Study on Spectrum Management in the field of Broadcasting

FINAL REPORT

Implications of Digital Switchover for Spectrum Management

Prepared for the European Commission (DG Information Society)

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CONTENTS

1 INTRODUCTION / TERMS OF REFERENCE

The transition from analogue to digital television broadcasting will ultimately result in a significant increase in the capacity of the radio spectrum currently allocated to broadcasting to carry electronic communication services or content. This will both reduce the amount of spectrum required to deliver existing broadcast services and create an opportunity for the delivery of new content, services or applications. The extent of this "digital dividend" will depend on many factors, in particular the nature of the digital television services that are broadcast, for example picture quality, the number of programme channels and the extent to which mobile reception or regional services are required. During the transition period from analogue to digital TV services, the need to protect existing analogue transmissions from interference has the potential to constrain severely the spectrum available both for digital TV and for other, new services and it is therefore desirable to expedite the switchover process as far as possible.

Currently there is no consensus on how any digital dividend should be used, beyond a general presumption that the most economically and socially attractive use would entail some element of mobility and/or audiovisual content. This reflects the fact that the spectrum concerned is ideally suited to wide area, non-line of sight communication and that recent growth in demand for radio spectrum has mainly been for mobile and broadcast applications.

This document is the final report of a Study on Spectrum Management in the Field of Broadcasting, prepared for the European Commission (EC) Directorate for the Information Society (DG INFSOC) by Aegis Systems Ltd, Indepen Consulting Ltd and IDATE. The report focuses on the implications of digital switchover and the growing convergence between broadcast and telecommunications for radio spectrum management. In line with the EC's stated terms of reference of the Study, the report addresses the following specific issues:

i) **General Overview of broadcasting and radio spectrum management in Europe:** the report and annexes provide an overview of national approaches to digital television rollout and radio spectrum management in the context of migration from analogue to digital broadcasting. Technical and regulatory background on radio spectrum management and wireless communication is also provided, including references to relevant EU legislation and other regulatory instruments.

ii) **Spectrum implications of the digitisation of broadcasting and convergence:** the report analyses the extent to which current approaches to radio spectrum management at national and international levels, which were established in an analogue, non-convergent environment, are challenged by digitisation and technology / service convergence.

iii) **Possible new approaches for better spectrum management in the field of broadcasting:** the report considers possible new technical, administrative and market-based approaches to spectrum management that might support flexibility and innovation in the future. Examples of convergent services and technologies and how these might be catered for in a future spectrum management framework, are addressed, along with techniques for improving spectrum efficiency in a digital world.

iv) **Possibilities for co-ordinated EU Action:** Finally, the report provides recommendations on potential roles for the EU with regard to spectrum and broadcasting policy that might help to maximise the benefits arising from digitalisation and convergence.

The structure of the report is as follows:

Chapter 2 provides a high level overview of the current status of radio spectrum management and broadcasting within the EU and in a broader international context. These topics are addressed in more detail the Annexes.

Chapter 3 examines the opportunities and challenges presented by the switchover from analogue to digital broadcasting, particularly in the context of how the greatest benefit might be derived from the increased transmission capacity and spectrum utilisation efficiency which digital technology provides.

Chapter 4 considers what national and international policymakers might do to ensure that the regulatory environment can best support the opportunities and overcome the challenges identified in Chapter 3.

Chapter 5 focuses specifically on the spectrum planning process and how this can provide the flexibility needed to maximise the benefit from switchover and convergence.

Chapter 6 summarises our key findings and conclusions, and considers potential roles for the EC in facilitating the switchover process and maximising stakeholder benefits.

Scope of the Study

Although the Study initially set out to address spectrum management issues relating to all broadcast services, the principal spectrum management issues identified by the authors relate to the impending switchover from analogue to digital television. The switchover process has already commenced in some EU countries and most are expected to complete the process within ten years, whereas there are not yet any definitive plans for such a process with regard to sound broadcasting. The main opportunities for flexibility in spectrum use relate to the UHF frequencies between 470 and 862 MHz, and it is this part of the spectrum upon which this report focuses.

The authors are aware of a number of longer term issues relating to digital sound broadcasting, including the status of the various digital standards (in particular the Eureka Digital Audio Broadcasting and Digital Radio Mondiale standards that are currently being deployed in some EU countries) and the extent to which convergent services might be delivered using digital sound broadcast technology. The balance between spectrum designated for television and sound broadcasting in Band III (173 – 230 MHz) may also become an issue as these two services develop. These are issues that in the authors' opinion would merit consideration as part of a separate future study.

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Whilst every effort has been made to ensure the accuracy of the information contained in this report, the authors can not accept any responsibility for actions or decisions that may be taken as a result of the information herein.

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2 BROADCASTING AND SPECTRUM MANAGEMENT IN THE EU: CURRENT SITUATION

2.1 Introduction

Broadcasting is a major contributor to the European economy. The overall turnover of the TV broadcasting sector in the European Union in 2000 was estimated at about € 53.9 billion with an annual growth rate of 8.5% for public and 13.7% for private TV broadcasters between 1995 and 2000[1]. The use of radio spectrum also embraces many other electronic communication services, as we explore in Annex B, and this is reflected in the contribution that radiocommunication services make to national economies. For example, a recent study[2] estimated that in 2000 the value of radio spectrum to the UK economy was £20 billion (€28.6 billion). Scaling this pro-rata to GDP would suggest a total value across the EU of around €160 billion or approximately 2% of gross domestic product.

The significance of broadcasting and radio spectrum in economic terms is matched by their importance at a social level. Broadcasting provides the main source of news, information and entertainment for EU citizens and virtually everybody accesses sound or television broadcasts on a daily basis. Mobile communications, the other major consumer use of radio spectrum has also reached the mass market in the last decade, with penetration exceeding 80% in most EU countries. Hence decisions on how spectrum resources are used can have a significant impact at both an economic and social level.

2.2 Radio Spectrum from a Regulatory and User Perspective

The radio spectrum is a finite natural resource that caters for an increasingly diverse range of wireless electronic communication as well as other critical applications, for example in support of aeronautical or maritime navigation. Because the use of radio spectrum by one user can interfere with other users, even across national borders, it is necessary to regulate access to spectrum in order to keep such interference at a minimum whilst enabling effective use of the resource. The following sections provide a high level introduction to the management of radio spectrum, in the form of a “top-down” description of the international framework and from the “bottom-up” perspective of a potential user wishing to gain access to radio spectrum. A detailed description of the international framework for spectrum management, and the underlying technical rationale relating to avoidance of harmful interference, is presented in Annex B.

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[1] “Cinema, TV and radio in the EU: statistics on audiovisual services, EC, 2003

[2] “The economic impact of radio”, Radiocommunications Agency, February 2001

2.2.1 International Framework for Spectrum Management

Essentially, there are three layers to the international regulatory framework, comprising global, regional (European) and national elements. Under this framework, individual countries retain control over who uses radio spectrum within their territories but they must ensure that such use does not compromise other legitimate users in other national territories.

At a global level, spectrum management is governed by the Radio Regulations (RR) under the auspices of the International Telecommunications Union's Radiocommunications Sector (ITU-R). The RR 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. Specific parts of the spectrum are allocated on a primary or secondary basis to the various services, with primary allocations enjoying the highest level of protection from interference. National administrations are required to comply with the terms of the RR, which have international treaty status. However, the RR includes provisions for administrations to allow spectrum use by services other than those specifically allocated in Article 5, so long as no interference is caused to any allocated service and no protection from any allocated service is sought.

The RR are updated on a periodic basis by means of World Radiocommunications Conferences (WRCs), which are held every two or three years. Regional Radiocommunications Conferences (RRCs) are also held from time to time to develop agreements concerning particular radiocommunication services or frequency bands within specific geographic areas or among specific groups of countries. Of particular relevance to this study is the RRC to address the planning requirements arising from the introduction of digital TV and audio services in the VHF and UHF bands, which is to be held in two stages in 2004 and 2006 (RRC-04 and RRC-06 respectively). This RRC is addressed in more detail in Section 5.3 of this report.

2.2.2 The Frequency Planning Process: Allocations, Assignments and Allotments

When discussing approaches to radio spectrum management it is important to differentiate between two distinct processes, namely the *allocation* of spectrum to particular service categories such as broadcasting or mobile (generally done at an international level) and the *assignment* of frequencies to individual users (generally done at a national level). The allocation process is intended primarily to ensure that only compatible systems share specific parts of the spectrum, thus minimising the risk of interference between users, whereas the assignment process involves deciding who may use the spectrum in accordance with national and international rules. An assignment typically includes details of the location of a radio transmitter and the key technical characteristics that relate to its interference potential, e.g. operating frequency, power level or height above ground.

In some cases, notably where very high power transmissions are involved whose coverage extends well beyond national boundaries, assignments may be planned internationally. Such is the case in the broadcast bands, where assignments have historically been planned at RRCs and subsequent changes agreed by multilateral international negotiations. These negotiations can be complex and protracted, particularly where large networks of transmitters are involved, and make it difficult to change the use of the spectrum substantially from that envisaged at the original RRC.

Allotment planning is an alternative approach to international frequency planning which is becoming increasingly popular where flexibility is required. Under allotment planning, rather than individual transmitters being considered, radio frequencies are allotted to specific geographic areas, the extent of which is based on the interference potential of a notional transmitter assignment within the area concerned. Rather than specifying the technical parameters of an individual transmitter, the allotment is defined in terms of specified interference limits at the boundary of the geographic area to which the allotment relates. These limits cover the amount of interference that the allotment may cause to other allotments or assignments outside the allotment area and the degree of protection from interference that a notional service within the allotment areas is entitled to receive. The notional transmitter and service on which the allotment is based will generally reflect the type of system to which the allotment currently relates, e.g. a high power broadcast transmitter serving rooftop-mounted receiving aerials. However, if a national administration or user decides to use the spectrum in a different manner, e.g. by installing a large number of low power transmitters rather than a single high power transmitter, this may be done without the need for international co-ordination so long as the boundary limits that apply to the allotment are not exceeded.

The allotment planning approach provides considerable additional flexibility in the use of radio spectrum , albeit at the cost of some loss of overall technical efficiency since a change of use is likely to mean that the original level of protection is greater than that required by the new use (it is unlikely that a change of use would result in an identical protection requirement and any increase in the requirement would require the same degree of co-ordination and negotiation as the assignment planning approach, negating the principal benefit of allotment planning). Allotment planning is being promoted by European participants in RRC-04. The role of allotment planning in facilitating flexible spectrum use is discussed further in Section 5.2.

