How can mobile and broadcasting Networks use adjacent bands?

Walid Sami
EBU TECHNICAL

The release of the band 790-862 MHz from broadcasting has started in several European countries and its use for LTE mobile networks is expected to become effective on a Pan-European scale in the next few years. Being immediately adjacent to the remaining UHF broadcasting band 470-790 MHz, interference may occur to broadcast reception from LTE base stations or user terminals using the band above 790 MHz. This article presents the theoretical studies performed in Europe by the CEPT in order to assess the *risk of interference* and to derive harmonised technical conditions that European Administrations will have to include in the licences for mobile network operators in this band, in order to reduce this risk as much as possible.

The article is intended to help regulators, inside and outside Europe, to understand the issue of adjacent-band interference from mobile networks into broadcasting networks, and to define adequately the means and the responsibilities for solving these problems when they occur.

1. Introduction

The UHF broadcasting spectrum is a resource which is "desired" by an increasing number of users, and the better spectrum efficiency of digital technology compared to analogue is often used as the main argument to reduce the spectrum allocated to broadcasting after the analogue switch-off. Development of other distribution means (historically cable and satellite and, recently, IPTV), depending on the countries, is another major argument used for this purpose. It is also argued that using the spectrum for electronic communications (e.g. mobile broadband) would generate larger economic and social benefits than if the spectrum continues to be used for broadcasting.

On the other side, terrestrial broadcasting is offering additional services which require spectrum resources, e.g. HDTV and possibly 3DTV in the future.

Several issues result from this situation, in particular:

- tighter planning of broadcasting networks is required, with a possible need to revise some planning principles;
- appropriate limitations on new users and sometimes additional protection measures are required to ensure protection of broadcasting from interference.

Abbreviations

3DTV	3-Dimension Television
ACLR	Adjacent Channel Leakage Ratio
ACS	Adjacent Channel Selectivity
ACT	Association of Commercial Television in Europe http://www.acte.be
BEM	Block Edge Mask
BNE	Broadcast Networks Europe http://www.broadcast-networks.eu/
CENELEC	European Committee for Electrotechnical Standardization http://www.cenelec.eu
CEPT	*Conférence Européenne des Postes et Télécommunications* (European Conference of Postal and Telecommunications Administrations) http://www.cept.org/
DigiTAG	Digital Terrestrial Television Action Group http://www.digitag.org/
DTT	Digital Terrestrial Television
ECC	(CEPT) Electronic Communications Committee
ECN	Electronic Communications Network
EIRP	Effective Isotropic Radiated Power
EMC	Electromagnetic Compatibility
ETSI	European Telecommunication Standards Institute http://pda.etsi.org/pda/queryform.asp
FDD	Frequency Division Duplex
GPS	Global Positioning System
HDTV	High-Definition Television
IMT	International Mobile Telecommunications
IPTV	Internet Protocol Televison
ITU	International Telecommunication Union http://www.itu.int
LTE	Long Term Evolution (4th generation mobile networks)
MFCN	Mobile and Fixed Communications Network
OOB	Out-Of-Band
PR	Protection Ratio
RSPP	Radio Spectrum Policy Programme
Rx	Receiver
SINR	Signal to Interference and Noise Ratio
TDD	Time Division Duplex
TS	Terminal Station
Tx	Transmitter
UMTS	Universal Mobile Telecommunication System http://www.umts-forum.org/
WRC-07	(ITU) World Radiocommunication

The World Radiocommunication Conference in 2007 (WRC-07) allocated 72 MHz from 790 to 862 MHz in Region 1 (which includes Europe) to mobile services on a co-primary basis with broadcasting. The allocation shall come into effect from 17 June 2015 and is immediate in a number of countries in Region 1. In addition, this same band in Regions 1 and 3 (which includes Asia-Pacific countries) is identified for use by administrations wishing to implement International Mobile Telecommunications (IMT) [1].

In accordance with this decision of WRC-07, several activities have been started in Europe by the European Conference of Postal and Telecommunications Administrations (CEPT) to define the technical conditions for the implementation of mobile services in the band concerned. Also, according to Resolutions 749 and 224 of WRC-07, studies have started in the ITU-R sector to assess the conditions for sharing between mobile services and existing services in the band concerned and the adjacent bands. Some studies and field tests have also been carried out in Sydney jointly by Free TV Australia and the EBU.

Currently, several European Administrations are preparing the licensing regimes for mobile service applications in the band 790-862 MHz. For this, they are considering the application of ECC decision (09)03 (30/10/2009) [1]. This decision was based on the detailed studies carried out by CEPT/ WGSE/PTSE42 between October 2008 and September 2009. The outcome of these studies was published in CEPT Report 30 (30/10/2009) [2].

The term ‘digital dividend’ corresponds in Europe to the band 790-862 MHz which is being released from broadcasting and will be used for mobile services in the future – in most, if not all, European countries.

1. Additionally, since WRC-07, an allocation has applied to several Asia-Pacific countries including China, Korea, Japan and New Zealand. Under Footnote 5.313B, the band 698-790 MHz is also identified for use by administrations wishing to implement IMT. It should be noted that this footnote also states *“This identification does not preclude the use of these bands by any application of the services to which they are allocated and does not establish priority in the Radio Regulations. In China, the use of IMT in this band will not start until 2015.”*

It should be noted that the mobile allocation in the digital dividend spectrum is strongly supported by the European Commission. CEPT Report 30 has been developed on the basis of the EC mandate to CEPT. The Commission has issued several documents (e.g. Communication COM(2009)586, Recommendation C(2009) 8287 and Decision 2010/267/EU [1]) which culminated in the proposed RSPP. The main objective is to make the mobile allocation mandatory in the EU countries by 1st January 2013.

This article attempts to explain the objectives, methodologies and results of the technical studies carried out on this subject. A good understanding of these aspects can help the stakeholders, especially regulators, to define adequate measures in the licences of the digital dividend users towards a good protection of the broadcasting services from interference. Several European Administrations have already started the process of defining these measures and they might find useful the explanations given in this article.

2. Sharing issues: studies in CEPT and the ITU

Following the WRC-07 decision in November 2007, several actions have been launched in the ITU and CEPT to study the sharing between mobile services in the upper UHF band and broadcasting services in the same band and in the lower adjacent band. Here are the working groups which have worked on this subject:

In Europe, several groups have been active and have produced several reports:

- **ECC/TG4** has produced several reports[2] on the technical aspects of the Digital Dividend. The main outcome of this group has been the proposal of reverse duplex and the development of a set of protection ratios for DTT interfered with by UMTS and LTE mobile telecommunications systems.
- **ECC/PT1** has defined the channelling arrangements for FDD and TDD systems[3].
- **SE42** has identified common and minimal (least restrictive) technical conditions for 790-862 MHz for the Digital Dividend in the European Union[4].

The content of CEPT Report 30, output of SE42, is presented in more detail later in this article.

ITU WP6A is completing the set of parameters required for the sharing studies (protection ratios and protection requirements).

Work was still ongoing at the end of 2010 on the revision of Recommendation BS.1368 including protection ratios from mobile systems into broadcasting and protection ratios for DTT silicon tuners.

ITU-JTG 5/6 has focussed on cross-border coordination issues. The main issue was the cumulative interference from a large number of cellular base stations, co-channel with broadcasting, in neighbouring countries.

The ITU-JTG 5/6 produced the CPM text related to agenda item 1.17 and a compendium of all technical studies submitted to the JTG 5/6 including those related to adjacent-band issues.

In addition, a joint working group **CENELEC-ETSI JWG** has been invited by the European Commission to update the relevant standards in order to improve the immunity (Electromagnetic Compatibility, EMC) of broadcasting receivers and cable networks from direct radiation from mobile equipments.

2. CEPT Report 22 and its complementary report 23, ECC reports 138 and 148
3. CEPT Report 31
4. CEPT Report 30

3. Consideration of channelling arrangements

Channelling arrangements were required in order to identify the possible spectral configurations to be considered in the studies. For this purpose, a reverse duplex configuration (e.g. the frequency sub-band used for mobile uplinks is above the sub-band used for downlinks) has been adopted as a preferred option in Europe for the FDD systems to be implemented in the Digital Dividend band. The reasons behind this decision were the following:

- A need to reduce the risk of adjacent-channel interference from the transmissions of mobile handhelds into portable DTT reception at short distances. Interference from mobile terminals is more difficult to predict and mitigate than from base stations. Increasing the frequency separation by adopting the reverse duplex reduces this risk.
- A need to reduce the risk of adjacent-channel interference from DTT high-power transmitters into reception of uplink signals at the mobile-service base stations. This is also ensured by increasing the frequency separation between DTT and the mobile uplink channels.
- The required guard band between the downlink and the adjacent DTT channel is smaller than between mobile uplink and DTT, provided that suitable technical conditions and mitigation measures are implemented.

For TDD systems, the uplink signal uses the same frequency as the downlink. It was therefore mandatory to define a larger guard band with regard to the DTT channel, as shown in the channelling arrangements adopted in CEPT Report 31 [3] *(see Tables 1a and 1b)*.

