A GLOSSARY

Term	Definition
ATSC	American Television Standards Committee (body responsible for developing North American digital TV standard; also the name of the standard itself)
AVC	Advanced Video Coding
CEPT	European Conference of Post and Telecommunications Administrations
COFDM	Coded Orthogonal Frequency Division Multiplex
CS	Consumer Surplus
DG INFSO	Directorate General for the Information Society
DTT	Digital Terrestrial Television
DVB-H	Digital Video Broadcasting (Handheld) standard (under development
DVB-M	Digital Video Broadcasting (Mobile) – precursor to DVB-X and DVB-H
DVB-T	Digital Video Broadcasting (Terrestrial) standard
DVB-X	Precursor to DVB-H
EBU	European Broadcasting Union
EC	European Commission
ECC	European Communications Committee (part of CEPT)
ECTA	European Competitive Telecommunications Association
EU	European Union
FCC	Federal Communications Commission
FFT	Fast Fourier Transform
FM-PT	Frequency Management Project Team (of ECC)
GPRS	General Packet Radio Service (GSM packet data transmission standard)
GSM	Global System for Mobile (current European mobile phone standard)
HDTV	High Definition Television
ICT	Information and Communications Technology
IPDC	Internet Protocol Datacasting
ISDB	Integrated Services Digital Broadcasting (Japanese digital TV standard)
ITU	International Telecommunications Union

MBMS	Multimedia Broadcast and Multicast Service (part of UMTS standard)
MFN	Multi-Frequency Network
MHP	Multimedia Home Platform (European standard for interactive television)
MPEG	Motion Picture Experts Group (global standards body)
MPEG2	Currently main standard for coding digital video material
MPEG4/AVC	New standard for coding digital video material providing greater compression
MUX	Multiplex
NRA	National Regulatory Authority
PS	Producer Surplus
PSB	Public Service Broadcaster
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RRC	Regional Regulatory Conference (ITU)
SAB	Services ancillary to broadcasting
SAP	Services ancillary to programme making
SFN	Single frequency network
STB	Set Top Box (to enable digital reception on an analogue receiver or monitor)
T-DAB	Terrestrial Digital Audio Broadcasting
UMTS	Universal Mobile Telecommunications System (3rd generation mobile standard)
WGFM	ECC Working Group on Frequency Management
WLAN	Wireless local area network

B INTRODUCTION TO INTERNATIONAL SPECTRUM MANAGEMENT

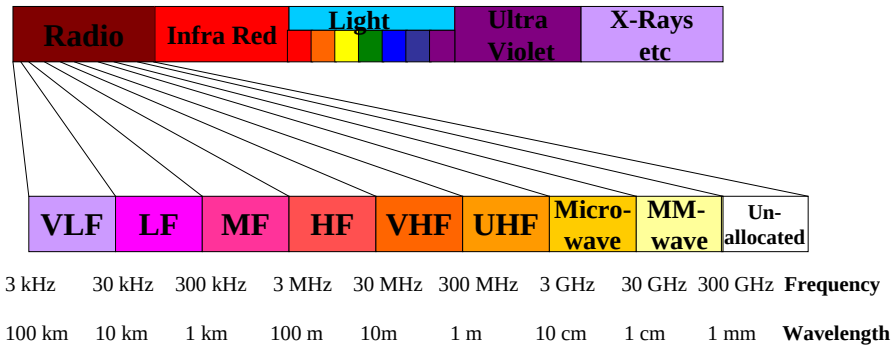
The radio spectrum is a vital but limited natural resource which provides the means to convey audio, video or other information content over distances from a few metres to thousands of kilometres. The medium is essential to the provision of mobile communication services and to provide mobile reception of broadcast services. It is also fundamental to the safe operation of air and maritime transport, is used widely by the military and emergency services and supports important scientific applications such as meteorology and radio astronomy. A significant amount of spectrum is currently designated for exclusive use by television broadcasters and the migration from analogue to digital transmission is likely to have a major bearing on how this spectrum is used in the long term. This chapter explains the nature of radio spectrum and the importance attached to its effective management.

B.1 Definition of Radio Spectrum

The radio spectrum lies at the lower end of the electromagnetic spectrum, which includes other categories of electromagnetic radiation such as infra-red, optical light and ultra-violet (see Figure B.1 below). Electromagnetic waves are characterised by either:

- ***frequency***, i.e. the number of sinusoidal oscillations, or "cycles" per second, usually specified in Hertz (Hz) where 1 Hz = 1 cycle per second, or
- ***wavelength***, i.e. the distance traversed by 1 cycle of a electromagnetic wave in free space (all electromagnetic radiation travels at a constant speed of 300,000 km/sec in free space)

The radio spectrum is generally considered to lie within the frequency range 3 kHz to 3,000 GHz, which corresponds to wavelengths between 100 km and 0.1 mm. Within this range, blocks of spectrum have been designated over the years for various applications, such as broadcasting, fixed or mobile communications. Note that frequencies above 300 GHz are currently unallocated, largely due to the lack of current technology to harness such frequencies for effective radio communication. The radio spectrum is further sub-divided into the following categories, each of which has distinct characteristics that make it suitable for particular applications.



Key:

VLF = very low frequency)
LF (low frequency)
MF (medium frequency)
HF (high frequency)
VHF (very high frequency)
UHF (ultra high frequency)
Microwave (sometimes referred to as SHF – super high frequency)
Millimetre wave (sometimes referred to as EHF – extra high frequency)

Figure B.1: The Electromagnetic Spectrum

B.2 Physical Characteristics of Radio Spectrum

The radio frequency (RF) bandwidth[1] available for specific applications is limited further by the physical characteristics of the various parts of the radio spectrum. At lower frequencies (below about 30 MHz), the limited bandwidth means only very narrow band services such as speech or low-rate data can be supported, but radio waves can traverse great distances. This is ideal for aeronautical and maritime communications or for low fidelity national or international broadcasting, but is impractical for high-density mobile communications or for high quality broadcasting. At the other extreme, the microwave and millimetre-wave bands above about 3 GHz provide much greater bandwidth but communication relies on a direct, unobstructed path between transmitter and receiver. This rules out its use for most mobile and terrestrial broadcast applications (an exception to the latter being reception by externally mounted fixed antennas where there is a clear line of sight to the transmitter).

B.3 Uses of Radio Spectrum

Since the first practical demonstration of radio at the beginning of the 20th Century, an enormous range of uses has evolved. Earliest use focussed on immediate priorities, such as improving safety at sea and supporting the military, but it was not long before the first broadcast stations appeared in the early 1920s. The following decade saw the launch of public TV services and by 1949 the first commercial mobile radio system had been launched, laying the foundations for today's mass market in mobile telephony. Further technological developments, such as colour TV

[1] The term "RF bandwidth" refers to the amount of radio spectrum required (usually expressed in kHz or MHz), as distinct from the more common reference to bandwidth as the transmission capacity of a network or system

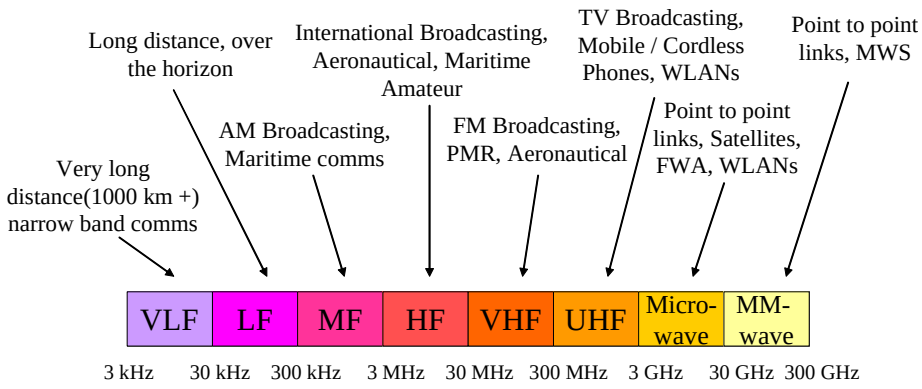
and FM sound broadcasting, combined with market liberalisation and the growth of competing services, have progressively increased the demand for radio spectrum.

In addition to the constraints imposed by the physical characteristics of different parts of the spectrum, the historical legacy of spectrum use can make it difficult to introduce new services where there is a large base of existing users who would be affected. This is a particularly significant factor in the case of TV and radio broadcasting which were the first uses to address the mass market.

Figure B.2 shows the principal uses of the various parts of the radio spectrum, reflecting the physical characteristics of the spectrum and the historical legacy. Note that terrestrial broadcasting is effectively constrained to frequencies below 3 GHz, since higher frequencies require a clear line-of-sight path to the transmitter. This constraint also applies to wide area mobile services such as GSM, UMTS and private mobile radio (including use by the military, public safety organisations and civil aviation), placing particular pressure on this part of the spectrum.

Ensuring equitable access to this valuable resource for those who need it, whilst maintaining the quality and usability of the resource by avoiding interference require very specific spectrum management skills, guided by an international regulatory framework that has evolved over many decades. This regulatory framework is discussed in the next section.

Figure B.2: Major uses of radio spectrum



B.4 International Regulatory Framework for Radio Spectrum

B.4.1 Introduction

Because radio transmissions are not constrained by national boundaries, an international regulatory framework has evolved to minimise the risk of interference between individual radio communication services. This framework can also support other international objectives such as facilitating the free circulation of wireless communications services and equipment. This can be achieved by encouraging, where appropriate, the harmonisation of frequency bands for specific purposes and

is a good example of how spectrum management can support broader EU objectives such as the development of the internal market for goods and services.

Within EU Member States, there are three regulatory layers affecting use of radio spectrum, comprising global, regional (European) and national layers. Global regulation is primarily the remit of the International Telecommunications Union (ITU), while regional regulatory matters are primarily addressed by the EU and the European Conference of Post and Telecommunications Administrations (CEPT). These bodies manage the broad framework within which all spectrum users must operate, and in some cases have developed harmonised approaches to spectrum use, to facilitate international services, open markets and minimise the risk of interference between users. National regulation typically involves one or more sectoral regulatory bodies as well as Government departments. The roles of these global, regional and national bodies with regard to management of radio spectrum are addressed in more detail in the following sections.

B.4.2 ITU

B.4.2.1 Introduction

Radio spectrum management and planning is the remit of the ITU Radiocommunications Sector (ITU-R), whose roles are defined by the ITU as[2]:

i) to effect allocation of bands of the radio frequency spectrum, the allotment of radio frequencies and the registration of radio frequency assignments and of any associated orbital position in the geostationary satellite orbit in order to avoid harmful interference between radio stations of different countries;

ii) to coordinate efforts to eliminate harmful interference between radio stations of different countries and to improve the use made of radio-frequencies and of the geostationary-satellite orbit for radiocommunication services.

The ITU-R operates a number of permanent Study Groups, each responsible for a specific area of radio spectrum management or planning, whose focus may be either horizontal (e.g. spectrum management or radio wave propagation) or vertical (e.g. broadcasting or mobile services). These Study Groups are involved in activities such as drafting technical bases for Radiocommunication Conferences, developing Draft Recommendations and compiling Handbooks. There is also a Conference Preparatory Meeting Study Group which co-ordinates preparations for World Radiocommunications Conferences. These conferences are where the key decisions are made regarding the allocation of spectrum to various services around the World and which are ultimately reflected in the Radio Regulations.

[2] Source: ITU-R Mission Statement

B.4.2.2 ITU Radio Regulations

The Radio Regulations are the international treaty governing the use of the radio-frequency spectrum and the geostationary-satellite and non-geostationary-satellite orbits. They provide the overall global framework for spectrum use, including the International Frequency Allocation Table (Article S5), 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.

The Radio Regulations are agreed at World Radio Conferences (see section B.4.2.4) and Member States that do not abide by the Regulations cannot expect any protection from interference for the service concerned. For example, if country A uses a radio frequency in a manner contrary to the Radio Regulations and causes harmful interference to a radiocommunication service in country B that is in accordance with the Radio Regulations, then the onus is on country A to stop interfering. Conversely, however, if country A interferes with country B and country A uses the frequency in accordance with the Radio Regulations while B uses the frequency in a manner contrary to the Radio Regulations, then country A has the right to continue to interfere, so long as the interference does not extend to services that are in accordance with the Radio Regulations.