2.2.3 Legacy and Liberalisation

The spectrum allocations defined in the RR largely reflect the historic (pre-liberalisation) situation where the principal spectrum users were state or public bodies, notably government (public safety / military), incumbent telecommunications operators and broadcasters. Each of these sectors acquired large amounts of spectrum over time, many of which were agreed internationally to facilitate cross-border co-ordination. Even when spectrum was made available for private use, in many countries the regulation of this spectrum was initially vested in the same (monopoly) organisation that was responsible for providing public telecommunications services, providing little incentive to make spectrum available for new or innovative applications that might compete with the incumbent's services.

Since the liberalisation process initiated in the 1980s, governments have endeavoured to improve access to radio spectrum both for private users and for those wishing to provide competitive telecommunications or broadcast services to the public. However, access is still constrained to a significant extent by the historical legacy of established allocations to existing services. In particular, allocations to major civil uses such as mobile communications, fixed links, broadcasting and satellite services still largely reflect the pre-liberalisation situation, despite the massive growth in sectors such as mobile telephony.

Governments also continue to make extensive use of radio spectrum, primarily for military and public safety / law enforcement applications. Whilst spectrum scarcity has forced many commercial users to make increasingly intensive use of their available spectrum (witness the massive growth in mobile base stations for example), government users have not generally faced the same incentives. In some cases this places direct constraints on commercial users, for example in some EU Member States parts of the UHF TV bands and the GSM mobile bands continue to be used by government services, to the exclusion of commercial users. The result is additional costs for the commercial users and in extreme cases fewer market players can be supported.

2.2.4 National Approaches to Managing Spectrum

In theory, national administrations enjoy considerable latitude in determining how spectrum is used within their territories, so long as they ensure that harmful interference is not caused to allocated services operating beyond their borders. In practice, the extent of this latitude depends largely on a country's geographic location, in particular the number of other neighbouring countries with which co-ordination is required. Hence the situation in countries such as Australia or New Zealand, who have no land boundaries to consider, is very different from central European countries where as many as nine directly adjacent countries need to be considered (the extent of co-ordination required may be even greater since the distance travelled by radio waves can extend well into the territories of countries beyond immediate neighbours).

In some cases, individual countries' use of spectrum is recognised formally by the insertion of footnotes in the RR. For example, in the UK and a number of Eastern European countries parts of the UHF TV broadcast spectrum is also allocated on a primary basis to aeronautical radars; as a consequence one or more TV broadcast channels may not be available for broadcast use in these countries. Where one or more countries wish to introduce radiocommunication services which differ from existing allocated services and wish these services to enjoy similar protection from interference to existing primary services, additional footnotes may be negotiated to create additional primary allocations in those countries. Such footnotes generally include the proviso that the additional allocation is not protected from, or entitled to interfere with, any future planned services operating under the existing RR allocation. An example is footnote 5.235 which relates to the use of the VHF Band III Broadcast band by mobile services in a number of European countries, and is worded thus:

> *"Additional Allocation: in Germany, Austria, Belgium, Denmark, Spain, Finland, France, Israel, Italy, Lichtenstein, Malta, Monaco, Norway, the Netherlands, the United Kingdom, Sweden and Switzerland, the band 174 – 223 MHz is also allocated to the land mobile service on a primary basis. However, the stations of the land mobile service shall not cause harmful interference to, or claim protection from, broadcasting stations, existing or planned, in countries other than those listed in this footnote"*

This footnote enabled countries such as the UK to establish commercial mobile networks in this frequency band, once appropriate bilateral agreements were reached with neighbouring countries to protect the broadcasting service.

Frequency assignments are generally determined at a national level but are subject to the provisions of the new EU Framework for Electronic Communications. In some cases, specific harmonisation measures may constrain NRAs in how spectrum is used (e.g. certain spectrum is harmonised internationally for second or third generation mobile services), but not the manner in which the spectrum is assigned to individual users. The three main approaches for assigning spectrum are first-come first-served, comparative selection and auctions, the latter two being used where the demand for spectrum exceeds the available supply. A detailed discussion of these and other options is presented in Annex B.

2.2.5 The Legacy Approach to Broadcast Spectrum Management

From the perspective of a user or potential user of radio spectrum, a key concern is how readily access to the spectrum required to deliver services can be obtained. Most incumbent users, particularly in the broadcast sector, were awarded spectrum rights of use under "command and control" regimes under which the amount of spectrum was determined on the basis of technical estimates of what was needed to meet specific objectives, notably coverage and service quality. Recommendations were developed in international bodies such as the ITU that enabled the amount of spectrum required to provide specified coverage and quality levels to be determined, based on assumptions about how such services would be delivered (e.g. the use of high powered, hilltop transmitters to maximise coverage and minimise network costs).

This approach, when applied to interference-sensitive analogue technology, results in a large amount of spectrum being required to deliver each service. This in turn limits the number of competing services that can be provided in the available radio spectrum.

2.2.6 The Need for a New Approach

At the time most analogue TV broadcasters were first granted rights of use there was no alternative to terrestrial transmission, hence there were strong arguments to support the universal availability of terrestrial services regardless of the spectrum implications. The situation today is very different, in that cable and satellite transmission is widely available and the latter in particular can provide virtually ubiquitous reception, at least to outdoor fixed aerials. Digitisation presents a further paradigm shift, in that there is much greater technical flexibility in how networks may be rolled out, with correspondingly greater flexibility in the spectrum that is required. As we will illustrate later in this report, simple replication of existing analogue services would produce a substantial spectrum dividend that could allow many new players or services into the market. On the other hand, incumbent broadcasters argue that they must provide more than the status quo to compete effectively with satellite and cable platforms, or to meet evolving customer expectations such as mobility or indoor reception.

Such arguments are used by some broadcasters as justification for retaining their entire existing spectrum, resulting in denial of spectrum to potential new users who may place a higher economic value on the spectrum than the incumbents. Such denial implies an opportunity cost. Opportunity cost is the value of goods and services that would have been produced had the resources used in carrying them out (in this case spectrum) been used instead in the best alternative way. At the social optimum, marginal opportunity cost (i.e. the opportunity cost of a unit of the resource in question) equals the marginal value or price of the resource in question. Under most current national regulatory regimes opportunity cost is not reflected in the price paid by the incumbents to use the spectrum.

NRAs are increasingly considering market-based approaches to spectrum management, such as auctions or trading, which enable the market to determine the appropriate price that should be paid for spectrum rights. Historically, broadcasters have argued that they should be exempt from such policies due to the unique general interest obligations that apply their services. It is questionable whether such an argument is valid for services beyond those to which general interest obligations currently apply, in which case it can be argued that any expansion of broadcast services should be subject to the same considerations as any other user of the spectrum, Such an approach would require broadcasters to base their future spectrum requirement on commercial considerations, such as the cost of alternative provision or the revenue that may be foregone by not providing a new service, rather than simply providing a technical justification for retaining their existing spectrum.

The implications of this move away from spectrum being awarded on the basis of a pre-defined service or content offering to a situation where users acquire only the spectrum they are willing to pay raise some complex issues in relation to broadcasting, which are considered further in Chapter 4.

2.2.7 Gaining Access to Spectrum: a User's Guide

To aid understanding of the spectrum management process, in can be helpful to consider this from the point of view of a potential user who wishes to gain access to spectrum for a new service or application. The historical approach to accessing spectrum in Europe is essentially an administrative one involving dialogue with government and/or regulatory bodies, and is described in the box below. This is still the principal approach for most types of spectrum access where an individual right of use is required, although several Member States have introduced auctions as a means of awarding particularly valuable rights of use such as those for 3G mobile. Some Member States are currently considering further market-based approaches to spectrum access, such as the establishment of a secondary market in which spectrum could be traded directly between users with only peripheral involvement of the regulator. These new approaches are discussed in more detail in Section 4.6.2.

Generalised approach to gaining access to spectrum in EU Member States

Where the requirement relates to a service that is already allocated spectrum in the Member State concerned, established procedures will apply. Depending on whether the demand for spectrum exceeds the available supply, the process will either be first-come first served, in which case a standard application form should be available from the NRA, or by means of a competitive process (auction or comparative selection procedure). The latter will require an application to be made in response to a public call by the NRA, which will only be made as and when appropriate spectrum becomes available.

If the proposed application does not correspond to an existing national spectrum allocation, the following procedure will typically apply:

1. The applicant should develop an outline business plan and identify technology partners as appropriate (equipment vendors, venture capital agencies etc).

2. The applicant should then approach government or NRA representatives – depending on the country this may be a government department responsible for industrial development / innovation or the telecommunications regulator. It is likely that the applicant will subsequently be referred to the national organisation or department responsible for managing and licensing radio spectrum, however initial dialogue with other government / regulatory departments may often help to strengthen the case for spectrum access, e.g. where the proposed application is supportive of national government policy objectives such as improving availability of broadband services.

3. The spectrum management body will advise on the availability of spectrum that might meet the requirement of the applicant. This might be licence-exempt

spectrum in the case of systems that can tolerate interference, but if the applicant requires access to “protected” or exclusive spectrum (e.g. in order to guarantee a particular grade of service) it will be necessary either to identify spectrum that is not already being used or to investigate the feasibility of sharing with existing users. If the latter approach is taken, technical trials are likely to be necessary along with discussions with the existing users.

4. It will also be necessary to agree the technical parameters of the proposed system, to ensure that interference will not arise to other users in adjacent areas or frequency bands. This process will be simplified considerably if the proposed system is compliant with an existing publicly available standard, such as those produced by the European Telecommunications Standards Institute. Otherwise it will be necessary for the applicant to demonstrate compliance with the essential requirements defined in the Radio and Telecommunications Terminal Equipment (RTTE) Directive, including the avoidance of harmful interference.

4. The next step (assuming any trials are successful) will depend on whether the availability of spectrum for the new application is likely to limited or not – if the number of licences is limited it will be necessary to for the NRA to consult with potential stakeholders in order to satisfy the requirements of the EU Communications Framework. Depending on the outcome of the consultation, it may then be necessary to initiate a competitive application procedure; otherwise a spectrum right of use may be granted on a first come, first served basis. The right of use will include technical and other conditions as defined in Annex B of the Authorisation Directive.

A simplified overview of the process is presented in Figure 2.1 below.

