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Network Aspects for DVB-H and T-DMB

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1. INTRODUCTION

There is a strong demand for multimedia services or applications. The demand originated within the mobile community combining the broadcasting service and the mobile service, but multimedia applications can also be foreseen as an advanced broadcasting service. Operators need to decide how they will deliver mobile TV and audio services to different types of customers in different situations (pedestrians, in car, in house, etc.). Among different technologies DVB-H and T-DMB are well-proofed techniques for mobile multimedia services in terms of coverage provided by infrastructure and their relative costs.

Two systems have been developed in Europe; DVB-H, which is a mobile broadcast system derived from DVB-T and T-DMB, which is a multimedia enabled version of T-DAB. They are designed for handheld reception; in particular, DVB-H has been optimised to be included in small devices such as mobile phones by using time slicing for less power consumption and an additional forward error correction (FEC) to provide more robust signals.

These multimedia-broadcasting technologies may use the same frequency spectrum as DVB-T/T-DAB, however due to their different applications, they are likely to require dedicated networks. This report discusses various aspects in relation to the deployment of multimedia services via DVB-H and T-DMB networks. The EBU document Tech 3317 'Planning parameters for handheld reception' covers planning parameters for DVB-H and T-DMB systems in Bands III, IV, V and the 1.5 GHz band.

2. GENERAL

Mobile media is a broadcast application using a common content broadcast by several transmitters to all users within the coverage area. The new features of DVB-H were introduced taking into consideration three principal issues in mobile use: mobility, varying signal reception conditions and limited receiver-battery time, whereas T-DMB added multimedia aspects to T-DAB.

Broadcasting a single, common signal for many users is efficient by using a few transmission sites to serve the maximum number of users within a defined area. Therefore, network operators will be looking for a broadcast model in terms of site deployment in order to keep the overall costs down.

Consequently, deployment of mobile media networks, though sharing features of both cellular radio and broadcast networks, is expected to differ from either, especially in a diversified mobile TV market.

Multimedia content can be broadcast to users through DVB-H or T-DMB terrestrial networks covering parts of, or a complete country. In some cases, where the complete coverage cannot be obtained in this way, using the concept of WAPECS[1], the multimedia content may be carried through a different type of radiocommunication infrastructure more or less customised for broadcasting and possibly combining multi-access network structures facilitated by multi-technology access terminals.

One of the most important constraints for handheld reception is the need of a high field strength compared to fixed roof top antenna reception[2]. In order to provide this field strength, high power transmitters or a great number of lower power transmitters are required. Even if an investment is foreseen for densely populated areas, where a large number of potential viewers exists, over scarcely-populated areas a large number of transmitters is still needed and an investment can be high and risky. As a result there might be no wide area terrestrial networks[3] built for this purpose. In the case where the user may move outside the DVB-H coverage area, a tight broadcast/cellular or broadcast/satellite synergy could enable the continuity of the multimedia service by routing it exclusively via the alternative network.

A great number of programmemes can be broadcast by a DVB-H or a T-DMB infrastructure suited for serving a densely populated area, although the scarcely-populated areas cannot justify investments in infrastructure, and transmission of media over radiotelephone networks (as GSM/GPRS or UMT/IMT2000) may be appropriate to provide content at the demand of viewers. Several hybrid or multi-access infrastructures associated to receivers in multiple-standard broadcast modes (TV, IPTV over Wi-Fi, streaming TV over HSDPA) are now well studied[4].

- DVB-H or T-DMB associated with mobile service infrastructure as GSM/UMTS (currently UMTS is delivering TV and can be complemented by DVB-H or T-DMB in densely populated parts of a country)
- DVB-H or T-DMB associated with satellite service. (Projects are under study in L-Band with hybrid S-DAB network using E-SDR ETSI standard[5] and in the 2 GHz SMS Band using the DVB-SH ETSI standard).

For other media, there are constraints that may influence the decision about the choice of infrastructure and standards and which are covered by the licence conditions such as regulations about:

- programmes and contents to be broadcasted, including language, local programmes…
- service area (size) to be served with a minimum of quality,
- ERP limits and RF hazards,
- interference constraints (national and international), frequency (Doppler shift, guard interval).

In addition, practical issues such as site availability, bit rate requirement, service area characteristics (morphology) need to be considered.

Because cellular networks are usually unicast (one to one) they need to support many unique communications paths and are, in a developed network, constrained by the capacity of individual

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[1] see Radio Spectrum Policy Group Opinion on Wireless Access Platforms for Electronic Communication Services RSPG05-102 final RSPG Opinion #3 and EC Commission Recommendation on the conditions attached to the rights of use for radio frequencies under the regulatory framework for electronic communications in the context of the Wireless Access Policy for Electronic Communications (WAPECS).

2 see BPN 067: Broadcasting to Handhelds: Systems and services considerations

[3] Teracom presentation to Forecast 2005

[4] Benefits and limitations of hybrid (broadcast/mobile) networks - Christoph Heuck – IST2005 COST 273

[5] TR 102 525: Satellite Earth Stations and Systems (SES); Satellite Digital Radio (SDR) service; Functionalities, architecture and technologies

cells. The number of users that can be supported by a cell is a function of the number of the available channels in any area. Given a limit on channels and the number of users in a cell, to permit channel reuse - to increase network capacity - the coverage of cell sites is often reduced, in some cases to a few tens of metres. The consequence of reduced cell size is that a large number of cells are required to serve an area.

Whereas high cell count equates to high network cost it also provides, apart from capacity, good coverage. The cell site distribution typically maps to the population density and hence building density and as a consequence good signal levels are available in the most difficult in-building reception environments.

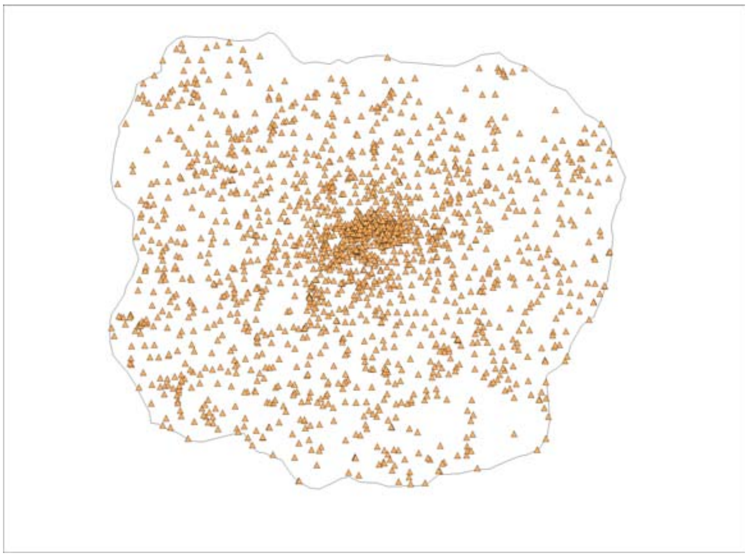

Figure 2.1: Typical cell site distribution (diameter around 50 km)

In comparison to cellular networks, broadcast networks deploy very few transmitter sites. Moreover, usually only a little part of these sites provide the bulk of the country coverage, whereas the majority of the sites serve as repeaters to handle interference effects or cover topographically hidden regions. Those transmitters, which are introduced to solve delayed image (ghosting) problems on the analogue system, would not necessarily be required in a digital network.

As an illustration Figure 2.1 and 2.2 compare site distributions in typical cellular and broadcasting networks planned to cover the same area.

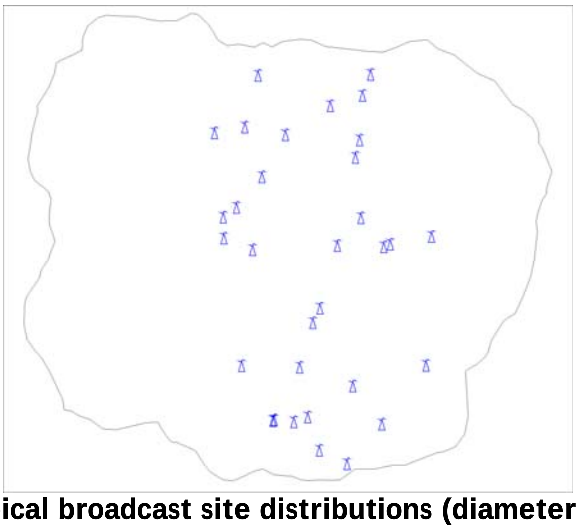

Figure 2.2: Typical broadcast site distributions (diameter around 50 km)

Hence at first sight a broadcast model appears to satisfy the requirement for reducing network costs – deployment costs being associated with sites.

However, broadcast networks are often designed to provide a service to directional aerials mounted on the roof, above the local clutter. As such the path loss in a broadcast network, depending on the receive environment, will be some 10dB to 50dB lower than that to a handheld device.

In addition to this loss it is anticipated that, at least at UHF, the receive-antenna in a handheld device will be inefficient, i.e., will have reduced gain. The poor antenna performance offsets any advantage arising from the use of more a robust modulation scheme. Antenna system loss, depending on frequency, is between -19dB (470 MHz) and -12dB (880 MHz) relative to fixed reception, and the benefit of a more robust modulation scheme is between 11dB (QPSK1/2) and 5dB (16QAM1/2) with respect to 64QAM2/3 used for fixed reception.

3. NETWORK TOPOLOGIES

As mobile media networks do not have the capacity constraints of cellular networks, the aim of a network planner must be to cover as many users as possible with each site. However, regulatory constraints associated with licence conditions such as service area (size), ERP limits, interference constraints (national and international), frequency (Doppler shift, guard interval) will influence the network topology as well as practical issues such as site availability, RF Hazards, bit rate requirement, service area characteristics (morphology).

Traditional broadcast networks consist of complex mixtures of transmitters, transposers and gap-fillers operating at powers varying from hundreds of kilowatts to only a few watts. In spite of complex structures, such networks can be assigned a certain hierarchy according to the sites' transmission power, and in general three categories can be distinguished:

- high-power network;
- medium-power network;
- low-power network.

Though three basic approaches to network deployment can be considered, it is likely that any network implementation is an amalgam of two or possibly all three of these approaches.

In general, it seems unlikely that national coverage can be achieved based on the use of an existing broadcast infrastructure only.

Another approach could use, e.g., a terrestrial network for DVB-H, or T-DMB associated with a satellite service. Projects are under study in L-Band with hybrid S-DAB network using E-SDR (European Satellite Digital Radio) ETSI standard or in the 2 GHz SMS (Satellite Mobile Service) Band using DVB-SH ETSI standard.

3.1 High power, sparse network (HPSN)

This type of network is based on existing broadcast infrastructure using ERPs up to 100 kW as a backbone. Such an approach is adopted in Germany by T-Systems. Another example is the DVB-H trials in Dublin by RTE.

Usually the term "high-power network" is applied to transmission sites operating at powers, comparable with the overall power of the network. Such sites receive the source signal from studios by means of well protected high-capacity point-to-point links (fibre or microwave) and form a frame for the transmission network in a sense that they:

a) provide the signal to the majority of the population;

b) serve as a source of signal for smaller transmission sites, transposers and gap-fillers.

The high-power networks are necessarily sparse, because high transmission power presumes large re-use distances for operational frequency channels. To maximise the coverage, transmission sites are usually located at high altitudes (mountains, hillcrests, etc.) overlooking vast plain areas and remote to the populated regions.

Broadcasting for handheld mobile terminals is often associated with low-power dense networks, which can provide high signal levels (at the close distances involved) and more uniform coverage within urban areas where a high level of attenuation considerably restricts the service area of a transmitter.

However in planning of mobile services, a flexible approach has to be exercised and the feasibility of using the traditional high-power networks should also be estimated. Practical experience indicates that a single transmission site operating at 25 kW ERP and overlooking a city from the effective height of 600 m can provide a DVB-H coverage within a medium density urban area (2-3 story high buildings with a moderate building penetration loss). This coverage can reach up to 15-20 km for indoor reception and up to 22 km from the transmitter for handheld mobile reception, with the exception of large modern shopping centres, tall block buildings, etc., where high values of building penetration loss requires the application of indoor repeaters. For reliable mobile handheld reception inside narrow street canyons low-power gap-fillers would also be required.

