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Annex 5 to Joint Task Group 4-5-6-7 Chairman's Report

DRAFT NEW REPORT ITU-R BT.[MBB_DTTB_470_694]

Sharing and compatibility studies between digital terrestrial television broadcasting and terrestrial mobile broadband applications, including IMT, in the frequency band 470-694/698 MHz

Sharing and compatibility studies were conducted between terrestrial mobile broadband applications, including IMT, and digital terrestrial television broadcasting (DTTB) in the frequency band 470-694 MHz under WRC-15 agenda item 1.1 both inside and outside the GE06 planning area. These studies have been compiled into two Sections in this Report:

Section I: Sharing and compatibility studies between digital terrestrial television broadcasting and terrestrial mobile broadband applications, including IMT, in the frequency band 470-694 MHz in the GE06 planning area.

Analysis of the studies in Section I indicated a range of frequency and geographic separation distances required for sharing between DTTB systems and mobile (IMT) systems. The ranges in the studies reflect the various assumptions and technical assumptions used in the studies.

The results of the studies described in Section I show that, if one country wants to use the frequency band for broadcasting and the other wants to deploy IMT networks, sharing will be very difficult.

Section II: Sharing and compatibility studies between digital terrestrial television broadcasting and terrestrial mobile broadband applications, including IMT, in the frequency band 470-694/698 MHz outside the GE06 planning area.

Analysis of the studies in Section II indicated a range of frequency and geographic separation distances required for sharing between DTTB systems and mobile (IMT) systems. The ranges in the studies reflect the various assumptions and technical assumptions used in the studies.

The co-channel studies in Section II show that separation distances between mobile (IMT) base-stations and DTTB receivers/transmitters are several tens of kilometres, which makes sharing difficult.

SECTION I

Sharing and compatibility studies between digital terrestrial television broadcasting and terrestrial mobile broadband applications, including IMT, in the frequency band 470-694 MHz in the GE06 planning area

1 Introduction

Sharing and compatibility studies have been conducted between terrestrial mobile broadband applications, including IMT, and DTTB in the frequency band 470-694 MHz in the GE06 planning area. These studies have been compiled into this Section.

2 Analysis

2.1 GE06 Agreement field strength parameters

The GE06 Agreement specifies (in Appendix 1 to Section I of Annex 4) the coordination trigger field strength of other primary services for the protection of broadcasting from the modifications to the plan.

The values are listed in Table A.1.9 of the GE06 Agreement and shown below.

TABLE 1

GE06 coordination trigger field strength of other primary services for the protection of broadcasting from the modifications to the plan.

Broadcasting service to be protected	Trigger field strength (dB(μV/m))(1)			
	Band III (174-230 MHz)	Band IV (470-582 MHz)	Band V (582-718 MHz)	Band V (718-862 MHz)
DVB-T	17	21	23	25
T-DAB	27	–	–	–
Analogue TV	10	18	20	22

(1) The trigger field-strength values are related to the bandwidth of the system to be protected.

Under agenda item 1.2, dealing with the frequency band 694-790 MHz, the coordination threshold is 23 (lower Band V) or 25 dBμV/m (upper Band V). This threshold corresponds to the median interference field strength at the border of a neighbouring country.

For fixed DTTB reception at a point located at the neighbouring country border with a receiving antenna oriented towards the affected country, a field strength at the antenna level of $E_{dB\mu V/m}$ represents an interference power level I_{dBm} at the receiver input of:

$$\boxed{I_{dBm} = E_{dB\mu V/m} + G_{dBi} - A_d - 77.2 - 20\log(F_{MHz})}$$

where:

G_{dBi} is the isotropic antenna gain, including feeder losses: 7 dBd (from Table 4 below) + 2.15 dB = 9.15 dBi;

A_d is the Antenna directivity discrimination. From Recommendation ITU-R BT.419-3 it is 16 dB for 180°;

F_{MHz} is the frequency in MHz.

With a median field strength value of 21 dBμV/m at 470 MHz the received interference power will be:

I_{dBm} = –116.5 dBm (including 16 dB antenna discrimination)

I_{dBm} = –100.5 dBm (no antenna discrimination)

With a noise level at the DTTB receiver input of -98.2 dBm (in 7.61 MHz bandwidth and 7 dB of noise figure), the median I/N, or *I*/*N* (50%) corresponding to the triggering field strength of 23 dBμV/m at 694 MHz is:

I/*N* (50%) = –18.3 dB (including 16 dB antenna discrimination)

I/*N* (50%) = –2.3 dB (no antenna discrimination)

With a median field strength value of 23 dBμV/m at 694 MHz the received interference power will be:

I_{dBm} = –117.9 dBm (including 16 dB antenna discrimination)

I_{dBm} = –101.9 dBm (no antenna discrimination)

With a noise level at the DTTB receiver input of -98.2 dBm (in 7.61 MHz bandwidth and 7 dB of noise figure), the median I/N, or *I*/*N* (50%) corresponding to the triggering field strength of 23 dBμV/m at 694 MHz is:

I/*N* (50%) = –19.7 dB (including 16 dB antenna discrimination)

I/*N* (50%) = –3.7 dB (no antenna discrimination)

2.2 Co-channel sharing studies

2.2.1 Interference from and to mobile service base-stations

2.2.1.1 Mobile service as an interferer: Interference from mobile service base-stations into broadcasting service reception

2.2.1.1.1 Scenario 1 I/N

Appendix 1 of Annex 2 contains a case study for this scenario.

2.2.1.1.1.1 Study 1a I/N

2.2.1.1.1.1.1 Description

In order to estimate the cumulative effect of co-channel interference from IMT BS to DTT in particular DVB-T receiving system, a single base-station is first evaluated and the required separation distance to meet the field strength threshold value corresponding to the required I/N criteria is calculated. Then a network of several IMT base-stations is modelled and the cumulative effect is evaluated. Finally, the new separation distance that would be required to reduce the cumulative effect to the original threshold is calculated.

2.2.1.1.1.1.2 Methods of calculation with formulas

A threshold field strength of 23 dB µV/m was used in the calculations which equivalents to an I/N of -10 dB (95% locations, 16 dB antenna discrimination) at the upper end of the 470-694 MHz band.

Step 1: Single base-station

All base-station parameters used in this study are as specified in Annex 1. Specifically, these are:

– Frequency: 700 MHz[1];

– Radiated Power: 55 dBm;

– Tx Antenna Height: 30m.

The separation distance R required to give the threshold field strength (23 dB(µV/m)) from a single base-station at 1% time is then calculated using Recommendation ITU-R P.1546.

It is found that R would be around 61 km (see figure 1 below), if the whole path between the base-station and the receiving point A is considered to be land.

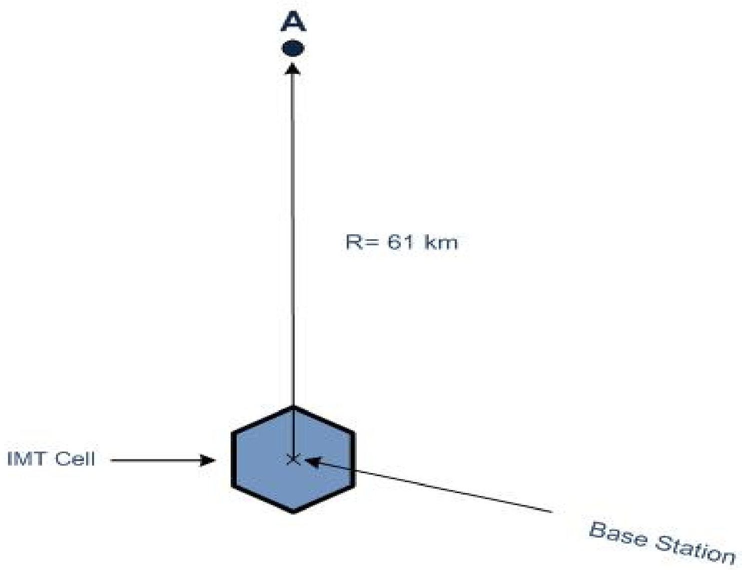

Figure 1

Step 2: Several base-stations

In Step 2, a network consisting of several IMT base-stations is modelled on either side of base-station in Step 1, and also behind it. All base-stations have the same characteristics as that in Step 1, as defined in Annex 1. The area in which this network operates is assumed to be urban and therefore a cell range of 1km is selected. This is within the range specified by the relevant ITU-R group (0.5 km – 5 km). The inter-site distance is 1.6 kilometres.

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[1] This frequency does not correspond to any specific IMT band plan. Rather, it is selected to be representative of both the 700 MHz band and the 600 MHz band. Results at other frequencies would be much similar and just slightly change.

The IMT network used in this study consists of alternately 15 or 16 cells across and 17 cells deep, making a total of 263 cells.

Now the field strength from each base-station in the extended IMT network is calculated at point A, according to the methodology given by the relevant ITU-R group (i.e. calculated at 2% time).

The field strengths from each base-station in the extended IMT network are summed to give accumulated field strength at A.

The resultant accumulated field strength is found to be 43.4 dBμV/m, i.e. an increase of 20.4 dB compared to the single cell case in Step 1.

Step 3: Derive a new separation distance

Having derived a value for the accumulated field strength, the distance modelled between the IMT network and the DTTB receiving point A can be recalculated such that the accumulated field strength drops to the original threshold.

In the case considered here, that is found to be about 212 kilometres.

2.2.1.1.1.1.3 Results

The results found above are summarised in the table below.

Interfering field strength threshold @700MHz	Initial separation distance R	Total cumulative field strength	Increase over original threshold	New required separation distance
dB(μV/m)	km	dB(μV/m)	dB	km
23	61	43.4	20.4	212

2.2.1.1.1.2 Study 1b I/N

2.2.1.1.1.2.1 Description

When assessing the interference from mobile service (MS) networks to broadcasting service it necessary to evaluate the interference field strength of MS base-stations (BS) in the test points at the territory of other country. Geneva-06 Agreement provides trigger value for consideration of the single assignment of mobile service BS to which a threshold value applied at any test point within the territory of the country concerned. However, at the time of the Geneva-06 Agreement development IMT implementation plans currently under consideration were not known. Those plans assume use of the same frequency throughout all country (frequency reuse factor 1).

2.2.1.1.1.2.2 Calculations

Single base-station

Calculations were performed for a single base-station with typical parameters (see Table 1) at 500 and 600 MHz. The distance at which the interfering base-station field strength decreases to the threshold value of 21 and 23 dBμV/m. This equivalents to an I/N of –19 dB (50% locations) and –10 dB (95% locations) at 470 MHz and 694 MHz, respectively.

Base-stations network

A network of base-stations created, with typical parameters corresponding to given in Table.2. Calculation of the increment of the total interference from the network of base-stations performed, and cumulative field strength compared to field strength from a single interferer. For the summation of multiple interfering signals the method proposed by the relevant ITU-R group is used.

After obtaining cumulative field strength values, the distance between the simulated network IMT and DTTB reception point A were recalculated until the cumulative field strength drops to the initial threshold of 21 or 23 dBμV/m.

TABLE 2

Network parameters for MS base-stations

Parameter	Scale	Value
e.i.r.p. without loss and G_{iso} for 10 MHz	dBm	58.00
Cable loss (L_{cable})	dB	3.00
Antenna factor (G_{iso})	dBi	15.00
Polarization discrimination	dB	3
Antenna height above ground	m	30.00
Antenna tilt, downside	Degrees	3
Main beam by 3 dB loss in H plane	Degrees	65
Main beam by 3 dB loss in V plane	Degrees	ITU-R F.1336-3. Annex 8 of this Recommendation and a k-value of 0.7
MS network type		Rural
Cell radius (r_{IMT})	4 km	8

2.2.1.1.1.2.3 Results

The results are shown in Table 3. Calculations were performed for a base-station antenna height of 30 metres.

TABLE 3

Separation distances and the increment of the field strength

Frequency	Trigger field strenngth	Propagation path	Separation distance for single BS	Total cumulative field strength	Increase over original threshold	Separation distance for MS network, km
MHz	dB(μV/m)		km	dB(μV/m)	dB	km
500	21	land	86	40,9	19,9	274
600	23	land	72	41	18	243
500	21	warm sea	695	47,5	26,5	>1000
600	23	warm sea	694	50,1	27,1	>1000

The case study indicating the increment of the cumulative interference from the multiple base-stations MS network with respect to a single interferer given in the Appendix 1 of Annex 1 to Section I.

The results show that the excess of the cumulative interference from MS network over the single interferer can be up to 21 dB what causes a significant increase of required separation distance when using the same field strength threshold for cumulative interference as for single entry interference. This study shows that when conducting compatibility studies, cumulative interference of signals from the MS base-stations should be considered.

2.2.1.1.2 Scenario 2: Degradation of Reception Location Probability

2.2.1.1.2.1 Introduction

The aim of this study is to assess the co-channel impact of a network of IMT base-stations in one country into DTTB reception in a neighbouring country in terms of degradation in location probability at different levels of the DTTB coverage area: at one pixel at the edge and in a ring of pixels at the coverage edge.

The study also assesses the required geographical separation, for co-channel operation, between IMT base-stations (single and multiple) and DTTB reception area for a land path and for different network configurations. It uses the methodology described in Annex 2 to Report ITU-R BT.2265.

2.2.1.1.2.2 Background

The study takes into account the guidance received from the relevant ITU-R group with regard to time percentages of individual base-stations (1.7% instead of 1%), and from the relevant ITU-R group on generic IMT networks to be used in sharing studies. All technical parameters are in line with the agreed parameters (see Table 4 further below).

2.2.1.1.2.3 Technical characteristics

In this study the cumulative effect of interference of a network of base-stations is considered. The base-stations are placed so that individually the GE06 coordination threshold is not exceeded at the border. A broadcast coverage area is placed on the opposite side of the border, just touching the border (see Figure 2). Tri-sector cell structure is used (see Figure 3). The interference probability is calculated, using Monte Carlo simulation, throughout a ring at the coverage edge, and at the two pixels on the coverage edge, closest to and farthest from, respectively, the base-station network. (See Figure 4).

FIGURE 2

Mobile network starts at the 'Single Cell Critical Distance', SCCD, from the border

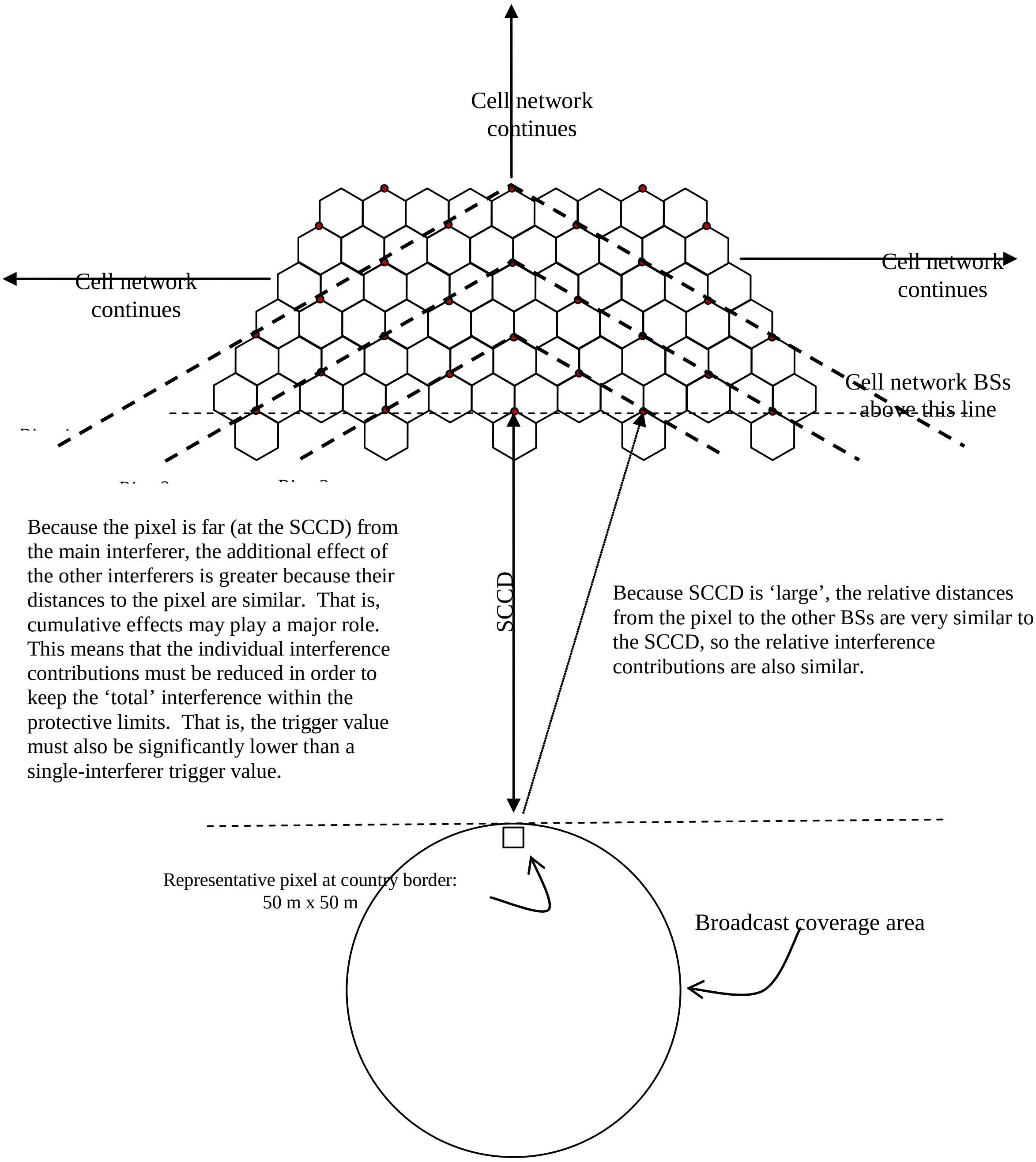

FIGURE 3

Cell structure

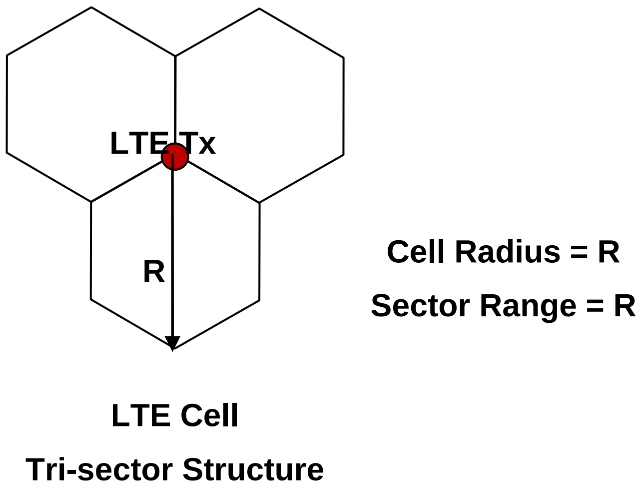

FIGURE 4

DTTB coverage area, coverage area edge, nearest and farthest pixels

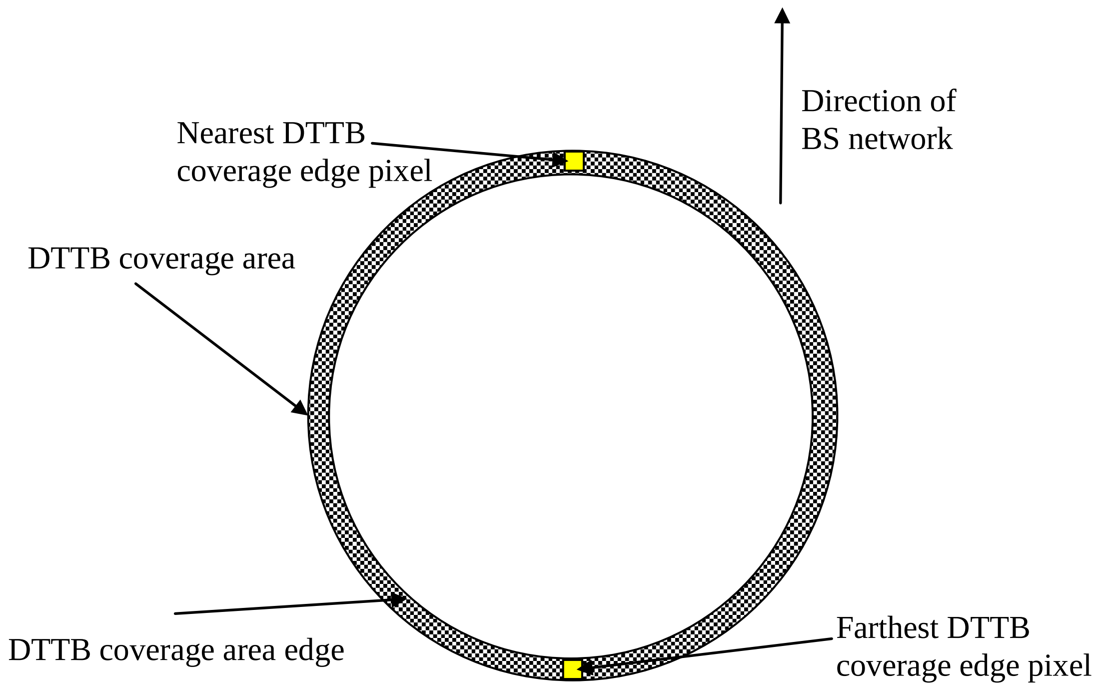

TABLE 4

Parameters for the study

Television tower (TT)	
e.i.r.p.	High power: 23 dBkW/(8 MHz) Medium power 7 dBkW/(8 MHz)
Coverage radius	Urban High power: 39.5 km Urban medium power: 12.6 km Rural high power: 70.5 km Rural medium power: 32.1 km
Antenna height	Urban: 300 metres Rural: 150 metres
Antenna pattern	Recommendation ITU-R BT.419
TV receiver (victim)	
Antenna gain (inc. feeder loss)	12 – 5 = 7 dBd
Antenna height	10 m
Receiver minimum C/N	21 dB
Antenna pattern	Recommendation ITU-R BT.419-3
Noise figure	7 dB
Noise equivalent bandwidth	7.6 MHz
BS transmitter	
e.i.r.p.	55 dBm
Cell range	Urban: 1 km Suburban: 2 km Rural: 8 km
Antenna height	30 metres
Antenna elevation pattern	Recommendation ITU-R F. 1336
Other parameters	
Operating frequency	708 MHz
Mean path loss	Recommendation ITU-R P.1546 model
Log-normal shadowing standard deviation:	3.5 dB for $d < d_0$, 5.5 dB for $d > d_0$, where for d_0 = 100 m.
Cross polarization (in the main lobe)	3 dB
Location probability for reception at the edge of broadcast coverage area	95%
Median Wanted field strength at the edge of broadcast coverage area	56.7 dBμV/m
Protection ratio (co-channel)	21 dB

2.2.1.1.2.4 Analysis

2.2.1.1.2.4.1 Degradation in reception location probability

Tables 5 to 9 provide degradation in reception location probability at the considered pixels/areas of the DTTB coverage area for different numbers of interferers. They also provide the SINR exceeded in 95% of the locations in the considered pixels/areas.

Urban DTTB coverage

TABLE 5

Urban cell network, high power urban DTTB coverage

Number of interferers (IMT 3-sector base-stations)	1	6	91	378
Degradation of reception location probability for a PR of 21 dB at the DTTB coverage edge	0.02%	0.12%	1.3%	3.6%
SINR exceeded in 95% of the locations in a ring of 100m at the DTTB coverage edge	21.1 dB	21.0 dB	20.4 dB	19.3 dB
Degradation of reception location probability for a PR of 21 dB at the border DTTB coverage	0.3%	1.7%	15.3%	30.5%
SINR exceeded at 95% of coverage at the border DTTB coverage	20.9 dB	20.2 dB	16.6 dB	13.9 dB
Degradation of reception location probability for a PR of 21 dB at the far DTTB coverage edge pixel	0%	0.03%	0.4%	1.6%
SINR exceeded at 95% of coverage at the far DTTB coverage edge pixel	21.1 dB	21.1 dB	20.9 dB	20.2 dB
1% time aggregated interference (1.7% time individual interference) Urban network: e.i.r.p. = 55 dBm, Htx = 30 m, cell range = 1 km, SCCD = 17.2 km Broadcast coverage: e.r.p. = 23 dBkW, Htx = 300 m, Hrx = 10 m, coverage radius = 39.5 km Thickness of Broadcast coverage edge: 100 m				

TABLE 6

Urban cell network, medium power urban DTTB coverage

Number of interferers (IMT 3-sector base-stations)	1	6	91	378
Degradation of reception location probability for a PR of 21 dB at the DTTB coverage edge	0.1%	0.5%	5.4%	14.3%
SINR exceeded in 95% of the locations in a ring of 100m at the DTTB coverage edge	21 dB	20.8 dB	18.9 dB	16.5 dB
Degradation of reception location probability for a PR of 21 dB at the border DTTB coverage edge	0.3%	1.7%	15.3%	30.5%
SINR exceeded at 95% of coverage at the border DTTB coverage edge	21 dB	20.9	16.6 dB	13.9 dB
Degradation of reception location probability for a PR of 21 dB at the far DTTB coverage edge pixel	0.1%	0.7%	8.7%	25.3%
SINR exceeded at 95% of coverage at the far DTTB coverage edge pixel	21 dB	20.7 dB	18.1 dB	14.7 dB
1% time aggregated interference (1.7% time individual interference) Urban network: e.i.r.p. = 55 dBm, Htx = 30 m, cell range = 1 km, SCCD = 17.2 km Broadcast coverage: e.r.p. = 7 dBkW, Htx = 150 m, Hrx = 10 m, coverage radius = 12.6 km Thickness of Broadcast coverage edge: 100 m				

Rural DTTB coverage

TABLE 7

Urban cell network, high power rural DTTB coverage

Number of interferers (IMT 3-sector base-stations)	1	6	91	378
Degradation of reception location probability for a PR of 21 dB at the DTTB coverage edge	0.04%	0.3%	3.4%	10.7%
SINR exceeded in 95% of the locations in a ring of 100m at the DTTB coverage edge	21 dB	20.9 dB	19.5 dB	16.9 dB
Degradation of reception location probability for a PR of 21 dB at the border DTTB coverage edge	0.3%	1.9%	22.2%	51.5%
SINR exceeded at 95% of coverage at the border DTTB coverage edge	20.9 dB	20.2 dB	15.4%	10.9 dB
Degradation of reception location probability for a PR of 21 dB at the far DTTB coverage edge pixel	0.03%	0.2%	2.6%	15%
SINR exceeded at 95% of coverage at the far DTTB coverage edge pixel	21 dB	21 dB	20 dB	17.6 dB
1% time aggregated interference (1.7% time individual interference) Urban network: e.i.r.p. = 55 dBm, Htx = 30 m, cell range = 1 km, SCCD = 47.1 km Broadcast coverage: e.r.p. = 23 dBkW, Htx = 300 m, Hrx = 10 m, coverage radius = 70.5 km Thickness of Broadcast coverage edge: 100 m				

TABLE 8

Urban cell network, medium power rural DTTB coverage

Number of interferers (IMT 3-sector base-stations)	1	6	91	378
Degradation of reception location probability for a PR of 21 dB at the DTTB coverage edge	0.1%	0.7%	10.3%	29.1%
SINR exceeded in 95% of the locations in a ring of 100 m at the DTTB coverage edge	21.1 dB	20.6 dB	17.5 dB	13.4 dB
Degradation of reception location probability for a PR of 21 dB at the border DTTB coverage edge pixel	0.4%	1.9%	22.2%	51.4%
SINR exceeded at 95% of coverage at the border DTTB coverage edge	20.9 dB	20.2 dB	15.4 dB	10.9 dB
Degradation of reception location probability for a PR of 21 dB at the far DTTB coverage edge	0.2%	1.5%	20.2%	52.4%
SINR exceeded at 95% of coverage at the far DTTB coverage edge pixel	20.9 dB	20.4 dB	15.7 dB	10.8 dB
1% time aggregated interference (1.7% time individual interference) Urban network: e.i.r.p. = 55 dBm, Htx = 30 m, cell range = 1 km, SCCD = 47.1 km Broadcast coverage: e.r.p. = 7 dBkW, Htx = 150 m, Hrx = 10 m, coverage radius = 32.1 km Thickness of Broadcast coverage edge: 100 m				

2.2.1.1.2.4.2 Relationship between Reception location probability degradation (Δ_{RLP}) and I/N criteria

This relationship is shown in Table 5 below.

TABLE 9

Reception location probability degradation (ΔRLP) as a function of I/N(50%) and I/N(95%)
RLP target = 95%

I/N (50%)[2]	–19 dB	–12.8 dB	–10 dB	–6 dB	0 dB
I/N (95%)[3]	–10 dB	–3.8 dB	–1 dB	+3 dB	9 dB
ΔRLP	0.23%	1%	1.84%	4.47%	14.68%

2.2.1.1.2.4.3 Separation distances

Tables 10 to 12 provide co-channel separation distances for a land path with single and multiple base-stations, for different network configurations, on the basis of protecting the nearest DTTB coverage edge pixel (with full Antenna discrimination).

TABLE 10

Co-channel separation distances for a land path with single and multiple base-stations for Urban IMT network (sector range = 1 km) into urban fixed DTT reception (at 20 m), suburban fixed DTT reception (at 10 m), rural fixed DTT reception (at 10 m) for different target levels of ΔRLP and corresponding I/N protection criteria

I/N (50%)	–19 dB	–12.8 dB	–10 dB	–6 dB	0 dB
I/N (95%)	–10 dB	–3.8 dB	–1 dB	+3 dB	9 dB
DRLP%	0.23%	1%	1.85%	4.48%	14.68%
Number of base-stations					
1	53.50 km	37.55 km	32.39 km	26.15 km	19.02 km
6	81.80 km	55.04 km	47.12 km	37.98 km	28.27 km
91	160.90 km	111.20 km	94.32 km	73.30 km	52.30 km
378	212.60 km	157.70 km	135.45 km	105.15 km	72.80 km

For example, as can be seen in Table 6 above, a single IMT base-station needs to be 53 km away from the border in order to be implemented without coordination. If 91 similar stations are implemented in an urban area beyond this distance they will similarly not need to be individually coordinated. In that case the impact on the DTTB coverage with that same separation distance would be increased by 19 dB in terms of I/N at the coverage edge and the degradation of location probability would be increased from 0.23% to 14.68% at that same coverage edge.

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[2] *I/N(50%) is the I/N exceeded in 50% of the location in the considered pixel.*

[3] *I/N(95%) is the I/N exceeded in 95% of the location in the considered pixel.*

TABLE 11

Co-channel separation distances for a land path with single and multiple base-stations for suburban IMT network (sector range = 2 km) into urban fixed DTT reception (at 20 m), suburban fixed DTT reception (at 10 m), rural fixed DTT reception (at 10 m) for different target levels of ΔRLP and corresponding I/N protection criteria

I/N (50%)	–19 dB	–12.8 dB	–10 dB	–6 dB	0 dB
I/N (95%)	–10 dB	–3.8 dB	–1 dB	+3 dB	9 dB
DRLP%	0.23%	1%	1.85%	4.48%	14.68%
Number of base-stations					
1	53.5 km	37.6 km	32.4 km	26.2 km	19.0 km
6	81.3 km	54.3 km	46.5 km	37.3 km	28.6 km
91	157.1 km	107.0 km	90.0 km	68.8 km	47.3 km
378	204.3 km	148.3 km	125.3 km	94.3 km	61.1 km

TABLE 12

Co-channel separation distances for a land path with single and multiple base-stations for Rural IMT network (sector range = 8 km) into urban fixed DTT reception (at 20 m), suburban fixed DTT reception (at 10 m), rural fixed DTT reception (at 10 m) for different target levels of ΔRLP and corresponding I/N protection criteria

I/N (50%)	–19 dB	–12.8 dB	–10 dB	–6 dB	0 dB
I/N (95%)	–10 dB	–3.8 dB	–1 dB	+3 dB	9 dB
DRLP%	0.23%	1%	1.85%	4.48%	14.68%
Number of base-stations					
1	53.5 km	37.6 km	32.4 km	26.2 km	19.0 km
6	76.6 km	48.9 km	40.6 km	31.2 km	21.4 km
91	126.0 km	74.1 km	57.7 km	39.9 km	24.5 km
378	142.8 km	84.3 km	63.9 km	42.3 km	25.1 km

2.2.1.1.2.5 Analysis of Results

The protection of DTTB from co-channel IMT downlink requires a separation distance to avoid coordination according to GE06. Calculations show that, even without accumulation of interfering field strength, a single IMT base-station will need to be positioned 53 kilometres (for land path) from the DTTB service edge, i.e. from the border of the affected Administration.

Including multiple interfering base-stations would increase the interfering field strength at the DTTB service edge by up to 20 dB. Based on the parameters used in this particular study, the resulting separation distance could be increased up to 200 kilometres when using the same field strength threshold for cumulative interference as for single entry interference (23 dBµV/m).

The calculations are made according to Report ITU-R BT.2265 which contains a method to assess the impact of interference from multiple base-station networks on DTTB reception.

2.2.1.1.3 Scenario 3 C/(N+I)

Appendix 2 of Annex 1 to Section I contains a case study for this scenario.

2.2.1.2 Mobile service as a victim: Interference from broadcasting transmissions into mobile base-stations

Appendix 2 of Annex 2 contains a case study for this scenario.

2.2.1.2.1 Introduction

This section presents results of co-channel interference calculations from existing DVB-T/T2 transmitters and GE06 Plan entries, into IMT uplink receivers. Calculations have been made for a generic case and for a Case study (see Appendix 3 of Annex 1 to Section I) including two countries, France and Germany using the existing and coordinated DTTB transmitters on a UHF channel.

The aim of this study is to assess the feasibility of using the same band for DTTB by one country and the IMT uplink in a neighbouring country.

The results show that such a simultaneous use would only be feasible beyond large separation distances even taking into consideration mitigation techniques such as cross-polarisation or relaxation of the percentage of time for the protection of the uplink.

2.2.1.2.2 Background

This study deals with the protection of the IMT networks, in particular the uplink receivers, from existing or planned DTTB transmissions.

The criteria used by the mobile service for the protection of the mobile and base-stations receivers are based on the I/N criteria. These criteria are used in this study where only the case of the base-station receiver is considered.

2.2.1.2.3 Technical characteristics

2.2.1.2.3.1 DTTB Transmitter data

For the generic study, two reference single broadcast transmitter configurations are considered. They are representative of actual deployments in the case of assignments used in the GE06 planning area.

- High power transmitter
  - e.r.p.: 200 kW
  - Effective antenna height: 300 m
  - Antenna height a.g.l.: 200 m
  - Antenna pattern:
    - Horizontal: Omnidirectional
    - Vertical antenna aperture: based on 24λ aperture with 1° beam tilt
- Medium power
  - e.r.p.: 5 kW
  - Effective antenna height: 150 m
  - Antenna height a.g.l.: 75 m
  - Antenna pattern:
    - Horizontal: Omnidirectional
    - Vertical: based on 16λ aperture with 1.6° beam tilt

For the case studies, the French DTTB transmitter data is based upon existing coordination data using about 100 transmitters. Highest e.r.p. is about 50 kW. Transmitters with an e.r.p. below 100 W have not been included in the calculation. The German DTTB transmitters are taken directly from the GE06 Plan, which means that a few transmitters have an e.r.p. of 200 kW. In both cases, only DTTB transmitters on channel 50 have been included in the calculations.

2.2.1.2.3.2 Mobile Network data

In Table 13 the calculation of the interference limits for an IMT base-station (uplink) is made. This limit is based on I/N of -6 dB as protection criteria, which corresponds to a 1 dB desensitization of the uplink receiver at the base-station.

TABLE 13

Calculation of interference threshold for base-station

Parameter	Value for base-station	Unit	Comment
Frequency	698	MHz	F
Rx Noise figure	5	dB	NF
Bandwidth	10	MHz	BW
Temperature	290	K	T
Thermal Noise (10 MHz)	–99,0	dBm	PN = 10log(kTB) + NF
I/N protection criterion	-6	dB	I/N
Interference power threshold	–105,0	dBm	PI = PN + I/N
Downtilt	3	°	
Rx antenna discrimination	1,19	dB	Dant (Rec ITU-R F 1336)
Polarization discrimination	3	dB	Dpol
Rx antenna gain	15	dB	Grx
Feeder loss	1	dB	Dfl
Field strength interference threshold at Rx antenna height	19,3	dBµV/m	Eunwanted = 77.21+PI+20log(F)-Grx+Dant+Dpol+Dfl
Antenna height	30	m	Hant

In Table 14 the field strength thresholds used in the plots are given, subject to different assumption on I/N and different polarization for the broadcast and the mobile IMT network.

TABLE 14

Field strength thresholds

Threshold	Value dB(μV/m)	Rx Antenna height m	Comment
Th1	19,3	30 m	I/N of –6 dB
Th2	25,3	30 m	Relaxed I/N from –6 to 0 dB
Th3	31,1	30 m	Cross polarization and I/N of –6 dB
Th4	37,1	30 m	Cross polarization and I/N of 0 dB

2.2.1.2.3.3 Field strength prediction and summation

For the generic study, only Recommendation ITU-R P.1546 was used.

For the case studies in Appendix 3 of Annex 1 to Section I, the calculations are made using the Recommendations ITU-R P.1812-2 and ITU-R P.1546-4 prediction models. For Recommendation ITU-R P.1546 terrain clearance angle has been used in order to more correctly take the terrain into account.

Calculation has been used using the PROGIRA-Plan broadcast planning software using 100 metre resolution clutter and height (topographical) data.

Field strength values are presented for 1%, 5% and 10% of time. No aggregation (summation) of field strength has been used. The plots for the case studies show the highest field strength in each pixel of calculation

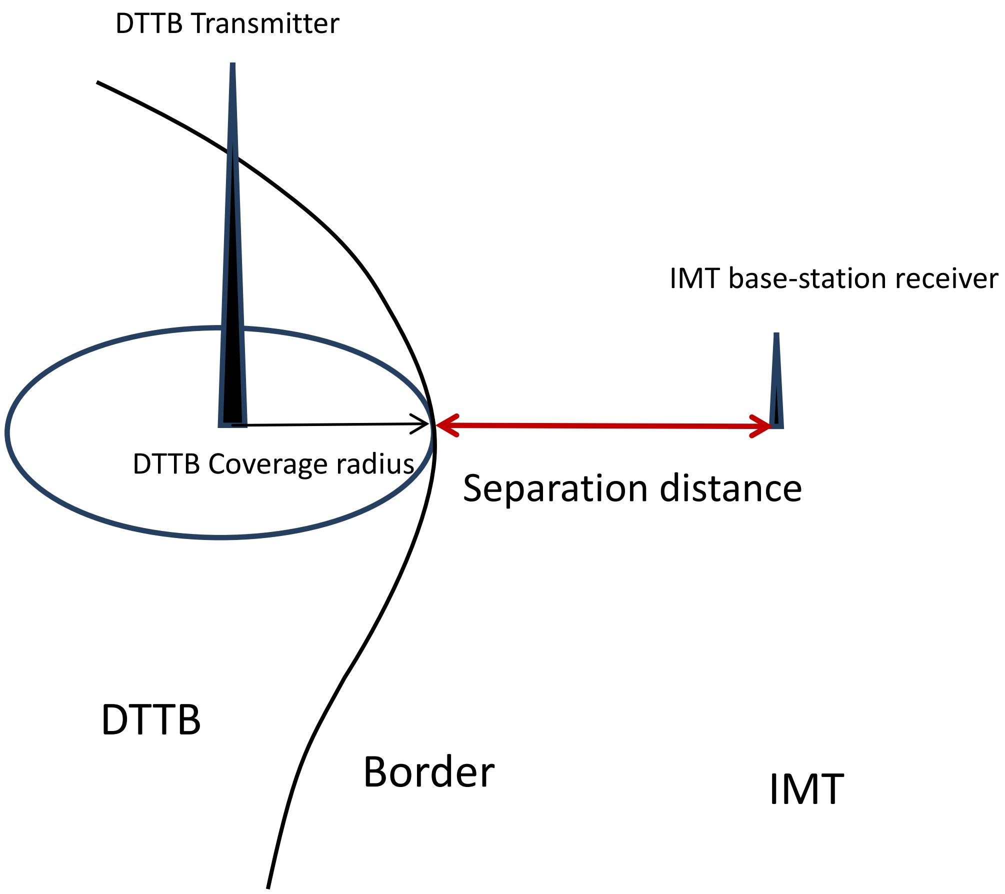
2.2.1.2.4 Analysis

2.2.1.2.4.1 Generic study

Figure 5 shows the basic configuration for the assessment of the separation distance between interfering DTTB transmitter and victim IMT base-station receiver (uplink).

FIGURE 5

Basic configuration for the assessment of separation distance between interfering DTTB transmitter and victim IMT base-station receiver (uplink)



For this generic study, only Recommendation ITU-R P.1546 was used. There is no point in using other methods based on terrain for generic studies.

The separation distances were calculated for all the field strength thresholds calculated in Table 14, which correspond to two different levels of protection and to the possible use of cross polarisation as a mitigation technique (or alternatively the use of full antenna discrimination).

Finally, the prediction was made for three percentages of time, 1%, 5 % and 10% to consider also a range of protection levels in terms of acceptable time percentage for the interference.

The DTTB coverage radius corresponding to the two reference transmitters are:

– 70.53 kilometres for the high power transmitter (HP);

– 32.11 kilometres for the medium power transmitter (MP).

TABLE 15

Required separation distances between interfering DTTB transmitter and victim IMT base-station receiver (uplink)

e.r.p.	Antenna height (m)	Target Field Strength (dBµV/m)	1% time	5% time	10% time	Comment
200 kW	300	19.3	427	355	318	I/N of –6 dB
200 kW	300	25.3	359	290	258	I/N of 0 dB
200 kW	300	31.1	297	235	207	Cross polar and I/N of –6dB
200 kW	300	37.1	235	183	159	Cross polar and I/N of 0dB
5 kW	150	19.3	269	215	192	I/N of –6 dB
5 kW	150	25.3	211	167	148	I/N of 0 dB
5 kW	150	31.1	161	126	110	Cross polar and I/N of –6dB
5 kW	150	37.1	117	89	76	Cross polar and I/N of 0dB

As can be seen in Table 15, separation distances up to 427 kilometres and 269 kilometres, for HP and MP BTTB transmitters respectively, would be required to protect the IMT base-station receiver (uplink) in 99% time for a target I/N of –6 dB and with no additional discrimination by cross polarization of antenna directivity.

The relaxation of the protection level to 90% time, a target I/N of 0 dB and mitigation by full antenna polarization and/or antenna discrimination would reduce the separation distances to 159 kilometres for HP and 76 kilometres for MP.

2.2.1.2.4.2 Case study

The results show that the two different propagation models Recommendation ITU-R P.1812 and ITU-R P.1546 are more or less equivalent. Although the fully terrain based Recommendation ITU-R P. 1812 tend to give slightly higher values in some areas.

The results are presented in Appendix 3 of Annex 1 to Section I. The following results are presented:

Plots 1 – 3: Interference from GE06 Channel 50 DTTB in France using Recommendation ITU-R P.1546, for 1%, 5% and 10% of time

Plots 4 – 6: Interference from GE06 Channel 50 DTTB in France using Recommendation ITU-R P.1812, for 1%, 5% and 10% of time

Plots 7 – 9: Interference from GE06 Channel 50 DTTB in Germany using Recommendation ITU-R P.1546, for 1%, 5% and 10% of time

Plots 10 – 12: Interference from GE06 Channel 50 DTTB in Germany using Recommendation ITU-R P.1812, for 1%, 5% and 10% of time

As expected the inference areas are reduced for “higher” time percentage (e.g. 10% of time) field strength, but the interfered areas are still significant for all the considered percentages of time.

It should be kept in mind that no aggregation of field strength has been made in the examples shown here. This means that field strength would be higher in case of for example an SFN with several transmitters.

It should be noted however that the results may change, in the sense of reducing the separation distances, when considering variation of certain parameters in the IMT network:

– the antenna height of some base-station may be lower than 30 metres, which would result in reduced levels of DTTB co-channel interference;
– the use of down tilt for the antenna of the base-station would also introduce an attenuation of the DTTB interference received from long distance;
– the acceptable level of I/N for the IMT uplink may be high depending on the extent to which a typical IMT network is noise limited or self-interference limited.

2.2.1.2.5 Analysis of results

The calculations show that co-channel sharing between DTTB broadcasting and IMT at UHF will be difficult due to significant interference into the IMT uplink receiver positioned at 30 metres height.

