Fixed systems at 26GHz, 28GHz and 40GHz.

Interference seems likely only to be a problem where systems are operating in very close geographical proximity. Should interference arise it would trigger the normal ITU co-ordination process. It should be noted that this could have an impact on the rights associated with a licence, for example requiring that a BFWA transmitter be moved further within UK territory, or that power be backed off.

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The case demonstrates that harmonisation can be both difficult to achieve and, in practice, unnecessary. The non-harmonised use of the 26 / 28GHz bands by the UK has not led to insurmountable interference problems, nor indeed has it had a major impact on the market, as the closeness of the two frequencies have enabled manufacturers simply to retune equipment destined for the UK market.

D.4.5 Market issues

The viability and nature of services offered in these bands is highly uncertain and may change in future, so there would seem likely to be merit in offering users as much flexibility as possible. This could be done by one or more of the following

1. Using the market to determine the packaging of spectrum auctioned
2. Allowing spectrum to be tradable
3. Allowing any use of spectrum consistent with the ITU regulations (e.g. for BFWA and fixed point to point systems).

While it is not possible to turn back the clock for the 28 GHz band the second and third point could be accommodated through licence changes.

Using the market to determine spectrum packages would involve defining basic spectrum building blocks and then allowing auction bidders to aggregate these as they wished. Interference limits already calculated for 28 GHz would apply and limits could similarly be developed at 40 GHz.

Making spectrum tradable could offer benefits by giving users flexibility to modify their assignments as the market evolves. Liberalisation of use is a matter of policy, but there is no international regulatory impediment and setting appropriate technical constraints is not a problem.

Arguably the greatest benefits come from implementing all three of the above approaches, as has been done in Canada for the 24 GHz and 38 GHz bands.

D.5 Co-existence between public and private systems around 5 GHz

In this final case study, we are not concerned with international co-existence (because of the low powers involved and the deregulated nature of the bands this is not really an issue), but rather the implications of delivering both public services (which implied expectations of a reasonable grade of service) and operating private services and systems in the bands.

Use of licence-exempt spectrum has become increasingly attractive, to some extent because there are no financial charges associated with its use. While recognising that there are several licence-exempt bands, most recent interest has been directed towards the bands available at 2.4 GHz and 5 GHz as these offer sufficient bandwidth to support higher data rate applications that are of widespread interest.

In addition there has been an interest in using these bands to provide licence-exempt public services, which is not possible under current legislation[36]. This issue is currently being addressed by the Radiocommunications Agency and is not considered further here.

36 It should however be noted that Atlantic has been licensed to provide a public Fixed Wireless Access service in the 2.4 GHz band.

From a technical point of view there are differences between the two bands, largely arising from the differing approach towards the bands adopted, at least in Europe.

D.5.1 The 2.4 GHz band

In the UK the 2.4 GHz band accommodates a wide variety of applications such as Short Range Devices (SRDs), including Radio Local Area Networks (RLANs) and Bluetooth, Electronic News Gathering and Outside Broadcast (ENG/OB) links, Fixed Wireless Access (FWA) and military installations. At the same time the band is somewhat polluted by emissions from Industrial, Scientific and Medical (ISM) equipment, including domestic microwave ovens. Licence-exempt operation in this band is limited to a number of different types of device each conforming to a particular power limit (ranging between 10 mW and 500 mW) depending on the application. However, apart from the two types of spread spectrum RLAN, the radio interface is specified in a generic way thereby allowing a very wide range of applications to operate in the band providing they can achieve what they set out to do within the power limit specified.

Previous work by Aegis for the Radiocommunications Agency and for the Spectrum Management Advisory Group (SMAG) has looked at the potential for congestion in the band and proposed approaches to mitigate the problem. Apart from the issue of not being able to provide licence-exempt public services in the band, there were two other aspects of importance identified in the report for SMAG.

Firstly, it was identified that the main potential for congestion relates to the systems that are used outdoors, namely FWA, ENG/OB and outdoor RLAN applications. It was foreseen that in the longer term it would not be possible for all three types of system to coexist in the band.

Secondly, It was also foreseen that there would be the potential for interference in hotspots when devices of 100 mW are used, particularly in public areas. It was felt that the coexistence of relatively high power (100 mW) wide area services with low power (1 mW) devices would be difficult.

D.5.2 The 5 GHz band

The lower part of the 5 GHz band was made available some years ago for the introduction of High Performance Radio Local Area Networks (HIPERLANs) which at the time were only on the drawing board. More recently the spectrum required by HIPERLANs was reassessed (330 MHz was requested) and significant extra spectrum (450 MHz) was designated across the 5 GHz band for use by HIPERLANs in Europe. In designating this spectrum the incumbent primary services were protected by imposing certain power and other operational limits on HIPERLAN devices. In addition it was deemed that HIPERLANs should employ Dynamic Frequency Selection (DFS). This type of frequency agility has a threefold purpose:

1. it detects radar emissions and moves to another frequency channel thereby avoiding interference to radars sharing the bands, and at the same time avoiding the reception of interference from radars

2. it spreads the HIPERLAN channel utilisation evenly across the bands thereby reducing the impact of interference to space services sharing the bands.
3. it detects other HIPERLAN emissions and moves to another frequency channel thereby allowing efficient use of all available channels in the most congested areas (hot spots).

In designating the spectrum it was recognised that the full 450 MHz would not be available in all locations because of other sharing services – hence the requirement for DFS. At the same time it has to be noted that this spectrum would not have been designated for HIPERLAN use had the requirement to employ DFS not been available as a spectrum management tool. In fact some administrations have not signed up to the ERC Decision designating the HIPERLAN spectrum while they await the results of tests to prove that DFS is capable of functioning as originally envisaged.

