

Implementation of the Digital Dividend

— technical constraints to be taken into account

Jan Doeven
KPN

At the RRC-06, a new Agreement and associated frequency plans for digital broadcasting and analogue TV broadcasting during the transition period were agreed (GE06). The next step is implementation of the new Agreement.

Broadcasting organisations, network operators, spectrum user forums and others have announced their opinions on the use of Bands III, IV and V. A term often used in relation to the implementation of the new Agreement is “digital dividend”. This article describes the technical constraints to be taken into account when using released spectrum for several digital dividend applications.

1. Introduction

At the RRC-06, a new Agreement and associated frequency plans for digital broadcasting and analogue TV broadcasting during the transition period were agreed (GE06) [1]. The next step is the implementation of the new Agreement. Broadcasting organizations, network operators, spectrum user forums and others have announced their opinions on the use of Bands III, IV and V. A term often used in relation to the implementation of the new Agreement is “digital dividend”. There may be many meanings of the term. For the countries in the European Union, the definition used by the Radio Spectrum Policy Group (RSPG) and the European Commission is most relevant.

“Digital Dividend” is, according to the RSPG, to be understood as the spectrum made available over and above that required to accommodate the existing analogue television services in a digital form in VHF (Band III: 174 - 230 MHz) and UHF (Bands IV and V: 470 - 862 MHz) [2]. It should be noted however that existing analogue television also makes use of Band I (47 - 68 MHz) and, after digital switchover, Band I spectrum could be considered as digital dividend too. Furthermore, Band III is also planned for T-DAB and many existing T-DAB services already make use of Band III. In addition, in a number of countries, non-broadcasting services make use of Bands III, IV and V.

Many possible applications of the digital dividend are under discussion. In its Communication on “EU spectrum policy priorities for the digital switchover in the context of the upcoming ITU Regional Radiocommunication Conference 2006 (RRC-06)” [3], the European Commission identified three categories:

- 1) Spectrum needed for the improvement of terrestrial broadcasting services: e.g. services with higher technical quality (notably HDTV), increased number of programmes and/or enhancement of TV experience (e.g. multi-camera angles for sports, individual news streams and other quasi-interactive options);
- 2) Radio resources needed for “converged” broadcasting services which are expected to be primarily “hybrids” of traditional broadcast and mobile communication services;

- 3) Frequencies to be allocated to new “uses” which do not belong to the broadcasting family of applications. Some of these potential new “uses” of the spectrum dividend are future services and applications which are not yet marketed and others are existing ones which do not operate yet in these frequencies (e.g. extensions of 3G services, short-range radio applications).

This article describes the technical constraints to be taken into account when using released spectrum for several digital dividend applications. Considerations on the use of the digital dividend are also described in [4].

2. Size of the digital dividend

2.1. “Layers”

A term often used when considering national input requirements and results of RRC-06 is the number of “layers”. A layer is not defined in the GE06 Agreement, nor was it defined at RRC-06, but for most European countries it may be described as a set of channels which can be used to provide full or partial nationwide coverage. The number of layers depends, among others, on the geographical situation, the level of accepted interference, transmission and reception characteristics and the way an Administration composes its layers out of the available Plan entries.

Administrations submitted their T-DAB and DVB-T requirements before RRC-06. Fulfilling these initial requirements would, in some areas, have required ten times the band capacity and, in most areas, two or three times. In defining input requirements, Administrations took into account their long-term broadcasting needs, their rights concerning use of other primary services operating in Bands III, IV or V (if any) and maybe, in some countries also, possible future use of other applications. However, as the planning process at RRC-06 allowed Administrations to make input requirements only for T-DAB or DVB-T, other possible applications needed to be described as broadcast requirements. Another element in defining input requirements was the wish for all Administrations to have an equitable access to the frequency bands. Therefore the T-DAB and DVB-T input requirements do not always necessarily represent the current minimum market requirements. Furthermore, it should be noted that a national requirement may seem unrealistic from a frequency-planning point of view, or even from the point of view of a neighbouring Administration, but could be political reality in a country.

During RRC-06 there was a strong pressure on Administrations to reduce their requirements in accordance with the following guidance:

Guidance for number of “layers”

Band III		Band IV/V
T-DAB	DVB-T	DVB-T
3	1	7-8

Most European countries were successful in achieving the above-mentioned number of layers.