High level protection of the IMT uplink from DTTB co-channel interference would require separation distances of up to 269 kilometres with a medium power DTTB station and up to 427 kilometres with a high power DTTB station.

This has also been shown also on a case study using planned assignments and allotments from the GE06 plan. Interference distances up to 200 kilometres into uplink in neighbouring countries are predicted with the use of certain mitigation techniques and relaxation of the protection requirements.

2.3 Adjacent-channel compatibility studies

2.3.1 Interference from and to mobile service user equipment

2.3.1.1 Mobile service as an interferer: interference from mobile service user equipment into broadcasting service reception

2.3.1.1.1 Scenarios

Laboratory and field trial of wireless broadband access system in the frequency band 470-694 MHz were conducted. As outcome, the field trial highlights the problems of compatibility between such systems and terrestrial television broadcasting. Since there is currently no way to conduct field trials of real IMT/LTE systems in this band, the results of this work is a good example that can be used for assessment of the problems of sharing TV broadcasting and mobile services within bands, allocated to BS.

2.3.1.1.1.1 Description

Studies of compatibility between terrestrial TV broadcasting and terrestrial mobile networks based on various simulation methods, show that there is the possibility of interference in the co-channel and multiple adjacent channels case. At the same time, no field trials for frequency bands sharing between two systems conducted yet. This contribution represents the results of field trials of the of wireless broadband access system, similar to the wireless broadband communications in the mobile networks (IMT/LTE). A topology, similar to that of mobile communication networks (base-station + user equipment (UE)), was used.

Equipment specification

Technical characteristics of wireless broadband access equipment are shown in Table 16.

TABLE 16

Basic technical characteristics of wireless broadband access equipment in the band 470-686 MHz

Parameter		Value	Unit
Type of channel separation		TDD	
Max e.i.r.p.	Base-stations	6	dBW
	UE	0	dBW
Minimum range of transmitter automatic power control (APC)		20	dB
Accuracy of automatic station location		50	m
Operating channels shall be selected by sending request to the database for protected systems, and if there is no response from the database, station emission must be automatically ceased			

Technical characteristics of wireless broadband access equipment are shown in Table 17.

TABLE 17

Technical characteristics of wireless broadband access equipment prototype

Parameter		Value
Operating frequency range, MHz		From 470 to 686
Frequency raster, MHz		1
Type of duplex		Time-division (TDMA)
Frequency tuning bandwidth, MHz		216
Type of modulation		BPSK / QPSK / QAM16 / QAM64 (programmable)
Coding		LDPC and block
Code rate		5/6 and 15/16
Transmission rate (main bit stream), Kbit/s		From 300 to 15 000 (programmable)
Frequency stability, ppm		±5
Transmitter output power, dBm		23 ± 1
Transmitter power control with 1 dB increment, dB		from +0 to –10
Transmitter emission bandwidth, MHz		1.5,3; 6; 12 (programmable)
Spurious emission level, dBc		–50
Minimum permissible signal level at the receiver input (sensitivity) dBW, with FER = 10^{-2} / 10^{-3}		from –128/ –125 to –98/95 (depending on type of modulation and emission bandwidth)
Maximum permissible signal level at the receiver input, dBm	Non-destructive	6
	with FER<=$1 \cdot 10^{-2}$	Not less than –3,
	with FER<=$1 \cdot 10^{-3}$	Not less than –10,
Permissible level of adjacent channel interference, dB		0
Power supply voltage, V		Nominal voltage (U_{sup}) minus 60 (–39...–72)
Power consumption, W		40
Maximum length of lead-in cable		Up to 100 m, with U_{sup} = –60 V;

2.3.1.1.1.2 Methods of calculation with formulas

Research conducted through laboratory and field tests.

2.3.1.1.1.2.1 Laboratory trial

Field test was preceded by laboratory tests. During the laboratory trial, basic operational modes of the equipment were tested, and basic technical characteristics and protection ratios were measured with interference from wireless broadband access system to the TV reception.

Measurement of protection ratios for wanted signals of digital terrestrial television DVB-T2, interfered with by broadband equipment sample 1

DVB-T2 signal parameters:

– Modulation: 64 QAM;

– Radio channel bandwidth: 8 MHz;

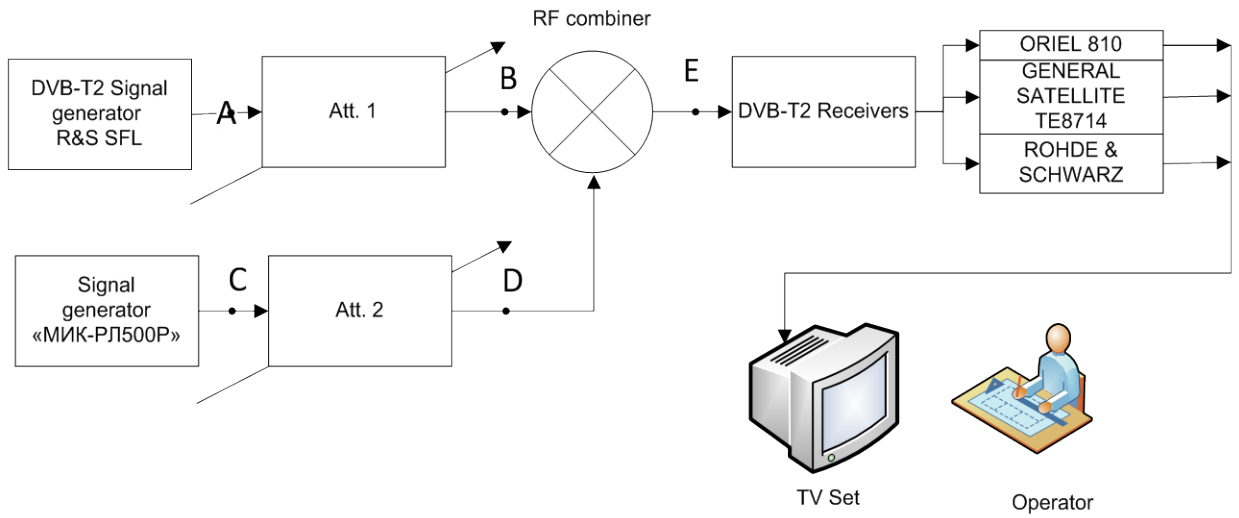
– Carrier mode: 32K;

– Code rate: 4/5.

Block-diagram for measuring is shown in Fig.6.

FIGURE 6

Block-diagram for measuring protection ratios for wanted DVB-T2 signal interfered with by wireless broadband access equipment



– A – DVB-T2 signal with constant level.

– B – DVB-T2 wanted signal with predetermined levels at the receiver input: –70 dBm, –60 dBm, –50 dBm, –40 dBm (corresponded spectrograms are plotted in Fig. 7).

– C – generated signal (spectrogram is plotted in Fig. 8).

– D – signal with variable level to determine interfering signal causing distortions.

– E – signal at the output of RF combiner, applied to the input of Set Top Box (STB) receiving device.

FIGURE 7

Spectrograms of DVB-T2 signals

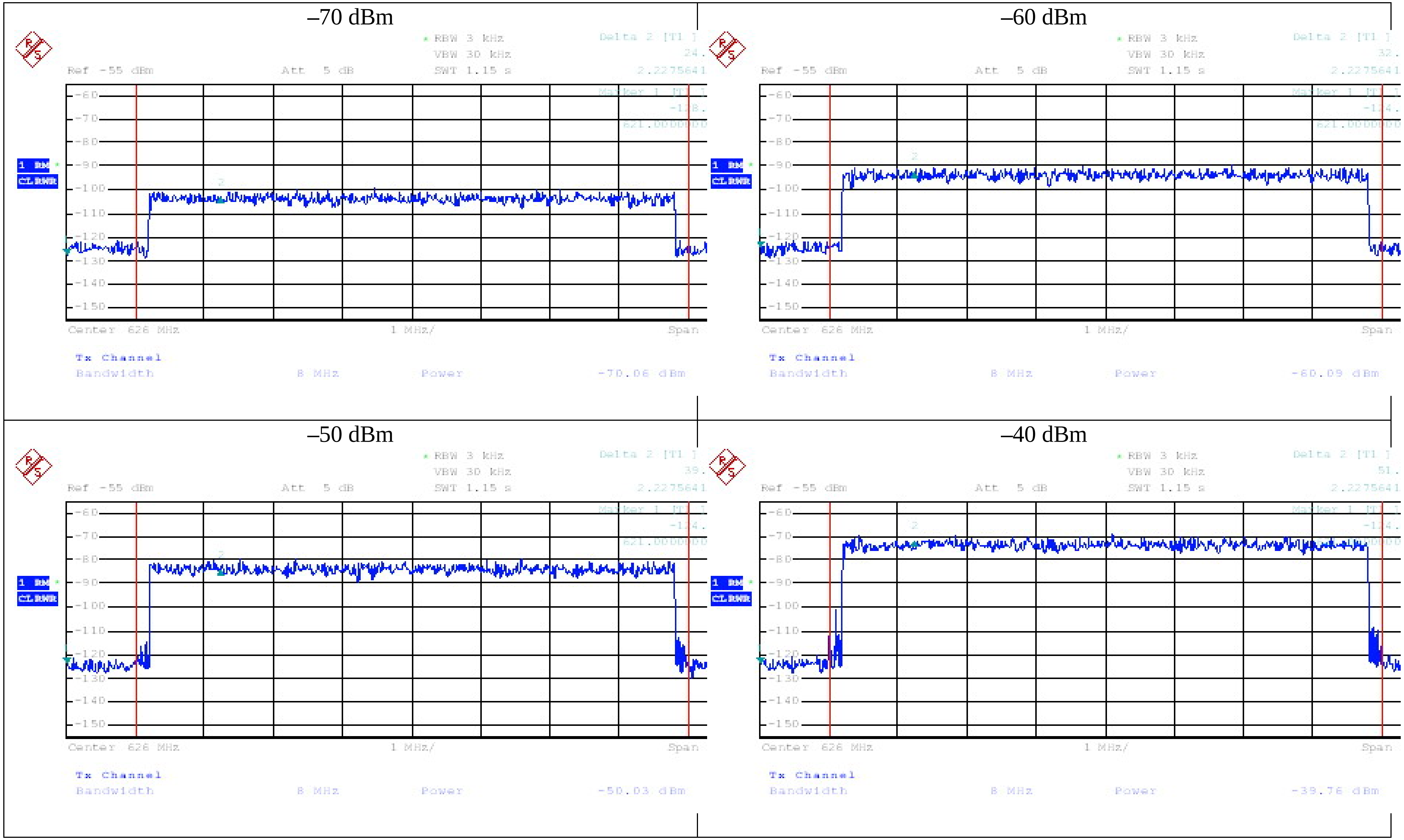
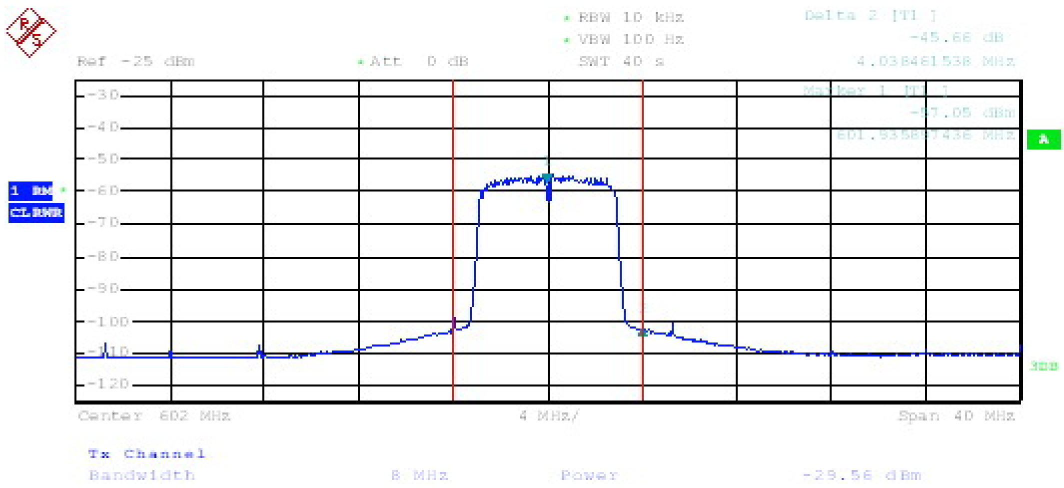


FIGURE 8

Spectrogram of wireless broadband access prototype 1 signal



2.3.1.1.1.2.2 Field tests of compatibility between broadcasting service and wireless broadband equipment (transmitters and receivers).

For different position configurations of the receiving TV antenna and the wireless broadband access system transmitting antenna (Fig. 9 and 10) and different frequency offsets, ratios of signal levels were measured and received TV signal quality was recorded.

FIGURES 9, 10

Positions of TV broadcasting receive antenna
and fixed wireless broadband access system transmit antenna

Technical and metrological means

The following equipment is necessary to conduct experimental studies in the pilot area:

– cars to install radio electronic equipment needed to perform radio measurements (mobile platforms) – 2 pieces;
– wireless broadband access base-stations with the set of standard antennas (previously installed and ready for operation in the selected points of installation);
– wireless broadband access UE with the set of standard antennas;
– receiving TV antenna with matched characteristics;
– TV signal analyser (e.g. R&S ETL);
– digital TV DVB-T2 STB;
– TV set to receive analogue TV programmes.

Measurement methodology

Position of the wireless broadband access system base-station retains fixed during the experimental studies.

During pilot studies the following aspects were evaluated:

– effect of the TV transmitter radiation on the operation of the wireless broadband access system UE at the edge of the base-station service area;
– effect of the wireless broadband access UE radiation on the operation of DVB-T2 STBs and measuring receiver (or analogue TV Set) at the edge of TV transmitter service area;
– effect of the wireless broadband access base-station radiation on the operation of DVB-T2 STBs and measuring receiver (or analogue TV Set) at the edge of TV transmitter service area.

Radiation effect of TV transmitter on the operation of the wireless broadband access UE is evaluated by assessing wireless broadband access base-station QoS using specified criteria, for points at the edge of base-station service area, located closest to the TV transmitter.

Radiation effect of wireless broadband access UE on the operation of DVB-T2 STBs and measuring receiver (or analogue TV Set) is evaluated by verifying the selected criteria of EMC for reception quality or, when using the DVB-T2 measuring receiver, for threshold value LBER = 10^{-7} when interfered with by subscriber station.

Minimum separation distance between wireless broadband access UE and subscriber TV STBs is evaluated, when the compatibility conditions are met.

Evaluating separation distances required to meet the compatibility conditions

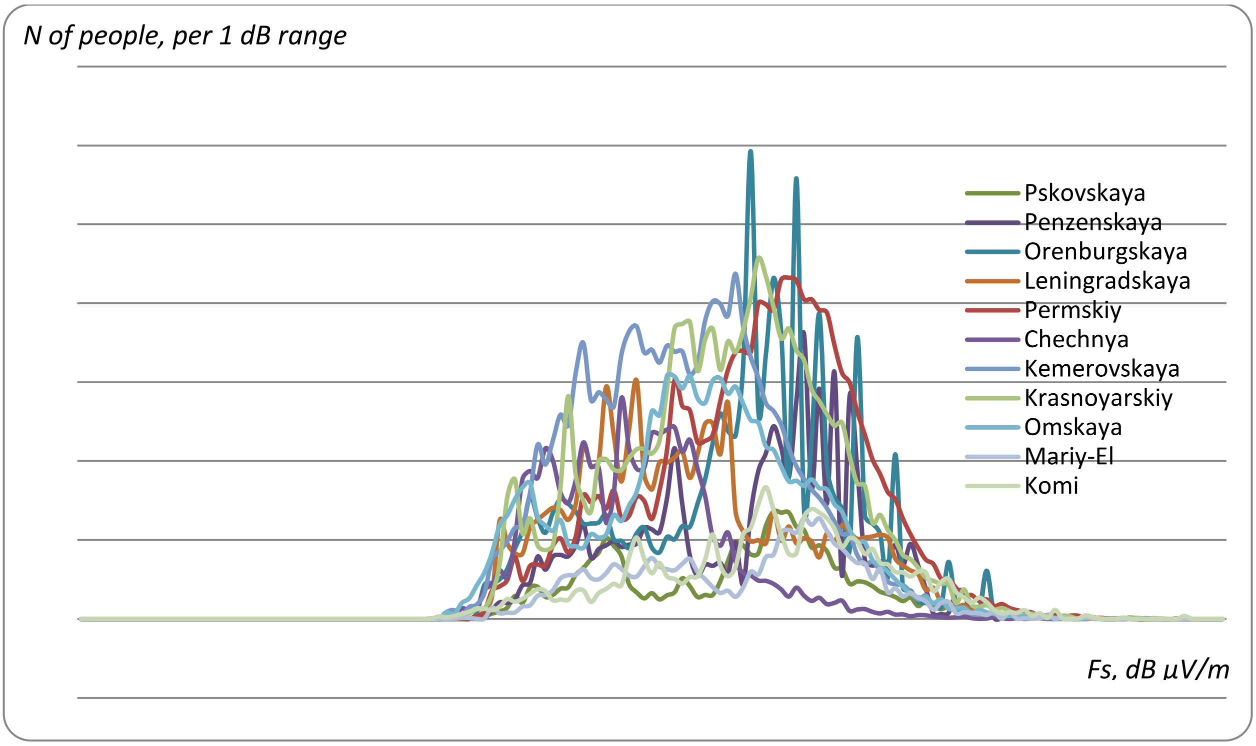
Separation distance between the mobile terminal and the TV broadcasting receiving antenna determined for fixed reception in rural environment. As the propagation model, Recommendation ITU-R P.1546 was used. Trigger value of allowable interference field strength from mobile service UE was determined based on the measured protection ratios and applied to the value of the field strength of the useful signal relevant to 95% of locations and 99 % of the time.
As a representative DVB-T2 modulation mode, 64 QAM 4/5 was used. The same mode was used in the measurements.

2.3.1.1.1.3 Calculations

Given below is a calculated estimate of the useful field strength values at digital terrestrial broadcasting system DVB-T2 signal reception locations for fixed antenna by population of the 11 regions of the Russian Federation and with different topologies of networks, the distribution of the population and terrain.

FIGURE 11

The distribution of the field strength of the useful signal networks of terrestrial digital television broadcasting in the public reception areas, dB µV / m



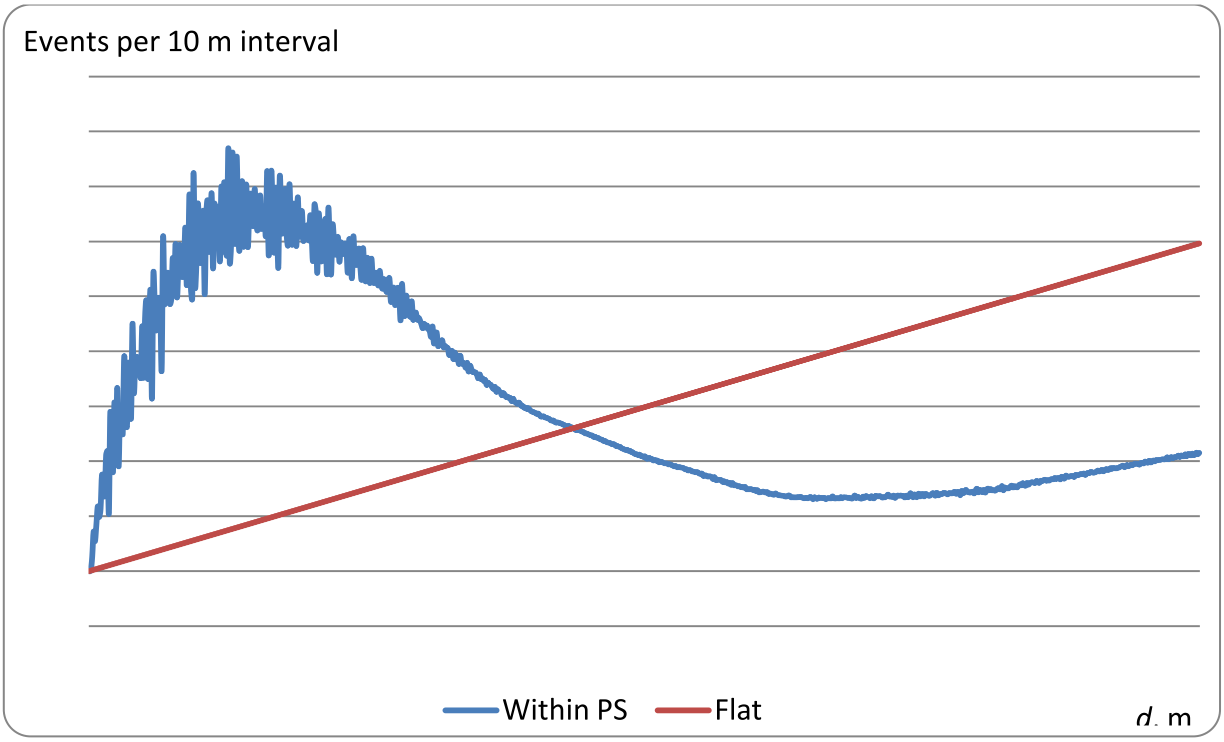
As can be seen in Fig. 11, the distribution of the field strength has two characteristic peaks. The first maximum is located in the 85-100 dBµV/m and exists due to the high density of the population living in cities near the broadcasting centres. The second maximum is in the region of 56-77 dBµV / m and caused by the large coverage in terms of space over rural areas with low and medium population density. Modulation mode of DVB-T2 networks in this example –64 QAM, 4/5.

With the distribution at Fig. 11 is easy to estimate the number of people that will be subject to interference if protection ratios are not met. The calculation of the interference for an arbitrary multiple adjacent channel can be made by using the method of minimal coupling loss or the Monte Carlo method, assuming compliance with the conditions 99% of the time and 95% of the TV broadcasting receiving antenna locations.

The non-flat distribution of the population through the territory also to be taken into account, which typically causes dense concentration of interference sources within borders of populated areas (villages, towns, etc.), in close proximity to broadcasting service receiving antenna locations (see Fig. 12). This applies most to IMT UE, but also typical for base-station locations.

FIGURE 12

The probability of distance between IMT terminal and the TV reception place when TV receivers and IMT terminals distributed evenly through the surface or within the boundaries of populated sites ("Within PS")



Graphs in Fig. 12 were obtained by simulation in regions of the Russian Federation. The test site of the TV broadcasting receiving antenna and IMT terminal located either evenly across the all territory, or within the boundaries of populated sites taken from hi-resolution digital map of relevant region ("Within PS").

2.3.1.1.1.4 Results

Protection ratios for wanted signals of digital terrestrial television DVB-T2, interfered with by broadband equipment sample 1 emissions

Protection ratios were measured for three different receivers operating in the DVB-T2 mode:

– ORIEL 810 – Table 18;

– GENERAL SATELLITE TE8714 – Table 19;

– ROHDE & SCHWARZ test equipment – Tables 20, 21 and 22.

TABLE 18

Protection ratios (dB) for DVB-T2 (Oriel 810 receiver) interfered with by wireless broadband access system

DVB-T2 signal power at the receiver input	–60 dBm	–50 dBm	–40 dBm
Channel	**Protection ratio, dB**	**Protection ratio, dB**	**Protection ratio, dB**
N-14	–41	–35.5	–
N-13	–40	–35	–
N-12	–40	–35	–
N-11	–39	–35	–
N-10	–39	–35	–
N-9	–38	–35	–
N-8	–38	–35	–
N-7	–38	–34.5	–
N-6	–38	–34	–
N-5	–38	–34	–
N-4	–38	–33.5	–
N-3	–38	–33	–
N-2	–37.5	–32.5	–31
N-1	–39.5	–29.5	–25
N	16	16	15
N+1	–37	–29.5	–25
N+2	–37.5	–33	–31
N+3	–38	–32	–
N+4	–38	–33	–
N+5	–38.5	–34	–

TABLE 19

Protection ratios (dB) for DVB-T2 (General Satellite TE8714) interfered with by wireless broadband access equipment

DVB-T2 signal power at the receiver input	**–70 dBm**	**–60 dBm**	**–50 dBm**	**-40 dBm**
Channel	**Protection ratio, dB**	**Protection ratio, dB**	**Protection ratio, dB**	**Protection ratio, dB**
N-14	–43.5	–42.5	–45.5	–
N-13	–43	–42	–45	–
N-12	–43	–42	–45	–
N-11	–43	–42	–45	–
N-10	–43	–42	–45	–
N-9	–43	–42	–45	–
N-8	–43	–42	–45	–
N-7	–43	–42	–38.5	–
N-6	–43	–42	–39	–
N-5	–42.5	–41.5	–39	–
N-4	–42	–41.5	–39	–
N-3	–42	–41	–39	–
N-2	–41	–41	–39	–
N-1	–34	–35.5	–31	–26
N	18	16	16	16
N+1	–35	–35	–30	–23
N+2	–40	–41	–40	–30
N+3	–41	–41	–36.5	–
N+4	–41	–41.5	–41	–
N+5	–41.5	–42	–42	–

TABLE 20

Protection ratios (dB) for DVB-T2 (Rohde & Schwarz test receiver) interfered with by wireless broadband access equipment

DVB-T2 signal power at the receiver input	**–50 dBm**
Channel	**Protection ratio, dB**
N-14	–40
N-13	–40
N-12	–40
N-11	–40
N-10	–40
N-9	–40
N-8	–40
N-7	–40
N-6	–40
N-5	–40
N-4	–40
N-3	–40
N-2	–40
N-1	–37
N	18
N+1	–37
N+2	–40
N+3	–40
N+4	–40
N+5	–40

Table 21 and Table 22 show protection ratios (dB) for the majority of DVB-T2 modes and two Pilot Patterns.

TABLE 21

Protection ratios (dB) for DVB-T2, PP4 (Rohde & Schwarz test receiver) interfered with by wireless broadband access equipment

DVB-T2 signal power –50 dBm at the receiver input			
Modulation	**Code rate**	**Protection ratio, dB**	
		Co-channel	**Adjacent channel**
QPSK	1/2	5.1	–46.6
QPSK	3/5	5.2	–46.5
QPSK	2/3	5.3	–464
QPSK	3/4	5.6	–46.0
QPSK	4/5	6.3	–45.8
QPSK	5/6	6.8	–45.7
16-QAM	1/2	8.4	–45.5
16-QAM	3/5	9.5	–45.3
16-QAM	2/3	10.5	–45.0
16-QAM	3/4	11.4	–44.2
16-QAM	4/5	12.2	–42.0
16-QAM	5/6	13.0	–40.4
64-QAM	1/2	12.1	–40.6
64-QAM	3/5	13.5	–40.3
64-QAM	2/3	14.9	–39.9
64-QAM	3/4	16.7	–39.7
64-QAM	4/5	17.7	–38.2
64-QAM	5/6	18.8	–37.0
256-QAM	1/2	16.3	–39.7
256-QAM	3/5	18.1	–38.7
256-QAM	2/3	19.9	–37.8
256-QAM	3/4	21.6	–30.8
256-QAM	4/5	22.7	–30.1
256-QAM	5/6	23.8	–29.4

TABLE 22

Protection ratios (dB) for DVB-T2 signal, PP7 (Rohde & Schwarz test receiver), interfered with by wireless broadband access system

DVB-T2 signal power -50 dBm at the receiver input			
Modulation	**Code rate**	**Protection ratio, dB**	
		Co-channel	**Adjacent channel**
QPSK	1/2	4.4	–46.8
QPSK	3/5	4.5	–46.6
QPSK	2/3	4.6	–46.4
QPSK	3/4	5.5	–46.2
QPSK	4/5	6.1	–46.0
QPSK	5/6	6.6	–45.9
16-QAM	1/2	7.4	–45.8
16-QAM	3/5	8.9	–45.5
16-QAM	2/3	10.5	–45.3
16-QAM	3/4	11.4	–45.0
16-QAM	4/5	12.2	–42.8
16-QAM	5/6	13.1	–40.5
64-QAM	1/2	11.8	–40.6
64-QAM	3/5	13.1	–39.5
64-QAM	2/3	14.8	–38.4
64-QAM	3/4	16.7	–36.9
64-QAM	4/5	17.5	–36.1
64-QAM	5/6	18.5	–35.3
256-QAM	1/2	16.7	–37.3
256-QAM	3/5	17.1	–35.5
256-QAM	2/3	19.6	–33.6
256-QAM	3/4	21.5	–31.0
256-QAM	4/5	22.6	–30.3
256-QAM	5/6	23.7	–29.5

Study results indicate very limited adjacent band selectivity of modern TV receivers from any signals within TV receiver tuning range. Based upon the trial results, general requirements for regulatory and technical restrictions for the use of wireless broadband access systems in TV bands were identified. To fulfil these conditions during these field trials, BS and mobile UEs should normally not go within borders of cities/towns/villages and nearby.

In particular, the protection ratios of the order of –43. –35 dB were measured over a wide frequency range (up to channel N +14 and beyond). In very many locations, due to difference in signal levels from distant broadcast transmitter and wireless broadband access system BS/UE located nearby, it means requirement for space separation between BS/UE and terrestrial broadcasting antennas necessary to reduce signal level emitted from BS/UE antenna system. Mandatory application of such a measure cannot be ensured because one end of wireless broadband access radio link is user-controlled.

Field test measurements confirmed the laboratory measurements results. Effect of interference from wireless broadband access UE and base-stations was experimentally confirmed. Regulatory and technical requirements were defined to be applied to the wireless broadband access system operating in the TV broadcasting frequency bands.

Results of field test measurements are shown in Table 23.

TABLE 23

Measured protection ratios for the case of interference to DTV

No. of measurement	Date	TV Frequency, MHz	TV channel	TV. Programme	Use of TV amplifier. STB	Signal at the TV antenna input, dBμV/m	Interference at the TV antenna input, dBμV/m	Actual E_{want}- E_{interf}, dB	Frequency spacing (f_{Interf} - f_{Wanted}), MHz	Interference scenario (interference channel)	Calculated protection ratio (lab test), dB	wireless broadband access frequency, MHz	wireless broad-band access e.r.p., dBm
34	06.03.2013	546	30	1 multiplex (DVB-T2)	No. General Satellite	52	97	–45	96	N+12	-43	642	30
106	07.03.2013	546	30	1 multiplex (DVB-T2)	No. Oriel	53	95	–42	96	N+12	-42	642	30
107	07.03.2013	546	30	1 multiplex (DVB-T2)	No. General Satellite	53	95	–42	96	N+12	-43	642	30
108	07.03.2013	546	30	1 multiplex (DVB-T2)	No. General Satellite	57	99	–42	96	N+12	-43	642	30
109	07.03.2013	546	30	1 multiplex (DVB-T2)	No. Oriel	57	99	–42	96	N+12	-42	642	30
105	07.03.2013	546	30	1 multiplex (DVB-T2)	No. Oriel	53	99	–46	-16	N-2	-42	530	30

Separation distances required to meet the compatibility conditions

Separation distance between the transmitting end-UE and the broadcasting receiving antenna determined for broadcasting service fixed reception in rural environment for the line of sight conditions. The calculation was performed for different levels of out-of-band emissions (OOBE). Corresponding separation distances are shown in Table 24.

TABLE 24

Required separation distances end-user equipment and the broadcasting receiving antenna determined for broadcasting service fixed reception in rural environment for the line of sight conditions

Channel	Protection ratio for 90_{th} receivers percentile, dB	Separation distance for OOBE –25 dBm/ 8 MHz, m	Separation distance for OOBE –46 dBm/ 8 MHz, m	Separation distance for OOBE –56 dBm/ 8 MHz, m
N-14	–35	725	190	180
N-13	–35	725	190	180
N-12	–35	725	190	180
N-11	–35	725	190	180
N-10	–35	725	190	180
N-9	–35	725	190	180
N-8	–35	725	190	180
N-7	–34	752	276	270
N-6	–34	752	276	270
N-5	–34	752	276	270
N-4	–33	785	357	352
N-3	–33	785	357	352
N-2	–32	825	437	433
N-1	–29	995	708	705
N+1	–29	995	708	705
N+2	–33	785	357	352
N+3	–32	825	437	433
N+4	–33	785	357	352
N+5	–34	752	276	270

Analysis of trial results

The trial results showed the following:

– It is necessary to have separation distance between transmitting antennas of wireless broadband access system and TV broadcasting receiving antennas to achieve electromagnetic compatibility between wireless broadband access system and terrestrial TV broadcasting system. The required separation can range from 180 to 995 metres (equipment was tested with different transmitting power levels and different transmitting frequencies), depending on technical characteristics of wireless broadband access system. During this study compatibility could not be provided for base-stations or UE in a sufficiently great number of cases. A special order of operation for base-stations and UE to be required, use of fixed antennas with limitation on possible places of installation, antenna orientation in the horizontal and vertical planes and technical parameters of antennas. It is evident that in the case of UE, to provide such order of operation is extremely difficult in practice.

– It was observed that protection ratio, needed for compatibility, depended on the operation mode wireless broadband access system, such as proportion between reception and transmission time intervals, when using TDD (50% reception vs 50% transmission, 90% reception vs 10% transmission, etc.).

– When considering possible locations for installation of wireless broadband access system, the effect of overload at the input stage of wireless broadband access receiver can be the limiting factor for some types of transmit and receive systems due to high-power TV and sound broadcasting stations, mobile communications and other systems, operating outside the bandwidth of the wireless broadband access radio channel (mirror channels).

In this study it was found that application of interference mitigation techniques, such as additional frequency-selective filters at the input of TV receivers was necessary to ensure compatibility. However it was found that, the use of frequency-selective interference filters within broadcasting baseband of 470-694 MHz is problematic because the receiver must be able to work with any RF channel within tuning range. There is small dependence of this effect from frequency separation and OOB limits, what means all broadcast TV channels reception in all UHF range to be affected by interference from mobile service operating within 470-694 MHz frequency band.

3 Summary

3.1 Summary of co-channel studies

3.1.1 Mobile service base-stations as an interferer into broadcast reception

The generic study in Section 2.2.1.1.1.1 showed that the cumulative effect of interference can exceed 20 dB and that a separation distance of more than 200 kilometres is needed to meet the field strength threshold of 23 dBµV/m which equivalents to an I/N of -10 dB (95% locations, 16 dB antenna discrimination) at the lower end of the 694-790 MHz band compared to 61 kilometres for a single base-station of the mobile service.

The results of another generic in Section 2.2.1.1.1.2 study showed that the excess of the cumulative interference from a mobile service network (from IMT to broadcast) over the single interferer can be up to 21 dB. This causes a corresponding increase of separation distance of up to 274 kilometres on land and up to a 1 000 kilometres for land/sea paths (warm), when using the same field strength threshold for cumulative interference as for single entry interference.

The case study in Appendix 1 of Annex 1 to Section I showed two particular examples where the excess of the cumulative interference from MS network over the single interferer can be up to 21 dB, even when using fixed directional receiving antennas

The generic study in Section 2.2.1.1.2 showed that even without accumulation of interfering field strength, a single IMT base-station will need to be positioned 53 kilometres (for land path) from the DTTB service edge, i.e. from the border of the affected Administration in order not to exceed 23 dBμV/m. This field strength is equivalent to an I/N of –10 dB (95% locations, 16 dB antenna discrimination) at the input of the DTTB receiver at the lower end of the 694-790 MHz band. . Including multiple interfering base-stations would increase the interfering field strength at the DTTB service edge by up to 20 dB which corresponds to a separation distance of up to 200 kilometres based on the parameters used in this particular study, when using the same field strength threshold for cumulative interference as for single entry interference.

The case study in Appendix 2 of Annex 1 to Section I showed that IMT base-stations in one country which are not individually subject to coordination, i.e. meeting the trigger threshold of GE06 (25 dBμV/m), will not interfere with the TV receivers in the neighbouring country, even if the cumulative effect of those base-stations is taken into account.

3.1.2 Broadcasting as an interferer into mobile service base-stations

The generic study in Section 2.2.1.2 showed that separation distances up to 427 kilometres and 269 kilometres, for high power (HP) and medium power (MP) DTTB transmitters respectively, would be required to protect the IMT base-station receiver (uplink) for 99% time, a target I/N of –6 dB and with no additional discrimination by cross polarization or receive antenna directivity. The relaxation of the protection level to 90% time, a target I/N of 0 dB and mitigation by full receive antenna polarization and/or discrimination would reduce the separation distances to 159 kilometres for HP and 76 kilometres for MP.

The case study in Appendix 3 of Annex 1 to Section I showed that co-channel sharing between DTTB broadcasting transmitters and an IMT uplink receiver positioned at 30 meters height, will require separation distances of the order of 200 kilometres on land paths even with antenna cross polarization and a relaxation of the percentage of time for the interfering signal from 1 to 10%.

3.2 Summary of the adjacent channel study

3.2.1 Mobile service base-stations as an interferer into broadcast reception

The field trial study indicated that necessary line-of-sight separation distance between transmitting antennas of wireless broadband access system and TV broadcasting receiving antennas ranges from 180 to 995 metres for specified technical parameters in this study (depending from OOBE limit and frequency separation) in frequency range till at least 112 MHz (N-14) offset, taken into account fundamental difficulties with application of such mitigation techniques as additional sideband filters within 470-694 MHz frequency band. During trials, it was no way found for further mitigation improvement while maintaining the basic features of wideband access system available, because one end of radio link is user-controlled.

ANNEX 1 (TO SECTION I)

Co-Channel Case Studies

APPENDIX 1 OF ANNEX 1 (TO SECTION I)

Study for specific examples of coordination situation, indicating the increment of the cumulative interference from the MS network with respect to a single interferer

The calculation of the increment of the cumulative interference field strength from the MS network in relation to a field strength from single interference source carried out in the following order:

1) to select country A and country B;

2) create along the borders of countries A and B of the regular network of MS base-stations with typical parameters (see Table 1.) within the territory of the country A at a distance up to *X* km from the border, so that the first row of the BS stay close to the border;

3) to create test points on the territory of country B on the border of countries A and B, and inland to a distance *Dt* km by step, for example 10 kilometres.

4) In each test point to calculate:

   a) the highest interfered field strength (for 1% of the time) from a single base-station at an altitude of 10 meters, but without take into account receiving antenna directivity;

   b) the highest interfered field strength (for 1% of the time) from a single base-station at an altitude of 10 meters, taking into account receiving antenna directivity with the orientation of the fixed receiving antenna to the TV station with the strongest signal;

   c) cumulative interference field strength from all base-stations in MS network, but without taking into account receiving antenna directivity, using the guidance from the relevant ITU-R group for the 1% of time interfering signals summation.

   d) cumulative interference field strength from all base-stations in MS network, taking into account receiving antenna directivity, using the guidance from the relevant ITU-R group for the 1% of time interfering signals summation.

5) to plot the distributions of the variables a, b, c, d by the number of test points on the same graph;

6) to plot the distributions of the variables $c - a$ and $d - b$ in respective test points, by the number of control points.

TABLE 25

Network parameters for MS base-stations

Parameter	Scale	Value
e.r.p. without loss and G_{iso} for 10 MHz	dBm	58.00
Cable loss (L_{cable})	dB	3.00
Antenna factor (G_{iso})	dBi	15.00
Polarization discrimination	dB	3
Antenna height above ground	m	30.00
Antenna tilt, downside	Degrees	3
Main beam by 3 dB loss in H plane	Degrees	65
Main beam by 3 dB loss in V plane	Degrees	ITU-R F.1336-3. Annex 8 of this Recommendation and a k-value of 0.7
MS network type		Rural
Cell radius (r_{IMT})	km	8

Fig. 13 shows an example of MS network, located along the border of the neighbouring state (blue dots indicate the place of base-stations sites) and covering close-to-border part of the country. Evaluation of increase of cumulative interference field strength from MS network over maximum interference field strength from one base-station was carried out at the test points established in the territory of the neighbouring country (black dots). Fig. 14 shows an example of the reverse situation – when MS network located in opposite country.

FIGURE 13

Example 1 – MS network base-stations sites (blue circles) within the borders of one country and the test points (black circles) on the territory of another country

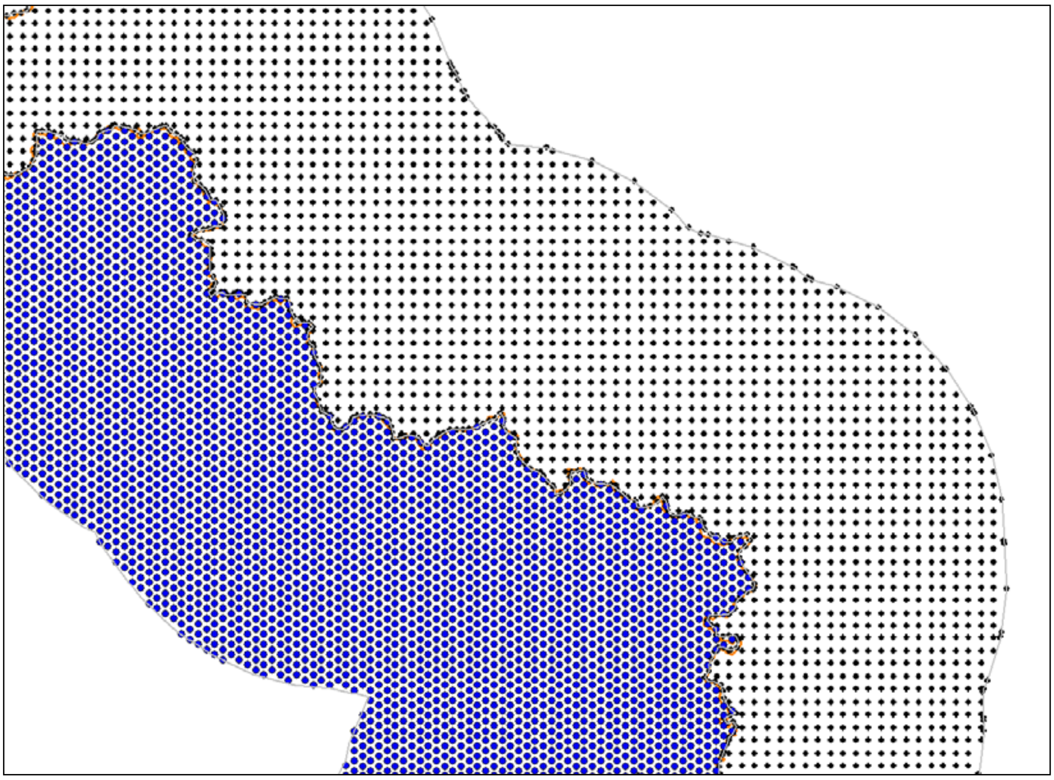
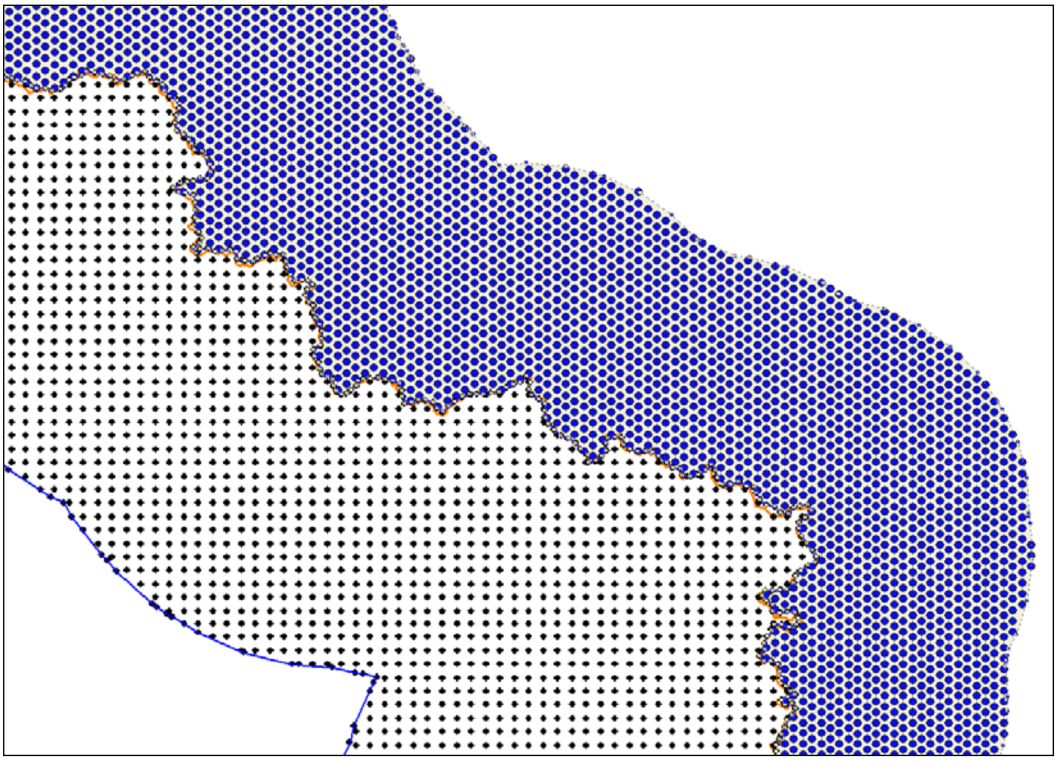


FIGURE 14

Example 2 – MS network base-stations sites (blue circles) within the borders of second country and the test points (black circles) on the territory of first country



The distribution of the interfering fields in the test points of Example 1 shown in Fig. 14 Example 2 – Fig. 16.

