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Working Party on Telecommunication and Information Services Policies

THE SPECTRUM DIVIDEND: SPECTRUM MANAGEMENT ISSUES

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FOREWORD

This report was presented to the Working Party on Communications Infrastrures and Services Policy in May 2006 and was declassified by the Committee for Information, Computer and Communications Policy in October 2006.

The report was prepared by Mr. Jaebum LEE of the OECD's Directorate for Science, Technology and Industry. It is published under the responsibility of the Secretary-General of the OECD."

TABLE OF CONTENTS

EXECUTIVE SUMMARY

After analogue TV signals are switched off with the shift to digital transmission ("analogue switch-off"), a significant amount of spectrum bandwidth is expected to be freed-up, potentially making it available for other applications rather than replicating the similar quality analogue TV programmes ("spectrum dividend"). This paper discusses spectrum management issues in relation to digitalisation of terrestrial television broadcasting ("digital switchover").

Taking into account spectrum scarcity, 120 countries in Europe, Africa and the Middle East agreed to use Digital Video Broadcasting-Terrestrial (DVB-T) and Terrestrial-Digital Audio Broadcasting (T-DAB) technologies in VHF frequency Band III (174-230 MHz) and DVB-T technology in the UHF frequency Band IV/V (470-862 MHz) at the ITU Regional Radiocommunications Conference in 2006 (Geneva-06 Plan). However, the actual use of channels is flexible in that some of the channels may be allocated to new services such as mobile TV, HDTV, datacasting, or other as yet unspecified services provided that the services only operate under the 'spectral mask' [1] of digital entries of the Geneva-06 Plan.

In countries where the digital switchover has come to be associated with the introduction of HDTV as a key differentiator for digital services, a single TV channel bandwidth is normally assigned to each existing analogue terrestrial TV broadcaster. In this case, a spectrum dividend is possible after the analogue switch-off by stacking digital TV channels more tightly, thereby occupying less spectrum to cover all existing analogue terrestrial TV stations.

For efficient and effective use of the spectrum dividend from the digital switchover, spectrum management authorities need to find an appropriate mix between spectrum management models.

- The traditional 'command-and-control' approach could be effective in achieving 'public interest' policies, such as those related to providing spectrum for public safety and homeland security, cultural diversity, pluralism of information, international agreements, and interference protection requirements. The command-and-control approach also could be effective in achieving harmonised spectrum use by providing customers and manufacturers with international interoperability (roaming) and economies of scale in the development of equipment and international services. However, it is noted that a market-based, property rights approach also may promote harmonisation when the resulting benefits are significant.
- Taking into account the expected competing demands to use the spectrum dividend and the uncertainty of technology development and convergence of services, it could be generally appropriate to apply a 'market-based property rights approach' (exclusive usage rights + tradability) coupled with flexible spectrum use (in broader terms), subject to public interest objectives such as cultural diversity and pluralism of information, international agreement, interference protection and efficient spectrum use. The market-based approach would induce technology innovation in the rapidly changing environment, but potentially less harmonised use of spectrum than the command-and-control model.[2]
- Application of a 'commons' model to the spectrum dividend can stimulate and drive technological innovation of spectrum-efficient radio technologies by lowering barriers to access to spectrum and reducing the time to market, however the spectrum management model may potentially lead to overuse (tragedy of commons) taking into account the expected competing demands and high value of the spectrum dividend.

- An 'easement' model can be a practical option to achieve efficient use of spectrum while co-existing with exclusive usage models ('command-and-control' and 'market-based property rights'), using spectrum-sharing technologies including cognitive radio. One example of the application of the 'easement' model is the proposed rules by the US regulator, FCC to allow unlicensed radio devices to operate in unused broadcast TV spectrum ('white spaces') on a secondary basis with primary use of the spectrum given to broadcast TV stations, except some channels. The unused TV channels in a given area[3], which exist to avoid interference between co-channel and/or adjacent channel stations, can be utilized with spectrum-sharing technologies in the form of, for example, unlicensed radio devices with built-in cognitive radio capability. However, such a model should be carefully designed taking into account the extent of harmful interference which spectrum-sharing devices may make against existing and future primary use of a frequency band.

Where a decision has been made to have a mandatory switch-off date, the use of "overlay licensing" whereby new licensees share spectrum with existing analogue TV channels during a transition period (ensuring no harmful interference) can be an effective tool to relocate analogue TV operators to designated digital TV bands.

I. INTRODUCTION AND SCOPE

Digital transmission enables more efficient use of spectrum than analogue transmission. After analogue TV signals are switched off with the shift to digital transmission ("analogue switch-off"), a significant amount of spectrum bandwidth is expected to be freed-up, making it available potentially for other applications than replicating the same analogue TV programs ("spectrum dividend"). This paper discusses spectrum management issues in relation to digitalization of terrestrial television broadcasting (digital switchover). First, it discusses the issue of how to determine the size of the spectrum dividend after digital TV switchover; it then addresses the issue of future use of the released spectrum resources including demand assessment and application of appropriate spectrum management models. Finally, the question of how to facilitate relocation of incumbent analogue television broadcasters to release spectrum dividend is discussed.[4]

This paper deals with spectrum issues in relation to terrestrial television broadcasting. It does not cover issues dealing with radio, cable TV, satellite TV. However, issues raised in the paper may apply to radio broadcasting since digital technology does not differentiate between video or sound signals and terrestrial sound broadcasting can be incorporated into a TV channel[5]. Digital transmission of Cable TV does not involve major over-the-air spectrum issues[6] while satellite TV broadcasting in many cases started in a digital transmission and due to its relative high frequencies compared with terrestrial TV broadcast, does not appear to have pressing demands.

Spectrum dividend can be used for the provision of enhanced TV services including high definition TV (HDTV[7]), more standard definition TV (SDTV) channels or portable/mobile reception[8] of TV program or some advanced wireless communications services such as 3G mobile telephony and wireless broadband Internet access or public safety and homeland security.

This spectrum dividend stems both from the elimination of the analogue portion of the transitional analogue-digital broadcasting simulcast regime, and from digital technologies. Digital encoding and compression technologies make digital signals more resilient to interference, and digital receivers finely distinguish between adjacent frequencies. These digital technologies allow digital TV channels to be squeezed more tightly into fewer channels.

Furthermore, digital multiplexing (de-multiplexing) technology enables one TV channel, with the same frequency bandwidth per channel with analogue TV, to broadcast several sub-channels of programming or data services by allowing for a combination of several audio/video/data channels into one coherent bit stream on a single TV channel and then, at the other end, to split its bit stream into several individual channels of programming or data services. (For example, on channel 7, you could watch 7-1, 7-2, 7-3 or 7-4).

The terrestrial TV frequency bands such as VHF and UHF[9] frequencies can travel longer distance, thus, cover broader area with fewer transmitting towers, and more likely to penetrate obstacles, such as cement walls, than higher frequency-based systems such as cellular mobile phones but the terrestrial TV bands can carry less data than higher frequencies[10]. The propagation characteristic of this frequency can be best achieved when greater area is covered with high signal power. If signal power is lowered in a two way communications setting to accommodate more customers, the relatively long wave of TV bands may cause more harmful interference than higher bands.

II. SIZE OF SPECTRUM DIVIDEND

1. Calculation of spectrum dividend

The size of spectrum dividend depends on various factors including the number of programme channels involved, the extent of coverage area, the required picture quality (whether HDTV broadcast is planned), the reception mode (fixed rooftop reception or portable/mobile reception), the type of frequency network (in case of DVB-T standard; multiple frequency network or single frequency network[11]), and the degree of cross-border co-ordination required. It also depends on the degree of public interest obligations and general interest objectives that are required in broadcasting, such as must-carry or national coverage requirements, since the size of the spectrum dividend can be a question about how much spectrum bandwidth must be allocated to traditional terrestrial TV broadcasting (*i.e.* one-way over-the-air point-to-multipoint fixed transmission of TV programmes) without having the possibility to make this available for the other uses. Decision on the size of frequency bands for public terrestrial broadcasting may need to reconsider existing policy frameworks in light of today's multi-platform broadcast environment where most national citizens may be reached by broadcasting platforms other than terrestrial TV.

The size of spectrum dividend is calculated in terms of technical perspective on a theoretical and practical basis. The degree of technical efficiency differs according to the digital TV standard adopted. In Europe and Australia, DVB-T (Digital Video Broadcasting-terrestrial) was adopted as a standard of digital terrestrial TV. ATSC (Advanced Television Systems Committee) is a standard in North America and Korea. ISDB-T (Integrated Services Digital Broadcasting-Terrestrial) is used in Japan. Most other countries have yet to decide on the standard they wish to adopt. ISDB-T is similar to DVB-T and can share front-end receiver and demodulator components. The DVB-T standard uses 7 or 8 MHz frequency bandwidth per channel and the modulation method is COFDM with either 64 or 16 state Quadrature Amplitude Modulation (QAM). The amount of data that can be transmitted (and therefore the number of channels) is directly affected by the modulation method of the channel. In general a 64QAM channel is capable of transmitting a greater bit-rate, but is more susceptible to interference. The ATSC standard uses 6 MHz frequency bandwidth per channel and calls for 8 VSB (Vestigal SideBand) modulation.[12]

In the context where DVB-T standard is adopted and high definition television (HDTV) is not sought, there is a theoretical study[13] to quantify the potential spectrum dividend. According to the study, in the analogue scenario, an analogue TV programme occupies one 8-MHz channel and consumes nine channels to have national coverage to avoid interference between broadcasting areas (one programme with national coverage needs 9 TV channels; 9x8MHz = 72MHz). There are the 49 channels of the UHF band (470-862MHz; 49x8=392MHz) thus, theoretically 5.4 programmes (5 in practice) at national level can be allowed (49/9=5.4). If analogue TV broadcasting is switched to digital transmission, one multiplex broadcast station can cover up to six analogue programme channels via its single 8-MHz channel based on current coding schemes. Therefore, in the simplest case, if these same five analogue programmes were broadcast digitally, they would fit on a single multiplex station. One multiplex would need six 8-MHz channels (48 MHz) for nationwide transmission with MFN frequency planning. Therefore the possible vacated spectrum after analogue switch-off would be 344 MHz (=392MHz-48MHz; digital transmission is about eight times more efficient than analogue in spectrum use). The size of cleared spectrum would vary according to certain assumptions as in the below table.

Table 1

Case	Assumptions* (64QAM modulation, 95% reception in the zone)	No. of 8MHz channels necessary for nationwide transmission of a multiplex	Amount of spectrum dividend in the EU UHF band (392MHz) (unit: MHz)
1	MFN with fixed rooftop reception, Transmitting antenna height: 300 m	6 (48MHz=6x8MHz)	344 (=392-48)
2	MFN with indoor reception antenna, Transmitting antenna height: 150 m	15 (120MHz=15x8)**	272 (=392-120)
3	SFN with fixed rooftop reception, Transmitting antenna height: 300 m	3 (24MHz=3x8)	368 (=392-24)
4	SFN with indoor reception antenna, Transmitting antenna height: 300 m	4 (32MHz=4x8)	360 (=392-32)

* mobile reception assumption is not dealt with.

** In this case, 3.2 multiplexes are possible (=392/120). Thus, the number of multiplex that can be used at simulcast period is limited to 3.

Source: adapted from BIPE Consulting Study for the European Commission; refer to endnote 4.

However, in practice, spectrum management authorities which adopt the DVB-T standard assign frequencies for terrestrial digital TV (*i.e.* set the number of multiplex) to accommodate the existing number of analogue TV channels as well as the new digital broadcasting services. If digital terrestrial TV merely replicates existing analogue TV channels, customers would not be willing to purchase digital TV reception device (and antenna, if necessary). It means that the spectrum authorities are already using the whole (or some portion of) spectrum dividend for enhanced digital broadcasting offerings, which may include SDTV, HDTV, mobile TV, interactive data services.

For example, in the United Kingdom, 6 multiplexes were assigned to enable over 50 primarily free-to-air TV channels including the existing 5 national analogue TV channels (BBC1, BBC2, ITV, Channel 4 and five) and over 20 radio channels and over 10 text/interactive services.[14] In France, even though there are 6 existing analogue terrestrial TV channels, 29 national digital terrestrial TV channels were or will be licensed (of which 23 channels were licensed) to compose 6 multiplexes,[15] and new services are foreseen to be added, in particular high definition TV services.

In European countries, the planning of the UHF and VHF bands for digital television and radio services, results from the second session of the ITU Regional Radiocommunications Conference (Geneva-06 Plan).[16] Due to spectrum scarcity, 120 countries in Europe, Africa and the Middle East agreed to transmit Digital Video Broadcasting-Terrestrial (DVB-T) and Terrestrial-Digital Audio Broadcasting (T-DAB[17]) technologies in VHF frequency Band III (174-230 MHz) and DVB-T technology in UHF frequency Band IV/V(470-862 MHz).

