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Annex 22 to Joint Task Group 4-5-6-7 Chairman's Report

PRELIMINARY DRAFT NEW ITU-R REPORT ON SHARING AND COMPATIBILITY STUDIES UNDER AGENDA ITEM 1.2

Summary

[tbd]

1 Introduction

2 Adjacent-channel compatibility studies

Laboratory and field trial of wireless broadband access system prototype in the frequency band 694-790 MHz indicate the presence of interference caused by relatively high levels of in-band emissions from located nearby wideband access base stations and user equipment (UE), falling within TV receiver tuning range. Any unwanted high-power signal within tuning range [confuse] receiver input circuits, reducing the ability to demodulate less powerful useful signals from broadcasting stations, with almost no respect to given frequency separation. 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)[1] .

This effect can be described as limited adjacent channel selectivity (ACS) of a broadcasting receiver to any unwanted signal within its tuning range, 470-862 MHz in the UHF range. The number of locations within a conventional broadcast network coverage area, where the useful signal level is relatively low, is significant.

Limited ACS of broadcasting receiver to any unwanted signal within its tuning range is to be taken into account. Studies to be performed for both cases - when no mitigation is applied, and when mitigation applied in all necessary cases with indication of number of such cases.

[1] This kind of interference occurs from all types of unwanted signals – ATV, other DTV, wideband access mobile or fixed systems, etc. In terrestrial TV networks this problem at the receiver side also may occur in some places - but very seldom, due to normally uniform topology of TV transmission networks at all channels within UHF range and the fact that useful signal itself in most cases taken from broadcast station with strongest signal levels in the area.

2.1 Interference from and to mobile service base stations

2.1.1 Mobile service as an interferer: interference from mobile service base stations into broadcasting service reception

2.1.1.1 Scenarios

2.1.1.2 Methods of calculation with formulas

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

– first, the field strength threshold of an IMT base station is calculated using I/N criteria. Then, a single base station is evaluated and the required separation distance to meet this value is calculated. Then a network of IMT consisting of several base stations is constructed and the cumulative effect is evaluated. Finally, the required separation distance by considering cumulative effect is calculated. The above steps are further described in detail in the following sections.

2.1.1.3 Calculations

Field strength threshold of an IMT base station at different frequency offsets

In order to calculate the field strength threshold of IMT base station at different frequency offsets, the *I/N* criterion [as prescribed by Working Party 6A (WP 6A)] (*I/N*= -10 dB) is used. The methodology is [fully in line with WP 6A advice and is] similar to what proposed in Report ITU-R BT.2265 (Annex 1).

Then, using protection ratios at different frequency offsets [as presented by WP 6A] and assuming $f_{(MHz)}$ = 690 MHz[2], median effective interfering field strength threshold for a reception location probability of 95% (E_{INT}) will be derived as shown in Table 1 below.

[2] 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 frequency bands. Results at other frequencies would be much similar and just slightly change.

TABLE 1

Interferer offset N/(MHz)	**PR (dB)**	**EINT (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

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

Case of several base stations

Now, a network consisting of several IMT base stations is constructed at the two sides of the above base station and also behind it. All base stations have nominal characteristics [submitted by WP 5D]. The area is assumed as urban and the cell size is 1 kilometre.

Now the field strengths from each base station in the extended IMT network is calculated [according to the guidelines given by WP 3K in Document 3K/69 (i.e. 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 the cumulative effect) would be equal to threshold value are presented in Table 3.

2.1.1.4 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

2.1.1.5 Experience of the interference from 800 MHz IMT base stations into fixed DTTB reception in France

Appendix 8 contains a description on the experience of the initial deployment of the mobile service (MS) in France dealing with the impact of interference from MS base stations into the digital terrestrial television broadcasting (DTTB) reception in adjacent band.

2.2 Interference from and to mobile service user equipment

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

The studies have the objective to study the interrelation between the following four parameters:

1 The UE maximum transmit power.

2 The minimum width of guard band above 694 MHz.

3 The target ACS of the DTTB receiver for the frequencies above the guard band.

4 The out of band emission limits of the UE below 694 MHz.

2.2.1.1 Scenario 1: Minimum coupling loss study

Minimum coupling loss (MCL) is a generic term used to describe deterministic methods to calculate, for a specified level of interference:

– the Out of Band (OOB) limits for an LTE UE, and

– the DTTB receiver ACS.

2.2.1.1.1 Description

The MCL approach uses deterministic calculations to analyse the maximum level of interference from an IMT UE into a DTTB receiver, under a particular set of conditions. Typically, the scenario modelled in a MCL type analysis assumes a number of conditions and events occur at the same time.

2.2.1.1.2 Methods of calculation with formulas

The basic MCL method is based upon the following key elements:

– use of a reference geometry in order to identify the critical case for interference from an handheld LTE terminal into a DTTB receiving antenna, normally located at the edge of the DTTB coverage area;

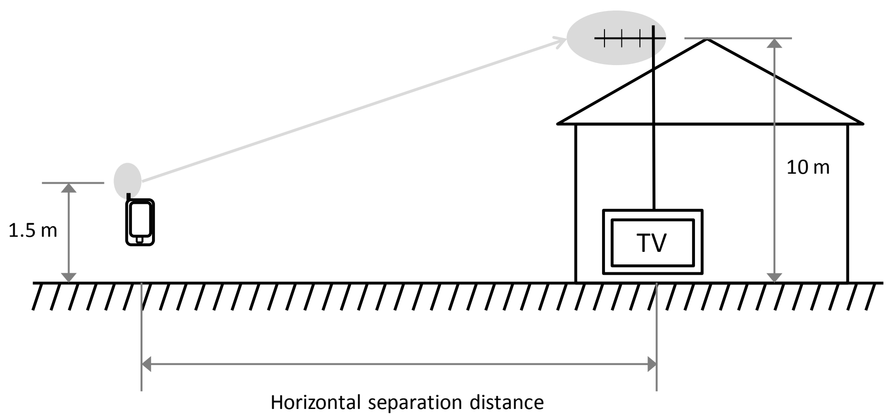
– the ACS of DTT receivers; and

– the use of free space propagation model to determine the maximum allowed OOB emissions from the LTE UE for a certain guard band between the LTE downlink and the broadcasting service.

For fixed DTTB reception the reference geometry consists of a fixed rooftop receiving antenna at a 10 meter height, interfered by a LTE UE at 1.5 meters above ground. The situation is illustrated in Figure 1:

FIGURE 1

Reference geometry for fixed rooftop reception



The reference geometry is used to determine the horizontal separation distance between the rooftop antenna and the LTE terminal, resulting in the highest interference levels into the DTT antenna. When determining this critical distance the following parameters are taken into account:

– the antenna gain and horizontal discrimination of the rooftop antenna in using Recommendation ITU-R BT.419-3;

– propagation loss between the two antennas, normally applying the free space loss model (Recommendation ITU-R P.525-2).

The resulting critical distance is found to be around 22 meters.

In order to determine ACS there is a need to determine the protection ratio (PR) applicable for a given guard band between the two services. For example the PR for a DTTB receiver at 690 MHz (channel 48) and an IMT UE operating in a 10 MHz Bandwidth using the APT band plan (centred at 708 MHz). When deriving ACS values from protection ratios, it becomes clear that additional filtering of the DTTB receiver will be needed and an external filter is usually assumed based on the experience of operating DTTB receivers in proximity to LTE-800 services. The calculations of MCL assume a realistic external filter before the DTTB receiver, which will improve the PR and provide an acceptable ACS value.

Before the required OOB for the IMT UE terminal can determined, there is a need to make an assumption about the allowed loss of receiver noise performance. In Recommendation ITU-R BT.1895 the value of -10dB I/N is recommended. However, in some cases an I/N threshold of –6 dB (corresponding to a desensitization of the DTT receiver of 1 dB) may be considered to provide adequate protection.

Also, in practice, IMT UE will not usually operate at maximum power. The actual transmit power of an IMT UE is influenced by a number of factors including its location in relation to its serving cell, whether it is indoors or outdoors, the specifics of the scheduler and power control algorithms employed, the data-rate demanded, etc. [Document 4-5-6-7/49 provides] time averaged IMT UE transmit powers for two example scenarios: 2 dBm for a macro rural scenario; and –9 dBm for a for macro urban/suburban scenario.

Table 4 below provides for the two examples at 2 dBm and –9 dBm the corresponding maximum OOB emission level calculated to protect fixed rooftop DTT reception for I/N thresholds of –6 dB and –10 dB. Table 4 also provides the values for an IMT UE terminal operating at maximum power; 23 dBm. For these calculations a DTT receiver ACS of 79.25 dB has been assumed together with an 18 MHz frequency offset between the centres of the 8 MHz TV channel and the 10 MHz LTE channel.

TABLE 4

OOB emission levels to meet I/N thresholds of–6 and –10 dB

I/N Threshold (dB)	**OOB emission level (dBm/(8MHz)**		
	UE 23 dBm **Maximum power**	**UE 2 dBm** **Average power rural macro scenario**	**UE –9 dBm** **Average power urban/suburban macro scenario**
–6	–50.20	–49.24	–49.24
–10	–56.25	–53.25	–53.24

Based upon these simple input data it is then possible to calculate the maximum allowed OOB of the LTE terminal. This typically yields values below –50 dBm / 8MHz

2.2.1.1.3 DTT receiver adjacent channel selectivity

The ACS of the DTT receiver, for a particular frequency offset Δf, can be calculated from PR and adjacent channel leakage ratio (ACLR) values as follows:

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

The ACS values for DVB-T and DVB-T2 have been calculated as reported in the Table below.

TABLE 5

Unfiltered ACS values for DVB-T and DVB-T2 receivers

Interferer offset N/(MHz)	**Unfiltered ACS (dB)**	
	DVB-T	DVB-T2
1/(10 MHz)	30.6	36.7
2/(18 MHz)	34.0	42.4
3/(26 MHz)	40.9	46.8
4/(34 MHz)	47.0	56.5
5/(42 MHz)	47.6	57.5
6/(50 MHz)	52.7	59.1
7/(58 MHz)	46.8	61.5
8/(66 MHz)	53.5	61.6
9/(74 MHz)	51.2	62.6

The unfiltered ACS values in the Table above combined with an assumed DTT filter performance of 34 dB for frequency offsets of 18 MHz or greater and 7.5 dB for a frequency offset of 10 MHz gives the filtered ACS values in the following Table:

TABLE 6

Filtered ACS values for DVB-T and DVB-T2 receivers

Interferer offset N/(MHz)	**Filtered ACS (dB)**	
	DVB-T	DVB-T2
1/(10 MHz)	38.1	44.2
2/(18 MHz)	68.0	76.4
3/(26 MHz)	74.9	80.8
4/(34 MHz)	81.0	90.5
5/(42 MHz)	81.6	91.5
6/(50 MHz)	86.7	93.1
7/(58 MHz)	80.8	95.5
8/(66 MHz)	87.5	95.6
9/(74 MHz)	85.2	96.6

For DVB-T receivers, ACS performance is, in general poorer, than for DVB-T2 at the same frequency offset.

2.2.1.1.4 Results from MCL analysis

Rather that calculate the separation distance needed to meet the –10 dB I/N interference threshold, the same approach to calculate the UE OOB emissions into the DTT channel for any given separation distance can be used. A horizontal separation distance of 22 metres has been used since this provides the worst case geometry.

Results are only provided below for a frequency offset of 18 MHz as it is evident that for the 10 MHz frequency offset the calculated adjacent channel interference ratio (ACIR) is dominated by the DTT receiver ACS value, hence an improvement in UE ACLR will have no material effect. In fact even at a frequency offset of 18 MHz, a minimum separation distance of 22 metres cannot be achieved by improving UE ACLR alone. Therefore the UE OOB emission level necessary has been calculated to meet the –10 dB I/N interference threshold assuming the ACLR and ACS contribute equally to ACIR.

The Table below provides the results of this calculation where the UE is transmitting at maximum power (23 dBm).

TABLE 7

UE OOB emissions – rooftop reception – with additional filtering

Parameter	Value	Unit	Comment
Frequency offset	10	MHz	
Tx height	1.5	metres	h_{Tx}
Rx height	10.0	metres	h_{Rx}
Rx noise figure	7	dB	NF
Thermal noise (7.6 MHz)	–98.17	dBm	P_N = 10log(kTB) + NF
Protection criterion	–10	dB	I/N
Target interference power	**–108.17**	**dBm**	**$P_I = P_N + I/N$**
ACS	79.25	dB	With additional filtering
ACLR	79.25	dB	
ACIR	**76.24**	**dB**	$ACIR^{-1} = ACLR^{-1} + ACS^{-1}$
Tx Transmit power	23	dBm	P_{Tx}
Rx antenna bore-sight gain	9.15	dBi	G_{Rx}
Rx antenna discrimination gain	–0.45	dB	G_{Dir}
Tx antenna gain	–3	dB	G_{Tx}
Body loss	4	dB	L_{Body}
Required propagation loss	**56.63**	**dB**	**L_{Prop}**
Horizontal separation distance	**22.00**	**metres**	**At 690 MHz**
UE OOB	**–56.25**	**dBm/8MHz**	**OOB = Tx Power - ACLR**

This result demonstrates that to meet the -10 dB I/N interference threshold for the worst case geometry when UE are transmitting at full power, both of the following are necessary:

– additional filtering at the DTT receiver; and

– improved UE OOB emissions.

The extent of the necessary additional DTT filtering is of the order of 45 dB in the case of DVB-T and 37 dB in the case of DVB-T2.

It is clear from these results that the –26.2 dBm/6MHz spurious emission limit currently included in 3GPP 36.101 for band 28 across the frequency range 662-694 MHz is not adequate to achieve compatibility with DTT.

In practice UE will rarely operate at maximum power. The actual transmit power of a UE is influenced by a number of factors including its location in relation to its serving cell, whether it is indoors or outdoors, the specifics of the scheduler and power control algorithms employed, the data-rate demanded, etc.

It should be noted that Recommendation ITU-R BT.1895 recommends the use of an I/N threshold of –10 dB as a guideline above which compatibility studies on the effect of radiations and emissions from other co-primary applications and services into the broadcasting service should be undertaken. Hence, the use of an I/N threshold of –10 dB to set the maximum OOB emission level of UE guarantees compatibility (according to Recommendation ITU-R BT.1895). However, in many cases an I/N threshold of –6 dB (corresponding to a desensitization of the DTT receiver of 1 dB) may be considered to provide adequate protection. It is also interesting to see the impact on the results for the case of an I/N threshold of 0 dB corresponding to a desensitization of the DTT receiver of 3 dB).

The Table below provides the maximum OOB emission level calculated to protect fixed rooftop DTT reception for UE transmit powers of 23 dBm, 2 dBm and –9 dBm and for I/N thresholds of 0 dB, –6 dB and –10 dB. For these calculations we have assumed a DTT receiver ACS of 79.25 dB. All results assume an 18 MHz frequency offset.

TABLE 8

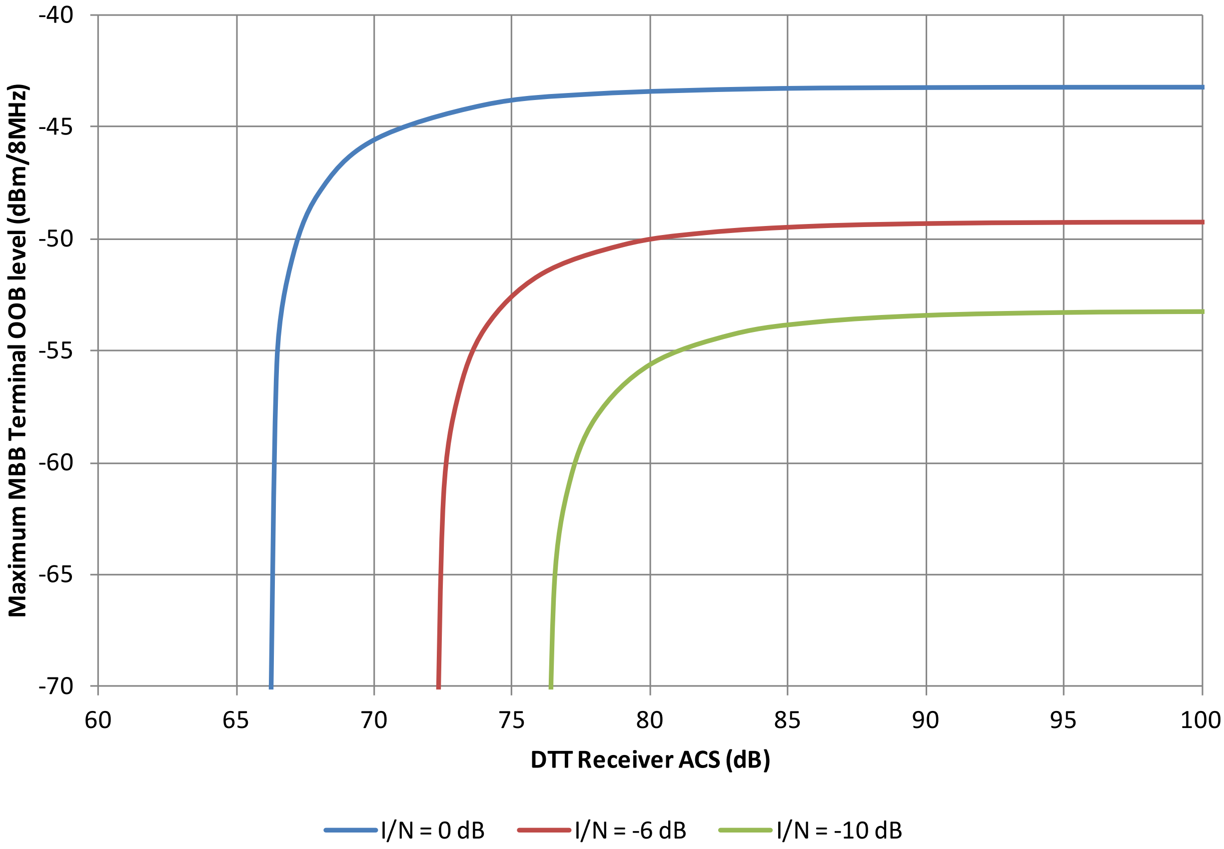
OOB emission levels to meet I/N thresholds of 0, –6 and –10 dB

I/N Threshold (dB)	OOB emission level (dBm/(8MHz)		
	UE 23 dBm Maximum power	UE 2 dBm Average power rural macro scenario	UE –9 dBm Average power urban/suburban macro scenario
0	–43.46	–43.24	–43.24
–6	–50.20	–49.24	–49.24
–10	–56.25	–53.25	–53.24

The sensitivity of the calculated maximum OOB emission level necessary to protect rooftop DTT reception (at the worst case separation distance of 22 metres) to variation in the assumed DTT receiver ACS is explored in the following Figure. For this sensitivity analysis it is assumed that the UE is transmitting at maximum power (23 dBm).

FIGURE 2

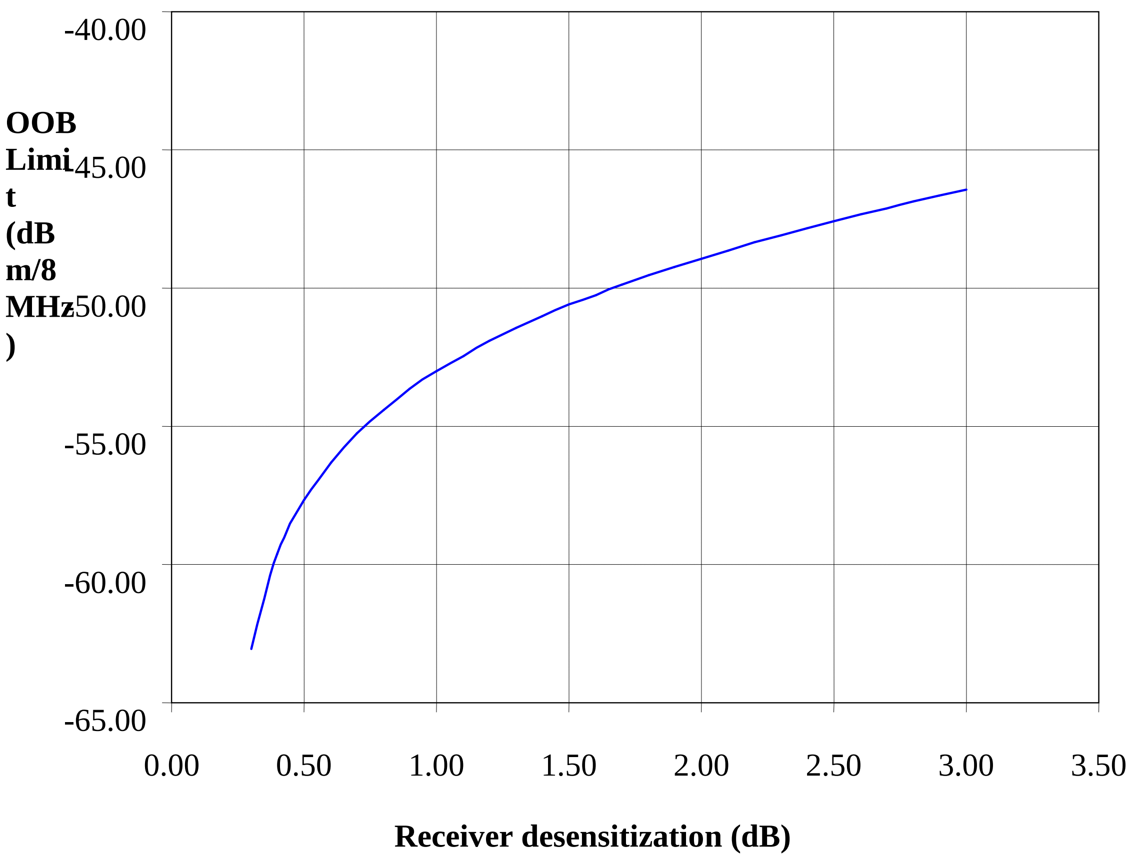
Sensitivity of maximum OOB emission level to assumed DTT receiver ACS



The UE OOB limit is a function of the permitted degradation in sensitivity for a given receiver ACS value. Assuming a receiver ACS of 79 dB, the permitted level of UE OOB is given by the graph below:

FIGURE 3

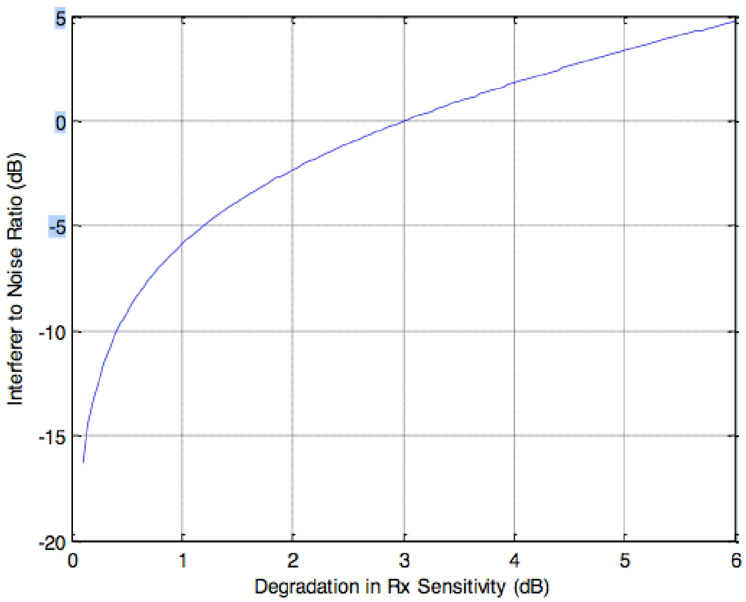
UE OOB limit as a function of receiver desensitization



The relationship between receiver desensitization and I/N is given below:

FIGURE 4

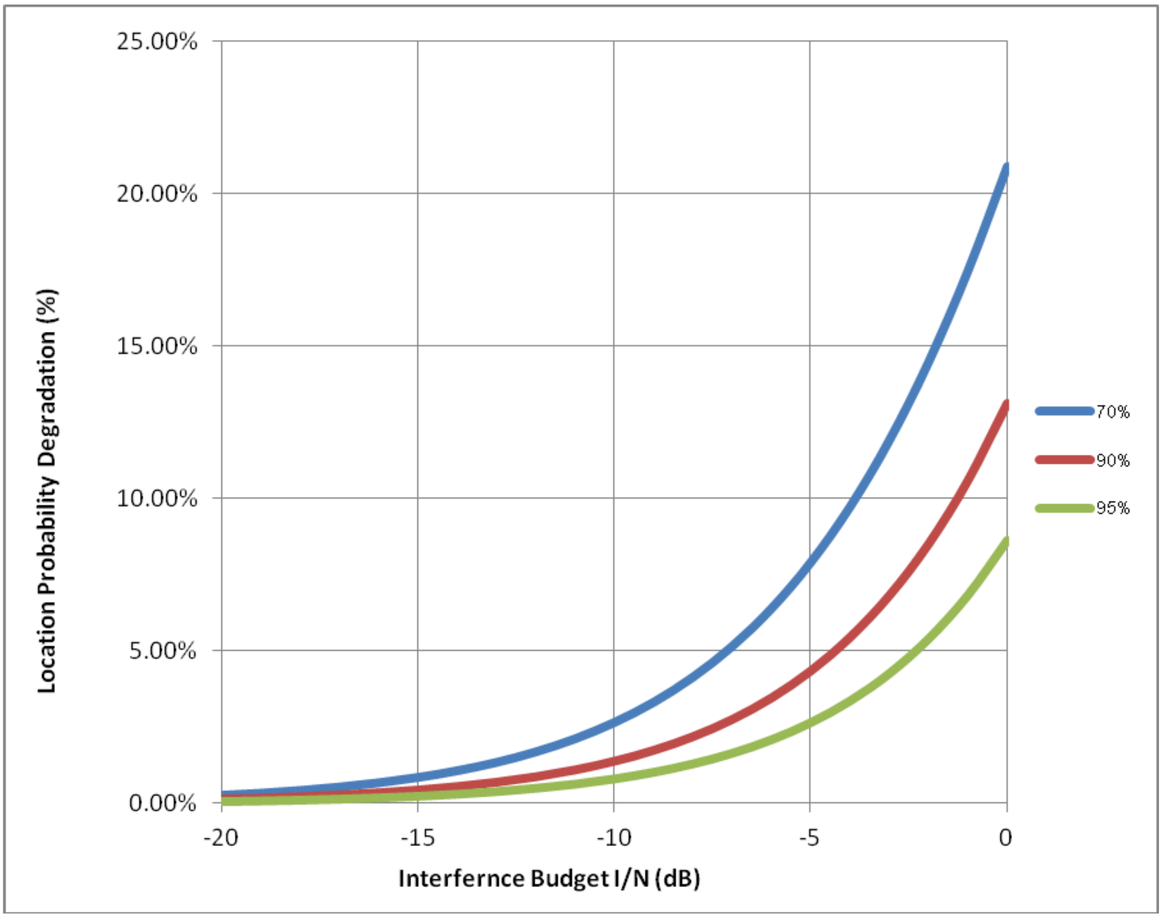
Calculation of I/N for a given desensitization



A given I/N budget will result in a degradation in the broadcast coverage, characterised by a reduction in the location probability. This can be calculated using numerical methods or analytical approximations and is given by the following graph:

FIGURE 5

Degradation in location probability vs I/N for a given location probability at the broadcast cell coverage edge



Note the degradation in broadcast coverage is a function of the standard deviation of the path loss in the propagation model used to predict the interference from the LTE-UE device. For the graph in Figure 5, the standard deviation is set to zero to facilitate calculations.

Measurements of recently manufactured DTTB receivers, with additional external filtering, and when the interference was generated from an LTE source with suitable filtering to reduce its out-of-band emissions, support the assumptions made in this study that working ACS values of around 80 dB are achievable.

The MCL study indicates that, due to the limited ACS of broadcasting receiver to any unwanted signal within its tuning range, the compatibility of new mobile service in 694-790 MHz band and broadcasting service in 470-694 MHz band may not be provided without mitigation techniques application.

With the known distribution field strength at receiving locations it is easy to estimate the number of people that will be subject to interference if the protection criteria are not met.

2.2.1.2 Scenario 2: Monte Carlo study

In general a Monte Carlo analysis employs statistical modelling and therefore provides an approach to model the behaviour of UE in order to simulate an IMT network and provide an indication of the level of interference that would be experienced by DTTB receivers in practice.

2.2.1.3 Scenario 2a: Monte Carlo studies

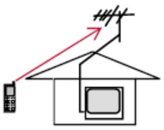
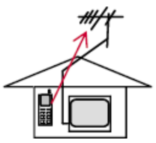
2.2.1.3.1 Description

The Monte Carlo modelling described here is the widely used form of Monte Carlo modelling as implemented for example in the SEAMCAT tool. The modelling has been applied to calculating the probability that a DTT receiver will be affected by interference from IMT.

The interference scenarios between broadcasting and mobile (IMT) services considered in this compatibility study are summarized in Table 9 below.

TABLE 9

Interference Scenarios

Scenario	UE (Interferer) Location	Digital television receiver (Victim) antenna location
	Outdoor	Fixed reception/Outdoor rooftop
	Indoor	Fixed reception/Outdoor rooftop

Two simulation scenarios are provided, both of them described in Annex 1:

– In the first scenario, a pixel of 100 m x 100 m is placed at DTT coverage edge. At each simulation run (event), a DTT receiver is randomly positioned within this pixel following a uniform distribution. For each generated DTT receiver point in the pixel, an IMT network cluster of 7 tri-sector sites (21 cells) is created around it. At simulation run (event), the relative position between the victim DTT receiver and the reference IMT base station (base station at the centre of the cluster) is randomly generated. The maximum distance between the DTT receiver and the IMT cluster is always equal to IMT cell range. (See Figure 6).

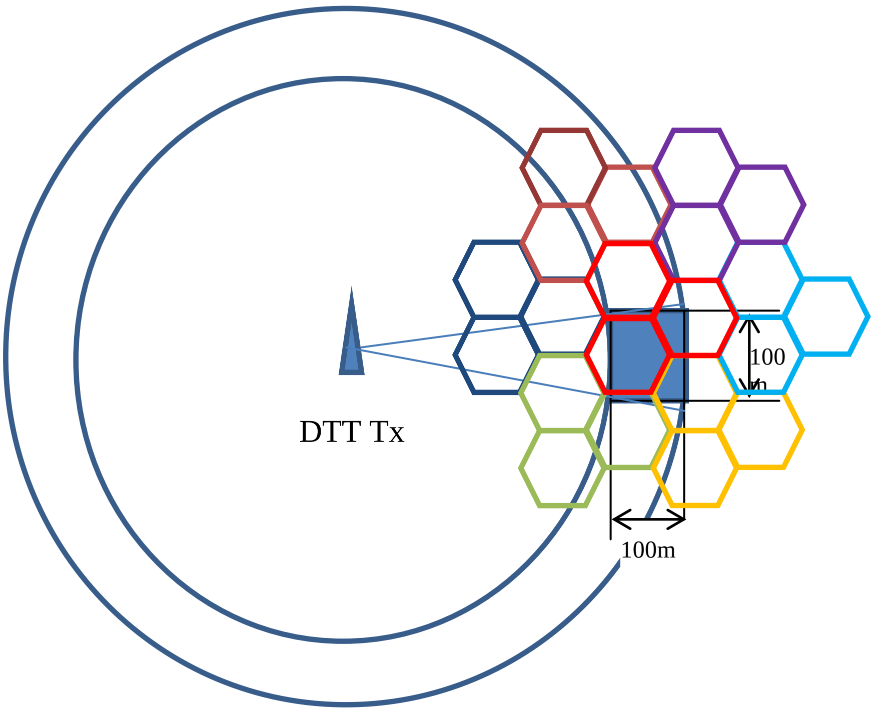
– In the second scenario, the DTT receiver is located randomly, following a uniform distribution, within the whole DTT coverage area. (See Figure 7).

The majority of the modelling that has been conducted has assumed that the DTT receivers are all located at the edge of TV coverage from an isolated TV transmitter, as in the first scenario above. In practice, most DTT receivers will be located further inside a TV coverage area/cell rather than at the extreme coverage edge, and/or TV cells will be overlapping with DTT receivers within the coverage area of more than one DTT transmitter. For the majority of DTT receivers there will therefore be a significant margin between the (median) level of received TV signal at a DTT receiver, and the level when it is assumed in the modelling that DTT receivers are at the edge of the TV coverage area.

Interference probability results will be significantly lower for scenarios where there is adjacent or overlapping coverage from different TV transmitters, and where the DTT receivers are located across the TV coverage area as a whole as in the second scenario above, rather than all at the edge of TV coverage. There will also in practice be local fluctuations in received TV signal levels, which will cause errors for DTT receivers at the edge of TV coverage, regardless of whether or not there is any potential interference from IMT.