FIGURE 15

Distribution of the interfering field strength at the test points of Example 1 in cases a, b, c and d

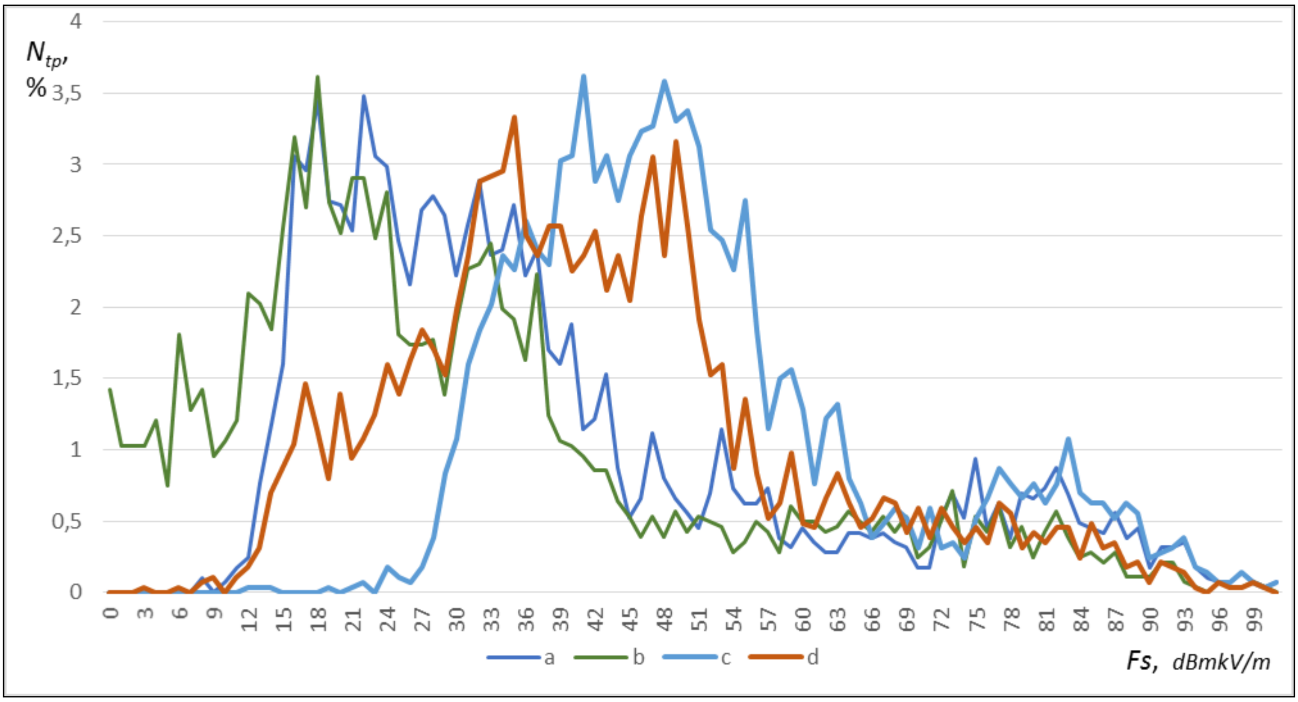
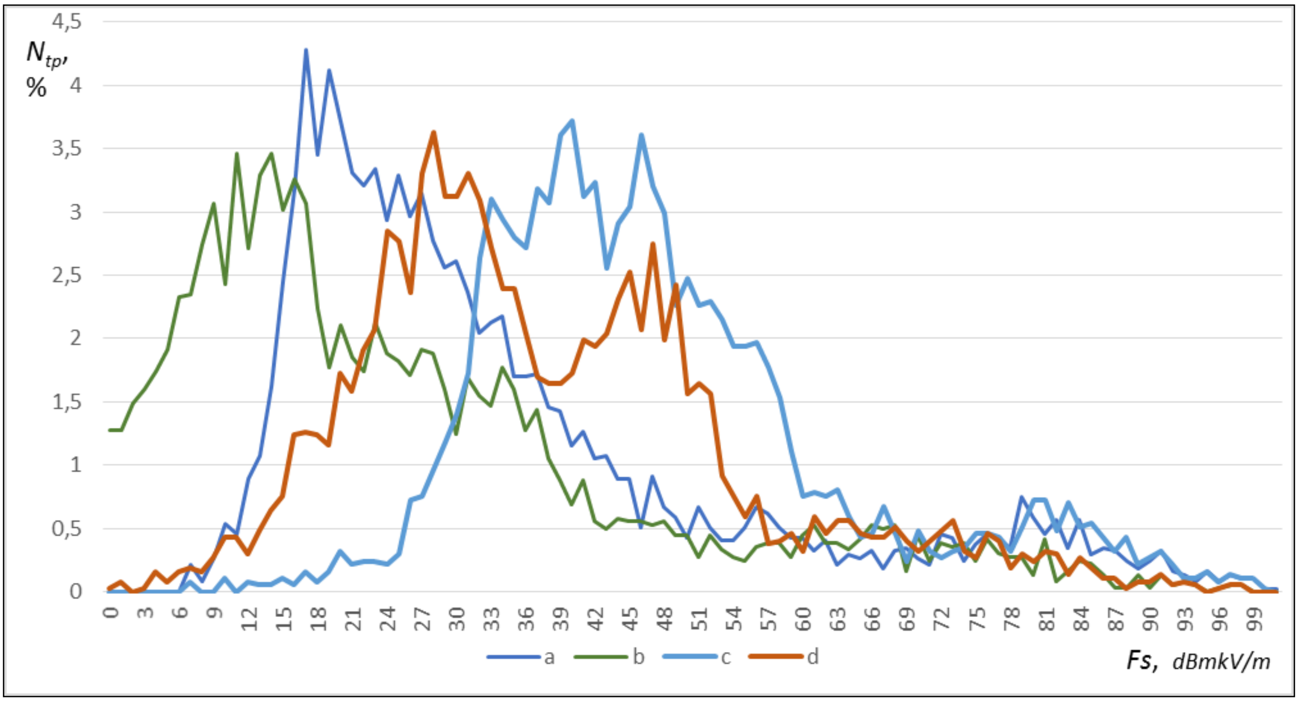


FIGURE 16

Distribution of the interfering field strength at the test points of Example 2 in cases a, b, c and d



At Figures 15 and 16, cases a, b, c and d correspond to those previously described:

a) the highest interfered field strength (for 1% of the time) from a single base-station at an altitude of 10 meters, but without take into account receiving antenna directivity;

b) the highest interfered field strength (for 1% of the time) from a single base-station at an altitude of 10 meters, taking into account receiving antenna directivity with the orientation of the fixed receiving antenna to the TV station with the strongest signal;

c) cumulative interference field strength from all base-stations in MS network, but without taking into account receiving antenna directivity, using 1% of time interfering signals summation;

d) cumulative interference field strength from all base-stations in MS network, taking into account receiving antenna directivity, using 1% of time interfering signals summation.

The resulting distribution of the increments of the total strength of the interfering field with respect to the maximum field strength of the interfering signal from one station is shown in Figures 17 and 18.

Figures 17 and 18 show results for the case of using omnidirectional receiving antenna, and for the case of using the receiving antenna oriented in direction to TV station with the highest level of the desired signal. The receiving TV antenna modelled according to Recommendation ITU-R BT.419.

FIGURE 17

Distribution of cumulative interfering field strength from MS network increments over the maximum field strength from a single MS base-station in example 1

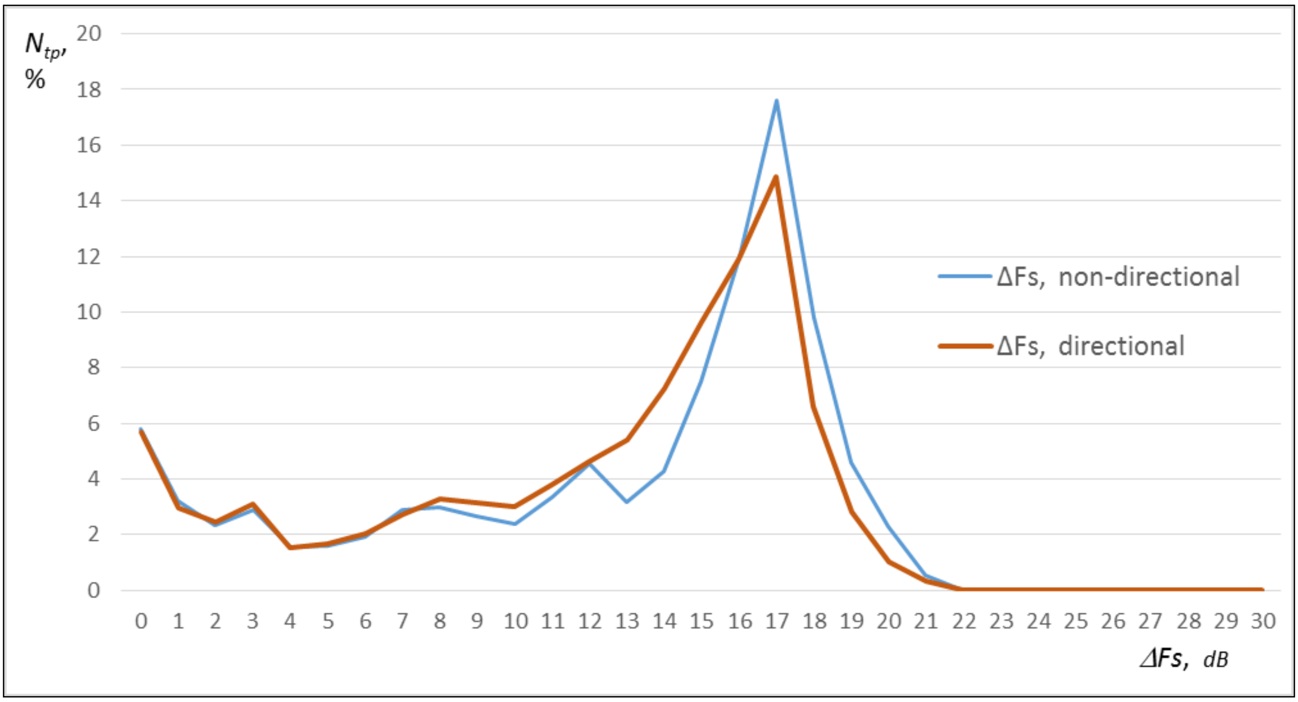
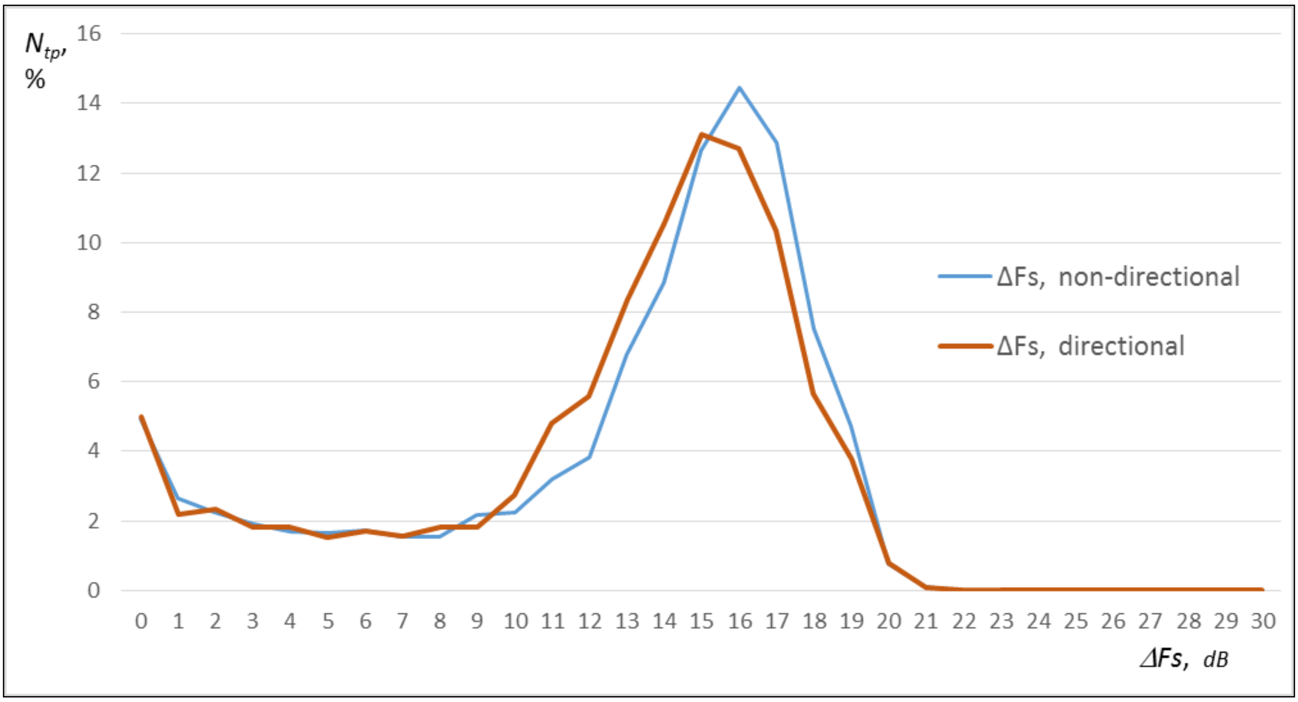


FIGURE 18

Distribution of cumulative interfering field strength from MS network increments over the maximum field strength from a single MS base-station in example 2



Conclusion

The results show that the excess of the cumulative interference from MS network over the single interferer can be up to 21 dB (using the receiving antenna). This study shows that when conducting compatibility studies, cumulative interference of signals from the MS base-stations should be considered.

APPENDIX 2 OF ANNEX 1 (TO SECTION I)

A2.1 Description

This section presents a summary of the results of a co-channel sharing study in the UHF band, based on a real mobile network , in order to assess the potential impact of multiple sources of interference in terms of C/N+I at different points at the border between two countries and inside the victim country.

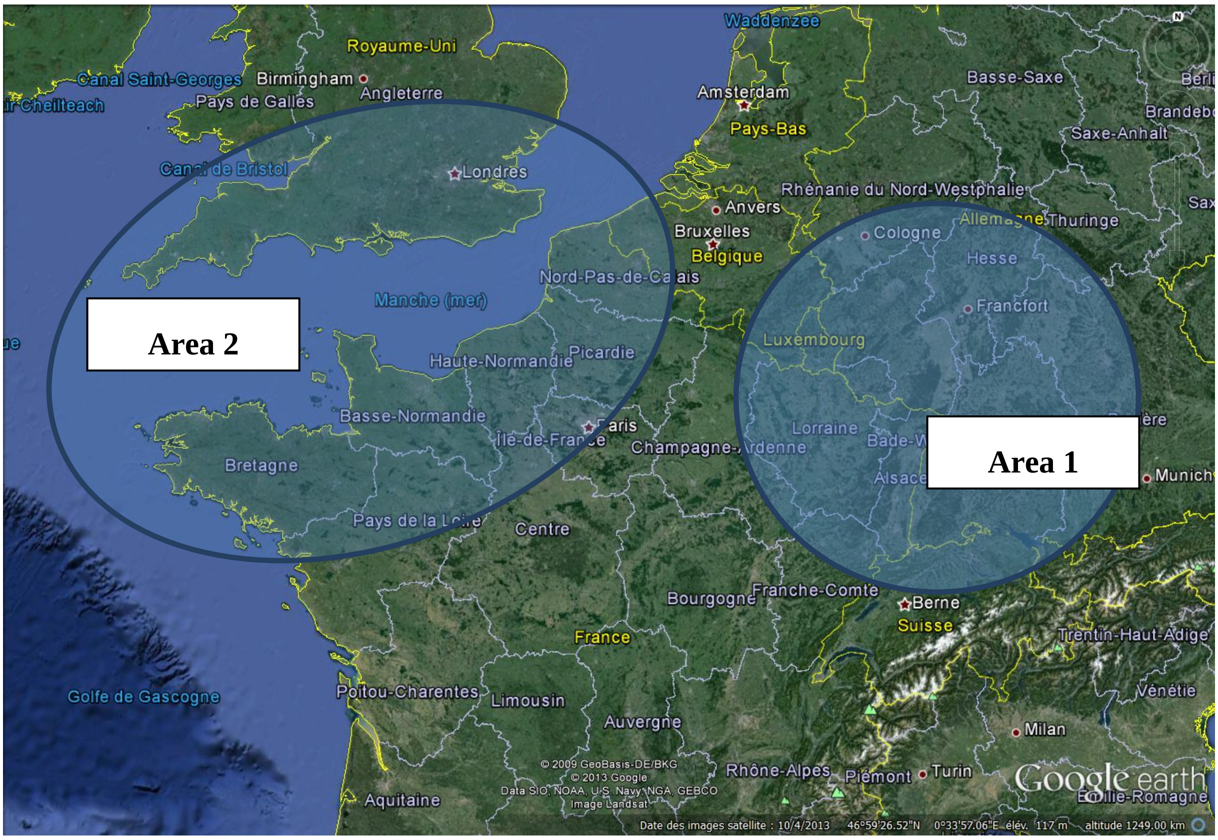
Two areas are studied in this section:

– Area 1: Bordering area between France and Germany;

– Area 2: Bordering area between France and United Kingdom.

FIGURE 19

Areas of the study



Both areas have a different DTT planning strategy as DTT is planned for portable outdoor reception (RPC2) in Germany and for fixed rooftop reception (RPC1) for United Kingdom.

The coordinated DTT networks, which are currently on air, have been used for both areas[4] and base-stations of the GSM 900 have been used for mobile service[5]. In order to simplify the calculations, the base-stations are considered as omnidirectional with 0° downtilt. As a consequence, the simulated field strength of the IMT network is overestimated. Due to the level of details the level of the DTT field strength is also overestimated.

The methodology of the study consists first, on a large set of test points, on the border or inside the victim country, in computing the DTT wanted field strength from all broadcasting stations. We can consider that the DTT reception antenna is receiving the maximum of all the field strength provide by all the broadcasting stations, taking into account the antenna directivity depending on the RPC. Thus, for each test points, the maximum of the median field strength, E_{wanted} is determined.

The second step consists in computing the interfering field strength for each test point and from each base-station.

In order to consider only the base-stations not subject to the coordination process under the condition of GE06 Agreement, the base-stations providing an interfering field strength above or equal to 25 dBµV/m on, at least, one test point on the border are withdrawn from the simulation

For each test point where E_{wanted} is above the minimum median DTT field strength, the cumulative median interfering field strength, $\mathbf{I_{MedCmul}}$, is computed with all the "non-coordinated" base-stations, using the power summing methodology.

The minimum median DTT field strength are taken from the GE06 Agreement (table A-3-5-1 of Annex 3.5) here reproduced in Table 26.

TABLE 26

RPCs 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 f_r = 200 MHz	50	67	76
Reference $(E_{med})_{ref}$ (dB(µV/m)) at f_r = 650 MHz	56	78	88

$(E_{med})_{ref}$: Reference value for minimum median field strength

RPC 1: RPC for fixed 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

The appropriate frequency correction factor is used to adjust the minimum median DTT field strength.

The calculations were performed at 790 MHz. The coordinated antenna pattern was used for the horizontal plane of the antenna while for the vertical plane an omnidirectional pattern was used.

[4] More information at "http://www.anfr.fr/fr/planification-international/coordination/recherche-daccords/television-et-radio-numerique.html".

[5] Information at "http://www.cartoradio.fr/cartoradio/web/".

For the field strength calculations, the propagation model of the Recommendation ITU-R P 1546 is used, 50% of time for the DTT and 2% of the time for the IMT network.

Finally, each $I_{MedCumul}$ is compared with E_{maxint} defined as:

$$E_{max\,int} = E_{wanted} - q\sqrt{(\sigma_w^2 + \sigma_i^2)} - PR - IM + D_{dir} + D_{pol} \qquad (1)$$

where:

TABLE X

Parameters of the study

E_{maxint}	Maximum median allowable base-station field strength in 8 MHz bandwidth at the wanted receiving antenna (dB(μV/m))
E_{wanted}	Median wanted BS field strength at the wanted (BS) receiving antenna (dB(μV/m))
σ_w	Standard deviation (dB) of the normal distribution of the wanted signal level (BS signals). The value of 5.5 dB is used for both cases.
σ_i:	Standard deviation (dB) of the normal distribution of the interfering signal (base-station signals). The value of 5.5 dB is used for both cases.
Q	Correction factor obtained from the complementary cumulative inversed normal function Q(x%), where x% represents the locations where a certain field strength is present; and is equal to 95%
$q\sqrt{(\sigma_w^2 + \sigma_i^2)}$	"Propagation correction factor" (Recommendation ITU-R P.1546) (dB);
PR	Appropriate BS protection ratio (dB), the value of 19 dB is used according to Recommendation ITU-R BT.1368.
IM	Allowance for inter-service sharing (dB). The value of 0 dB is used
D_{dir}	BS receiver antenna directivity discrimination with respect to base-station signal (dB). For RPC1 the Recommendation ITU-R BT.419 is used and for RPC2 , no antenna discrimination is considered.
D_{pol}:	BS receiver polarization discrimination with respect to base-station signal (dB). It is assumed that base-station signals are cross polarized. The receiver antenna polarization discrimination is, therefore, assumed to be 3 dB for RPC1 and 0 dB for RPC2.

An interference situation occurs when the cumulative interference field strength, $\mathbf{I_{MedCmul}}$, from the selected set of base-stations is above the maximum median allowable base-station field strength, $\mathbf{E_{maxint}}$.

As a consequence, the following criteria must be kept to avoid interference situation

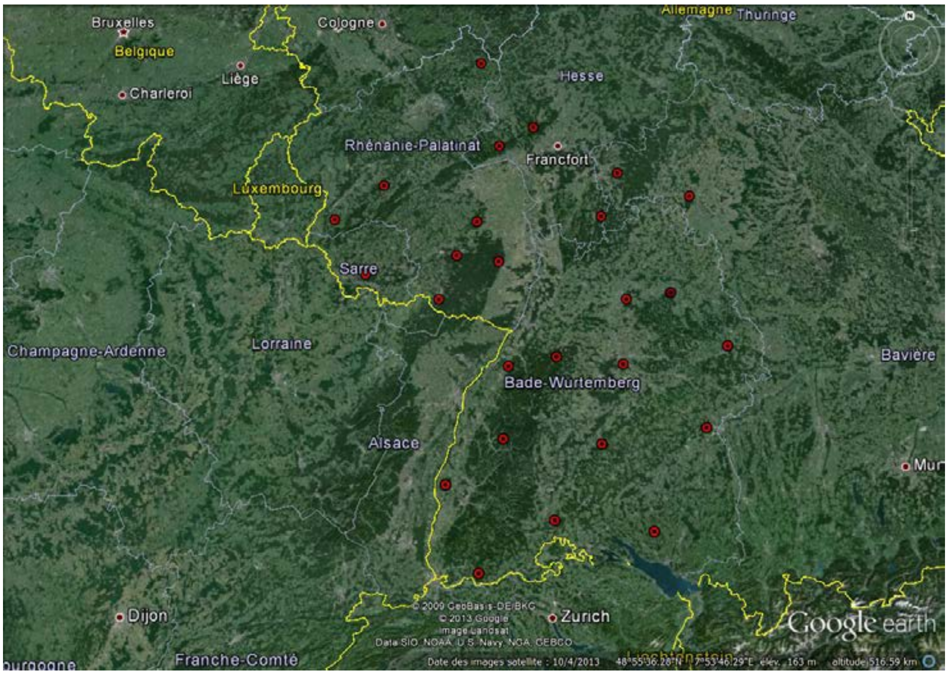
$$I_{MedCmul} < E_{maxint} \qquad (2)$$

A2.2 Area 1: Bordering area between France and Germany

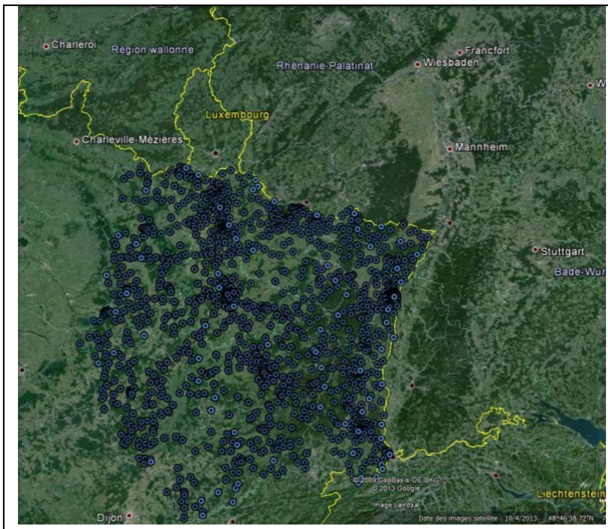
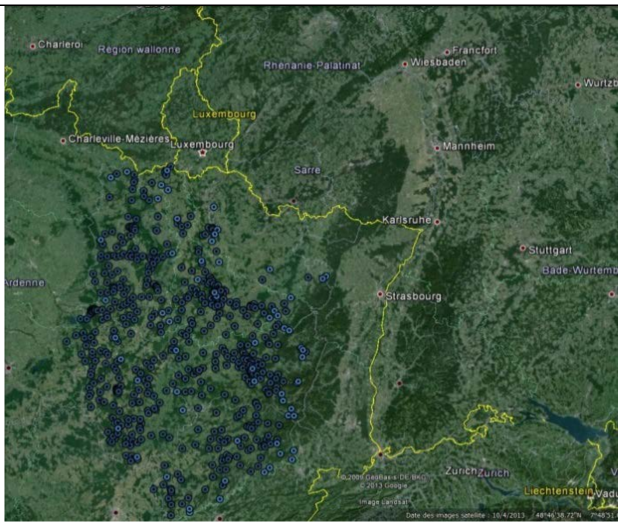
The DTT network used for this case study is illustrated below.

FIGURE 20

DTT network



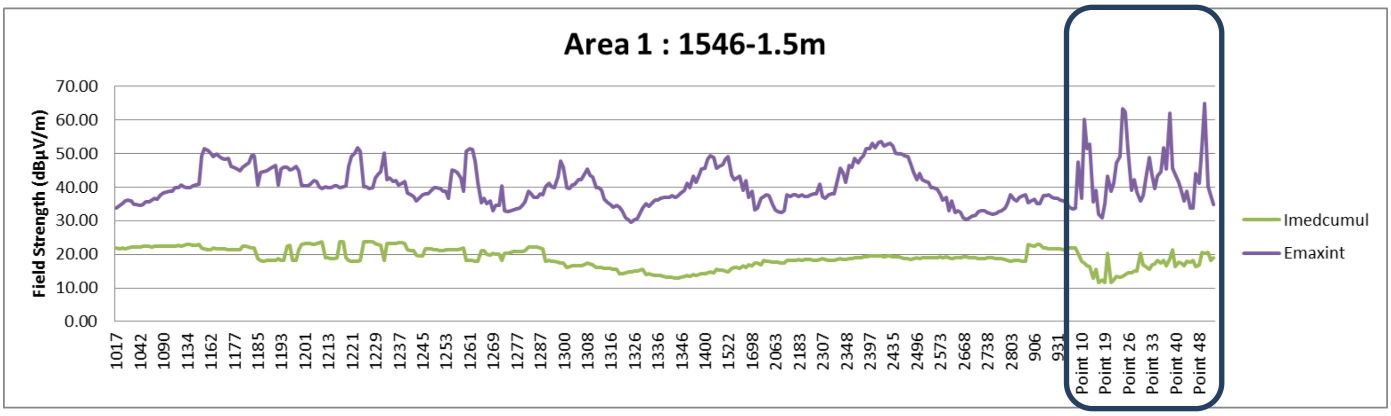
The IMT network is illustrated below. The figure on the left corresponds to all the considered IMT stations and the figure on the right correspond to all the IMT stations not concern by the international coordination, i.e. interfering field strength is below the triggering threshold according to the GE06 Agreement.

	
IMT Network (1 384)	Non coordinated IMT Network (519)

The considered test points are illustrated below.

	
Test points at the border (328)	Complementary test points (48)

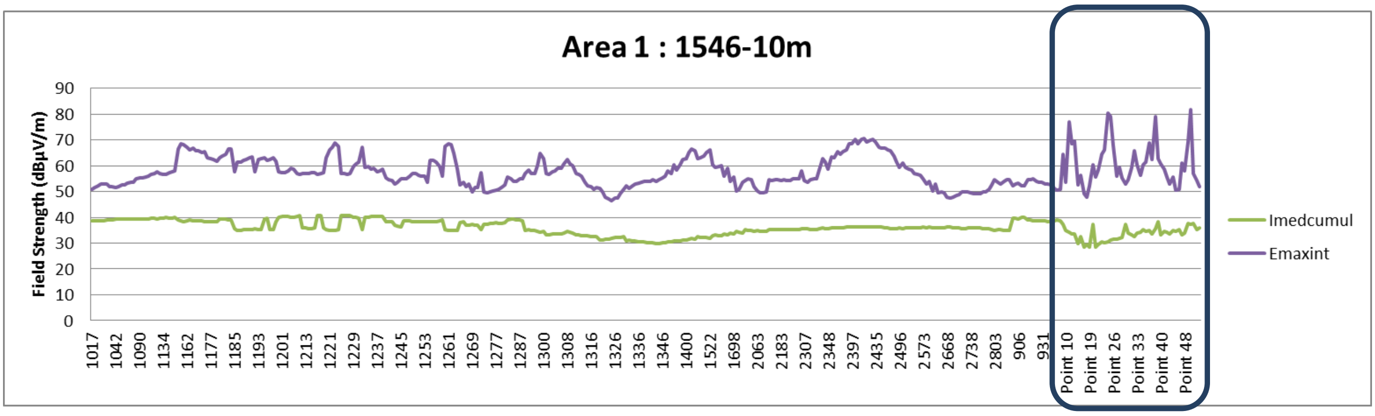
The results of the simulations with a 1.5 m receiving antenna height are illustrated below.



Complementary test points

For all the test points where C/N ≥ PR, the cumulative median interfering field strength is below the maximum median allowable base-station field strength in 8 MHz bandwidth at the wanted receiving antenna. The criterion (2) is always respected.

The results of the simulations with a 10 metres receiving antenna height are illustrated below.



Complementary test points

The same conclusion applies.

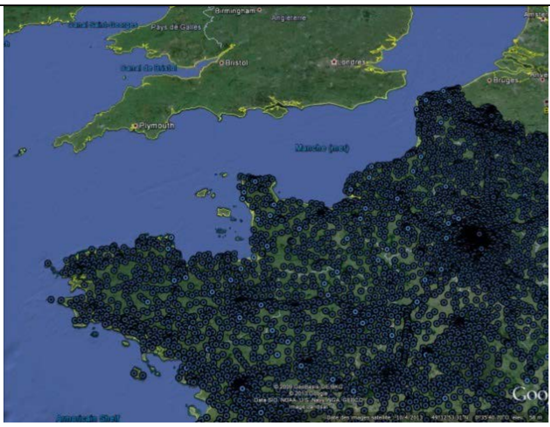
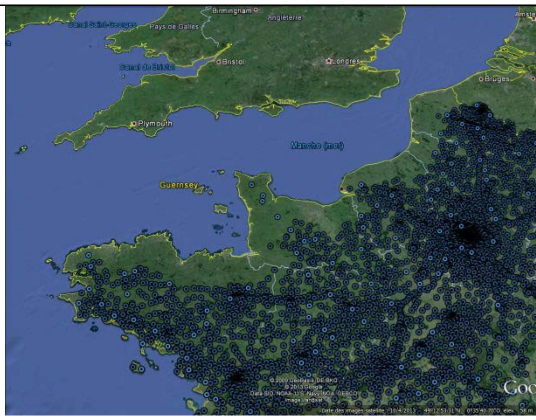
A2.3 Area 2: Bordering area between France and United Kingdom

The DTT network used for this case study is illustrated below.

FIGURE 21

DTT network

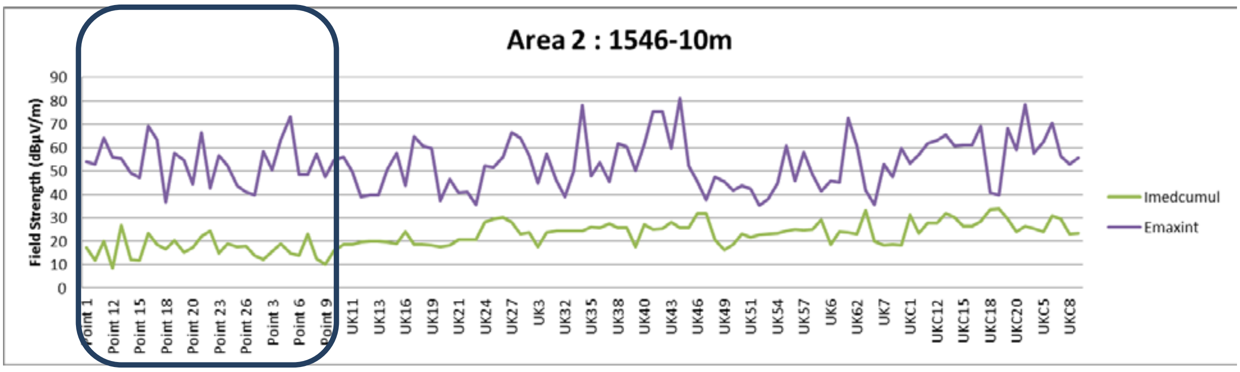
The IMT network is illustrated below. The figure on the left corresponds to all the considered IMT stations and the figure on the right correspond to all the IMT stations not concern by the international coordination, i.e. interfering field strength is below the triggering threshold according to the GE06 Agreement.

	
IMT Network (6 811)	Non coordinated IMT Network (5 137)

The considered test points are illustrated below.

	
Test points at the border (84)	Complementary test points (29)

The results of the simulations with a 10 metres receiving antenna height are illustrated below.



Complementary test points

For all the test points where C/N ≥ PR, the cumulative median interfering field strength is below the maximum median allowable base-station field strength in 8 MHz bandwidth at the wanted receiving antenna. The criterion (2) is always respected.

A2.4 Conclusions

The purpose of GE-06 coordination trigger threshold evaluations is to indicate when it is advisable to have discussions with your neighbours. In this study the stations that would have been subject to coordination have been left out. In normal bilateral situations it would be advisable to discuss the whole of the proposed network with your neighbours. If these discussions do not take place the study above would provide an indication of potential residual interference field strength of the remaining stations omitted from the coordination.

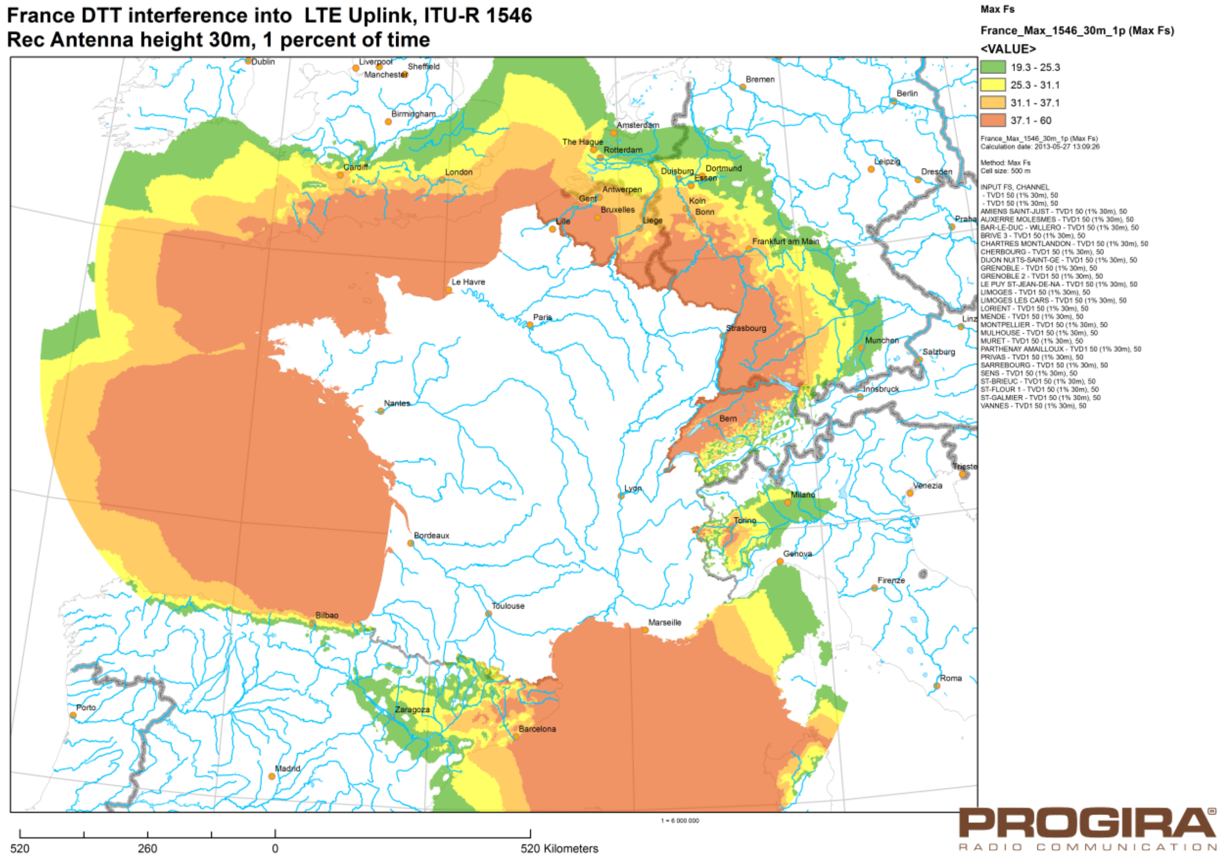
With the parameters and assumptions taken for this study, it is shown that the strict application of GE-06 Agreement (including its coordination threshold) adequately protects the reception of the broadcasting service. In this case study, those base-stations in one country which are not individually subject to coordination will not interfere with the TV receiving station in the neighbouring country even if the cumulative effect of those base-stations is taken into account.