The Radio Regulations require ITU Member States to:

a) endeavour to limit the number of frequencies and the spectrum used to the minimum essential to provide the necessary services and to apply the latest technical advances as soon as possible; and

b) 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

The Radio Regulations contain specific provisions that are binding on all ITU Member States to protect certain frequencies or frequency bands that are used for safety of life services (e.g. aeronautical and maritime distress frequencies) or for scientific research (e.g. certain frequencies are reserved for passive use only such as for detection of emissions from deep space). ITU Member States are not required to implement the ITU Table of Frequency Allocations in its entirety, but are subject to the obligations set out in the following articles of the Regulations:

> ***Art 4.2****: Member States undertake that in assigning frequencies to stations which are capable of causing harmful interference to the services rendered*

by the stations of another country, such assignments are to be made in accordance with the Table of Frequency Allocations and other provisions of these Regulations"

Art 4.4: *Administrations shall not assign to a station any frequency in derogation of either the Table of Frequency Allocations…or the other provisions of these Regulations, except on the express condition that such a station…shall not cause harmful interference to, and shall not claim protection from harmful interference caused b, a station operating in accordance with…these Regulations.*

A national administration can therefore depart to a considerable extent from the international Table if it considers it to be in its national interest to do so.

As the European Community is not a party to the ITU, whereas the Member States are, the obligations they assume in the ITU framework have to be implemented in accordance with their obligations under EC law. This was reiterated by a formal declaration signed by the 15 EU Member States and the 10 acceding countries and deposited with the ITU for incorporation in the WRC-03 Final Acts. The Declaration reads:

"The delegations of the Member States of the European Union declare that the Member States of the European Union will apply the revision of the radio Regulations adopted at this Conference in accordance with their obligations under the EC Treaty."

B.4.2.3 ITU-R Recommendations

ITU-R Recommendations provide guidance on the use of radio spectrum by specific services and apparatus, including technical criteria for planning coverage and avoiding interference. Recommendations do not have the same legal status as the Radio Regulations - they are intended to be advisory rather than mandatory. However, most national 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.

B.4.2.4 World Radio Conferences (WRCs)

WRCs are held every two to three years. Their purpose is to review and, if necessary, revise the RADIO REGULATIONS. Revisions are made on the basis of an agenda determined by the ITU Council, which takes into account recommendations made by previous WRCs. The general scope of the agenda of WRCs is established four to six years in advance, with the final agenda set by the ITU Council two years before the WRC, requiring the concurrence of a majority of ITU Member States.

Under the terms of the ITU Constitution, a WRC can:

- revise the Radio Regulations and any associated Frequency assignment and allotment Plans;
- address any radiocommunication matter of worldwide character;
- instruct the Radio Regulations Board[3] and the Radiocommunication Bureau[4], and review their activities;
- determine Questions for study by the Radiocommunication Assembly and its Study Groups in preparation for future Radiocommunication Conferences.

B.4.3 Regional Regulatory Conferences (RRCs)

RRCs are conferences of either an ITU Region or a group of countries with a mandate to develop an agreement concerning a particular radiocommunication service or frequency band. RRCs cannot modify the Radio Regulations unless subsequently approved by a WRC and the Final Acts of RRC are only binding on those countries that are party to the agreement. RRCs have led to the development of established internationally frequency planning agreements such as the ST-61 and GE-89 agreements for the VHF and UHF broadcast bands. A further conference is being held in two stages in 2004 and 2006 to address the planning requirements arising from the introduction of digital TV and audio services.

B.4.4 The European Conference of Posts and Telecommunications Administrations (CEPT)

CEPT, formed in 1959, is the regional regulatory electronic communications body for Europe and currently has a membership of 44 European countries, including all EU Member States and Accession candidates. CEPT's European Communications Committee (ECC)[5] co-ordinates the use of radio spectrum across Europe. It has five permanent working groups concerned with frequency management (FM), spectrum engineering (SE), radio regulation (RR), WRC preparation and ITU conference (WRC / RRC) preparation.

The ECC's stated aim is "to ensure that European administrations, industry, broadcasters, service providers, operators and users derive maximum benefit from the finite spectrum resource". In line with wider European moves to develop a fully integrated single market, the ECC is endeavouring to harmonise as far as possible frequency allocations throughout Europe. In some instances, this harmonisation

[3] A twelve member body responsible for approving Rules of Procedure, used in applying the provisions of the RADIO REGULATIONS and registering frequency assignments made by ITU Member States;

[4] The Bureau is responsible, inter alia, for applying the provisions of the ITU-RR

[5] The ECC was formed in 2002 following the merger of the European Radiocommunications Committee (ERC) and the European Committee for Telecommunications Regulatory Affairs.

extends beyond allocations to defining the requisite standard, for example, mobile services such as GSM, DECT and TETRA are all now mandated by CEPT. In the past, such mandates took the form of European Commission Directives; however in recent years the Commission has tended to delegate this responsibility to CEPT, whose mandates take the form of "Decisions", whereby administrations commit themselves to the implementation of harmonised use of specific frequency bands or standards.

ECC Decisions often specify the service and the technical standards to be used. ECC Decisions are agreed by consensus and do not have any legal status in international law. The intention of a national administration to conform to a Decision is signalled by signing the Decision, an act which is strictly optional. The substance of the Decision may subsequently, at an individual Member States' discretion, be incorporated into national law. The discretionary nature of ECC Decisions means that they provide a somewhat less certain route towards harmonisation than legally binding EU Directives or Decisions. Where EU member states do not support CEPT measures which the European Commission (EC) would like to see implemented, it may become necessary for the EC to have the measures implemented through EU legislation.

B.5 EU Role and Objectives in Spectrum Management

B.5.1 Introduction

Radio spectrum has an important bearing on many areas of EU Policy, such as the information society, environment, transport, health and social inclusion. EU policy objectives with regard to spectrum management and broadcasting are defined in various sector-specific legislation but generally reflect the broad aims and objectives enshrined in the EC Treaty, such as:

i) Supporting the internal market and the free movement of goods and service *(Art. 3.1(c))*

ii) Promoting competition (*Arts. 3.1(g), 81, 82 and 86)*

iii) Encouraging the development of trans-European networks and promotion of co-operation in the field of Community research *(Arts. 3.1(o) and 164)*

iv) Protecting consumers *(Art. 3.1(t) and 153)*

v) Promoting services of general economic interest *(Art.16)*

vi) Ensuring cultural diversity (*Arts. 3.1(q) and 151)* and non-discrimination *(Art. 12)*

vii) Maintaining subsidiarity and proportionality (*Art. 5).*

There are four main areas of EU legislation which impact upon spectrum management and broadcasting, namely:

- The spectrum management policy framework (notably the Spectrum Policy Decision[6] and Radio Spectrum Policy Group Decision[7])
- The new regulatory framework for electronic communications and services (notably the Framework Directive[8] and Authorisation Directive[9])
- The "new approach" directives which govern the placing of electronic communications equipment onto the market (notably the Radio and Telecommunications Terminal Equipment Directive[10])
- Audiovisual (AV) policy, including content regulation and general interest obligations (notably the Television Without Frontiers Directive[11]).

The first three of these fall within the remit of the DG INFOSOC, whereas AV policy is the responsibility of the DG for Education and Culture. It should be noted that EU competence does not extend to the assignment of frequencies to individual users. Assignment is a matter for individual Member States, although the principles of assignments and rights of use for radio frequencies are governed by the terms of the Authorisation Directive. Note that unlike ECC Decisions, EU Directives and Decisions are legally binding on all Member States.

The following sections describe the main elements of the above four legislative areas that relate to spectrum management and broadcasting.

B.5.2 EU Policy Framework for Spectrum Management

In December 1998, the European Commission published a Green Paper on radio spectrum policy. Following consultation with industry and regulatory stakeholders, the Commission concluded that it should enhance its role in determining spectrum

[6] Decision 676/2002/EC, on a regulatory framework for radio spectrum policy in the European Union, OJ L 108, p. 1

[7] Decision 2002/622/EC, on establishing a Radio Spectrum Policy Group, OJ L 198, p.49

[8] Directive 2002/21/EC, on a common regulatory framework for electronic communications networks and services, OJ L 108, p. 33

[9] Directive 2002/20/EC, on the authorisation of electronic communications networks and services, OJ L 108, p. 21

[10] Directive 1999/5/EC, on Radio Equipment and Telecommunications Terminal Equipment and the mutual recognition of their conformity, OJ L91, p. 10

[11] Directive 97/36/EC of the European Parliament and of the Council of 30 June 1997 amending Council Directive 89/552/EEC on the coordination of certain provisions laid down by law, regulation or administrative action in Member States concerning the pursuit of television broadcasting activities, OJ L202 , 30/07/1997 P. 0060 - 0070

policy at a European and global level. This ultimately led to the issuing in 2002 of two EU Decisions specifically relating to spectrum management, namely the Radio Spectrum Decision and the Radio Spectrum Policy Group (RSPG) Decision.

The aim of the Radio Spectrum Decision as defined in Article 1 is consistent with the high level EU objectives of supporting the internal market and promoting competition:

> *"…to establish a policy and legal framework in the Community in order to ensure the co-ordination of policy approaches and, where appropriate, harmonised conditions with regard to the availability of radio spectrum necessary for the establishment and functioning of the internal market in Community policy areas such as electronic communications, transport and research and development"*

By facilitating the policy making process with regard to spectrum management, the Decision further aims to optimise the use of radio spectrum and avoid harmful interference. The Decision also seeks to ensure that harmonised conditions exist within the Community for the availability and efficient use of radio spectrum[12].

To support these aims, the Decision establishes a "Radio Spectrum Committee" (RSC), to whom the Commission is required to submit appropriate technical implementing measures, with a view to ensuring harmonised conditions. Where such measures fall within the remit of CEPT (see section B.4.4), the Decision empowers the Commission to issue mandates to CEPT setting out the tasks to be performed and related timescales. The Decision notes that radio spectrum needs to take into account economic, political, cultural, health and social considerations, and that it shall also consider and balance the respective needs of telecommunications, broadcasting, transport, law enforcement, military and the scientific community[13].

The RSPG has a membership comprising representatives from Member State administrations and the Commission, along with observers from the European Parliament, EEA, CEPT and ETSI. The role of the RSPG is defined in Article 2 of the RSPG Decision as:

> *"to assist and advise the Commission on radio spectrum policy issues, on co-ordination of policy approaches and, where appropriate, on harmonised conditions with regard to the availability and efficient use of radio spectrum necessary for the establishment and functioning of the internal market"*

In fulfilling this role, the RSPG is required to consult extensively and at an early stage with market participants, consumers and end-users.

[12] Article 1.2(b)

[13] Recital 8

Spectrum policy also is one of the areas identified for action in the Commission's *eEurope 2005* Action Plan[14] , which states that:

> "*The Commission will use the new regulatory framework for radio spectrum policy to ensure spectrum availability for, and efficient spectrum use by, wireless broadband services (e.g. Wireless Local Area Networks) and to co-operate with Member States' with regard to the introduction of such services. The Commission will initiate a discussion on new approaches to spectrum valuation and trading of rights-of-use of frequencies."*

The Action Plan also includes a further, specific action in relation to digital television, namely:

> *"Member States should publish by end 2003 their intentions regarding a possible switchover. These could include a road map, and an assessment of market conditions, and possibly a date for the closure of analogue terrestrial television broadcasting which would enable the recovery and refarming of frequencies."*

The EU's interest in spectrum management is also reflected in the DG INFSO mission statement on Radio Spectrum Policy, namely:

> *"Implementation of a policy and legal framework in the European Union so that radio spectrum policy approaches could be co-ordinated and conditions could be harmonised in view of ensuring availability and efficient use of radio spectrum necessary for the internal market in the European Union. Policies covered include telecommunications, broadcasting, transport, space and research and development. Such activities will develop through the new Radio Spectrum Committee and Radio Spectrum Policy Group, through appropriate involvement of all actors involved, both public and private. This also includes appropriate relations with other European and international bodies active on radio spectrum as well as international negotiations in the World Radio Conference".*

B.5.3 New EU Regulatory Framework for Electronic Communication Networks and Services ("the New Framework")

B.5.3.1 Introduction

The 1999 EU Review of electronic communications infrastructure and associated services led to the development of a new regulatory framework, enshrined in a series of legislative measures adopted by the European Parliament in February 2002. These measures significantly overhaul the regulation of electronic communications networks and services in all EU Member States, with a view to ensuring a consistent regulatory approach across all electronic communications sectors.