The actual use of channels allocated to DVB-T services is flexible in that some of the channels may be allocated to additional TV channels, whereas others may be allocated to new broadcast services such as mobile TV, datacasting or even interactive datacasting[18] provided that the services are compatible to DVB-T standards. The mobile TV standard, DVB-H, can be transmitted using much of the same infrastructure and frequency plans as DVB-T and thus, can be used within DVB-T multiplex transmissions. If necessary, DVB-T multiplex can be operated as a dedicated DVB-H multiplex. Further, DVB-T multiplex can be used to provide interactive data services with return path[19] using different networks. New services using standards such as T-DAB, DVB-T, DVB-H, DMB (Digital Multimedia Broadcasting) or other as yet unknown standards can be accommodated under the Geneva-06 Plan provided that they operate only under the envelope of a digital entry of the Geneva-06 Plan and that the other alternative uses demand no greater protection than would be given to receivers of primary use.[20]

In the United Kingdom, for example, the regulator Ofcom estimated up to 112 MHz of spectrum dividend in the UHF Band for new uses additional to the 6 DTT multiplexes already provided for. In the UK, the spectrum bandwidth for analogue terrestrial TV channels in the UHF band is 368 MHz (46 8-MHz channels) ranging from channel 21 to 68 (470-854 MHz) except channel 36 (for radar use) and 38 (for radar astronomy). The assigned 6 multiplexes need 32 8-MHz channels (256 MHz) to meet specified broadcasting coverage with certain technical parameters.[21] Therefore, up to 112 MHz of spectrum in the UHF band can be released (112 MHz = 368 – 256).

In countries where ATSC (Advanced Television Systems Committee) standard for digital terrestrial TV is adopted, digital TV switchover may be closely tied to the introduction of HDTV as a key differentiator for digital services. One TV channel (6 MHz) may be occupied by one HDTV programme and ancillary interactive data services based on current digital compression technology. Where this is the case, one TV channel is normally assigned to each existing analogue terrestrial TV broadcaster. In this case, spectrum dividend after switch-off is made possible by stacking digital TV channels more tightly, thereby occupying fewer TV channels to cover all existing analogue terrestrial TV stations.

In the United States, where HDTV has been promoted by broadcasters in SDTV broadcasting as a key selling point for digital TV, the FCC estimated the amount of freed spectrum as 108 MHz (channel 52 - 69; 698 – 806 MHz). In the United States 456 MHz of spectrum[22] in the VHF and UHF bands is allocated for analogue (NTSC) terrestrial television stations (channel 2 – 69 except channel 37).[23] The regulator, FCC, made spectrum planning to move digital terrestrial TV stations to channels2 and 51 (270 MHz) except channel 37 (used for radio astronomy and medical telemetry service).

ISDB-T standard can be flexibly applicable to all 6, 7 and 8 MHz channel bandwidth systems. In Japan, The MIC (Ministry of Internal Affairs and Communications) estimated 118 MHz of freed spectrum after analogue switchover (90-108 MHz, 170-222 MHz, 722-770 MHz). In Japan, 370 MHz of spectrum in the VHF and UHF bands is allocated for analogue terrestrial television stations. The MIC in Japan designated the 240 MHz spectrum band (470-710 MHz) for digital terrestrial TV use and is currently reviewing whether to use additional 12 MHz bandwidth (710-722 MHz) for digital TV.

2. Unused cannels in the trrestrial TV spectrum

Apart from the spectrum dividend which will be released after analogue switchover, some OECD countries recognisd that there would be a number of unused analogue and digital TV channels, in a given geographical area, during and after digital switchover. This is because such terrestrial TV stations will not be able to operate without causing interference to co-channel or adjacent channel stations. For example, in the United States, the rules for new digital TV allotments require minimum distance separations ranging from 196.3 to 273.6 kilometers for co-channel stations, and separations of 110 kilometers for adjacent channel stations. These minimum distances between stations were determined based on the assumption that the stations will operate at maximum power. Thus, low power transmitters, for example, could potentially operate on vacant channels that could not be used by high power TV stations due to interference concerns, provided such operations did not cause harmful interference to the TV service and did not negatively impact or slow down the transition from analogue to digital television.[24] In the case of analogue TV stations in the United States, the sensitivity of the NTSC broadcast system to interference allows the use of only 102 MHz of spectrum at any given location in the 456 MHz of broadcast TV spectrum in the VHF and UHF bands.[25]

The UK regulator, Ofcom, in the same context noted in its Digital Dividend Review that there would be some unused spectrum where a frequency used by a transmitter in one part of the country is effectively unoccupied outside the range of that transmitter in another part of the country (known as ‘interleaved spectrum’) and that, of the 32 channels which will be used for digital terrestrial TV, only 6 channels will be

used at any one site. The Ofcom estimated that around 208 MHz of interleaved spectrum might become available.[26] In order to utilise these unused/underused TV channels, most member countries allow the use of broadcasting ancillary systems, such as wireless microphones, to use the spectrum of these TV channels.

III. FUTURE USE OF SPECTRUM DIVIDEND

1. Possible current demands

The possible demands for spectrum would include enhanced terrestrial TV services such as HDTV or an increased number of SDTV programmes, and/or converged mobile broadcasting services such as mobile TV and datacasting, and/or non-broadcasting services such as 3G mobile services, fixed wireless services (broadband Internet access via WiFi, WiMAX, etc.), and public safety and homeland security.[27] It is noted that the enhanced terrestrial TV services are logically necessary to give consumers sufficient incentives to change their analogue TV set to digital TV.

Current frequency allocations by OECD countries are based on international agreement at the ITU. In the same sense, the allocation of spectrum dividend is also expected to be based on ITU frequency allocation tables while it is noted that the service classifications of ITU may require revisions in consideration of convergence between services such as between broadcasting and telecommunication services or fixed and mobile services.

According to the current ITU frequency allocation, most of the spectrum bands used for analogue TV are allocated to 'broadcasting'[28] service only or on a primary basis with some other uses on a secondary basis. For example, in ITU Region I, including European countries according to ITU frequency allocation table, the 174 – 223 MHz and 470 – 790 MHz bands are allocated to broadcasting use only, which may reflect a severe level of spectrum scarcity for broadcasting in the region mainly due to many neighbouring countries. The 223 – 230 MHz bands in the region are allocated to broadcasting service on a primary basis with fixed[29] and mobile[30] services on a secondary basis.[31] In Region II, the ITU allocation includes co-primary allocations for fixed, mobile and broadcasting services in the 806-890 MHz band.

Under the high level of spectrum scarcity for broadcasting services and subject to the current ITU allocation status, European countries have planned UHF Band IV/V solely to DVB-T standard (fixed roof top reception, portable outdoor and indoor reception), and VHF Band III to a shared use of DVB-T (portable outdoor) and T-DAB standards (portable indoor reception) in the second session of RRC in May and June 2006 (RRC-06). With this decision, European countries, where appropriate, would accommodate new broadcasting services such as mobile TV (DVB-H or DMB) and interactive datacasting via introduction of a spectral mask concept provided that the new services can operate under the envelope of a digital Plan entry. It means that, in Europe, spectrum dividend coming from digital switchover may be less likely to be used for non-broadcast services such as 3G mobile services. However, it is certainly possible for countries which have signed up to the spectral mask concept to allow non-broadcast uses in these bands. These bands will also be reviewed by the next World Radiocommunications Conference in 2007 (WRC-07) under an agenda item relating to identification of new spectrum for improving IMT-2000 coverage.

Where it is possible to re-farm[32] TV frequencies in order to release more usable contiguous spectrum slots by relocating existing TV broadcasters into contiguous TV-only bands, it may be more likely for the spectrum dividend from the digital switchover to be used for non-broadcast services. Several countries such as the United States and Japan have planned a reallocation of this kind, releasing a contiguous sub-band which can be used for innovative services including non-broadcast services. The European Commission, through the Radio Spectrum Policy Group, an advisory group to the Commission, and some

EU Member States are examining the possibility and the opportunity to identify a harmonised sub-band for innovative services. They are considering allocation of certain UHF bands to mobile service on a primary basis at the World Radiocommunications Conference in 2007 (WRC-2007) in order to align Europe with other regions, to allow full flexibility offered by the RRC-06 agreement, and to pave the way for the identification of a harmonised sub band at WRC-2010.

In Japan, commercial mobile TV began in April 2006 using one segment out of a total of 13 segments in each of Japan's terrestrial digital channels. The segmentation of a TV channel is made possible by ISDB-T standard. In Korea, mobile TV started on a commercial basis using Terrestrial-Digital Multimedia Broadcasting (T-DMB) technology in December 2005. The mobile TV service in Korea is using unused TV channels (channel 8 and 12 in metropolitan areas). In the United States, MediaFLO™ USA Inc., a subsidiary of QUALCOMM, plans to deploy and operate a nationwide "mediacast" network in the 700 MHz (UHF channel 55) to deliver multimedia interactive content to wireless mobile devices in conjunction with CDMA2000 1x, 1xEV-DO and WCDMA cellular networks of its partnering cellular operators. QUALCOMM acquired the frequency bandwidth in the June 2003 FCC Auction No.49, and the remainder in October via a transaction with the original licensee.[33]

In Europe, many countries started mobile (hand-held portable) TV pilot trials in 2005, including the United Kingdom, France, Germany, The Netherlands, Spain, Finland, and Italy using two standards of DVB-H and T-DMB in various frequency bands including terrestrial TV bands. The European Commission is considering the potential for harmonized frequency bands across Europe for mobile TV to get started until early 2007 and, if further bandwidth is necessary in the medium term, as mobile TV takes off, to consider further harmonised use for services such as mobile TV in the spectrum dividend.[34]

The spectrum dividend from digital switchover could be made available for use by wireless broadband Internet access technologies such as Wi-Fi, WiMAX, mobile Fi, ZigBee, IMT-2000 and beyond, etc. TV broadcast frequencies can be suitable for deploying wireless broadband Internet technologies in rural areas where the smaller number of users could be covered by fewer transmitters and improving coverage of cellular (3G) networks. If the wireless broadband Internet access devices are used between short distances with low power (as is now), Internet access by the devices may be allowed in unused TV channels on a secondary basis with primary use of TV broadcasts[35].

The freed spectrum can also be used for other important services such as public and safety services (police and fire departments, emergency rescue) as in the case of the United States. In the United States, channels 63-64 (12 MHz) and 68-69 (12MHz) were allocated for Public Safety out of 108 MHz of freed spectrum (channels 52-69 (698-806 MHz)).

In the United States, the FCC proposed rules in May 2004 to allow unlicensed radio devices such as Wi-Fi to operate in unused broadcast TV spectrum.[36] The proposal envisioned that low-power unlicensed devices could operate successfully in vacant TV bands without causing harmful interference to authorised services as long as they incorporate means to ensure that they operate only on vacant channels and comply with appropriate operating frequency and power limits.[37] [38]

2. Future demands

To predict future demands of the spectrum dividend is difficult given the rapid development and often unforeseen development of digital technologies. In addition, digital technologies have led to competition between wireless services in various spectrum bands, which has also meant forecasting future services in certain bands is not always feasible.

Due to the uncertainty of radio technologies and convergence of wireless services, it may be more future-proof to allocate the spectrum dividend to flexible uses. In the United States, the FCC designated the spectrum in the 698-806 MHz Band (comprising the spectrum dividend) for new fixed, mobile, and other services. This spectrum will be auctioned no later than January, 2008. Certain portions of the 698-806 MHz Band will be assigned for public safety use, but most of the band will be assigned for commercial and other new operations. The FCC also has designated other spectrum bands for new fixed, mobile, and other advanced services. The FCC refers to these as "advanced wireless services," which include the 1710-1755 MHz, 2110-2155 MHz, 1915-1920 MHz, 1995-2000 MHz, 2020-2025 MHz, and 2155-2180 MHz bands. In Europe, the radio spectrum policy experts from the European Union Member States agreed on an ambitious initiative called Wireless Access Policy for Electronic Communications Services (WAPECS) in November 2005[39] which called for action across Europe to allow more flexible use of spectrum for mobile, broadcasting, fixed wireless and other electronic communications services.

IV. SPECTRUM MANAGEMENT MODELS FOR SPECTRUM DIVIDEND

1. Strength and weakness of spectrum management approaches

The "Command-and Control" Model

In many countries, the "command-and-control" spectrum management model has been used where government including regulators plans and manages spectrum by designating appropriate uses, technologies and users. This model is useful in pursuing general interest objectives at the national or international level in such areas such as broadcasting, defence, security or astronomy, etc. Under the traditional command-and-control approach, appropriate incentives are necessary to ensure that licensees return unused spectrum or replace old technologies by new solutions requiring less spectrum.

Proponents who support a market-based approach argue that with the command-and-control approach spectrum is often occupied by older, less efficient technologies while new technologies can only get access to higher frequencies with limited propagation and higher roll-out costs[40] and that this has economic and societal costs as well as slowing down new innovation and the development of new services.

The command-and-control model may also be the most effective spectrum management tool when (international) harmonization of spectrum use is necessary, while avoiding fragmentation in terms of technical standards so as to provide customers and manufacturers with interoperability (roaming) and economies of scale in the development of equipment and international services.