To conclude; planning for a mobile service requires a flexible approach and all the available options have to be taken into account. The same level of coverage can be provided by means of different types of networks. However, when compared with a dense low-power network, using a high-power site complemented by a few low-power gap-fillers would require less investment into the infrastructure and would considerably reduce the risk of the "hole-punching" effect.

3.2 Medium power, medium density (MPMD)

Medium power, medium density networks generally require new sites but may use some existing broadcast infrastructure. The ERP is in the range from 2 kW to 40 kW. The Dutch broadcast infrastructure provider KPN Broadcast (former Nozema) has adopted this approach for portable DVB-T/DVB-H deployment in the Netherlands. Digita has also adopted this approach in Finland (see **Annex A1** for details).

3.3 Low power, dense network (LPDN)

Low power, dense networks could possibly use part of existing cellular networks with ERPs in the range 500 W to 5 kW. This approach has been adopted by Modeo[1] for deployment of their L-Band (1670 MHz) DVB-H network in the USA. Another example is the Arqiva DVB-H trial network using UHF frequencies in Oxford as well as the DVB-H pilot network performed by Teracom in Stockholm. T-System has also adapted this network topology for a T-DMB network that has been in operation in L-band since the FIFA World Championships in Germany in June 2006.

Annex A2 provides detailed illustrations of the LPDN topology through the examples of the Oxford DVB-H network, Teracom DVB-H network and T-Systems Media &Broadcast GmbH T-DMB network.

The implementation of such a LPDN network is facilitated by the use of compact size equipment, which could be produced in sufficient number to equip all the required transmitting sites (see illustrations in **Annex A2**).

[1] Modeo's deployment strategy was dictated by licence conditions that limit site EiRP to 2 kW

The protection of DVB-T or analogue reception in the surrounding area of a DVB-H site requires the use of a selective filter at the output of the DVB-H transmitter in order to comply with the critical mask of the signal (as specified in GE06 Final Acts). This may generate a 20-30 % overhead on the cost of the site, but its use is critical.

One main advantage of the LPDN topology is the diversity offered by the multiple signal sources. This structure increases the probability of receiving at least one signal with sufficient signal strength. Also some network gain, due to the contribution of multiple constructive echoes in the receiver could be expected in some parts of the network. The assessment of such gain is still subject to further investigations.

The main delays in the network construction are due to Planning and Access. Obtaining land-lord agreement is quite difficult, especially in urban areas. Optimal sites from the planning point of view may not be accessible and compromises are often made. As an example, for the Oxford network the delay between project kick-off and build was about 18 months.

3.4 Main characteristics of the network topologies

Table 3.1 compares some characteristics of different network topologies introduced in the previous sections.

Table 3.1: Main characteristics of the network topologies

Topology	Typical Antenna Height	Typical ERP	Possible Bands	Possible feeding system
HPSN	150-300 m	25-100 kW	VHF-UHF	Fixed Links or Satellite
MPMD	60-150 m	2-50 kW	VHF-UHF	Fixed links Satellite
LPDN	30-60 m	0.1-5 kW	UHF-1.5 GHz	Satellite or UHF

For typical ERP values and different frequency bands, Table 3.2 provides some typical coverage radii of transmitters deployed in different network topologies.

Table 3.2: Typical transmitter coverage radius of the different network topologies and different frequency bands

Topology	Typical Antenna Height	Typical ERP	Typical Coverage radius				Freq.	System*
			Class B**		Class C***			
			Emed (dBuV/m) @1.5m	Radius (km) 1546 urban	Emed (dBuV/m) @1.5m	Radius (km) 1546 rural		
HPSN	300 m	25 kW	66	17.9	50	46.5	200 MHz	T-DMB, (DVB-H)
HPSN	300 m	100 kW	76	9.8	52	46.6	500 MHz	DVB-H
HPSN	300 m	100 kW	75	9.2	56	38.3	800 MHz	DVB-H
MPMD	150 m	2.5 kW	66	5.8	50	21.3	200 MHz	T-DMB
MPMD	150 m	10 kW	76	3.1	52	22.2	500 MHz	DVB-H
MPMD	150 m	10 kW	75	3.0	56	17.1	800 MHz	DVB-H
MPMD	150 m	10 kW	75	2.6	60	13.1	1.5 GHz	T-DMB, DVB-H
LPDN	37.5 m	2 kW	76	1.2	52	7.8	500 MHz	DVB-H
LPDN	37.5 m	2 kW	75	1.1	56	5.9	800 MHz	DVB-H
LPDN	37.5 m	2 kW	75	1.0	60	4.5	1.5 GHz	T-DMB, DVB-H
LPDN	37.5 m	0.5 kW	76	0.8	52	5.6	500 MHz	DVB-H
LPDN	37.5 m	0.5 kW	75	0.8	56	4.2	800 MHz	DVB-H
LPDN	37.5 m	0.5 kW	75	0.7	60	3.2	1.5 GHz	T-DMB, DVB-H

* *for DVB-H, the system variant considered is QPSK, 1/4 GI, 1/2 CR, MPE-FEC 3/4*

** *Class B: ground floor indoor reception where a portable receiver with an attached or built-in antenna is used*

*** *Class C: outdoor reception with a moving terminal where the receiver is moved while being used*

4. COVERAGE ASPECTS

4.1 Consideration on system variants

There are a large number of system variants available for DVB-H. Different modulation schemes (QPSK, 16 QAM and 64 QAM) can be combined with different code rates and MPE-FECs.

As always in network planning, there will be a need to make a trade off between transmission capacity (bit rate) and the coverage quality (or the size of the coverage area) provided. Higher capacity requirements mean that a less robust system variant needs to be used, resulting in higher power and/or more sites needed to cover a specified area, this will increase the investment cost as well as the operational cost of the network.

From a consumer point of view it seems desirable to provide indoors handheld reception, which is the most demanding receiving mode. In order to provide indoor reception with sufficient quality there will in most cases be a need to use the more robust system variants such as QPSK with a code rate of, for example, 1/2 with MPE-FEC 3/4. Many of the existing field trials with DVB-H as well commercial services in operation actually use the QPSK modulation.

It is generally effective to use SFNs (dense or medium sized) to provide indoor coverage due to the signal diversity provided by the different transmitters in the network. However there will be a need to choose a sufficiently long guard interval, adapted to the structure and the size of the network in order not to create problems arising from self-interference. In the single (high power) transmitter case, a short guard interval may be used, resulting in a higher net bit rate available to provide the services.

4.2 Intended service (mobile, handheld)

Depending on the demand, broadcasting operators could plan networks dedicated to:

- Mobile reception for rural areas, high-speed ways, trains, bus lines or limited services in towns
- Indoors handheld reception for densely populated cities. Indoor handheld reception in rural and in less populated parts of a country does not seem to be economically viable.

Quality of terminals as, for example, their ability to receive signals of low strength (receiver sensitivity), and possible use of diversity would have a benefit impact on the link budget.

4.3 Propagat ion issue

Propagation also has an impact on the link budget. This means that the frequency bands used will influence the choice of the infrastructure depending on the target aimed at by the operator.

At higher frequencies electromagnetic waves are obstructed to a larger extent by obstacles than at lower frequencies, where the diffraction 'mitigates' the effects of obstacles. Therefore, path attenuation is higher at higher frequencies and that results in a smaller transmitter coverage radius (see Table 2.2). Hence, the deployment of multimedia networks in L-band should be realised preferably within the MPMD and LPDN topology, whereas VHF and UHF bands can be well suited for both HPSN and MPMD network topologies. It should be also noted that the variation of the propagation loss across a distinct band is roughly offset by antenna efficiency and other issues, so this does not provide any other significant reason for selecting one frequency over another. A significant change in the path loss is only observed when changing the frequency band (VHF, UHF, L-band).

4.4 Zero dB echo issue

The advantage of using SFNs is that they provide signal diversity. This is particularly important in the case of indoor reception since reception from many signal sources will increase the probability of reception due to the network gain.

However, from a reception point of view the use of two or more transmitters means that several copies of the same signal may be available at the receiver input, and if these signals have more or less the same power-level the situation is referred to as a "zero dB echo", which could cause reception problems. **Annex A3** provides the details of the zero dB echo issue as well as discusses possible ways to mitigate the eventual reception problems.

5. INTERFERENCE ASPECTS

5.1 Self-interference considerations

5.1.1 Self-interference

The signals (or echoes) in an SFN arriving at any given coverage point may combine in a constructive manner to enhance reception, leading to a concept entitled 'network gain'. On the other hand, transmitters in a given SFN (or echoes) may cause interference if the delay limits between signals are exceeded. This will depend on the structure of the network (e.g., transmitter separation distances) and network parameters (e.g., guard interval), as well as on the relative signal strengths and protection ratios. This effect is termed self-interference. For example, a strong signal arriving at a receiving antenna could be rendered useless by a weaker signal from the same SFN if the weaker signal is sufficiently time delayed. These effects can restrict the dimensions of the coverage area of an SFN.

5.1.2 ‘Self-interference zone'

The 'self-interference zone' of an SFN can be represented as a two-dimensional 'coverage radius' (ordinate) vs. 'transmitter separation distance' (abscissa) diagram (see Figure 2.3). The boundary of the 'self-interference zone' is defined by (and is contained within) a broken line segment in the two-dimensional diagram. The broken line segment consists of either:

- a vertical line at the left which intersects, and continues with, a line sloping upwards towards the right, or,
- a vertical line at the left which intersects, and continues with, a horizontal line running towards the right, which in its turn intersects, and continues with, a line sloping upwards towards the right.

For each value of the guard interval, the vertical line on the left indicates the threshold of the transmitter separation distances (abscissa) at which self-interference may start (i.e. when the delay exceeds the guard interval). Self-interference will then only occur if the coverage radius exceeds the ordinate of the lowest point of the boundary of the self-interference zone. Once this separation-distance threshold has been exceeded (and the given coverage radius is sufficiently large), self-interference will occur. This condition persists at increasing transmitter separation until the transmitter separation exceeds the abscissa of the point (corresponding to the given coverage radius) on the line sloping towards the right; at larger transmitter separation distances self-interference will cease (because of the weakness of the potentially self-interfering signal).

In Figure 5.1, a set of 'self-interference zones' is indicated as a function of the guard interval size, ranging from 7 μs to 224 μs, in the case of a uniform SFN with transmitters having effective antenna heights equal to 75 m, for transmissions subject to a 14.5dB protection ratio.

For example, for the case of a guard interval of 112 μs, if the coverage radius of each transmitter is less than about 5 km, the transmitter separation distance between any pair of transmitters in the network can have any value without introducing potential self-interference. If the coverage radius is greater than 5 km, then a SFN with no self-interference cannot exceed a total size (maximum transmitter separation distance) of about 35 km. A SFN consisting of coverage areas with radius greater than 5 km can exist without self-interference only if the network is 'sparsely' covered. As an example, for a coverage radius of 10 km, self-interference can be generally avoided only if all transmitter separation distances are greater than about 77 km. This situation would lead to most of the area between (77 km separation) transmitters (having a 10 km coverage radius) not being covered, thus not leading to a reasonable SFN implementation.

