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Dedicated to Kai and Chris

Contents

List of Figures

List of Tables

List of Acronyms

3DTV	Three-Dimensional Television
3GPP	Third Generation Partnership Project
ABA	African Broadcasting Area
ACLR	Adjacent Channel Leakage Power Ratio
ACS	Adjacent Channel Selectivity
BEM	Block Edge Mask
BR	Radiocommunication Bureau of the ITU
CEPT	Conférence Européenne des Administrations des Postes et des Télécommunication
CERP	European Committee on Postal Regulation
CNG	Coordination and Negotiation Group
COFDM	Coded Orthogonal Frequency Division Multiplex
CPG	Conference Preparatory Group
CPM	Conference Preparatory Meeting
DAB	Digital Audio Broadcasting
DD	Digital Dividend
DQPSK	Differential Quadrature Phase Shift Keying
DRM	Digitale Radio Mondiale
DTT	Digital Terrestrial Television
DVB	Digital Video Broadcast
DVB-NGH	Digital Video Broadcast-Next Generation Handheld
DVB-T	Digital Video Broadcast-Terrestrial
DVB-T2	Digital Video Broadcast-Terrestrial 2
EBA	European Broadcasting Area
EBU	European Broadcasting Union
EC	European Commission
ECA	European Common Allocation Online Database
EIRP	Effective Isotropically Radiated Power
EP	European Parliament
ERC	European Radiocommunications Committee
ECO	European Communication Office

ERP	Effective Radiated Power
FCC	Federal Communications Commission
FDD	Frequency Division Duplex
FFT	Fast Fourier Transform
FIC	Fast Information Channel
FM	Frequency Modulation
GE06	Final Acts of the Regional Radiocommunication Conference, Geneva, 2006
GE89	Final Acts of the Regional Administrative Radio Conference, Geneva, 1989
GSM	Global System for Mobile Communication (formerly: Group Spécial Mobile)
HbbTV	Hybrid Broadcast Broadband Television
HDTV	High Definition Television
IPG	Intersessional Planning Group
ITU	International Telecommunication Union
JTG5-6	Joint Task Group of ITU-R Study Groups 5 and 6
LNM	Log-Normal Method
LTE	Long Term Evolution
MIFR	Master International Frequency Register
MPEG	Moving Picture Expert Group
PAL	Phase Alternating Line
PXT	Planning eXpert Group
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RA	Radiocommunication Assembly
RPG	Regulatory and Procedural Group
RRC-04	First Session of the Regional Radiocommunications Conference, Geneva, 2004
RRC-06	Second Session of the Regional Radiocommunications Conference, Geneva, 2006
RSC	Radio Spectrum Committee of the European Commission
RSD	Radio Spectrum Decision
RSPG	Radio Spectrum Policy Group of the European Commission
SAB/SAP	Services Ancillary to Broadcasting and Programme Making
SDR	Software Defined Radio
SDTV	Standard Definition Television
SRD	Short Range Devices
ST61	Final Acts of the European VHF/UHF Broadcasting Conference, Stockholm, 1961
TDD	Time Division Duplex
TFA	Table of Frequency Allocations
TRU	Temporary Retune Units
UHDTV	Ultra High Definition Television
UHF	Ultra High Frequency

UMTS	Universal Mobile Telecommunications System
UN	United Nations
UPU	Universal Postal Union
VHF	Very High Frequency
WRC-07	World Radiocommunication Conference 2007

Chapter 1
Introduction

The decades before and after the millennium stand for a dramatic change of the way we work, communicate and spend our spare time. What has started some 20 years ago can without any doubt be called a revolution, a digital revolution. Digital technologies spreading out into any area of daily life have transformed our planet irreversibly. Computers and telecommunication devices are omnipresent. Information in digital form can be accessed virtually from everywhere at any time. Even though the digital revolution concentrated on the introduction of more and more powerful computers and advanced communication devices at the beginning, digital technologies are meanwhile infiltrating any aspect of a modern society. And it seems like there is no end. What we saw so far might just be a digital dawn.

Quite naturally the digitization had a tremendous impact on the way people are consuming media too. It seems like half a century ago life was pretty simple in that respect. There were printed media like newspapers or books, radio and television services, and if one wanted to make a phone call either a fixed line at home or a telephone booth had to be used. All these sources and means of information were clearly separated and arranged. Today our world is different. New devices allow to access any kind of media content on a single technical platform. Also, instead of a limited number of available radio and television programs, the offer seems to be infinite, only restricted by bandwidth and money to be paid to get access.

Digitization has also turned up side down the whole broadcasting sector. The entire production chain of radio and television programs has been switched to digital technology in the meantime. Digital cameras, digital cut but in first line digital archive systems are meanwhile taken for granted. On the other side, the delivery of programs to listeners and viewers still has not been fully migrated to digital transmission technology. It is true that in Europe and the USA both on cable and satellite digital services are constantly gaining ground. But, in particular, on the terrestrial distribution platform analogue transmission still holds a significant share.

Any transition from analogue to digital distribution technology paves the way to more efficient spectrum usage. Sophisticated compression techniques allow a dramatic increase of the data capacity that can be provided within a given portion of the electromagnetic spectrum. The consequences are also apparent in the case

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of terrestrial broadcasting. Migrating from analogue towards digital terrestrial broadcasting led to the definition of one of the most famous terms in the field of spectrum management in recent years, namely the Digital Dividend. For many people, this term is a like red rag to a bull, others get teary-eyed thinking about the opportunities the Digital Dividend might promise or is believed to promise. The perception is rather black-or-white, there does not seem to be any in-betweens and it obviously depends on which community people belong to.

In the first place, the Digital Dividend refers to releasing spectrum allocated to terrestrial television services in the UHF bands. When switching from analogue to digital terrestrial broadcasting more than one programme can be accommodated within a single television channel. Roughly speaking, four or more digital programmes can be offered instead of one analogue programme. From a technological point of view, this can be achieved by combining a set of programmes into a multiplex.

The simple straightforward calculation to quantify the Digital Dividend is to say if a single TV channel can accommodate four instead of one programme, then only 25% of the once occupied spectrum needs to be retained for terrestrial television after the digital transition. The remaining 75% could be released and consequently used for other purposes. Not surprisingly, broadcasters are not willing to subscribe to such an over-simplified point of view. Firstly, the idea to bundle programmes into multiplexes does not comply necessarily with the coverage demands of all the different broadcasters. Secondly, from the very beginning of the Digital Dividend discussion it seemed to be self-evident that any released spectrum should be given with priority to mobile services. It is obvious that such understanding can hardly be shared by broadcasters.

There is no doubt that introducing digital terrestrial broadcasting technologies will lead to more efficient use of spectrum. Consequently, part of the spectrum will be released. The amount of released spectrum depends on many parameters such as existing broadcasting coverage types which certainly differ from country to country and last but not the least the employed digital broadcasting technology. Hence, the crucial question in that respect is not whether there is a Digital Dividend after the transition from analogue to digital terrestrial broadcasting, but which service is to use how much of it and under what conditions.

This book tries to shed some light on the Digital Dividend discussion from a broadcaster's point of view. Furthermore, a Europe centric position is mainly taken. The current situation in international frequency management is briefly sketched. Several aspects regarding the Digital Dividend are addressed such as the digital switch-over in terrestrial broadcasting and consequences arising from the identification of spectrum that could be released for other purposes. The impact on terrestrial broadcasting is discussed by having a look on situations in countries in different regions of the world. Finally, a cautious glimpse into the future of the broadcasting sector is provided trying to highlight those trends and developments that might affect terrestrial broadcasting as a whole. This is concluded by a discussion of the consequences that seem to give rise to a new broadcasting paradigm.

Chapter 2
Digital Terrestrial Broadcasting Systems

The success story of radio and television was originally based on terrestrial transmission. At a suitable location a transmitter was erected that would broadcast radio and TV signals using corresponding equipment and antennas. The listener or viewer was expected to make a certain reception effort. In the case of television, he or she was to erect an antenna on top of the roof of the house with a sufficiently high directivity. Most of the stationary receivers were fed by correspondingly adopted antenna systems.

At the end of the twentieth century the supremacy of terrestrial broadcasting over other distribution paths was definitely lost. Other distribution forms like cable and satellite had significantly overrun the terrestrial platform in many countries. Also, consumption of audio and video content across the Internet has gained ground. However, there are still many regions around the globe where terrestrial broadcasting constitutes the primary means to deliver radio and television programmes to the listeners and viewers.

When it comes to distribution the situation is different in several aspects for television and radio. Today, terrestrial broadcasting is still the most important way to deliver audio programs to the listeners. This is mainly due to the fact that listening to radio is something people do while being involved in other activities such as driving in a car, being at work or during leisure time. Most of these activities can be described by mobile or portable reception conditions using simple portable receivers. The dominance of mobile and portable consumption of radio services is to some extent in contradiction with the planning principles for FM transmission which has not been designed for mobile reception in a vehicle. Originally, only fixed reception using a roof top antenna was foreseen. However, the technological development of new receivers allowed to provide FM services also under portable and mobile receiving conditions.

Analogue terrestrial broadcasting of both radio and television services got under pressure due to two fundamental problems. Firstly, with the advent of digital media such as CDs customers got used to high audio and video quality. This could not always be provided across terrestrial distribution platforms. Moreover, the lack of spectrum did not allow to provide a greater variety of programmes. Hence, more

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efficient spectrum usages became an important issue. This was certainly one of the reasons for the development of digital terrestrial broadcasting systems. To this end, primary objectives were a resource saving usage of radio frequencies, high transmission quality, and a large enough data capacity to allow for a sufficient number of attractive programs. In the case of radio, the possibility for mobile reception even at high velocities was an important issue in order to reach in particular vehicles moving on highways and also high velocity trains.

Over the last two decades several digital terrestrial broadcasting systems have been developed. Even though they might target at different services under different conditions, they exhibit several common technical features. Usually, multi-carrier technology is employed and psycho-acoustic or psycho-visual effects are exploited to significantly reduce the amount of data that needs to be transmitted in order to maintain a certain level of quality of the audio or video signals. Furthermore, the transmission is protected against perturbation by the application of sophisticated error protection mechanisms. In the following section some important systems will be described very briefly.

2.1 Digital Terrestrial Radio Systems

Many different digital terrestrial broadcasting systems have been proposed for the delivery of radio content over the last 20 years. Since audio content requires only limited data rate between 48 and 192 kBits/s radio content has often been provided piggyback on television systems if spare data rate was available. However, radio and television programmes quite often have different coverage and reception targets. Therefore, it is reasonable to develop broadcasting systems that are optimized for distribution of radio programmes. The three most important systems currently being implemented or already in operation are briefly sketched in the following subsections.

2.1.1 The DAB-Family

The digital terrestrial broadcasting system known as Digital Audio Broadcast – Terrestrial (T-DAB) has been drafted around 1990 in the framework of the European research and development program Eureka 147 [EUR96]. It has been standardized in 1997 [ETS97a] and rests on four basic pillars, namely an appropriate source coding technology (MPEG-1, layer II [ISO93] also known as MUSICAM), special channel coding algorithms (punctured convolutional codes[Pro89]), multiplexing of several programs, and coded orthogonal frequency division multiplex (COFDM) as the modulation scheme (MS) for the signal transmission.

Originally, the intention was to develop a radio broadcasting system that could become a successor of FM radio in Band II, i.e. 87.5–108.0 MHz. The idea was to

Table 2.1 The four possible operation modes for T-DAB

	Mode I	Mode II	Mode III	Mode IV
Number of carriers	1536	384	192	768
Carriers spacing Δf (kHz)	1	4	8	2
Symbol length T_S (μs)	1246.0	311.5	155.75	623.0
Guard interval T_G (μs)	246.0	61.5	30.75	123.0

fade out FM transmissions and use the released spectrum for T-DAB. However, it turned out that this was not feasible due to the simple fact that broadcasters were not willing to shut down any analogue FM stations on which their entire business models rely and take the risk of introducing a digital system. Fortunately, T-DAB was designed to be used in Band III (174–230 MHz) and the L-Band (1452–1479.5 MHz) as well. These are actually the primary frequency bands for T-DAB today. However, it seems that even the L-Band is no longer attractive to be used for T-DAB network implementation.

The COFDM of T-DAB utilizes a nominal bandwidth of 1.75 MHz for the generation of the T-DAB signals. Since T-DAB has been designed for mobile reception in the first place a very robust modulation scheme was mandatory. Therefore, the differential modulation DQPSK[1] has been chosen.

Each T-DAB signal is built by a sequence of successive COFDM symbols. A number of 76 symbols is grouped to build a so-called T-DAB frame which is preceded by the null symbol. During the duration of the null symbol there is no power output of the transmitter at all. It allows a first rough synchronization of the receiver. The null symbol is followed by the phase reference symbol whose carrier phases are known to the receiver. This constitutes a repeated starting point for the calculation of the phase differences of the carriers of successive symbols.

Four different sets of COFDM parameters can be selected in order to adapt T-DAB to different coverage environments and coverage targets. Table 2.1 gives an outline of the four sets of allowed COFDM parameters.

The usage of a guard interval allows operating T-DAB in a single frequency network (SFN) mode. This means that all transmitters in a network providing the same content can make use of the same frequency. In areas where signals from several transmitters are received better reception can be provided in contrast to analogue system where under the same conditions harmful interference would result. More information on SFN planning can be found in [Beu04a] and [Beu08].

The integration of four different system variants in the DAB standard enables T-DAB networks for different purposes. The standard mode, mode I, allows the implementation of networks for large area coverage on the basis of few high power transmitters. Preferably, these should not be separated by more than 73 km. This distance corresponds exactly to the route electromagnetic waves can travel within the period of a guard interval of 246.0 μs. Inter-transmitter distances beyond this

[1] DQPSK means *D*ifferential *Q*uadrature *P*hase *S*hift *K*eying.

limit will then give rise to so-called self-interference. More details concerning different aspect of T-DAB technology can be found in [Wor11].

The system design of T-DAB was optimized with respect to providing audio services (plus additional data) for portable and mobile reception conditions. This determined the choice of COFDM parameters but also had an influence on coding schemes and error protection mechanisms employed. T-DAB allows to transmit pictures or figures but it is not foreseen to broadcast movies or video clips.

Since the early days of T-DAB there has been discussion about the system capabilities. It was argued that even for the broadcasting of audio content only the source coding employed for T-DAB would not be efficient enough. Clearly, T-DAB has been standardized almost two decades ago. Therefore, in recent years the argument was repeatedly put forward that MPEG-1, layer II is outdated. As a consequence and since efficient coding schemes had been introduced in the meantime, an enhancement of T-DAB which is called DAB+ was standardized in 2007 [ETS07].

There are two significant changes in comparison to T-DAB. Firstly, MUSICAM was substituted by the more advanced coding scheme HE AAC v2 [ISO05a]. An overview about this coding scheme can be found e.g. in [Mel06]. This allows higher data reduction rates compared to T-DAB. Secondly, the channel coding has been enhanced as well by adding Reed-Solomon coding in order to make the transmission more robust [Ree60].

The audio program is transmitted as a standard T-DAB data stream after having been encoded by HE AAC v2 and Reed-Solomon. This is actually the reason why in principle it is possible to combine DAB and DAB+ content. In other words, a DAB+ multiplex can be build from audio programs coded with MPEG-1, layer II, i.e. standard T-DAB content, together with others that employ HE AAC v2 [Wor11]. The system is very flexible in that respect.

DAB+ has been optimized to carry audio content rather then video. This is reflected in the fact that video codecs are not supported. Furthermore, all features incorporated into T-DAB like packet mode or the possibility to include program associated data are fully maintained. This would allow broadcasters to continue the production of broadcasting content without any change in case T-DAB is to be substituted by DAB+.

The fact that DAB/DAB+ do not support the distribution of video content has been considered as a major drawback by many people, in particular, as access to video content has become more and more important in recent years. Customers are keen to consume audio and video programs while on the road or in trains. Consequently, the idea emerged to build a system that would allow to satisfy exactly this demand. Digital Multimedia Broadcasting (DMB) as an extension of T-DAB has been developed for that purpose.

For the transmission of audio and video programs to portable and mobile receivers most likely being equipped only with rather small screen and limited storage capacity, a mixture of difference source coding schemes has been employed in T-DMB. Since video transmission calls for higher data rates, better coding algorithms than MPEG-1 layer II are needed. Once MPEG-4 was available the door was open for this. In T-DMB, video content is compressed on the basis of MPEG-

4/AVC [ISO05b] while audio programs are encoded with the help of HE AAC v2 [ISO05a]. This choice reflects the fact that T-DMB has been optimized to broadcast television content. Even though, in principle, audio programs can be broadcast as well via DMB, this is usually not recommended.

2.1.2 Digital Radio Mondiale

Terrestrial radio broadcasting can make use of several different frequency ranges. The DAB family of standards described above is intended to be put into operation in the frequency band III and the L-Band, i.e. 174–230 MHz and 1452–1479.5 MHz respectively. T-DAB systems are considered as broadband systems because they occupy a bandwidth of 1.75 MHz.

Many broadcasters have not been very fond of T-DAB at all. In particular, many commercial broadcasters were and still are reluctant to subscribe to the idea of putting their programmes in a multiplex together with their direct competitors. In a FM world radio services are provided on the basis of the philosophy of "one frequency – one station – one programme". This gives rise to unique coverage areas and associated quality of service for particular receiving conditions. As a matter of fact, this creates a situation where a direct comparison between different programmes in terms of covered population or area is not straightforward. In relation to negotiations with the advertising industry this can be an advantage.

However, if programmes are bundled into multiplexes all contained programmes have the identical coverage area and they can be received at the same quality of service throughout this area. If a particular programme has more listeners than another one, the difference can no longer be disguised. This may lead to problems when it comes to attract advertisement partners. Certainly, this is one of the reasons why in some countries commercial broadcasters are reluctant to switch to DAB.

A system that follows more closely the traditional analogue philosophy of using spectrum is called Digital Radio Mondiale (DRM). It is a COFDM system like T-DAB, too. According to the standard [ETS05] DRM can be used below 30 MHz, i.e. in the short and medium wave regime. In the first place, DRM is a digital terrestrial broadcasting system which is meant to substitute the analogue AM transmissions. Therefore, it employs a bandwidth of 9 or 10 kHz only. Compared to the T-DAB family of standards this is very narrowband. However, such a bandwidth has been chosen to fit DRM into the existing AM channel raster.

Based on the coding scheme MPEG-4 HE AAC v2 [ISO05a] a bandwidth of 10 kHz allows to obtain between 8 kBits/s and 20 kBits/s depending on the amount of data capacity that needs to be dedicated to achieve a certain degree of ruggedness against propagation perturbations. HE AAC v2 is the right choice for audio content. For speech programs other coding schemes like MPEG-4 CELP or MPEG-4 HVXC (which are both part of the MPEG-4 family) can be utilized. These coding schemes are particularly adapted to these kinds of input signals.

Similar to T-DAB the several program input streams can be bundled into one multiplex but this is not mandatory. Channel coding to protect the transmission against propagation errors is added, too, as well as time interleaving. In order to allow the receiver to synchronize to the signal pilot carriers are included as well. A very detailed description of the DRM system can be found on the website of the DRM forum [DRM11].

AM broadcasting is still very important in many parts of the world. Countries such as Russia, China, India, Brazil, and many African countries need to cover very large areas. This is where AM transmissions are very well suited due to the far reaching wave propagation conditions in the AM frequency bands. Furthermore, in comparison to analogue AM transmissions DRM offers a quantum leap in terms of quality of service. Typically, DRM in the AM bands can provide radio services with a quality sometimes almost as good as FM in Band II depending on the circumstances.

For Europe AM is no longer a very attractive option. The operational costs of AM networks are high and since the coverage is far reaching the system does not very well suit the needs of regional or local radio broadcasters. However, what is attractive is that like FM one broadcaster could make use of one station, using one frequency to broadcast a single programme.

Therefore, the DRM standard was extended in 2009 to the broadcasting frequency bands up to 174 MHz [ETS09]. This frequency range includes the broadcasting bands I and II, i.e. 45–85 MHz and 87.5–108 MHz. Instead of creating a new standard it was decided to add an additional mode, mode E, which corresponds to the DRM variant to be use at higher frequencies. Mode E of the DRM standard is usually addressed as DRM+.

The most important change is the extension of the occupied bandwidth to 100 kHz. All COFDM parameters are adapted appropriately. This was done in order to make DRM+ compatible with the existing European frequency raster in Band II which is 100 kHz. Therefore, subject to the definition of corresponding sharing and compatibility criteria with FM services DRM+ could be used to migrate from analogue to digital broadcasting also in Band II.

The development and standardization of DRM+ constitutes a large step forward on the way to the digital switch-over for terrestrial radio services. At the beginning of this process T-DAB and DRM+ were considered as competing systems. In the meantime, however, it became clear that they rather should be seen as complements in the sense that DRM+ could build the bridge across which commercial broadcasters could go to digital terrestrial broadcasting because it might better suit their special needs.

Due to the fact that the Band II frequency range is overcrowded in most countries in Europe it was proposed to even further extend the spectrum range for DRM+. The idea is to include the entire Band III range for broadcasting, i.e. 174–230 MHz. The process has been initiated and it can be expected that in the coming years the DRM standard will modified correspondingly.

2.1.3 HD Radio

In the USA, a proprietary standard for a digital terrestrial radio broadcasting system, called HD Radio, has been developed. It can be employed in the AM and FM bands. The development was governed by the intention to support simultaneous operation of legacy analogue services, while allowing for gradual transition to digital services. Currently, the system is implemented in the USA and it is considered in some other countries. The technical specification of the system can be found at [NRS11]. Details about the roll-out can be found in [HDR11] or at [iBi11].

The basic idea of HD Radio is to transmit one or two digital signals alongside with an analogue AM or FM signal. The digital signals employ COFDM modulation techniques. In the FM case, the digital blocks are located at ± 150 kHz from the centre frequency of the analogue FM signal. In principle, any frequency separation could be used. However, both the US frequency raster of 200 kHz (in contrast to the European 100 kHz raster) and system design aspects suggest such a separation. Adjusting the power levels of the digital side lobes appropriately, i.e. requesting for example a power reduction of 23 dB with respect to the analogue signal, results in a signal configuration which does not lead to unacceptable interference in a typical US frequency environment.

HD Radio can be operated in several different modes. In principle, the analogue signal can be accompanied by one or two digital COFDM components each occupying a bandwidth of optionally 70 or 100 kHz. Therefore, a maximum bandwidth of 400 kHz is occupied. If analogue and digital signals are broadcast in parallel, the system is said to work in hybrid mode. However, at a certain point in time the broadcaster can decide to cease the analogue–digital simulcast and switch off the analogue part in the middle. The released centre spectrum can re-used by transmitting a third COFDM block instead. This would constitute the full digital mode of HD Radio. In hybrid mode, a bit rate of the digital part of 96 kBit/s can be achieved. This allows for up to three digital programmes to be broadcast. One of these, however, has to be identical to the analogue FM programme. In the all-digital mode, the bit rate is up to 300 kBit/s.

Designing HD Radio the way it is known today was driven by the wish to support new digital receivers while retaining backward compatibility with existing analogue receivers under US regulation. Furthermore, existing equipment and infrastructure of radio stations should be utilizable as much as possible in order to minimize conversion costs. Finally, HD Radio should allow for a potential migration to all-digital services when conditions are favorable (e.g. when digital receiver penetration is sufficient).

In particular for public service broadcasters, it is important to note that HD-Radio is a proprietary system that requires annual license fees to be paid by broadcasters.

2.2 Digital Terrestrial Television Systems

Several digital terrestrial broadcasting systems for the distribution of television services have been developed and rolled-out in different parts of the world. Some of them are briefly introduced here.

2.2.1 Digital Video Broadcasting (DVB-T)

In the beginning of the 1990s digital video broadcasting (DVB-T) was developed. Several international organizations like the European Telecommunications Standards Institute (ETSI) [ETS11], the European Committee for Electrotechnical Standardization (CENELEC) [CEN11], and the European Broadcasting Union (EBU) [EBU11] have been actively involved in the development process. DVB-T constitutes an open standard as does T-DAB.[2]

Obviously, television broadcasting has a different focus than audio broadcasting. In the first place, a significantly larger technical effort is necessary than in the case of audio broadcasting. This is related to the data capacities that are required to provide a satisfying television service. They exceed those of typical audio programs by an order of magnitude. This did not change in the digital age either. Furthermore, the acceptable error rates for television broadcasting are significantly smaller at the same time.

Analogue television has been planned for fixed roof top reception. Even though portable analogue reception might be feasible in the vicinity of a transmitter, mobile reception does usually not work. On the contrary, DVB-T was designed to allow reception of television content also under portable and mobile receiving conditions. Portable can refer to both indoor and outdoor portable reception. For mobile reception it might be necessary to foresee a larger receiving effort to be taken such as multiple antennas.

As in the case of T-DAB several television programmes are bundled to form a programme multiplex. A programme consists of video signals, audio signals and pure data. All three types of data undergo data reduction procedures based on MPEG-2. MPEG-2 offers the freedom to assign different data rates to each of the programs in the multiplex in an independent manner. This means the data rate for each of the programs can be adapted to comply with predefined coverage targets. Once the data reduction is accomplished for the video, audio, and data part of a single television program, they are bundled into a sub-multiplex. Together with further programs and service information the DVB-T multiplex is subsequently built.

[2]There are different definitions of the term open standard. However, publication of all details of the standard accessible to anybody free of royalty fees are common elements of all definitions.

Table 2.2 Potential COFDM parameters for DVB-T [ETS97b]

	2k mode			8k mode		
Bandwidth of TV channel [MHz]	6	7	8	6	7	8
Evaluation window T_W [μs]	298	256	224	1194	1024	896
Carrier spacing Δf [Hz]	3348	3906	4464	837	977	1116
DVB-T bandwidth B [MHz]	5.72	6.66	7.612	5.71	6.66	7.609

Channel coding is the next step. Several mechanisms are applied for that purpose. Reed–Solomon and punctured convolutional codes are employed in order to make the transmitted data more rugged against transmission errors. In order to further enhance the Reed–Solomon coding a bit interleaving step is introduced before the convolutional coding is carried out. Finally, the baseband signal is generated by a COFDM modulator. Details of the whole process can be found in [Rei01] or in the standard of DVB-T itself [ETS97b].[3]

One additional important difference between T-DAB and DVB-T is worth mentioning. In the case of T-DAB, the data reduction and channel coding are applied before the multiplex is generated, while for DVB-T the protection against propagation influences is added only after the multiplex has been built. As a consequence, for T-DAB there is no need to decode the entire signal in order to access a particular programme. This is different for DVB-T where first the entire data stream needs to be decoded before the information relating to a particular programme can be further processed.

In Europe, there are several channel rasters used in the spectrum ranges allocated to television broadcasting. Basically, the spectrum bands are subdivided into 8 MHz channels. This holds in particular for the UHF range. In VHF, there are countries, in particular European countries, which use a 7-MHz bandwidth. In other parts of the world, there are also channel rasters based on a 6-MHz spacing. The standardization of DVB-T took account of this and consequently DVB-T can be operated on the basis of the channel bandwidths 6, 7 or 8-MHz, respectively. The system has been designed initially for the 8 MHz case only. Values for system parameters connected to a bandwidth of 6 or 7 MHz can be derived from the 8 MHz values by a corresponding scaling of the underlying system clock by a factor 6/8 and 7/8, respectively.

Apart from the basic decision which bandwidth is to be utilized there are two fundamental system configurations that can be implemented. They differ by the number of carriers employed for the COFDM modulation. It is possible to use either 1705 or 6817 carriers. They are called 2k or 8k mode, respectively. Depending on the used bandwidth different durations of the evaluation window T_W and the carrier spacing Δf result. Table 2.2 summarizes the most important parameters.

[3] DVB-T has been adopted by the International Telecommunications Union (ITU) as well. In the ITU world it is referred to as system B described in [ITU09].

For the two modes a total of six different guard intervals T_G have been defined. The four values $T_G = 224, 112, 56,$ and $28\,\mu$s can be used in 8k mode while for the 2k mode $T_G = 56, 28, 14,$ and $7\,\mu$s are allowed. So, the values $56\,\mu$s and $28\,\mu$s are available for both modes. If two transmitters in a DVB-T SFN are separated by more than a distance $\Delta r = c * T_G$ self-interference can result. The quantity c denotes the velocity of light. This has a direct impact on the network implementation. As DVB-T is a COFDM system making use of a guard interval large area coverage can be provided in terms of a single frequency network. However, in order to avoid self-interference the only viable option is to employ the 8k mode together with $T_G = 224\,\mu$s.

In contrast to T-DAB, it is possible to employ several different modulation schemes. Either QPSK, 16-QAM or 64-QAM can be applied.[4] The amount of data that can be transmitted increases from QPSK to 64-QAM. On the other hand, the transmission becomes less rugged at the same time. In fact, from QPSK to 64-QAM an increasing protection ratio between the useful and the unwanted signal contributions has to be taken into account. As a matter of fact, more elaborate network structures might be needed. Fortunately, DVB-T offers the possibility to adjust different error protection levels (EPL). This can be used to counterbalance the consequences of higher MSs.

DVB-T does not use a differential MS. Therefore, it is necessary to dedicate a fraction of the total data capacity for synchronization purposes. A subset of the total number is utilized as pilot carriers. They have precisely defined amplitudes and phases which are known to the receiver. There exist two types of pilots. The first type has fixed positions within the used bandwidth. Furthermore, there are pilots which change their position within the spectrum from one symbol to the next. The way they change their position is purely deterministic and also known to the receiver. This offers additional protection for the synchronization against degradation caused by narrow band fading as a consequence of multi-path propagation conditions.

The net data rate of DVB-T is independent of the chosen mode. Both 2k as well as 8k allow the transmission of the same amount of data per second. It is true that the 8k mode employs four times more carriers than in the 2k case. But, at the same time the symbol length is four times as large for 8k variants, so that after all the data capacity remains the same. The crucial factors determining the data capacity are the MS applied, the EPL, the duration of the guard interval and the bandwidth used. By varying these parameters a huge variety of different operational system variants can be put into practice. Table 2.3 presents the most important possibilities. For a more profound discussion it is referred to [Rei01].

The total data capacity of DVB-T allows to broadcast a multiplex containing 4–6 television programmes in standard quality. However, in principle, it is also possible to utilize the available capacity to broadcast 1–2 programs in HDTV quality. More information on HDTV can be found for example in [Woo06]. Even though from

[4]QPSK means *Q*uadrature *P*hase *S*hift *K*eying whereas QAM stands for *Q*uadrature *A*mplitude *M*odulation.

Table 2.3 Net data rates for different DVB-T operation modes in the case of an 8-MHz TV channel[ETS97b]

		Net bit rate (MBits/sec)			
MS	EPL	$T_G/T_W = 1/4$	$T_G/T_W = 1/8$	$T_G/T_W = 1/16$	$T_G/T_W = 1/32$
QPSK	1/2	4.98	5.53	5.85	6.03
QPSK	2/3	6.64	7.37	7.81	8.04
QPSK	3/4	7.46	8.29	8.78	9.05
QPSK	5/6	8.29	9.22	9.76	10.05
QPSK	7/8	8.71	9.68	10.25	10.56
16QAM	1/2	9.95	11.06	11.71	12.06
16QAM	2/3	13.27	14.75	15.61	16.09
16QAM	3/4	14.93	16.59	17.56	18.10
16QAM	5/6	16.59	18.43	19.52	20.11
16QAM	7/8	17.42	19.35	20.49	21.11
64QAM	1/2	14.93	16.59	17.56	18.10
64QAM	2/3	19.91	22.12	23.42	24.13
64QAM	3/4	22.39	24.88	26.35	27.14
64QAM	5/6	24.88	27.65	29.27	30.16
64QAM	7/8	26.13	29.03	30.74	31.67

a technical point of view this is certainly feasible it has to be borne in mind that HDTV via DVB-T will then result in a demand for frequencies similar to that of analogue television.

2.2.2 Digital Video Broadcasting-Handheld (DVB-H)

Portable and mobile reception is becoming a more and more important issue both for network providers as well as for providers of any kind of telecommunication services including broadcasters. This led to the demand that also television services should be receivable under these conditions. DVB-T as it has been standardized in [ETS97b] is not the appropriate system. Under certain conditions, e.g. using antenna diversity in order to boost the antenna gain, it is possible to achieve mobile reception for DVB-T, too. But it is not a very efficient way to provide mobile television. In principle, T-DMB could be employed for this (see Sect. 2.1.1). However, the data rates that can be reached might not be sufficient.

Therefore, a variant of DVB-T has been designed which should be able to provide television services in particular for portable and mobile usage with acceptable quality. This means that in the first place a handheld receiver has to be targeted at. This includes multimedia mobile phones with color displays as well as personal digital assistants or pocket PC types of receivers. All these devices have one thing in common, namely that they are rather small, having only light weight and – very important – are energized by batteries. Apart from that, portable and mobile reception naturally includes indoor reception, sometimes even deep indoor, i.e. in

Table 2.4 COFDM parameters for DVB-H

	2k mode	4k mode	8k mode
Number of carriers	1705	3409	6817
Evaluation window T_W [μs]	224	448	896
Guard intervals T_G [μs]	7;14;28;56	14;28;56;112	28;56;112;224
Carrier spacing Δf [Hz]	4464	2232	1116

basements or deep inside concrete buildings. This requirement is however in conflict with the small dimensions of the receiving devices since handheld devices employ built-in antennas. These usually have rather poor receiving characteristics both in terms of antenna gain as well as directivity. A multi-antenna diversity approach to improve the receiving characteristics is all but impossible under such conditions.

In November 2004, the digital video broadcasting – handheld (DVB-H) standard has been published by ETSI [ETS04a]. DVB-H is to large extent compatible with DVB-T. This has been explicitly taken care of when designing the system because one of the requirements in particular of broadcasters was to be able to implement DVB-H networks with the help of existing DVB-T networks, too.

Nevertheless, several major changes in relation to DVB-T have been introduced. The energy problem linked to battery operation of receiving devices has been tackled by introducing a special power-saving mechanism called time slicing. In the case of DVB-T, the whole data stream has to be decoded before individual programs can be accessed. This poses a severe problem for handheld devices powered by batteries due to high power consumption. For the DVB-H standard this problem has been resolved by transmitting the data associated with a particular service not continuously but only throughout dedicated time slices. In between these slices when other DVB-H services are broadcast the receiver switches to a power-saving mode [ETS04b].

Furthermore, an enhanced error-protection scheme has been incorporated. It is called "multi-protocol-encapsulation – forward error correction" (MPE-FEC). A prerequisite of this is that in contrast to DVB-T where the DVB transport stream is based on MPEG-2, DVB-H is based on IP. This is accomplished by adapting the DVB Data Broadcast Specification to allow for the "Multi-Protocol–Encapsulation" [ETS04b]. On the level of MPE additional forward error protection is added which is MPE-FEC. It basically consists of a special Reed–Solomon code together with a block interleaver. MPE-FEC imposes a frame structure which is aligned with the time slicing technology of DVB-H. More details can be found, for example, in [Kor05] or [Far06].

A further modification of the DVB-T standard for DVB-H relates to the incorporation of an additional COFDM mode. DVB-T allows to use either the 2k or the 8k mode. DVB-H can be operated in terms of a 4k mode as well. Table 2.4 shows the differences of the three modes for some COFDM parameters for the case of a 8-MHz channel.

The 4k mode has been introduced in order to allow for network structures which can benefit from both DVB-T modes, namely 2k and 8k. Due to larger guard intervals in comparison to 2k mode, 4k-DVB-H operated in SFN mode allows for a less denser network, i.e. the inter-transmitter distance can be increased without causing self-interference. Moreover, the susceptibility to Doppler shift is reduced compared to the 8k mode. This is particular important in relation to providing services for mobile reception.

2.2.3 Second Generation DVB (DVB-T2)

An ever increasing demand for capacity, for example to provide higher quality, has triggered the development of a second generation digital terrestrial system called second generation DVB (DVB-T2). Similar to the situation of T-DAB also for DVB-T there has been a discussion about the source coding technology MPEG-2. The DVB-T standard has been issued in 1997 and hence the employed source coding could no longer be considered state-of-the art by 2005. Other algorithms had been developed in the meantime. In particular, MPEG-4 is currently the favored machinery to prepare audio and video data for distribution via terrestrial broadcasting systems. Consequently, DVB-T has been extended to make use of MPEG-4 in order to achieve higher data rates.

More capacity can be used to provide more television content in the first place. On the other hand, having more data capacity available opens the door to transmit services of a higher quality such as HDTV. Furthermore, it is also important that part of the additional data rate can be utilized to increase the amount of redundant information in the digital signal and therefore leads to more robustness against propagation influences. In any case, increasing the data rate by applying better source coding algorithms is certainly a big step forward in terms of more efficient usage of spectrum.

DVB-T2 employs also a COFDM scheme similar to DVB-T. However, additional configurations have been included to better adapt the signal robustness versus data rate to particular coverage targets and propagation conditions. Several options are available such as the number of carriers, guard interval sizes and pilot signals, so that the administrative overheads can be optimized for any target transmission channel.

Apart from the different MSs the most significant modification is certainly the incorporation of more advanced error correction capabilities. Instead of convolutional coding together with Reed–Solomon codes, low density parity check (LDPC) coding combined with Bose–Chaudhuri–Hocquengham (BCH) coding is applied. In addition, rotated constellations provide significant additional robustness under difficult propagation conditions.

Further new technologies have been added as well. One of the new features DVB-T2 offers is called multiple physical layer pipes (PLP). Multiple PLPs enable service-specific robustness. For example, a single DVB-T2 transmission multiplex could carry a mixture of high definition services aiming at household television sets fed by rooftop aerials as well as some low-bit rate, more rugged services aiming at portable television receivers or even radio services. Extended interleaving, including

Table 2.5 Comparison of DVB-T and DVB-T2

	DVB-T	DVB-T2
Error correction	Convolutional coding + Reed-Solomon, 1/2, 2/3, 3/4, 5/6, 7/8	LDPC + BCH, 1/2, 3/5, 2/3, 3/4, 4/5, 5/6
Modes	QPSK, 16QAM, 64QAM	QPSK, 16QAM, 64QAM, 256QAM
Guard interval	1/4, 1/8, 1/16, 1/32	1/4, 19/128, 1/8, 119/256, 1/16, 1/32, 1/128
FFT Size	2k, 8k	2k, 4k, 8k, 16k, 32k
Scattered pilots	8% of total carrier	1%, 2%, 4%, 8% of total carrier
Continual pilots	2.6% of total carrier	0.35% of total carrier
Max. data rate	29 MBit/s	47.8 MBits/s

bit, cell, time and frequency interleaving have become part of the specification, too. Table 2.5 summarizes these new features by comparing DVB and DVB-T2.

The DVB-T2 specification was approved in 2008 and published by ETSI in September 2009 [ETS09a]. More information and further references on the DVB-T2 system can be found at [DVB11a].

2.2.4 Next Generation Handheld DVB (DVB-NGH)

DVB-H has been a commercial success in only a very limited number of countries. Therefore, DVB Project [DVB11] initiated the development of a successor system which is called Digital Video Broadcast-Next Generation Handheld (DVB-NGH). It should be more efficient than DVB-H in order to cope with the expected increase of media consumption. The standardization process has been started in spring 2010 and the DVB Project targets the publication of the related ETSI standard(s) in 2011. Under optimistic assumptions the first commercial NGH devices could then become available in 2013.

DVB-NGH is based on DVB-T2 which has already been designed to operate in an mobile environment. However, with DVB-NGH emphasis has been put on the investigation of the possibility to adopt further new technologies which are specific for a mobile scenario. Among possible new approaches under study the most important are the so-called multiple input–multiple output (MIMO) techniques. This means to employ multiple antenna systems in order to improve the performance thanks to spatial diversity. In contrast to DVB-T2 where MIMO is envisaged only on the transmitter side it is foreseen to integrate several antennas into the receivers for DVB-NGH as well.

For video encoding, the scalable video coding (SVC) profile of H.264/AVC standard is under study. It divides the signal stream in two or more quality levels, with different transmission protection, decreasing for higher levels. This ensures, even in the most critical reception (indoor), a minimum quality of service, increasing with more favorable reception conditions (outdoor). It is expected that this way more robustness can be achieved under mobile receiving conditions with velocities of upto 350 km/h.