The "Market-based Property Rights" Model

Another alternative spectrum management model is "market-based property rights," which can enable government administrations to manage spectrum efficiently and effectively in an environment of rapid technology development and converging services. Under the market-based property rights model, users have exclusive rights to use spectrum plus rights to trade spectrum in secondary markets. This model allows individual licensees to get exclusive rights to use spectrum for a predetermined type or family of services initially via administrative (comparative selection) or market mechanisms (auction) and then to trade the spectrum rights in secondary markets. The tradability can be maximised if coupled with policies allowing flexible usage of spectrum, allowing users to decide the best use and technical standards of spectrum subject to international agreements and certain requirements such as interference and public interest. There are a wide range of options in the context of spectrum trading policies. Spectrum trading may be restricted to the lease or sale of certain types of whole licenses with no other changes permitted, or greater freedom may be allowed, such as reconfiguring licences (sub-dividing and aggregating by geography or frequency), short or long-term leasing or sharing of some of the licence rights, and even changing use or technical standards to several degrees. Spectrum trading coupled with flexible spectrum use may allow licensees themselves to evaluate the opportunity cost of spectrum, creates financial incentives to utilise their spectrum efficiently, and may result in unused spectrum being released onto the market.[41]

The main argument for a market-based property rights approach is that it creates incentives for those with spectrum usage rights to apply their spectrum to the highest valued uses as demanded in the market. That is this approach would grant flexibility to apply spectrum in response to changing market demands,

and it also would grant tradability, such that those with rights could sell them to others, in the event these other parties were better positioned to meet market demands. Concerns about the market-based property rights model relate to the risk of decreased government capacity to pursue and preserve social objectives, and potential increased interference, the potential for anti-competitive conduct, higher transaction costs in assembling spectrum bands for contiguous geographical areas, reduced benefits from international harmonisation and standardisation[42]. The presence of such concerns makes it understandable if countries decide to introduce spectrum trading through a phased stage-by-stage approach, and underlines the continuing need for a wide range of regulatory tasks to establish and sustain well-functioning secondary markets for spectrum.[43] However, the command-and-control model may be the most effective spectrum management tool to promote public interest objectives at the national or international level in such areas as broadcasting, defence, or astronomy. In addition, the command-and-control model may be the most effective approach to promote harmonisation of spectrum, though the market-based, property rights approach also may promote harmonisation when the resulting benefits are significant.

It has been argued that the market-based property rights approach is particularly appropriate in bands where scarcity is relatively high and the transaction costs associated with market-based negotiation of access rights are relatively low. Where spectrum is scarce but transaction costs are high, the approach may still be the most appropriate, since wherever scarcity exists, there will be competing claims to this resource.[44] However, where there are high transaction costs and competing claims to scarce resources, it may not be possible using a market-based approach to obtain the necessary assembly of spectrum bands for the most profitable usage.

In the United States, the regulator, FCC, has authority to allocate electromagnetic spectrum so as to provide flexibility of use, if such use is consistent with international agreements and if the FCC finds that such an allocation would be in the public interest and such use would not deter investment in communications services and systems, or technology development, and would not result in harmful interference among users[45].

In line with this authority, when the FCC adopted rules in January 2000 for licensing and operation in the portion of 700 MHz bands that have been reallocated from their previous use solely for the broadcasting service, the FCC opened the bands to a variety of wireless services including terrestrial fixed and mobile wireless services and new broadcast-type services provided that those services complied with prescribed technical rules to protect from interference both analogue and digital TV operations currently operating on the same frequency bands.[46]

The European Commission proposed that an EU-wide political agreement should try to establish functioning spectrum markets by 2010, with substantial parts of the spectrum (including one third of the spectrum below 3 GHz) tradable and subject to flexible use.[47] The EC has proposed the creation of markets for frequencies currently used for the purposes of terrestrial TV and radio broadcast services (local, regional and national broadcasting), terrestrial mobile communication services (such as GSM, 3G), and terrestrial fixed wireless communication services (such as Wireless Local Loop, Broadband Wireless Access and microwave links). As for the risk of anti-competitive hoarding, the EC envisages making substantial parts of bands available tradable to minimise the risk of hoarding of spectrum, as operators would not have the resources or the incentive to establish a dominant position. The EC considers that competition law provides in principle adequate and sufficient remedies to the extent that competition problems would arise. The EC proposal would not include, as part of spectrum trading, the frequencies used for public interest purposes such as defence and scientific services, or managed at the global level such as aviation and satellites. It is noted, however, that some EU countries have expressed strong concerns about such a new spectrum management approach and the proposal will be discussed in the next few years in the process of the review of the electronic communications regulatory frameworks.

As of 1 December 2005, twelve EU Member States have adopted legal provisions in their national law to enable spectrum trading in certain bands. However, for the time being, spectrum trading has not become a common practice in any of the Member States.[48]

The radio spectrum policy experts from the European Union Member States agreed on an ambitious initiative called Wireless Access Policy for Electronic Communications Services (WAPECS) in November 2005 which called for action across Europe to allow more flexible use of spectrum for mobile, broadcasting, fixed wireless and other electronic communications service. WAPECS is a framework for the provision of electronic communications services within a set of frequency bands to be identified and agreed between European Union Member States in which a range of electronic communications networks and electronic communications services may be offered on a technology and service neutral basis, provided that certain technical requirements to avoid interference are met, to ensure the effective and efficient use of the spectrum, and the authorization conditions do not distort competition.[49] Therefore, different networks can provide mobile, portable, or fixed access services under one or more frequency allocations (mobile, broadcasting, fixed) deployed via terrestrial and/or satellite platforms using a variety of technologies to seamlessly deliver these services to users. Noting that WAPECS could apply to both licensed and unlicensed frequency bands, the spectrum experts group identified three bands as suitable bands for WAPECS in the broadcasting bands (*i.e.* 174-230 MHz, 470-862 MHz, 1452-1479.5 MHz).[50]

In this EU context, the UK regulator, Ofcom, published a consultation document on the award of wireless telegraphy licences in the 1.5 GHz band (1452-1492 MHz, also known as the 'L-Band') in March 2006.[51] In the document, the Ofcom proposed its intention that the licensee obligations would not specify either the technology to be used or the services that may be offered and that the licences will contain the minimum necessary technical conditions to ensure compliance with international agreements, effective use of the licensed frequencies, controlling interference between different licensed services.[52]

The "Commons" model

Spectrum management authorities have witnessed that the "commons" approach to spectrum has helped facilitate recent technological innovations. In a spectrum commons model, spectrum is available to all users who comply with established technical limits (*i.e.* power limits) and equipment certification requirements to mitigate potential harmful interference. Usage rights are flexible and in general only limited by the technical rules.

The commons model, by lowering barriers to access to spectrum and reducing the time to market, stimulated and drove technological innovation of spectrum-efficient radio technologies including Ultra Wideband (UWB), smart radios and antennas, software-defined radios, cognitive radios, and mesh, *ad hoc* or viral networks[53]. These technologies enable users to help eliminate interference to other legitimate users even when transmitting at the same time, in the same place, and on the same parts of the spectrum. However, the commons approach can potentially lead to overuse of spectrum which could result in excessive interference ("the tragedy of the commons") which can make relevant spectrum bands much less useful for communications. In this regard, the commons model is most suitable in bands where scarcity is low and the transaction costs related with market mechanisms are high.[54] When the level of spectrum demand is low, the risk of spectrum overuse would be less likely.

The "Easement" model

Smart spectrum-sharing technologies which have emerged from a spectrum commons approach have enabled unlicensed devices with built-in smart technologies to use the same spectrum bands at a given area with licensed users who hold exclusive rights to use spectrum. This "easement" model is already in place in several countries where the new technologies are permitted to operate in specified frequency bands on a

secondary basis in which primary exclusive-use licensees are in use. The easement model, a mix between "market-based property rights" and "commons" models, would be inappropriate when the relevant spectrum bands are in intensive use due to high risk of overuse and its subsequent increased harmful interference.

Recent smart-technology transmitter approvals

In the United States, the FCC has approved several Software Defined Radios (SDRs) which use software to make intelligent and smart radios which can be updated to use the available spectrum. Recent grants have been issued to Vanu Inc. for the first SDR cellular base stations that can support multiple modulations, to Cisco Systems Inc. for a flexible Wi-Fi router that can be updated to support cognitive techniques for dynamic frequency selection, and to Meteor Communications Corp. for a flexible network radio that can adapt its behaviour depending on its operations mode. The FCC also certified Adapt4's XG1™, a data communications cognitive radio device. The XG1™ operates in the 217-220 MHz range under a nationwide FCC secondary user license. According to Adapt4, the cognitive radios use patented technology in which the radio may use up to 45 radio channels simultaneously, each of which can instantly change without human intervention to avoid interference. The cognitive radio identifies unused bandwidth and creates a selection of channels available for use by the XG1 network. When any XG1 adaptive radio in the network recognises the presence of another licensed user (*i.e.* primary user) within the specified band, that frequency is immediately removed from the selection of available channels until the network again determines that it is not being used. The XG1 continually monitors User ID/Password, Authorized Site Lists, and unalterable Electronic Serial Numbers to maximise security. (source: www.adapt4.com)

2. One size does not fit all

The discussions and experiences on spectrum management models for more efficient use of spectrum show that "one size does not fit all." Spectrum management authorities need to find the most appropriate model or mix between models in various frequency bands and technological environment, to achieve differing policy objectives.

The traditional "command-and-control" model may be effective for (internationally) harmonised spectrum use in order to provide customers and manufacturers with interoperability (roaming) and mass market (economy of scale), or for ensuring public interests. It is noted that the "market-based property rights" approach may also result in some level of market–led harmonisation, to the extent that the benefits from harmonisation are expected to be significant (and thus worth pursuing in the market). However, the government-administered method may not work when technology develops and converges rapidly in unexpected directions. In this environment, the "market-based property rights" model (exclusive usage rights + tradability) plus flexible spectrum use or "common" model can be more effective and sustainable alternatives. The "market-based property rights" model may be effective when spectrum scarcity is high and the transaction costs associated with market-based negotiation of access rights are relatively low. The "commons" and "easement" model (spectrum sharing model) may be most effective when spectrum is not congested so that the risk of overuse can be minimal.

3. Appropriate spectrum management of the spectrum dividend

The most valuable spectrum has already been allocated to particular services and assigned to individual users especially below 3 GHz[55]. Terrestrial television spectrum bands were, in many cases, assigned without paying market clearing price or opportunity costs for spectrum usage in consideration of public interest obligations of terrestrial TV broadcasting. Due to strong social and cultural implications of terrestrial TV broadcasting, spectrum management authorities have not usually allowed trading of TV frequencies nor spectrum sharing with other uses, even though terrestrial TV spectrum is considered as prime spectrum bands ("beach-front" location) with its superior propagation characteristics.

The expected release of a substantial part of these broadcast bands after digital TV switchover, therefore, gives spectrum management authorities a valuable opportunity to apply the lessons from studies and discussions on spectrum management models for efficient and effective use of spectrum.

It is not expected that countries that want to move forward quickly to take advantage of the digital dividend will hold back in order to have greater international co-ordination in this area. National spectrum planning in a country reflects not only technical and economic efficiency considerations, but also national or regional growth strategies including industry promotion[56]- and the latter are expected to take precedence in the decision making of countries.

It is expected that many spectrum management authorities would apply the command-and-control approach to some of the spectrum dividend in order to achieve harmonised spectrum use for some of the current identified spectrum demands such as enhanced TV offerings (*i.e.* mobile TV, HDTV, datacasting), any of the ITU-identified 3G and systems beyond, or public safety and homeland security, thereby designating common technologies in specified bands, to achieve policy objectives of interoperability between terminal equipments. Technical efficiency of the spectrum is optimised when the same systems with common performance and planning parameters (such as channel bandwidth) share the same band and the same geography (including across national boundaries). The European Commission, through the Radio Spectrum Policy Group, an advisory group to the Commission, and some EU Member States are examining the possibility and the opportunity to identify a harmonised sub-band dedicated to new services.

A market-based property rights approach, coupled with flexible spectrum use for the spectrum dividend, may be the most efficient in accommodating the expected competing demands for the spectrum dividend and the uncertainty of technology development and convergence of services, subject to public interest objectives, international agreements, interference protection requirements, and efficient spectrum use. The approach can also facilitate more technology innovation by allowing more flexibility in spectrum use. However it could lead to potentially less harmonised use than the command-and-control model.[57]

Tradability without change of spectrum use can be introduced to the whole of spectrum dividend in the form of spectrum leasing or trade of ownership of right to use spectrum. The eligibility of users can be guaranteed with government authorisation to the extent necessary.

Spectrum trading may be activated when coupled with flexible use. However, there is a concern that if flexible use is applied to analogue TV spectrum, non-profit use of the spectrum (such as citizen-related public service broadcasting or broadcasting services contributing to general interest objectives) would be 'crowded-out' by market-based competition processes.[58] To address this concern, the flexible spectrum use approach may not need to be applied to public service broadcasting channels fulfilling general interest objectives so that the channels continue to be used for public service broadcast purpose. The question of how much spectrum should be set aside for public interest objectives such as media pluralism and cultural diversity, and thus should not be subject to flexible spectrum use, may require reconsideration of today's multi-platform broadcast environment where public service programs can be broadcast over various kinds of broadcast platforms to most national citizens if appropriate public funding can be provided to the broadcaster(s) who deliver the public service programmes.