[14] COM(2002)263

The measures comprise four Directives relating to various aspects of communications regulation, namely:

- The *Framework Directive*, which sets the overall context and defines overall principles and approaches;
- The *Authorisation Directive*, which describes the mechanisms through which services and networks may be provided, including granting of general authorisations or rights of use for radio frequencies;
- The *Access Directive*[15], which describes how networks and service may be accessed and how interconnection between public network and service providers will be regulated; and
- The *Universal Service Directive* [16], which considers how universal service will be protected and regulated and also addresses consumer rights

The Radio Spectrum Decision is also often referred to in the context of the New Framework; however its horizontal scope extends beyond the electronic communications sector to encompass other users of the radio spectrum such as transport and research and development.

The provisions of the new Framework took effect on 25th July 2003 in all EU Member States. Under the new Framework, Member States can pursue general interest objectives related to broadcasting, such as universal access, plurality of the media, cultural diversity, etc and can impose certain measures and conditions on providers of electronic communications networks and services. These are addressed in detail in a previous European Commission study[17]. A number of other provisions within the new Framework have a direct bearing on spectrum management policy and these are discussed below.

B.5.3.2 Scope of the New Framework

A fundamental difference between the New Framework and its predecessor, the Licensing Directive[18] is that the scope is extended horizontally to cover all electronic communication networks and services. For the first time, NRAs are required to apply a common regulatory regime to both telecommunications and broadcast

[15] Directive 2002/19/EC, on access to, and interconnection of, electronic communications networks and associated facilities, OJ L 108, p. 7

[16] Directive 2002/22/EC, on universal service and users' rights relating to electronic communications networks and services, OJ L 108, p. 51

[17] "Assessment of the Member States measures aimed at fulfilling certain general interest objectives linked to broadcasting, imposed on providers of electronic communications networks and services in the context of the new regulatory framework", prepared by Eurostrategies, March 2003

[18] Directive 97/13/EC,on a common framework for general authorisations and individual licences in the field of telecommunications services, OJ L 117, 7/5/97, p. 15

transmission networks. Note however that there continue to be separate regulatory approaches for audiovisual transmission and content. For transmission, the New Framework places an emphasis on deregulation and competition, whilst content regulation continues to focus on defined public interest objectives.

The Framework Directive includes specific provisions with regard to radio spectrum. In particular, to support the policy objective of promoting competition in the provision of electronic communications networks and services, Member States are required to encourage efficient use and ensure effective management of radio frequencies[19].

B.5.3.3 Assignment of Frequencies: General Authorisations and Individual Rights of Use

The Authorisation Directive aims to implement an internal market in electronic communications networks and services through the harmonisation and simplification of authorisation rules and conditions in the Community. A key element of this simplification is the requirement that provision of electronic communication networks or services should be subject only to a general authorisation, except where such provision involves the use of scarce radio frequency or telephone numbering resources.[20] Where such scarce resources are involved, NRAs may grant an individual right of use, however in the case of radio frequencies this should be avoided where the risk of harmful interference is negligible[21]. Where such a risk does exist, the Directive requires NRAs to have in place open, transparent and non discriminatory procedures for granting individual rights of use (i.e. assigning frequencies).

Furthermore, no limitation of the number of rights of use should apply unless this is necessary to ensure the efficient use of spectrum. Where this is the case, Article 7 of the Directive specifies in broad terms the procedure that NRAs should follow. This includes a requirement to consult on and publish any decision to limit the granting of rights of use, and requires the granting of rights of use to be based on selection criteria that are objective, transparent, non-discriminatory and proportionate. Note however that the Directive does not prescribe any particular approach to selection, leaving individual NRAs to decide on whether a comparative selection or market-based (auction) approach is used[22].

The conditions that may be attached to individual rights of use for radio frequencies are specified in Annex B of the Authorisation Directive and include:

[19] Article 8.2(d)

[20] The Authorisation Directive also includes provisions relating to special obligations arising from the Access and Universal Service Directives, however these are outside the scope of this Study)

[21] Article 5.1

[22] A detailed comparison of these approaches is presented in section B.7

- The type of networks or technology – including where applicable the exclusive use of a frequency for the transmission of specific content or audiovisual services;
- Effective and efficient use of frequencies, including coverage requirements;
- Technical and operational conditions for the avoidance of harmful interference and for limiting public exposure to electromagnetic radiation;
- International obligations;
- Conditions for transfer of rights between undertakings.

Note that there is considerable latitude in how individual NRAs may interpret these requirements, for example with regard to the type of technology or the transmission of specific content or services. Historically, radio spectrum authorisations have been highly prescriptive in these regards; however some Member States are now considering a more flexible approach under which any technical constraints would be limited to those necessary to avoid harmful interference or to ensure compliance with EU harmonisation measures.

B.5.3.4 Fees for Rights of Use for Radio Spectrum

Article 13 of the Authorisation Directive makes provision for NRAs to impose fees for rights of use which reflect the need to ensure their optimal use. This is in contrast to the charges that may be levied for general authorisations, which are limited to recovery of the costs associated with the authorisation regime. A number of EU Member States now apply such fees to some of their licensed radiocommunication services, although in most cases this does not currently include broadcast spectrum. Spectrum fees can be a useful instrument in ensuring the efficient and effective use of spectrum and are discussed in more detail in section B.7.4.

B.5.3.5 Spectrum Allocation and Harmonisation of Spectrum Use

Article 9 of the Framework Directive defines how NRAs should approach spectrum management for electronic communication services and includes requirements for objective, transparent, non discriminatory and proportionate criteria for allocation and assignment of radio frequencies. This Article also requires Member States to promote the harmonisation of use of radio frequencies, “consistent with the need to ensure effective and efficient use thereof” and allows Member States to make provisions for the transfer of rights of use for radio frequencies between undertakings. NRAs therefore have considerable latitude under the New Framework to determine how radio spectrum is used on a national basis, so long as the requirements of the RADIO REGULATIONS and any specific EU harmonisation measures are complied with.

The EU has been instrumental in promoting the harmonisation of radio frequency use where this has been identified as supporting high level objectives, such as facilitating provision of trans-European networks or promoting services of general economic interest. Harmonisation has, for example, been a key factor in the

development of a mass market for mobile telephony services in Europe, and has led to the adoption of the European GSM standard as a de-facto standard in much of the rest of the world. Other initiatives, such as the attempt to create a harmonised European paging service based on the ERMES standard, have been less successful (though in the case of ERMES this is at least partly a consequence of GSM's success in replicating paging functionality). Nevertheless, the growth of GSM has demonstrated the potential benefits of a harmonised approach to spectrum utilisation and supporting harmonisation where it is appropriate is therefore a key element of the New Framework package.

It should be noted that harmonisation is not in itself a new concept. For example, most broadcast spectrum has long been harmonised throughout the world, at least in terms of its high level application for TV or sound broadcasting. In the case of AM and FM sound broadcasting, where there are also globally harmonised technical standards, this has facilitated a global mass market in low-cost receivers. Harmonisation at the equipment level has been less prominent in the TV world, partly reflecting different local priorities (e.g. early introduction of colour transmission) and partly reflecting the reduced importance of mobility. However this situation may well change with the onset of digitisation and convergence.

B.5.4 The New Approach Directives

The New Approach refers to a series of 21 EU Directives relating to harmonisation of technical standards and conformity assessment. These Directives have the dual purpose of establishing a level playing field for free circulation of products in the Internal EU Market and guaranteeing a high level of protection for consumers. The common element in this legislation is that it is limited to the adoption of mandatory essential requirements, the definition of appropriate conformity assessment procedures and the introduction of the CE marking. Business and industry are therefore given the greatest possible choice of how to meet their obligations under the Directives. The European standards bodies such as ETSI (European Telecommunications Standards Institute) have the task of drawing up technical specifications which offer one route to complying with these obligations. Member States are required to assume conformity with the essential requirements if manufacturers make use of such harmonised standards.

Of particular relevance to this study is the *Radio and Telecommunications Terminal (R&TTE) Directive*[23], which governs the marketing and use of all but a few categories of equipment that use the radio spectrum. The Directive replaces national standards and compliance regimes and addresses potential problems arising from the non-harmonised use of frequency spectrum in the Community. To facilitate the development of an internal market even where spectrum use is not

[23] 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, OJ L 091, 07/04/1999 P.0010 - 0028

harmonised, the Directive requires NRAs to publish interface standards containing the necessary information for suppliers wishing to enter the national market.

"Essential Requirements" lie at the heart of the R&TTE Directive, and in the case of radio equipment these include the avoidance of harmful interference. Manufacturers may use any appropriate standard to demonstrate conformity with the essential requirements. The R&TTE Directive plays a key role in protecting consumers, by ensuring minimum standards of compliance are met and that approved equipment is clearly marked as such. The Directive obliges manufacturers to inform users of the intended use and the limitations of use of equipment both on the packaging and in the manual. This includes informing the user about the networks for which a terminal has been designed and which radio frequencies it may operate on in individual Member States in the case of non-harmonised frequencies.

Note that since the R&TTE Directive essential requirements relate to causing interference, receive-only devices such as TV sets do not fall within its scope.

B.5.5 EU Audiovisual Policy and its implications for Radio Spectrum Management

The focus of EU audiovisual policy is largely on content regulation and the achievement of certain defined public interest objectives such as:

- freedom of expression and pluralism
- cultural and linguistic diversity
- protection of minors
- consumer protection.

Member States remain free to require certain content to be transmitted on certain frequencies, but transmission services must be assigned according to open, transparent procedures. This approach reflects the split between the operation of broadcast transmission networks and the provision of content which has already taken place in many Member States. This split is a logical consequence of the migration to digital transmission, which enables many services to be multiplexed over a single network or radio frequency.

A key instrument of EU audiovisual policy is the *TV Without Frontiers (TVWF)* Directive, which provides the legal framework for television broadcasting within the Community. The main objective of the TVWF Directive is to create the conditions necessary for the free movement of television broadcasts in the Community. As a general rule, the Directive requires that Member States must ensure freedom of reception and must not restrict the retransmission on their territories of television broadcasts from other Member States for reasons falling within the fields

coordinated by the Directive[24]. The Directive is subject to regular reviews to take account of market and technological developments.

B.5.6 EU position on Digital Broadcasting

On 26th September 2002, the European Parliament adopted a resolution calling for the successful introduction of digital television in Europe. Parliament requested the European Council to adopt an EU action plan as soon as possible and called on the Commission to present a clear timetable for the steps it intends to take. Parliament expressed the view that digital broadcasting is an essential tool to guarantee access of all European citizens to the services of the information society. Member States and the Commission were encouraged to outline the measures they intend to take in order to encourage the use of an open interoperable European standard for digital television.

B.5.7 Summary of EU Objectives with regard to Spectrum Management

EU spectrum management objectives, as enshrined in legislation, can be summed up in terms of the high level objectives arising from the EC Treaty as follows:

i) Supporting the internal market and the free movement of goods and services (Framework Directive Art. 7, Authorisation Directive Art. 1), Spectrum Decision (Art. 1), R&TTE Directive (Art. 1)

ii) Promoting competition (Framework Directive Art. 8.2)

iii) Encouraging the development of trans-European networks and promotion of co-operation in the field of Community research (Framework Directive Art. 8.3(b))

iv) Protecting consumers (Framework Directive, Art. 8.4, R&TTE Directive, Art.12)

v) Ensuring cultural diversity (Framework Directive, Art, 8.1, TVWF Directive).

B.6 Interference and co-existence between Radio services

The RADIO REGULATIONS define interference as:

> "*The effect of unwanted energy due to one or a combination of emissions, radiations or inductions upon reception in a radiocommunication system, manifested by any performance degradation, misinterpretation or loss of information which could be extracted in the absence of such unwanted energy*"[25]

Interference manifests itself in various ways, depending on the nature of the interferer and the victim. Perhaps the most familiar effect is the presence of

[24] Article 5

[25] ITU Radio Regulations, Article 1.166

"ghosting" or other visual distortion of a TV picture, or the simultaneous reception of local and distant AM radio stations during the hours of darkness. The effects of interference can vary from slight (a barely perceptible increase in the level of background noise) to catastrophic (the complete blocking of vital aeronautical or public safety communications). For example, one recent high profile case reported in the UK involved the reception of signals from a faulty baby alarm by airline pilots attempting to communicate with the nearby airport.

Various categories of interference are defined by the ITU, and these are described in more detail in the next section. However, it is the avoidance of the most severe category, "harmful interference", which underpins most spectrum management activity.