Another important issue concerning mobile reception is power consumption and thus battery run-time. This has been a particular area of effort during the specification of the system. More details can be found at [DVB11b] and the references given there. Whether DVB-NGH is a successful step forward towards attractive mobile television in view of the developments on the mobile communication side remains to be seen.

2.2.5 *Integrated Service Digital Broadcasting (ISDB-T)*

In the 1990s, the development of a digital terrestrial broadcasting system for television was started in Japan. Two basic constraints had to be taken into consideration during the system design. Firstly, as it is commonplace in many locations around the planet also in Japan spectrum is considered a scarce resource. Therefore, a new digital terrestrial television system had to make use of the available spectrum in an efficient manner. Secondly, HDTV had been an issue in Japan for quite a long time already in contrast to Europe where this has become a hot topic in recent years only. At the same time standard definition quality broadcasting was very successful in Japan. Therefore, any new system would need to able to accommodate SD and HD services side by side.

The 1990s did also see the take-off of the Internet. Forecasts predicted a dramatic growth of this kind of electronic communication. Hence, data cast capabilities have been integrated from the very beginning. Also, it was recognized that portable and mobile reception would become more and more important in the future. This was explicitly taken into consideration when defining the system parameters

Table 2.6 COFDM parameters for ISDB-T

Modulation	QPSK, DQPSK, 16QAM, 65QAM
Error correction coding	Convolutional coding, Reed-Solomon, 1/2, 2/3, 3/4, 5/6, 7/8
Guard interval	1/4, 1/8, 1/16, 1/32
Interleaving	Time, frequency, bit, byte

of integrated service digital broadcasting (ISDB-T). The Japanese digital terrestrial broadcasting system was standardized in 2001 [ARI01].[5] Since 2003, ISDB-T services are operational in Japan.

ISDB-T is a COFDM system like DVB-T. Actually, both are very similar apart from some fundamental differences. ISDB-T can only employ 6 MHz channels. However, more flexibility is offered in the way the occupied bandwidth is used. In the case of ISDB-T, the entire bandwidth of 6 MHz is subdivided into 13 frequency segments. These segments can be independently allocated to different services such as HDTV, SDTV or mobile TV. So, 13 segments can be used for 1 HD (12 segments) plus 1 mobile TV offer (1 segment) or 3 SDTV programmes (3×4 segments). It has to be noted, however, that this organization of spectrum usage differs from the way DVB-T combines several programmes. In both cases, the transmitted signal contains several programmes. However, in DVB-T programmes are multiplexed on the level of sources while in ISDB-T different COFDM blocks are allocated to different programmes. A subset of system parameters are shown in Table 2.6.

Concerning the source coding ISDB-T employs MPEG-2 for audio and video coding even though also MPEG-4/H.264 AVC can be used in the case of one segment utilized to carry programmes targeting at portable and mobile receiving devices. An overview and further references on ISDB-T are to found at [ISD11].

In 2007, an enhancement development to ISDB-T has been standardized which is called ISDB-T International. The main difference between the two systems is that ISDB-T International employs MPEG-4/H.264 AVC also for SDTV and HDTV. More information can be found at [ISD11a].

2.2.6 Advanced Television System Committee (ATSC)

Almost at the same time as the development of a digital terrestrial broadcasting system for television was started in Europe and Japan an effort was made to develop such a system also in the US. Starting from the existing regulatory framework and US market conditions a system was put forward that fundamentally differs

[5] ISDB-T has been adopted by the ITU as well. In the ITU world it is referred to as system C described in [ITU09].

from DVB-T and ISDB-T. It is called Advanced Television System Committee (ATSC) as the organization in charge, i.e. the ATSC. A set of standards are bundled under the ATSC heading in order to define a digital broadcasting system [ATS11]. The standards have been adopted by the FCC in 1996.[6]

ATSC uses TV channels of 6 MHz bandwidth. The first striking difference between ATSC and DVB-T or ISDB-T is that ATSC is not a COFDM system. In contrast to multi-carrier systems ATSC employs a single carrier. This carrier is AM modulated with a baseband signal onto which the broadcasting content has been modulated in terms of a so-called 8VSB modulation. More information on the technical details of the modulation scheme can be found on [ATS11a]. In the 6-MHz channel used for broadcast ATSC, 8VSB carries a gross bit rate of 32 MBit/s, and a net bit rate of 19.39 MBit/s of usable data. The net bit rate is lower due to the addition of forward error correction codes.

The usage of a single carrier system has incontestable disadvantages compared to COFDM systems. First of all, spectrum cannot be used as efficiently as it is possible with the systems described in the preceding sections since the option to deploy SFN networks is not available. Moreover, SFN mode operation rests on the COFDM modulation together with a carefully chosen guard interval. Consequently, such a system is rather robust against interference caused by multi-path propagation conditions which are typically encountered in urban areas.

On the other hand, 8VSB modulation gives rise to better signal-to-noise ratios which is an advantage in terms of ruggedness but also in terms of power consumption both on the side of the transmitter as well as on the receiver side. Using the same transmit power a significant larger area can be covered by ATSC than with a COFDM system. Actually, this was one of the reasons why 8VSB was chosen instead of COFDM because in the US there are large area to be covered with very low population density.

ATSC allows to broadcast up to six SDTV programmes within the bandwidth of a 6-MHz TV channel or a single 1,920 × 1,080 HDTV programme. In 2009, the standard of ATSC was revised in order to include H.264/AVC video coding. Furthermore, ATSC can broadcast 5.1 Dolby Surround sound using Dolby's AC-3 audio coding. The broadcasting content can be enriched by adding several auxiliary datacast services.

It can be noted that the situation is similar to the radio case when comparing Europe and the US. Also, here a system, i.e. HD Radio, has been designed which perfectly fits into the US regulation framework and market but cannot easily be deployed in other environments as well.

[6] ATSC has been adopted by the ITU as well. In the ITU world, it is referred to as system A described in [ITU09].

Chapter 3
Management of the Electromagnetic Spectrum

Telecommunication is omnipresent today. Nearly every household in the western world owns several radios and most of the families have at least one television set. In some countries, for example, in Scandinavia, already in 2003 the number of customers having exclusively a mobile phone contract exceeded the number of cable based subscriptions. Further wireless telecommunication systems are pushing into the market trying to gain ground and customers. The latest success stories of smartphones lead by the famous iPhone clearly underline the importance of terrestrial telecommunication systems.

All these systems are utilizing a part of the electromagnetic spectrum. In order to guarantee interference free coexistence, several international organizations are monitoring and controlling the spectrum usage. The electromagnetic spectrum is subdivided into many bands in which particular services such as broadcasting, mobile or fixed services can be operated under certain conditions. These conditions are set up by international conferences on a world-wide or regional level. Also, bi- and multilateral arrangements govern the spectrum usage.

3.1 International Organizations and Bodies

In the first place, spectrum management falls in the realm of the International Telecommunications Union (ITU). With focus on Europe the Conference Européenne des Administration des Postes et des Télécommunications is taking care of this task. In recent years the European Commission (EC) started to get more and more involved into the field of international frequency management in order to harmonize the spectrum usage amongst members of the European Union. In other parts of the world spectrum management issues are addressed by dedicated regional organizations such as the Inter-American Telecommunication Commission (CITEL) or the Asia-Pacific Telecommunity (APT).

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3.1.1 International Telecommunications Union (ITU)

The ITU [ITU10] has been founded in 1865. Nowadays, it constitutes one branch of the United Nations (UN) and is subject to UN's rules of procedure. This is the basis for successfully coordinating the usage of the electromagnetic spectrum on a global level. The ITU was created to act as an impartial international organization giving a framework in which national governments represented by their administrations and industries can work together in order to operate telecommunication networks and provide services. Moreover, the further development of telecommunication technologies is an important issue dealt with by the ITU as well.

As a matter of course, everyday people around the globe use their telephones to talk to each other. In the past, this came to pass mainly via fixed telephone connections, in the meantime mobile phones are getting more and more important. Access to the Internet and sending and receiving an E-mail has become irreplaceable both in the business sector and in private activities. Travelling is more and more dependent on the telecommunication services. This refers to planning business or leisure trips via the Internet or relying on navigation systems based on GPS. Short Range Devices (SRD) are penetrating our daily lives which means, for example that any new car which is sold somewhere on the planet is equipped with corresponding devices to open and close the doors. All these examples make use of some kind of telecommunication system which benefits from the work of the ITU of managing the radio-frequency spectrum.

The ITU maintains and tries to extend international cooperation between all its Member States in order to allow for a rational use of any kind of telecommunication systems. Organizations and companies in the field of telecommunication are encouraged to participate in all corresponding activities, i.e. research, development and standardization. One of the main objectives of the ITU is to offer technical assistance to developing countries in terms of mobilizing any kind of resources to improve access to telecommunication services in such countries.

The structure of the ITU reflects its main tasks. It is subdivided into three sectors, namely Radiocommunication (ITU-R), Telecommunication Standardization (ITU-T), and Telecommunication Development (ITU-D). Their activities cover all aspects of telecommunication, from setting standards to improving telecommunication infrastructure in the developing world. Each of the three ITU Sectors works through conferences and meetings, where members negotiate agreements which serve as the basis for the operation of global telecommunication services. Study groups made up of experts drawn from leading telecommunication organizations worldwide carry out the technical work of the Union, preparing the detailed studies that lead to authoritative ITU Recommendations. More Information on the scope and structure of the ITU can be found in [ITU11].

ITU-R draws up the technical characteristics of terrestrial and space-based wireless services and systems, and develops operational procedures. It also undertakes important technical studies which serve as a basis for the regulatory decisions made at radiocommunication conferences. In ITU-T, experts prepare the technical specifications for telecommunication systems, networks and services, including their operation, performance, and maintenance. Their work also covers the tariff principles and accounting methods used to provide international service. ITU-D experts focus their work on the preparation of recommendations, opinions, guidelines, handbooks, manuals, and reports, which provide decision-makers in developing countries with “best business practices” relating to a variety of issues ranging from development strategies and policies to network management. Each Sector also has its own Bureau which ensures the implementation of the Sector’s work plan and coordinates activities on a day-to-day basis.

ITU-R is the sector that is to monitor the usage of the electromagnetic spectrum. The technical characteristics and operational procedures under which the spectrum can be utilized are developed here. Member States develop and adopt a large set of particular rules for spectrum usage, called the Radio Regulations (RR) [ITU08]. They serve as a binding international treaty governing the use of the radio spectrum by some 40 different services around the world. Since the global use and management of frequencies requires a high level of international cooperation, one of the principal tasks of ITU-R is to oversee and facilitate the complex intergovernmental negotiations needed to develop legally binding agreements between sovereign states. These agreements are embodied in the RR and in regional plans adopted for broadcasting and mobile services. The RR apply to frequencies ranging from 9 kHz to 400 GHz, and now incorporate over 1000 pages of information describing how the spectrum may be used and shared around the globe.

An important component of the RR is the so-called Table of Frequency Allocation (TFA) in Article 5 of the RR. It describes in detail which part of the electromagnetic spectrum can be used in which geographical region by which service and under which conditions. The portion of the radio-frequency spectrum suitable for communications is divided into “blocks”, the size of which varies according to individual services and their requirements. These blocks are called “frequency bands” and are allocated to services on an exclusive or shared basis. The full list of services and frequency bands allocated in different regions forms the TFA. Even though a particular frequency band might be allocated to a special service like broadcasting, mobile or fixed service, this can be overruled or extended by means of footnotes containing special arrangements between individual countries.

Changes to the TFAs and to the Radio Regulations (RR) themselves can only be made by a World Radiocommunication Conference (WRC). Modifications and revisions of the RR are achieved on the basis of negotiations between national delegations, which work to reconcile demands for greater capacity and new services with the need to protect existing services. If a country or group of countries wishes a frequency band to be used for a purpose other than the one listed in the TFA, changes may be made provided a consensus is obtained from other Member States. In such a case, the change may be indicated by a footnote, or authorized by the application of a RR procedure under which the parties concerned must formally seek the agreement of any other nations affected by the change before any new use of the band can begin.

In addition to managing the TFA, a WRC may also adopt assignment plans or allotment plans for services where transmission and reception are not necessarily restricted to a particular country or territory. In the case of assignment plans, frequencies are allocated on the basis of requirements expressed by each country for each station within a given service, while in the case of allotment plans, each country is allotted frequencies to be used by a given service, which the national authorities then assign to the relevant stations within that service.

With the help of its Bureau ITU-R acts as the central registrar of international frequency use, recording and maintaining the Master International Frequency Register (MIFR). It contains entries for more than a million terrestrial frequency assignments and more than 100,000 entries relating to different satellite services. Furthermore, ITU-R is the central organization coordinating efforts that ensure that all the different telecommunication services can coexist without causing harmful interference to each other. Several computer based tools are offered to Member States to carry out corresponding analyses.

ITU-R prepares the technical groundwork which enables radiocommunication conferences to make sound decisions, developing regulatory procedures, and examining technical issues, planning parameters and sharing criteria with other services in order to calculate the risk of harmful interference.

3.1.2 European Conference of Postal and Telecommunications Administrations (CEPT)

The European Conference of Postal and Telecommunications Administrations (CEPT)[1] [CEP10] is a European regional organization dealing with postal and telecommunications issues and presently has members from 48 countries. It was founded in 1959. Its basic objective is to deepen the relations between members, promote their cooperation and contribute to the creation of a dynamic market in the field of European posts and electronic communications. Any European country can become a Member of CEPT as long as it is a member of the Universal Postal Union (UPU) [UPU10] or a Member State of the ITU. In 1988, CEPT decided to create European Telecommunications Standards Institute (ETSI) [ETS10] into which all its telecommunication standardization activities were transferred.

Representatives of ITU and UPU are usually invited to assemblies of CEPT while other intergovernmental organizations may be invited to participate as observers. This is also possible for organizations having signed a memorandum of understanding with CEPT declaring to subscribe to the rules of procedure of CEPT. Finally, the EC and the Secretariat of the European Free Trade Association (EFTA) are invited to participate in CEPT activities in an advisory manner, with the right to speak but not to vote.

[1]The acronym “CEPT” stems from the French name “Conference Européenne des Administration des Postes et des Télécommunications”.

The CEPT shows a hierarchic structure consisting of several bodies collaborating in clearly defined way. The highest body of CEPT is the Assembly which is chaired by the Presidency. The latter also acts as the secretariat for the Assembly which adopts major policy and strategic decisions and recommendations within the postal and electronic communications sectors. Committees may be set up by the Assembly dealing with different tasks assigned to them. Currently (2011), there are three committees, namely the European Committee on Postal Regulation/Comité Européen de Réglementation Postale (CERP), the Electronic Communications Committee (ECC) responsible for radiocommunications and telecommunications and the Committee for ITU-Policy (Com-ITU). The latter committee shall organize the coordination of CEPT actions for the preparation for principle ITU events. i.e. meetings of the ITU Council, Plenipotentiary Conferences of ITU, World Telecommunication Development Conferences and World Telecommunication Standardization Assemblies.

Each committee has several Working Groups dedicated to special aspects of postal and telecommunications issues. The Committees and the Working Groups are supported by the European Communications Office (ECO) located in Copenhagen. ECO is the distribution point for all ECC documentation and also provides detailed information about the work of the ECC and its Working Groups via the ECO web site [ECO10]. The major responsibilities of ECO includes the drafting of long-term plans for future use of the radio frequency spectrum at an European level. Furthermore, national frequency management authorities of CEPT Members are supported in their work. Consultations on specific topics or the usage of parts of the frequency spectrum are conducted by ECO. An important task is also the publication of ECC Decisions and Recommendations and to keep record of the implementation of telecommunication services in Europe. An overview about the current CEPT structure can be found in [CEP10].

From the six Working Groups currently emanating from the ECC there are three having outstanding meaning for the usage of the electromagnetic spectrum in Europe. The first one is Working Group Frequency Management (WGFM), the second is called Working Group Spectrum Engineering (WGSE), and finally there is the Conference Preparatory Group (CPG). WGFM is covering all issues which are connected to allocating spectrum to different telecommunication services like for example the harmonization of spectrum for SRD or the future of the Terrestrial Flight Telephone System (TFTS) bands. Broadband Fixed Wireless Access in the 3.5-GHz and 5.8-GHz bands is another issues as well as any activities connected to the harmonization of frequency bands for IMT-2000 (International Mobile Telecommunications 2000) [IMT00]. Broadcasting issues are touched upon in terms of the preparation of WRCs of the ITU. Furthermore, future usage of Band II (87.5–108 MHz) and the L-Band (1452–1492 MHz) for broadcasting services are in the scope of the project teams of WGFM.

In WGSE, more technical issues of spectrum usage are dealt with. In particular, this refers to the preparation of technical guidelines for the use of the frequency spectrum by various radiocommunication services. Furthermore, sharing criteria between radiocommunication services, systems or applications using the same frequency bands are studied and assessed by WGSE. This is directly connected to the investigation of compatibility criteria between radiocommunication services using different frequency bands. Results of studies and discussions are to be published in terms of CEPT-Recommendations and CEPT-Reports as necessary. The preparation of the draft ECC Decisions lies also in the scope of WGSE as far as technical issues are to be addressed. As any other CEPT Committees or other group WGSE contributes to the preparation of WRCs of the ITU and also to related work within ITU-R, for example, the corresponding relevant Study Groups. Collaboration with ETSI and other international and European organizations is part of WGSE's task, too. In recent years in particular the Digital Dividend issues have been addressed within several project teams, namely ECC-TG4, ECC-PT1, and WGSE-SE42. These groups were created in the first place to cope with mandates the EC had issued to CEPT.

The third Working Group of CEPT having a significant relevance for spectrum usage issues including broadcasting system is CPG. From a strategic point of view it might even be considered the most important one because its scope comprises in particular the preparation of agreed European positions to be forwarded to ITU conferences like WRCs or Radiocommunication Assemblies (RA). Moreover, CPG is to develop, as required, coordinated positions in order to assist CEPT Administrations that are Members of the ITU Council in presenting a European position in respect of discussions concerning Conference agendas and timing. Within ITU-R there also exists a group dealing with the preparation of ITU conferences, called Conference Preparatory Meeting (CPM) to which CPG contributes as well. European views for WRCs or RAs are typically expressed in terms of so-called European Common Proposals (ECP) whose preparation is supervised by CPG. In relation to ECPs explanatory documents, called Briefs, are developed under the control of CPG. These Briefs are intended to support members of CEPT national delegations in order to present the European positions at WRCs and RAs.

The CEPT maintains the so-called "European Common Allocation Online Database" which is hosted on the ECO website [ECO10a]. Basically, this is an excerpt from the RR including all relevant footnotes. It was cast into the form of a web interface. So, it is very easy and straightforward to extract information about the spectrum usage in Europe within a given frequency band. Furthermore, there is also information coming from investigations carried out by ECO on the expected spectrum usage in Europe beyond 2010.

3.1.3 European Commission (EC)

In 2002, the European Parliament issued a Decision of the EC on a regulatory framework for radio spectrum policy in the European Community which goes under the name of "Radio Spectrum Decision" (RSD) [RSD02]. It introduced a new policy and legal framework in order to ensure coordination of policy approaches and, where appropriate, harmonized conditions with regard to the availability and efficient use of radio spectrum necessary for the establishment and functioning of the internal market in Community policy areas, such as electronic communications, transport, and R&D. Its objective is to provide the means for technical implementation of any Community policies that are linked to spectrum usage issues. To this end, a committee, namely the Radio Spectrum Committee (RSC) has been set up to assist the EC in the process of developing and adopting these technical implementation measures. Basically, this refers to defining the technical parameters and constraints under which a harmonized spectrum usage amongst Member States should be envisaged. The RSC consists of representatives of the Member States and is chaired by a representative of the EC.

In case harmonization cannot be dealt with on a purely technical level, the EC may submit a proposal to the European Parliament and to the European Council. It was explicitly noted in the RSD that any radio spectrum policy cannot be based only on technical parameters but also needs to take into account economic, political, cultural, health and social considerations. Moreover, the ever increasing demand for the finite supply of available radio spectrum very likely will lead to conflicting pressures to accommodate the various groups of radio spectrum users in sectors such as telecommunications, broadcasting, transport, law enforcement, military, and the scientific community. Therefore, EC and Parliament request radio spectrum policy to take into account all sectors and to balance the respective needs.

A Decision of the European Parliament is binding for Members States according to Community law. There are only few exceptions from this and usually will lead to either transitional rules or sharing mechanisms for those telecommunication services that are affected by the European harmonization process. In order to take account of various different interests of commercial and non-commercial spectrum users the EC may base its Decisions on the outcome of public consultations.

The primary objective of the RSD is to manage the spectrum usage across Europe in a harmonized manner. It is not intended to cover frequency assignment or licensing procedures on a national level. The RSC is expected to cooperate with experts from national authorities in the field of spectrum management; in particular, collaboration with the CEPT is foreseen. Usually, this is based on a mandate issued by the Commission to the CEPT asking to elaborate on certain aspects of spectrum usage. In the first place, the RSD aims to make the use of radio spectrum more flexible and to ensure the development of a European single market for equipment and services.

This philosophy is reflected by the second annual progress report on the RSD in 2005 [Com05a] which proposed a market-based approach to spectrum management in Europe [Com05b]. In particular, the EC has proposed that specific bands – spectrum used for "electronic communications services"- should be subject to tradability throughout the EU. Spectrum trading means buying or selling the right to use a frequency band. The idea is that trading can help to determine the "market value" of spectrum, so the introduction of this approach would help to reconcile demand and supply. Furthermore, the EC considers spectrum trading a tool to drive innovation and the development of new wireless technologies.

In addition to the RSC, there is another group dedicated to spectrum issues. This group is called Radio Spectrum Policy Group (RSPG). It was established as one of the actions following the adoption of the RSD. The RSPG shall adopt opinions, which are meant to assist and advise the EC on radio spectrum policy issues, on coordination of policy approaches and on harmonized conditions with regard to the availability and efficient use of radio spectrum. The members of the group are representatives of the Member States and of the Commission. Furthermore, several observers, e.g. from the European Parliament, CEPT and ETSI, attend the meetings of RSPG as well. The EC expects the RSPG to consult extensively and in a forward-looking manner on technological, market and regulatory developments relating to the use of radio spectrum in the context of EU policies on electronic communications, transport and research and development. Such consultations should involve all relevant radio spectrum users, both commercial and non-commercial, as well as any other interested party.

Both groups, i.e. RSC and RSPG, were driving the activity from a EC's point of view concerning the Digital Dividend. Several mandates inviting CEPT to carry out technical studies on harmonization of spectrum usage in Europe and developing the technical conditions thereto with a view on the introduction of new mobile service technologies have been issued (e.g. [ECo07a]). The reports put together by corresponding CEPT working groups built the technical basis for the EC Decision on the band 790–862 MHz.

3.1.4 Inter-American Telecommunication Commission (CITEL)

The American counterpart to CEPT is called Comisión Interamericana de Telecomunicaciones (CITEL) or the Inter-American Telecommunication Commission [CIT10]. Members are administrations of states of the Americas. However, the organization is open to any entity, organization or institution related to the telecommunications industry to participate as an associated member. International or regional telecommunication organizations such as ITU can become associated members as well.

The primary objective of CITEL is to facilitate and promote the development of telecommunications in the Americas. Most of CITEL's work is done within the framework of committees that meet periodically and also coordinate their activities. Until 2014, the CITEL structure consists of an Assembly with an associated Steering Group. Both are supported by the secretariat of CITEL. There are three committees, namely the Permanent Executive Committee (COM/CITEL), the Permanent Consultative Committee I (PCC.I) for "Telecommunications/Information and Communication Technologies (ICT)" and the Permanent Consultative Committee II (PCC.II) dealing with "Radiocommunication including Broadcasting". All of them can create working groups in order to fulfill their tasks.

COM/CITEL is the executive organ of CITEL. It is composed of representatives of thirteen Member states of CITEL elected at the Regular Meeting of the Assembly of CITEL. It has two major objectives, i.e. to carry out preparatory work for meetings of the ITU Council and world conferences and to develop the strategic plan of CITEL.

PCC.I constitutes an advisory committee of CITEL especially with respect to telecommunication/ICT policy, regulatory aspects, standardization, universal service, economic and social development, environment and climate change, and the development of infrastructure and new technologies. All relevant developments shall be monitored and discussed in order to harmonize the deployment of telecommunication services in the Americas. Currently, there are three working groups on regulation, development of technologies, and deployment of technologies.

Similarly, PCC.II acts as a committee covering frequency planning issues, coordination between Member States, harmonization and efficient usage of spectrum. Radiocommunication services and broadcasting across different distribution platforms are in the scope of PCC.II. Under this committee there are five working groups covering spectrum usage issues for different services such as satellite, mobile or broadcasting services. Therefore, the committees PCC.I and PCC.II can be considered as CITEL's corresponding groups to the CEPT working groups WGSE and WGFM.

CITEL offers several databases providing information about spectrum usage in the Americas. In particular, from the CITEL website information can be obtained about regional mobile services as well as allocation of spectrum to services can be queried [CIT10].

3.1.5 Asia-Pacific Telecommunity (APT)

The role that CEPT and CITEL play in Europe and the Americas is filled by the APT in ITU Region 3 [APT11]. APT was founded in 1979 and since then it brings together administrations, telecommunication services and network providers, manufactures and R&D organizations to foster the development and deployment of telecommunications in Asia and the Pacific region. The preparation of global ITU conferences such as ITU Plenipotentiary Conference (PP) or WRC are within the scope of APT as an important objective.

APT is promoting development and regional cooperation in telecommunications, including radio communications and standard development. It undertakes studies relating to developments in telecommunication and information infrastructure technology. APT seeks to facilitate coordination between administrations within the region with regard to deploying telecommunication services.

The primary objective of the APT is to support the development of telecommunication services and information infrastructure throughout the Asia-Pacific region. Particular emphasis is given to the expansion and development of telecommunication services in less developed areas in Asian and Pacific countries. APT extends from Iran in the West over India, China to Japan in the East. All of Indonesia and the Philippines is included as well as Australia and New Zealand.

APT has a structure which consists in the first place of a General Assembly, a Management Committee and a Secretariat. The Management Committee has the task to implement the policies and decisions of the General Assembly, while the Secretariat has a similar function like ECO in the case of CEPT (see Sect. 3.1.2).

The working areas of APT are Policy and Regulation, Radiocommunication, Standardization, Human Resources and ICT Development. This structure is largely along the lines the ITU is organized which facilitates contributing to the ITU work. APT publishes several documents for its members and the public. These are the annual APT Yearbook, an APT e-Newsletter and also reports on workshops or studies carried out under the custody of APT. All this and more can be found on the website of APT [APT11].

Chapter 4
Frequency Planning Frameworks

The usage of the electromagnetic spectrum is mainly managed by the international organizations and bodies described in Chap. 3. In the first place, spectrum usage is organized by allocating parts of the spectrum to particular services, i.e. broadcasting, mobile service, fixed service, aeronautical radionavigation service, or others. In most cases, a given spectrum range can be used by more than one service. This requires to properly define the characteristics of the systems providing these services and, very important, to specify the conditions under which spectrum can be shared.

The allocation of the spectrum to particular services is a task that is typically fulfilled by a World Radiocommunication Conference (WRC) of ITU-R. These conferences are regularly held every 3–4 years. The conditions under which sharing is accomplished is passed on to the Study Groups of ITU-R by a WRC. Between two conferences relevant Study Groups then prepare ITU-R Recommendations and ITU-R Reports dealing with all these aspects.

However, allocating spectrum to services and specifying the sharing conditions if more than one service is allowed to use a given spectrum range, is just one side of the coin. The details of spectrum usage for each service need to be defined and agreed between the administrations of different countries. There are basically two ways of accomplishing this. The first possibility is to convene international frequency planning conferences that elaborate detailed plans about which country can use which frequencies under which conditions in order not to cause harmful interference to the radiocommunication services of its neighboring countries. As as a result of such a process an agreement is established that is to be signed by administrations. Usually, the Radiocommunications Bureau (BR) of the ITU-R will then be involved in terms of carrying out calculations regarding the requests to use particular frequencies. Furthermore, the BR has to maintain corresponding data bases such as the Master International Frequency Register (MIFR) to monitor the actual spectrum usage.

The second way of aligning the demands and requirements of different countries is two work on the level of bilateral or multilateral coordinations only. This means

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there is no superordinate international agreement that needs to be applied and respected by administrations. Rather, it is left to administrations themselves to take care of their interests with regard to their neighbors.

Both approaches to frequency planning are currently employed around the world. In ITU-R Region 1 except Mongolia but including Iran from Region 3, the so-called GE06 Agreement governs the usage of frequency Bands III, IV and V while in Regions 2 and 3 the bilateral approach is applied. They are both discussed in the following together with the WRC-07 which proved to be the key event with respect to the Digital Dividend issue.

4.1 The GE06 Agreement and Plan

If new broadcasting systems are to be introduced in a spectrum range that is allocated to the broadcasting service it is necessary to establish a corresponding detailed frequency plan. Such a plan contains a list of transmitters or equivalent planning objects together with a specification of their technical characteristics and the frequency that can actually be used. Moreover, a frequency plan needs to be amended with a technical and regulatory framework providing the means to modify or extend the plan. Typically, frequency plans are addressed as “Arrangements” or “Agreements” between administrations of a certain region of the planet which signed the corresponding Final Acts of a planning conference.

Several frequency plans for analogue broadcasting have been set up over the last 100 years. The most important for Europe relating to terrestrial television was the so-called Stockholm Plan (ST61) established on International Telecommunications Union (ITU) level by a corresponding conference that was held in Stockholm, Sweden, in 1961 [ITU61]. It governed the usage of spectrum for terrestrial television for more than 40 years. For Africa and the Arabic countries a corresponding frequency plan has been set up in Geneva, Switzerland, in 1989 (GE89) [ITU89]. With the advent of digital terrestrial broadcasting it became necessary to develop a new plan for the new digital broadcasting systems. This process culminated in the GE06 Agreement which contains a frequency plan for DVB-T and T-DAB in the VHF and UHF range [ITU06]. The new plan superseded ST61 in Europe and GE89 in the African Broadcasting Area (ABA). GE06 was established in terms of two planning conferences that were held in 2004 and 2006 in Geneva, Switzerland.

4.1.1 Regional Radiocommunication Conference RRC-04

At the end of the last century it became obvious that a new frequency plan for digital terrestrial broadcasting was needed. Therefore, in 2000 the CEPT administrations led by Germany requested the ITU to consider convening a Regional

Fig. 4.1 Planning area of the RRC-06. It extends up to 170°E

Radiocommunication Conference (RRC) for the revision of the Stockholm Agreement ST61. The main target was to pave the way for a rapid introduction of DVB-T in the European Broadcasting Area (EBA).

In 2001, the ITU Council agreed on Resolution 1185 aiming to convene such a RRC in the EBA. The frequency bands 174–230 MHz and 470–862 MHz were to be re-planned for DVB-T and T-DAB in terms of two conference sessions. Member States of the ITU from the planning area of the Regional Agreement for VHF/UHF television broadcasting (GE89) [ITU89] in the ABA and neighboring countries also expressed the wish to take part in such a RRC for digital terrestrial broadcasting. Hence, the decision was taken to convene a RRC for the "planning of the digital terrestrial broadcasting service in Region 1 (parts of Region 1 to the west of meridian 170°E and to the north of parallel 40°S) and in the Islamic Republic of Iran, in the bands 174–230 MHz and 470–862 MHz, in two sessions". Figure 4.1 sketches the planning area.[1]

The first session of the planning conference which is usually called RRC-04 was to lay the technical foundations in terms of setting up and agreeing on planning parameters and sharing criteria. The second part, referred to as RRC-06, was to draft a new agreement which together with a corresponding new frequency plan should be adopted by the conference. In order to prepare for these two conferences ITU decided to establish Task Group 6/8 (TG 6/8) to draw up a report for RRC-04.

[1]This figure has been produced with ArcGIS based on the world map contained therein.

This report was to contain all relevant technical information which RRC-04 was invited to consider for integration into the new agreement. It covered planning concepts, technical criteria, compatibility issues between different types of services, and planning tools. This work was heavily supported both by CEPT and European Broadcasting Union (EBU) which both set up corresponding project teams dealing with these issues. The report was eventually submitted to the RRC-04 together with further independent contributions from CEPT and EBU.

On 10 May 2004, the RRC-04 started in Geneva [ITU04]. About 750 delegates from 95 countries participated in the conference lasting for three weeks. RRC-04 agreed on planning parameters and criteria such as minimum field strength values and protection ratios. However, planning principles have also been decided upon. First of all, it has been agreed that DVB-T will be the only standard to be dealt with in the conference as a representative for digital terrestrial television. Even though this decision reduces the planning effort significantly it is well known that DVB-T allows for a huge number of different system variants. All of them require different planning parameters which has a direct impact on the generation of a frequency plan.

This variety is a very important feature of DVB-T from which broadcasters are able to benefit when it comes to network planning. But on the other hand, it became clear during the preparations of the conferences that including every single detail of a system variant in a plan entry to a frequency plan constrains the freedom of network operators, in particular in view of the freedom DVB-T offers e.g. allowing Single Frequency Network (SFN) operation. Hence, in order to simplify the planning process as much as possible three so-called Reference Planning Configurations (RPC) have been developed. They were used as some kind of placeholders representing a large number of different system variants requesting similar planning parameters. The three RPCs represent fixed reception, portable outdoor or mobile reception and portable indoor reception. Furthermore, four different reference networks (RN) have been included which during the plan generation process allow the assessment of the interference a typical network would impose on other networks. By choosing an appropriate combination of RPC and RN intended coverage targets could be mapped to mathematical objects that could be appropriately dealt with by the frequency planning process of RRC-06.

Another important issue of the RRC-04 was to make appropriate provisions for T-DAB planning. CEPT had already made frequency plans for T-DAB in the years before and many T-DAB networks have been put into operation. The usage of Band III spectrum resources for T-DAB in Europe was governed by the so-called Wiesbaden Arrangement (WI95)[CEP95] which was revised in 2007 in Constanta (CO07)[CEP07d]. From a CEPT perspective it was important to ensure that this Arrangement could somehow be integrated into the new frequency plan for VHF. Initial resistance against allowing T-DAB to make use of “television frequencies” could be overcome. Similar to DVB-T two RPCs and two RNs were proposed for T-DAB in the report submitted to RRC-06. One of the RPCs corresponded to the planning scenario of WI95 referring to mobile reception while the new RPC reflected the fact that also portable indoor reception would be important for the future development of T-DAB [Bru05].

Soon it became clear that not only allotment planning as in WI95 was requested by administrations. ST61 was an assignment plan and there were many administrations in the planning area which wanted to base their input requirements to the new frequency plan on ST61. Basically, they were pursuing some kind of conversion strategy from analogue to digital broadcasting which nevertheless meant that they favored a planning approach based on assignments. Therefore, in the end it was decided that both types of requirements should be dealt with.

Bands III, IV, and V are not exclusively used for broadcasting. There are many other services which are listed in the Radio Regulations of ITU-R as primary services. Therefore, administrations have to coordinate with affected administrations whenever a broadcasting service or one of these other services is newly introduced or an existing station is modified. Thus, the plan generation process for digital terrestrial broadcasting had to take into account the protection of other services. Amongst them there are fixed services, mobile services, aeronautical radionavigation services, radio astronomy, broadcasting-satellite services, and others. During the RRC-04 interference and protection criteria between digital broadcasting and these services were developed but it was not possible to cover all sharing situations. Therefore, this work had to be left to the intersessional period between RRC-04 and RRC-06.

Frequency planning rests on predictions of interference levels at given geographical points. This calls for appropriate wave propagation methods to predict the field strength a transmitter produces at a given point. Shortly before the RRC-04 ITU-R published a new Recommendation, ITU-R Rec.P1546, for field strength prediction in the frequency range from 30 to 3000 MHz [ITU01]. The propagation method which was proposed to be used for the RRC-06 was based on that Recommendation. There were several deviations from the original version, in particular in relation to the treatment of negative effective transmitting antenna heights and the way in which mixed path propagations were taken into account.

The large planning area of RRC-06 quite naturally brought together many very differently developed countries. In Europe, digital terrestrial broadcasting had already been introduced to some extend while in Africa or the Arabic countries deployment of analogue television was still in full swing. Therefore, it is evident that there were different ideas about when and how the transition to an all-digital broadcasting world should be accomplished. During the so-called transition period existing and planned analogue station would need to be protected. After that date the protection rights of analogue services would cease. The date when the transition period should end caused some conflict even during the preparation of the RRC-04. It was not possible to come to a common view on this issue and hence RRC-04 identified two options for the end of the transition period. In particular, CEPT-countries favored to cease analogue transmissions as soon as possible but not later than 2015. The other option said that the end of the transition period should not be only before 2028 but also not later than 2038. It was left to RRC-06 to finally decide on the end of the transition period.

The clash about the transition period triggered the development of a new element to be included in the digital terrestrial broadcasting plan. It is what was later called the envelope concept. At the beginning it was referred to as mask concept which was later abandoned in order not to mix it with the idea of spectral masks for T-DAB or DVB-T emissions. Confronted with the fact that there was no consensus in sight in relation to the transition period, the question was asked within CEPT if some measure could be developed which would allow to continue the operation of analogue services even beyond the end of the transition period. The proposal was to operate the analogue station under the envelope of a digital plan entry. According to the planning principles, the technical characteristics of a plan entry precisely define the amount of interference that will be produced at any given point. Vice versa, it would be also clear how much interference this plan entry would have to accept at the boundaries of its own service area. The envelope concept simply stated that the operation of an analogue station would be feasible if not more protection is claimed nor more interference is produced as determined by the associated plan entry.

Finally, RRC-04 laid the foundations for the structure of the planning process itself. Basically, the same methodology as used in WI95 was adopted apart from necessary modifications due to the different systems that had to be taken into account. Therefore, the planning process consisted of the two steps compatibility analysis and plan synthesis which could be iterated if necessary. More details on the RRC-04 can be found in [Pui04] and [Beu04].

4.1.2 The Regional Radiocommunication Conference RRC-06 and the GE06 Agreement

The RRC-04 laid the foundations for RRC-06 by establishing the technical basis and providing the planning criteria and parameters for the new plan. Since during the RRC-04 not all tasks could be finished the two years between the two conferences were a busy time for frequency planners. The intersessional period was used by ITU, CEPT and EBU to fill those gaps that were left by RRC-04. At ITU level several working groups were established. This was foreseen by RRC-04 in terms of several Resolutions. Three of these group had particular importance, namely the Intersessional Planning Group (IPG), the Planning eXercise Team (PXT) and the Regulatory and Procedural Group (RPG). The IPG was to develop draft plans during the intersessional period, taking account of bi- and multilateral negotiations carried out by the administrations. PXT should test the planning software which was provided by the Technical Department of the EBU by carrying out planning exercises. Finally, RPG had the task to prepare the regulatory and procedural framework which was to be drawn up in the new agreement.

RRC-06 took place from 15 May 2006 until 16 June 2006. More than 1000 delegates from 104 different countries participated. The conference was structured by setting up six Committees dealing with different items. Committee 4 (Planning Committee) and 5 (Regulatory Committee) constituted the core of the planning conference. Committee 4 was subdivided into five so-called Coordination and Negotiation Groups (CNG) which were created to divide the entire planning area into smaller regions. They were defined in a way that these areas could be considered as more or less independent from each other. CNG1 covered Europe and the North Eastern part of the planning area. CNG2 represented Western and Central Africa. CNG3 was responsible for Eastern and Southern Africa, CNG4 covered the Red Sea area where extreme propagation conditions are encountered, while CNG5 contained countries around the Mediterranean Sea. Committee 5 was dealing with regulatory, procedural and technical aspects of using Bands III, IV, and V. In particular, the development of the agreement text was in the scope of Committee 5.

The Technical Department of the EBU had developed the software that was used for the planning process of the RRC-06. This covered both the compatibility analysis and the plan synthesis. The Radiocommunication Bureau of the ITU (BR) provided software tools to capture and validate the input data and to visualize the results of the planning process. A joined team of EBU and ITU experts carried out the intensive calculations during the conference. In particular, the compatibility analysis required so much computational power that the computing facilities of European Organization for Nuclear Research (CERN) [CER10] in Geneva had to be exploited.