No firm decision has been made in the UK as to whether use of the 5 GHz band by HIPERLANs will be licence-exempt, but it is expected that this might be the case.

D.5.3 Europe v US

In the US the regulation of these bands falls under the Part 15 rules where the controls are not onerous. By and large the limits concentrate on power levels and are to some extent technology neutral (although there are distinctions for direct sequence and frequency hopping spread spectrum systems). In the UK the situation is very similar for Short Range Devices operating in the 2.4 GHz band. In the 5 GHz band however the situation is different in a number of ways:

- In the US only the lower 5 GHz band and the 5.8 GHz ISM band is available for U-NII devices.
- In Europe in addition to the lower 5 GHz band an extensive mid 5 GHz band is available but the 5.8 GHz ISM band is only available at a very low power level
- Devices operating in the US are governed by Part 15 rules. For the 5 GHz bands that are available the rules mainly specify the maximum transmitter spectral power density with an associated limit on antenna directionality. There is no requirement for power control or frequency agility.
- Devices operating in Europe are required to comply with the HIPERLAN standard and are mandated to use Dynamic Frequency Selection and Transmitter Power Control. It can be anticipated that there will be attempts to deploy US equipment (IEEE 802.11a) once it can be demonstrated that the essential requirements of the R&TTE Directive are met by the equipment. This situation has not been formally tested yet.

D.5.4 Summary

The main technical issues arising with respect to the two licence-exempt bands discussed above, concern:

- the density of devices anticipated along with their mode of deployment and the potential for congestion
- sharing with other services and the potential for interference between them

Congestion in itself is not problem as long as users accept the condition that they are not protected from interference[37]. The situation is likely to be self regulating - as the occurrence of interference increases usage will level out or decline. From a spectrum management point of view very little needs to be done – a maximum power density level needs to be specified. The lower the power level the higher the density of devices that can be supported, but at the same time the lower the power level the greater the constraint on application flexibility. The difficulty arises in setting the appropriate power level for the anticipated demand. Ultimately though, whatever power level is selected, utilisation will be self regulating. In the event that congestion occurs, market forces will either devise a means to overcome the congestion or will move applications to another frequency band.

If shared with authorised users of other services (i.e. users that are afforded protection from interference) then a "no interference, no protection" proviso and the specification of mandatory mitigation techniques may have to be applied to the licence-exempt devices. However it might be argued that the R&TTE Directive essential requirement of no interference may be adequate. In this case it will be necessary to demonstrate that a particular type of device will not cause interference. It is likely that in order to do so a mitigation technique similar to, or the same as, the mandated alternative would have to be part of the devices capability. Even when mitigation techniques are employed there is still the potential for congestion, although it should be noted that, for the frequency agile type of mitigation technique to be used effectively, an abundance of spectrum has to be available.

Finally, there is the question of guaranteed service in this sort of interference environment. In the case of authorised primary users operating in an environment where the licence-exempt devices are obliged to employ effective mitigation techniques, guaranteed service should be possible. For licence-exempt devices merely conforming to a maximum power level, their behaviour will depend greatly on the modulation / access techniques employed. For example the Radio Local Area Network (RLAN) devices using Direct Sequence Spread Spectrum (DSSS) are limited in the number of devices that can operate on a co-located basis so congestion in a given area will occur relatively quickly and guaranteed service would be difficult to provide. Frequency Hopping Spread Spectrum (FHSS) RLANs have a greater potential to coexist and therefore avoid congestion quite so early. However

[37] The only problem likely to arise is user dissatisfaction.

this is at the expense of throughput. Their behaviour is more graceful as the interference (collisions in frequency slots) between devices increases. RLANs employing frequency agility on a macro basis (i.e. Dynamic Frequency Selection) are likely to be able to provide guaranteed service from the point of view of interference from other primary services (providing enough spectrum is provided for DFS to function properly), as noted above, but there will still ultimately remain the problem of congestion. DFS will also be able to reconfigure RLANs in the presence of interference from other RLANs but, depending on the relationship between the density of devices and the amount of spectrum available, congestion will occur sooner or later and at that point guaranteed service is no longer a possibility.

E ROLE OF E-COMMERCE IN SPECTRUM MANAGEMENT

The study thus far suggests that market mechanisms will have a distinct role to play in the furtherance of dynamic spectrum management. However, use of such mechanisms will also intensify the demands made on the Agency to make available information regarding “spectrum rights owners” and to speed the process by which such rights are made available and / or transferred. One option that merits consideration is the use of E-commerce, which is becoming an increasingly valuable tool in both the public and private sectors. The UK Government is committed to maximising the use of e-commerce where ever such use is appropriate. How then can e-commerce be used to assist in the application of market mechanisms?

E-commerce has the potential to offer the information access, security and speed required to allow market mechanisms to operate at their most efficient. Already, internet access to regulatory information, and though less comprehensively in most countries, to licence application processes, is speeding and stream-lining spectrum management. The UK has been in the vanguard of this activity, having established many years ago a policy of placing key documentation and consultation papers on-line. The experience of the UK in this area means that use of e-commerce to support dynamic spectrum management is genuinely feasible. A variety of possible uses can be foreseen, such as access to licence databases and technical information, access to basic interference management simulators, through to application and fee paying systems.

However, whilst e-commerce offers great opportunities, a slight note of caution must be raised. It will be essential that data be accessible only in a controlled fashion. Financial transactions must be free from the possibility of fraud, whilst commercially confidential or militarily sensitive information must be accessible only by legitimate users. However, what information exactly will be considered "confidential" will itself be an issue - in New Zealand and Australia a considerable amount of data is publicly available. What ever the decisions made regarding data access however, the growing sophistication of on-line security systems mean that these issues should not be of undue concern, but should be matters for explicit planning.