Table 1a
Preferred harmonized chanelling arrangement for the band 790-862 MHz in Europe

790-791	791-796	796-801	801-806	806-811	811-816	816-821	821-832	832-837	837-842	842-847	847-852	852-857	857-862
Guard band	**Downlink**						Duplex gap	**Uplink**					
1 MHz	30 MHz (6 blocks of 5 MHz)						11 MHz	30 MHz (6 blocks of 5 MHz)					

Table 1b
TDD chanelling arrangement for the band 790-862 MHz in Europe

790-797	797-802	802-807	807-812	812-817	817-822	822-827	827-832	832-837	837-842	842-847	847-852	852-857	857-862
Guard band	**Unpaired**												
7 MHz	65 MHz (13 blocks of 5 MHz)												

4. Brief summary of the field tests carried out in Sydney in August 2008 and January 2009

A joint action was carried out in Australia by EBU TECHNICAL and Free TV Australia in August 2008 and January 2009, with the aim of benefiting from the first operational UMTS 800 MHz network already implemented anywhere. This would allow assessment of the real risk of interference from a UMTS network into DTT in the lower adjacent band. This action included field tests using real UMTS signals in suburban and urban areas and laboratory measurements. The detailed report has been submitted to the ITU-R JTG5/6 and is publicly available for downloading [4]. The tested configurations are shown in *Fig. 1*.

The main outcome of these tests can be summarized as follows:

With regard to transmissions from base stations, i.e. the downlink:

- The impact from base stations on the DTT roof-top reception could be significant and measures are needed to mitigate the risk of interference when implementing a mobile network in an area covered by an adjacent broadcasting channel;

- A limitation to the out-of-band emissions from the base stations is required. Also a guard band[5] of between 1 and 5 MHz would be required to reduce the number of possible interference cases;
- Additional measures, called mitigation techniques, would be needed on a case-by-case basis to solve the possible interference cases: for example, use of cross polarization, reducing the base station EIRP, use of low-pass filters in the DTT receiving installation or increasing the DTT signal level to overcome the interference.

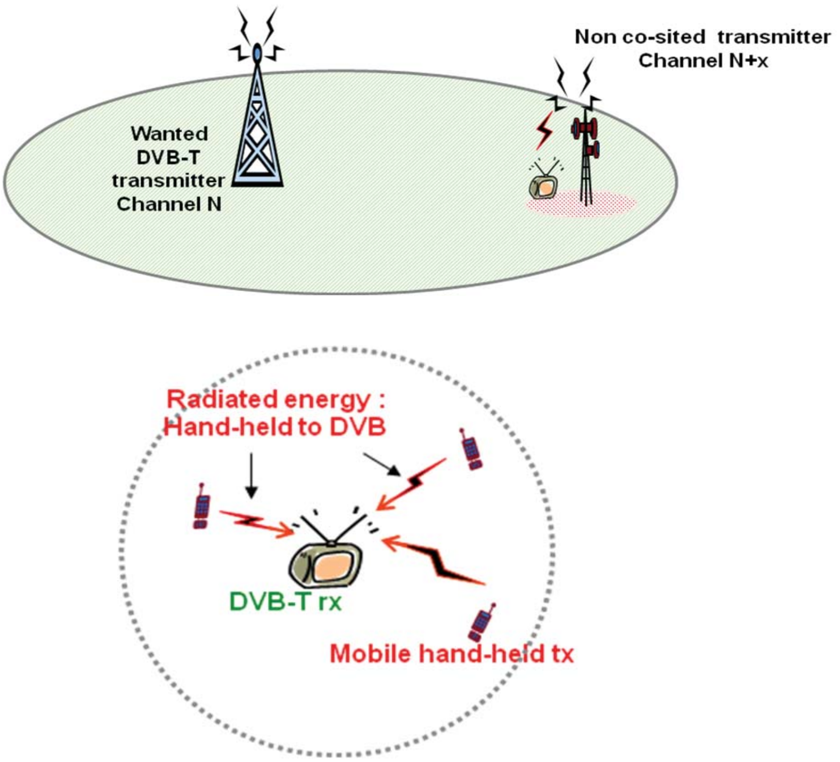

Figure 1
Possible interference configurations between mobile services and broadcasting
(Upper) **Interference from base stations:** *(Lower)* **Interference from mobile terminals**

With regard to transmissions from mobile terminals:

- The impact from mobile terminals is particularly critical on portable indoor reception of DTT.
- A limitation to the out-of-band emissions from mobile terminals is required. Also a relatively large guard band is needed between the DTT channel and the uplink channel (between 7 and 21 MHz). In this respect, the reverse duplex adopted in Europe provides a sufficiently large guard band (42 MHz).
- The main mitigation technique to solve possible interference cases is to use low-pass filters at the input of the DTT receiver to reject the uplink channels.

It should be noted that the channelling arrangement in Australia, and the decision to avoid using channels 68 and 69 in DTT planning, creates a de facto guard band of 19 MHz between the last effective DTT channel and the first UMTS uplink channel. Furthermore, the only channel in operation is the second one, which is separated by 24 MHz from the last effective DTT channel.

5. Common and minimal (least restrictive) technical conditions for re-use of the 790-862 MHz band in the European Union

This section presents the outcome of the studies carried-out between October 2008 and September 2009 by the CEPT/SE42 group in Europe, with regard to the compatibility between Mobile and Fixed Communications networks on the one hand and the broadcasting service on the other hand, in adjacent bands. The results are intended for inclusion in equipment standards and in the licensing regimes for future users of the Digital Dividend spectrum.

5. “Guard band” is the frequency separation between the upper edge of one service and the lower edge of another service to achieve frequency planning compatibility between these services.

NB: Most of the figures in the following sections are taken from CEPT Report 30.

Firstly, here are some definitions:

Block-Edge Mask (BEM)

The BEM consists of a set of in-block and out-of-block emission limits for the interfering signal, for different frequency offsets relative to the wanted signal.

Adjacent Channel Leakage Power Ratio (ACLR)

ACLR is a measure of transmitter performance. It is the ratio of an interfering transmitter's mean power within its assigned channel to its mean power within an adjacent channel.

Adjacent Channel Sensitivity (ACS)

ACS is a measure of receiver performance. It is the ratio of the received power from a given source in an assigned channel ("in-channel") to the received power from a given source in an adjacent channel ("out-of-channel") which passes through the receive filter.

ACLR and ACS are illustrated in *Fig. 2*.

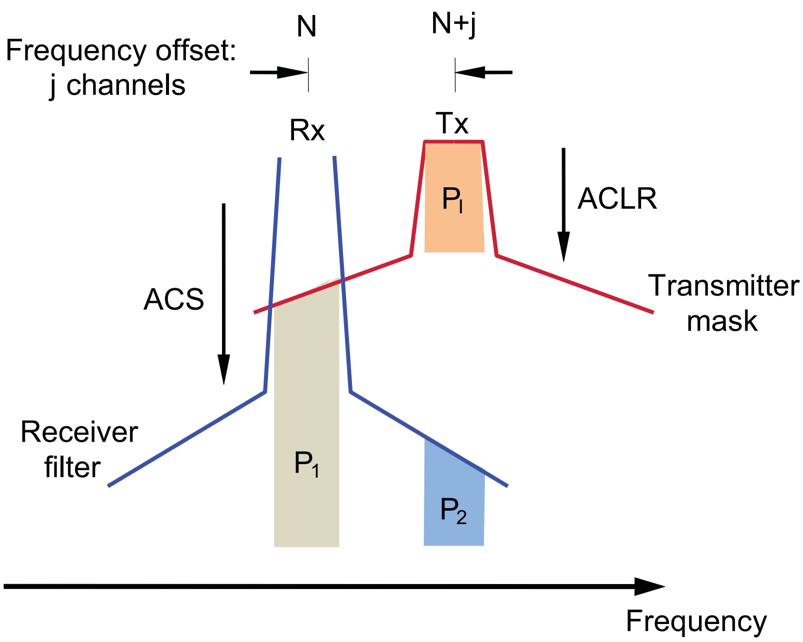

Figure 2
Illustration of ACLR and ACS

Relationships:

$$PR(\Delta f) = PR_0 + 10\log(10^{\frac{-ACS}{10}} + 10^{\frac{-ACLR}{10}})$$

$PR(\Delta f)$ is the protection ratio for DTT vs an interferer with an offset of Δf.

PR_0 is the protection ratio for DTT vs a co-channel interferer.

In *Fig. 2*, the out-of-block signal (P1) falling in the DTT channel gets into the DTT receiver without any attenuation whereas the in-block signal of the base station (PI) gets into the DTT receiver after being attenuated by the selectivity of the receiver (P2). Interference occurs when the ratio of signal to total power resulting from these two components and noise at the receiver input falls below the minimum required level.

5.1. Derivation of the BEM applicable to base stations

Due to the cellular network architecture used for the mobile service coverage, a base station using an adjacent channel to that of a DTT transmitter can be located anywhere in the coverage area of this DTT transmitter. Its signal can therefore be received at a high level by the DTT receiving installation nearby. A critical situation for example consists in having the base station located between the DTT transmitter and the receiving installation (no angular discrimination) and when the same polarization is used by both systems, as shown in *Fig. 3*.