The compatibility analysis was needed to identify whether two requirements for digital broadcasting could share a frequency or not. Furthermore, the impact of digital requirements on assignments to other primary services including existing or planned analogue television assignments to be protected had to be evaluated as well. These calculations resulted in a list of available frequencies for each digital broadcasting requirement. The results of the compatibility analysis were taken into account during the plan synthesis which was based on the implementation of several thousands of different graph theoretical algorithms for the frequency assignment process. They were run concurrently as much as possible by distributing the task onto the several hundreds of computers available at the CERN computer centre.

4.1.2.1 Overview of the Results of the RRC-06

A total of 118 administrations submitted requirements to be taken into account in the planning process. They were asking for frequencies, i.e. T-DAB blocks or TV channels, in the frequency ranges 174–230 MHz and 470–862 MHz. In the UHF Bands IV and V a channel raster of 8 MHz was used throughout the entire planning area. However, in Band III the situation was more complicated. A mixture of different raster schemes needed to be taken into account. T-DAB employs spectrum blocks of 1.75 MHz bandwidth. This was unique but for DVB-T both 7 MHz and 8 MHz had to be considered in Band III.

The first set of input requirements at the beginning of the conference comprised more than 80000 data sets out of which roughly a fourth referred to VHF. This pile of input data was the starting point for the planning marathon. Planning was carried out iteratively in terms of four iterations. The overall objective of the planning activities was to satisfy as many requirements as possible, i.e. to find frequencies for them. However, it turned out that the number of submitted requirements in connection with the constraints imposed by the other primary services to be protected was far beyond what could be accommodated in the spectrum at hand. Therefore, administrations were having extensive bi- and multilateral coordination meetings in order to figure out under which conditions the incompatibilities between parts of their requirements could be overcome.

The coordination efforts resulted in a very large number of so-called “agreements by administrative declarations” which became a crucial means for the successful plan generation. Providing an administrative declaration basically meant that two or more administrations carried out detailed geographically limited studies on the basis of more developed and sophisticated planning tools than those agreed to be employed by RRC-06. As a result of these investigations, requirements were declared mutually compatible thereby overwriting the formal findings of the compatibility analysis.

Very often it was clear for administrations and broadcasters that for digital terrestrial broadcasting networks the existing transmitters sites so far used for analogue broadcasting must be used for the implementation of the digital transmitter network due to economical reasons, too. In some cases where this led to obvious interference conflicts between transmitter sites, administrations simply agreed to accept higher levels of mutual interference. Hence, they provided corresponding administrative declarations.

It has to be borne in mind that in the context of RRC-06 the level of interference was evaluated on the basis of the wave propagation method adopted which was based on ITU-R Recommendation P.1546 [ITU01]. However, special topographic and morphologic conditions cannot be taken into account by that method. From their long-time experience of operating transmitters under very different conditions, broadcasters were quite aware of the mutual interference potential between different transmitter sites. For example, there are many cases in which terrain shielding basically leads to a decoupling of two transmitter sites so that they can share a channel in practice even though investigations based on ITU-R Recommendation P.1546 [ITU01] might indicate that spectrum sharing is not possible. Furthermore, detailed calculations employing more developed and sophisticated prediction methods showed that spectrum sharing could be envisaged if proper antenna design is considered.

In some regions of the planning area, like parts of Africa or the Arabic countries where no coordination had been carried out between administrations before the RRC-06 during the preparation phase, a general relaxation of the planning criteria by up to 5 dB was agreed in order to get requirements into the plan which otherwise would not have been assigned a frequency. In such cases, it was obvious that any implementation of a plan entry will need to be coordinated before bringing a station into operation.

One of the issues which lead to sometimes fierce arguments in the preparation of GE06 was the protection of analogue TV stations. RRC-06 was to draw up a frequency plan for digital terrestrial broadcasting in a spectrum range which was more or less fully occupied. The planning activities carried out by the PXT during the intersessional period clearly showed that there is no hope to establish a new frequency plan if the plan generation process would need to protect existing and planned analogue TV assignments. Consequently, RRC-06 quickly decided not to protect analogue stations during the plan generation process. This paved the way for a successful plan for DVB-T and T-DAB.

Even though analogue transmissions would not be protected by the final digital plan it was nevertheless clear that the introduction of digital terrestrial broadcasting would not be accomplished over night. A transition period during which analogue transmissions would be granted protection would be necessary. Basically, protection of analogue stations means that a digital station can only be put into operation after successful coordination with administrations whose analogue transmissions would be affected.

Opinions diverged heavily about the duration of the transition period. RRC-04 had already not been in a position to decide on the duration of the transition period. After very lengthy discussion it was finally decided by RRC-06 that 17 June 2015 should be the end of the transitions period. As an exception from this rule, it was agreed that for some non-European countries 2020 should be applied as the end of the transition period for VHF. CEPT was of the opinion that 2015 would still be too far away and decided that 2012 should be valid for its members. Administrations were in addition encouraged to go digital as fast as possible. It should be noted that other primary services than analogue TV were fully protected for the generation of GE06. Therefore, the term transition period exclusively refers to the protection of analogue terrestrial broadcasting.

In order to know which analogue stations would need to be protected during the transition period it was necessary to establish a reference situation for analogue television. It was decided that for the territories governed by ST61 and GE89 the reference situation should be given by the corresponding updated frequency plans. Thus, all assignments successfully coordinated until 15 March 2006 would be included in the reference situation. For assignments to other primary services also a reference situation was defined comprising all successfully coordinated assignments which have been notified to the ITU at the same date. This decision had already been prepared by RRC-04 and therefore administrations knew since then that if they wanted to claim protection for analogue stations or assignments to other primary services they had to take the effort to bring their notifications to the ITU up to date.

The digital switch-over, how the transition from analogue to digital broadcasting is also called, was and is still a very complex enterprise. In many cases, neighboring countries have entirely different ideas about the time horizon of the transition as well as the manner in which it could be accomplished. However, this poses a problem since along national borders the transition strategies need to be aligned. Some administrations are in favor of a hard changeover, i.e. switching off analogue transmission at a defined date and starting digital transmissions seamlessly. Others want to introduce T-DAB and DVB-T by gradually switching from analogue to digital broadcasting on a transmitter by transmitter basis.

Those digital plan entries which are not in conflict with any other co-channel users can be implemented in the short term without problems. For those plan entries whose operation is subject to the protection of analogue transmissions successful coordination between administrations has to be achieved prior to bringing digital plan entries into operation. However, it might nevertheless be possible to realize a partial network implementation. In the case of an assignment plan entry, this means to use reduced Effective Radiated Power (ERP) or specially adapted antenna patterns for the time when analogue stations need to be protected. For allotment plan entries there is more freedom. An allotment can be implemented in terms of building only part of a full SFN in a first step. This means not the whole allotment area will be covered but only that part which is far-off existing analogue transmissions. This way it is possible to limit the interference to analogue transmissions to an acceptable level during the transition period.

The key to achieve consensus amongst the administrations participating in RRC-06 concerning the duration of the transition period was the development of the envelope concept. This idea had been put forward by RRC-04 already. Basically, it allows to make use of a plan entry for DVB-T or T-DAB for another system as long as not more protection is requested and not more interference is produced than the underlying digital plan entry would do. Clearly, "another system" could also be analogue television. A digital assignment of the GE06 plan could be used as a "placeholder" under which an analogue station can be operated even beyond the end of the transition period when the protection of analogue transmission would have ceased.

The envelope concept is described in Article 5.1.3 of the GE06 Agreement [ITU06]. It states that a digital plan entry might be used for systems whose technical characteristics are different from those appearing in the plan. Both broadcasting services and also other primary services can be implemented. However, they need to be in conformity with the Radio Regulations (RR) of the ITU [ITU08]. This is in the first place a regulatory constraint which means that only those systems can exploit GE06 under the envelope concept which are defined as primary services in the Bands III, IV, or V already. From a technical point of view, the basic condition to be met is that the peak power density in any 4-kHz interval shall not exceed the spectral power density in the same 4-kHz as produced by the digital plan entry.

The generation of the GE06 frequency plan was accomplished after four planning iterations. Administrations had to submit their requirements at a given time usually before the weekend. They were given a bit more time to prepare the administrative declarations which were taken into account only after the full pairwise compatibility analysis had been carried out. This information was taken into account during the plan synthesis process. The large number of inputs to the first iteration resulted in only ca. 65% and 74% of satisfied requirements in VHF and UHF, respectively.

From one iteration to the next, administrations were urged to keep the number of changes of their input data to a minimum and for the fourth iteration only corrections of mistakes to the already existing input data sets like typos were accepted. The only modifications to the input that were always accepted was a reduction of the number of input requirements and the provision of more administrative declarations in order to make channel sharing possible. In the end, the total number of requirements for digital terrestrial broadcasting had dropped from roughly 80000 to about 72000 and the number of satisfied requirements increased to 93% and 98% in VHF and UHF, respectively.

The RRC-06 planning process provided three sets of results, namely a digital plan for T-DAB and DVB-T containing both allotments and assignments, a frequency plan for analogue television that need to be protected during the transition period and a list of assignments to other primary services in the frequency bands under consideration. In particular, in CEPT countries allotment planning was favored. In the end, the majority of CEPT countries obtained seven national coverages of DVB-T in UHF and three or four layers for T-DAB and DVB-T in VHF.

The majority of DVB-T plan entries, roughly 65%, refers to fixed reception which in the case of allotments is represented by RPC1. The rest corresponds almost entirely to portable outdoor reception (RPC2) because the number of portable indoor reception entries (RPC3) is almost negligible compared to the other two cases. For T-DAB, the situation is similar concerning the two possibilities, namely mobile (RPC4) and portable reception (RPC5). Also, here the number of mobile allocations is almost twice as large as that of portable indoor reception. Concerning the statistics of allocated frequencies it has to be noted that lower channels in UHF have been requested more often and subsequently allocated more frequently. In particular, starting with channel 61 the channel usage significantly decreases. This can very likely be addressed to the fact that in many countries of the GE06 planning area this spectrum range is allocated to other primary services as well. Therefore, this part of the spectrum was not available for digital terrestrial broadcasting. In the case of Band III, DVB-T allocations are primarily in channels 5–10 for the 7-MHz raster. This is due to the fact the WI95 allocations for T-DAB which most administrations wanted to be included in the new plan as well, were concentrated in channels 11 and 12.

As discussed above, administration provided a vast number of administrative declarations in order to get their requirements in the plan. As a consequence, implementation of these plan entries will be subject to the conditions agreed by the concerned administrations. Basically, there are three different types of conditions to be taken into account. For some entries coordination with respect to existing or planned analogue TV stations is explicitly required before the digital plan entry can be brought into operation. The second category refers to special conditions agreed by administrations in relation to other digital broadcasting plan entries. Actually, this corresponds to the standard case of getting broadcasting requirements into the plan which failed the compatibility analysis. Finally, there are cases where conditions have to be met relating to the protection of other primary services where administrations had agreed on special measures to be taken. In any case, the details of the agreement between administrations are not contained within the GE06 plan. It includes only remarks that there are some constraints to be considered. Administrations take the responsibility themselves to be able to retrieve the proper wording of their agreements. A more detailed analysis of the results of RRC-06 in terms of channel usage and geographical distribution of channels can be found in [Ole06]. Clearly, the most comprehensive source of information is the ITU-R website dealing with GE06 [ITU06].

4.1.2.2 GE06 Article 4: Plan Modification Procedure

Setting up the GE06 plan was certainly a big task. However, it was also clear that the new plan will not be static. There will be changes to it, either new plan entries need to be added, existing ones might be modified or some might even be deleted. In any case, it was one of the objectives of RRC-06 to provide the regulatory and technical means for all these intentions. Committee 5 took care of that very difficult and politically delicate task. To this end, Article 4 of GE04 was prepared to contain procedures which specify in detail what has to be done by an administration wishing to make a change to the GE06 plan. Any addition or modification will very likely have an impact on other digital plan entries, assignments to other primary services and during the transition period will need to protect existing and planned analogue TV assignments. Consequently, coordination with all affected administrations need to be sought.

Originally, it was intended to base the new frequency plan on two planning objects, namely assignments and allotments. Already, this decision had been an innovation since in the past either assignment plans have been drawn up (ST61 and GE89) or allotment plans were established (WI95). Therefore, mixing assignment and allotment planning was already a step into uncharted waters. However, during the preparation of the RRC-06 it turned out that administrations had very different demands that could only be satisfied by introducing a total of five different planning objects identified by five distinct plan entry codes.

The simplest planning object is a single assignment. This reflects exactly the same way of planning as in ST61 or GE89, i.e. an administration provides all technical characteristics of a transmitter site which are necessary to assess its interference impact at any given geographical location. A natural extension of a single assignment is a set of assignments which are combined by the same SFN identifier (SFN-ID). The intension is to use them in SFN mode, i.e. using the same frequency to broadcast the same content. Then, a single allotment could be provided as input to the planning process. It is given in terms of a set of geographical vertices defining an area to be covered by an appropriate transmitter network. An allotment is associated with a RPC and a RN. This information is sufficient to assess the interference produced by the allotment and the protection it needs to be granted. Plan entry code 4 refers to an allotment with linked assignment(s) and a SFN-ID. Linking assignments was invented to bring together the concept of allotment with existing transmitter sites. Employing such a construct allows to take into account the features of transmitters which are intended to implement the allotment but can however not be represented by the characteristics of the allotment, i.e. RPC and RN. Finally, a fifth planning object was introduced which consists of an allotment to which a single assignment is linked but no SFN-ID is provided. The intention of this was to combine the concept of a defined service area as given by an allotment area and special transmission characteristics which can be modelled by providing a corresponding assignment.

Since the five different plan entry codes have very different properties it is evident that they need to be treated differently. Both Articles 4 and 5 procedures require to calculate field strength values produced by these planning objects at given points. To this end, it has to be clearly defined what the source of interference for each of these cases is. For a single assignment and a single allotment the situation is obvious. The technical characteristics of the assignment and the RPC/RN combination will be used, respectively. However, for the mixed cases field strength values based on both information have to be calculated for a given geographical point. Then the larger value is defined as the field strength produced there by the planning object.

Another important aspect for both Articles 4 and 5 is the definition of a point of reference for each plan entry code. Both GE06 Articles 4 and 5 employ geometrical concepts on which their calculation methods are based. Depending on the task a set of geometrical contours has to be calculated. To this end, a geographical point of reference is needed. In the case of a single assignment it is straightforward to use the location of the transmitter site thereto. However, already for an allotment this becomes a tricky issue, in particular because a single allotment can consist of several distinct polygons. According to the GE06 rules this can be employed in order to more accurately treat main land and offshore islands as a single allotment. In principle, the centre of gravity of the allotment is used as the point of reference. In case of a set of assignments, more sophisticated rules apply. More details can be found in [EBU07].

The objective of the procedure anchored in Article 4 is to determine which services could be potentially affected by a proposed modification or addition to the GE06 plan. Clearly, this means to identify the administration to which a particular service is associated. In this context, the term services refers to both broadcasting services and other primary services. In order to limit the computational effort to a reasonable amount, first of all a contour separated by 1000 km from the location of the proposed addition or modification to the GE06 plan is constructed. Only administrations whose territory falls into the identified area will have to be considered during the Article 4 procedure.

Any modification to the GE06 plan has to refer to one of the five plan entry codes. Depending on that the corresponding point of reference is determined. In case of assignment(s) the distance is measured from the transmitter site(s), while for an allotment the 1000 km are taken from the allotment boundary. Any country whose border is intersected is taken into consideration. Furthermore, the frequency for the new or modified plan entry is important for the subsequent analysis. Figure 4.2 sketches the situation. It shows a broadcasting allotment to be added in country A. The 1000-km contour – from which only a small part is indicated here on top of the figure – intersects with countries B, C, and D, so they will have to be considered as potential candidates with whom coordination might be required. In countries B,C, and D, there are broadcasting plan entries and assignments to other primary services which are indicated in terms of their corresponding service areas.

The measure of Article 4 to decide if an administration needs to be approached for agreement or not is to calculate so-called coordination contours. In principle, a coordination contour represents a curve along which the proposed plan modification will create a certain field strength level, namely the so-called coordination trigger value. The actual value of the trigger field strength depends on the technical

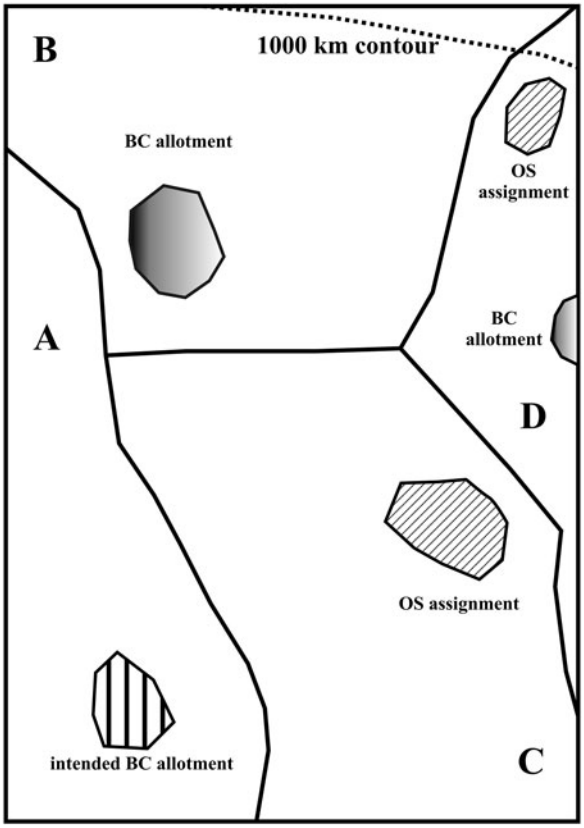

Fig. 4.2 1000 km contour derived from a broadcasting allotment that is to be added to the GE06 Plan according to an Article 4 procedure

characteristics of the intended plan modification and the type of service potentially affected. Therefore, the identification of affected administrations has to be carried out in relation to broadcasting plan entries in GE06 and against assignments to other primary services contained in the list attached to the GE06 Agreement. Actually, this might require to construct several different coordination contours.

In any case, there will be a contour relating to the broadcasting service. Different trigger field strength values for T-DAB and DVB-T are given in GE06. Until the end of the transition period analogue television will need to be considered as well. The trigger values differ according to the frequency band, i.e. III, IV, or V. In order to simplify the calculations only the most critical, i.e. smallest trigger value is employed to construct a single broadcasting coordination contour. If this contour intersects or encloses the national boundaries of a country which is located within the 1000 km contour coordination with the corresponding administration is required.

In the case of other primary services, the details of the identification process are different. In a first step, those other services are identified whose assignments are located within the 1000-km contour. From these only those will be taken into consideration which are contained in the list attached to the GE06 Agreement.

Then, it is checked whether there is a frequency overlap between the intended plan modification and the frequency used by the assignments to other primary services. Only if there is an overlap these assignments will be taken into account. It is important to note that this constitutes a significant difference between the treatment of broadcasting and other primary services. For the latter basically only co-channel usage can trigger coordination between administrations. In the case of broadcasting, the frequency is actually not taken into consideration.

Once the assignments to other primary services have been identified the relevant trigger field strength values are extracted from the GE06 Agreement and the corresponding coordination contours are generated. In contrast to the broadcasting case the national boundaries are not relevant, but coordination with an administration is required if the locations of the receiving stations or the service areas of these other primary services are intersected or enclosed by the coordination contour. For further details refer [EBU07].

Article 4 of GE06 contains the regulatory framework according to which an administrations has to act when wishing to modify the GE06 Plan. All technical issues in relation to Article 4 are given in Sect. I of Annex 4 to the GE06 Agreement. It specifies in detail how the coordination contours are constructed for a given assignment or allotment. Apart from the explanation given in the GE06 Agreement, a very good description of the relevant technical issues seen from a practical point of view can be found in [EBU07]. Figure 4.3 illustrates the different coordination contours.

It is assumed in Fig. 4.3 that there is only one type of other primary service inside the 1000-km contour. In that case two coordination contours have to be constructed, one for broadcasting and one for the other service. The broadcasting contour intersects with countries B and C. Therefore, coordination concerning broadcasting services is required with these two countries. In the case of other primary services, the service area or the location of the transmitter site is relevant, not the national border. This means that coordination is required with country B in relation to other primary services and not with country D.

4.1.2.3 GE06 Article 5: Notification Procedure

Setting up a frequency plan and having the means to modify existing plan entries gives administrations and broadcasters the possibility to operate transmitter networks for broadcasting services. However, it is necessary to introduce rules which guarantee that the implementation of a network is carried out in conformity with the characteristics of the plan entries. This means that the network implementation must not produce more interference than the associated plan entry will do. To this end, Article 5 has been included in the GE06 Agreement which contains the technical details how the conformity check between plan entry and network implementation has to be carried out.

The operation of a transmitter under the GE06 Agreement calls for two requirements to be fulfilled, namely there must be a plan entry in GE06 with

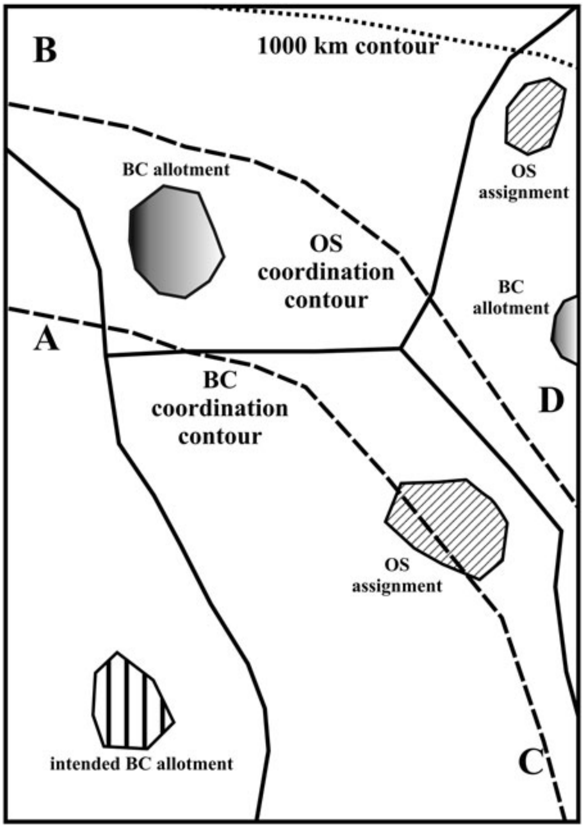

Fig. 4.3 Two coordination contours derived from a broadcasting allotment that is to be added to the GE06 Plan according to an Article 4 procedure

which the operational transmitter can be associated and furthermore an assignment corresponding to the technical characteristics of the transmitter has to be recorded in the ITU-R MIFR. The latter process is called "notification".

Basically, there are three cases in which an Article 5 procedure is needed. Two of them refer to particular modifications of plan entries resulting from an Article 4 procedure and one is a "true" Article 5 issue. The latter refers to the straightforward intention of an administration to use a particular plan entry in order to implement a transmitter network. An implementation can be accomplished in terms of one or several assignments. The technical characteristics of the assignment(s) are fed into the machinery of the conformity check in order to prove that the intended network will not produce more interference than is calculated on the basis of the plan entry characteristics.

Furthermore, Article 5 has to be employed in relation to a modification of an allotment plan entry under Article 4, i.e. the conversion of an allotment plan entry into a set of assignments. This idea was taken over from the WI95 [CEP95] and CO07 [CEP07d] Arrangements of CEPT relating to T-DAB. In principle, this means to substitute the original allotment plan entry by a number of assignments which then will become part of the plan. Such a plan modification is only allowed if the aggregated interference of the set of transmitters does not exceed the limits imposed by the allotment plan entry. This is assessed by applying the conformity check defined by Article 5 of GE06.

The second Article 4 case where reference to the conformity check is made concerns a plan modification which claims to produce less interference than the original plan entry it refers to. Also, in such a situation a check is needed in order to confirm this claim.

As in the case of Article 4 of GE06 concerning an intended plan modification, the regulatory framework an administration has to apply when submitting a notification to the ITU is given in the main body of the GE06 Agreement under Article 5 while all technical issues are presented in Sect. II of Annex 4 to the Agreement.

Application of an Article 5 procedure starts with the submission of administration of a set of assignments whose technical details have to be specified. Then, the conformity check of Article 5 comprises two examinations. First of all, the frequency and the location of the submitted assignments are checked. Clearly, the frequency has to be the same as that of the plan entry. Moreover, the location of the transmitter sites have to be close to the location of the plan entry. For an allotment this means that they are allowed to lie inside or outside the allotment area. The latter case is only acceptable if the transmitter sites are separated from the allotment boundary by not more than 20 km. In the case of an assignment, the transmitter location may deviate by 20 km from the geographical location recorded in the plan.

The second examination of the conformity check relates to the technical characteristics of a plan entry which allow the calculation of a corresponding interfering field strength value at an arbitrary geographical point. The field strength values at all possible points define an interference envelope of the plan entry. An implementation is considered as being in conformity with GE06 if the network implementation stays below that interference envelope.

As already mentioned in the previous section, the GE06 comprises five different types of plan entries distinguished by their plan entry codes. Thus, it comes as no surprise that all of them require a slightly different treatment for this comparison. For any type of plan entry it is possible to calculate a field strength value at any arbitrary geographical point. Therefore, the concept of an interference envelope is naturally a two-dimensional concept. In other words, the interference envelope of a plan entry can be imagined as a two-dimensional surface above a given area. This is just like a mathematical function of two independent variables x and y corresponding to geographical latitude and longitude. The height of the surface above any point represented by a pair of longitude and latitude values is then given by the field strength value produced there by the plan entry. Checking if a network implementation is in conformity with a plan entry would consequently require to check any point throughout a given area. Since this is not feasible from a practical point of view, a set of calculation points is defined where a comparison of the field strength produced by the plan entry and by the intended network implementation is carried out.

In order to limit the amount of computational effort, the area in which calculation points are located is bounded by a so-called cut-off contour. The cut-off contour is basically a trigger field strength contour similar to those used in the application of the Article 4 procedure. However, in contrast to these there is only one cut-off contour which takes into account both broadcasting and other primary services appropriately. The first step of the construction of the cut-off contour is the determination of the point of reference of the plan entry for which a particular implementation is to be assessed. For a single assignment, this point corresponds to the location of the assignment. In case a set of assignments is dealt with, the centre of gravity of all locations is chosen while as soon as an allotment is involved the centre of gravity of the allotment area is used. Then, radials are drawn every 1° starting at the point of reference and extending to infinity. Along these radials the point is identified where the field strength produced by the actual implementation of the plan entry reaches the broadcasting trigger field strength as defined in Article 4. Just to avoid any misunderstanding, the cut-off contour is calculated on the basis of the technical characteristics of the transmitter(s) submitted for notification. In the case of an allotment, already notified assignments that have already been entered into the MIFR have to be included too, since they make part of the network implementation of the allotment. Clearly, this is also valid for the comparison in each calculation later in the process.

All points found that way are subsequently connected and the resulting polygon defines the cut-off contour. However, there are additional conditions to be taken into account. If the constructed contour lies entirely inside the territory of the administration whose plan entry is considered then other primary services have to be accounted for as well. This might lead to a modified cut-off contour whose calculation is then based on the trigger values of other primary services. Annex 2 of [EBU07] explains in details all possible implications of different conditions on the construction. Figure 4.4 sketches a simple layout for the case of a single assignment and a single allotment plan entry.

Once the cut-off contour has been generated the calculation points have to be identified. As a general rule, calculation points must lie inside the area delimited by the cut-off contour. At the same time only those calculation points are considered which are located outside the territory of the administration whose Article 4 or 5 request initiates the conformity check. This means that there can be cases where no calculation points are found at all. In that case, conformity with the GE06 plan is granted by definition.

If the cut-off contour extends beyond the national boundary the location of the calculation points have to be determined. To this end, a set of geometrical contours are generated. They constitute contours which are separated from the location of the plan entry by a constant distance; in particular the distances 60 km, 100 km, 200 km, 300 km, 500 km, 750 km, and 1000 km are employed. For assignment plan entries the contours are concentric circles around the geographical location of the assignment which at the same time acts as point of reference. In the case of an allotment, the geometrical contours correspond to buffer zones around the allotment area. Figure 4.5 shows some geometrical contours.

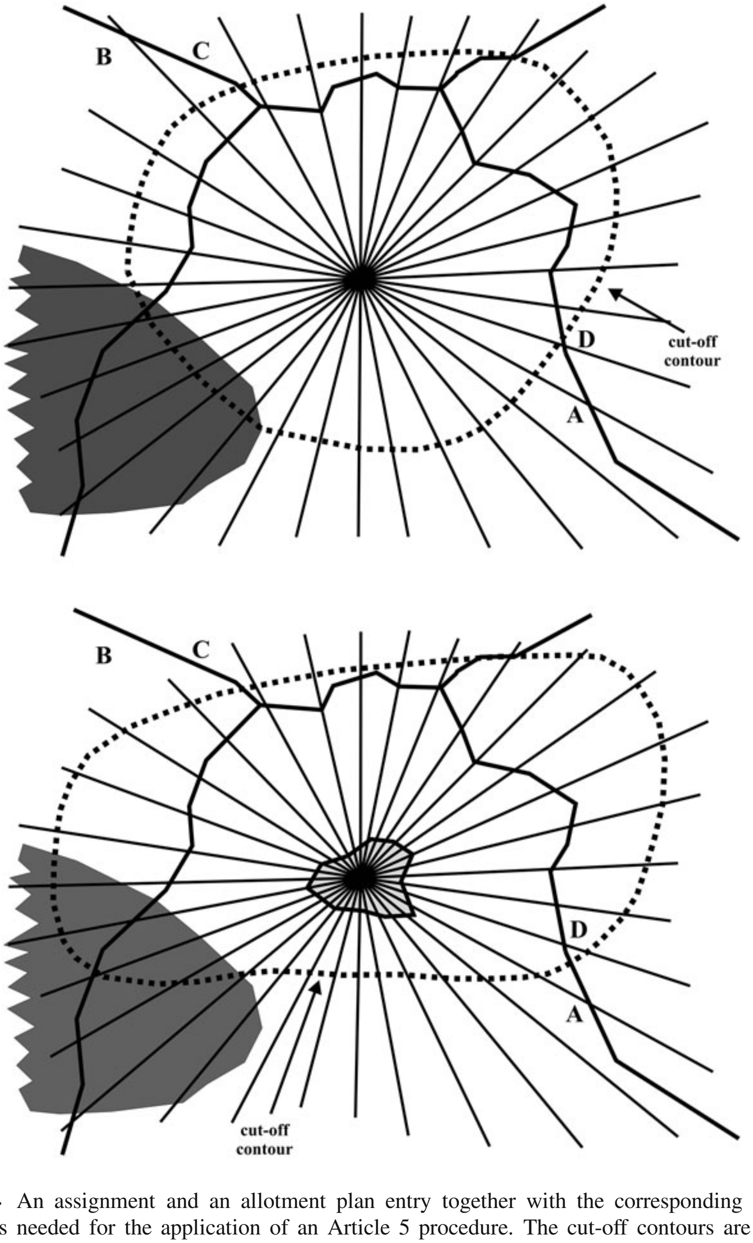

Fig. 4.4 An assignment and an allotment plan entry together with the corresponding cut-off contours needed for the application of an Article 5 procedure. The cut-off contours are meant as examples. They depend on the technical characteristics of the plan entries, i.e. RPC/RN or ERP, antenna height and antenna diagram, respectively

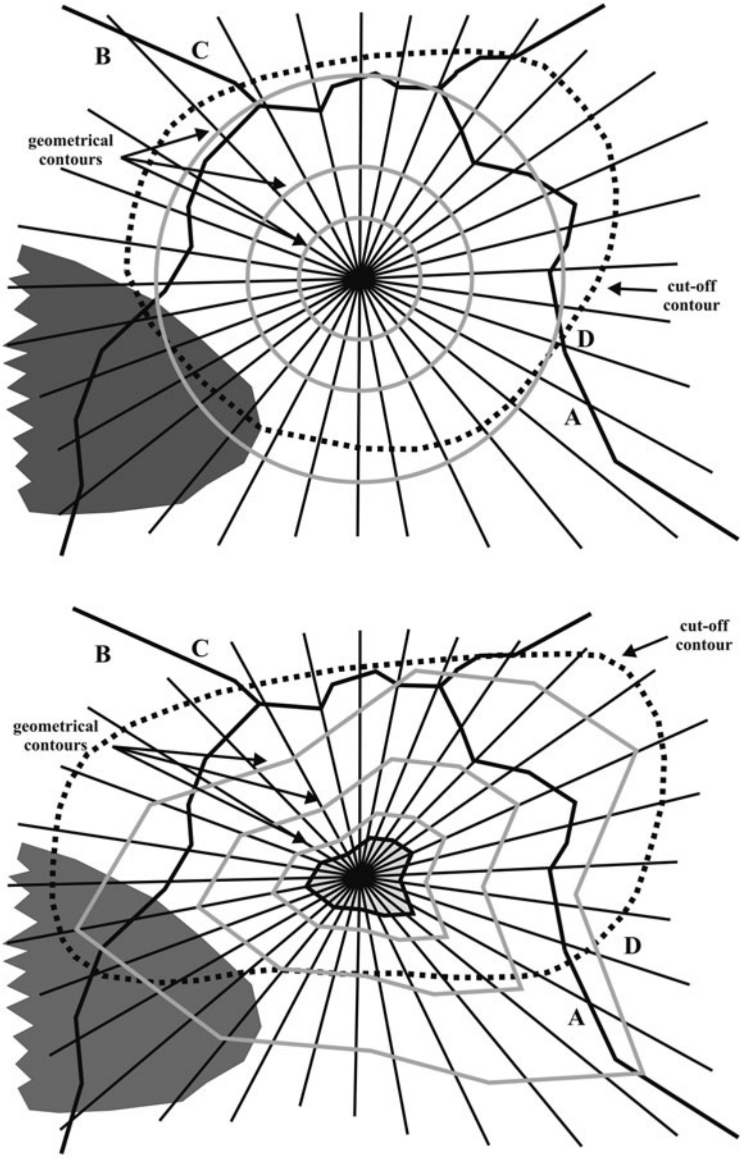

Fig. 4.5 An assignment and an allotment plan entry together with the corresponding cut-off contours and geometrical contours. The *dark area* on the *lower left* represents sea

The point where the radials emerging from the point of reference of the plan entry under consideration and the geometrical contours intersect are the locations of potential calculation points. The word "potential" is to indicate that not all intersection point are employed. Rather, only those points lying outside the national territory of the notifying administration and inside the cut-off contour are utilized as calculation points. Whether they are located on land or above water is not important, both are taken into account. Due to the fact that the radials are separated by 1° and that there are seven geometrical contours the maximum number of calculation points that ever might need to be considered is $360 \times 7 = 2520$. However, it can be expected that in practice the number will be significantly less. Figure 4.6 presents the locations of the calculation points for the examples considered here.

The technical implementation of Article 5 as given in Sect. II of Annex 4 of GE06 exhibits one very important feature. The location of the calculation points is derived exclusively from characteristics of the plan entry. Both point of reference and circular contours or buffer zones are calculated from the geometrical features of the assignments or allotments in the plan, respectively. However, the cut-off contour is determined on the basis of the technical characteristics of the intended network implementation by calculating field strength levels and comparing them with trigger field strength values. This is reasonable from the point of view that e.g. a high power assignment plan entry could be implemented in terms of low power station. This will certainly have a rather limited impact on other plan entries or already existing networks. Consequently, it is not relevant to carry out intensive calculations at distances where the field strength values produced by the intended network implementation has fallen already below irrelevant levels.

Once the location of the calculation points has been determined, the actual assessment if the network implementation is in conformity with the characteristics of the plan entry can be accomplished. To this end, two calculations are carried for each calculation point. Firstly, the field strength value is calculated that will be produced by the plan entry at the given calculation point. Then, the technical characteristics of the assignment(s) representing the intended network are used to evaluate the field strength which is produced at the same point. All calculations are based on the wave propagation model described in Chap. 2 to Annex 2 of the GE06 Agreement. Aggregation of several signal contributions is based on the application of the power sum method as described in Sect. 3.5 of Chap. 3 to Annex 2. The network implementation is considered as being in conformity if the field strength of the plan entry is larger than that of the implementation at each calculation point. If only at a single point this condition is not met the notifying administration has to modify its network implementation and re-submit the new technical characteristics. In case this is not feasible, a plan modification procedure according to Article 4 could be envisaged in order to match plan entry and network implementation.

For an assignment plan entry which is to be implemented in terms of a single assignment the calculations are pretty straightforward. For each calculation point only two calculations need to be carried out. However, it should be borne in mind that even that simple case allows for relatively much freedom when it comes to implementation. First of all, the location of the assignment in the plan and the actual location of the transmitter site may differ by up to 20 km. This might lead to different efficient heights that have to be taken into account when calculating the field strength according to the wave propagation model of the GE06 Agreement. Moreover, both ERP and the antenna height above ground of the real transmitter can be different

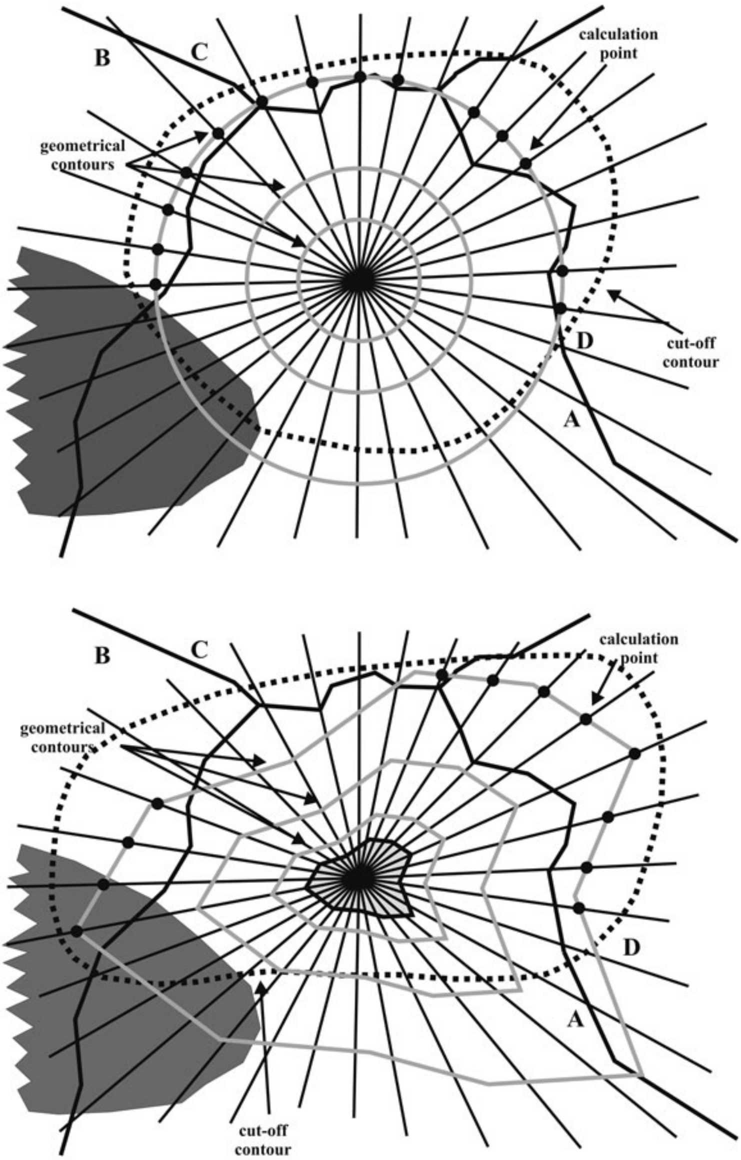

Fig. 4.6 An assignment and an allotment plan entry together with the corresponding cut-off contours, geometrical contours and calculation points. The *dark area* on the *lower left* represents sea

from what is recorded in the GE06 plan. But then it is obvious that a conformity check is mandatory in order to guarantee that the implementation stays below the interference envelope of the plan entry at every single calculation point. Figure 4.7 illustrates the situation.