In most countries there are four analogue TV services and these can in general be accommodated into one DVB-T multiplex for which one DVB-T layer is needed. However countries with five or more analogue TV services and using DVB-T with a robust modulation, may need two DVB-T multiplexes and thus two layers for broadcasting their existing analogue TV services in digital format.

For a successful introduction of DVB-T, more multiplexes are needed than the number of channels containing the current analogue TV programmes (*see Section 6.1*) but, following the RSPG definition, in general out of the eight to

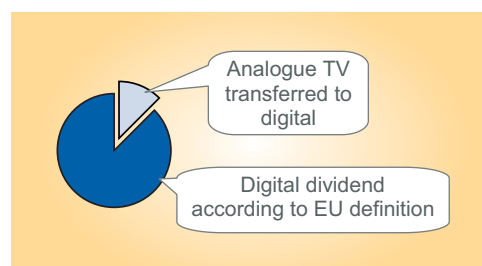


Figure 1
Band III, IV & V spectrum

nine achieved DVB-T layers, six to eight DVB-T layers and the three T-DAB layers could be seen as digital dividend (see Fig. 1).

2.2. Frequency bands

Band I (47 - 68 MHz) was not planned for digital broadcasting at RRC-06 and is regulated by the revised Stockholm Agreement [5]. The band is not included in the RSPG definition of digital dividend. However, after analogue TV has been switched off, it may also be considered for new applications, taking into account that there are already non-broadcasting services in a number of countries. Band I is less attractive than Bands III, IV or V for many services due to:

- its long wavelength, and therefore large antenna dimensions;
- its susceptibility to ionospheric interference from the Sporadic E-layer;
- the high levels of man-made noise at these frequencies [6].

In general, not much interest has been expressed for Band I. Currently some DRM (Digital Radio Mondiale) experiments take place in this band.

Band III (174 - 230 MHz) has been planned for T-DAB and DVB-T. A number of countries are considering implementing DVB-T only in Band IV/V, and to use Band III exclusively for T-DAB or multimedia applications making use of a T-DAB based system. There is currently no interest in applying new non-broadcasting services in this band.

For digital dividend applications, the band is considered as 1st and 2nd category (see Section 1).

Band IV/V (470 - 862 MHz) is subject to most of the discussions on digital dividend, covering all three categories (see Section 1). In addition to broadcasting, the UMTS lobby sees it as an attractive band for mobile communication systems.

3. GE06 Agreement

The Plan entries of GE06 will only become fully available after analogue switch-off. The European Union proposes to switch off analogue TV before 2012 [7]. According to the GE06 Agreement, analogue TV will have no right of protection after 17 June 2015 (and, in some African and Middle East countries, after 17 June 2020 in the case of VHF transmissions).

The GE06 Agreement offers two options to achieve flexibility in the application of Plan entries (Article 5):

- **Different characteristics of a Plan entry** can be applied as long as the “conformity check” is fulfilled. The main criterion is that interference from the application is not more than that of the Plan entry. This mechanism can for instance be applied to convert a Plan entry into a Single Frequency Network or a different reception mode (see Section 4);
- **Alternative applications of a Plan entry** (that is other than DVB-T or T-DAB) are possible in the Broadcasting, Mobile and Fixed services if three conditions are fulfilled:
 - band allocation in the Radio Regulations to the relevant service;
 - not exceeding the spectral power density of the associated Plan entry;
 - not claiming more protection than afforded to the associated Plan entry.

A more detailed description of the options for achieving flexibility is given in [8].

In addition, the GE06 Agreement contains a procedure for modification of the Plan (Article 4). Under this procedure, the agreement of all potentially-affected countries is needed to make a change to a Plan entry. The Article 4 procedure also needs to be followed in cases where services other than broadcasting, which have co-primary status, are introduced or modified.

Depending on the impact on the GE06 Agreement, two uses of the digital dividend can be distinguished:

- **Applications making use of Plan entries** which require no or limited modifications to the GE06 Plan;
- **Applications making use of a dedicated sub-band** with the consequence of considerable modifications to the GE06 Plan.

4. Applications making use of GE06 Plan entries

The GE06 Agreement has harmonised planning parameters for use of the 174 - 230 MHz band by T-DAB and DVB-T and the 470 - 862 MHz band by DVB-T. T-DAB has been planned for mobile and portable reception, DVB-T for rooftop and portable reception.

4.1. Reception mode

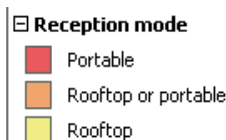
Each Plan entry has a specified reception mode. The most used for DVB-T are a set of characteristics for rooftop reception or portable outdoor reception. The latter term stands also for portable indoor or mobile reception at a lower coverage quality. *Fig. 2* shows the specified DVB-T reception mode for the European countries.