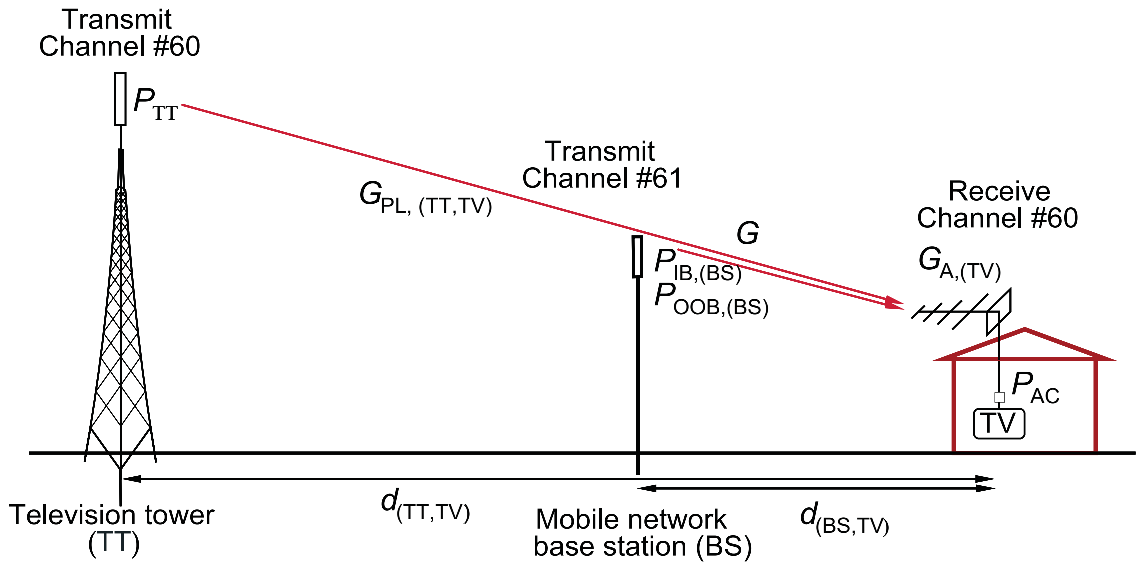

Figure 3
Interferer geometry in the case of no angular discrimination

An example of cellular deployment in the 800 MHz band is shown in *Fig. 4*. It is located in St-Clair, Sydney, Australia. The cells' boundaries were assessed using GPS coordinates and a cell phone with a software providing cell-IDs. The average cell radius was around 1.2 km.

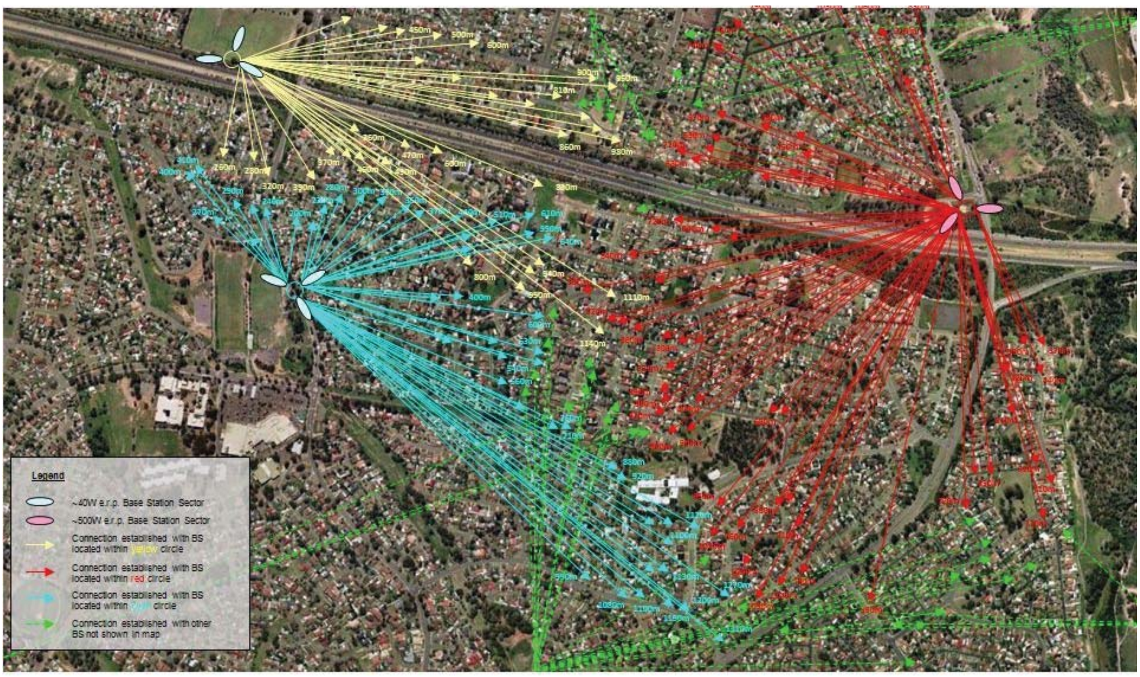

Figure 4
Example of mobile network coverage

The effect of interference can be shown in terms of a resulting reduction of the location probability for DTT. Compared to a planned DTT service, for say 95% locations in the absence of interference, the resulting location probability will be reduced when interference from the mobile service base station is added, as shown in *Fig. 5*.

The largest reduction occurs as expected in the vicinity of the base station where the interference is the highest. Then the location probability recovers progressively when moving away from the base station. The variation of the location probability depends on several parameters: in particular, the in-block and out-of-block transmit powers of the base station, the selectivity of the DTT receiver for the considered frequency separation, and the level of the wanted signal in the area.

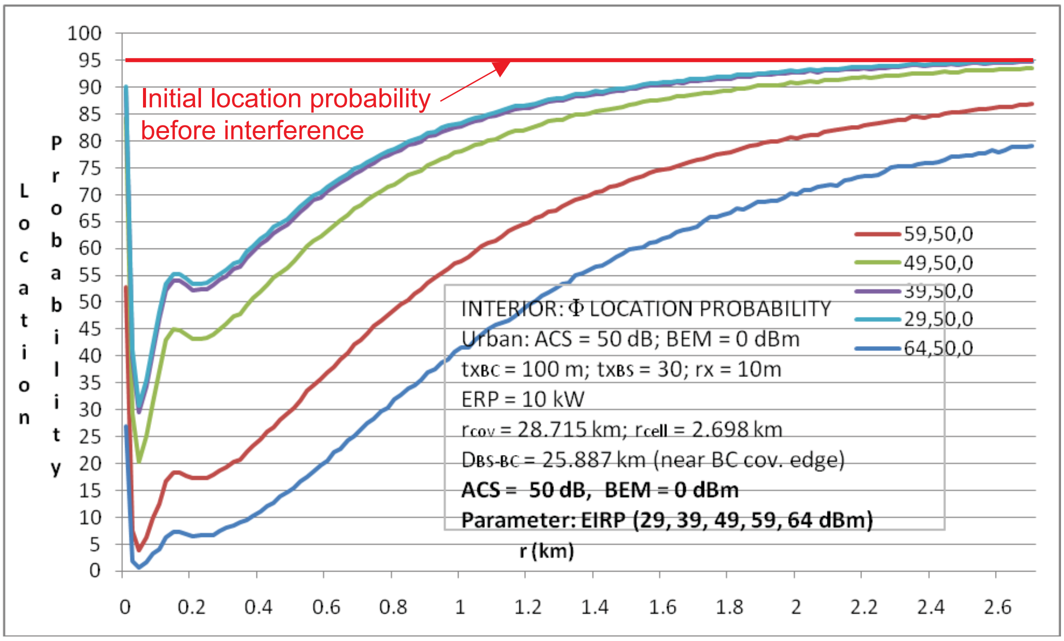

Figure 5
DTT location probability versus distance from the base station

When considering this location probability reduction in all radials, we get holes in the DTT coverage as shown in *Fig. 6* where peaks of interference are shown around each base station.

In fact, if we define the interference probability as the complement to 1 of the coverage location probability, then the holes are represented as peaks of interference probability. The height of a peak and the radius of the 'hole' vary with the location of the base station relative to the DTT transmitter, the largest peaks being located near the DTT coverage edge. On the contrary, holes could be reduced to zero near the DTT transmitter, where the wanted field strength is high enough to overcome the interference.

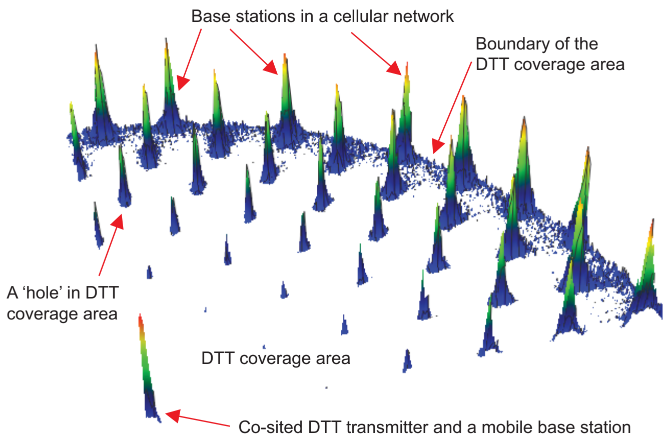

Figure 6
Interference from a network of base stations

The TV receiver is supposed to function correctly if :

$$SINR = \frac{P_s}{P_N + P_1 + P_2} \geq SINR_T$$

Where: P_S is the wanted DTT signal power at the receiver input;

P_N is the noise power at the receiver input;

SINR is the Signal to Interference Ratio at the DTT receiver input;

$SINR_T$ is the target Signal to Interference Ratio, required for reception;

P_1 is the interference power due to the out-of-block emission of the Base station, which is co-channel (CC) with the DTT channel *(cf: Fig. 2)*;

P_2 is the interference power due to the in-block emission of the base station, which is in the adjacent channel to the DTT channel *(cf: Fig. 2)*.