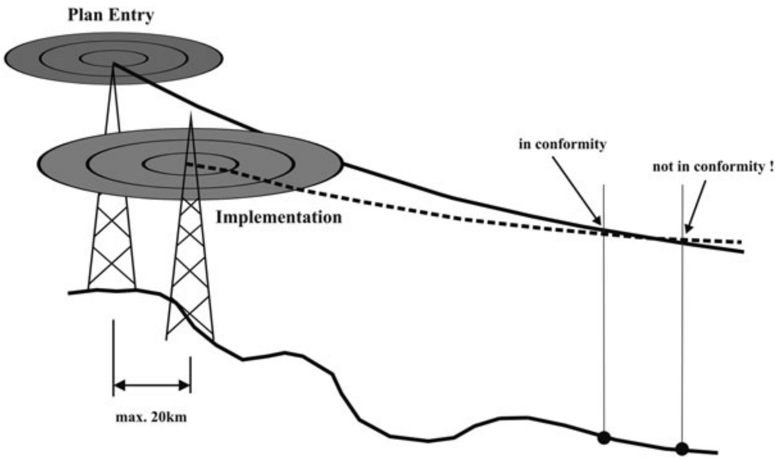

Fig. 4.7 Characteristics of a plan entry and an intended implementation of an assignment can differ significantly which calls for an appropriate conformity check even for this simple situation

The situation becomes more complex in the case of an implementation of an allotment plan entry. Still the same principle applies, namely to compare the interference produced by the plan entry with that of the intended network implementation. However, due to the larger freedom allotment planning offers the computations are more elaborate. An allotment is represented by a combination of RPC and RN. They define the interference envelope of an allotment. At any arbitrary point a field strength value can be calculated by properly adjusting the RN along the allotment boundary. It is positioned at each vertex of the allotment polygon[2] and the aggregated field strength produced by the set of transmitters in the RN is computed at the point of reception under consideration. Then, the maximum value obtained is defined as the field strength the allotment produces there. These calculations are repeated for each vertex. Figure 4.8 visualizes the layout.

It has to be noted that the orientation of the RN relative to allotment boundary depends on the direction of the line connecting the calculation point and the vertices of the allotment. As a consequence, there are situations where the transmitters of the RN will lie outside the allotment area. They might be located in the territory of an adjacent country or in the sea. This caused a lot of heated discussion during the RRC-06. In the end, administrations could agree to that concept notifying that the same mechanism is used in the plan generation process during the compatibility analysis and therefore plan generation and conformity check are consistent.

Allotment planning gives the freedom to use as many transmitters for the network implementation as considered appropriate by an administration. From a principle point of view there is no limit as long as the total interference of such a network

[2] The details about the positioning of the RN at a given vertex can be found in [ITU06] in Appendix 2 to Sect. II of Annex 4 to the GE06 Agreement.

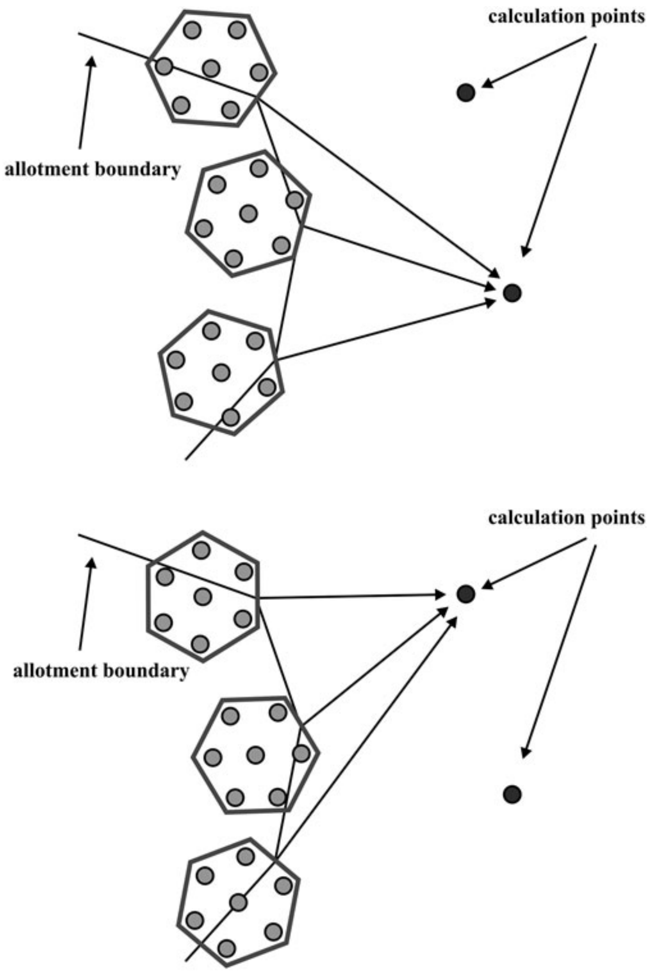

Fig. 4.8 Calculation of the interference of an allotment plan entry by positioning of a RN along the vertices of an allotment boundary. The orientation of the RN varies depending on the direction of the connecting line between calculation point and vertex

stays below the interference envelope of the corresponding allotment plan entry. Nevertheless, at the stage of implementation the technical characteristics of the transmitters need to be specified so that they can be used for the conformity check under Article 5. The set of notified transmitters is employed to calculate the aggregate field strength produced at the same calculation points as before. Figure 4.9 shows the scenery corresponding to the computation of Fig. 4.8.

Already during the preparation of the RRC-06 and during the RRC-06 there were heated discussions about the conformity check. It was considered as too complicated and computationally challenging. Even if this might be true, it has to be noted that the decision to base the plan generation on assignments

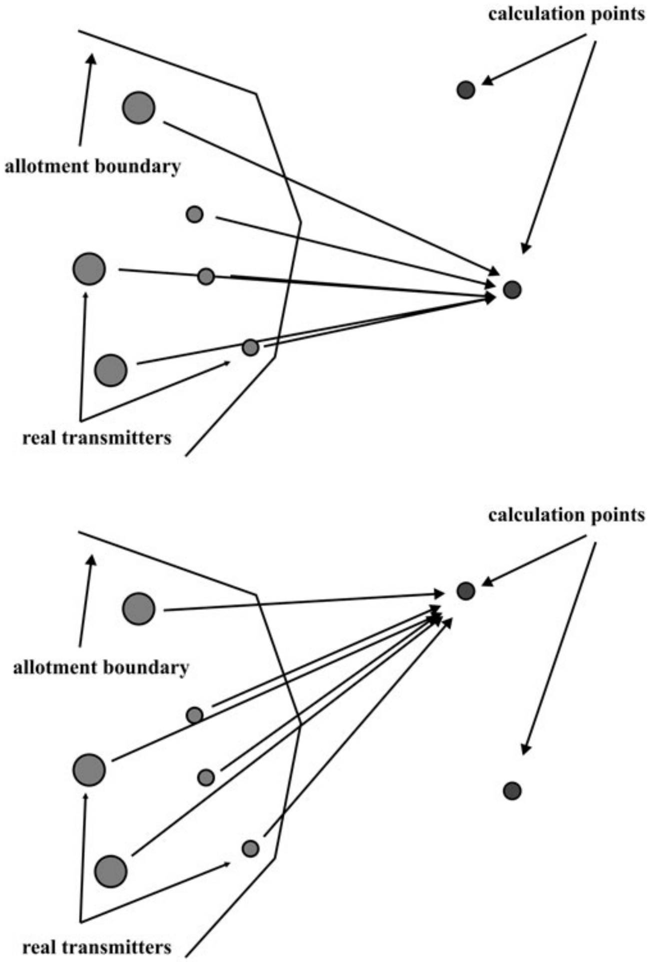

Fig. 4.9 Calculation of the interference produced at given calculation points by transmitters implementing an alltoment plan entry

and allotments enforced the development of a methodology which is flexible to cope with all potential implementation situations. The idea of an interference envelope under which administrations can virtually do whatever they like seemed to be very attractive in view of the rapidly changing digital telecommunications and broadcasting sector leaving enough freedom to adapt to future demands. In the first place, this required to replace the one-dimensional analysis along a given curve or polygon as included for example in the WI95 Arrangement of CEPT by a two-dimensional approach.

However, the issue became complicated when some administrations demanded the introduction of a cut-off contour. This led to plenty of conceptional problems. Still it has not been fully proven that the way the cut-off contour is now calculated does indeed properly cover any eventuality. The original proposal not to use a cut-off contour, i.e. not to reduce the number of calculation points by suppressing some of them might have established a more sound and transparent basis for the conformity check. However, any measure included in the GE06 Agreement has undergone a lengthy and tedious political consensus building process. So, it should not come as a surprise that technical shortcomings have to be borne as a consequence.

4.2 Bilateral Frequency Planning in ITU-R Region 3

The GE06 Agreement for digital terrestrial broadcasting is an example for formalized frequency planning. Over several years the planning conference has been prepared by ITU and regional organizations such as CEPT. The usage of a certain part of the electromagnetic spectrum is governed by formal rules laid down in the GE06 Agreement and to be supervised by the Radiocommunication Bureau of ITU-R. A corresponding data base, i.e. the GE06 Plan and the List, are maintained to keep track of all individual spectrum usages.

However, such an approach is not the only possibility to cope with spectrum usage issues on an equitable access basis. In ITU Region 3, no equivalent formal frequency planning framework exists. Frequency planning for all kind of services is carried out by means of bi- and multilateral coordination only. It has to be noted that such coordination activities nevertheless need to be embedded into the general framework of the ITU-R Radio Regulations (RR) together with the Table of Frequency Allocations (TFA) forming a part of the RR. They contain articles that in general terms govern the spectrum usage and in particular specify measures in order to avoid harmful interference into other telecommunication services.

Any spectrum usage needs to be in accordance with the rules of the RR and the entries of the TFA in first line and secondly any such usage has to be notified to the ITU-R Bureau. The Bureau assesses the conformity of the request with respect to the TFA and other relevant provisions of the RR. In case of a so-called favorable finding the request for spectrum usage is included as an assignment into the MIFR.

Clearly, administrations wishing to use a frequency for a particular service will seek the agreement of their potentially affected neighbors before sending a notification to the ITU-R. Therefore, administrations of neighboring countries are negotiating about their rights to use spectrum along a common border between themselves without taking into account anything else than their needs and the requirements of their neighbors. Neither there are procedures to be followed as in the case of GE06 nor are administrations bound to given calculation methods in order to assess the consequences of an intended spectrum sharing scenario between the same or different services.

In order to put the ITU-R Bureau in the position to carry a proper assessment of the potential interference of a new station administrations are requested to provide all relevant technical characteristics of the new station. Based on this information the Bureau can then assess whether the use of the frequency, under the notified conditions, could cause interference to stations of any other administrations whose assignments are recorded in the MIFR.

Table 4.1 Overview about frequency allocation in ITU-R Radio Regulations after the WRC-07 in the frequency range 470–890 MHz

<table>
<tr><th>Region 1</th><th>Region 2</th><th>Region 3</th></tr>
<tr><td rowspan="7">470 – 790
BROADCASTING</td><td>470 – 512
BROADCASTING
Fixed
Mobile</td><td rowspan="2">470 – 585
BROADCASTING
FIXED
MOBILE</td></tr>
<tr><td rowspan="2">512 – 608
BROADCASTING</td></tr>
<tr><td rowspan="2">585 – 610
BROADCASTING
FIXED
MOBILE
RADIONAVIGATION</td></tr>
<tr><td rowspan="2">608 – 614
RADIOASTRONOMY
Mobile-satellite except aeronautical mobile-satellite (earth-to-space)</td></tr>
<tr><td rowspan="6">610 – 890
BROADCASTING
FIXED
MOBILE 313A,317A</td></tr>
<tr><td>614 – 698
BROADCASTING
Fixed
Mobile</td></tr>
<tr><td rowspan="2">698 – 806
BROADCASTING
MOBILE 313B, 317A
Fixed</td></tr>
<tr><td rowspan="2">790 – 862
BROADCASTING
FIXED
MOBILE except aeronautical mobile 316B, 317A</td></tr>
<tr><td rowspan="2">806 – 890
BROADCASTING
FIXED
MOBILE 317A</td></tr>
<tr><td>862 – 890
BROADCASTING 322
FIXED
MOBILE except aeronautical mobile 317A</td></tr>
</table>

In Region 3, the UHF band has been used for broadcasting, mobile and fixed services on a primary basis already for a long time. A quick look to the TFA of the RR of the ITU e.g. in the case of the band 470–890 MHz illustrates the situation (see e.g. Table 4.1 in Sect. 4.4 below).

4.3 World Radiocommunication Conference 2007

WRCs are conducted by ITU every three to four years. Usually, each WRC has to review, and, if necessary, revise the ITU-R Radio Regulations (RR). The RR constitute the international framework for the usage of the radio-frequency spectrum and all satellite orbits. WRCs are conducted on the basis of an agenda determined by the ITU Council. This agenda is prepared several years in advance by relevant ITU groups such as the Conference Planning Meeting (CPM).

Under the terms of the ITU Constitution, the competence of a WRC comprises revisions to the RR and any associated frequency plans. It shall identify issues (called "Questions" in ITU terminology) which should be studied by corresponding Study Groups of ITU. Results of these technical and regulatory studies are presented to subsequent WRCs and may influence decisions on frequency allocations to particular services and sharing between services. Different ITU-R Study Groups are usually tasked to gather information on different WRC agenda items.

As a matter of fact, spectrum usage is not globally harmonized around the planet. This is due to a certain amount of historical legacy in different regions but also because different regions obviously have different needs in relation to radio- and telecommunications services. However, in order to confine fragmentation of spectrum usage the spectrum management is organized at ITU level in terms of subdividing the world into three ITU Regions. Basically, Region 1 covers Europe, Africa and the former Soviet states now forming what is called Commenwealth of Independent States (CIS). Region 2 corresponds to the Americas and Region 3 comprises the Asian-Pacific area. These geographical regions are considered independent so that different spectrum allocations can be made, if necessary.

Between 22 October 2007 and 16 November 2007 ITU conducted the WRC-07 in Geneva [ITU07]. More than 2500 representatives from ITU Member Sates, Regional Organizations, and other organizations and companies participated in the conference. By definition, the entire electromagnetic spectrum range relevant for telecommunication services ranging from 9 kHz up to 1000 GHz is under review during a WRC. In order to structure the whole process the agenda of a WRC contains many items which either refer to particular spectrum ranges or to services. With regard to the Digital Dividend the most important agenda item (AI) of WRC-07 was AI 1.4 "Candidate Bands for IMT" [IMT00]. The term IMT (International Mobile Telecommunication) describes a global broadband multimedia communication system. ITU has supported the development of the such a system for a long time, in particular with a focus on the global harmonization aspect. In the meantime, the next step called "IMT-advanced" has been made. This system is to provide a global platform on which to build the next generations of mobile services paving the way to fast data access, unified messaging and broadband multimedia consumption.

Before the WRC-07 CEPT was passing through a preparation process which is followed before any important event at ITU level. Several groups had been established to prepare European Common Proposals (ECP) and CEPT Briefs. ECPs contain explicit proposals for modifications of the RR or they call for adoption of ITU Resolutions in which tasks for ITU Study Groups are formulated or other general regulatory measures are put forward. Briefs provide the background information relating to ECPs.

Hence, CEPT submitted a set of ECPs referring to the different agenda items. Concerning AI 1.4 the European proposals consisted of two fundamental statements. Firstly, CEPT was proposing no change to the RR in the band 470–862 MHz at the WRC-07. Furthermore, it was proposed to foresee an agenda item for the next WRC in 2011[3] by which allocations to the mobile service in relevant parts of the band 470–862 MHz should be considered. If appropriate, the need for the identification of a sub-band for IMT should be envisaged, as well as a Resolution to invite studies on the potential use of the band 470–862 MHz by new mobile and broadcasting applications on a co-primary basis. Clearly, this also calls for consideration of any relevant harmonization measures an identification of a sub-band for IMT would require.

The justification for such an approach was that Europe at that time had started to investigate the use of the upper part of the band 470–862 MHz for mobile applications after digital switch-over from analogue to digital terrestrial broadcasting. Since the technical studies were still ongoing and no final decision had been taken yet, CEPT felt it would be pre-mature to request the frequency allocation for mobile services in the UHF band. Rather, CEPT explicitly declared that they would prefer to take a decision on this issue at WRC-11, after studies have been completed. Nevertheless, a fall back position had been slipped into the proposal by saying that Europe would be prepared to consider proposals from outside CEPT at WRC-07 and take appropriate action.

The CEPT proposal at WRC-07 for an agenda item at WRC-11 read in detail that Europe proposes [ITU07c]

> to consider allocations to the mobile service in the band 470–862 MHz, taking into account the current and planned use of this band by services to which this band is allocated, and to consider the need for the identification of a sub-band for IMT, in accordance with Resolution [EUR/10A4/17–UHF] (WRC-07).

A corresponding draft for the Resolution mentioned in the text was attached to the ECP as well.

Even though this was the official course of action of CEPT, at the end of WRC-07 it was decided to accommodate a new allocation in the band 790–862 MHz in Region 1 already during the 2007 conference. Mobile services would be allowed to use that band on a co-primary basis together with broadcasting and fixed services. In Regions 2 and 3, such an allocation existed already before the WRC-07. Moreover, in Region 2 mobile services could be accommodated down to 614 MHz while in Region 3 the entire UHF band 470–862 MHz was allocated to the mobile service.

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[3] At the time of the WRC-07 it was foreseen to convene the conference in 2011. However, due to other big events being scheduled in Geneva in 2011 there was no possibility to find a large enough time slot to host the WRC. Therefore ITU decided to postpone the conference to February 2012.

The allocation of UHF spectrum to the mobile service is subject to several footnotes to the TFA of the RR. Some of these footnotes were existing ones that were modified at WRC-07, others were newly introduced. The first important aspect of this new spectrum allocation is that the spectrum was identified for IMT services. This is expressed by the modified footnote 5.317A which refers to the band 790–960 MHz for Regions 1 and 3 and to the band 698–960 MHz. However, no priority is given to IMT with respect to other services. Secondly, footnote 5.316B essentially says that the allocation is effective as of 17 June 2015. For Region 1, this is a special date since it coincides with the end of the transition period of GE06. Clearly, since the band 790–862 MHz is governed by GE06 in Region 1 any base station of a mobile service network introduced in that spectrum range is subject to successful application of the GE06 procedures, i.e. Articles 4 and 5.

Furthermore, for Region 1 footnote 5.316 was modified and a new footnote 5.316A was added. They govern the usage of the upper UHF band for mobile services even before 17 June 2015 on a no-interference-no-protection basis. These immediate allocations end by 16 June 2015 when footnote 5.316B comes into effect. The two footnotes were introduced to find a work-around allowing to include a long list of countries in a footnote of the RR. However, since still many European countries did not ask for inclusion in the list of the footnotes coordination according to GE06 will be required for the introduction of mobile services. This might lead to delays for the roll-out of mobile services in the band 790–862 MHz.

Due to the fact that in the other two ITU-Regions a mobile allocation had already existed before the WRC-07 the situation was easier to resolve. First of all, there is no regional agreement like GE06 that governs the usage of the UHF bands by broadcasting and other services, neither in Region 2 nor in Region 3. Therefore, any spectrum usage has to be addressed on the level of bi- and multilateral coordination. To support this approach, for Region 2 just a reference to the modified footnote 5.317A was necessary to identify the range from 698 to 862 MHz for IMT. In Region 3, the same reference was included which means that similar to Region1 the band 790–862 MHz was opened for mobile services. Furthermore, a footnote 5.313A was also added which extends the allocation down to 698 MHz for a list of nine countries in Region 3.

In addition to these modifications, WRC-07 adopted two Resolutions, both calling for sharing studies between IMT and those services to which the bands under considerations are allocated. ITU-R Resolution 224 [ITU07a] requested to

> study the potential use of the band 790–862 MHz in Region 1 and Region 3, the band 698–806 MHz in Region 2 and in those administrations mentioned in No. 5.313A in Region 3 by new mobile and broadcasting applications, including the impact on the GE06 Agreement, where applicable, and to develop ITU-R Recommendations on how to protect the services to which these bands are currently allocated, including the broadcasting service and in particular the GE06 Plan, as updated, and its future developments;

while ITU-R Resolution 749 [ITU07a] declares to

> invite ITU-R to conduct sharing studies for Regions 1 and 3 in the band 790–862 MHz between the mobile service and other services in order to protect the services to which the frequency band is currently allocated.

The studies called for in Resolution 224 were carried out by ITU-R Study Groups 5 and 6 while in order to carry the investigations resulting from Resolution 749 the Joint Task Group 5–6 [ITU10a] was established. In summer 2010, the group delivered its results.

The question how it came to be that the initial CEPT intention not to change the RR, i.e. not to allocate the band 790–862 MHz to mobile services in Region 1, was abandoned and who initiated the process is a delicate one. It can be speculated that this has been the unofficial objective of CEPT from the very beginning. It might well be that at the time of the WRC-07 European administrations felt that little more than just one year after the assembly of the GE06 broadcasting plan it was too risky to openly go for an allocation of the upper UHF band to the mobile service. However, a WRC is autonomous in its decisions. To plant the seed at the conference itself probably seemed to be more promising.

During the conference this change of mind caused a lot of tension between broadcasters in Europe and their administrations. Apart from the fact that some broadcasters felt that CEPT had double-crossed them, this decision on a new allocation constitutes some kind of precedence. Usually, a frequency range is identified for allocation to a service. Then during the following study cycle the sharing conditions are investigated and corresponding sharing parameters are defined e.g. in terms of ITU Recommendations. Only after this is accomplished the frequency allocation is adopted and coming into effect. This time the process was turned upside down, first came the allocation and then the definition of the circumstances under which sharing between services would be feasible should be tackled. Such a course of action clearly shows that the political and economical pressure to open a new band for mobile services must have been tremendous.

4.4 Frequency Allocations for Broadcasting and Mobile Services

After the WRC-07 an updated version of the ITU-R Radio Regulations (RR) was published including a modified TFA [ITU08]. Modifications relating to any of the services dealt with at a WRC such as broadcasting, mobile, fixed, aeronautical, and other services had been included. However, for the discussion about the Digital Dividend and its impact on terrestrial broadcasting only a small part of the TFA is relevant. In the first place, only those entries referring to the mobile service are interesting at all.

The term mobile service encompasses many different applications at ITU level such as individual communication systems, military mobile services or Public Mobile Radio (PMR). They can have very different technical characteristics. Only a subset of all those mobile applications make up IMT, for example GSM, UMTS, LTE, or WIMAX. It is important to note that the RR only contain allocations to services and not to applications.

In order to harmonize the spectrum usage and to give clear indications to the industry ITU-R identifies part of the frequency ranges allocated to the mobile service for IMT usage. In the first place, this constitutes a kind of recommendation that the considered frequency ranges should be used for IMT rather than for other applications of the mobile service. However, it does not exclude the usage of these frequencies for other applications of the mobile service because if an application is part of a certain service it can be brought into operation within any spectrum range that is allocated to this service as long as the corresponding constraints and conditions for the spectrum usage are met. Obviously, by means of footnotes additional restrictions can be imposed by mentioning them explicitly.

Therefore, administrations can in principle ignore the identification for IMT expressed by ITU. But it is evident that as soon as applications are likely to have an impact on spectrum usages in neighboring countries it starts to become unattractive not to harmonize the usage of applications. Only in exceptional cases of very large countries such as the US or Russia this might be a viable option.

Before the WRC-07 several frequency bands had already been identified for IMT. These were the bands 806/860–960 MHz, 1710–2025 MHz, 2110–2200 MHz, and 2500–2690 MHz. In 2007, WRC-07 has identified additional spectrum for IMT in the following bands:

- 450–470 MHz on a global level
- 698–790 for nine countries[4] in Region 3
- 698–806 MHz for Region 2 (Americas)
- 790–862 MHz for Region 1 (Europe, Middle-East and Africa)
- 790–960 for Region 3 (Asia-Pacific)
- 2300–2400 MHz on a global level and
- 3400–3600 MHz in 82 countries

It has to be noted that these identification do not in all cases properly reflect the availability of the spectrum due to special national arrangements in some of the countries.

Directly relevant for the broadcasting service are only the identifications in the UHF bands. Table 4.1 gives an overview about the frequency allocations in the frequency range between 470 and 862 MHz in the three different ITU Regions. Services written in capital letters have primary status in a given frequency range while standard notation refers to secondary status. In some cases, additional text is provided to highlight constraints on the usage of the spectrum by the corresponding service. Also, footnote labels are given wherever they apply.

[4]These countries are Bangladesh, China, Korea (Rep. of), India, Japan, New Zealand, Papua New Guinea, Philippines and Singapore.

The Digital Dividend discussion focuses on the UHF range. However, a sound assessment of the way in which IMT services are exploiting frequency resources has to take into consideration all frequency allocations across the entire electromagnetic spectrum range. This is, in particular, important in relation to addressing the issue of future spectrum requirements of IMT.

Chapter 5
Digital Switch-Over in Broadcasting

Digital terrestrial broadcasting systems are currently introduced around the world in many countries. The transition from analogue to digital transmissions is envisaged both for radio and television services. However, in relation to the Digital Dividend the migration of television is of more relevance than switch-over in radio. This is due to the fact that the focus of the Digital Dividend discussion lies on the UHF band in which terrestrial television services are provided. Digital radio mainly takes place in the VHF Band III which for example is the primary frequency resource for the introduction of DAB based services. Therefore, the overview given in this chapter concentrates on the status quo and the developments concerning the introduction of digital terrestrial television services in the UHF frequency range.

Digital television offers new possibilities for broadcasters and viewers. The main reason for this is that spectrum is used more efficiently by digital than by analogue technologies. This allows to provide more programmes within the same occupied bandwidth. In contrast to analogue television, portable and mobile reception are supported by digital terrestrial television. The more efficient usage of spectrum results in higher net data rates which open the door to providing improved quality of image and sound, including HDTV. Additional services can be added such as Electronic Programme Guides (EPG). From the perspective of the national administrations and regulators this provides the basis to establish an alternative, competitive digital distribution platform along with cable and satellite distribution.

5.1 Overview About the Digital Switch-Over in Europe

In Europe, the transition from analogue to digital terrestrial broadcasting is taking place both for radio and television. Digital radio services will be based almost exclusively on the systems of the DAB-family. Nevertheless, there has been an increasing momentum to further develop digital radio on the basis of DRM+ in order to complement DAB based offers in late 2010. In particular, smaller commercial broadcasters were reluctant for a long time to adopt the DAB concept of providing

R. Beutler, *The Digital Dividend of Terrestrial Broadcasting*, DOI 10.1007/978-1-4614-1569-5_5, © Springer Science+Business Media, LLC 2012

programmes in terms of multiplexes. Sharing a programme multiplex with the direct competitors was not very welcomed because it involves additional negotiations and potentially costs. DRM+, on the contrary, offers the possibility to stick to the old tradition of radio broadcasters, namely "one frequency – on station – one programme".

Even though digital radio is foreseen to be deployed in Band III there are countries in Europe that envisage to use VHF spectrum for digital television services. Depending on the further developments in the UHF band under the umbrella of the Digital Dividend, Band III will become affected as well once terrestrial television services will be moved from UHF to VHF frequencies. However, for the discussion here this is not relevant. Therefore, the focus of the presentation lies on UHF and thus on digital switch-over for terrestrial television services.

Digital terrestrial television has been a success story in Europe. The major success factor was the adoption of a single European standard, i.e. the DVB-T standard [ETS97b]. The development of this standard was driven by an industry initiative which was strongly supported by broadcasters. In 2006, the door to the introduction of DVB-T was finally pushed open by the generation of the Geneva Plan [ITU06] (see Sect. 4.1 for more details). It harmonized the spectrum ranges 174–230 MHz (VHF Band III) and 470–862 MHz (UHF Bands IV/V) for digital terrestrial broadcasting (both European Standards T-DAB and DVB-T) in 118 countries. The Regional Radiocommunication Conference 2006 (RRC-06) resulted in a situation where most European countries were given 7–8 DVB-T layers/multiplexes of national coverages in the UHF spectrum range.

The flexibility of the DVB-T standard (different system variants, reception modes, etc.) is an attractive feature both for broadcasters and consumers. In particular, the possibility to receive television signals outside the living room, e.g. during a barbecue in the garden, is very welcomed by viewers. DVB-T receivers are widely available and they are quite cheap. There are many different models allowing everybody to select the type that suits best his or her needs.

RRC-06 set out a final date for analogue switch-off in 2015. However, in Europe it was decided by administrations to bring forward the end of the transition period by 3 years. So, the European target is to complete the transition to digital terrestrial television by 2012 already. This is an ambitious objective facing the different European countries. Each of them has a national regulator that is pursuing its own telecommunication and broadcasting policy. Moreover, even though there is a common European market there are distinct differences in most areas concerning the type and focus of domestic telecommunication industries. This results in different paces on the way to full analogue switch-off.

In 2010 the digital switch-over situation in Europe was quite irregular [Dig10]. There were countries that had already completed the transition, while others had not even started:

- In Germany, Sweden, Norway, Finland, Spain, Netherlands, Belgium, Luxemburg, Denmark and Switzerland analogue switch-off was achieved.
- In UK, France, Italy, Austria, Czech Republic, Latvia and Estonia digital switch-over had been started and the target was to complete it before 2015.

- Countries such as Portugal, Greece, Poland, Hungary and other East European countries had not even started the transition process by introducing digital terrestrial networks apart from some trials.

The different national broadcasting policies are clearly reflected in the type of services which will be offered, the strategy followed for the digital switch-over and the choice concerning the DVB-T system variant and network topology.

Countries like UK, France, Italy, and Spain very heavily rely on terrestrial distribution of television programmes. Nevertheless, they are different in the sense that in UK and Spain all services on DVB-T are free-to-air while in France and Italy there is a part of DVB-T services which is pay-TV. In all Scandinavian countries with a medium market share of terrestrial distribution, the DVB-T platform is a pay-platform. Those countries having a low penetration of terrestrial broadcasting as a primary means for reception of television services (Germany, The Netherlands, and Switzerland) are favoring either free-to-air or pay services on DVB-T. Table 5.1 gives an overview about the status quo in some European countries at the end of 2010. More information can be found in [Dig10].

DVB-T can be deployed according to the European Telecommunications Standards Institute (ETSI) standard published in 1997 [ETS97b]. This is based on MPEG2 compression and provides enough data capacity per multiplex to offer 4–6 programmes in standard definition quality. However, DVB-T can be operated with MPEG4 as well which almost doubles the data capacity. This opens the door to a more efficient usage of spectrum in the sense of being able to offer more programmes within the same occupied bandwidth. But this is not end of the story. Most countries in Europe will in the medium or long term switch to DVB-T2. Then television programmes can be delivered in HD quality also on the terrestrial platform. For those countries that started already a long time ago with the introduction of digital terrestrial television this poses some kind of a legacy problem. In a market that is saturated with first generation DVB-T receivers, an upgrade to MPEG4 or DVB-T2 corresponds to another switch-over scenario. But as UK has shown already such a digital-to-digital migration or upgrade can be managed [DVB10].

The introduction of digital terrestrial television services was and still is envisaged by applying different strategies. Digital switch-over does not happen by itself. Broadcasters, customers, and last but not the least manufactures need to have good reasons to go digital. Therefore, for all of them there have to be appropriate incentives to let them carry the switch-over burden which in most cases comes down to spending money. Spending money will only happen if people see some advantage or benefit.

Clearly, depending on the market share of terrestrial broadcasting different switch-over strategies might be required. In markets where terrestrial distribution is the dominant or a very important means of delivery of broadcasting content, a critical mass of appealing free-to-air content must be provided. If the existing programmes cannot be received on the digital platform it is not attractive for viewers to move from analogue to digital terrestrial broadcasting. However, just putting existing programmes into DVB-T multiplexes is not enough. New services,

Table 5.1 Overview about digital switch-over in Europe

Country	Terrestrial market share	Business model	Switch-off date
UK	High	Free	2012
Spain	High	Free	Completed
France	High	Free/pay	2011
Italy	High	Free/pay	2012
Croatia	High	Free/pay	2011
Finland	Medium	Pay	Completed
Denmark	Medium	Pay	Completed
Norway	Medium	Pay	Completed
Sweden	Medium	Pay	Completed
Czech republic	Medium	Free	2011
Estonia	Medium	Pay	Completed
Latvia	Medium	Pay	Completed
Hungary	Medium	Free/pay	2011
Poland	Medium	Free/pay	2013
Lithuania	Medium	Pay	2012
Slovenia	Medium	Free/pay	Completed
Germany	Low	Free	Completed
NL	Low	Pay	Completed
Switzerland	Low	Free	Completed

maybe even exclusively accessible via the terrestrial platform constitute the decisive element to boost the success of terrestrial broadcasting. Since in an environment which is dominated by terrestrial broadcasting many customers rely on this delivery mechanism a long simulcast period might be required before analogue transmissions can finally be phased out. Countries like France, UK, Spain and Italy are good examples where exactly such an approach can be observed.

In countries such as Germany, The Netherlands, or Switzerland with a very high cable and satellite penetration terrestrial broadcasting has to focus on portable and mobile reception as the primary target to be achieved. Terrestrial broadcasting can usually not compete with satellite distribution in terms of the number of offered programmes due to limited spectrum resources for terrestrial delivery. This might be also true in comparison to cable distribution. Therefore, the only possibility to enter the market and get hold of a big enough share is the portable/mobile section. Germany can act as a good example to support this view, since the share of terrestrial television rose from less than 10% to 15–20% (including secondary reception). The main reason why it was attractive was the simple fact that for example during big sport events such a the world championship in football people were watching matches in the open while having a barbecue. As a consequence of low penetration of terrestrial television the switch-over period can be reduced which is very attractive from a cost point of view, too.

An approach somewhere in between was chosen in the Scandinavian countries. In the first place, the terrestrial digital platform is employed as a pay-platform. Clearly, there are also free-to-air programmes available but the future development potential certainly lies with the commercial offers. As a consequence, new programmes are offered which have not been available terrestrially before. Furthermore, since this is connected to defined business models analogue switch-off has been promoted more aggressively than in other television markets. This goes hand in hand with the possibility to shorten the switch-over period as much as possible in order to avoid additional costs caused by extended simulcast phases.

Most countries in the Eastern part of Europe are also having plans to migrate to digital terrestrial television. However, they have particular conditions to be met. Television markets are rather small, so some countries are waiting for their neighbors to start the switch-over. In other parts of Europe, there is only a very small fraction of commercial broadcasters who might not want to change their current analogue distribution strategy because they could not afford any simulcast period.

The situation in Russia has certainly a large impact on many countries in East Europe. Obviously, Russia constitutes a huge market. However, the country is also very large which in turn means that the investments to be made in order to roll-out digital terrestrial broadcasting networks are tremendous. In any case, the intention is to go digital in Russia and to start with public service broadcaster's content. That should be complemented by pay-TV services at later stage. A particular problem is that there is also a large portion of the population for which the price of a new DTT receiver is not easy to bear. Therefore, cheap receivers are needed to provide the basis for sufficient penetration of DVB-T throughout the country. Nevertheless, officially Russia intends to follow the European switch-over plan laid down in GE06 by 2015.

5.2 Overview About the Digital Switch-Over Outside Europe

Digital terrestrial broadcasting is in the focus in other regions of the world outside Europe as well. It has to be noted however, that this does not necessarily mean that DVB-T networks will be put into operation. There are several other competing standards available which are in use (see Sect. 2.2).

This section does not intend to give a full picture about digital switch-over around the globe. Rather, it is meant to give some insights into television markets that are subject to other political, commercial and economic constraints than they can be found in Europe.

5.2.1 Digital Switch-Over in Australia

The discussion about the digital switch-over in Australia goes back to the year 1992 when the Australian government issued the general legal framework that paved the way to a conversion from analogue to digital terrestrial television. In particular, this laid the task upon the Australian Broadcasting Authority (ABA) to work out two transitions plans, one for commercial broadcasting and one for national public service broadcasting. ABA came up with a corresponding proposal around the year 2000 which was then approved by the Australian parliament [ABA02].

The basic element of these transition plans was to foresee frequency planning activities such that enough spectrum would be available in order to sustain an appropriate period of simulcasting analogue and digital programmes in parallel. For the commercial broadcasting sector it was foreseen to start with digital transmission in urban areas at the beginning of 2001 while the regional areas should be allowed to receive digital programmes by 2004. All content should be offered in SDTV quality and a simulcast period of 8 years was fixed. No definite dates were set for the national public switch-over including the simulcast phase, however, also here SDTV should be provided at the beginning as well.

Broadcasters were given one or two additional channels in order to deliver digital TV programmes. According to the Australian channel raster both analogue and digital channels were employing a channel bandwidth of 7 MHz. Furthermore, it was requested that any digital coverage should reach the amount of the analogue coverage both in terms of covered area as well as reception quality as soon as practical.

The introduction of digital terrestrial television broadcasting was based on the European DVB-T standard specified by ETSI [ETS97b] which was nevertheless adapted to better cope with Australian peculiarities [StA99]. Together with broadcasters, both commercial and public, ABA and relevant national authorities produced a handbook on digital terrestrial broadcasting in 2005 which addresses all technical issues relevant for the switch-over and the digital operation [ACM05]. Publication of this handbook was accomplished just before 1 July 2005 when the Australian Communications and Media Authority (ACMA) was built by bringing together the ABA and the Australian Communications Authority (ACA).

Before digital transmissions turned from test to operational transmissions several key points were defined in the national Australian discussion as objectives to be achieved for the digital broadcasting services. A minimum of six digital television services should be envisaged during simulcast. Furthermore, any frequency plans for digital terrestrial broadcasting had to make sure that enough capacity would be provided even at the edge of the coverage areas in order to allow for HDTV services

Table 5.2 Australian channels for terrestrial television

Band	Frequency range	Channel
I	45 – 52 MHz	0
I	56 – 70 MHz	1 – 2
II	85 – 108 MHz	3 – 5
III	137 – 144 MHz	5A
III	174 – 230 MHz	6 – 9, 9A, 10 – 12
IV	526 – 582 MHz	28 – 35
V	582 – 820 MHz	35 – 69

at a later stage. In order to facilitate frequency planning during simulcast, co-siting of analogue and digital transmission had to be applied, i.e. no new transmission sites were foreseen at that stage. In case the intended coverage cannot be provided across the envisaged areas SFN network topology should be employed in order to increase the efficiency of spectrum usage.

Efficient spectrum usage was a very important motivation of switching to digital broadcasting. In Australia, several parts of the VHF and UHF bands have been allocated to terrestrial television broadcasting. A channel raster of 7 MHz is used in all frequency ranges. The frequency resources are summarized in Table 5.2.

As can be seen from Table 5.2 the available spectrum in the VHF and UHF bands results in a total of 57 channels (15 in VHF and 42 in UHF) or 399 MHz of spectrum for analogue television. It was decided by the Australian government not to use all these channels for digital television transmissions. Only the VHF channels 6–12 and the whole set of UHF channels should be usable for DTT. This refers to a total of 50 channels or 350 MHz of spectrum. Also for digital terrestrial television a 7 MHz channel bandwidth was envisaged. However, it was requested that channels 68 and 69 should be used only in exceptional cases due to a potential impact on other primary (mobile) services in the adjacent spectrum above [ABA02].

Since terrestrial television broadcasting has a significantly higher relevance than in many European countries where other distribution platforms constitute the dominant way of broadcasting content delivery, it was of utmost importance that any inconvenience either in terms of additional costs (apart from having to buy a receiver for digital terrestrial broadcasting) or suffering form interference should be kept at bay for consumers. Additional costs may arise if channels are chosen for digital terrestrial broadcasting which call for installing a new antenna adapted to another frequency range than in the analogue case.

Similar principles should be considered with respect to the broadcasting industry. The allocation of channels to particular areas for digital television has to be carried out to minimize the costs for all broadcasters and related companies. Basically, it means that existing infrastructure should be reused as much as possible.

The Australian approach towards a digital switch-over was therefore focusing on a transition which could be accomplished as smoothly as possible with the clear aim to minimize the economic impact of this enterprise. However, this also means that the greater flexibility that digital terrestrial transmission offers to broadcasters in terms of using frequency resources was not fully exploited.