APPENDIX 3 OF ANNEX 1 (TO SECTION I)

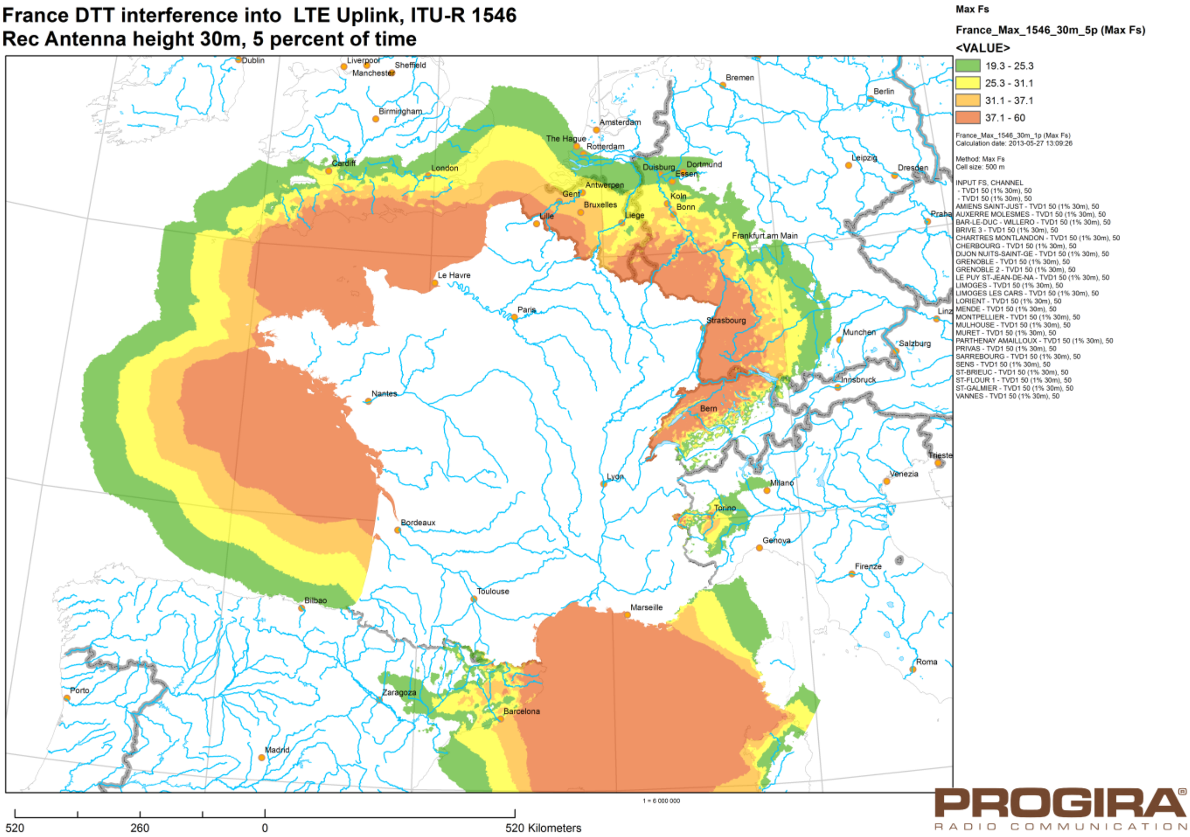
Results of calculations

FIGURES 22-24

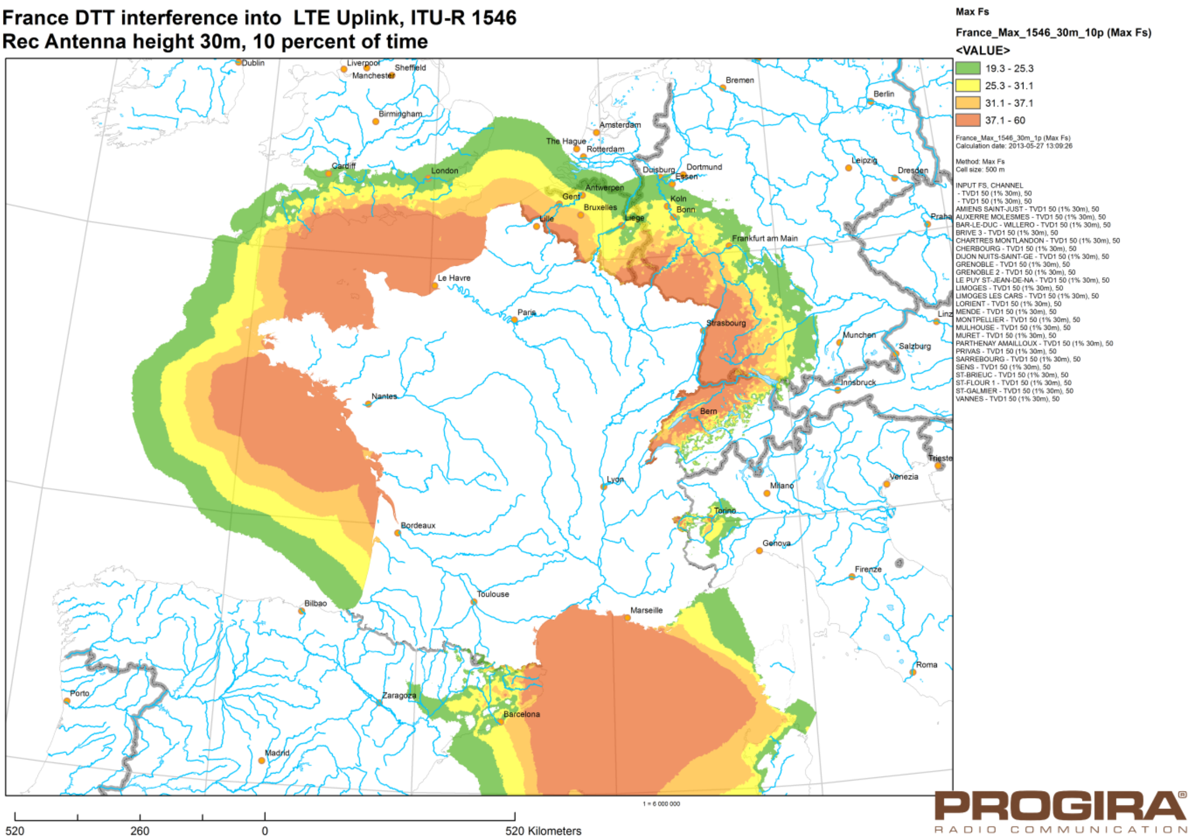
Interference from GE06 channel 50 DTTB in France using Recommendation ITU-R P.1546, for 1%, 5% and 10% of time



France DTT interference into LTE Uplink, ITU-R 1546
Rec Antenna height 30m, 5 percent of time

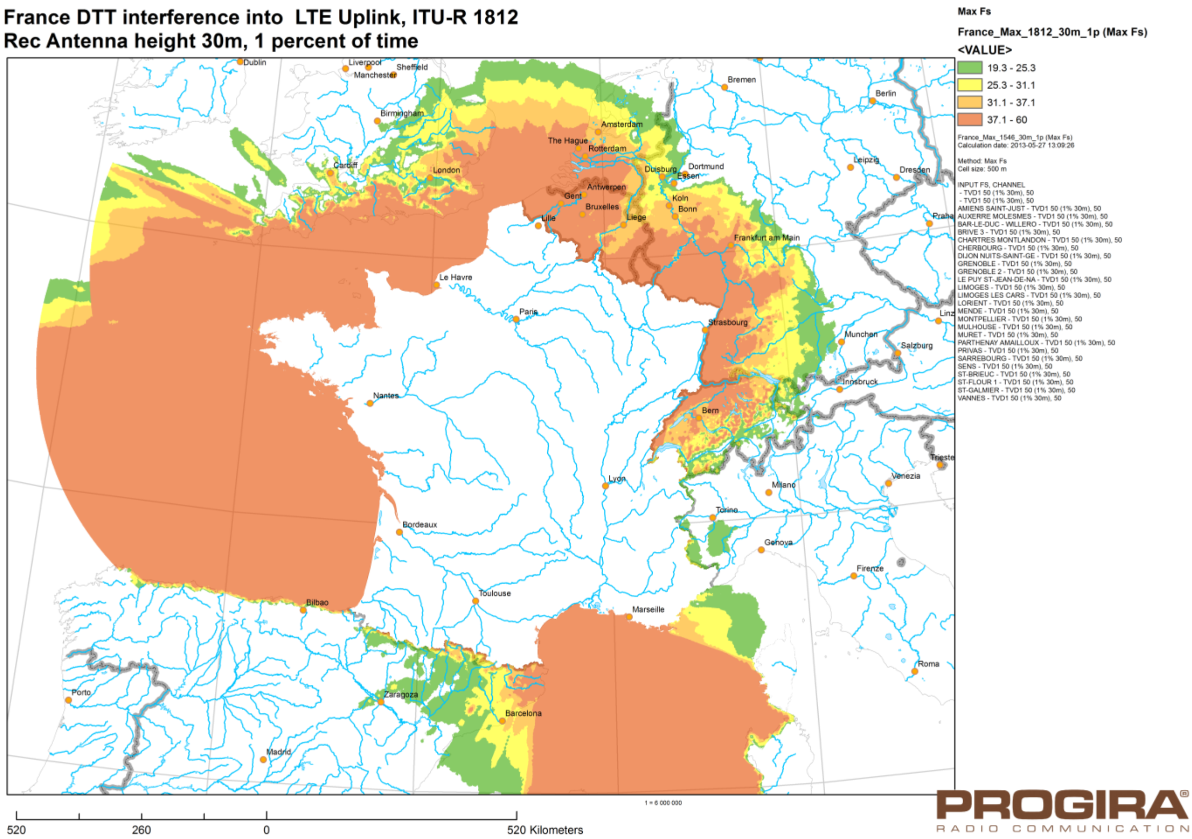


France DTT interference into LTE Uplink, ITU-R 1546
Rec Antenna height 30m, 10 percent of time

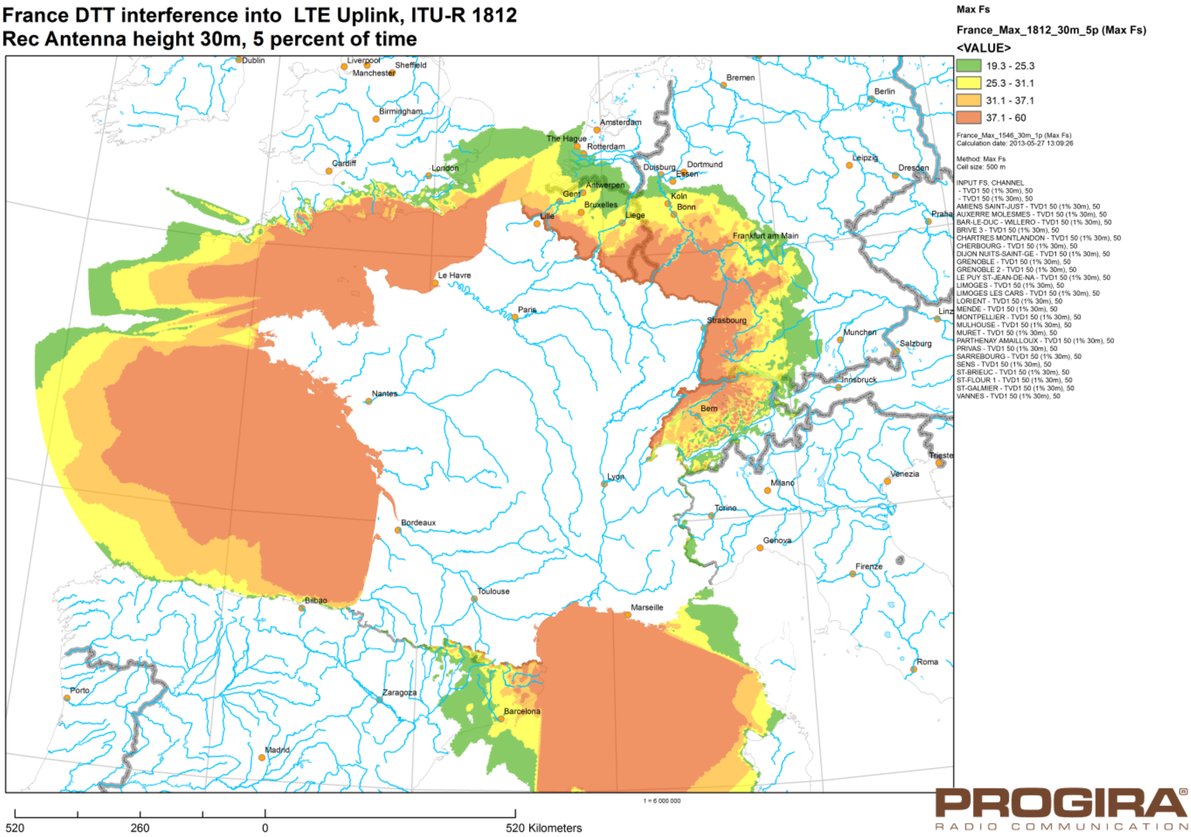


FIGURES 25- 27

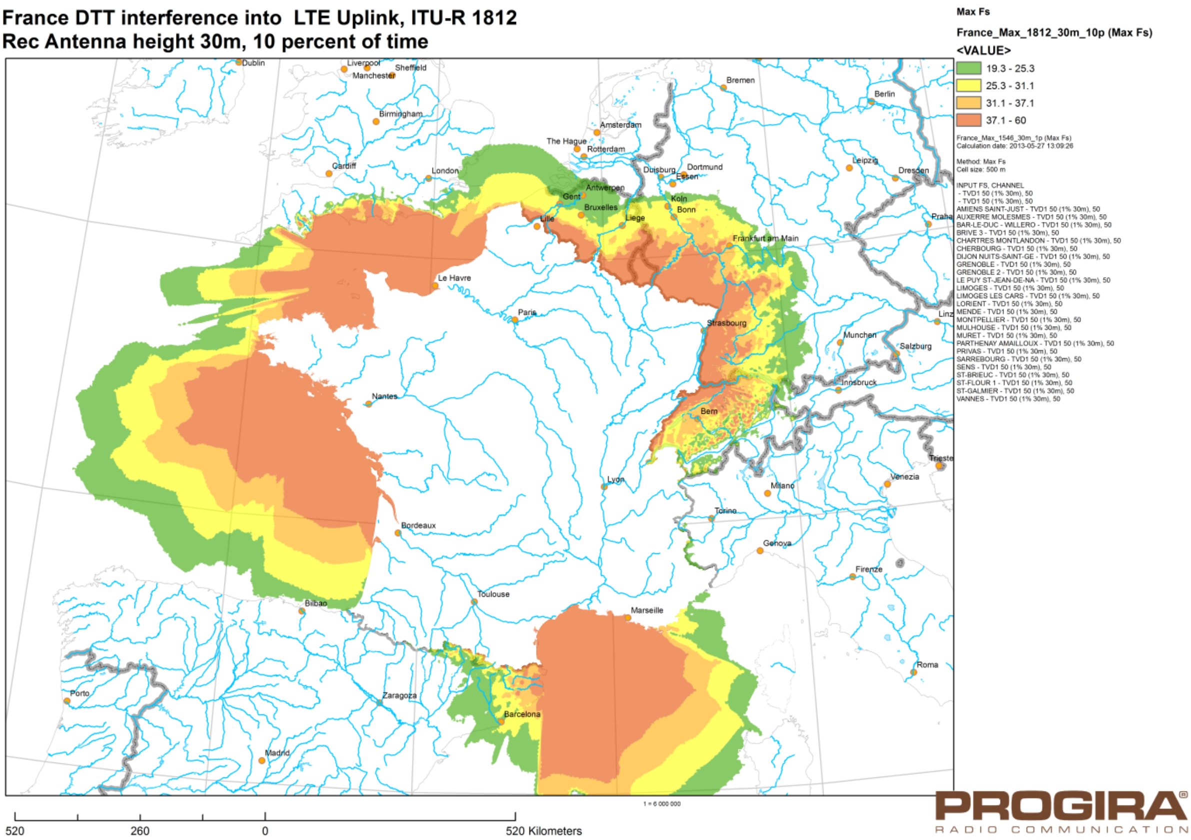
Interference from GE06 channel 50 DTTB in France using Recommendation ITU-R P.1812, for 1%, 5% and 10% of time



France DTT interference into LTE Uplink, ITU-R 1812
Rec Antenna height 30m, 5 percent of time

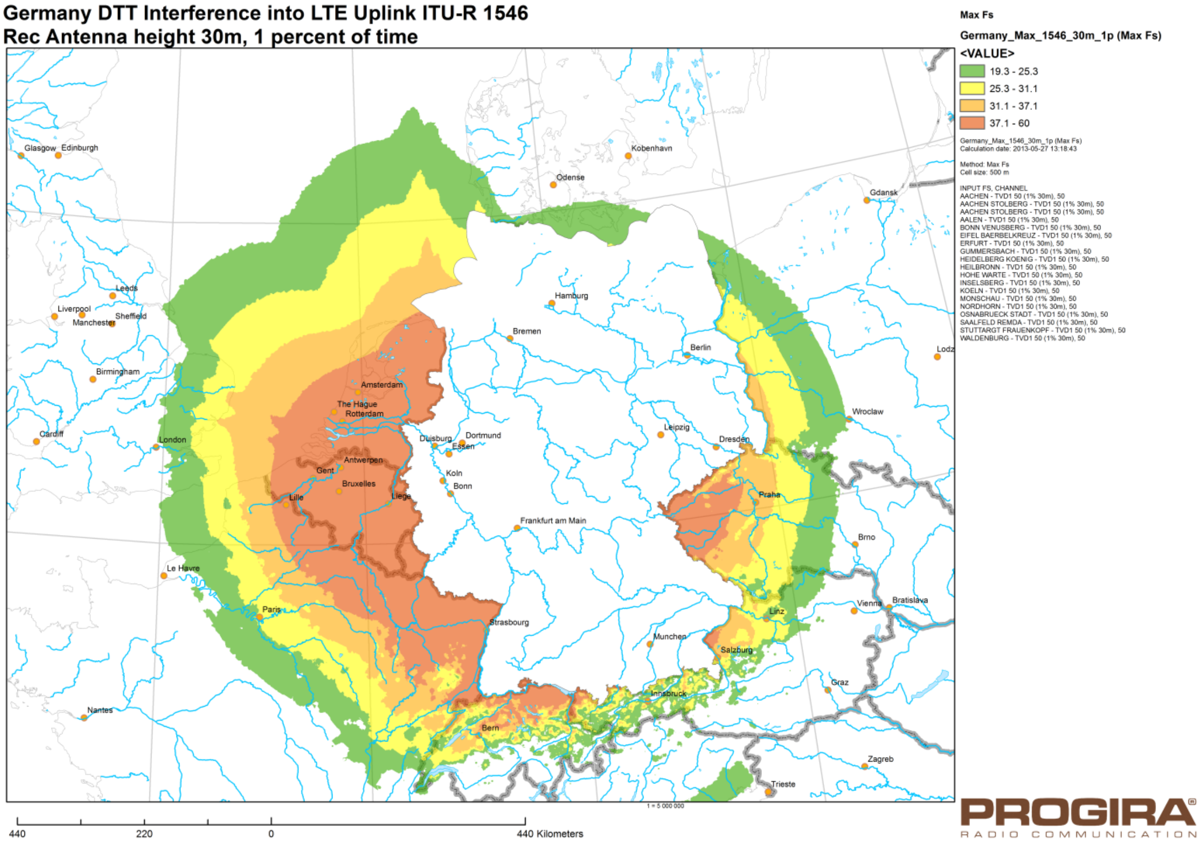


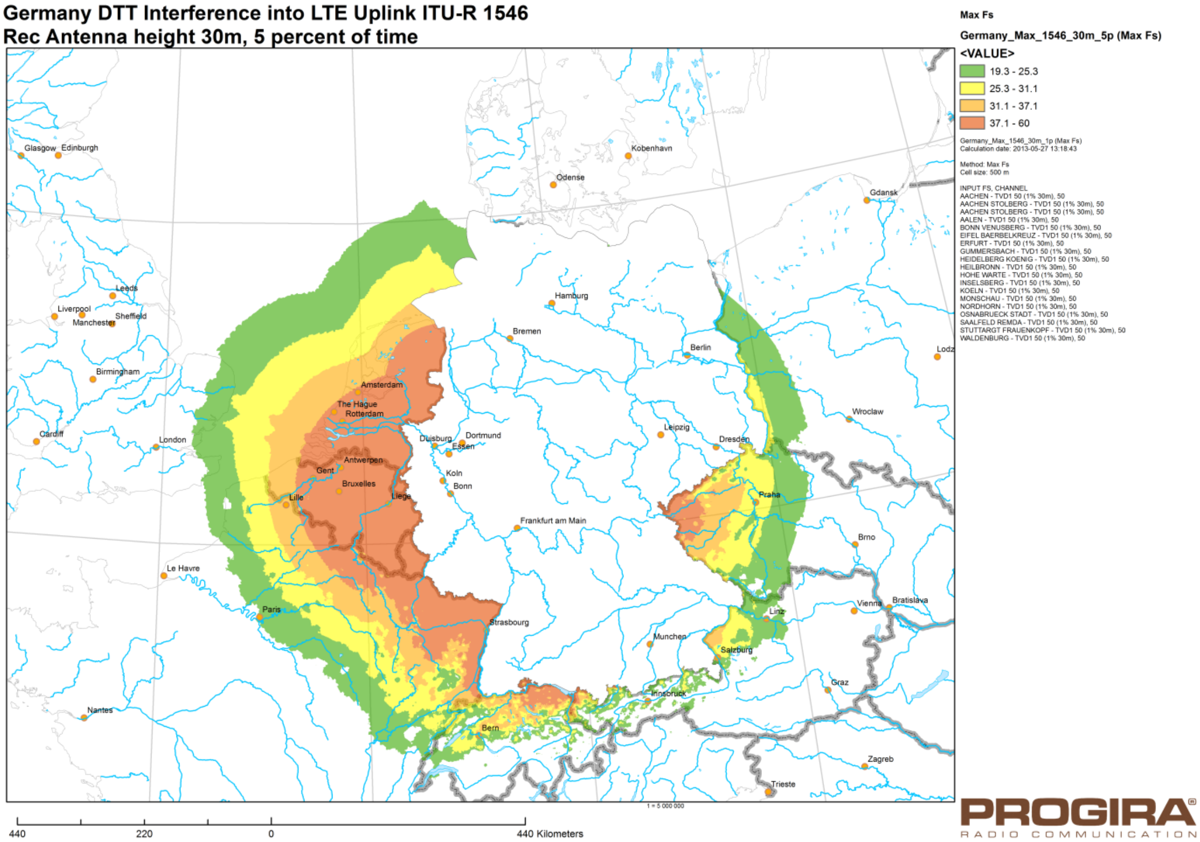
France DTT interference into LTE Uplink, ITU-R 1812
Rec Antenna height 30m, 10 percent of time

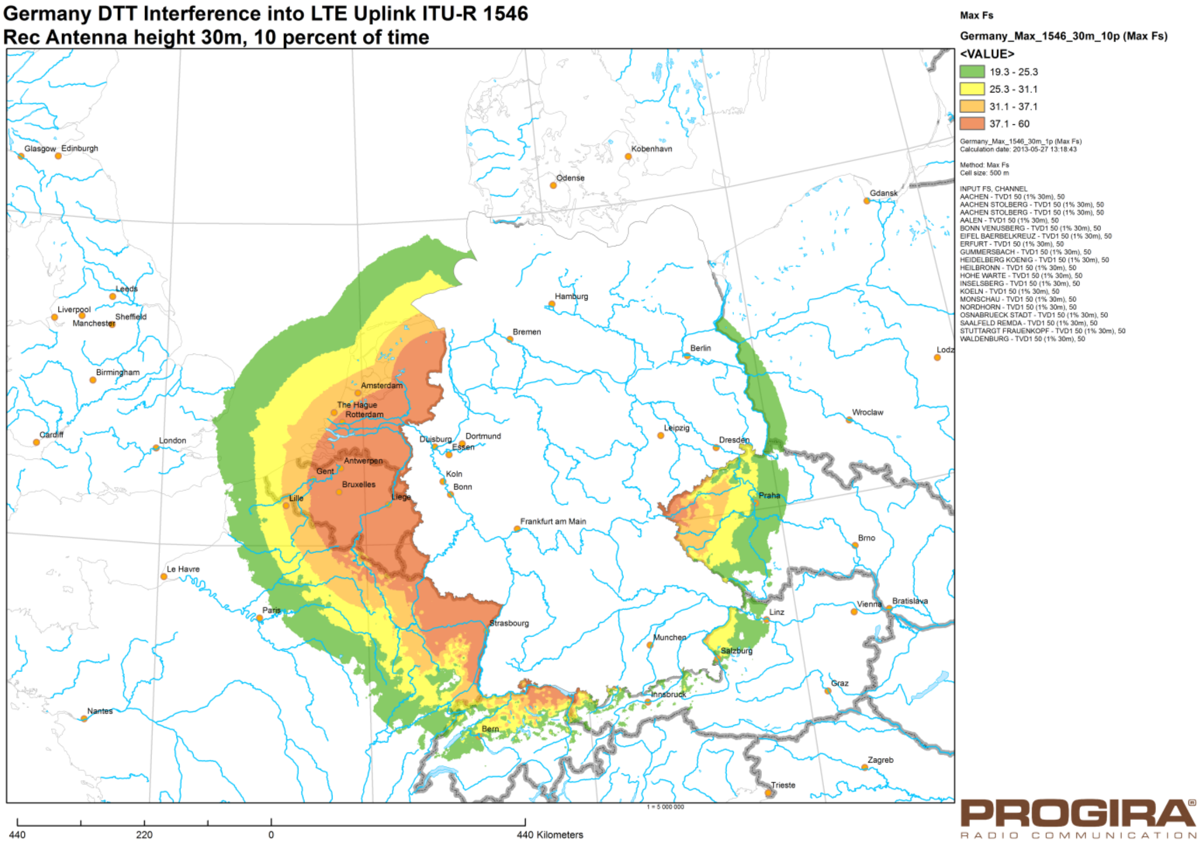


FIGURES 28-30

Interference from GE06 channel 50 DTTB in Germany using Recommendation ITU-R P.1546, for 1%, 5% and 10% of time

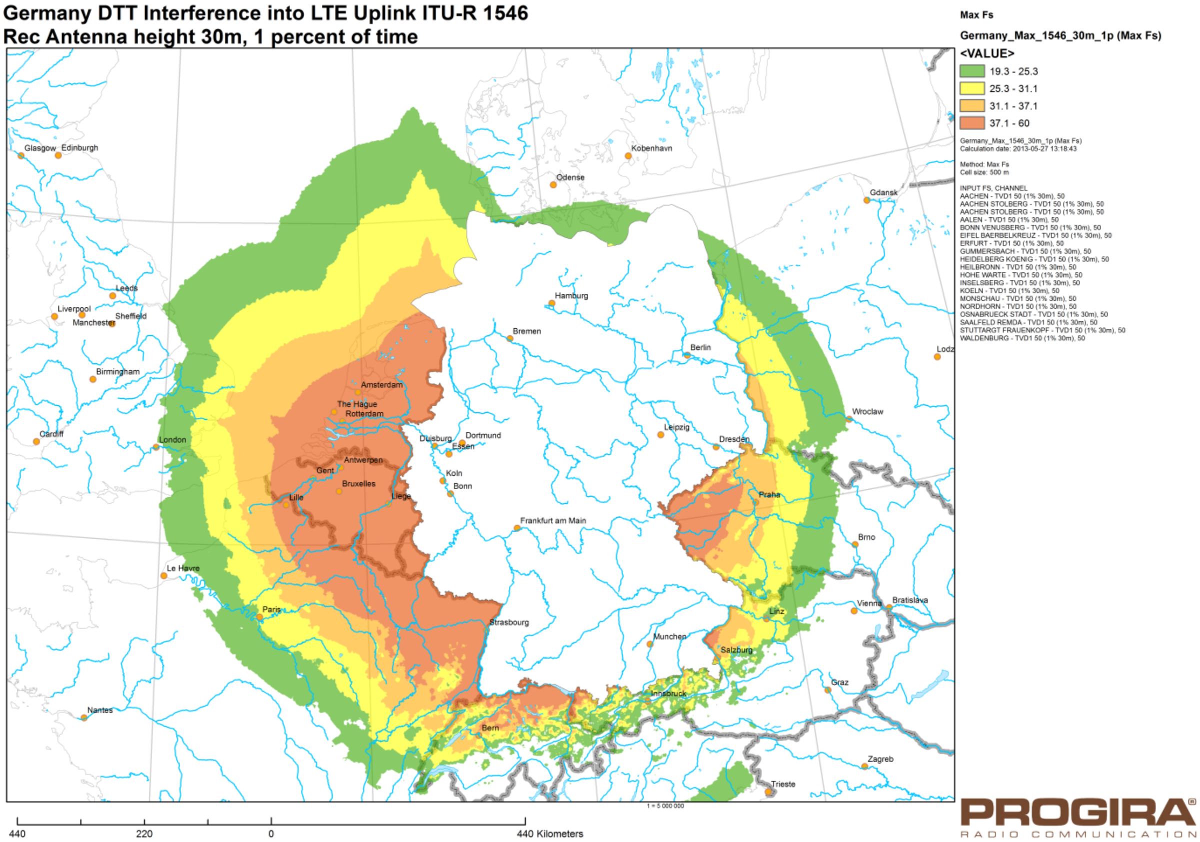


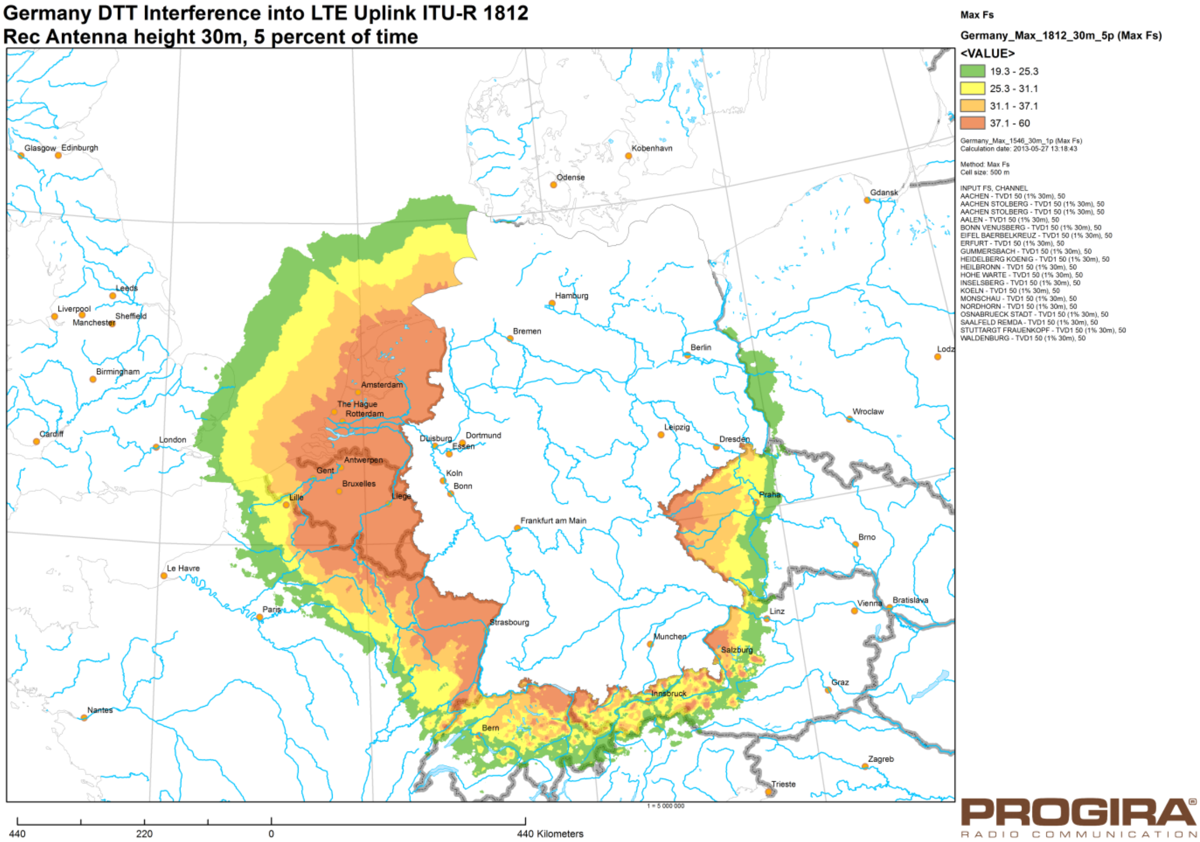



Germany DTT Interference into LTE Uplink ITU-R 1546
Rec Antenna height 30m, 10 percent of time
Max Fs
Germany_Max_1546_30m_10p (Max Fs)
<VALUE>
19.3 - 25.3
25.3 - 31.1
31.1 - 37.1
37.1 - 60
Germany_Max_1546_30m_1p (Max Fs)
Calculation date: 2013-05-27 13:18:43
Method: Max Fs
Cell size: 500 m
INPUT FS, CHANNEL
AACHEN - TVD1 50 (1% 30m), 50
AACHEN STOLBERG - TVD1 50 (1% 30m), 50
AACHEN STOLBERG - TVD1 50 (1% 30m), 50
AALEN - TVD1 50 (1% 30m), 50
BONN VENUSBERG - TVD1 50 (1% 30m), 50
EIFEL BAERBELKREUZ - TVD1 50 (1% 30m), 50
ERFURT - TVD1 50 (1% 30m), 50
GUMMERSBACH - TVD1 50 (1% 30m), 50
HEIDELBERG KOENIG - TVD1 50 (1% 30m), 50
HEILBRONN - TVD1 50 (1% 30m), 50
HOHE WARTE - TVD1 50 (1% 30m), 50
INSELSBERG - TVD1 50 (1% 30m), 50
KOELN - TVD1 50 (1% 30m), 50
MONSCHAU - TVD1 50 (1% 30m), 50
NORDHORN - TVD1 50 (1% 30m), 50
OSNABRUECK STADT - TVD1 50 (1% 30m), 50
SAALFELD REMDA - TVD1 50 (1% 30m), 50
STUTTARGT FRAUENKOPF - TVD1 50 (1% 30m), 50
WALDENBURG - TVD1 50 (1% 30m), 50
Glasgow
Edinburgh
Kobenhavn
Odense
Gdansk
Leeds
Liverpool
Sheffield
Manchester
Hamburg
Bremen
Berlin
Lodz
Birmingham
Amsterdam
The Hague
Rotterdam
Wroclaw
Cardiff
London
Duisburg
Dortmund
Essen
Leipzig
Dresden
Antwerpen
Gent
Koln
Bruxelles
Bonn
Lille
Liege
Praha
Frankfurt am Main
Brno
Le Havre
Paris
Vienna
Bratislava
Linz
Strasbourg
Munchen
Salzburg
Innsbruck
Graz
Nantes
Bern
Zagreb
Trieste
1 = 5 000 000
440
220
0
440 Kilometers
PROGIRA
RADIO COMMUNICATION

FIGURES 31-33

Interference from GE06 channel 50 DTTB in Germany using Recommendation ITU-R P.1812, for 1%, 5% and 10% of time




Germany DTT Interference into LTE Uplink ITU-R 1812
Rec Antenna height 30m, 5 percent of time
Max Fs
Germany_Max_1812_30m_5p (Max Fs)
<VALUE>
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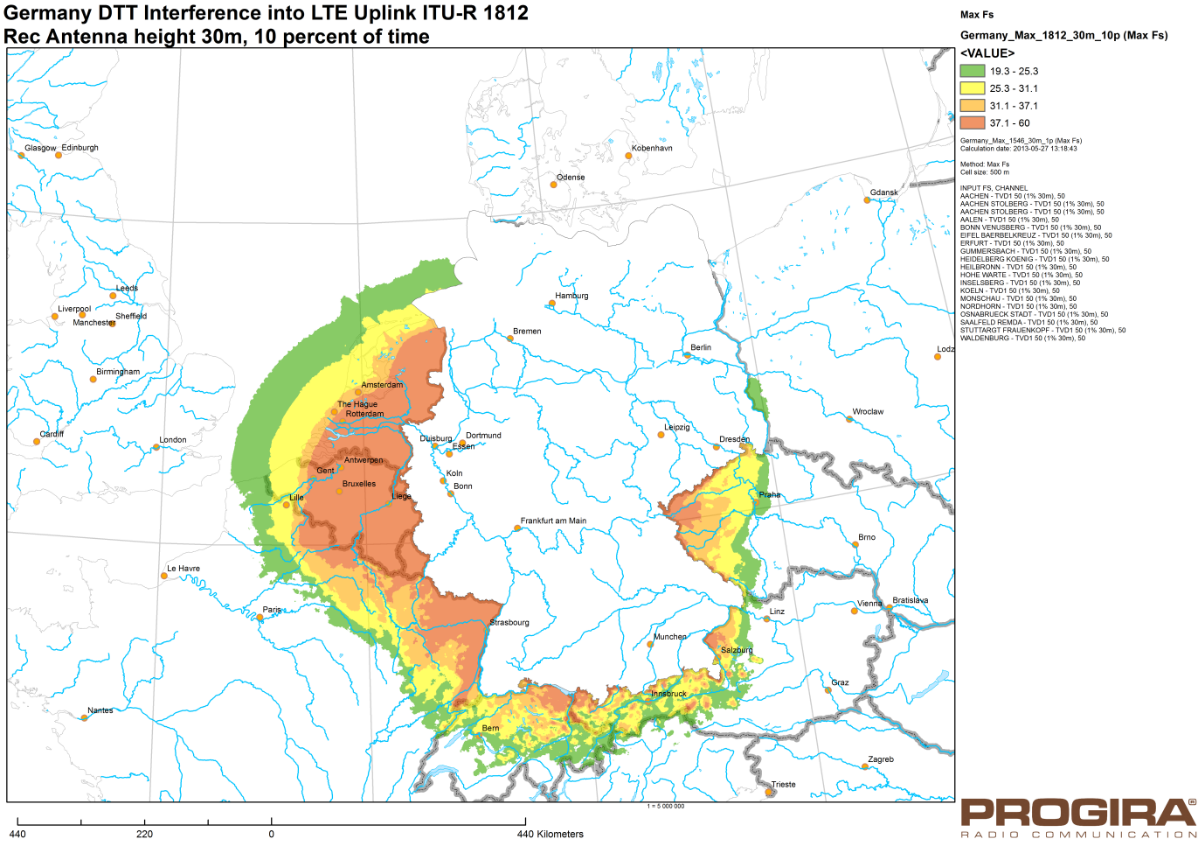
25.3 - 31.1
31.1 - 37.1
37.1 - 60
Germany_Max_1546_30m_1p (Max Fs)
Calculation date: 2013-05-27 13:18:43
Method: Max Fs
Cell size: 500 m
INPUT FS, CHANNEL
AACHEN - TVD1 50 (1% 30m), 50
AACHEN STOLBERG - TVD1 50 (1% 30m), 50
AACHEN STOLBERG - TVD1 50 (1% 30m), 50
AALEN - TVD1 50 (1% 30m), 50
BONN VENUSBERG - TVD1 50 (1% 30m), 50
EIFEL BAERBELKREUZ - TVD1 50 (1% 30m), 50
ERFURT - TVD1 50 (1% 30m), 50
GUMMERSBACH - TVD1 50 (1% 30m), 50
HEIDELBERG KOENIG - TVD1 50 (1% 30m), 50
HEILBRONN - TVD1 50 (1% 30m), 50
HOHE WARTE - TVD1 50 (1% 30m), 50
INSELSBERG - TVD1 50 (1% 30m), 50
KOELN - TVD1 50 (1% 30m), 50
MONSCHAU - TVD1 50 (1% 30m), 50
NORDHORN - TVD1 50 (1% 30m), 50
OSNABRUECK STADT - TVD1 50 (1% 30m), 50
SAALFELD REMDA - TVD1 50 (1% 30m), 50
STUTTARGT FRAUENKOPF - TVD1 50 (1% 30m), 50
WALDENBURG - TVD1 50 (1% 30m), 50
PROGIRA
RADIO COMMUNICATION
440
220
0
440 Kilometers


Germany DTT Interference into LTE Uplink ITU-R 1812
Rec Antenna height 30m, 10 percent of time
Max Fs
Germany_Max_1812_30m_10p (Max Fs)
<VALUE>
19.3 - 25.3
25.3 - 31.1
31.1 - 37.1
37.1 - 60
Germany_Max_1546_30m_1p (Max Fs)
Calculation date: 2013-05-27 13:18:43
Method: Max Fs
Cell size: 500 m
INPUT FS, CHANNEL
AACHEN - TVD1 50 (1% 30m), 50
AACHEN STOLBERG - TVD1 50 (1% 30m), 50
AACHEN STOLBERG - TVD1 50 (1% 30m), 50
AALEN - TVD1 50 (1% 30m), 50
BONN VENUSBERG - TVD1 50 (1% 30m), 50
EIFEL BAERBELKREUZ - TVD1 50 (1% 30m), 50
ERFURT - TVD1 50 (1% 30m), 50
GUMMERSBACH - TVD1 50 (1% 30m), 50
HEIDELBERG KOENIG - TVD1 50 (1% 30m), 50
HEILBRONN - TVD1 50 (1% 30m), 50
HOHE WARTE - TVD1 50 (1% 30m), 50
INSELSBERG - TVD1 50 (1% 30m), 50
KOELN - TVD1 50 (1% 30m), 50
MONSCHAU - TVD1 50 (1% 30m), 50
NORDHORN - TVD1 50 (1% 30m), 50
OSNABRUECK STADT - TVD1 50 (1% 30m), 50
SAALFELD REMDA - TVD1 50 (1% 30m), 50
STUTTARGT FRAUENKOPF - TVD1 50 (1% 30m), 50
WALDENBURG - TVD1 50 (1% 30m), 50
PROGIRA
RADIO COMMUNICATION
440
220
0
440 Kilometers

SECTION II

Sharing and compatibility studies between digital terrestrial television broadcasting and terrestrial mobile broadband applications, including IMT, in the frequency band 470-694/698 MHz outside the GE06 planning area

Sharing and compatibility studies have been conducted between terrestrial mobile broadband applications, including IMT, and DTTB in the frequency band 470-698 MHz outside the GE06 planning area. These studies have been compiled into this Section.

Study 1 – Compatibility between broadcast service systems and proposed IMT systems in the 470-698 MHz frequency range outside the GE06 area (Annex 1).

Study 2 – Sharing and compatibility study between IMT operating at frequencies offset from a Digital Terrestrial Television Broadcasting (DTTB) System A (ATSC) channel in the 470-694/698 MHz Band outside the GE06 area (Annex 2).

Study 3 – Co-channel sharing and compatibility study between IMT and the Digital Terrestrial Television Broadcasting (DTTB) System A (ATSC) in the 470-694/698 MHz Band outside the GE06 area (Annex 3).

Study 4 – Co-channel and adjacent channel sharing and compatibility study of Digital Terrestrial Television Broadcasting (DTTB) System A (ATSC) interference into an IMT base-station in the 470-694/698 MHz Band outside the GE06 area (Annex 4).

Study 5 – Mobile service as an interferer: interference from mobile service base-stations into broadcasting service reception outside the GE06 area (Annex 5).

Study 6 – Cumulative effect of co-channel interference from IMT BS to DTT outside the GE06 area (Annex 6).

Study 7 – Adjacent channel sharing and compatibility studies between DTTB System C (ISDB-T) and IMT in the 470-694/698 MHz frequency band outside the GE06 area (Annex 7).

Study 8 – Assessment of interference from IMT into DTTB and sharing criteria outside the GE06 area (Annex 8).

Study 9 – Co-channel coexistence study between IMT and DTT in 470-694/698 MHz outside the GE06 area (Annex 9).

Finally, Annex 10 includes a List of Acronyms used in this Report.

ANNEX 1 (TO SECTION II)

Study 1 -- Compatibility between broadcast service systems and proposed IMT systems in the 470-698 MHz frequency range outside the GE06 area

1 Introduction

This study examines the compatibility of proposed International Mobile Telecommunications (IMT) systems and broadcasting service (BS) systems operating in the 470-694/698 MHz frequency range.

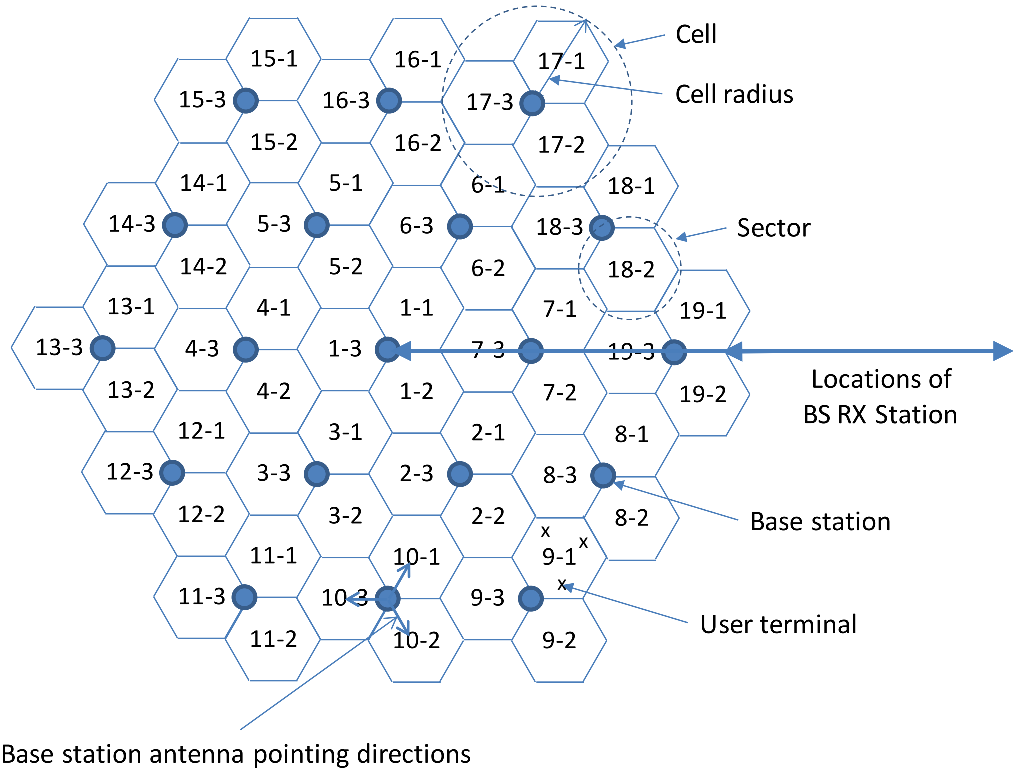
2 Methodology

This analysis examines the required frequency rejection as a function of separation distance for compatible operation of IMT and BS systems. Two interference scenarios are considered: IMT base-station into BS receive station and IMT mobile station into BS receive station. Three deployment environments for IMT systems are considered: macro urban, macro suburban, and macro rural. Propagation loss is calculated using Recommendation ITU-R P.1546-5.

The IMT network layout is illustrated in Figure 1. Nineteen cells are arranged in a hexagonal pattern with each cell consisting of three sectors. An IMT base-station is located at the centre of each cell and operates with a 3-sector antenna. Each antenna serves a single sector covering 120 degrees of the cell.

FIGURE 1

IMT Network layout



The interference calculation methodology used depends on the interference scenario considered:

2.1 IMT base-station into BS receive station

Both co-channel and adjacent channel scenarios are addressed.

For the co-channel scenario, the interference from a single IMT base or mobile station pointing in azimuth toward the BS receive station is computed over a range of azimuths and distances. The result is presented as a plot of the required separation distance around the BS receive station.

For the adjacent channel scenario, the BS receive station is positioned adjacent to the IMT network base-stations. The aggregate interference into the BS station is computed assuming varying separation distances. At each distance, the required rejection is determined based on a specified protection requirement (I/N). The result is presented as a plot of the required rejection as a function of separation distance. The required frequency separation between the two systems is then determined based on the out-of-band emission characteristics of the IMT base-station signal and the adjacent channel selectivity of the BS receiver.

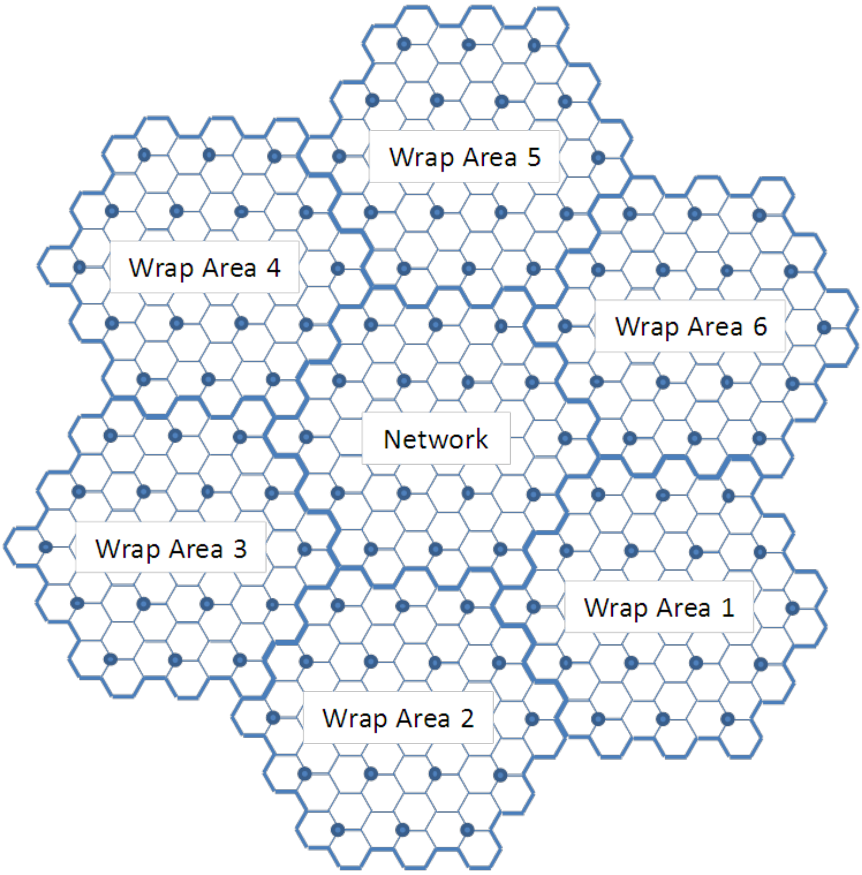
2.2 IMT mobile station into BS receive station

Aggregate interference from IMT mobile stations is modelled based on the Monte Carlo methodology. The methodology consists of 1) randomly positioning IMT mobile stations throughout the IMT network area, 2) randomly assigning these mobile stations to an IMT base-station based on the propagation loss and a specified "handover margin", 3) randomly locating the mobile stations either indoors or outdoors based on a specified percentage of indoor devices, and 4) applying a power control algorithm to the mobile stations based on their path loss distribution. The calculations are repeated for a number of "snapshots", from which statistics are extracted. Elements of the methodology pertinent to this analysis are presented below:

The network region relevant for simulations is the cluster of 19 cells illustrated in Figure 1. Additional clusters of 19 cells are repeated around this central cluster based on a "wrap-around" technique employed to avoid the network deployment edge effects as shown in Figure 2.