The interference probability can be assessed using numerical techniques (Monte Carlo simulation):

1) A simple configuration is used consisting of a ring of mobile network cells with a central base station and six surrounding base stations, as shown in *Fig. 7*;
2) A large number (tens of thousands) of random locations are generated within the central base station cell area;
3) At each location, snapshots of the different signals (wanted signal from the DTT transmitter and unwanted signals from each of the base stations of the structure considered) are generated using suitable propagation models and corresponding statistical distribution with location;
4) The protection condition above is checked at each location and the ratio between the interfered locations (e.g. locations where protection criteria is not met) and the total number of locations in the cell area gives the interference probability.

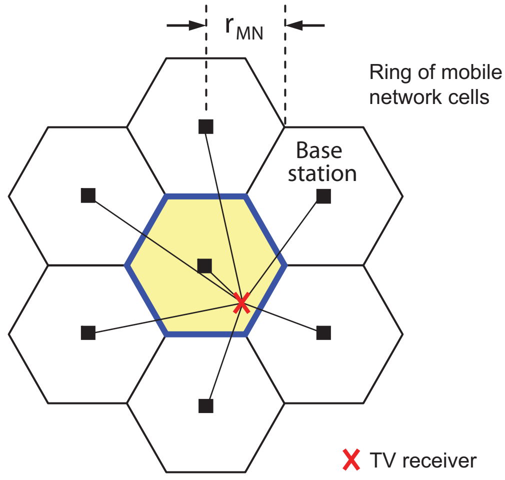

Figure 7
Monte Carlo simulations to calculate the interference probability

Example: An interference probability of 10% means that in 10% of the base station cell area, the broadcasting receivers could be subject to interference from the base station. It should be noted that the interfered locations are concentrated around the base station.

The simulation is repeated by moving the basic structure across the DTT coverage area, as shown in *Fig. 8*. The resulting figure of overall interference probability is therefore the average between the worst cases, corresponding to the edge of the DTT coverage area, and the best cases corresponding to locations close to the DTT transmitter.

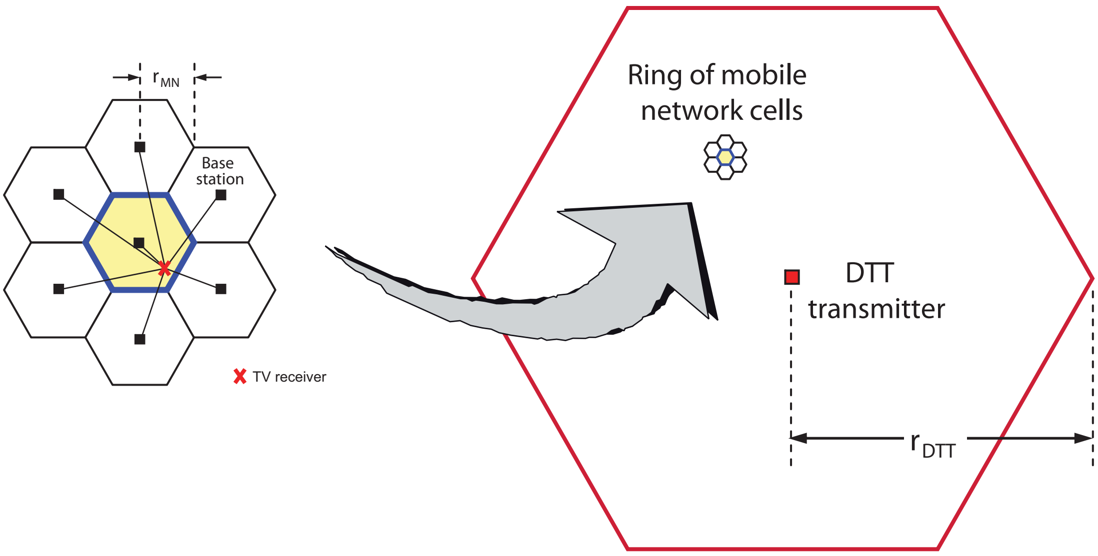

Figure 8
Averaging through the DTT coverage area

The variation of overall interference probability (or failure rate) with the out-of-block emission level can then be calculated and represented in the form of a curve, as shown in Fig. 9.

It can be seen that the interference probability across the DTT coverage area does not improve significantly with a reduction of the out-of-block emission level of the base station below 0 dBm/8 MHz.

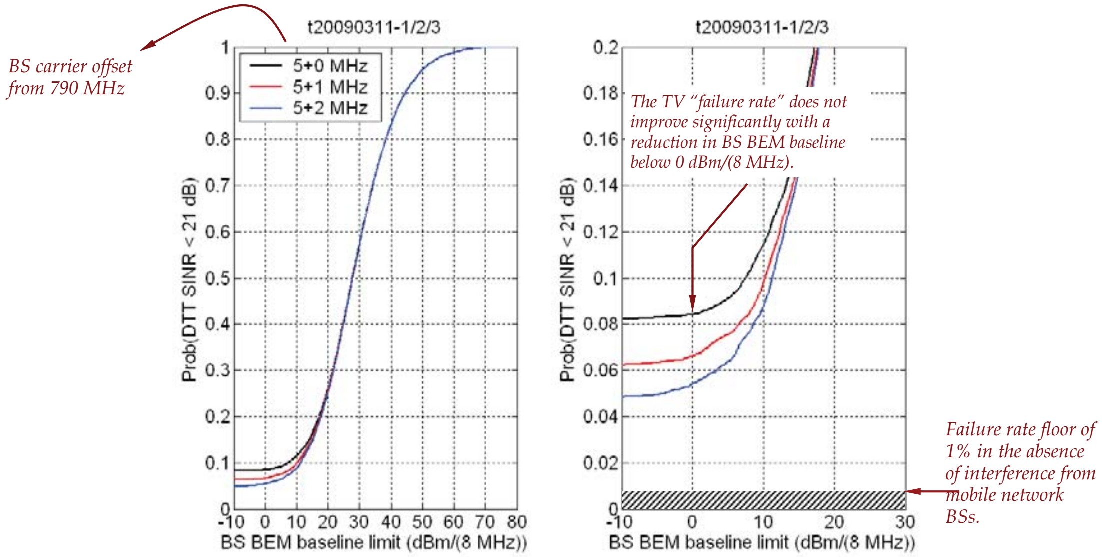

Figure 9
Interference probability across DTT cell for fixed reception
1st adjacent channel (guard bands of 0, 1, 2 MHz)

It can also be seen that a guard band improves the protection to some extent. However, the choice of the final figure for the guard band (1 MHz) in the channel arrangements has been made as a compromise between the improvement that it provides and the loss of spectrum-use efficiency that it causes.

This way of "measuring" the effect of the out-of-block emission level can then be used to measure the effect of other parameters, with the general aim of reducing the interference probability on DTT as much as possible. *Fig. 10* shows the effect of TV receiver ACS (Adjacent Channel Selectivity).

The DTT receiver selectivity is shown to have a major effect on the interference probability. Improving the ACS by 10 dB from the nominal figure of 50 dB would divide the interference probability by more than three times.

Another important parameter is the EIRP of the base station. The value of 0 dBm / 8 MHz for the out-of-block emission level is suitable for high-power base stations as the contribution of the in-block

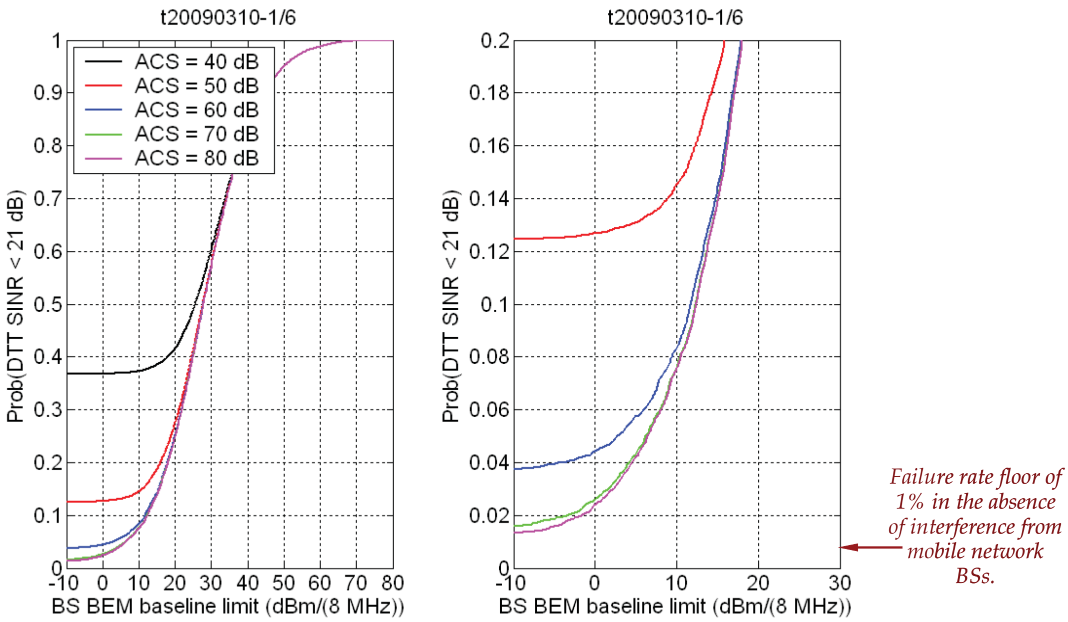

Figure 10
Probability of failure rate as a function of BEM baseline limit and TV receiver ACS (nominal values)

power due to the finite selectivity of the DTT receiver is high enough to mask the effect of reducing the out-of-block power. However, when the BS power is reduced, the contribution of the out-of-block emission becomes predominant. This is clearly shown in *Fig. 11*.