At the beginning of 2010 more than 4600 terrestrial television transmitters were licensed in Australia. More than 75% of these were still analogue transmitters at that time while about 1000 digital transmitters were either in operation or planned. The government decided about a detailed switch-over plan in combination with a switch-over timetable. According to this, the switch-over will take place at different times in different regions of the country. It started in 2010 and the process is foreseen to be finalized by 2013. Then, also in remote areas consumers will be able to receive digital terrestrial television services.

As already mentioned above, the switch-over process has to ensure that at the end of the transition period all those consumers currently using analogue TV services have to have access to the digital transmissions without imposing additional costs or other efforts. Both SDTV and HDTV services will be provided during the transition period and after. Services of even higher quality such as UHDTV might be considered in the future as well. However, this will be evaluated in relation to the discussion about the Digital Dividend and the future developments on the wireless broadband sector. More information on the digital switch-over in Australia can be found on the website of ACMA [ACM11] and the five year's spectrum outlook that is updated and published regularly [ACM10].

5.2.2 Digital Switch-Over in the USA

The spectrum range that could be used for terrestrial broadcasting transmission in the US extended from 470 to 806 MHz before 2003. In contrast to Europe and Australia TV channels in the UHF range occupy 6 MHz only. Therefore, 56 TV channels could be accommodated in the UHF band in the USA.

The switch-over from analogue to digital transmission has been finalized in the US by 12 June 2009. Two basic legislations paved the way thereto. In 1996, the Telecommunications Act [Tel96] defined the fundamental principles under which transition from analogue to digital broadcasting should be pursued. The development of this framework with respect to broadcasting can be considered as a reaction to the developments in Japan where HDTV technologies had been presented already years before. There was growing concern that the US might fall back in terms of technological development. As a consequence, the American HDTV standard was defined by a group of concerned organizations and companies (see also Sect. 2.2.6).

In order to enable the digital switch-over additional spectrum was given to broadcasters in order cope with a more or less extended simulcast phase. It was foreseen that at the end of this process this spectrum would need to be handed back. Nevertheless, the transition process did not really take off. Therefore, additional measures were taken in order to boost the digital switch-over. At the beginning of 2002 the Federal Communications Commission (FCC) scheduled a five year's programme targeting at including receivers for digital television in all receivers and television sets on the market [FCC02]. By 1 July 2006 every TV receiver equipped with a 36″ screen or above had to be able to receive DTV. By 1 July 2007 even receivers with screen sizes down to 13″ should comply with this.

Imposing the inclusion of digital receiving units in TV receivers obviously does not solve all problems that will arise during a transition process from analogue to digital terrestrial transmission. The US faced similar problems as did broadcasters and administrations in other regions of the world. In particular, there is always a problem with the existing stock of analogue receivers in the market. In 2005 roughly 19% of US households were using terrestrial television as their primary means of receiving television content. About 57% of households were having a cable subscription while another 20% was using satellite television [Gol05]. In order to enable an analogue TV set to display digital signals it was proposed to provide digital-analogue converter set-top boxes that would then allow further usage of older TV equipment [DTV11a].

Still the uptake of DTV was not satisfying. Therefore, in 2006 the Digital Television Transition and Public Safety Act passed the US Congress which opened the door to finalize the digital switch-over in the US [DTA05]. The key points that were addressed by this Act were the following:

- A firm date for the DTV transition was set at 18 February 2009.
- Dates were fixed for the auction of licenses from the released analogue spectrum.
- A digital-to-analogue converter box program was called for.
- It was decided that part of the auction proceeds should be made available for funding the digital transition process, in particular the digital-to-analogue converter box program.

The Digital Television Transition and Public Safety Act mandated that the spectrum auctions should start no later than by the end of January 2008 with the aim to finalize the auction process by the end of June 2008. Spectrum has been considered a very important economic value as in many other places around the globe. Therefore, it was evident that spectrum released by the digital switch-over process should be given to those services generating the largest economic value.

However, integral part of the Act was the order to use parts of the proceeds of the auctions to enable a faster and more successful transition to digital transmissions. Several programs have been set up amongst which the digital-to-analogue converter box program was the largest [TVC05]. A total amount of three billion dollars was allocated to this program. Its primary intention was to provide coupons to US households that could be used when buying digital television set-top boxes.

Even though a big effort has been put into the digital switch-over process including funding of different activities it turned out that the deadline requested by the Digital Television Transition and Public Safety Act could not be met. Therefore, an extension of the transition period was agreed by the Congress. To this end, the so-called DTV Delay Act was adopted that changed the final date of the digital switch-over to 12 June 2009. More information on the digital switch-over in the US can be found at [DTV11, Kru08, DTr11].

Chapter 6
Implementing the Digital Dividend

The development of digital terrestrial broadcasting systems opened up a once-in-a-lifetime opportunity in the broadcasting sector. Compared to the analogue broadcasting era more programmes can be delivered, higher quality can be offered, and the variety of possible system configurations allows enabling very robust transmission. In addition, the delivered programmes can be consumed under fixed, portable and mobile receiving conditions.

However, the brighter the light the sharper the shadows become. Hence, this big step forward came along with the biggest challenge to terrestrial broadcasting ever. Introducing more efficient telecommunication systems immediately gives rise to the question what to do with the spectrum that apparently is no longer necessary. This initiated the struggle for what today is called the Digital Dividend.

6.1 Defining a Digital Dividend

The simplest and straightforward definition of the Digital Dividend can be given by making reference to the increase in transmission capacity when comparing analogue and digital terrestrial television broadcasting. Within a given TV channel[1] a single analogue TV programme can be offered. With DVB-T several programmes are put into a single multiplex. A simple calculation for the amount of Digital Dividend spectrum starts from the idea to bundle all existing analogue TV programmes into digital DVB-T multiplexes. A typical DVB-T variant like 16 QAM, code rate 2/3 which is quite common in Europe, provides a net bit rate of 14.93 MBits/ s. A standard definition TV programme requires between 3–4 MBits/sec in MPEG-2 coding. Therefore, the capacity of a 8 MHz TV channel would give rise to 3–4 TV digital programmes under such conditions. Consequently, only between 25–33% of

[1]In Europe in UHF a channel bandwith of 8 MHz is used, while in the VHF range 7 MHz are employed. In other regions such as th USA 6 MHz channels are utilized.

R. Beutler, *The Digital Dividend of Terrestrial Broadcasting*,
DOI 10.1007/978-1-4614-1569-5_6,

the channels would be needed to accommodate all television content. Thus, 66–75% of the previously occupied channels could be released for other purposes.

A closer look reveals, that such an estimate is based on oversimplified assumptions. A typical television broadcasting environment consists of several offers of different kind. There are usually programmes targeting at a national audience and hence need to achieve national coverage. Then, many broadcasters have regional programmes. The term regional can have very different meanings in the sense that the size of the regions might differ significantly from each other. In some countries, a region extends over 100–300 km while in other countries the size of what is called a region reaches a considerably smaller extension only. In addition, there are local, for example urban coverages of interest to broadcasters.

If aspects like these are taken into consideration when mapping analogue to digital coverages then the straightforward idea to bundle programmes into multiplexes is not a valid approach anymore. Providing national, regional, and local content at the same time throughout an entire country can only be achieved by providing distinct multiplexes which are filled with programmes targeting at identical coverage areas. If at a given point of reception national, regional and local content should be offered then several distinct TV channels have to be used, one for each multiplex. As a consequence, the spectrum usage as a whole increases. Furthermore, the simple calculation to identify the amount of spectrum that can be easily released does no longer apply. More details about the subtleties of frequency planning for broadcasting services can be found in [Beu04a, Beu08].

A short look at the results of the GE06 Plan can help to illustrate the situation. During the RRC-06 it was agreed that in the UHF band the concept of layers should be employed in order to enable equitable access to the spectrum. The term layer corresponds to a set of allotment areas that taken together make up all or a significant part of the national area of a country. Seven layers for each country could be obtained as a result of RRC-06 based on the available spectrum between 470–862 MHz.

This upper limit of seven layers was a direct consequence of the planning principles that had been adopted during the preparation conference two years before already (see Sects. 4.1.1 and 4.1.2 for more details). It turned out that strict application of the planning principles would not allow more frequency allocations[2] than seven layers for every country. Figure 6.1 displays one of the seven German DVB-T layers in the UHF band that resulted form the planning process of the RRC-06. The numbers in the grey allotment areas correspond to the UHF channels allocated to each of them, respectively.

As a matter of fact, a realistic estimate of the amount of spectrum that could be released as a consequence of the digital switch-over depends on several factors that lie beyond purely technical descriptions. The available amount of spectrum

[2] Actually, even the seven layers were reached in Europe only on the basis of a huge number of so-called administrative declarations that were meant to overwrite any incompatibilities found during the planning process by defining two allocations as compatible. The implementation of real networks making use of the corresponding Plan entries would be subject to coordination between administrations signing the associated administrative declarations.

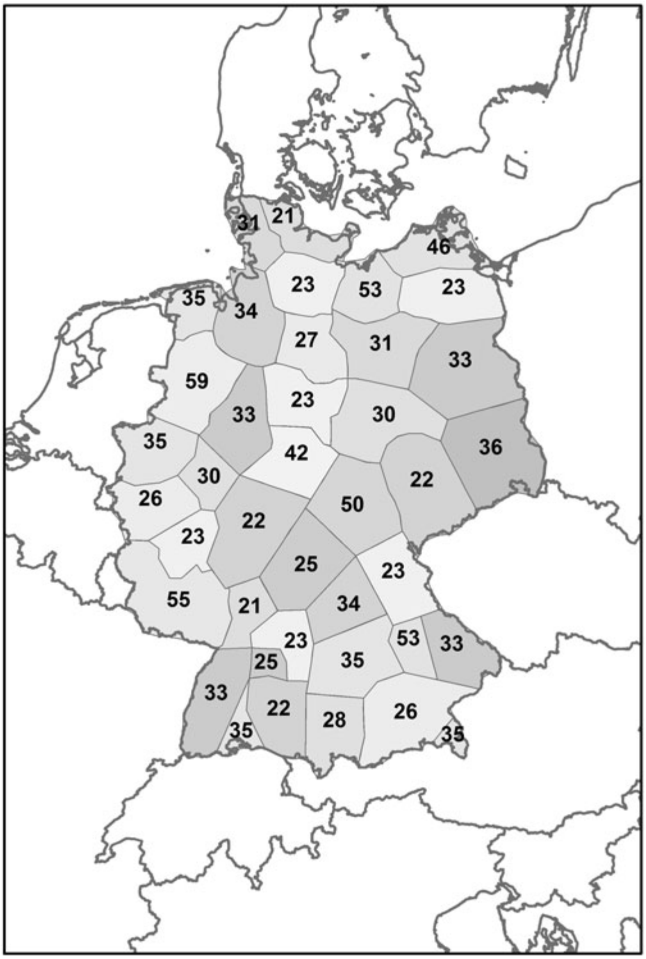

Fig. 6.1 One of the seven UHF allotment layers of Germany resulting from the planning process of the RRC-06. The numbers in the alloments indicate the UHF channel that has been allocated to each of the areas, respectively

is certainly limited by demand for broadcasting services but in the first place the media policy of a country implemented by its administration is the crucial factor. The number of programmes on the terrestrial broadcasting platform can be restricted on political grounds, in particular if there are other means of distribution of broadcasting content than the terrestrial platform. On the other hand, if terrestrial broadcasting is considered a viable option within a given country then a sufficient number of programmes has to be provided in order allow the terrestrial platform to be competitive in comparison with other platforms.

Such constraints determine the number of programmes and thus the number of multiplexes that need to be offered throughout a given area. National, regional, and local demands define the shape and size of these areas. For the purpose of generating a frequency plan they are represented by corresponding allotment areas.[3]

According to the underlying planning principles to each of the allotment area a suitable TV channel is allocated. As a consequence of these principles together with the identified programme demand cast into multiplexes, seven layers of the type shown in Fig. 6.1 have been derived in the GE06 planning process consuming the entire spectrum range between 470 and 862 MHz in Europe.

The only possibility to estimate the amount of Digital Dividend spectrum consists of an analysis of several steps. First of all, a certain range of channels is identified which are supposed to be freed from broadcasting usage. It is assumed that the total set of allotments of a given national frequency plan is to be kept, meaning that also their shapes and sizes are maintained.

Then a subset of allotments exists which were given channels that are now supposed to be released. By means of a suitable allocation method new channels taken from the remaining part of the spectrum for broadcasting have to be found for this subset of allotments. If this exercise is successful under the given principles for broadcasting planning then the previously determined spectrum range can indeed be called the Digital Dividend spectrum. Otherwise, the envisaged Digital Dividend spectrum apparently cannot be freed. Then, another analysis has to be carried out based on a smaller Digital Dividend spectrum range. If on the contrary, the alternative channels could be found without problems then probably the Digital Dividend spectrum could be even increased.

Apparently, the determination of the amount of Digital Dividend spectrum depends on many parameters and conditions that might vary from country to country. Thus, it is obvious that there does not exist a generally valid and straightforward way to estimate the maximum Digital Dividend spectrum in the UHF band. More information on this issue can be found in [ECC10].

This procedure describes a scientific way to define the amount of the Digital Dividend. Unfortunately for broadcasters, in most cases administrations simply defined a certain spectrum range as the Digital Dividend on purely political grounds without going through such considerations in detail. As a consequence, there might be several areas for which no alternative TV channel can be provided anymore in a way consistent with the broadcasting planning principles. This then corresponds to a real loss of spectrum for terrestrial broadcasting.

[3] Allotment planning is the natural way to generate frequency plans for digital terrestrial broadcasting systems that can be operated as single frequency networks (SFNs). It is flexible enough to fully exploit all degrees of freedom at the stage of network implementation. Assignment planning has been used at RRC-06 as well for DVB-T. However, future modifications of network configurations under assignment plan entries usually call for successful coordination beforehand.

6.2 White Spaces in the UHF Range

The GE06 planning principles can be cast into so-called channel re-use distances (see, e.g. [Beu04a, Beu08] for more details). This basically corresponds to the distance between two co-channel DVB-T coverage areas. Depending on the system variant assumed for planning re-use distances between 100 and 150 km are realistic values. In order to understand these figures it has to be borne in mind that the GE06 Agreement and Plan are based on typical broadcasting network infrastructure. This means that high tower transmitters with an output power between 1 and 100 kW are assumed. They are suitable to cover large areas with only a limited number of stations, however, their interference impact is far reaching. This prohibits smaller re-use distances without imposing unacceptable interference levels onto other co-channel usages.

Figure 6.2 sketches a typical geographical layout of a GE06 frequency allocation. For some central European countries the allotment areas of UHF channel 27 are shown. The geographical layout of the allotment areas shown in Fig. 6.2 very well reflects the consequences of the underlying planning principles of GE06. The borders of the allotments are typically separated from each other by a distance which is in the order of the values derived for the re-use distances from theoretical calculations. However, there is a huge number of cases in which the actual separation falls below the required re-use distance. In GE06, these cases are covered by corresponding administrative declarations in which concerned administrations define between themselves the conditions under which usage of a channel in the given areas can be achieved.

Looking at Fig. 6.2 with the eyes of someone who is not familiar with the principles of broadcasting planning, one could get the impression that there seem to be a lot of areas where a given channel is not used. This "non-usage" of spectrum is usually referred to as the white spaces of UHF. Having spotted so much not used spectrum the question immediately pops up if these resources could not be exploited by other services. Cognitive radio networks are usually brought forward as the primary candidates (see Sect. 7.2.3). Even though this might be feasible under certain conditions it implies a wrong interpretation of frequency planning for broadcasting services.

Broadcasting planning is not as static as it is quite often perceived. Actually, the provisions of GE06 foresee the possibility to change the Plan and add more plan entries. This is nothing new. The International Telecommunications Union (ITU) Stockholm Plan of 1961 [ITU61] governing spectrum usage for analogue television over 40 years started with a situation where at every location in Europe only three channels were available and therefore three analogue TV programmes could be offered. In 2006, when ST61 was abrogated and replaced by GE06 many more channels were on air across Europe. Clearly, this usage was not homogeneous. However, in big cities such as Berlin, Paris or London up to 25 analogue TV programmes could be received. In Rome, the offer was even significantly more

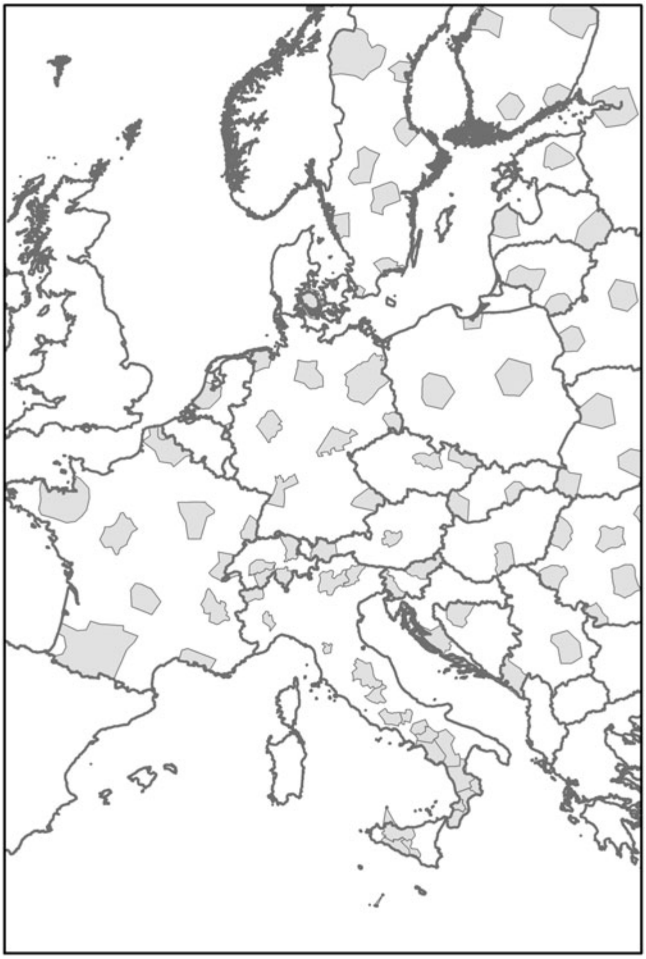

Fig. 6.2 Channel allocations of UHF channel 27 onto allotement areas in some European countries according to GE06

than 30 programmes. What had happened was that the white spaces generically contained in ST61 had been exploited very successfully by broadcasters to enrich their programme offer over the years.

Even though the results of GE06 did foresee seven layers of DVB-T multiplexes everywhere at the beginning, there are administrations that definitely intend to go beyond that such as France and Italy. As a consequence, it can be expected that more and more broadcasting services will be introduced over time thereby dramatically decreasing the amount of white spaces that seem to be available in the UHF bands at the moment. The introduction of new broadcasting services on top of what GE06 provided in 2006 can be accomplished by careful network planning.

Frequency planning for broadcasting is carried out on the basis of certain assumptions concerning wave propagation, link budgets in order to provide satisfying service and compatibility criteria between broadcasting services themselves but also in relation to other services (see Sect. 4.1 for more details). Based on this, frequency plans for broadcasting constitute a formal framework in terms of defining rules for spectrum usages under which the actual operation of networks has to be carried out. In a certain way, any broadcasting frequency plan such as ST61 [ITU61] or GE06 [ITU06] defines nothing more than an envelope and associated rights for spectrum usage.

Seen from that perspective, the concept of re-use distances has also regulatory implications. To a first approximation, an allotment area which is separated by a distance larger than the relevant re-use distance need not be coordinated with neighboring countries. This has significant consequences in terms of potential usage of a given channel within a country. In principle, all co-channel allotment plan entries can be joined by carefully respecting the re-use distance towards the national borders. This results basically in a large area within a country throughout which an administration can make use of that channel for television broadcasting almost independently from its neighbors. Such an area is called the channel potential area of a given channel. Figure 6.3 shows the channel potential area for Germany in the case of UHF channel 27 as derived from the layout given in Fig. 6.2.

The dark grey area together with the light grey allotment areas represents a conceivable channel potential area of channel 27 in Germany. The distances towards the German border are chosen such that within the depicted area channel 27 could be used for DVB-T without the need to coordinate with neighboring countries. Seen form this perspective the original allotment areas that have been agreed at the RRC-06 and subsequently entered into the GE06 Plan only set up some kind of a framework for potential usage of channel 27. Actually, the German administration together with the German broadcasters could decide to design entirely different allotment areas lying within the given channel potential area. In principle, even usage of a channel across its entire channel potential area in terms of a SFN could be envisaged. Clearly, the technical feasibility of such an idea is a different question at this stage.

There is no doubt that there are many white spaces in the UHF band when looking into typical planning layouts for digital terrestrial broadcasting as depicted in Fig. 6.2. However, first of all it has to be borne in mind that frequency plans like the GE06 Plan have to be considered as planning frameworks that ensure and safeguard the future development of terrestrial broadcasting. They do contain an associated frequency plan which at any point time is nevertheless just a snapshot of the current situation. Since white spaces are crucial for the future development of terrestrial broadcasting they are likely to be exploited by broadcasters themselves for broadcasting services over time.

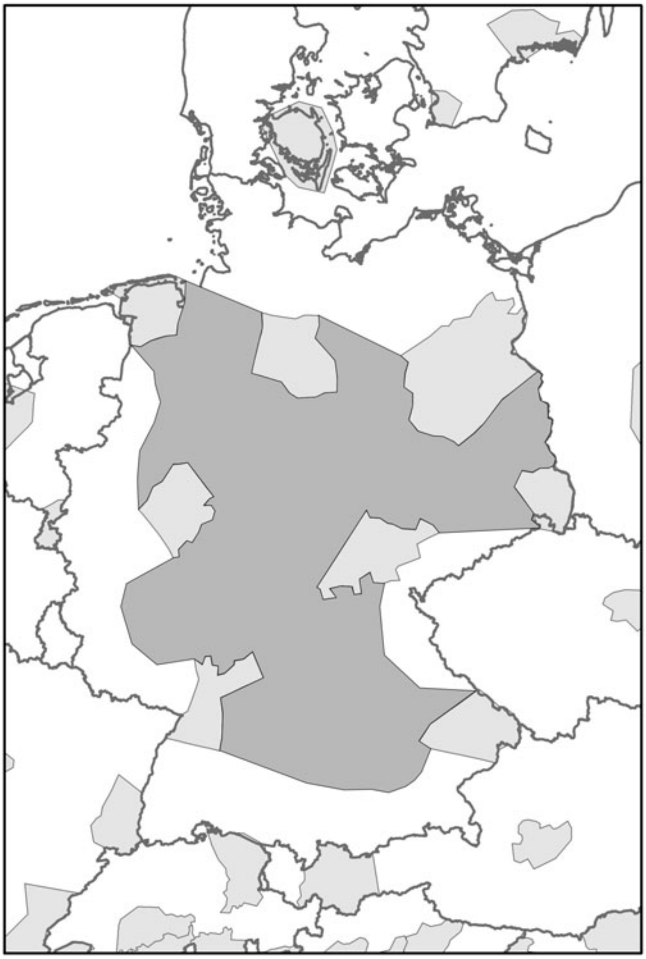

Fig. 6.3 Channel potential area of channel 27 in Germany

6.3 Digital Dividend in Different Regions

It is very difficult to link the appearance of the term Digital Dividend to a certain date. Clearly, already after digital terrestrial broadcasting systems have been standardized at the end of 1990s of last century, it became clear that spectrum could be more efficiently used in the future when employing such systems. Some may even argue that this expectation was one of the driving forces behind the development of new digital terrestrial broadcasting systems such as Digital Audio Broadcasting (T-DAB) [ETS97a] or Digital Video Broadcasting (DVB-T) [ETS97b] in Europe or the Advanced Television System Committee (ATSC) Digital Television Standard for the USA [ATS11].

6.3.1 Digital Dividend in Europe

Since 1961, the so-called Stockholm Agreement (ST61) [ITU61] had governed the spectrum usage for analogue terrestrial television services in bands III, IV, and V in Europe. The Stockholm conference resulted in a frequency plan which provided as a matter of principle three coverages for each participating country throughout its national territory, respectively. This planning target represented the application of the principle of equitable access to the spectrum. Expressed in terms of television programmes three coverages correspond to three analogue programmes that could be offered everywhere. It has to be noted that depending on the geographical conditions there were areas where more than that was achieved.

In ITU Region 1 (including Iran but excluding Mongolia), a new frequency plan for digital terrestrial broadcasting has been established in 2006. The GE06 Agreement [ITU06] provides all regulatory and technical measures to plan and bring into operation DAB and digital video broadcasting (DVB) networks in Bands III, IV, and V. During the Regional Radiocommunication Conference in 2006 (RRC-06) that gave rise to the GE06 Agreement, it was agreed to use a planning target of seven nation-wide coverage layers. Similar to ST61 this approach represents the manifestation of the principle of equitable access during the RRC-06. In contrast to ST61, however, the allocation of a TV channel in a given area allows to provide a set of programmes bundled into a multiplex. The number or programmes ranges from 4 to 8 if DVB-T is used and the parameters of the system variant are chosen appropriately. As a consequence, seven times four gives 28 programmes as a minimum at any given location within each country. No doubt, this is strong evidence for the superior efficiency of digital terrestrial broadcasting in comparison to analogue transmissions regarding spectrum usage. Hence, already at the time of the RRC-06 the seed for the future debate about the Digital Dividend was laid out openly for everybody to see.

At the beginning of 2007 the European Commission (EC) issued a mandate to CEPT [Com07] targeting at potential ways to harmonize the Digital Dividend in Europe. EC said among other things:

> This mandate intends to launch an initial step to explore the technical feasibility of relevant potential uses of the future digital dividend, to identify any major coexistence limitations of these potential uses due to interference issues, and to assess possible spectrum management strategies to address those issues.

Thus, CEPT decided to set up a task group, called ECC-TG4, that should deal with issues requested in that mandate. The work resulted in a set of reports, namely CEPT Reports 21 [CEP07a], 22 [CEP07b], 23 [CEP07c], 24 [CEP08a], and 25 [CEP08b]. Even though the task of the mandate was formulated in a general way it was decided by ECC-TG4 from the very beginning to carry out the work under the assumption to identify a sub-band in UHF for mobile services.

For Europe, the issue of the Digital Dividend became hot after the end of the World Radiocommunication Conference (WRC) of the ITU in 2007 (WRC-07) [ITU07]. WRC-07 decided to allocate the frequency band 790–862 MHz in the UHF range, the so-called 800-MHz band, to mobile services on a co-primary status in ITU Regions 1 and 3. Furthermore, WRC-07 approved Resolution 749 inviting ITU-R to carry out sharing studies between those services to which the band is currently allocated and the mobile service. This decision led to the creation of ITU-R Joint Task Group 5–6 which was commissioned to carry out the corresponding sharing studies.

CEPT and EC had actively worked towards such a frequency allocation for the mobile service. As a consequence, EC issued a second mandate to CEPT regarding the Digital Dividend [Com08]. The intention of this mandate was clearly stated. The results obtained by CEPT should build the basis for future political measures within EU to pave the way for an introduction of mobile services in the band 790–862 MHz across Europe in a harmonized manner. Three CEPT groups, namely ECC-TG4, WGSE-SE42 and ECC-PT1, were tasked to deal with issues raised in this mandate. As with the first mandate, another set of reports was created, i.e. CEPT Reports 29 [CEP08c], 30 [CEP09a], 31 [CEP09b] and 32 [CEP09c].

On 6 May 2010, EC published an EC Decision on the Digital Dividend [Com10]. It does not bind EU Members to open the band 790–862 MHz for mobile services. However, if a Member State decides to do so, they shall comply with the conditions defined for sharing with other services by CEPT. Furthermore, EC favors to use the 800 MHz band for mobile services across Europe in a harmonized manner. Member States should bear that in mind and should facilitate the introduction of these services wherever possible.

Apparently, there are different paces in Europe with respect to the digital switch-over (see Sect. 5.1). This directly carries over to making available the 800 MHz band for mobile services. According to the GE06 Plan there were many frequency allocations for DVB-T across the entire UHF band. However, switching-over from analogue to digital television does not necessarily mean that all frequencies are actually used by broadcasting networks. In some countries like Germany the upper UHF channels were not put into operation while in Spain and Italy there were already some networks in that frequency range. Therefore, using the 800 MHz band for mobile services calls for two principle actions. Firstly, the channels already used have to be moved below 790 MHz and secondly, the usage by mobile services has to be addressed. The latter means to plan the spectrum auctions of this band.

In Germany, The Netherlands, and Denmark the auctions of the 800 MHz band took place already in 2010. Corresponding licenses were issued. In Germany the role-out of LTE started already by the end of 2010. Other countries like France followed in 2011 while the spectrum auction in UK was envisaged for 2012.

6.3.2 Digital Dividend in the USA

In other regions of the world, the spectrum usage of the broadcasting bands is not governed by an international agreement or a treaty similar to GE06. Rather, planning of broadcasting services is carried out by means of bi- and multilateral coordination between administrations only. The only constraints to be obeyed are given by the general rules contained in the RR of the ITU-R (see also Sect. 4.2). In line with this framework, administrations could more or less decide themselves how to exploit the Digital Dividend spectrum.

This was particularly the case in the USA. An important difference compared to Europe is the fact that before 2003 only the spectrum between 470–806 MHz was foreseen to be used by analogue terrestrial broadcasting. This means in particular that the spectrum which was in the centre of interest in Europe, i.e. the 800 MHz band between 790–862 MHz was never part of the discussion about the digital switch-over and any subsequent use.

With the advent of digital terrestrial television, spectrum could be used more efficiently than by analogue television (see Sect. 5.2.2). Therefore, FCC decided in 2002 that channels 52–69 (698–806 MHz) should be released from broadcasting usage so this part of the spectrum was reallocated from the broadcasting to the mobile services. This frequency range is usually referred to as the 700-MHz band. Any future digital terrestrial transmissions were confined thereby to the remaining spectrum in channels 14–51 (470–698 MHz). It was decided that broadcasters would need to free the band until 2006 if the analogue-to-digital transition period is not extended. Actually, the switch-over took much longer and even led to the Delay Act [DeA09] which constitutes the formal basis for this extension.

FCC auctioned off part of the 700 MHz band, namely channels 52–59 (698–746 MHz) in terms of two different auctions [FCC04]. Since in this spectrum range many incumbent broadcasting services were previously operating it was decided that any new entrant services that in principle were allowed the usage of the spectrum would need to protect both existing analogue and new digital broadcasting services in that band.

The licenses acquired through the auction process for the lower 700 MHz band were pretty flexible with respect to the services that can be offered under these licenses. Any licensee could provide services to target fixed, portable and mobile reception in the band 698–746 MHz. Concerning the service type, a licensee is free to make use of the spectrum for digital broadcasting and fixed/mobile wireless services. The rules governing the lower 700 MHz Band can be found in [FCC09].

The upper 700 MHz band between 746 and 806 MHz was auctioned in 2008. Only 32 MHz of the total amount of spectrum was allocated to commercial use, 24 MHz were foreseen for public safety and security services while the remaining 4 MHz are to be used as guard bands in order to decrease potential interference between different services. Since in contrast to the auction of the lower 700 MHz band for the upper band a firm switch-over date for terrestrial broadcasting was given the auction raised more money. This was simply due to the fact that bidders knew exactly when they would have access to that spectrum. More details about the auction and the licenses can be found in [FCC11]. An overview about the resulting band plan is shown in [FCC11a].

6.3.3 *Digital Dividend in Asia*

Also in Asia the UHF band is the primary spectrum resource for terrestrial television services. The upper limit up to which broadcasting services can be deployed is not the same in the different Asian countries. Typical upper limits are 806 MHz or 860 MHz while in Australia 820 MHz had been chosen by the national administration in the past.

At the same time, across Asia the spectrum in the upper UHF band has been used for mobile services already for a along time on a co-primary basis. In particular, several bands had been identified for IMT before WRC-07 already. In the UHF range this refers to the band 806/860–960, respectively (see Sect. 4.4). In 2007, WRC-07 has identified additional spectrum for IMT between 790–960 MHz. For seven countries, i.e. Bangladesh, China, Korea (Rep. of), India, Japan, New Zealand, Papua New Guinea, Philippines, and Singapore, the lower limit was set to 698 MHz according to footnote 5.313A of the ITU-R Radio Regulations.

In contrast to Europe or the US, there is no single organization or body like the EC or the FCC that could decide about a formal regulatory framework concerning the implementation of the Digital Dividend for all or at least a group of Asian countries. In general, spectrum management is bound to bilateral coordination and consequently it is up to individual countries to decide themselves about their strategy concerning the spectrum usage.

The most important forum that tries to coordinate and harmonize the national activities on an international level in ITU Region 3 is the Asia-Pacific Telecommunity (APT). It constitutes a platform on which Asian countries can define and agree on common views and approaches with respect to spectrum usage. In 2009, an APT Report was published [APT09] that contained a review of current spectrum usage and future plans in the region as well as the results of a questionnaire. This survey had been distributed in order to get an overview about the different ideas concerning the usage of the Digital Dividend in the Asia-Pacific region.

The report identified some general constraints that have considerable impact on any exploitation of the Digital Dividend in Asia. There are still many countries that use the UHF spectrum for analogue television. Furthermore, the usage of frequencies for this purpose is not uniform across APT countries. Some countries have already introduced digital terrestrial television services, however, different standards are employed such as DVB-T, ATSC, ISDB-T, etc. Also, there is no harmonized switch-over scenario. Some countries made significant progress in that direction while others are still considering how and when. And finally, as mentioned above already, the UHF band is used for many different services, not only broadcasting. Protection of these services will impose severe constraints on harmonized ways forward.

The responses to the questionnaire indicated that APT Members plan to use UHF spectrum for many different services such as advanced mobile services, mobile broadband services, mobile television, public safety and security services, intelligent transport systems, and last but not the least for digital broadcasting services. Nevertheless, it became also apparent that APT Members are of the view that harmonizing the band above 698 MHz for mobile services including IMT would bring significant benefits to Asian countries. Therefore, individual administrations in Region 3 are contributing heavily to international harmonization activities of this band for example in ITU-R Working Party 5D which is the ITU-R group that among other tasks is looking into the issue of channel arrangements for mobile services in the 698–790 MHz band.

The discussion in APT led to a further report that has been published in 2010 [APT10] which combines the different views formulated in [APT09] by firstly reiterating the position that the band 698–806 MHz shall be used for mobile services in the future and proposing an agreed channel raster including corresponding guard bands.

Even though the Asia-Pacific countries put forward a clear view on what the future usage of the upper UHF spectrum should be, so far only some administrations have made first steps towards a reallocation of the band above 698 MHz to mobile services. The Australian government decided in 2011 that from the entire spectrum that was allocated to terrestrial television broadcasting between 520–820 MHz a total amount of 126 MHz, namely the band 694–820 MHz shall be reallocated to mobile services representing the Australian Digital Dividend of terrestrial broadcasting. It can be expected that during or towards the end of 2012 auctioning of this spectrum range will be targeted at. Similar intentions are reported from India which even presume that by the end of 2011 the 700 MHz band should be freed from broadcasting usage [Tel11].

6.4 Sharing Between Broadcasting and Mobile Service

In 2006, the Regional Radiocommunication Conference RRC-06 was held in Geneva to establish a frequency plan and corresponding regulatory measures in order to use the UHF band between 470 and 862 MHz in ITU-R Region 1 (without Mongolia but including the Islamic Republic of Iran) for digital terrestrial broadcasting services. As has been discussed in previous chapters only the introduction of digital broadcasting technologies paved the way to what is today called the Digital Dividend. The decision to reallocate part of this UHF band to mobile services including IMT imposes constraints on future spectrum usage for all services to which this band is allocated on a primary basis that call for careful analysis of spectrum sharing conditions. This stems from the simple fact that different services require different provisions for protection which need not necessarily be compatible in the first place.

As of 2007 activities on different levels have been initiated. In Europe this was primarily carried forward by an effort of the EC and the national administrations under the roof of CEPT. EC requested CEPT to study relevant issues connected to re-allocating the 800-MHz band to mobile services. Therefore, CEPT set up several groups that were tasked to deal with different issues.

ECC Task Group 4 (TG4) was looking into many relevant technical issues and came up with several reports. The main result of the work of this group consisted in the proposal to employ a reversed duplex configuration of the mobile service and to provide a set of protection ratios for the protection of digital terrestrial television from the mobile service signals (see CEPT Reports 21 [CEP07a], 22 [CEP07b], 23 [CEP07c], 24 [CEP08a], 25 [CEP08b], 29 [CEP08c], and ECC Reports 138 [ECC09] and 148 [ECC10]). In the project team ECC-PT1, a channelling scheme for the mobile service in the band 790–862 MHz was developed [CEP09b]. Furthermore, the spectrum engineering group WGSE-SE42 of CEPT put together a report containing "common and minimal (least restrictive) technical conditions for 790–862 MHz for the Digital Dividend in the European Union" [CEP09a]. These reports built the technical basis on which the decision of EC is based to reallocate the 800 MHz band in Europe and to work for a harmonized usage of this band. This decision was published in 2010 [Com10].

On a global level work on sharing was going on until the end of 2010 primarily in two ITU-R groups, namely ITU-R WP6A and the Joint Task Group JTG5-6, that was set up as a common group of Study Groups 5 and 6 in the preparation of WRC-12. While WP6A focussed on the derivation of appropriate protection ratios for broadcasting vs. mobile services and other sharing criteria, JTG5-6 concentrated its work on carrying out cross-border sharing studies between neighboring countries. JTG5-6 was working on the basis of Resolution 749 of WRC-07. One of the most important results of the work of JTG5-6 corresponds in highlighting the so-called cumulative effect of mobile networks (see below). Furthermore, it became crystal clear that sharing of the same band between broadcasting and mobile services is not feasible without one or the other side being forced to accept significant interference levels leading to degradation of the quality of service or to a loss of significant portions of coverage along common borders to countries where the other service would be implemented, respectively.

Even though the results of the CEPT groups are derived from a European context, they are still generally applicable. Consequently, it is very likely that they will not be totally overwritten by work carried in other parts of the World. This can be seen already from the activities that in the meantime (2011) have been started in ITU-R WP5D on sharing issue. Since WP5D is the ITU-R group addressing all relevant technical issues related to the introduction and deployment of mobile networks, in particular IMT networks, the work on sharing with the broadcasting service in WP5D targets primarily on the protection of the mobile service. But in any case, the results of JTG5-6 will need to be incorporated. The results and the consequences will be summarized in the following sections. More details can be found in [Sam11].

6.4.1 Channelling Arrangements in the 800 MHz Band in Europe

Mobile systems represent a two-way communication mechanism, i.e. there is communication from the base stations to the mobile handheld devices (usually called the downlink) and vices versa (the uplink). Clearly, appropriate measures need to be taken in order to avoid interference between these two communication paths. Amongst all the different possibilities two ways to cope with this are discussed for IMT systems, namely either a so-called Frequency Division Duplex (FDD) or a Time Division Duplex (TDD) configuration. In the first case, uplink and downlink are realized by using different frequency bands separated far enough. Traditionally, the downlink is implemented at higher frequencies than the uplink. In TDD configuration, the communication stream is subdivided into very short time slots which are allocated to either up- or downlink. Basically, this means that up- and downlink are using the same frequency band.

The general assumption of the work of CEPT groups was that eventually the band 790–862 MHz should be freed from broadcasting services in Europe. In other words, broadcasting should take place only up UHF channel 60 in the future which ends at 790 MHz. Implicitly, this also means that the only source of interference that should be addressed is connected to adjacent-channel usage. Co-channel usage can only be an issue between two countries if one country decides to continue to use the 800 MHz band for broadcasting while the other migrates to usage by mobile services. In any case, in order to decide on the appropriate channelling arrangement for the mobile service the protection of DVB-T reception needs be ensured as well as the avoidance of interference into mobile base stations and handheld devices.

During the discussions it turned out that European administrations would favor the FDD configuration. However, the more important decision was to employ a reversed duplex configuration which means to allocate the uplink at higher frequencies than the downlink part. There were several reason for that. Firstly, the interference from mobile handheld devices cannot be predicted with high enough precision as a matter of principle. By putting the uplink in a frequency band which is more separated from the remaining broadcasting services interference can be reduced. Secondly, interference from high power broadcasting transmitters into the receiving part of the mobile base stations (which is using uplink frequencies) needs to be reduced as much as possible. Again, the larger the separation is between the two transmitting systems the smaller the potential interference will be.