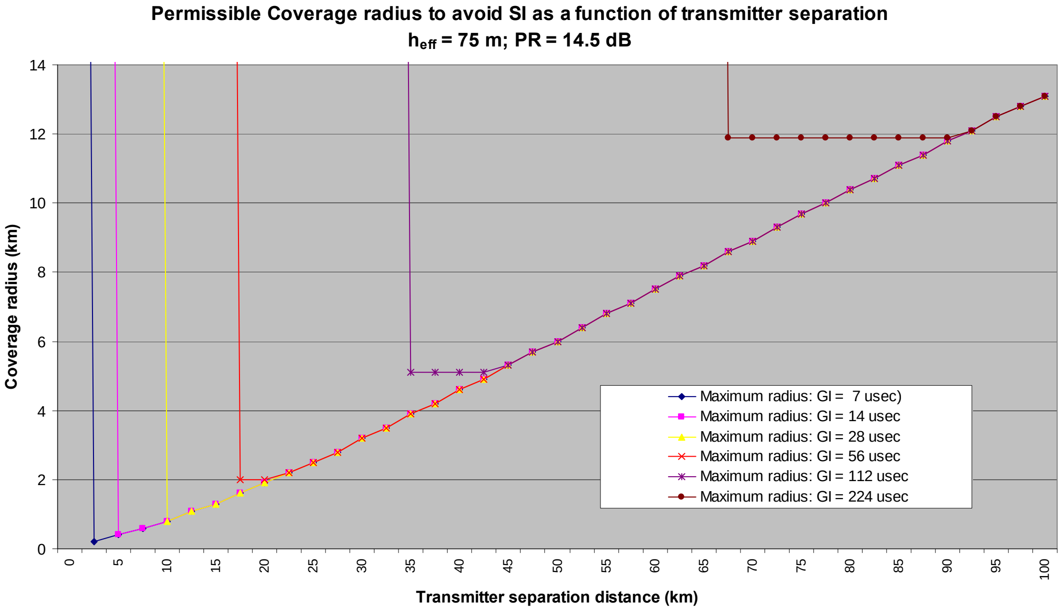

Figure 5.1: Coverage radius to avoid self-interference.

5.1.3 General restrictions on SFN size

It is seen that the restrictions on the coverage radius become less severe as the size of the guard interval increases. Likewise, the restrictions also become less with decreasing protection ratio.

It can be shown that the avoidance of self-interference in an SFN can lead to many network restrictions. These restrictions include transmitter coverage size and/or SFN size. There is a certain, though minimal, relaxation of the upper bound of the transmitter coverage radius when using a weighted guard interval cut-off as compared to a sharp guard interval cut-off (as presented in Figure 5.1).

To provide nationwide DVB-H coverage (assuming a large Emin = 100 dBµV/m) with a single SFN would require

- many transmitters with a very large ERP (hundreds of kW), which may not be practical
- low ERP transmitters in huge numbers (tens or hundreds of thousands), which also may not be practical.

Use of larger guard intervals (e.g. 224 µs) in a SFN would allow larger cell limit radii than smaller guard intervals (e.g. 7 µs). However, a larger guard interval is only introduced at the expense of data capacity. Thus, the total amount of data transmitted may also be restricted when developing a suitable SFN configuration.

5.2 Adjacent channel interference

Adjacent channel interference is caused when a receiver tuned to the wanted service is subject to interference from another service operating in an adjacent channel. If the two services are transmitted from the same location using appropriate power levels and an appropriate spectrum mask it is possible to ensure that there is no destructive interference in the coverage area of both services. However, if the two services are transmitted from different locations and/or at significantly different power levels it is much harder to specify how to protect the wanted service across its entire coverage area.

This situation is especially relevant to the protection of DVB-T services broadcast from a high power/tower transmitter network (which typically employs a relatively small number of sites) from another service operating at medium power using a dense network. In the vicinity of the transmitters of a dense network the relative field strength of the service transmitted using the dense network signals could be significantly higher than that of the high power network near the edge of its coverage area, due to the different propagation distances from the transmitters. This is particularly true when the required field strength of the dense network intended for DVB-H/T-DMB is high. This can result in destructive adjacent channel interference (referred to as hole-punching) to receivers close to the transmitters used in the dense network. The problem should be considered on the first adjacent channels (N±1) and beyond (N±M, M>1).

The problem between networks, when the transmitters are not co-sited is schematically demonstrated in Figure 5.2.

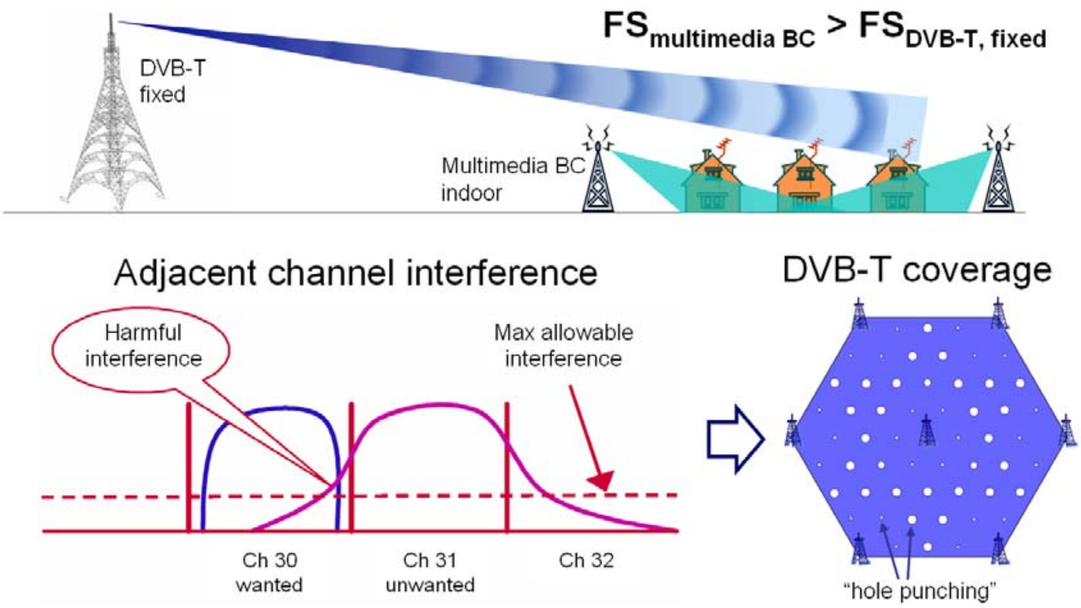

Figure 5.2: Adjacent channel interference from DVB-H broadcasting network into DVB-T service

5.2.1 Co-existence of DVB-T and DVB-H networks

It should be stated that:

- compatibility between DVB-H and DVB-T services using non co-sited transmitters is an issue that must be considered;
- technical measures could be taken to solve this issue on a case by case basis.

In general, the best transmitting configuration to cover the same area by several transmitters still is to co-site them and to use the same antenna system. A less-good solution could be to use the same site but with different antenna systems or to use very close sites. The most difficult configuration is to use different and widely separated sites. If this latter configuration is unavoidavle, then several measures are recommended in order to ensure the compatibility between the non co-sited transmitters.

For protection of DVB-T fixed reception from non co-sited DVB-H transmitters, the following actions are recommended:

- Use of critical spectrum mask (as defined in the GE06 Agreement) for the DVB-H service transmitter;

- Use of cross polarization between the DVB-T and the DVB-H transmitter;
- Adjusting the power of the interfering mobile broadcast transmitter, taking into account the local conditions, in particular the level of the wanted field strength received in the area where the mobile broadcast transmitter is to be implemented;
- Adjusting the antenna height of the interfering DVB-H transmitter with regard to the surrounding DVB-T receiving antennas, with correct usage and control of its vertical radiation pattern;
- Increasing the field strength of the wanted DVB-T transmitter. This could also be realised by installing additional DVB-T transmitter(s) to cover the concerned area;
- Applying adequate frequency separation between the wanted and the unwanted signals depending on the difference of levels between the two signals;
- Installing rejecting filters on the fixed reception installations located near the DVB-H transmitter to reduce the interferer signal level. When relevant, this helps to avoid the possible overload of the DVB-T receiver input or any wideband antenna amplifier used in receiving installation.

The effect of careful network planning has been theoretically demonstrated when studying an implementation scenario that considers a simultaneous deployment of DVB-T and multimedia broadcasting networks in either small or large areas. The details of the study are provided in **Annex A4**.

6. INTERACTIVITY - INTEROPERABILITY WITH OTHER RADIO SYSTEMS

Convergence or cooperation between broadcasting and telecommunication services has been studied deeply in their various aspects and standards[1] have been produced. Now, the introduction of mobility for TV has introduced new opportunities for mobile multimedia (Figure 6.1). The arising mobile multimedia interactivity requires the investigation of interoperability with other telecommunication systems and in particular radiocommunication systems. That covers the feasibility of standards but also the electromagnetic compatibility issues between parallel transmission and reception within a terminal or closely located terminals.

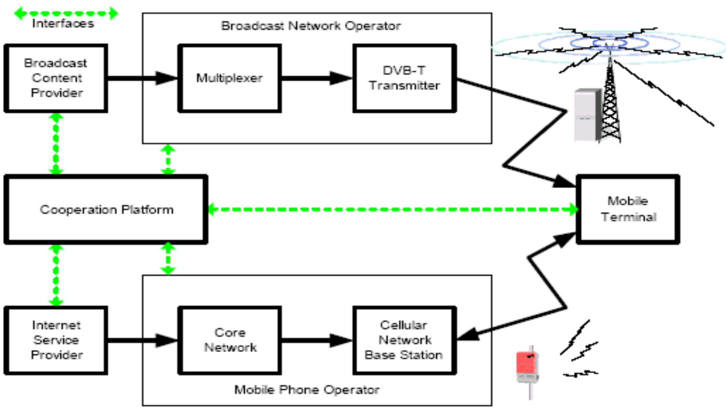

Figure 6.1: Convergence of broadcasting and mobile services.

[1] ETSI ES 202 218 – Digital Video Broadcasting (DVB); Interactive channel through the General Packet Radio System (GPRS), ETSI EN 301 195 - Digital Video Broadcasting (DVB); Interaction Channel through the Global System for Mobile communications (GSM) and ETSI EN 301 958 - Digital Video Broadcasting (DVB); Interaction Channel for Digital Terrestrial Television (RCT) incorporating Multiple Access OFDM.

6.1 Interactivit y

The multimedia applications can be made available to a multimedia receiver. This receiver may be a dedicated handheld receiver, an in-car mobile receiver, a portable computer or a handheld mobile phone. The receiver may be combined with a return (interactive) path that can either be a fixed line or more generally a mobile (radio)link. In this case, the multimedia receiver is part of the terminal and consequently, compatibility with the mobile transmitters needs to be carefully taken into account. Another option is that the multimedia receiver is associated to the telecommunication network, and it can benefit from other, short-range networks[1], not exclusively mobile networks, such as Bluetooth, UWB, R-LAN or WIFI.

Mobile application scenarios can be distinguished according to the degree of interactivity they require:

- Non interactive applications are unidirectional, as data are broadcast to the terminals, allowing only for limited local interactivity between the user and the terminal.
- Low interactivity applications include the occasional transmission of small blocks of data calling back to the broadcaster, via a network (for example: quizzing via SMS or IP).
- Fully interactive applications require a bi-directional flow of data between the broadcaster and the customers. Especially, the combined cellular-broadcast topology can be used to retrieve the data on-demand.

The first two scenarios have been developed over many years[2]. The third scenario reflects the current demand of mobile operators. It offers interactive multimedia applications and requires a common coverage of networks for both multimedia broadcasting application and for mobile applications (return path). Therefore, the mobile multimedia infrastructure configuration may need to be evaluated from high tower/high transmitted power to lower site/medium transmitted power suited to the potential interactive service areas, in particular indoors coverage.

6.2 Interoperability with other radio systems

In the scope of mobile multimedia interactivity, one of the main aspects of interoperability with other radio systems concerns the proximity of mobile terminal emission with in-built TV receivers. This problem arises for GSM/GPRS transmission in the 900 MHz band and implies limitation of TV mobile band in UHF up to channel 55. This problem still exists when the mobile TV terminal is separated from the mobile terminal, but it is less severe.

7. IMPLEMENTATION OF T-DMB OR DVB-H UNDER THE PROVISIONS OF EXISTING PLANS

7.1 Frequency bands and channel spacing

There has been no international planning for T-DMB and DVB-H services. T-DMB and DVB-H networks can however be implemented within the provisions of existing frequency plans for DVB-T and T-DAB. Table 7.1 summarises such possibilities.

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[1] see ETSI standards; IST Projects CISMUNDUS, INSTINCT, CONFLUENT and DRIVE.