The concept of harmful interference is particularly important as it is also one of the criteria, identified under the new EU Regulatory Framework for electronic communications services, to justify the issuing of individual rights of use (licences) for radio frequencies[26]. Avoidance of harmful interference is also identified in the Radio Spectrum Decision as one of the two underlying aims of the Decision, along with optimising the use of radio spectrum[27].

Harmful interference is defined in the Radio Regulations as:

> *"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."*[28]

The definition of harmful interference used in the EU Authorisation Directive is substantially the same, except that the reference to the Radio Regulations is replaced by a reference to "applicable Community or national regulations"[29]. The Radio Regulations also define two other levels of interference, which can be interpreted in a more quantifiable fashion in particular cases. These are:

- ***Permissible interference*** *– Observed or predicted interference which complies with quantitative interference and sharing criteria contained in these Regulations*

[26] Article 5 of the Authorisation Directive states that "Member States shall, where possible, *in particular where the risk of harmful interference is negligible*, not make the use of radio frequencies subject to the grant of individual rights of use…", hence the risk of harmful interference is the key criterion for determining in the first instance whether a particular use of radio spectrum should be subject to an individual right of use or covered solely by a general authorisation.

[27] Article 1.2 (a)

[28] RADIO REGULATIONS Article 1.169

[29] Article 2.2 (b)

or in ITU-Recommendations or in special agreements as provided for in these Regulations[30].

- ***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[31].*

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.

It should be noted that the Radio Regulations only provide a high level framework within which national administrations should operate. Using the technical characteristics specified in the Regulations for various types of radio service does not guarantee 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, subject to further regional and/or national considerations.

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.

Avoidance of interference requires a number of precautionary measures to be taken, including:

[30] RADIO REGULATIONS Article 1.167

[31] RADIO REGULATIONS Article 1.168

i) ensuring that services or users that might mutually interfere with one another and are required to operate in the same geographical area are allocated distinct radio frequencies, and that the separation of these frequencies is sufficient to prevent interference occurring, assuming that equipment conforms to certain minimum technical requirements;

ii) defining relevant technical parameters and enforcing compliance with these, to ensure that emissions are limited to specific frequencies and levels, enabling appropriate interference avoidance measures to be planned;

iii) ensuring sufficient geographic separation between users of the same radio frequency.

These measures are supported by various regulatory instruments and technical standards, which may be determined at a global (ITU), regional (e.g. European) or national level. Such measures are described in more detail in chapter B.4. However, of particular importance in the avoidance of interference are the allocation and assignment of radio spectrum to specific services and users. These processes are defined by the ITU Radio Regulations (RADIO REGULATIONS)[32] as follows:

- ***allocation*** *of a frequency band refers to its entry in a Frequency Allocation Table (FAT) for the purpose of its use by one or more radiocommunication services or the radio astronomy service under specified conditions.*
- ***assignment*** *of a radio frequency or channel refers to an authorisation given by an administration for a radio station to use a radio frequency or channel under specified conditions.*

Note that the reference to an FAT may be either the global table forming Article 5 of the RADIO REGULATIONS, a regional table such as the CEPT Common Table published in ERC Report 25, or the national FATs published by each national administration.

The ITU also defines a third specific term in relation to frequency management, which is particularly relevant to broadcasting. An ***allotment*** of a radio frequency or channel is defined as:

- *the entry of a designated frequency channel in an agreed plan, adopted by a competent conference, for use by one or more administrations for a radiocommunication service in one or more identified countries or geographical areas and under specific conditions.*

The concept of allotments and assignments may be used in the drawing up of international plans for the use of radio spectrum, for example by high-power broadcast stations. The planning of broadcast services has traditionally been by way of agreeing a set of assignments that may be used by each administration, chosen to minimise mutual interference between stations. Planning agreements are

[32] see section B.4.2.2 for a more detailed description of the RADIO REGULATIONS

reached by way of Regional Radiocommunications Conferences, which are addressed in section B.4.3.

Such assignments will specify relevant details of transmitter, including: the frequency, location, aerial height and radiated power. Following the agreement of the plan, an administration may bring these transmitters into operation without further negotiation, on the condition that these parameters are (within specified limits) unchanged. A significant change will require further bilateral co-ordination with interested parties. This 'assignment planning' method was used for the Stockholm Plan of 1961 (ST-61), which forms the basis for the current use of broadcast spectrum in Bands I, III, IV and V, and for the Geneva Plan of 1986 (GE-86), addressing FM sound broadcasting in Band II.

This assignment planning approach has the merit that it can lead to an efficient use of the spectrum; however its two drawbacks are the very considerable amount of detailed network planning required in advance of the co-ordination conference, and the lack of flexibility inherent in the resulting plan.

These drawbacks can be addressed by adopting a planning approach based on the use of allotments. In this case, the eventual plan allows the use of a specific frequency within a defined area; transmitter sites and powers are not specified, but maximum acceptable interference levels are defined at 'test points' outside the area. The network operator is then free to roll out any transmitter network that does not cause these limits to be exceeded. This 'allotment planning' approach was adopted for the T-DAB conferences at Wiesbaden (WI-95) and Maastricht (MA-02).

Allotment planning is very flexible and minimises the detailed preparatory work required. The drawback is that, because detailed information about the transmitters is, by definition, unknown, a degree of 'safety margin' must be built into the plan and this may lead to inefficiency in the use of spectrum.

B.7 Approaches to Frequency Assignment

B.7.1 Introduction

Within the international regulatory framework described in the preceding sections, NRAs have considerable latitude regarding how radio spectrum is managed in their own territories. This latitude principally relates to how spectrum is assigned to individual users. Although there are also some national differences in the broad service categories, these are constrained by the need to comply with the Radio Regulations, and in particular the need to protect primary services in neighbouring countries.

Historically, most radio frequencies were assigned on a first come, first served basis or were reserved for use by public telecommunications or broadcasting organisations. With the advent of telecommunications and broadcasting liberalisation, increasing demand for radio spectrum to deliver competing services has made it necessary to "ration" the most sought-after spectrum. There are two

principal approaches that can be taken to assigning spectrum where demand exceeds supply namely, administrative (comparative selection) and market-based approaches (auctions and trading). Whichever approach is taken, the procedure must comply with the principles defined in Article 7 of the Authorisation Directive ("Procedure for limiting the number of rights of use to be granted for radio frequencies"). Under Article 7 selection criteria must be objective, transparent, non-discriminatory and proportionate, and give due weight to achieving the objectives set out in Article 8 of the Framework Directive (including consumer benefit, efficiency and single market objectives).

Where applying administrative charges for rights of use the NRA must take account of Article 12 of the Authorisation Directive and when applying fees aimed at ensuring the optimal use of radio spectrum, the NRA must take account of Article 13 of the Authorisation Directive and Article 8 of the Framework Directive. A market-based approach to spectrum management may also include provisions for holders of rights of use for radio frequencies to transfer these to other undertakings (i.e. trading), subject to the provisions of Article 9 of the Framework Directive.

The following sections describe these issues in more detail.

B.7.2 Administrative Approaches

Possible administrative approaches to assigning licences include first come first served, comparative selection and lotteries.

B.7.2.1 First come, first served (FCFS)

The FCFS approach works best when the demand for spectrum is unlikely to exceed the supply for then it does not matter that there is no mechanism to ensure the spectrum is assigned to more efficient or higher value users. However, the approach is sometimes also used in circumstances where demand may exceed supply. For example, FCFS is typically used to assign spectrum in bands for point-to-point links and private mobile radio, both of which tend to involve many small users of spectrum, often with bespoke spectrum requirements and whose demands can change from year to year. In these circumstances, FCFS provides a flexible approach to assigning spectrum with low transaction costs compared with the alternatives of auctions or comparative tenders.

In bands where congestion arises the spectrum manager has few options for promoting more efficient use of the spectrum. It has been suggested that administrative incentive pricing could have a role to encourage the reassignment of spectrum from low to high value users. This is discussed further below.

In practice, NRAs sometimes do not literally assign spectrum to whoever demands it under the first come first served approach, but rather use administrative rules (and in some cases discretion) to determine the frequencies and bandwidth an applicant is permitted. These may include rules related to optimising the use of frequencies, for example many NRAs require point to point links to operate in the highest available frequency band compatible with the link length, thus preserving lower

frequency bands for longer links that can only operate in those bands. Such rules should always be objective, transparent and non-discriminatory.

B.7.2.2 Comparative Selection

Comparative selection (often referred to as a beauty contest) refers to a process whereby licences are assigned by the NRA to the "best qualified" of the competing applicants. Key issues in the design of comparative selection procedures are the criteria used to choose the winning applicant, the precision and transparency of the criteria (i.e. publication in advance of the tender), the weighting given to different criteria and the transparency of reasons for the final decision. In most countries comparative selection procedures happen behind closed doors with decisions made by a group of administrators. The time taken for making decisions is sometimes specified in advance, but in any case is constrained by the Authorisation Directive, which requires the decision to be made within eight months after receipt of applications.

By contrast, in the US the comparative selection process for many licences, including broadcasting licences, was conducted through public hearings using a public interest test to assign licences. However, these hearings proved time consuming and expensive and were criticised for assigning licences based on insignificant and arbitrary differences, or even pure political favouritism[33]. Since 1994 comparative hearings have been replaced by auctions.

Comparative selection processes have traditionally been characterised by opaque criteria, with no guidance on the weightings and minimal publication of reasons for decisions[34]. In these circumstances applicants can only guess at what is required in putting together their bids and outcomes can be subject to undue political influence. The winning bidder is therefore unlikely to be the most economically efficient supplier. Opaque comparative selection processes are also susceptible to legal challenge which can in turn lead to long delays in awarding licences and substantial loss of economic welfare[35].

If comparative selection processes are objective, transparent and non-discriminatory, as is required under the Authorisation Directive[36], then many of their disadvantages can in principle be overcome. In particular, if measurable criteria

[33] Where do we go from here? The FCC Auctions and the Future of Radio Spectrum Management, Congressional Budget Office, 1997

[34] Examples from Canada, France and South Korea are given in *Why auction spectrum?* John McMillan Telecommunications Policy, November 1994.

[35]The delays in cellular licensing in the US are estimated to have $25bn per year. See J Hausman Valuing the Effect of Regulation on New Services in Telecommunications, Brookings Papers: Microeconomics, 1997

[36] As was required under the Licensing Directive and now the Authorisation Directive.

are used with an explicit weighting system then the "amounts" bid can be written into licences and the winning bidder should be the applicant that best fulfils society's objectives (as defined by the NRA or government). This kind of comparative selection process is similar to an auction except that the bid is couched in terms of commitments to provide certain services or infrastructure and not a financial sum. Note that the similarity only holds if the government/NRA is prepared to enforce the winning bidder's licence commitments. The cost associated with such commitments can often be significant, for example according to Eurostrategies[37], anecdotal evidence from the UK and Sweden indicates that the cost to broadcasters of meeting the coverage obligation is around a factor of 3 to 4 times higher than that associated with the provision of a commercially viable coverage.

Comparative selection is normally used in tenders for broadcasting (content) licences. Some examples of comparative tenders for broadcasting licences are as follows:

- In France, a comparative selection procedure was used to assign commercial digital multiplex licences in 2001/2. Eight selection criteria were used, relating to content diversity, production requirements, speed of DTT development, technical aspects (coverage, approach to service providers), financial competence, applicants' experience and competition.
- In Sweden local radio licences are awarded by comparative tender. The selection criteria used are the amount of local or in-house production, ownership of other stations in the area (a negative factor) and the availability of technical and financial resources to provide high quality broadcasting.

Public service broadcasting (PSB) objectives (e.g. universal service, catering for a variety of tastes, interests and cultures, linguistic diversity, educational programming, providing high quality services) and sometimes also ownership criteria and the composition and experience of the management team are typically included in the selection criteria. Criteria relating to public broadcasting objectives, such as high quality broadcasting, cannot be defined or measured precisely and so are difficult to evaluate and monitor. This can make comparative selection of broadcasting licensees rather opaque which can in turn weaken competition for licences[38]. Note that unlike transmission networks, broadcast content licences are not subject to the requirements of the Authorisation or Framework Directives.

[37] Assessment of the Member States measures aimed at fulfilling certain general interest objectives linked to broadcasting, imposed on providers of electronic communications networks and services in the context of the new regulatory framework", March 2003

[38] This is discussed further in Franchising in Practice: The Case of Independent Television in the UK, S Domberger and J Middleton, Fiscal Studies 1985.