The interference from base stations into DVB-T receivers can be mitigated if appropriate technical measures are taken. This is possible because the location of the base station is fixed in contrast to a mobile handheld device that is typically moving. For example, the diagram of the transmitting antenna of the base station can be designed in a way not to impose unacceptable field strength levels into given directions. But still a certain probability of interference cannot be ruled out under all circumstances. This suggests to introduce a guard band between the broadcasting services and the mobile downlink. It turned out that the required guard band between broadcasting and the mobile uplink is significantly higher which additionally supported the decision to make use of a reversed duplex in Europe in the 800-MHz band. The latter finding provides also one of the reasons why the TDD configuration was put down. Since up- and downlink would use the same spectrum a large guard band due to the uplink interference potential would need to be used in this case.

790-791 MHz	791 - 821 MHz	821 - 832 MHz	832 - 862 MHz
Guard Band 1 MHz	Downlink 30 MHz (6 blocks of 5 MHz)	Duplex Gap 11 MHz	Uplink 30 MHz (6 blocks of 5 MHz)

Fig. 6.4 Proposed FDD channelling arrangement for the mobile service in the band 790–862 MHz in Europe

790 - 797 MHz	797 - 862 MHz
Guard Band 7 MHz	Unpaired Spectrum 65 MHz (13 blocks of 5 MHz)

Fig. 6.5 Proposed TDD channelling arrangement for the mobile service in the band 790–862 MHz in Europe

Even though FDD was selected as the preferred option for Europe in the end, for both FDD and TDD a corresponding channelling was put forward by ECC-PT1 in CEPT Report 31 [CEP09b]. Figures 6.4 and 6.5 sketch the channelling arrangements, respectively.

6.4.2 *Common and Minimal Technical Conditions for the Usage of the 800 MHz Band in Europe*

Between autumns 2008 and 2009, the CEPT group WGSE-SE42 was working on the task to derive the so-called common and minimal technical conditions for the usage of the band 790–862 MHz by mobile services in particular IMT. The acronym "SE" in the name of the group stands for "Spectrum Engineering" which means that the focus of SE42 lay on defining spectrum masks and out-of-band emissions. This creates a framework for manufactures both of transmitters and handheld devices when designing corresponding equipment. However, a very important issue deriving from this is the decision about the maximum allowed radiated power of transmitters and mobile phones in order to protect broadcasting services in adjacent bands or channels. The results of WGSE-SE42 were published in CEPT Report 30 [CEP09a]. A very detailed description of more technical nature of the results can be found in [Sam11].

The fundamental problem when defining the sharing criteria between mobile and broadcasting services in adjacent bands is that planning principles and approaches for both services are not the same. In the broadcasting case, the wanted and the interfering signals are always treated as indivisible signals. Even though there are out-of-band emission as a matter of principle for any electromagnetic signal no distinction is made between in-band and out-of-band components. It is just assumed that all signals respect defined spectrum masks. Then, protection ratios are measured as a function of the relative frequency separation between wanted and interfering signals. Consequently, a given protection ratio always reflects the impact of one signal onto another including all existing out-of-channel emissions [ITU06].

This is different in the world of mobile services. Here, a distinction is made between in-band and out-of band emissions. These components are then treated as independent signals when interference into other signals has to be assessed. Two parameters are used thereto, namely the Adjacent Channel Leakage Power Ratio (ACLR) and Adjacent Channel Selectivity (ACS).

ACLR describes the out-of band characteristics of the transmitter. It corresponds to the ratio of the mean power of a signal within is allocated channel and the mean power in a given adjacent channel, not necessarily the next-adjacent one. Basically, ACLR reflects the emission mask of the transmitter. The other parameter, i.e. ACS, measures the receiver performance and can be interpreted as some kind of susceptibility. It relates the power received within the channel to which the receiver is currently tuned to the power received in the adjacent channel that is used by the interfering source. Therefore, ACS is a particular representation of the receiver filter characteristics (see [CEP09a] and [Sam11]). Nevertheless, the two descriptions, protection ratio vs. ACLR/ACS can be linked to define limits for the emission of the mobile service in order to protect broadcasting services in adjacent frequency bands, in this case the UHF band below 790 MHz.

IMT systems can be deployed in terms of different occupied bandwidths, e.g. 5, 10 or 20 MHz. The occupied spectrum is usually called a block rather than a channel. The effort of SE42 resulted in the definition of a set of in-block and out-of-block emission limits for the mobile signals, for different frequency offsets relative to the wanted broadcasting signal. These limits as a function of frequency separation are called Block-Edge Masks (BEM). The powers of the mobile stations are usually given in terms of Effective Isotropically Radiated Power (EIRP). Table 6.1 contains the limits that were adopted in CEPT Report 30 [CEP09a].

SE42 came up with three different cases for protection of broadcasting. The idea was that administrations should be free to decide themselves what level of protection would best suit their needs in their countries. The values shown in Table 6.1 were included in the EC Decision on the harmonized usage of the 800 MHz band for mobile services in Europe [Com10]. EC Decisions are mandatory for EU Member States and have to be cast into corresponding national law. SE42 was also providing upper limits for the maximum permissible EIRP of handheld devices. It was decided that a maximum value of 23 dBm in-band power level should not be exceeded. Only in special cases a margin of 2 dB could be added. For the protection of broadcasting services a maximum mean out-of-band power below 790 MHz of −65 dBm/8 MHz was selected. It is important to note that the EC Decision took into consideration the in-band limit while the out-of-band limits have not been included.

Table 6.1 Block edge masks for mobile service base stations operating in the band 790–862 MHz in order to protect broadcasting services below 790 MHz

Case	Protection Requirements for Broadcasting	In-Block EIRP P (dBm / 10 MHz)	Maximum Mean Out-Of-Block EIRP
A	DTT broadcasting is protected	P ≥ 59	0 dBm
		36 ≤ P < 59	(P - 59) dBm
		P < 36	-23 dBm
B	DTT broadcasting is subject to an intermediate level of protection	P ≥ 59	10 dBm
		36 ≤ P < 59	(P - 49) dBm
		P < 36	-13 dBm
C	DTT broadcasting is not protected	No Restriction	22 dBm

6.4.3 Mitigation Techniques

Field measurements and extensive theoretical studies were carried out in order to understand the implications of using the band 790–862 MHz for mobile services (see e.g. [ITU09a] for a field trial carried out in Australia). European Broadcasting Union (EBU) contributed significantly to the work of SE42 by conducting several investigations based on Monte Carlo simulations (see [Sam11] for an overview) that clearly showed that the protection criteria defined by SE42 are not sufficient to ensure appropriate protection of broadcasting services. They have to be understood as a framework which gives guidance to manufactures in the first place rather than helping to avoid interference problems during network implementations. The latter calls for special mitigation techniques.

Basically, there are the two cases that need to be distinguished, i.e. interference from handheld devices and interference caused by base stations. Their respective impact is different with regard to measures that can be taken in order to protect broadcasting.

Handheld devices or terminals as they are often called, are permanently changing their position. People are carrying their mobiles wherever they go and they use them in any circumstances, be it outdoors, indoors which can be quite close to DVB-T receivers or on the move in cars, trains and public transport. This means it is not predictable how many mobiles are located in the vicinity of a DVB-T receiver or a roof-top antenna at a given point in time. Consequently, situations occur where the field strength levels imposed by mobile terminals can lead to unacceptably high interference levels. The only possibility to reduce the interference of handheld devices is to limit their emission level or to employ more efficient filters in the DVB-T receivers. The former has been set by the work of SE42 and cast into binding law for Europe by the EC Decision of 2010 [Com10]. So, only the filter option is actually left. However, in view of millions of legacy receivers on the market it remains to be seen how this issue can be resolved.

The situation is more promising with respect to mitigating interference from base stations. Since base stations are at fixed locations it is possible to assess their interference impact onto broadcasting reception both theoretically and experimentally. Then, the technical characteristics of the base station can be correspondingly adapted by adjusting the total EIRP, employing specially designed antenna patterns and filters to further reduce the out-of-band emission. Also, cross-polarization with respect to broadcasting signals can be exploited which can significantly add to reducing the interference potential of base stations [Sam11]. Even though all this is well known and in principle straightforward to use it all comes down to the fact that these measures are not for free. Money has to be spent and furthermore some of the remedies such as co-siting broadcast and mobile services require the collaboration between broadcasters and mobile network operators. At the end of the day, national regulators will have to develop a regulatory framework which clearly defines who is responsible for which consequences and also who has to take the effort to eliminate the problems.

6.4.4 Cumulative Interference Effect of Mobile Networks

The introduction of IMT systems as a particular application under the mobile service definition of ITU-R gives rise to a new type of interference problem that was not encountered with other mobile systems before. IMT systems such as LTE or LTE-Advanced allow a frequency reuse of 1 [Mot07]. This basically means that each cell in a mobile network uses the same frequency, i.e. the same spectrum range of 5, 10, or 20 MHz, respectively. Sophisticated techniques are employed to reduce the impact of inter-cell interference which in such configurations is unavoidable from a wave propagation point of view.

The GE06 Agreement governs the usage of UHF spectrum not only for broadcasting but also for other services including the mobile service. Any operation of a station of the broadcasting, mobile or fixed service is subject to successful coordination following an Article 4 procedure of GE06 (see Sect. 4.1.2.2). An administration wishing to bring into operation a mobile base station (including IMT) would need to start an Article 4 procedure with the aim that after successful coordination this station would be included in the Master International Frequency Register (MIFR) of ITU-R. Only this would grant protection of this new station according to the ITU and GE06 principles. To this end, a corresponding Article 4 request has to be sent to the BR of ITU-R.

The Article 4 procedure foresees a so-called trigger mechanism which after its application signals if coordination between administrations is required or not. The details of the coordination are not covered by Article 4 of GE06. Concerned administrations are free to decide amongst themselves on which technical basis coordination should be carried out (see Sect. 4.1.2.2).

At the time when the GE06 Agreement was prepared and finalized it was assumed that mobile networks would be configured in a way that individual base stations were using different frequencies. Hence, the corresponding treatment within an Article 4 procedure is based on a station-by-station analysis. Mobile base stations even though they might belong to the same network are considered as independent. Article 4 of GE06 foresees in that case that if the base station would impose a field strength level of 25 dBμV/m (related to a bandwidth of 8 MHz) at 10 m above ground at the country border of another administration then coordination would be required. However, confronted with mobile networks employing a reuse factor of 1 this approach might no longer be the right way to decide if coordination between administrations is required or not.

In an urban or sub-urban mobile network, typical distances between different base stations are in the order of 500 m–2 km. A typical maximum EIRP value is 55 dBm which corresponds to 316 W EIRP while an antenna height above ground between 20 and 30 m is usually assumed (see for example [ITU10b]). According to ITU-R Recommendation P.1546 [ITU01] such a base station produces a field strength level of 25 dBμV/m at a distance of about 9 km. If a mobile network is planned with an inter-station distance between 0.5 and 2 km then clearly many stations would contribute to the field strength at a given point on the border.

Figure 6.6 sketches the situation for a particular choice of network parameters. The distance to the point of reception was chosen such that the maximum field strength value imposed by the closest station is just below the trigger threshold value of 25 dBμV/m. The three base stations indicated in Fig. 6.6 are assumed to transmit their signals from an antenna mounted at a height of 30 m while the receiving antenna at the receiving point is assumed to be at 10 m. The output power of each base station transmitter is chosen to be 0.316 kW and a frequency of 800 MHz is used here. Furthermore, the calculation is carried out for an urban environment.

Individually, none of the base stations in Fig. 6.6 would trigger coordination according to Sect. 4 of GE06. However, apparently already the sum of the three selected base stations would provide a cumulative field strength at the point of reception which is larger than the trigger field strength. In this particular example this point is located at the boundary between two neighboring countries. This corresponds to a geographical layout as it would be the case during the application of the GE06 trigger mechanism. The example shows that while individual mobile base station may not trigger the need for coordination a number of base stations could impose cumulative interference levels that would require coordination. It is exactly such a situation which is not covered by the provisions of GE06.

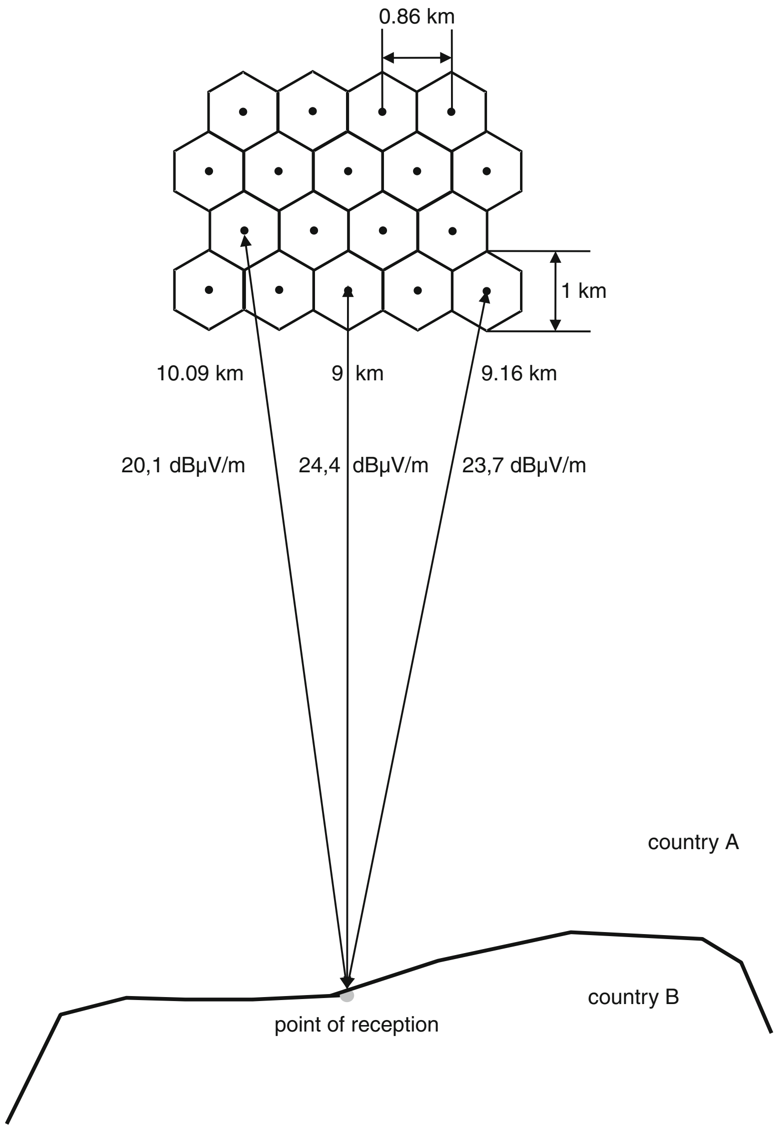

Fig. 6.6 Visualization of the cumulative interference effect of mobile networks operated in reuse 1 mode. The cells of the mobile networks are approximated by hexagons with the transmitters located at the centres, respectively

Calculations carried out during the work of ITU-R JTG5-6 clearly showed that the cumulative effect of all stations in the mobile network could generate a field strength level at a given point on the border which is up 20 dB higher than the value imposed by an individual base station (see in particular the EBU contribution to the work of JTG5-6 [ITU10a]). It is important to understand that all these studies were conducted within the technical framework given by the GE06 Agreement enhanced by corresponding generic information on mobile networks. This refers to technical planning parameters, planning concepts as well as wave propagation modelling.

During the work of JTG5-6 there was an ongoing debate about the issue that the underlying assumptions of the studies would not reflect "real mobile networks", i.e. the selected approach would not properly reflect or take into account the detailed technical characteristics and methodologies of network planning of mobile services. This is certainly true in the same way as it is true for the case of broadcasting. But this argument just underlines the fundamental misconception of what GE06 actually represents and what it does not cover.

The GE06 Agreement constitutes a planning framework based on general principles to decide about spectrum usage in the UHF band. It allows the identification of those cases where coordination is required. Furthermore, application of the GE06 procedures results in allocation of frequencies and associated usage rights as well as protection obligations to administrations. The GE06 Agreements does not say anything about the details of network roll-out nor does it prescribe what principles or methodologies administrations have to apply during the detailed coordination work.

Nevertheless, the findings of JTG5-6 clearly indicated that mobile networks operated in reuse-1-mode generate a cumulative interference effect. GE06 does not foresee any provisions to cope with such an option. This shortcoming constitutes a substantial conceptual gap. When trying to bring a reuse-1-mode type mobile network into operation it is thus possible to submit individual base station requests under Article 4 to the ITU. Each base station can be configured in a way not to trigger coordination, i.e. individually it does not exceed the $25\,\mathrm{dB}\mu\mathrm{V/m}$ at the border. Consequently, it can be included in the MIFR. This applies for all base stations individually. Even though individually the base stations do not trigger coordination there is a certain probability that their cumulative effect would exceed the allowed threshold level.

During the preparation of WRC-12 proposals have been made by broadcasters to overcome this obvious gap in GE06. However, in JTG5-6 administrations could not agree on a common view to resolve the issue. Thus the issue of the cumulative effect will have to be addressed by WRC-12 in order to find an appropriate solution.

6.5 Impact of Spectrum Reallocation on Frequency Plans for Broadcasting

The decision to reallocate spectrum that is in use by broadcasting will have a significant impact on all parties involved such as content providers, network providers and last but not least listeners and viewers. As all studies in ITU and other organizations such as CEPT have clearly shown that sharing of a given band between broadcasting and mobile services is not possible without forcing one or the other service in a position where they can no longer fulfil their coverage and service obligations in a satisfying manner (see Sect. 6.4). Seen from that respect, the decision of the EC to free the 800 MHz from broadcasting service is natural and straightforward even though clearly not welcome by broadcasters.

The allocation of the band 790–862 MHz to the mobile service imposed the need for European broadcasters to look for ways to move broadcast usages in that band to the remaining broadcasting band below 790 MHz. In other regions of the world, similar activities have to be started also. The details of the process might be different, however, the consequences are nevertheless very similar. In order to illustrate the situation two examples are presented here. They differ in many respects starting from the frequency bands under consideration up to the approach employed to frequency planning for broadcasting networks. Irrespective of that both examples show that the problems broadcasters are confronted with are the same.

The technical or mathematical difficulties of finding appropriate new channels for broadcasting services that have to be moved from one spectrum range to another one is just one side of the coin. This could be seen as some kind of academic exercise. However, setting up broadcasting networks requires huge investments on network infrastructure. Once a network is rolled out it needs to be up and running for a long time to achieve a return on that investment. Migrating transmissions from one spectrum range to another forces broadcasters to adjust their networks to new frequencies. This cannot be achieved without another large investment. Currently (2011), the debate is still on in many countries who is to bear the costs for this change in the end, i.e. broadcasters, customers or the recipients of the Digital Dividend – the mobile industry.

6.6 Different National Cases

Freeing spectrum from broadcasting services has led to intensive discussions and activities around the globe. Apart from technical considerations to solve such a migration with respect to frequency and network planning issues the whole process is in the first place a political issue. Current spectrum usages by broadcasting services reflect the needs of broadcasters, users and regulators and in all cases are subject to regulatory and market constraints. In the broadcasting sector allocated spectrum is usually fully exploited, i.e. it is used in a way to meet the requirements while minimizing any degrading influences such as interference levels or limitations concerning an intended coverage area. Therefore, it is evident that any migration of existing or planned services from a given part of the spectrum into another part due to reduction of available spectrum will not go without problems. Some of these issues are sketched in the following two cases.

6.6.1 Germany

Germany is of the many countries that signed the GE06 Final Acts. This Agreement governs the usage of the UHF band 470–862 MHz for different primary services. In the first place, GE06 was developed to build a solid framework for the planning of and migration to digital terrestrial broadcasting services.

For the preparation of the GE06 Plan Germany favoured an allotment planning approach (see Sect. 4.1.2.1). Allotments are given in terms of geographical areas described by simple polygons. To each allotment a frequency or channel is allocated which can be used throughout this area in order to deploy terrestrial broadcasting networks preferably in terms of Single Frequency Networks (SFN). As it was agreed across Europe this resulted in seven layers of allotments. A layer of allotments corresponds to a set of contiguous allotments that together add up to cover the entire territory of a given country.

The set of German allotment plan entries in the UHF band 470–862 MHz comprises a total of 367 allotments. These 367 allotments can be divided into seven sub-sets which correspond to the seven nation-wide allotment layers. The geographical layout, i.e. size and shape of the allotment areas, differs from layer to layer. Size and shape of the allotments have been chosen to reach a trade-off between efficient spectrum usage in terms of SFNs and the need to reflect national, regional and local coverage requirements of broadcasters. The latter is determined by the media political conditions in Germany where broadcasting lies within the competence of the German Federal States, i.e. the German Bundesländer. Figure 6.7 depicts the first German UHF layer as it has been established during the RRC-06 and subsequently entered into the GE06 Plan.

A total of 65 allotments out of the 367 German allotments have been allocated a UHF channel above channel 60. Table 6.2 summarizes the specifics of the German UHF plan entries of GE06. At a first glance it is obvious that re-allocating the band of channels 61–69 to mobile services will mainly affect the seventh German UHF layer. However, also other layers are affected even though the impact is significantly smaller.

In total a percentage of 17.5% of the German plan entries are affected by the decision to free the 800 MHz band from broadcasting services. From a broadcaster's perspective there are basically two options, i.e. either to abandon these channels or to look for other frequencies below 790 MHz that could be used instead. Giving up the idea of having seven DVB-T layers at disposal is not an option for German broadcasters. Therefore, the second possibility has been investigated in detail.

One of the investigations was carried out by Task Group 4 of the ECC. Their results are contained in CEPT Report 22 in Sect. 5 [CEP07b]. In Sect. 5.2 of this document, it is stated that it might be difficult if not impossible to find alternative channels by any means of re-organizing the given frequency allocation. Several approaches to re-construct the existing GE06 layers are discussed there. Part of the methods proposed in Sect. 5.2 of [CEP07b] correspond to significant modifications

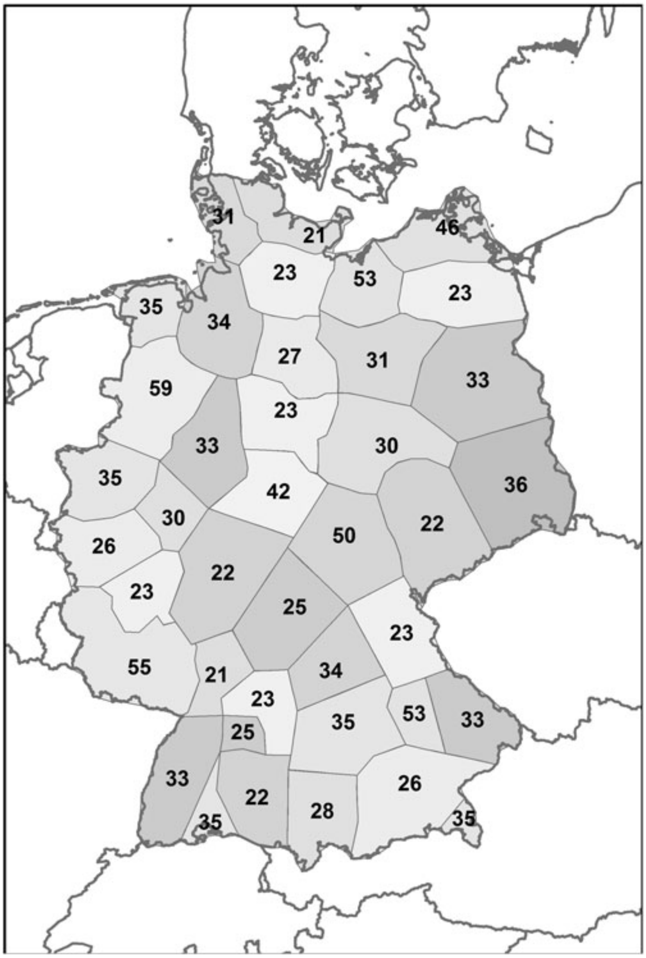

Fig. 6.7 First German UHF allotment layer as it has been established during the RRC-06 and entered into the GE06 Plan. The numbers indicate the UHF channel that has been assigned to each of the allotments, respectively

of the number and geographical layout of the GE06 allotments, i.e. allotments could be downsized, adjacent ones combined or even deleted. Most of these options will require bi- or multilateral coordination activities.

During the preparation of the RRC-06 there was a long and difficult debate in Germany about the appropriate size and location of the allotment areas. In many cases, the final layout was the result of political compromises for which the discussion cannot be reopened. This means any attempt to analyze the possibility to migrate the frequency allocations in the 800 MHz band into the part below 790 MHz, has to assume the set of German UHF allotments being fixed.

Table 6.2 Overview of the German UHF allotment plan entries in the GE06 Plan

	all channels	channels above 60	percentage channels above 60
Total UHF plan entries	367	65	17.7%
Plan entries of layer 1	40	0	0%
Plan entries of layer 2	59	0	0%
Plan entries of layer 3	48	3	6.3%
Plan entries of layer 4	53	2	3.8%
Plan entries of layer 5	55	4	7.3%
Plan entries of layer 6	55	3	5.5%
Plan entries of layer 7	57	53	93.0%

In contrast to the options described in [CEP07b] to find new frequencies for those plan entries that have been originally allocated a UHF channel in the range 61–69 a systematic approach based on mathematical optimization strategies could be employed. This corresponds to mapping the German situation into a clearly defined frequency assignment problem including in particular appropriate boundary conditions and constraints. Typically, such mathematical problems are tackled with the help of stochastic optimization algorithms. More details on such approaches for frequency assignment and network planning methods in terrestrial broadcasting can be found in [Beu04, Beu08].

The fundamental issue for finding alternative channels for allocations above channel 60 is how to treat the neighboring countries. In principle, these countries also face the problem to look for solutions in their territories. Since changes in one country have an impact on neighboring countries at least along the common borders they are not independent of each other and consequently should be dealt with at the same time. However, seriously taking into account this fact would immediately lead to the need to convene a new planning conference for all European countries which is not feasible. Therefore, the only possibility is to look for solutions within one country while taking into account reasonable boundary conditions for the adjacent areas. In essence, this means making assumptions on the spectrum usage in neighboring countries and keeping these channel allocations fixed while trying to find new channels inside the given country which are compatible.

But even then, there are two conceivable ways of addressing the problem. On one hand, one could keep all allocations below channel 60 inside Germany fixed as they are and just try to find new allocations for those above channel 60. This would mean that such frequency assignments would need to be compatible with the boundary conditions imposed by the spectrum usage in the neighboring countries but also they would need to comply with the remaining national allocations.

On the other hand, subject to the frequency assignments in neighboring countries new channels for all 376 allotments could be allocated. From an optimization point of view this is certainly the approach that is more promising. Practically speaking, this might be not an option at all since it has to be borne in mind that any reallocation within a given area is connected to costs arising both for broadcasters and viewers. An entire transmitter network needs to be adjusted to a new frequency. New equipment at the transmitter sites is likely to be required such as antennas or feeding and filtering installations. For the viewers also new antennas may be necessary, too.

Studies have been carried out based on stochastic optimization algorithms. They were presented to all relevant groups working on the reallocation issue, e.g. the ECC Task Group 4 working on the mandates from the EC [Beu07]. The results presented there do not come as a surprise. It was shown that the remaining spectrum in the UHF band between 470 and 790 MHz, i.e. channels 21–60, is not sufficient to close the gaps generated by reallocating the 800 MHz to mobile services. It turns out that 1–2 layers will be lost for digital terrestrial broadcasting.

Clearly, these results have to be seen in the light of the underlying assumptions of the frequency assignment simulations. This means in particular that during the study neither the number of allotments nor their geographical layout has been changed. As mentioned above, the number and size of the GE06 allotments is the result of lengthy and difficult internal German discussions before the RRC-06. This cannot be changed easily in order to facilitate the problem of reallocation of channels for example by applying the methods proposed in [CEP07b]. As a consequence, finding new channels for those allotments that have to be migrated from the band 790–862 MHz to the spectrum below 790 MHz can only be achieved in close cooperation with all neighboring administrations of Germany.

Corresponding coordination activities have been initiated. More or less regularly neighboring administrations are convening meetings to resolve the migration issues. To this end, it is necessary to explicitly take into consideration very detailed information of transmitter characteristics. In principle, the use of sophisticated network planning methods as for example described in [Beu95] or [Beu98] would constitute a powerful tool to solve the frequency assignment problems. Such approaches might help to design the networks in a way to minimize their interference impact on other networks and consequently allow reduced re-use distances.

Unfortunately, there is still not much support for these kinds of approaches amongst European administrations due to many reasons. Lack of knowledge and lack of faith in new up-to-date methodologies might be the most relevant. This is not understandable knowing that in other areas of telecommunications such as the mobile service or cognitive radio sector (see Sect. 7.2.3)these methods are quite common. Therefore, replanning is carried out on the basis of a case-by-case analysis. As a consequence, very likely spectrum usage remains suboptimal.

6.6.2 Australia

The Australian situation with respect to spectrum usage is quite different than the German one. This applies basically to any kind of service. Germany lies in the very centre of Europe surrounded by ten neighboring countries. It is true that the size of the German territory is larger than that of many other European countries, however, it is not large enough for example to fully decouple the spectrum usage of broadcasting services on the eastern part from the western part. Any agreement about frequency allocation agreed during coordination with the neighbors on one side of the country constrains the spectrum usage on the other side of Germany.

This is quite different in Australia which first of all is geographically well isolated in the Indian and Pacific Oceans. Clearly, in the northern part of Australia the distances towards Indonesia and Papua New Guinea are such that coordination may be an issue if there were broadcasting networks developed along that coastline. Furthermore, the country is roughly twenty times larger than Germany. Consequently, constraints that might be imposed on the northern side of Australia do not have an impact on other areas. The area is so large that there is enough freedom in frequency planning to decouple different geographical regions.

In Australia, digital terrestrial television broadcasting has been allocated the spectrum in the frequency ranges between 174 and 230 MHz in the VHF band and 520 MHz and 820 MHz in the UHF band. A channel raster of 7 MHz is used in both bands. This gives rise to 57 TV channels in total for DTT (see Sect. 5.2.1). In 2011, the Australian government decided that from the entire UHF spectrum that was allocated to terrestrial television broadcasting a total amount of 126 MHz, namely the band 694–820 MHz, i.e. channels 52–69, shall be reallocated to mobile services representing the Australian Digital Dividend of terrestrial broadcasting. Furthermore, 14 MHz of the VHF spectrum shall be retained for the introduction of digital terrestrial radio, i.e. DAB/DAB+. As a consequence, what is left for DTT in Australia adds up to 6 VHF and 24 UHF channels.

Following the list of broadcast transmitter data published by ACMA in May 2011 [ACM11b] this corresponds to a significant portion of the total broadcasting transmitters in operation across the country. Table 6.3 summarizes the situation.

Traditionally, planning of analogue television services in Australia was based on regular frequency assignment schemes for individual stations. At each transmitter site at most five different channels could be used. They are grouped to form a set of sequential channels separated by one channel in the VHF band and by two channels in the UHF band. The spectral separation was introduced to reduce adjacent channel interference. For example, channels 54, 57, 60, 63, 66 and 69 could build such a set of allocated channels for a given transmitter site. Shifting down by one or more channels would create other sets of channels, i.e. sequences such as channel 53, 56, 59, 62, 65 and 68 or the set 52, 55, 58, 61, 64 and 67. When digital terrestrial television was introduced channels in the gaps between the analogue usage were employed. Intensive care was taken to adjust the digital transmission in order not to interfere the analogue signals. Even though this approach was successful it

Table 6.3 Australian frequency allocations for terrestrial television as of May 2011

	analogue allocations	digital allocations
total	3207	1346
total in VHF	401	174
total in UHF	2806	1172
above channel 51	2234	665

resulted in frequency allocations for DVB-T which were spread out across the entire spectrum range [ACM11c].

In February 2011 ACMA issued several documents on conceivable ways to accomplish the migration of the broadcasting services in order to free the band 694–820 MHz (see [ACM11c, ACM11d, ACM11e]). The clearing of digital television services from this Digital Dividend band is referred to as the "restack" in Australia. This restack effort is to be carried out in two steps. Firstly, a new target channel plan will be developed including intermediate channel allocations on a temporary basis in order to facilitate the migration. The second step then requires the broadcasters and network operators to implement the corresponding channel changes. Document [ACM11c] contains all relevant considerations on which appropriate decisions will be taken by ACMA after corresponding consultation with all interested stakeholders. In May 2011, ACMA took the decisions about the restack process which can be found in [ACM11f].

In order to guide the migration of broadcasting services out of the band 694–820 MHz ACMA set up a list of fundamental principles. They should be understood as the framework under which the restack process is to be accomplished. ACMA proposes among other things [ACM11c]

- to release the band 694–820 MHz as soon as possible;
- to allocate six TV channels at each transmitter site;
- to use six VHF channels for stations in urban areas;
- to make sure that the coverage areas of the six allocated channels are similar; and
- to dedicate 14 MHz of the VHF spectrum for digital radio.

Clearly, all this has to be carried out under the existing legislation and regulatory framework. Furthermore, it is of paramount importance for the Australian administration to minimize the costs incurred on viewers as well as any conceivable disruption when receiving TV programmes. Aiming to reduce migration costs applies also to public and commercial broadcasters.

ACMA distinguishes between planning approaches and implementation methods. Planning approach refers to developing frequency plans including frequency migration scenarios. This means starting from a given frequency allocation in the band 694–820 MHz, first of all a target frequency plan has to be generated and secondly a path how to change the current channels to the final ones is needed. Implementation method corresponds to the way the channel change at a given transmitter location is then practically accomplished.

Two different planning approaches were discussed and assessed by ACMA. They are called block planning approach and minimum move approach. Block planning means to use six contiguous channels at each transmitter site. Hence, the remaining UHF spectrum between channels 28–51 is subdivided into four sets consisting of six channels each, i.e. 28–33, 34–39, 40–45 and 46–51. In VHF six of the eight available channels will be used. An important feature of block planning is that only channels in UHF or VHF but no mixture shall be used at a given transmitter site. In contrast, the minimum move approach has the objective to find new channels at a given site such that the number of frequencies that need to be changed has to be minimal. Additionally, the channel span should be minimized as far as this can be realized. Clearly, the final set of channels then need not be contiguous.

Both approaches were checked against several criteria in particular the expected costs both for viewers and broadcasters. Furthermore, the level of disruption was also used in order to determine which of the two approaches is better suited to fulfil the principles listed above.

In order to carry out the migration two implementation methods have been discussed an assessed by ACMA. One is called the "Temporary Retune Units" method (TRU) and the other is the replacement method. The latter describes the process of replacing the relevant transmitting equipment at a selected site meaning that a complete new transmission chain up to the antenna feeder is built while the current services remain on air. However, this might be necessary independently for different channels, in particular if they are significantly spectrally separated. Concerns were expressed that disruption longer than one night might be encountered. The TRU method is based on using temporary retune transmitter unit consisting of transmitters and combiners. This is employed to continue broadcasting the services as long as the existing equipment (primarily the transmitters and the combiner) is retuned. Once this is accomplished the temporary retune unit is detached in order to be reused at another transmitter site.

The analysis of ACMA regarding which planning approach is more suitable indicates that first of all both approaches can be used to obtain a successful reallocation of broadcasting services from the band 694–820 MHz to the remaining spectrum in VHF and UHF. Obviously, employing one of the planning approaches in one geographical area requires to apply the same method in adjoining regions in order not create planning incompatibilities leading to non-acceptable interference levels in practice.

However, in case relevant geographical areas are substantially separated by distances beyond 300–400 km depending on topography it might be feasible to employ different planning approaches if there was evidence for a corresponding advantage doing so. For example, the area extending from Port Douglas in the north Queensland down to Tasmania is apparently not decoupled due the underlying regional and urban coverage topology. Hence, a single planning approach would need to be applied. When looking at the central or the far eastern parts of Australia the situation is different. These areas are well separated from the western metropolitan regions. Therefore, frequency planning in the central and eastern areas could be carried out independently from the western parts.

It seemed that the block planning approach might incur higher costs with respect to some aspects of the entire restack process, but its future benefits prevail. For example, the requirement to provide coverage areas as similar as possible is more easily achieved with block planning than with a minimum move approach. Also, if new receiving antenna systems are needed then they would be simpler and smaller for contiguous TV channels than if they are spread across the entire available spectrum or even use different bands. Consequently, ACMA is of the view that a block planning approach should be utilized in order to free the Digital Dividend band. The question remains whether Australia will have sufficient contiguous TV channel blocks to achieve the required terrestrial coverage.

The situation is more pronounced in relation to the implementation method. The analysis showed that a significantly larger impact on costs and the question of disruption is encountered when the wrong implementation method is chosen. The costs resulting from the application of the replacement method are much larger than imposed by the TRU method. Even though implementation of the results obtained by the selected planning method has to be adopted by the broadcasters and network operators in the end, it is expected that a modification of the TRU and replacement methods will be used. More details can be found in [ACM11a, ACM11c, ACM11d, ACM11e, ACM11f].

6.6.3 Some Observations on National Cases

The difference between the approaches taken by the administration(s) in order to free the bands that have been identified as the Digital Dividend of terrestrial broadcasting and to support the migration of broadcasting services to other bands is striking. While in Australia the administration is actively leading the migration process in a constructive manner the European administrations stick to the formal framework set up by CEPT in CEPT Reports 21–30 (see [CEP07a]–[CEP09a]) and the EC Decision on the future usage of the 800-MHz band [Com10].

There is no doubt that reallocating 126 MHz of UHF to mobile services as decided by the Australian administration is a challenge for broadcasters. However, the approach taken by the Australian government nevertheless reflects the relevance and importance that apparently terrestrial broadcasting still has in Australia. Unfortunately, this does not seem to be the case in Europe. Rather, at the beginning of the discussion about the Digital Dividend in Europe several opinions were expressed that in particular terrestrial broadcasting can be phased out in the mid- to long-term in favor of fixed and mobile broadband services.

It is true that there are national differences across Europe when it comes to dealing with the consequences of releasing the DD spectrum. However, in most cases appropriate measures were not defined, neither was the issue of who is to bear the costs of such a reallocation of spectrum addressed in full details. The most intensive discussion were taking place in the UK where the national regulator established at least a framework to identify the corner stones for using the Digital Dividend spectrum by mobile services [Ofc11].

Chapter 7
Future Developments

The digital switch-over from analogue to digital terrestrial broadcasting opened the door to a significantly more efficient usage of spectrum. This means that existing broadcasting services could be offered by using less spectrum. The amount of spectrum that is left and therefore could be released for other purposes is usually addressed as the Digital Dividend. Broadcasters would like to make use of that spectrum in order to offer more (high quality) services and hence make the terrestrial platform competitive with other distribution means like cable, satellite or the Internet.

However, other services also cast an eye on the spectrum ranges so far occupied by terrestrial broadcasting. In the first line, mobile service providers have been keen to get a share of the precious UHF spectrum. But also other usages such as cognitive radio are in need of appropriate spectrum. Consequently, a competition for the UHF spectrum resources is going on and it seems that terrestrial broadcasting is loosing ground.

Economic viability issues are more and more dominating rather than principle political decisions. This is in particular an issue for public service broadcasters as they are usually bound to national regulation. Thus, they cannot act as other market participants which focus on economic success in the first place without having the need to fulfil special regulatory obligations. This section is meant to shed some light on some issues that might become import in the mid- or long-term for broadcasters.

7.1 Digital Dividend II

In many European countries and also in Australia the question how to reorganize the remaining spectrum for broadcasting in the UHF band is currently a hot topic. This might become an even hotter topic during and after the upcoming World Radiocommunication Conference in 2012. There are proposals on the table already

R. Beutler, *The Digital Dividend of Terrestrial Broadcasting*,
DOI 10.1007/978-1-4614-1569-5_7,

today to open the whole UHF band for mobile services in the future. This would have a dramatic impact on terrestrial broadcasting putting its future at stake.