FIGURE 2

IMT Network layout with "wrap-around" clusters



The simulation of interference on the IMT uplink is structured as follows:

For i=1:# of snapshots

1 Distribute sufficiently many UE randomly throughout the system area such that to each cell within the handover margin of 3 dB the same number K_{UL} of users is allocated as active UE.

– calculate the path-loss from each UE to all cells and find the smallest path-loss;

– link the UE randomly to a cell to which the path-loss is within the smallest path loss plus the handover margin of 3 dB;

– select K_{UL} UE randomly from all the UE linked to one cell as active UE. These K_{UL} active UE will be scheduled during this snapshot.

2 Perform UL power control

– Set UE transmit power to $P_t = P_{\max} \times \min\left\{1, \max\left[R_{\min}, \left(\frac{PL}{PL_{x-ile}}\right)^{\gamma}\right]\right\}$

where Pt is the transmit power of the UE, Pmax is the maximum transmit power, Rmin is the ratio of UE minimum and maximum transmit powers Pmin / Pmax and determines the minimum power reduction ratio to prevent UE with good channel conditions to transmit at very low power level. PL is the path-loss for the UE from its serving BS and PLx-ile is the x-percentile path-loss (plus shadowing) value.

With this power control scheme, the 1-x percent of UE that have a path-loss larger than PLx-ile will transmit at Pmax. Finally, $0<\gamma<=1$ is the balancing factor for UE with bad channel and UE with good channel.

The analysis assumes that there are a sufficient number of IMT mobile stations in each sector to fully occupy the bandwidth of the BS receive station receiver. The number of “snapshots” used for the Monte Carlo simulation is set to 50. Note that this methodology gives a small deviation in the power levels and the results converge with a small number of runs.

Again, both co-channel and adjacent channel scenarios are addressed.

Interference levels are calculated as follows:

$$I_0 = PD_{tx} - FL_{tx} - HL_{tx} + G_{tx}(\theta_{tx}) - BL_{tx} - PL - BL_{rx} + G_{rx}(\theta_{rx}) - FL_{rx} - HL_{rx} - PD$$

where:

I_0 = Interference power density, dBW/Hz

PD_{tx} = Transmit station signal power density, dBW/Hz

FL_{tx} = Transmit station feeder loss, dB

HL_{tx} = Transmit station head loss (applicable only to hand-held mobile stations), dB

$G_{tx}(\theta_{tx})$ = Transmit station antenna gain in direction of receive station, dBi

BL_{tx} = Building penetration loss (applicable only to indoor transmit stations), dB

PL = Propagation loss, dB

BL_{rx} = Building penetration loss (applicable only to indoor receive stations), dB

$G_{rx}(\theta_{rx})$ = Receive station antenna gain in direction of transmit station, dBi

FL_{rx} = Receive station feeder loss, dB

HL_{rx} = Receive station head loss (applicable only to hand-held mobile stations), dB

PD = Polarization discrimination, dB

The required rejection is determined from the interference level as follows:

$$I / N = I_0 - N_0$$

$$R = I / N - I / N_{reqt}$$

where:

N_0 =Receive station noise power density, dBW/Hz

R = Rejection needed to meet protection requirement, dB

I/N_{reqt} = I/N protection requirement, dB

3 System characteristics

The following tables summarize the IMT and BS characteristics considered for this analysis.
Note that a BS receive antenna height of 20 metres was used instead of 10 metres and that BS reference material does not directly specify adjacent channel selectivity values, and levels similar to those for the IMT base-station are assumed for this analysis.

TABLE 1

IMT base-station characteristics

Parameter	Macro Urban	Macro Suburban	Macro Rural
Deployment			
Number of cells	19	19	19
Number of sectors per cell	3	3	3
Cell radius	2 km	2 km	8 km
Percent indoor	0%	0%	0%
Base-station			
Antenna			
Height	30 m	30 m	30 m
Frequency range	470-698 MHz	470-698 MHz	470-698 MHz
Peak gain	15 dBi	15 dBi	15 dBi
Gain pattern	F.1336 *recommends 3.1*	F.1336 *recommends 3.1*	F.1336 *recommends 3.1*
ka	0.7	0.7	0.7
kp	0.7	0.7	0.7
kh	0.7	0.7	0.7
kv	0.3	0.3	0.3
k	n/a	n/a	n/a
Horizontal beamwidth	65 degrees	65 degrees	65 degrees
Downtilt	–3 degrees	–3 degrees	–3 degrees
Transmitter			
Power	16 dBW	16 dBW	16 dBW
Activity factor	3 dB	3 dB	3 dB
Signal bandwidth	10.0 MHz	10.0 MHz	10.0 MHz
Channel spacing	10.0 MHz	10.0 MHz	10.0 MHz
Feeder loss	3 dB	3 dB	3 dB
ACLR			
1st adjacent	45 dB	45 dB	45 dB
2nd adjacent	45 dB	45 dB	45 dB
Spurious	54 dB	54 dB	54 dB

TABLE 2

IMT mobile station characteristics

Parameter	Macro Urban	Macro Suburban	Macro Rural
Deployment			
Percent indoor	70%	70%	50%
Mobile Station			
Antenna			
Height	1.5 m	1.5 m	1.5 m
Frequency range	470-698 MHz	470-698 MHz	470-698 MHz
Peak gain	-3 dBi	-3 dBi	-3 dBi
Gain pattern	ND	ND	ND
Transmitter			
Maximum power	-7 dBW	-7 dBW	-7 dBW
Minimum power	-39 dBW	-39 dBW	-28 dBW
Signal bandwidth	10.0 MHz	10.0 MHz	10.0 MHz
Channel spacing	10.0 MHz	10.0 MHz	10.0 MHz
Feeder loss	0 dB	0 dB	0 dB
Power control			
Handover margin	3 dB	3 dB	3 dB
Balancing factor (gamma)	1.0	1.0	1.0
Percent at maximum power	10%	10%	10%
ACLR			
1st adjacent	30 dB	30 dB	30 dB
2nd adjacent	33 dB	33 dB	33 dB
Spurious	53 dB	53 dB	53 dB

TABLE 3

Broadcast service station characteristics

Parameter	Fixed Reception	Portable Reception
Broadcast Station		
Antenna		
Height	20 m	1.5 m
Peak gain	12	0
Gain pattern	BT.419	ND
Downtilt	0 degree	0 degree
Receiver		
Signal bandwidth	7.6 MHz	7.6 MHz
Channel spacing	8.0 MHz	8.0 MHz
Feeder loss	5 dB	0 dB
Noise figure	7 dB	7 dB
I/N requirement	-10 dB	-10 dB
ACS		
1st adjacent	45 dB	45 dB
2nd adjacent	50 dB	50 dB
> 2nd adjacent	55 dB	55 dB

Propagation loss is based on Recommendation ITU-R P.1546-5. The propagation characteristics used in this analysis are shown in Table 4.

TABLE 4

Propagation characteristics

Parameter	Macro Urban	Macro Suburban	Macro Rural
Propagation			
Model	P.1546-5	P.1546-5	P.1546-5
Percentage of time basic loss is not exceeded	1.75%	1.75%	1.75%
Reference transmit station height	20 m	10 m	10 m
Reference receive station height	20 m	10 m	10 m
Polarization discrimination			
IMT base station	3 dB	3 dB	3 dB
IMT mobile station	0 dB	0 dB	0 dB
Other propagation effects			
Building penetration loss (indoor stations only)	20 dB	20 dB	15 dB
IMT mobile station body loss	4 dB	4 dB	4 dB

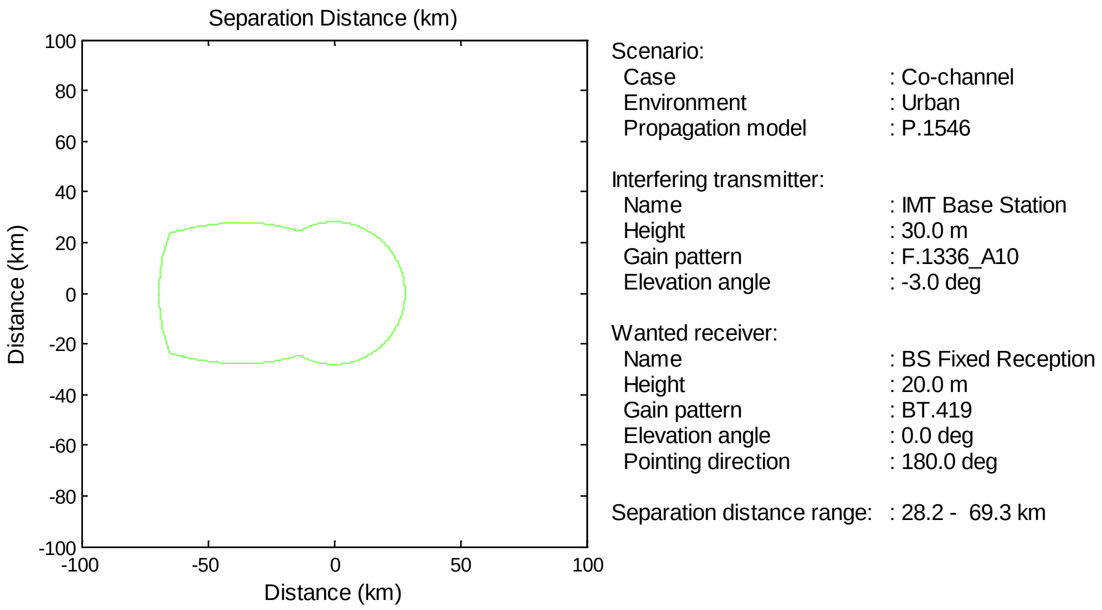
4 Results of Interference Calculations

4.1 Co-channel

The interference from a single IMT base or mobile station pointing in azimuth toward the BS receive station is computed over a range of azimuths and distances. From this data, a contour is drawn at the locations around the BS receive station that meet interference protection requirement.

FIGURE 3

Separation distance IMT base-station into BS receive station



Applying this methodology to the interference scenarios and deployment environments shown in the tables above gives the following results:

TABLE 5

Co-channel separation distance

Scenario	BS Type	Environment	Separation distance
IMT base station into BS receive station	Fixed reception outdoor	Macro Urban Macro Suburban Macro Rural	28.2 - 69.3 km 28.2 - 69.3 km 28.2 - 69.3 km
	Portable reception outdoor	Macro Urban Macro Suburban Macro Rural	~13 km ~19 km ~19 km
	Portable reception indoor	Macro Urban Macro Suburban Macro Rural	~10 km ~10 km ~12 km
IMT mobile station into BS receive station	Fixed reception outdoor	Macro Urban Macro Suburban Macro Rural	< 1.0 km < 1.0 km < 1.0 km
	Portable reception outdoor	Macro Urban Macro Suburban Macro Rural	< 1.0 km < 1.0 km < 1.0 km
	Portable reception indoor	Macro Urban Macro Suburban Macro Rural	< 1.0 km < 1.0 km < 1.0 km

It should be noted that mobile operators can determine which locations are suitable for the deployment of IMT base-stations which can prove advantageous in terms of meeting any required separation distances.

4.2 Adjacent channel

Nineteen IMT base-stations are positioned over the network area as illustrated in Figure 1.
The BS receive station is initially positioned at the centre of the IMT network area. The pointing angle of the BS receive antenna is along the -x axis. (The pointing angles in the following figures are measured counter-clockwise from the x-axis.) This positioning (180 degree case) creates the worst case scenario for receiving interference from the IMT network. As such, it could be expected that in reality interference is somewhat lower due to varying pointing direction of BS receive station with respect to IMT network. Next, the aggregate interference from the IMT base-stations into the BS receive station is computed. Then the BS receive station position is moved incrementally along the x-axis and the aggregate interference is recomputed at each of these positions. This aggregate interference is compared with the BS protection requirement to determine the additional rejection needed to meet the protection requirement as a function of separation distance. The results are illustrated in the following figures. For Figure 4A, the separation distance is measured from the centre of the cluster, and for Figure 4B, the separation distance is measured from the edge of the cluster.

FIGURE 4A

Required rejection
IMT base-station into BS receive station
BS receive station located within IMT deployment area

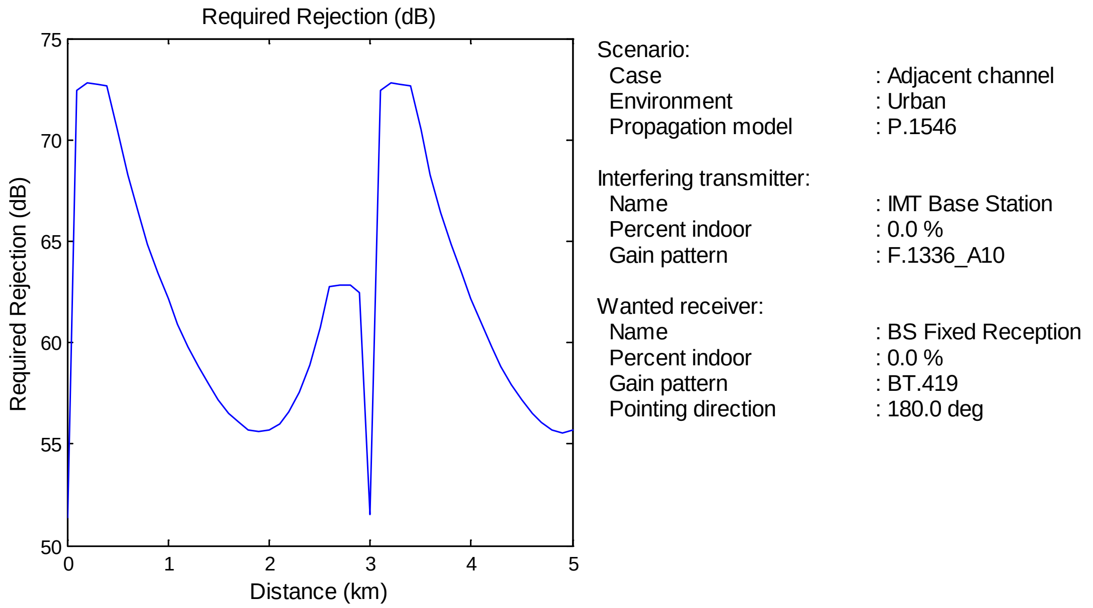
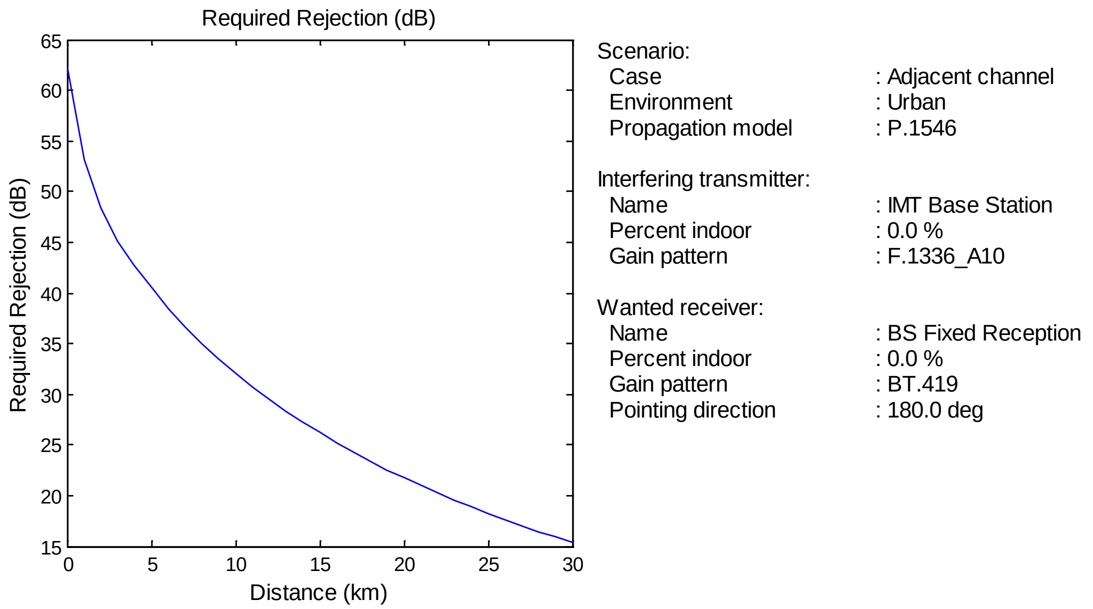


FIGURE 4B

Required rejection
IMT base-station into BS receive station
BS receive station located adjacent to IMT deployment area



For the scenario of aggregate interference from IMT mobile stations, a Monte Carlo simulation is used to determine the interference into the BS station receiver. The IMT mobile terminals are randomly positioned over each sector in sufficient numbers to ensure that the entire bandwidth of the BS receiver is fully occupied by interfering signals. A specified percentage of the IMT terminals are assumed to be located indoors. As described above, a power control algorithm is applied to assign path loss and transmit power levels to each of the mobile terminals. Again, the BS receive station is initially positioned just to the right of the IMT network area and its antenna is pointed along the –x axis, or directly toward the IMT service area. The aggregate interference is computed for a range of separation distances and compared with the BS protection requirement to derive the needed rejection as a function of distance. This calculation is repeated 50 times.

These methodologies are applied to the deployment environments shown in the tables above, but, for brevity, plots of these results are not included here.

4.3 Results of frequency separation calculations

Frequency dependent rejection (FDR) is dependent on the characteristics of the interfering signal and the wanted receiver filter. . FDR is calculated from the following equation:

$$FDR(\Delta f) = 10\log_{10}\left[\frac{\int_{-\infty}^{+\infty} S(f)df}{\int_{-\infty}^{+\infty} S(f)F(f+\Delta f)df}\right]$$

where:

FDR = Frequency dependent rejection, dB

S = Power spectral density of the interfering signal, W/Hz

F = Frequency response of the wanted receiver, relative power fraction

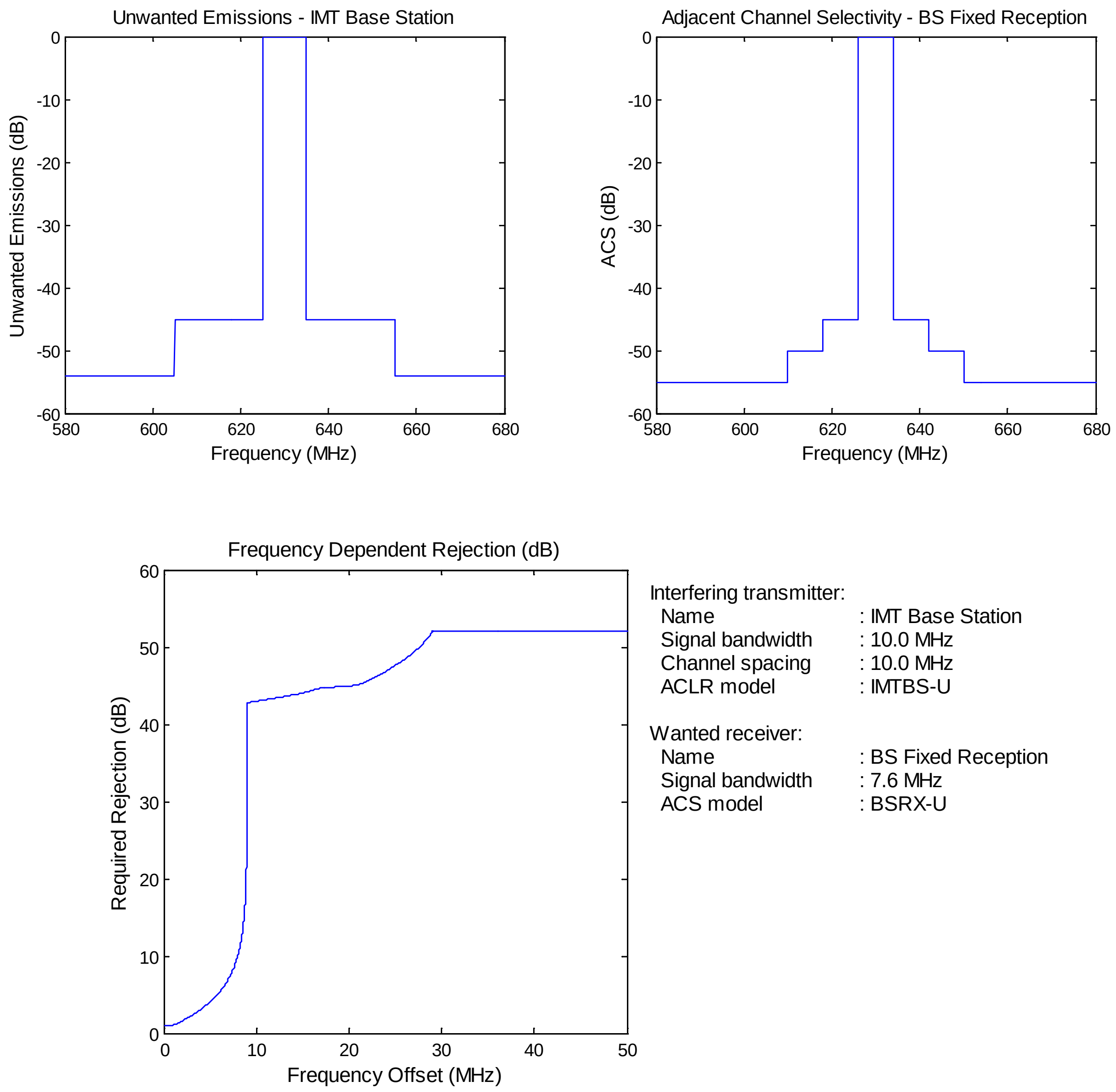
f = Frequency, Hz

Δf = Frequency offset between the IMT and BS channel centres, Hz

The interfering signal, S, is modelled as a flat spectrum within the signal bandwidth and a specified adjacent channel leakage ratio (ACLR) curve outside the signal bandwidth. Similarly, the wanted receiver filter response, F, is modelled as a flat response within the receive signal bandwidth and a specified adjacent channel selectivity (ACS) curve outside the signal bandwidth. The following figures show the interfering signal, wanted receiver frequency response, and resulting FDR for an IMT base-station and a BS fixed reception station.

FIGURE 5

Frequency dependent rejection IMT base-station into BS receive station



This methodology is applied to the other combinations of IMT and BS station types, but, for brevity, plots of these results are not included here.

The adjacent channel interference levels and FDR curves computed above are combined to derive the frequency separation (centre-to-centre) necessary to meet the stated protection requirement at various separation distances. Table 6 provides results for selected separation distances for the various interference scenarios and deployment environments considered here.

TABLE 6

Adjacent channel frequency/distance separation
IMT signal bandwidth = 10.0 MHz, BS signal bandwidth = 7.6 MHz

Scenario	Environment	BS Pointing Angle	Frequency Separation				
			1.0 km	5.0 km	10.0 km	20.0 km	30.0 km
IMT base station into BS fixed reception station	Macro Urban	180 deg	-	9.0 MHz	9.0 MHz	8.9 MHz	8.7 MHz
		90 deg	9.0 MHz	9.0 MHz	8.8 MHz	6.3 MHz	1.0 MHz
	Macro Suburban	180 deg	-	9.0 MHz	9.0 MHz	8.9 MHz	8.7 MHz
		90 deg	9.0 MHz	9.0 MHz	8.8 MHz	6.3 MHz	1.0 MHz
	Macro Rural	180 deg	9.0 MHz	9.0 MHz	8.9 MHz	8.7 MHz	7.9 MHz
		90 deg	9.0 MHz	8.6 MHz	7.2 MHz	1.0 MHz	1.0 MHz
IMT mobile station into BS fixed reception station	Macro Urban	180 deg	0.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz
		90 deg	0.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz
	Macro Suburban	180 deg	0.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz
		90 deg	0.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz
	Macro Rural	180 deg	0.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz
		90 deg	0.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz

Scenario	Environment	BS Location	Frequency Separation				
			1.0 km	5.0 km	10.0 km	20.0 km	30.0 km
IMT base station into BS portable reception station	Macro Urban	Outdoor	9.0 MHz	8.1 MHz	2.1 MHz	0.0 MHz	0.0 MHz
		Indoor	8.9 MHz	7.0 MHz	1.0 MHz	0.0 MHz	0.0 MHz
	Macro Suburban	Outdoor	9.0 MHz	8.8 MHz	7.5 MHz	0.0 MHz	0.0 MHz
		Indoor	9.0 MHz	8.4 MHz	4.1 MHz	0.0 MHz	0.0 MHz
	Macro Rural	Outdoor	8.7 MHz	6.6 MHz	0.0 MHz	0.0 MHz	0.0 MHz
		Indoor	8.6 MHz	6.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz
IMT mobile station into BS portable reception station	Macro Urban	Outdoor	0.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz
		Indoor	0.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz
	Macro Suburban	Outdoor	0.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz
		Indoor	0.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz
	Macro Rural	Outdoor	0.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz
		Indoor	0.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz

5 Conclusions

The co-frequency channel results, taking into account only one base-station as interferer, show that the required separation distance can range from 10-12 kilometres for portable indoor BS systems and around 13-19 kilometres for portable outdoor BS systems. The co-channel results for fixed outdoor reception BS systems range from around 28-70 kilometres. These results are based on worst-case assumptions including the pointing direction of the IMT station and the application of the propagation model. Furthermore, mobile operators can determine which locations are suitable for the deployment of IMT base-stations which can prove advantageous in terms of meeting any required separation distances.

The adjacent channel results show that in the worst-case scenarios (BS receive station pointing directly toward a macro suburban or rural deployment of IMT base-stations), a distance separation of around 5 kilometres combined with a frequency separation one channel bandwidth is needed in order to meet the BS protection requirement. However, these pointing scenarios should be avoidable in practice, and for more realistic pointing scenarios, the interference can be mitigated through a combination of geographic separation and frequency separation. For these cases, the interference can be mitigated with a separation distance on the order of one kilometre coupled with a frequency separation of about one channel bandwidth. It is important to note that the frequency separation results reflect channel centre-to-channel centre separations and not guard bands, which are usually expressed as channel edge-to-channel edge.

These results also show that the interference from the IMT mobile stations is acceptable with a geographic separation as low as one kilometre.

It should be noted that certain assumptions such as BS receive station placement and direction, use of propagation model, etc. may overestimate interference from the IMT network.

ANNEX 2 (TO SECTION II)

Study 2 -- Sharing and compatibility study between IMT operating at frequencies offset from a Digital Terrestrial Television Broadcasting (DTTB) System A (ATSC) channel in the 470-694/698 MHz Band outside the GE06 area

1 Introduction

This Annex provides a sharing and compatibility study between IMT base-stations and UEs operating at frequencies offset from fixed digital terrestrial television broadcast (DTTB) systems operating on a channel in the 470-694/698 MHz band. The 470-694/698 MHz band with its propagation characteristics and limited environmental noise is ideal for a single DTTB transmitter to service vast numbers of receivers within a given coverage area.

This analysis is based upon the latest IMT parameters below 1 GHz provided in Report ITU-R M.2292. The analysis is also based upon the parameters for DTTB System A.

1.1 Requirement

Sharing and compatibility between the mobile service and the broadcasting service requires that the protection criteria for each service be met in order to minimize interference between the services.

1.2 Study elements

This study addresses the following elements:

1) The impact of a single IMT base-station on fixed DTTB receiving systems (System A).

2) The impact of a single IMT UE on fixed DTTB receiving systems (System A).

The study takes into account various ITU-R Recommendations and Reports.

2 Background

Numerous ITU-R Recommendations and Reports are relevant to this study. Additionally, Recommendation ITU-R BT.2036 provides the characteristics of the DTTB reference receiver. Recommendation ITU-R P.1546-5 provides propagation methodologies for point-to-area predictions for terrestrial services including DTTB. With respect to IMT systems, IMT related parameters are provided in Report ITU-R M.2292. Propagation models for IMT UEs are provided in Report ITU-R SM.2028.

3 Technical characteristics

3.1 DTTB System A -- Receiving system parameters

The System A planning parameters for DTTB reception using a fixed antenna are tabulated in Table 1 based upon a reference receiving system described in Recommendation ITU-R BT.2036. The symbols correspond to those in Report ITU-R BT.2265.

The isotropic antenna gain including feeder loss, G_R, is given by:

$$G_R = G_d + 2.15 – L_f$$

TABLE 1

System A Planning Parameters

Planning Parameter	**Symbol**	**Value**	**Units**
Channel bandwidth		6	MHz
System bandwidth	B	5.38	MHz
Temperature	T	290	K
Receive system noise figure	F	7	dB
Receiver inherent noise power	N_R	–129.7	dBW
Feeder loss	L_f	4	dB
Receiver antenna gain	G_d	10	dBd
Isotropic receive antenna gain including feeder loss	G_R	8.15	dBi
Receive antenna height	h_2	10	m
Reception location probability	*RLP*	50	Percent
Reception time probability	*RTP*	90	Percent

In addition to interference within the DTTB channel, the broadcasting receiving System A is susceptible to interference from signals on frequencies offset from the DTTB channel.
The deterioration in the ATSC receiver sensitivity from interference at frequencies offset from the main channel is determined by the total power of the interfering signal within the respective offset channel. The protection ratios for System A from Recommendation ITU-R BT.1368 are summarized in Table 2.

TABLE 2

Protection ratios for interference at frequencies offset from the broadcast channel N for System A

Interference channel	**Protection ratio (dB)**
N (Co-channel)	+2.5
N – 1 (Lower adjacent channel)	−28
N + 1 (Upper adjacent channel)	−26
N ± 2	−44
N ± 3	−48
N ± 4	−52
N ± 5	−56
N ± 6 to *N* ± 13	−57
N ± 14 and *N* ± 15	−50

3.2 IMT transmitter parameters

The relevant parameters for studying IMT interference into the terrestrial broadcast receiving system are tabulated in Table 3. Two types of devices are considered: 1) a fixed transmitter for a base-station with an antenna height between 30 (HAAT) and an e.i.r.p. of 58 dBm; and 2) a UE transmitter operating at a height of 1.5 metres (HAAT) with a lower e.i.r.p. of 16 dBm. The interference location probability is 50 percent. Since only one interferer is being considered as opposed to an aggregation of interferers, the interference time probability is one percent.

TABLE 3

Study parameters for two IMT devices

Planning Parameter	Value	Units
Frequency band	470-694/698 MHz	--
Interference location probability	50	Percent
Interference time probability	1	Percent
Base-station transmitter:		
Maximum power	46	dBm
Feeder loss	3	dB
Antenna gain	15	dBi
Maximum e.i.r.p.	58	dBm
Antenna height (HAAT)	30	m
Antenna downtilt	3	degrees
User equipment transmitter:		
Maximum power	23	dBm
Antenna gain	-3	dBi
Body loss	4	dB
Maximum e.i.r.p.	16	dBm
Antenna height (HAAT)	1.5	m

3.2.1 IMT System Bandwidth

The study includes two IMT channel bandwidths of 5 and 10 MHz with system bandwidths of 4.5 and 9 MHz, respectively, in accordance to Report ITU-R M.2039.

3.2.2 IMT Base-station antenna downtilt

The application of downtilt in the base-station antenna will effectively reduce the IMT power interfering with the DTTB System. The reduction in power is determined by the vertical radiation pattern of the IMT base-station antenna. Recommendation ITU-R F.1336-3 provides the relative antenna gain for various angles of azimuth and elevation. This study uses the parameters tabulated in Table 4 to determine both the peak and average gains for the IMT antenna. The worst case or average relative gain of –1.9 dB was used to reduce the effective interference into the DTTB receiving system.

TABLE 4

Parameters used to determine IMT base-station relative antenna gain due to antenna downtilt[6]

Parameter	Value	Units
Azimuth angle	0	degrees
Elevation angle	0	degrees
Horizontal 3dB beamwidth	65	degrees
Vertical 3 dB beamwidth	9.1	degrees
k	0.3	
Downtilt	3	degrees
Average relative gain	–1.9	dB
Peak relative gain	–1.22	dB

3.2.3 Additional parameters

The following additional parameters are used to determine separation distances:

– Broadcasting protection criteria, I/N = –10 dB

For specific application scenarios, directivity discrimination may be considered. Report ITU-R BT.2265 provides methodologies for discrimination as well as multiple interferers.

It should be noted that multiple interferers on various DTTB frequencies may be significant. It has been reported[7,8] that combinations of undesired signals can cause interference on a desired DTTB channel. For example, as reported, if the desired DTTB channel is N, signals on channels N + K and N + 2K, where K is an integer between 1 and 10, will combine to cause interference into the desired channel N. These results have confirmed with the observation of single and double interferers on frequencies near the DTTB channel[9].

4 Analysis

4.1 Assumptions

– A single interferer is assumed.

– Peak interference power is used since the minimum noise burst duration performance for the DTTB System A is 165 microseconds (per Recommendation ITU-R BT.2036).

– Propagation curves for one percent time variability are used for interference thresholds.

– Propagation over land is assumed; sea paths are not considered.

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[6] Note that for small elevation angles at zero azimuth, the relative antenna gains are equal for all approaches being considered in Recommendation ITU-R F.1336-4.

[7] Martin, S. F., "RF Performance of DTV Converter Boxes - An Overview of FCC Measurements" IEEE *Transactions* on Broadcasting, Vol. 56, No. 4, December 2010.

[8] "Interference rejection thresholds of consumer digital television receivers available in 2005 and 2006", FCC/OET 07-TR-1003, 30 March 2007.

[9] Salehian, K., Y. Wu and G. Gagnon, "Performance of the Consumer ATSC-DTV Receivers in the presence of single and double interference on adjacent/taboo channels", IEEE *Transactions* on Broadcasting, Vol. 56, No. 1, March 2010.

– No specific terrain information is implied so a representative clutter height of 10 metres is used.

– Polarisation discrimination is not considered.

– DTTB System A channel frequency for this study is 692 to 698 MHz.

– DTTB elevation pattern per Recommendation ITU-R BT.419 does not impact the required separation distances between the IMT UE and a fixed DTTB receiving system for horizontal separations greater than 24 metres.

– Indoor applications are not considered.

4.2 Methodology

The methodology for determining the separation distance between single IMT transmitters (base-station and UE) involves the following steps:

1 The field strength for an IMT base-station transmitter as a function of distance and frequency is calculated based upon propagation curves in Recommendation ITU-R P.1546 adjusted for frequency, transmitter power output, antenna gain, antenna height, feeder loss, and downtilt angle.

2 The field strength for an IMT UE transmitter as a function of distance (up to 100 km) and frequency is calculated based upon the “Modified Hata” propagation model described in Report ITU-R SM.2028.

3 The effective field strength threshold for the DTTB receiving system is calculated from the equivalent noise field strength based upon the receiver bandwidth, noise factor, antenna gain, antenna lead loss, frequency, protection ratios, and the protection criterion, *I/N*.

4 If the interfering IMT signal occupies a bandwidth greater than the DTTB bandwidth, it is necessary to apportion the power of the interference and its impact in the corresponding DTTB channel. For the case of System A, the interference is directly related to the total power in the DTTB channel. As the IMT signal is offset from the occupied channel or channels, the interference caused by the IMT signal is lessen by the protection ratio of the DTTB channel. For System A, the total effective field strength is calculated using the protection ratios in Recommendation ITU-R BT.1368.

5 The separation distance is calculated at the point at which the total effective field strength from the IMT signal equals the DTTB effective field strength threshold. The separation distance is further calculated for each MHz of frequency separation between the centre of the IMT signal and the centre of the DTTB signal up to ±90 MHz.

4.3 Calculations

4.3.1 IMT Propagation curves

Recommendation ITU-R P.1546 contains propagation curves of field-strength values for a nominal 1 kW effective radiated power (e.r.p.) transmitter at nominal frequencies of 100, 600, and 2 000 MHz as a function of path type (land and sea), discrete transmitting antenna heights (10, 20, 37.5, 75, 150, 300, 600, and 1 200 metres HAAT), and distance from the transmitter (1 to 1 000 km). The curves represent field-strength values exceeded at 50 percent of the locations within any area of approximately 500 m by 500 m and for 50 percent, 10 percent, and one percent of the time. For the purposes of this study with a single interferer, curves for land paths and one percent of the time were used.

4.3.1.1 Transmitting antenna height interpolation

Since a base-station antenna height of 30 metres is to be considered, the propagation curves are interpolated using equation 8 in section 4.1 of Annex 5 to Recommendation ITU-R P.1546.

4.3.1.2 Frequency interpolation

The propagation curves in Recommendation ITU-R P.1546 are specified for the nominal frequencies of 100, 600, and 2 000 MHz. These curves are interpolated using equation 14 in section 6 to Annex 5, for the specific frequencies from 605 to 785 MHz (695 ± 90 MHz).

4.3.1.3 Transmitter power

The propagation curves in Recommendation ITU-R P.1546 are specified for a nominal transmitter of 1 kW e.r.p. or 0 dBkW e.r.p. The relationship between e.r.p. and e.i.r.p. is given by the equation:

$$\text{e.r.p.} = \text{e.i.r.p.} - 2.15$$

Consequently, the e.i.r.p. and e.r.p. for the IMT transmitters to be considered are shown in Table 5.

TABLE 5

Transmitter powers for IMT base-station and UE

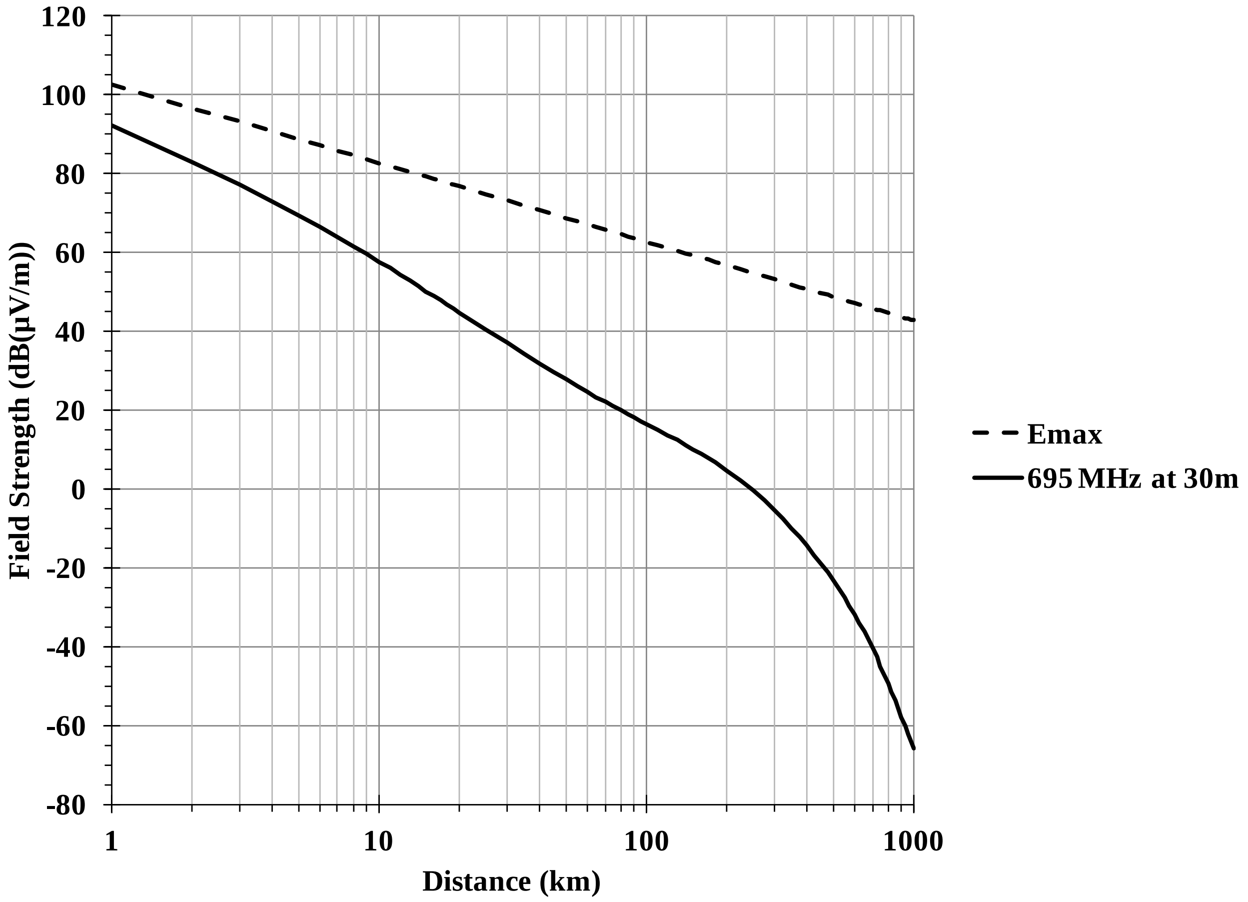
IMT Transmitter	Power	Units
Fixed base-station:		
Maximum e.i.r.p.	58	dBm
Maximum e.r.p.	55.85	dBm
Maximum e.r.p.	–4.15	dBkW
User terminal:		
Maximum e.i.r.p.	16	dBm
Maximum e.r.p.	13.85	dBm
Maximum e.r.p.	–46.15	dBkW

4.3.1.4 Example propagation curves for an IMT fixed base-station transmitter

Figure 1 illustrates the resulting propagation curve interpolated from Recommendation ITU-R P.1546 for a fixed IMT base-station transmitter operating at an antenna height of 30 metres HAAT with an e.i.r.p. of 58 dBm. The curves have been interpolated for 695 MHz. Emax is the free-space field-strength propagation curve.