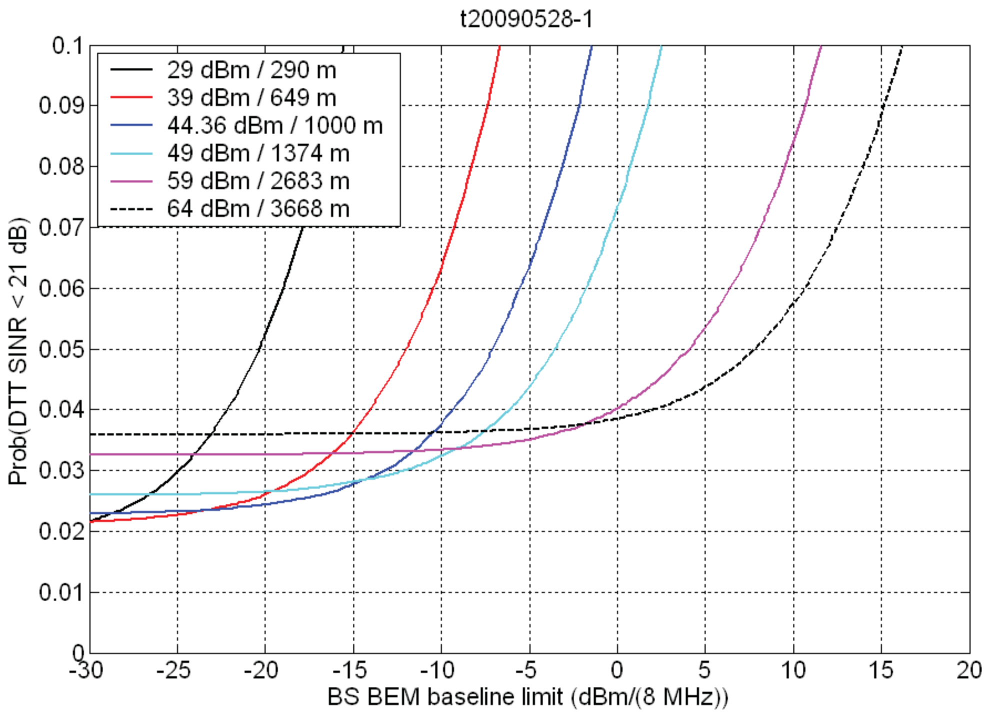

Figure 11
Failure rate as a function of BEM baseline limit for different BS EIRPs/cell radius

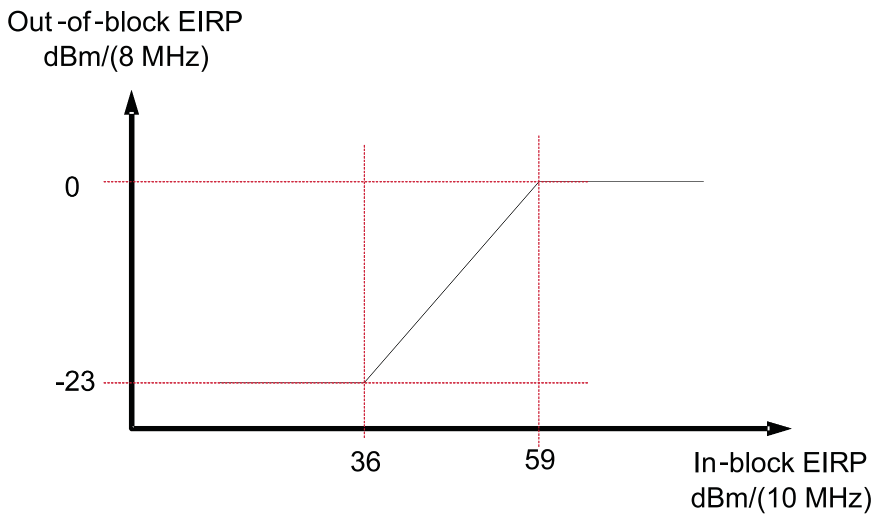

Figure 12
Out-of-block power limits of the base station

Therefore, the out-of-block emission limit should be related to the base station's in-block power.

The specified out-of-block emission limit is shown in *Fig. 12* and *Table 2*. A fixed level of 0 dBm / 8 MHz is specified for high-power base stations greater than 59 dBm EIRP, i.e. around 800 W. For lower EIRPs, down to 36 dBm, i.e. around 4 W, a fixed attenuation of 59 dB is specified. Then below 36 dBm, another fixed level of -23 dBm / 8 MHz is specified.

In some countries, the Administrations may decide not to use some of the immediately adjacent channels for broadcasting (e.g. Ch60, Ch59) and can therefore decide to apply more relaxed specifications.

Three levels have been specified:

- For DTT frequencies where broadcasting is protected, levels are those based on the studies (Case A);
- For DTT frequencies where broadcasting is subject to an intermediate level of protection, the limits were relaxed by 10 dB (case B);

- For DTT frequencies where broadcasting is not protected, the limits were relaxed by more than 20 dB (case C).

Table 2
Baseline requirements – BS BEM out-of-block EIRP limits over frequencies occupied by broadcasting

Case	Frequency range of out-of-block emissions	Conditions on base station in-block EIRP, P (dBm/10 MHz)	Maximum mean out-of-block EIRP	Measurement bandwidth
A	For DTT frequencies where broadcasting is protected	P ≥ 59	0 dBm	8 MHz
		36 ≤ P < 59	(P-59) dBm	8 MHz
		P < 36	-23 dBm	8 MHz
B	For DTT frequencies where broadcasting is subject to an intermediate level of protection	P ≥ 59	10 dBm	8 MHz
		36 ≤ P < 59	(P-49) dBm	8 MHz
		P < 36	-13 dBm	8 MHz
C	For DTT frequencies where broadcasting is not protected	No condition	22 dBm	8 MHz

We can make the following comments on the approach used to derive the BEM of the base station:

1) The approach is based on an average case, whereas considerably worse cases than the average can exist in real situations. In order to show the effect of averaging the interference probability through the DTT coverage, the simulation made on a ring at the coverage edge shows significantly higher figures of interference probability – up to three times the average figure. This is shown in *Fig. 13* and by comparison with *Fig. 9*.

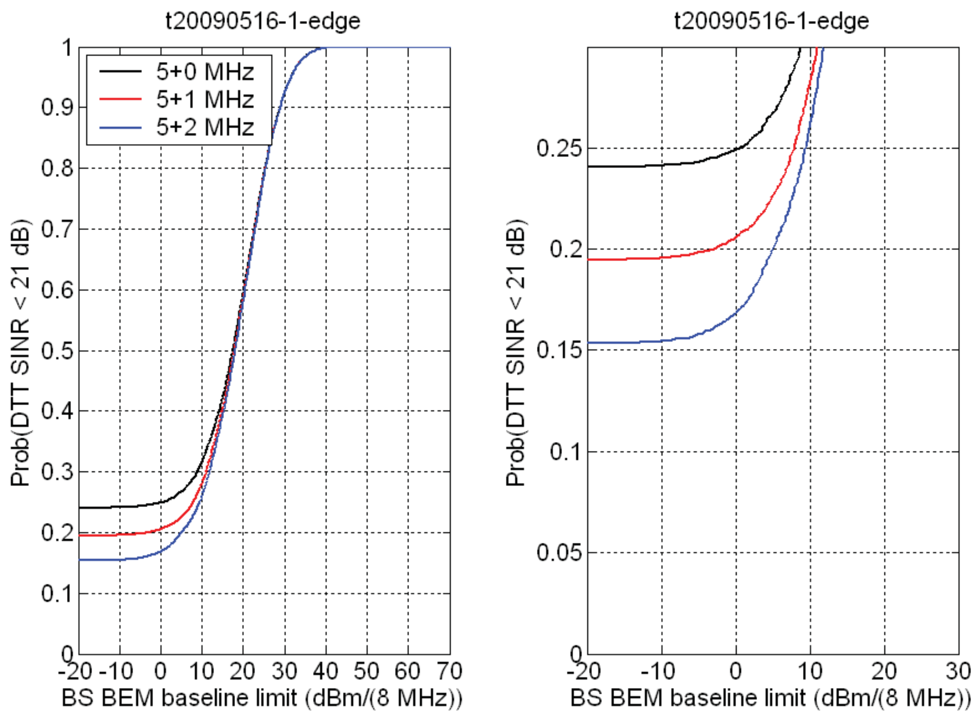

Figure 13
Failure rate at DTT cell-edge for fixed reception: 1st adjacent channel (guard-bands of 0, 1, 2 MHz)

Fig. 13 shows that, with a 1 MHz guard band, up to 20% of the base-station cell area could be responsible for causing interference to the broadcasting channel when the base station is located at the DTT cell edge, compared to 6.5% of the base station cell area on average when the base station is located randomly within the DTT cell area, given the same 1 MHz guard band.