The most-used basic characteristics of the DVB-T reception modes in Band IV/V are:

Reception mode	Rooftop	Portable
Capacity	≤ 24 Mbit/s	≤ 16 Mbit/s
Required field strength	56 dB μ V/m	78 dB μ V/m

A transmission based on a Plan entry specified for rooftop reception can be used for portable reception if a reduced coverage area is acceptable. If it is not, a dense Single Frequency Network (SFN), that fulfils the conditions of the conformity check of Article 5 of the GE06 Agreement, is a possibility to improve coverage. It may also be necessary to seek international agreement for modifying the Plan entry with a higher power by applying the Article 4 procedure of the GE06 Agreement.

If a transmission based on a Plan entry that was specified for portable reception is used for rooftop reception, a larger coverage area will be obtained and there may be an overlap of (rooftop) coverage of two or more adjacent transmitters. In practice, portable coverage may be restricted to built-up areas. In the surrounding rural areas, the wanted field strength is likely to be sufficient for rooftop reception but the received interference levels associated with the portable Plan entry may be too high for full rooftop coverage of the area. There is likely to be more than one possible



[provided by the EBU]

Figure 2
Reception mode as specified in GE06

wanted transmitter, because of the overlap of coverage areas. In some cases, instead of directing the rooftop antenna towards the transmitter giving the highest signal strength, a better signal-to-interference ratio may be obtained by aligning the antenna on another transmitter. In some areas, a very directional (and hence, a much more expensive) rooftop antenna may be needed. It may also be necessary to optimize the transmitter characteristics, or the SFN, taking care that the conformity check of Article 5 of the GE06 Agreement is fulfilled.

The field-strength requirements for handheld reception in Band IV/V range from 85 to 107 dB μ V/m, depending on the modulation and reception conditions [9] and are higher than for portable reception. A transmission based on a Plan entry for portable reception can be used for handheld reception under comparable conditions to those indicated above for the case of a Plan entry for fixed reception being used for portable.

4.2. Different network topologies

If, in a given area, the network topology of one or more of the multiplexes is different to that of the other multiplexes (e.g. if dense networks are used for some multiplexes), adjacent channel interference may occur around non co-sited stations. Such interference may occur on the first, second and even third adjacent channel on both sides of the wanted channel.

Adjacent channel interference is a local problem. A possible solution is co-locating fill-in transmitters at the site of the interfering transmitter. The question will arise however who will have to pay for these provisions.

5. Applications making use of a dedicated sub-band

For applications with up-links and different channelling schemes, dedicated sub-bands are considered [2][18] e.g. for UMTS. In the case of UMTS, an allocation to Mobile services in the Radio Regulations needs to be agreed at ITU WRC-07 or WRC-11 and a sub-band would be required from which the GE06 Plan entries are deleted.

5.1. Replanning Band IV/V

A new non-broadcasting application needs to be agreed by all potentially-affected countries in accordance with the Article 4 procedure of GE06 and has to be incorporated in the “List” of Annex 5

Abbreviations

CEPT	<i>Conférence Européenne des Postes et Télécommunications</i> (European Conference of Postal and Telecommunications Administrations)	ITU-R	ITU - Radiocommunication Sector http://www.itu.int/ITU-R/publications/rec/index.asp
CRT	Cathode Ray Tube	RRC	(ITU) Regional Radiocommunication Conference
DAB	Digital Audio Broadcasting (Eureka-147) http://www.worlddab.org/	RSPG	Radio Spectrum Policy Group
DRM	Digital Radio Mondiale http://www.drm.org/	SAB	Services Ancillary to Broadcasting
DVB	Digital Video Broadcasting http://www.dvb.org/	SAP	Services Ancillary to Programme-making
DVB-H	DVB - Handheld	SFN	Single-Frequency Network
DVB-T	DVB - Terrestrial	ST61	Stockholm Frequency Plan of 1961
EU	European Union	T-DAB	Terrestrial - DAB
GE06	Geneva Frequency Plan of 2006	UHF	Ultra High Frequency
ITU	International Telecommunication Union http://www.itu.int	UMTS	Universal Mobile Telecommunication System
		VHF	Very High Frequency
		WRC	(ITU) World Radiocommunication Conference

of GE06 in order to be protected from GE06 Plan entries and further modifications of the GE06 Plans. In order to obtain agreement, the new application may be subject to restrictions because Plan entries of other countries need to be protected and interference from Plan entries of other countries accepted.