FIGURE 1

Field-strength propagation curve for an IMT fixed base-station transmitter operating with a 58 dBm e.i.r.p., at 695 MHz, and a 30 metre (HAAT) antenna height

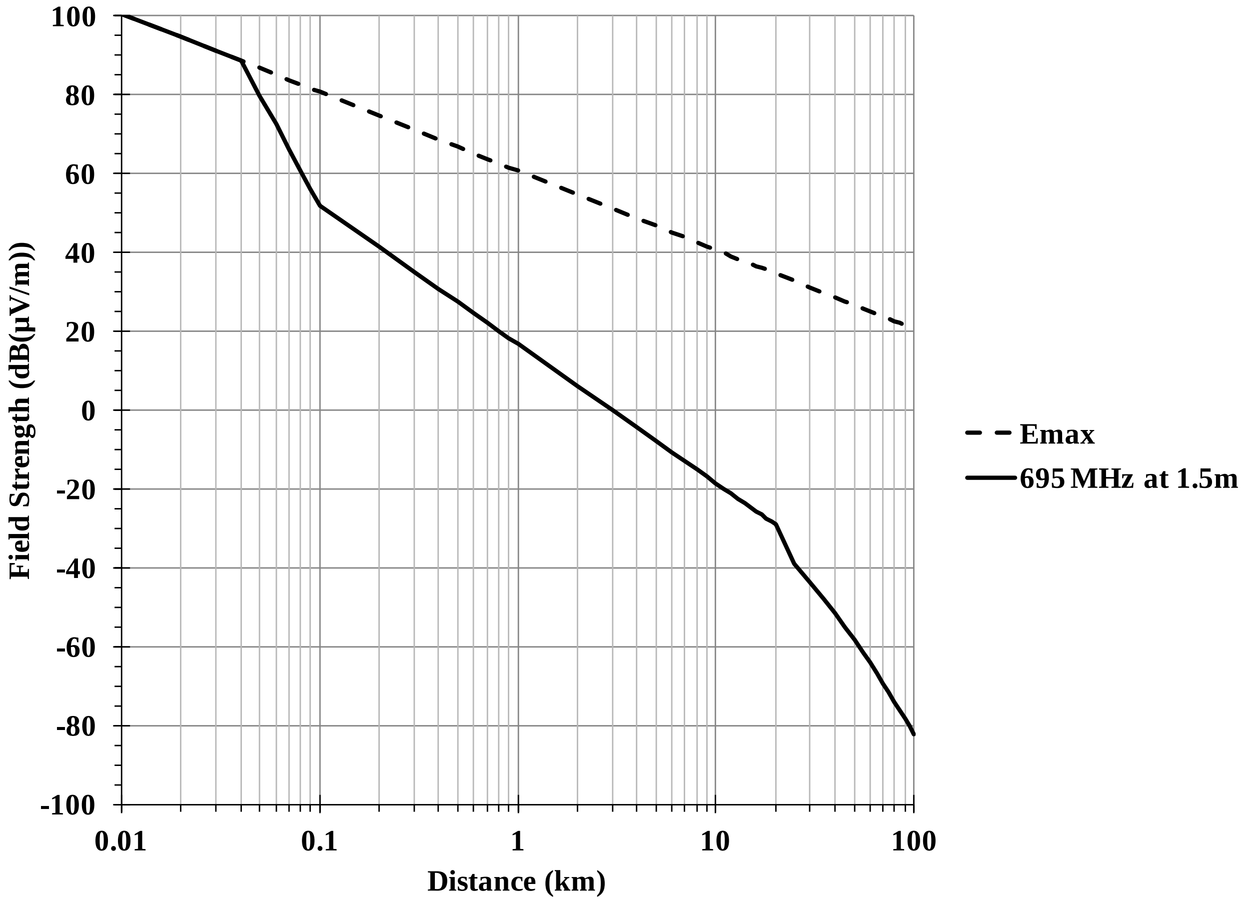


4.3.1.5 Example propagation curves for an IMT UE transmitter

Figure 2 illustrates the resulting propagation curve using the “Modified Hata” model described in Report ITU-R SM.2028 for an IMT UE transmitter operating in an urban environment at an antenna height of 1.5 metres HAAT with an e.i.r.p. of 16 dBm.

FIGURE 2

Field-strength propagation curve for an IMT UE transmitter in an urban environment operating with a 16 dBm e.i.r.p., at 695 MHz, and a 1.5 metre (HAAT) antenna height



4.3.2 Receiving system noise equivalent field-strength

The DTTB receiving system noise equivalent field-strength, E_{NR}, is calculated from Equation 3 of Report ITU-R BT.2265. Since the field-strength is frequency dependent, values have been chosen to include the limits of the 470-694/698 MHz band as well as the DTTB channel being considered with a centre frequency at 695 MHz. The results are tabulated in Table 6. Field-strengths for other frequencies can be interpolated using the methodology in section 5 of Annex 5 to Recommendation ITU-R P.1546.

TABLE 6

Noise equivalent field-strength, E_{NR}, at various frequencies for the receiving System A

Frequency	470 MHz	695 MHz
Noise equivalent field-strength, $E_{NR,}$ (dB(μV/m))	22.8	26.2

In addition to the thermal noise power, environmental noise is present at the broadcast receive antenna. However, as shown in Report ITU-R BT.2265, the impact of environmental noise in the 470-694/698 MHz band is minimal and is not considered here.

4.3.3 Individual median effective interfering field-strength threshold

The individual median effective interfering field-strength threshold, E_{eff}, for the DTTB system, is derived from the noise equivalent field-strength in Table 6, the protection ratios in Table 2, and the protection criterion, *I/N*. The results for the various frequencies are tabulated in Table 7.

TABLE 7

Individual median effective interfering field-strength thresholds (E_{eff}) for a DTTB System A receiving system at various frequencies and frequency offsets

Type of interference	Frequency Offset[10] (MHz)	Interference field-strength threshold (dB(μV/m))	
		470 MHz	695 MHz
Co-channel (*N*) interference	0	10.3	13.7
Lower adjacent channel interference (*N* – 1)	-6	38.3	41.7
Upper adjacent channel interference (*N* + 1)	+6	36.3	39.7
N±2	±12	54.3	57.7
N±3	±18	58.3	61.7
N±4	±24	62.3	65.7
N±5	±30	66.3	69.7
N±6 to N±13	±36 to ±78	67.3	70.7
N±14 and N±15	±84 and ±90	60.3	63.7

4.3.4 Separation distance interpolation

The separation distance between the interfering IMT transmitter and the broadcast receiving system is determined by the intersection of the individual median effective interfering field-strength threshold, E_{eff}, with the appropriate field-strength propagation curve. Since the tabulated data for the curves utilize discrete distance values, it is necessary to interpolate to obtain a precise separation distance. The equation for the separation distance, d_{sep}, is given by:

$$d_{sep} = d_{inf} \, (d_{sup} / d_{inf})^{\Delta E} \quad (1)$$

where:

$$\Delta E = (E_{eff} - E_{inf}) \, (E_{sup} - E_{inf})$$

and where:

d_{sep}: separation distance

E_{inf}: nearest tabulation field-strength less than E_{eff}

E_{sup}: nearest tabulation field-strength greater than E_{eff}

d_{inf}: distance value for E_{inf}

d_{sup}: distance value for $E_{sup.}$

4.4 Results

This study considers the separation distances necessary to avoid interference between IMT transmitters (base-station and UE) operating at frequencies within 90 MHz of a DTTB System A receiver channel.

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[10] Frequency offset is the separation between the channel centres of IMT and DTTB systems.

In addition, to frequency separation between the IMT transmitter and the DTTB receiver, IMT channel bandwidths of 5 and 10 MHz are considered.

4.4.1 Separation distances for IMT base-stations operating within 90 MHz of a DTTB channel

The separation distances at the individual median effective interfering field-strength threshold for IMT base-stations operating at 58 dBm e.i.r.p., 30 metre antenna heights (HAAT), three degree downtilt, and 5 and 10 MHz channel bandwidths are tabulated in Table 8. The table includes the separation distances for IMT base-station interferers into a broadcast receiving System A for any of the 15 DTTB channels above or below (up to *N±15*) the main DTTB channel, *N*. Separation distances are calculated with the centre of the IMT signal offset by multiples of six MHz from the centre frequency (*N* = 695 MHz) of the DTTB signal.

TABLE 8

Separation distances at the interference threshold for an IMT base-station interfering with a 6 MHz DTTB System A receiver at 695 MHz in the 470-694/698MHz band

(IMT base-station operating at 58 dBm e.i.r.p. with a 30 metre HAAT antenna and 5 or 10 MHz bandwidths within 90 MHz of a DTTB channel)

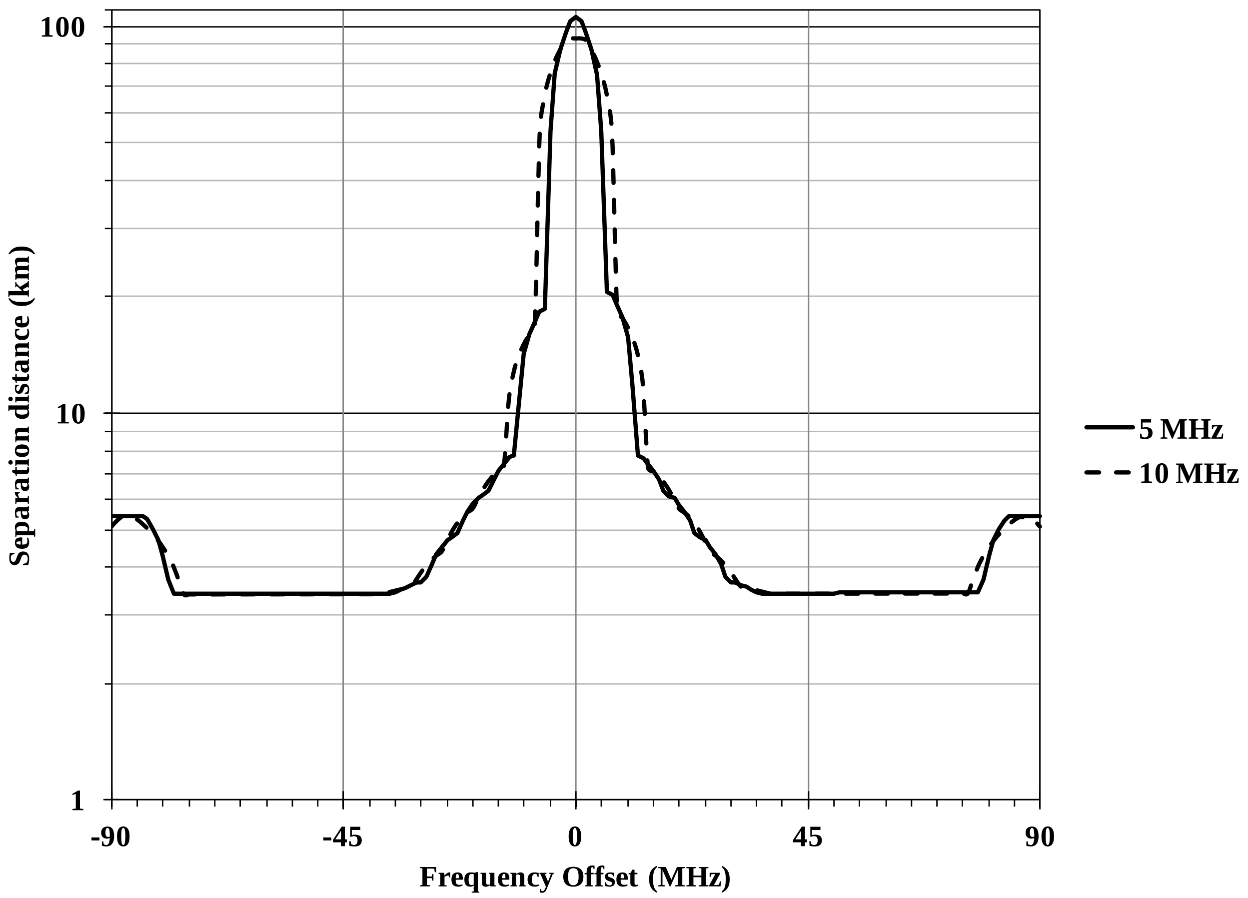
IMT Centre Frequency (MHz)	IMT Channel Bandwidth	
	5 MHz	10 MHz
Co-channel (N = 695)	106 km	94.7 km
Channel N+1 (701)	20.7 km	64.9 km
Channel N-1 (689)	18.6 km	65.1 km
Channels N±2 (683, 707)	7.8 km	12.7 km
Channels N±3 (677, 713)	6.1 km	6.4 km
Channels N±4 (671, 719)	4.8 km	5.0 km
Channels N±5 (665, 725)	3.7 km	3.9 km
Channels N±6 to N±13 (617, 623, 629, 635, 641, 647, 653, 659, 731, 737, 743, 749, 755, 761, 767, 773)	3.4 km	4.0 km
Channels N±14 and N±15 (605, 611, 779, 785)	5.4 km	5.2 km

Figure 3 illustrates the separation distances required to maintain the interference threshold as a function of frequency offset between the centres of the IMT and DTTB channels.

FIGURE 3

Separation distance versus frequency offset required to maintain the interference threshold for an IMT base-station interfering with a fixed 6 MHz DTTB System A receiver at 695 MHz in the 470-694/698MHz band

(IMT base-station operating at a 58 dBm e.i.r.p. with a 30 metre HAAT antenna and 5 or 10 MHz bandwidths within 90 MHz of the DTTB channel centre frequency; DTTB antenna height is 10 m)



4.4.2 Separation distances for IMT UEs operating within 90 MHz of a DTTB channel

The separation distances at the individual median effective interfering field-strength threshold for IMT UE operating at 16 dBm e.i.r.p., 1.5 metre antenna height (HAAT), and 5 or 10 MHz channel bandwidths are tabulated in Table 9. The table includes the separation distances for IMT UE interferers into a broadcast receiving System A for any of 15 DTTB channels above or below (up to *N±15*) the DTTB channel, *N*. Interference is calculated with the centre of the IMT signal offset by a multiple of six MHz from the centre frequency (*N* = 695 MHz) of the DTTB signal.

TABLE 9

Separation distances at the interference threshold for an IMT UE interfering with a 6 MHz DTTB System A receiver at 695 MHz in the 470-694/698MHz band

(IMT UE operating at a 16 dBm e.i.r.p. with a 1.5 metre HAAT antenna and 5 or 10 MHz bandwidths within 90 MHz of a DTTB channel)

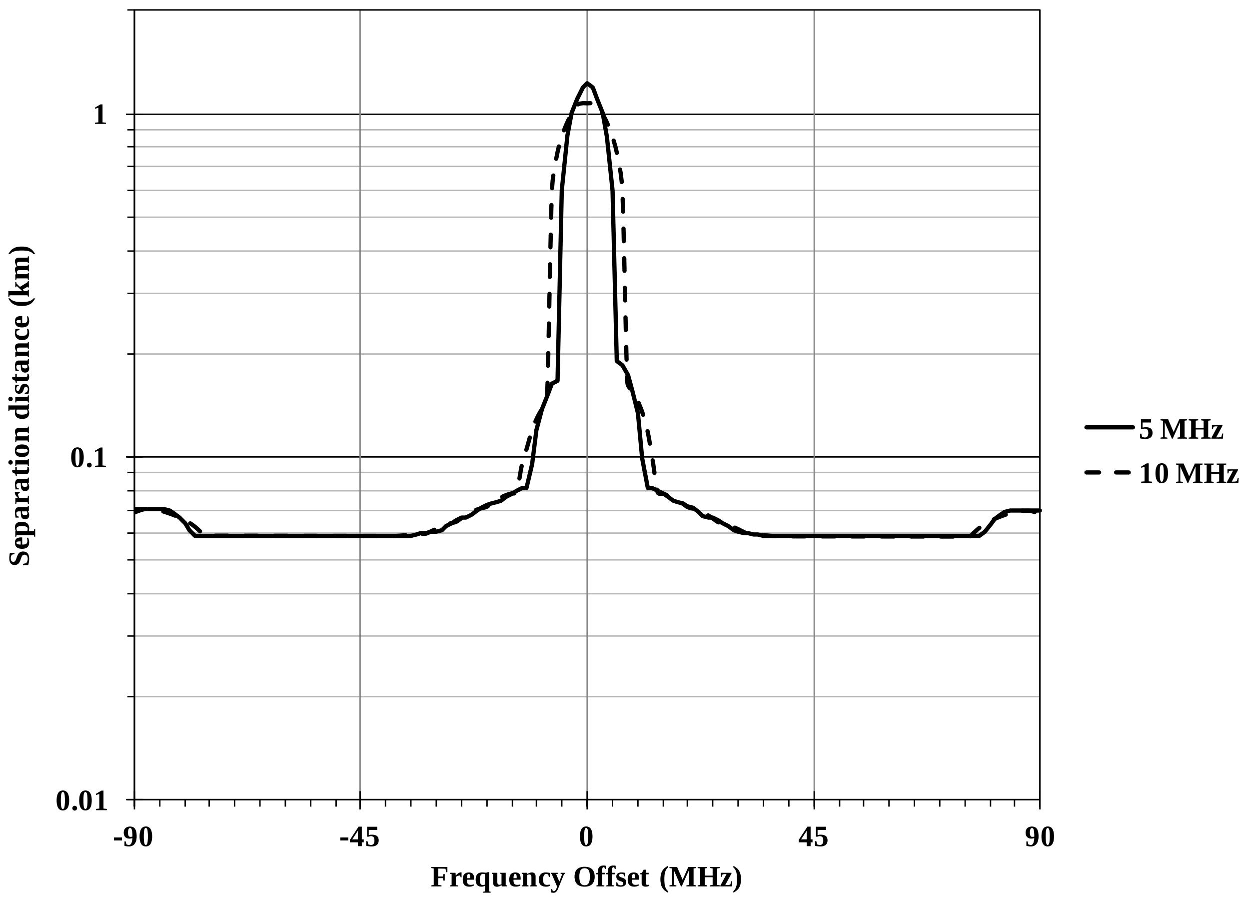
IMT Centre Frequency (MHz)	IMT Channel Bandwidth	
	5 MHz	10 MHz
Co-channel (N = 695)	1.22 km	1.09 km
Channel N+1 (701)	0.19 km	0.74 km
Channel N-1 (689)	0.17 km	0.74 km
Channels N±2 (683, 707)	0.082 km	0.104 km
Channels N±3 (677, 713)	0.074 km	0.075 km
Channels N±4 (671, 719)	0.067 km	0.068 km
Channels N±5 (665, 725)	0.060 km	0.062 km
Channels N±6 to N±13 (617, 623, 629, 635, 641, 647, 653, 659, 731, 737, 743, 749, 755, 761, 767, 773)	0.059 km	0.062 km
Channels N±14 and N±15 (605, 611, 779, 785)	0.071 km	0.069 km

Figure 4 illustrates the separation distances required for to maintain the interference threshold as a function of frequency offset between the centres of the IMT and DTTB channels.

FIGURE 4

Separation distance versus frequency offset required to maintain the interference threshold for an IMT UE interfering with a fixed 6 MHz DTTB System A receiver at 695 MHz in the 470-694/698 MHz band

(IMT UE operating at a 16 dBm e.i.r.p. with a 1.5 metre HAAT antenna and 5 or 10 MHz bandwidths within 90 MHz of a DTTB channel)



5 Summary

The required separation distances needed in order to meet the protection criterion of *I/N* = –10 dB for interference of IMT into DTTB are significant for a single IMT transmitter (base-station or UE). Furthermore, the required frequency separations needed to meet protection levels are also significant. The study illustrates the possibility of interference from IMT transmitter operating in proximity, both distance and frequency, to a broadcast receiving system.

ANNEX 3 (TO SECTION II)

Study 3 -- Co-channel sharing and compatibility study between IMT and the Digital Terrestrial Television Broadcasting (DTTB) System A (ATSC) in the 470-694/698 MHz Band outside the GE06 area

1 Introduction

This Annex provides a sharing and compatibility study between IMT base-stations and UE and fixed digital terrestrial television broadcast (DTTB) systems operating on a co-channel and near co-channel basis in the 470-694/698 MHz band. The 470-694/698 MHz band with its propagation characteristics and limited environmental noise is ideal for a single DTTB transmitter to service vast numbers of receivers within a given coverage area.

This analysis is based upon the latest IMT parameters below 1 GHz in Report ITU-R M.2292. The analysis is also based upon the parameters for DTTB System A.

1.1 Requirement

Sharing and compatibility between the mobile service and the broadcasting service requires that the protection criteria for each service be met in order to minimize interference between the services.

1.2 Study elements

This study addresses the following elements:

1) The impact of a single IMT base-station on fixed DTTB receiving systems (System A).

2) The impact of a single IMT UE on fixed DTTB receiving systems (System A).

The study takes into account various ITU-R Recommendations and Reports.

2 Background

Numerous ITU-R Recommendations and Reports are relevant to this study. Additionally, Recommendation ITU-R BT.2036 provides the characteristics of the DTTB reference receiver. Recommendation ITU-R P.1546-5 provides propagation methodologies for point-to-area predictions for terrestrial services including DTTB. With respect to IMT systems, IMT related parameters are provided in Report ITU-R M.2292. Propagation models for IMT UE are provided in Report ITU-R SM.2028.

3 Technical characteristics

3.1 DTTB System A -- Receiving system parameters

The System A planning parameters for DTTB reception using a fixed antenna are tabulated in Table 1 based upon a reference receiving system described in Recommendation ITU-R BT.2036. The symbols correspond to those in Report ITU-R BT.2265. . The isotropic antenna gain including feeder loss, G_R, is given by:

$$G_R = G_d + 2.15 - L_f$$

TABLE 1

System A Planning Parameters

Planning Parameter	Symbol	Value	Units
Channel bandwidth		6	MHz
System bandwidth	B	5.38	MHz
Temperature	T	290	K
Receive system noise figure	F	7	dB
Receiver inherent noise power	N_R	–129.7	dBW
Feeder loss	L_f	4	dB
Receiver antenna gain	G_d	10	dBd
Isotropic receive antenna gain including feeder loss	G_R	8.15	dBi
Receive antenna height	h_2	10	m
Reception location probability	*RLP*	50	Percent
Reception time probability	*RTP*	90	Percent

In addition to interference within the DTTB channel, the broadcasting receiving System A is susceptible to interference from signals on frequencies offset from the DTTB channel. The deterioration in the ATSC receiver sensitivity from interference at frequencies offset from the main channel is determined by the total power of the interfering signal within the respective offset channel. The protection ratios for System A from Recommendation ITU-R BT.1368 are summarized in Table 2.

TABLE 2

Protection ratios for interference at frequencies offset from the broadcast channel N for System A

Interference channel	Protection ratio (dB)
N (Co-channel)	+2.5
$N – 1$ (Lower adjacent channel)	−28
$N + 1$ (Upper adjacent channel)	−26

3.2 IMT transmitter parameters

The relevant parameters for studying IMT interference into the terrestrial broadcast receiving system are tabulated in Table 3. Two types of devices are considered: 1) a fixed transmitter for a base-station with an antenna height between 30 (HAAT) and an e.i.r.p. of 58 dBm; and 2) a UE transmitter operating at a height of 1.5 metres (HAAT) with a lower e.i.r.p. of 16 dBm. The interference location probability is 50 percent. Since only one interferer is being considered as opposed to an aggregation of interferers, the interference time probability is one percent.

TABLE 3

Study parameters for two IMT devices

Planning Parameter	**Value**	**Units**
Frequency band	470-694/698 MHz	--
Interference location probability	50	Percent
Interference time probability	1	Percent
Base-station transmitter:		
Maximum power	46	dBm
Feeder loss	3	dB
Antenna gain	15	dBi
Maximum e.i.r.p.	58	dBm
Antenna height (HAAT)	30	m
Antenna downtilt	3	degrees
User equipment transmitter:		
Maximum power	23	dBm
Antenna gain	–3	dBi
Body loss	4	dB
Maximum e.i.r.p.	16	dBm
Antenna height (HAAT)	1.5	m

3.2.1 IMT System Bandwidth

The study includes two IMT channel bandwidths of 5 and 10 MHz with system bandwidths of 4.5 and 9 MHz, respectively, in accordance to Report ITU-R M.2039.

3.2.2 IMT Base-station antenna downtilt

The application of downtilt in the base-station antenna will effectively reduce the IMT power interfering with the DTTB System. The reduction in power is determined by the vertical radiation pattern of the IMT base-station antenna. Recommendation ITU-R F.1336 provides the relative antenna gain for various angles of azimuth and elevation. This study uses the parameters tabulated in Table 4 to determine both the peak and average gains for the IMT antenna. The worst case or average relative gain of –1.9 dB was used to reduce the effective interference into the DTTB receiving system.

TABLE 4

Parameters used to determine IMT base-station relative antenna gain due to antenna downtilt[11]

Parameter	Value	Units
Azimuth angle	0	degrees
Elevation angle	0	degrees
Horizontal 3dB beamwidth	65	degrees
Vertical 3 dB beamwidth	9.1	degrees
K	0.3	
Downtilt	3	degrees
Average relative gain	–1.9	dB
Peak relative gain	–1.22	dB

3.2.3 Additional parameters

The following additional parameters are used to determine separation distances:

– Broadcasting protection criteria, *I/N* = -10 dB

For specific application scenarios, directivity discrimination may be considered. Report ITU-R BT.2265 provides methodologies for discrimination as well as multiple interferers.

4 Analysis

4.1 Assumptions

– A single interferer is assumed.

– Peak interference power is used since the minimum noise burst duration performance for the DTTB System A is 165 microseconds (per Recommendation ITU-R BT.2036).

– Propagation curves for one percent time variability are used for interference thresholds.

– Propagation over land is assumed; sea paths are not considered.

– No specific terrain information is implied so a representative clutter height of 10 metres is used.

– Polarisation discrimination is not considered.

– DTTB System A channel frequency for this study is 692 to 698 MHz.

– DTTB elevation pattern per Recommendation ITU-R BT.419 does not impact the required separation distances between the IMT UE and a fixed DTTB receiving system for horizontal separations greater than 24 metres.

– Indoor applications are not considered.

4.2 Methodology

The methodology for determining the separation distance between single IMT transmitters (base-station and UE) involves the following steps:

1 The field strength for an IMT base-station transmitter as a function of distance and frequency is calculated based upon propagation curves in Recommendation ITU-R P.1546 adjusted

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[11] Note that for small elevation angles at zero azimuth, the relative antenna gains are equal for all approaches being considered in Recommendation ITU-R F.1336.

for frequency, transmitter power output, antenna gain, antenna height, feeder loss, and downtilt angle.

2 The field strength for an IMT UE transmitter as a function of distance (up to 100 km) and frequency is calculated based upon the "Modified Hata" propagation model described in Report ITU-R SM.2028.

3 The effective field strength threshold for the DTTB receiving system is calculated from the equivalent noise field strength based upon the receiver bandwidth, noise factor, antenna gain, antenna lead loss, frequency, protection ratios, and the protection criterion, *I/N*.

4 If the interfering IMT signal occupies a bandwidth greater than the DTTB bandwidth, it is necessary to apportion the power of the interference and its impact in the corresponding DTTB channel. For the case of System A, the interference is directly related to the total power in the DTTB channel. As the IMT signal is offset from the occupied channel or channels, the interference caused by the IMT signal is lessen by the protection ratio of the DTTB channel. For System A, the total effective field strength is calculated using the protection ratios in Recommendation ITU-R BT.1368.

5 The separation distance is calculated at the point at which the total effective field strength from the IMT signal equals the DTTB effective field strength threshold. The separation distance is further calculated for each MHz of frequency separation between the centre of the IMT signal and the centre of the DTTB signal up to ±6 MHz.

4.3 Calculations

4.3.1 IMT Propagation curves

Recommendation ITU-R P.1546 contains propagation curves of field-strength values for a nominal 1 kW effective radiated power (e.r.p.) transmitter at nominal frequencies of 100, 600, and 2 000 MHz as a function of path type (land and sea), discrete transmitting antenna heights (10, 20, 37.5, 75, 150, 300, 600, and 1 200 metres HAAT), and distance from the transmitter (1 to 1 000 km). The curves represent field-strength values exceeded at 50 percent of the locations within any area of approximately 500 m by 500 m and for 50 percent, 10 percent, and one percent of the time. For the purposes of this study with a single interferer, curves for land paths and one percent of the time were used.

4.3.1.1 Transmitting antenna height interpolation

Since a base-station antenna height of 30 metres is to be considered, the propagation curves are interpolated using equation 8 in section 4.1 of Annex 5 to Recommendation ITU-R P.1546.

4.3.1.2 Frequency interpolation

The propagation curves in Recommendation ITU-R P.1546 are specified for the nominal frequencies of 100, 600, and 2 000 MHz. These curves are interpolated using equation 14 in section 6 to Annex 5, for the specific frequencies from 605 to 785 MHz (695 ± 90 MHz).

4.3.1.3 Transmitter power

The propagation curves in Recommendation ITU-R P.1546 are specified for a nominal transmitter of 1 kW e.r.p. or 0 dBkW e.r.p. The relationship between e.r.p. and e.i.r.p. is given by the equation:

$$\text{e.r.p.} = \text{e.i.r.p.} - 2.15$$

Consequently, the e.i.r.p. and e.r.p. for the IMT transmitters to be considered are shown in Table 5.

TABLE 5

Transmitter powers for IMT base-station and UE

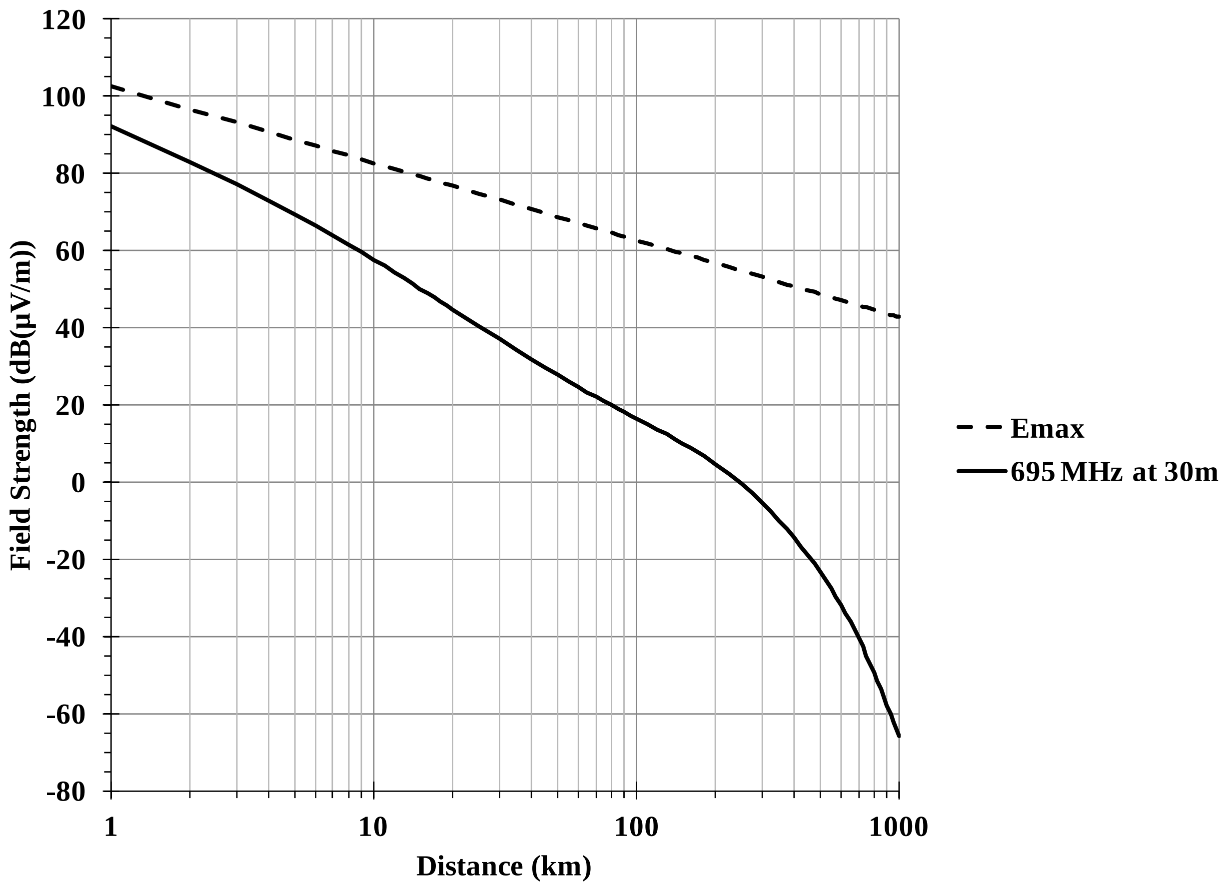
IMT Transmitter	Power	Units
Fixed base-station:		
Maximum e.i.r.p.	58	dBm
Maximum e.r.p.	55.85	dBm
Maximum e.r.p.	–4.15	dBkW
User equipment:		
Maximum e.i.r.p.	16	dBm
Maximum e.r.p.	13.85	dBm
Maximum e.r.p.	–46.15	dBkW

4.3.1.4 Example propagation curves for an IMT fixed base-station transmitter

Figure 1 illustrates the resulting propagation curve interpolated from Recommendation ITU-R P.1546 for a fixed IMT base-station transmitter operating at an antenna height of 30 metres HAAT with an e.i.r.p. of 58 dBm. The curves have been interpolated for 695 MHz. Emax is the free-space field-strength propagation curve.

FIGURE 1

Field-strength propagation curve for an IMT fixed base-station transmitter operating with a 58 dBm e.i.r.p., at 695 MHz, and a 30 metre (HAAT) antenna height

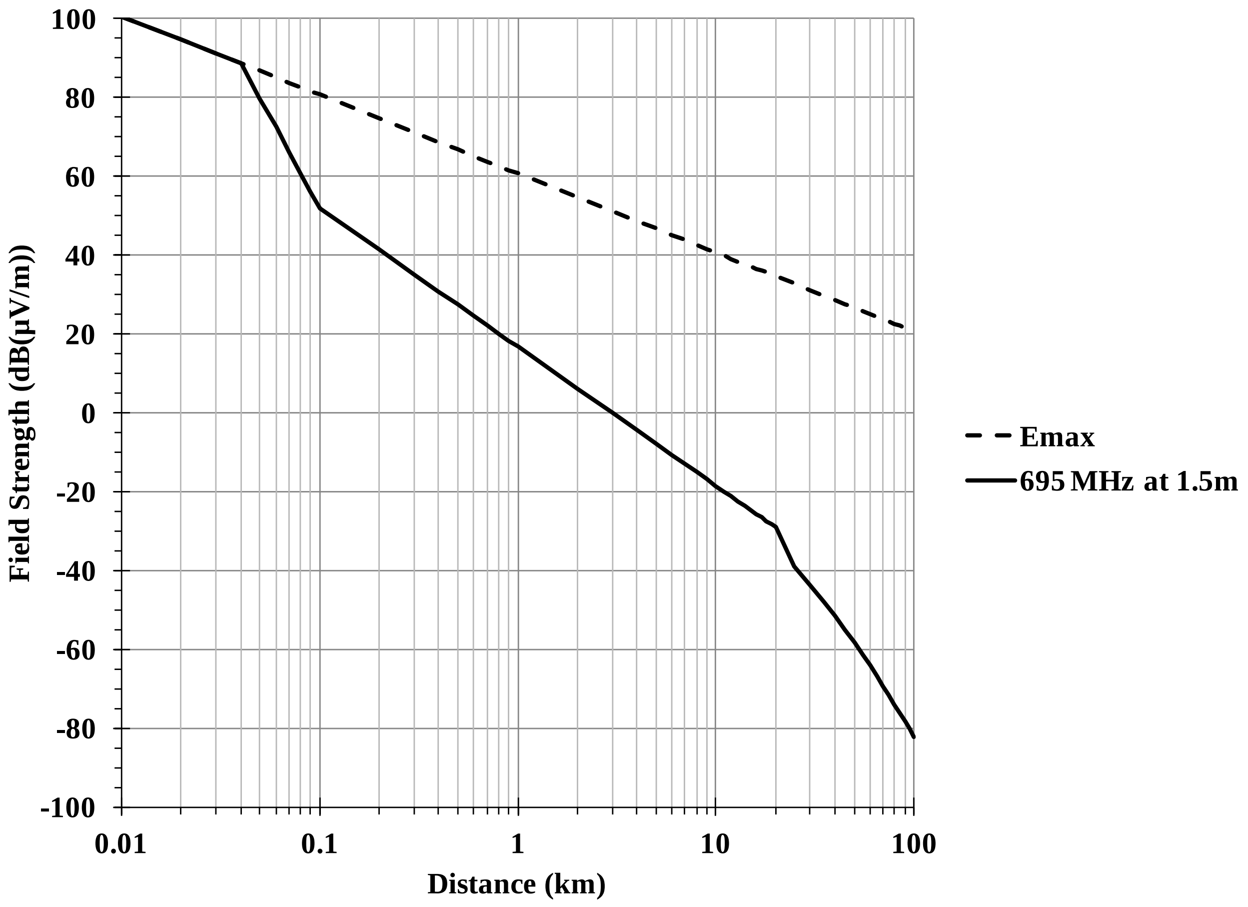


4.3.1.5 Example propagation curves for an IMT UE transmitter

Figure 2 illustrates the resulting propagation curve using the "Modified Hata" model described in Report ITU-R SM.2028 for an IMT UE transmitter operating in an urban environment at an antenna height of 1.5 metres HAAT with an e.i.r.p. of 16 dBm.

FIGURE 2

Field-strength propagation curve for an IMT UE transmitter in an urban environment operating with a 16 dBm e.i.r.p., at 695 MHz, and a 1.5 metre (HAAT) antenna height



4.3.2 Receiving system noise equivalent field-strength

The DTTB receiving system noise equivalent field-strength, E_{NR}, is calculated from equation 3 of Report ITU-R BT.2265. Since the field-strength is frequency dependent, values have been chosen to include the limits of the 470-694/698 MHz band as well as the DTTB channel being considered with a centre frequency at 695 MHz. The results are tabulated in Table 6. Field-strengths for other frequencies can be interpolated using the methodology in Section 5 of Annex 5 to Recommendation ITU-R P.1546-4.

TABLE 6

Noise equivalent field-strength, E_{NR}, at various frequencies for the receiving System A

Frequency	470 MHz	695 MHz
Noise equivalent field-strength, $E_{NR,}$ (dB(μV/m))	22.8	26.2

In addition to the thermal noise power, environmental noise is present at the broadcast receive antenna. However, as shown in Report ITU-R BT.2265, the impact of environmental noise in the 470-694/698 MHz band is minimal and is not considered here.

4.3.3 Individual median effective interfering field-strength threshold

The individual median effective interfering field-strength threshold, E_{eff}, for the DTTB system, is derived from the noise equivalent field-strength in Table 6, the protection ratios in Table 2, and the protection criterion, *I/N*. The results for the various frequencies are tabulated in Table 7.

TABLE 7

Individual median effective interfering field-strength thresholds (E_{eff}) for a DTTB System A receiving system at various frequencies and frequency offsets

Type of interference	Frequency Offset[12] (MHz)	Interference field-strength threshold (dB(μV/m))	
		470 MHz	695 MHz
Co-channel (*N*) interference	0	10.3	13.7
Lower adjacent channel interference (*N* – 1)	–6	38.3	41.7
Upper adjacent channel interference (*N* + 1)	+6	36.3	39.7

4.3.4 Separation distance interpolation

The separation distance between the interfering IMT transmitter and the broadcast receiving system is determined by the intersection of the individual median effective interfering field-strength threshold, E_{eff}, with the appropriate field-strength propagation curve. Since the tabulated data for the curves utilize discrete distance values, it is necessary to interpolate to obtain a precise separation distance. The equation for the separation distance, d_{sep}, is given by:

$$d_{sep} = d_{inf}\,(d_{sup} / d_{inf})^{\Delta E} \qquad (1)$$

where:

$$\Delta E = (E_{eff} - E_{inf})\,(E_{sup} - E_{inf})$$

and where:

d_{sep}: separation distance

E_{inf}: nearest tabulation field-strength less than E_{eff}

E_{sup}: nearest tabulation field-strength greater than E_{eff}

d_{inf}: distance value for E_{inf}

d_{sup}: distance value for $E_{sup.}$

[12] Frequency offset is the separation between the channel centres of IMT and DTTB systems.

4.4 Results

This study considers the separation distances necessary to avoid interference between IMT transmitters (base-station and UE) and receivers for the DTTB System A where the IMT transmitter is operating at or near the same frequency of the DTTB System A.

In addition, to frequency separation between the IMT transmitter and the DTTB receiver, IMT channel bandwidths of 5 and 10 MHz are considered.

4.4.1 Co-channel separation distances for IMT base-stations

The separation distances at the individual median effective interfering field-strength threshold for IMT base-stations operating at 58 dBm e.i.r.p., 30 metre antenna heights (HAAT), three degree downtilt, and 5 or 10 MHz channel bandwidths are tabulated in Table 8. The table includes the separation distances for co-channel and first adjacent-channel (*N±1*) interferers into a broadcast receiving System A. Separation distances for adjacent channel interference are calculated with the centre of the IMT signal offset by 6 MHz from the centre frequency (695 MHz) of the DTTB signal.

TABLE 8

Separation distances at the interference threshold for an IMT base-station interfering with a 6 MHz DTTB System A receiver at 695 MHz in the 470-694/698MHz band

(IMT base-station operating at 58 dBm e.i.r.p. with a 30 metre HAAT antenna and 5 or 10 MHz bandwidths on co-channel and/or first adjacent channels)

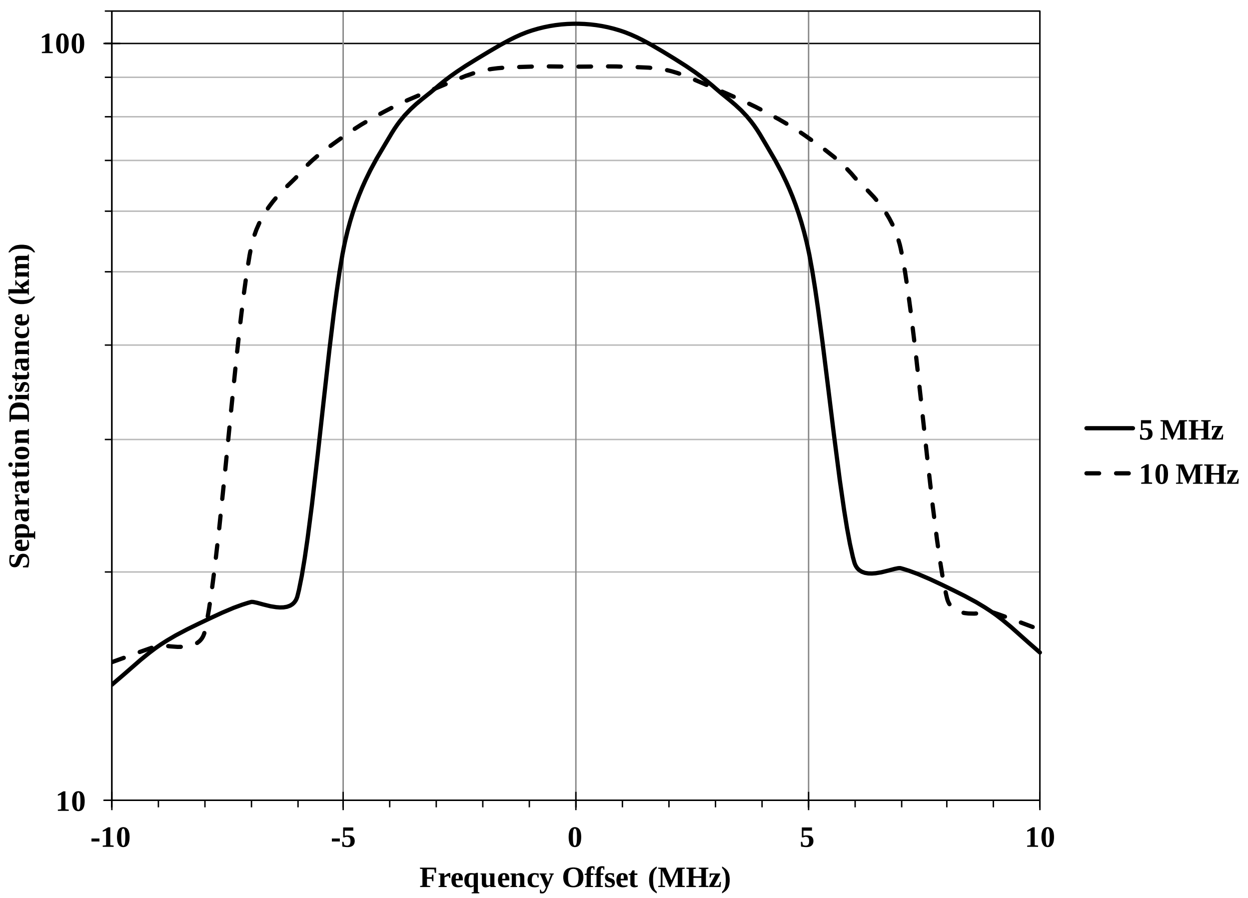
IMT Centre Frequency	IMT Channel Bandwidth	
	5 MHz	10 MHz
Channel N+1 (701 MHz)	20.7 km	64.9 km
Co-channel (N = 695 MHz))	106 km	94.7 km
Channel N-1 (689 MHz)	18.6 km	651 km

Figure 3 illustrates the separation distances required to maintain the interference threshold as a function of frequency offset between the centres of the IMT and DTTB channels. Note that increasing the IMT bandwidth may lower the separation distance required in the co-channel but extends the frequency separation requirement.

FIGURE 3

Co-channel separation distance versus frequency offset required to maintain the interference threshold for an IMT base-station interfering with a fixed 6 MHz DTTB System A receiver at 695 MHz in the 470-694/698 MHz band

(IMT base-station operating at 58 dBm e.i.r.p. with a 30 metre HAAT antenna and 5 or 10 MHz bandwidths on co-channel and/or first adjacent channels; DTTB antenna height is 10 m)



4.4.2 Co-channel separation distances for IMT UE

The separation distances at the individual median effective interfering field-strength threshold for IMT UE operating at 16 dBm e.i.r.p., 1.5 metre antenna height (HAAT), and 5 and 10 MHz channel bandwidths are tabulated in Table 9. The table includes the separation distances for co-channel and first adjacent-channel (*N±1*) interferers into a broadcast receiving System A. Separation distances are calculated with the centre of the IMT signal offset by 6 MHz from the centre frequency (695 MHz) of the DTTB signal.