E.1 Electronic support to spectrum engineering

The internet offers two main mechanisms by which to support spectrum engineering; firstly through the provision of information, and secondly through the simplification and acceleration of licence applications and processing.

The Agency’s interest in the possible use of the internet to support its activities is in line with the government’s strategy to introduce increase use of the internet, as detailed in the Treasury document “*E-government: a strategic framework for public services in the Information Age*”. This strategic paper declares that public sector organisations will:

• establish new ways of doing business
• implement common standards and framework policies
• develop e-business strategies
• provide services which are accessible via the government and other portals.

Furthermore, it is the government's declared intention that all services should be available on-line by 2005.

As noted above, the Agency has already been active in providing information on-line with the development of an extensive, regularly updated web site that provides a substantial volume of regulatory and explanatory documentation. However, binding transactions, such as payment for licences, have not been widely available on-line, although the Agency does now facilitate on-line payment by credit card and other automatic bank transfers. One of the problems that has faced any radical developments in the use of the Internet for legally binding transactions has been the need for writing, signatures and allied activities based on the use of written documents such as witnessing, posting, delivering etc. However, the Electronic Communications Act 2000 introduced powers to remove these barriers, enabling the Agency to think freely about the range of transactional services that it might wish to offer. In developing an e-government strategy the Agency might also wish to have an eye to the future, developing a consistent m-commerce strategy as part of the overall approach.

This section considers how developments in the use of the internet may be exploited to help provide further services on-line. Three main issues need to be addressed:

- What are the possibilities for using an open access, on-line frequency and technical register of licences in creating a dynamic and / or market based spectrum management regime?
- How might issues such as commercial confidentiality and national security be addressed?
- How can this process be carried forward?

Each is now considered.

E.2 Services to be provided

On-line services offer the clear potential to assist with the creation of a market based spectrum management regime. A number of services that would be of help can be identified:

- On-line licensing
- Publication of the assignment and planning criteria and databases
- On-line provision of planning tools

However, as the following discussion illustrates, the contribution to a new, more dynamic, management regime is likely to be maximised by the introduction of a combination of inter-linked supporting services.

E.2.1 On-line licensing

Putting administrative transactions on-line is consistent with the strategic objectives of e-government. On-line licensing is an implicit, and sometimes explicit objective of many Administrations around the world. It should enable speedier processing and can reduce administrative costs. It can also be simpler for the user. Within Europe however, the approach has yet to be implemented fully in any country, although a number of Administrations have taken steps towards on-line licensing.

A recent survey conducted by ERC WG RR revealed that over half of CEPT administrations had begun, planned or thought they would in the future offer some form of electronic licensing. Of these, nine (Belgium, Denmark, Finland, Germany, Hungary, Ireland, Netherlands, Norway and the UK) claimed to be already introducing or developing on-line systems. In Finland, applicants are able to submit licence applications by e-mail; currently licences are still issued in paper format but the intention is to deliver these electronically in future, via a secure server.

The survey concluded that benefits accrue for both licensees and NRAs. Licensees gain from improved service quality and reduced costs, while NRAs gained from reduced paper work, simpler upkeep of records and information retrieval. Among the issues still to be resolved were the electronic processing of fees and the authentication of applicants’ details (although in principle it seems these issues should be no different to those involved in other types of e-commerce transaction). In pilot trials involving PMR and maritime services, typically 30% of applicants had opted for the electronic approach.

In Canada, the concept of on-line licensing has become well established. Licensees for a variety of applications are able to obtain licence application forms, submit the application, track the progress of the application and pay for the licence (assuming success, up to $5,000) all via the Administration’s web site. Substantial help is provided, including a tutorial package which explains the process.

In order to support on-line licensing a number of elements must be in place. Firstly, the information required to determine what licences are available, and whether the application is likely to be successful in terms of acceptable interference must be provided. This is considered in moment. Secondly, a trusted means by which to pay for a license is required. Developments in on-line security should ensure that this is not a serious obstacle for transactions. Again this is explored below. Finally however, it must be remembered that although the “front office” may be almost completely automated, it is likely that for many years to come a human element will still be required for the final adjudication of more complex applications. Thus although on-line licensing may help increase productivity, there remains a clear need for professional spectrum engineers. Even in the highly automated Canadian example, the ultimate decision on whether to grant a licence remains with the staff of Industry Canada.

In Australia and New Zealand, licence forms are available on-line, but the forms have still to be completed manually and posted to an ACA office with a paper cheque.

For on-line licensing to work in practice it will be necessary to provide considerable information on-line. This is discussed in the next section. The process may also require further support, for example through the provision of on-line planning tools, if it is to be of value to new entrants as well as to incumbents, as addressed in the third section.

E.2.2 Publication of information

There exists a growing tendency world-wide to publish more, rather than less, information regarding spectrum use in nation states. The publication of assignment and planning criteria and databases should allow users to make better-informed requests for assignments and to suggest ways of changing assignments to use spectrum more efficiently. This is already undertaken in a number of other countries e.g. Denmark, the Netherlands, Australia, New Zealand and the USA. When the proposed Decision on a Regulatory Framework for Radio Spectrum Policy in the EC comes into force, Member States will be required to make available information on existing frequency assignments.[38]

The Australian Communication Authority's Register of Radiocommunications Licences contains real-time information derived from the ACA's RADCOM database. Users can extract details of who holds radiocommunication licences, technical aspects of these licences and transmitter site details. Searches can be conducted by licence holder, licence number, frequency, site or postcode. The Australian site also holds a current listing of all embargoed bands, that is to say bands reserved for a future use.