In general in the GE06 Plan, the frequencies at a given site or in a certain area are scattered over the whole band. A sub-band for Mobile services, such as UMTS, could therefore affect all DVB-T “layers” (*for the meaning of “layers” see Section 2.1*) as it would create “holes” in the layers (areas not covered because the frequencies are no longer available due to the sub-band).

The remaining part of the band will need to be re-planned in order to obtain the original envisaged DVB-T coverage, with a reduced number of layers, by applying the Article 4 procedure of the GE06 Agreement. This re-planning means in practice a re-doing of the GE06 Plan. However Plan entries of other countries need to be protected and interference from those Plan entries of other countries accepted.

The re-planning process is likely to be complex and time-consuming and it is not guaranteed that the original coverage can be repaired. DVB-T has already been introduced in 14 European countries (see Fig. 3) and, by the time the process is completed, many more DVB-T transmitters will be in operation. A transition from the original GE06 Plan to a re-planned GE06 Plan will be necessary.

5.2. Guard bands

In order to avoid interference between uplink transmissions and adjacent (downlink) broadcast transmissions, guard bands are needed. The width of a guard band depends on many factors and, according to ongoing studies in ITU-R and elsewhere, may be more than 10 MHz. Also a guard band is needed between the uplink and the downlink sub-band. The total guard bands and thus the unused spectrum may add up to several DVB-T channels.

6. Spectrum use

Bands III, IV and V are the only available bands for obtaining wide-area DVB-T and DVB-H coverage. Following an “Opinion” of the Radio Spectrum Policy Group of the European Union on the introduction of multimedia services [10], CEPT has been mandated to identify appropriate technical and regulatory parameters for opening up the band 1452 to 1479.5MHz to allow flexible use by a wide range of mobile multimedia technologies. However the propagation characteristics and the width of this band (25.5 MHz) are in general not adequate to plan nationwide coverage in each of the European countries, even if a 5 MHz DVB-T or DVB-H bandwidth is chosen.

UMTS services can be operated in several bands and a series of possible extension bands have been identified including Band IV and V [11].

6.1. Broadcasting use of Band IV and V

In order to motivate consumers to buy a digital receiver for terrestrial services, an attractive broadcast package needs to contain 20 to 30 popular programmes. Such a number is also needed to

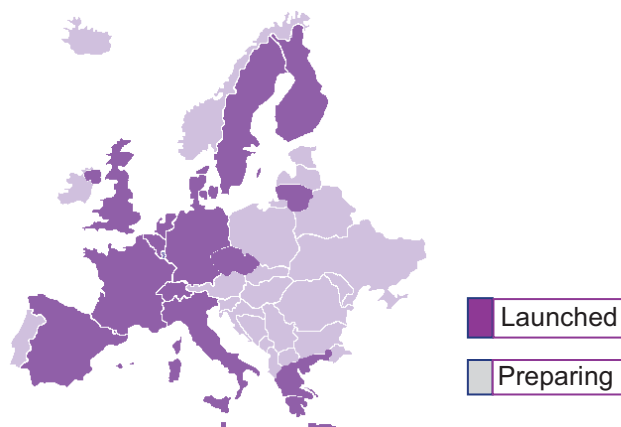


Figure 3
European DVB-T map (from DigiTag)

provide better competition to satellite and cable delivery. A large number of programmes that are of high individual interest to only a few people can best be delivered by means of on-demand services: for example, via UMTS in the case of reception on small screens. This could be facilitated by means of a common Electronic Service Guide (ESG). These on-demand services could include public and commercial programmes received outside the national territory, for instance by travellers and tourists wishing to receive their homeland programmes.

The number of layers which can be provided by GE06 is very large and significantly increases the spectrum usage as compared to ST61; in fact, this usage exceeds the theoretical capacity of the frequency bands, at least for the technical conditions used at RRC-06. These “extra” layers have been achieved at the expense of accepting higher interference levels which may result in lower quality services and/or reduced coverage areas. To overcome these difficulties when implementing the Plan and in order to provide reliable services, it may be necessary to deploy additional transmitters and additional frequencies.

In order to provide an acceptable video and audio quality on conventional displays, three to four programmes can be accommodated in a multiplex for portable reception (16 Mbit/s) and five to six programmes in a multiplex for rooftop reception (24 Mbit/s). The average data capacity allocated to each programme could be from 3 to 4 Mbit/s depending on the DVB-T variant used and depending on the statistical multiplexing, if used [12].