TABLE 9

Separation distances at the interference threshold for an IMT UE interfering with a 6 MHz DTTB System A receiver at 695 MHz in the 470-694/698 MHz band

(IMT UE operating at 16 dBm e.i.r.p. with a 1.5 metre HAAT antenna and 5 or 10 MHz bandwidths on co-channel and/or first adjacent channels)

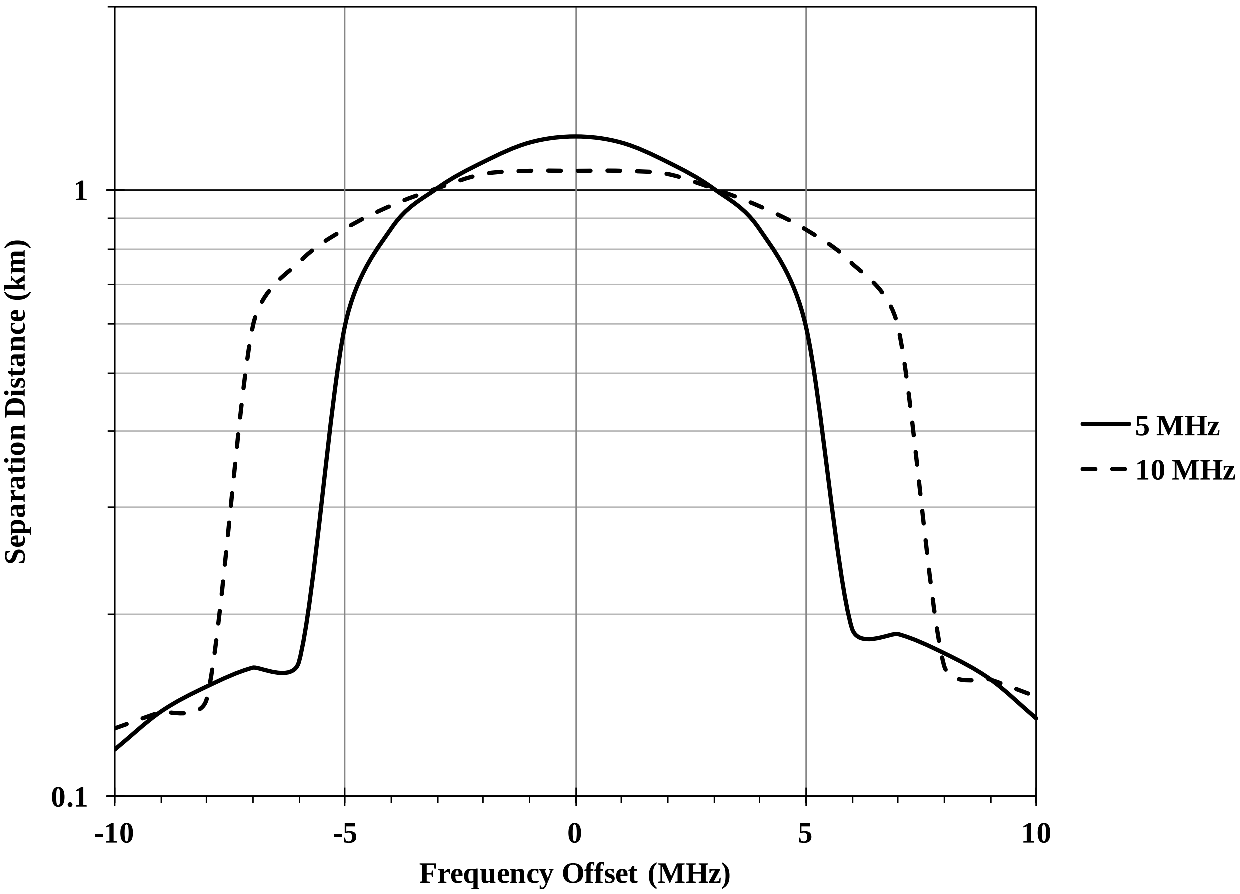
IMT Centre Frequency	**IMT Channel Bandwidth**	
	5 MHz	**10 MHz**
N+1 (701 MHz)	0.19 km	0.74 km
Co-channel (N = 695 MHz)	1.22 km	1.09 km
N-1 (689 MHz)	0.17 km	0.74 km

Figure 4 illustrates the separation distances required to maintain the interference threshold as a function of frequency offset between the centres of the IMT and DTTB channels. Note that increasing the IMT bandwidth may lower the separation distance required in the co-channel but extends the frequency separation requirement.

FIGURE 4

Co-channel separation distance versus frequency offset required to maintain the interference threshold for an IMT UE interfering with a fixed 6 MHz DTTB System A receiver at 695 MHz in the 470-694/698 MHz band

(IMT UE operating at 16 dBm e.i.r.p. with a 1.5 metre HAAT antenna and 5 or 10 MHz bandwidths on co-channel and/or first adjacent channels; DTTB antenna height is 10 m)



5 Summary

The required separation distances needed in order to meet the protection criterion of *I/N* = –10 dB for interference of IMT into DTTB are significant for a single IMT transmitter (base-station or UE). Furthermore, the required frequency separations needed to meet protection levels are also significant. The study illustrates the possibility of interference from IMT transmitter operating in proximity, both distance and frequency, to a broadcast receiving system.

ANNEX 4 (TO SECTION II)

Study 4 -- Co-channel and adjacent channel sharing and compatibility study of Digital Terrestrial Television Broadcasting (DTTB) System A (ATSC) interference into an IMT base-station in the 470-694/698 MHz band outside the GE06 planning area

1 Introduction

This Annex provides a sharing and compatibility study between IMT base-station receivers operating at frequencies offset, both co-channel and first adjacent channel, from fixed DTTB transmission systems operating on a channel in the 470-694/698 MHz band. The 470-694/698 MHz band with its propagation characteristics and limited environmental noise is ideal for a single DTTB transmitter to service vast numbers of receivers within a wide coverage area.

This analysis is based upon the latest IMT parameters below 1 GHz in Report ITU-R M.2292. The analysis is also based upon the parameters for DTTB System A.

1.1 Requirement

Sharing and compatibility between the mobile service and the broadcasting service requires that the protection criteria for each service be met in order to minimize interference between the services.

1.2 Study elements

This study addresses the following elements:

The impact of a single DTTB (System A) transmission system at various power levels and antenna heights on a fixed IMT base-station receiving system.

The study takes into account various ITU-R Recommendations and Reports.

2 Background

Numerous ITU-R Recommendations and Reports are relevant to this study. Recommendation ITU-R P.1546-5 provides propagation methodologies for point-to-area predictions for terrestrial services including DTTB. Recommendation ITU-R BT.1206-1 provides spectrum characteristics for DTTB System A. With respect to IMT systems, IMT related parameters are provided in Report ITU-R M.2292. The parameters related to this study are provided below.

3 Technical characteristics

3.1 DTTB System A -- Transmission system parameters

The System A parameters for DTTB transmission using a fixed antenna for three power levels are tabulated in Table 1.

TABLE 1

System A Transmission Parameters

Planning Parameter	Value	Units
Channel bandwidth	6	MHz
High Power e.r.p.	1 000	kW
Antenna height (HAAT)	365	metres
Medium Power e.r.p.	400	kW
Antenna height (HAAT)	550	metres
Low Power e.r.p.	50	kW
Antenna height (HAAT)	550	metres

3.1.1 DTTB System A antenna downtilt and radiation pattern

The field strength in the vicinity of the broadcast UHF transmitting station is a function of the vertical radiation pattern of the transmitting antenna. Table 2 tabulates the radiation pattern as a function of the angle from the horizon.

TABLE 2

Vertical UHF radiation pattern

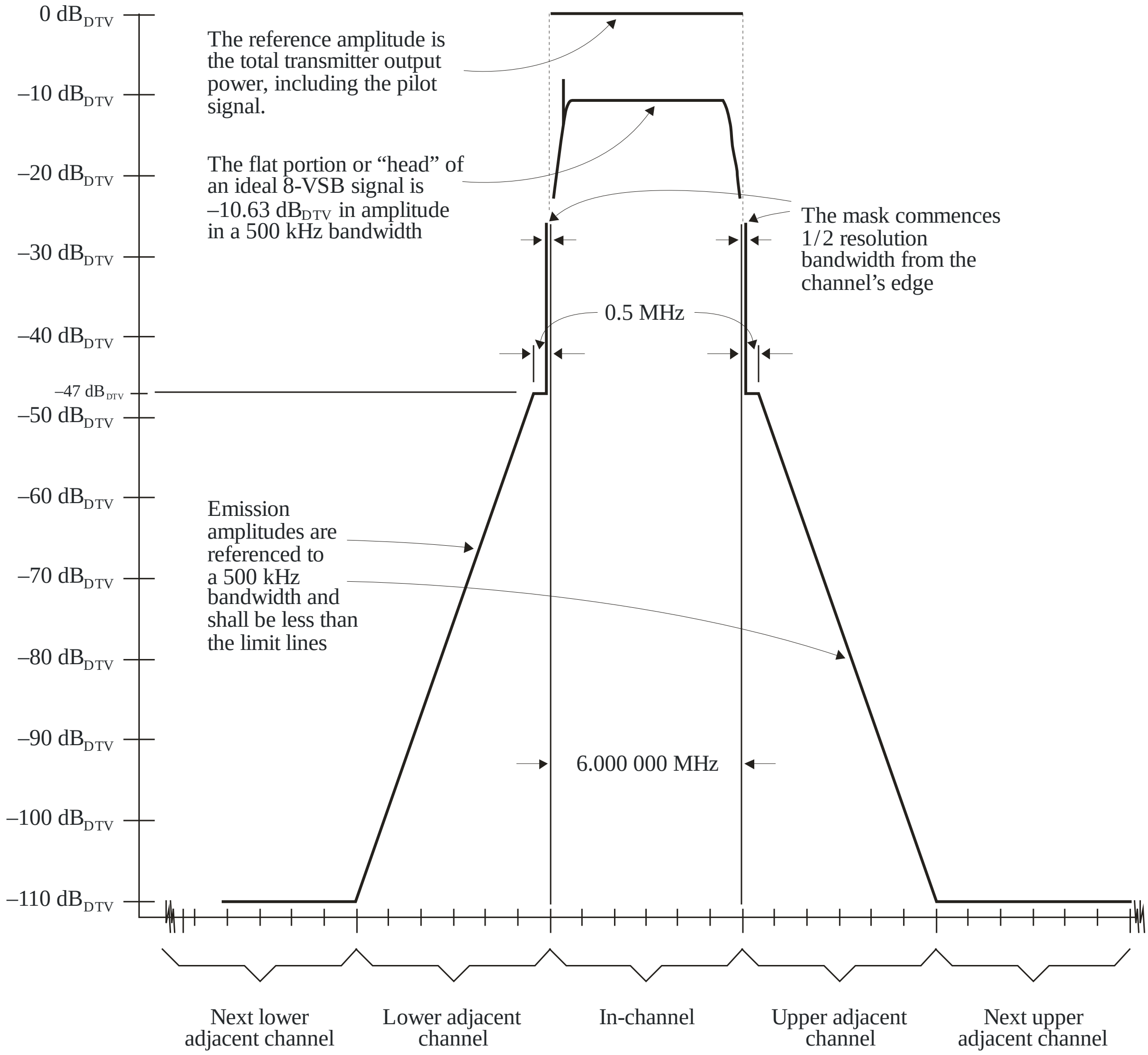
Angle from horizon (degrees)	Relative Field Strength
0.75	1.000
1.50	0.880
2.00	0.690
2.50	0.460
3.00	0.260
3.50	0.235
4.00	0.210
5.00	0.200
6.00	0.150
7.00	0.150
8.00	0.150
9.00	0.150
10.00	0.150
To allow for null fill the value of the relative field strength is not less than 0.150 at all angles.	

3.1.2 DTTB System A transmitter spectrum

Since this study considers the impact of the DTTB signal into the adjacent channels, it is necessary to consider the power emitted outside of the designated DTTB channel. The spectrum limit mask for a high power DTTB transmitter is described in Recommendation ITU-R BT.1206-1 and is illustrated graphically in Figure 1.

FIGURE 1

Spectrum limit mask for 6 MHz high power 8-VSB digital terrestrial television systems (System A)



BT.1206-01

3.2 IMT base-station receiving system parameters

The relevant parameters for studying DTTB interference into an IMT base-station receiving system are tabulated in Table 3.

TABLE 3

Study parameters for IMT base-station receiving system

Planning Parameter	Value	Units
Frequency band	470-694/698 MHz	--
Base-station receiving system:		
Channel bandwidth	10	MHz
System bandwidth	9	MHz
Antenna gain	15	dBi
Antenna height (HAAT)	30	M
Antenna downtilt	3	degrees
Feeder loss	3	dB
Receiver noise figure	5	dB
Temperature	290	K
Receiver inherent noise	–129.4	dBW
Reference sensitivity level	–101.5	dBm
Dynamic range:		
Wanted signal mean power	–70.2	dBm
Interfering signal mean power	–79.5	dBm
ACS:		
Wanted signal mean power	–95.5	dBm
Interfering signal mean power	–52	dBm
Interference location probability	50	Percent
Interference time probability	1	Percent

3.2.1 IMT Base-station antenna downtilt

The application of downtilt in the base-station antenna will effectively reduce the DTTB power interfering with the IMT System. The reduction in power is determined by the vertical radiation pattern of the IMT base-station antenna. Recommendation ITU-R F.1336 provides the relative antenna gain for various angles of azimuth and elevation. This study uses the parameters tabulated in Table 4 to determine both the peak and average gains for the IMT antenna. The worst case or average relative gain of –1.9 dB was used to reduce the effective interference into the IMT receiving system.

TABLE 4

Parameters used to determine IMT base-station relative antenna gain due to antenna downtilt[13]

Parameter	Value	Units
Azimuth angle	0	degrees
Elevation angle	0	degrees
Horizontal 3dB beamwidth	65	degrees
Vertical 3 dB beamwidth	9.1	degrees
k	0.3	
Downtilt	3	degrees
Average relative gain	–1.9	dB
Peak relative gain	–1.22	dB

3.2.2 Additional parameters

The following additional parameters are used to determine separation distances:

– Protection criteria, I/N = -10 dB

For specific application scenarios, horizontal directivity discrimination may be considered.

4 Analysis

4.1 Assumptions

– A single interferer is assumed.

– Propagation curves for one percent time variability are used for interference thresholds.

– Propagation over land is assumed; sea paths are not considered.

– No specific terrain information is implied so a representative clutter height of 10 metres is used.

– Polarisation discrimination is not considered.

– DTTB System A channel frequency for this study is 692 to 698 MHz.

– Indoor applications are not considered.

4.2 Methodology

The methodology for determining the separation distance between single IMT transmitters (base-station and UE) involves the following steps:

1 The field strength for a DTTB System A transmitter as a function of distance and frequency is calculated based upon propagation curves in Recommendation ITU-R P.1546 adjusted for frequency, transmitter power output, antenna emission pattern, antenna height, and spectrum mask.

2 The effective field strength threshold for the IMT base-station receiving system is calculated from the equivalent noise field strength based upon the receiver bandwidth, noise factor, antenna gain, antenna lead loss, frequency, protection ratios, and the protection criterion, *I/N*.

[13] Note that for small elevation angles at zero azimuth, the relative antenna gains are equal for all approaches being considered for the revision of Recommendation ITU-R F.1336.

3 If the interfering DTTB signal occupies a portion of the spectrum outside of the IMT bandwidth, it is necessary to apportion the power of the interference and its impact in the corresponding IMT channel. As the IMT channel is offset from the DTTB channel, the interference caused by the DTTB signal is lessen by the Adjacent Channel Selectivity (ACS) of the IMT receiving system.

4 The separation distance is calculated at the point at which the total effective field strength from the DTTB signal equals the IMT effective field strength threshold. The separation distance is further calculated for each 0.5 MHz of frequency separation between the centre of the IMT signal and the centre of the DTTB signal up to 15.5 MHz. Note that the separation distances are nearly equal in both directions of frequency separation.

4.3 Calculations

4.3.1 IMT Propagation curves

Recommendation ITU-R P.1546 contains propagation curves of field-strength values for a nominal 1 kW effective radiated power (e.r.p.) transmitter at nominal frequencies of 100, 600, and 2 000 MHz as a function of path type (land and sea), discrete transmitting antenna heights (10, 20, 37.5, 75, 150, 300, 600, and 1 200 metres HAAT), and distance from the transmitter (1 to 1 000 km). The curves represent field-strength values exceeded at 50 percent of the locations within any area of approximately 500 m by 500 m and for 50 percent, 10 percent, and one percent of the time. For the purposes of this study with a single interferer, curves for land paths and one percent of the time were used.

4.3.1.1 Transmitting antenna height interpolation and extrapolation

Since DTTB antenna heights of 365 and 550 metres are to be considered, the propagation curves are interpolated using equation 8 in section 4.1 of Annex 5 to Recommendation ITU-R P.1546-5. The DTTB antenna height of 1 800 metres is extrapolated using equation 8.

4.3.1.2 Frequency interpolation

The propagation curves in Recommendation ITU-R P.1546-4 are specified for the nominal frequencies of 100, 600, and 2 000 MHz. These curves are interpolated using equation 14 in section 6 to Annex 5, for the specific frequency of 695 MHz.

4.3.1.3 Transmitter power

The propagation curves in Recommendation ITU-R P.1546 are specified for a nominal transmitter of 1 kW e.r.p. or 0 dBkW e.r.p. The e.r.p. and associated antenna height above average terrain (HAAT) for the System A DTTB transmitters to be considered are shown in Table 5.

TABLE 5

Transmitter powers and antenna heights (HAAT) for System A DTTB

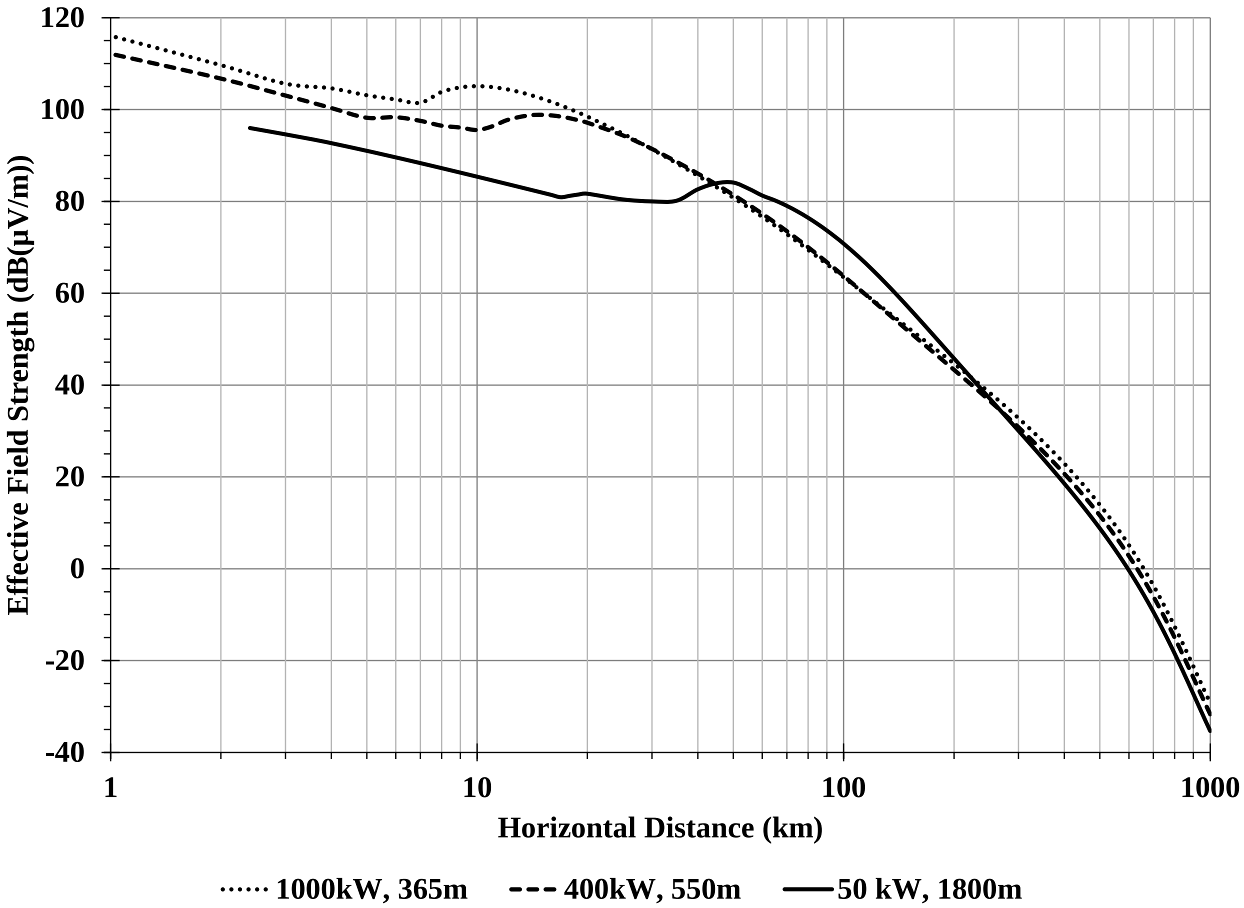
DTTB Transmitter	Power	Units	HAAT	Units
High Power:				
e.r.p.	1 000	kW	365	metres
e.r.p	30	dBkW		
Medium Power:				
e.r.p.	400	kW	550	metres
e.r.p.	26	dBkW		
Low Power				
e.r.p.	50	kW	1 800	metres
e.r.p.	17	dBkW		

4.3.1.4 Example propagation curves for a System A DTTB transmitter

Figure 2 illustrates the resulting propagation curves at an IMT base-station receive site derived from Recommendation ITU-R P.1546 for a System A DTTB transmitter operating at an antenna heights of 365, 550, and 1 800 metres HAAT with an e.r.p. of 1 000, 400, and 50 kW, respectively. The curves have been compensated for the DTTB transmitter vertical emission pattern, the IMT antenna pattern and downtilt, and the effective horizontal distance.

FIGURE 2

Effective field-strength propagation curves for various System A DTTB transmitters operating at 695 MHz with e.r.p. levels of 1 000, 400, and 50 kW and antenna heights of 365, 550, and 1 800 metres (HAAT), respectively, and accounting for antenna patterns and downtilt



4.3.2 Separation distance interpolation

The separation distance between the interfering DTTB transmitter and the IMT receiving system is determined by the intersection of the individual median effective interfering field-strength threshold, E_{eff}, with the appropriate field-strength propagation curve. Since the tabulated data for the curves utilize discrete distance values, it is necessary to interpolate to obtain a precise separation distance. The equation for the separation distance, d_{sep}, is given by:

$$d_{sep} = d_{inf} (d_{sup} / d_{inf})^{\Delta E} \quad (1)$$

where:

$$\Delta E = (E_{eff} - E_{inf}) (E_{sup} - E_{inf})$$

and where:

d_{sep}: separation distance

E_{inf}: nearest tabulation field-strength less than E_{eff}

E_{sup}: nearest tabulation field-strength greater than E_{eff}

d_{inf}: distance value for E_{inf}

d_{sup}: distance value for $E_{sup.}$

4.4 Results

This study considers the separation distances necessary to avoid interference between DTTB transmitters operating at frequencies within the IMT receiver co-channel and adjacent channel.

The separation distances for various System A DTTB transmitters are tabulated in Table 6.

The table includes the separation distances for DTTB interferers into an IMT base-station receiving system for a DTTB channel centred about the IMT co-channel as well as the IMT adjacent channel.

TABLE 6

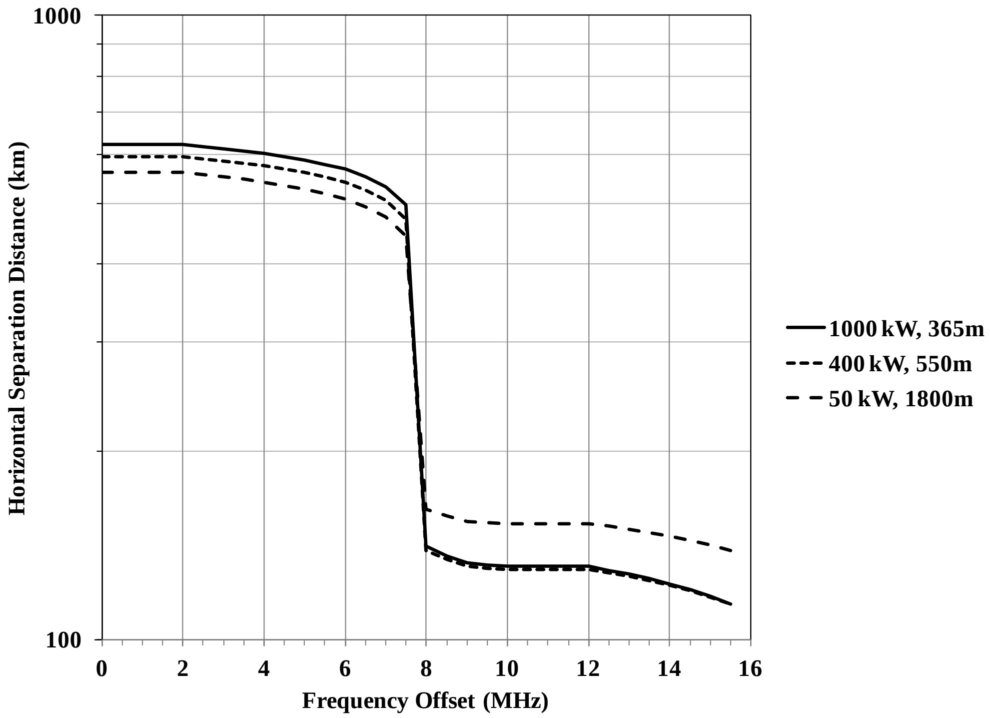
Horizontal separation distances at the interference threshold for a 6 MHz System A DTTB transmitter at 695 MHz and various power levels and antenna heights centred within the 10 MHz co-channel and adjacent-channel of an IMT base-station receiving system in the 470-694/698MHz band

DTTB Transmitter	Power (kW)	Antenna Height (HAAT)	Co-channel Separation Distance (km)	Adjacent Channel Separation Distance (km)
High Power	1 000	365	621	131
Medium Power	400	550	593	129
Low Power	50	1 800	559	153

Figure 3 illustrates the separation distances required to maintain the interference threshold as a function of frequency offset between the centres of the IMT and DTTB channels. Note that the separation distances will be symmetrical for frequency offsets above and below the IMT channel.

FIGURE 3

Horizontal separation distances at the interference threshold for a 6 MHz System A DTTB transmitter at 695 MHz and various power levels and antenna heights within the 10 MHz co-channel and adjacent-channel of an IMT base-station receiving system in the 470-694/698MHz band



The separation distances shown in Table 7 and Figure 3 are significant when compared with the total radio horizon distances resulting from a 30 metre IMT antenna height and a System A DTTB transmitter antenna height or 365, 550, or 1 800 metres. Table 7 provides the comparison and illustrates that co-channel interference will occur for all cases. Adjacent-channel interference will occur to the radio horizon for both the high power and medium power cases.

TABLE 7

Comparison of horizontal separation distances with total distances to the radio horizon for various DTTB transmitter heights and an IMT antenna height of 30 metres.

DTTB Transmitter	Antenna Height (HAAT)	Co-channel Separation Distance (km)	Adjacent Channel Separation Distance (km)	Radio Horizon Distance (km)
High Power	365	621	131	101
Medium Power	550	593	129	119
Low Power	1 800	559	153	197

5 Conclusions

The required separation distances for interference of DTTB into IMT base-stations are significant for both co-channel and adjacent-channel scenarios. Since the separation distances exceed radio horizons, it is unlikely that spectrum sharing between DTTB and IMT is possible within a given geographic location.

ANNEX 5 (TO SECTION II)

Study 5 -- Mobile service as an interferer: interference from mobile service base-stations into broadcasting service reception outside the GE06 area

1 Methods of calculation with formulas

In order to estimate multiple adjacent channels cumulative effect of interference from IMT base-station (BS) to DTT in particular DVB-T system, following steps are done:

– first, the field strength threshold of IMT BS is calculated using I/N criteria;

– then, single base-station is evaluated and required separation distance to meet this value is calculated;

– then a network of IMT consisting of several base-stations is constructed and cumulative effect is evaluated;

– finally, required separation distance by considering cumulative effect is calculated.
The above steps are further described in detail in following sections.

2 Calculations

2.1 Field strength threshold of IMT BS at different frequency offsets

In order to calculate the field strength threshold of IMT BS at different frequency offsets, the *I/N* criterion *I/N*= –10dB is used. The methodology is similar to what proposed in Report ITU-R BT.2265 (Annex 1). Frequency offset is the separation between the channel centres of the IMT and DTT systems.

Then, using protection ratios at different frequency offsets and assuming $f_{(MHz)}$ = 690 MHz[14], median effective interfering field strength threshold for a reception location probability of 95% (E_{INT}) will be derived as shown in table 1 below.

TABLE 1

Interferer offset N/(MHz)	**PR PR (dB)**	**E_{INT} (dBµV/m)**
1/(10 MHz)	–25.7	51.3
2/(18 MHz)	–21.9	47.5
3/(26 MHz)	–24.9	50.5
4/(34 MHz)	–28.9	54.5
5/(42 MHz)	–32.8	58.4
6/(50 MHz)	–35.0	60.6
7/(58 MHz)	–37.8	63.4
8/(66 MHz)	–38.9	64.5
9/(74 MHz)	–39.2	64.8

[14] This frequency does not correspond to any specific IMT band plan. Rather, it is selected to be representative for both 700 MHz and 600 MHz bands. Results at other frequencies would be much similar and just slightly changed.

2.2 Single base-station separation distance

A base-station with nominal characteristics submitted by WP 5D is considered. The required separation distance is then calculated using Recommendation ITU-R P.1546, so that the 1% time field strength from base-station just reaches values of E_{INT} as specified above. Table 2 shows the results.

TABLE 2

Interferer offset N/(MHz)	E_{INT} (dBμV/m)	Separation distance (km)
1/(10 MHz)	51.3	13.3
2/(18 MHz)	47.5	16.4
3/(26 MHz)	50.5	14
4/(34 MHz)	54.5	11.2
5/(42 MHz)	58.4	9
6/(50 MHz)	60.6	8
7/(58 MHz)	63.4	6.6
8/(66 MHz)	64.5	6.2
9/(74 MHz)	64.8	6.1

2.3 Case of several base-stations

Now, a network consisting of several IMT base-stations is constructed at the two sides of above base-station and also behind it. All base-stations have nominal characteristics. The area is assumed as urban and cell size is one kilometre.

Now the field strengths from each base-station in the extended IMT network is calculated at 2% time, and summed to give an accumulated field strength.

The increase in field strength (cumulative effect) and final separation distance at which the total field strength (considering cumulative effect) would be equal to threshold value are presented in Table 3.

3 Results

TABLE 3

Interferer offset N/(MHz)	E_{INT} (dBμV/m)	Initial separation distance (km)	Increase in field strength (Cumulative effect)(dB)	Final separation distance(km)
1/(10 MHz)	51.3	13.3	15	35.2
2/(18 MHz)	47.5	16.4	15.5	45.5
3/(26 MHz)	50.5	14	15.2	37.4
4/(34 MHz)	54.5	11.2	13.4	28.5
5/(42 MHz)	58.4	9	12.2	22
6/(50 MHz)	60.6	8	11.5	18.7
7/(58 MHz)	63.4	6.6	11	15.3
8/(66 MHz)	64.5	6.2	10.5	14.3
9/(74 MHz)	64.8	6.1	10.5	14

ANNEX 6 (TO SECTION II)

Study 6 -- Cumulative effect of co-channel interference from IMT BS to DTT outside the GE06 area

1 Description

In order to estimate the cumulative effect of co-channel interference from IMT base-station (BS) to DTT in particular DVB-T receiving system, a single base-station is first evaluated and the required separation distance to meet the field strength threshold value corresponding to the required I/N criteria is calculated. Then a network of several IMT base-stations is modelled and the cumulative effect is evaluated. Finally, the new separation distance that would be required to reduce the cumulative effect to the original threshold is calculated.

2 Methods of calculation with formulas

The methodology used here is as specified in Report ITU-R BT.2265 (Annex 1). The value of *I/N* specified in Recommendation ITU-R BT.1895, -10 dB, is used.

At $f_{(MHz)}$ = 700 MHz[15], assuming no receiving antenna directivity discrimination, the median effective interfering field strength for a reception location probability of 95% would be E = 7.85 dB(μV/m). In some cases of fixed DTTB reception, antenna directivity discrimination of 16 dB as specified in Recommendation ITU-R BT 419-3 could be assumed, and therefore a value of E around 23 dB(μV/m) can be calculated.

It should be noted that in practise, for example in the case that there is less than 60^{o} directivity or in case of portable reception, this would not always apply. However, the increase in interfering field strength due to the cumulative effect in either case would be similar.

3 Calculations

Step 1: Single base-station

All base-station parameters used in this study are as specified. Specifically, these are:

– Frequency: 700 MHz;

– Radiated Power: 55 dBm;

– Tx Antenna Height: 30 m.

The separation distance R required to give the threshold field strength (23 dB(μV/m)) from a single base-station at 1% time is then calculated using Recommendation ITU-R P.1546.

It is found that R would be around 61 kilometres (see figure 1 below) if the whole path between the base-station and the receiving point A is considered to be land.

[15] This frequency does not correspond to any specific IMT band plan. Rather, it is selected to be representative of both the 700 MHz band and the 600 MHz band. Results at other frequencies would be much similar and just slightly change.

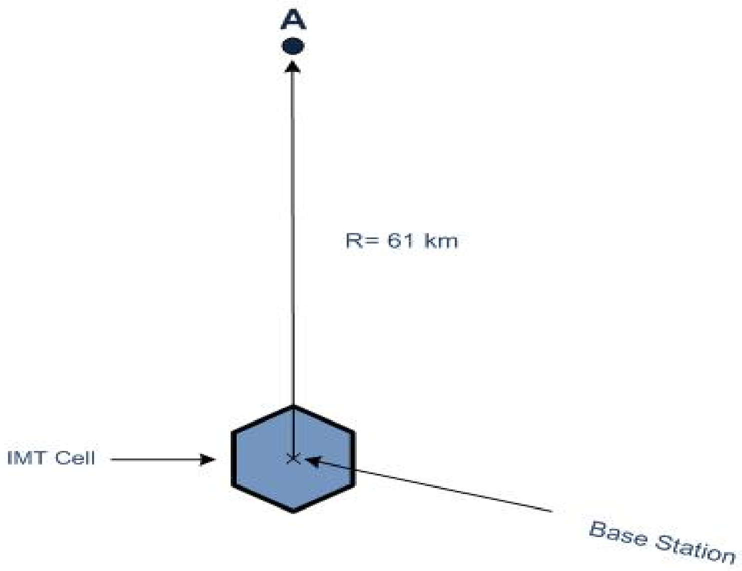


Figure 1

Step 2: Several base-stations

In Step 2, a network consisting of several IMT base-stations is modelled on either side of base-station in Step 1, and also behind it. All base-stations have the same characteristics as that in Step 1. The area in which this network operates is assumed to be urban and therefore a cell range of one kilometre is selected. This is within the specified range specified 0.5 kilometres – 5 kilometres.

The IMT network used in this study consists of alternately 15 or 16 cells across and 17 cells deep, making a total of 263 cells.

Now the field strength from each base-station in the extended IMT network is calculated at point A at 2% time.

The field strengths from each base-station in the extended IMT network are summed to give an accumulated field strength at A.

The resultant accumulated field strength is found to be 43.4 dB(μV/m), i.e. an increase of 20.4 dB compared to the single cell case in Step 1.

Step 3: Derive a new Separation Distance

Having derived a value for the accumulated field strength, the distance modelled between the IMT network and the DTTB receiving point A can be recalculated such that the accumulated field strength drops to the original threshold. In the case considered here, that is found to be about 212 kilometres.

4 Results

The results found above are summarised in Table 1 below.

TABLE 1

Interfering field strength threshold @700 MHz	**Initial separation distance R**	**Total cumulative field strength**	**Increase over original threshold**	**New required separation distance**
dB(μV/m)	km	dB(μV/m)	dB	km
23	61	43.4	20.4	212

ANNEX 7 (TO SECTION II)

Adjacent channel sharing and compatibility studies between DTTB System C (ISDB-T) and IMT in the 470-694/698 MHz frequency band outside the GE06 area

1 Introduction

The minimum coupling loss (MCL) method and the Monte Carlo simulation are the main methods for sharing studies between broadcasting and mobile services, especially for IMT. Both methods have their respective merits for the sharing study, and do not preclude other methods to estimate the fundamental technical conditions.

This report provides a study of the protection of the 6 MHz DTTB System C (ISDB-T) from a mobile broadband terminal (MBB). The findings of this report provide insight for feasibility of coexistence of ISDB-T receivers and MBB terminals.

The result shows that the separation distance of 15 metres is required to achieve the I/N of under -10 dB when assuming the MBB transmitter output power of –9 dBm, the maximum OOB of -55 dBm and the DTTB receiver ACS of 80 dB.

1.1 Study elements

This study addresses the minimum separation distance to protect the indoor portable reception of an ISDB-T receiver from a MBB terminal being operated in the same room.

2 Background

There are many scenarios for studying the sharing conditions of DTTB and IMT. In the case of DTTB indoor reception, with poor antenna gain and large wall loss, the receiving C/N is generally lower compared to outdoor fixed reception. It means the interferences tend to affect the quality of DTTB indoor reception. Hence, a study of indoor DTTB reception and a MBB terminal being operated in the same room needs to be considered.

This study looks at the sharing conditions of ISDB-T indoor reception and a MBB terminal being operated in the same room.

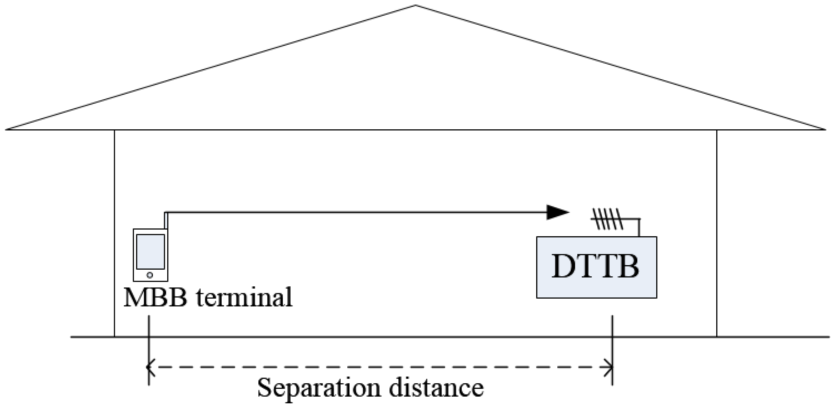
3 Technical characteristics

3.1 Geometry of DTTB receiver and MBB

The geometry is shown in FIGURE 1. The minimum separation distances between the ISDB-T receiver and the MBB are estimated with the MCL method.

FIGURE 1

Model for portable indoor reception



3.2 DTTB receiver filter characteristics

This study assumes ACS values of 40, 60 and 80 dB, given the varying ACS characteristics of actual receivers. The ACS value of 60 and 80 dB may not be achieved only with an internal filter of the DTTB receiver, which means an external filter may also be required.

3.3 DTTB parameters (portable indoor reception)

Table 1 below lists the DTTB receiver parameters of portable indoor reception.

TABLE 1

DTTB receiver parameters of portable indoor reception (ISDB-T)

Parameter	Value	Unit	Symbol
Noise Figure	7	dB	NF
Noise equivalent bandwidth	5.6	MHz	B
Antenna gain	2.15	dBi	G_{Rx}
Antenna height	1.5	metre	H_{Rx}
Receiver ACS	40, 60, 80	dB	*ACS*

3.4 MBB terminal parameters

Table 2 below lists the MBB terminal parameters assumed in this study. Transmitter output power (P_{TX}) at 23 dBm (maximum power), 2 dBm (average power in macro rural scenarios), and –9 dBm (average power in macro urban/suburban scenarios) are assumed for the purposes of comparison.

TABLE 2

MBB terminal parameters

Parameter	Value	Unit	Symbol
Transmitter output power	23, 2, -9	dBm	P_{Tx}
Antenna gain	-3	dBi	G_{Tx}
Antenna height	1.5	metre	H_{Tx}
Antenna pattern	Omni-directional		
Body loss	4	dB	L_{Body}

4 Analysis

4.1 Minimum separation distance for portable indoor reception

Table 3 below lists the calculation details of the frequency used in this study. The study assumes the frequency of 695 MHz, which is the centre frequency of the Japanese CH50.

TABLE 3

Frequency parameters

Parameter	Value	Unit	Symbol
Centre Frequency	695	MHz	f
Thermal noise (290K, 5.6 MHz)	–106.5	dBm/5.6MHz	P_N = 10log(kTB) + NF

where:

k = Boltzmann constant = 1.38×10^{-23} (J/K)

T = noise temperature of the receiver (K)

The propagation loss L_P is given by the following equation:

For $d \leq 0.04$ km,

$$L_P(d) = 32.4 + 20\log f(MHz) + 20\log d(km),$$

For d = 0.1 km,

$$L_P(0.1) = 69.5 + 26.66 \log f(\text{MHz}) - 13.82 \log[\max(30, H_{tx}(m))] - \min(0, 20\log(H_{tx}(m)/30) - \{44.9 - 6.55 \log[\max(30, H_{tx}(m))]\}\log(0.1).$$

For 0.04 km < d < 0.1 km

$$L_P(d) = L_P(0.04) + \frac{\log(d/0.04)}{\log(0.1/0.04)}\left[L_P(0.1) - L_P(0.04)\right]$$

The total maximum equivalent isotropically radiated power (e.i.r.p.) of the MBB terminal is given by:

$$P_{e.i.r.p.} = P_{Tx} + G_{Tx}$$

where:

P_{Tx} = transmitter output power of the MBB terminal; and

G_{Tx} = MBB terminal antenna gain.

The in-band interference power seen by the victim DTTB receiver is given by:

$$I_{IB} = P_{OOB} + G_{Tot}$$

where:

P_{OOB} = maximum OOB emission level of the MBB terminal at the DTTB receiving channel frequency; and

G_{Tot} = total coupling gain between the MBB terminal and the DTTB receiver.

The study assumes -35, -45 and -55 dBm for the maximum OOB emission levels of the MBB terminal (P_{OOB}) at the DTTB receiving channel. The ACLR of 55, 65, and 75 dB are respectively required to achieve these OOB emission levels for P_{Tx} = 23 dBm and G_{Tx} = -3 dB.

The adjacent channel interference power seen by the victim DTTB receiver is given by:

$$I_{AC} = P_{e.i.r.p.} - AC \quad + G_{Tot}$$

The total coupling gain between the MBB terminal and the DTTB receiver is given by

$$G_{Tot} = \mathrm{G_{Rx}} - \mathrm{L_{Wall}} - \mathrm{L_{Body}} - L_P$$

where:

G_{Rx} = DTTB receive antenna gain including cable losses;

L_{Wall} = wall loss (= 0 dB); and

L_{Body} = body loss at the MBB terminal.

The total interference power seen by the victim DTTB receiver is given by:

$$I_{Tot} = 10\log\left(10^{\left(\frac{I_{IB}}{10}\right)} + 10^{\left(\frac{I_{AC}}{10}\right)}\right)$$

From the above, I/N is calculated as follows:

$$I/N = I_{Tot} - (10\log(kTB) + NF)$$

Table 4 gives an example of the calculation of separation distance for the case of P_{OOB} = –55 dB, P_{Tx} = –9 dBm and ACS = 80 dB. In case of this large ACS, the value of total interference power mostly depends on In-band interference power.

TABLE 4

Example of the calculation to achieve I/N = -10 dB in P_{OOB} = -55 dBm, P_{Tx} = -9 dB, *ACS* = 80 dB

Noise equivalent bandwidth *B*	**5.6**	**MHz**
Noise figure : NF	7	dB
Thermal noise (290K, 5.6 MHz) : P_N	–106.5	dBm/5.6MHz
Total interference power : I_{Tot}	–109.6	dBm
In-band interference power : I_{IB}	–109.6	dBm
Adjacent channel interference power : I_{AC}	–146.6	dBm
Total coupling gain : G_{Tot}	–54.6	dB
Tx output power : P_{Tx}	–9	dBm
Tx antenna gain : G_{Tx}	–3	dBi
Tx e.i.r.p. : $P_{e.i.r.p}$	–12	dBm
Maximum OOB : P_{OOB}	–55	dBm
Rx adjacent channel selectivity : *ACS*	80	dB
Rx antenna gain : G_{Rx}	2.15	dBi
Wall loss : L_{Wall}	0	dB
Tx Body loss : L_{Body}	4	dB
Propagation loss : L_P	52.8	dB
Frequency : *f*	695	MHz
Separation distance : *d*	15	m
I/N ratio	–10.12	dB

Tables 5, 6 and 7 summarise the calculations of the separation distances necessary to achieve the target I/N value of –10 dB for the three different *ACS* and P_{Tx} assumptions. This I/N value is based on the Recommendation ITU-R BT.1895.