In Canada too there is a publicly available database of licences auctioned and corresponding licensees. The Assignment and Licensing System (ALS) database contains technical, administrative, and financial data pertaining to all radio licences in Canada. The contents of the ALS database have been available to the public for some time upon request, however the ALS is now on the Administration's web site, allowing public access to current data in real time. It may be noted that some "protected" data is not available in the public domain. However, legitimate users (as determined by Industry Canada) can gain access to this data on-line.

A similar situation applies in the US. However, the current US databases are somewhat difficult to use, and with the advent of spectrum leasing the FCC recognises the need for more detailed databases containing assignment information, and have proposed that this should be managed by the private sector.

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38 See article 9 and Annex 1 of COM(2000)407.

Within Europe, Administrations are developing an ever more transparent attitude towards data. This is in line with the requirements of the forthcoming Spectrum Decision.

E.2.3 On-line planning tools

Perhaps the most contentious of the three areas, the provision of on-line planning tools would allow users to self assign spectrum, though it is recognised this may raise copyright / intellectual property right concerns on the part of the tool provider.

E.2.3.1 Licence applications

A licence application is unlikely to be successful if it has the potential to cause unacceptable interference to incumbents. To determine whether the application has any chance of success therefore, the applicant needs extensive knowledge of the radio environment currently existing in the location / frequency / service of interest. This issue will be addressed by providing on-line information. However, whilst most of the larger organisations applying for licenses will be in a position to undertake their own interference analysis, many others will not have the necessary tools, and would depend upon the Administration undertaking the analysis on their behalf. This is potentially wasteful of both the applicant’s and the Administration’s time, and will introduce possibly lengthy delays into the application procedure.

The problem has to some extent been tackled by other Administrations. In Australia the ACA has developed and released a number of tools. RadDEM - an integer digital elevation model for Australia; together with the DEM (Digital Elevation Model) an effective site height program have both been made publicly available for a small fee. In Canada, where the shared border with the US introduces sharing complexities, downloadable, free software is provided to help applicants determine whether cross-border co-ordination may be required.

Whether the Agency would wish to provide such tools may well be a trade-off between the effort required to develop robust and accurate software (which may be costly even if undertaking comparatively simple calculations) as against the possible effort saved in sifting out unacceptable applications. Furthermore, there will also be a cost (in terms of training and possibly usage / licensing) to the user to be off-set against the benefit of the time and effort saved in avoiding multiple iterations when applying for a licence.

E.2.3.2 Secondary trading

The introduction of secondary trading is likely to raise a more substantive need for common tools – which may or may not be provided by the Agency, on-line. It may be recalled that in Sweden, during the recent 3G licensing process, applicants used their own tools to predict coverage. However, when the coverage predictions were compared with the PTS predictions there were found to be variances in a number of cases. Under a secondary trading regime it is likely that licensees in adjoining licence areas will wish to negotiate regarding acceptable power levels at specific points. If different models are used by each licensee disputes might well be anticipated. The possible provision / specification of common tools to avoid such recurrent problems merits further thought.

E.3 Security and confidentiality

Both national security and commercial confidentiality issues will need to be addressed when considering the extent of information that can be provided on line. This will shortly be the subject of an Agency consultation activity.

At a minimum, information available in printed form should be available in electronic form. In their response to the Consultation on the independent review the CAA note that much of their spectrum use information (apart from radars and some transmitters) is already available in print in the public domain and so could be made available electronically. The level of detail placed in the public domain can of course be varied depending upon the nature / sensitivity of the application involved. In light of the new, more sensitive security environment the Agency might wish to revise any view on what is, and what is not, appropriate information to be released into the public domain.

In the US a database of national Federal Government spectrum assignments is produced on a monthly basis by the NTIA. The information held in the database, which relates to government use of spectrum, is classified and hence not in the public domain. In Canada some records within the overall national frequency database are protected from public view. Within certain designated bands the Protected Microwave Frequency Information Search identifies protected licence holders who may be using frequencies within the band specified and in the general geographic area indicated by the searcher. The results it generates are purposefully vague, to protect the confidentiality of the users. However, searchers are provided with sufficient information (namely frequency owner and contact details) to enable them to contact all potential protected licence holders within the area of concern. Each search takes into account both existing frequency records, and pending frequency records (where an application has been received for use of a frequency, that frequency will be marked as unavailable). Technical information is not provided.

F GENERIC EU DIRECTIVES AND DECISIONS

F.1 Framework Directive

The proposed Framework Directive (COM/2000/0393, updated by 2000/0184) seeks to establish a harmonised framework for regulation of electronic communications throughout the Community. The Directive covers a wide range of issues, and a number of the Articles may be interpreted as constraining possible future actions by the Agency. The extent and importance of the constraint varies significantly from one Article to another; specific articles are indicated (Ax). This section considers the possible ramifications of the Directive for key areas of interest.

F.1.1 National Regulatory Authorities

The NRA must be entirely independent; legally distinct from and functionally independent of all network, equipment or service suppliers (A3). The Agency is therefore prohibited from engaging in any form of joint venture, ownership, or other controlling relationship with an operator, manufacturer etc.

Any provider affected by the Agency's decisions has the right of appeal to an independent tribunal, the decision being subject to subsequent review by court or tribunal (A4). The Agency may therefore on occasion find that it faces lengthy (time consuming and costly) legal review of its decisions. A dispute resolution process may therefore usefully be developed. It may also be noted that as the appeal provisions are likely to be amended under current Commission proposals to include merit as well as facts, it is likely that an independent appeals tribunal will need to be established.

F.1.2 Information, consultation and transparency

The Agency is required to provide a variety of information to the Commission (A5). Furthermore, any information provided to one EU NRA must, on substantiated request, be provided to other EU NRAs. Whilst issues of confidentiality are to some extent recognised by the Article, the requirement for disclosure could have implications for bi-lateral negotiations, to the extent that the negotiations depend upon certain information remaining confidential between the two negotiating authorities.