[2] IST projects: CISMUNDUS, INSTINCT and DRIVE

Table 7.1: Implementation of T-DMB and DVB-H networks in frequency bands allocated to broadcasting

Frequency bands (MHz)	Channel raster (No. of channels)	Possible systems	Comments
174 - 230	7 MHz (8) 1.5 MHz (32) 8 MHz (7)	T-DAB; T-DMB DVB-T DVB-H	With regard to RRC-06, T-DMB and DVB-H could be implemented by means of the mask concept. Currently, there are no DVB-H receivers in Band III.
470 - 862	8 MHz (49)	DVB-T DVB-H	DVB-H restricted to channels below 55 (750 MHz) in case of interactivity between DVB-H and GSM/GPRS in the same terminal. With regard to RRC-06, DVB-H could be implemented by means of the mask concept.
1452 - 1479.5	1.5 MHz (16)	T-DAB T-DMB DVB-H	MA02revCO07 Special Arrangement. Introduction of DVB-H requires larger channel bandwidths which may be achieved by aggregating adjacent T-DAB frequency blocks

There is, however, a minimum number of channels that needs to be made available before starting a national implementation. Calculations have shown that the quality of service of the reception is linked with this available number of channels.

7.2 Frequency planning options in VHF/UHF band

The GE06 Agreement has been optimised for digital terrestrial broadcasting by creating a de facto harmonisation of planning criteria and parameters. Moreover, provisions contained in §5.1.3 *of the GE06 Agreement* allow the introduction of multimedia applications, provided the interference and the protection requirements are kept within the so-called interference envelope of the corresponding Plan entry (Figure 7.1).

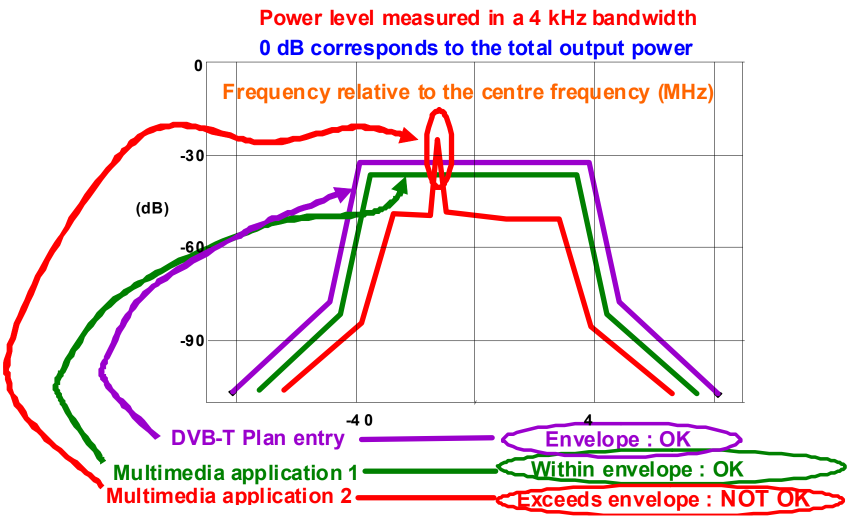

Figure 7.1. Interference envelope concept of the GE06 Agreement.

There exist two possibilities to implement multimedia networks in the VHF- and UHF-bands. The first is to use the existing GE06 Plan entries. The second consists in applying the provisions of the GE06 Agreement to evolve continuously the GE06 Plan towards one or several harmonised sub-bands for multimedia applications.

7.2.1 Planning in the whole VHF/UHF band

The GE06 Agreement has been optimised for digital terrestrial broadcasting by creating a de facto harmonisation of planning criteria and parameters. According to the GE06 Agreement, on average 7 UHF layers and 1 VHF layer have been allocated for DVB-T to each European Administration. On a national basis the flexibility is given to arrange the frequencies of the GE06 Plan such that several national layers result with assigned frequencies below a certain threshold (e.g. <750 MHz) or within certain sub-band(s).

Those layers may be assigned to multimedia broadcasting services. The network structure of such multimedia broadcasting services may be based on conventional (broadcasting like) or cellular like networks or on a combination of both (distributed networks).

The GE06 Plan includes entries for fixed rooftop reception, portable outdoor/mobile reception and portable indoor reception for DVB-T services. The technical parameters of each plan entry are the result of a complex international coordination process, which took several years to complete. Some Administrations decided to use the spectrum within their territories more densely than did their neighbours, by planning more coverages / allocations for digital broadcasting and other primary services. As a consequence, those Administrations had to adapt the technical parameters of their plan entries such that it was possible to reach a compromise between the number of coverages and the envisaged purpose for these allocations. The GE06 Plan does not include entries, for example, for digital TV services designed for reception on handheld receivers (e.g. DVB-H). Nevertheless, by means of spectrum mask concept the GE06 Agreement is flexible enough to allow for implementation of such services.

When the plans to implement multimedia services have been already incorporated into the GE06 Plan, administrations do not have to apply Article 4 of the GE06 Agreement to implement multimedia services avoiding additional delay in the deployment of mobile multimedia services nor in the deployment of DVB-T services.

In European countries, the implementation of multimedia broadcasting services is indeed possible and has already started in many countries on the basis of the GE06 Plan and its provisions. Depending on the outcome of bi-lateral negotiations between neighbouring administrations, with regard to the transition period, an immediate implementation of multimedia broadcasting services is possible.

Under this approach, the whole band IV/V can be used in a flexible way for all broadcasting applications, including mobile multimedia.

7.2.2 Planning in one or several sub-bands of VHF/UHF band

Administrations may also wish to deploy mobile multimedia networks using a harmonised sub-band, taking into account the benefits of using a harmonised narrow sub-band. A sub-band for multimedia applications is to be understood as a number of contiguous channels with a total bandwidth narrower than the UHF/VHF band.

The harmonization of a narrow sub-band (up to 10% of the centre frequency) may allow an improvement of the technical characteristics of receivers (better antenna gain). As a consequence the implementation costs for networks can be reduced provided the network topology is broadcasting-based.

It should be noted, however, that the implementation of such approach by an administration should not delay the introduction of mobile multimedia networks. In other words, the implementation of one or another approaches is not mutually exclusive and an administration may wish to start the implementation of a mobile multimedia network based on the first approach and, later, implement a new mobile multimedia network based on the second approach, although in this case terminals designed for the reception in the sub-band only may not be able to access to the services offered over the network operating under the first approach.

The harmonisation of such a sub-band would require a certain re-allocation of frequencies at national level and additional international coordination. Therefore, the introduction of multimedia services will need to be preceded by changes of the GE06 Plan entries by applying Article 4 of the GE06 Agreement and an associated coordination activity.

Based on the new GE06 Plan, many licenses for digital broadcasting or multimedia broadcasting services have already been granted in Europe for the next 10 to 15 years. Therefore, the European wide harmonization and implementation of a sub-band for multimedia broadcasting services is not realistic before at least 2020. Therefore, harmonisation of a sub-band for multimedia services may only be considered in the long term with countries adopting harmonised channels for multimedia where feasible and beneficial.

7.3 Conversion from a plan entry

The new frequency plan of GE06 is designed for DVB-T and T-DAB. The VHF band is used for both systems. The UHF band is used exclusively for DVB-T. The plan was optimized with regard to these two systems. But, additionally, Article 5 of the GE06 Agreement allows any other service as long as it is in accordance with the Radio Regulations. This envelope concept gives high flexibility for implementation as long as the interference potential of the new implementation does not exceed the limit of the plan entry. It has to be ensured that the implemented network does not cause more interference than the coordinated reference network. And the new implementation should not claim more protection from interference of other co-block/co-channel plan entries than the coordinated allotment.

The proceeding development of handheld systems leads to a high interest in conversions of DVB-T and T-DAB allotments into DVB-H and T-DMB networks.

The high flexibility for implementation is based on a fundamental planning concept: the allotment planning. Allotment planning means that only the service area together with a set of general network implementation rules are given, but no transmitters are specified. Due to the envelope concept any service operating in conformity with the Radio Regulations is allowed for implementation.

There are three practical options of conversions. In the VHF band the GE06 Plan provides mainly T-DAB allotments, but there are also DVB-T allotments. Both could be converted into T-DMB networks: one T-DMB block fits into one T-DAB block and up to four T-DMB blocks are possible within a DVB-T channel. The UHF band is planned exclusively for DVB-T. The DVB-T allotment could be converted into a DVB-H network. These are the most favoured options of conversion for the time being (see Figure 7.2).

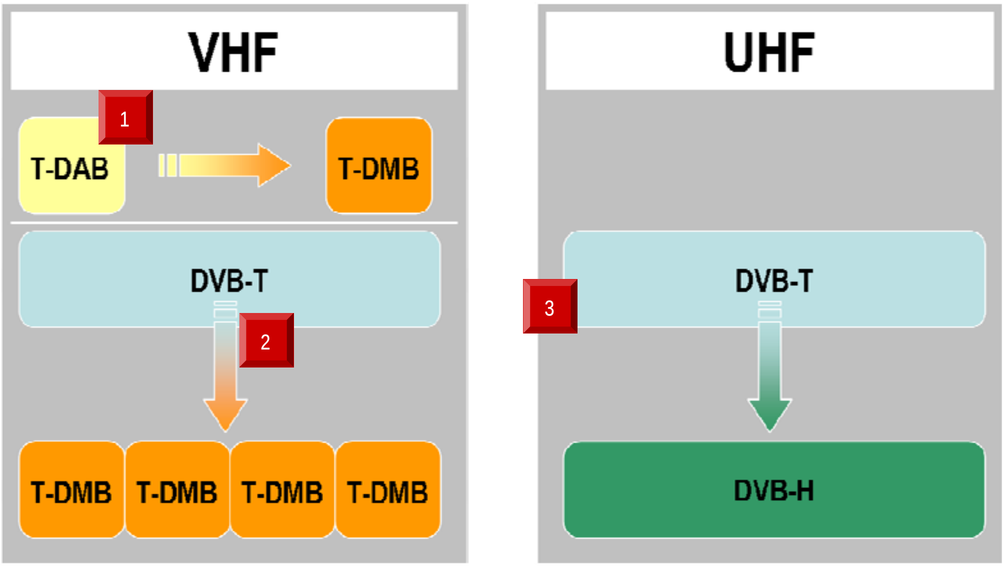

Figure 7.2. Practical options of conversions

7.3.1 Important characteristics to be taken into account in handheld and mobile TV reception networks

GE06 has established the plan for three configuration types for DVB-T and 2 configuration types for T-DAB with a minimum median equivalent field strength given in Tables 7.2 and 7.3.

Table 7.2: Reference planning configurations for DVB-T.

RPC	RPC 1	RPC 2	RPC 3
Reference location probability	95%	95%	95%
Reference *C/N* (dB)	21	19	17
Reference $(E_{med})_{ref}$ (dB(μV/m)) at 200 MHz	50	67	76
Reference $(E_{med})_{ref}$ (dB(μV/m)) at 650 MHz	**56**	**78**	**88**

$(E_{med})_{ref}$: *minimum median equivalent field strength*

RPC 1: *RPC for fixed roof-level reception*

RPC 2: *RPC for portable outdoor reception or lower coverage quality portable indoor reception or mobile reception*

RPC 3: *RPC for higher coverage quality for portable indoor reception.*

Table 7.3: Reference planning configurations for T-DAB.

Reference planning configuration	RPC 4	RPC 5
Location probability	99%	95%
Reference *C/N* (dB)	15	15
Reference $(E_{med})_{ref}$ (dB(μV/m)) at 200 MHz	**60**	**66**

$(E_{med})_{ref}$: *minimum median equivalent field strength*

RPC 4: RPC for mobile reception

RPC 5: RPC for portable indoor reception

Some examples of field strengths required for DVB-H and T-DMB are given in tables below (taken from EBU Tech 3317)

DVB-H (16 QAM 1/2) at 500 MHz	Class A Urban	Class B urban	Class C rural	Class D rural
Minimum median equivalent field strength at 10 m agl; 50% time and 50 % locations [dBμV/m]	91.5	106.7	74.2	95.1

DVB-H (16 QAM 1/2) at 800 MHz	Class A Urban	Class B urban	Class C rural	Class D rural
Minimum median equivalent field strength at 10 m agl; 50% time and 50 % locations [dBμV/m]	91.5	106.8	79.3	95.2

T-DMB at 200 MHz	Class A Urban	Class B urban	Class C rural	Class D rural
Minimum median equivalent field strength at 10 m agl; 50% time and 50 % locations [dBμV/m]	77.7	88.0	63.0	81.7

The procedure to check a possible conversion of allotments is divided into two main parts. The first constraint is the outgoing interference. The interference field strength of the new implementation must not exceed the interference potential of the original reference network. But sufficient minimum field strength has to be ensured for a good handheld coverage. The conformity of the network is checked in regard to the total power of the signals. On the other hand the maximum allowable interference field strength from other co-channel allotments should not affect the functionality of the real implementation. The new implementation shall not claim more protection than the plan entry.