It is often suggested that bidders "pay" for their licence through commitments to onerous PSB obligations[39]. This will be the case so long as PSB commitments are tightly defined and can be enforced in cases of licence breaches through fines and ultimately withdrawal of the licence. If the threat of enforcement is weak and governments are prepared to modify licences rather then terminate them, then applicants in comparative selection processes are likely to "over bid" on the assumption that they will be able to renegotiate their licence in the event of unfavourable outcomes[40].

B.7.2.3 Lotteries

Lotteries involve assigning spectrum to qualified applicants on the basis of a random process. This clearly does not directly support efficiency or public interest objectives. The only experience of lotteries for spectrum licences that we are aware of comes from the US where lotteries were introduced in 1983 for the first licences allocated to cellular telephone services. Lotteries and later auctions were intended to provide a low cost and fast means of assigning licences.

Lotteries did not prove successful. The value of the rights to use spectrum was publicly revealed when winners sold their licences reaping very large windfall gains, undermining the political credibility of the process. The FCC was swamped with licence applications which meant the process was more costly and slower than expected.

B.7.3 Market-based approaches

Two market based approaches to licence assignment are auctions and trading. Auctions concern the initial assignment of a licence by the NRA, whereas trading of licences between licensees is clearly only feasible once licences have been assigned by the NRA.

B.7.3.1 Auctions

Auctions involve assigning licences to those who bid the largest sums of money and often applicants are only eligible to bid if they pass certain pre-qualification thresholds or tests (for example, relating to technical and financial competence). In addition, non-monetary requirements may be specified in licence conditions requiring licensees to provide particular services (e.g. for broadcasting services licences may specify the programme formats, minimum amounts of programming of certain types or coverage obligations) or meet certain regulatory requirements (e.g. for mobile services there may be roaming obligations).

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[39] Though in the UK at least some licence winners have made substantial windfall gains from selling on their licences, in some cases before they have started operation.

[40] See Franchise Bidding for natural monopolies – in general and with respect to CATV, O E Williamson, Bell Journal of Economics, 1976.

Over the last 10 years auctions have been used increasingly to assign spectrum licences. A range of auction designs have been used including:

- First price, sealed bid (e.g. Danish 3G mobile auction, Swedish radio licences, UK national radio licences)
- Second price, sealed bid (e.g. first three New Zealand auctions for UHF TV, cellular, microwave distribution system and sound broadcasting licences)[41]
- Simultaneous multi-round ascending auctions (e.g. initially used in 1994 in the US PCS auctions and subsequently in many jurisdictions)
- Open auction, followed by a sealed bid auction (e.g. GSM mobile licence auction in Nigeria)[42]

There is an on-going debate in the economics literature about the efficiency of different auction designs. For example, Klemperer[43] argues that auctions are likely to be successful if they attract numerous bidders and deter bidders from colluding. These outcomes are promoted if there are more licences than incumbents, there are restrictions on joint bidding, auctions are decided by sealed bids (although an open bid stage offers the advantages of information revelation) and reserve prices are not set too low.

Auctions are not often used for broadcasting licences because their purported economic efficiency benefits are not considered to be as important as achieving broadcasting policy objectives (e.g. public service broadcasting objectives). Examples where money auctions have been used to assign broadcasting licences are as follows:

- In New Zealand, all commercial broadcasting licences are auctioned using a multiple round ascending bid auction. Spectrum is reserved for public service broadcasting services and is assigned using a comparative selection procedure.
- In the UK, national commercial radio licences were assigned in 1991 to the highest bidder, though licences could have been awarded to a lower bidder in "exceptional circumstances" (e.g. if the bid was judged not be sustainable). The format of the radio stations was pre-specified by the NRA.

[41] New Zealand Spectrum Management, A Decade in Review 1989-199, Ministry of Economic Development, June 2000.

[42] On the design and implementation of the GSM auction in Nigeria – the world's first ascending clock spectrum auction, C Doyle and P McShane (2001), Charles River Associates.

[43] See P Klemperer: What Really Matters in Auction Design, Journal of Economic Perspectives, 2002; How (not) to run auctions: the European 3G telecom auctions, European Economic Review, 2002.

- In the UK, commercial TV licences were assigned in 1992 (for Channel 3) and 1995 (for Channel 5) using a hybrid auction. Bidders had to pass a quality threshold and at the next stage the highest bidder won if the bid was judged sustainable and other bids were not of "exceptional" quality.
- In Australia and the US, licences for satellite broadcasting services have been auctioned.
- In Sweden, local commercial radio licences were auctioned in 1993, but this policy was reversed in 1995 and following two government inquiries comparative selection procedures were put in place under the Swedish Radio and TV Act 2001.
- In Denmark, radio licences have been auctioned since the start of 2003 using an open cry auction.
- In the US, the FCC has auctioned spectrum currently occupied by TV broadcasters (in the lower 700 MHz band) for flexible fixed, mobile and broadcast uses. New licensees must protect incumbent broadcasters from harmful interference. Incumbents may be required to vacate the band by the end of 2006 but only if less than 15% of households in their market do not have access to digital TV.

B.7.3.2 Auctions vs Comparative Selection

There has been much written on the relative pros and cons of auctions versus comparative tenders. The process of assigning 3G licences in Europe gives a case study of the two approaches and here we summarise the main points made by commentators and review evidence from the 3G experience so far.

Critics of 3G auctions have argued that:

- Raising revenue is given priority by governments over innovation and new service introduction
- High upfront fees create a barrier to entry and/or effective competition
- Incumbents and large operators have significant advantages under an auction approach because of their "deep pockets"
- Roll-out will be delayed because operators do not have the funds for network investment and/or because the cost of financing has risen significantly
- Industry consolidation, and hence reduced competition, will be a consequence of the auctions
- End-users will pay higher prices as operators seek to recover auction payments
- The large sums raised in 3G auctions in Western Europe (€100bn) are one reason for the weak financial position of the mobile sector.

Against this, economists have argued that auction payments are sunk costs and so will not affect operator behaviour i.e. prices will not increase and roll-out will not be

delayed. Indeed it is argued that operators will have strong incentives to roll-out services to recover their initial investment. It is also argued that auctions have the benefits of being more transparent than comparative tenders[44], promoting economic efficiency and economic welfare[45], and giving the state a fair return for the use of a public asset.

The evidence and analysis shows that:

- Lump sums paid in 3G auctions were much higher than those paid in comparative tenders and higher roll-out and coverage commitments were obtained in comparative tenders as compared with auctions. McKinsey (2002) [46] have analysed the total licence plus network infrastructure cost to 3G operators by European Union member states for the period 2000-2015. Interestingly they find that by far the highest costs per head of population are faced by operators in Sweden and Finland[47], where licence fees are low but commitments to roll-out networks are onerous. This underlines the point that governments need to be mindful of the total costs imposed by their intended licensing method, not just the more visible licence fees.
- Postponement of roll-out targets has happened more often in countries that had comparative tenders (Portugal, Spain, and Sweden) than those with auctions (Italy, UK, and Austria). This suggests bidders may "over-bid" whatever the format and early roll-out may not be achieved by choosing a comparative tender rather than an auction.
- New market entry, number of bidders, licences left unassigned and licences subsequently returned seem to be unaffected by the choice of tender format. The main difference appears to be that global and regional operators are more likely than local operators to win licences in auctions as compared with comparative tenders.

[44] Transparency promotes competition as the opaqueness of comparative tenders can allow governments to favour incumbents.

[45] Well designed auctions should result in licences being assigned to the most efficient operator. Also auctions are a more efficient (i.e. less distorting) way of raising government revenues than most forms of taxation.

[46] McKinsey, Comparative assessment of the licensing regimes for 3G mobile communications in the European Union and their impact on the mobile communications sector, report for the European Commission, 25 June 2002.

[47] See Exhibit 16, McKinsey (2002)

B.7.3.3 Transferring rights of use between undertakings (Spectrum Trading)

The Framework Directive allows undertakings to transfer rights of spectrum use[48]. This opens up the possibility of a range of different arrangements for trading spectrum including:

- Leasing of rights to a third party for a specified period of time
- Change of ownership
- Change of ownership and reconfiguration of rights (i.e. partitioning or aggregation of rights)
- Change of ownership, reconfiguration and change of use (e.g. change from broadcast to mobile or vice-versa).

Few countries have implemented any of these forms of trading[49]. In the US the FCC has recently adopted spectrum leasing rules[50], in Canada and Guatemala auctioned licences may be divided and transferred and in New Zealand and Australia all forms of spectrum trading are permitted for holders of spectrum licences[51]. The UK government has undertaken a consultation on spectrum trading but no firm proposals have yet been made.

The main argument for introducing spectrum trading is similar to that justifying the use of markets for trading other rights of access to scarce resources (such as land, oil and minerals), namely that it promotes economic efficiency. In particular, it is argued that by making rights tradable users have financial incentives to economise on spectrum use, spectrum will be reassigned to the highest value users and, if change of use is permitted, spectrum will be reallocated to the highest value use of spectrum in a timely manner. The efficiency benefits from trading are unlikely to be fully realised unless:

- Tradable rights of access to spectrum are defined clearly and users are given adequate protection against harmful interference.
- Transaction costs associated with undertaking trades and enforcing rights are low.

[48] Article 9.3

[49] Reviews of experience with trading are given in Implementing Spectrum Trading, Consultation Document, UK Radiocommunications Agency, July 2002;Implications of international regulation and technical considerations on market mechanisms in spectrum management, Aegis and Indepen for the Independent Spectrum Review, November 2001.

[50] FCC Adopts Spectrum Rules and Streamlined processing for Licence Transfer and Assignment Applications, and Proposes Further Steps to Increase Access to Spectrum through Secondary Markets, FCC, May 15 2003.

[51] In Australia apparatus licences are also tradable, however broadcasting licences are not.

- There are sufficient safeguards against anti-competitive behaviour.
- NRAs provide sufficient information about their intentions concerning the future release of spectrum, as their actions can have a major impact on market prices and confidence in trading.

Establishing a system of tradable licences potentially involves a number of fundamental changes to the spectrum management regime that involve transferring decisions over spectrum use and enforcement from the NRA to users and moving the role of the NRA towards that of a market facilitator. Issues associated with the tradable spectrum licences will be considered in more detail in the next stage of the work, in the context of potential new approaches to managing broadcasting radio spectrum.

The Framework Directive acknowledges (recital 19) that transfer of radio frequencies can be an effective means of increasing efficient use of spectrum, as long as there are sufficient safeguards in place to protect the public interest. Taking the specific case of spectrum licences for broadcasting, it is possible that governments may wish to reserve spectrum for public service broadcasting and broadcasters may be constrained in their ability to change their spectrum use (e.g. because of coverage obligations). In these circumstances, there may be little benefit from trading except for allowing a change of ownership. Constraints arising from international planning requirements may also limit the scope for broadcasters to trade spectrum, although there may be some scope for allowing limited leasing of spectrum to promote efficient spectrum use (e.g. leasing on a time limited basis when broadcast services are not being transmitted).

However, trading of broadcasting licences could offer significant benefits in the context of terrestrial digital TV broadcasting. Switch-over has the potential to release spectrum for new services and if not all of the DTV multiplexes need to be reserved for PSB then non-PSB multiplexes could be used to provide a wide range of services (data as well as audiovisual) with potentially flexible coverage areas. Technology developments taking place within the DVB and 3G mobile communities would enable such services to be accommodated within the existing broadcast spectrum providing sufficient flexibility exists within the planning framework. This issue will be addressed more fully in the second phase of this study.

B.7.4 Setting fees for rights of use for radio frequencies

Radio spectrum licences historically attracted licence fees which were used to fund the NRA's spectrum management activities, although many NRAs recover these costs from individual licensees in a manner which reflects the amount of spectrum resource involved[52]. Under Article 12 of the Authorisation Directive such cost-based

[52] For review of fees set in Europe see Study on administrative and frequency fees related to the licensing of networks involving the use of frequencies, Report for DG Info Soc, Aegis Consulting November 2001.

fees fall within the category of “administrative charges”. These charges must in total cover the administrative costs of the NRA and must be imposed in an objective, transparent and proportionate manner. These requirements give considerable latitude in setting administrative charges. For example, charges could be set so that users cover the administrative costs they individually cause (cost causality principle) or so that total costs are covered and each user pays on the basis of an objective measure such as number of licences or bandwidth occupied.