When implementing measures that will ensure conformance with the Directive and which might have significant impact on the market (A6), the Agency is obliged to engage in public consultation. Where obligations relating to an organisation having significant market power are to be imposed or lifted the consultation must include the Commission and other NRAs. The draft measure, together with the underlying rationale and supporting information must be provided. The current draft does not include spectrum and pricing decisions, however it is understood that there exists some Commission pressure to amend this.

The Agency can set its own duration for the public consultation, by default however the Commission and NRAs must respond within one month.

Furthermore, if the Commission is unhappy with the proposed measures it can extend the process by a further month. The requirement for a consultation process will constrain the rapidity with which the Agency can act to implement the Directive. It may however be noted that the Article makes provision for the NRA to act without consultation “in exceptional circumstances” namely when competition is to be safeguarded or user interests must be protected.

F.1.3 Objectives and Principles

The Directive states a number of objectives towards which the Agency must work (A7). Of particular interest are the following requirements to:

- work towards technologically neutral regulation (within the constraints set by the Specific Directives)
- promote choice, price and quality through active competition: spectrum trading could be argued to support this objective
- develop the internal European market by removing obstacles and encouraging interoperability: this implies the use of common standards and common allocations
- protect the interests of European citizens in areas such as data privacy, consumer protection, social inclusion

The breadth of issues addressed in this Article is considerable. The type of constraint that might be foreseen would include issues such as the prohibition of favourable treatment of UK companies / SMEs / new entrants; requirement to ensure that providers address sparse and remote rural communities as well as the more accessible and profitable urban communities; prohibition of regulation based upon favoured technologies, which might constrain attempts to encourage inward investment, eg from US or Japan, by adopting a more liberal approach to use of spectrum.

F.1.4 Frequency management

Member States are required to "ensure that the allocation and assignment of radio spectrum by national regulatory authorities is based on objective, transparent, non-discriminatory and proportionate criteria" (A8). The Agency is therefore limited in the extent to which it can, for example, actively encourage innovation within UK industry by allowing preferential access to the spectrum.

On a positive note, the Article makes provision for NRAs to permit the transfer of rights to use radio spectrum between undertakings, subject to notification to the NRA and on the condition that competition is not distorted as a result of such transfer. Where spectrum use has been harmonised through Decision COM(2000)407 (on a regulatory framework for radio spectrum policy in the EC) the transfer cannot result in a change of use: the term “change of use” is not defined.

Thus the Agency may, within limits (i.e. no change of use), allow secondary trading to occur.

F.1.5 Significant market power

The NRA is required firstly to define markets, and then to determine whether each market is competitive. Where the market is not competitive regulatory obligations must be imposed upon any organisation enjoying significant market power. Where the market is deemed to be competitive, any existing regulatory obligations must be removed. This issue is addressed in Articles 13 to 14a inclusive.

F.1.6 Standardisation

The Commission maintains a list of standards (published in OJEC) that are to be used to encourage harmonisation. In broad terms (A15), standards drawn up by the European Standards Organisations (CEN, CENELEC, ETSI) are given priority to the extent strictly necessary to ensure interoperability and choice for users. When an appropriate ESO standard does not exist, NRAs are encouraged to use standards from the ITU, ISO or IEC instead. The Commission reserves the right to mandate use of certain standards if it considers that harmonisation is at risk by use of alternatives. The ability of the UK to evaluate standards and select those use of which would contribute most fully to the national economy is therefore somewhat unclear. Furthermore following intervention by the World Trade Organisation "equivalent" standards are permitted (specific WTO intervention arose regarding UMTS). Thus if standards can be shown to be "equivalent", e.g. the TETRA and TETRAPOL standards as some have argued, choices can still be made.

F.1.7 Harmonisation

The Commission publishes Recommendations to assist with the harmonisation implications of the provisions of the Framework Directive. These are in effect advisory.

F.1.8 Dispute resolution

The NRA has an obligation to resolve, within four months, any dispute arising between organisations affected by the provisions of this Directive (A17). The parties in the dispute retain the right to go to court. As experience within the Community has demonstrated (in the Republic of Ireland for example), such disputes can be costly to the NRA and may lead to significant delays in achieving the overall objectives of provision of services and competition.

Where a dispute arises between parties in different Member States (A18) the NRAs of the affected Member States have an obligation to co-operate to resolve the dispute. As with national disputes, a four month duration is cited. The course of action should the NRAs fail to reach agreement is not addressed within the Directive.

F.2 Authorisation Directive

The proposed Authorisation Directive (COM/2000/0386, updated by 2000/0184) seeks to create a legal framework that will minimise the restrictions that can be placed upon providers of electronic communications and services by Member States. In summary, it will require NRAs to issue general authorisation for all electronic communication networks and services, but will allow for individual rights of use (i.e. licences) to be issued for radio spectrum where this is necessary, for example to avoid harmful interference. NRAs may limit the number of such rights of use only where this is necessary to ensure the efficient use of radio frequencies. The basic assumption built into the Directive is that, by default, electronic communications services or network have the right to operate within a Member State subject only to a general authorisation. A simple notification to the NRA is sufficient to entitle an organisation to begin provision of services, unless it seeks to provide a service, or use a medium that is subject to additional constraints. As the remainder of this section illustrates, use of radio frequencies are commonly subject to additional constraints as parts of the spectrum may be considered a scarce resource.

F.2.1 Assignment & licensing procedures

Where possible, and especially where interference is not an issue, the NRA is required to permit use of the spectrum under the auspices of the general authorisation – and may not therefore require individual rights of use to be granted.