Clearly, there are new developments in the broadcasting sector (see Chap. 2)that enable more and more efficient spectrum usage. This is usually put forward as an argument to say that broadcasting does not need the entire spectrum of the bands allocated to it anymore. This, however, is a difficult discussion and depending from which side it is looked at different views are expressed.

What is clear is that in order to provide an attractive offer of content sufficient spectrum will be required for terrestrial broadcasting services. The term "attractive offer" does not only refer to a larger number of programmes. It also relates to higher quality of the content. Transmitting surround sound or HD quality requires more capacity than simple stereo or SD television. Furthermore, new trends such as three-dimensional television (3DTV) or ultra HDTV (UHDTV) are getting more and more important. Both technologies are currently taken up momentum. Market shares of 3DTV are rising and UHDTV is getting in the focus of broadcasters as a viable opportunity due the fact that the size of flat TV screens is steadily increasing. More information on current 3DTV developments can found for example at [EBU10,DVB11c] while UHDTV information is available for example at [NHK11].

Apparently, safeguarding the future of broadcasting is build on more programmes and higher quality offers. However, this compensates the gain in efficient use of spectrum by introducing new broadcasting technologies. Therefore, broadcasters are of the view that they cannot free more spectrum for other non-broadcasting usages without damaging the development perspectives of future terrestrial broadcasting.

In the process of the preparation of the WRC-12, a discussion was started about the increasing spectrum demand of mobile services in particular IMT services. The driving force behind this hunger for spectrum is an increasing demand for audio and video content on mobile devices. As a matter of fact, this is linked to the exploding market penetration of smartphones and tablet computers in recent years. Actually, only their availability enabled the consumption of media content on portable communication devices. With traditional mobile phones media consumption would never have taken up so dramatically thus pushing data traffic higher and higher.

Spectrum demand for mobile services including IMT and IMT-Advanced has been a topic of investigation at the International Telecommunications Union (ITU) already for some years [ITU06a]. As as first step a methodology had been developed that allows the calculation of spectrum requirements. Several aspects are accounted for when applying this methodology. Service types and traffic classes are taken into consideration as well as usage patterns including density distribution of users. Traffic in mobile networks is varying in time and is also different in different areas which is both an integral part of the analysis. Based on this capacity requirements can be derived which are mapped into corresponding spectrum requirements.

In 2006, ITU also published the results of an investigation concerning the future spectrum demand of IMT and its follow-up systems. The results are contained in ITU-R Report M.2078 [ITU06b]. The report comes out with a total spectrum demand for the year 2020 between 1280–1720 MHz for the mobile service including those ranges that have been previously already allocated. Obviously, depending on the market condition different demands have to be expected.

Already today (2011) 1085 MHz of spectrum are allocated to the mobile service and identified for IMT in Europe (see Sect. 4.4). Furthermore, there are several additional candidate bands that might be accessible for IMT in the future, i.e. the bands 3600–3800 MHz and 3800–4200 MHz which correspond to additional 600 MHz in total. Thus the total future amount of IMT spectrum might be 1685 MHz in the mid- or long-term future. This does not include further options between 4500–4800 MHz and 6725–7025 MHz. From this it can be concluded that the spectrum requirements identified by ITU in its report are pretty much covered by the foreseen spectrum already.

However, the ITU investigations refer to a time when smartphones did not yet exist as a mass market device. Since then their market penetration has significantly increased. It is widely excepted that within a few years smartphones will become the standard mobile phone device almost entirely replacing traditional mobile phones. Smartphones being enabled for broadband access as a matter of principle very likely will drive and determine the future spectrum demand of the mobile communication sector.

This is supported also by a very comprehensive study about development of Internet traffic published in early 2011 by CISCO [CIS11]. The investigation included not only fixed Internet traffic but was dealing with mobile broadband access prospects, too. CISCO came out with several fundamental statements about the future development of IP traffic across fixed and mobile networks. Concerning mobile phones it is expected that around the globe more than seven billion mobile devices will be in use. This will clearly have a significant impact on the amount of data traffic which is expected to grow more than 26 times between 2010 and 2015. At the same time mobile network speeds will increase roughly by a factor of 10.

Whether or not the forecasts of current studies are indeed coming true or not is to be awaited. As usual, such forecasts should be taken with a pinch of salt.[1] Nevertheless, without doubt there will be a growth of IP traffic also across mobile networks. Consequently, mobile operators are claiming that to this end more spectrum would be required to satisfy the future spectrum demands of the mobile communication sector. Unfortunately for broadcasters, an important part of the additional spectrum targeted at lies in the UHF bands below 790 MHz. This band is currently used by terrestrial television broadcasting in many countries around the world.

As a first approximation, growing the traffic by a factor X would require X times the spectrum. Therefore, a growth as projected by the CISCO study for the next years can certainly not be contained by using more and more spectrum. If UHF spectrum can really help to resolve the issue remains doubtful. This can be understood by a simple argument. For Europe, the first Digital Dividend corresponded to 72 MHz (UHF channels 61–69) out of originally 392 MHz (UHF channels 21–69). Hence, even if the entire UHF spectrum would be made available

[1] Like Mark Twain already correctly remarked, “predictions are very difficult, in particular as far as they refer to the future”.

for mobile services that would just add another 4.4 times the first DD spectrum. Compared to an expected growth factor of 26 it becomes crystal clear that either a lot more spectrum would be needed in other spectrum ranges or other ways of increasing data throughput without increasing the spectrum resources have to be implemented. Building denser networks or using more sophisticated network structures and technologies might need to be considered thereto. Clearly, this all cannot be achieved for free and therefore investments of the mobile network operators are required.

Nevertheless, mobile operators are pushing heavily to get hold of UHF spectrum for mobile services. Two arguments are usually put forward in that context. The first one is that spectrum below 790 MHz is needed in order to cover rural areas. Admittedly, the rural area coverage target can be achieved more easily by UHF spectrum than by other frequencies. The extraordinary wave propagation conditions of UHF Band IV and V frequencies allow the creation of larger cells in the mobile network. So, instead of having cell sizes of up to 2 km diameter 10 km or more can be reached and thus with relatively few base stations throughout a large area services can be provided. As a consequence, the network cost are going down.

Coverage is certainly important but the more crucial factor is the total traffic in a cell that can be covered by a given bandwidth. Clearly, in urban areas the limiting factor is always the traffic and not limitations due to wave propagation issues. Therefore, typical cell sizes are less than 2 km. But even in rural areas there are cities with significant population densities. There again traffic becomes an important issue which not necessarily calls for UHF frequencies to be used.

The second argument to justify the hunt for spectrum below 790 MHz is that mobile operators are pushing for harmonized spectrum usage around the globe. Naturally, global harmonization opens the door for economies of scale which means that a mobile phone device could be developed and put onto the market that could be sold everywhere on the planet. As a consequence, prices will drop. The possibility to use the same range of spectrum everywhere is therefore very attractive.

However, for the time being spectrum usage for mobile services is very different in different regions of the world (see Sect. 6.3). Spectrum usage is always governed by a two-step process. On one side there is the frequency allocation as decided by a World Radiocommunication Conference (WRC) of ITU. These decisions build the general framework of spectrum usage. Table 4.2 shows the relevant part of the Table of Frequency Allocations. Since in many cases a given spectrum range can be used by several services on a co-primary basis it is the prerogative of a national administration to decide on the spectrum usage within its territory. Usually, in order to minimize harmful interference between different services spectrum usages are aligned within ITU Regions. Nevertheless, there are differences from Region to Region in particular with respect to spectrum for mobile services below 1 GHz.

In the US, which belongs to ITU Region 2, the implementation of the plans to allocate further spectrum in the UHF bands to the mobile service are very advanced. The range between 698–806 MHz has been auctioned off already between 2004 and 2008 (see Sect. 6.3.2). A band plan for this so-called 700-MHz band has been developed [FCC11a]. This part of the spectrum is usually addressed in the US by calling it the lower 700 MHz band (698–746 MHz) and the upper 700 MHz band (746–806 MHz). In the lower part a classical FDD band plan has been put forward with uplinks at lower frequencies and downlinks at the higher frequencies while in the upper 700 MHz band a reversed duplex has been chosen. However, the US band plan seems to be very fragmented. In the lower 700 MHz part FDD uplink is foreseen between 698 and 716 MHz, then 12 MHz of TDD spectrum follow and between 728 and 746 MHz the FDD downlink is put. The upper part of the 700 MHz starts with 17 MHz of FDD downlink, followed by 12 MHz of public safety service downlink using LTE technology. Starting with 776 MHz the corresponding FDD uplink parts are allocated in the same order as the downlinks including public safety services.

Looking at the discussion in ITU Region 3 as given in [APT10] it seems that the APT view is different from the US approach. In the case of FDD it is foreseen to employ a lower guard-band of 5 MHz between 698 and 703 MHz and an upper guard-band of 3 MHz between 803 and 806 MHz. The FDD uplink should be allocated in the range 703–748 MHz while downlinks will be placed between 779 and 805 MHz. This gives rise to a duplex band of 10 MHz.

Europe has not yet fully started to release the spectrum below 790 MHz. If ever such a decision will be taken then it seems to be very likely that the band plans depicted in Figs. 6.4 and 6.5 will be extended towards lower frequencies which might give yet another way to use the spectrum. It can be expected that in such a case traditional duplex would be envisaged, i.e. uplink at lower and downlink at higher frequencies. However, due to slightly different band limits the allocations in ITU Regions 1 and 3 would not match.

Real global harmonization probably looks different. Any attempts to overcome this issue have to cope with the fact that all these spectrum usages are typically based on long-term contracts as a result of spectrum auctions, they cannot be simply overwritten by formal spectrum allocations at ITU or national level. However, it has to be noted that in Regions 2 and 3 UHF spectrum down to 698 MHz is foreseen to be used by mobile services already. Even though there might be differences in the details of the spectrum usages the pressure in Region 1 to free the same range will very likely increase significantly due to this. Therefore, there is a high probability that ITU Region 1 will be aligned to Regions 2 and 3 in the long run.

As explained in Sect. 6.5 freeing part of the UHF bands from broadcasting services is a challenge for broadcasters already when only 72 MHz of spectrum has to be released as was the case in Europe. If at one of the upcoming WRCs a new frequency allocation for mobile services down to 694 MHz would be decided for ITU Region 1 that would certainly have a dramatic impact on terrestrial television broadcasting as a whole. Tremendous efforts would be needed to replan the broadcasting networks which will incur a huge pile of money to be spent on this. It is very likely that under such conditions a new planning conference for terrestrial broadcasting services has to be convened.

Furthermore, it might put terrestrial broadcasting in a very difficult position in terms of no longer having enough spectrum resources available that safeguard future development and competitiveness with respect to other platforms such as satellite or cable. Depending on the countries and their different dependency from the terrestrial delivery platform for broadcasting content it might well pose the fundamental question if terrestrial television broadcasting is a viable option for the future at all.

7.2 Relevant Technological Trends

The attempt to satisfy spectrum requirements for existing systems such as IMT is just one aspect that puts terrestrial broadcasting under pressure. On the other side new technologies are steadily developing. They comprise next evolutions of existing telecommunication standards as well as completely new concepts. This section is meant to give a quick overlook about those trends that without any doubt will influence the future direction of terrestrial broadcasting.

7.2.1 Next Generation Mobile Networks

The evolution of mobile network technology is governed and steered by the 3GPP organization [3GP11]. It unites several industry bodies which are devoted to the development of future telecommunication systems. The 3GPP activity started in 1998 with the target to develop a third generation mobile system as a successor of GMS. In the meantime, ten releases on further developments of mobile systems have been published and sent to ITU-R to be included in the corresponding ITU-R Recommendations. Standards such as W-CDMA, HSDPA, HSPA+, etc. were introduced over the years. Starting with release 8 the system called LTE was promoted. Release 10 of the 3GPP specifications is referring to what is usually called LTE-Advanced [3GP11a].

LTE-Advanced is a natural evolution of LTE. LTE was designed to allow for highly efficient use of spectrum. To this end, the downlink is based on OFDM signals where several different bandwidths can be employed, i.e. 1.4, 3, 5, 10, 15, and 20 MHz. For the uplink a single carrier FDMA technology is used. In both cases, multi-antenna techniques can significantly improve the receiving and transmitting characteristics. Using OFDM for the downlink opens the door to make use of single frequency networks (SFNs) thereby further increasing efficient spectrum usage. That is in particular interesting in connection with multicast or broadcast modes. These allow switching from unicast, i.e. one-to-one distribution of audio or video content requested by several users within the same cell at the same time, to a more efficient way of using available spectrum resources. Furthermore, LTE can be deployed in FDD and TDD mode. Under optimal conditions a maximum data rate of 300 Mbps for the downlink and 75 Mbps for the uplink can be reached [3GP11b].

The most striking improvement in the step from LTE to LTE-Advanced is certainly the increase of the possible data rates. LTE-Advanced may offer, again under optimal conditions, 1 Gbps for the download and up 500 Mbps in the uplink. This increase becomes possible by supporting larger bandwidths. The key to achieve this is the capability to aggregate spectrum that might be available. Both adjacent and separated spectrum blocks can be used jointly. Thereby, a maximum bandwidth of 100 MHz is achievable. Especially with respect to FDD deployments of networks, this provides the means to use spectrum asymmetrically, i.e. different bandwidth for downlink and uplink. Also, multi-antenna features are significantly enhanced in LTE-Advanced. More details about technical characteristics of LTE-Advanced can be found for example at [Nak09].

7.2.2 Software Defined Radio

In the past typical broadcasting receivers made use of special hardware components in order to receive and convert the electromagnetic waves to baseband signals. Then the signals can be demodulated and decoded by specific chipsets. However, since quite some time there is a trend to substitute hardware components by software processing based on general purpose chipsets. The idea to carry out the entire signal processing of a high frequency transmitter or receiver in terms of software is usually called software defined radio (SDR). Preferably, such a software defined platform should be reconfigurable in order to allow modifying the employed radio technology standard.

Reconfiguration can be achieved by exploiting a combination of different hardware and software technologies. The hardware elements are implemented in terms of programmable processing technologies on which corresponding software or firmware is running. Hardware solutions comprise field programmable gate arrays (FPGA), digital signal processors (DSP), general purpose processors (GPP), programmable System on Chip (SoC) or other application specific programmable processors. All these technologies allow modifying or extending the features and capabilities of the receivers without the need to change the hardware [WIF11].

Today, in principle all digital broadcasting receivers for the DAB or DVB family of standards intensively exploit software based solutions [Bec11]. Depending on the standard they use different antenna feeds. They are equipped with specific computational power, storage and specific hardware accelerations for channel and source decoding. However, these types of receivers cannot be considered as SDR since an upgrade of the broadcasting standard requires replacements of the existing device by a receiver of the new generation.

Apparently, the more tasks are performed in terms of software within the receiver the more flexible the device becomes. A look at contemporary broadcasting standards reveals that both the used modulation and coding schemes are very similar. Almost all systems are based on OFDM modulation. Moreover, source coding is more and more making use of wide spread efficient coding schemes such as MPEG-4 (see Chap. 2). Thus, in order to realize true SDR a straightforward idea would be to digitize the electromagnetic field received by the antenna as soon as possible. In order to retrieve the transmitted audio or video information from the digitized baseband signal a general purpose SDR device should then be employed. The overall objective of such devices would be to easily switch from DVB-T to DVB-T2 or ISDB-T or some other digital OFDM television standard if necessary.

The "closer to the antenna" the digitization is carried out the more computational power the receiver needs to possess. This is due to the required clock rates and the associated storage. It gets even worse if modern hierarchical modulation schemes (MS) are employed or if very different OFDM configurations should be covered by a single receiver design. Just looking at the table of possibilities for DVB-T imposes a burden on any SDR design because all conceivable combinations would need to be verified during the development process.

Technological progress and flexibility of devices are features that call for extensive research and development effort. From a manufacturers point of view this will always be contrasted with economical benefit. Implementing SDR solutions will certainly lead to higher receiver prices, at least in the beginning before economies of scale are reached. The crucial question is then whether the consumers are willing to pay for the overhead of opportunities and the fact that the device may be future-proof.

On the other hand, pushing for the development of SDR systems could be important in the future for all stakeholders in the whole chain from the content provider to the listeners or viewers. There seems to be no doubt that it remains an illusion that a single standard for the distribution of broadcasting content will prevail. Therefore, multi-standard receivers will be necessary quite naturally. Furthermore, the system development will not stop. Consequently, migrating from one system to another will be required. In case flexibly reconfigurable software defined receivers would be in the market the switch from one standard to another one would no longer pose such a difficult and expensive enterprise as it is at the moment for example when going from DVB-T to DVB-T2. Under such conditions, SDR could become an economically viable solution in the long run. More information on SDR can be found at [WIF11].

7.2.3 Cognitive Radio

The concept of cognitive radio is rather new. The idea emerged just before the millennium. It is probably safe to say that this field of research was officially kicked off with the dissertation of Joseph Mitola in 2000 [Mit00]. It defines the term cognitive radio as a radio device that possesses a certain level of self-awareness in the sense of having the ability to autonomously act and react to changing environment conditions. In its ultimate form it could combine a SDR architecture with hardware and software components allowing the communication with other devices. Thereby, the device is able to gather relevant information in order to take decisions on operational configurations and resource management. This gives rise to autonomous operation and a certain level of self-organization of different devices connected in the same network.

Many research projects have been initiated since 2000 looking into different aspects of cognitive radio technology. The EC has actively supported these efforts in terms of several funded research projects within the 7th Framework of the EC [Com11]. For example, the QoSMOS project [QoS11] has the primary objective to develop a framework for cognitive radio systems with the target to improve utilization of radio spectrum consistent with coexistence requirements with other services. Quality of service under mobile usage conditions is the central topic of this project. Furthermore, the intention is to develop and prove critical technologies in terms of using a test-bed. The initial focus is on opportunistic use of radio spectrum, in particular so-called white spaces of the UHF bands (see Sect. 6.2). Quite similar activities are pursued in a project called CogEU [Cog11]. Here the focus is more on the introduction and promotion of real-time secondary spectrum trading and the definition of new methodologies for equipment certification and compliance by explicitly addressing coexistence issues with the DVB-T standard.

The central aspect of all these investigations and projects on cognitive radio from a broadcaster's perspective is that the primary spectrum resource they are looking at are these white spaces in the UHF bands. In simple terms, white spaces are the areas between the edges of broadcasting coverage areas in which a given channel cannot be used by broadcasting transmitters in order not to cause harmful interference (see also Sect. 6.1).

Despite this fact administrations have made first provisions to pave the way for the introduction of cognitive radio systems in the UHF bands. In Europe, CEPT has published a first report on cognitive technologies [ECC11]. This is certainly not the last word because further work is carried out on this issue. In particular, the issue of the actually available amount of white spaces might is getting more and more into focus. As discussed in Sect. 6.2 white spaces correspond always to a snap shot in time of actual spectrum usage by broadcasting because broadcasting plans are not static. Rather, they are meant to evolve over time towards introducing more and more broadcasting services. Any network operator would need to consider if under such conditions a business model for cognitive radio solely based on UHF white spaces would constitute a viable option, in particular since the introduction of cognitive radios on a large scale requires significant investment.

Chapter 8
Strategic Considerations

The advent of the Internet some 20 years ago and its dramatic development has irreversibly changed our lives. In the western world access to the Internet is omnipresent and more and more businesses but also public administrations are relying and depending on it. Clearly, this also had and has a huge impact on broadcasting in general. This section is meant to give an overview about the current trends and developments and the consequence arising therefrom for terrestrial broadcasting.

8.1 Change of Paradigm in Broadcasting

The changes currently encountered in the broadcasting sector basically constitute a change of paradigm. In the analogue era, broadcasting had a very central meaning in any society around the globe. Broadcasters provided audio and video content to a mass audience across large coverage areas by means of terrestrial broadcasting technologies. All content was linear content which means that listeners and viewers tuned in to real-time transmissions which had been created and edited by the corresponding editorial departments of the public and commercial broadcasting companies. This picture seems to be changing. The driving force behind the change is the digital revolution which manifests itself in the dizzying development of the Internet and the technological progress of the telecommunication sector. It is obvious that this affects also all aspects of broadcasting from production to distribution.

8.1.1 Context of Media Usage

One of the first observations concerning the changes going on in broadcasting refers to the context in which audio and video content is accessed and used. From a broadcaster's point of view the media usage context has become both more complex and fragmented at the same time.

R. Beutler, *The Digital Dividend of Terrestrial Broadcasting*,
DOI 10.1007/978-1-4614-1569-5_8,

For most of the time the distribution of broadcasting content was planned for fixed reception. In the early days families gathered in the living room sitting around a radio receiver to listen to music or news. This carried over to television which happened primarily in the living room as well. Fixed reception can be targeted at easily by terrestrial broadcasting. However, listeners and viewers needed to take an effort in terms of setting up appropriate roof top antennas.

However, the development of broadcasting technology paved the way for other receiving conditions as well. Already FM transmissions were able to reach mobile receivers, primarily in cars. Indeed, reaching listeners in cars still is one of the most important aspects when it comes to the planning of radio networks. With the introduction of digital broadcasting technology the restriction to be able to distribute broadcasting content only to fixed receivers has been finally overcome. Today, television and radio programmes can be received in high speed trains and cars as well as when walking in the street or waiting for the bus with a handheld receiver.

In addition to this, portable reception has become an important issue for broadcasters as well. Watching a football match in the open while having a barbecue has become a very popular example for portable reception. Everything one needs is a receiver that can be easily moved from one place to another. Clearly, terrestrial broadcasting has a clear advantage here in comparison to cable and satellite reception.

Broadcasting content is listened to or watched in all conceivable places. These can be rural areas or big cities with very large buildings. When it comes to radio for example the other very important receiving environment apart from cars is indoors. This comprises people at home or at work, sometimes deep inside large buildings or even underground. Since a large audience can be reached in such circumstances broadcasters have to find ways to provide their content there as well.

Under all different receiving conditions listeners are able to tune in to their favorite programmes. But tuning in to real-time programmes means that the programme schedule is fixed. If one misses a particular movie or documentary on television one can only hope that it is repeated at another, more suitable time. Clearly, with appropriate audio and video recorders listeners and viewers can obtain more autonomy about when they would watch or listen to a programme. Fortunately, in the meantime many receivers, at least those for digital broadcasting signals, naturally offer to record content. This gives the possibility to catch up with programmes that were missed. It seems to be quite common these days to watch weekly series at a time which is more appropriate than the one at which the programme is actually broadcast. Also, for the sake of skipping commercials it is convenient to record a movie and watch it time-shifted.

In an Internet world, this dependence on a schedule that some editorial journalists had decided upon is no longer an issue. One of the most important features of Internet access to audio and video content is the autonomy of users with respect to time and more and more also with respect to location. The market penetration with smartphones and tablets together with more and more fixed broadband connections has led to a widespread IP connectivity experience. Therefore, people are used to accessing audio and video content in self-determined way. As a consequence, this is more and more expected from broadcasting services as well. Hence, there is an increasing request for real on-demand broadcasting content which puts the broadcasters in a position to reflect this change in their programme offers.

The technical possibilities also have an impact on social interactions in relation to media consumption. At the beginning of radio transmissions more than 100 years ago listening to radio was a shared experience, i.e. families gathering in the living room as mentioned above. Even though habits changed watching a film or video together with other people in front of the television set is still quite common. However, shared experience can look quite different today as well. Many computers are equipped with cameras or webcams which can be used to see the person with whom one is connected. Exchanging any kind of information including text, audio and video in multi-user sessions generates a new level of shared experience where participants of the group need not necessarily be in the same room, not even in the same country or continent.

People quite naturally communicate by employing social networks such as Facebook [Fac11] or MySpace [MyS11] or send short messages across website like Twitter [Twi11]. These are actually the vehicles which give rise to a shared experience of a group of people that was impossible before. This is complemented by websites such as e.g. YouTube [You11] and Picasa [Pic11] that dedicatedly offer the opportunity to publish and share any kind of media content. Probably even more important, they offer the possibility to distribute content that was generated by people themselves virtually to a worldwide audience.

On the other side there is the personal experience of media consumption which however is no longer only linked to traditional radio or television receivers only. Still people are listening to radio when they are on their own as well as they watch movies all alone. However, what can be observed is that in addition to this traditional personal media usage there is an increasing trend to use different media at the same time. That means while watching a film people use their laptops in parallel to chat with their friends or look for additional information on the Internet relating to the movie on the screen.

8.1.2 Evolution of Content

Traditionally, broadcasting has been understood as linear audio or video content provided in real-time. Every broadcasting company has editing departments where journalists generate a 24 h/7 d a week programme containing a variety of different formats such as news, shows, daily soaps, series or movies. Live transmissions from big sport events are very important, too. Over the last decades the number of TV channels but also radio stations has steadily increased. Meanwhile, there is a very large variety of different programmes to tune to.

But not only the quantity is changing. There is also a dramatic change concerning the quality of content. The digital revolution definitely supported the development of high quality broadcasting. During the period of analogue television transmissions standard definition television (SDTV) was the way to produce and deliver television. In Europe the PAL specification was used which corresponds to a TV picture with a resolution of 720 × 526 pixels while in those countries using NTSC pictures of 640 × 480 pixels could be offered.

However, digital technology has evolved. Today, high definition television (HDTV) has become the new de-facto standard. This means that it is not yet used everywhere and under all circumstances but it will certainly be so in the mid-term future. HDTV can provide as much as 1920 × 1080 pixels which is usually referred to as Full-HD because there are other configurations possible with lower resolution. This is roughly twice as much as SDTV. Most modern flat screen television sets sold today in Europe, Asia, and the US are able to display full-HD pictures.

But it seems this is not the end of the story. Since quite some time the so-called ultra high definition standard for television (UHDTV) is promoted in particular in Japan and Korea. This variant of television would allow for a maximum resolution of 7680 × 4320 pixels. Significantly larger screens than in the case of HDTV could be envisaged thereby.

Progress on the picture quality for television is complemented by progress on the audio side as well. Stereo sound has been around for a while but now surround sound can be offered on any of the digital terrestrial audio broadcasting platforms, too. Clearly, for low cost radio receivers this is probably not very interesting. However, in the case of fixed reception, in particular in the living room, this certainly is an attractive option.

Internet presence in terms of offering corresponding websites has become a must for broadcasters. It has to be noticed, however, that in the case of broadcasters providing an attractive Internet portal is not just done for the sake of doing a bit of up to date promotion and customers relation. On the contrary, Internet portals have become a crucial means to offer many kinds of non-linear broadcasting services.

Major contemporary radio and television programmes are nowadays usually associated with a corresponding website on which listeners and viewers can get additional information about programmes or have access to complementary content. At least for radio there is typically the possibility to tune in to a live stream of the radio programme. Some broadcasters offer a surround sound live stream in parallel to the stereo stream. Moreover, the possibility to listen to content that already has been broadcast is usually offered. This allows catching-up with missed radio shows. Clearly, catch-up services are also an attractive feature for television. Web-only content is available both for radio and television which quite often corresponds to editing existing content in order to make it available in a web-suitable form be it in terms of quality or length/duration.

All these broadcasting websites are connected to external social network platforms such as Facebook or Twitter which provide a natural way to get in contact with the audience. It has even become popular to create dedicated groups on Facebook to report on and bundle all activities relating to a special event such as a big rock festival. In addition, there are programmes that entirely rely on listener or viewer participation for example radio shows covering particular aspects of travelling or reporting about a given country.[1]

For the time being linear and non-linear broadcasting offers are only loosely linked. They are provided by different technologies, i.e. broadcasting technology on one side and an Internet connection on the other side. Listeners and viewers have to decide themselves which medium to use.

However, there is a trend getting stronger and stronger at least on the television side, which is called Hybrid Broadcast Broadband Television (HbbTV) [Hbb11]. HbbTV constitutes a technological platform that is meant to seamlessly combine broadcasting content delivered via broadcasting technologies and IP based distribution forms on a single display device, typically a large flat screen TV set. Based on the digital video broadcasting (DVB) standard the broadcasting path can be a terrestrial, satellite or cable source. HbbTV has been standardized in June 2010 by European Telecommunications Standards Institute (ETSI) [ETS10]. The standard provides the features and functionality required to deliver complementary broadcast and Internet services. It has to be noted however, that this is realized on the level of services only so far. Merging broadcast and broadband networks could be the next step (see Sect. 8.1.4).

Without any doubt there is an increasing demand in non-linear offers. Catch-up usage of broadcasting content is very popular as for example the tremendous success of the BBC iPlayer shows [BBC11]. However, it can also be expected that linear content will remain strong for a long time. There are many broadcasters that are even of the opinion that linear content is and remains the killer application of broadcasting for at least the mid-term future. This is obvious for radio as radio is usually listened to while doing something else. People are listening to radio while working in their offices, during workout or gardening or when driving in a car or public transport. But also for television this seems to be true. People typically start to watch TV in the evening after coming home from work and having completed home duties. Many of them will then hop through the channels until they find an attractive programme. If there is a non-linear offer on top of the linear content then people might eventually get carried away. But the entry point into the non-linear world of television is linear content.

Clearly, there are a lot of households where the TV set is running all day. But this corresponds to a TV usage as radio is used, i.e. using TV while doing something else. Under such circumstances there is probably even less demand for non-linear services because the linear content is (mis)used as background entertainment without attracting too much attention anyway.

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[1] Two examples of websites where all these features are implemented can be found at [SWR11] or [ARD11]. The first example corresponds to the website of the youth radio programme of Südwestrundunk which is one of the German public service broadcasters while the second example refers to a website that complements the major daily news shows on German public television.

8.1.3 Future Receiver Technology

A large variety of different devices that can receive and play back or display broadcasting content is available in the shops. There are more and more digital audio receivers and on the television side the trend to ever larger flat screens shows no signs of waning. Prices for them are steadily going down, so they are established as the standard target display device for any kind of video content. At the same time, many PCs or laptop computers automatically come with card receivers for digital terrestrial television. In Europe this are DVB-T cards in the first place. The great variety of different broadcasting receivers on the market are complemented by a plethora of smartphones and tablet computers that by virtue of broadband access technology allow streaming audio and video content.

Nevertheless, it is very important to understand that even though there are many distribution technologies and corresponding receivers available listeners and viewers are usually not interested in technology per se. It is true that there are technology aficionados which are interested in knowing all the details. Others do not care about technology but still fall in the category of "early adopters" because they just want to possess the latest technological gimmicks. However, the vast majority of people are only interested in getting their preferred services at an acceptable price. It sometimes seems that not even quality is an issue. Otherwise people would not accept unsatisfying coverage of mobile networks for example.

Such an attitude might be an important factor in analyzing why some technologies like digital terrestrial audio broadcasting did not take off as expected by many experts. DAB has been promoted for a long time by highlighting the possibility to offer CD quality sound. However, it turned out that this obviously was not a convincing argument. A greater variety of content on the other side or content which is available exclusively by means of a particular technology seems to be more important.

Bringing together the large number of different technological standards on one side and the lack of customer's interest in technology on the other side naturally suggests offering multi-standard receivers. In the case of audio broadcasting, this gives rise to receivers which can receive radio programmes via FM, the DAB-family of standards and via an Internet connection, be it wired or wireless. In the latter case a streaming offer from a broadcaster's web portal is typically used. There might be even an incentive in the future to integrate the digital radio mondiale (DRM) family of standards.[2]

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[2]Not all broadcasters are happy to jump onto the DAB train due to the simple fact that they do not want to share a multiplex with their direct competitors or they just cannot afford it. In their eyes, solutions such as DRM/DRM+ or HD Radio (see Sects. 2.1.2 and 2.1.3, respectively) offer more promising opportunities. These broadcasters basically follow the traditional philosophy of the analogue distribution world, i.e. "one transmitter – one frequency – one coverage area". It seems to be obvious that an incentive for listeners to migrate to digital radio is the availability of the entire spectrum of audio programmes. Therefore, it might be necessary to consider integrating these other technologies in multi-standard receivers as well.

Multi-standard receivers for radio are on the European market for quite some time. For the time being the user has to select the source type, i.e. FM, DAB or IP. However, taking on the missing interest in technologies of consumers it can be expected that the next generations of receivers will allow the listener or the viewer to tune to a radio station or a television programme and then the receiver will decide itself which input path to use. Depending on which distribution technology the wanted content can be accessed under given circumstances the device then utilizes the option that offers the best quality for example. Hence, for the user the reception becomes entirely transparent, it is basically reduced to what actually lies in his or her proper interest, i.e. the content and not the way it is delivered.

In principle, this also applies to television receivers. Most flat screen TV sets incorporate at least two receivers, namely a cable and terrestrial receiver, but some also include a satellite receiver. More and more TV receivers come with IP functionality and therefore the option to let the devices decide where to get the requested content from is obvious.

It is just a small step from this to further enhancements of receiver functionality. Storage equipment has become very cheap over last decade. Thus, equipping receivers with corresponding hard disks in order to record audio and video content is straightforward. This is actually done today already. What is only missing is a little bit of smart software that allows to define personal profiles according to which the device can record and store content that complies with the preferences of the users whenever via one of the available connections, i.e. broadcasting or broadband, corresponding programmes are spotted. It seems that the obstacle for the introduction of such technologies is not a technical problem. Rather, legal issues such as copyrights may be the key issue to be resolved in that context.

From a broadcaster's point of view the future receiver development could be an easy issue, technically involved and maybe expensive but solvable. The major problem that needs to be addressed is that currently the market for smartphones and tablet computers is dramatically increasing which is not necessarily the case for broadcasting receivers. This alone is not critical, but the point is that smartphones and tablet computers usually do not incorporate a broadcasting receiver. It is possible to access audio and video content on mobile phones or tablet computers via streaming from web portals using special apps. But apart from FM receivers there are no digital radio receivers nor any kind of digital television receivers included in smartphones or tablets at this point in time. For the time being, smartphone and tablet manufacturers but also the associated network and services operators are not keen changing that. For broadcasters, however, it might become a vital issue to safeguard the accessibility to their broadcasting services also on those devices which are gaining more and more importance in people's daily lives.

8.1.4 Hybrid Distribution Networks

Apparently, the future of broadcasting with respect to the service types will be based on a portfolio of linear and non-linear programme offers. For the time being, the delivery of these two different types are accomplished by means of distinguished distribution mechanism, i.e. broadcasting networks on one side and broadband networks on the other side. Currently, broadcasters are still running their own terrestrial networks or commission such networks to broadcasting network operators. This is done in order to provide linear radio and television programmes for a mass audience across large coverage areas at a given quality of service. In addition, broadcasters are placing contracts with Internet services providers to enable the distribution of their content via corresponding web portals where listeners and viewers have access to a variety of non-linear services.

First steps to integrate both worlds into a single programme offer are currently undertaken for examples by HbbTV [Hbb11] or YouView [YoV11] which is an alternative approach to HbbTV. On the radio side there are similar activities going on. One of these is called RadioDNS which targets at enabling the convergence of radio broadcasting and IP-delivered audio services [Rad11]. In both cases, the idea is to bring together services delivered via broadcasting technology or via the Internet on the same device. Furthermore, seamless switching from one offer to the other is one of the major objectives of these enterprises. However, it has to be noted that all that happens on the level of services only. It requires a device which is connected to a broadcasting and a broadband network and constitutes just the technical platform to offer the content to the user.

But this is certainly the first step only. Bringing together two networks that are both adapted to different objectives might be the next step. But this might be a real challenge. However, the technical difficulties might pose the smaller problem in that respect. The real obstacle to seamlessly join independent broadcast and broadband networks lies in the different ownership and thus in diverging business models. Therefore, what might be envisaged in the future is a single network that is able to fulfil both requirements, i.e. delivering linear and non-linear content depending on the circumstances, demands and resources.

Without any doubt the optimal solution to distribute linear audio and video content to a mass audience over large areas at a given quality of service is broadcasting technology. This refers to efficient use of spectrum as well as cost effectiveness. In order to cover an area of about 100 km diameter with several TV programmes in SD quality it suffices to use a single high power transmitter. On the other hand, such a transmitter cannot deliver on-demand services tailored to local demands at the same time. Consequently, a network might be favorable that consists of a typical broadcasting part as some kind of an overlay network complemented by smaller cells in which mobile broadband technologies such as LTE are used. Since the objective is to distribute non-linear broadcasting content across the mobile network part highly asymmetrical traffic would result, i.e. much capacity is needed for individual audio or video downlinks but only a small amount of traffic will incur due to users requesting content.

Such a real hybrid network, controlled by a single operator whose intent is to offer linear and non-linear broadcasting content in a seamlessly intertwined way would offer substantial benefits. Firstly, there is a clear operational advantage. Very likely such a network would not be run by a broadcaster. Rather, it can be expected that there would be a network operator hosting the distribution of any kind of broadcasting content under one roof. From a broadcaster's point of view this would facilitate the business relations in order to safeguard the content delivery.

Furthermore, distribution could be perfectly tailored according to actual demands. For example, in many countries there are several TV channels that attract many viewers every day. Others have a significantly less audience. If all linear TV programmes are distributed in terms of digital terrestrial television than corresponding capacity in a multiplex would need to be foreseen also for those programmes requested only by few people. In a hybrid network there would be a possibility to employ multicast or even broadcast modes in particular cells of the underlying mobile network part to deliver these channels within limited areas to a limited number of viewers. The released capacity in the DTT multiplex could then be used for other purposes such as other programmes or time-shifted offers of already existing mass attractive programmes. This also nicely links to the discussion in Sect. 8.1.3 about future receivers that could access content they are requested to store according to user profiles. Consequently, future hybrid networks should incorporate three fundamental elements. These are distribution via broadcast and broadband technology together with smart receiver solutions.

These kinds of concepts have already left the status of vague ideas. Within the DVB Project the discussion about a conceivable successor system after DVB-T2 is currently in full swing. The objective is exactly to bring together the two worlds, namely the broadcasting and the broadband world, under the name "DVB-Next Generation Handheld" (DVB-NGH). Even though there might be no consensus at the moment whether the new standards should be based on T2-technology or the starting point should for example be LTE-Advanced, there is no doubt about the need to develop a system that could be used in way as described above. While the work in the DVB Project is very technical there is also conceptual work going on. European Broadcasting Union (EBU) Technical published a report on the future role of the terrestrial platform in which the idea of hybrid networks is promoted as a very promising option for the future delivery of broadcasting services [EBU11a]. In [Rei10] further technical aspects of this concept are presented.

Merging two complementary networks is certainly the major issue with regard to hybrid distribution networks for broadcasting content. However, there is another aspect that is important in this context. Terrestrial networks are usually targeting at particular reception situations. For a long time terrestrial broadcasting networks were providing services for fixed reception only. But it is no secret that most of the radio listening is done through portable devices or under mobile conditions in a car. Moreover, portable reception quite often goes hand in hand with indoor reception. This is actually the most important case. The situation is different for television where much of viewing still happens in the living room. Nevertheless, there is an increasing number of portable TV receivers including PCs and laptops with corresponding DTT cards.

Building terrestrial networks for portable and mobile reception is more expensive than for fixed reception. Significantly more money has to be spent in order to deliver indoor services. This is in particular becoming an issue as more houses or other buildings are equipped with metal-coated windows which increases the penetration loss of the electromagnetic waves carrying the radio and television signals. This directly translates into higher network costs because then higher transmitter powers or more transmitters are required. Whether this would be possible at all from an international spectrum management point of view is another important question.

On the other hand great efforts are made around the planet to provide broadband access to citizens. For example, in 2010 the EC has issued its so-called Digital Agenda [ECo10] which among many other things foresees

> to bring basic broadband to all Europeans by 2013 and seeks to ensure that, by 2020, (i) all Europeans have access to much higher Internet speeds of above 30 Mbps and (ii) 50% or more of European households subscribe to internet connections above 100 Mbps.

It is not explicated in detail if Internet access is wired or wireless. But assuming that there is a vast majority of European citizens having a fixed Internet broadband connection in their homes the question arises whether terrestrial networks, broadcasting or broadband, providing indoor coverage are still needed. Clearly, a fixed access point somewhere inside the home leads to the same problems as there are for cable and satellite reception of broadcasting services. It might be a perfect solution for fixed reception but not for portable or handheld. However, this issue constitutes another hook for the concept of hybrid distribution networks.