A further constraint, which has to be fulfilled, is the compliance with the mask concept. For this purpose the peak power density in any 4 kHz of the implementation shall not exceed the spectral power density in the same 4 kHz of the digital plan entry. Due to the uniform power distribution across the bandwidth of the considered signals the mask concept will be fulfilled automatically, if the conformity in respect of the total power is given.

Since there is no official guidance provided yet by the BR concerning the details of the regulatory procedure for notification of DVB-H or T-DMB assignments on the basis of the conversion from DVB-T or T-DAB allotment, the following statements deal only with the technical feasibility of the conversion from DVB-T or T-DAB into one of the new handheld systems.

The interference potentials of DVB-T and T-DAB are given by the associated reference network of the GE06 Final Acts of the RRC06. RN1 RPC2 (DVB-T) and RN RPC5 (T-DAB) have been chosen as representatives. The calculation of the interference field strength of DVB-H and T-DMB is based on the parameters from the EBU Tech Doc. 3317 Planning parameters for handheld reception.

7.3.2 T-DAB into T-DMB

The first example is the conversion from a T-DAB allotment into a T-DMB network. Figure 7.3 shows the interference field strength of the four T-DMB classes in comparison with the interference potential of the reference network RN RPC5 at a distance of 88 km from the allotment border (re-use distance of two RN RPC5 allotments).

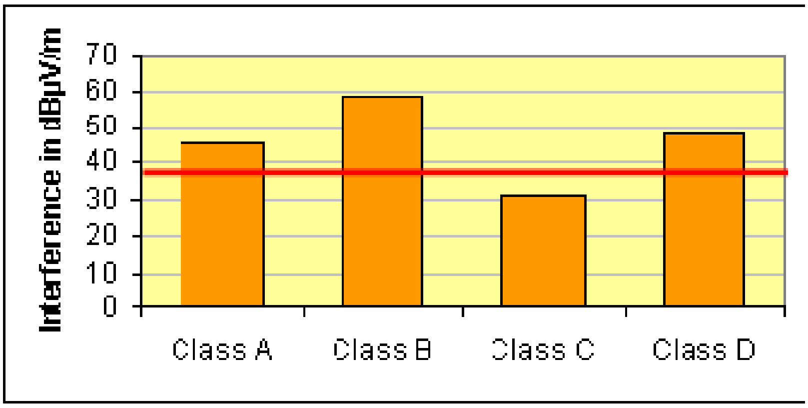

Figure 7.3: The interference field strength of the four T-DMB classes in comparison with the interference potential of the reference network RN RPC5.

Class C is the least critical case, the interference field strength does not exceed the limit of the reference network. The investigation of the claim of protection shows that the T-DMB implementation for class C needs more protection than the coordinated T-DAB reference network. That means that the new implementation is not well protected against other co-channel allotments. But due to the low interference field strength it would be possible to increase the power of the T-DMB network up to the maximum interference field strength of the reference network RN RPC5. This will improve the protection of the new implementation.

For the other three cases A, B and D the interference field strength of the T-DMB implementation is higher than the interference potential of the reference network RN RPC5. On the other hand these reception modes are very rugged concerning the interference from other co-channel allotments. They will not have any problems with their claim of protection. The main problem of these classes is the outgoing interference field strength. As a possible solution a more sophisticated network design may help reduce the outgoing interference. Another possibility is to choose a coverage area, which is well separated from other co-channel allotments, for example due to topographic conditions or because the network is located in the centre of the allotment (hotspot coverage instead of full area coverage).

7.3.3 DVB-T into T-DMB

The next example is the conversion from a DVB-T allotment into a T-DMB implementation. Up to four T-DMB blocks are possible within a DVB-T channel. Four T-DMB blocks are the worst case in respect of total power and outgoing interference. Figure 7.4 shows the interference field strength of four T-DMB blocks in comparison with the interference potential of the reference network RN1 RPC2 at a distance of 159 km from the allotment border. (Re-use distance between RN1 RPC2 and RN RPC5, which is the worst case regarding the re-use distance – re-use distance between two RN1 RPC2 allotments is 162 km).

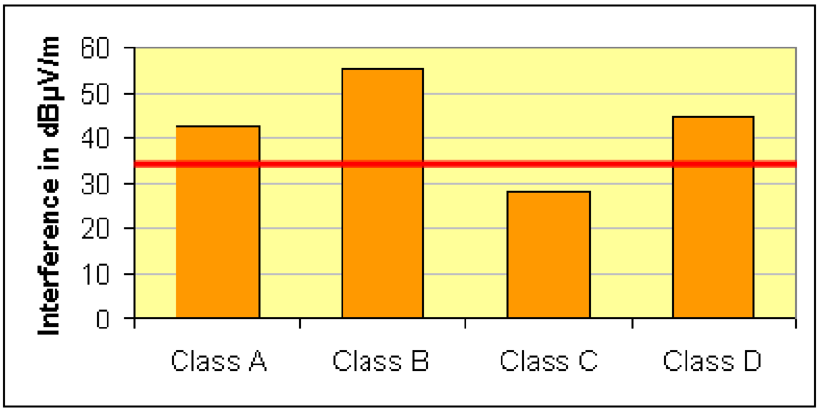

Figure 7.4: Interference field strength of four T-DMB blocks in comparison with the interference potential of the reference network RN1 RPC2

Class C is again the least critical case. The interference field strength of the new implementation does not exceed the limit of the maximum interference potential of the reference network RN1 RPC2. Furthermore there will be no increased influence due to interference from other co-channel allotments, because the T-DMB implementation needs nearly the same protection as the coordinated DVB-T reference network. The conversion from a DVB-T allotment into four T-DMB blocks of class C is possible without any problems.

For the other three cases A, B and D the interference field strength exceeds the limit of the reference network RN1 RPC2. On the other hand the claim of protection is less than coordinated. Again the outgoing interference is the limiting factor for these classes. A more sophisticated network design may help reduce this interference. Also the choice of an appropriate coverage area, which is well separated from other co-channel allotments, may facilitate the implementation.

7.3.4 DVB-T into DVB-H

The last example is the conversion from a DVB-T allotment into a DVB-H network. There are different planning parameters for DVB-H in Band IV and V. Therefore the calculations are carried out for both frequency bands. Figure 7.5 and 7.6 show the interference field strength of a DVB-H network (system variant 16 QAM 2/3) in comparison with the interference potential of the reference network RN1 RPC2 at a distance of 130 km from the allotment boarder (re-use distance of two RN1 RPC2 allotments). Figure 7.5 is calculated for the frequency Band IV, Figure 7.6 for the frequency Band V.

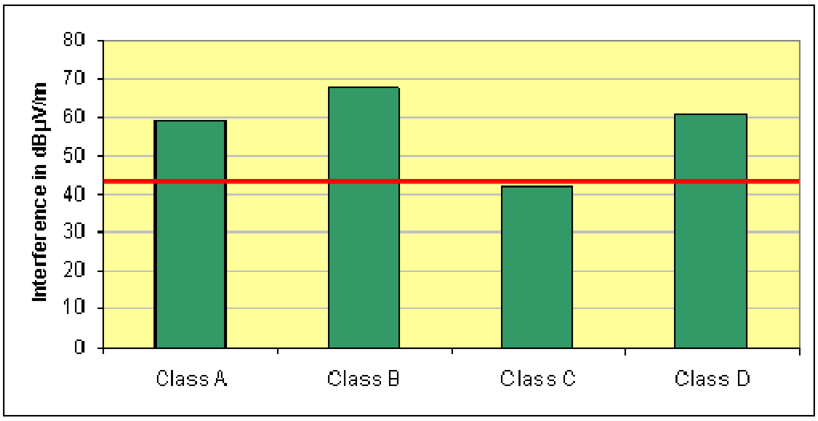

Figure 7.5. The interference field strength of a DVB-H network (system variant 16 QAM 2/3) in comparison with the interference potential of the reference network RN1 RPC2 at 500 MHz.

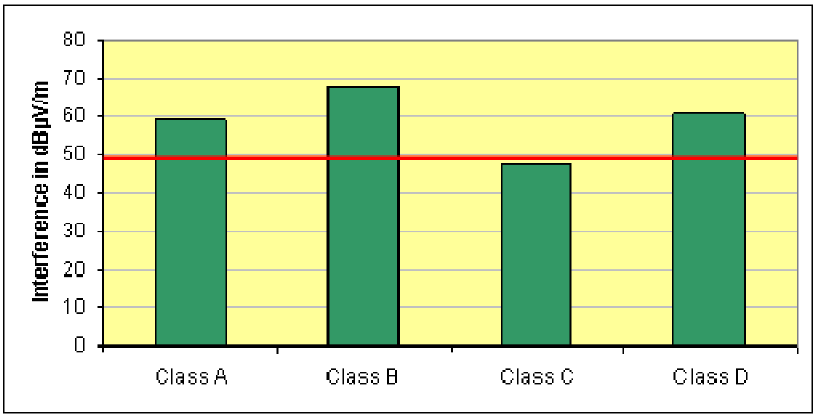

Figure 7.6. The interference field strength of a DVB-H network (system variant 16 QAM 2/3) in comparison with the interference potential of the reference network RN1 RPC2 at 800 MHz.

It is a similar situation regarding the outgoing interference for Band IV and V. Class C is the less critical case in both frequency bands. The interference field strength of the new implementation does not exceed the limit of the maximum interference potential of the reference network RN1 RPC2. But the investigation of the maximum allowable interference field strength has shown that the DVB-H implementation for class C needs more protection than the coordinated DVB-T reference network. A clever network design may compensate for the lack of protection without increasing the outgoing interference.

For the other three classes A, B and D the interference field strength of the DVB-H implementation is higher than the interference potential of the reference network RN1 RPC2. On the other hand these reception modes are very rugged concerning the interference from other co-channel allotments. They will not have any problems with their claim of protection. The main problem of these classes is the outgoing interference field strength. Also a more sophisticated network design or an appropriate location of the coverage area may help reduce the interference field strength in those cases.

7.3.5 Practical considerations

A conversion from a DVB-T allotment (RN1 RPC2) into DVB-H or T-DMB and from a T-DAB allotment (RN RPC5) into T-DMB is possible. The best coverage is achievable for class C, the mobile reception with an adapted antenna. A good coverage is also possible for handheld reception in specific areas that are well separated from other co-channel allotments, for example a hotspot area in the centre of an allotment. The choice of an appropriate coverage area may facilitate the conversion. Better topographic or morphological conditions than assumed for the calculations will improve the quality of coverage, too. And finally the antenna gain of integrated antennas, which is the most limiting item for the achievable coverage, could be improved by developments in the near future. Better handheld antenna gains would directly affect the reception quality within the converted allotments.

As far as handheld TV reception is concerned; the following characteristics have to be recalled:

- Handheld TV reception needs high field strength which implies high power or/and dense networks.
- RPC 2 and 3 (for DVB-H and T-DMB) or RPC 5 (for T-DMB) could be used.
- The choice of an appropriate coverage area may facilitate the conversion
- RPC1: the permissible power in this configuration is too low for a DVB-H or T-DMB service (except some specific cases where the transmitters are located in the centre of the service area)

- Better handheld antenna gains would directly affect the reception quality within the converted allotments.

It should be also noted that the existing analogue networks are not taken into account in the conversion considerations. These networks need to be protected until 2015.

Suitable choice of network topologies may simplify the conversion from DVB-T Plan entry into DVB-H or T-DMB networks.