Spectrum dividend will be subject to ITU allocation of spectrum uses. Where the ITU allocation of analogue terrestrial TV bands applies only, or mainly, to "broadcasting,"[59] the spectrum dividend from the TV bands would be limited to broadcasting purpose, which may include mobile TV and interative datacasting services.[60]

Even when a market-based flexible spectrum management approach is used in the context of the spectrum dividend there will still be a requirement to ensure that there is protection against interference,. In

other words, the use of spectrum will be subject to limits according to the degree of interference so if a certain use is deemed to put excessive restraints on other legitimate uses, the particular spectrum use may be restricted for efficient spectrum use. When the FCC adopted rules in January 2000 for licensing and operation in the portion of 700 MHz bands, the FCC did not allow conventional television to be used in these bands. The FCC found that, after all existing TV stations had been relocated into digital terrestrial TV-only bands, if new conventional TV stations started operation in the cleared bands, they would create too much interference on other wireless uses, resulting in inefficient spectrum use by other wireless services.[61]

While application of 'commons' model may lead to overuse (tragedy of commons) taking into account the expected competing demands and high value of the spectrum dividend from digital switchover, the 'easement' model can be a practical option to achieve efficient use of spectrum while co-existing with exclusive usage models ('command-and-control' and 'market-based property rights'), using spectrum-sharing technologies including cognitive radio. Unlicensed devices equipped with built-in cognitive radio capability can share spectrum dividend bands with primary licensees on a secondary basis[62] subject to requirements for interference protection. However, if the spectrum dividend is in intensive use by license holders, the economic justification for developing and deploying spectrum-sharing radios in spectrum dividend bands may be weakened.

One example of the application of the 'easement' model is the proposed rule by the US regulator, FCC, in May 2004 to allow unlicensed radio devices to operate in unused broadcast TV spectrum ('white spaces') on a secondary basis with primary use of the spectrum given to broadcast TV stations. On 18 October, 2006, FCC released a First Report and Order and Further Notice of Proposed Rulemaking taking the first important steps toward allowing these new low power devices to operate in the broadcast television spectrum at locations where channels in that spectrum are not in use by television stations or other authorised services. In the First Report and Order, it concluded that fixed low power devices can be allowed to operate on TV channels in areas where those frequencies are not being used for TV or other incumbent licensed services. The FCC declined to permit operation on TV channel 37 that is used by radio astronomy and wireless medical telemetry services; and on TV channels 52-69, which have been reallocated for public safety and other mobile services. It also declined to permit the operation of personal/portable devices on TV channels 14-20, which are used by public safety service in 13 cities, leaving for further consideration the issue of whether fixed devices might be used in that band. Marketing of such devices may commence on 18 February, 2009, after the digital television (DTV) transition is complete in the United States and all TV stations are in operation on their permanent DTV channels. In the Further Notice, the FCC invited further comment on a number of issues that were raised in response to the May 2004 Notice of Proposed Rule Making. It solicited additional information that is needed to determine whether personal/portable devices can operate in any of the TV channels without causing harmful interference. It also invited comment to explore whether low power devices should be permitted on TV channels 2-4, which are used by TV interface devices such as VCRs, and whether fixed low power devices can be permitted on TV channels 14-20. Furthermore, the FCC invited comment on the desirability of requiring licensing for devices operating in the TV bands and it sought comments on the relative benefits of both the licensed and unlicensed approaches. The FCC made detailed technical proposals to facilitate use of a dynamic frequency selection (DFS) mechanism to ensure that TV band devices operate only on vacant TV channels. In addition, it sought further comment on implementation details for the geo-location and control signal interference avoidance approaches. The FCC plans to conduct extensive testing to assess the potential interference from low power devices operating in the TV bands before adopting final rules.[63]

V. FACILITATING RELOCATION OF INCUMBENT ANALOGUE BROADCASTERS

Terrestrial TV broadcasters are often reluctant, where applicable, to migrate to digital TV bands and want to make use of analogue and digital spectrum bands as if the bands are theirs. Where mandatory switch-off is in place, one way to facilitate relocation of analogue TV operators would be to apply overlay licensing.[64] Overlay licensing is to allocate existing analogue TV spectrum bands to new uses and users in advance of switchover with incumbent analogue broadcasters still using the bands as sitting tenants.

Spectrum management authorities may give the licences via auction or comparative selection process (beauty contest). Due to mandatory switch-off in place, the incumbent analogue TV operators must evacuate the existing bands to designated bands on a certain date in the future. If the licensees would want to relocate the sitting analogue TV operators earlier than the mandatory evacuation date, the licensees need to compensate analogue TV operators for the earlier move. Licensees have an incentive to relocate the existing analogue TV broadcasters earlier than the mandatory relocation date so as to release the spectrum bands for other services.

Before the evacuation date, analogue TV operators have rights to get protection from interference caused by new licensees. To avoid disputes over rights to interference protection, incumbents' and new users' rights need to be defined unambiguously.

In the context of auction, encumbered spectrum is likely to be valued less than unencumbered spectrum. The creation and auctioning of overlay rights provides a pragmatic response to the issue of migrating incumbents. Overlay licenses have been created in a number of frequency bands in Australia, Canada, New Zealand and the United States.

In the US, the Digital Television Transition and Public Safety Act of 2005[65], passed in February 2006, designates a mandatory switch-off date as 17 February, 2009 and requires the FCC to conduct an auction of the recovered spectrum bands commencing by 28 January, 2008. The auction will be applied to commercial channels 52-62, 65-67 (84 MHz) among recovered spectrum except channels 63-64, 68-69 (24 MHz) for public safety. The auction winner must protect incumbent broadcasters from harmful interference but can ask incumbents to vacate the band with compensation before the analogue switch-off date. Incumbents have a right to stay by the switch-off date.

APPENDIX – COUNTRY INFORMATION

Australia[66]

The Minister for Communications, Information Technology and the Arts proposed in a discussion document, "Meeting the Digital Challenge: Reforming Australia's media in the digital age," in March 2006, that the digital switch-off date is delayed from 2008 to 2012. Commencement of progressive switch-off is recommended to start in 2010. A Digital Action Plan will be drawn up with the aim of determining and ensuring that the switchover process meets its planned goals. The discussion document is a key part of this process. The discussion document suggests that the Government could remove the Australian simulcast requirement that the HDTV version of a digital TV service be a simulcast of the SDTV service, which may prevent multicasting, while retaining the current HDTV quota of 1 040 hours per year (20 hours per week) until the end of the simulcast period.

The document also suggests that two reserved digital channels of terrestrial spectrum would be allocated as soon as practicable in 2007 in markets for new digital services. Options for these services may include subscription TV services, free-to-air niche 'narrowcasting' services, as well as interactive and short video or 'datacasting' services, whether delivered to fixed or mobile television receivers, but would not include services that mirror traditional television services. Until analogue television services cease, there are only two unallocated digital channels in the broadcasting service band in most licence areas.

The Australian Government has no formal position on the future use of freed spectrum as a result of the digital switchover as of May 2006.[67]

Austria

Three analogue terrestrial channels exist with two PSB channels (ORF). The Austrian government has awarded broadcast network operator, ORS, a license in February 2006 to launch digital terrestrial TV services in Austria. The digital TV services are expected to be launched in October 2006. Viewers will be able to receive three TV programs; ORF1, ORF2 and commercial service ATV+. Following analogue switch-off on a region-by-region basis, a second multiplex may be launched. Analogue switch-off is likely to begin in 2007 following a 6 month simulcast of analogue and digital terrestrial services and to finish in 2010. During the switch-off phase, additional space will be available for an additional 5 to 6 multiplexes which will then be offered for new multiplex operator applications.[68]

The whole planning spectrum for terrestrial TV (174-223 MHz and 470-862 MHz) is used for analogue TV at the moment and - from a legal point of view - can be used for digital terrestrial TV. Until now there has been no decision in Austria on the amount or the usage of any spectrum dividend resulting from analogue turn-off.[69]

Belgium[70]

From July 2003, regular DVB-T transmissions started with one multiplex in the Antwerp region. In May 2004, this was extended to cover the whole Flanders area. For the French Community, two DVB-T transmitters are now operational in Brussels. An extension to the whole French community is planned for early 2006. Belgium has decided to spend EUR 3 million Euros on new transmitters for its terrestrial network to replace the existing infrastructure which is 15-20 years old. Rather than continuing with an analogue network Belgium will take this opportunity to switch to a digital platform which should cover 90% of the country by the end of 2006. Belgium is a heavily cabled country with 90% of households already connected. The new digital terrestrial TV service is intended to be receivable on simple rod antennas and should allow cheap installation of digital terrestrial TV set top boxes. Some Freeview services will also be available.

Canada[71]

The regulator, CRTC (Canadian Radio-television and Telecommunications Commission) decided in June 2002 not to enforce a single date for transitioning to digital broadcasts, opting to let the economy decide when the switchover will occur. The general time frame for analogue switch-off is at the end of 2007 but the Canadian Digital Television organisation (CDTV) estimated that it's likely to be beyond the year 2010.

Spectrum dividend: Spectrum coordination with the United States is being undertaken in the border regions. Canada has identified 60 MHz of this spectrum, in channels 60-69, to accommodate public safety and commercial mobile requirements.

Digital TV licensing: The CRTC gave out one digital channel (6 MHz bandwidth) for every existing regular analogue TV station based on the principle that digital technology will be treated as a replacement for analogue technology. DTV licensees are allowed to broadcast a maximum of 14 hours per week of high definition programming that is not duplicated on the analogue version of the service. A minimum of 50% of this unduplicated high-definition programming must be Canadian and all of the unduplicated programming must be in HDTV format. The CRTC encourages digital TV licensees to ensure that two-thirds of their schedules are available in a HDTV format by 31 December 2007.

Czech Republic

Digital terrestrial TV broadcasting was launched in Prague and the surrounding area in October 2005, and as of January 2006, 8 digital terrestrial TV programmes were available on a trial service using MPEG-2 with two multiplexes. The Council for Radio and Television Broadcasting (RRTV), regulator for broadcasting contents, allocated 6 digital terrestrial TV licenses to commercial broadcasters in April 2006. The DTT license holders are expected to begin broadcasting services within the next 360 days. The licenses are valid for a period of 12 years. Analogue transmissions are expected to be switched-off by or before the end of 2010. As for mobile TV services, T-Mobile (Czech Republic) has been testing mobile TV at the INVEX trade fair in Brno using DVB-H technology as of October 2005.[72]

As of July 2006, it is possible to receive regular digital broadcasting of Multiplex A in the area of three large cities (Prague, Brno, Ostrava) which offer 5 TV programmes and 7 radio broadcasting programmes. DVB-T experimental transmissions are in progress, namely that of Multiplex B (area of the capital city of Prague, offering 6 TV and 3 radio broadcasting programs) and that of Multiplex C (area of Prague and Brno, only testing data sequences). Another broadcasting pilot underway is in regional TV broadcasting using a DVB-T system in the area of Ostrava with 28th channels.

The government expects that any spectrum dividend coming from a digital switchover would be used for increasing the number of digital TV and radio programmes, and implementation of new broadcasting forms (such as multimedia, mobile broadcasting, HDTV and other future services in the long-term perspective).[73]

Denmark[74]

The end of October 2009 has been set by the Government as the official switch off date for analogue television in Denmark. Regarding the use of spectrum (*e.g.* the amount used for radio, TV or other services) political decisions will be taken based upon the outcome of the ITU Regional Radiocommunications Conference, RRC-06.

Denmark has launched DTT services using one multiplex in April 2006. The services are free-to-air and include services from the Public Service broadcasters DR, DR2 and TV2. Further multiplexes will be launched later when frequency allocations are decided. Interactive services based on the MHP DVB standard will be used from the start of the digital terrestrial TV service."

Finland

On 4 March 2004, the Ministry of Transport and Communications adopted a resolution stating its intention to replace all analogue TV broadcasting in Finland with digital broadcasting as of 31 August 2007.[75]

Four analogue terrestrial channels (TV1, TV2, MTV3, Nelonen) exist in Finland with 2 PSB channels (YLE; TV1, TV2). The government licensed each channel via beauty contest to compose 3 multiplexes with 4-5 channels per multiplex. One of the multiplexes on which 5 channels can be carried has been allocated to YLE. The other 2 multiplexes have been divided among private television companies. All digital TV operating licences are valid until 31 August, 2010. A fourth multiplex was intended to launch a mobile TV service using DVB-H technology and the Government announced in March 2006 that it awarded a licence to build and operate a DVB-H mobile TV network to Digita. The Government also announced plans to grant a new digital TV licence for a fifth multiplex in February 2006, specifically for the transmission of Swedish television programmes.[76]

In March 2006 the Government has established a comprehensive national working group, whose task is to prepare proposals on how to use the freed spectrums after switchover.[77]

France

On 5 May 2006, a Strategic Committee chaired by the Prime Minister and including the Minister of Media, the Minister of Industry, the Minister of Territorial Development and the chairmen of CSA and ARCEP, was established in order to address the issues of digital terrestrial television deployment, analogue switch-off and spectrum dividend. This Committee has started to proceed with wide consultations on these issues. According to a draft law on digital television, due to pass through Parliament in the forthcoming months, the Committee will propose a National Plan for the switchover, for adoption by the Government. This document will also determine general policy for the use of digital dividend.