Portable indoor coverage could be accomplished by picking up the broadcasting signal from whichever source it might be available and then redistribute it inside a house by other technical distribution means. Conceivable sources for broadcasting signals could be a roof top antenna for terrestrial broadcasting, cable, satellite, or a broadband connection to the Internet. A straightforward solution to redistribute audio and video content could be WiFi. Another possibility would be to employ mobile service femtocells [Fem11]. Traditionally, femtocells can be considered as some kind of extension of mobile service indoor coverage when the link to a mobile base station is not strong enough to let mobile handheld devices connect directly to the base station. But in principle there is no reason why femtocells could not be further developed in order to recast broadcasting content that they get from other sources. Finally, cognitive radio could be a very good option to complement terrestrial networks in all those situations and under all those conditions where traditional broadcasting networks are either to expensive or are not able to comply with the requirements such as delivering non-linear content (see Sect. 7.2.3).

In any of these cases, collaboration between different types of networks is required. Whereas the combination of broadcasting technology and mobile service or cognitive radio networks would lie in the domain of the broadcaster and the corresponding network operator, recasting of broadcasting content via WiFi or femtocells will probably be in the hands of end users. Whatever option will be considered as a viable solution to comply with demands for portable indoor services, it is important to note that all these networks are terrestrial networks and therefore require corresponding spectrum. One possibility could be to make use of the whites spaces in the UHF bands for the complementary distribution of broadcasting content. In particular, in the case of hybrid networks consisting of broadcasting and mobile service or cognitive radio technology it would not even be necessary to allocate spectrum to services other than broadcasting at least within International Telecommunications Union (ITU) Regions 1. GE06 contains the famous Article 5.1.3 which is also known as the envelope concept. This article states that a given plan entry for broadcasting can be used for other purposes than broadcasting as long as the other usage does not claim more protection nor produces any harmful interference onto other services. This regulation is in place in the GE06 region and can be used right away.

8.2 New Strategic Direction

The switch-over from analogue to digital terrestrial broadcasting led to the Digital Dividend as a very welcome spin-off. Going digital enabled to provide the same content as in analogue times concerning variety, quality and coverage while employing just a fraction of the spectrum that was needed by analogue distribution technology. From a broadcaster's point of view unfortunately, this fact was immediately spotted by companies and organizations outside the broadcasting sector as well. Furthermore, administrations also realized that the digitization of terrestrial television broadcasting offered a once-in-a-lifetime opportunity to reorganize national spectrum usage.

With the RRC-06 coming to an end in 2006 broadcasters in ITU Region 1 were pretty enthusiastic about the potential of the GE06 Agreement in terms of promising a prosper terrestrial broadcasting future. Therefore, the decision in Europe to give the 800 MHz band to mobile services came as some kind of a shock to many broadcasters. However, as shown in the previous sections broadcasting has evolved since 2006 and there might be other opportunities now to exploit the released spectrum for broadcasting purposes. To do so new ideas or visions are needed. This may give rise to a new strategic orientation of broadcasters.

The starting point for critically reviewing the broadcasting philosophy is certainly the notion of future hybrid distribution networks and the need to provide both linear and non-linear broadcasting content. New media usage contexts will trigger new offers both in terms of programme format as well as distribution paths. Media usage will become more and more independent of space and time. While people would like to listen to or watch audio and video content, respectively, their environment will change over the day and thus the way they access the content. For example, after getting up in the morning and during breakfast people are listening to the radio on their fixed or portable receivers. They leave the house to go to work or school which would bring them to use their smartphones. They can do that on public transport while in their cars very likely they switch on the radio or connect their mobile phones or MP3 players to listen to their own recorded music. During work many people can use PCs or laptops to access broadcasting content. Back at home most likely the large flat TV screen will become the centre of attraction, but also second screens, i.e. other TV sets in sleeping rooms and kitchens are relevant.

A seamless integration of all these options under a common broadcasting delivery roof is a big challenge. Following the investigations that were undertaken on this issues by EBU Technical in 2011 [EBU11a] several conclusions can be drawn. Basically, they can be cast into three categories, i.e.

- developing a vision on the future of broadcasting;
- lobbying for broadcaster's interests; and
- engaging in research and development.

The days when the broadcasting sector ruled the media usage seem to belong to history. In order to safeguard their future broadcasters need to know what kind of services they will need to provide in the future, under what conditions this content can be produced and how this programmes will be delivered to listeners and viewers. Therefore, it is absolutely crucial that broadcasters develop a vision of their future. A roadmap into that future has to be developed indicating where broadcaster would like to be in five or ten years time and beyond. Only this way it is possible to reap the fruit of introducing digital terrestrial broadcasting thereby giving rise to a more efficient use of spectrum. Broadcasters should take care that they benefit themselves from the Digital Dividend they once created. They have to be creative when it comes to thinking about how to exploit the Digital Dividend.

Broadcasters have to be more proactive in terms of taking any chances to lobby for their interests. They have to adopt a proactive attitude in promoting the interests of the broadcasting community at national and international (EU, CEPT and ITU) levels and in all relevant domains, e.g. technical, regulatory and commercial. These lobbying activities should be based on the broadcasters' vision for the future. Obviously, this also means that it is necessary to formulate clear and concise positions on regulatory issues, in particular the spectrum policy. This refers in particular to requesting a regulatory decision from administrations that the costs of releasing the digital dividend spectrum should not be borne by the broadcasters or the viewers.

It is crucial that a serious discussion is initiated on a national strategy for the introduction of digital terrestrial broadcasting with regulators and commercial broadcasters. The roadmap into the future as part of broadcasters' vision needs to consider the introduction and progressive transition to DVB-T2 in order to cope with the demands for capacity and quality, recognizing that in some countries DVB-T and DVB-T2 may need to coexist for a longer period of time. Also, transition to digital radio should be part of the roadmap.

It is very important for broadcasters to seek to align positions with commercial broadcasters, broadcasting network operators and the industry. Only if all stakeholders come together and try to develop a common view at least on basic issues there is a chance to make digital terrestrial broadcasting a lasting success.

Apparently, there is still a lot of research on different issue to be done. One of the most important questions that need to be answered is the question about the future spectrum requirements of terrestrial broadcasting. For a long time access to spectrum was taken for granted by broadcasters. With the first round of the Digital

Dividend and the release of the 800-MHz band in Europe for mobile services this is certainly no longer true. Hence, broadcasters need to justify and provide the evidence for their spectrum requirements. Indeed, there is much truth in the words “use it or lose it” when applied to UHF spectrum. Either broadcasters make use of these frequencies or they will be allocated to other services. One of the constraints under which such evidence is to be provided is the consideration of broadcasting networks for portable and mobile reception and also where technically and commercially feasible, indoor coverage. This applies both to radio and television programmes as portable and mobile reception will be the key market for any terrestrial distribution platform in the future.

Where broadcasting networks do not provide adequate indoor coverage or where it is too expensive alternative solution have to be actively investigated by broadcasters. They need to engage in research in these areas as well as in the development of a concept of trans-coding broadcasting signals to IP-based technologies (e.g. WiFi, femtocells). Clearly, engagement means allocating money and people for these activities. Further very important studies comprise to look into the feasibility of using mobile broadband (e.g. LTE MBMS) for distributing broadcasting content. If necessary, broadcasters need to liaise with mobile industry in this process to achieve an integrated broadcast and broadband service environment. This is basically part of the more general need to engage in the development of hybrid networks and the corresponding receiver technology.

Development of new converged networks and technologies does also imply to reduce the number of relevant technological standards to a minimum. A good example where currently the trend goes into the opposite direction are the many different solutions for hybrid broadcast broadband television. There are too many put forward at the moment which is definitely counterproductive. Obviously, it will be more than one transmission standard surviving in the end since there is no hope to reach consensus on these kind of issues as history shows. But this means that broadcasters have to convince the manufacturers to develop multi-standard broadcasting receivers that incorporate all relevant standards. On the side of smartphones and tablet computers broadcasters have to encourage manufactures to integrate broadcasting receivers into mobile personal devices in order to converge from both sides into the right direction.

Finally, joining the broadcast and the broadband world in order to provide the full range of linear and non-linear broadcasting services will have a regulatory impact. Broadcasting regulation differs significantly from country to country. There are countries in which network operators are allowed to operate both broadcasting as well as mobile networks. In other countries this is not possible. However, the idea of rolling out a single network that is both a broadcasting and mobile network at the same time calls for an appropriate regulatory framework. This also applies to aspects such as net neutrality, rights to distribute the same content via all platforms, must carry rules for linear services and QoS for non-linear services.

The future broadcasting world is without doubt hybrid. However, broadcasters need to make an effort to bring this vision to life. They need to be actively involved in the process of this new broadcasting world. This certainly calls for changes within their organizations but also for changes with regards to the collaboration with other players in the market such as manufactures, network operators and regulators. The Digital Dividend is a once-in-a-life opportunity, also for broadcasters. However, they need to be bold enough to grasp it.

References

[ABA02] Australian Broadcasting Authority (ABA), *The ABA's General Approach to Digital Terrestrial Television Broadcasting Planning*, http://www.acma.gov.au/webwr/aba/tv/licence/digitaltv/planning/documents/general_approach_to_digital_tv_planning.pdf, 2002

[ACM05] Australian Communication and Media Authority (ACMA), *Digital Terrestrial Television Broadcasting Planning Handbook*, http://www.acma.gov.au/webwr/aba/newspubs/radio_tv/broadcast_planning/documents/dttb_march2005.pdf, 2005

[ACM10] Australian Communication and Media Authority (ACMA), *Five-year Spectrum Outlook 2010–2014 - The ACMA's spectrum demand analysis and indicative work programs for the next five years*, http://www.acma.gov.au/WEB/STANDARD/pc=PC_312080, 2010

[ACM11] Australian Communication and Media Authority (ACMA), http://www.acma.gov.au, 2011

[ACM11a] Australian Communication and Media Authority (ACMA), *Reallocating the 700 MHz (digital dividend) band*, http://www.acma.gov.au/WEB/STANDARD/pc=PC_312315, 2011

[ACM11b] Australian Communication and Media Authority (ACMA), *Broadcast Transmitter Data*, http://www.acma.gov.au/WEB/STANDARD..PC/pc=PC_9150, 2011

[ACM11c] Australian Communication and Media Authority (ACMA), *Clearing the Digital Dividend - Planning objectives and principles for restacking digital television channels*, http://www.acma.gov.au/WEB/STANDARD/pc=PC_312460, 2011

[ACM11d] Australian Communication and Media Authority (ACMA), *Digital Dividend: Case study comparison of two restack planning approaches*, Report TPS2011/01, http://www.acma.gov.au/WEB/STANDARD/pc=PC _312460, 2011

[ACM11e] Australian Communication and Media Authority (ACMA), *Digital Dividend: Comparison of the costs of implementing two restack planning approaches*, Report TPS2011/02, http://www.acma.gov.au/WEB/STANDARD/pc=PC_312460, 2011

[ACM11f] Australian Communication and Media Authority (ACMA), *Clearing the Digital Dividend - Decisions on planning principles for restacking digital television channels*, http://www.acma.gov.au/WEB/STANDARD/pc=PC_312460, 2011

[APT09] Asia-Pacific Telecommunity, *APT Report on UHF band usage and considerations for realizing the UHF Digital Dividend*, APT/AWF/REP-11, http://www.apt.int/AWF-RECREP, 2009

[APT10] Asia-Pacific Telecommunity, *APT Report on harmonized frequency arrangements for the band 698 - 806 MHz*, APT/AWF/REP-14, http://www.apt.int/AWF-RECREP, 2010

[APT11] Asia-Pacific Telecommunity, http://www.aptsec.org/, 2011

R. Beutler, *The Digital Dividend of Terrestrial Broadcasting*,
DOI 10.1007/978-1-4614-1569-5, © Springer Science+Business Media, LLC 2012

[ARD11] ARD, *ARD Tagesschau - Die Nachrichten der ARD*, http://www.tagesschau.de, 2011

[ARI01] Association of Radio Industries and Businesses (ARIB), *Transmission System For Digital Terrestrial Television Broadcasting*, ARIB Standard B31, http://www.arib.or.jp/english/html/overview/doc/6-STD-B31v1_6-E2.pdf, 2001

[ATS11] Advanced Television System Committee, *A/53: ATSC Digital Television Standard* http://www.atsc.org /cms/index.php/standards/published-standards, 2011

[ATS11a] Advanced Television System Committee, *A/53: ATSC Digital Television Standard, Part 2 - RF/Transmission System Characteristics,* http://www.atsc.org/cms/standards/a53/a_53-Part-2-2007.pdf, 2011

[BBC11] BBC iPlayer, http://www.bbc.co.uk/iplayer, 2011

[Bec11] Becker, K-A., private communication, Harman/Becker Automotive Systems GmbH, 2011

[Beu95] Beutler, R., *Optimization of Digital Single Frequency Networks*, Frequenz **49** (1995) 245

[Beu98] Beutler, R., *Digital Single Frequency Networks : Improving Optimization Strategies by Parallel Computing*, Frequenz **52** (1998) 90

[Beu04] Beutler, R., et. al., *Ergebnisse des 1. Teils der Regionalen Planungskonferenz (RRC-04) zur Revision des Stockholmer Abkommens*, FKT, **11** (2004) 551

[Beu04a] Beutler, R., *Frequency Assignment and Network Planning for Digital Terrestrial Broadcasting Systems*, Springer, NewYork, 2004

[Beu07] Beutler, R., *The impact of dedicating a sub-band in UHF to mobile communication services on the GE-06 Plan*, contribution to the 6th meeting of ECC-TG4 held in Bologna, Italy, http://www.ero.dk, 2007

[Beu08] Beutler, R., *Digital Terrestrial Broadcasting Networks,* Springer, NewYork, 2008

[Bru05] Brugger, R., Meyer, K., *RRC-06 - Technical Basis and Planning Configurations for T-DAB and DVB-T*, EBU Technical Review, **302** (2005), Geneva, Switzerland

[CEN11] European Committee for Electrotechnical Standardization, http://www.cenelec.eu, 2011

[CEP95] CEPT, *Final Acts - CEPT T-DAB Planning Meeting, Wiesbaden, 1995*, European Conference of Postal and Telecommunications Administrations, Wiesbaden, Germany, 1995

[CEP96] CEPT, *Final Acts of the T-DAB Planning Meeing (2), Bonn, 7-8 November 1996*, European Conference of Postal and Telecommunications Administrations, Bonn, Germany, 1996

[CEP97] CEPT, *The Chester 1997 Multilateral Coordination Agreement relating to Technical Criteria, Coordination Principles and Procedures for the Introduction of Terrestrial Digital Video Broadcasting (DVB-T)*, European Conference of Postal and Telecommunications Administrations, Chester, United Kingdom, 1997

[CEP02] CEPT, *Final Acts of the T-DAB Planning Meeing (4), Maastricht, 2002*, European Conference of Postal and Telecommunications Administrations, Maastricht, The Netherlands, 2002

[CEP07a] Conference Européenne des Administration des Postes et des Télécommunications, CEPT Report 21, *Compatibility issues between "cellular / low power transmitter networks" and "larger coverage / high power / tower" type of networks,* http://www.erodocdb.dk/Docs/doc98/official/pdf/CEPTREP021.PDF, 2007

[CEP07b] Conference Européenne des Administration des Postes et des Télécommunications, CEPT Report 22, *Technical Feasibility of Harmonising a Sub-band of Bands IV and V for Fixed/Mobile Applications (including uplinks), minimising the Impact on GE06*, http://www.erodocdb.dk/Docs/doc98/official/pdf/CEPTREP022.PDF, 2007

[CEP07c] Conference Européenne des Administration des Postes et des Télécommunications, CEPT Report 23, *Technical Options for the Use of a Harmonised Sub-Band in the Band 470 - 862 MHz for Fixed/Mobile Application (including Uplinks)*, http://www.erodocdb.dk/Docs/doc98/official/pdf/CEPTREP023.PDF, 2007

[CEP07d] CEPT, *Final Acts of the CEPT T-AB Planning Meeting, Constanta, 2007 (WI95revCO07)*, European Conference of Postal and Telecommunications Administrations, Constanţa, Romania, 2007

[CEP08a] Conference Européenne des Administration des Postes et des Télécommunications, CEPT Report 24, *A preliminary assessment of the feasibility of fitting new/future applications/services into non-harmonised spectrum of the digital dividend (namely the so-called "white spaces" between allotments),* http://www.erodocdb.dk/Docs/doc98/official/pdf/CEPTREP024.PDF, 2008

[CEP08b] Conference Européenne des Administration des Postes et des Télécommunications, CEPT Report 25, *Technical Roadmap proposing relevant technical options and scenarios to optimise the Digital Dividend, including steps required during the transition period before analogue switch-off,* http://www.erodocdb.dk/Docs/doc98/official/pdf/CEPTREP025.PDF, 2008

[CEP08c] Conference Européenne des Administration des Postes et des Télécommunications, CEPT Report 29, *Technical considerations regarding harmonisation options for the digital dividend in the European Union,* http://www.erodocdb.dk/Docs/doc98/official/pdf/CEPTREP029.PDF, 2008

[CEP09a] Conference Européenne des Administration des Postes et des Télécommunications, CEPT Report 30, *The identification of common and minimal (least restrictive) technical conditions for 790 - 862 MHz for the digital dividend in the European Union,* http://www.erodocdb.dk/Docs/doc98/official/pdf/CEPTREP030.PDF, 2009

[CEP09b] Conference Européenne des Administration des Postes et des Télécommunications, CEPT Report 31, *Frequency (channelling) arrangements for the 790-862 MHz band,* http://www.erodocdb.dk/Docs/doc98/official/pdf/CEPTREP031.PDF, 2009

[CEP09c] Conference Européenne des Administration des Postes et des Télécommunications, CEPT Report 32, *Recommendation on the best approach to ensure the continuation of existing Program Making and Special Events (PMSE) services operating in the UHF (470-862 MHz), including the assessment of the advantage of an EU-level approach,* http://www.erodocdb.dk/Docs/doc98/official/pdf/CEPTREP032.PDF, 2009

[CEP10] Conference Européenne des Administration des Postes et des Télécommunications, http://www.cept.org, 2010

[CER10] European Organisation of Nuclear Research, http://www.cern.ch, 2010

[CIS11] CISCO, *Cisco Visual Networking Index: Global Mobile Data, Traffic Forecast Update, 2010–2015*, http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.pdf, 2011

[CIT10] Comisión Interamericana de Telecomunicaciones, http://www.citel.oas.org, 2010

[Cog11] CogEU, *COGnitive radio systems for efficient sharing of TV white spaces in EUropean context*, Specific Target Research Project (STREP) supported by the 7th Framework Programme of the European Commission, http://www.ict-cogeu.eu, 2011

[Com05a] Commission of the European Communities, *Communication from the Commission to the Council and European Parliament: A forward-looking rdaio spectrum policy for the European Union; Second Annular Report*, COM (2005) 411, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2005: 0411:FIN:EN:PDF, 2005

[Com05b] Commission of the European Communities, *Communication from the Commission to the Council, the European Parliament and the European Economic and Social Committee and the Committee of the Regions: A market-based approach to spetrum management in the European Union*, COM (2005) 400, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2005: 0400:FIN:EN:PDF, 2005

[Com07] Commission of the European Communities, *Mandate to CEPT on Technical Considerations Regarding Harmonisation Options for the Digital Dividend*, http://ec.europa.eu/information_society/policy/ecomm/radio_spectrum/_document_storage/mandates/mandate_ dig_div.pdf, 2007

[Com08] Commission of the European Communities, *Second mandate to CEPT on technical considerations regarding harmonisation options for the digital dividend in the European Union*, http://ec.europa.eu/information_society/policy/ecomm/radio_spectrum/_document_storage/rsc/rsc23_public_docs/rscom08-06.pdf, 2008

[Com10] Commission of the European Communities, *Commission Decision of 6 May 2010 on harmonised technical conditions of use in the 790-862 MHz frequency band for terrestrial systems capable of providing electronic communications services in the European Union,* Official Journal of the European Union, **L 177** (2010) 95, http://www.erodocdb.dk/Docs/doc98/official/pdf/2010267EU.PDF

[Com11] Commission of the European Communities, CORDIS, *Seventh Framework Programme (FP7)*, http://cordis.europa.eu/fp7/home_en.html, 2011

[DeA09] DTV Delay Act, http://www.gpo.gov/fdsys/pkg/BILLS-111s352enr/pdf/BILLS-111s352enr.pdf, 2009

[Dig10] Digital Terrestrial Television Action Group - DigiTAG, http://www.digitag.org, 2010

[DRM07] Deutsches DRM-Forum, *Broadcasters' User Manual*, www.deutsches-drm-forum.de/Broadcast_ManualV2.pdf, 2007

[DRM11] Digital Radio Mondiale (DRM), http://www.drm.org, 2011

[DTA05] Digital Television Transition and Public Safety Act of US Congress, http://www.ntia.doc.gov/otiahome/dtv/index.html, 2005

[DTr11] Wikipedia, *Digital television transition in the United States,* http://en.wikipedia.org/wiki/DTV_transition_in_the_ United_States, 2011

[DTV11] The Digital TV Transition, http://www.dtv.gov, 2011

[DTV11a] The Digital TV Transition, http://www.dtv.gov/buyconverter.html, 2011

[DVB10] Digital Video Broadcast Project (DVB), http://www.dvb.org/about_dvb/dvb_worldwide/united_kingdom/, 2010

[DVB11] Digital Video Broadcast Project (DVB), http://www.dvb.org, 2011

[DVB11a] Digital Video Broadcast Project (DVB), http://www.dvb.org/technology/dvbt2/, 2011

[DVB11b] Digital Video Broadcast Project (DVB), http://www.dvb.org/technology/dvb-ngh/, 2011

[DVB11c] Digital Video Broadcast Project (DVB), *Digital Video Broadcasting (DVB); Frame Compatible Plano-Stereoscopic 3DTV (DVB-3DTV)*, DVB Document A154, http://www.dvb.org/technology/standards/a154_DVB-3DTV_Spec.pdf, 2011

[EBU98] European Broadcasting Union, *Technical Bases for T-DAB Services Network Planning and Compatibility with Existing Broadcasting Services*, EBU BPN Doc. 003-Rev.1, Geneva, Switzerland, 1998

[EBU01] European Broadcasting Union, *Terrestrial Digital Television Planning and Implementation Considerations - Edition 3*, EBU BPN Doc. 005, Geneva, 2001

[EBU02] European Broadcasting Union, *Planning Criteria for Mobile DVB-T*, EBU BPN Doc. 047, Geneva, Switzerland, 2002

[EBU03] European Broadcasting Union, *Impact on Coverage of Inter-Symbol Interference and FFT Window Positioning in OFDM Receivers*, EBU BPN Doc. 059, Geneva, Switzerland, 2003

[EBU05] European Broadcasting Union, *Guide on SFN Frequency Planning and Network Implementation with regard to T-DAB and DVB-T*, EBU BPN Doc. 066, Geneva, Switzerland, 2005

[EBU07] European Broadcasting Union, *Broadcasting Aspects Relating to the Procedures fo Coordination and Plan Conformity Agreement in the GE06 Agreement*, EBU BPN Doc. 083, Geneva, Switzerland, 2007

[EBU10] European Broadcasting Union, *3D Briefing Document for Senior Broadcast Management*, Technical Report 10, http://tech.ebu.ch/docs/techreports/tr010.pdf, 2010

[EBU11] European Broadcasting Union, http://www.ebu.ch, 2011

[EBU11a] European Broadcasting Union, *The Future of Terrestrial Broadcasting*, Technical Report 013, Geneva, Switzerland, 2011

[ECC09] Electronic Communications Committee (ECC), *Measurements on the Performance of DVB-T Receivers in the Presence of Interference from Mobile Service (Especially from UMTS)*, ECC REPORT 138, http://www.erodocdb.dk/Docs/doc98/official/pdf/ECCREP138.PDF, 2009

[ECC10] Electronic Communications Committee (ECC), *Rearrangement Activities for Broadcasting Services in order to free the Sub-Band 790 - 862 MHz*, ECC REPORT 142, http://www.erodocdb.dk/Docs/doc98/official/pdf/ECCREP142.PDF, 2010

[ECC11] Electronic Communications Committee (ECC), *Technical and Operational Requirements for the Possible Operation of Cogniteive Radio Systems in the 'White Spaces' of the Frequency Band 470-790 MHz*, ECC REPORT 159, http://www.erodocdb.dk/Docs/doc98/official/pdf/ECCREP159.PDF, 2011

[ECo07] European Commission, *Mandate to CEPT on Technical Considerations Regarding Harmonisation Options for the Digital Dividend*, DG INFOSO/B4, Brussels, 2007

[ECo07a] European Commission, *Communication from the Commission to the Council, the European Parliament and the European Economic and Socail Committee and the Committee of the Regions - Reaping the Full Benefits of the Digital Dividend in Europe: A Common Approach to the Use of the Spectrum Released by the Digital Switchover*, COM(2007) 700, Brussels, 2007

[ECo10] European Commission, *Communication from the Commission to the European Palrliament, the Council, the European Economic and Social Committee and the Committee of the Regions: A Digital Agenda for Europe*, COM(2010) 245, Brussels, http://ec.europa.eu/information_society/digital-agenda/index_en.htm, 2010

[ECO10] European Communications Office, http://www.ero.dk, 2010

[ECO10a] European Communications Office, *European Common Allocation Online Database*, http://apps.ero.dk/eca/, 2010

[ETS97a] European Telecommunications Standards Institute ETS 300 401, *Radio Broadcasting Systems; Digital Audio Broadcasting (DAB) to mobile, portable and fixed receivers*, 1997

[ETS97b] European Telecommunications Standards Institute ETS 300 744, *Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for digital terrestrial television (DVB-T)*, 1997

[ETS04a] European Telecommunications Standards Institute EN 302 304 V1.1.1, *Digital Video Broadcasting (DVB); Transmission system for handheld terminals (DVB-H)*, 2004

[ETS04b] European Telecommunications Standards Institute EN 301 192 V1.4.1, *Digital Video Broadcasting (DVB); DVB specification for data broadcasting*, 2004

[ETS05] European Telecommunications Standards Institute ES 201 980 V2.2.1, *Digital Radio Mondiale; System Specification*, 2005

[ETS07] European Telecommunications Standards Institute TS 102 563 V1.1.1, *Digital Audio Broadcasting; Transport of Advanced Audio Coding (AAC) audio*, 2007

[ETS09] European Telecommunications Standards Institute ES 201 980 V3.1.1, *Digital Radio Mondiale (DRM); System Specification*, 2009

[ETS09a] European Telecommunications Standards Institute EN 302 755 V1.1.1, *Frame structure channel coding and modulation for a second generation digital terrestrial television broadcasting system (DVB-T2)*, 2009

[ETS10] European Telecommunications Standards Institute ETSI TS 102 796 V1.1.1, *Hybrid Broadcast Broadband TV*, 2010

[ETS11] European Telecommunications Standards Institute, http://www.etsi.org, 2011

[EUR96] Eureka 147 Projekt, *Digital Audio Broadcasting*, 1996 [available from von Dr. Thomas Lauterbach c/o Robert Bosch GmbH, Abt. FV/SLM, Robert-Bosch-Straße 200, 31139 Hildesheim]

[Fac11] Facebook, www.facebook.com, 2011

[Far06] Faria, G., et. al., *DVB-H: Digital Broadcast Services to Handheld Devices*, Proceedings of the IEEE, **94** (2006) 194

[FCC02] Federal Communications Commission, *FCC Introduces Phase-In Plan For DTV Tuners*, http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-225221A1.doc, 2002

[FCC04] Federal Communications Commission, *About Lower 700 MHz*, http://wireless.fcc.gov/services/index.htm?job=about &id= lower700, 2004

[FCC09] Federal Communications Commission, *Code of Federal Regulations - Titel 47, Parts 1 and 27*, http://www.gpo.gov/fdsys/pkg/CFR-2009-title47-vol2/pdf/CFR-2009-title47-vol2-part27.pdf, 2008

[FCC11] Federal Communications Commission, *Auction 73 - The 700 MHz Band*, http://wireless.fcc.gov/auctions/default.htm?job= auction_factsheet&id=73, 2011

[FCC11a] Federal Communications Commission, *Revised 700 MHz Band Plan for Commercial Services*, http://wireless.fcc.gov/auctions/data/bandplans/700MHz Band-Plan.pdf, 2011

[Fem11] FemtoForum, http//:www.femtoforum.org, 2011

[Gol05] Mark L. Goldstein, *The Role of Technology in Achieving a Hard Deadline for the DTV Transition*, hearing before the Subcommittee on Telecommunications and the Internet, Committee on Energy and Commerce, U.S. House of Representatives, 109th Congress, 1st Session, February 17, 2005, Serial No. 109-9, Washington, D.C.: U.S. Government Printing Office, 2005

[Hbb11] Hybrid Broadcast Broadband Television (HbbTV), http://www.hbbtv.org, 2011

[HDR11] HD Digital Radio, http://www.hdradio.com, 2011

[iBi11] iBiquity Digital Cooperation, http://www.ibiquitiy.com, 2011

[IMT00] International Mobile Telecommunications 2000, http://www.itu.int/home/imt.html, 2000

[ISD11] Integrated Services Digital Broadcasting-Terrestrial (ISDB-T), http://www.dibeg.org/, 2011

[ISD11a] Integrated Services Digital Broadcasting-Terrestrial (ISDB-T), http://www.dibeg.org/techp/aribstd/harmonization.htm, 2011

[ISO93] International Organisation for Standardization, ISO/IEC 11172-1:1993, *Information technology – Coding of moving pictures and associated audio for digital storage media at up to about 1,5 Mbit/s – Part 3: Audio*, 1993

[ISO05a] International Organisation for Standardization, ISO/IEC 14496-3:2005, *Information technology – Coding of audio-visual objects – Part 3: Audio*, 2005

[ISO05b] International Organisation for Standardization, ISO/IEC 14496-10:2005, *Information technology - Coding of audio-visual objects – Part 10: Advanced Video Coding*, 2005

[ITU61] International Telecommunications Union, *Final Acts of the European VHF/UHF Broadcasting Conference*, Stockholm, Sweden, http://www.itu.int/ITU-R/terrestrial/broadcast/plans/st61/index.html, 1961

[ITU89] International Telecommunications Union, *Final Acts of the Regional Administrative Radio Conference for the Planning of VHF/UHF Television Broadcasting in the African Broadcasting Area and Neighbouring Countries*, Geneva, Switzerland, http://www.itu.int/ITU-R/terrestrial/broadcast/plans/ge89/index.html, 1989

[ITU01] International Telecommunications Union, ITU-R Recommendation P.1546, *Method for point-to-area predictions for terrestrial services in the frequency range 30 to 3 000 MHz*, http://www.itu.int/rec/R-REC-P.1546/en, Geneva, Switzerland, 2001

[ITU03] International Telecommunications Union, *World Radiocommunication Conference 2003 (WRC-03)*, www.itu.int/ITU-R/go/WRC/en/, 2003

[ITU04] International Telecommunications Union, *Regional Radiocommunication Conference (RRC-04)*, Geneva, Switzerland, http://www.itu.int/ITU-R/conferences/rrc/rrc-04/index.asp, 2004

[ITU06] International Telecommunications Union, *Final Acts of the Regional Radiocommunication Conference for planning of the digital terrestrial broadcasting service in parts of Regions 1 and 3, in the frequency bands 174-230 MHz and 470-862 MHz (RRC-06)*, Geneva, Switzerland, http://www.itu.int/ITU-R/terrestrial/broadcast/plans/ge06/index.html, 2006

[ITU06a] International Telecommunications Union, Recommendation ITU-R M.1768, *Methodology for calculation of spectrum requirements for the future development of the terrestrial component of IMT-2000 and systems beyond IMT-2000*, http://www.itu.int/rec/R-REC-M.1768-0-200603-I/en, Geneva, Switzerland, 2006

[ITU06b] International Telecommunications Union, ITU-R Report M.2078, *Estimated spectrum bandwidth requirements for the future development of IMT-2000 and IMT-Advanced*, http://www.itu.int/pub/R-REP-M.2078-2006, Geneva, Switzerland, 2006

[ITU07] International Telecommunications Union, *World Radiocommunication Conference 2007 (WRC-07)*, http://www.itu.int/ITU-R/go/WRC/en/, 2007

[ITU07a] International Telecommunications Union, *Final Acts WRC-07*, http://www.itu.int/publ/R-ACT-WRC.8-2007/en, 2007

[ITU07b] International Telecommunications Union, www.itu.int/ITU-R/terrestrial/broadcast/plans/ge06/index.html, 2007

[ITU07c] International Telecommunications Union, *European Common Proposals for the Work of the Conference - Part 4 Agenda Item 1.4*, http://www.itu.int/md/R07-WRC07-C-0010/en, 2007

[ITU08] International Telecommunications Union, *Radio Regulations*, http://www.itu.int/pub/R-REG-RR/en, 2008

[ITU09] International Telecommunications Union, ITU-R Recommendation BT.1306-4, *Error-correction, data framing, modulation and emission methods for digital terrestrial television broadcasting*, http://www.itu.int/rec/R-REC-BT.1306/en, Geneva, Switzerland, 2009

[ITU09a] International Telecommunications Union, *Detailed results of field study of compatibility between DVB-T and UMTS*, European Broadcasting Union / Free TV Australia Ltd., ITU-R Document JTG5-6/84-E, 2009

[ITU09b] International Telecommunications Union, ITU-R Recommendation BT. 1368-8, *Planning Criteria for Digital Terrestrial Television Services in the VHF/UHF Bands*, Geneva, Switzerland, 2009

[ITU10] International Telecommunications Union, http://www.itu.int, 2010

[ITU10a] International Telecommunications Union, *Joint Task Group 5-6 - Studies on the use of the band 790-862 MHz by mobile applications and by other services,* http://www.itu.int/ITU-R/index.asp?category=study-groups&rlink=rjtg5-6&lang=en, 2010

[ITU10b] International Telecommunications Union, *Joint Task Group 5-6: Report on the fifth and final meeting of Joint Task Group 5-6*, JTG5-6 document 180, Annex 2, Attachment 2, http://www.itu.int/md/R07-JTG5.6-C/en, 2010

[ITU11] International Telecommunications Union, http://www.itu.int/net/about/structure.aspx, 2011

[Kor05] Kornfeld, M, Reimers, U., *DVB-H - The emerging standard for mobile data communication*, EBU Technical Review, **301** (2005), Geneva, Switzerland

[Kru08] Kruger, L. G., *CRS Report fo Congress: Digital Television - An Overview*, Congressional Research Service, Order Code RL31260, http://www.usembassy.it/pdf/other/RL31260.pdf, 2008

[LTE08] Long Term Evolution (LTE), www.3gpp.org/Highlights/LTE/LTE.htm, 2008

[Mel06] Meltzer, S., Moser, G., *HE ACC v2 - audio coding for today's digital media world*, EBU Technical Review, **305** (2006), Geneva, Switzerland

[Mit00] Mitola, J., *Cognitive Radio - An Integrated Agent Architecture for Software Defined Radio*, Dissertation, Royal Institute of Technology (KTH), Kista, Sweden, http://web.it.kth.se/˜maguire/jmitola/Mitola_Dissertation8_Integrated.pdf, 2000

[Mot07] Motorola, *Long Term Evolution (LTE): Overview of LTE Air-Interface - Technical White Paper*, http://business.motorola.com/experiencelte/pdf/LTEAirInterfaceWhitePaper.pdf, 2007

[MyS11] MySpace, www.myspace.com, 2011

[Nak09] Nakamura, T., *Proposal for Candidate Radio Interface Technologies for IMT-Advanced Based on LTE Release 10 and Beyond (LTE-Advanced)*, ITU-R WP5D Workshop on IMT-Advanced, 15 October 2009, http://www.3gpp.org/IMG/pdf/2009_10_3gpp_IMT.pdf, 2009

[NHK11] NHK, *8K Television System "Super-Hi Vision" is the TV Technology of our Dreams*, http://www.nhk.or.jp/digital/en/super_hi/index.html, 2011

[NRS11] National Radio Systems Committee (NRSC), *NRSC-5 Standard and Reference Documents*, http://www.nrscstandards.org/SG/NRSC-5-B.asp, 2011

[Ofc11] Ofcom, *Digital Dividend Review*, http://stakeholders.ofcom.org.uk/spectrum/project-pages/ddr/, 2011

[Ole06] O'Leary, T., Puigrefagut, E., Sami, W., *GE06 — Overview of the Second Session (RRC-06) and the Main Features for Broadcasters*, EBU Technical Review, **308** (2006), Geneva, Switzerland

[Pic11] Picasa, www.picasa.com, 2011

[Pro89] Proakis, J. G., *Digital Communications*, McGraw-Hill, New York, USA, 1989

[Pui04] Puigrefagut, E., O'Leary, T., *RRC-04/06 - An Overview of the First Session (RRC-04)*, EBU Technical Review, **300** (2004), Geneva, Switzerland

[QoS11] QoSMOS, *Quality of Service and MObility driven cognitive radio Systems*, Framework 7 Integrating Project supported by the European Commission, http://www.ict-qosmos.eu/home.html, 2011

[Rad11] RadioDNS, www.radiodns.org, 2011

[Ree60] Reed, I., Solomon, I., Solomon, G., *Polynomial codes over certain finite fields*, Journal of the Society for Industrial and Applied Mathematics. [SIAM J.], **8** (1960) 300

[Rei01] Reimers, U., *Digital Video Broadcasting - The International Standard for Digital Television*, Springer-Verlag, Berlin, Germany, 2001

[Rei10] Reimers, U., *The Future of Digital Broadcasting*, http://www.isce2010.org/20100609_The Future of Digital Broadcast.pdf, 2010

[RSD02] Radio Spectrum Decision, *Decision No 676/2002/EC of the European Parliament and of the Council of 7 March 2002 on a regulatory framework for radio spectrum policy in the European Community (Radio Spectrum Decision)*, Official Journal of the European Communities, (2002) L108

[Sam11] Sami, W., *How can mobile and broadcasting networks use adjacent bands?*, EBU Technical Review 2011-Q1, 2011

[StA99] Standards Australia, *Digital television - Terrestrial broadcasting - Characteristics of digital terrestrial television transmissions, AS4599-1999*, http://infostore.saiglobal.com/store/Details.aspx?ProductID =316598, 1999

[SWR11] Südwestrundfunk, *DasDing - Live, Laut, Lässig*, http://www.dasding.de, 2011

[Tel96] Telecommunications Act, *Telecommunications Act of 1996,* http://www.fcc.gov/telecom.html, 1996

[Tel11] Telecom Asia, *India to auction 700MHz spectrum in 2012*, http://www.telecomasia.net/content/india-auction-700mhz-spectrum-2012, 2011

[TVC05] TV Converter Box Coupon Program, http://www.ntia.doc.gov/dtvcoupon/index.html, 2005

[Twi11] Twitter, www.twitter.com, 2011

[UPU10] Universal Post Union, http://www.upu.int, 2010

[WIF11] Wireless Innovation Forum, *What is Software Defined Radio?*, http://www.wirelessinnovation.org/page/What_is_SDR, 2011

[Woo06] Wood, D., *High Definition for Europe - An progressice approach*, EBU Technical Review, **300** (2006), Geneva, Switzerland

[Wor11] WorldDMB - Digital Multimedia Broadcasting, http://www.worlddab.org, 2011

[You11] YouTube, www.youtube.com, 2011

[YoV11] YouView, www.youview.com, 2011

[3GP11] The 3rd Generation Partnership Project (3GPP), http://www.3gpp.org, 2011

[3GP11a] The 3rd Generation Partnership Project (3GPP), *3GPP specifications*, http://www.3gpp.org/specifications, 2011

[3GP11b] The 3rd Generation Partnership Project (3GPP), *LTE*, http://www.3gpp.org/LTE, 2011

[3GP11c] The 3rd Generation Partnership Project (3GPP), *LTE-Advanced*, http://www.3gpp.org/LTE-Advanced, 2011

The list of references given here has to be considered as a subjective subset of those documents that might be relevant. It is by no means exhaustive. Rather, it reflects the author's knowledge and usage of literature. It might give first indications and hints for further reading. Additional references can be found with the help of any Internet search engine without problems.

Some of the references given point to documents that are not officially available. However, in most cases these documents are not classified and can be obtained by addressing the organisations or the authors directly.

Index

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