8. ESTIMATION OF INVESTMENT COSTS OF DVB-H AND T-DMB NETWORKS

8.1 Introduct ion

This section provides rough estimations of the costs involved in the implementation and operation of DVB-H and T-DMB networks. Assessments were performed for hypothetical network scenarios using simple geometrical considerations. Multiple cost sources were averaged and converted to arbitrary units on a per site basis. Therefore the findings should be considered as estimations for the purpose of comparing one network configuration relative to another. Further more detailed analysis would be required for more accurate assessments of cost investment for a particular network and the circumstances under which it would operate.

8.2 General

The costs of network investment include capital investment (CAPEX) and operational expenditures (OPEX). CAPEX covers the investment costs for network infrastructure, network equipment, etc. OPEX includes current costs such as network maintenance, electricity, and support and network management.

The costs of the network are determined mainly by the costs of individual transmitting sites and the distribution of the transport stream from the multiplexer to the network sites. The costs of an individual transmitter site depend on the operational frequency band and the transmitting power. The documents listed in §8.6 provide the sources of information used to collate the material for this section.

Normally broadcasters would attempt to re-use existing broadcast and mobile transmitting sites for the implementation of their DVB-H/T-DMB networks. However, there may be a need for some new sites to be established in new locations (green field) that will increase implementation costs. In this study, the cost estimation is based entirely on green field sites.

It should be further noted that the costs for a single multiplex are significantly higher than for additional multiplexes. In this report, the costs are considered for a single multiplex only.

8.2.1 Implementation costs (CAPEX)

Investment involved in the implementation of a transmitter site comprises the costs for:

- Transmitter, including spectrum mask filter and RF system, electrical power supply equipment, cooling equipment, installation, etc;
- Redundancy to transmitter equipment;
- Antenna system, combiner/filter, feeder;
- Other.

Table 8.1 provides the implementation cost obtained by averaging and expressing in arbitrary units the information extracted from the source documents. This cost presentation methodology was chosen because of the large spread in the estimated costs gathered from various sources. There may be various reasons for this spread and inconsistency like, for example, references to different manufactures, the dependence of the costs on the number of transmitters purchased, cost estimates obtained in different years, etc.

Table 8.1: Costs (in arbitrary units, a.u.) per transmitting site (single multiplex) for different frequency bands and different transmitting power

VHF	UHF	L-Band
2.5 kW ERP: 5-6 25 kW ERP: 8-10	0.5 kW ERP: 1-2 2 kW ERP: 3-5 10 kW ERP: 8-12 100 kW ERP: 16-20	2 kW ERP: 4

8.2.2 Operational costs (OPEX)

Investment involved in the operation of a transmitter site comprises the costs of:

- Power consumption of the transmitter;
- Technical maintenance and reparation;
- Site rental;
- Site insurance;
- Network monitoring;
- Annual frequency licenses.

In general, the operational costs per year can be roughly assessed as being 20-30% of the capital investment costs.

In addition, the operational costs include the distribution costs associated with the delivery of the transport stream from the multiplexer to the transmitter. Typically, the main sites are fed via optic fibre, fixed link or satellite while the secondary sites are most economically fed by an off-air feed.

Some information for the distribution costs by fixed link and satellite is listed in Table 8.2 in absolute figures as extracted from [LFK1]. The distribution costs by satellite depend on a number of factors including the satellite operator and the type of leasing.

Table 8.2: Distribution costs per year (from [LFK1])

Means	Costs
Fixed link	25000 € / per line / per section
Satellite	160000 € / per line

8.3 Methodol ogy

The network implementation costs have been approximated using a simplified representation of real-world situations together with geometrical calculations.

8.3.1 Scenarios

Two scenarios for the network implementation have been chosen as shown in Figure 8.1:

- Urban area scenario: a dense populated urban area of radius 10 km has been assumed to be served with hand held indoor reception (Class B).
- Motorway scenario: mobile reception in car (Class D) has been assumed along a rural route of 100 km.

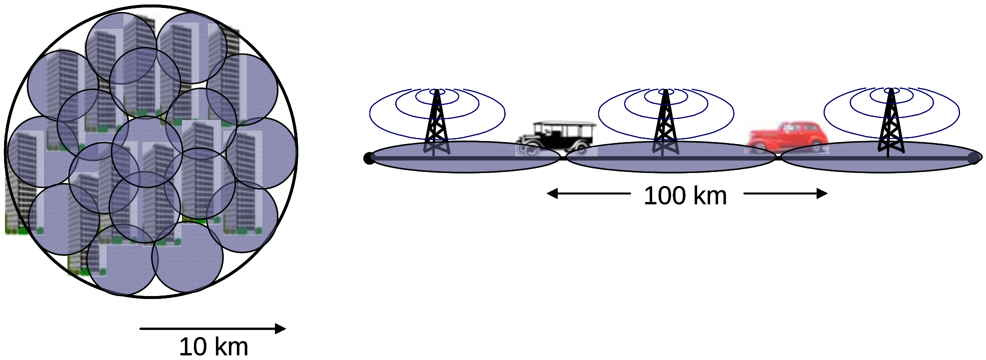

Figure 8.1: Network implementation scenarios considered for the cost analysis: urban area (left) and rural route (right).

8.3.2 Calculations

The required number of transmitters to cover an area of S_a can be obtained as follows:

$$n = 1.21 \frac{S_a}{S_t},$$

Where S_t is the coverage area per an individual transmitter, and

the 1.21 coefficient corresponds to the ratio between the area of a hexagon with a vertex R_t and the area of a circle with a radius R_t.

In case of coverage along the route, the number of transmitters is calculated as:

$$n = \frac{L}{2R_t},$$

Where L is the length of the route and R_t is the coverage radius of an individual transmitter.

Table 8.3 lists the power assumptions made on ERP values in the present study for different network topologies introduced in this document. The coverage radii calculated using Rec. ITU-R 1546 are given as well. Table 8.4 provides the calculated number of transmitters required to serve the area for different network implementation scenarios.

Table 8.3: Power assumptions and coverage radii of individual transmitters for different network topologies, different frequency bands and implementation scenarios

Network topology	VHF	UHF	L-Band
High power, sparse network	25 kW ERP: Urban: 17.9 km Motorway: 46.5 km	100 kW ERP Urban: 9.2 km Motorway: 38.3 km	*not relevant*
Medium power, medium density	2.5 kW ERP Urban: 5.8 km Motorway: 21.3 km	10 kW ERP Urban: 3.0 km Motorway: 17.1 km	10 kW ERP Urban: 2.6 km Motorway: 13.1 km
Low power, dense network	*not relevant*	2 kW ERP Urban: 1.1 km Motorway: 5.9 km	2 kW ERP Urban: 1.0 km Motorway: 4.5 km
Very low power, dense network	*not relevant*	0.5 kW ERP Urban: 0.8 km Motorway: 4.2 km	0.5 kW ERP Urban: 0.7 km Motorway: 3.2 km

Table 8.4: Number of transmitters required to serve the area in different network topologies and for different frequency bands and implementation scenarios.

Network topology	VHF	UHF	L-Band
High power, sparse network	Urban: 1 Motorway: 1	Urban: 2 Motorway: 2	*not relevant*
Medium power, medium density	Urban: 4 Motorway: 3	Urban: 13 Motorway: 3	Urban: 18 Motorway: 4
Low power, dense network	*not relevant*	Urban: 100 Motorway: 8	Urban: 121 Motorway: 11
Very low power, dense network	*not relevant*	Urban: 189 Motorway: 12	Urban: 247 Motorway: 16

8.3.3 System variants

DVB-H and T-DMB networks have been assumed to provide the services with the characteristics given in Tables 8.5 and 8.6, respectively.

Table 8.5: Characteristics of DVB-H systems

Parameter	VHF	UHF	L-Band
RF Channel bandwidth	7 MHz	8 MHz	6 MHz
Transmission mode	8k	8k	8k
Guard Interval	1/4	1/4	1/4
Constellation	QPSK	QPSK	QPSK
Code Rate	1/2	1/2	1/2
MPE-FEC Code Rate	3/4	3/4	3/4
Bit Rate	3.28 Mbit/s	3.75 Mbit/s	2.81 Mbit/s

Table 8.6: Characteristics of T-DMB systems

Parameter	VHF	L-Band
RF Channel bandwidth	1.71 MHz	1.71 MHz
Transmission mode	1	1
Guard Interval	1/4	1/4
Code Rate	1/2	1/2
Bit Rate	1.06 Mbit/s	1.06 Mbit/s

It is assumed that one service (programme) needs 250 kbit/s.

8.4 Results

Estimated costs of the implementation of the DVB-H and T-DMB networks and the costs per service (programme) are given in Tables 8.7 and 8.8, respectively. As mentioned above the costs of a single multiplex are significantly higher than for additional multiplexes. Adding more multiplexes will, therefore, reduce the estimated costs per service (programme).

Table 8.7: Estimated relative implementation costs (CAPEX) of the DVB-H and T-DMB networks for different network topologies, different frequency bands and implementation scenarios.

Network topology	VHF	UHF	L-Band
High power, sparse network	Urban: 8-10 Motorway: 8-10	Urban: 32-40 Motorway: 32-40	*not relevant*
Medium power, medium density	Urban: 20-24 Motorway: 13-18	Urban: 104-156 Motorway: 24-36	*no data*
Low power, dense network	*not relevant*	Urban: 300-500 Motorway: 24-40	Urban: 484 Motorway: 44
Very low power, dense network	*not relevant*	Urban: 189-378 Motorway: 12-24	*no data*

Table 8.8: Estimated relative implementation costs (CAPEX) per service (programme) for the DVB-H and T-DMB networks for different network topologies, different frequency bands and implementation scenarios.

Network topology	VHF	UHF	L-Band
High power, sparse network	*T-DMB (1 mux)** Urban: 2-2.5 Motorway: 2-2.5 *DVB-H* Urban: 0.62-0.77 Motorway: 0.62-0.77	*DVB-H* Urban: 2.13-2.67 Motorway: 2.13-2.67	*not relevant*
Medium power, medium density	*T-DMB (1 mux)** Urban: 5-6 Motorway: 3.25-4.5 *DVB-H* Urban: 1.54-1.85 Motorway: 1.0-1.38	*DVB-H* Urban: 6.93-10.4 Motorway: 1.6-2.4	*no data*
Low power, dense network	*not relevant*	*DVB-H* Urban: 20.0-33.3 Motorway: 1.6-2.67	*T-DMB (1 mux)** Urban: 121 Motorway: 11 *DVB-H* Urban: 44 Motorway: 4
Very low power, dense network	*not relevant*	*DVB-H* Urban: 12.6-25.2 Motorway: 0.8-1.6	*no data*

* In case of implementation of 4 co-sited T-DMB multiplexes, the implementation costs per service (programme) are roughly 60% of the costs per service (programme) estimated for a single T-DMB multiplex.

8.5 Conclusions

The cost information included in this report was gathered from multiple sources and showed a large spread. The costs were therefore averaged and were subsequently converted to arbitrary units on a per site basis to make cost comparison easier. A good estimation for the relative cost investments involved in the network implementation in different frequency bands and for different network scenarios has then been made.

The results show that implementation of DVB-H and T-DMB networks in L-Band are likely to be more expensive in comparison to the deployment in VHF and UHF bands.

It also appears that VHF can host DVB-H networks with better cost efficiency than UHF.

The figures obtained should be considered as approximations only and they should be critically analysed and further updated with more accurate information on the costs of individual transmitter sites. Moreover, a consideration of a specific real-world scenario and the particular circumstances in which it might operate is required to assess the network investment costs more accurately.

8.6 Source documents used in collating §8

[HARRIS1] One mobile technology: infrastructure considerations and planning implications, Richard Redmond, Harris Corporation, 24 May 2008.

[HARRIS2] Considerations in choosing an RF frequency band for mobile television, Glodina Connan, Harris Corporation, http://www.cable-satellite.com/conference/Presentations/Glodina%20Connan.pdf

[LFK1] Kosten von DAB, DAB+ bzw. DMB –Sendernetzen in Baden-Württemberg, Studie erstellt von LFK, VPRA und VPRT, Stuttgart, 27 September 2007.

[LFK2] Strukturen und Kosten von DVB-H-Netzen, LFK, 2005.