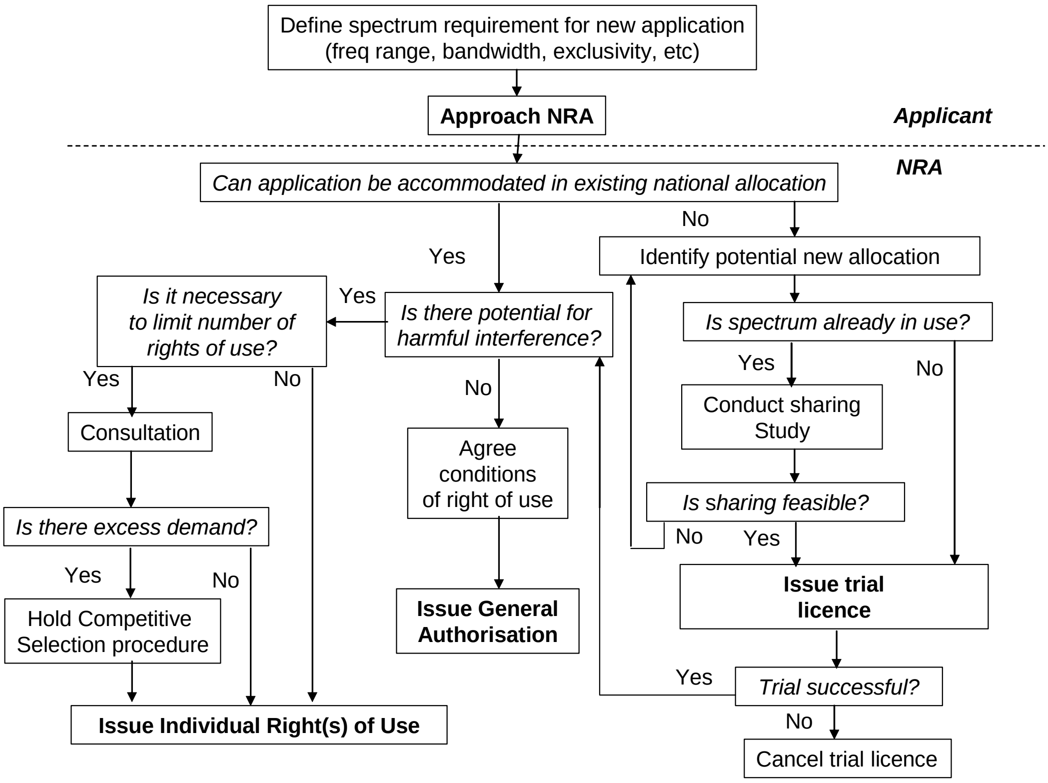

Figure 2.1: Typical process involved in gaining access to spectrum for new applications

2.3 Use of Radio Spectrum for Broadcasting in the EU

Most of the internationally allocated broadcast spectrum is 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 government usage which pre-dates the introduction of broadcast 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 (notably in the VHF bands below 230 MHz) to other uses, typically mobile radio.

A summary of the current use of the internationally allocated broadcast bands is presented in Annex E.

2.4 Radio Spectrum and Broadcasting Policy in the EU

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[3] and Radio Spectrum Policy Group Decision[4])
- The new regulatory framework for electronic communications and services (notably the Framework Directive[5] and Authorisation Directive[6])
- The "New Approach" Directives which govern the placing of electronic communications equipment onto the market (notably the Radio and Telecommunications Terminal Equipment Directive[7])
- Audiovisual (AV) policy, including content regulation and general interest obligations (notably the Television Without Frontiers Directive[8]).

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.

A description of the main elements of the above four legislative areas and other aspects of EU policy that relate to spectrum management and broadcasting is presented in Annex B.

2.5 The Situation Elsewhere

Although the focus of this study is on developments within the EU, it is helpful for comparison purposes to review briefly the approaches being taken in other parts of the world. The following sections summarise the approaches to spectrum management and broadcast digitisation being taken in the USA, Australia and

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

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

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

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

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

[8] 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

Japan. A more detailed discussion of developments in these countries is presented in Annex D.

2.5.1 USA

In the USA, both broadcasting and spectrum management are regulated by the Federal Communications Commission (FCC). Under impetus from the FCC, DTT began broadcasting in 1998, with 42 stations affiliated with the major networks and covering 25 cities across the country. Unlike the situation in Europe, the launch of DTT in the US is tied closely to the penetration of integrated digital TV sets and to high-definition TV broadcasting (HDTV).

As of May 2003, more than 1,000 stations were on the air with DTT signals, and every major TV market was served by at least one DTT station. The target date set by Congress for the completion of the transition to DTT is December 31, 2006. However, that date may be extended depending on whether most homes (85%) in an area are able to receive DTT programming. After the transition, analogue broadcasting will cease and the spectrum used by analogue services will be put to other uses.

The FCC has already re-allocated the upper part of the currently allocated TV broadcast spectrum to allow other wireless services, once analogue services have ceased. Under the FCC's scheme, the "core" spectrum for digital television services will be below 698 MHz, while frequencies above 698 MHz have been re-allocated to permit a variety of new fixed, mobile or broadcast services. During the transition to digital broadcasting, existing television services in the spectrum above 698 MHz would continue to be protected. Originally scheduled for 2001, successive postponements of the upper 700 MHz auction have taken place and a final date has still not been fixed for the auction. This is largely due to difficulties reaching agreement with incumbent broadcasters over release of the spectrum.

Unlike the European DVB-T standard, the technology adopted for DTT in the US will not support mobile reception. Any broadcaster wishing to provide mobile reception will therefore need to find other ways to realise this, for example delivering content over an existing mobile network or acquiring some of the re-allocated spectrum in the 700 MHz band. This distinction between fixed and mobile TV reception prompted the following comment by the Head of the FCC's Office of Technology and Engineering, in response to lobbying from some industry players to adopt the European DVB standard[9]:

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[9] From Oversight Hearing on High-Definition Digital Television and Related Matters before the Committee on Commerce, Subcommittee on Telecommunications, Trade and Consumer Protection, US House of Representatives, July 25, 2000

"…I am also concerned that one of the primary motivations behind this review of the DTV standard by some members of the broadcast industry appears to be a purported advantage of COFDM to provide portable and mobile services -- rather than any ability of COFDM to provide improved or enhanced television broadcast service. I believe that this raises fundamental issues regarding the intent of Congress and the Commission's rules providing broadcasters with a free second channel for DTV operations….. To the extent that some broadcasters may desire to enter the market for the provision of mobile services, they can do so by acquiring licenses in the newly reallocated spectrum at 700 MHz or some other spectrum that is allocated for mobile services."

It is important to bear this distinction in mind when considering the spectrum requirements for broadcast and mobile services in Europe and the USA, since several EU Member States consider mobile TV reception to be a standard digital broadcast offering.

2.5.2 Australia

The broadcasting landscape in Australia is similar to that in most European countries, with a mix of commercial and general interest broadcasters. There are three free to air commercial television networks, complemented by two national broadcasters (the Australian Broadcasting Corporation, ABC, and Special Broadcasting Service, SBS), a community television station in some areas, and three main subscription television providers. Terrestrial remains the dominant delivery platform for broadcasting.

Under the current regulatory regime, the licence that provides the right to broadcast content and regulates the behaviour of the broadcaster cannot be separated from the licence that grants access to the spectrum. The Australian Communications Authority (ACA) has overall responsibility for planning and licensing the radio frequency spectrum. However, under the Radiocommunications Act 1992, part of that responsibility is delegated to the ABA, which plans and licenses that part of the spectrum designated as the broadcasting services bands. Recently, the ACA has adopted the concept of "spectrum licences" for major users such as cellular telephony; however the concept has not yet been applied to broadcasting. In August 2002, The Minister for Communications, Information Technology and the Arts released a discussion paper on possible changes to the roles and responsibilities of the ABA and the ACA, including the most effective arrangements for the management of broadcasting and telecommunications spectrum.

The Federal Government has put in place a regulatory framework for the conversion of free to air television to digital mode, and has provided the free to air broadcasters with additional spectrum to simulcast programs in digital and analogue modes for at least eight years from the commencement of digital transmissions. Digital transmissions have commenced in all mainland State capital cities and a number of regional areas. The rollout of digital services must commence in other metropolitan and regional licence areas before January 2004.

After considering the merits of the American and European standards, the ACA chose to adopt the DVB-T standard for its DTT services. A similar decision was subsequently made by the New Zealand government.

2.5.3 Japan

Both Spectrum Management and Broadcasting in Japan is the responsibility of the Department of the Telecommunications Bureau, which is part of the Ministry of Public Management, Home Affairs, Posts and Telecommunications (MPHPT). Broadcast services are provided by the licence-fee funded national broadcaster, Nippon Hoso Kyokai (NHK) and a number of commercial, advertising-funded broadcasters. NHK operates two national analogue terrestrial channels and three satellite channels, which are simulcast in analogue and digital format. At least four commercial terrestrial channels are available for 89% of the population. Japan has pioneered the delivery of HDTV, with commercial analogue HDTV services available over satellite.

The Japanese government plans to spend 180bn Yen over the next ten years to fund analogue to digital migration. The Government's objective is to achieve a total migration to digital by 2011, with simulcast continuing in the meantime. It will be necessary to change some of the frequency assignments used for terrestrial analogue services to facilitate the rollout of digital. Broadcasting legislation is being amended, to include a re-definition of TV broadcasting. In 2001, a National Council for the Promotion of Terrestrial Digital Broadcasting was created, to promote a smooth transition form analogue to digital services and to further the spread of digital broadcasting. Ten local DTT R&D facilities have been established by the trade body Telecommunications Advancement Organisation of Japan (TAO), to develop new content and applications for the digital platform. So far, 16 companies representing the three major broadcasting networks have applied for DTT licences, in addition to NHK. The Japanese ISDB standard has yet to be adopted anywhere outside Japan.

3 OPPORTUNITIES AND CHALLENGES PRESENTED BY SWITCHOVER

3.1 Introduction

The switchover from analogue to digital transmission will provide substantial benefits in terms of additional transmission capacity, allowing a wider range of content and services to be brought to the market. However, the process of switchover is immensely complex, involving the replacement or upgrading of hundreds of millions of TV receivers and the re-planning of thousands of transmitters. The relatively high powers used by many TV transmitters means that co-ordination is necessary over distances of hundreds of kilometres to avoid interference to distant receivers. Furthermore, the analogue services cannot be switched off until the overwhelming majority of users have acquired the means to receive a digital or non-terrestrial alternative. In most countries this entails the simultaneous transmission of analogue and digital services for a period of many years, further complicating the co-ordination process.