FIGURE 6

Edge of DTT coverage simulation scenario



[*Ed. note: Proportions should be correct. Figure indicates hexagons.*]

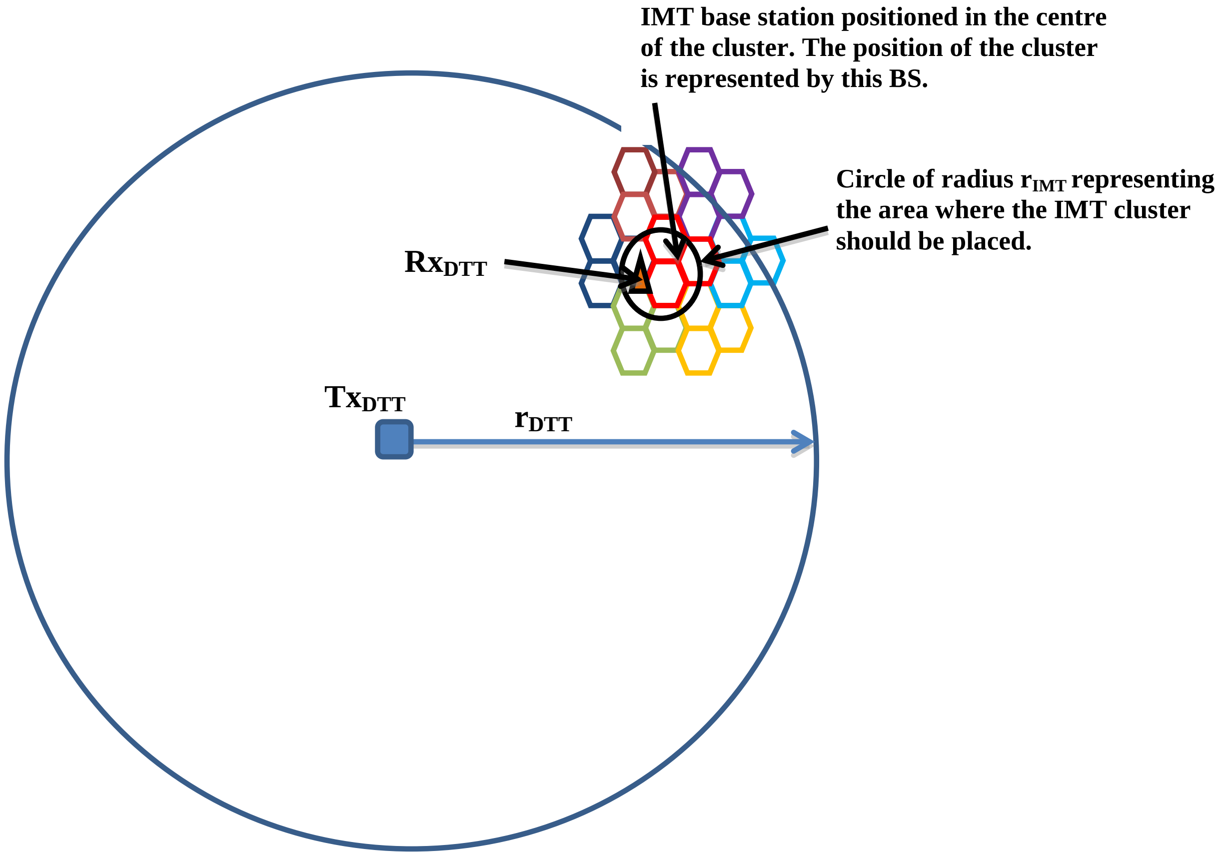
The probability of interference to DTT fixed roof top antenna reception by IMT UE emissions is calculated. The simulations are carried out for different active IMT UE densities and DTT receiver ACS, as a function of UE out of band emission (OOBE) levels.

The total probability of interference, as well as the probability of interference due to DTT receiver ACS and UE ACLR are calculated for DTT receivers located in the pixel at DTT coverage edge, since this is the worst case.

The interference impact in the whole DTT coverage area is also assessed. The considered scenario is the following:

FIGURE 7

Full DTT Coverage Simulation Scenario



Simulation assumptions

TABLE 10

IMT system parameters

IMT UE parameters		
Parameter	**Value**	**Source**
Frequency (MHz)	708[1]	
Channel BW (MHz)	10	[Document 4-5-6-7/49]
Maximum number of resource blocs (RBs)	50	
Antenna height (m)	1.5	[Document 4-5-6-7/49]
Power (dBm)	23	[Document 4-5-6-7/49]
Antenna gain (dBi)	-3	[Document 4-5-6-7/49]
e.i.r.p. (dBm) = Power + Antenna gain	20	
Body loss (dB)	4	[Document 4-5-6-7/49]
Antenna pattern	Omni-directional	[Document 4-5-6-7/49]
Distribution of active UE (%indoors / %outdoors) Urban Rural	 30 / 70 50 / 50 [Wall loss and std dev to be included]	[Document 4-5-6-7/49]
ACLR	The range 40-80 dB [consider specific values in the range for facilitating comparison]	
Transmit power control parameters	See Appendix 5	
IMT base station parameters		
Cell ranges: Urban Rural	 1 km [2 km?] 8 km	[Document 4-5-6-7/236]
Antenna height (for all environments)	30 m	[Document 4-5-6-7/236]
Sectorization	3 sectors	[Document 4-5-6-7/236]
Down tilt	3 degrees	[Document 4-5-6-7/236]
Frequency reuse	1	[Document 4-5-6-7/236]
Antenna pattern	See Annex 7 to Rec. ITU-R F.1336-4	[Document 4-5-6-7/236]

[1] This value is chosen as a representative in terms of the propagation loss and is not linked to any channelling arrangements.

TABLE 11

DTT system parameters for fixed outdoor reception

DTT receiver parameters for fixed roof top antenna in urban and rural environments			
Parameter	**DVB-T Value**	**DVB-T2 Value**	**Source**
Frequency (MHz)	690	690	[Document 4-5-6-7/126]
Channel BW (MHz)	8	8	
Environment	Urban and rural	Urban and rural [add perhaps suburban]	
Antenna height (m)	10	10	[Document 4-5-6-7/126]
Antenna gain including losses (dBi)	9.15	9.36	[Derived from the parameter values given in Document 4-5-6-7/126]
Antenna pattern	See Rec. ITU-R BT.419	See Rec. ITU-R BT.419	[Document 4-5-6-7/126]
Antenna polarisation discrimination (dB) vis-à-vis IMT UT	0	0	
Modulation scheme	64 QAM (CR=2/3, GI=1/32)	64 QAM (CR=2/3, GI=1/32) [T2?]	[What mode to protect?]
3 dB BW (MHz)	7.6	7.77	[Document 4-5-6-7/126]
Noise floor (dBm)	-98.17	-99.07	[Derived from the parameter values given in Document 4-5-6-7/126]
C/N (dB)	21	20	[Document 4-5-6-7/126]
P_{min}(dBm) at the receiver input	-77.17	-79.07	[Derived from the parameter values given in Document 4-5-6-7/126]
E_{min} (dBµV/m) at 10 m above the ground	47.87		[Derived from the parameter values given in Document 4-5-6-7/126]
P_{med} (dBm) at the receiver input	-68.12		[Derived from the parameter values given in Document 4-5-6-7/126]
E_{med} (dBµV/m) at 10 m above the ground, P_{loc} = 95%	56.72	54.52 [only for adjacent channel]	[Derived from the parameter values given in Document 4-5-6-7/126]
Receiver ACS (dB)	38, 40, 45, 50, 55, 60, 70 and 80	38, 40, 45, 50, 55, 60, 70 and 80 [for which freq sep are these given etc? Ref. Doc. 185]	
Protection criterion	C/(I+N) = 21 dB	C/(I+N) = 20 dB	

ACLR correction factors

UE OOBE limits are defined for full channel bandwidth occupation in 3GPP specification TS36.101. Furthermore simulations and laboratory measurements have shown that when a UE is transmitting in partial band, the UE OOBE level is reduced by different levels. Therefore a correction factor has been applied to adjust the UE OOBE levels accordingly. The correction factor of UE OOBE from 20 MHz channel to 10 MHz channel is 8 dB. For 10 MHz channel, the following correction factors used are described in tables 12 and 13 hereafter.

TABLE 12

UE OOBE Correction factor

Variation of UE OOBE as a function of the number of RBs used for 10 MHz IMT channel bandwidth		
LTE users (#RBs)	**DTT channel**	
	#48	**#47**
1 (50RB)	0 dB	11 dB
2 (25RB)	12 dB	29 dB
3 (16RB)	19 dB	41 dB
4 (12RB)	19 dB	41 dB
5 (10RB)	19 dB	41 dB
6 (8RB)	19 dB	41 dB
8 (6 RB)	19 dB	41 dB
10 (5RB)	19 dB	41 dB

TABLE 13

Variation of UE OOBE as a function of the number of RBs used for 10 MHz IMT channel bandwidth

Variation of UE OOBE as a function of the number of RBs UE e.i.r.p. = 23 dBm; OOBE for 1 active UE = -25 dBm		
Number of active UE per sector	**Density (1/km^2)**	**ACLR for a channel bandwidth of 10 MHz (dB)**
1	1,539600717	23 – (-25) = 48
2	3.079201436	23 – (-25) +12=60
4	6.158402871	23 – (-25) +19=67
6	9.237604307	23 – (-25) +19=67
8	12.31680574	23 – (-25) +19=67
10	15.39600718	23 – (-25) +19=67

All the studies are carried out for a 10 MHz IMT system. The simulation method, assumptions, system parameters and the correction factors used are presented in detail in Appendix 1 to 4.

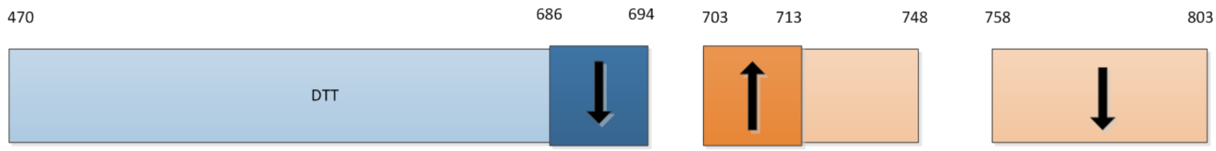
It should be noted that, for the purpose of comparison, several simulations have been performed with and without ACLR correction factors.

IMT channel arrangement

The channel arrangement A5 of Recommendation ITU-R M.1036-4 is used. The potential interference from an IMT system uplink of 10 MHz channel bandwidth into the DTT channel 48 with an 8 MHz channel bandwidth is assessed. The used IMT frequency arrangement and its position relative to DTT band is shown in Figure 8.

FIGURE 8

IMT Frequency arrangement and co-existence scenario



These assumptions relating to the frequency channel usage scenario are pessimistic. The IMT UE are assumed to be transmitting on the lowest IMT uplink channel (703-713 MHz) within the 700 MHz IMT frequency band. Furthermore, all of the DTT receivers are assumed to be always receiving a TV channel that is being transmitted on the highest frequency channel within the DTT spectrum (686-694 MHz), whereas in practice this will not be the case as the majority of DTT receivers will be receiving TV channels that are being transmitted on frequencies that are significantly lower than this.

Propagation model

For the case of simulation of the whole DTT coverage area, propagation model contained in Recommendation ITU-R P.1546-4 is used for the DTT link between transmitter and receiver, that is, the point-to-area predictions for terrestrial services.

The Extended Hata[3] model is used for the link from the IMT UE, to the IMT base station, as well as for the interfering link from IMT UE to DTT receiver.

2.2.1.3.2 Methods of calculation with formulas

The non-uniform distribution of the population through the sub-urban and rural areas must be taken into account to avoid underestimation of interference. Non-uniform population distribution typically causes dense concentration of interference sources within borders of populated areas (villages, towns, etc.), in close proximity to broadcasting service receiving antenna locations. Typically, the ratio between square of populated and non-populated areas for most areas may be taken as, for example 1:10 for rural scenario. In general studies, such a ratio is to be modelled using random-generated geometric shapes in order to obtain a proper distribution of distances between the broadcasting site and the UE location.

In the case of co-channel and adjacent channel interference from IMT into fixed or portable DTT reception, criteria such as $\frac{I}{N}$ and $\frac{C}{I+N}$ may be used to assess the interference. This method adopts the criteria of $\frac{C}{I+N}$ arguing that it provides a direct indication of the existence of interference on the broadcasting service.

[3] The version of Extended Hata model used is in accordance with Appendix 1 to Annex 2 of Report ITU-R SM.2028-1.

Principles of the Monte Carlo method

The Monte Carlo method is the simulation of random variables, by their defined probability density functions (distributions), for solving mathematical problems or for analysing and understanding complex real-life problems encountered in various areas like economics, industry and spectrum management.

The Monte Carlo method permits to model a large range of radio systems and to simulate various interference scenarios.

The Monte Carlo method uses various radio parameters (transmitter power, antenna height, diagram and gain, receiver sensitivity, noise floor, propagation model,…) to construct the interference scenario under consideration. It uses all the parameters to generate interference cases based on the constructed interference scenario. For each case the Monte Carlo method calculates the strength of the desired received signal strength (*dRSS*) and the interfering received signal strength (*iRSS*) and stores them in separate data arrays. This process is repeated K times, where K is the number of cases.

One output from such Monte Carlo simulations is, typically, the interference probability ($_{IP}$). This is calculated from the generated data arrays *dRSS* and *iRSS*, based on a given interference criteria threshold (*C/(I+N)*):

$$_{IP}=1-_{NIP} \tag{1}$$

where $_{NIP}$ is the probability of non-interference of the receiver.

The interference criterion *C/(I+N)* should be used for assessing IMT uplink interference impact on DTTB reception. Consequently, $_{NIP}$ *i*s defined as follows:

$$NIP = P\left(\frac{dRSS}{iRSS+N} \geq \frac{C}{I+N}\right),\ for\ dRSS > sens \tag{2}$$

$$= \frac{\sum_{i=1}^{M} 1\left\{\frac{dRSS(i)}{iRSS_{composite}(i)+N} \geq \frac{C}{I+N}\right\}}{M}$$

where

$$1_{\{condition\}} = \begin{Bmatrix} 1, & \text{if condition is satisfied} \\ 0, & \text{else} \end{Bmatrix}$$

$$iRSS_{composite} = \sum_{j=1}^{L} iRSS(j)$$

L = number of interfering UE;

M = number of events where dRSS>sens.

One possible way to calculate the degradation of reception of the wanted signal is to compare the values of the probability of interference in the case of noise only with the values of the probability of interference in the case of presence of noise and interference, as follows:

$$\Delta IP = NIP_{N} - NIP_{(N+I)} \tag{3}$$

where

$IP_{(N)}$: *IP* in the presence of noise only;

$IP_{(N+I)}$: *IP* in the presence of noise and interference.

In case of a fixed source of interference (e.g. IMT base station), the reception location probability (p_{RL}) is calculated as follows:

$$p_{RL} = 1 - IP \quad (4)$$

The degradation of the reception location probability is calculated as follows:

$$\Delta p_{RL} = p_{RL\_N} - p_{RL\_N+I} \quad (5)$$

where

p_{RL_N} : p_{RL} in the presence of noise only;

p_{RL_N+I} : p_{RL} in the presence of noise and interference.

In case of a moving source of interference (e.g. IMT user equipment), calculation of Δp_{RL} may not be so straight forward.

In this case, the IP represents the average probability that n active IMT UE located in an IMT sector will interfere with a DTTB receiver located randomly within the IMT sector at any one instant in time, i.e. it is representative of the interference of a static network consisting of n active UE; where n = 1 to 10.

A number of Monte Carlo studies used to assess the probability of IMT UE interference are based just on the IP. These studies and their results are detailed in section [XX].

As the IP is the probability of interference in one instant in time it does not represent the probability that a DTTB receiver will be subject to interference in a time window, e.g. one hour. To allow the IP to be used to assess interference in a time window it has been proposed to calculate the probability P of observing at least one harmful interference from IMT UE to DDTB receiver. P is based on uncorrelated changes to the IMT network state (e.g the transmission mode or position of UE). This approach and the studies using this approach are detailed in section [YY].

The Monte Carlo study to calculate the change in percentage of locations served (ΔRLP) is detailed in section [ZZ].

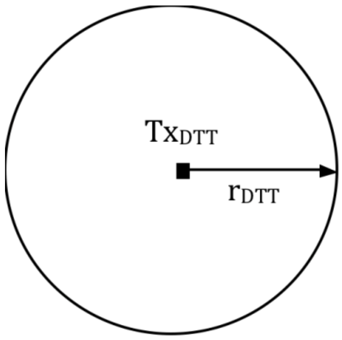
Basic geometry and simulation steps

Geometry

Firstly a DTT coverage area is built up according to the link budget analysis presented in Annex [x]. The DTT transmitter is placed at the centre of the coverage area as depicted in Figure 9.

FIGURE 9

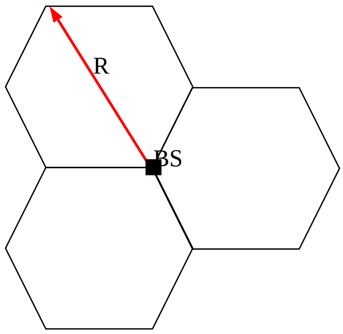
DTT coverage area of radius r_{DTT}



Then, a single frequency IMT cell composed of a single radio site is built up according to the link budget analysis presented in Annex [2]. The IMT base station is placed at the centre of the cell. Each IMT cell is composed of three sectors as depicted in Figure 10.

FIGURE 10

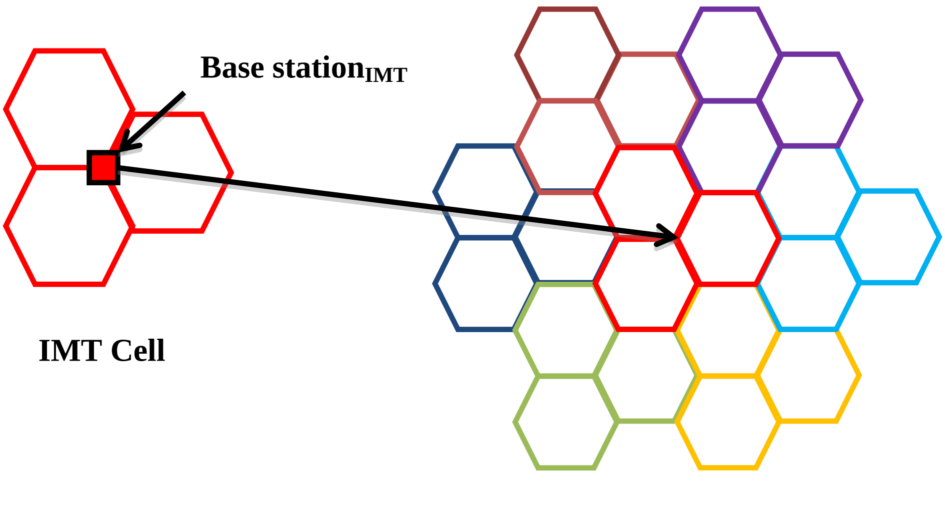
IMT cell: Hexagonal three-sector cell layout (R: cell range)



This IMT cell is repeated to build up a perfectly homogeneous single frequency IMT cluster composed of 7 cells (base stations) as depicted in Figure 11. A cluster of size 7 is composed of 21 (7 x 3) hexagonal-shaped sectors.

FIGURE 11

Single frequency IMT cluster



Simulation steps

For the case of assessment of interference on the DTT coverage edge:

At each Monte Carlo trial *i* (*i*=1, 2, ..., M):

1) The DTT receiver is located randomly, following a uniform distribution, within the DTT coverage area for the general case and within a pixel on the DTT coverage edge

for the assessment of the worst case situation. The azimuth orientation of the TV receiver antenna is directed toward the DTT transmitter in case of fixed rooftop reception.

2) Around the DTT receiver an IMT cluster is randomly located following a uniform distribution, the maximum distance between the DTT receiver and the IMT cluster being equal to IMT cell range. The cluster position is defined by the position of the central cell's base station position as depicted in Figure 12.

3) The active IMT user equipment (UE) are located randomly, following a uniform distribution, within each cell of the IMT cluster.

4) The probability of interference (p_I) is calculated according to equations (1) and (2) for two cases:

- across a pixel of 100 m x 100 m at the edge of the DTT coverage area as depicted in Figure 13. At least 100 000 events are generated to consider all possible interference cases in this pixel. This will allow to determine the impact in the worst case scenario;
- across the whole DTT coverage area as in Figure 12.

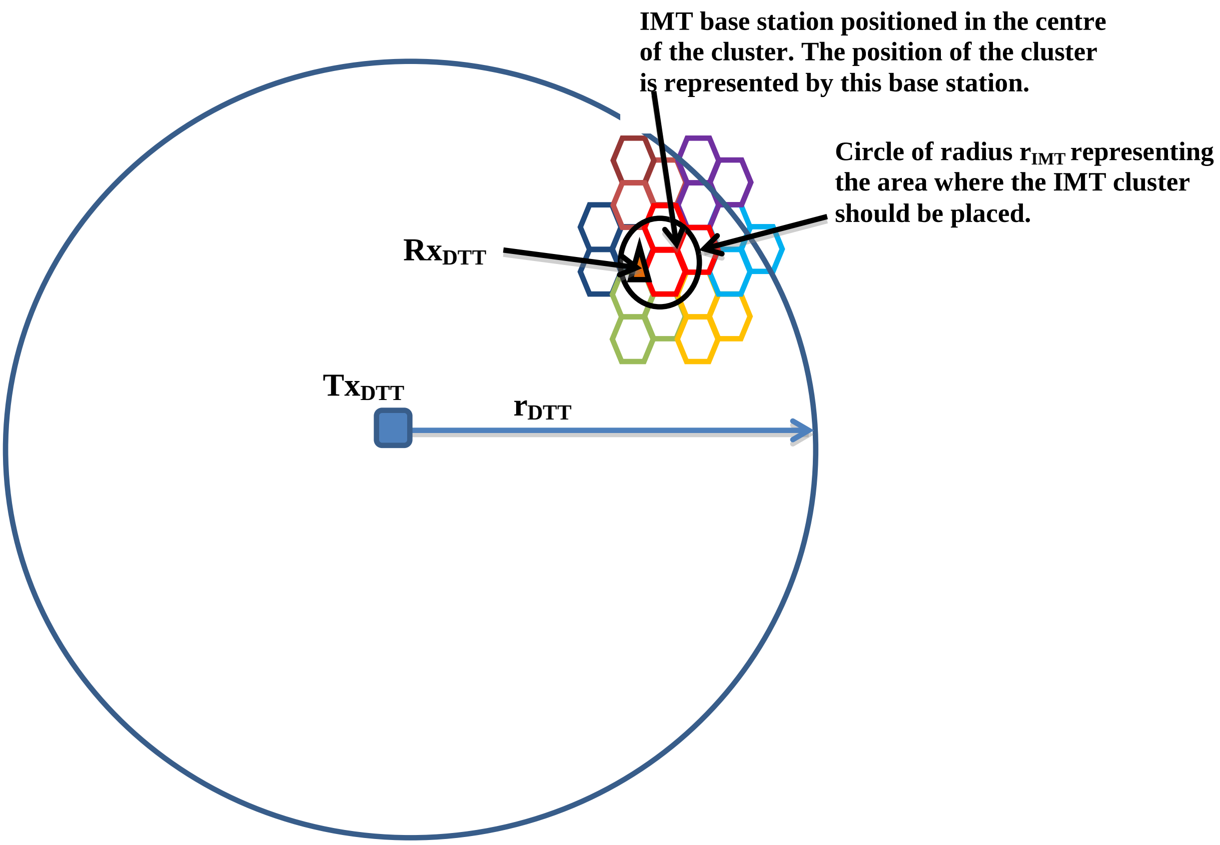
5) Δp_I is calculated according to equation (3).

6) The simulation results (p_I) are presented, for different active IMT UE densities and DTT receiver ACS, as a function of UE OOBE level or ACLR. For some simulations, an OOBE correction factor is applied for different UE RBs configurations as described in Tables [A.1.4 and A.1.5.]

7) An UE OOBE limit is determined corresponding to the UE OOBE level that does not have any contribution to the probability of interference of the DTT reception by the UE emissions (OOBE+in band emission).

FIGURE 12

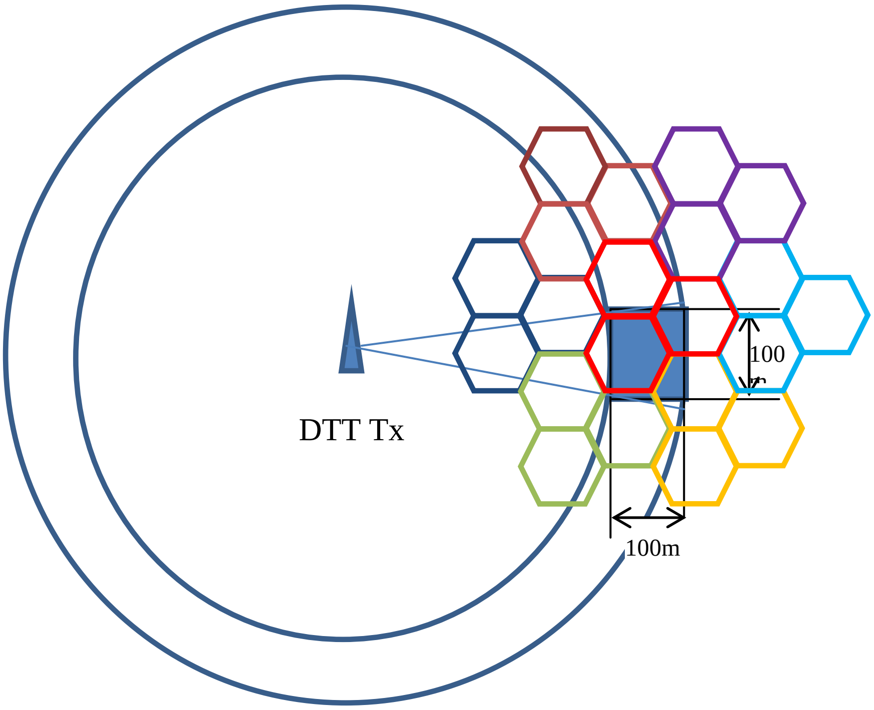
Position of the IMT cluster around the victim DTT receiver (a single Monte Carlo event)



Editorial note: RxDTT should be placed at the centre of the circle!

FIGURE 13

Edge of the DTT coverage area



Understanding the calculated probability of interference

In section 2, we have described how the probability of interference (p_I) was calculated in Monte Carlo simulations. In this section we explain how to read and understand the probabilities of interference presented in Section [3] of this document. In the document two main interference scenarios have been considered, namely urban and rural interference scenarios. In both cases, p_I was calculated across *a pixel of 100 m x 100 m at the edge of the DTT coverage area as described in section [A2.3.2].*

For urban scenario 100 000 events were generated, while for rural scenario the number of events generated was 200 000. According to the basic DTT parameters, at the DTT cell edge, the useful signal level (dRSS) would be below the sensitivity of DTT receivers for 5% of the generated events, since the DTT cell-edge coverage probability is 95%. For example, for urban scenario we can write:

K= 100000, for urban interference scenarios;

M= 95000, for urban interference scenarios;

where

K: number of events generated;

M: number of events where dRSS>sens.

The following table give concrete information on the probability of interference (***p_I***) that may results in Monte Carlo simulation. The tables can be extended beyond a ***p_I*** of 0.0105%

TABLE 14

Numerical examples of the probability of interference

Numerical examples of the probability of interference (p_I) calculated

across a *pixel of 100 m x 100 m in urban scenarios*			
K (# generated events)		100 000	
M (# of events where dRSS>sens)		95 000	
NI (# events without interference)	**# events with Interference**	p_{NI} **(%) = 100*(NI/M)**	p_I **(%) = 100*(1-(NI/M))**
95 000	0	100	0
94 999	1	99,99894737	0,00105263
94 998	2	99,99789474	0,00210526
94 997	3	99,99684211	0,00315789
94 996	4	99,99578947	0,00421053
94 995	5	99,99473684	0,00526316
94 994	6	99,99368421	0,00631579
94 993	7	99,99263158	0,00736842
94 992	8	99,99157895	0,00842105
94 991	9	99,99052632	0,00947368
94 990	10	99,98947368	0,01052632
p_{NI}: *probability of non-interference* p_I: *1-* p_{NI}: *probability of interference*			

It is important to note here that a p_I of 0.0105% means that in a run (simulation) of 95 000 events, across a pixel of 100 m x 100 m, only 10 interference cases were predicted.

2.2.1.3.3 Overview of studies

Multi Monte Carlo studies have been conducted. The input assumptions to the studies are summarized in the table below.

Study	DTTB System	UE Power Control	Building Entry loss , Standard Deviation[4,5]	Number of UE	Cell Sites[6]	Sec-tors	Simulations[7, 8, 9]	Environment & Building Indoor%/ Outdoor%	DTT Rx position
A [F/417]	DVB-T Fixed	10% of UE @ 23 dBm	11 dB, no stdv.	1, 2, 4, 6, 8, 10	7	21	100 000 urban, & suburban, 200,000 rural & urban 500 000 urban	70/30 Urban, Suburban 50/50 Rural	Edge
B [ATU/557]	DVB-T2 Fixed	10% of UE @ 23 dBm	11 dB, no stdv.	4, 6, 10	7	21	100 000 Urban	70/30 Urban,	Edge
C [Arab/368]	DVB-T & DVB-T2 Fixed	10% of UE @ 23 dBm	11 dB, no stdv.	1	7	21[10]	100 000	70/30 Urban 50/50 Rural	Area[11]
D [Nokia/447]	DVB-T Fixed	2% ~3% of UE @ 23 dBm	11 dB, 6 dB	1, 2, 4, 6, 8, 10	9	19	100 000	70/30 Urban, Suburban 50/50 Rural	Edge
E [GSMA/545]	DVB-T Fixed	According to scenario	11 dB, 6 dB	1, 2, 4, 6, 8, 10	7	21	10 000 000	70/30 Urban, Suburban	Edge
F [EBU/579]	DVB-T2 Fixed	122 dB	11 dB, 6 dB	1, 10	23	19	2e9	0/100, 14/86, 70/30 Urban	Edge
G	DVB-	122 dB	11 dB, 6 dB	1	19	57	10 000 000	70/30 Urban,	Edge

4 To use a value that is common to both IMT and DTTB services [JTG 4-5-6-7 agreed to use] the building entry loss and associated standard deviation values specified in Recommendation ITU-R P.1812-2, Table 6, Page 23.

5 [The effect of omitting building standard deviation on the calculated interference probability is assessed in Doc. 4-5-6-7/561 [replace with reference to Annex to report]].

6 WP 5D in a liaison to Doc. 4-5-6-7/236, Annex 2, provided details of the IMT network configuration to be used in Monte Carlo modelling of interference to DTTB reception as well as details of the IMT UE power control to be used.

7 The number of simulations affects the precision in the results of Monte Carlo simulations.

8 France also modelled 1 & 10 UE using 500 000 simulations.

9 An MC simulation treats a large number of 'events'. Each event considers a random set of UE locations. Some simulations have been carried out with a single random DTTB receiver site (SEAMCAT) and others (Nokia & EBU) with a large number of random DTTB receiver sites within a pixel (100 m x 100 m). Nokia used 10 000 random DTTB receive locations within the pixel and EBU used 100 000.

10 Sectors modelled as Rhombus not Hexagon.

11 The vertical antenna pattern in this study is different than the one provided [by WP 6A].

Study	**DTTB System**	**UE Power Control**	**Building Entry loss , Standard Deviation**[4],[5]	**Number of UE**	**Cell Sites**[6]	**Sec-tors**	**Simulations**[7, 8, 9]	**Environment & Building Indoor%/ Outdoor%**	**DTT Rx position**
[BNE/563]	T2 Fixed	Urban & Suburban, 123.3 dB Rural[12], see JTG 4-5-6-7 Doc 559 [Ed. note: foodnote to be added]						Suburban 50/50 Rural	
H [TDF/508]	DVB-T Portable outdr.	10% of UE @ 23 dBm	11 dB, no stdv.	1, 2, 4, 6, 8, 10, 12	7	21	10 ,000, several with up to 400 000	70/30 urban	Edge

In the following subsections the results of each of the studies are reflected.

Sensitivity studies using Monte Carlo analysis has also been carried out:

Study	**DTTB System**	**UE Power Control**	**Building Entry loss , Standard Deviation**[13], [14]	**Number of UE**	**Cell Sites** [15]	**Sec - tors**	**Simulations** [16]	**Environment & Building Indoor%/Outdoor %**
I [TDF /509]	DVB-T Fixed	10% of UE @ 23 dBm	11 dB, no stdv.	1, 2, 4, 6, 8, 10, 12, 16	7	21	100 000, several with up to 400 000	Edge 70/30 urban, but no body loss
I [TDF /509]	DVB-T Fixed	10% of UE @ 23 dBm	11 dB, no stdv.	1, 2, 4, 6, 8, 10	7	21	100 000, several with up to 400 000	Edge 30/70 urban
I [TDF /509]	DVB-T Fixed	10% of UE @ 23 dBm	11 dB, no stdv.	1, 2, 4, 6, 8, 10, 20	7	21	100 000, several with up to 400 000	Edge 30/35/35 urban, partly no body loss

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[12] The power control values were chosen to limit the proportion of UE operating at maximum power to ~1% Urban, ~2% Suburban and ~5% in rural environments using the methodology provided to JTG 4-5-6-7 by WP 5D.

[13] To use a value that is common to both IMT and DTTB services JTG 4-5-6-7 agreed to use the building entry loss and associated standard deviation values specified in Recommendation ITU-R P.1812-2, Table 6, Page 23.