The Directive enables spectrum to be assigned both to network and service providers, and to organisations that use the networks / services (e.g. broadcast content providers). NRAs are permitted to impose certain restrictions upon the use of the assigned frequencies, so long as such restrictions meet the usual criteria of being transparent, objective, non-discriminatory and proportionate. The acceptable conditions are published as an Annex to the Directive. A wide range of conditions are included, such as: interference criteria, public safety, use of standards and others. Interestingly, one of the criteria specifically cited with regard to rights of use is that of transfer. The right of use must clearly indicate whether, and under what conditions, the rights can be transferred at the initiative of the rights holder (Article 5.2). Decisions on the grant of a right of use for a frequency allocated a specific purpose within the National Frequency Table must be communicated within 6 weeks.

Where frequencies are scarce, the NRA is permitted to assign rights to use in such a way as to optimise use of the resource. However, this position must be regularly reviewed to ensure that the granting of rights of use remains appropriate, in terms of benefits to users and development of competition.

In granting rights of use the NRA is permitted to use competitive or comparative selection procedures. Where comparative selection procedures are chosen the NRA is permitted to take up to eight months to ensure a fair result. Should some potential operators be excluded this is accepted, so long as the chosen selection procedure is objective, non-discriminatory etc. Furthermore, the NRA is permitted to verify whether any potential applicant will be in a position to conform to the licence obligations should such a licence be awarded. The applicant may be rejected should the response suggest that the applicant will not be able to conform.

Where the spectrum has been harmonised within the European, and / or wider international community, the Member States must act in accordance with the harmonised structure (A8).

F.2.2 Non-compliance

Responsibility for adherence to the restrictions lies with the entity to whom the right of use of the frequency has been assigned. Where a service provider fails to meet the obligations imposed by the NRA, written notice must first be given; where the offender fails to remedy the situation penalties may be applied, so long as the penalties are commensurate with the offence (A10). The Directive suggests that it will rarely be appropriate to withdraw the right of an operator to use radio frequencies, though it acknowledges that where a serious threat to health, security or competition arises, urgent action may be required. Any entity against whom compliance action is taken has the right of appeal.

F.2.3 Administrative and other charges

The Directive supports the concept that NRAs should impose upon operators a charge equal to the costs incurred by the NRA in managing the spectrum (authorisation, granting rights of use, market analysis, international work, compliance monitoring) (A12). The charging system adopted may not however distort competition, nor create a barrier to entry.

The Directive specifically cites use of radio frequencies as an instance in which additional usage charges may also be imposed as a mechanism by which to ensure optimal use of a scarce resource. Once again however a caveat is raised, in this instance, the imposition of charges must not hinder innovation, nor detrimentally affect competition within the market (A13).

The basis for charging, together with costs and charges received, must be published on an annual basis.

F.2.4 Provision of information

The NRA is permitted to request from licensees certain information required to meet its obligations at a national and European level. The type of information that can be requested includes information required for:

- Verification of compliance, whether invoked by a complaint or not
- Assessment of a request to grant a right of use
- Publication of price and quality of service information aimed at consumers
- National / international statistical data
- Market analysis

F.3 Competition Directive

Building on the earlier Directive of 1990, the 1996 Directive (96/19/EC) seeks to ensure free and strong competition within the European telecommunications sector, with the objective of providing users with choice, quality and fair pricing. The Directive covers the whole telecom market, including numbering, leased lines and other non-RF related issues. However, it also addresses a number of issues that are central to the future use and regulation of the spectrum.

The NRA is constrained in the extent to which it can restrict the entrance of new competitors to the telecommunications market. Licensing or declaration procedures may only be imposed where such procedures are indispensable to achieve compliance with other Directives and objectives, such as the provision of universal service. Public service obligations can be included within some categories of licence. Licences may not be employed where a simple declaration would suffice. In both cases, the relevant conditions must be objective, non-discriminatory, proportionate and transparent. Refusal to grant a licence must be accompanied by an explanation, and a procedure for appeal must be developed.

Where licences are required, the number of licences can only be limited where they address scarce resources. Thus licences may be imposed for certain parts of the spectrum (addressing frequency and / or geographical scarcity), but may not be imposed where the spectrum resource is adequate to meet demand. In all cases, the Commission must be kept informed of all conditions attached to licences and declarations.

The Directive addresses environmental issues / town and country planning issues, noting that new entrants may be at a disadvantage where incumbents enjoy an infrastructure that was established some years ago and simply could not be implemented today. The Directive requires Member States to ensure that, where technically feasible, new entrants are able to gain access on reasonable terms to the infrastructure of existing operators, such that they can create a viable infrastructure of their own. Given the increasing hostility of the general public towards radio masts, on both health and aesthetic grounds, this will be an issue for roll-out of future radio based telecom infrastructure.

F.4 Spectrum Policy Decision

The proposed regulatory framework for radio spectrum policy in the EC (COM(2000)407) has four key objectives:

1. To create a policy platform that will be responsive to market and technological developments, and that will include a consultation role
2. To establish a procedural and legal framework for frequency harmonisation
3. To increase the availability of information regarding spectrum use
4. To safeguard EU interests during international negotiations that may have ramifications for wider EU policies

The Decision clearly indicates the Commission view that it is necessary to address spectrum issues that could affect EU interests within the EU itself, and not through a third party, such as the CEPT or ITU. It notes that at present, the larger commercial bodies can on occasion have a disproportionate influence over spectrum allocation due to their substantial resources. The voice of non-commercial groups, many of which are socially meritorious, may be lost, potentially resulting in an imbalance of access to the spectrum.

Existing decisions have tended to be sector specific. However, with the rapid rate of technological change and innovation, this slightly cumbersome approach risks delaying the introduction of new services. The concept of an agreed, harmonised regulatory framework seeks to overcome this problem by ensuring that the broad framework is in place in advance of innovation, allowing a rapid and flexible response. However, this does of course rely upon the architects of the framework having considerable insight into how innovation may develop within the near to medium term.