TABLE 5

Minimum separation distance to achieve I/N < -10 dB (Maximum OOB = -35 dBm)

	***ACS* = 40 dB**	***ACS* = 60 dB**	***ACS* = 80 dB**
P_{Tx} = 23 dBm (maximum power)	49 m	44 m	44 m
P_{Tx} = 2 dBm (average power in macro rural scenarios)	44 m	44 m	44 m
P_{Tx} = -9 dBm (average power in macro urban/suburban scenarios)	44 m	44 m	44 m

TABLE 6

Minimum separation distance to achieve I/N < -10 dB (Maximum OOB = -45 dBm)

	ACS **= 40 dB**	***ACS*** **= 60 dB**	***ACS*** **= 80 dB**
P_{Tx} = 23 dBm (maximum power)	49 m	43 m	41 m
P_{Tx} = 2 dBm (average power in macro rural scenarios)	43 m	41 m	41 m
P_{Tx} = -9 dBm (average power in macro urban/suburban scenarios)	41 m	41 m	41 m

TABLE 7

Minimum separation distance to achieve I/N < -10 dB (Maximum OOB = -55 dBm)

	ACS **= 40 dB**	***ACS*** **= 60 dB**	***ACS*** **= 80 dB**
P_{Tx} = 23 dBm (maximum power)	49 m	42 m	17 m
P_{Tx} = 2 dBm (average power in macro rural scenarios)	42 m	17 m	15 m
P_{Tx} = -9 dBm (average power in macro urban/suburban scenarios)	15 m	15 m	15 m

5 Summary

The minimum separation distances between a DTTB System C (ISDB-T) receiver and a mobile broadband (MBB) terminal operated in the same room have been presented. A minimum separation distance of 15 metres is required to achieve I/N of –10 dB, even in instances where the MBB transmitter output power of –9 dBm, the OOB emission level of –55 dBm and the receiver ACS of 80 dB.

Considering the actual usage of a DTTB and a MBB terminal in the same room, this separation distance seems unrealistic. In addition, to achieve the ACS value of 80 dB requires an insertion of external filters to the receivers concerned. Although it has not been considered in this study, additional measures may need to be taken into account for the effect of direct interference from a MBB terminal into a DTTB receiver circuit. The above shows the difficulties of coexistence of both ISDB-T receivers and IMT in the same band in the same geographical area.

ANNEX 8 (TO SECTION II)

Study 8 -- Assessment of interference from IMT into DTTB and sharing criteria outside the GE06 area

1 Technical characteristics

1.1 Description of the digital terrestrial television system

The digital terrestrial television system under study is the System C (ISDB-T) operating in the frequency range between 470 and 698 MHz. The analysis has focused in an intermediate frequency within this range, in particular, 581 MHz, corresponding to channel 32 in some countries, and with a 6 MHz channelling.

1.1.1 General parameters

The system's technical parameters are the ones defined mainly for the ISDB-T system. However, for some parameters this Annex refers to technical and operational characteristics of the System B (DVB-T), similar to those of the ISDB-T. The values of the ITU Recommendations in the reference have also been considered.

Table 1 summarizes the system's general parameters to be taken into account for the sharing studies. The table also shows the reference document from which the adopted value has been taken.

TABLE 1

General characteristics of the DTTB system under study

Parameter/Characteristic	Value
Band	UHF
Central frequency	581 MHz
Channel bandwidth	6 MHz
Noise bandwidth	5,6 MHz
Propagation model	Recommendation ITU-R 1546-4
Minimum field strength	46 dBμV /m

As regards the propagation model adopted, it is deemed necessary to study the effects of the different environments. Thus, the study will include cases of urban and rural deployments.

1.1.2 Parameters for the transmitter

All cases show a single transmitter with high power configuration.

Table 2 details the parameters adopted for the television transmitting station.

TABLE 2

Technical characteristics for DTTB transmitter

Parameter/Characteristic	Value
Configuration	High power
	Single transmitter
Effective radiated power	200 kW
Horizontal radiation pattern	Omnidirectional
Vertical antenna aperture	24λ
Vertical beam tilt	1°
Antenna gain	0 dBd
Mean height of the antenna	300 m
Minimum receiver input voltage (1) Recommendation ITU-R BT. 2036	29.3 dBμV
Coverage radius (for (1))	Urban: 55 km/Rural: 90 km

1.1.2.1 Radiation pattern of the transmitting antenna

All television transmission configurations use an antenna with a radiation pattern in a horizontal plane, of omnidirectional type. As opposed to this, in the vertical radiation pattern, the beam's aperture and inclination depend on the configuration. For a high power transmitter like the one considered in the study, the parameters defining the vertical radiation pattern are the following:

– Aperture: 24λ;

– Beam tilt: 1°.

A null fill of 0.15 and 0.1 (minimum electric field) has been used for the first and second null of the pattern respectively. From the third null on, the fill is of 0.05.

1.1.3 Parameters for the receiver

Fixed rooftop reception with an outdoor antenna, assuming also that this receiver is located at a certain distance from the television transmitting station, so that the useful signal received equals the minimum useful signal level required at its entry (i.e., its sensitivity). In all cases, the radiation pattern of the receiving antenna is oriented towards the transmitting plant, both in terms of azimuth and elevation.

Table 3 and Table 4 detail the parameters adopted for the digital terrestrial television receiver.

TABLE 3

Technical characteristics for DTTB receiver

Parameter/Characteristic	Value
Reception mode	Fixed roof top
Antenna radiation pattern	Recommendation ITU-R BT.419-3
Antenna gain (at 500 MHz)	10 dBd
Polarization discrimination	16 dB
Antenna height above ground level	10 m
Feeder loss	3 dB
Noise bandwidth	5,6 dB
Thermal noise density	–173,98 dBm/Hz
Receiver noise figure	7
Carrier-to-noise relationship (C/N)	22 dB
Interference-to-noise relationship (I/N)	–10 dB

TABLE 4

PR and O_{th} values for a 6 MHz
ISDB-T 64-QAM with code rate 7/8 signal interfered with by a 10 MHz LTE base-station or UE signal in a Gaussian channel environment for all tuners and traffic loadings (see Notes 1 to 4)

Interferer offset N/(MHz)	LTE Base-station		LTE UE	
	PR (dB)	O_{th} (dBm)	PR (dB)	O_{th} (dBm)
Co-channel (AWGN)	20.2	-	20.2	-
Co-channel (LTE)	20	-	19.5	-
1/(9 MHz)	–22.5	–12	–4.2	–20
2/(15 MHz)	–34.9	–10	–9.8	–17.5
4/(27 MHz)	–36.2	–8	–32.5	–16
6/(39 MHz)	–37.2	0	–50.1	–15.5
18/(111 MHz)	–38.9	0	–46.9	–6
19/(117 MHz)	–38.9	0	–45.8	–7

NOTE 1 – PR is applicable unless the interfering signal level is above the corresponding O_{th}. If the interfering signal level is above the corresponding O_{th}, the receiver is interfered with by the interfering signal whatever the signal to interference ratio is.

NOTE 2 – At wanted signal level close to receiver sensitivity, noise should be taken into account, e.g. at sensitivity +3 dB, 3 dB should be added to the PR.

NOTE 3 − Note the UE PR values in N=1 and N=2 are corrected based on the assumption that the ACLR of the interferer is equal to 24.5 dB (N+1), 30.0 dB (N+2). The PR values for all other offsets are based on an ACLR of 88 dB.

NOTE 4 – The LTE base-station interference signals used in the measurements had ACLRs of 60 dB or greater for N-1, and significantly higher ACLRs for N-2 and beyond.

The required I/N value (–10 dB or lower) is essential at the time of assessing, by simulation, whether a television receiver will be interfered or not by an IMT system. Those cases in which the I/N ratio obtained after the simulation is higher than the one required will be regarded as interfered.

1.2 Description of the IMT system

From the set of parameters provided by the IMT specifications, this study considers a channel bandwidth of 10 MHz, operating in the Frequency Division Duplex (FDD) mode for its calculations and simulations.

The general characteristics of the IMT system under study can be found in Table 5.

TABLE 5

General characteristics of the IMT system for uplink and downlink

Parameter/Characteristic	Value
Duplex mode	FDD
Channel bandwidth	10 MHz
Channel central frequency	581 MHz
Propagation model	Extended Hata
Carrier Aggregation	NO
MIMO	NO

Like in the case of DTTB, it is deemed necessary to study the effects of different environments. Thus, the study will include cases of urban and rural deployments.

1.2.1 Specification-related parameters

Table 6 details the specification-related parameters for the base-station, when operating as a transmitter in the downlink. The reception parameters in the uplink are not listed here since the interference into the station is not part of the present analysis.

TABLE 6

Technical characteristics for IMT base-stations

Parameter/Characteristic	Value
Class	Wide Area
Channel bandwidth	10 MHz
Signal bandwidth	9 MHz
Maximum output power at 10 MHz	46 dBm
Spectral Mask	Table 6.6.3.1-3 of 3GPP TS 36.104 V11.2.0 (2012-09) [16](Category A)

Likewise, Table 7 details the specification-related parameters for the mobile station when operating as a transmitter in the uplink. The reception parameters in the downlink are not listed here since the interference into the station is not the subject of this study.

[16] As referenced in Report ITU-R M.2039.

TABLE 7

Technical characteristics for IMT mobile stations

Parameter/Characteristic	Value
Channel bandwidth	10 MHz
Signal bandwidth	9 MHz
Transmitter	
Maximum output power	23 dBm
Power dynamic range	63 dB
Spectral Mask	Table 6.6.2.1.1-1of 3GPP TS 36.101 V11.2.0 (2012-09)[17]

1.2.2 Deployment-related parameters

The deployment-related parameters, necessary to conduct sharing studies, define aspects of the base-stations and the cells' structure such as height and radiation pattern of the antenna, sectorization and dimensions of the cell, among others. For some of them, variation ranges were provided, but at the same time it was suggested to use typical values in order to simplify sharing studies. Table 8 establishes the values that are taken into account for this study. Please note that the deployment environment can be urban or rural.

TABLE 8

Deployment-related parameters for IMT base-stations

Parameter/Characteristic	Value
Cell radius (urban environment)	2 km
Cell radius (rural environment)	8 km
Network layout	19 cells with Wrap Around
Antenna height	30 m
Sectors per site	3
Radiation pattern	Recommendation ITU-R F.1336 *recommends* 3.1
Antenna gain	15 dBi
Downtilt	3°
Feeder loss	3 dB

For the mobile station, the deployment-related parameters are those listed in Table 9.

[17] As referenced in Report ITU-R M.2039.

TABLE 9

Deployment-related parameters for IMT mobile stations

Parameter/ Characteristic	Value
Radiation pattern	Recommendation ITU-R F.1336 *recommends* 3.1
Antenna gain	–3 dBi
User terminal density in active mode (urban environment)	2.16 /5MHz.km^2
User terminal density in active mode (rural environment)	0.17 /5MHz.km^2

1.2.2.1 Radiation pattern for IMT base-station antenna

Recommendation ITU-R F.1336 has been used when performing the sharing studies.

Recommends 3.1 in this Recommendation provides mathematical equations to improve the reference radiation patterns of the sectoral antennas. Also, the parameters agreed are the following:

– ka = 0.7;

– kp = 0.7;

– kh = 0.7;

– kv = 0.3;

– horizontal 3 dB beamwidth: 65;

– antenna gain: 15 dBi;

– downtilt: 3.

The parameters may be applied for both average and peak side lobes; however the equations for them are different, so the resulting patterns differ from one case to the other. In this study, peak side lobes have been taken into account.

2 Analysis

2.1 Methodology

Two interference scenarios are under study. The first one involves determining the interfering signal levels present in a digital television receiver, caused by the group of downlinks of an IMT network, i.e., the transmission from the base-stations to the mobile stations. The second scenario involves determining the interfering signal levels present in a digital television receiver, caused by the group of downlinks of an IMT network, i.e. the transmission into the base-stations.

In both scenarios, the procedure must be carried out considering that both systems operate in an urban or rural environment.

It is assumed that the digital TV receiver is located at such a distance of the DTTB transmitter that the useful signal level at its entry is the minimum necessary so as to guarantee proper reception (i.e., equal to its sensitivity). Said distance turns out to be of approximately 55 kilometres in an urban propagation environment and of approximately 90 kilometres in a rural propagation environment.

The study assumes that the central cell of the IMT network is co-located with this receiver and operates in a co-channel manner with respect to it, i.e., at a central channel frequency of 581 MHz. For this modality, the Monte Carlo simulation method is used to assess the total interfering signal (regarded as the sum of unwanted emissions and blocking signal) present in the television receiver, caused by the transmissions made from the base-stations into the mobile stations.

Thus, and considering that the interference criterion is I/N higher than or equal to –10 dB, it is estimated that the probability of interference, calculated as the quotient between the number of simulated cases in which the interference criterion is satisfied, divided by the total number of simulations.

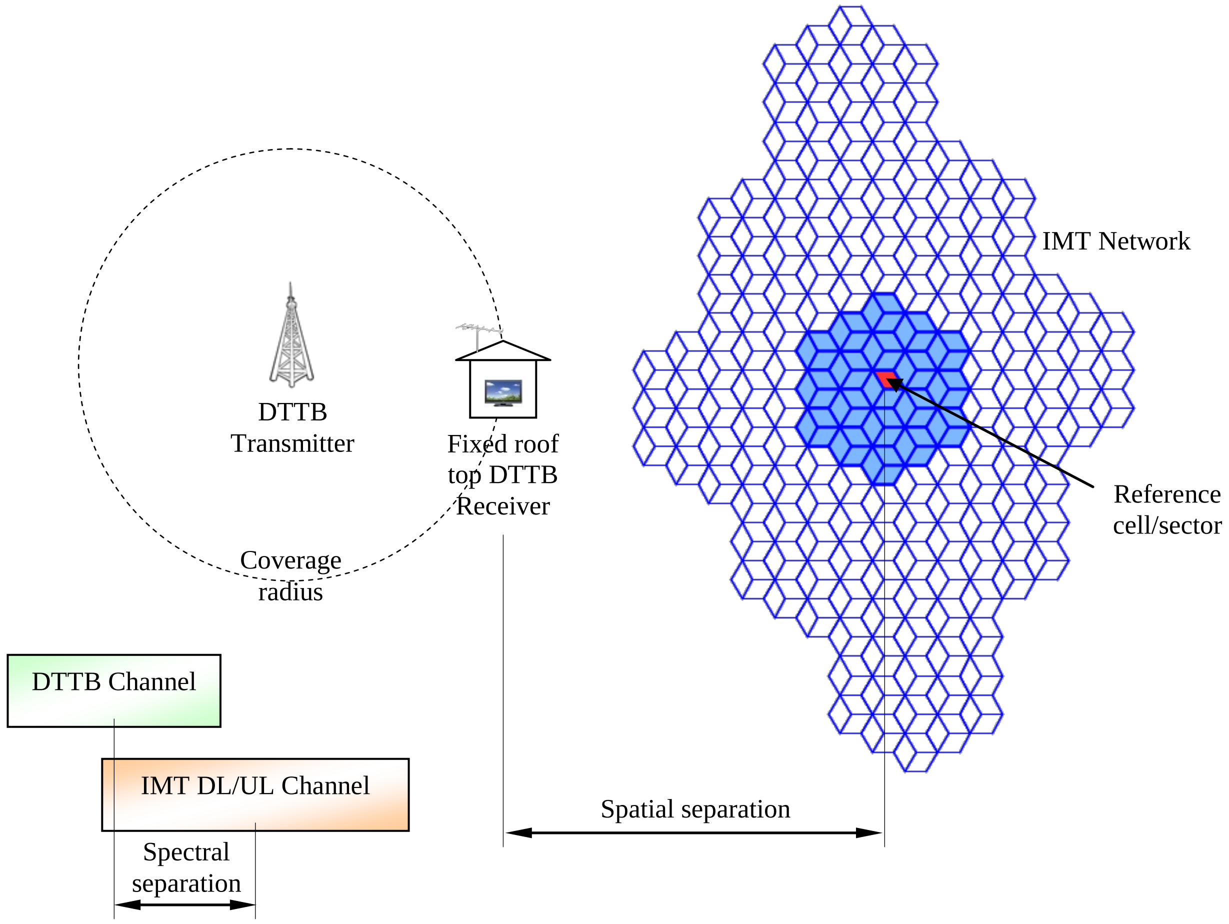
The study is repeated for spatial separations of up to 50 kilometres, in 5 kilometre steps, and frequency separations of up to 18 MHz, in 2 MHz steps.

Within the spatial range of 18 MHz, the presence of a single DTTB channel and a single IMT channel is assumed, ruling out the cumulative interfering effects of various IMT adjacent channels with each other on one or more DTTB channels.

The way in which the systems under study are laid out, both spatially and spectrally, can be seen in Figure 1.

FIGURE 1

Spatial and spectral separation between DTTB system and IMT network



The simulations under the Monte Carlo method are carried out with SEAMCAT software, developed within the frame of the CEPT (European Conference of Postal and Telecommunications Administrations).

The separation criterion is defined as a pair of spatial and spectral separation values for which the probability of interference is equal to or lower than 10%.

2.2 Results

By using the methodology described above, the following results have been obtained for each scenario.

2.2.1 Scenario 1. Interference from IMT downlink into DTTB receiver

2.2.1.1 Urban environment

TABLE 10

Probability of interference values obtained with the simulation method

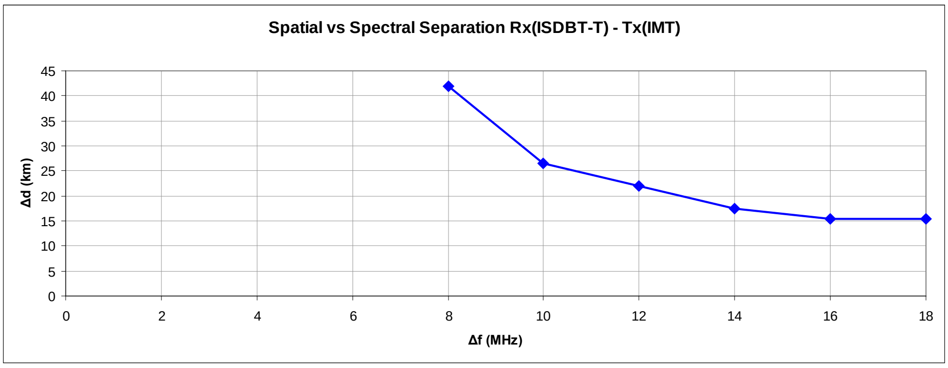
		Δf (MHz) – Frequency separation Rx(ISDB-T) / Tx(IMT)									
		0 (co-channel)	2	4	6	8	10	12	14	16	18
Δd (km) - Spatial separation Rx(ISDB-T) / Tx(IMT)	0	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%
	5	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%
	10	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	98,27%	91,92%	90,99%
	15	100,00%	100,00%	100,00%	100,00%	100,00%	98,32%	70,60%	25,69%	14,89%	14,59%
	20	100,00%	100,00%	100,00%	100,00%	100,00%	56,88%	15,79%	3,17%	1,81%	1,38%
	25	100,00%	100,00%	100,00%	100,00%	98,03%	14,12%	2,84%	0,45%	0,28%	0,32%
	30	100,00%	100,00%	100,00%	100,00%	72,15%	3,17%	0,38%	0,04%	0,06%	0,02%
	35	100,00%	100,00%	100,00%	100,00%	32,27%	0,82%	0,28%	0,00%	0,02%	0,04%
	40	100,00%	100,00%	100,00%	100,00%	10,77%	0,34%	0,00%	0,00%	0,00%	0,00%
	45	100,00%	100,00%	100,00%	100,00%	3,79%	0,06%	0,00%	0,00%	0,00%	0,00%
	50	100,00%	100,00%	100,00%	100,00%	1,57%	0,02%	0,00%	0,00%	0,00%	0,00%

Spatial separation Rx(ISDB-T) - Tx(IMT) (km) for PI ≤ 10% (2)

Δf (MHz)	0	2	4	6	8	10	12	14	16	18
Δd (km)	#N/A	#N/A	#N/A	#N/A	42	26,5	22	17,5	15,5	15,5

FIGURE 2

Spatial and spectral separation curve for PI ≤ 10%



2.2.1.2 Rural environment

TABLE 11

Probability of interference values obtained with the simulation method

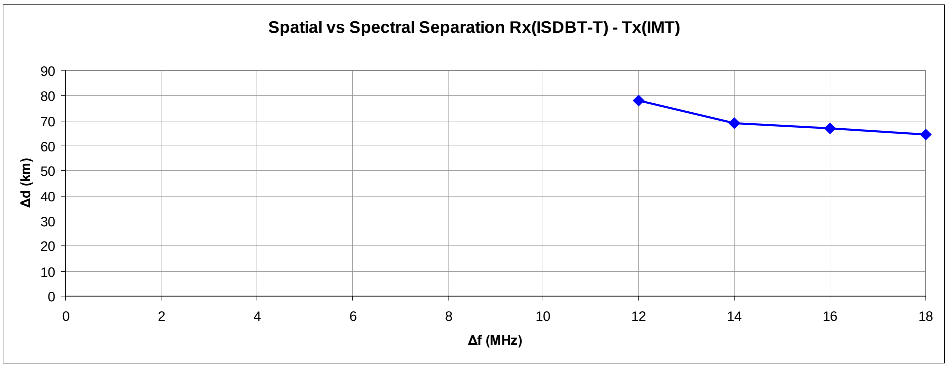
Δd (km) - Spatial separation Rx(ISDB-T) / Tx(IMT)	**Δf (MHz) - Frequency separation Rx(ISDB-T) / Tx(IMT)**									
	0 (co-channel)	2	4	6	8	10	12	14	16	18
0	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%
5	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%
10	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%
15	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%
20	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%
25	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%
30	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%
35	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%
40	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	99,71%	99,61%
45	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	98,49%	92,80%	91,81%
50	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	99,43%	86,35%	69,03%	66,99%

Spatial separation Rx(ISDB-T) - Tx(IMT) (km) for PI ≤ 10%

Δf (MHz)	0	2	4	6	8	10	12	14	16	18
Δd (km)	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	78	69	67	64,5

FIGURE 3

Spatial and spectral separation curve for PI ≤ 10%



Note: In this case, the simulation was extended up to 100 kilometres in order to find the required spatial separation.

2.2.2 Scenario 2. Interference from IMT uplink into DTTB receiver

2.2.2.1 Urban environment

TABLE 12

Probability of interference values obtained with the simulation method

		Δf (MHz) - Frequency separation Rx(ISDB-T) / Rx(IMT)									
		0 (co-channel)	2	4	6	8	10	12	14	16	18
Δd (km) - Spatial separation Rx(ISDB-T) / Tx(IMT)	0	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	70,91%	48,98%	35,71%	28,33%
	5	100,00%	100,00%	100,00%	100,00%	97,87%	84,00%	55,93%	29,03%	26,42%	18,00%
	10	87,50%	85,96%	57,41%	28,57%	12,77%	0,00%	0,00%	0,00%	0,00%	0,00%
	15	13,46%	3,70%	2,17%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
	20	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
	25	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
	30	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
	35	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
	40	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
	45	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
	50	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%

2.2.2.2 Rural environment

TABLE 13

Probability of interference values obtained with the simulation method

Δd (km) - Spatial separation Rx(ISDB-T) / Tx(IMT)	**Δf (MHz) - Frequency separation Rx(ISDB-T) / Rx(IMT)**									
	0 (co-channel)	2	4	6	8	10	12	14	16	18
0	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	79,59%	50,00%
5	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	81,82%	72,00%
10	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	98,00%	90,74%	69,09%
15	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	91,07%	88,00%	72,58%	63,83%
20	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	76,36%	71,15%	33,33%	31,75%
25	100,00%	100,00%	100,00%	100,00%	98,15%	90,00%	58,93%	64,71%	48,08%	29,09%
30	100,00%	100,00%	100,00%	100,00%	90,74%	22,58%	11,29%	5,66%	1,89%	2,00%
35	100,00%	100,00%	100,00%	97,96%	45,83%	5,45%	0,00%	0,00%	0,00%	0,00%
40	100,00%	100,00%	98,31%	81,25%	23,08%	1,96%	0,00%	0,00%	0,00%	0,00%
45	98,44%	98,18%	68,00%	56,86%	7,55%	1,82%	0,00%	0,00%	0,00%	0,00%
50	73,33%	65,00%	43,64%	24,49%	1,82%	0,00%	0,00%	0,00%	0,00%	0,00%

3 Summary

a) The simulations performed show that the interfering signal levels caused by the downlink of the IMT system on the DTTB receiver, and as a consequence of the probability of interference, are greater and require spatial separations up to 4 times as much as those required in the case of the uplink, under equal frequency separation conditions between both systems.

b) Due to the propagation conditions, the interfering signal levels produced by the IMT system on the DTTB receiver in a rural environment are higher and require spatial separations of up to 4 as much as those necessary in an urban environment, under equal frequency separation conditions between both systems.

c) The interfering signal levels caused by the IMT uplinks show greater deviations than in the case of the downlink, due to higher randomness in the position of the mobile stations and their transmitted power. For this reason there were no separation curves in terms of distance versus frequency. However, the values in Tables 12 and 13 are regarded as representative within a variation margin of ±5 kilometres.

d) In an urban environment, simulations for the IMT downlink show that sharing between both systems is only possible for spectral separations equal to or higher than 8 MHz between both systems. For a separation of 8 MHz, a 45 kilometres distance is required between the DTTB receiver and the central cell of the IMT network. For a separation of 18 MHz, a 20 km distance is required between the DTTB receiver and the central cell of the IMT network.

e) The spectral separation of 8 MHz particularly corresponds to the case in which both systems operate in an adjacent way. However, should there be more than one IMT channel and/or more than one DTTB channel in the same simulated spectral range, something usual in real conditions, more interference cases between them are to be expected.

f) In a rural environment, the simulations of the IMT downlink show that the sharing between both systems is only possible for spectral separations equal to or higher than 12 MHz between both systems, and with distances exceeding 50 kilometres.

g) In an urban environment, the simulations of the IMT uplink show that co-channel sharing is possible if a distance equal to or higher than 20 kilometres is guaranteed, and 15 or 10 kilometres if a frequency offset of up to 8 MHz or higher is introduced, respectively.

h) In a rural environment, the simulations of the IMT uplink show that sharing between both systems is only possible for spectral separations equal to or higher than 8 MHz between both systems, with distances that under no circumstances are lower than 30 kilometres.

i) Considering that the IMT downlink causes more limitations, as indicated in the conclusion point 0, the separations indicated in points 0 and 0 are the ones that should be observed for sharing purposes.

Based on the results of the sharing study conducted, the following is recommended:

a) to avoid the co-channel sharing of IMT mobile and terrestrial broadcasting systems operating under the ISDB-T standard, both in urban and rural environments;

b) to avoid the sharing of IMT mobile systems and terrestrial broadcasting systems operating under the ISDB-T standard both in urban and rural environments, with lower separation than those established in the sharing criteria of this document;

c) to apply the methodology proposed herein to assess the new interference scenarios, especially in the case of IMT systems operating with channel bandwidths lower or higher than 10 MHz, and in mixed propagation environments (urban/rural);

d) to apply the methodology proposed herein to assess the interfering cumulative effect of two or more IMT adjacent channels with each other, into one, two or more DTTB adjacent channel with each other.

ANNEX 9 (TO SECTION II)

Study 9 -- Co-channel coexistence study between IMT and DTT in 470-694/698 MHz outside the GE06 area

1 Introduction

This study considers the feasibility of co-channel coexistence between IMT and DTT systems operating in the 470-694/698 MHz band. The study focuses on the impact of interference from IMT into DTT systems. Due to relatively high antenna gains, e.i.r.p. values and fixed antennas positioned above the clutter, the protection of DTT receivers from IMT base-station (BS) interference is assumed to be the key issue to investigate in this context.

This annex provides a description of the system parameters and analysis methodology used in the study, followed by results from the interference analysis and some conclusions. IMT BS transmitter and DTT receiver parameters used in the study were taken from relevant ITU-R documents.

2 Technical characteristics

This section provides an overview of parameter values assumed for the interference analysis.

2.1 DTT parameters

Table 1 summarises the DTT receiver characteristics that have been assumed for the interference modelling in this study.

TABLE 1

DTT receiver parameters

	ATSC	DVB-T	DVB-T2	ISDB-T	Notes
Frequency	650 MHz				
Antenna Gain	9.15 dBi (including 4 dB feeder loss)				Based on 11 dBd gain and 4 dB feeder loss at 650 MHz.
Antenna Height (a.g.l.)	10 m				Fixed rooftop reception.
Antenna Pattern	ITU-R BT.419 Band IV & V				Front-to-back ratio is 16 dB.
Polarization Discrimination[18]	not applicable	3 dB	3 dB	3 dB	
Channel Bandwidth	6 MHz	8 MHz	8 MHz	6 MHz	DVB-T signal bandwidth is 7.6 MHz, DVB-T2 signal bandwidth is 7.77 MHz and ISDB-T & ATSC signal bandwidth is 5.6 MHz
Noise Figure	7 dB	7 dB	6 dB	7 dB	
Noise Floor	−99.5 dBm	−98.2 dBm	−99.1 dBm	-99.5 dBm	kTBNF
Minimum Median Wanted Signal Field Strength	50 dBμV/m (−74.31 dBm @ RX input)	56 dBμV/m (−68.31 dBm @ RX input)	54 dBμV/m (−70.31 dBm @ RX input)	47 dBμV/m (−77.31 dBm @ RX input)	Defined for fixed reception at 10 m for 95% location probability.
Coverage Radius	113.4 km (Assuming DTT TX is at 550 m with 400 kW ERP)	33.1 km (Assuming DTT TX is at 150 m with 5 kW ERP)	35.9 km (Assuming DTT TX is at 150 m with 5 kW ERP)	46.2 km (Assuming DTT TX is at 150 m with 5 kW ERP)	Using “Medium power” reference configurations in 4-5-6-7/393 Annex 2. Path loss is assumed to be Recommendation ITU-R P.1546 for 50%.
Co-channel Protection Ratio	23 dB	18 dB & 21 dB	19 dB & 21 dB	20 dB	C/N+I ratios (see below)

where k = Boltzmann constant = 1.38×10^{-23} (J/K)
T = noise temperature of the receiver (K)
B = bandwidth (Hz)

The above C/N+I protection ratios used in this study are co-channel PR values (for LTE base-station). Additionally, for DVB-T & DVB-T2, the higher value of 21 dB has also been used.

[18] Polarization discrimination has not been taken into account in this study.

2.2 IMT parameters

Table 2 provides the parameter values assumed for the modelling in this study.

TABLE 2

IMT base-station parameters

Parameter	Value	Notes
Channel Bandwidth	10 MHz	
e.i.r.p.	55 dBm	
Antenna Gain	12 dBi (including 3 dB feeder loss)	
Antenna Height (a.g.l.)	30 m	
Antenna Pattern	Recommendation ITU-R F.1336	Horizontal and vertical patterns defined for a 3-sector BS TX.
Antenna Downtilt	3 deg	
Cell Radius	2 km	Typical cell radius for suburban deployment.
Path Location Variability Factor	12.7 dB (normal distribution with 5.5 dB std. dev.)	To account for 95% DTT RX location probability.
Interference Path Loss Model	Recommendation ITU-R P.1546	Propagation percentage time of 1.75% is used for each IMT BS interference path.

3 Analysis

In this section, a brief description of the interference analysis method is given. This is followed by the analysis results.

3.1 Methodology

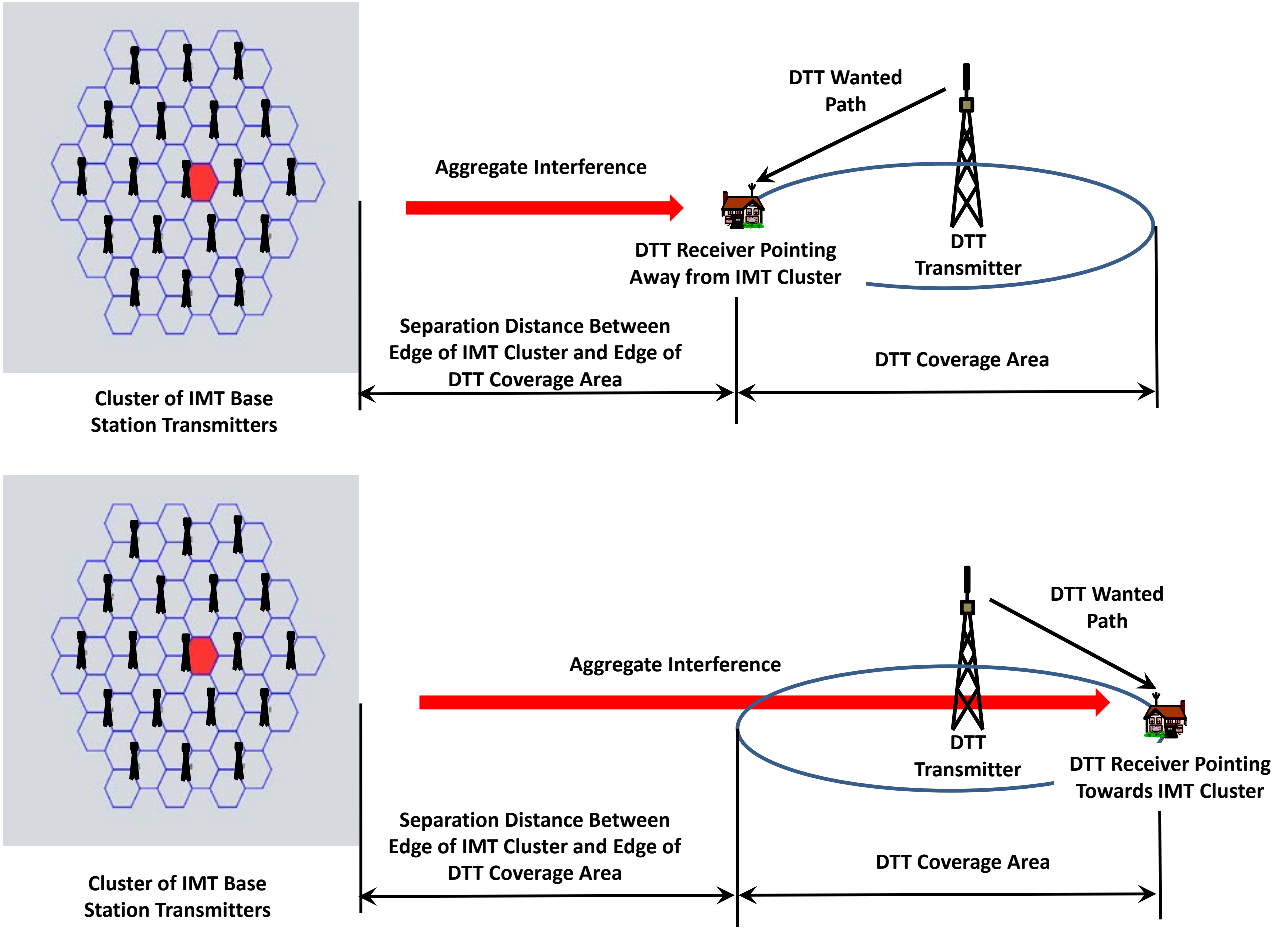
The aim of the interference analysis was to assess the impact of interference from IMT base-station transmitters into DTT receivers. Deterministic analysis was performed to calculate worst-case separation distances between an example IMT network and a DTT coverage area. The CEPT's SEAMCAT tool was used in order to calculate aggregate interference levels from the IMT network, using SEAMCAT's built-in IMT BS site cluster (part of the OFDMA module), and noise was then added to that. Note that SEAMCAT was used as a means to calculate signal levels in minimum coupling loss (MCL) analysis, rather than as a statistical Monte Carlo analysis tool. The aggregate interference was calculated by means of a power sum.

A total of 19 cell sites each with three sectors were placed at a given distance from the DTT coverage area, with one of the antennas at each site pointing directly towards the DTT coverage area. The path loss on the wanted DTT path was calculated using SEAMCAT's built-in Recommendation ITU-R P.1546 propagation model by setting the path loss percentage time to 50%. Path losses on interference paths were also calculated using Recommendation ITU-R P.1546 by setting the path loss percentage time to 1.75%. A path loss factor of 12.7 dB was introduced to accommodate for the location variability in the pixel where the DTT receiver was assumed to be located.

In the MCL analysis, the DTT receiver was assumed to be located at the edge of the DTT coverage area. The distance between the DTT receiver and the IMT BS transmitter cluster was then varied until the protection ratio was satisfied. Two scenarios were examined. The first scenario assumed that the DTT receiver was pointing away from the IMT BS cluster and the second scenario assumed that the DTT receiver was pointing towards the IMT BS cluster. These scenarios are illustrated in Figure 1 below.

FIGURE 1

Edge of coverage interference scenarios



3.2 Results without mitigation

Table 3 provides the separation distances calculated for each DTT technology, corresponding to MCL scenarios where the DTT receiver is assumed to be located at the edge of the DTT coverage area pointing towards / away from the IMT cluster as shown in Figure 1.

TABLE 3

Separation distance analysis results (no mitigation)

DTT Technology	Required separation (km) between the edge of the IMT BS cluster and the edge of the DTT coverage area	
	DTT receiver pointing away from IMT BS cluster (scenario 1)	DTT receiver pointing towards IMT BS cluster[19] (scenario 2)
ATSC	72 km	Not relevant
DVB-T (18 dB PR)	30 km	Not relevant
DVB-T (21 dB PR)	37 km	Not relevant
DVB-T2 (19 dB PR)	37 km	Not relevant
DVB-T2 (21 dB PR)	43 km	Not relevant
ISDB-T	72 km	Not relevant

The results indicate that the worst-case separation from the edge of the DTT coverage area to the edge of the IMT cluster is dominated by the scenario where the DTT receiver is at the edge of the TV coverage area closest to the IMT network and pointing away from the IMT network towards the DTT receiver. The worst-case separation varies according to the DTT technology, between 30 kilometres and 72 kilometres for the DTT technologies considered in the modelling (30-43 kilometres for DVB-T/T2 and 72 kilometres for ATSC and ISDB-T).

3.3 Effect of mitigation

This section examines the implications of one possible mitigation measure, namely pointing IMT BS transmitter antennas away from the victim DTT receiver. This is just one example of a number of possible mitigation techniques that may potentially be used (including also antenna downtilt, transmit powers and antenna heights), as part of the network planning process. Pointing of mobile antennas away from a DTT coverage area is a standard practice that is widely used in such scenarios.

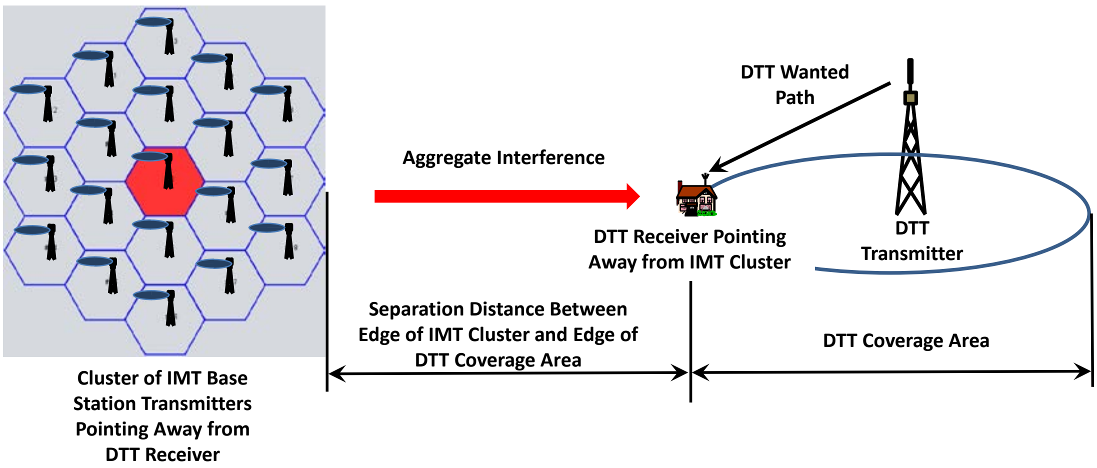
3.3.1 IMT base-station transmitter antenna pointing

The first (worst-case) scenario where it was assumed that the DTT receiver located at the edge of DTT coverage area was pointing away from the IMT BS cluster was modified so that each IMT BS transmitter is pointing away from the DTT receiver. The e.i.r.p. of the IMT base-stations was increased by 3 dB. It is worth noting that the IMT BS transmitter antenna front to back ratio is approximately 15 dB in the horizontal plane.

[19] These separation distances were found to be lower than the sum of the corresponding separation distance for scenario 1 plus the DTT cell diameter.

FIGURE 2

IMT BS transmitter antenna pointing for interference mitigation



In Table 4, calculated separation distances for this scenario with and without the IMT BS transmitter antenna pointing mitigation are compared.

TABLE 4

Comparison of separation distances with and without IMT BS antenna pointing mitigation

DTT Technology	Required separation (km) between the edge of the IMT BS cluster and the edge of the DTT coverage area	
	No mitigation	With mitigation
ATSC	o	33 km
DVB-T (18 dB PR)	30 km	14 km
DVB-T (21 dB PR)	37 km	17 km
DVB-T2 (19 dB PR)	37 km	17 km
DVB-T (21 dB PR)	43 km	20 km
ISDB-T	72 km	33 km

Under this scenario, with antennas pointing away from the DTT coverage area, the separation distances are reduced to 14-20 kilometres for DVB-T/T2 and 33 kilometres for ATSC and ISDB-T.

4 Summary

This study calculated aggregate interference from a cluster of 19 IMT base-station sites into DTT receivers for ATSC, DVB-T, DVB-T2 and ISDB-T technologies. Initial deterministic calculations with IMT base-station antennas directed towards the DTTB coverage area indicated that separation distances between the edge of the DTT coverage area and the IMT network ranged from 30-43 kilometres (for DVB-T/T2) to 72 kilometres (for ATSC and ISDB-T).

Further analysis was then conducted to examine the potential impact of one possible mitigation technique which may be considered as standard practice when planning IMT networks close to borders. It was calculated that the separation distances were reduced to 14-20 kilometres (for DVB-T/T2) and 33 kilometres (for ATSC and ISDB-T) when it was assumed that the IMT base-station antennas were pointing away from the DTT coverage area.

ANNEX 10 (TO SECTION II)

List of Acronyms

3GPP	3rd Generation Partnership Project
ACLR	Adjacent Channel Leakage Ratio
ACS	Adjacent Channel Selectivity
ATSC	Advanced Television Standards Committee
CEPT	European Conference of Postal and Telecommunications Administrations
C/N	Carrier-to-Noise Ratio
dBd	Antenna gain in dB relative to a dipole antenna
dBi	Antenna gain in dB relative to an isotropic antenna
DTTB	Digital Terrestrial Television Broadcasting
DTT	Digital Terrestrial Television
DTV	Digital Television
DVB-T	Digital Video Broadcasting - Terrestrial
DVB-T2	2nd Generation Digital Video Broadcasting - Terrestrial
e.i.r.p.	Equivalent Isotropically Radiated Power
e.r.p.	Effective Radiated Power
FCC	Federal Communications Commission
FDD	Frequency Division Duplex
FDR	Frequency Dependent Rejection
GE06	Geneva 2006 Agreement
HAAT	Antenna Height Above Average Terrain
IEEE	Institute of Electrical and Electronics Engineers
IMT	International Mobile Telecommunications
I/N	Interference-to-Noise Ratio
ISDB-T	Integrated Services Digital Broadcasting - Terrestrial
LTE	Long Term Evolution
MBB	Mobile Broadband
MCL	Minimum Coupling Loss
MIMO	Multiple Input Multiple Output
OOB	Out-of-Band
PR	Protection ratio
SEAMCAT	Spectrum Engineering Advanced Monte Carlo Tool
UE	User Equipment
UHF	Ultra High Frequency