Another complicating factor is that the extent to which digital television has penetrated the market varies enormously among Member States, as does the projected timescale for analogue switchoff (see Figure 3.1).

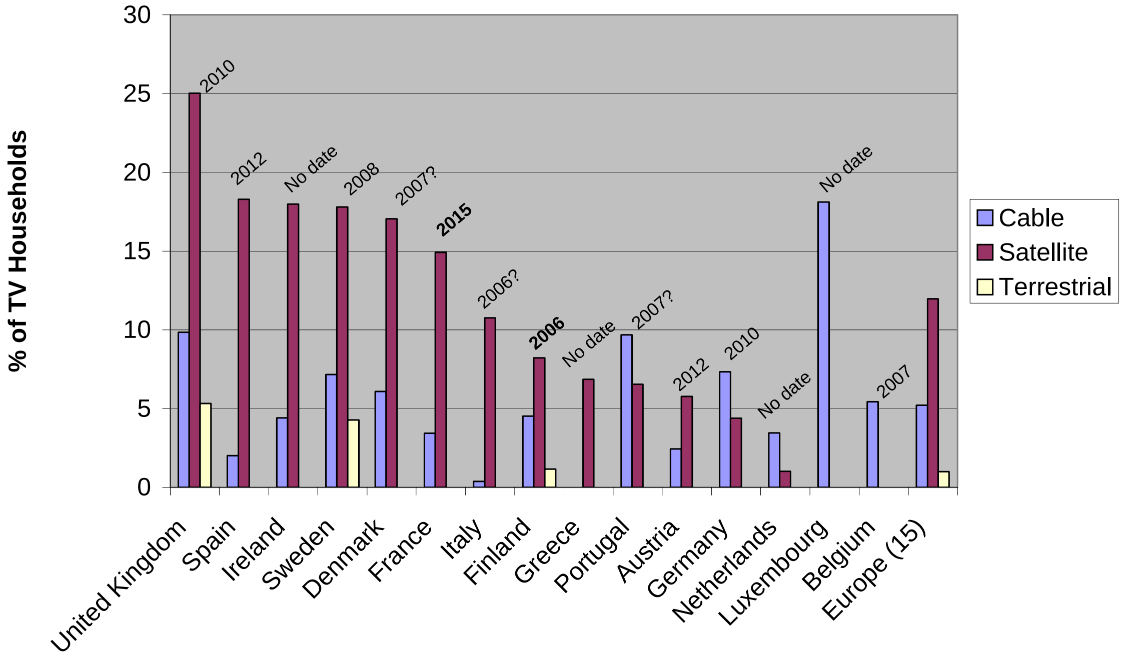

Figure 3.1: Market Penetration of Digital TV platforms and projected analogue switch-off dates in EU Member States (source: IDATE)

In this chapter, we consider the potential benefits that could arise from digitisation and the challenges that must be overcome in order to reap these benefits.

3.2 Estimating the Digital Dividend

3.2.1 Introduction

The increased capacity arsing from digital transmission raises the prospect of a “digital dividend” that could lead to spectrum being made available for a range of applications beyond the simple replication of today’s analogue TV services. This digital dividend could be used to enhance the range, picture quality or reception capability of terrestrial TV services, or to facilitate new services which may or may not be based on broadcasting technology. In order to estimate the potential scale of this dividend we have considered the spectrum that might reasonably be required to replicate the current provision of national, free-to-air analogue TV services in a typical EU Member State.

In practice, this will depend on various factors, including:

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

The results presented here are intended to be territory-independent, and assume that all analogue television services have ceased. 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.

Our detailed calculations and the underpinning technical considerations (including a description of the main technical parameters of DTT that affect spectrum utilisation) are presented in Annex F.

3.2.2 Results of Analysis

Our analysis concluded that national coverage of a single multiplex with regional programme variations and providing reception via rooftop-mounted aerials would require between 4 and 9 UHF frequency channels[10], depending upon the choice of

[10] The term “frequency channels” refers to the 49 channels in the range 470 – 862 MHz, each of 8 MHz bandwidth, as defined by the ITU in the 1961 Stockholm Plan.

technology (notably the modulation scheme and whether single frequency or multi-frequency networks are deployed) Providing high quality coverage to indoor portable receivers via set-top aerials or to mobile receivers would require significantly more spectrum – between 9 and 39 frequency channels per multiplex.

By comparison, most EU Member States have up to four analogue programme channels providing national coverage (98% or more of population), each requiring typically eleven frequency channels to deliver this coverage. However, analogue transmission conveys only one programme channel per frequency channel compared to as many as six for digital transmission based on current coding schemes. It is therefore helpful to compare the various digital technology options on the basis of how many frequency channels are required per national programme channel. This is illustrated in Figure 3.2 below.

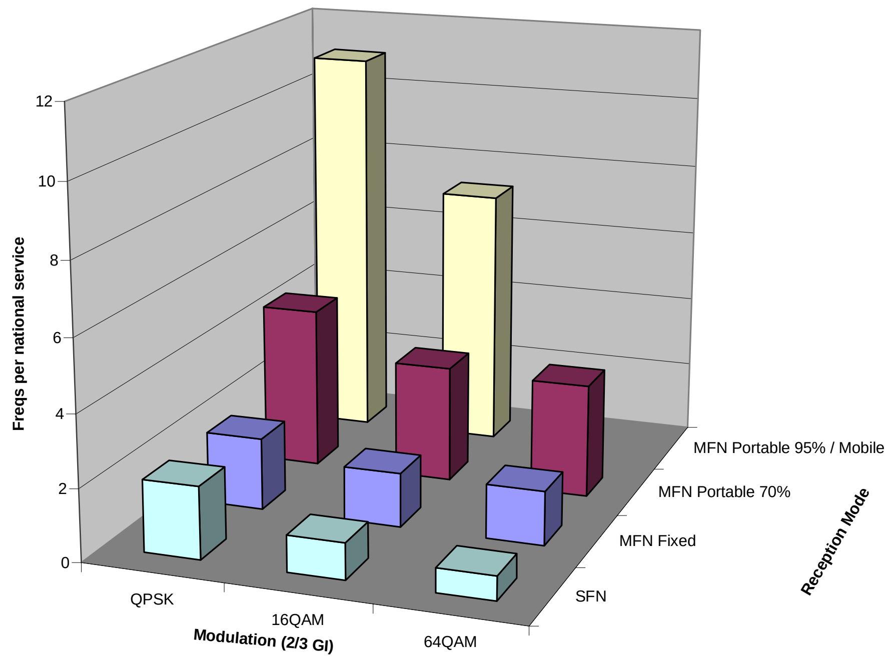

Figure 3.2: Spectrum Requirement per Programme Channel for analogue and digital terrestrial TV

Note that in the worst case (i.e. a multi-frequency network with widespread mobile and indoor reception capability) the spectrum requirement is the same as for analogue, whereas the best case represents over an order of magnitude reduction. If we assume that regionality and a reasonable degree of indoor portable coverage (corresponding to today's analogue services) is required, it appears that between 3 and 4 frequency channels per programme channel are sufficient. This would suggest, for example, that up to 24 frequencies would be needed to deliver six national programme channels.

Although single frequency networks provide a significant reduction in the spectrum requirement nationally, the extent to which this can be achieved in practice will be severely constrained where there is a need to co-ordinate with several neighbouring countries. To achieve this level of spectrum efficiency in practice would probably require the adoption of a radically different approach to broadcast network planning across Europe, based on a high-density cellular infrastructure at a considerably higher cost than today's high power transmitter networks.

Our calculations suggest that adoption of digital transmission based on the DVB-T standard would enable existing national terrestrial TV services to be delivered with typically between a third and a half of the existing spectrum requirement. This figure assumes that a high degree of regionality is required and that indoor coverage is available at 70% of locations, broadly comparable with today's analogue coverage (though in the analogue scenario much of this indoor coverage would suffer from degraded picture quality). Planning based on fixed, rooftop aerial reception only would provide a significant reduction in the spectrum requirement (to as little as 10% of the current analogue requirement), whereas providing for widespread mobile reception would increase the requirement to approximately the same level as the current analogue services.

In most scenarios, therefore, there is a substantial "digital dividend" if today's analogue services are broadly replicated in a digital environment. This dividend will however be largely or wholly offset if DTT in its present form is required to cater for enhancements such as mobile or high definition TV, or if the number of channels is expanded in an attempt to match the offerings of cable or satellite networks. As we will see in the later sections of this report, technology developments may have the potential to overcome this problem, providing a flexible approach to standards and frequency planning is adopted.

3.3 Implication of the Analogue Legacy for Digital TV Planning

Whilst it is clearly important to maintain existing terrestrial free-to-air services on general interest grounds, there may also be an economic case for doing so. A survey carried out by the UK Radiocommunications Agency[11] (now part of Ofcom) in 2001 estimated that the consumer surplus (i.e. the amount users are willing to pay less the amount they actually pay) from terrestrial TV services was about £146 (€204) per household per annum for analogue services and £176 (€246) for digital.[12]

These estimates do not take account of the opportunity cost of the spectrum i.e. its value in the best alternative use of the spectrum. For example, we note that by contrast users' consumer surplus from mobile phone services in the UK has been estimated at about £180 (€252)/annum for a private individual and £507(€709) per

[11] The Economic Impact of Radio, February 2001 (http://www.radio.gov.uk/topics/economic/eis-report.pdf)

[12] The economic impact of radio 2001, Radiocommunications Agency, February 2001; The economic impact of radio, 2002 update. Radiocommunications Agency April 2002.

annum for a business user. Using data on the number of TV households and mobile users gives total consumer benefits of £4bn (€5.6bn) for TV and £7bn (€9.8bn) for cellular mobile services. As TV services occupy more spectrum than mobile services (roughly 300 MHz compared with 200 MHz respectively) this indicates a higher average economic value for mobile as compared with TV services. However, this does not necessarily mean that spectrum should be reallocated from TV to mobile services. Marginal rather than average values and general interest considerations should inform any such decision. Furthermore spectrum is not a homogenous resource and in this case the value of UHF spectrum to a mobile operator is likely to be less than the value of the 900 MHz and 1800 MHz spectrum that mobile operators currently occupy (because it can be less intensively used and there is currently no equipment available). And of course it should also be recognised that values may differ considerably between Member States as consumer attitudes and the services offered will differ.