[14] [The effect of omitting building standard deviation on the calculated interference probability is assessed in Doc. 4-5-6-7/561 [replace with reference to Annex to report]]

[15] WP 5D in a liaison to Doc. 4-5-6-7/236, Annex 2, provided details of the IMT network configuration to be used in Monte Carlo modelling of interference to DTTB reception as well as details of the IMT UE power control to be used.

[16] The number of simulations affects the precision in the results of Monte Carlo simulations.

The results of these sensitivity studies are also reflected in the relevant subsection.

Study A, B and C:

Simulations are done for urban and rural environments. These simulations have been done for different values for DTT ACS, IMT UE ACLR and OOBE, and different IMT UE densities.

Further information on values taken for the simulations are contained in the following Appendices of Annex 4 :

Appendix 2: Example values of active user densities for sensitivity analysis in sharing studies

Appendix 3: Transmit power control

Appendix 4: Examples of DTT and IMT link budgets

Study A:

For the case of the assessment of interference at the edge of the DTT coverage, the simulation results can be found in the excel file hereafter.

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Further simulations for a selection of ACS and ACLR values have been done with an increased number of runs (500 000 runs). These results are presented in the following excel file :

France results 500.000 runs.xlsx

These second set of simulations have been made with the following parameters :

– Number of active UE per sector = 1 and 10;

– ACS = 65 dB;

– ACLR = 63, 65, 67 and 69 dB;

– ACLR correction factor (for 10 UE) = 9 and 19 dB;

– TW = 1800 s (30 min) and 3600 s (60 min);

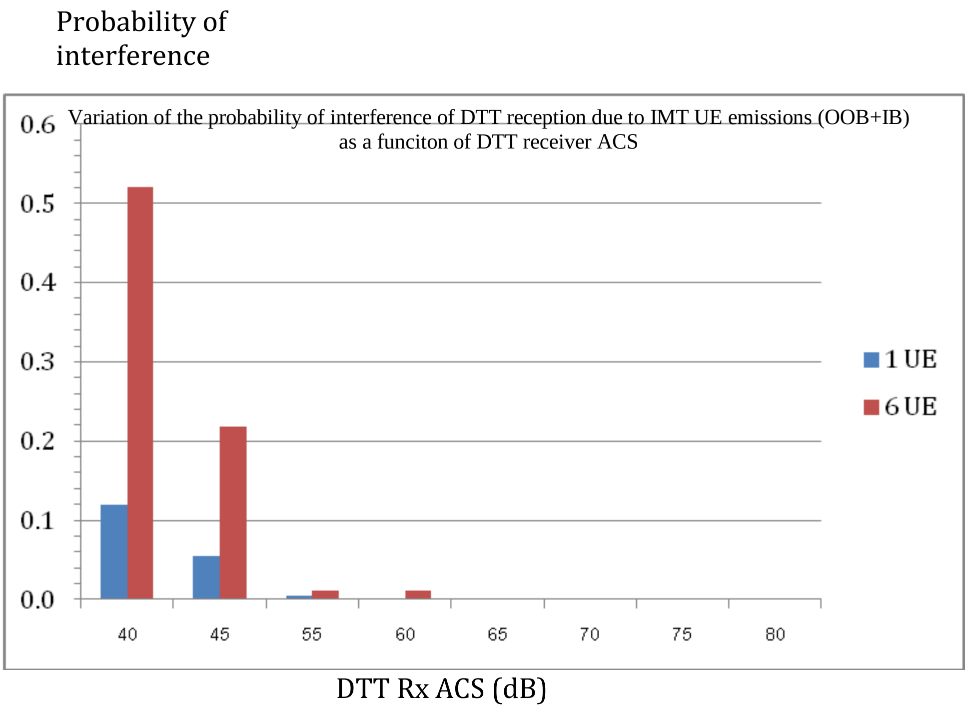
– DT = 1, 10 and 100 s.

In order to evaluate the impact of IMT UE OOBE levels at DTT reception, it is useful to look both at the probability of interference due to UE OOBE and due to DTT receiver ACS.

The variation of the probability of interference, due to IMT UE emissions (OOB+IB), as a function of DTT receiver ACS for different IMT UE densities is shown in Figure 15. It can be seen that the probability of interference increases with number of transmitting UE per cell, and decreases rapidly with the increase of DTT receiver ACS values. For DTT receiver ACS>=55 dB, the probability of interference is quite low (0.01%).

FIGURE 15

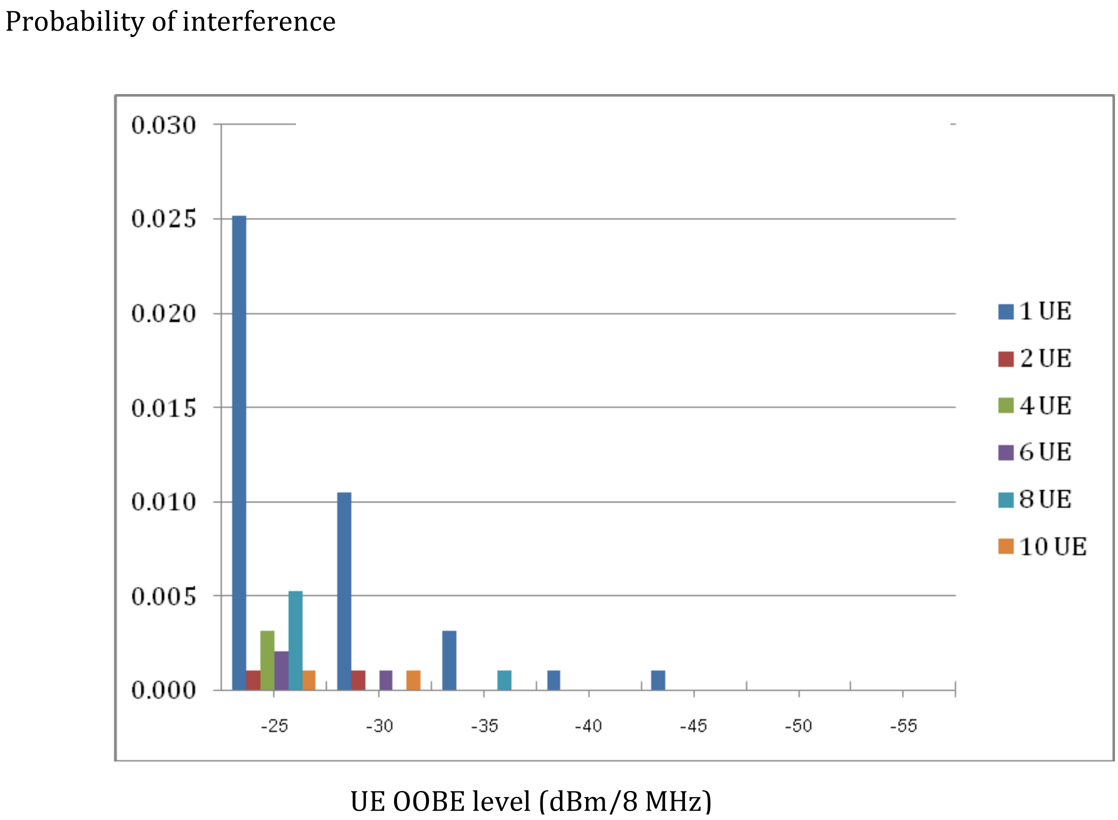
Variation of the probability of interference of DTT reception due to IMT UE emissions (OOB+IB) as a function of DTT receiver ACS



The variation of the probability of interference of DTT reception, for a DTT ACS of 60 dB, as a function of UE OOBE is shown in Figure 16. At UE OOBE = –25 dBm/8 MHz, the probability of interference is below 0.025%, at UE OOBE = –30 dBm/8 MHz, the probability of interference is about 0.01%. The probability of interference goes down to 0.003% (only about 3 interference cases over 95 000 simulated events) at UE OOBE = –35 dBm/8 MHz.

FIGURE 16

Variation of the probability of interference of DTT reception due to UE OOBE, as a function of UE OOB level



As shown in Figure 16, at 10 MHz channel LTE UE OOBE level of –25 dBm/8 MHz, the probability of interference is below 0,025%, at UE OOBE level of –30 dBm/8 MHz, the probability of interference is about 0,01%.

The simulation results show that at DTT coverage edge:

1) The worst interference scenario from IMT/LTE uplink to DTT is found in an urban environment for the reason of smaller cell size (higher active user density).

2) The total probability of interference decreases with the increase of DTT receiver ACS, and the increase of IMT UE ACLR (decrease of UE OOBE level).

3) For a given DTT receiver ACS, total probability of interference will not decrease with the increase of IMT UE ACLR (decrease of UE OOBE level) above certain level, since it is limited by DTT receiver ACS.

4) In a rural environment the probability of interference is mainly dominated by UE in-band (IB) power. This power can only be attenuated by the DTT receiver ACS. In order to evaluate the impact of IMT UE OOBE levels at DTT reception, it would be more appropriate to consider the probability of interference due to UE OOBE in an urban environment.

5) Furthermore, for the second set of simulations done for 500 000 runs, it can be concluded that for 10 UE per sector, the probability of interference is mainly dominated by the UE in-band power (IB).

Study B:

The probability of interference (P_I) due to UE OOBE and DTT receiver ACS imperfections are presented below. Simulations were conducted for different configurations of active IMT UE density, DTT receiver ACS and IMT UE ACLR.

TABLE 15

Interference probability for DTT receivers positioned at the DTT coverage edge (No ACLR correction factor)

Urban Area ACS = 55 dB			
Active UE OOBE [dBm/8MHz]	4	6	10
-25	P_I = 0.06%	P_I = 0.10%	P_I = 0.14%
-30	P_I = 0.04%	P_I = 0.05%	P_I = 0.08%
-35	P_I =0.02%	P_I = 0.03%	P_I = 0.05%
ACS = 60 dB			
Active UE OOBE [dBm/8MHz]	4	6	10
-25	P_I = 0.06%	P_I = 0.08%	P_I = 0.13%
-30	P_I = 0.02%	P_I = 0.04%	P_I = 0.06%
-35	P_I = 0.01%	P_I = 0.02%	P_I = 0.03%
ACS = 65 dB			
Active UE OOBE [dBm/8MHz]	4	6	10
-25	P_I = 0.05%	P_I = 0.07%	P_I = 00.10%
-30	P_I = 0.02%	P_I = 0.03%	P_I = 0.06%
-35	P_I = 0.01%	P_I = 0.01%	P_I = 0.02%

The following figures demonstrate the variation in probability of interference (P_I) based on varying OOBE levels and fixed ACS and active user densities.

FIGURE 17

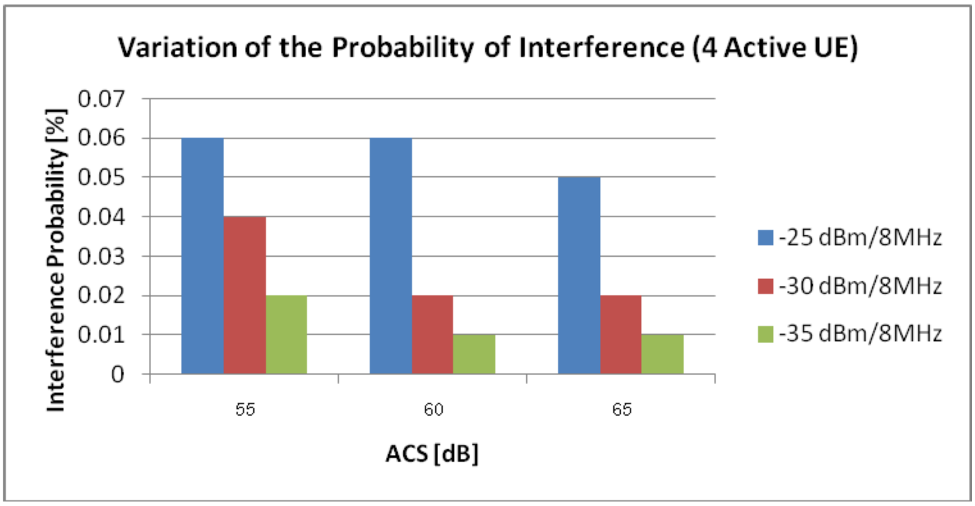


FIGURE 18

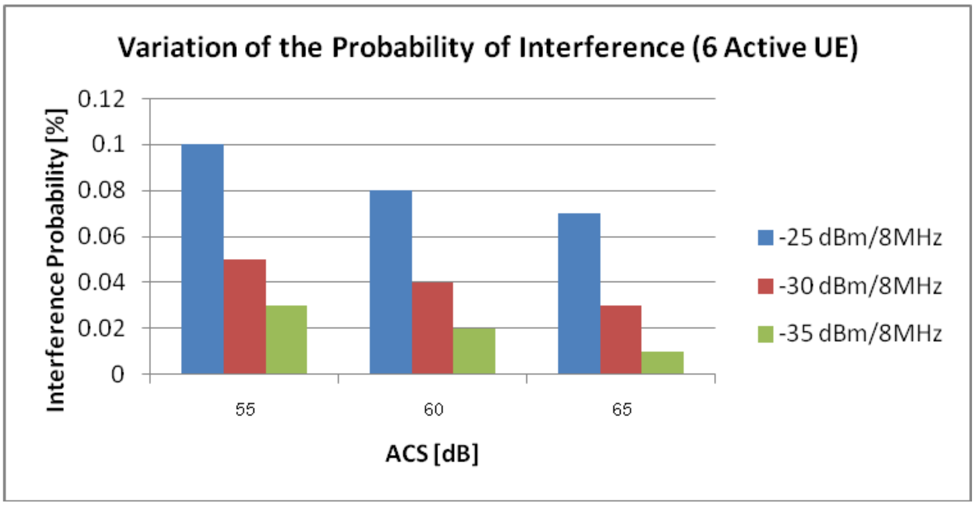
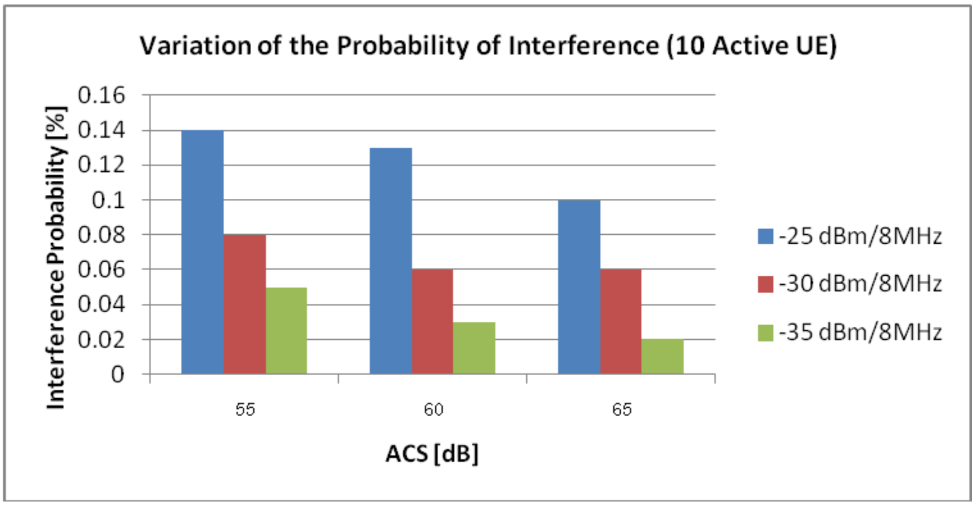


FIGURE 19



This study has considered the probability of interference from IMT UE uplink to fixed rooftop DTT receivers, using Monte Carlo analysis. According to this study, as evidenced by simulation results, the worst case P_I encountered in urban areas is 0.14%. Furthermore, results show that P_I decreases with increasing values of ACS and more stringent OOBE limits.

However, the sensitivity analysis has revealed that imposing more stringent OOBE values of up to -35 dBm/8 MHz, will lead to a minimal reduction in P_I, 0.10% at most. On the basis of this minimal reduction in $P_I$the adobtion of stricter OOBE limits is not warranted. In view of the above results, and taking into account the potential benefits of harmonisation, it is proposed that an OOBE limit of -25 dBm/8 MHz be adopted as a suitable value.

Study C:

This study indicates that at the whole DTT coverage area, for a given IMT UE transmitter blocking mask or ACLR which are based on the APT OOBE that are recommended not to exceed -34 dBm/MHz below 694 MHz, the results of the simulations for different DTT receiver ACS values show that the total interference probability is less than 1% in all cases.

When considering the impact of IMT UE in the whole DTT coverage area, without applying any ACLR correction factor, the obtained results are the following:

Case ACLR -48 dB (100 000 events)

TABLE 16

Urban area DTT in-cell coverage interference probability

Fixed outdoor DTT TV Receiver and outdoor UE							
IMT Network Scenario	**ACS**	**DVB-T**			**DVB-T2**		
		IP (U)%	**IP (B)%**	**IP (U+B)%**	**IP (U)%**	**IP (B)%**	**IP (U+B)%**
Urban	**25**	0.02%	0.39%	0.41%	0.03%	0.46%	0.49%
Urban	***38***	***0.02%***	***0.10%***	***0.12%***	***0.03%***	***0.11%***	***0.14%***
Urban	**50**	0.02%	0.02%	0.04%	0.03%	0.02%	0.05%
Urban	**60**	0.02%	0.00%	0.02%	0.03%	0.00%	0.03%
Rural	**25**	0.00%	0.01%	0.01%	0.00%	0.00%	0.00%
Rural	***38***	***0.00%***	***0.00%***	***0.00%***	***0.00%***	***0.00%***	***0.00%***
Rural	**50**	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Rural	**60**	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

TABLE 17

Urban area DTT in-cell coverage interference probability

Fixed outdoor DTT TV Receiver and indoor UE							
IMT Network Scenario	**ACS**	**DVB-T**			**DVB-T2**		
		IP (U)%	**IP (B)%**	**IP (U+B)%**	**IP (U)%**	**IP (B)%**	**IP (U+B)%**
Urban	**25**	0.01%	0.15%	0.16%	0.00%	0.16%	0.16%
Urban	***38***	***0.00%***	***0.03%***	***0.03%***	***0.00%***	***0.03%***	***0.03%***
Urban	**50**	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%
Urban	**60**	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%
Rural	**25**	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Rural	***38***	***0.00%***	***0.00%***	***0.00%***	***0.00%***	***0.00%***	***0.00%***
Rural	**50**	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Rural	**60**	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Some example of simulation scenarios used can be found in the attachments hereafter:

Rural InOut 1-10-13 DVB-T.sws

Study D:

Monte Carlo simulation results and analysis presented in one study [(Document 4-5-6-7/447)] show a very low interference probability in the worst case (urban environment, 1 user with full resource block (RB) allocation, low ACS of DTT receiver) and almost zero potential of interference in the majority of scenarios and parameter combinations.

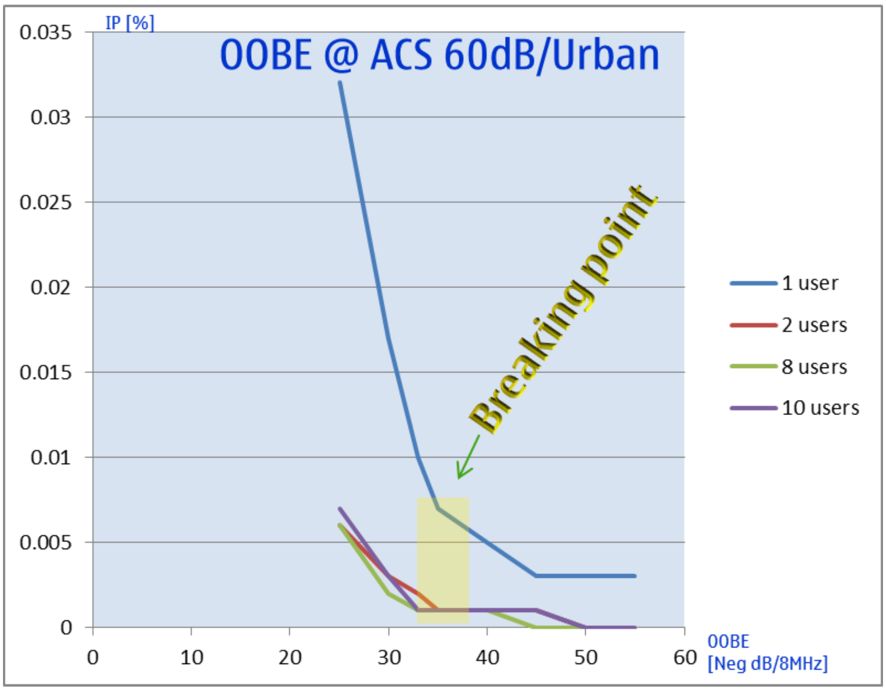
The detailed results of the study are contained in the Excel file below:

Study D.xlsx

It is observed that the Interference Probability is more sensitive to the DTT ACS than to the LTE UE OOBE level, so that means that after certain breaking point, more stringent OOBE does not decrease IP anymore, as can be seen from below Figure 20.

FIGURE 20

Breaking point in an urban scenario at the DTT coverage edge, ACS 60 dB



Therefore, it can be concluded that with a reasonably high DTT ACS, e.g. ACS = 60 dB or higher, the LTE UE OOBE level of –33 dBm / 8 MHz for the 10 MHz LTE channel is sufficiently low to avoid interference to frequencies below 694 MHz.

Study E:

The modelling results [in Document 4-5-6-7/358] indicate that, for IMT UE OOBE levels below −25 dBm/8 MHz, the OOBE value selected does not significantly influence the probability of interference to the DTT receiver, since the ACS of the TV receiver provides the dominant source of interference. Considering that −25 dBm/8 MHz (−26.2 dBm/6 MHz) was already specified for other regions, it is proposed that the same IMT UE OOBE level of −25 dBm/8 MHz should be used as regulatory limit for Region 1 for frequencies below 694 MHz.

The modelling results indicate that the OOBE value for IMT UE has very little impact on the interference probability results, whereas the ACS value of DTT receivers has a much more significant impact. The results demonstrate that the OOBE value selected does not significantly influence the protection that is provided to TV receivers, due to the ACS providing the major source of interference.

Study F:

Using Monte Carlo simulations the IP has been calculated for the three environments specified, urban, suburban and rural, using the parameters detailed in Annex 1.
Each simulation used 10 000 000 trials.

The results of these simulations are shown in Figures 21, 22 and 23.

The results of these simulations have subsequently been used to calculate the out-of-band emissions for IMT UE to achieve a specified probability of interference.

FIGURE 21

Interference Probability: Urban: 70% Indoor/30% Outdoor: CLxile = 122 dB

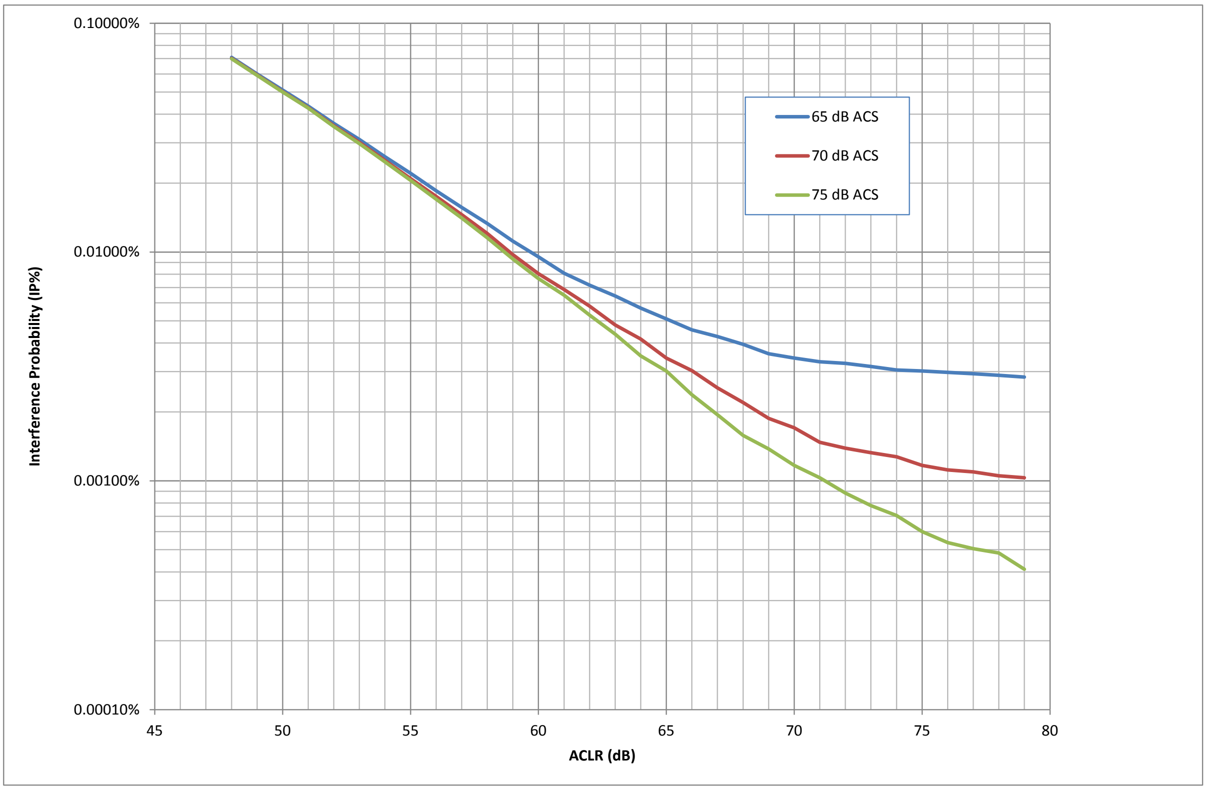


FIGURE 22

Interference Probability: Suburban: 70% Indoor/30% Outdoor: CLxile = 122 dB

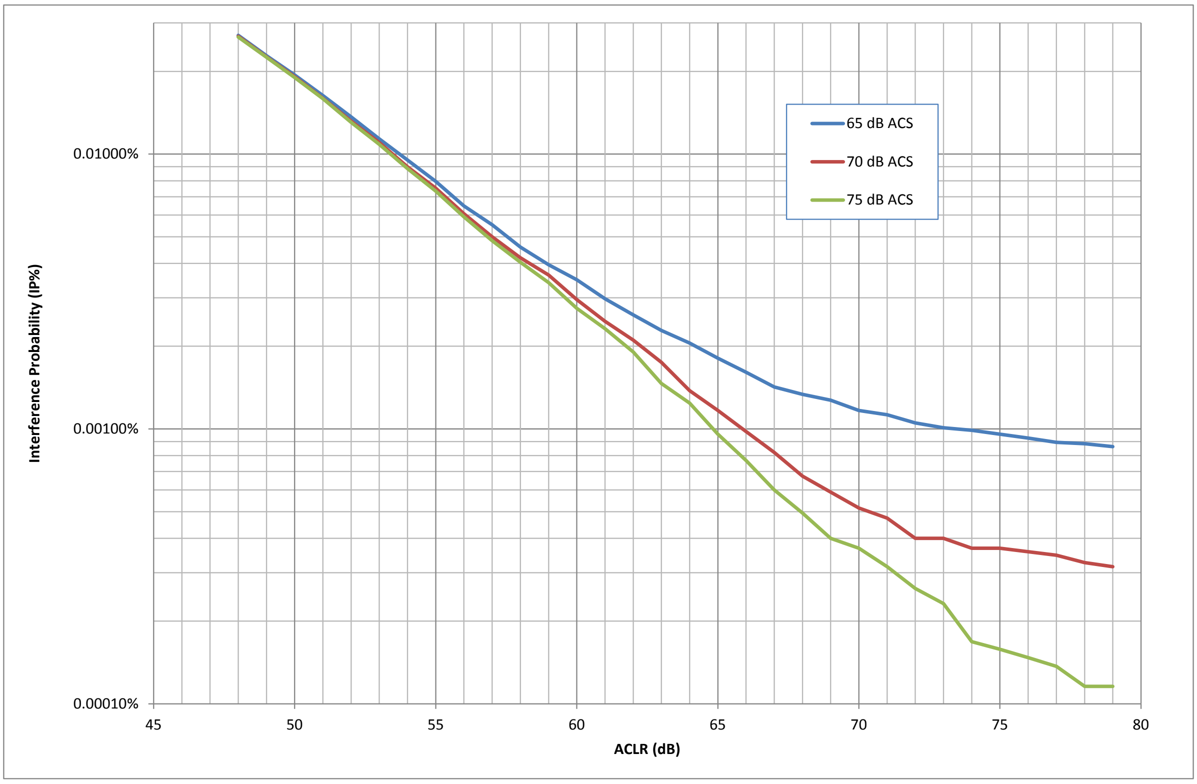
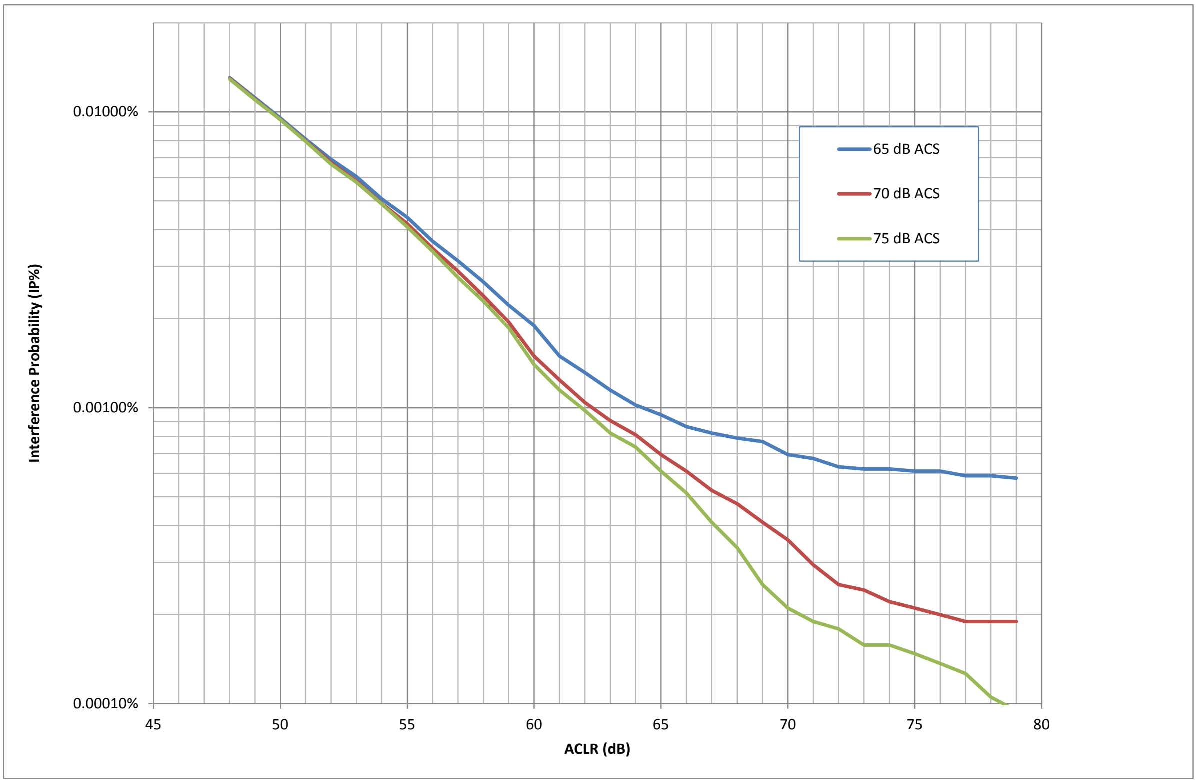


FIGURE 23

Interference Probability: Rural: 50% Indoor/50% Outdoor: CLxile = 123.3 dB



Study G:

Studies were carried out for DTT portable outdoor reception in an urban environment. Simulations have been done for different values for DTT ACS, IMT UE ACLR and OOBE, for different IMT UE densities as well as (in some cases) using different number of events (at least 100 000, in several cases 400 000). No standard deviation of building penetration loss has been taken into account.

Several sensitivity studies were carried out for fixed DTT reception in urban environment, e.g. on the impact of different body loss or higher antenna gain, a different ratio between outdoor and indoor traffic and higher number of active users. The studies were based on at least on 100 000 events, many up to 500 000 events. No standard deviation of building penetration loss has been taken into account.

The aim of these studies was to provide information relative to those provided by another study and the same input files have been used, with modifications only in those areas which were needed for the sensitivity analysis.