Six analogue terrestrial channels exist in France with 3 PSB channels (France Television and ARTE). French contents regulator the *Conseil Superieur de l'Audiovisuel* (CSA) licensed on a per-channel basis, composing 5 multiplexes via beauty contest with 5-6 channels per multiplex. One more multiplex has been planified, the use of which is not yet decided. Digital terrestrial broadcast in France was launched at the end of March 2005 (branded as *La Télévision Numérique pour Tous*, or digital television for all). TNT

offers 18 free-to-air digital channels and 10 pay-TV digital channels[78] and reached 2.5 million homes as of end March 2006, one year after its launch. [79] *Groupement TNT* is being run as a joint venture between public broadcaster France Television/ARTE and Parliamentary channels and a number of TV services generally exiting in cable and satellite.

The Ministry of Culture and Communications announced that France will end its analogue terrestrial television services on 30 November 2011. Analogue switch-off is expected to take place region-by-region beginning in 2007.

In a statement issued on 24 May 2005, the Ministry of Economy announced that the MPEG-4 (H.264) compression standard must be used for HDTV services on any terrestrial channel both pay and free-to-air. MPEG-4 is already obligatory for Pay TV operators whilst free-to-air operators (among which public service) can continue to use MPEG-2 for standard definition digital terrestrial services. The CSA announced plans to clear channels for HDTV trials on a temporary basis in Paris, Lyon and Marseille. The CSA has invited interested parties to apply for licences permitting terrestrial HDTV services for the trials which will last for a period of nine months. Applicants will be able to use MPEG-4 compression to provide two HDTV services in the allocated channel slot. A first experiment was made during the Roland Garros tennis cup and the football World Cup.

As for mobile TV, despite channel scarcity, CSA have found the frequencies necessary for four trials to take place simultaneously in Paris. Three use DVB-H in the UHF TV band and one uses DMB-T in the VHF band.

Germany

The number of analogue terrestrial channels ranges from 3 to 12 depending on the region (PSB: ARD, ZDF). Regional regulators gave licences on a per-channel and per-multiplex basis. The PSBs receive a total of 3 multiplexes (2 for ARD, one for ZDF). 2 major commercial broadcasters (RTL and the ProSiebenSAT.1) also receive one multiplex each[80.] Business model in Berlin Brandenburg is pure free-to-air.

Switch-off dates of analogue terrestrial TV started in Berlin in 2003 and will be continued in most conurbations and completed by end of 2007.[81]

In Berlin, a trial of mobile digital terrestrial reception using DVB-H ('Broadcast Mobile Convergence'; BMCO project) is under way. In the trial, new TV content and interactive services are broadcast to portable and mobile end devices. Pay content being trialled includes the channel '13th STREET' from Universal Studios.

Greece[82]

Plans for digital terrestrial television using DVB-T are at an early stage and are not likely to materialise quickly. It was reported that DTT planning by the Greek Administration began last year with the priority being to cover the Attiki region around Athens which would immediately cover 50% of the population. This will also be a pilot project to define a network for the rest of Greece using both SFN and MFN networks.

Hungary

Analogue switch-off will be implemented on a gradual basis and finished on 31 December 2012.[83] Antenna Hungária Co. launched the free-to-air regular DVB-T broadcasting on 12 October 2004, with two

multiplexes in Budapest on UHF 43 and 51 channels, and in Kabhegy with the Budapest 1 multiplex on UHF 64 channel. To ensure more stable service in the Northern Budapest region on channel 28 there is a relay station in place with the same settings as the master transmitter. Currently, both multiplexes contain the national public channels mtv, m2 and DUNA TV. Furthermore, these programmes are accompanied with the EPG (Electronic Program Guide) and Superteletext services.[84]

On 2 March 2005, the government accepted the strategic objectives for the terrestrial digital television switchover. Based on these objectives, the National Radio and Television Board (ORTT) will be able to conduct the competition for the three nation-wide multiplexes in 2007. The primary task of the Cabinet is to create the statutory rules, provide the frequencies and to make DVB-T marketable. Establishment of the national multiplex is planned to start with isolated installations, first covering the areas with higher population density.[85]

Iceland

As yet there are no digital services. In March 2004, the Minister of Transport laid out an ambitious plan to introduce digital TV and radio. If all goes to plan, digital services will be available to 99.9% of the population by 2008.[86]

Ireland

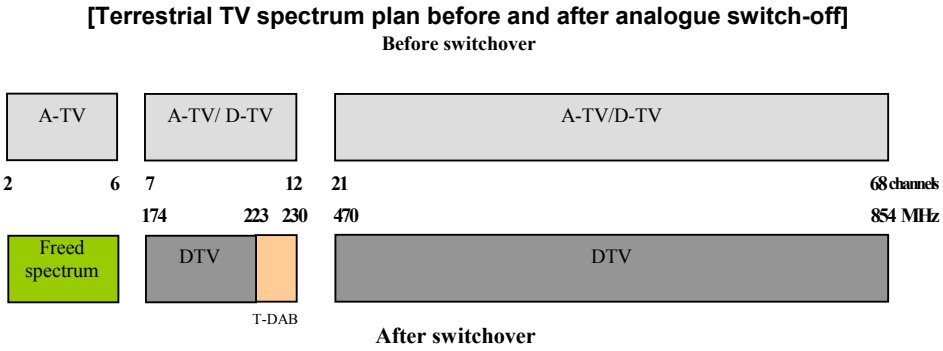
The Government plans a pilot digital television project in Dublin for 2006. It will enable consumers with a digital television to receive up to 12 television and radio channels for free without having to pay a subscription fee. The Minister for Communications said in March 2005 that the Government would switch off analogue free-to-air television services sometime between 2010-2015 but a particular switch-off date was not determined.[87]

When analogue TV signals cease, the 470-862 MHz band will be available for the following uses:[88]

- Transmission of existing TV programme services by digital means.
- Increase the number of programme services and/or enhance the TV experience (*e.g.* multi-camera angles for sports, individual news streams and other quasi-interactive options that are accessed using the remote control).
- Deliver services with higher technical quality (notably HDTV) or to portable and mobile receivers.
- Enable electronic communication services other than broadcasting.

Italy

There are 11 national analogue terrestrial channels with 3 PSB channels (RAI). The government licensed four of the existing analogue terrestrial TV operators five multiplexes; The public service broadcaster, RAI, has two multiplexes, Mediaset has one multiplex, Telecom Italia/TV International and D-Free (TF1 and HCS) have one multiplex each. The business model is free-to-air[89]. Analogue TV switch-off in Sadegna and Valle d'Aosta regions will be implemented in July 2006 with the other regions in 2008.[90]



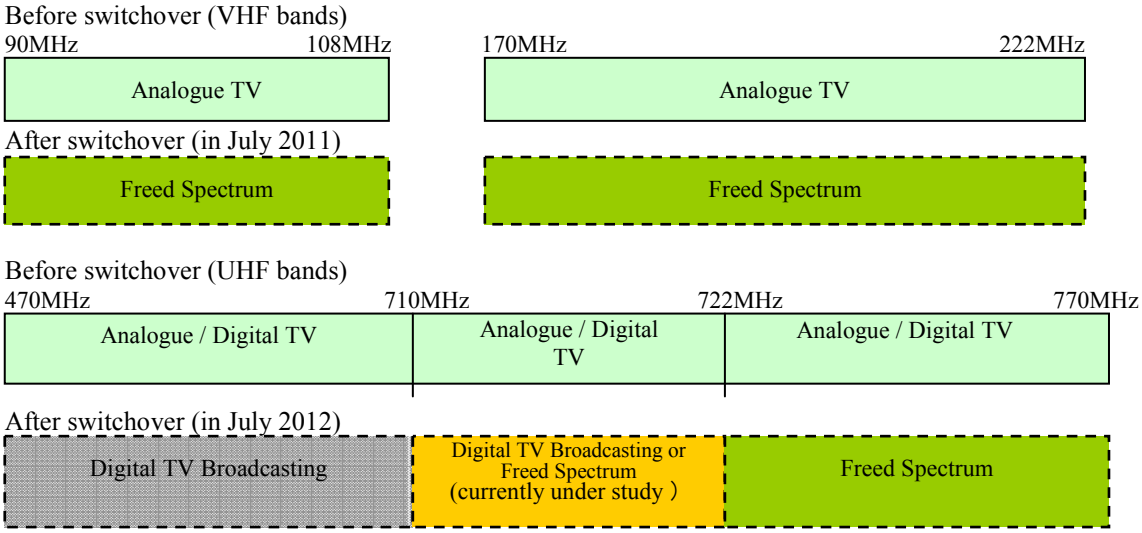
* channel 69 is used by Ministry of Defense

Source: Ministry of Communications.

Japan

Six nationwide analogue channels exist with two PSB channels (NHK). Terrestrial digital broadcasting was launched in three metropolitan areas (Kanto, Chukyo, and Kinki) in December 2003, and expanded steadily to cover prefectural seats of six prefectures in the Tohoku region as well as Tochigi and Gunma Prefectures in December 2005. In 2006, nationwide digital terrestrial broadcast is expected. Termination of analogue terrestrial TV will take place on 24 July 2011. All terrestrial TV broadcasters must provide simulcasting until 2011 to ensure a smooth transition. The ratio of airtime per day for simulcast programming shall be two-thirds or more and the ration of air-time of HDTV per week shall be 50% or more.[91]

Spectrum Planning for Terrestrial TV Before and After Analogue Signal Switch-off: Regarding future use of the freed spectrum, in March of this year the Ministry of Internal Affairs and Communications (MIC) charged the technical subcommittee of Information and Communication telecommunications Council with the study of the technical requirements for effective use of frequency, including possible modifications of spectrum allocation and the frequency-sharing conditions with adjacent systems. The interim report is scheduled to be compiled by June 2007.[92]

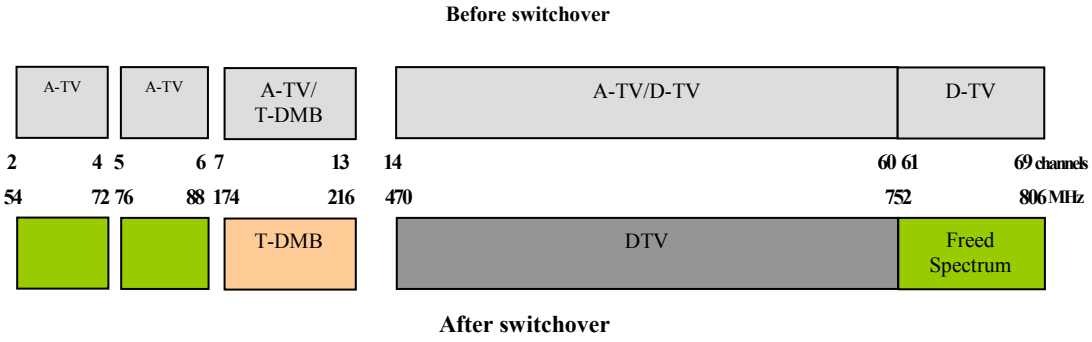


Source: Ministry of Internal Affairs and Communications.

Korea

In Korea, where HDTV is a main driver of the digital TV switchover, the Ministry of Information and Communiation (MIC) finished digital TV licensing in 2005 by providing existing 6 MHz channel analogue terrestrial TV broadcasters with access to another 6 MHz channels for digital broadcasting. To do simulcasting, the MIC reallocated part of the UHF bands (752-806 MHz; channels 61-69) in May 2001, which had been designated for fixed and mobile services, to broadcast on a temporary basis during simulcast period. A non-binding analogue switch-off date was originally set in 2010, but due to lower-than-expected digital TV receiver sales, the MIC is considering comprehensive measures to facilitate digital TV transition, including a mandatory switch-off date which could be set after 2010.

Spectrum Planning for Terrestrial TV Before and After Analogue Signal Switch-off: Analogue terrestrial TV operates in channels 2 through 69 and will migrate to digital TV bands from channels 14 through 60 (470-752 MHz) after analogue switch-off. The amount of freed spectrum after analogue switch-off is estimated at 84 MHz (54-72MHz, 76-88MHz, 752-806MHz). The future use of the spectrum is to be decided.



Source: Ministry of Information and Communication.

The MIC licensed mobile TV operators using unused TV channels in bands 174-216 MHz. In metropolitan areas, two TV channels (channels 8 and 12) are used to create six mobile TV operators, with each the right to use spectrum bandwidth of 1.54 MHz. The licensed mobile TV operators include three existing terrestrial analogue TV operators and three new entrants.