Maintaining free to air broadcasting services in an all-digital broadcasting environment has a number of cost implications beyond the simple replacement of analogue transmitters and receivers by digital, especially if achieving spectrum efficiency is one of the goals. Transmitter networks are currently configured to reflect the interference characteristics of analogue reception. This requires large separation distances between transmitters using the same frequency channel (up to hundreds of km for the highest powers), even if the same material is being broadcast. Digital technology in some configurations has less stringent protection requirements and is better suited to high-density transmitter networks, enabling a more intensive re-use of frequencies to be achieved. Furthermore, DVB-T has the facility to deliver “single frequency networks” (SFNs) whereby the same frequency can be intensively re-used in the same area to enhance reception (see Annex).

A DVB-T transmission network that is planned for optimum spectrum efficiency can therefore deliver a significant reduction in the overall spectrum requirement compared to existing analogue networks - perhaps an order of magnitude in the spectrum required per programme channel. However this would be at the expense of wholesale re-planning of transmission networks, perhaps using a model more akin to cellular telephone networks with their many thousands of transmission sites rather than a conventional broadcasting approach where a hundred or fewer transmitters can provide substantially national coverage of large territories. This could have significant implications in terms of site acquisition costs, international co-ordination and potential public concern about proliferation of transmitter masts.

A further constraint is the need for viewers to be able to upgrade to digital at minimum costs. Any re-alignment or replacement of rooftop aerials to accommodate changes in transmission site or frequency represents significant additional cost and disruption which it will be necessary to take into account when the costs and benefits of different switchover options are compared.

In practice, achieving switchover in a reasonable timescale and at reasonable cost, whist minimising disruption to existing analogue services in the interim, requires digital planning largely to reflect the configuration of analogue networks, at least for as long as they have to co-exist with analogue services and probably for some time thereafter if significant disruption is to be avoided.

3.4 Use of Broadcast spectrum by non-broadcast services

Another consequence of the analogue legacy is that broadcasting spectrum is used extensively on a secondary basis by broadcasters and others for services ancillary to broadcasting, public entertainment or other special events. Various terms are used to describe these applications, including Programme Making and Special Events services (PMSE), outside broadcasting, SAB and SAP. Activities include, for example, outside broadcast links used to report news or sports events and wireless microphones used in concerts and theatrical productions. SAB/SAP services are often able to use analogue channels that are unusable locally for broadcast transmission due the high protection requirements that apply (sometimes referred to as “taboo channels”).

ECC Report 002[13] recognised SAB/SAP operations as an essential part of programme making, noting that the broadcasting bands III, IV and V were already used extensively by SAB/SAP services on a secondary basis and that this facility would need to be maintained, or even increased, in the future. In particular radio microphones and talkback production systems were used. Current frequency requirements for such applications are estimated at up to six 8 MHz TV channels and this is expected to rise to up to ten channels within the next 5 years. However, it was also noted in the report that SAB/SAP operations should not hamper the development of DVB-T or T-DAB.

The continuing availability of spectrum for SAB/SAP services may be affected by any long-term change of use in the broadcast bands. Whilst the broadcasting community is able to co-ordinate SAB/SAP services in a manner which avoids interference to primary broadcast services, this may be more difficult to achieve if new non-broadcast services are introduced. The ability of DVB-T to use spectrum more intensively is also likely to reduce the availability of “taboo channels” for SAB/SAP use.

Many EU member states have allocated parts of the broadcast spectrum to other services. The principal other use is for government and military services in the top part of the UHF band (above 792 MHz), although some countries (e.g. the Netherlands and UK) have allocated parts of VHF Band III to mobile services.

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[13] “SAP/SAB (Incl. ENG/OB) spectrum use and future requirements”, European Communications Committee (ECC), February 2002

These other services will be taken into account during the forthcoming regional regulatory conference (RRC) to re-plan the broadcasting bands for digital transmission (see Section 4.3) and may therefore continue to constrain the rollout of DTT or other new services in the spectrum even when analogue TV transmissions have ceased.

3.5 Making the most of the spectrum dividend in an uncertain market environment

There are a number of ways in which any spectrum released as a result of analogue switchoff might be used in the future. These include enhanced or expanded broadcasting services, mobile services, fixed wireless services, "converged" services combining elements of two or more of these services or even completely new applications that have not yet been thought of. This uncertainty presents a particular challenge to spectrum managers, since a decision to introduce a particular type of new service may constrain the ability to introduce other services or to maintain the quality of existing services. Regulators also need to balance the potential spectrum needs of new market players or services and the benefits such services may provide against the cost implications for incumbents of vacating spectrum and any loss of existing services in order to make way for such services. These trade-offs often need to be made in advance of technologies being fully developed and the deployment of services. There is therefore always a risk that demand for the new services will not materialise (e.g. because of competition from other services or changes in consumer preferences).

It might be argued that the prudent thing for regulators to do in these circumstances is to wait until technology and market developments become clearer. However, in some circumstances the decision to allocate the spectrum on a European basis is necessary to stimulate investment in technology. While this is not always the case, it will be particularly important in situations where scale economies are so large as to require a potential market the size of Europe as a whole and/or where international mobility is an important feature of the service.[14] A case by case analysis is required to determine when decisions concerning spectrum allocations need to be made. In all cases – whether decisions are made early or late- there is a risk that demand will not materialise and spectrum will be left idle. It is important therefore that spectrum allocation or harmonisation measures can be changed or a framed with sufficient flexibility to allow the allocated use of spectrum to also change where necessary.

Access to spectrum for non-TV services post-switchover will depend on the regulatory approach taken to new broadcast services, including new programme

[14] This is discussed further in "Costs and Benefits of International Frequency Harmonisation and Standardisation, Indepen and Aegis Systems, a Report for the UK NRA Ofcom, March 2004 (available on the Ofcom web site www.ofcom.org.uk).

channels and enhancements such as mobile or HDTV. In particular, it will depend on whether these services are subject to similar general interest considerations to those applied to existing analogue services or whether they are treated in the same manner as any other potential user of the spectrum. The latter approach, which we believe is justified by the increasing convergence between broadcasting and other communication services such as 3G mobile and the Internet, would ensure that new broadcast services face the same economic incentives to deliver services efficiently as other users of the spectrum. This can be achieved by employing market-based approaches to spectrum management, such as the ability to trade spectrum between different users and applications, or by administrative means such as the application of spectrum fees that take account of the economic value of the spectrum. These approaches are discussed in chapter 4.

3.6 Potential Developments in Broadcasting and the Implications for Spectrum Management

3.6.1 Background and Context

Historically, terrestrial free-to-air broadcasting has been constrained by the limited availability of radio spectrum and the relative inefficiency of delivering broadcast content using analogue technology. In practice, this has meant that in most EU Member States the number of television channels that can be delivered nationally over the terrestrial networks has been limited to no more than four or five (although sometimes several more channels may be available on a localised basis, e.g. to serve major population centres). Cable and satellite platforms are able to provide much greater capacity even using the same analogue technology. This enables delivery of an extensive array of both free-to-air and subscription-based channels to users that are within their service area and are willing to install the necessary reception equipment.

Unlike analogue terrestrial free-to-air services, access to satellite and cable services typically involves subscription to a single service provider, which acts as “gateway” to both its own services and those of third party providers who have negotiated access to the provider’s platform. Satellite services further benefit from having only a single transmission point. This lends itself much more readily to rapid upgrading of technology, with the result that satellite platforms have so far made much more progress in migration to digital transmission than terrestrial or cable broadcasters.

Digitisation has further enhanced the capacity advantage that cable and satellite already had, to the extent that these platforms can now deliver several hundred television channels and are able to complement these with further services such as high speed internet access and "near-video on demand" (NVOD) services[15].

The following sections consider how broadcasting services might evolve over the coming years, given the current state of markets and technologies, and the potential implications for radio spectrum management.

3.6.2 Portability and Mobility

3.6.2.1 Overview

Reception by mobile and portable receivers represent two significant and somewhat distinct segments of the television receiver market. There is a long-established and sizeable market for portable analogue receivers, typically used as second or third sets inside homes or by travellers in boats, caravans etc. Typically between a third and two thirds of households in EU countries have more than one TV set (see Figure 2.2 below). Portable sets are essentially smaller versions of large screen sets, capable of connection to either set-top or rooftop aerials. More recently, low cost, hand-held mobile receivers using LCD technology have become available, enabling limited (pedestrian) mobile reception of relatively low-resolution pictures in many areas by means of a built-in telescopic aerial.

The differences between these two reception modes are particularly significant in the context of digital television. Portable sets deliver high resolution pictures in fixed locations and generally connect to either mains or vehicle power supplies. The only fundamental difference from large screen TV sets is that portables are less likely to have access to an external rooftop aerial feed. Mobile receivers on the other hand have much lower resolution (a consequence of the much smaller screen size) but are required to operate at potentially high speeds and in highly variable reception conditions. This places different requirements on the transmitted signal which may be incompatible with optimising reception by fixed receivers. These issues and the possible implications for spectrum management are considered further in the following sections.

[15] i.e. the delivery of the same material on multiple channels but time-shifted to allow the viewer a choice of when to view

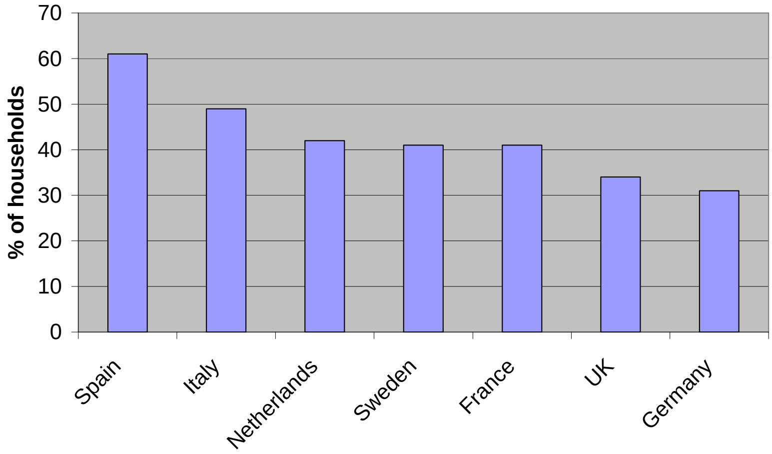

Figure 3.3: Proportion of households with two or more TV sets:

Definitions

Indoor and outdoor **portable** reception is defined in the following manner:

- ***outdoor:*** reception where a portable receiver with an attached antenna is used at no less than 1.5m above ground level;
- ***indoor:*** reception where a portable receiver with an attached antenna is used at no less than 1.5m above floor level in ground floor rooms with a window in an external wall.