The first parameter which has been varied is the body loss (no body loss, i.e. reduction by 4 dB) or an increase in UE antenna gain by 4 dB. This was to simulate devices which are not body worn, categories of devices which clearly have no body loss at all (e.g. routers and in-car installations) or categories of devices which have higher antenna gains (again, e.g. routers and in-car installations)

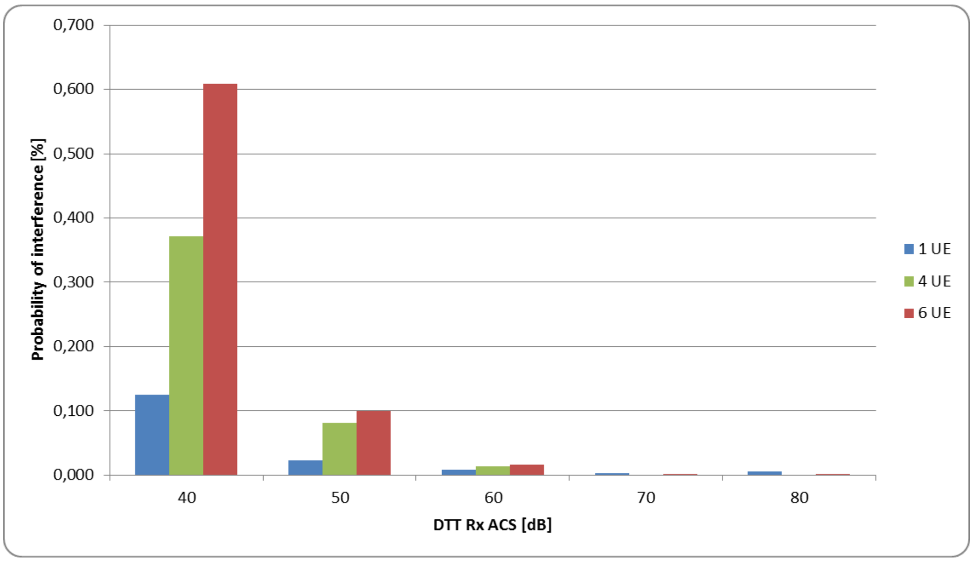
The second parameter which has been varied is the ratio between traffic generated indoor vs. traffic generated outdoor. This has been set to 30% for indoor traffic vs. 70% for outdoor traffic, e.g. to consider that the vast majority of mobile data traffic from indoor is offloaded e.g. via WiFi.

In a third sensitivity study, different values for the transmit power were used. Furthermore, it was simulated that only 30% of the traffic is generated indoor, while 35% of traffic is generated outdoor with a body loss of 4 dB and lower antenna gain (–3 dBi) and the remaining 35% of traffic is generated outdoor without body loss and an antenna gain of 0 dBi.

The variation of the probability of interference (IP), due to IMT UE emissions (OOB and IB), as a function of DTT receiver ACS for different IMT UE densities is shown in Figure 24, for an ACLR of 58 dB (plus a correction of 19 dB for 4 and for 6 UE). All results are provided in the EXCEL-file attached below.

FIGURE 24

Variation of the IP for portable outdoor DTT reception due to IMT UE emissions (OOB+IB) as a function of DTT receiver ACS, for UE ACLR of 58 dB (plus correction where appropriate)



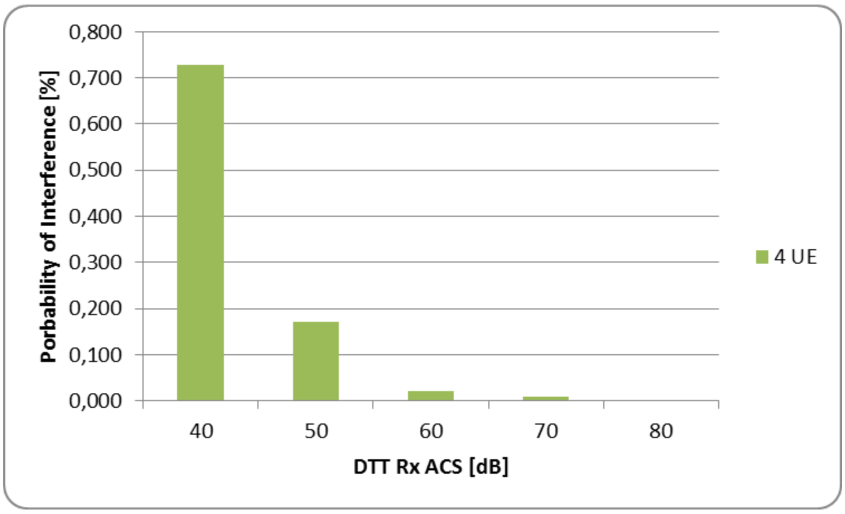
The IP increases with an increasing number of UE. According to the results, the values of IP are slightly larger than those for fixed reception using the same parameters.

Some results on sensitivity studies are contained in the EXCEL file. The variation of the IP, due to IMT UE emissions (OOB and IB) but at reduced antenna gain (by 4 dB, e.g. simulating no body loss), as a function of DTT receiver ACS for 4 UE's, is shown in Figure 25.

Results_portable.xls

FIGURE 25

Variation of the IP for portable outdoor DTT reception due to IMT UE emissions (OOB+IB) as a function of DTT receiver ACS, for a UE ACLR of 77 dB (58 dB plus correction of 19 dB)



The results are by a factor 2 higher than those shown in Figure 24, for the same number of UE's. This is in line with results of other sensitivity studies.

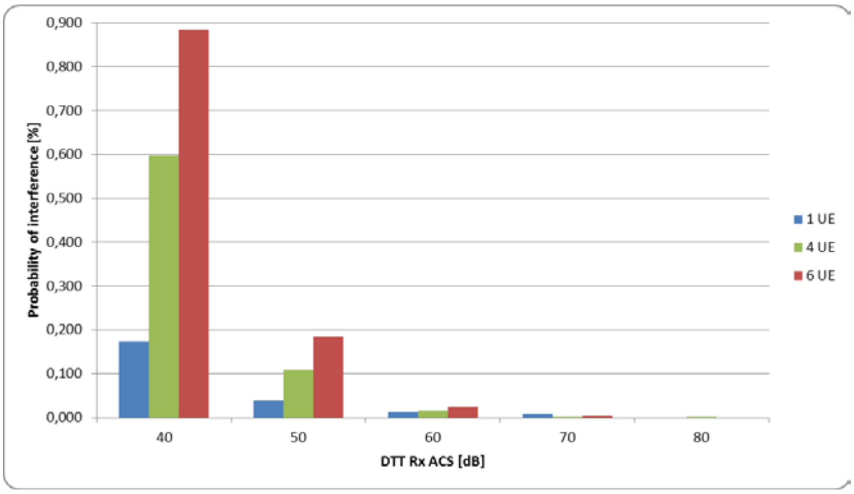
Study I: Sensitivity

All results are provided in the relevant EXCEL sheets attached below. ACLR values which differ from those used by other studies are marked in light orange.

The resulting IP's with no body loss (or higher UE antenna gain by 4 dB) are by a factor of 2 or more above the IP's that have been derived by other studies with a body loss of 4 dB, for the same set of common parameters (ACS, ACLR and number of UE). The variation of the IP, due to IMT UE emissions (OOB and IB), as a function of DTT receiver ACS for different IMT UE densities is shown in Figure 26, for an ACLR of 58 dB (plus a correction of 19 dB for 4 and for 6 UE).

FIGURE 26

Variation of the IP value for fixed DTT reception due to IMT UE emissions (OOB+IB) as a function of DTT receiver ACS, for UE ACLR of 58 dB (plus correction where appropriate), 70% indoor 30% outdoor UE, BL=0 dB



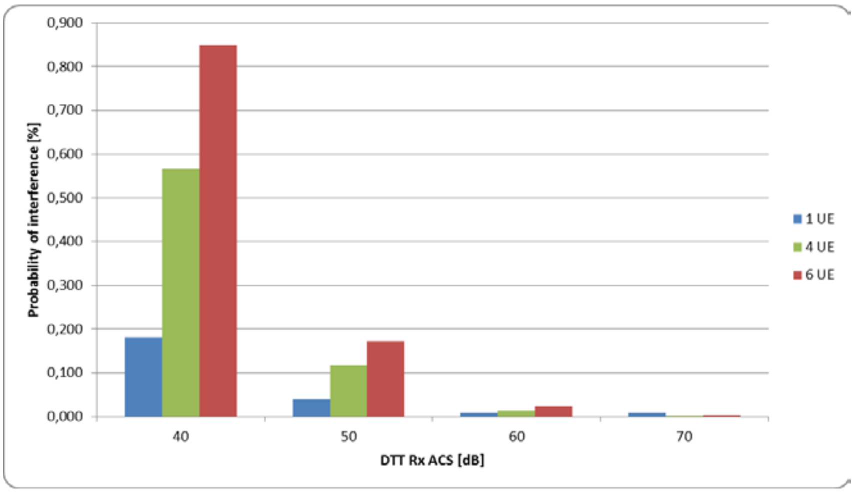
Results_BL0.xls

The resulting IP's, with 30% indoor and 70% outdoor UE and a body loss of 4 dB are well above the IP's that have been reported for other studies, up to a factor of 2 or more for the same set of common parameters (ACS, ACLR and number of UE's).

The variation of the IP, due to IMT UE emissions (OOB and IB) with 30% of UE's from indoor and 70% from outdoor, as a function of DTT receiver ACS for different IMT UE densities is shown in Figure 26, for an ACLR of 58 dB (plus a correction of 19 dB for 4 and for 6 UE's).

FIGURE 27

Variation of the IP value for fixed DTT reception due to IMT UE emissions (OOB+IB) as a function of DTT receiver ACS, for UE ACLR of 58 dB (plus correction where appropriate), 30% indoor 70% outdoor UE



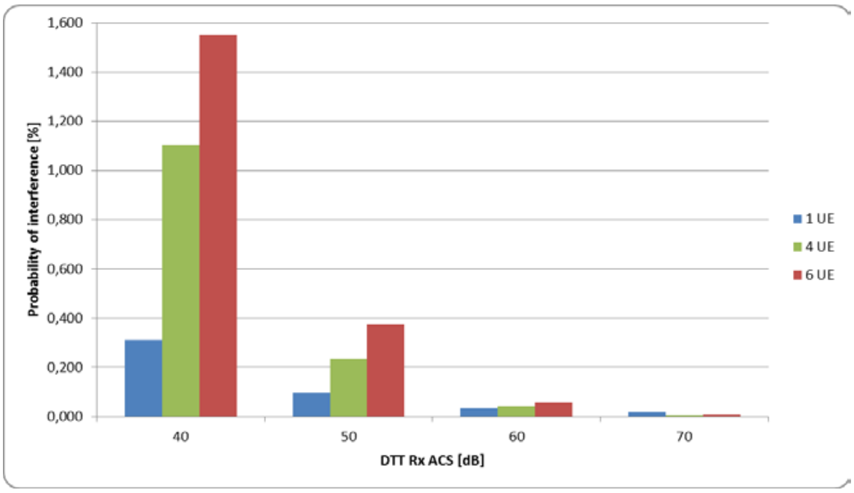
Results_IO3070.xls

The resulting IP's for 30% of traffic generated indoor, 35% outdoor with a body loss of 4 dB and lower antenna gain (–3 dBi) and the remaining 35% of traffic generated outdoor without body loss and an antenna gain of 0 dBi are by a factor of 3 or more above the IP's that have been reported from other studies, for the same set of common parameters (ACS, ACLR and number of UE).

The variation of the IP, due to IMT UE emissions (OOB and IB), as a function of DTT receiver ACS for different IMT UE densities is shown in Figure 28, for an ACLR of 58 dB (plus a correction of 19 dB for 4 and for 6 UE).

FIGURE 28

Variation of the IP value for fixed DTT reception due to IMT UE emissions (OOB+IB) as a function of DTT receiver ACS, for UE ACLR of 58 dB (plus correction), 30% indoor, 35% outdoor with BL=4 dB and antenna gain -3 dBi and 35% outdoor with BL=0 dB and antenna gain 0 dBi



Conclusions

The simulation results show that at DTT coverage edge the IP decreases with the increase of DTT receiver ACS, and the increase of IMT UE ACLR (decrease of UE OOBE level). Furthermore, the IP increases significantly with the number of active UE. The levels of IP are slightly larger than those for fixed reception, for the same parameters.

2.2.1.4 Scenario2b: Monte Carlo study – with time element

2.2.1.4.1 Description

For the simulation of packet-switched LTE and LTE-Advanced systems, there is need for a traffic model for the services supported by the system and a scheduler algorithm for the allocation of network resources (time and frequency) to different users. The selection of the traffic model and the scheduler in the aggressor network has a crucial impact on modelling the amount of interference caused to the victim network. Therefore, realistic assumptions for the traffic model and scheduler in the LTE network are key for a fair assessment of coexistence between LTE and other services.

Interference from an IMT network differs significantly from that which broadcast networks have been planned for. This new type of interference is due to user terminals transmitting intermittently from unpredictable locations. They may stay in one location, or may change their locations while transmitting. Their interference impact is limited to short distances. However, depending on the situation several terminals may interfere at the same time. If not suitably regulated, it will result in interference (which shows as visible impairments or “glitches”) to a TV picture occurring in an apparently random manner. How often this interference occurs will depend on the parameters adopted for IMT UE OoB emissions and the filtering on DTTB receivers.

The usual broadcast planning standard for DTTB reception is “quasi error free”, which is taken to mean one error event per hour, or less. For reference, a list of standards documents and regional agreements where this principle has been accepted is given below. The threshold of interference probability is derived on the basis that for DTT, visible picture impairment due to interference from LTE UE should be limited to less than one error per hour on any TV receiver. This is the practical effect of the accepted quasi-error free (QEF) target for DVB delivery of one uncorrected error event per transport stream per hour.

For the assessment of IMT UE interference into broadcast receivers the following assumptions are made. They refer to a single base station and its associated cell area.

The IMT cell structure is as follows:

1) It is assumed that a base station is located at the common central vertex of three contiguous hexagonal cells of range "R" (see Figure 29).

2) The cell area is subdivided into a grid of small areas, called pixels, of for example 100 m x 100 m. These pixels are the basic elements on which network planning for broadcast services is carried out including intra- or inter-service interference assessment.

3) The cell in which the simulations are carried out lies at the centre of 18 surrounding cells (see Figure 30). The UE in these 18 cells are also taken into the interference calculations. The least transmitter e.i.r.p. of each UE is calculated, using TPC, on the basis of the 20 base stations indicated in Figure 30.

4) The DTTB receiving locations within one pixel are represented by the centre of the pixel with a sufficiently large number (the number used in the paper is 100 000) random values of the wanted field strength taken from the Gaussian distribution around the median field strength received at the centre. These random values of wanted field strength are held fixed during the simulation in order to determine the temporal interference effects of the active UE in addition to the overall spatial interference effects.

5) During the simulations the UE will be placed randomly within the cells for each simulation event; a fixed number of UE per cell is used in each simulation. The simulations are repeated for 1, 2, 4, 6, 8 and 10 UE per cell.

Figures 29 and 30 sketch the geometrical layout of the DTTB coverage pixels and the IMT cell structure.

FIGURE 29

Geometrical layout of the DTTB coverage pixels with regard to the IMT cell structure

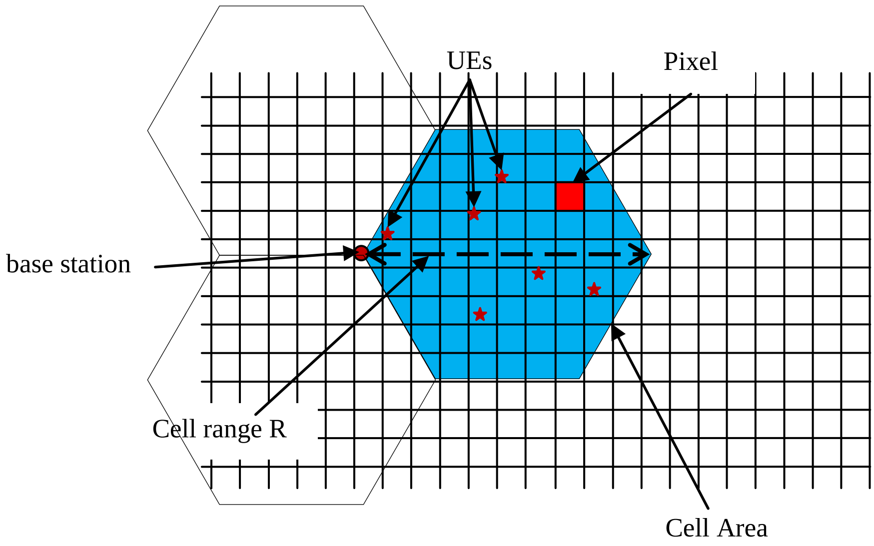
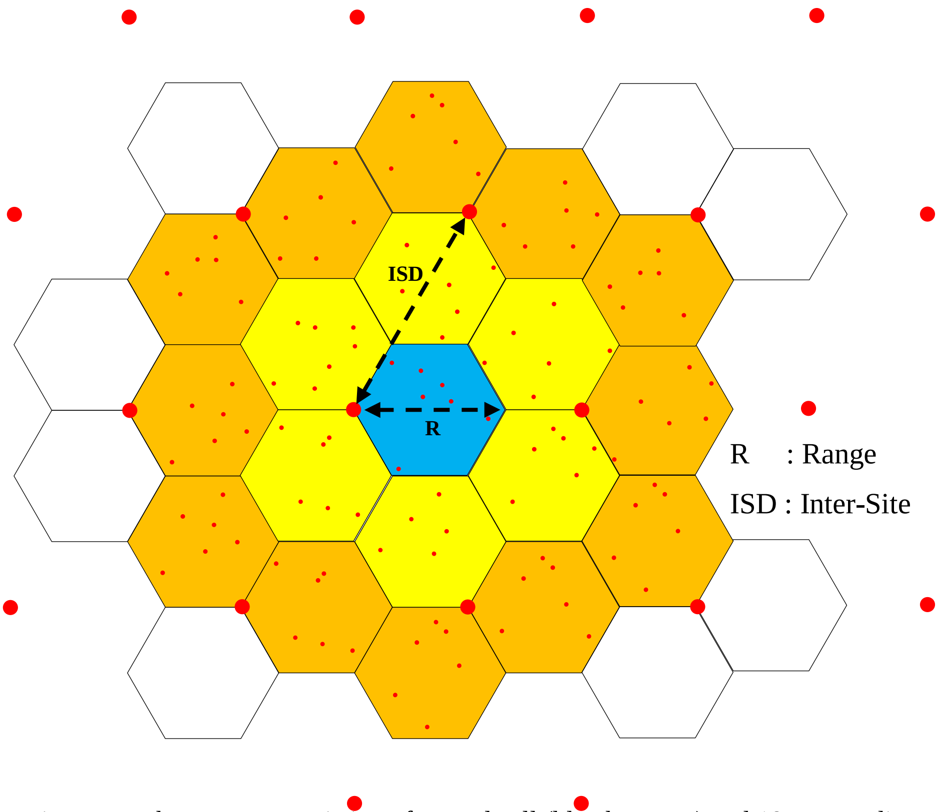


FIGURE 30

Geographical Layout of the IMT cell network



- The base station network structure consisting of central cell (blue hexagon) and 18 surrounding cells (yellow and orange hexagons)
- 23 tri-sector base stations (large red dots)
- The central cell (blue hexagon) contains the DTTB receive sites/pixels to be considered in the MC simulation.
- In each event, N UE are distributed randomly in each cell (small red points inside the cells); N ∊ {1, 2, ... 10}.

Note: the number of surrounding cells and tri-sector base stations may be increased if desired.

During the operation of the IMT network, moving/intermittent UE will be switched on within the cell area and connect to the base station to transmit and receive information during each event and at random positions.

2.2.1.4.2 Methods of calculation with formulas

[*RUS:*

The DTTB receiver recovery time, which typically may be taken as 1 second, needs to be considered to obtain the proper estimation of interference due to the fact that the resource block allocation time in MS is 10 ms or shorter, and in the next interval active users in the MS network may change.]

[EBU:

Monte Carlo simulation algorithm

The simulation process is structured in general terms as follows:

1) A particular IMT cell is selected at the centre of a network of IMT cells. The DTTB interference situation within this central cell is to be considered taking into account UE within this cell as well as UE in the surrounding cells (see Figure 30 [below] of the main text).

2) Select a pixel, within the central IMT cell area, to be considered. The pixel will be represented by its centre coordinates.

3) For the selected DTTB pixel, calculate (or stipulate, e.g. for a pixel located at the DTTB coverage edge) the median value of the wanted field strength (or the wanted receive power) at its centre. Generate a set of M random values of wanted field strengths (e.g. M = 100 000) around that median value according to a Gaussian distribution with standard deviation of 5.5 dB. These values represent a set of M DTTB receiver locations within the pixel and will be fixed for the entire Monte Carlo simulation.

4) Calculate the value of C/N for each DTTB receiver location. If $C/N \geq PR_{co}$, the DTTB location has acceptable reception. If $C/N < PR_{co}$, the DTTB location is not covered and it is not considered further. PR_{co} is the co-channel protection ratio for DTTB wanted signal interfered with by a noise-like unwanted signal. We are only interested in the DTTB locations which have acceptable reception in the presence of noise only, and we will determine how many of those DTTB locations are interfered with by the presence of active UE.

   In the presence of UE interference, let N_C represent the number of DTTB locations within the pixel where $C/(I+N) \geq PR_{co}$, and N_I represents the number of DTTB locations where $C/(I+N) < PR_{co}$. (For a detailed treatment of this protection criterion in the adjacent channel case see Appendix 4).

   If the area containing the set of DTTB receivers is the size of a pixel, the ratio N_C $/(N_I + N_C)$ is called the location probability (LP) of the pixel.

   An ‘interference counter’ for each of the DTTB receiver locations is initialized. That is, for each DTTB receiver location, the interference counter is set equal to 0 if $C/N \geq PR_{co}$ and is set equal to E_{max} if $C/N < PR_{co}$. E_{max} is the number of events that will be used in the simulation; those DTTB receiver locations with $C/N < PR_{co}$ will be interfered with during each event because $C/N < PR_{co}$ holds for every event; these locations do not need to be explicitly considered further during the simulation.

5) The simulation will be carried out for a large number of events.

6) The number of active UE per cell per event is either a fixed number (e.g. 6 per cell) or could be varied from event to event, and from cell to cell, according to some specific traffic model.

   For event “i” there will be a set of active UE attributed to each cell in the cell network. The locations of the active UE are chosen randomly for this event using a uniform spatial distribution of UE over the cell area.

7) The transmit power for each active UE is calculated as a function of its position relative to the base stations, taking into account the propagation model, base station receive antenna discrimination, body loss, etc., and the transmit power control mechanism (TPC)[17]. The algorithm for TPC is described in Appendix 5. The smallest UE transmit power calculated for each base station is the value used in the interference calculation.

8) For the active UE during the event “i”, the propagation loss, receive antenna discrimination, etc., is calculated relative to each DTTB receiver location (i.e. those locations for which $C/N \geq PR_{co}$). The power variation due to the random Gaussian behaviour of the propagation is taken into account in determining the interfering power; wall loss and wall-loss standard deviation is taken into account in the case of indoor reception or transmission.

9) The power sum of the interference contributions to each DTTB receiving location from all active UE during event “i” is calculated, leading to a C/(I+N) for each DTTB receiver location for the event “i”.

10) For event “i” a vector of C/(I+N) values is stored corresponding to the DTTB receiving locations.

For event “i” the counters are increased by 1 for those DTTB receiver locations for which $C/(I+N) < PR_{co}$.

11) Steps 6 to 11 are repeated for each event.

12) The quotient of all interference events by the product of the number of DTTB receiver locations and the number of events yields the IP (Interference Probability)[18] for the pixel or set of pixels.

13) The percentage of interference events, IE%, is calculated for each DTT location. Depending on an agreed acceptable threshold, $IE\%_{threshold}$, for IE%, the percentage of DTT locations, LP%, where $IE_{threshold}$ is not exceeded is the resulting location probability, LP_{UE}, taking UE interference into account. The difference between the original LP and LP_{UE} is the degradation in reception location probability Δ_{RLP}:

$$\Delta_{RLP} = LP - LP_{UE}.$$

Examples of results of this Monte Carlo methodology are presented in the Appendix 6.

The relationship between PRco, PRadj, ACIR, ACLR, ACS

The criterion for DTTB compatibility with UE interference is

$$C/(I \oplus N) \geq 21 \text{ dB} \qquad (6)$$

“21 dB” is the co-channel protection ratio (PR_{co}) and ⊕ means the power sum of I (the interference) and N (the noise).

[17] The parameters for the TPC algorithm must be specified according to the IMT UE modelling; e.g., the percentage of UE using maximum transmit power.

[18] The IP for the simulation is the average IP for all the time slots and locations in the simulation. Although IP has no significance for protecting broadcasting, it is calculated as a means to compare with simple MC simulation methods which do not take into account the time element of the mobile UE interference situation vis-à-vis broadcast reception.

The interference of a single UE is specified as:

$$I = P_{UE} – PL$$

with:

P_{UE} = the UE e.i.r.p., and

PL = path loss (including antenna discrimination, etc.).

If there are “n” UE interference sources, then the total interference, $\Im$, is the power sum of the individual interferences of the UE:

$$I_T = \oplus I_i$$

where:

$\oplus$ represents power sum of the interference contributions, I_i with i = 1, 2, ..., n.

If the interference is due to UE in an adjacent channel, it is necessary to take the adjacent channel interference ratio, ACIR[19], into account, so that the equation 6 becomes:

$$\frac{C}{(\ \mathrm{I_T}\ \text{-}\ \mathrm{ACIR}) \oplus\ \mathrm{N}} \geq PR_{co} \qquad (7)$$

With suitable mathematical rearrangement, the term PR_{co} can be brought to the left hand side of equation 7:

$$\frac{C}{(\ \mathrm{I_T}\ \text{-}\ \mathrm{ACIR} + PR_{co}) \oplus\ (\mathrm{N} + PR_{co})} \geq 0 \qquad (8)$$

There is a relationship between the co-channel protection ratio, PR_{co}, the adjacent channel protection ratio, PR_{adj}, and ACIR:

$$\mathrm{ACIR} = PR_{co} – PR_{adj}. \qquad (9)$$

Then equation 8 can be expressed in terms of the co-channel and adjacent channel protection ratios:

$$\frac{C}{(\ \mathrm{I_T} + PR_{adj}) \oplus\ (\mathrm{N} + PR_{co})} \geq 0 \qquad (10)$$

The terms $(\ \mathrm{I_T} + PR_{adj})$ and $(\mathrm{N} + PR_{co})$ are referred to as the ‘interference nuisance field’ and the ‘noise nuisance field’, respectively.

The relationship between the ACIR, the UE ACLR (adjacent channel leakage ratio), and the DTTB ACS is:

$$10^{-ACIR/10} = 10^{-ACLR/10} + 10^{-ACS/10} \qquad (11)$$

Knowing the ACLR, ACS and PR_{co}, then ACIR and PR_{adj} can be calculated using equations 9 and 11.

[19] ACIR effectively reduces the UE interference impact for an interference source in an adjacent channel.

Technical parameters

(Editorial note: This section can be common with scenario 2a and may be moved in a new common section)

The technical parameters used are described in the following Tables 18 to 23.

TABLE 18

DTTB reception parameters

	Fixed outdoor DTTB	Portable indoor DTTB
Receiver height	10 m	1.5 m
Median wall loss	-	11 dB
Standard deviation of the wall loss σ_{WL}	-	6 dB
Standard deviation of the path loss σ_{prop}	5.5 dB	5.5 dB
Noise floor	-98.17 dBm	-98.17 dBm
C/N	21 dB	19 dB
95% rx power level at rx	-68.12 dBm	-65.78 dBm
DTTB antenna gain (including feeder loss)	9.15 dBi	2.15 dBi
DTTB antenna pattern	Recommendation ITU-R BT.419	Omni-directional

TABLE 19

UE interference parameters

Frequency	708 MHz
Transmit power	-40 dBm to 23 dBm
Channel Bandwidth	10m
Antenna gain G_{UE}	-3 dB
Antenna pattern	Omni-directional
Body loss	4 dB
TPC settings	$\gamma = 1$; P_{x_ile} = 122 dB (see Appendix 3)
Propagation and path loss standard deviation σ_{UE_prop}	Modified Hata as defined in Report ITU-R SM.2028
UE height	1.5 m
Indoor usage	70%
Outdoor usage	30%

TABLE 20

Base station parameters

Base station height	30 m
Base station antenna	Tri-sector (Rec. ITU-R F.1336, see Appendix 4)
Antenna gain G_{BS}	15 dBi
Feeder loss	3 dB
Propagation, including σ_{UE_prop}	Modified Hata as defined in Report ITU-R SM.2028
Base station cell structure	Hexagonal sectors
Base station network structure	19 sectors
Urban environment	Cell range = 1 km, tilt = 6°
Suburban environment	Cell range = 2 km, tilt = 4°

Rural environment	Cell range = 8 km, tilt = 2°

TABLE 21

MC simulation parameters

# Events	250 000
Pixel distribution	Random over the central sector
# DTTB points within pixel	100 000
DTTB median field within pixel	95% location probability
# Base station sectors	19
# UE/sector	1, 2, 4, 6, 8, 10
UE distribution	Random over each sector
ACS level	55 dB to 80 dB in 5 dB steps
ACLR level	40 dB to 80 dB in 5 dB steps
Interference Event (IE%) threshold	0.028%
Acceptable degradation in Location probability (ΔRLP%)	1%

TABLE 22

Interference from UE Indoor to DTTB outdoor

Wall loss	11 dB
Standard deviation of the wall loss σ_{WL}	6 dB

TABLE 23

Interference from UE Indoor to DTTB indoor

Wall loss	11 dB
Standard deviation of the wall loss σ_{WL}	6 dB
$dist_{sep} \leq 3$ m	0 walls (same room)
3 m < $dist_{sep} \leq 10$ m	1 wall (different rooms, same building)
10 m < $dist_{sep}$	2 walls (different rooms, different buildings
Indoor usage	70%
Outdoor usage	30%

The protection of the DTTB coverage edge was considered. That is, in the presence of noise only, the location probability within a coverage edge pixel is 95 %.

The simulation was carried out in such a manner that the DTTB pixel could be randomly situated within the central sector of an LTE network, i.e. close to, or far from the base station, or anywhere in between (see Figure 29).

The percentage of the events for which each ‘point’ was interfered (called the “IE%” value) was calculated.

In order to maintain the integrity of DTTB networks to the target of one error per hour, an error rate of 0.00028, which means 0.028%, or lower, is required. Hence, an interference criterion of IE% = 0.028% was chosen as the upper limit of acceptable interference[20].

The corresponding degradation of location probability, Δ_{RLp}, was calculated. Interference is considered acceptable if Δ_{RLP} = 1% (i.e. a degradation of LP from 95% to 94%).

Illustrative example

A simple illustration of of the service matrix for the case of broadcast, noise and UE interference is given in Table 24. In vertical direction the locations in the pixel are given while horizontally the time slots are shown. The last column contains the time probability of interference for each location

TABLE 24

Simple illustration of service matrix for the case of broadcast, noise and UE interference

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	P
L1	0	0	0	0	0	0	1	0	0	0	0.1
L2	1	0	0	1	0	0	0	0	0	0	0.2
L3	0	0	0	0	0	0	0	0	0	1	0.1
L4	0	0	0	0	1	0	0	1	0	0	0.2
L5	0	0	1	0	0	0	0	0	0	0	0.1
L6	0	0	0	1	0	0	0	0	0	0	0.1
L7	0	1	0	0	0	0	0	0	0	1	0.2
L8	1	1	1	1	1	1	1	1	1	1	1
L9	0	0	0	0	1	0	0	0	0	0	0.1
L10	0	0	0	0	0	0	1	1	0	0	0.2
L11	0	0	0	0	0	0	0	1	0	0	0.1
L12	0	0	0	0	0	1	0	0	0	0	0.1
L13	0	0	0	0	0	0	0	0	0	0	0
L14	1	0	0	0	0	0	0	0	0	0	0.1
L15	0	0	0	1	0	1	0	0	0	0	0.2
L16	0	0	0	0	0	0	1	0	0	1	0.2
L17	1	0	0	0	0	0	0	0	1	0	0.2
L18	0	0	0	0	0	1	0	0	1	0	0.2
L19	0	1	0	0	0	0	0	0	0	1	0.2
L20	0	0	0	0	0	0	0	0	0	0	0

– Assuming for example a threshold of 0.1, i.e. 10%, for P (which represents the % time of interference for each location in the last column above, called also IE%), the additional interfered locations ΔRLP compared to the Situation with Noise alone is

[20] An interference level of 1 second per hour is considered to be acceptable. 1 second per hour is equivalent to IE% = 0.028%.

calculated as the number of red cells in the last column, except for L8 which is due to Noise alone, over the total number of cells in this column: 9/20=0.45, i.e. 45% of the locations.

– For purpose of comparison, the IP is calculated as the number of pink cells in the whole table, without the last column, over the total number of cells in the table: 36/200=0.18, i.e. 18%. This value cannot be assimilated to ΔRLP.

Note: These values are given only as a simple illustration and do not correspond to a real simulation.]

2.2.1.4.3 Calculations

[*EBU:*

The full set of results is given in the embedded Excel file. Results of calculation of Δ_{RLP}

% for IE=0.028% are given. Results of calculation of IP% ([as explained in Annex ###1### of this contribution]) are also given for information.