NRAs may also impose fees for the rights to use radio frequencies which reflect the need to ensure optimal use of these resources (Article 13). If the objective of the optimal use of spectrum is interpreted to mean the welfare maximising use of spectrum, then economic principles can be applied to derive fees that will help to achieve this objective. In particular, economic theory suggests that fees should be set to reflect the opportunity cost of spectrum i.e. the forgone opportunities from using the spectrum in its current use. For example, if a block of spectrum is allocated on a co-primary basis to the mobile and broadcasting services and is currently used for broadcasting but could potentially be deployed for mobile telephony, the price of the spectrum to the broadcaster should be no less than the forgone benefits of using the spectrum for mobile telephony. If another broadcaster that cannot get access to the spectrum has higher value then the price would be more than the mobile value.

In practice, service and technology convergence means that the distinction between “broadcast spectrum” and “mobile spectrum” becomes less important. Since the broadcasting service can be used to support the provision of audiovisual material to mobile users, then this opportunity cost approach may even be extended to spectrum that is exclusively allocated to the broadcasting service, for example by considering the benefits foregone by using the spectrum for conventional broadcasting as opposed to delivering mobile multimedia services. In principle, opportunity cost ought to be based on measures of welfare (consumer and producer surplus); however, in practice it is difficult to acquire information on forgone welfare.

This opportunity cost based approach to setting spectrum charges is sometimes referred to as “administrative incentive pricing” (AIP) – note that this should not be confused with administrative fees which are limited strictly to recovery of the administrative costs of the NRA. At present few NRAs impose AIP for spectrum, two exceptions being Spain and the UK (some other administrations have applied above-cost fees to specific services such as GSM, ostensibly to promote efficiency, but the basis of these fees in economic terms is unclear).

In Spain, the 1988 General Telecommunications Act empowers the NRA to apply AIP to all types of licensed spectrum use. Fees for each service category are defined annually in the General Budget (currently Article 63 of Law 52/2002) using a formula that takes account of the area occupied, the bandwidth occupied and five coefficients which relate to the degree of congestion in the geographic area and frequency band concerned, the type of service, characteristics of the band used, the

equipment and technology used and the economic value of the use of the spectrum respectively.

In the UK, AIP has been implemented since 1998 and is based on assessing how a user's costs vary as the amount of spectrum available varies. The price is set based on the least cost alternative of using a given amount of spectrum, where this may be use of an alternative frequency band, use of an alternative technology (e.g. wired rather than wireless) or investment in additional infrastructure[53]. AIP is applied in bands and geographic locations that are regarded as congested and to services where the use of spectrum is not heavily restricted by international obligations (e.g. spectrum used for many aeronautical and maritime applications). AIP is currently applied to the following services: defence, fixed links, maritime business radio, private business radio, programme making and special events, public mobile networks, public safety services and satellite uplinks.

The application of spectrum fees for broadcast services is complicated by the existence in many cases of obligations relating to coverage or content which may impose additional costs on the spectrum user or restrict the user's flexibility to reduce the spectrum held. The extent to which digitisation and the emergence of multi-platform delivery might affect these constraints, and the scope for applying market principles to any "re-farmed" broadcast spectrum, will be addressed in the next phase of the Study.

B.7.4.1 Recognised Spectrum Access

The UK NRA has also proposed that AIP should be extended to transmissions from outside the UK that receive protection in the UK but that are not currently licensed (e.g. space to earth satellite transmission or emissions from outer space monitored by radio astronomers). It is proposed that in future these transmissions will be protected through the grant of "recognised spectrum access" (RSA). If a user opts for RSA AIP could in principle be applied. A similar proposal has recently been put forward by the Irish NRA with regard to satellite broadcasts originating from outside Ireland.

[53] The methodology and its implementation are discussed in the annual spectrum pricing reviews given on the Radiocommunications Agency website www.radio.gov.uk. The NRA is currently reviewing the appropriateness of this approach.

C CURRENT STATUS OF DIGITAL BROADCASTING IN EUROPE AND ELSEWHERE

Just as there are significant variations between Member States' policies towards digital broadcasting, so the progress that has been made towards its introduction varies considerably. Nevertheless, the take-up of digital in Europe compares favourably with that in Japan and where take-up is greatest is comparable to that in the US.

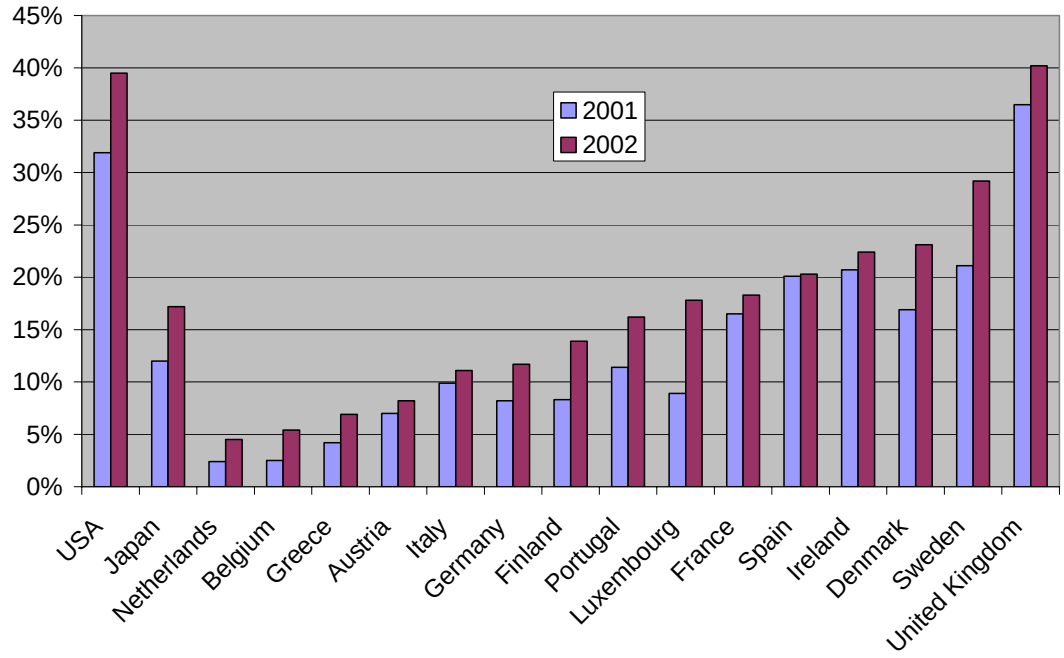

Figure C.3: Take up of Digital Television (all platforms) in EU Member States, Japan and the US

Five Member States have so far launched DTT services and several others have announced firm launch dates. However, relatively few have stated any specific targets with regard to analogue switchoff. Digital cable and satellite services are available to some extent in all Member States, though take-up varies considerably. Eight Member States have launched DAB services and several others are due to follow. Table C.1 compares the current status of each digital broadcast platform in each EU Member State.

Since 1996 and the launch of the first digital satellite offers in Europe, digital TV has established a firm presence in both European minds and households. Digital is now synonymous with a greater number of channels and a better quality of picture and sound. Parallel to the development of digital TV offers, we have also witnessed the increasing popularity of wide screen TV sets and DVD players.

Satellite has been the prime driving force behind the launch of digital television in Europe and in many cases this has prompted cable operators to develop competitive

offerings to match the increased choice available via digital satellite. Whilst satellite and cable development has been almost exclusively driven by private initiatives, DTT remains largely under State control in all of the countries being studied. The introduction of DTT has been the subject of lengthy discussions in all countries, which has delayed the launch of digital terrestrial offers or at least created a substantial gap between DTT and cable and satellite platforms. Hence while all of the countries being studied have digital satellite and cable offers, very few have successfully launched digital terrestrial TV.

While digital terrestrial's pioneers in the UK and Spain went off the air in 2002 (the UK platform has since re-launched with a revised, free-to-air business model and appears to be making good ground), a number of European countries are expected to begin broadcasting their initial offers in 2003. The various launches will make it possible to see whether the new packages are able to draw on the tough lessons learned by their predecessors.

As it stands, a breakdown of digital households into satellite, cable and terrestrial reveals a clear lead for satellite over rival platforms in most EU Member States. In the US, however, digital cable subscribers are beginning to catch up, and are now overtaking digital satellite subscribers. In Europe, it will be some time before cable catches up to satellite, but the systematic migration of analogue cable subscribers in Benelux, Germany and Austria to digital is likely to make cable the leading digital TV broadcasting platform by the end of the decade.

Table C.1: Current Status of Digital Broadcasting in EU Member States

	DTT	Satellite	Cable	DAB
BE	Yes – Trials	No national platform	Le Bouquet / Canal+ Belgique launched in January 1999 in the French-speaking community Canal Digitaal/Het Boeket launched in April 1998 in the Dutch-speaking community	VRT has a multiplex covering 98% of the Flemish Community; RTBF has a multiplex covering 98% of the French Community. Data services are planned in 2003.
DE	Yes – First services launched in November 2002 in Berlin with an analogue switch-off scheduled by the end of 2003. Spot by spot transition.	Premiere World launched in October 1999 The public service broadcasters (ARD and ZDF) and the main commercial broadcasters (RTL and Kirch) have launched free satellite offers	Premiere World launched in October 1999	65% of the population are covered and most of the 16 Federal States have now launched services. There are > 150 stations on air
DK	Yes – Trials	Canal Digital launched in October 1998. TV 1000 launched in April 2000	Tele Danmark launched digital services in Spring 1998. STOFA launched digital services in November 1998	Launched in Oct 2002 and currently available to 80% of population with plans to extend coverage to 100% by the end of 2003.
ES	Yes – Quiero TV, a pay-TV platform, launched in May 2000 but went bankrupted in April 2002. All analogue national channels are also available in DTT since April 2002 as well as 2 new free channels (Veo TV and Net TV). RTVE should lead the future development of Spanish DTT.	CanalSatélite Digital launched in February 1997 Vía Digital launched in September 1997 CanalSatélite Digital and Vía Digital merged in May 2002. The new platform, named Digital+, should be relaunched in July 2003.	Madritel launched its digital services in 1999. ONO launched its first digital offer in the city of Valencia in June 2003 and should extend its offer in the .cities of Cádiz, Huelva, Palma de Mallorca, Castellón, Alicante, Albacete and Murcia in the first half of July 2003.	Launched in 1998 and now provides mix of public and commercial broadcasting, with 18 stations transmitting digitally. There are plans for local DAB Digital Radio stations, including a public tender for Catalonia, and broadcasters are experimenting with data services. Coverage is 50% of population and is set to rise to 80% by 2006.
GR	No plan	Nova- MultiChoice Hellas launched its digital offer in December 1999. Alpha Digital Synthesis launched in October 2001. The two Greek platforms announced their willingness to merge in September 2002.	No cable development	No
FR	Launch planned by end of 2004 with a combination of free and pay channels. There will be local channels, but details remain to be decided in that respect. The failure of many foreign experiences has	Canal Satellite launched in April 1996. TPS launched in December 1996.	NC Numéricâble launched its first digital services in April 1997, followed by Noos and France Telecom Câble in September 1997.	Some 15 million people, or 25% of the population, are covered by regular DAB transmissions, among them around 17% in the Greater Paris area. Due to the elections taking place in