Mobile reception is defined by the EBU as "reception while in motion, covering speeds from walking to motorway driving".

3.6.2.2 Portable Reception

In many Member States 40% or more of the households are equipped with two or more sets (Figure 3.3). A significant proportion of these sets rely on indoor "set top" aerials. Maintaining this "indoor portable" reception capability in a digital transmission environment presents a challenge, especially during the transition period when digital services must be provided alongside analogue. Part of the problem is the "all or nothing" nature of digital reception: whereas an analogue TV signal experiences gradual degradation in the presence of interference or insufficient signal strength, digital reception tends to be either perfect or non-existent. Whilst viewers may be willing to tolerate imperfect analogue reception they are likely to be less tolerant of a complete loss of service. Hence matching the current availability of analogue TV services by portable receivers may require enhancements to network coverage and/or improvements in receiver sensitivity, incurring additional costs in each case. The cost in terms of spectrum utilisation could also be significant, as we saw in Section 2.2.

The economic case for delivering universal portable reception is at best questionable and at worst non-existent. For example, we estimate that extending indoor portable coverage from 80% to 99% in France would require an increase from 300 to over 3,000 transmitters, incurring an additional cost of billions of euros. In many cases, in-home distribution networks are likely to provide an acceptable and more cost-effective alternative for second sets used in the home, whilst it is generally feasible to install an external antenna on boats, caravans and vehicles (some have even installed satellite receivers). It should be noted that current analogue networks are not designed to provide ubiquitous indoor coverage hence any move to do so with DTT would represent a significant change from the status quo.

The EBU has suggested that for indoor portable reception, planning for 70% locations would be sufficient and seems to be the best way to reduce the spectrum requirements.

3.6.2.3 Mobile Reception

Effective mobile reception of DVB-T presents a different challenge, particularly if reception is required in fast moving vehicles. Such reception incurs two significant problems, namely the Doppler Effect[16] and multipath interference[17]. The DVB-T standard can be optimised for resilience against either one of these effects but not currently for both. The 2k mode of DVB-T is significantly more resilient to Doppler effects than 8k, whilst the 8k mode is more resilient to multipath interference, at least in a static environment and is currently the only mode capable of being deployed in single frequency networks (SFNs). Apart from the spectrum saving demonstrated in Section 2.2, SFNs offer advantages in network cost and planning, enhanced signal strength in transmitter overlap areas and provide seamless handover from one transmitter to another, which is a significant advantage for mobile reception.

Planning parameters for DVB-T mobile reception at high speeds are under development. Several European broadcasters are interested in mobile reception and have actively contributed with detailed test measurements results. A large improvement has been observed by using antenna diversity (i.e. providing two physically separate antennae, either on the device itself or externally, e.g. attached to the roof of a vehicle). Diversity is likely to be essential for mobile reception of DTT using the 8k transmission mode.

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[16] Doppler effect causes an increase or decrease in the apparent frequency of the received signal as the transmitter and receiver move towards or away from each other

[17] Multipath is due to the received signal being reflected of objects or surfaces between the transmitter and receiver, resulting in multiple versions of the transmitted signal being received, each with a different delay

Reception by handheld terminals is more challenging than reception by in-vehicle receivers using external antennae The very small antenna sizes required for handheld devices implies low antenna gains and correspondingly high field strength values. This would require either a big increase in transmitter powers or a much denser network infrastructure, akin to cellular telephone networks. Interference and health and safety concerns limit the scope for power increases whereas adoption of a cellular approach could give rise to both cost and environmental problems.

A further problem associated with DVB-T reception on handheld devices is the digital processing overhead in the receiver. This increases power consumption to the extent that a hand-held DTV receiver would be unlikely to have a battery life of more than one or two hours with current technology. Whilst technology enhancements are likely to improve this performance, it will remain the case that a transmission format that is optimised for reception on high-resolution, large screen receivers at fixed locations is unlikely to be best suited to mobile reception on small hand-held terminals.

The most promising solution to the delivery of mobile TV or other audiovisual services to small handheld devices is likely to involve the use of a transmission mode that is optimised for such reception, although the success of this will depend on the availability of spectrum for such transmission. The next section reviews the work that is currently underway to develop such mobile-optimised standards.

3.6.2.4 Mobile TV Standards

Mobile digital TV is likely to benefit from the introduction of new standards such as DVB-H (Handheld), which are optimised for reception by small, low power devices. Work started on a mobile-optimised DVB standard in 2002, then referred to as DVB-M (mobile). This subsequently evolved into DVB-X and more recently still into DVB-H.

The new standard is based on DVB-T but takes into account the need for low power consumption in the terminal, reliable network coverage in a handheld or indoor reception environment and resilience to interference. DVB-H technical requirements include power consumption of less then 100 milliwatts, a data rate of 15 Mbit/s, operation via large, single-frequency networks and reception at high driving speeds. DVB-H devices may also be capable of receiving conventional DVB-T signals where coverage is configured to provide good indoor portable reception, but the degree of DVB-T/DVB-H interoperability has yet to be defined by DVB.

Commercial implementation of the DVB-H standard is targeted for around 2006. Technology trials are planned in a number of EU Member States, including Finland, Germany and the UK (see Section 3.10.2).

3.6.2.5 Demand for Mobile TV

The Technical Research Centre of Finland (VTT) has carried out a study to assess consumer attitudes and habits with regard to mobile digital television, as part of

Finland's plans to develop mobile DTT services. The study investigated users' reactions to a variety of mobile TV applications. Two types of terminal device were used in the study, based on a laptop computer and a personal digital assistant (PDA). The devices were tested in various transport modes (train, bus, boat and car) and in public places such as cafés, railway stations and a university entrance hall, as well as in users' private homes or gardens.

The study indicated positive attitudes to mobile TV. Those participating in the study were willing to pay an average of €0.50 per programme or €20 for a monthly subscription. The most popular types of programme in the study were news, children's programmes, entertainment and films. Of the ancillary services, the search and TV guide functions were the most popular. The devices tended to be used mainly while waiting or killing time. Mobile TV services are currently being trialled in Finland as part of a wider initiative relating to mobile IP datacasting (see Section 3.10.2.1).

3.6.3 Multi-Platform Delivery

Digital television can be delivered to fixed receivers by three principal means, namely cable, satellite and DTT. Cable networks incur substantial infrastructure costs and are best suited to urban or suburban areas with a highly concentrated residential population. Cable is near-ubiquitous in some EU Member States but almost non-existent in others. Satellite enables 100% geographic coverage to be provided, so long as line of sight visibility of the satellite can be achieved at the viewer's premises. This may be difficult at certain locations, e.g. urban centres with a preponderance of high buildings or in mountainous areas. The latter present a particular problem as they are unlikely to be served by cable networks. For example, research commissioned by the UK Independent Television Commission (now part of Ofcom) indicated that up to 4% of UK households would not have satellite coverage.

The existence of multiple platforms means that it is not necessary to rely exclusively on terrestrial networks to achieve universal access to TV services, at least for the provision of reception to a fixed point in the home. A multi-platform approach is consistent with the technology-neutral nature of the new EU Regulatory Framework but may have implications for content, which would need to be delivered transparently and not be dependent on the transmission platform. This is a particular challenge for enhanced services such as interactivity.

One argument that is sometimes put forward in support of ubiquitous terrestrial coverage is that it is the only way to deliver reception to mobile and portable receivers. However, as we have seen, the higher transmitter powers required to deliver mobility and portability from a DTT network primarily intended for fixed reception leads to a significantly higher spectrum demand even in an all-digital environment. Hence alternative approaches to achieving mobility based on technology optimised for this reception mode may be preferable if overall spectrum efficiency is an objective.

Another argument for universal terrestrial coverage is the difficulty in achieving truly ubiquitous satellite coverage in practice, for example due to terrain or planning restrictions on satellite dishes. A recent EU Communication[18] limits public authorities' possibilities to hinder erection of dishes, however there may still be problems with private law agreements affecting apartment blocks etc. In such cases low power "self-help" relay stations, perhaps re-transmitting the signal from a nearby satellite reception facility may provide an effective solution.

It should be remembered that, depending on the technology, coverage may not be a significant driver of DTT spectrum demand. Within a given region the use of localised single frequency networks (SFNs) means that that there is essentially no difference in the spectrum required whether a single transmitter or several are deployed, so long as the exported interference limit is not exceeded. Hence any decision on what constitutes an acceptable level of coverage for DVB-T may be driven by cost / practicality constraints rather than spectrum constraints, at least where SFNs are deployed. This is likely to be particularly relevant in the case of commercially funded services.

The existence of established cable or satellite networks in some countries may ease the transition to DTT, since it becomes necessary to migrate only a minority of the population to digital via DTT. In Berlin for example, only 8.9% of analogue viewers relied on terrestrial reception prior to the switch off which took place earlier this year[16]. There may also be a strong incentive for some cable and satellite viewers to switch to free-to-air DTT services if they currently pay for analogue cable or satellite services with a limited number of channels. In Berlin 40% of the households that acquired terrestrial set top boxes were existing subscribers to cable or satellite[19].

Conversely, in those countries where analogue terrestrial broadcasting still predominates it is necessary to offer a credible alternative that will provide an incentive for this majority to make a swift transition to digital, while not penalising them in terms of coverage or access cost.

Care needs to be taken in a multi-platform environment to ensure that undue preference is not given to any particular option. In Germany, the offering of free-to-air DTT multiplexes has prompted allegations from the cable sector that DTT has been a beneficiary of state aid, in the form of subsidies via the state broadcasting licence fees. A formal complaint has been lodged with the European Commission

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[18] EU Communication on the Application of the General Principles of Free Movement of Goods and Services – Articles 28 and 49 EC – Concerning the use of Satellite Dishes, available on the EU web site at http://europa.eu.int/comm/internal_market/en/media/satdish/antenna_en.htm

[19] Source: "DVB-T in Europe, Dr Chris Weck, IRT, presentation to CISMUNDUS Project Final Workshop, 10th February 2004

(DG COMP) by the cable operator ANGA and an investigation into the complaint is currently underway. Depending on the outcome, this could have implications for the future financing of DT T rollout in Germany and elsewhere.