Luxembourg

Nationwide digital terrestrial TV services were launched in Luxembourg in April 2006 using a single multiplex. Viewers can access six television programme services, three in French (RTL TVI, Club RTL and Plug TV) and three in Dutch (RTL4, RTL5 and RTL7). A six-month trial service of RTL Télé Letzëbuerg has also been launched. Services are broadcast free-to-air and use the MPEG-2 video compression standard. With the launch of DTT services, the analogue terrestrial transmission of RTL TVI, RTL4 and RTL5 has been switched off.[93]

Mexico

The implementation of digital broadcasting got underway in Mexico in July 1999 with the creation of the Consultative Committee for Digital Broadcasting Technologies (CCTDR), composed of representatives from the government and industry. In October 2003 the CCTDR presented its final report, which recommends adoption of the ATSC system, as well as the allocation of an additional channel to incumbent licensees to simulcast their existing programming during the transition period and the establishment of a six-phase adoption plan. The government established an 18-year plan for the implementation of digital TV

divided intp six phases, starting with the launch of digital services in the main cities (Mexico DF, Guadalajara, Monterrey, Mexicali, and Tijuana) by the end of 2006 and concluding with the full-blown launch of digital services across the Mexican territory by the end of 2021. However, the plan does not establish a precise date for the switch-off of analogue transmissions.[94]

The Netherlands

In the Netherlands there are only three analogue terrestrial channels (all are public service broadcaster, NOS, channels) due to the lack of available spectrum. The government licensed four multiplexes to pay-TV platform, Digitenne, and reserved and multiplex for free-to-air public service broadcaster, NOS. NOS offers simulcasts of its analogue channels Nederland 1, Nederland 2 and Nederland 3. The analogue switch-off of the PSB channels will be decided in early 2006. Channels per multiplex are 5-6. In the Netherlands, only 1-2% of TV households depend on terrestrial means to watch television. The majority of TV viewers are accustomed to paying a monthly subscription fee to cable operators for analogue TV. Thus, a pay-TV platform, Digitenne, differentiated itself as TV with portable reception (indoor reception) at any location in the home as well as in the garden or on a boat.[95]

New Zealand[96]

New Zealand has chosen the DVB-T technology as its digital TV standard. At present digital satellite pay-TV ('Sky') is the main delivery medium for digital TV and New Zealand terrestrial TV broadcasters have yet to determine when digital terrestrial services will be introduced.

In 2003, the Government launched a digital broadcasting strategy, which instructed government-owned TVNZ and Maori Television to prepare plans for digital services. The Government invited broadcasters and relevant parties to form a digital television group but an effective group did not emerge. Although TVNZ has been the main driver of digital terrestrial transmission, the millions of dollars required to set up digital transmission (whether it be via satellite, digital terrestrial transmission or a mixture of mediums) means that TVNZ needs other free-to-air broadcasters on board. However, CanWest (TV3 and C4) and Prime appear to be in no hurry. In an effort to speed up the transition process, the Government appointed New Zealand on Air CEO as the first digital broadcasting director at the Culture and Heritage Ministry in July 2005. The director will look at whether the Government needs to intervene with legislation, funding, or an analogue switch-off date.[97]

Norway

In September 2005, Norges televisjon (NTV) applied to the Ministry of Transport and Communications and the Ministry of Culture and Church Affairs for a licence to develop and operate a DTT platform in Norway. In its application, NTV guarantees the development of three multiplexes covering 95% of households. Of these, one multiplex will also provide coverage to households located in satellite shadow areas. one multiplex contains between 7 and 10 TV programme services.

NTV proposes a development plan that will involve digital terrestrial TV roll-out in 11 regions, with the first region in Autumn 2006. Analogue switch-off in the last region will be possible by the end of 2008. The digital TV platform will use the MPEG-4 video compression standard so as to allow for the eventual transition to HDTV. Both pay and free-to-air services will be offered to viewers. Norsk rikskringkasting AS, TV 2 Gruppen AS and Telenor Broadcast Holding AS each own one third of NTV.[98]

Poland

Four analogue terrestrial TV channels are available with one PSB channel (TVP). Allocation of licences is now expected at the end of 2006. A debate regarding the video compression standard to be used has raised the possibility of using MPEG-4 instead of or as well as MPEG-2. It is expected that two multiplexes will be assigned to existing analogue terrestrial broadcasters, public and commercial using MFN networks that allow regional disconnecting (thus enabling regional content to be broadcast). In the second stage, a further five multiplexes are expected via beauty contest.[99] The analogue switch-off date is proposed in 2014, subject to earlier possibility according to the market situation.[100]

Portugal

The National Communication Authority in Portugal, Anacom, has authorised a few technical trials of digital terrestrial television using DVB-T. The trials also tested reception of DVB-H on mobile terminals and used MPEG-4 compression technology. It is intended to call a public tender at the beginning of 2007 to award digital terrestrial TV licences in an attempt to re-launch the market.

Terrestrial TV Spectrum plan before and after analogue signal switch-off: channels 11 and 12 (216-230 MHz) are already allocated to T-DAB. After the switch-off, channels 2 and 4 will not be used for TV broadcasting services. The services that will use this frequency band are yet to be defined. Channels 5 to 10 (174-216 MHz) are planned for DVB-T and T-DAB but their implementation depends on the development of both services. Channels 21 to 69 were planned for DVB-T and DVB-H in RRC-06. There is no decision yet in Portugal on the amount of spectrum dividend resulting from TV analogue switch-off.

Slovak Republic

The analogue switch-off date in Slovakia has been set for 2012, though it still remains unclear when a full service will make its debut. A four-channel DTT trial operated by Slovak Telecom, a subsidiary of Rádiokomunikácie, has begun in Bratislava. In 2004, Deutsche Telekom-backed Slovak Telecom was granted frequencies in Banska Bystrica-Zvolen.[101]

Spain

Five analogue terrestrial channels exist in Spain with two PSB channels (RTVE). The government licensed each channel via beauty contest to comprise five national and one regional multiplexes with 4-5 channels per multiplex. One multiplex was reserved for simulcasting the existing terrestrial broadcasters. Spain was of the pioneers of digital terrestrial TV: Quiero TV, a pay-TV platform, was launched as early as May 2000 with a multi-channel and interactive offering. However, Quiero was shut down in May 2002. Currently the five national channels, together with Veo TV and Net TV, continue to offer free-to-air digital terrestrial TV services. However, these are being broadcast in order to maintain the licences that may otherwise be taken back by the government.[102]

Sweden

Sweden has three analogue terrestrial channels with two PSB channels (SVT). The regulator licensed individual digital channels via a beauty contest for inclusion in a specific digital terrestrial channels (‘licensing per channel’). Five multiplexes were made up with four to seven channels per multiplex. The business model includes most pay-TV channels and a few free-to-air channels. The government set February 2008 as the deadline for analogue switch-off[103].

Switzerland

Once the frequencies allotted to Switzerland are known (after the ITU Regional Radiocommunications Conference in May and June 2006 in Geneva (RRC-06) where the frequency resources currently used by the analogue TV will be distributed between the various countries) the Swiss OFCOM will examine is the interest for these frequencies in the country via a public consultation during the second part of 2006.[104]

Turkey

The Communications High Council has confirmed the DVB standard for Turkey. Transition will be taking place in three phases, test, simulcast and digital (analogue switch-off) with a 10-year transition period tentatively agreed. Trial digital terrestrial TV broadcasts began in Ankara and Istanbul on 3 February 2006. The single multiplex offers four television programme services and is available in Ankara on channel 31 and in Istanbul on channel 23[105].

United Kingdom

Five analogue terrestrial channels exist in the United Kingdom - two BBC Public Service Broadcasting (PSB) channels funded by a licence fee, and three commercially funded PSB channels (ITV1, Channel 4 and Five). The regulator (then 'ITC') licensed six multiplexes (1,2,A,B,C,D) to broadcasters via a beauty contest (licensing per multiplex). Multiplex operators chose channels and can choose the network they want to be served by (ntl and Crown Castle are the network operators). Channels per multiplex range from four to six. The business model includes free-to-air (Freeview) and pay-TV (Top Up TV) channels.[106]

To make efficient use of TV spectrum, the UK government endorsed the application of spectrum pricing (AIP) to broadcasters, taking account of the public policy obligations. However, the government gave a commitment that charging for analogue spectrum will not start before 2006 at the earliest and that charging for digital TV licensees will not start before 2010[107].

Outline of band pla:; The frequency range 470-854 MHz (channel 21-68) is by convention partitioned into 48 channels, each of 8 MHz. After digital TV switchover 14 channels are expected to become completely clear in the United Kingdom and available for new uses. In addition, of the 32 channels which will be used for DTT broadcasting, only six will be used at any one site. Unused channels at each site may be available for other uses in an interleaved pattern (the "interleaved spectrum"). Two channels are not used for broadcasting in the United Kingdom: channel 38 which is used for radio-astronomy, and channel 36 which is used for radar. These channels are not subject to digital switch-over, and they will be considered by the project described in this note only to the extent that they are relevant. The VHF spectrum band 217.5-230 MHz was allocated to T-DAB.

[Band plan for UHF bands]

21	22	23	24	25	26	27	28	29	30	31	32
33	34	35	36	37	38	39	40	41	42	43	44
45	46	47	48	49	50	51	52	53	54	55	56
57	58	59	60	61	62	63	64	65	66	67	68

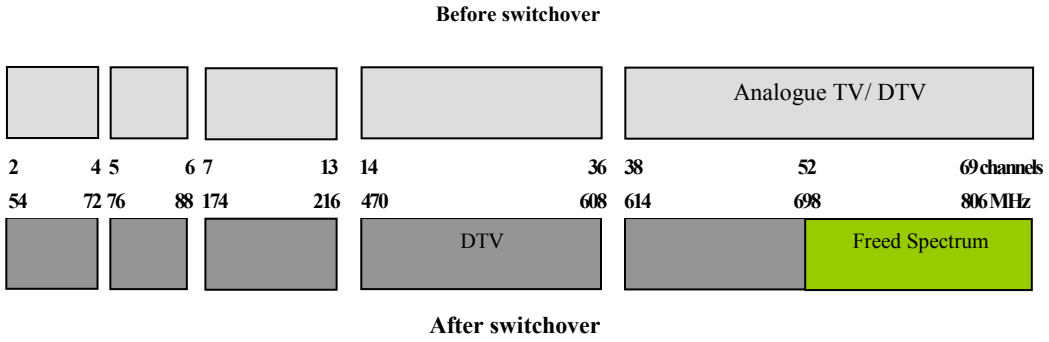
	available spectrum from digital switch-over - these channels will become free for new uses
	unavailable spectrum - 36 is radar; 38 is radio astronomy
	spectrum assigned to six DTT multiplexes, and resulting "interleaved" spectrum

The United States

Analog Switch-off date: 17 February, 2009 was set as firm deadline when only full-power television stations[108], not low-power stations, must stop analogue broadcasting by the Digital Television Transition and Public Safety Act of 2005. Under the previous governing legislation,[109] analog terrestrial television broadcasters do not have to be switched off until 85% of households are able to receive television signals in a digital format. The 85% condition was sometimes pointed out as a loophole in the law in that the condition would be difficult to achieve.

Digital TV Core Spectrum: The regulator of the United States, the Federal Communications Commission (FCC), adopted a Policy Statement on principles for reallocation of spectrum to encourage the development of telecommunications technologies for the new millennium on 18 November, 1999. In the context of this Policy Statement, the FCC is committed to spectrum efficiency and to the recovery of spectrum for the introduction and deployment of new services, including terrestrial digital television service. The analogue NTSC terrestrial television stations have been using over 400 MHz of spectrum in the VHF and UHF bands. However, the sensitivity of the NTSC broadcast system to interference allows the use of only 102 MHz of spectrum at any given location.[110] The FCC made spectrum planning through a consultation process in which all digital terrestrial TV services would be located in a core region of 270 MHz between channels 2 and 51 (VHF channels 2 to 13 (54-72, 76-88, 174-216 MHz), and the spectrum at UHF channels 14-51 (470-698 MHz)).

[Digital Television Core Spectrum]



Digital TV licensing and spectrum dividend: To facilitate transition, the FCC provided all existing 6 MHz channel analogue terrestrial broadcasters with access to another 6 MHz channel for digital broadcasting for the duration of the transition period. At the time of analogue television switch-off, each terrestrial broadcaster will surrender one 6 MHz channel and will use one 6 MHz channel in the core region between channels 2 to 51 for digital transmission. Broadcasters get to choose which channel they will keep and which they will surrender, subject to FCC approval.

Spectrum Dividend and allocation: 108 MHz of spectrum from upper UHF channels, *i.e.* channels 52-69 (698-806 MHz) can be freed up. Channels 52-62 (66 MHz) and 65-67 (18 MHz) were assigned for commercial and other new operations, and channels 63-64 (12 MHz) and 68-69 (12MHz) were allocated for Public Safety. The FCC also has designated other spectrum bands for new fixed, mobile, and other advanced services. The FCC refers to these as "Advanced Wireless Services," which includes the 1710-1755 MHz, 1915-1920 MHz, 1995-2000 MHz, 2110-2155 MHz, 2020-2025 MHz, and 2155-2180 MHz bands.