IP&RLP_results_ACLR-JTG-Oct13.xlsx

The ACS values used in the simulations ranged from 55 dB to 80 dB. The ACLR values used in the simulations ranged from 40 dB to 80 dB. It was found that an ACS = 80 dB and an ACLR in the range 65 to 80 dB would be necessary to achieve Δ_{RLP} = 1% for IE% = 0.028% for almost all the configurations (different reception modes, environments and number of active UE), with the following exceptions:

1) For DTTB fixed roof top reception in rural environment with 10 active UE (the Δ_{RLP} could not be brought below 1.5%);

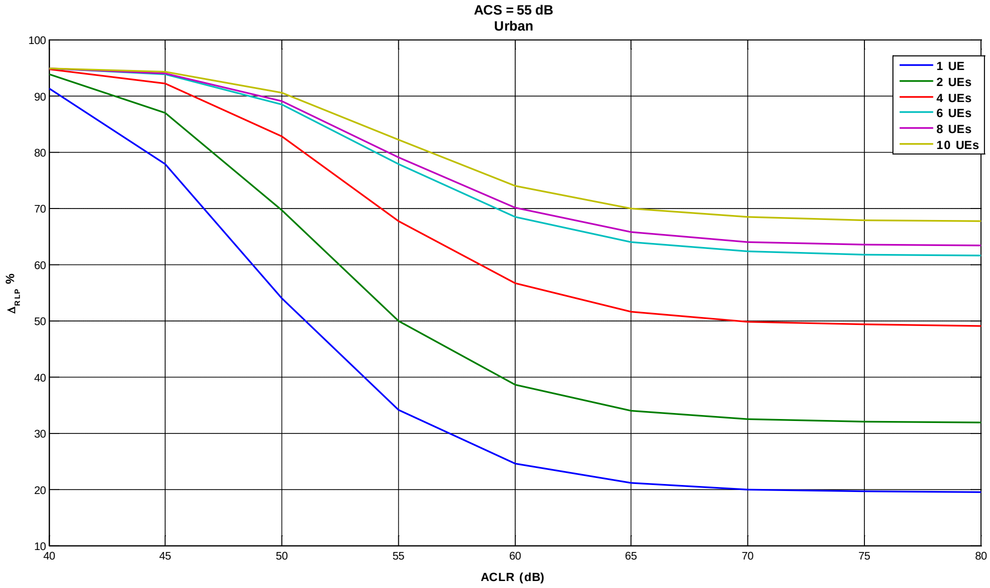
2) For DTTB portable indoor reception in urban environment with 8 and 10 active UE (the Δ_{RLP} could not be brought below 1.3% and 2.4% respectively).

Overall, taking into account the results for the different configuration, we refer to the urban environment to derive the requirements on the UE ACLR.

Figure 30 shows a graphic representation of the results (ΔRLP% as a function of the UE ACLR) for ACS=55 dB and for 1, 2, 4, 6, 8 and 10 active UE.

FIGURE 30

ΔRLP% as a function of the UE ACLR for ACS=55 dB and for 1, 2, 4, 6, 8 and 10 active UE



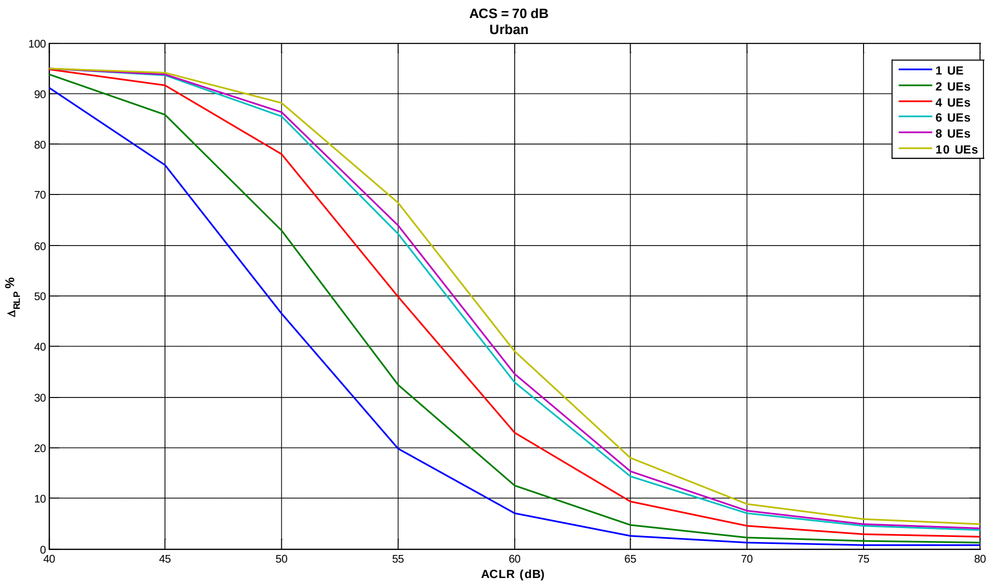
Study	EBU	oct.13										
Scenario	Urban	Fixed DTT	IE% = 0.028%									
IMT Channel BW (MHz)		10										
ACS (dB)	55											
# active UE	1		2		4		6		8		10	
ACLR (dB)	**IP%**	**DRLP %**	**IP%**	**DRLP %**	**IP%**	**DRLP %**	**IP%**	**DRLP %**	**IP%**	**DRLP %**	**IP%**	**DRLP %**
40	0.279	91.3	0.523	93.8	1.074	94.7	1.61	94.9	2.155	94.9	2.693	94.9
45	0.146	77.8	0.27	87	0.567	92.2	0.854	93.8	1.135	94	1.427	94.3
50	0.076	53.9	0.14	69.6	0.3	82.8	0.453	88.5	0.595	89.1	0.753	90.5
55	0.044	34.1	0.081	50	0.177	67.7	0.268	77.8	0.348	79.1	0.443	82.1
60	0.032	24.5	0.059	38.6	0.129	56.7	0.195	68.5	0.252	70.1	0.321	74
65	0.027	21.1	0.051	34	0.112	51.6	0.17	64	0.219	65.7	0.279	69.9
70	0.026	19.9	0.049	32.5	0.106	49.8	0.161	62.3	0.208	64	0.265	68.4
75	0.025	19.6	0.048	32	0.105	49.3	0.159	61.7	0.204	63.5	0.26	67.8
80	0.025	19.5	0.048	31.8	0.104	49.1	0.158	61.6	0.203	63.3	0.259	67.7

It can be seen that with such a poor ACS value a high percentage of locations would suffer more than 1 visible error (of 1 second) per hour. The improvement of ACLR would help but would not be enough.

By improving the ACS from 55 to 70, Figure 31 shows that the results improve significantly. However, the target level of ΔRLP% of less or equal than 1% could not be reached for all the considered configurations.

FIGURE 31

ΔRLP% as a function of the UE ACLR for ACS=70 dB and for 1, 2, 4, 6, 8 and 10 active UE

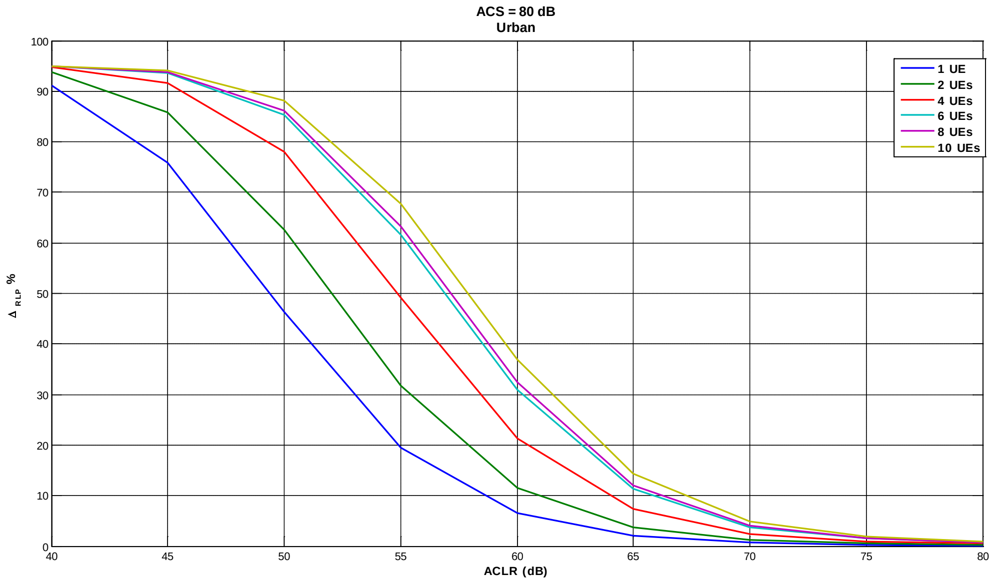


ACS (dB)	70											
# active UE	1		2		4		6		8		10	
ACLR (dB)	**IP%**	**DRLP %**	**IP%**	**DRLP %**	**IP%**	**DRLP %**	**IP%**	**DRLP %**	**IP%**	**DRLP %**	**IP%**	**DRLP %**
40	0.274	91.1	0.514	93.7	1.056	94.7	1.583	94.9	2.119	94.9	2.649	94.9
45	0.138	75.9	0.254	85.9	0.535	91.7	0.806	93.6	1.071	93.8	1.347	94.1
50	0.063	46.6	0.115	62.9	0.249	78.1	0.376	85.5	0.493	86.3	0.625	88.2
55	0.026	19.9	0.049	32.5	0.106	49.8	0.161	62.3	0.208	64	0.265	68.4
60	0.01	7.1	0.02	12.6	0.044	23	0.066	33	0.083	34.6	0.107	39.1
65	0.004	2.6	0.008	4.8	0.019	9.3	0.028	14.4	0.035	15.3	0.045	18
70	0.002	1.3	0.004	2.3	0.01	4.5	0.014	7.1	0.018	7.5	0.023	8.9
75	0.001	0.8	0.003	1.5	0.007	2.9	0.01	4.6	0.012	4.9	0.016	5.9
80	0.001	0.7	0.002	1.3	0.006	2.4	0.008	3.8	0.01	4.1	0.014	4.9

With ACS=80 dB Figure 32 shows that the target of limiting the ΔRLP% to 1% can be reached. This would require different ACLR values depending on the number of active UE.

FIGURE 32

ΔRLP% as a function of the UE ACLR for ACS=80 dB and for 1, 2, 4, 6, 8 and 10 active UE



ACS (dB)	80											
# active UE	1		2		4		6		8		10	
ACLR (dB)	**IP%**	**DRLP %**	**IP%**	**DRLP %**	**IP%**	**DRLP %**	**IP%**	**DRLP %**	**IP%**	**DRLP %**	**IP%**	**DRLP %**
40	0.274	91.1	0.514	93.7	1.055	94.7	1.583	94.9	2.118	94.9	2.647	94.9
45	0.137	75.8	0.254	85.9	0.534	91.7	0.805	93.6	1.069	93.7	1.345	94.1
50	0.062	46.3	0.115	62.6	0.247	78	0.374	85.3	0.489	86.2	0.621	88.1
55	0.025	19.5	0.048	31.8	0.104	49.1	0.158	61.6	0.203	63.3	0.259	67.7
60	0.009	6.5	0.018	11.6	0.04	21.3	0.061	30.9	0.077	32.5	0.099	36.9
65	0.003	2.1	0.007	3.8	0.015	7.3	0.022	11.4	0.028	12.1	0.036	14.3
70	0.001	0.7	0.002	1.3	0.006	2.4	0.008	3.8	0.01	4.1	0.014	4.9
75	0	0.3	0.001	0.5	0.002	0.9	0.003	1.5	0.004	1.6	0.006	1.9
80	0	0.1	0	0.2	0.001	0.5	0.002	0.7	0.002	0.8	0.003	0.9

Table 25 shows the detailed figures and the ACLR figures which correspond to ΔRLP% of exactly 1% for three numbers of active users:

1 active user corresponds to the least stringent case (lower probability of impact on DTTB when only one UE is active in an IMT cell).

2 active users corresponds to a more stringent case as the probability of impact increases, but in the same time each of UE uses half of the IMT channel (50% of the resource blocks).

6 active users which corresponds to a further stringent case. However, it is taken as a compromise in the range between 3 and 10 UE.

TABLE 25

ACS (dB)	80					
# active UE	1	2	4	6	8	10
ACLR (dB)	**ΔRLP %**	**ΔRLP %**	**ΔRLP %**	**ΔRLP %**	**ΔRLP %**	**ΔRLP %**
40	91.1	93.7	94.7	94.9	94.9	94.9
45	75.8	85.9	91.7	93.6	93.7	94.1
50	46.3	62.6	78	85.3	86.2	88.1
55	19.5	31.8	49.1	61.6	63.3	67.7
60	6.5	11.6	21.3	30.9	32.5	36.9
65	2.1	3.8	7.3	11.4	12.1	14.3
69	**1**					
70	0.7	1.3	2.4	3.8	4.1	4.9
72		**1**				
75	0.3	0.5	0.9	1.5	1.6	1.9
78				**1**		
80	0.1	0.2	0.5	0.7	0.8	0.9

As expected and explained in Annex [1], the IP% values calculated for each case and shown in the embedded Excel file are very low. However they do not inform about the extent of the impact in terms of percentage of DTTB locations.]

2.2.1.4.4 Results

[*EBU (chapter name Proposals):*

Based on these results and with a target of ΔRLP of 1% for IE% = 0.028%, the following characteristics of DTTB adjacent channel selectivity and of UE adjacent channel leakage ratio and Out-of-band emission limits are proposed.

DRLP=1% for IE% = 0.028%		
IMT Channel Bandwidth (MHz)	10	
Target ACS of the DTTB receiver	80	
	ACLR (dB)	OOBE (dBm/8 MHz)
UE using the full 50 RB of the 10 MHz uplink channel (corresponding to one active UE per cell)	69	-46
UE using the lowest 25 RB of the 10 MHz uplink channel (corresponding to two active UE per cell)	72	-49
UE using the lowest 17 RB of the 10 MHz uplink channel (corresponding to three active UE per cell)	78	-55

The proposal is illustrated in Figure 33 below:

FIGURE 33

EBU proposal for the OOBE limits of IMT UE in the frequency below 694 MHz

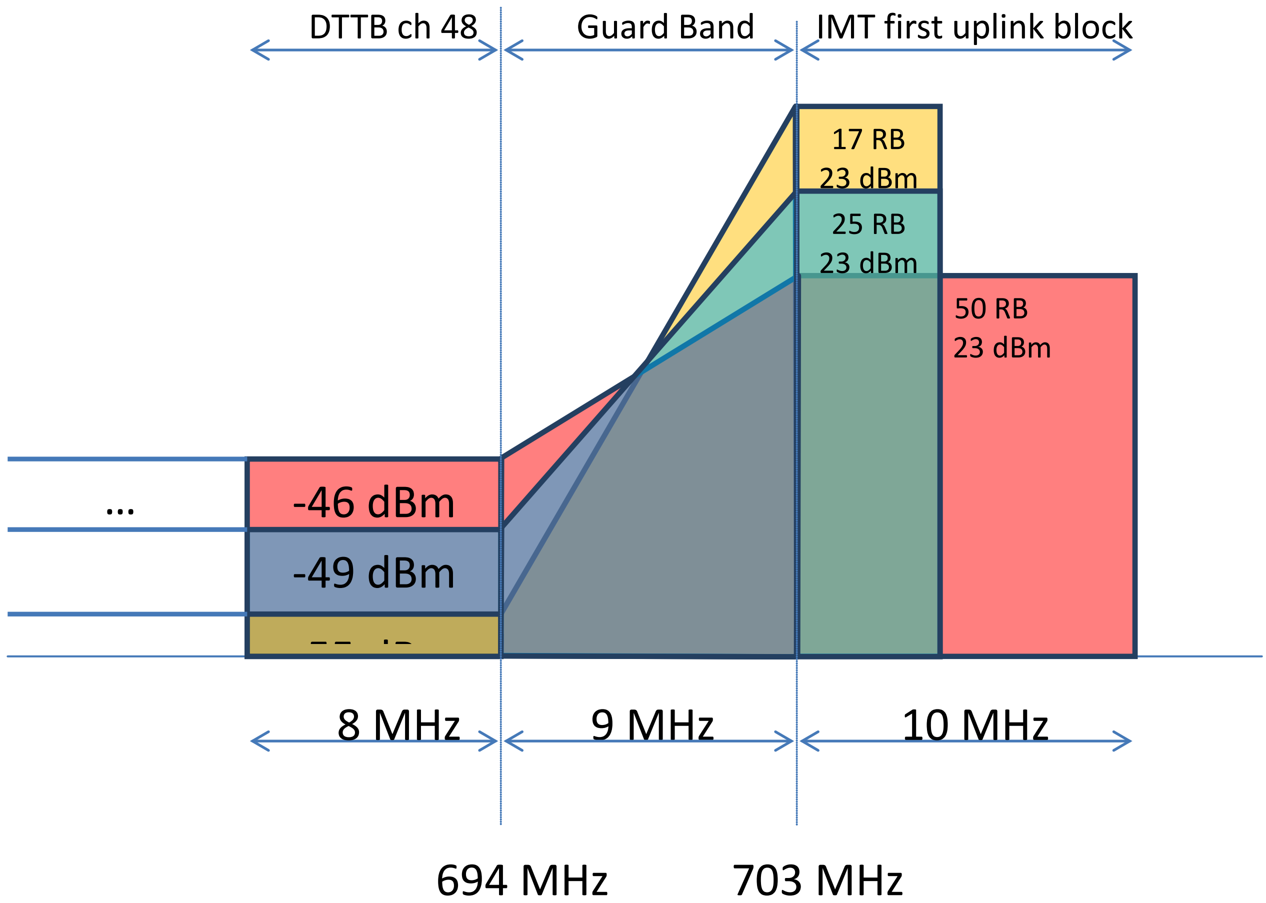


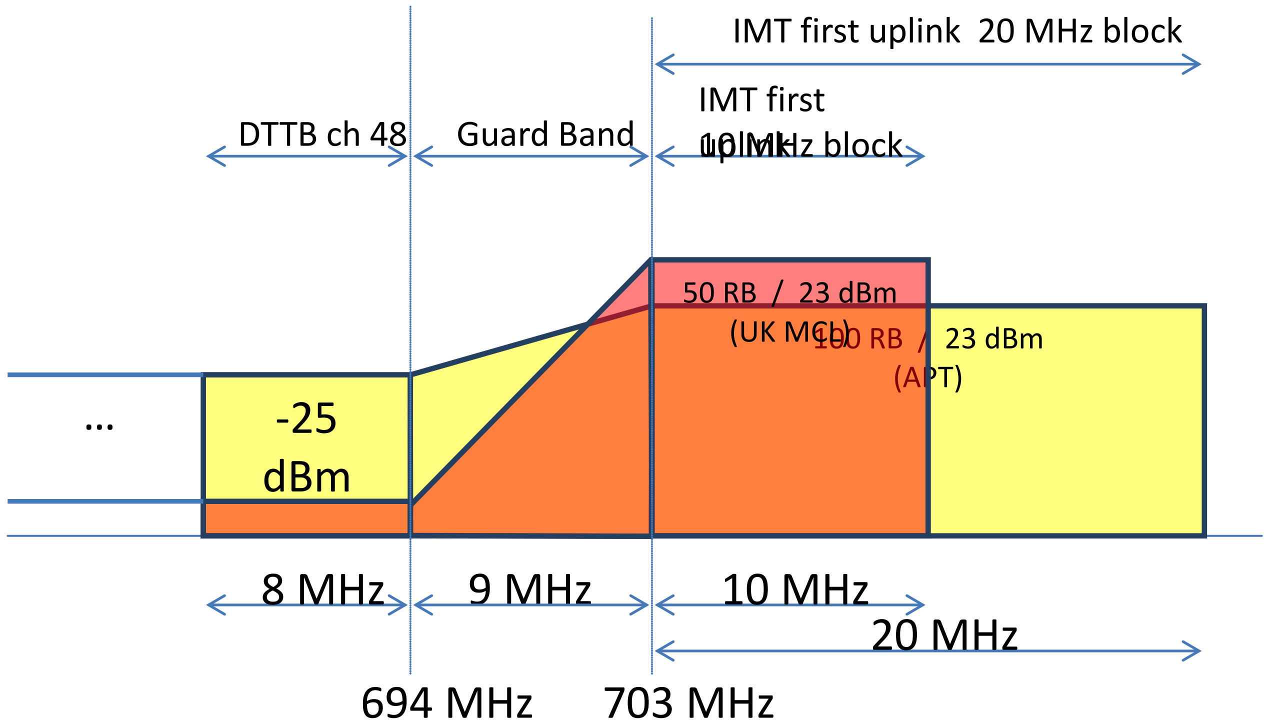
Figure 34 below shows a comparison of the current proposals submitted [to the JTG 4-5-6-7].

1) the APT proposal: an OOBE limit of –25 dBm/8 MHz for a UE using the full 100 resource blocks of a 20 MHz channel located above 703 MHz;

2) the UK proposal: and OOBE limit of –56 dBm/8 MHz for a UE using the full 50 resource blocks of a 10 MHz channel located above 703 MHz.

FIGURE 34

EBU proposal for the OOBE limits of IMT UE in the frequency below 694 MHz



As can be seen from Figures 33 and 34 above, the EBU proposal represents a compromise between the two current proposals (APT and UK) by taking into account the statistical difference in impact due to various number of active UE in an IMT cell.]

2.2.1.5 [Scenario 2c: Alternative Approach for Interpreting the Monte Carlo Simulation Results/ Considerations on the time aspect in the assessment of interference]

As the Monte Carlo modelling predicts the IP at one instant in time, to assess interference in a time window, a post processing can be performed by converting the IP into a probability which would better reflect the impact of interference on the TV viewer.

If IP is derived from the Monte Carlo simulations and *C* is the number of network state changes during a certain time window (TW), assuming that two consecutive network states are independent (not correlated), then the probability *P* of TV viewer observing LTE UE causing at least one harmful interference to DTTB reception is given by:

$$P = 1 - (1 - IP)^C$$

Such probability P could be understood as the probability of having a disruption when watching TV during a given time window. This time window should reflect what is considered acceptable for the TV viewer.

C could be calculated as follows

$$C = TW/DT$$

Where :

TW : time window;

DT : average "decorrelation" time describing the uncorrelated changes of all IMT UE.

"Decorrelation" time depends first on the services used by the IMT user and secondly on the movement. It is a measure to indicate un-correlated interference events.

A time window of one hour is a representative watching period taking into account the quality of service criterion.

2.2.1.5.1 Implications of post processing

The method for post-processing of Monte Carlo modelling results uses a relatively simple formula, however the probability P that it calculates may not provide an accurate reflection of reality. The formula assumes that different/consecutive time windows are all independent and uncorrelated. This inherent assumption is not consistent with real word scenarios.

The use of multiple multiplications in the formula will compound any possible errors in the IP% value that is calculated using “static” Monte Carlo modelling (which will lead to over-estimation of the interference probability). This compounding will result in inaccurate values of P being calculated. If the value of IP is pessimistic/conservative and the value of C is large, then the value of P that is calculated will be grossly exaggerated.

Monte Carlo modelling (such as SEAMCAT) is used to calculate the probability of interference from an IMT network to DTT receivers under certain assumptions. However, many of the input parameters, interference scenarios and assumptions used in Monte Carlo simulation studies have been conservative/pessimistic:

– They usually assume that the network is heavily loaded or fully loaded (including in the uplink).

– Monte Carlo simulations were performed for the extreme DTT receiver location, i.e. the DTT coverage edge. The Interference Probability is naturally substantially lower for locations within the DTT coverage area, where the DTT field strength is higher than at the coverage edge.

– All interference probability results refer to the highest DTT channel 48 (686-694 MHz), i.e. the closest channel to the lowest IMT channel (703-713 MHz). All other DTT channels suffer far less interference from IMT (higher attenuation on OOB emissions) and present lower interference probability. So, in practice, this worst case combination will happen very seldom, as majority of DTT receivers will be receiving on other frequencies below channel 48, and not all IMT UE will be transmitting on the lowest IMT channel.

– The OOBE attenuations used in some Monte Carlo simulations provided by partial LTE RB allocation have been chosen from the extreme situation when UE has its RB allocation at the lower edge of band 694-790 MHz. However, that is the most pessimistic case as for example, if all RB (at given channel BW) are shared by 6 UE, only 1/6 would have that lowest attenuation to OOBE according to the value used in MC simulations and 5/6 would have higher attenuation and cause less interference.
– The OOBE used in the Monte Carlo simulations is based on the extreme case design target from an interference point of view. In practice for the UE to meet the OOBE limit, the band selection duplex filter is assumed to provide minimum suppression over the DTT frequencies, while due to production tolerances and operating temperature drift, the typical suppression is significantly higher. Also the UE transmitter ACLR must be met in extreme operating conditions, whereas in typical conditions the ACLR would be better. As the design target of a UE transmitter is that the extreme operating conditions has to be met, in reality a significant majority of the UE operate in normal conditions and perform better.

The extrapolation of static Monte Carlo modelling results into the time domain by means of post processing in [method 2C] will inevitably lead to the multiplication/double-counting of conservative/pessimistic parameters and scenario assumptions used in Monte Carlo simulations studies. This will ultimately result in inflated P values. In order to obtain realistic results, such analysis would need to utilise a more complex “dynamic” network simulation, in combination with more realistic traffic model(s).

2.2.1.5.2 Post processing: Further analytical discussion [567]

As demonstrated in 2.2.1.5, the formula covering the proposed post processing assumes that different/consecutive time windows are all independent and uncorrelated. As this is not the case in the real world, the methodology may lead to unrealistic conclusions.

It is to be observed that the Monte Carlo simulation, gives the time average of a particular realization of a stochastic process, so if we consider how the fraction of time is taken into consideration when deriving the probability of interference, we see that:

If *i* states have caused interference with probability of PT, during the overall observation period of CxDT, the interference occurred

$$\frac{i \times DT}{C \times DT} = \frac{i}{C} \text{ of the time.}$$

Consequently, the probability when i *states cause interference is thus given by*:

$\binom{C}{i}\frac{i}{C}IP^{i}(1-IP)^{C-i}$, *where* i takes the values from 1 to C, and $\binom{C}{i}$ are the binomial coefficients (C choose i)

Therefore the total probability of interference is

$$P = \sum_{i=1}^{C}\binom{C}{i}\frac{i}{C}IP^{i}(1-IP)^{C-i} = IP \qquad (12)$$

So, (12) is basically saying that, the probability of interference occurred during a certain period, is actually equal to IP, in other words, that the time average over the observation period equals exactly the probability of interference for each state.

Example for illustration:

If IP = 0.1%, and the observation period is 1 hour, then [2] establishes that during this 1 hour period, 0.1% of the time or around 3.6 seconds (may or may not be consecutive), you may experience interference.

However, this is not happening by coincidence as the theorem of the Strong Law of large Numbers **[2] has already predicted such behaviour** as the Monte-Carlo simulation methodology is exactly based on the theorem of the law of large numbers.

This analysis of post processing shows that:

– the Monte-Carlo simulation tool has already taken into account the time element in such a way that the probability of interference obtained from the Monte-Carlo simulation represents the average probability of interference over time and therefore does not depict temporal correlation.

[Ed note: Idea split text to calculations and results respectively.]

The following table gives the calculated probability P for different IP/DT/TW.

TABLE 26

Calculation of P (observing at least one interference during the time window TW

OOBE(dBm/8 MHz)	IP (%)	TW (ms)	DT (ms)	C	P (%)
-33	0,01683%	3600000	193548	18,6000372	0,31%
	0,01048%	3600000	193548	18,6000372	0,19%
	0,00105%	3600000	193548	18,6000372	0,02%
	0,01683%	1800000	193548	9,3000186	0,16%
	0,01048%	1800000	193548	9,3000186	0,10%
	0,00105%	1800000	193548	9,3000186	0,01%
	0,01683%	60000	193548	0,31000062	0,01%
	0,01048%	60000	193548	0,31000062	0,00%
	0,00105%	60000	193548	0,31000062	0,00%

It can be seen from Table 26 that the P depends TW, IP, and DT. For UE OOBE level at –33 dBm/8 MHz, the calculated probability P (probability observing at least one interference) is quite small, much smaller than that calculated for the definition of QEF.

[GSMA Doc. 4-5-6-7/546, Ed. note the deleted text will have to be redrafted for another chapter, not touching a specific study.]

[Ed. note: Deleted text below to be taken into account for new xx section further down.]

[

Ed. note: has to be revised for readability and inter-text consistency. Content on the reasoning behind TW, has to be checked for Region 1 applicability. Viewing is continues (also for commercials).

2.2.1.5.3 Elements related to DT-parameter

"Decorrelation" time depends first on the services used by the IMT user and secondly on the movement. It is a measure to indicate un-correlated interference events. Even if the DT parameter is yet to be more clearly defined, most likely the value of DT is depending on the actual service/application what UL UE is associated with. For example, a static UL UE (like a tablet in the home) can do Skype videophone, lasting over an hour. The case is rather different than with a smartphone that is in high speed train and is just updating a Facebook-server with one TCP/IP Ack. This can in the end mean a huge variation for DT value, depending on the used application.

Related to DT-parameter, one element describing it is the usage time of different mobile Apps (and how many Apps there are in each category type). From http://readwrite.com/2012/01/17/study_average_app_session_lasts_about_1_minute#awesm=~onPJdd7iIEB4dm below table can be found.

Category	Apps	Avg. usage	Examplary Apps
unknown	4,823	36.37 sec	-
Finance	307	37.01 sec	Mint.com Personal Finance, Bank of America, Google Finance, iStockManager
Travel	782	44.72 sec	Google Maps, Yelp, Waze
Communication	881	46.92 sec	Google Mail, Handcent SMS, K-9 Mail
Productivity	1,062	61.49 sec	Calendar, Evernote, GTasks
Shopping	326	61.71 sec	Market, Barcode Scanner, Craigslist
Social	538	62.69 sec	Facebook for Android, Twitter, TweetDeck
Sports	385	65.98 sec	Yahoo! Fantasy Football '10, ESPN ScoreCenter, NFL Mobile
News	784	68.11 sec	NewsRob, reddit is fun, BBC News
Settings	1	68.71 sec	Default Settings App
Browser	10	74.01 sec	Default Browser, Skyfire Browser, Dolphin Browser
Entertainment	84	76.90 sec	IMDb Movies & TV, TV Guide Mobile, PhotoFunia
Multimedia	130	82.79 sec	Pandora Radio, Music, Camera
Comics	3,242	91.33 sec	DailyStrip, XkcdViewer, Dilbert Mobile
Games	2,822	114.25 sec	Angry Birds, Wordfeud FREE, Solitaire
Health	424	153.80 sec	CardioTrainer, Sleep Bot Tracker Log, Baby ESP
Lifestyle	956	167.77 sec	DailyHoroscope, Gentle Alarm, Epicurious Recipe
Reference	764	176.28 sec	Kindle for Android, Aldiko Book Reader, Audible
Tools	3,004	206.26 sec	AppBrain App Market, Apps Organizer, Google Goggles
Themes	1,061	258.28 sec	Zune Home, Fingerprint Screensaver, HomeChange
Libraries & Demos	240	274.23 sec	Google Services Framework, default Updater, Motorola Updater, Bubbles Demo, Ride Logger Demo, ES Task Manager

Table 2. Number of apps investigated in our study and average usage time of every categories' apps from opening to closing.

If you calculate the average usage time of an application, it is 106 seconds and if you calculate the weighted average (taking into account the number of Apps in each category), the usage time is 107 seconds.

Another aspect impacting to DT (but not reflected in the table) is, how users/UE are moving when these Apps are in use.

Apps are very popular on smartphones. Many of these apps "call" for updates, i.e. in order to get latest news from a social network or an update on the weather forecast. On one hand, this signalling causes problems for network operator since it generates a lot of traffic (signalling). On the other hand, the number of RB required by these apps usually is low and the number of parallel requests easily could be higher than values currently used in compatibility studies in areas where many people are present. The typical duration of such signalling is well in the sub-second range, and some of the devices ping the network as often as 2 400 times per hour.

Another important aspect to be considered is speech. So far speech is not implemented in LTE networks, but for sure it is to be implemented in future (VoLTE). However, speech is an application with has a very low data rate and has a profile which differs e.g. from a data upload (only few RB needed per terminal, but more users may connect/call at the same time).

Based on the above presented average usage time of an application, DT is proposed to be 100 seconds.

The Report ITU-R M.2290 gives the data usage forecast for 2020, the market attribute in the year 2020 for unicast uplink (higher user density settings) is given in Annex 2 of the Report ITU-R M.2290, the worst case is the service category 15: 18,6 uplink data session/h/user. Using this worst case forecast uplink data sessions rate, the estimated DT=3600/18.6=193.548 s.

The average "decorrelation" time reflects the fact that when a terminal is interfering with the broadcasting receiver, it will keep the resource of the network for a certain time before this resource is allocated to another terminal which may, or may not, cause interference to the broadcasting receiver.

The range of DT could be:

– from 1 ms which is the the subframe time : it is not realistic to assume that each terminal will transmit;
– to the full time window. If this time window is as large as one hour, this is neither realistic since it would assume that each terminal is permanently transmitting traffic data (other than signalling). In addition, for such large time, the movement of the terminal would also create another dimension of decorrelation, since the interference potential could significantly vary between the positions of the terminal during one hour.

2.2.1.5.4 Elements related to TW-parameter

A time window of one hour is a representative watching period taking into account the quality of service criterion.

Some indicate a TW equal to one hour. The basis for this value could be an average viewing time for a given TV program.

Concerning TW, the duration of a typical live news broadcast is ~15 minutes whilst a movie lasts up to and over 2 hours.

Related to degradation criteria, in IEC 62002-1, section 10.3 there are some DVB-T and DVB-H degradation criteria: DVB-T standard defined Quasi Error Free (QEF) criteria is 1 error per 1 hour, however, when mobility aspect is considered, it introduces ESR5 (Erroneous second ration 5%) criterion, which allows 1 erroneous second over 20 second observation period (also in the Annex 7 of Recommendation ITU-R BT.1368-10). However, those are (both 1h and 20 second) more like a TV system/networks planning criteria, whilst parameter TW is understood to estimate the TV-viewers user experience to observe harmful interference to DTTB reception.