3.6.4 HDTV / Wide Screen

The recent history of broadcasting in Europe has been one of massive growth in the number of channels available in most Member States, principally delivered by cable and satellite platforms. However the fundamental nature of TV receivers has changed relatively little over the last three decades. Whilst there have been some enhancements such as the introduction of stereo sound and widescreen pictures, picture resolution still reflects the 625-line standard established in the 1950s. This also applies to all the current European digital services, with the exception of the recently launched Euro 1080 satellite service (see box below).

Elsewhere, notably North America, Japan and Australia, the transition to digital television is linked to the introduction of high definition television (HDTV)[20], which is seen as a key differentiator for digital services. Until recently the prevailing view in Europe has been that there is little demand for HDTV, however the increasing popularity of DVD players and wide screen standard definition TV sets suggests that consumers are becoming more aware of picture quality and are increasingly willing to pay a premium for enhancements. The anticipated launch of HD DVD players in the European market and the recent launch of the first HDTV satellite service may stimulate demand for HDTV sets which in turn could encourage broadcasters to develop further HDTV services.

HDTV in Europe.

On 1 January, 2004, Euro1080, operated by Alfacam in Belgium launched Europe’s first HDTV service, broadcasting from the Astra 1H satellite. There are two channels – a main channel serving households across continental Europe and an event channel serving public venues with coverage of major sporting or cultural events. The newsletter Satcoms Insider reports that HDTV set-top boxes will start appearing in electrical stores towards the end of the year priced at around €500, from manufacturers like Thomson, Pioneer and Panasonic. A smart card will be included in every box, valued at €100 which will be Euro1080's total fee for the service.

HDTV provides increased horizontal and vertical resolution within the picture, providing a viewing experience more akin to the cinema. In the USA, where HDTV has been promoted by the regulator and industry as a key selling point for digital TV, the resolution increases from 486 x 720 pixels to as many as 1,080 x 1,920 pixels, more than doubling the resolution and increasing the aspect ratio (width to height)

[20] Analogue HDTV services are already available in Japan but only via satellite

from 4:3 to 16:9. This is the same format that has been chosen by the Euro 1080 service.

In the US, HDTV prices have fallen considerably since HD services were introduced by broadcasters as part of their digital offering. At the time of writing, the cheapest wide-screen HDTV compatible model was retailing at $799. According to the US Consumer Electronics Association (CEA), HDTV sets accounted for 87% of DTV sales (over half a million units at a value of $800 million) in September 2003. The CEA expects 9 million households to purchase HDTV products over the next 18 months and has said that another 30 million consumers consider themselves likely purchasers within the next three years.

According to the Yankee Group, about 7 million homes in the US already have televisions capable of displaying HDTV images, but fewer than 2 million of those homes are actually watching high-definition signals. One reason for the gap is that after buying a HDTV set, consumers must often purchase an additional HDTV decoder or rent one from a cable company to display HDTV signals. HDTV makers are beginning to deliver sets that can automatically decipher high-definition signals transmitted over cable, without an external decoder. The FCC has recently extended the “plug and play” rules that require TV receivers to be capable of direct connection to cable networks to include digital as well as analogue services, including HDTV services where the TV is capable of displaying HDTV pictures.

Other administrations around the world have included HDTV as part of the rollout requirement for digital TV. For example, the Canadian regulator has stipulated that all Canadian digital programs aired by licensees between 6 p.m. and 12 p.m. must be available in HD format, where such a version exists. Broadcasters must also ensure that, by the end of December 2007, two thirds of their schedules are available in the HD format. In Japan, Government guidelines state that HDTV should be transmitted for more than half of DTT output, whilst in Australia broadcasters are required to provide an average 20 hours per week of HDTV programming in each mainland capital city.

In the medium term it seems likely that HDTV demand will be addressed by satellite or cable services, however if these offerings are successful the likelihood of its longer term introduction over terrestrial networks must be considered. This raises issues in relation to coding and compression standards, which are addressed in the next section.

In Europe, HDTV may emerge as a logical extension to the development of wide screen standard definition TV, which the EU has endeavoured to promote as a service differentiator for digital TV. In 1993 the EU launched a 4 year action plan to ensure wide screen reached the market. The aim was to achieve a critical mass of wide screen TV services and programming, supported by EU contributions and matching industry funding. However, the plan suffered mixed fortunes depending on the degree of support from broadcasters in individual Member States. With the exception of the UK where an agreement was reached between all the major broadcasters to migrate to widescreen[21], almost no free-to-air commercial broadcasters participated in the plan. Consequently, the take-up of wide screen sets varies enormously and bears little correlation with the take-up of digital, as illustrated in Figure 3.4 below.

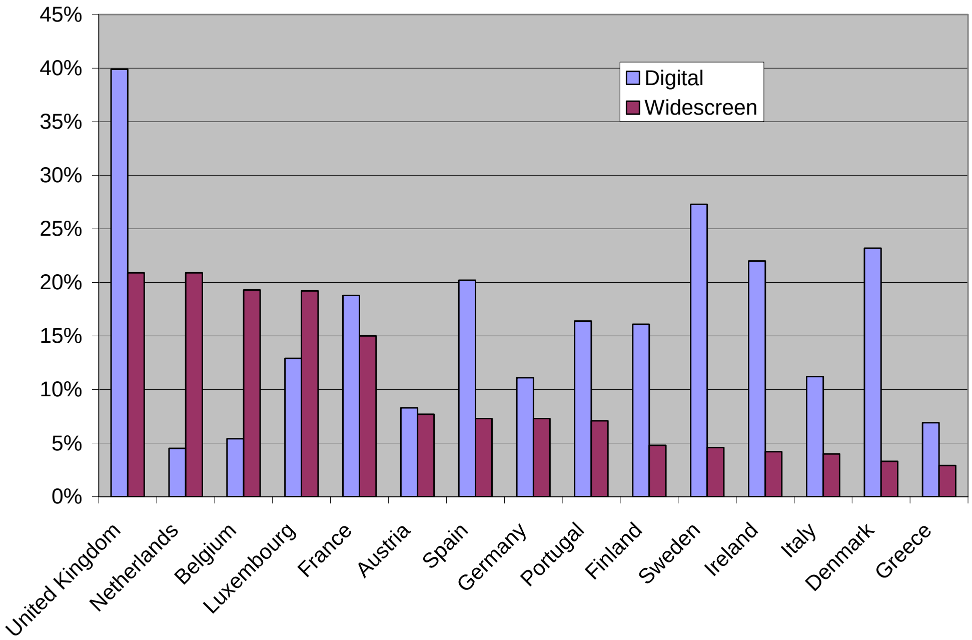

Figure 3.4: Penetration of wide screen and digital television in EU Member States (sources: Widescreen - OMSYC, the World Audiovisual Market 2002, p.134; Digital - IDATE)

3.6.5 Coding and Compression Standards

Currently digital TV transmission is based exclusively on the MPEG2 standard. Provision of HDTV services over terrestrial networks using current MPEG-2 coding would have a significant impact on spectrum requirements, since only a single programme channel could be carried per multiplex. HDTV using MPEG-2 requires 15-20 Mbit/s whereas MPEG4/AVC reduces this by around 50% and the proprietary Windows Media 9 (WM9) platform claims to reduce this even further to around 6 Mbit/s, comparable to existing standard definition services using MPEG-2.

It is therefore questionable whether a single default compression standard (MPEG2) should continue to apply to DTV transmission or whether multiple systems could be accommodated in the future. The latest chip sets support delivery of MPEG4 coded content over an MPEG2 transport stream, allowing at least twice as many programmes to be transmitted within a given bandwidth, yet retaining compatibility with most existing DVB infrastructure and head-end equipment. Vendors claim that MPEG-4 video quality meets or exceeds that of MPEG-2.

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[21] Commission Staff WP on widescreen, , p.20 (sec 3.4.1)

IPR royalties could however be a potential barrier to the adoption of MPEG4. Whereas MPEG2 licensing is based on a fixed charge per receiver, the planned regime for MPEG4 is per hour of use, which broadcasters see as a deterrent to its take-up. Microsoft has announced that it will not charge per use with WM9, raising the possibility that this format could emerge as a de-facto standard for HD coding. From the perspective of spectrum policy, new compression schemes merit policy makers' attention, broadcasters should be encouraged to use them and IPR holders encouraged to make them available on reasonable terms.

3.6.6 Value-Added services

Digital broadcasting allows more than just audio and video to be conveyed. The medium can also be used to provide access to a range of other material in digital form. For example, in the US recently enacted Homeland Security measures include the ability to broadcast emergency information over DTT channels. In Finland, from the beginning of 2004, a trial to deliver real-time public transport information on digital television will be conducted. The services will eventually cover timetables, routes, on-line traffic data, and weather and road conditions and will be the first of a range of value added services to be provided, based on the MHP standard. Finnish broadcasters have committed to use MHP in providing value added services in connection with their own transmissions.

The popularity of existing teletext services delivered over analogue TV networks demonstrates the demand for such add-on services. Although there is as yet little evidence that users are willing to pay for such services, they can provide a worthwhile source of advertising revenue and a useful conduit for public information distribution (as in the US and Finnish examples cited above).

3.6.7 Social / Cultural Diversity

The additional capacity afforded by digital television relative to analogue could be used to support general interest objectives such as cultural or linguistic diversity, enabling minority content to be provided either on a commercial basis (e.g. where there is a high local demand), a not-for-profit basis or as part of an extended general interest remit. Cable platforms already carry some local content and some offer specialist premium channels for particular ethnic groups. Satellite and cable are also used to deliver a growing range of international channels that originate from inside or outside the EU, or to deliver the national services of other Member States. DTT could prove particularly attractive for the delivery of localised services, although as previously noted this tends to increase the overall spectrum requirement.

3.6.8 Interactivity

Interactivity is a further enhancement that can be provided by digital television (to a limited extent this can also be provided by analogue transmission, e.g. by linking telephone or SMS voting to live programmes, but digital provides for a much richer interactive multimedia experience combining attributes of the Internet with conventional TV broadcasts). Interactivity implies that a "return path" is needed and to date this has been provided by means of a telephone modem. Work has been underway within the DVB standards group on an in-band return path facility that would use the same radio frequencies as the DTT transmissions, however currently there appears to be little support for this initiative among the broadcast community. The regulatory and technical implications of operating bi-directional services in broadcast spectrum are discussed further in Section 3.7.3.