2) The approach does not always provide the required level of protection for victim services (e.g. broadcasting);

3) In order to resolve the remaining cases of interference, additional *mitigation techniques* need to be applied.

5.1.1. Mitigation techniques

As shown in the field study described in *Section 4* and in the simulations described in *Section 5.1*, mitigation techniques are required either to further reduce the risk of interference or to solve the possible interference cases which would occur despite the application of the general measures in terms of out-of-band emission limitations.

For this, the following mitigation techniques can be used:

- To co-site base stations and DTT transmitters, so keeping the difference between the wanted and interfering signal constant everywhere;
- To use cross polarization, which gives up to 16 dB improvement in protection compared to co-polarization;
- To reduce the power of the base station;
- To improve the filtering of the base station transmitters (at 790 MHz), beyond the baseline specified in CEPT report 30;
- Adjusting the base station transmitter antenna characteristics (height, pattern, tilt and direction), taking into account local conditions, to decrease the interfering signals received in the vicinity of the base station;
- Installing rejection filters in the DTT receivers, to attenuate the interfering base station signal levels;
- Increasing the power of the DTT transmitters, to overcome the interference. This technique can also include adding DTT on-channel repeaters at base stations sites.

The effect of two mitigation techniques on the calculated interference probability is assessed and shown in *Fig. 14*: i.e. the use of cross polarization and the use of rejection filters. It is shown that

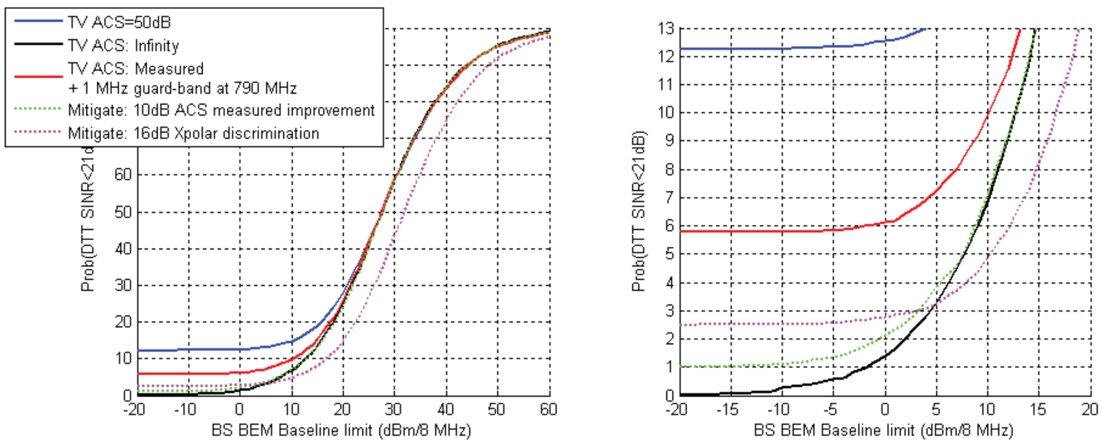

Figure 14
Summary of the different impact assessments on the probability of TV failure rate as a function of BEM baseline limit for EIRP BS of 64 dBm

both techniques improve significantly the situation. However, one major difference exists in the application: cross polarization requires only one action at the base station whereas the installation of rejection filters in the DTT receivers requires several actions for the viewers:

- communication with the users to identify the cases of interference;
- providing the filters to the users concerned;
- possibly an intervention at the user's premises to install the filters if required.

The cost can be significantly different between the two techniques.

On the other hand, the filtering solution has limitations: the response of a practical low-cost filter (as at the end of 2009) is shown in *Fig. 15*. The filter could provide approximately a 2 dB attenuation of the emissions (in a 10 MHz channel) centred at 797 MHz, 4 dB at 802 MHz, 10 dB at 807 MHz and greater than 20 dB at 812 MHz and above. This means that the effect of filtering can only be efficient (with 10 dB attenuation) for the second adjacent or third adjacent channel and beyond.

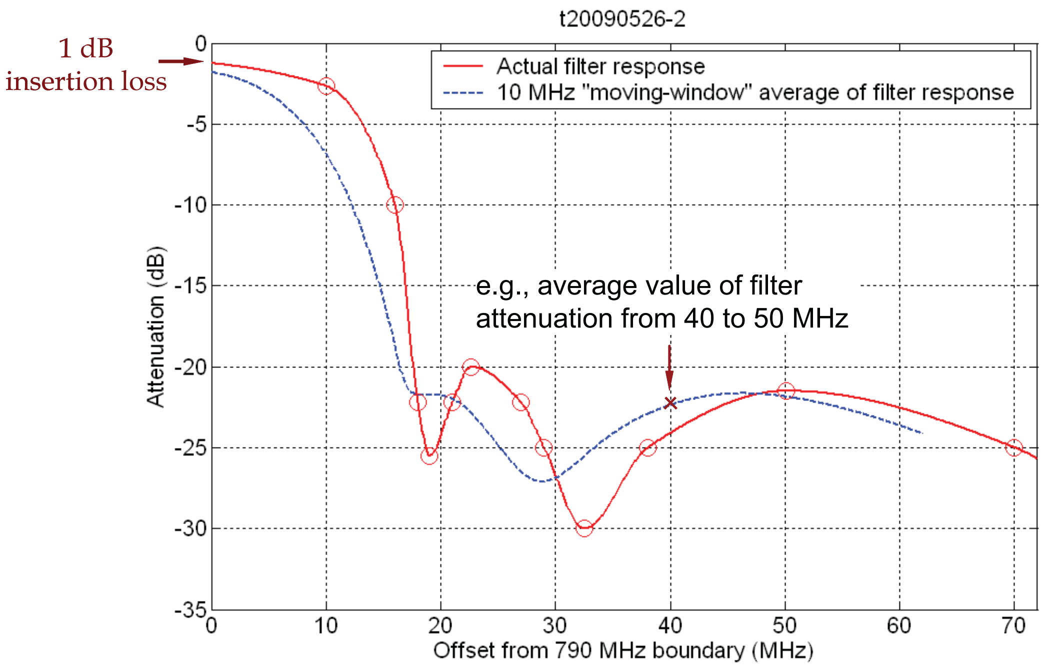

Figure 15
Practical 'low cost' band-edge TV filter (with an edge at 790 MHz), as at the end of 2009

5.2. Derivation of the BEM applicable to ECN terminal stations

Concerning the interference from mobile terminal stations into DTT fixed reception, the geometry of this scenario is shown in *Fig. 16*. We note the effect of the vertical radiation pattern of the DTT receiving antenna on the level of interference.

Due to this effect of the vertical antenna pattern, the worst configuration corresponds to a horizontal separation distance of 22m between the mobile terminal and the DTT receiving antenna. Analytical calculations can then be made to derive the out-of-block emission level of the mobile terminal, falling in the same channel as DTT, which causes a desensitization of the DTT receiver by 1 dB. This corresponds approximately to limiting the interference level to 6 dB below the noise floor. A guard band of 42 MHz is assumed, according to the agreed channelling arrangements.

With these assumptions, the out-of-block emission from the mobile terminal should be limited to -50 dBm /8 MHz (according to the calculations carried out in CEPT report 30).

Having calculated this out-of-block limit, simulations were made to assess the impact of the terminal station on DTT fixed reception for different frequency offsets with this out-of-block level of -50 dBm /

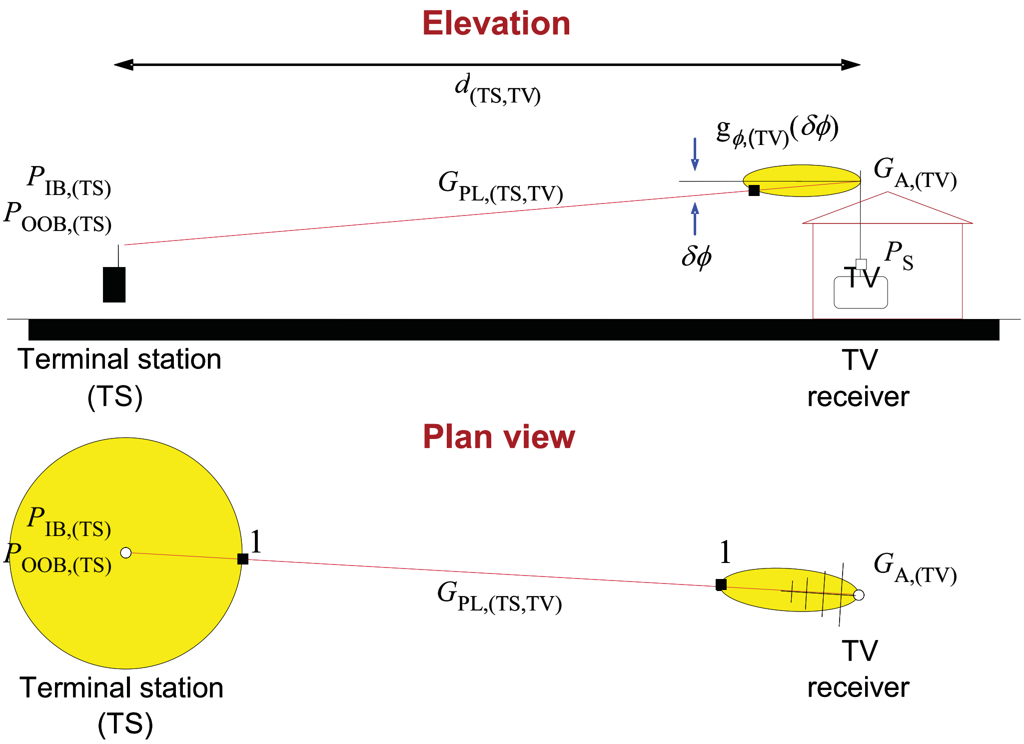

Figure 16
Terminal station to fixed roof top TV geometry

8 MHz. For this, a TV receiving antenna was randomly located in the DTT coverage area and an interfering mobile terminal was randomly located in a circular area around the TV receiving antenna at 40m radius, as shown in *Fig. 17*.