Recognising the importance of certainty to the major investors in future communication systems, the Decision proposes a move away from the largely voluntary approach of the CEPT, to a system whereby once agreed, the EU policy will become mandatory for all Member States. On a similar line, the Decision goes on to propose that a common EU position be developed with regard to international negotiations, and that the Community play a more active role within such negotiations.

To assist in implementing these proposals, the Decision proposes a system whereby the Commission (largely through the auspices of the newly created senior Official Radio Spectrum Policy Group) will mandate the CEPT to address key spectrum issues. The potential constraint arises in that the Commission reserves the right to make the results of the mandate compulsory for all Member States, with implementation required by a Commission defined deadline. The areas covered by this procedure have yet to be defined and so the extent and potential impact of this approach upon UK spectrum management cannot at present be determined.

F.5 R&TTE Directive

The R&TTE Directive (1999/5/EC) addresses Radio equipment and Telecommunications Terminal Equipment, with regard to the mutual recognition of their conformity. It seeks to establish a regulatory framework to assist in the development of a free market in radio and telecom equipment, minimising barriers between Member States and encouraging harmonisation, whilst ensuring that certain fundamental, but generic, standards of performance and safety are adhered to.

F.5.1 Essential requirements & harmonisation

The “essential requirements” lie at the heart of the R&TTE Directive. These form the legal basis for compliance of radio and telecommunications equipment with the

R&TTE Directive. Manufacturers may use any appropriate standard to demonstrate conformity with the essential requirements. However, Member States are required to assume conformity with the essential requirements if manufacturers make use of relevant harmonised standards which have been referenced in the Official Journal of the European Communities. These standards will be / have been developed by the European standardisation organisations, ETSI, CEN and CENELEC, and detail technical requirements based on the applicable essential requirements.

Should a Member State feel that a relevant harmonised standard does not in fact achieve compliance with the essential requirements the Commission may publish guidelines on the interpretation of the standard in question or, after consultation, may withdraw the standard all together.

The R&TTE Directive essential requirements relate to causing interference; receiver characteristics are therefore not essential requirements. In the UK it is intended that the RA will publish the receiver characteristics used during any spectrum planning undertaken, but these receiver characteristics will not be mandatory. Users of the spectrum can then decide whether to use receivers having a different performance than that assumed by the RA and accept the consequences.

F.6 Service specific Directives and Decisions

F.6.1 GSM

In seeking to establish, quickly and effectively, a community wide cellular digital mobile communications system, the Commission drew upon the work of CEPT and ETSI – a pattern that is found throughout the application specific Directives. CEPT proposed that the bands 890 – 915MHz and 935 – 960MHz be allocated to digital mobile communications. The GSM Directive (87/372/EEC) supports the broad recommendation but, recognising that the technology and market would take some years to become fully established, required that all Member States make available the 905 – 914MHz and 950 – 959 MHz parts of the band for exclusive use of GSM systems by 1 January 1991, allowing the remaining parts of the CEPT suggested bands to come into use as quickly as commercial demand required. With regard to exclusivity, one exception was allowed for: pre-existing point to point connections were permitted to remain in the bands on a non-interfering basis.

F.6.2 ERMES

At the time of introduction of the ERMES Directive (90/544/EEC) a range of paging systems operated within the Community, many being incompatible. The Directive sought to establish system parameters that would enable the economic benefits of a Community wide market to be seen.

The Directive calls upon the ETSI European Radio Messaging System (ERMES) standard to define appropriate technology, and upon the CEPT identified unpaired spectrum at 169.4 – 169.8MHZ to provide suitable harmonised spectrum. Within the proposed band four channels are priorities and protected, namely: 169.6 MHz, 169.65 MHz, 169.7 MHz, 169.75 MHz.

F.6.3 DECT

The DECT Directive (91/287/EEC) recognises the importance of a common (Community wide) frequency allocation for, and the need for mutual recognition of equipment conformity. In doing so it draws upon the work of the CEPT (Rec T/R 22-02) in designating the band 1880 – 1900 MHz for use by DECT systems. Such systems are defined as any technology that conforms with the Digital European Cordless Telecommunications standard, as developed by ETSI.

DECT systems are not awarded sole occupancy of the band, but are granted primacy over all other occupants.

This spectrum is therefore available for use by other systems, subject to new entrants not interfering with systems conforming to the ETSI DECT standard.

F.6.4 S-PCS

Community wide, and indeed global, agreement is particularly important in the case of Satellite Personal Communication Systems (S-PCS) in order to make any such system commercially viable.

Within the S-PCS Directive frequency harmonisation is sought, once again, through the auspices of CEPT, although Member States are permitted, where spectrum scarcity justifies such a move, to limit the number of S-PCS systems authorised. However where the number of systems is limited Member States are required to co-ordinate in an effort to ensure that a common set of systems can operate throughout the Community. It is a requirement that free movement of technical equipment be allowed in line with the European Common Technical Regulations.

Article 4 outlines the process by which the Commission seeks to offer a “one stop shop” for applicants. Potential system operators are able to apply for a licence, or make notification in the case of general authorisations, to a number of Commission designated bodies. The designated body then passes the application / notification to all affected NRAs for processing. Each NRA is allowed up to six weeks to decide upon whether or not to grant a licence, with a four month extension permitted where comparative selection is to be used. In the case of a general authorisation the NRA is permitted to prevent the operator from bringing a new system into use for a period of four weeks from submission of notification.

In light of the wider international nature of S-PCS systems, the Directive includes a process through which the Commission may be mandated to negotiate with third countries where difficulties have been encountered in the introduction of S-PCS services. Such negotiations may not be contrary to any international agreements.