[NOKIA] System comparison T-DMB vs DVB-H, Nokia 2006, http://www.mobiletv.nokia.com/resources/files/system_comparison_TDMB_V_DVB-H.pdf

[FLAM] K. Van Bruwaene et all, Determining the Viability of a Mobile TV Ecosystem with the Monte Carlo Method, TEMU2008, International Conference on Telecommunication and Multimedia, 16-18 July 2008, and reference [9] therein.

[NETZ] W. Berner, B. Jamborek, Netzplanung und Kosten von DAB+/DMB-Netzen, FKT, 4/2008.

[RTR] Chancen und Risiken des digitalen Hörfunks für Österreich, RTR, 2008

ANNEX A1: EXAMPLES OF MPMD TOPOLOGY DEPLOYMENT

Digita, Finland has adopted the MPMD topology for its pilot DVB-H network. The Digita DVB-H network was rolled out in December 2006 in three areas: the capital area of Helsinki and the cities of Turku and Oulu. The network comprises 16 medium power stations, with the ERP in the range of 2 kW to 13 kW: 13 sites in Helsinki, two sites in Turku and one site in Oulu. The covered population amounts to 25 % of the people living in Finland. The network is operated regionally in an SFN mode with the parameter set: 8k 16 QAM Code Rate 1/2 Guard Interval 1/8 and MPE-FEC 5/6. In December 2007 the DVB-H network will be extended to the city of Tampere and in 2008, it is planned to expand the network to cover about 40 % of the population.

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ANNEX A2: EXAMPLES OF LPDN TOPOLOGY DEPLOYMENT

A2.1 Arqiva UHF network in Oxford

The Arqiva DVB-H network in Oxford comprises 8 DVB-H low/medium power transmitters (100 W-350 W ERP) operated in an SFN mode on channel 31. It should be noted that Oxford's DVB-T services are provided by a main transmitter sited 6 km outside the city, with ERPs of around 8 to 10 kW. The DVB-H system variant used is QPSK, Code Rate 1/2 and Guard Interval 1/4.

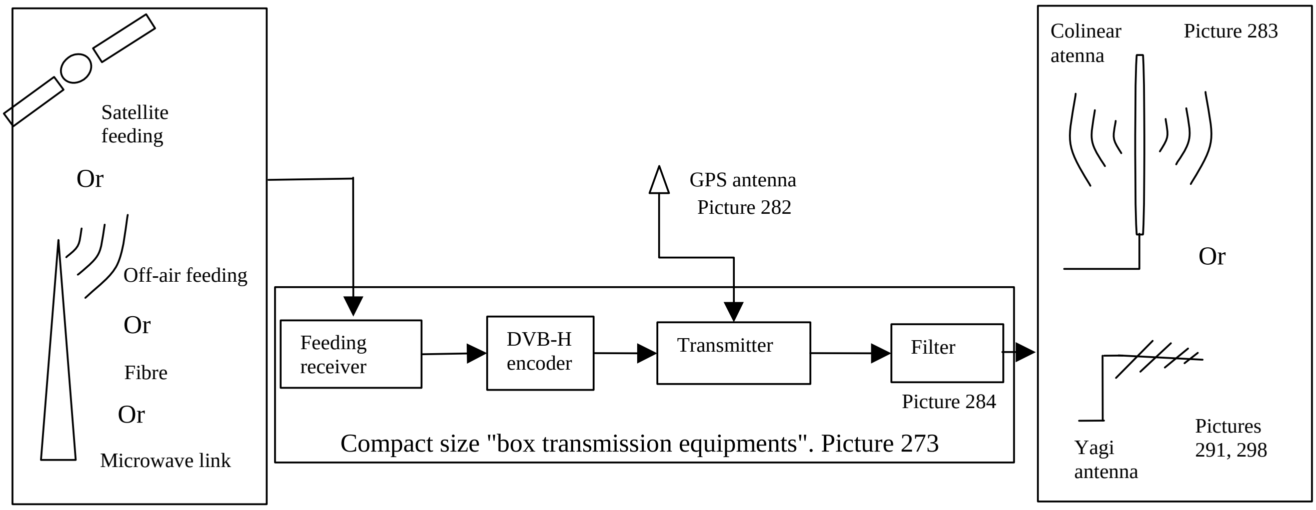

Figure A2.1: Simplified block diagram of a typical site of the LPDN topology

Photo 273 shows the "box transmission equipment" of one given transmitter (Cantay House, shown on the Map in Figure A2.2)

The transmitter of the Cantay House site delivers a 110 W signal using two amplifiers. A selective filter (see Photo 284) is used to comply with the critical mask of the DVB-H RF signal. The antenna used is a Colinear antenna made with four dipoles (see Photo 283). The antenna has 5 dBd gain. The resulting ERP (taking into account the transmitter power, the filter insertion loss, the feeder loss and the antenna gain) is 250 W. The radiation pattern is omnidirectional. The antenna is at 21 m above ground level.

Other sites of the network were equipped with Yagi antennas to have a directional pattern (see photos 291 and 298.

The SFN synchronisation is performed using the GPS signal. Photo 282 shows the GPS antenna used.

Photo 273

Photo 284

Photo 283

Photo 291

Photo 298

Photo 282

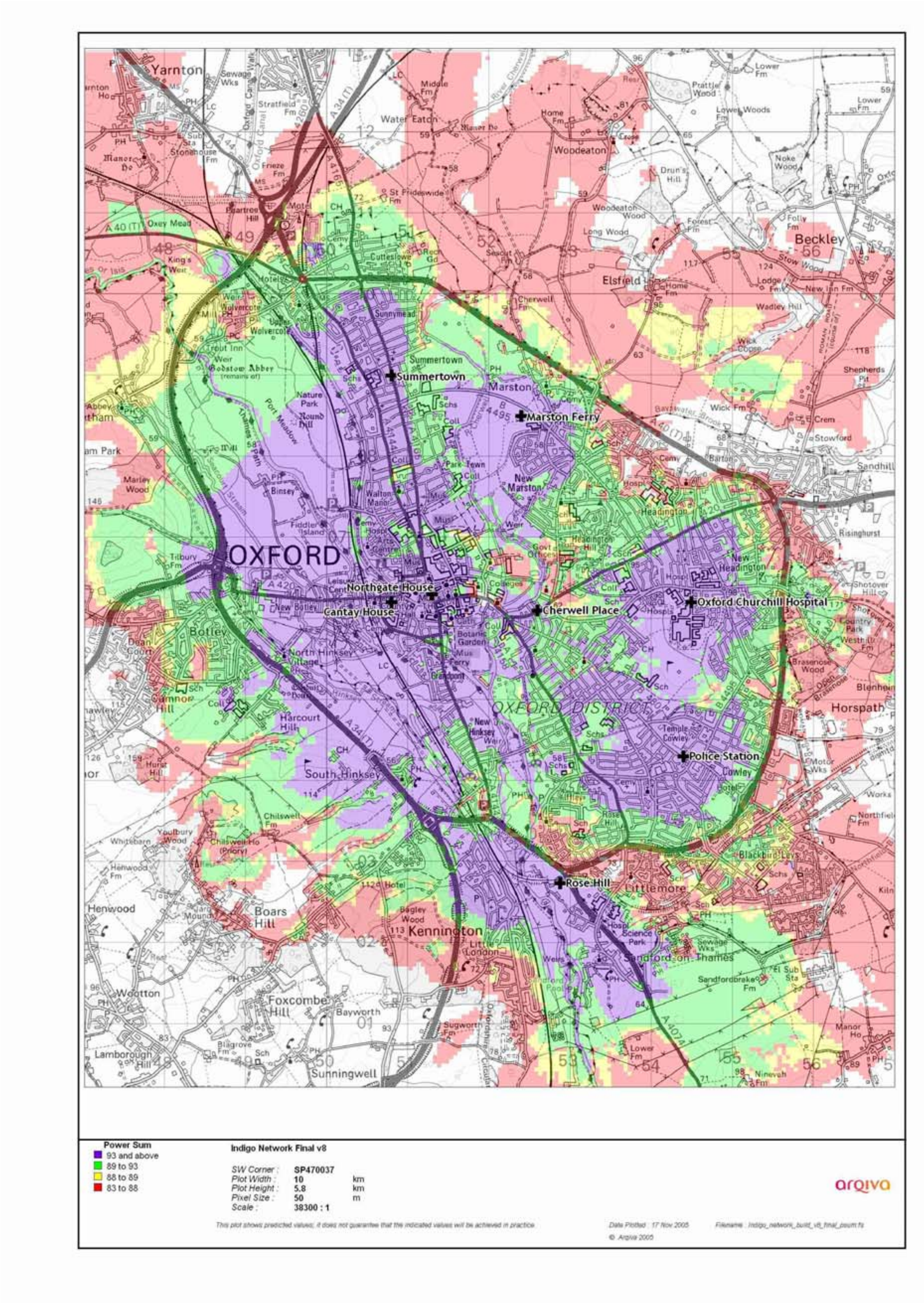

Figure A2.2: Map of the DVB-H network in Oxford

A2.2 Teracom network in Stockholm

From October 2006 to January 2007 Teracom and partners performed a commercial DVB-H pilot in Stockholm. The main purpose with the pilot was to evaluate commercial aspects and user behaviour. However, the network was in operation some months both before and after the commercial pilot period. During that time also some technical aspects were evaluated.

Network Topology & System parameters

The network was designed for handheld portable indoor coverage in downtown Stockholm and in the suburb of Sundbyberg, where Teracom has its office.

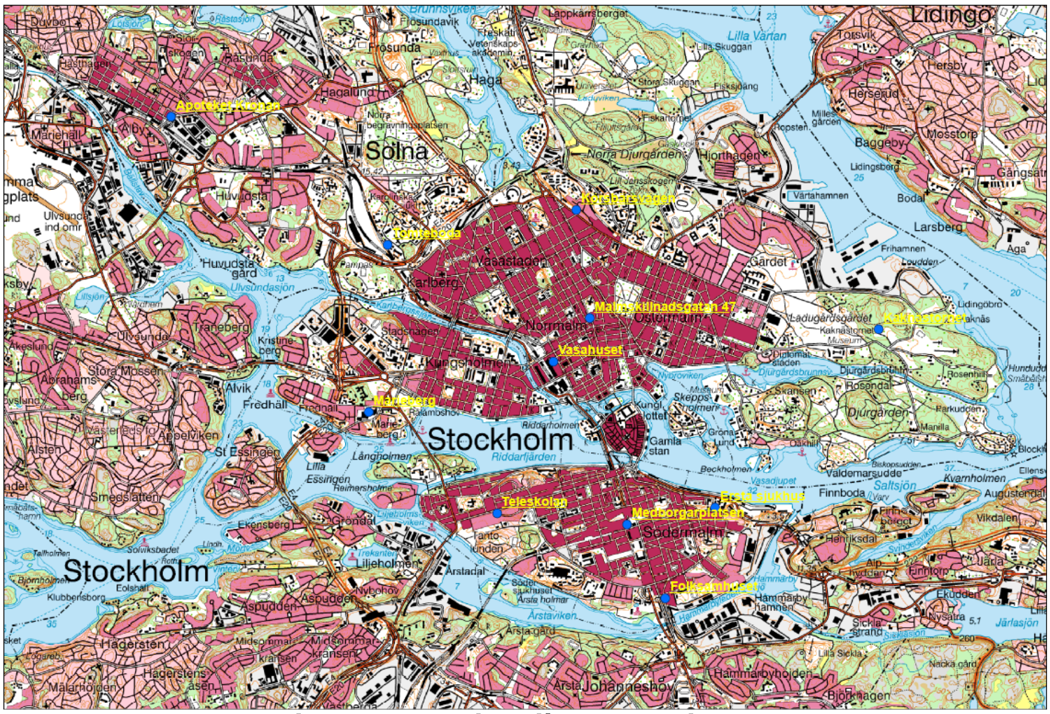

Figure A2.3: The pilot network area

The network consisted of 11 transmitter sites with ERPs between 200 W and 2.5 kW.

All transmitters but one used vertical polarisation. The transmitter using horizontal polarisation is also used for the regular DVB-T transmissions. The other 10 transmitter sites were exclusive DVB-H sites, not used for any other broadcast transmissions. All but one of those 10 where located in sites belonging to different mobile operators but with Teracom as owner of the DVB-H installation itself.