Furthermore, how TV-viewer observe any interference is strongly depending on the TV-content and on the focus level of the user viewing the TV content. For example, during commercial break, many users do to really focus on watching TV and would not notice - or if noticed, would not bother much at all - if there is interference during the commercial break.

Based on http://www.marketingcharts.com/wp/television/average-hour-long-show-is-36-commercials-9002/ typically a 1 hour primetime commercial TV program contains ~40 minutes of the actual content with the ~20 minutes of commercials filling the reminder of the hour (however, in some countries there are some regulatory limitation for the amount of TV commercials).

Based on the above, TW is proposed to be 30mins (average of 15 min and 40 mins is 27 mins).

Thus 30 minutes and 60 minutes were chosen for the study conducted.

]

2.2.1.5.5 General considerations on the acceptable value of P

For a given value of IP that depends on assumptions on ACLR and ACS values, P will indicate the probability of interference [lasting at average DT time to occur] during a period of time defined by TW.

The analysis of what is the probability P acceptable by a TV viewer depends on the choice of the parameters TW and DT. For example, if TW is equal to 1 hour and DT equal to 1 second; P will indicate the probability that an interference event of 1 second occurs during a viewing time of 1 hour. Another example, if TW is equal to 1 hour and DT equal to 10 seconds, P will indicate the probability that an interference event of 10 seconds occurs during a viewing time of 1 hour. A subjective assessment on what is the acceptable value of P can be easily derived from the examples above, and therefore an acceptable value of P should be lower as the value of DT increases.

2.2.1.5.6 Overview of studies

Multiple Monte Carlo studies applying post-processing to the IP have been conducted. The input assumptions to the studies are summarized in the table below:

Study	DTTB System	UE Power Control	Building Entry loss , Standard Deviation[21], [22]	Number of UE	Cell Sites [23]	Sec-tors	Simulations[24], [25]	Environment & Building Indoor%/ Outdoor%	DTT Rx position
A [F/417]	DVB-T Fixed	10% of UE @ 23 dBm	11 dB, no stdv.	1, 2, 4, 6, 8, 10	7	21	100 000 urban, & suburban, 200,000 rural & urban 500 000 urban	70/30 Urban, Suburban 50/50 Rural	Edge
B [BNE/564]	DVB-T2	122 dB Urban & Suburban, 123.3 dB Rural[26]	11dB, 6dB	1	19	57	10 000 000	70/30 Urban, Suburban 50/50 Rural	Edge

In the following subsections the results of each of the studies are reflected.

Study A

This section provides some calculations for given ACLR and ACS values for different values of DT.

The choice for ACS is derived from [the CEPT contribution to the JTG in Document 4-5-6-7/185] (Table 5). This table is also included in ###Table 27 of Annex 5### for information.

Noting that the centre frequency separation is 4 +9 + 5 = 18 MHz between the DTT channel 48 and the first IMT channel above 703 MHz, the ACS values for 50th percentile vary between 60 and 66.2 dB. The values of ACS = 60, 65 and 70 dB have been chosen for simplification.

---

21 To use a value that is common to both IMT and DTTB services [JTG 4-5-6-7 agreed to] use the building entry loss and associated standard deviation values specified in Recommendation ITU-R P.1812-2, Table 6, Page 23.

22 [The effect of omitting building standard deviation on the calculated interference probability is assessed in Doc. 4-5-6-7/561 [*Note: replace with reference to Annex to report*]].

23 [WP 5D in a liaison to Doc. 4-5-6-7/236, Annex 2,] provided details of the IMT network configuration to be used in Monte Carlo modelling of interference to DTTB reception as well as details of the IMT UE power control to be used.

24 The number of simulations affects the precision in the results of Monte Carlo simulations.

25 France also modelled 1 & 10 UE using 500 000 simulations.

26 The power control values were chosen to limit the proportion of UE operating at maximum power to ~1% Urban, ~2% Suburban and ~5% in rural environments [using the methodology provided to JTG 4-5-6-7 by WP 5D].

Taking into consideration the results of MCL studies submitted to both PTD and JTG in terms of choice of ACLR and ACS values, the value of ACLR should be approximately the same as the value of ACS in order to obtain the maximum benefits of the combination of both. This can also be seen when considering the following formula :

$$PR'(\Delta f) = PR_0 + 10\log(10^{\frac{-ACS}{10}} + 10^{\frac{-ACLR'}{10}}) \qquad (13)$$

In the calculations below only the case of a single UE (with no reduction on the value of ACLR) has been considered in order to provide with the worst case scenario in terms of impact of OOB. That is, when several UE are transmitting at the same time in the same cell, each one use part of the resource blocks and measurements have shown that the OOB emission is then reduced.

Extracting the corresponding cells from the excel tables in section *2.2.1.3.3 study A*, and applying equation (12) the following values are obtained:

TABLE 27

IP values for ACS = 60 and 70 dB; and ACLR = 58, 63, 68 and 73 dB

ACS (dB)		**60**		**TW (s)**	**DT (s)**	**DT (s)**	**DT (s)**	**DT (s)**
# active UE		**1**		**3600**	**1**	**10**	**100**	**200**
ACLR correction factor (dB)		**0**						
OOBE (dBm/8 MHz)	**UE ACLR (dB)**	**IP(OOB)**	**IP(IB)**	**IP(OOB+IB)**	**P1 %**	**P2 %**	**P3 %**	**P4 %**
-35	**58**	4.21E-05	2.63E-05	6.85E-05	21.8	2.43	0.24	0.12
-40	**63**	2.10E-05	3.68E-05	6.31E-05	20.3	2.24	0.22	0.11
ACS (dB)		**70**						
# active UE		**1**						
ACLR correction factor (dB)		**0**						
OOBE (dBm/8 MHz)	**UE ACLR (dB)**	**IP(OOB)**	**IP(IB)**	**IP(OOB+IB)**	**P1 %**	**P2 %**	**P3 %**	**P4 %**
-40	**63**	1.05E-05	< 5E-06	1.05E-05	3.71	0.37	0.037	0.018
-45	**68**	5.26E-06	< 5E-06	5.26E-06	1.87	0.18	0.018	0.009
-50	**73**	5.26E-06	< 5E-06	5.26E-06	1.87	0.18	0.018	0.009

Note : the simulations in the table above have been made with 200 000 samples, resulting in an accuracy which cannot be better than 5E-06.

The results show the need to balance expected ACS and required ACLR. In addition, it provides an illustration that lower DT will correspond to higher probability of occurrence in a one hour time window. On the other hand, it has to be pointed out that lower decorrelation time would also correspond to shorter and less disruptive interference. Therefore, there is a balance between the level of the probability P (%) and the impact of a single interference situation.

3 Assumptions and results of supplementary calculations

Supplementary simulations have been carried out according to the following parameters:

- Number of active UE per sector = 1 and 10;
- ACS = 65 dB;
- ACLR = 63, 65, 67 and 69 dB;
- ACLR correction factor (for 10 UE) = 9 and 19 dB;
- TW = 1 800 s (30 min) and 3 600 s (60 min);
- DT = 1, 10 and 100 s.

500 000 events (runs) have been simulated resulting in an accuracy which cannot be better than 2E-06. These results obtained are presented in Table 28 and in Figures 35 to 38 (see Annex ###3#### for the interpretation of the calculated IP).

TABLE 28

Simulation results for 500000 events (runs)

IP values for ACS = 65 and 70 dB; and ACLR = 63, 65, 67 and 69 dB

Evaluation of the probability of interference (IP) from IMT UE to DTTB rooftop fixed reception (MC simulations)				
Scenario	**Urban rooftop fixed DTTB reception**			
IMT Channel BW (MHz)	10			
IMT UE e.i.r.p. (dBm)	23			
Reference OOBE (dBm) level is defined for full resource allocation (50 RB) to a single UE				
ACS (dB)	**65**			
# active UE/Sector		1	10	
ACLR correction factor (dB)		0	19	9
OOBE (dBm/8 MHz)	**UE ACLR (dB)**	**IP-Case 1**	**IP- Case 2**	**IP- Case 3**
-40	63	1.47E-05	6.10E-05	6.31E-05
-42	65	1.26E-05	5.04E-05	5.56E-05
-44	67	6.31E-06	4.73E-05	5.08E-05
-46	69	6.30E-06	4.42E-05	4.63E-05

Note : the simulations in the table above have been made with 500 000 samples, resulting in an accuracy which cannot be better than 2E-06.

It should be noted here that the IP obtained in the case of 10 UE transmitting simultaneously in an IMT base station sector is higher than the IP obtained in the case of a single UE. However, this is due to the in-band emission of the UE and not due to their OOBE.

FIGURE 35

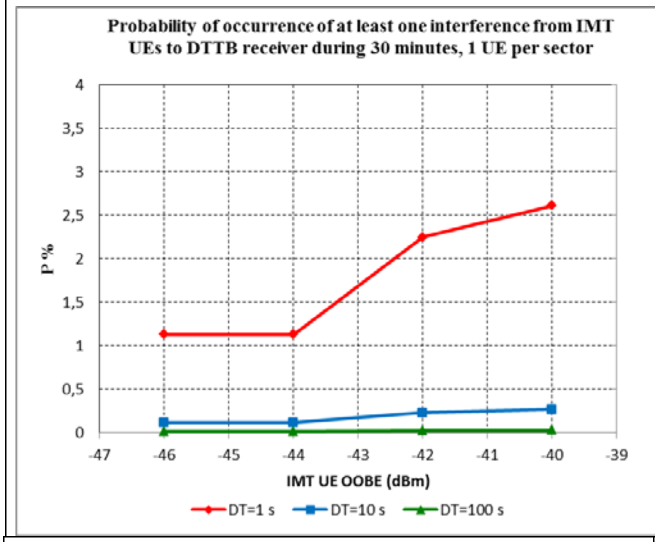


FIGURE 36

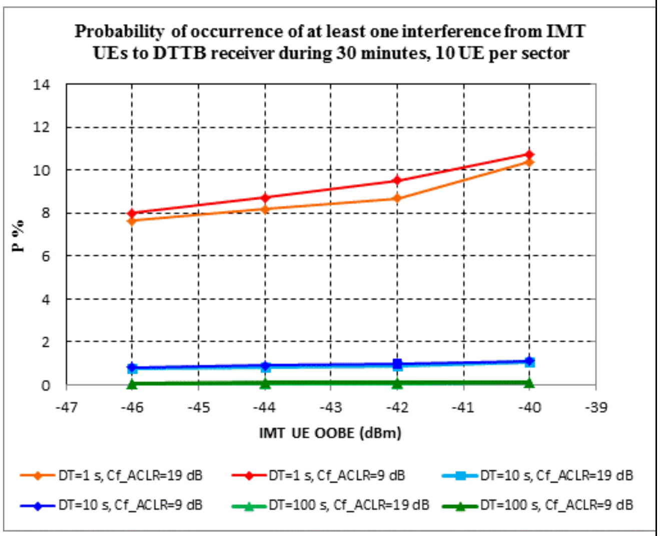


FIGURE 37

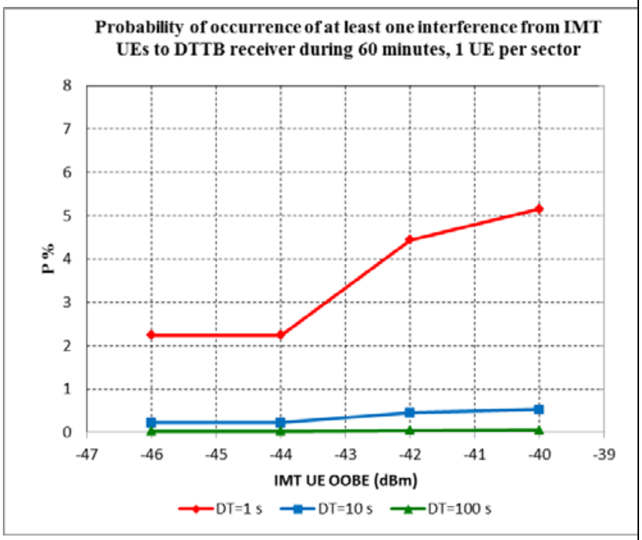
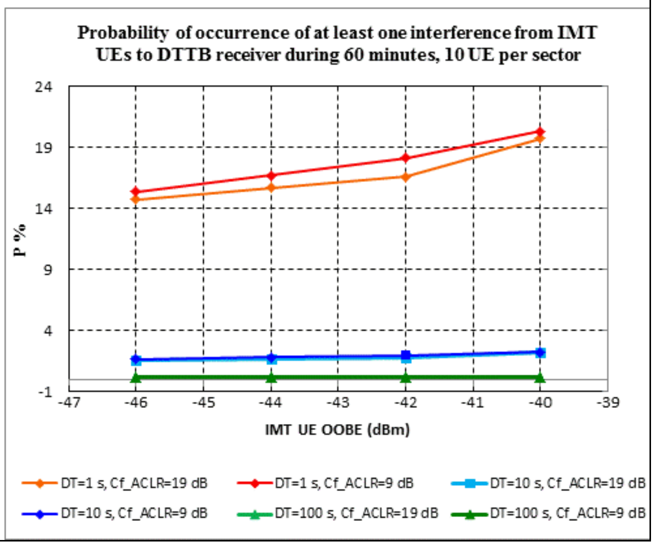


FIGURE 38



The probability of occurrence P (%) of at least one interference from IMT UE to DTTB receiver during a given time window (TW = 30 min or 60 min) are represented in Figures 35 to 38, for different number of active UE (1 or 10), different values of decorrelation time (DT = 1 s, 10 s or 100 s) and different ACLR correction factors (0 dB, 9 dB or 19 dB). The ACS is 65 dB.

It is to be noted that, for the case of DT = 1 s, the difference between the curves considering ACLR reduction factors of 9 and 19 dB should be read with caution, as the corresponding probabilities of interference (IP) and DT considered are very low.

FIGURE 39

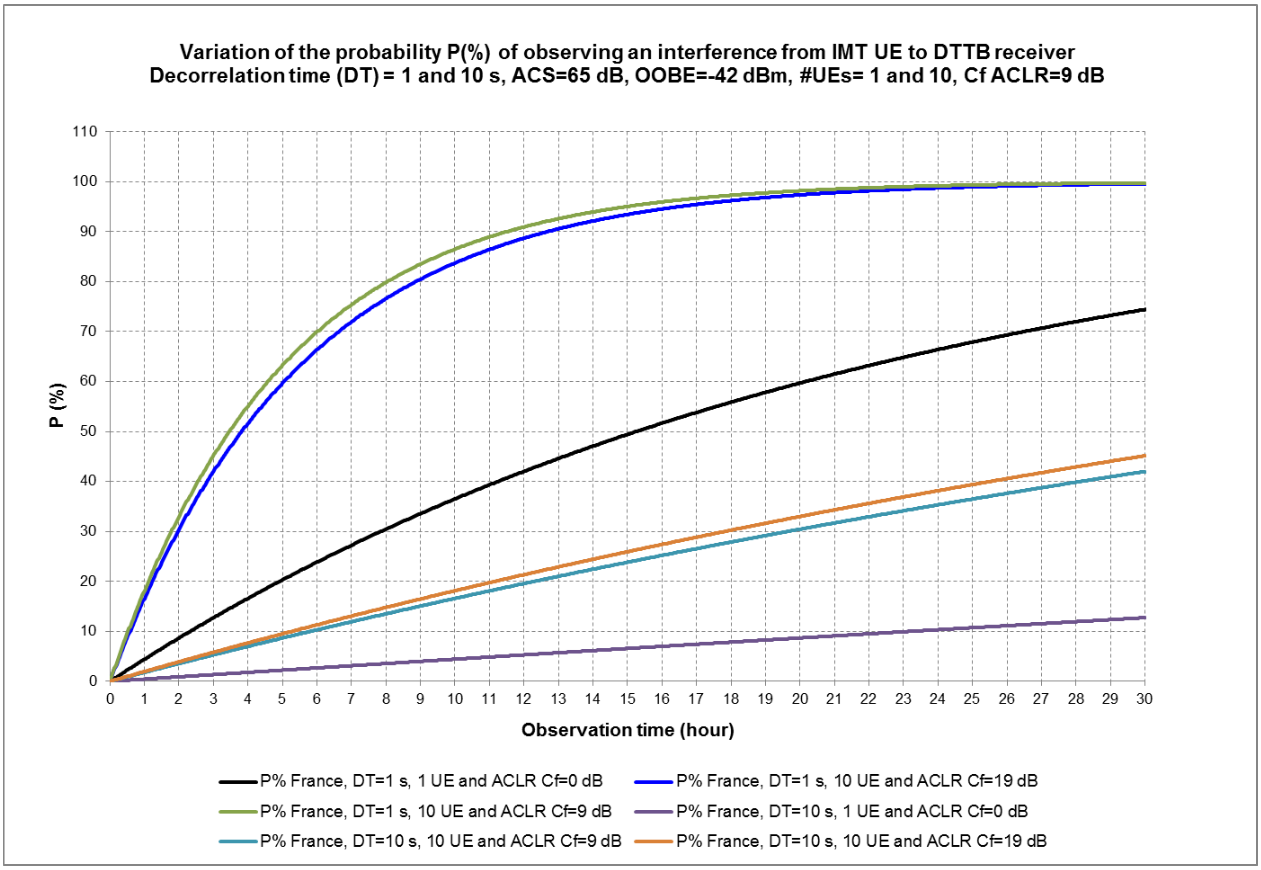


Figure 39 gives a better insight into the meaning of P. The P curves presented in this figure, based on the PI presented in Table 28, show that even a probability P=18 % of observing an interference from IMT UE to DTTB reception during an observation time (TW) of 1 hour, probability that can be considered high, doesn't mean that an interference will occur in this TW since the instantaneous IP from IMT UE to DTTB reception is quite low (see Tables 28 and ###2###). Actually, to be sure that interference will occur, it is needed to wait more than 20 hours!

Conclusions

For an observation time (TW) of 1 hour (3 600 seconds), DTTB receiver ACS = 65 dB and IMT UE ACLR = 65 dB (IMT UE OOBE=-42 dBm), the probability P(%) of observing an interference from IMT UE to DTTB receivers is 4.4, 0.45 and 0.045% respectively for decorrelation times (DT) of 1, 10 and 100 s. These probabilities are fairly higher in case of 10 active UE per IMT base station sector. However, the increase of P is due to the in-band (IB) emissions of IMT UE.

Bearing in mind that these P(%) are calculated for a DTTB reception in a pixel (100x100 m) at the edge of the DTTB coverage and the average ACS of recent DTTB receivers is in the range of 62 to 65 dB (see Annex ###4###), it is proposed that the OOBE of IMT user equipment operating in the frequency band 694-790 MHz should not exceed **-42 dBm/8 MHz** for a 10 MHz LTE channel bandwidth in the frequency band 470-694 MHz for the protection of the broadcasting service in this frequency band. This value represents already the protection under some worst-case conditions (coverage edge, ACS assumptions). It is expected that DTTB receivers ACS will be improved in the future.

Study B

Broadcast Networks Europe have carried out an assessment of the probability of interference P to DTTB reception (DVB-T2) from IMT UE based on IMT network changes within a time window. This assessment is based on the method for calculating P from IP detailed in Section [XX].

Introduction

It has been proposed that to properly assess the probability of interference to DTTB reception using Monte Carlo simulations to derive the IP, the number of network changes that occur in a given time window need to be taken in to account; the number of changes in a time window being a function of the "decorrelation time".

The "decorrelation time" is a difficult concept to determine as it depends on a number of factors, including the length of the time window, *TW*.

If TW is short, i.e. of the order of 1 second, then *C*, the number of changes, will be primarily due to active UE position changing as a result of the resource scheduler. This will depend on the traffic a network is carrying, the number of UE a sector is managing and how resources are allocated to the UE within the sector. Elements of this, such as the resource allocation algorithm are not readily available.

However, if TW is so short that UE physical movement will have little influence on the number of changes, *DT* will depend primarily on the total number of UE that are active (*N)* during TW. In such circumstances, as a simple approximation, *DT* could be considered to be;

$$DT = \frac{TW}{N} \tag{14}$$

However, a *TW* of the order of 1 second would not address concerns of broadcasters nor address the issue of identifying whether interference is at a level that is detrimental to the DTTB service and finally not determine a viewer's ability to watch a programme without interruptions.

To better reflect what may be considered as acceptable to TV viewers, a longer *TW* needs to be considered; [contributions[27]] from broadcasters indicate that *TW* should be set to one hour.

Using such a *TW*, UE physical movement rather than changes in position due to the resource scheduler will become the dominant source of uncorrelated changes to the network.

Based on UE movement the number of independent events (uncorrelated changes), *C*, that occur in a specified *TW* can be derived as follows.

Given *C*, the IMT UE out-of-band emission (OOBe) limits can be derived from the Monte Carlo simulations of *IP*, for a given probability of interference *P* to the DTTB receiver and the adjacent channel selectivity (ACS) of the receiver.

Method

The number of uncorrelated changes within the specified TW may be determined by UE movement and the distance a UE has to move before signals received are no longer correlated. When a signal is assumed as no longer being correlated, interference at this point can be assumed to be independent and we have a change in the network in terms of interference. If change is based on

[27] [Documents 4-5-6-7/172, 4-5-6-7/174, 4-5-6-7/325, 4-5-6-7/326, 4-5-6-7/381, 4-5-6-7/382.]

movement and the assumption that a UE must move a certain distance before a change occurs, the time associated with changes will generally be much greater than changes associated with the resource scheduler. As such, events associated with scheduling can be ignored, as though the resource scheduler may activate a UE many times in a period of time, unless that UE has moved a sufficient distance to create a change (a new interference event), the interference potential of the network doesn't change.

C is the number of network state changes during a certain TW, assuming that two consecutive network states are independent (not correlated). It will have a range of values depending on how many UE are in a cell, the cell utilization and the mobility of the UE.

The lower bound on *C* will be for the case where the UE transmits but does not move, the upper bound will be where all UE move at maximum velocity. The former is easier to define so will be dealt with first. Whilst UE are not static, they are part of a mobile network, the lower bound is a useful way of ascertaining the minimum requirements of DTTB receiver ACS and UE ACLR required to meet a certain probability that a receiver will be subject to interference.

The lower bound for C – the static case

The lower bound for *C* is of interest, as it helps us to understand, for a given probability of interference - in our specified time window, the maximum level of out-of-band emissions for an IMT UE.

Two main mechanisms can generate independent events:

1. Active UE position changes due to the resource scheduler.
2. Physical movement of the UE.

If we assume that during the TW no UE physically move - unlikely for a mobile network and a TW of one hour, but useful in establishing the lower bound – then the number of changes *C* will be determined by the total number of different UE active during the TW. If the TW is long enough it is likely that all UE in a sector will be active at some point during the TW and will thus contribute to the number of changes. The number of UE in a sector can be determined from the population density using methodology established in JTG 5-6[28].

[28] Document 5-6/180 (Annex 4), Annex 2 to the Joint Task Group 5-6 Chairman's Report, 'List of IMT systems characteristics for use in sharing studies in the band 790-862 MHz.

In a typical suburban area[[29]] in the UK the population density is ≥5 000 people/km^2, i.e. ≥12 500[30] people in a 2 kilometre radius suburban IMT sector. Using the methodology from JTG 5-6 for apportioning users by available spectrum; where for the suburban case the traffic is divided between the 800 MHz LTE, GSM900, GSM1800 and UMTS 2 GHz. Assuming 1 IMT device per person[31] then the number of UE in a suburban sector that could be using the lower 10 MHz block of the 700 MHz band is:

$$10/230 * 12500 = 543$$

For the purpose of deriving the probability of interference *P*, if a UE doesn't move - regardless of how many times it transmits within the TW - it can be assumed that it only generates 1 unique (uncorrelated) interference event (remember that *P* is the probability of experiencing one or more interference events). If it is assumed that each of the UE is active at least once in the TW then *C* = 543.

Given the number of events *C* and the probability P that a DTTB receiver is subject to interference in a specified time window TW, we can calculate the *IP* to ensure the probability *P* is not exceeded, equation 15.

$$IP = 1 - (1 - P)^{\frac{1}{C}} \qquad (15)$$

If for example, our target probability[32] *P* is 1% in a TW of 1 hour and we have 543 UE that are static (as described above) but transmit at least once during the TW, then the *IP* required to achieve this probability is given by;

$$IP = 1 - (1 - 0.01)^{\frac{1}{543}}$$

$$IP = 0.0019\%$$

This specific *IP* can be compared with IP values derived from Monte Carlo simulations to determine the ACLR and hence OOB limits for IMT UE for specific DTTB ACS values, Figure 40 and Table 29.

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[29] [Document 4-5-6-7/328 shows typical suburban areas.]

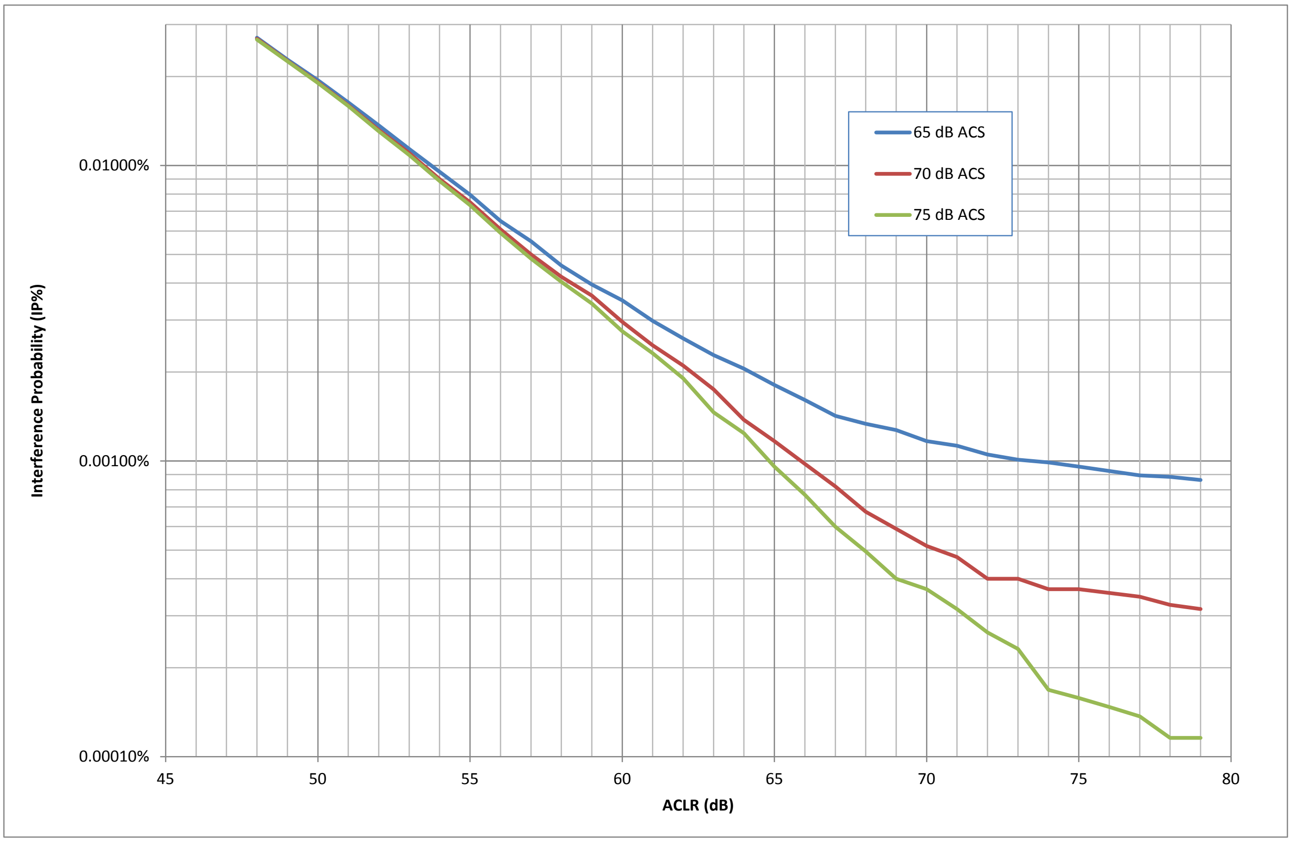
[30] UMTS Forum Report No 6, 06/99, 'UMTS/IMT-2000 Spectrum', quotes for a suburban environment a density of potential users of 7200 per km^{2}.

[31] For Europe this is a conservative figure – mobile phone usage is between 100 and 150 devices per 100 people http://en.wikipedia.org/wiki/List_of_countries_by_number_of_mobile_phones_in_use.

[32] If the probability that a receiver experiences interference in TW is 1%, then it can be expected that 1% of the population of receivers in similar circumstances, i.e. are at the edge of coverage will experience interference.

FIGURE 40

Interference probability: Suburban environment: 1 UE



Note: Details of the methodology used to derive the IP are provided in Annex 1.

TABLE 29

IMT UE OOB emission levels based on a static suburban environment with probability of interference to DTTB reception = 1%, C=543

ACS dB	65	70	75
ACLR dB	64	62	62
OOB dBm/8MHz	-41	-39	-39

As this IP is for the static case, i.e. the lowest level of interference, it equates to the highest level of OOB emission. Movement of UE will generate more changes and will lead to a smaller value for IP and hence will lead to more restrictive OOB limits than those shown in Table 29.

Discussion:

The static case provides an easy approach for calculating the upper bound to the level of OOB emissions for a given probability of interference to DTTB within a specified time window.

However, the results depend on the population of UE that are active in the 700 MHz band and the basis of the methodology used for deriving this was previously established [in JTG 5-6] taking account of information supplied [by Working Party 5D].

Taking the lower bound number of changes as 543 is a very conservative approach which allows for just 1 UE per person. It does not account for:

– In many countries the number of active devices is up to 50% greater than the number of people; if the actual device usage is factored in then the number of UE (changes) used in the calculations for the static case would be up to 814.

– UE will roam between the available frequency bands and given the amount of traffic generated by social media apps and email it is highly likely that more than 543 UE would be active within the time window.

– The population density in urban areas is higher than in suburban areas and the probability of interference for the static case will probably be higher.

The second point is particularly pertinent as the growth area in mobile usage is predicted to be data and the IMT 700 MHz and 800 MHz band should, as they are designed for data, be expected to see the heaviest traffic in future. As such equal apportionment of UE by spectrum availability, [as done within JTG 5-6,] may underestimate the number of UE that would be using the 700 MHz band.

Whilst this static case, which has been used to provide an indication of the minimum number of changes, may be conservative, it does indicate that to prevent interference occurring to more than 1% of the DTTB receivers at the edge of service the OOB emissions from 700 MHz IMT UE should be below –41 dBm/8 MHz (DTTB receiver ACS 65 dB).

Whilst the static case is useful in helping to understand the upper level of OOB emissions, because we are dealing with mobile not fixed devices, the actual OOB emissions levels required to protect DTTB reception will need to be lower.

The mobile case:

Taking account of UE movement when assessing interference requires information on the following:

– The velocities that UE move at.

– The distance a UE needs to move before an interference event caused by a UE is classed as ‘uncorrelated’ relative to a previous event, i.e. occurs to a different DTTB receiver.

UE Velocities:

An indication of UE velocities has been provided in a 3GPP meeting in New Jersey [1] and is replicated in Table 30 and Figure41.

TABLE 30

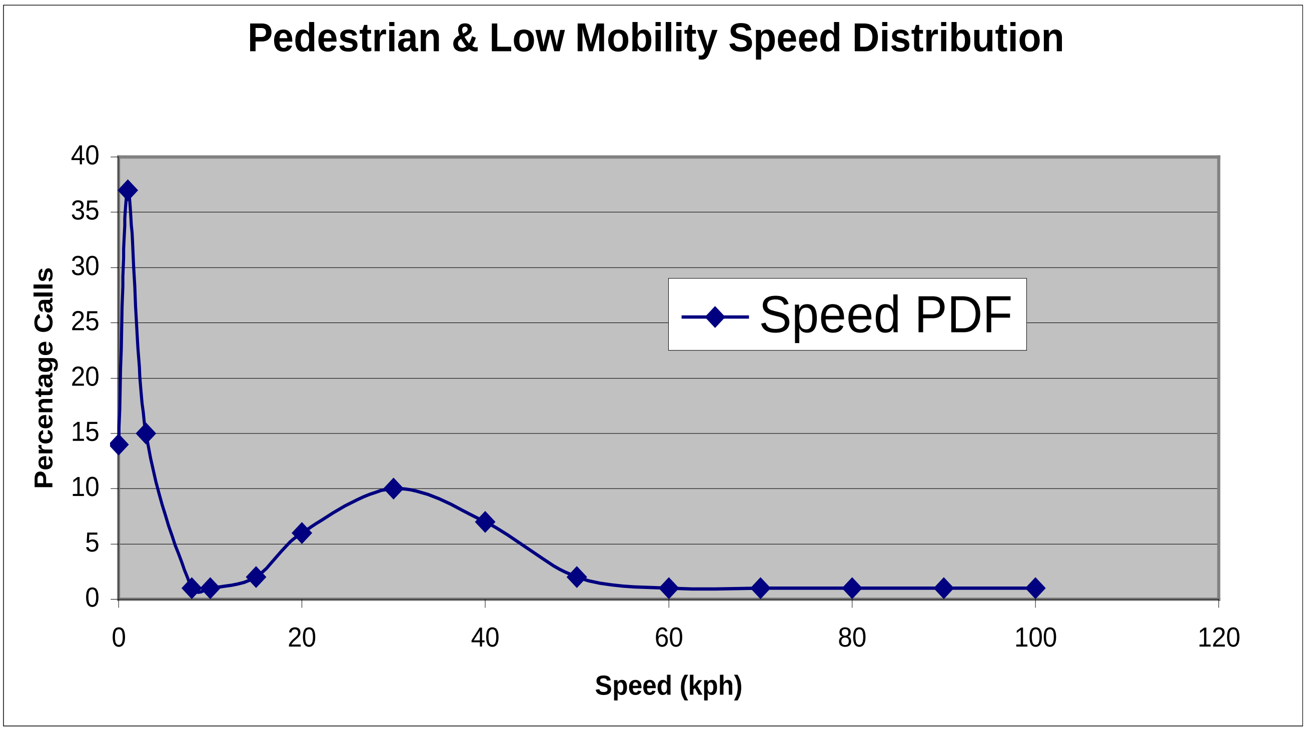
UE velocities

$V_{km/hr}$	0	1	3	8	10	15	20	30	40	50	60	70	80	90	100
% calls	14	37	15	1	1	2	6	10	7	2	1	1	1	1	1

These velocities need to be apportioned according to whether they are indoor or outdoor. Velocities of 0 to 3 km/h (66% of UE traffic) could be taken as representing pedestrian movement and the velocities above 3 km/h vehicular movement (34%). Whilst these proportions almost align with the 70% indoor and 30% outdoor usage [that WP 5D have] provided, it must be assumed that some of what has been labelled as pedestrian traffic is outdoor. If the proportion of UE that move at speeds of between 0 km/h and 1 km/h is allocated to indoor (51%) and the UE moving at velocities between 1 km/h and 3 km/h is allocated to outdoor pedestrian (15%), this gives a ratio of indoor to outdoor traffic of 51% to 49%.