Assignment of recovered spectrum: The Digital Television Transition and Public Safety Act of 2005 passed in February 2006 which amended the Communications Act of 1934, requires the FCC to conduct an auction of the recovered spectrum commencing by 28 January 28. The auction will be applied to commercial channels 52-62, 65-67 (84 MHz) among recovered spectrum except channels 63-64, 68-69 (24 MHz) for public safety. FCC has auctioned spectrum currently occupied by TV broadcasters in the lower 700 MHz band. The auction winner must protect incumbent broadcasters from harmful interference but can ask incumbents to vacate the band with compensation before the analogue switch-off date (17 February, 2009). Incumbents have a right to stay until the switch-off date.[111]

Status of Digital Television Transition: The FCC published its 12th annual report on annual assessment of the status of competition in the market for the delivery of video programming on 3 March, 2006. According to the report, as of June 2005, there are almost 15.4 million (14.02%) U.S. TV households that do not subscribe to a multi-channel video programming distributor (MVPD) service including cable services and satellite broadcasting service, thus rely solely on over-the-air broadcast television for their video programming.[112] According to a staff report of the FCC's Media Bureau dated 28 February, 2005 the reasons for their not subscribing to an MVPD are about 60% lack of interest, 30% lack of funds, and 10% other.[113] As of 13 July, 2006, 1703 television stations (98.9%) have been granted a digital television construction permit or licence. There are a total of 1 584 stations on the air with digital television operation including all 119 of the top-four network affiliates in the top 30 television markets.[114]

DTV Tuner Requirement: FCC adopted a plan that gradually requires a digital television tuner in new TV sets from large screen size to small size. The final step in the phase-in plan requires that all new TV sets in all size ranges and other devices that receive TV signals such as VCRs and digital video recorders include a DTV tuner beginning 1 March, 2007. (Previously, the deadline for small sets (13"- 24") and for other TV receivers was 1 July, 2007). This phase-in plan is intended to allow manufacturers to realise increasing economies of scale with production volume, so that digital tuner costs will be lower when the tuners are required in smaller sets.[115]

Digital-to-Analog Converter Box Assistance Program[116]: To help consumers who wish to continue receiving broadcast programming over the air using analogue-only televisions not connected to cable or satellite service, the Digital Television Transition and Public Safety Act of 2005 authorises the National Telecommunications and Information Administration (NTIA) to create a digital-to-analogue converter box assistance program. Under the program, the NTIA is initially allocated up to $ 990 million of the spectrum auction revenues to send by US mail up to two $ 40 coupons to each US. household that requests to participate and qualify as eligible for the program. Consumers may use the coupons toward the purchase of eligible digital-to-analogue converter-boxes. In July 2006, NTIA issued a Notice of Proposed Rulemaking and a Request for Comments to determine eligibility and ways to implement the digital-to-analog converter box coupon program pursuant to the Digital Television Transition and Public Safety Act of 2005. The NTIA recognises that there will be a number of solutions, including market-based solutions, to address potential disruption of television service resulting from the analog to digital transition. Many consumers will neither need nor want a coupon to purchase a converter box. For example, many households that are now receiving over-the-air analog television signals will have purchased digital receivers by the time that analog broadcasting ends. NTIA also assumes that many households that currently receive over-the-air television transmissions will begin receiving digital service through one of the multi-channel video programming distributors, such as cable or satellite service. Therefore, this coupon program represents one of a number of solutions to accommodate consumers once analog broadcasting ends.[117]

NOTES

[1] 'Spectral mask' defines the level of emissions (interference) which are acceptable within specified geographical and frequency boundaries. Any other alternative primary uses may be allowed to operate provided that the other primary uses cause an interference level below the acceptable level, and that the alternative uses demand no greater protection than would be given to receivers of primary use.

[2] Noting that the harmonisation approach can also facilitate innovation in the course of harmonisation and standardisation of spectrum usage.

[3] This notion of unused channels should be taken with care because many of these channels are assigned to complementary transmitters (gap-fillers) planned with precision frequency offset which improve the protection ratio, or to microphones devices sharing the band with broadcasting.

[4] This paper complements previous OECD work, Secondary Markets for Spectrum: Policy issues (DSTI/ICCP/TISP(2004)11/FINAL) (http://www.oecd.org/dataoecd/59/2/34758854.pdf).

[5] In Europe, one option in VHF Band III (174-230MHz) is to construct digital TV network (DVB-T) to accommodate digital radio demands rather than to construct digital audio-only network on grounds that DVB-T terminal costs less than audio-dedicated DAB receiver and that construction of a TV network in VHF bands is likely to require considerably less infrastructure than in the UHF bands. (Source: ComReg Information Notice, ComReg Response to Consultation on Frequency Spectrum Policy for Digital Broadcasting, 01 November 2004).

[6] Faulty cable lines may cause some harmful interferences against over-the-air transmission.

[7] HDTV is one of formats that comprise the ATSC Digital TV Standard. HDTV standard pictures will have 6 times the resolution of current TV with a full 60 frames per second temporal resolution which is twice the current analogue images. The picture will be displayed in a panoramic 16:9 horizontal-to-vertical aspect ratio to be more like movies and add a feeling of realism to TV.

[8] Portable reception can be either indoor reception where a portable receiver with an attached antenna is used at no less than 1.5m above ground level or outdoor 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 as reception while in motion, covering speeds from walking to motorway driving. (Source: Ægis/IDATE/Indepen. Implications of Digital Switchover for Spectrum Management).

[9] Very High Frequency (VHF) is the frequency band from 30 to 300 MHz and Ultra High Frequency (UHF) is the frequency band from 300 to 3000 MHz.

[10] It is said that lower radio frequency (RF) bandwidth (below about 30 MHz) can carry only very narrow band services such as speech or low-rate data, but radio waves can traverse greater distances than higher frequencies. This is ideal for aeronautical and maritime communications, but is impractical for high-density mobile communications or for high quality broadcasting. At the other extreme, the microwave and millimetre-wave bands above about 3 GHz carry much more data in a band but signals can radiate shorter distance and rely on a more direct, unobstructed path between transmitter and receiver than lower frequencies.

[11] A single-frequency network or SFN is a type of radio network of synchronised transmitting stations radiating identical signals in the same radio frequency channel. To avoid interference, each station is usually run synchronously with the others, using GPS or a signal from the main station or network as a reference clock. SFN can make efficient use of spectrum but may not be appropriate for wider areas due to the possibility of self-interference. The vice-versa is multiple-frequency network, MFN. In this way, two network topologies are complementarily used to cover large territory. In the SFN context, synchronisation of multiple signals can prove to be very difficult, particularly in systems that require high bandwidth. Most attempts at repeating analog television on the same channel results in "ghosting," since the repeater creates a second path of information (multipath). However, the conversion to digital television will allow SFNs to be used reliably for carrying moving images. This will be easiest in systems that use COFDM as the transmission mechanism. COFDM uses a large number of very low-bandwidth signals, so it is fairly easy to synchronise multiple transmitters. DVB-T (used in Europe and many other areas) and ISDB-T (used in Japan) both use COFDM and are well-suited to SFN operation. COFDM is also widely used in digital radio systems. The 8VSB modulation system used in the United States for digital TV potentially allows the use of single-frequency networks there, as well. A pending Federal Communications Commission rulemaking proceeding addresses the use of digital transmission system technologies. (FCC, Clarification Order and Notice of Proposed Rulemaking, Digital Television Distributed Transmission System Technologies, MB Docket No. 05-312 adopted 3 November, 2005)

[12] http://en.wikipedia.com

[13] BIPE Consulting Study for the European Commission, Digital Switchover in broadcasting, p. 114, and Annex Part 2., p.100.
(www.europa.eu.int/information_society/topics/telecoms/regulatory/studies/index_en.htm)

[14] From Wikipedia, searched with 'digital terrestrial television in the United Kingdom' (http://en.widipedia.org)

[15] Analysys, DTT development in Member States, final report for the European Commission, Annex A, A.77.
(http://europa.eu.int/information_society/policy/ecomm/doc/info_centre/studies_ext_consult/dttv/final_report_on_dtt_for_the_ec_as_sent_04_10_05.pdf)

[16] From 15 May and 16 June 2006, 120 administrations from parts of Region 1 and 3 will meet in Geneva, Switzerland for the second session of the Regional Radiocommunication Conference (RRC-06) to establish an Agreement for the planning of the digital terrestrial radio and television services and to revise the GE89 and ST61 Agreements for analogue broadcasting services. The planning area covers parts of Region 1 situated to the west of meridian 170° E (Eastern boundaries of Russia) and to the north of parallel 40° S (including the whole of Africa), except the territory of Mongolia and the Islamic Republic of Iran.

GE-06 sets 17 June 2015 as the date when countries will no longer need to protect the analogue services of neighbouring countries and can freely begin using the frequencies assigned to them for their digital services. It is possible for countries to begin implementing the GE-06 digital plan during the transition period (between 17 June 2006 and 17 June 2015), however, doing so will require the prior agreement of neighbouring countries that may be affected.
(http://www.digitag.org/DVBHandbook.pdf#search=%22digitag%20analogue%20switch-off%22, page6)

[17] The acronym DAB is used both to identify the generic technology of digital audio broadcasting, and specific technical standards. Here T-DAB indicates the Eureka 147 standard, which is promoted by the World DAB Forum, representing more than 30 countries but excluding the United States. The United States has opted instead for a system called HD Radio or IBOC.

[18] Interactive datacasting can enable viewers to do T-commerce or to access Internet.

[19] ComReg Response to consultation on Frequency spectrum Policy for Digital Broadcasting (DTT) (01 November 2004), p. 15-17.

[20] Ægis / IDATE / Indepen. Implications of Digital Switchover for Spectrum Management (June 2004), prepared for the European Commission, p. 79. (http://www.indepen.co.uk/panda/docs/broadcast_spectrum_management.pdf); Wikipedia (http://en.wikipedia.org/wiki/Spectral_mask).

[21] As for broadcasting coverage, approximately 80% for BBC multiplexes (1 and 2); 73% for all multiplexes. For technical parameters, the United Kingdom adopted modulation type of 16QAM for multiplexes 1, B, C and D and 64QAM for multiplexes 2 and A. The national network is a multiple frequency network (MFN). Method for FEC (forward-error-correction) is ¾ for 16QAM, 2/3 for 64QAM. Guard interval is 1/32 (Analysys, DTT development in Member States, final report for the European Commission, Annex A, A.13.)

[22] Channel 2-4 (18 MHz; 54-72 MHz), channel 5-6 (12 MHz; 76-88 MHz), channel 7-13 (96 MHz; 174-216 MHz), channel 14-36 (138 MHz; 470-608 MHz), channel 38-69 (192 MHz; 614-806 MHz).

[23] FCC, Sixth Further Notice of Proposed Rule Making, MM Docket No. 87-268, para. 20. (adopted July 25, 1996).

[24] FCC, Notice of Inquiry in ET Docket No. 02-380., In the Matter of Additional Spectrum for Unlicensed Devices

Below 900 MHz and in the 3 GHz Band, para.11 (http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-02-328A1.pdf), 17 FCC Fcd 1022 (2002), para. 11.

[25] FCC, Sixth Further Notice of Proposed Rule Making, MM Docket No. 87-268 (adopted 25 July, 1996), footnote 26 (p.9).

[26] http://www.ofcom.org.uk/media/news/2005/11/nr_20051117.

[27] Adapted from EC Communication, EU spectrum policy priorities for the digital switchover in the context of the upcoming ITU Regional Radiocommunication Conference 2006 (RRC-06), COM(2005)461, 29 September 2005, p.5.

[28] 'Broadcasting' service is "a radiocommunication service in which the transmissions are intended for direct reception by the general public". This service may include sound transmissions, television transmissions or other types of transmission.

[29] Fixed service is a radiocommunication service between specified fixed points.

[30] Mobile service is a radiocommunication service providing links between mobile and land stations, or between mobile stations.

[31] Stations of a Secondary service shall not cause harmful interference to stations of primary services to which frequencies are already assigned or to which frequencies may be assigned at a later date and cannot claim protection from harmful interference from stations of a primary service to which frequencies are already assigned or may be assigned at a later date and can claim protection, however, from harmful interference from stations of the same or other secondary service(s) to which frequencies may be assigned at a later date.

[32] Refarming refers to changing the allocation status of spectrum, for example from broadcast to mobile service.

[33] Quoted at www.qualcomm.com/press/releases/2004/041101_mediaflo_700mhz.html.

[34] Viviane Reding's speech at International CeBIT Summit, "Television is going Mobile – and needs a pan European policy approach", Hannover, Germany, 8 March 2006 (http://europa.eu.int/information_society/newsroom/cf/comnews.cfm?type=sp)

[35] If TV stations are the primary users, a secondary user may be subject to interference from the primary user at any time, but must not cause interference with the primary user.