The 11 transmitters operated in an SFN on channel 28. They were all fed from the main broadcast transmitter station “Stockholm Nacka” on channel 64. The latter station didn’t contribute to the coverage but was used for feeding only and is not shown in Figure A2.3.

<u>System parameters:</u>

Modulation: QPSK

Code rate: 1/2

Guard interval: 1/8

TS bit rate: 5.529412 Mbit/s

MPE-FEC: None

IP net bit rate: approximately 5.2 Mbit/s

Coverage aspects

Feedback from the test pilots with respect to coverage

The commercial pilot comprised approximately 400 consumers living within the coverage area, i.e. in downtown Stockholm or in the suburb of Sundbyberg. Generally, the consumers found the reception quality good or even very good within the whole coverage area.

Coverage in commercial and public buildings

Some coverage measurements in commercial and public buildings have been made. Those measurements indicate that to cover commercial and public buildings a high measured field strength level outside on street level is generally needed. When the measured field strength level outside on street level is in the range 80-90 dBµV/m or higher the coverage is generally good even inside relatively big buildings. However, the coverage is strongly dependent on the design of the building with respect to material and windows. An observation related to building design was that rooftop windows make it a lot easier to receive the DVB-H signal inside relatively big buildings.

A2.3 T-System Media & Broadcast GmbH T-DMB network in Germany

The M&B network for MFD (Mobiles Fernsehen Deutschland) was established originally for the FIFA World Championship in Germany, June 2006. In a first step, 15 cities/areas were covered by small networks of 2-6 transmitters with an ERP of 2-4 kW. It is planned to extend the number of coverage zones in the coming years for cities with more than 120,000 habitants. The current coverage areas can be found at http://www.mfd-tv.de/index.php?id=110, where there is a link to the "Mobile TV-locator".

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ANNEX A3: ZERO dB ECHO ISSUE

The advantage of using SFNs is that they provide signal diversity. This is particularly important in the case of indoor reception since reception from many signal sources will increase the probability of reception due to the network gain.

However from a reception point of view the use of two or more transmitters means that several copies of the same signal may be available at the receiver input, and if these signals have more or less the same power level the situation is referred to as a “zero dB echo”, which could cause reception problems.

If the zero dB echo receiving situation occurs, the resulting signal will become more “complex” since two signals (with corresponding differing amplitudes and phases) are physically added, creating a more difficult “radio channel”. This will result in large amplitude variations across the signal bandwidth of 8, 7 or 1.5 MHz. Some parts of the bandwidth are amplified while others are attenuated. This happens if the individual COFDM carriers are phase shifted by 180 degrees. In particular, under unfavourable receiving conditions, a substantial part of the bandwidth maybe affected. This may occur for example when the time delay between the two signals is small.

At the receiver side such “complex” signals become more difficult to decode and may result in a need for a higher requirement for C/N in order to ensure proper decoding. The increase in required C/N will vary with the system variant (modulation and code rate). For the more robust system variants the effect is smaller compared to the less robust variants.

The increase in required C/N also depends upon the actual receiver used. Poor receiver design may also adversely effect the impact of a “zero dB echo”.

Wherever there are co-timed transmitters of equal power in a network there will be signals of nominally equal amplitude arriving close to a line midway between the transmitters. In this area, dependent on the actual distance to the contributing transmitters in terms of wavelengths, signals will add and subtract and because of the relatively small time difference when signals subtract this will occur over quite a large bandwidth, resulting in a flat fade. Large numbers of carriers maybe damaged and signal integrity is lost.

The worst case occurs when two signals of equal amplitude are present. As more signals contribute, the probability of signal cancellation decreases. Consequently the effect is most pronounced in open areas, illuminated by a small number of (2 off) transmitters. In urban areas where many echoes are present, or if there are more than two transmitters serving the area, the effect will be small.

Other mitigating methods are:

- Varying the power between transmitters in a network so that at equal amplitude the path difference is large. Although this does not prevent a zero dB echo, as the time difference is great, a flat fade is avoided.
- Delaying transmissions so that when signals are co-timed they are of different amplitude.
- Modifying the timing of a transmitter to move the problem into a non-critical area.
- Using a denser SFN, so that many signals of usable strength arrive at any given location.

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ANNEX A4: ILLUSTRATION OF THE POSSIBLE IMPACT OF AN INTRODUCTION OF A DVB-H NETWORK IN A DVB-T PLANNING SCENARIO.

A4.1 Introduction

Different engineering techniques can be employed to mitigate the problem of adjacent channel interference between DVB-T and multimedia broadcasting networks. This has been studied theoretically by assessing a co-existence scenario between DVB-T and DVB-H networks.

A4.2 Methodology

A4.2.1 DVB-T planning parameters

A single frequency DVB-T network consisting of 7 transmitters situated at the centre and at the vertices of a hexagonal lattice of 115 km in diameter has been considered. The service area is defined as the hexagon formed by the peripheral transmitters.

The transmitter antenna height h has been fixed to 150 m and the ERP of the transmitters - to 42.8 dBW.

The median field strength value of 56 dB(µV/m) required for fixed outdoor reception has been used.

A4.2.2 DVB-H planning parameters.

A single frequency DVB-H network deployed across a hexagonal lattice of 40 and 115 km in diameter has been considered.

4K QPSK 2/3 DVB-H system variant has been considered in the study. The minimum field strength has been fixed to 105 dB(µV/m) that corresponds to indoor floor level reception.

A4.2.3 Adjacent channel protection ratios

A protection ratio C/I of –40 dB has been used in calculations. This describes DVB-T adjacent channel protection for the second (N±2) adjacent channel.

The influence of polarisation discrimination Dpol of 16 dB due to horizontally polarised DVB-T signal and vertically polarized DVB-H signal has been studied as well.

A4.2.4 Propagation

Propagation calculations have been made at 650 MHz using Recommendation ITU-R P.1546. For distances less than 1 km a linear approximation (in logarithmic scale) has been assumed.

A4.2.5 Maximum allowable interfering field strength

The maximum allowed interference field strength ($E_{\max\text{int}}$) is calculated as follows:

$$E_{\max\text{int}} = E_{\min med} - LC - PR + D_{pol} = 99 \text{ dBµV/m},$$

where:

$E_{\min med}$ is the minimum median field strength of DVB-T service (56 dBµV/m);

LC is the propagation correcting factor for 95% of locations (13 dB);

PR is the protection ratio (-40 dB)

D_{pol} is the polarization discrimination (16 dB)

A4.2.6 DVB-H network optimisation

The power distribution to the DVB-H transmitters and inter-transmitter distances have been optimised in a simplified manner such that at a given location the DVB-H coverage is maximised for indoor reception up to the limits defined by “no disturbance” into the DVB-T service.

The simultaneous optimisation of power distribution and inter-transmitter distances allows the reduction of a total number of DVB-H transmitters required to cover the intended area.

An example of the optimised locations of DVB-H transmitters for a 40 km wide network is presented in Figure A4.1. The central transmitter is assigned with 50.5 dBW of ERP, whereas the transmitters in the 1st, 2nd and the 3rd circles with 46.5, 36 and 32.5 dBW, respectively. The antenna height of the central transmitter is assumed to be 150 m, for others, 37.5 m. There are in total 73 transmitters in the network with the total power budget of 58.3 dBW. For comparison, the total power budget for RPC 3 (RN1) in Band IV/V is 60.85 dBW.

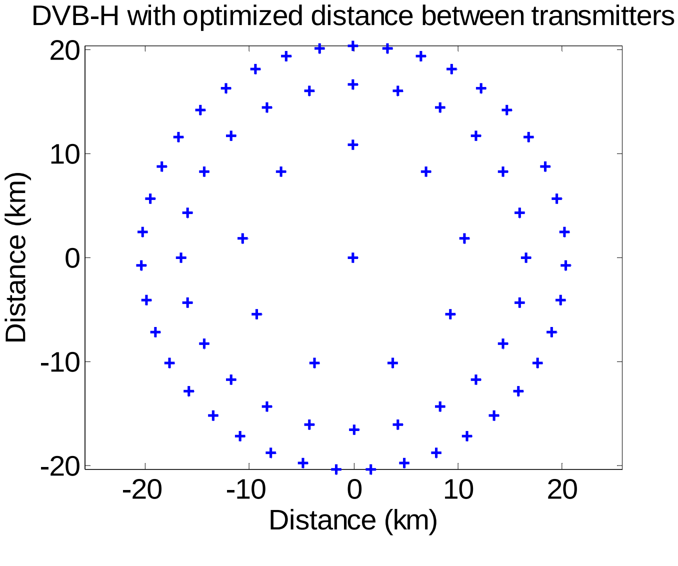


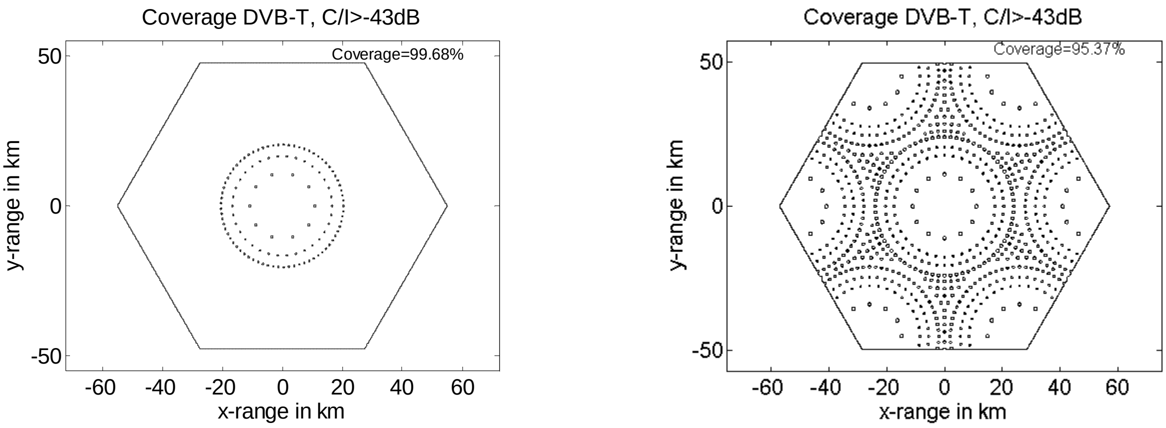
Figure A4.1: Optimised locations (blue crosses) of DVB-H transmitters in the network.

Optimisation of transmitter locations in the 115 km wide DVB-H network has resulted in a total of 715 transmitters in the network. Note, however, that the present optimisation of transmitter power levels and locations is used here for demonstration purposes only. It could certainly be further improved in terms of reducing the interference into the overlapping DVB-T service.

A4.3 Coverage

With the proposed topology optimisation the DVB-H networks covers 100% of the intended service area. The coverage of DVB-T network interfered with by the DVB-H network is shown in Figure A4.2. The DVB-T network serves 99.7% and 95.4% of its intended coverage area in the presence of DVB-H interfere from 40 km and 115 km wide networks, respectively.

As can be seen, the DVB-H transmitters “punch” holes in the DVB-T coverage. The size of the so-called exclusion zones is controlled by the employment of engineering measures such as the adjustment of the power levels of the interfering transmitters, their locations, antenna heights and use of polarisation discrimination. It should be pointed out that the use of mitigation techniques in this study has been applied within the limits of calculation facilities and the tools available. More thorough planning will give better results in terms of reduced interference into the DVB-T service.



40 km wide DVB-H network **115 km wide DVB-H network**

Figure A4.2: Service coverage of the DVB-T network in the presence of DVB-H interfere on an adjacent channel.

A4.4 Conclusions

Studying an implementation scenario of a simultaneous deployment of DVB-T and DVB-H networks it is demonstrated that both networks may reach a target coverage level. Detailed DVB-H and DVB-T network planning, including the employment of different mitigation techniques can achieve a reduction of interference from a DVB-H network into a DVB-T service on an adjacent channel.

It is also shown that a detailed optimisation of DVB-H network topology results in a reasonable number of transmitters required in serving the given area.