F.6.5 UMTS Decision[39]

This Decision addresses the co-ordinated introduction of a third generation mobile and wireless communication system (UMTS) in the community. Its broad objective is to facilitate the "rapid market access for seamless, global coverage and low cost and innovative service offering" which is perceived to be of strategic importance to the European telecommunications industry, to the development of the information society and indeed to the wider European economy and employment.

The constraints associated with the Decision arise from its recognition of the importance of pan-European interoperation. It requires that all Member States adhere to the CEPT (ERC Decision ERC/DEC/(97)/07) regarding harmonised frequency bands (ie 1900 – 1980, 2010 – 2025, 2110 – 2170 MHz for terrestrial elements and 1980 – 2010, 2170 – 2200 MHz for the satellite element). The UK is therefore compelled to ensure that these bands remain allocated to mobile / mobile satellite use.

The Decision notes that some systems that seek recognition within the IMT2000 family may prove to be incompatible. Member States are required to co-ordinate with a view to ensuring that all systems operating within the Community are compatible. This therefore constrains the UK with regard to the technical specification of any system that may operate in the bands defined above.

Pursing the objective of pan-European coverage and interoperability, the Decision indicates that Member States should encourage UMTS network suppliers to negotiate cross-border roaming agreements.

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39 Decision No 128/1999/EC of the European Parliament and of the Council of 14 December 1998 on the co-ordinated introduction of a third-generation mobile and wireless communications system (UMTS) in the Community (In force 22/01/99 – 21/01/03)

G MATRIX

(see separate A3 format document)

H GLOSSARY

3G	Third Generation mobile system
ACA	Australian Communication Authority
ACCC	Australian Competition and Consumer Commission
AFA	Autonomous Frequency Assignment
ALS	Assignment and Licensing System
BFWA	Broadband Fixed Wireless Access
CAA	Civil Aviation Authority (UK)
CDMA	Code Division Multiple Access
CEN	European Standards Committee
CENELEC	European Electrotechnical Standards Committee
CEPT	European Conference of Postal and Telecommunications Administrations
DAB	Digital Audio Broadcast
DCS1800	Digital Cellular System 1800 (former term for GSM services operating at 1800 MHz)
DECT	Digital Enhanced Cordless Telecommunications
DEM	Digital Elevation Model
DFS	Dynamic Frequency Selection
DSSS	Direct Sequence Spread Spectrum
DTB	Digital TV Broadcasting
DTV	Digital TV
DVB-T	Digital Video Broadcasting - Terrestrial
EC	European Commission
ECAT	European Common (Frequency) Allocation Table
EIRP	Effective Isotropically Radiated Power
EMC	Electro-Magnetic Compatibility
ENG/OB	Electronic News Gathering/Outside Broadcast
ERC	European Radiocommunications Committee
ERMES	European Radio Messaging System
ERO	European Radiocommunications Office
ERP	Effective Radiated Power

ESO	European Standards Organisations
ETO	European Telecommunications Office
ETSI	European Telecommunications Standards Institute
EU	European Union
FCC	Federal Communications Commission (US)
FD	Framework Directive
FDMA	Frequency Division Multiple Access
FEC	Forward Error Correction
FHSS	Frequency Hopping Spread Spectrum
FWA	Fixed Wireless Access
GATS	General Agreement on Trade in Services
GSM	Global System for Mobile Communications
GWCS	General Wireless Communications Services
HIPERLAN	High Performance Radio Local Area Network
IC	Industry Canada
IEC	International Electrotechnical Commission
IMT-2000	International Mobile Telecommunications 2000 (Family of air interface standards for 3G mobile services)
ISM	Industrial, Scientific and Medical
ISO	International Organisation for Standardisation
ITU	International Telecommunications Union
ITU-R	ITU-Radiocommunications Sector
ITU RR	ITU Radio Regulations
MMDS	Multichannel Multipoint Distribution Service
MoU	Memorandum of Understanding
MSC	Mobile Services Committee
MVDS	Multipoint Video Distribution System
MWS	Multimedia Wireless System
NRA	National Regulatory Authority
NTIA	National Telecommunications and Information Administration (US)
ONP	Open Network Provision

OSS	One Stop Shop
OJEC	Official Journal of the European Commission
PAMR	Public Access Mobile Radio
PFD	Power Flux Density
P-MP	Point to Multi-Point
PMR	Private Mobile Radio
P-P	Point to Point
PTS	Post & Telestyrelsen (Sweden)
RA	Radiocommunications Agency (UK)
RADCOM	Radiocommunications database (Australia)
RF	Radio Frequency
RLAN	Radio Local Area Network
RR	Radio Regulations
RTG	Rural Telecommunications Group (US)
R&TTE	Radio & Telecommunications Terminal Equipment
SAB	Services Ancillary to Broadcasting
SDMA	Spatial Division Multiple Access
SMAG	Spectrum Management Advisory Group (UK)
SME	Small and Medium size Enterprises
SMR	Specialised Mobile Radio
S-PCS	Satellite Personal Communications System
SPD	Spectrum Policy Decision
SRD	Short Range Device
STU	Standard Trading Unit (of spectrum)
TACS	Total Access Communication System (analogue cellular standard)
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TETRA	Terrestrial Trunked Radio (ETSI digital trunked radio standard)
TETRAPOL	Proprietary digital trunked radio standard
TPC	Transmitter Power Control

UMTS	Universal Mobile Telecommunications System (3G mobile standard)
U-NII	Unlicensed National Information Infrastructure
USO	Universal Service Obligation
UWB	Ultra Wide Band
W-CDMA	Wideband Code Division Multiple Access
WGRR	Radio Regulatory Working Group (CEPT / ERC)
WTO	World Trade Organisation