For each location, snapshots of the different signals are generated using suitable propagation models and corresponding statistical distribution with location. The protection condition is checked at each trial and the calculated ratio of interfered cases to total number of trials gives the interference probability. The resulting figure corresponds to an average case across the DTT coverage area, so there are cases where the interference probability is higher than the calculated figure. However this method does permit us to evaluate the effect of the different parameters on the interference potential.

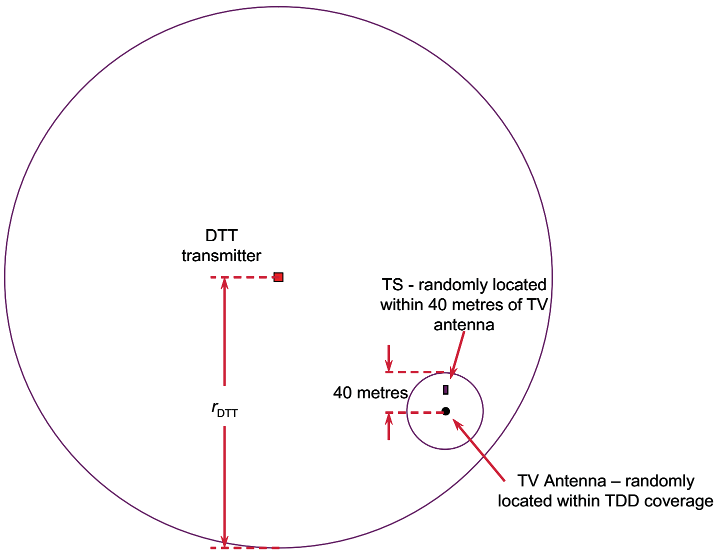

Figure 17
Simulations to assess the impact of terminal station on DTT fixed reception for different frequency offsets

With this method, the interference probability is calculated for different frequency offsets of the uplink relative to the DTT channel. Furthermore, the effect of adding a filter at the DTT receiver input is shown in a second curve (see *Fig. 18*). The result shows that for the protection of fixed-rooftop DTT reception, a guard band of 7 MHz would require additional filtering at the DTT receiver, while a guard band of 12 MHz or greater would require no additional filtering at the DTT receiver.

A similar analysis is also made for the case of DTT portable indoor reception interfered with by mobile terminals, based on the geometry shown in *Fig. 19*. No critical separation distance between the mobile terminal and the portable receiving antenna could be fixed beforehand. Therefore, analytical calculations are made at different separation distances to derive the out-of-block emission level of the mobile terminal, falling in the same channel as DTT, which causes a desensitization of the DTT receiver by 1 dB (approximately limiting the interference level to 6 dB below the noise floor). A guard band of 42 MHz is assumed, according to the agreed channelling arrangements.

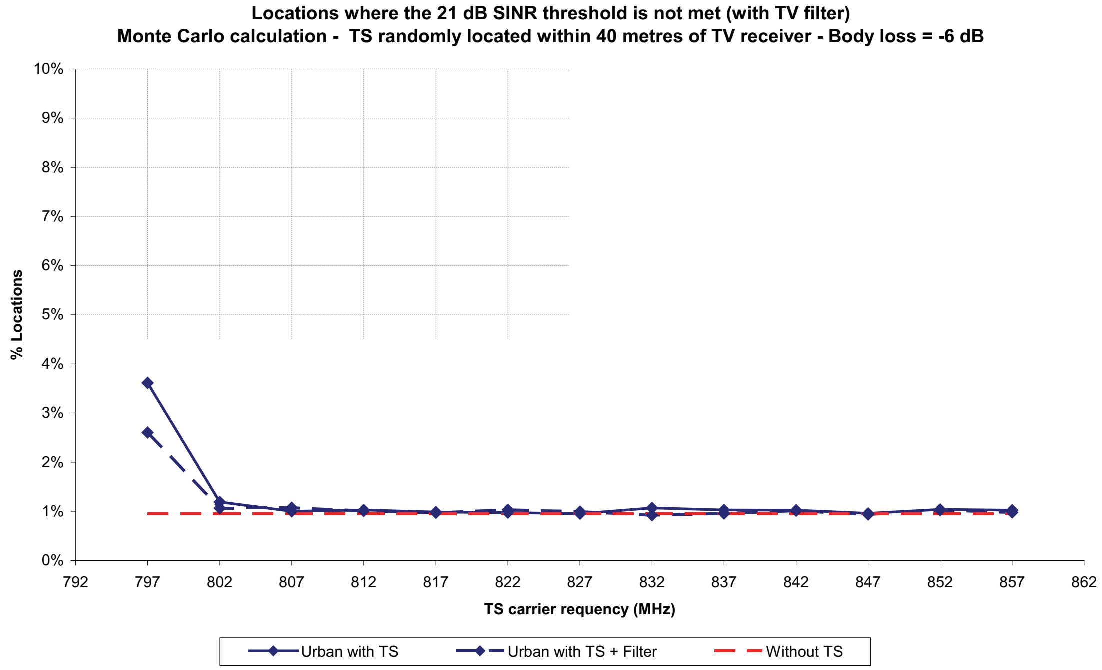

Figure 18
Interference probability for different frequency offsets of the uplink relative to the DTT channel, fixed reception

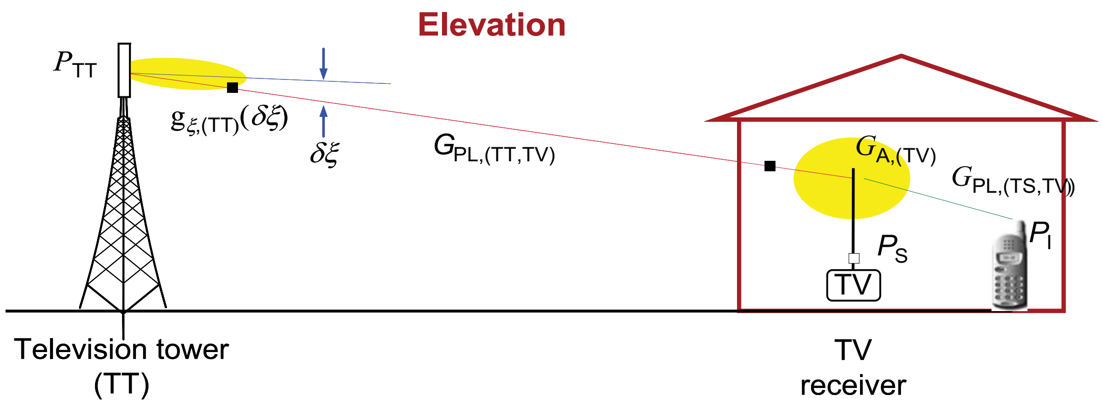

Figure 19
Terminal station to portable indoor TV geometry

With these assumptions, the calculation presented in *Fig. 20* shows that the interference probability flattens out for a baseline level of -65 dBm / 8 MHz and below, i.e. for baseline levels lower than -65 dBm / 8 MHz there is minimal improvement in separation distance.

Again, a simulation based on the Monte Carlo technique is carried out to assess the impact of a terminal station on DTT fixed reception for different frequency offsets with the out-of-block level of -65 dBm / 8MHz. The result presented in *Fig. 21* shows that for the protection of portable-indoor DTT reception, a guard band greater than 7 MHz would be required. Appropriate guard bands might be 37 MHz without additional filtering at the DTT receiver and 17 MHz with additional filtering at the DTT receiver.

It should be noted here that there is a good correlation between the results of the theoretical studies and the preliminary conclusions formulated in the field trials made in Sydney prior to the studies *(see Section 4)*.