3.7 Alternative Uses of Broadcasting Spectrum

3.7.1 Introduction

The increased efficiency brought about by digital transmission implies that, depending on the broadcasting scenario that emerges, a substantial amount of spectrum could become available for other uses. It is important therefore to consider what these other uses might be, and how attractive the released spectrum might be compared to other options that currently or might in the future exist.

The characteristics of terrestrial broadcast spectrum are particularly well suited to applications requiring wide area, non-line of sight coverage. Two applications immediately spring to mind, namely mobile communications and fixed wireless access, although other more specialised applications such as location tracking or even radar systems can also be envisaged. However by far the most economically attractive option is likely to be some form of mobile or broadcast offering, or a combination of the two. The following sections consider the potential deployment of conventional mobile and hybrid mobile / broadcast services in the broadcast spectrum post-switchover.

3.7.2 Regulatory implications of non-broadcast services operating in broadcast spectrum

Other non-broadcast services providing area coverage (e.g. two-way mobile communications) can be operated in broadcast spectrum even where broadcasting is the sole primary allocation, but only on a non-protected, non-interference basis. In practice, the use of the spectrum to deliver convergent services such as the delivery of multimedia content to mobile phones is likely to be compatible with the current ITU-R definition of broadcast services and hence such services would enjoy protection within the limits defined for broadcast services at the forthcoming RRC. These limits are likely to be expressed in terms of a protected field strength at the edge of the coverage area applicable to the assignment or allotment under consideration.

Increasing convergence between broadcast and telecommunications services has led to moves within the ITU to revisit traditional service definitions. A new service concept referred to as “Terrestrial Wireless Interactive Multimedia Services” (TWIMS) was discussed at the 2003 WRC and will be further considered in 2010, when it will be clearer how emerging markets such as DTT and 3G mobile are developing. The TWIMS concept and related issues are addressed further in Section 5.2.3.

3.7.3 Mobile Services

Market demand for mobile telephony services has grown to the extent where the penetration of such devices exceeds that of fixed line telephones in most EU Member States, although traffic levels per subscriber are generally much lower. It is conceivable that in the future mobile networks will increasingly compete with fixed line networks for voice traffic and that call tariffs and traffic profiles will converge. This could lead to pressure for further spectrum allocations to facilitate network expansion.

The UMTS Forum, which represents European 3G mobile operators and equipment suppliers, has recently reiterated that the long-term spectrum requirement for 3G mobile services beyond the already-available 2G and 3G spectrum would be of the order of 190 MHz[22]. Of this, 155 MHz is currently available in the 2.6 GHz band, which was identified at WRC-2000 as future expansion spectrum for IMT-2000 services, along with the band 806 – 880 MHz immediately below the current GSM 900 band. The latter includes the upper seven channels in the UHF TV broadcast band (Band V).

Discussion with mobile industry representatives has indicated that there is currently little or no demand in Europe for conventional two-way mobile services in the broadcast bands; this is also borne out by responses to recent consultations on the future use of the UHF and VHF broadcast bands conducted by the UK regulator. This situation may change in the longer term: we note for example that the UMTS Forum has suggested that harmonised spectrum in the UHF broadcast band could be attractive for extending 3G mobile services into remote areas[23]. This presents a significant technical challenge, since it would be necessary to define two fixed, contiguous blocks of spectrum to cater for uplink and downlink traffic. Agreement would need to be reached on the amount of spectrum required, the size of any guard bands to protect the adjacent mobile and broadcast services and the optimum location of the spectrum within the UHF bands. Reaching such agreements internationally would involve protracted negotiation and would also be contingent on the complete removal of analogue TV services, at least from the uplink frequencies, since these high power signals would interfere with reception of much lower power mobile transmissions.

The UHF band provides greater coverage than 2.6 GHz, but does not allow such intensive re-use of available frequencies. Interest among key stakeholders in the

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[22] "Frequency Spectrum for Mobile Services", Joseph Huber, ANRT & ETSI Conference, Casablanca, April 2003

[23] Document FM(04)99, input to ECC FM meeting on 26th – 30th April 2004.

mobile industry is currently focussed on the 2.6 GHz band. For example Nokia's response to a recent UK consultation stated a clear preference for spectrum above 2.5 GHz and that Nokia did not see a requirement for any refarmed analogue TV spectrum to be used for cellular systems, arguing that any refarmed spectrum should continue to be used for digital broadcast technologies[24].

Nevertheless, the interest recently expressed by the UMTS Forum suggests that there would be merit in considering further allocations to the mobile service below 860 MHz and it would seem appropriate to pursue this at the 2007 World Radio Conference if the objective is to cater for such services when analogue services cease. The potential refarming of broadcast spectrum should also be considered alongside the future refarming 2G mobile services to 3G, which is expected to take place once the latter have become fully established.

In the meantime, there is a growing consensus that any mobile or convergent services deployed in the UHF broadcast bands should use frequencies below 806 MHz, to avoid interference from GSM900 mobile transmissions which would require the addition of bulky and expensive additional filtering in terminal devices.

Should such demand arise in the longer term, it seems likely that this could be accommodated within the currently proposed planning framework. The possibility of spectrum sharing between DVB and mobile services has been explored as part of the CEPT preparations for RRC-04. For example, work by Ericsson has suggested that a CDMA network could be deployed in the current TV broadcast spectrum alongside DTT services and that it would be feasible to accommodate two CDMA carriers within a single 8 MHz TV channel[25].

3.8 Market Evolution and Convergence

3.8.1 Introduction

Convergence refers to the increasing deployment of multiple digital media such as broadcasting, telecommunications and information technology to deliver integrated multimedia content and services These may include textual, audio (speech or music) and/or video material. Radio spectrum in general and broadcasting spectrum in particular has considerable potential for the mobile delivery of convergent services and content. The market for mobile multimedia services is far from mature, but is showing signs of accelerating growth. For example, camera-

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[24] Nokia response to UK Government consultation on the use of the analogue TV spectrum, April 2002

[25] "Contribution on possible example sharing scenarios between upstream and downstream applications using CDMA schemes and public broadcasting video (DVB-T) applications and improving the total spectrum efficiency in the band 470 – 862 MHz", ECC Joint ad-hoc group between CPG/PT1 and FM WG, December 2002

enabled phones already outsell conventional digital cameras, despite having been introduced only two years ago[26].

The first 3G mobile services were launched recently, bringing mobile video services to the market for the first time. These services include one-to-one video telephony and access to video clips of premium content such as sports highlights or adult material. They do not currently provide any access to off-air broadcast material; however in Japan Vodafone will shortly be launching a phone that includes a built-in TV receiver.

A logical consequence of converging technologies is that broadcast and "one to one" audiovisual material could be received and viewed on the same device; indeed the characteristics of the two may be virtually identical in terms of bit rate, coding, etc. Depending on how the market for mobile multimedia evolves, in particular the balance between broadcast or streamed material and one to one communication, broadcast technologies could play a significant role in facilitating the economic delivery of such services.

3.8.2 Combining the Benefits of Broadcasting and Telecommunications

Broadcasting involves the simultaneous real-time transmission of content to multiple recipients, whereas telecommunications involves the flow of information between two or more specific parties, either by means of physical connections between those users or by routing packets of data though a distribution network such as the Internet. Broadcasting is highly efficient where a large number of users wish to access the same material at the same time, but is not best suited to delivering individual content on a large scale. It is also unsuitable for delivery of critical content such as data files where there is an appreciable risk of interruption to the transmission. Hence a broadcast medium is unlikely to be a viable substitute for a packet data network such as UMTS where data integrity is critical.

On the other hand, using a cellular data network to distribute live video material to a mass audience would require an enormous overhead in network infrastructure, since each individual recipient would be utilising network resources for the duration of the transmission. Hence there is an attraction in combining these two transmission technologies to enable delivery of content in the most appropriate manner.

The potential synergies between digital broadcasting and mobile technologies and services were highlighted by the UMTS Forum, which represents the major players in the mobile industry, in a recent presentation[27]. According to the Forum, UMTS

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[26] Strategy Analytics report "Camera Phones Outsell Digital Still Cameras in H1 2003 and Beyond", October 2003

[27] "Actual Situation of UMTS, presentation by Bosco Fernandes to CISMUNDUS final project workshop, February 2004.

and DVB will complement each other, DVB offering a useful multicast extension for UMTS and UMTS providing both a return path and an additional delivery path for DVB.

Another important factor which is likely to have a major impact on the quality and economic viability of mobile multimedia services is the capacity of storage media. In keeping with "Moore's Law[28]", the capacity of digital storage media has continued to double roughly every two years, while costs per megabyte have fallen at a similar rate. Combined with parallel developments in data compression, this means it is already possible to accommodate up to four hours of video material onto a storage device no larger than a postage stamp and costing no more than €100[29].

The prospect of low-cost mass storage may on the one hand largely negate the need to access on-line material whilst on the move (the material could be downloaded via a high-speed connection prior to departing), but could also make datacasting more attractive by enabling "live" material to be buffered locally so that any short breaks in transmission can be recovered and re-inserted by a conventional IP connection before the viewer becomes aware of the problem.

3.8.3 Potential overlap between 3G mobile and digital broadcast services

We have observed that broadcast technologies can provide a useful complement to existing mobile services, by providing a cost-effective platform for delivery of content to mobile terminals. However, technologies such as UMTS already include the capability to deliver "broadcast" content, including audiovisual material, to mobile phones. This blurring of the distinction between broadcasters and mobile networks strengthens the argument for treating new broadcast services in the same regulatory manner as other wireless content delivery platforms such as 3G mobile, particularly in relation to rights of use for radio spectrum.

3.8.4 Research Activities on converged services

There are a number of ongoing research programmes under the EU 5th Framework initiative addressing the potential for combining mobile and broadcast technologies to deliver converged multimedia services. One example of particular interest is the *CISMUNDUS* Project - Convergence of IP-based Services for Mobile Users and Networks in DVB-T and UMTS Systems.

The goal of the CISMUNDUS Project is to achieve co-operation between two complementary wireless access networks, namely a "point-to-point" mobile network (typically UMTS, but also GSM/GPRS) and a "point-to-multipoint" broadcast network (DVB-T or DAB). The ultimate goal is to ensure a seamless and wireless interactive connection to various multimedia converging services for people on the move.

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[28] "Cramming More Components Onto Integrated Circuits", Electronics, April 1965 (ftp://download.intel.com/research/silicon/moorespaper.pdf)

[29] Based on coding at 256 kbit/s and storage on a 512 MByte Smart Media storage card