	DTT	Satellite	Cable	DAB
	raised some concerns.			2002, progress for a legal framework for DAB has been delayed.
FI	Yes – Launch in August 2001 The 4th MUX will be used for mobile services.	Canal Digital launched in October 1998. TV 1000 launched in April 2000	HTV launched its first services in August 2001.	Launched in May 1999; public broadcaster currently covers 40% of population. Coverage expansion and commercial services planned.
IT	The new Media Law plans that DTT trials should cover 50% of the population by the end of 2004. PSB and commercial broadcasters are currently conducting pilots. These include portability and mobility trials. Spot by spot approach with a "time-sharing simulcast" approach.	D+ launched in March 1996. Stream launched in September 1998. D+ and Stream announced their merger in April 2001, modified in June 2002, and which will become effective in July 2003. The new platform will name Sky Italia.	Recent re-launch of fibre optic networks (FastWeb).	Two trial multiplexes, one PSB and one commercial. Coverage 30%, focussed on North-East of Italy, Rome and Turin. DAB shares VHF channel 12 with TV. DAB could also use L-Band, but this is not favoured because of propagation problems.
IE	No for the moment, but a launch expected not before 2007 or 2008.	Sky Digital launched at the beginning of 1999.	NTL launched its first digital services in October 2000. Chorus launched its digital offer, named Go Digital, in August 2001.	6-service pilot system in Dublin launched in 1999 carrying PSB and commercial services. Currently suspended awaiting availability of low-cost receivers.
LU	Yes	No national platform	SelecTV launched in November 2000.	
NL	Yes – Digitenne launched in April 2003 with a priority given to portability.	Canal Digitaal launched a digital offer at the end of 1999.	Mr Zap, the name of the digital service of Mediakabel, became available from February 2000. Casema and UPC launched their digital offers respectively in May and at the Autumn 2000. TV Home Digitaal exists since August 2002.	1 PSB multiplex launched in Feb 2002, currently covering the West of the country. Government has postponed the planned auction for commercial DAB until Sept 2003.
AT	Trials – Launch planned (Dec 2003)	Premiere Digital launched in October 1999	Premiere Digital launched in October 1999	One multiplex operating in Vienna covering 19% of population. Also trial services in the Tyrol region.
PT	No (licence issued but subsequently revoked). Initially, the Pereira Coutinho consortium (PDTD), lead by TV Cabo, should begin to broadcast in 2003 with a switch-off planned in 2008.	TV Cabo launched a digital satellite platform in September 1998.	TV Cabo began to digitalise its networks in 2001.	There are 34 transmitters in use, 25in the mainland, 4 in Azores and 5 in Madeira, covering more than 75% of the population. Portugal's 750 km coastline is already fully served.
SE	Yes – Senda/Boxer launched in April 1999.	Canal Digital launched in June 1998 TV 1000 launched in April 2000	Com Hem launched its first digital services in November 1997. UPC Sverige AB launched at the beginning of 2001.	PSB service launched in 1995 but Coverage recently reduced to 35% of population, due to financial difficulties and shift of emphasis to developing content rather than coverage.

	DTT	Satellite	Cable	DAB
UK	Yes – OnDigital/ITV Digital first launched in November 1998 and went bankrupted in April 2002. Freeview, a free-to-air platform lead by the PSB BBC, took up the licences and began its services in November 2002.	Sky Digital launched in October 1998	NTL / CWC launched their first digital services in July 1999. Telewest launched in November 1999.	2 national multiplexes (1 PSB and 1 commercial) and 10 regional. Coverage 85% (commercial) and 65% (PSB), expansion underway. Commercial services let by comparative selection.

D CURRENT USE OF BROADCAST SPECTRUM IN EU MEMBER STATES

All of the internationally allocated broadcast bands are intensively used within the EU, however in the TV broadcasting bands there are a number of national variations, whereby certain channels or in some cases entire bands have been allocated to other uses, either on an exclusive or shared basis. There are principally two reasons for this:

i) Historical: in many countries there is a legacy of military or other State usage which pre-dates the introduction of television services, particularly in parts of the UHF bands; and

ii) New initiatives: in some countries, decisions have been made to re-allocate former broadcast spectrum in VHF bands to other uses, typically mobile radio.

The sub-band 608 – 614 MHz (corresponding to UHF channel 36) is used in a number of countries for radio astronomy purposes. Although this is a secondary allocation in the radio regulations, it is formally protected from interference at various locations within Europe and a number of countries have requested that this protection be maintained when the new digital TV frequency plan is developed at the 2004 Regional Regulatory Conference.

Table D.2 below summarises the main uses of the VHF and UHF broadcast bands in each EU country. VHF Band II is used exclusively for analogue sound broadcasting throughout the EU.

Table D.2: Current utilisation of VHF Broadcast Bands in EU Member States

Country	Band I	Band III	Band IV/V
BE	Analogue TV; Land Military Systems	174-223 MHz: analogue TV and various short range devices 223 – 230 MHz: DAB (not yet launched)	470-608 and 614-790 MHz: analogue TV and radio microphones (DTV planned) 608-614 MHz: Radio Astronomy 790-862 MHz: tactical radio relay (military), shared with analogue TV up to 830 MHz; DTV planned up to 838 MHz
DE			608-614 MHz: Radio Astronomy
DK	Analogue TV, Wind Profiler Radars, Amateur (50-52 MHz)	Analogue TV, wireless microphones and hearing aids TDAB (219.584 - 221.120 and 226.592 - 228.128 MHz). Note Broadcasting allocation secondary above 223 MHz	Analogue and Digital TV up 790 MHz. Exclusive military use above 790 MHz (except for certain low power wireless microphones). Wind Profilers up to 494 MHz
ES	PMR; Radiolocation (secondary allocation)	SAB / wireless microphones	Analogue TV; mobile above 830 MHz
GR	Military, but may be used for low power TV	Analogue TV & radio microphones up to 223 MHz;	Analogue TV & radio microphones up to 838 MHz;

Country	Band I	Band III	Band IV/V
	transponders in specific geographic areas, subject to national co-ordination; SRDs (49.8-49.99 MHz); Amateur (50-52 MHz)	TDAB planned above 223 MHz	Military use & radio microphones above 838 MHz
FR	PMR, Amateur (50-54 MHz)	Analogue TV; some Government use	Analogue TV; some Government use
FI	Analogue TV (2 transmitters in use); Hobby radio (PMR), 67.5 MHz, Amateur (50-52 MHz)	Analogue TV and DAB	Analogue TV; some mobile use by broadcasters (channels 21 and 23); Radio Microphones DTV planned. Sharing with military above 790 MHz – only 4 TV transmitters and no new usage in this sub-band
IT	Military (47-52.5 MHz), Analogue TV and PMR (52.5-68 MHz); Wind Profilers	Analogue TV and radio micro-phones up to 223 MHz; Analogue TV and TDAB above 223 MHz	Analogue TV up to 854 MHz; Military fixed services above 854 MHz
IE	TV broadcasting ceased; currently unused except for SRDs (49 MHz) and Amateur (50-52 MHz)	Analogue TV; TDAB; SRDs	Analogue TV (DTV planned); Studio-Transmitter and OD links above 790 MHz (to be relocated)
LU	Military & Amateur (50-52 MHz)	Analogue TV; Military use above 225 MHz – planned for TDAB	Analogue TV (DTV planned) up to 790 MHz; Military use above 790 MHz; Wireless microphones
NL	PMR (47-61 MHz); Analogue TV (61-68 MHz); Amateur (50-50.45 MHz)	Analogue TV up to 195 MHz; TDAB ; SAB; Medical Telemetry (202.65-205.15 MHz)	Analogue TV up to 846 MHz; Radio Astronomy (608-614 MHz); SAB
AT	Analogue TV	Analogue TV; wireless earpieces	Analogue TV; Wireless Microphones; Digital TV planned
PT	Analogue TV; some Government use (47.25-49.5, 50.5-51; 54-68 MHz)	Analogue TV (174-216 MHz); TDAB (219-230 MHz); Government (225-230 MHz)	Analogue TV; DTV planned above 646 MHz; Fixed use above 790 MHz (studio – transmitter links) recently discontinued; FAT refers to IMT-2000 expansion above 806 MHz
SE	Analogue TV; military land mobile systems	Analogue TV; TDAB	Analogue & Digital TV
UK	PMR; Amateur (50-52 MHz); SRDs (47 – 50 MHz).	Mobile (PMR/PAMR) up to 217.5 MHz; TDAB above 217.5 MHz; Military use above 225 MHz	Analogue & Digital TV

The following figures indicate the primary or protected services in each Member State:

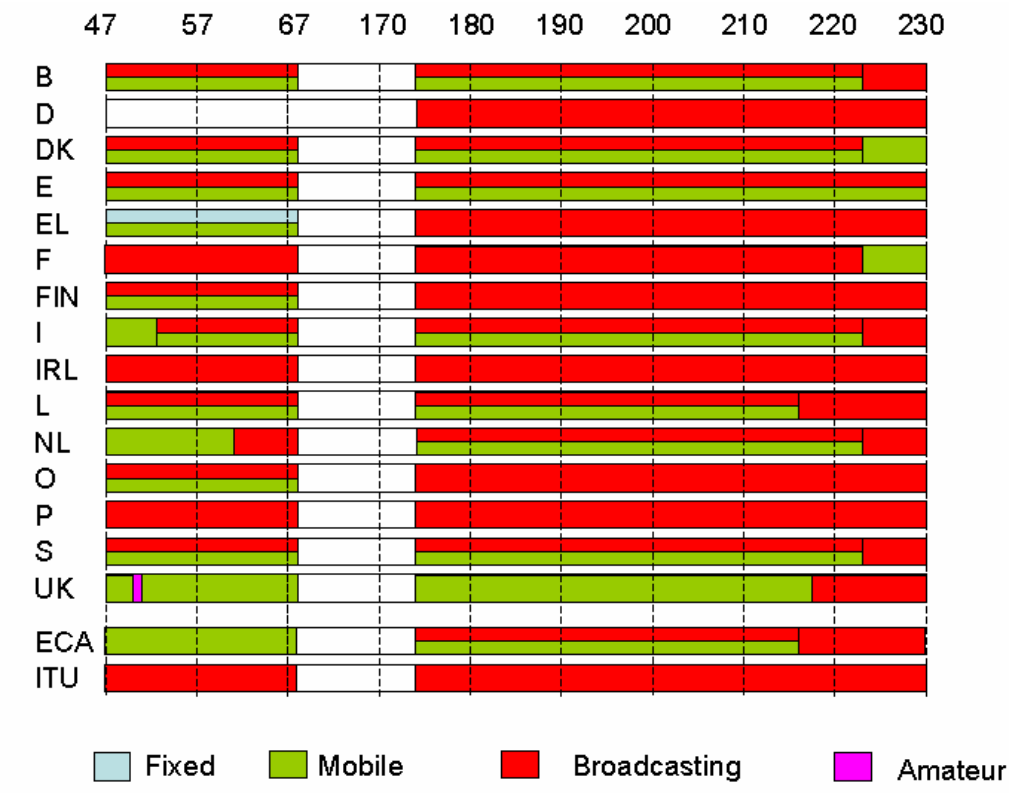

Figure D.4: Primary allocations in VHF Bands I and III

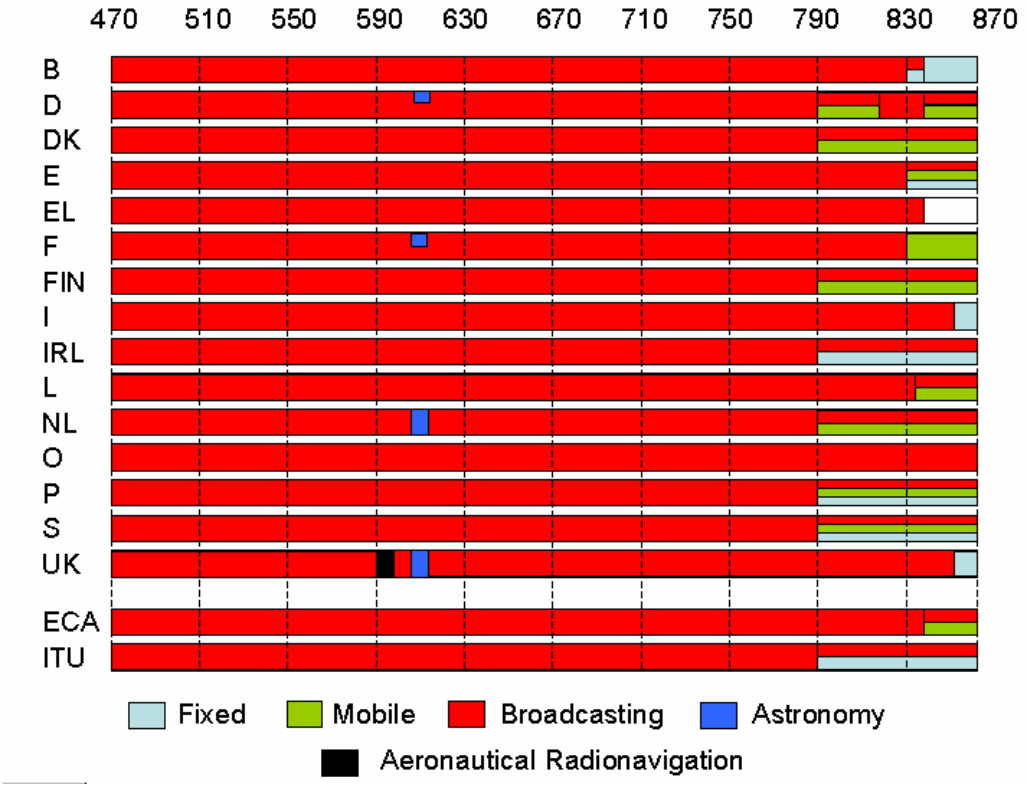

Figure D.5: Primary allocations and protected services in UHF Bands IV and V

E ESTIMATION OF SPECTRUM REQUIREMENT FOR DTT

E.1 Assumptions

In practice, potential efficiency gains post-switchover depend on various factors, including:

- the number of programme channels to be provided
- the extent of coverage
- the degree of regionality
- whether portable and/or mobile reception is required
- the required picture quality, in particular whether high definition TV broadcasts (HDTV) are planned
- the degree of cross-border co-ordination required.