It should be noted that quality requirements need to be increased with the advent of flat-panel screens. These kinds of screens are very popular and are, or will be, used soon in many households. EBU investigations have shown that flat screens are more sensitive to artefacts and, for a good picture, require about twice the bitrate needed for Cathode Ray Tubes (CRTs) [13] [14].



The video compression system MPEG-4 will enable a lower bitrate compared to MPEG-2, while maintaining the same quality. Use of MPEG-4 could therefore compensate for the higher bitrate demand of flat-panel displays. A number of countries, where DVB-T is yet to start, are considering or have already decided to use MPEG-4 with DVB-T. However countries that have already introduced DVB-T will need to use additional layers for introducing MPEG-4, with the exception of France where some multiplexes have already been introduced with MPEG-4 (for pay-TV).

Currently DVB-H pilot transmissions are taking place in several countries and are already operational in Italy [15]. In planning DVB-H services, a balance needs to be found between, on the one hand, the radiated power and number of transmitters required to obtain the wanted coverage and, on the other hand, the available bitrate. As the reception conditions are very demanding [8], most operators tend to choose a robust system variant with the consequence of a limited net bitrate. Therefore 10 to 15 programmes may be accommodated in a DVB-H multiplex.

It is expected there will be more than 50 million HD-ready TV sets in Europe by 2010 [16] and, consequently, there will also be a high demand for HDTV programmes. Currently HDTV programmes are delivered by satellite but many European broadcasters are planning to transmit HDTV on terrestrial networks. EBU studies [17] indicate that two HDTV programmes can be accommodated in a DVB-T multiplex for rooftop reception (24 Mbit/s). HDTV is not compatible with standard definition TV reception and therefore HDTV needs to be transmitted in parallel to DVB-T multiplexes.

6.2. UMTS considerations

One option for use of the digital dividend, which is being considered by CEPT, is UMTS. The UMTS Forum considers that 2 x 30 MHz of paired spectrum, based on 5 MHz channelling, would provide a viable minimum coverage extension band for UMTS [18]. This requirement includes a guard band between the uplink and downlink sub-bands and would also require guard bands of 10 to 16 MHz between it and the adjacent sub-bands used for DVB-T.

6.3. Other uses

Assignments to other services having primary status in the Radio Regulations have been taken into account at RRC-06 if so requested by the Administrations concerned. These services include radio navigation and fixed or mobile services for military applications and are shown in the "List" of Annex 5 of GE06. In any re-planning process, if so required, these services need to be taken into account.

In addition there are services with secondary status in the Radio Regulations in Band IV/V. These services are not taken into account when primary services are planned. However, on a national basis, these services could be of great importance, for instance the Radio Astronomy Service in channel 38 and Services Ancillary to Broadcasting and Programme making (SAB/SAP).

SAB/SAP services are of increasing importance because an increase in the number of broadcast programmes means also an increase in the need for facilities to produce broadcast programmes. This is true in spite of the fact that the use of SAB/SAP in Band IV/V is becoming more restricted since the band is densely planned for DVB-T, leaving less room for SAB/SAP transmissions.

7. Digital Dividend choices

From a technical point of view there are two alternative options for digital dividend applications:

Either,

- **Applications making use of Plan entries** that require no or limited modifications to the GE06 Agreement, such as DVB-T, HDTV, DVB-H
 - Some restrictions may be expected because of power limitations and interference levels of the corresponding GE-06 Plan entries.
 - In most cases the services can be implemented under Article 5 of the GE-06 Agreement and no international agreement is needed.
 - In some cases plan modifications may be needed by applying Article 4 of the GE-06 Agreement, requiring the agreement of potentially affected countries.
 - Adjacent channel problems may occur if different network topologies in Band IV/V are used in the same area. These problems need to be solved nationally.

Or,

- **Applications making use of a dedicated sub-band** with the consequence of considerable modifications to the GE06 Plan.
 - In case of uplink transmissions, an allocation in the Radio Regulations for Mobile services would be needed. In addition, guard bands are needed.
 - For new applications, Article 4 of the GE06 Agreement needs to be applied. Restrictions are to be expected in order to protect the GE06 Plan entries of other countries; interference from Plan entries of other countries needs to be accepted.
 - Some technical constraints may arise if different network topologies and systems co-exist in the same bands. Feasibility studies are needed.