FIGURE 41

Probability distribution of UE velocities



Correlation distance

To calculate the number of unique events that can cause interference, an understanding is required of how far a UE has to move before interference events, it generates, become uncorrelated. Correlation distance is a concept already used in mobile planning for slow fading [2,3]; it being the distance a device needs to move from a previous position before the signals, received or transmitted, from the device are assumed not to be correlated. A correlation distance value of 20 metres is often quoted for vehicles (outdoor) and a value of 5 metres for indoor to outdoor events.

On first inspection and prior to receiving further information, these distances appear to be reasonable for assessing the number of uncorrelated changes generated by UE movement.

In the indoor case, 5 metres would take you from one side of a house to another which, with respect to interference to DTTB reception, could easily result in a new event, i.e. there could be a significant change in the interfering signal level at a DTTB receiver.

For the outdoor case, 20 metres, when coupled with the directional pattern of the DTTB receive aerial, could move you from a position of not causing a problem, to one causing a problem, i.e. there could be a significant change in the interfering signal level at a DTTB receiver.

Deriving C from UE velocity and correlation distance

For a given TW and the distribution of UE velocity, the proportion of UE moving a certain distance can be readily calculated. From the distance UE move and the correlation distance the number of uncorrelated events can be derived.

The number of events *c* generated by a mobile UE is given by:

$$c = TW\sum_{i=1}^{k}\frac{P_i V_i}{D_i}$$

Where:

- D is the Correlation distance in metres;
- TW is the time window in seconds;
- V is the UE velocity in metres/second;
- P is the proportion of UE moving at velocity V;
- k is the number of velocity values.

The total number of events C is given by:

$$C = N + cA$$

Where:

- N is the number of UE in a sector;
- c is the number of events generated by a single UE;
- A is the average number of active UE.

Assuming 543 UE in our suburban sector and a UE velocity distribution as shown in Table 29, the number of events *C* in a TW of one hour, if only one UE is active, is 1 315. For a probability of interference of 1%, using equation 15, the IP can be derived.

$$IP = 1-(1-0.01)^{\frac{1}{1315}}$$

$$IP = 0.0007\%$$

From the derived *IP* the ACLR and hence OOB values for specified ACS, to limit the probability of interference to DTTB reception, can be derived from Figure 40 [1] and are summarised in Table 31.

TABLE 31

IMT UE OOB emission levels based on a mobile suburban environment with probability of interference to DTTB reception = 1%, C=1 315

ACS dB	65	70	75
ACLR dB	NA	68	66.2
OOB dBm/8MHz	NA	-45	-43.2

For an urban environment the number of users in an urban sector is taken as 216[33] which results in 938 events. For a probability of interference of 1%, using equation 15, the IP can be derived.

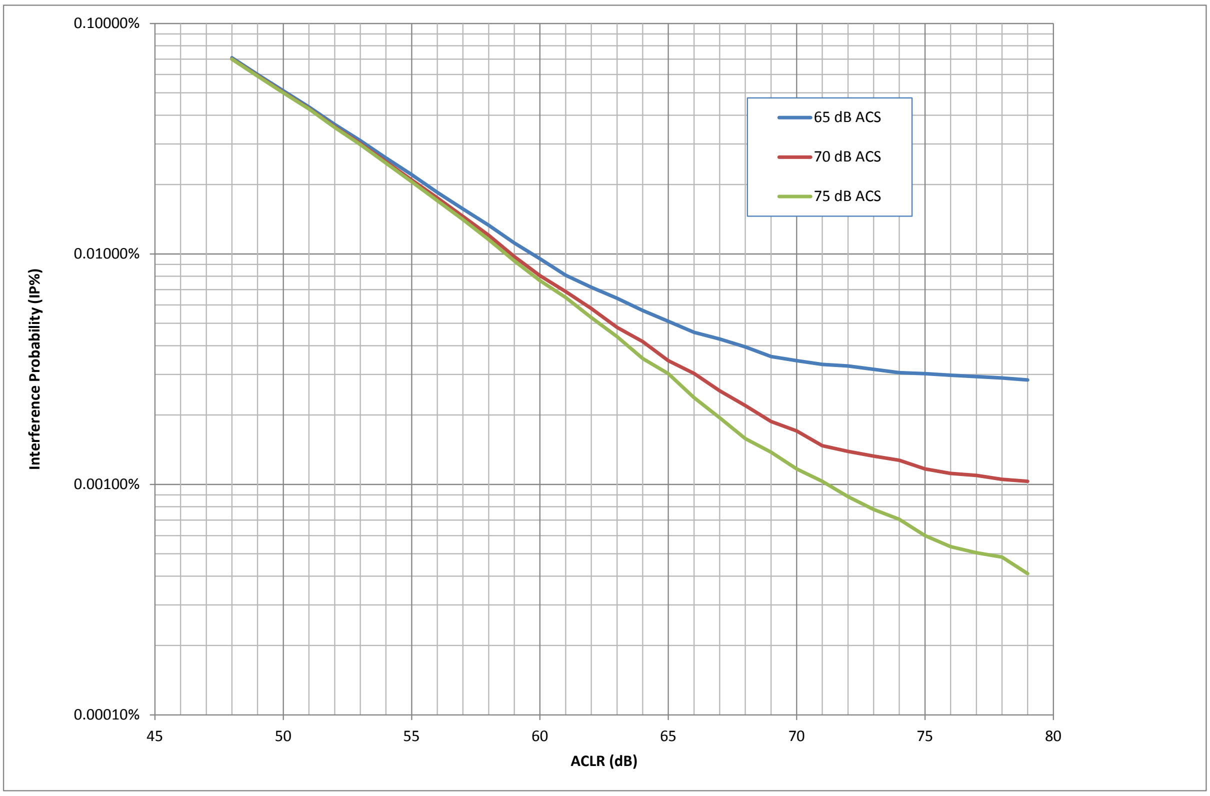
[33] Based on a population density of 10 000 users/km^2 a sector area of 0.65km^2 and the traffic is divided between the 800 MHz LTE, GSM900, GSM1800, UMTS 2 GHz and 2.6 GHz, Number of users = 0.65*10 000*10/300 = 216.

$$IP = 1 - (1 - 0.01)^{\frac{1}{938}}$$
$$IP = 0.0011\%$$

From the derived *IP* the ACLR and hence OOB values for specified ACS, to limit the probability of interference to DTTB reception, can be derived from Figure 42 and are summarised in Table 32.

FIGURE 42

Interference probability: Urban environment: 1 UE



Note: Details of the methodology used to derive the IP are provided in Annex 1.

TABLE 32

IMT UE OOB emission levels based on a mobile Urban environment with probability of interference to DTTB reception = 1%, C=938

ACS dB	65	70	75
ACLR dB	NA	76	71
OOB dBm/8MHz	NA	-53	-48

From the curves in Figure 4 for the urban context it can be seen that to restrict the probability of interference to DTTB reception to 1% of receivers, the DTTB receiver ACS should be in the range 70 dB to 75 dB and the IMT UE ACLR should also be in the range 70 dB to 75 dB. This IMT UE ACLR range corresponds to out-of-band emissions limits of between -47 dBm/8 MHz and –52 dBm/8 MHz.

Conclusion

The number of uncorrelated interference events in a time window generated by IMT UE movement can be calculated from information on the distribution of UE velocities and the correlation distance. The number of events can then be used to derive the out-of-band emission levels that should be set for IMT UE to limit the probability of interference to the DTTB service.

With information on population density and the distribution of UE velocities, using the approach described the IP derived from Monte Carlo simulations can be directly converted to an equivalent maximum permissible UE OOB levels necessary to limit interference to DTTB reception to a specified probability.

References:

1. Harmonization Meeting on 3GPP HSDPA and 3GPP2 1xEV-DV Work, New Jersey, 13-14 Nov. 2001.

2. ‘The UMTS Network and Radio Access Technology: Air Interface Techniques for Future Mobile Systems’, Jonathan P Castro, page 34.

3. ‘Correlation Model for Shadow fading in Mobile Radio Systems’, M. Gudmundson, 5 Sept. 1991, Electronic letters 7 November 1991, Vol. 27 No. 23.

4 Analysis on Monte Carlo studies

All different types of Monte-Carlo studies performed show the main following general conclusions :

– [Mobile UE ACLR and DTT receiver ACS values should be of the same order of magnitude (+/- 5 dB) in order to obtain the best results in terms of out-of-band emissions filtering. For a given DTTB receiver ACS, above a certain level, an improvement of the ACLR (and thus further tightening of OOBE limit) doesn’t reduce significantly the overall interference situation [Ed note. Visa versa explanation of ACS] Ed note revise description of ACS and ACLR linkage offline].

[Ed. note: Alternative to above:

Mobile UE ACLR and DTT receiver ACS values should be of the same order of magnitude (+/- 5 dB) in order to obtain the best results in terms of out-of-band emissions filtering. For a given value of ACS, improving the value of ACLR beyond value (with consequential reduction in OOBE) will give little improvement in interference.]

In particular, the simulation results at DTT coverage edge show that:

1) The worst interference scenario from IMT/LTE uplink to DTT is found in an urban environment for the reason of smaller cell size (higher active user density).

2) The total probability of interference decreases with the increase of DTT receiver ACS, and the increase of IMT UE ACLR (decrease of UE OOBE level).

3) For a given DTT receiver ACS, total probability of interference will not decrease with the increase of IMT UE ACLR (decrease of UE OOBE level) above certain level, since it is limited by DTT receiver ACS.

4) In a rural environment the probability of interference is mainly dominated by UE in-band (IB) power. This power can only be attenuated by the DTT receiver ACS. In

order to evaluate the impact of IMT UE OOBE levels at DTT reception, it would be more appropriate to consider the probability of interference due to UE OOBE in an urban environment.

5) For 10 UE per sector, the probability of interference is mainly dominated by the UE in-band power (IB) and thus, above a certain level, a limitation on the OOBE doesn't improve the overall interference situation.

6) Without body loss, for a UE antenna gain of +1dB or if 30% of mobile traffic would be generated from indoor and 70% generated from outdoor, the probability of interference is by a factor of 2 higher.

7) The probability of interference is slightly higher for portable outdoor reception than for fixed reception.

In view of the results of Monte-Carlo Studies specified in Scenarios 2a, 2b and 2c, it can be concluded that the limit for IMT UE OOBE in order to protect the DTT reception should be set in the following ranges :

Studies in Scenario 2a : OOBE limits between XX1 and YY1.

Study in Scenario 2b : OOBE limits between XX2 and YY2.

Study in Scenario 2c : OOBE limits between XX3 and YY3.

4.1 Scenario3: Study based on test trial results [302, 488]

4.1.1 Scenarios

Laboratory and field trial of wireless broadband access system in the frequency band 694-790 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 the broadcasting service.

4.1.2 Description

Studies of compatibility between terrestrial TV broadcasting and terrestrial mobile networks based on various simulation methods show that there is a possibility of interference in the co-channel and multiple adjacent channels cases. 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). Topology, similar to mobile communication network (base station + UE), used.

Equipment specification

Technical characteristics of wireless broadband access equipment are shown in Table 33.

TABLE 33

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 34.

TABLE 34

Technical characteristics of UE 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 15000 (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<=$1\cdot10^{-2}$	Not less than -3,
	with FER<=$1\cdot10^{-3}$	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;

4.1.3 Methods of calculation with formulas

Research conducted through laboratory and field tests.

4.1.3.1 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

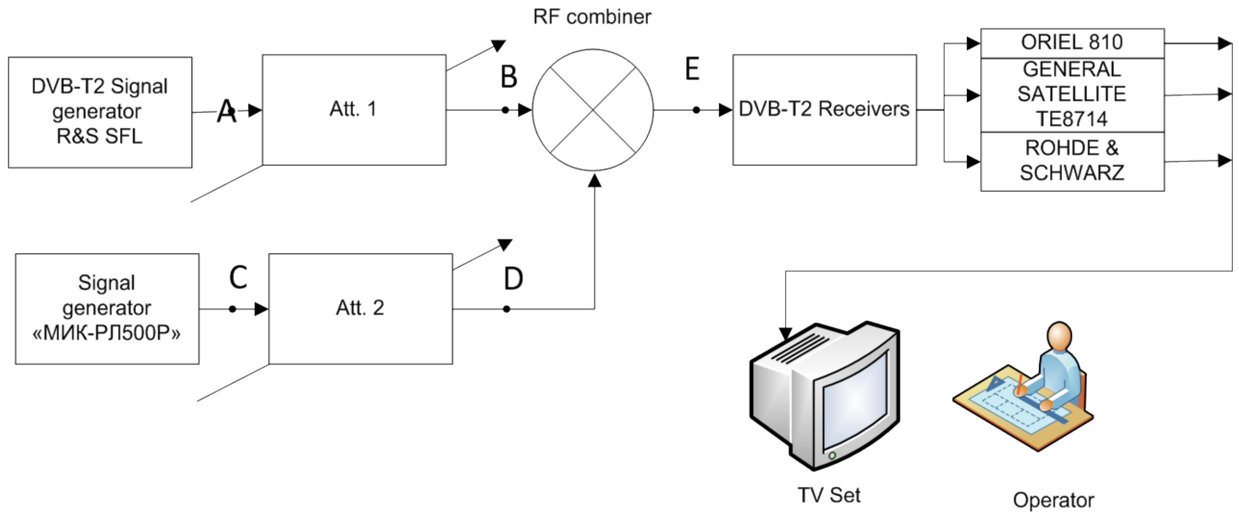
DVB-T2 signal parameters:

- Modulation: 64 QAM;
- Radio channel bandwidth: 8 MHz;
- Carrier mode: 32K;
- Code rate: 4/5.

Block-diagram for measuring is shown in Fig. 43.

FIGURE 43

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. 44)
- C –generated signal (spectrogram is plotted in Fig. 45)
- D –signal with variable level to determine interfering signal causing distortions
- E –signal at the output of RF combiner, applied to the input of STB receiving device

FIGURE 44

Spectrograms of DVB-T2 signals

–70 dBm	–60 dBm
–50 dBm	–40 dBm

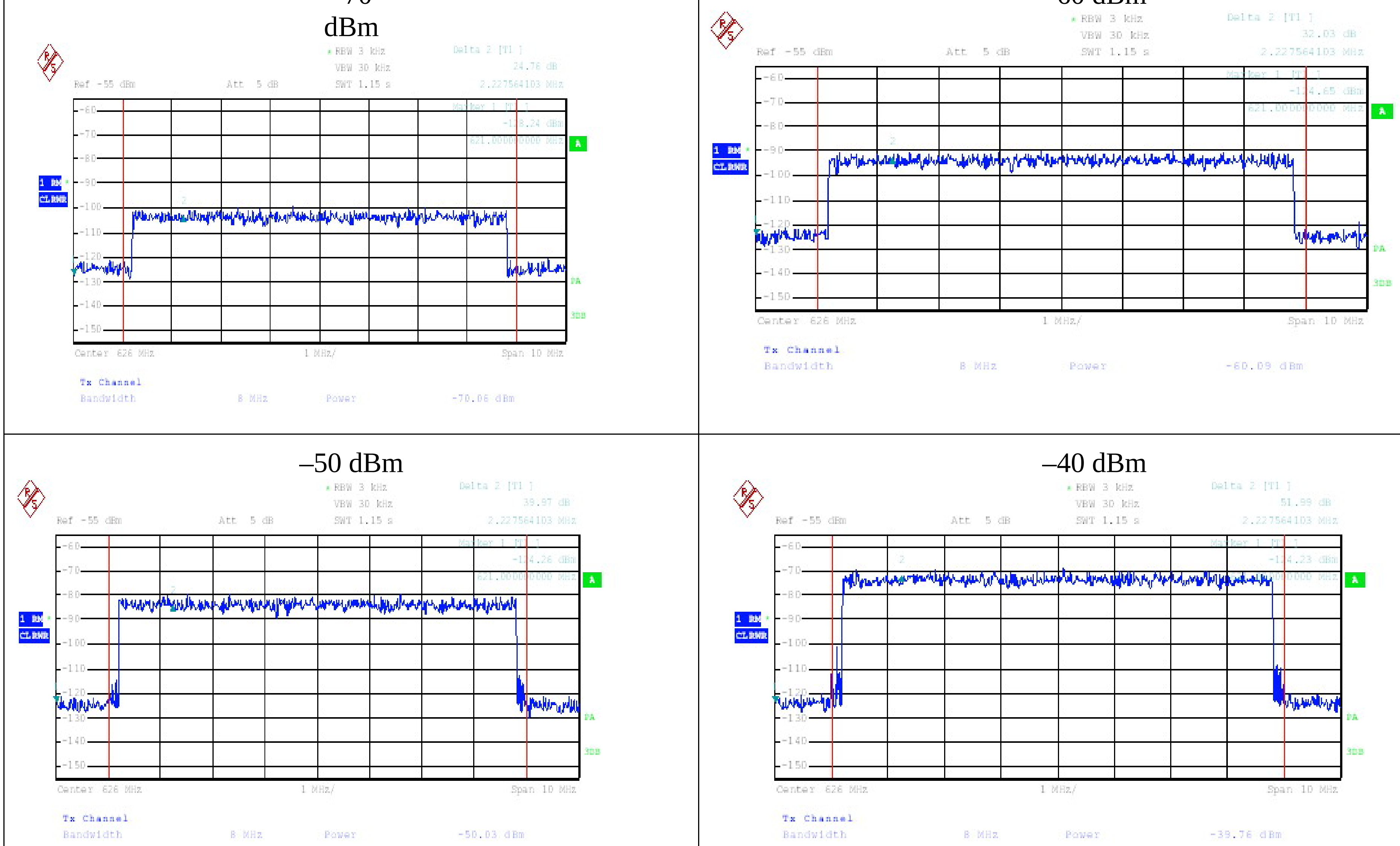
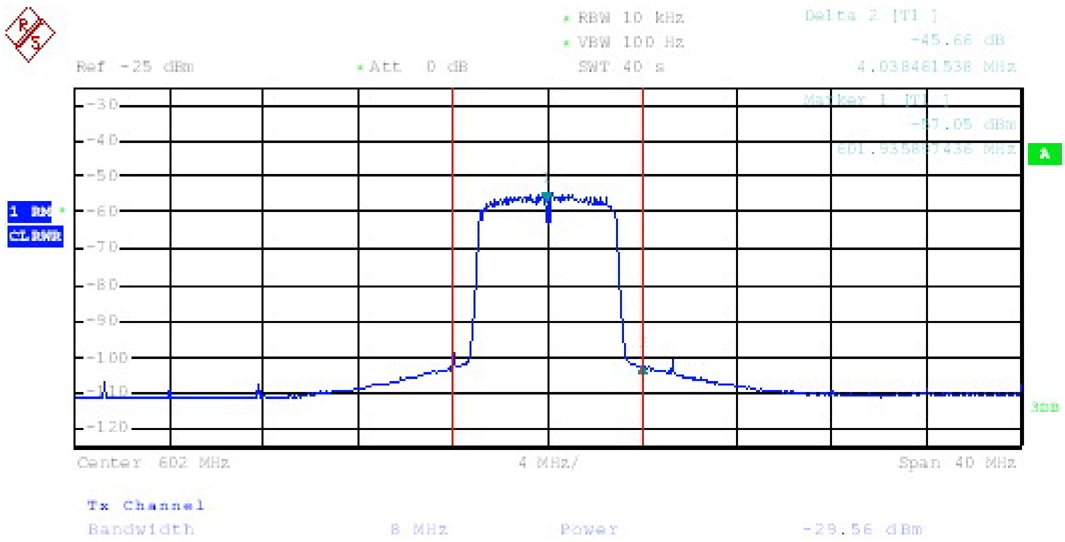


FIGURE 45

Spectrogram of wireless broadband access prototype 1 signal



4.1.3.2 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 (Figs. 46 and 47) and different frequency offsets, ratios of signal levels were measured and received TV signal quality was recorded.

FIGURES 46 AND 47

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 user equipment with the set of standard antennas;

– Receiving TV antenna with matched characteristics;

– TV signal analyser (e.g. R&S ETL);

– Digital TV DVB-T2 Set-Top-Boxes;

– TV set to receive analogue TV programmes.

Measurement methodology

The position of the wireless broadband access system base station remains 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 user equipment at the edge of the base station service area;

– effect of the wireless broadband access user equipment 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 user equipment 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 user equipment 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 user equipment and subscriber TV STBs is evaluated, when the compatibility conditions are met.

Evaluating separation distances required to meet the compatibility conditions

The 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-RRC06 was used. Trigger value of allowable interference field strength from mobile service user equipment 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.

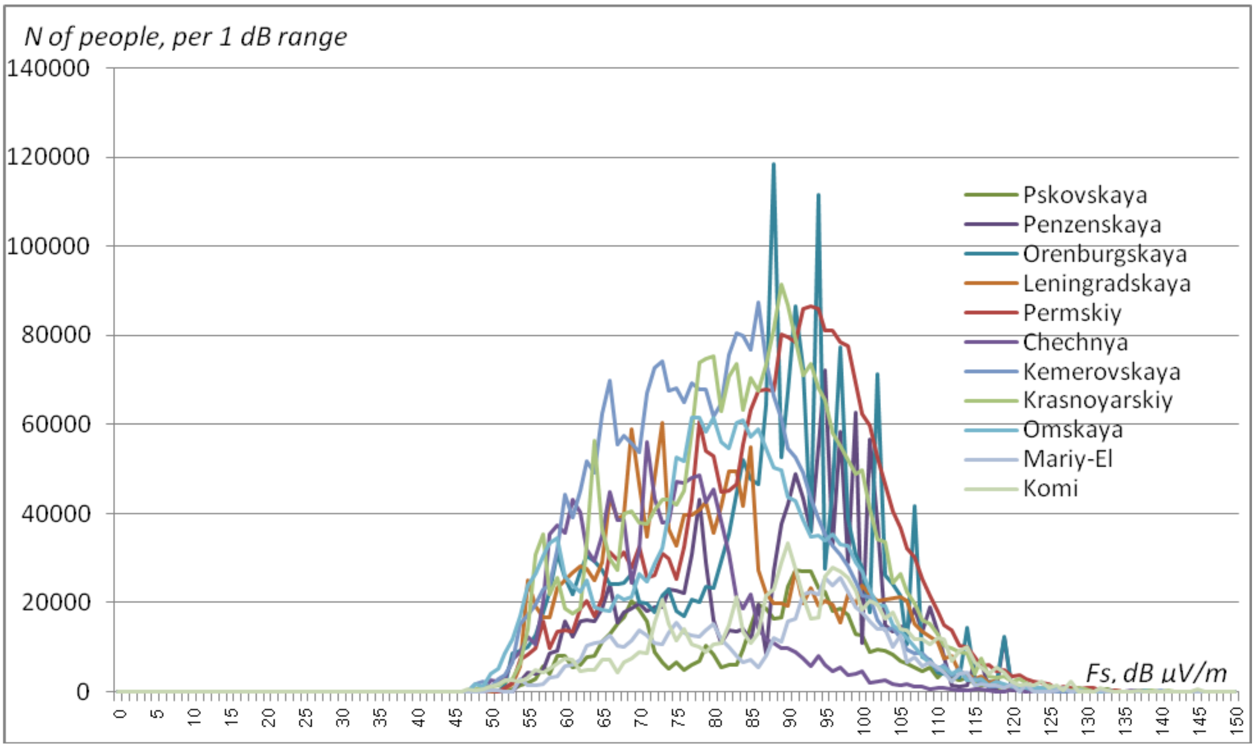
As a representative DVB-T2 modulation mode, 64 QAM 4/5 was used, which is the same mode, as was used in the measurements.

4.1.4 Calculation

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 48

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. 48, 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. 48 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.

4.1.5 Results

4.1.5.1 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 35.

– GENERAL SATELLITE TE8714 – Table 36.

– ROHDE & SCHWARZ test equipment – Tables 37, 38 and 39.

TABLE 35

Protection ratios (dB) for DVB-T2 signal (ORIEL 810 receiver) interfered with by wireless broadband user equipment

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 36

Protection ratios (dB) for DVB-T2 (General Satellite TE8714) interfered with by wireless broadband user 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 37

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

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 identified. Such restrictions should include a ban on the use of base stations and mobile user equipment within borders of cities/towns/villages and nearby, what actually will prevent any kind of practical implementation.

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 base station/UE located nearby, it means requirement for geographical separation between base stations/UE and terrestrial broadcasting antennas necessary to reduce signal level emitted from base stations/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 user equipment and base stations experimentally confirmed.

Results of field test measurements shown in Table 38.

TABLE 38

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 accessfrequency, MHz	wireless broadband accesse.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

4.1.5.2 Separation distances required to meet the compatibility conditions

Below given separation distances between the transmitting user equipment and the broadcasting receiving antenna (fixed reception in rural environment) for the line of sight conditions. The calculation performed for different levels of out-of-band emissions (OOBE). Corresponding separation distances with and without additional filtering are shown in
Tables 39 -41.

TABLE 39

Required separation distances user equipment and the broadcasting-receiving antenna determined for broadcasting service fixed reception in rural environment for the line of sight conditions without additional filtering

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

TABLE 40

Required separation distances user equipment and the broadcasting receiving antenna determined for broadcasting service fixed reception in rural environment for the line of sight conditions with presence of the sideband filter with attenuation of 15 dB

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	703	70	38
N-13	-35	703	70	38
N-12	-35	703	70	38
N-11	-35	703	70	38
N-10	-35	703	70	38
N-9	-35	703	70	38
N-8	-35	703	70	38
N-7	-34	704	79	52
N-6	-34	704	79	52
N-5	-34	704	79	52
N-4	-33	705	88	66
N-3	-33	705	88	66
N-2	-32	707	99	79
N-1	-29	713	140	127
N+1	-29	713	140	127
N+2	-33	705	88	66
N+3	-32	707	99	79
N+4	-33	705	88	66
N+5	-34	704	79	52

TABLE 41

Required separation distances for user equipment and the broadcasting-receiving antenna determined for broadcasting service fixed reception in rural environment for the line of sight conditions with presence of the sideband filter with attenuation of 25 dB

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	702	63	22
N-13	-35	702	63	22
N-12	-35	702	63	22
N-11	-35	702	63	22
N-10	-35	702	63	22
N-9	-35	702	63	22
N-8	-35	702	63	22
N-7	-34	702	64	25
N-6	-34	702	64	25
N-5	-34	702	64	25
N-4	-33	703	66	28
N-3	-33	703	66	28
N-2	-32	703	67	31
N-1	-29	703	74	44
N+1	-29	703	74	44
N+2	-33	703	66	28
N+3	-32	703	67	31
N+4	-33	703	66	28
N+5	-34	702	64	25

Protection ratios shown in Tables 39-41 were determined in accordance to results of broadband access system laboratory and field test trial in the frequency band 694-790 MHz. These protection ratios are slightly different from the protection ratios for LTE system signals. When considering the level of out-of-band emission limit, the difference between measured protection ratios and protection ratios for LTE system need to be taken into account.

In Tables below corresponding separation distances recalculated for protection ratios from the Recommendation ITU-R BT.2033 for DVB-T2 interfered with by LTE for 90% and 50% of silicon tuners are given.

In Tables 42 and 43, compatibility conditions calculated using the frequency band 694-790 MHz mobile service terminals and the corresponding loss of service by the example of the 11 regions in Russian Federation given on Figure 48.

As it can be seen from the calculation results in Tables 42-43, to provide compatibility it is necessary to use both methods to limit interference:

– establishing a limit for the level of UE out-of-band emissions in the bands below 694 MHz;

– installation of the additional rejection filter for frequency band 694-790 MHz at the input of TV receivers.

The attenuation of out-of-band emissions (OOBE) in UE, operating in the band 694-790 MHz, is to be implemented in UE itself.

TABLE 42

Conditions of use of the band 694-790 MHz by the mobile user equipment LTE system in the transmit mode, indicating the number of the affected population for 90th percentile of TV receivers

Increase of the minimum field strength, dB	Population affected, %	Conditions of use with OOBE X dBm/8 MHz, fixed reception				
		-25	-42	-46	-52	-56
0	-	1113	157	99	50	32
1	0,15	992	140	89	45	29
2	0,24	884	125	79	40	25
3	0,39	788	111	70	35	23
4	0,67	702	99	63	32	F50
5	1,10	626	88	57	28	F40
6	1,68	558	79	51	25	F40
7	2,40	497	70	45	F50	F40
8	3,28	443	63	40	F40	F40
9	4,35	280	56	42	F30	F30
10	5,58	249	50	37	F30	F30
11	6,89	222	44	33	F30	F30
12	8,18	198	40	29	F30	F30
13	9,54	176	35	F50	F30	F30
14	10,96	157	31	F40	F30	F30
15	12,48	140	28	F30	F30	F30
16	14,03	125	25	F30	F30	F30
17	15,69	111	F40	F30	F30	F30
18	17,26	99	F30	F30	F30	F30
19	18,95	88	F30	F30	F30	F30
20	20,63	79	F30	F30	F30	F30
21	22,28	70	F30	F30	F30	F30
22	24,11	63	F30	F30	F30	F30
23	26,04	56	F30	F30	F30	F30
24	28,02	50	F30	F30	F30	F30
25	29,94	44	F30	F30	F30	F30
26	31,93	40	F30	F30	F30	F30
27	33,98	35	F30	F30	F30	F30
28	36,25	31	F30	F30	F30	F30
29	38,72	28	F30	F30	F30	F30
30	41,19	25	F30	F30	F30	F30

xx Required separation distance, m, if more than 22[34] m, even with the maximum mitigation technique (50 dB filter) applied - incompatible.

Fxx Necessary to install a filter with suppression not less than xx dB.

TABLE 43

Conditions of use of the band 694-790 MHz by the mobile user equipment LTE system in the transmit mode, indicating the number of the affected population for 50th percentile of TV receivers for 50th percentile of TV receivers

Increase of the minimum field strength, dB	Population affected, %	Conditions of use with OOBE X dBm/8 MHz, fixed reception				
		-25	-42	-46	-52	-56
0	-	**1113**	**157**	**99**	**51**	**31**
1	0,15	**992**	**140**	**88**	**45**	**28**
2	0,24	**884**	**125**	**79**	**40**	**25**
3	0,39	**788**	**111**	**70**	**36**	F40
4	0,67	**702**	**99**	**63**	**32**	F30
5	1,10	**626**	**88**	**56**	**28**	F30
6	1,68	**558**	**79**	**50**	**25**	F30
7	2,40	**497**	**70**	**44**	F40	F30
8	3,28	**443**	**63**	**39**	F30	F30
9	4,35	**280**	**56**	**35**	F30	F30
10	5,58	**249**	**50**	**31**	F30	F30
11	6,89	**222**	**44**	**28**	F30	F30
12	8,18	**198**	**39**	**25**	F30	F30
13	9,54	**176**	**35**	F30	F30	F30
14	10,96	**157**	**31**	F30	F30	F30
15	12,48	**140**	**28**	F30	F30	F30
16	14,03	**125**	**25**	F30	F30	F30
17	15,69	**111**	F30	F30	F30	F30
18	17,26	**99**	F30	F30	F30	F30
19	18,95	**88**	F30	F30	F30	22
20	20,63	**79**	F30	F30	20	20
21	22,28	**70**	F30	F30	18	18
22	24,11	**63**	F30	F30	16	16
23	26,04	**56**	F30	21	14	14
24	28,02	**50**	20	19	13	13
25	29,94	**44**	18	17	11	11
26	31,93	**39**	16	15	10	10
27	33,98	**35**	14	13	9	9
28	36,25	**31**	13	12	8	8
29	38,72	**28**	11	11	7	7

34 For separation distances less than 22 meters, more interference attenuation occurs due to radiation pattern of the receiving antenna in vertical plane.