As a general rule it is assumed that digital terrestrial networks should provide at least the same degree of programme choice as current analogue terrestrial networks. In most EU Member States this amounts to 3 – 5 national networks plus a varying number of local services that may typically only be available in major cities[54]. The extent of any "digital dividend" will depend on the nature of the nature of the digital services that are provided post-switchover. In particular, the number of channels and whether or not reception by portable receivers is planned. What constitutes an "attractive" DTT offering is debateable but it is reasonable to assume that it should offer at least one new channel beyond the existing digital channels.

The results presented here are intended to be territory-independent, and assume that all analogue television services have been terminated. It is assumed that five programme channels are to be provided with substantially national coverage, using a single DTT multiplex and providing regional content corresponding to the typical coverage area of today's high power analogue transmitters.

All services are assumed to be provided in UHF spectrum (470 – 862 MHz) and for fixed reception viewers are assumed to be using modest, directional rooftop aerials. It is assumed that these aerials have been tailored to the digital services (i.e. there is no analogue legacy in terms of pointing or aerial type), but that the transmitter network topology will be similar to that of the analogue network, i.e. with a pattern of high power main stations at elevated sites, supported by a somewhat larger population of lower-power relay sites.

[54] EBU planning handbook for DVB (BPN005/PT24(01)40) states "As a generalisation, it can be stated that all European countries have 2 to 4 nationally available programme chains which each cover in excess of 98% of the population and such a generalisation applies to most countries in the EBA. Some countries have additional chains and/or individual stations covering densely populated areas."

E.2 DVB-T System Parameters

Before proceeding with the analysis it is helpful to review the main technical parameters within the DVB-T standard and how the values chosen for these parameters can impact on the spectrum requirement. The following table summarises the key parameters that influence spectrum utilisation by DVB-T networks. Note that there is generally a trade-off between bandwidth efficiency (the amount of information that can be carried per frequency channel) and the extent to which the same frequency can be re-used in different locations. The overall spectrum efficiency is a combination of these two factors.

Table E.3: DVB-T Key Technical Parameters

Parameter	Description	Options	Impact on spectrum
Modulation Scheme	Determines no of bits per second that can be conveyed per MHz of spectrum and affects tolerance to interference	QPSK (most robust), 16QAM, 64QAM (least robust)	64QAM can carry 4 times as much data per 8 MHz channel but requires greater separation between transmitters
Transmission Mode	Defines number of individual radio frequency carriers per 8 MHz channel – more carriers means greater robustness to interference	2k (1,705 carriers), 8k (6,817 carriers), 4k (under development)	Only 8k currently supports SFNs with wide coverage areas; only 2k or 4k suitable for mobility
Code Rate	Defines the fraction of transmitted bits that are used to carry information. Lower values more robust	1/2, 2/3, 3/4, 5/6, 7/8	Lower values reduce data that can be carried in each channel but allow improved frequency re-use
Guard interval	Time spacing between transmitted data bursts, as a fraction of the burst duration. Higher value improves robustness	1/32, 1/16, 1/8, 1/4	Higher values reduce data that can be carried in each channel but allow larger area SFNs to be deployed

The multi-carrier modulation scheme used by DVB-T uses a Fast Fourier Transform (FFT) process to convert data from the time domain to the frequency domain (i.e. multiple radio frequency carriers). This multi-carrier approach improves resilience to interference, as the information transmitted is spread over many different carrier frequencies and it is unlikely that all will suffer interference at the same time. The time and frequency domain characteristics of a DVB-T signal are illustrated in the following diagram:

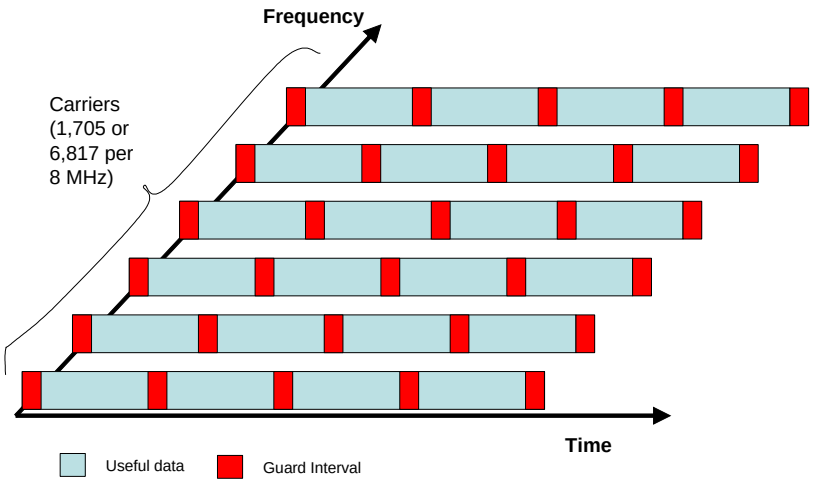

Figure E.6: DVB-T Signal in time and frequency domains

For example, the initial UK DVB-T network was planned using 64QAM modulation, a code rate of 2/3 and the 2k mode with a 1/32 guard interval. This allowed a net bit rate per multiplex of 24 Mbit/s, typically allowing 6 programme channels to be carried, but with relatively poor robustness which led to reception problems in many instances. Following the demise of the initial service, some multiplexes were re-engineered to use 16 QAM with a 3/4 code rate, giving an increase in robustness but reducing the data capacity to 18 Mbit/s, corresponding to 4 programme channels.

E.3 Single or Multi- Frequency Networks

One significant differentiator of DVB-T from analogue transmission is the ability to operate in "single frequency network" (SFN) mode. This means that, within a given geographic area, the same frequency can be used by multiple transmitters, enabling reception to be enhanced without requiring additional spectrum. Currently, only the 8k mode is capable of SFN operation over a reasonably wide area (more than a few km). As our analysis in the next section will show, SFN planning can provide a significant reduction in the amount of spectrum required relative to MFN planning.

Unfortunately the earliest DVB-T receivers only accommodated the 2k transmission mode and as a consequence some of those networks that have already launched (e.g. the UK) are based on this mode. 2k is also the only mode that currently allows mobility, although as we will see later in this report mobile reception is likely to be better addressed by means of a dedicated platform, for which standards are currently under development.

Disadvantages of SFNs include the need for a larger guard interval (and hence less data capacity), synchronisation of transmitters and less flexibility to vary the degree of regionality in the future.

E.3.1 Multi-frequency network (MFN) approach

At first consideration, it might seem that, to provide contiguous coverage over an area using a multi-frequency network would require the use of four channels (the 'four colour map theorem'[55]). This, however, would require that interference to a given receiver could only come from immediately adjacent transmitters. In practice, particularly for small time percentages, interference may be generated by quite distant transmitters. The severity of such interference will depend, in a complex manner, on the distance between transmitter sites in the network, the terrain, the transmit and receive antenna heights, and the mix of transmitters (high, medium and low power) within the network.

[55] The theorem stating that if a plane is divided into connected regions which are to be coloured so that no two adjacent regions have the same colour (as when colouring countries on a map of the world), it is never necessary to use more than four colours.

These considerations will tend to increase the number of channels required to provide a uniform service above the 'baseline' of four. The most spectrum-efficient solution would involve a dense, cellular type network of low-height, low power transmitters with less than 20 km separation, using a robust modulation mode such as QPSK. However, such a network would be expensive to implement and would have a limited data capacity (only 2 programme channels per multiplex could be carried).

Simulations have been undertaken[56] to determine the channel requirements for the provision of 'universal' coverage (based on service availability at 95% and 70 % of locations within a given area). Results are set out in the table below:

Table E.4: No. of frequency channels required under various DTT scenarios

Modulation/coding rate	64-QAM 2/3	16-QAM 2/3	QPSK 2/3	Availability
Fixed, roof	9	6	4	95% of locations
Portable, indoor	39	29	22	95% of locations
Portable, indoor	19	13	9	70% of locations

For the results shown above, a transmitter aerial height of 150m above average terrain was assumed, with a transmitter spacing of 60 km. These values are representative of existing networks of main television transmitters in the EU.

It must be borne in mind that the data capacity for the three different modulation options in the table is different. Thus the 64-QAM variant will support six services, the 16-QAM four and the QPSK mode only two (assuming the minimum guard interval in all cases). To provide the notional five national services corresponding to current availability of free-to-air analogue services in some Member States, either two 16-QAM multiplexes will be required, or a single multiplex will need to be used in a mode with a higher capacity (e.g. 16-QAM, 5/6). The former case would require 12 channels (with a surplus of data capacity), while the later case would need 8-9 channels.

If mobile reception is considered, it is likely that it will be necessary to use the 2k mode, if realistic vehicle speeds are to be accommodated. Reasonable mobile performance has been achieved using 16-QAM modulation with a code rate of 1/2. Taking into account the lower receive antenna height, the fast fading encountered in a mobile environment and Doppler effects, the required field strength will be considerably higher than that for rooftop coverage, probably comparable to that required for good indoor portable coverage, i.e. the number of channels required is likely to rise to 13 – 29 channels per multiplex, which given the limited data capacity of 16QAM would imply that most or all of the available frequency channels would be required just to provide five programme channels.

[56] EBU Report BPN 038, 2001

E.3.2 Single frequency network (SFN) approach

It might seem that, ignoring the requirement for regionality, a single frequency network would allow nationwide coverage using a single 8 MHz channel. This would only be possible if the 8k FFT mode was adopted, allowing the use of long guard intervals. The use of such long intervals, however, has a substantial impact on overall multiplex capacity. If it is assumed that a minimum of 4 Mbit/s is required per programme service, an overall multiplex bit-rate of around 20 Mbit/s will be necessary, implying the use of 64QAM modulation for useful guard interval durations.

The maximum available guard interval of 1/4 corresponds to 224 µs, implying transmitter spacing of the order of 67 km. This corresponds well to typical European networks. To carry 5 programme channels with this guard interval it will be necessary to use a higher order modulation scheme and low coding rate (R). The only likely options are 64QAM with R=2/3 or 3/4 (the former option is used for two of the current UK multiplexes, though with a 2k FFT).

In practice, a limit is imposed to the maximum size of an SFN by considerations of self-interference. For small percentage times, anomalous propagation will give rise to interference from distant parts of the network that fall outside the receiver guard interval. Simulations have suggested that SFN coverage areas may be limited to around 150 km – 200 km diameter, if existing broadcast infrastructure is to be re-used.

This would imply, in the UK case, that 13 - 24 individual SFNs would be required. The re-use distance for the (least robust) 64-QAM mode is around 120 km, so the total channel requirement approaches the colouring-theorem limit of four. This mixed M / SFN approach will probably allow sufficient regionality to be incorporated (i.e. areas with a diameter of 150-200 km) in the UK but this may not be the case in other Member States. Smaller regions would require more spectrum.

E.4 Conclusion

From the figures above, national coverage might be achieved using 9 channels (MFN approach) or 4 channels (SFN approach). In comparison, the four main analogue networks in the UK use 11 channels each.

Studies carried out by the UK Radiocommunications Agency (now part of Ofcom), indicated that up to 14 channels (112 MHz) would be released nationally upon completion of switchover, along with additional “interleaved” spectrum that could be used in certain areas[57]. This is based on deployment of six national multiplexes using MFN technology with 93% coverage (the balance being provided by cable / satellite).

[57] Cost-benefit analysis of digital switchover, Dept of Trade and Industry / Dept of Culture Media & Sport, September 2003 (http://www.digitaltelevision.gov.uk/pdfs/cost_benefit_analysis_sept_03.pdf)