Jan Doeven received a bachelor degree in Electrical Engineering in 1971. All through his career, he held leading positions in frequency management and the application of new technologies for broadcasting. He is currently Strategic Technology Advisor of KPN Broadcast Services.

He has participated in EBU activities in the field of radio and television broadcasting for 30 years and has been chairman of the Broadcast-technology Management Committee (BMC) since 1997.

Since the early nineties, Jan Doeven has been deeply involved, nationally and internationally, in the planning and implementation of digital broadcasting networks. He chaired the European preparatory groups for RRC-04 and RRC-06 (CEPT Project Team FM24 and CEPT Working Group RRC-06 respectively) and during RRC-06 he was the overall CEPT coordinator and vice chairman of the Conference.

- Re-planning of the remaining part of the band is needed for DVB-T, requiring application of Article 4 of the GE06 Agreement.
- A transition from the original GE06 plan to a modified plan is needed.
- Re-planning and transition to a modified plan will be a complex and time-consuming process requiring several years of intense international coordination.

In several European countries, five or six multiplexes for DVB-T or DVB-H have been licensed or will be licensed soon. This means that in those countries a considerable part of the digital dividend will be used for categories 1 and 2 (*see Section 1*).

After having licensed five or six multiplexes for DVB-T or DVB-H, in general one or two layers remain. These could in principle be considered for all three digital dividend categories. For application of the third category only (a new use such as 3G), a dedicated sub-band must be considered and consequently a re-planning process. However it raises the following questions:

- Would WRC-07 or WRC-11 indicate Band IV/V as a 3G extension band when there are so many alternatives bands, while Bands III, IV and V are the only possibilities for wide-area coverage of DVB-T and DVB-H?
- Would Administrations be interested in involving themselves in another intensive period of re-planning for digital broadcasting with unpredictable results after having experienced the two sessions of the RRC and more than six years of preparing for these?
- Would broadcasters and network operators be willing to bear the nuisance and the costs of another transition period without the benefit of transmitting additional services?

Only the future will tell!

References

- [1] **Final Acts of the RRC-06 and associated Frequency Plans and List**
ITU, Geneva, 16 June 2006
- [2] Draft RSPG Opinion on EU spectrum policy implications of the digital dividend
- [3] Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions; **EU spectrum policy priorities for the digital switchover in the context of the upcoming ITU Regional Radio-communication Conference 2006 (RRC-06)**
COM(2005) 461, Brussels 29.9.2005
- [4] **Digital dividend**
Editorial by Philip Laven, EBU Technical Review No. 308 (October 2006)

- [5] **Final Acts of the Regional Radiocommunication Conference for the revision of the Stockholm 1961 Agreement (RRC-06-Rev. ST61)**
Geneva, 16 June 2006
 - [6] EBU doc. Tech 3313: **Band I Issues**
EBU, August 2005
 - [7] Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions; **on accelerating the transition from analogue to digital broadcasting**
COM(2005) 204 final, Brussels, 24.05.2005
 - [8] Terry O'Leary, Elena Puigrefagut and Walid Sami: **GE06 – overview of the second session (RRC-06) and the main features for broadcasters**
EBU Technical Review No 308, October 2006
 - [9] EBU doc. Tech 3317: **Planning parameters for hand-held reception, considering the use of DVB-H and T-DMB in Bands III, IV, V and 1.5 GHz**
EBU, November 2006
 - [10] Radio Spectrum Policy Group Opinion on **the introduction of multimedia services in particular in the frequency bands allocated to the broadcasting services**
EU, 25 October 2006
 - [11] Draft CPM report, Chapter 1, ITU-R Document CPM07-2/1-E; 4 October 2006
 - [12] EBU doc I37-2006: **Guidelines for the RRC-06**
EBU, Geneva
 - [13] EBU doc I35-2002: **The potential impact of flat panel displays on broadcast delivery of television**
EBU, Geneva
 - [14] EBU doc I39-2004: **Maximizing the quality of conventional quality broadcasting in the flat panel environment**
EBU, Geneva
 - [15] DVB-H services; <http://www.dvb-h.org/services.htm>
 - [16] **High Definition Television: Global Uptake and Assessment To 2010**
Screen Digest, March 2006
 - [17] EBU doc Tech 3312: **Digital Terrestrial HDTV Broadcasting in Europe; The data rate capacity needed (and available) for HDTV**
EBU, February 2006
 - [18] **Coverage Extension Bands**
Report No. 38 from the UMTS Forum
-