[36] FCC, Notice of Proposed Rulemaking (NPRM) Unlicensed Operation in the TV Broadcast Bands, ET Docket No. 04-186, (adopted 13 May, 2004) (http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-04-113A1.doc)

[37] The proposed rule-making identifies two general categories of unlicensed broadband devices that could be authorised: Lower-power "personal/portable" devices, such as Wi-Fi cards, and higher-power "fixed access" devices used to provide commercial Wireless Internet Service Provider (WISP) services subject to typical technical requirements in Part 15, a part of the Code of Federal Regulations. The FCC proposed several methods these devices could use to avoid causing harmful interference, which involve cognitive radio and geo-location technology. The FCC expected that broadcasters would benefit from the new regulations to expand their services to provide interactive broadcast services and in-home wireless video distribution.

[38] http://www.wrf.com/publication.cfm?publication_id=8447

[39] EU Radio Spectrum Policy Group (RSPG), Opinion on Spectrum Implications of Switchover to Digital Broadcasting, (November 19, 2004). (http://rspg.groups.eu.int/doc/documents/meeting/rspg8/rspg_05_102.pdf)

[40] EC Communication, A Market-based Approach to Spectrum Management in the European Union, COM(2005)400, 14 September 2005, p.2.

[41] Adapted from Bjorn Wellenius and Isabel Neto, op. cit., p.20-21

[42] Ibid., p.20-21

[43] Patrick Xavier and Dimitri Ypsilanti, Policy issues in spectrum trading, Info, Vol. 8, No. 2, 2006, p.58.

[44] Ibid., p.38.

[45] 47 U.S.C. § 303(y)

[46] FCC, First report and order, service rules for the 746-764 and 776-779 MHz bands, and revisions to Part 27 of the Commission's Rules, WT Docket No. 99-168 (adopted 6 January, 2000), para.16. (http://www.fcc.gov/Bureaus/Wireless/Orders/2000/fcc00005.doc)

[47] EC Communication, A Market-based Approach to Spectrum Management in the European Union, COM(2005)400, 14 September 2005, p.7-8.

[48] European Electronic Communications Regulation and Markets 2005 (11th report), COM(2006)68, 20 February 2006, p.54 (http://europa.eu.int/information_society/policy/ecomm/doc/implementation_enforcement/annualreports/11threport/com_2006_68_en_final.pdf)

[49] RSPG, op.cit., p.2-3.

[50] RSPG, op.cit., p.5. The other bands identified for WAPECS included mobile and fixed bands and short range devices.

[51] Ofcom, Consultation document, Award of available spectrum 1452-1492 MHz (31 March 2006), p.6 (http://www.ofcom.org.uk/consult/condocs/1452-1492/1452-1492.pdf)

[52] The Ofcom noted in the demand assessment section of the consultation document that the spectrum band can include new services such as mobile multimedia (using standards like DVB-H or DMB) and broadband wireless access (using technologies such as TDD-IP and WiMAX) as well as T-DAB, S-DAB and PMSE (program-making and special events). The Ofcom added that the technical conditions will comprise a constraint on use defined by reference to a spectrum mask.

[53] UWB is another spectrum-sharing technology to transmit data at very high speeds by spreading a data signal over a wide range of frequencies but at very low power levels. All electronic devices produce radiation at various frequencies, making some level of interference, commonly referred to as noise floor. Licensed radio devices are made to send and receive signals above the noise floor. The UWB technology is able to communicate below the noise floor, often referred to as "underlay". If underlay technologies such as UWB work as advertised, these technologies offer the potential to drastically increase spectrum efficiency in that licensed radios can continue in normal operation without even sensing simultaneous broadcasts from the underlay equipment on the same frequency. Smart radios add context-sensitive intelligence to signal processing, so receivers can distinguish among different signals sharing the same frequencies. This is similar to human hearing discriminating between noise and signal to focus on a particular conversation with others going on around. Smart antennas can discriminate among signals coming from different directions. Software-defined radios can switch operating frequencies dynamically in response to spectrum congestion and noise. Cognitive radios sense and respond to their environment by choosing communications characteristics that are compatible with it. Mesh, *ad hoc* and viral networks are all related concepts applying to network topology, and gravitate around the notion of incremental or decentralised networks, needing no central backbone, infrastructure, or organisation in order to work, but using "neighbors" as resources for communication. Wireless mesh networks are multi-hop systems in which end-user devices assist each other in transmitting data through the network, especially in adverse conditions.

[54] FCC, Spectrum Policy Task Force, Report of the Spectrum Efficiency Working Group, 15 November 2002; directly quoted in Patrick Xavier and Dimitri Ypsilanti, Policy issues in spectrum trading, Info, Vol.8, No.2, 2006, p.38.

[55] Snider, J. (2003), An Explanation of The Citizen's Guide to the Airwaves, New America Foundation, Washington DC (www.newamerica.net/templets/ssl_forms/download/airwaves.pdf)

[56] It means that national spectrum management may, sometimes, pay much attention to the nationality of a wireless technology as well as efficient use of spectrum.

[57] *See* footnote 2.

[58] RSPG, op.cit. Annex I (public consultation), p.15.

[59] ITU-R defines broadcasting as "a radiocommunication service in which the transmissions are intended for direct reception by the general public. This service may include sound transmissions, television transmissions or other types of transmission."

[60] This does not mean that these new broadcasting services should be subject to the traditional broadcasting regulations.

[61] FCC, First report and order, service rules for the 746-764 and 776-779 MHz bands, and revisions to Part 27 of the Commission's Rules, WT Docket No. 99-168 (adopted 6 January, 2000), para.16. (http://www.fcc.gov/Bureaus/Wireless/Orders/2000/fcc00005.doc)

[62] In the United States, the FCC rulemaking contemplating operation of unlicensed radios with cognitive radio capability in unused broadcast TV channels is considering whether to allow such operation before digital switchover subject to certain interference requirements. In Korea, mobile TV service using T-DMB technology is using unused broadcast in unused TV broadcast channels subject to certain interference requirements.

[63] *In the matter of Unlicensed Operation in the TV Broadcast Bands; Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band* in ET Docket No. 04-186, ET Docket No. 02-380, *First Report and Order and Further Notice of Proposed Rule Making* (released 18 October, 2006) (http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-06-156A1.doc)

[64] Adapted from Ægis / IDATE / Indepen. Implications of Digital Switchover for Spectrum Management (June 2004), prepared for the European Commission, p. 67-68 (http://www.indepen.co.uk/panda/docs/broadcast_spectrum_management.pdf)

[65] The Digital Television Transition and Public Safety Act of 2005 became Public Law 109-171. The Act's text can be found on NTIA's website (http://www.ntia.doc.gov/otiahome/dtv/S1932.pdf). The Act became law as part of the wider Deficit Reduction Act of 2005 (http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=109_cong_public_laws&docid=f:publ171.109.pdf)

[66] Australian Discussion Paper, "Meeting The Digital Challenge" Reforming Australia's media in the digital age, March 2006 (www.dcita.gov.au/_data/assets/pdf_file/37572/Media_consultation_paper_Final_.pdf).

[67] comments from DCITA.

[68] http://www.dvb.org/about_dvb/dvb_worldwide/austria/

[69] Comments from GmbH.

[70] http://www.dvb.org/about_dvb/dvb_worldwide/belgium/

[71] HiQ Data AB, Digital Switchover and Spectrum Dividend – Market Status outside Europe 2006, p.8-10. (http://www.pts.se/Archive/Documents/SE/digital_DTV_Status_outside_Europe_2006_RevB.pdf).

[72] http://www.dvb.org/about_dvb/dvb_worldwide/czech_republic/

[73] Comments from Czech Telecommunication Office, regulator responsible for transmission.

[74] http://www.dvb.org/about_dvb/dvb_worldwide/denmark/

[75] http://www.mintc.fi/scripts/cgiip.exe/WService=lvm/cm/pub/showdoc.p?docid=2411&menuid=409.

[76] http://www.dvb.org/about_dvb/dvb_worldwide/finland/

[77] Comments from LVM/Ministry of Transport and Communications.

[78] http://en.wikipedia.org/wiki/Digital_terrestrial.

[79] http://www.dvb.org/about_dvb/dvb_worldwide/france/

[80] Analysys, Ibid., Annex A, p.45.

[81] European Commission Working Document, Information from Member States regarding roll out of digital terrestrial TV and switch off of analogue terrestrial TV (11 January 2006) (http://europa.eu.int/information_society/policy/ecomm/doc/todays_framework/digital_broadcasting/switchover/cocom05_51final_corr_digital_tv_update1.pdf).

[82] http://www.dvb.org/about_dvb/dvb_worldwide/greece/

[83] European Commission Working Document, Ibid.

[84] http://www.ahrt.hu/en/services/1FCC9EB7E1AF428A89E065D4B74090B9.php

[85] http://www.ahrt.hu/en/services/1FCC9EB7E1AF428A89E065D4B74090B9.php

[86] European Media Landscape (http://www.ejc.nl/jr/emland/iceland.html#3)

[87] http://www.dvb.org/about_dvb/dvb_worldwide/ireland/

[88] Comments from ComReg.

[89] Analysys, Ibid., Annex A, p.58.

[90] European Commission Working Document, Ibid.

[91] HiQ, Digital Switchover and Spectrum Dividend-Market Status outside Europe 2006, p.14-16. (http://www.pts.se/Archive/Documents/SE/digital_DTV_Status_outside_Europe_2006_RevB.pdf)

[92] Comments from MIC of Japan

[93] http://www.dvb.org/about_dvb/dvb_worldwide/luxembourg/

[94] http://www-rcf.usc.edu/~hernang/Digital%20Broadcasting%20in%20Latin%20America.pdf

[95] Analysys, Ibid., Annex A, p.65-69. / European Commission Working Document, Ibid.

[96] http://www.dvb.org/about_dvb/dvb_worldwide/new_zealand/

[97] http://www.stuff.co.nz/stuff/0,2106,3424230a28,00.html.

[98] http://www.digitag.org/DTTNews/article.php?Id=1040.

[99] Analysys, Ibid., Annex A, p.91.

[100] European Commission Working Document, Ibid.

[101] http://www.dvb.org/about_dvb/dvb_worldwide/slovakia/

[102] Analysys, Ibid., Annex A, p.27-33.

[103] Analysys, Ibid., Annex A, p.21-23.

[104] Comments from Swiss OFCOM

[105] http://www.dvb.org/about_dvb/dvb_worldwide/turkey/

[106] Analysys, Public policy treatment of digital terrestrial television (DTT) in communications markets, (Oct., 2005), Annex A, p.5-8.

[107] Indepen, Aegis systems and Warwick Business School, An Economic Study to Review Spectrum Pricing, (Feb., 2004) p.91 (www.indepen.co.uk/panda/docs/spectrum_pricing_review.pdf)

[108] The bill also clarifies that only full-power stations, not low-power stations, must cease analog broadcasting by 18 February, 2009. Low-power stations, including Class A stations, may continue broadcasting in analog format after 18 February, 2009, subject to future decisions by the FCC on how to complete the digital television transition for such stations. Low-power stations other than Class A stations may also continue such analog broadcasting above channel 51, subject to future FCC decisions, so long as those stations' use of those channels is secondary to the use of those channels by the auction winners and public safety officials.

[109] 47 USC 309(j)(14)(B) specified 3 conditions under which the FCC shall extend the switchoff date of analog television service to a period that beyond December 31, 2006 ; (i) …four largest national television networks are not broadcasting a digital television service signal… (ii) digital-to-analog converter technology is not generally available in such market… (iii) …15% or more of the television households in such market do not subscribe to a multichannel video programming distributor that carries one of the digital television service programming channels of each of the television stations broadcasting such a channel in such market; and…

[110] FCC, Sixth Further Notice of Proposed Rule Making, MM Docket No. 87-268, para. 16, footnote 26 (adopted 25 July, 1996).

[111] Ægis / IDATE / Indepen. Implications of Digital Switchover for Spectrum Management (June 2004), prepared for the European Commission, p. 67-68 (http://www.indepen.co.uk/panda/docs/broadcast_spectrum_management.pdf)

[112] FCC, Twelfth Annual Assessment of the Status of Competition in the Market for the Delivery of Video Programming, MB Docket No. 05-225, released Mar. 3, 2006, Table B-1 at 115 (http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-06-11A1.doc)

[113] FCC Media Bureau Staff Report Concerning Over-The-Air Broadcast Television Viewers, para. 16., p.7. (http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-257073A1.pdf)

[114] http://www.fcc.gov/mb/video/files/dtvsum.html: The top 30 television markets (Nielsen DMAs) in the United States represent 53.6% of television households for the 2005-2006 television season.

[115] FCC press release, FCC Modifies Digital Tuner Requirements To Advance Dtv Transition (3 November, 2005)

[116] http://www.benton.org/benton_files/dtvbillsummary.doc p.2.

[117] For more information, see:http://www.ntia.doc.gov/ntiahome/frnotices/2006/couponprogram_nprm_07202006.htm