The conclusions for the technical conditions related to mobile terminals are as follows:

1) Maximum mean in-block power: 23 dBm (subject to a tolerance of up to +2 dB);
2) Maximum mean out-of-band power below 790 MHz: -65 dBm / 8 MHz;
3) The specified FDD channelling raster (reverse duplex) provides a large guard band (42 MHz) favourable for the protection of broadcasting from terminal stations, especially for the case of DTT indoor portable reception;
4) In case of interference, the only solution is to add a filter at the input of the DVB-T receiver;

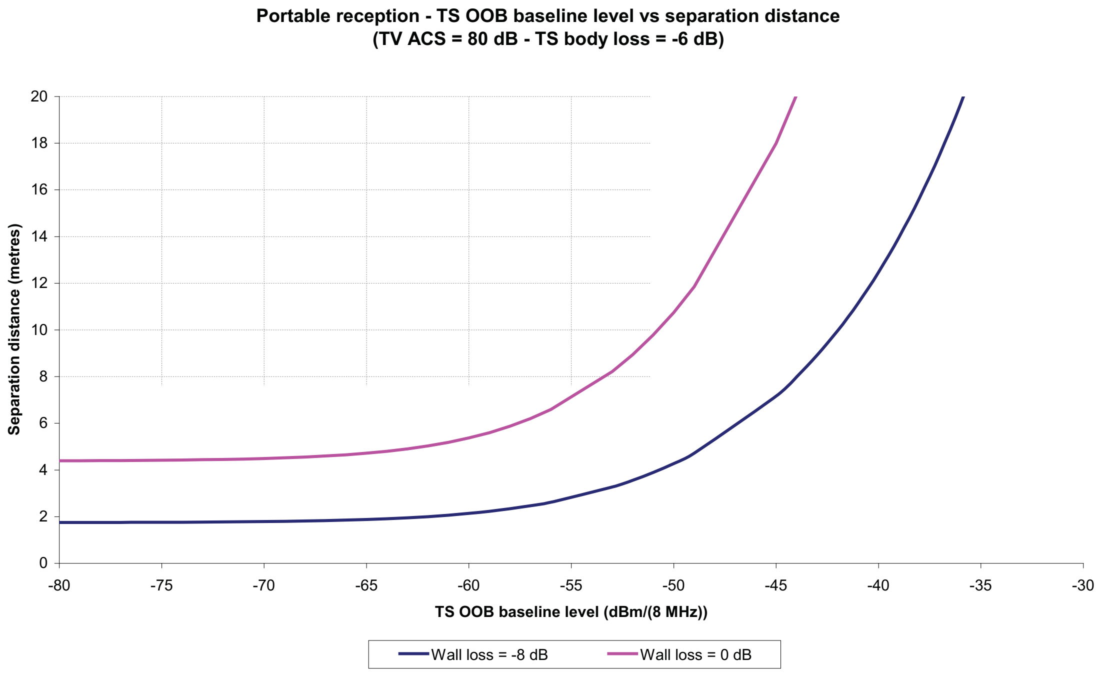

Figure 20
Impact of the out-of-block level of Terminal station

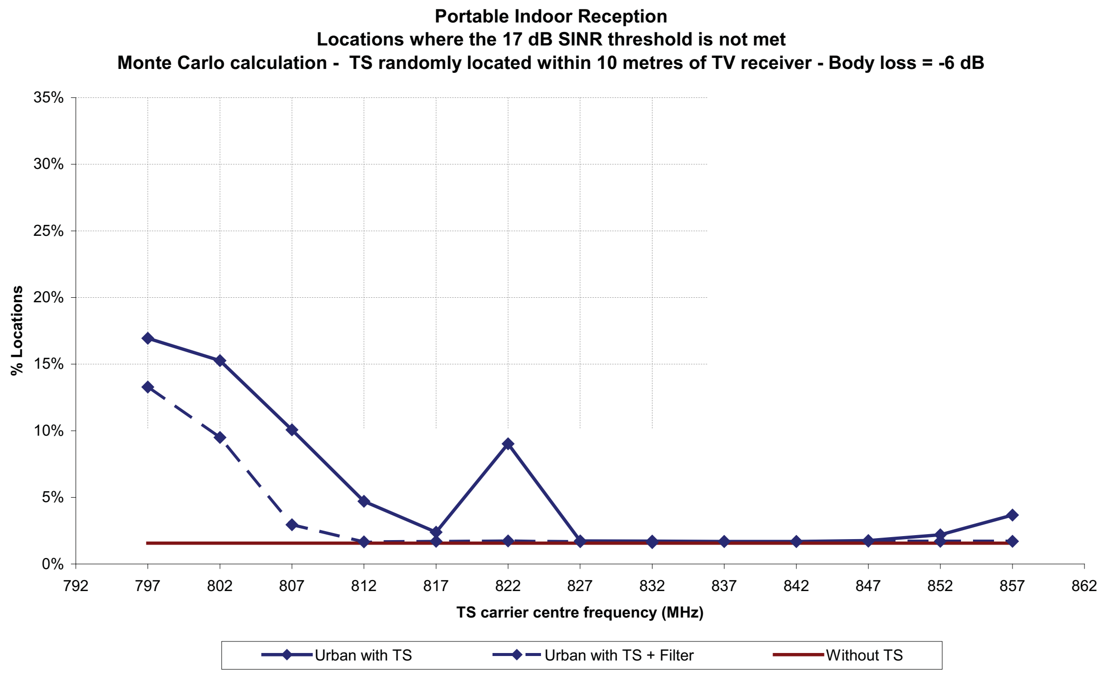

Figure 21
Interference probability for different frequency offsets of the uplink relative to the DTT channel, portable in-door reception

5) The 7 MHz guard band in the TDD channelling raster IS NOT sufficient for the protection of portable indoor reception, even with additional filtering.

The out-of-block emission limits (-50 or -65 dBm / 8 MHz depending on whether only fixed DTT reception is protected or indoor portable reception is protected as well) for the mobile terminal are intended to be implemented by the mobile terminal manufacturers.

However, these limits for out-of-band emission of the terminal station have not been made mandatory in the ECC decision (09)03 (30/10/2009).

6. Conclusions

Field studies and simulations carried out on the subject of compatibility between IMT networks and broadcasting networks using adjacent bands have shown that:

- Limitations on the transmission characteristics of the mobile network are needed in order to reduce the interference probability on broadcasting. In Europe, these limitations have been harmonised and have been made mandatory by a Decision of the European Commission. However, a certain degree of freedom was left to the individual Administrations to chose between several levels of restrictions, depending on their targeted protection level.
- It is shown that the risk of interference cannot in any case be reduced to zero and therefore there is a need for additional *mitigation techniques* to solve the possible interference cases that could occur during the implementation. In Europe, the obligations of the licence holders, in terms of choosing and bearing the cost of implementing the mitigation techniques, were left to the decision of the individual Administrations.

Based on the above, in preparing their licensing regimes and procedures, the Administrations will have to take decisions based on the analysis of studies, such as those presented in this article, but also on new studies, sometimes involving field tests that they might find useful to carry out.

The material presented in this article is intended to help understanding the background calculations which have led to the harmonised technical conditions for the implementation of mobile networks in the band 790-862 MHz in Europe.

In addition, Recommendations on this subject have been issued jointly by DigiTAG, the EBU, BNE and ACT in order to provide an appropriate level of protection to DTT services below 790 MHz from interference generated by the base stations [5]. These Recommendations can be downloaded from: **http://www.digitag.org/PressRelease_Recommendations_22Nov2010.pdf**.

Another set of Recommendations in being prepared with regard to interference generated by mobile terminals.

The overriding requirements in these Recommendations are:

- The best level of protection of the broadcasting service should be selected in the licence obligations, and this level should be applied in all cases, i.e. not only in locations where the broadcasting channel concerned is in use. This is required to allow future use of the channel concerned.
- The management of possible interference cases after implementation should not be put under the unique responsibility of the mobile network operators but should be made by a separate entity which can ensure a prompt and effective resolution of interference cases in a timely manner.
- The cost of managing the interference cases and applying the mitigation techniques should not be borne by broadcasters, broadcast network operators or viewers.

Walid Sami received an Electrical Engineering Degree from the Lebanese University in 1986 and a Doctorate in Physics from Supelec/Université de Paris Sud in 1991. He then joined the Research Centre of TDF *(Télédiffusion de France)* where he worked on spectrum-sharing studies and frequency planning for digital broadcasting systems. In 1998, he joined the CSA *(Conseil Supérieur de l'Audiovisuel)* in Paris where, as head of the Television Planning Department, he was in charge of planning for digital terrestrial television in France. In 2001 he obtained a Master of Business Administration degree from IAE Sorbonne, Paris.

In November 2005, Dr Sami joined the EBU Technical Department as a Senior Engineer, to undertake studies and co-ordinate the joint technical activities of EBU Members on subjects relating to frequency planning and spectrum-sharing issues. He represents the EBU in a number of international committees, in the ITU and CEPT, and has been particularly involved since 2007 in studies related to the protection of digital terrestrial broadcasting.

7. References

[1] ECC decision (09)03 and European Commission decision (2010/267/UE): **on harmonised conditions for mobile/fixed communications networks (MFCN) operating in the band 790 - 862 MHz**
ECC, 30 October 2009.

[2] 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**
ECC, 30 October 2009.

[3] CEPT Report 31: **Frequency (channelling) arrangements for the 790-862 MHz band**
ECC, 30 October 2009.

[4] ITU-R Document 5-6/84-E: **Detailed results of field study of compatibility between DVB-T and UMTS**
European Broadcasting Union / Free TV Australia Ltd., 6 May 2009.

[5] Doc. SE42(09)102: **Out-of-block power limit (BEM) vs. Base Station in-block power limit**
EBU TECHNICAL contribution to the CEPT/SE42 group, 27th May 2009.

[6] Joint recommendations from DigiTAG, the EBU, BNE and ACT: **Minimizing the potential interference to Digital Terrestrial Television (DTT) broadcasting services from Mobile/ Fixed Communications Networks (MFCN) operating in the 790-862 MHz frequency band**
November 2010.

This version: 23 March 2011

Published by the European Broadcasting Union, Geneva, Switzerland

ISSN: 1609-1469

Editeur Responsable: Lieven Vermaele

Editor: Mike Meyer

E-mail: tech@ebu.ch

The responsibility for views expressed in this article rests solely with the author