30	41,19	**25**	10	9	6	6

xx Required separation distance, m, if more than 22[35] m, even with the maximum mitigation technique (50 dB filter) applied - incompatible.

Fxx Necessary to install a filter with suppression not less than xx dB.

Calculations were carried out for fixed reception, the field strength changes are relative to the minimum median field strength of the wanted signal 49 dB µV/m (at TV channels 47-48) corresponding to the DVB-T2 system mode 64 QAM 5/6, used on DTTB networks in the Russian Federation, necessary to achieve at least 70% location probability. The protection ratio -24 or -41 dB used, relevant to the frequency shift of more than 18 MHz (TV channel 48) and to 90% or 50% of the receivers accordingly.

The results in Tables 42-43 related to the case when the user terminal operates with maximum power. To assess the impact of changes in the power level of the user terminal (using a different method than f Monte Carlo) the following simplified model may be considered.

In general, a mobile networks and broadcasting networks have different topologies, thus the distance from the TV reception place to the mobile network base station may be considered as a random variable that does not correlated with the distance to broadcasting transmitting station.

The transmitter power of mobile communication terminal will depend on the loss in the radio link between the UE and the base station, varying in the range of -47 dBm (near base stations) to 23 dBm (close to border of base station service area). We assume for simplicity that the transmitter power of the UE transmitter depends linearly upon the measured path loss in the current radio link.

Let's consider the example in which base station antenna has a height of 30 meters above ground and the radius of the service area of 8 kilometres. The value of the channel path loss at different distances from the base station is determined by the Okumura-Hata model for suburban areas.

The maximum radiation level of the UE for a period of time (e.g. 1 hour) will be determined by the movement of the terminal and changes of the radio channel conditions. To account for the possibility of exceeding the average rated power of the UE due to transient changes of the radio channel conditions, it is advisable to use a correction factor of 5 dB (corresponding to a transition from 90 % to 99% probability of a standard deviation of 5.5 dB), or higher.

The probability *P (UE>X)* of the UE power more than *X(Rx)* is defined as the ratio between the base station coverage area part where r> Rx, and the total BS service area, where *R* is distance from the UE to the base station.

Figure 49 below shows calculation results for the service area of a base station approximated as a circle having a radius R_{max} = 8 km with the centre at the base station installation site.

When considering the distribution of distances between broadcast receiving locations and IMT base station it is necessary to take into account that the frequency spectrum of IMT in one band shared between several operators, operating in adjacent frequency blocks within same band, and often using different base station installation sites. Consequently, the probability of being near to the edge of the BS service area of at least one of several IMT networks is increased.

35 For separation distances less than 22 meters, more interference attenuation occurs due to radiation pattern of the receiving antenna in vertical plane.

FIGURE 49

Maximum expected UE operating power *X* at the distance *R* from base station and probability for broadcast receiving location to be at a distance *r* ≥ *R* from base station in the presence of one, two and three IMT networks

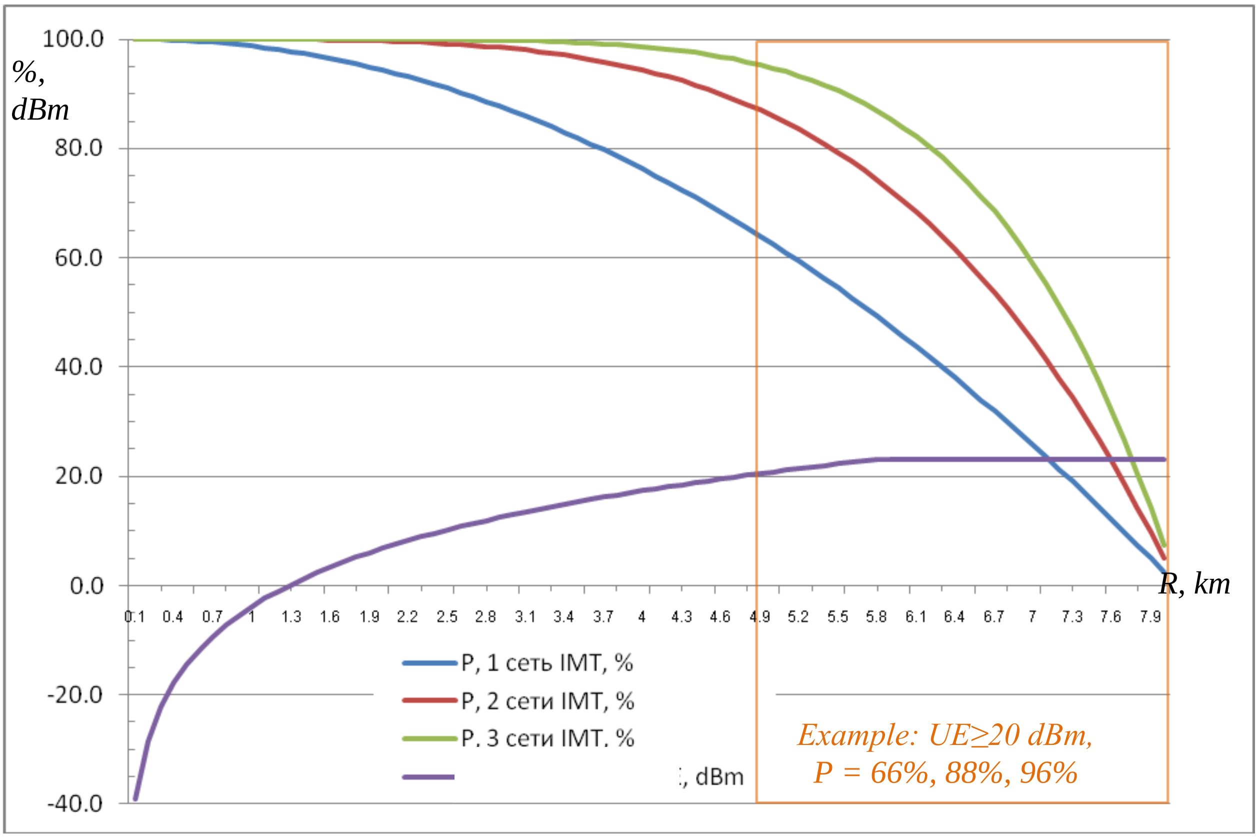


Figure 49 shows plots of maximum expected UE operating power at the distance *R* from base station (for representative time interval, i.e. 1 hour) and probability for broadcast receiving location to be at a distance *r* ≥ *R* from base station in the presence of one, two and three IMT networks. In real conditions, it is reasonable to expect that at least two of the three or four operators, using the frequency band 694-790 MHz, will have different network topologies. In case of full or partial use of common base station sites by some of them, estimate for a smaller number of operators, then actual number, may be applied.

In Figure 49, the probability of UE operation with a level greater than or equal to 20 dBm (through TV station coverage area) will be 68 % with a single operator network deployment, 87 % for network deployment by two operators and 96% - three (marked by orange rectangle). Given at Fig. 49 averaged probability for broadcast receiving location to be in area where broadcast receiving location to be at a distance r ≥ R from base station and maximum expected UE operating power is X dB, may be applied to the figures of the affected population in the Tables 4 and 5. For this, it is possible to assume that the decrease of UE power by 1 dB corresponds approximately to the increase of protected field strength by 1 dB given in tables. Integral summation of estimates for different values of the power terminal will provide more precise assessment of the affected population, with account of user terminal transmit power variations.

Numerical values from Figure 49 are given in Table 44.

TABLE 44

Probability of exceeding the threshold level of the user equipment power networks in the presence of one, two or three mobile service networks in TV broadcasting reception place

Max UE power decrease required Δ*P*, dB	Max UE power required *Px*, dBm	*Native* $D_{BS\text{-}UE}$, *km*	$P_{(UE>Px)}$, 1 network IMT, %	$P_{(UE>Px)}$, 2 networks IMT, %	$P_{(UE>Px)}$, 3 networks IMT, %
62.0	-39.0	0.1	100.0	100.0	100.0
51.4	-28.4	0.2	100.0	100.0	100.0
45.2	-22.2	0.3	99.9	100.0	100.0
40.8	-17.8	0.4	99.9	100.0	100.0
37.4	-14.4	0.5	99.8	100.0	100.0
34.6	-11.6	0.6	99.6	100.0	100.0
32.3	-9.3	0.7	99.4	100.0	100.0
30.2	-7.2	0.8	99.2	100.0	100.0
28.4	-5.4	0.9	99.0	100.0	100.0
26.8	-3.8	1	98.7	100.0	100.0
25.4	-2.4	1.1	98.4	100.0	100.0
24.0	-1.0	1.2	98.1	100.0	100.0
22.8	0.2	1.3	97.8	99.9	100.0
21.7	1.3	1.4	97.4	99.9	100.0
20.6	2.4	1.5	96.9	99.9	100.0
19.6	3.4	1.6	96.5	99.9	100.0
18.7	4.3	1.7	96.0	99.8	100.0
17.8	5.2	1.8	95.5	99.8	100.0
17.0	6.0	1.9	94.9	99.7	100.0
16.2	6.8	2	94.4	99.7	100.0
15.5	7.5	2.1	93.8	99.6	100.0
14.8	8.2	2.2	93.1	99.5	100.0
14.1	8.9	2.3	92.4	99.4	100.0
13.4	9.6	2.4	91.7	99.3	99.9
12.8	10.2	2.5	91.0	99.2	99.9
12.2	10.8	2.6	90.2	99.0	99.9
11.6	11.4	2.7	89.4	98.9	99.9
11.1	11.9	2.8	88.6	98.7	99.9
10.5	12.5	2.9	87.8	98.5	99.8
10.0	13.0	3	86.9	98.3	99.8
9.5	13.5	3.1	85.9	98.0	99.7
9.0	14.0	3.2	85.0	97.7	99.7
8.5	14.5	3.3	84.0	97.4	99.6

Max UE power decrease required ΔP, dB	Max UE power required *Px*, dBm	*Native D_{BS-UE}, km*	$P_{(UE>Px)}$, 1 network IMT, %	$P_{(UE>Px)}$, 2 networks IMT, %	$P_{(UE>Px)}$, 3 networks IMT, %
8.1	14.9	3.4	83.0	97.1	99.5
7.6	15.4	3.5	81.9	96.7	99.4
7.2	15.8	3.6	80.9	96.3	99.3
6.8	16.2	3.7	79.8	95.9	99.2
6.4	16.6	3.8	78.6	95.4	99.0
6.0	17.0	3.9	77.4	94.9	98.9
5.6	17.4	4	76.2	94.4	98.7
5.2	17.8	4.1	75.0	93.8	98.4
4.9	18.1	4.2	73.7	93.1	98.2
4.5	18.5	4.3	72.4	92.4	97.9
4.1	18.9	4.4	71.1	91.7	97.6
3.8	19.2	4.5	69.8	90.8	97.2
3.5	19.5	4.6	68.4	90.0	96.8
3.1	19.9	4.7	66.9	89.1	96.4
2.8	20.2	4.8	65.5	88.1	95.9
2.5	20.5	4.9	64.0	87.0	95.3
2.2	20.8	5	62.5	85.9	94.7
1.9	21.1	5.1	60.9	84.7	94.0
1.6	21.4	5.2	59.4	83.5	93.3
1.3	21.7	5.3	57.8	82.1	92.5
1.0	22.0	5.4	56.1	80.7	91.5

To get more precise estimate of the number of households that will be exposed to harmful interference from operating IMT networks, it is necessary using the Tables 42 or 43, for the given value of OOBE X dBm / 8 MHz, determine the maximum increase on the minimum field strength, $D_{Emin}(X)$, to which interference is still possible (lower red cell in the corresponding column).

To estimate the number of households what will be affected by interference in the absence of additional external filter or other mitigation measures to improve TV receivers ACS, the maximum increment for the minimum field strength, $D_{Emin}(X)$, for which installation of external filter necessary (indicated by F30, F40 or F50 mark in relevant cell), is used instead.

Adjusted ratio of households subject to interference determined by the following formula:

$$P_a(X) = \sum_{i=1}^{D_{E_{min}}(X)} \left(P_a(D_{E_{min}i}) - P_a(D_{E_{min}i-1}) \right) * P_{(UE>Px)}(i)$$

Where $P_{(UE>Px)}(i)$ to be taken from Table 44 for $\Delta P \approx i$ from column for 1, 2 or 3 IMT networks.

Table 45 shows an example of calculating the more precise number of households exposed to interference, taking into account the variations of IMT UE radiated power. Table covers increase of the minimum median field strengths up to 16 dB what corresponds to OOBE -42 dBm/8 MHz (assuming installation of external filters or other measures to improve TV receivers ACS applied).

TABLE 45

Calculation of the share of households subject to interference taken into account the power variations of IMT UE

D_{Emin}	$Pa_i(D_{Emin})$	ΔPa_i	$P_{(UE>Px)}$ 1 IMT network, %	$Pa_i(X)$ 1 IMT network, %	$P_{(UE>Px)}$ 2 IMT networks, %	$Pa_i(X)$ 2 IMT networks, %	$P_{(UE>Px)}$ 3 IMT networks, %	$Pa_i(X)$ 3 IMT networks, %
1	0.15	**0.15**	56.1	0.08	80.7	0.12	91.7	0.14
2	0.24	**0.09**	60.7	0.05	85.1	0.08	94.3	0.08
3	0.39	**0.15**	66.4	0.10	88.7	0.13	96.3	0.14
4	0.67	**0.28**	71	0.20	91.5	0.26	97.5	0.27
5	1.1	**0.43**	74	0.32	93.3	0.40	98.2	0.42
6	1.68	**0.58**	77.4	0.45	94.9	0.55	98.9	0.57
7	2.4	**0.72**	80.3	0.58	96.1	0.69	99.2	0.71
8	3.28	**0.88**	82.9	0.73	97.1	0.85	99.5	0.88
9	4.35	**1.07**	85	0.91	97.7	1.05	99.7	1.07
10	5.58	**1.23**	86.9	1.07	98.3	1.21	99.8	1.23
11	6.89	**1.31**	88.5	1.16	98.7	1.29	99.9	1.31
12	8.18	**1.29**	90	1.16	99	1.28	99.9	1.29
13	9.54	**1.36**	91.5	1.24	99.3	1.35	99.9	1.36
14	10.96	**1.42**	92.3	1.31	99.4	1.41	100	1.42
15	12.48	**1.52**	93.3	1.42	99.5	1.51	100	1.52
16	14.03	**1.55**	94.2	1.46	99.7	1.55	100	1.55
Pa				**12.24**		**13.73**		**13.97**

From Table 45 it is easy to determine proportion of households exposed to interference taken into account the IMT UE power variations for different IMT UE out-of-band emission limits (assuming installation of external filters or other measures to improve TV receivers ACS applied).

The calculation assumes that the interference mitigation techniques are already applied, in particular - the installation of additional frequency-selective filter at TV receivers input, and possibly improvements of cable and tuner shielding then filter to cope against interference from IMT networks in the 694-790 MHz band. Installing the filter may be necessary for a large number of fixed receivers with the useful signal level below a certain limit and for potentially 100% of mobile and portable receivers. Even with this, it is impossible to eliminate interference in 100% of locations. Households/population loss figures are given in Table 46.

TABLE 46

Proportion of households subject to interference taken into account the power variations of IMT UE

OOBE, dBm/8MHz	% of receivers	$Pa_i(X)$ 1 network, %	$Pa_i(X)$ 2 networks, %	$Pa_i(X)$ 3 networks, %
-42	50, 90	**12.24**	**13.73**	**13.97**
-46	50, 90	**6.81**	**7.91**	**8.12**
-52	50, 90	**1.20**	**1.54**	**1.64**
-56	90	**0.24**	**0.33**	**0.37**
-56	50	**0.14**	**0.20**	**0.22**

In the absence of mitigation measures to limit interference, the proportion of households exposed to noise ratio will be much higher as indicated in Tables 42 and 43.

Table 46 indicates that for out-of-band emission levels more than -52 dBm/8 MHz will cause significant loss of digital TV broadcasting coverage (7-14%) and further mitigation will be possible only at the expense of limiting the maximum radiated power of IMT user terminals.

For example, the limit of out-of-band emissions for UE of -42 dBm / 8 MHz will not allow to meet sharing and compatibility conditions in reception areas, corresponding to 14% of households, even when using additional filters at the input of the receiver to improve the TV ACS.

There is a small dependence of this effect from frequency separation and OOB limits, what means TV reception in all broadcasting service UHF bands will be subject to interference. Calculations show that establishing lower out-of-band emissions limit will impose an unnecessary and excessive burden on national regulators and operators taking complicated measures to eliminate interference, including the need to limit the maximum UE power at a level below 23 dBm, which will significantly decrease the expected performance of IMT networks in 700 MHz band.

4.1.6 Analysis of trial study results

The trial results showed the following:

– It is necessary to have a separation distance between transmitting antennas of wireless broadband access system and TV broadcasting receiving antennas to achieve electromagnetic compatibility between wireless broadband access systems and terrestrial TV broadcasting systems. 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 user equipment in a sufficiently great number of cases. A special order of operation for base stations and user equipment 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 user equipment, 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).

This field trial study with a particular wireless broadband access system (non-3GPP LTE system) indicated that necessary line-of-sight separation distance ranges from 180 to 995 metres for specified technical parameters in this study (depending on OOBE limit in the range from -56 to -25 dBm/8 MHz and frequency separation) in the frequency range until at least 112 MHz (N-14) offset, when no mitigation technique is applied. With a rejection filter at broadcast receiver antennae input, separation distances decrease from a range of 180 to 995 metres to the range from 38 to 713 m for a 15 dB rejection, and to the range from 22 metres to 703 metres for a 25 dB rejection.

Considering protection ratios for a DVB-T2 system interfered with by LTE, it’s shown that to keep the number of households, affected by interference, at a manageable level (lower than 2%), it is necessary to limit user equipment OOBE to the level no higher than -52 dBm/8 MHz or -56 dBm/8 MHz (better, 0.5% households affected), with guard band not less than 9 MHz, 30..40 dB rejection filters and UE maximum power not exceeding 23 dBm.

4.2 Mobile service as a victim: Interference from broadcasting service transmissions into the mobile service user equipment

4.2.1 Scenarios

4.2.2 Methods of calculation with formulas

4.2.3 Calculations

4.2.4 Results

4.3 Measurements

4.3.1 DTTB receiver ACS

DTTB receiver ACS values were derived from the protection ratios given in Recommendations ITU-R BT.1368 and ITU-R BT.2033 , for use in sharing studies between DTTB and IMT UE. Protection ratios were tested on thirteen DVB-T/T2 TV receivers, currently available on the market, aiming at getting an insight into the performance of recent DTTB receivers.

The results of the measurement show that the tested DTTB receivers, the average ACS value being 62 dB, behave similarly in the presence of a continuous IMT UE signal, and behaved differently in the presence of a discontinuous (time varying) signal. The IMT UE ACLR tested was between 53 and 70 dB. Modern DVB-T2 receivers behave better in the presence of a discontinuous IMT UE signal than in the presence of a continuous IMT UE signal, while the performance of DVB-T receivers is reduced by about 20 dB. The impact of discontinuous IMT UE emissions on DTTB reception can only be efficiently combated by improving DTTB receivers’ AGC circuits, including the overall ACS of the receivers. For these reasons, when determining the IMT UE OOBE limits, only the impact of a continuous IMT UE signal on DTTB reception should be considered. The results of the measurements are presented in [Appendix 5].

The ACS of the TV sets as measured in one study with a 10 MHz LTE interferer with a centre to centre offset between the 8 MHz bandwidth DTTB TV channel and the LTE of 18 MHz was 64 to 65 dB unaided, and between higher at 74 to 79 dB when assisted with an external filter.

4.3.2 OOBE levels to protect portable indoor reception

A measurement study showed that for a 3 dB allowed de-sensitisation of a portable DTT receiver an out-of-band limit of -55 dBm/8 MHz is needed when the interferer is inside the same room. The results of the measurements are presented in [Appendix 1].

4.4 Measures to enable coexistence

4.4.1 Mitigation measures to be implemented on MS

[RUS:

Necessary mitigation techniques include:

1 For the mobile service – a requirement for space separation between base station/UE and terrestrial broadcasting antennas is necessary to reduce signal level emitted from base station/UE antenna systems at TV reception locations. Mandatory application of such a measure to the UE cannot be ensured in practice because this end of mobile service radio link is user-controlled.

]

4.4.2 Mitigation measures to be implemented on the broadcasting service

[*RUS:*

2 For the broadcasting service – the installation of additional sideband filters at the input of TV receivers and, possibly, improved shielding of cable and tuner circuits after that filter.

]

Below given examples of separation distances between the transmitting user equipment and the broadcasting receiving antenna (fixed reception in rural environment) for the line of sight conditions. Results for levels of UE out-of-band emissions (OOBE) of
–46 dBm/8 MHz and -56 dBm/8 MHz, with and without additional filtering are given in Tables 47 and 48.

TABLE 47

Examples of required separation distance between user equipment and the broadcasting receiving antenna, fixed reception in rural environment for the line of sight conditions with no presence and with presence of the sideband filter for OOBE -46 dBm/8 MHz

Channel	**Protection ratio for 90_{th} receivers percentile, dB**	**Separation distance with no filter, m**	**Separation distance with 15 dB attenuation filter, m**	**Separation distance with 25 dB attenuation filter, m**
N-14	-35	190	70	63
N-13	-35	190	70	63
N-12	-35	190	70	63
N-11	-35	190	70	63
N-10	-35	190	70	63
N-9	-35	190	70	63
N-8	-35	190	70	63
N-7	-34	276	79	64
N-6	-34	276	79	64
N-5	-34	276	79	64
N-4	-33	357	88	66
N-3	-33	357	88	66
N-2	-32	437	99	67
N-1	-29	708	140	74
N+1	-29	708	140	74
N+2	-33	357	88	66
N+3	-32	437	99	67
N+4	-33	357	88	66
N+5	-34	276	79	64

TABLE 48

Examples of required separation distance between user equipment and the broadcasting-receiving antenna, fixed reception in rural environment for the line of sight conditions with no presence and with presence of the sideband filter for OOBE -56 dBm/8 MHz

Channel	Protection ratio for 90_{th} receivers percentile, dB	Separation distance with no filter, m	Separation distance with 15 dB attenuation filter, m	Separation distance with 25 dB attenuation filter, m
N-14	-35	180	38	22
N-13	-35	180	38	22
N-12	-35	180	38	22
N-11	-35	180	38	22
N-10	-35	180	38	22
N-9	-35	180	38	22
N-8	-35	180	38	22
N-7	-34	270	52	25
N-6	-34	270	52	25
N-5	-34	270	52	25
N-4	-33	352	66	28
N-3	-33	352	66	28
N-2	-32	433	79	31
N-1	-29	705	127	44
N+1	-29	705	127	44
N+2	-33	352	66	28
N+3	-32	433	79	31
N+4	-33	352	66	28
N+5	-34	270	52	25

4.5 Conclusions for adjacent-band compatibility studies

5 Summary

5.1 IMT base station interference into DTTB

[Reference Document 4-5-6-7/311]

One study showed that the separation distances needed for different adjacent channels cases in order to protect DTTB from IMT base stations, considering the accumulative effect would vary from 15 to 35 kilometres.

[Ed. Note: further discussion is needed what to do with the next summary]

[[Reference Document 4-5-6-7/443]

The study of the interference situation between LTE base station downlinks and fixed roof-top DTT reception in adjacent band (in the 800 MHz band) in France shows that the distance between the interfering IMT base station and he fixed roof-top DTT receiving location is in 99% of cases below 1.3 kilometres. This interfering situation is essentially a national matter and does not require any provision in the RR. Almost all reported interference cases observed so far were identified as the LTE base station provoking DTT receiver saturation (active systems like amplifiers or DTT television / set-top box). All these cases had been successfully resolved by the administration and operators by introducing of an LTE 800 filter (either head-end filters or user filters). Regarding the saturation effects, the situation is likely to be similar in the 800 MHz band and in the 700 MHz band.]

5.2 IMT user equipment interference into DTTB

5.2.1 Minimum coupling loss calculations

[Reference Documents 4-5-6-7/218, 4-5-6-7/518]

One study showed that the MCL technique establishes known everyday configurations for study. This study showed the TV fixed reception critical distance is around 22 metres to the areas outside a house with a larger distance spread within a few dB. Using the ACS and OOB/ACLR values provided by the working parties the actual separation distance required between a UE and the fixed TV antenna is a lot greater. There would be no compatibility at maximum UE powers in lower TV reception signal strength areas at a separation distance of 22 metres. The potential improvements in compatibility with higher TV ACS values as found in newer TV sets were investigated plus additional external filter mitigation. To achieve compatibility the calculated required UE OOB level is -56 dBm/8 MHz for 23 dBm UE power, for a 10 MHz LTE signal, and given a TV receiver plus extra filter combined ACS of 80 dB.

[Reference Document 4-5-6-7/328]

A study showed that in a typical European suburban area there is a high probability, over 70% in the example provided, that the path loss between an IMT UE and a DTTB receiver using a fixed receive aerial will be within 6 dB of the minimum coupling loss.

[Reference Document 4-5-6-7/232]

One study based on MCL method derived the level of OOBE required to limit the degradation in sensitivity of a DTTB receiver, with fixed roof top antenna, to 0.41 dB; this degradation corresponds to an I/N of –10 dB. The results derived a minimum coupling distance of 22 meters and suggest an OOBE limit of –56 dBm/8MHz would be appropriate to manage the interference into a typical DVB-T2 receiver. The calculations assumed the DTT receiver ACS would be enhanced by using an external filter to give a total ACS value of 79 dB.

[Reference Document 4-5-6-7/339]

One study showed the following with measurements of the performance of three independent new design TV receivers on sale in the UK in the presence of LTE interference. The results also showed that the improved ACS values capabilities of these receivers could not be utilised unless improvements were also made to the ACLR of the UE. The studies showed the additional benefits that were possible with external TV receiving filters. Bandpass transmit filters on the UE were used to vary the OOB emissions. The achieved TV receiver ACS values were between 64 dB to 65 dB unaided and from nearly 74 dB to 80 dB with the aid of an external receiving filter.

The TV receiver overload thresholds were improved from around –10 dBm to above +10 dBm with the external receive filter.

5.2.2 Monte Carlo simulations

[Reference Documents 4-5-6-7/181, 4-5-6-7/374, 4-5-6-7/417]

A generic study on the impact of IMT UE into DTT reception at coverage edge showed that the less favourable interference scenario from IMT/LTE uplink to DTT is found in an urban environment for the reason of smaller cell size (higher active user density). In a rural environment the probability of interference is mainly dominated by UE in-band (IB) power, and that this power can only be attenuated by the DTT receiver ACS. It showed also that the total probability of interference decreases with the increase of DTT receiver ACS, and the increase of IMT UE ACLR (decrease of UE OOBE level). Furthermore, for a given DTT receiver ACS, the total probability of interference will not decrease with the increase of IMT UE ACLR (decrease of UE OOBE level) above certain level, since it is limited by DTT receiver ACS. When considering several UE (e.g 10) the probability of interference is mainly dominated by the UE in-band power (IB).

[Reference Document 4-5-6-7/557]

Another study indicated that imposing more stringent OOBE values of up to –35 dBm/8 MHz, will lead to a minimal reduction in IP = 0.10% at most. On the basis of this minimal reduction in IP the adoption of stricter OOBE limits is not warranted. In view of the above results, and taking into account the potential benefits of harmonisation, it is proposed that an OOBE limit of –25 dBm/8 MHz be adopted as a suitable value

[(Reference Document 4-5-6-7/368]

Another study indicated that in the whole DTT coverage area, for a given IMT UE transmitter blocking mask or ACLR which are based on the APT OOBE that are recommended not to exceed –34 dBm/MHz (ACS values of 25, 38, 50 and 60 dB were taken into account) below 694 MHz, the results of the simulations for different DTT receiver ACS values show that the total interference probability (IP) is less than 1% in all cases.

[Reference Document 4-5-6-7/447)]

Another study indicated a very low IP for its worst case (urban environment, one user with full resource block allocation, low ACS of DTT receiver) and almost zero potential of IP in the majority of scenarios and parameter combinations. Therefore, study indicated that with a reasonably high DTT ACS (e.g. ACS = 60 dB or higher) the LTE UE OOBE level of –33 dBm/8 MHz for the 10 MHz LTE channel is sufficiently low to avoid interference to frequencies below 694 MHz.

It was also observed that the IP is more sensitive to the DTT ACS than to the LTE UE OOBE level, so that means that after certain breaking point, more stringent OOBE does not decrease IP anymore. For example, in the urban scenario (worst case found) and with ACS values 55, 60 and 65 dB, the breaking point for OOBE is somewhere between -33 and -38 dBm/8 MHz (for the 10 MHz IMT channel).

[Reference Document 4-5-6-7/563]

Based on previous work testing input parameters, one study calculated the IP for a DTTB receiver ACS of 65, 70 and 75 dB and a range of UE ACLR from 48 to 79 dB. These studies were conducted using the TPC values and network configuration [specified by WP 5D] for studies and 10 000 000 simulations in the Monte Carlo calculations. IP results for urban, suburban and rural environments, for the ACS and ACLR ranges mentioned are presented.

[Reference Document 4-5-6-7/508]

Another study was carried out to calculate the probability of interference into portable outdoor DTTB reception. Its results indicate that this probability is slightly higher than it is for fixed reception, for the same parameters, and that it increases significantly with the number of active UE. The results also indicate that the probability of interferences increases by a factor of 2 if no body loss is taken into account or the UE has a higher antenna gain by 4 dB (+1 dB in total). Furthermore, the study indicates that more than 100 000 events should be used in order to get converging/reliable results.

5.2.3 Monte Carlo simulations with post-processing

[Reference Document 4-5-6-7/417 and 630]

One study based on Monte Carlo statistical simulations of the probability of interference into the DTTB reception in a pixel (100x100 m) at the coverage edge during an observation time (TW) of 1 hour indicated that, while the values of IMT UE ACLR and DTT receiver ACS should be similar in order to achieve the best performance configuration with respect to interference into DTTB reception, above a certain level of ACS (e.g. 65 dB, which is the average ACS of recent DTTB receivers), a further improvement of the IMT UE ACLR above a certain level (e.g. a value higher than 67 dB) there is no significant reduction of the overall probability of interference. This leads to a range of IMT UE OOBE limit values between -40 and -44 dBm/8 MHz for 10 MHz IMT channel. Further simulations showed that the OOBE of IMT user equipment operating in the frequency band 694-790 MHz should not exceed -42 dBm/8 MHz for a 10 MHz LTE channel bandwidth in the frequency band 470-694 MHz for the protection of the broadcasting service in this frequency band.

[Reference Documents 4-5-6-7/563, 4-5-6-7/564]

Another study used Monte Carlo analysis to generate the IP which was then post-processed to give the probability of interference to a DTTB receiver occurring in a specified TW. This post-processing used a number of independent events generated based on the user density and UE movement. The results of this post processing have been used to derive the out-of-band emissions for IMT UE required to limit interference of DTTB reception to 1%. The study concludes that to limit the interference into channel 48 and below, from IMT UE operating in the 700 MHz band, DTTB receiver ACS should be in the range 70 dB to 75 dB. IMT UE out-of-band emissions should be limited to the range –47 dBm/8 MHz to –52 dBm/8 MHz (an ACLR range of 70 dB to 75 dB).

5.2.4 Monte Carlo simulation with time element

[Reference Documents 4-5-6-7/579, 4-5-6-7/382]

One Monte Carlo study investigated adjacent band sharing between DTTB and IMT UE based on Δ_{RLP}, the degradation of reception location probability (RLP). This method was developed to deal with the time element of mobile transmission (e.g. movement of UE during a DTTB viewer’s time frame) and to take into account RLP which is the basis of broadcast planning. The MC methodology used to calculate Δ_{RLP} is described. The results cover a range of ACS values (55-80 dB) and ACLR values (40-80 dB) and UE density (1-10 UE/sector). It is shown that unacceptable interference from UE results, unless both improved OOBE filtering in the UE and increased ACS at the point of DTTB reception are implemented. Based on the results, an ACS of 80 dB, a set of OOBE limits for 10 MHz IMT UE are proposed: the OOBE shall not exceed a value of –55 dBm/8 MHz for an RB usage of 33%; a value of –49 dBm/8 MHz for an RB usage of 50%; and a value of –46 dBm/8 MHz for an RB usage of 100%.

5.2.5 Monte Carlo sensitivity studies

[Reference Documents 4-5-6-7/561, 4-5-6-7/560, 4-5-6-7/559]

Another set of studies were carried out to test how the results of Monte Carlo simulations varied for different input parameters. One study concluded that the number of simulations in a Monte Carlo analysis needed to provide confidence in the derived IP, should use more than 100 000 trials – ideally being between 1 000 000 and 10 000 000. Another study investigated the impact of omitting the standard deviation associated with building entry loss. This study concluded that doing so would result in an under estimation of the IP of up to 50% and that such values of IP calculated without building standard deviation should be adjusted appropriately. As the power control settings are key to determining the level of interference of IMT UE to DTTB reception, a further study was carried out to ensure settings are aligned with [advice from WP 5D]. Values were derived for urban, suburban and rural environments and used in studies to derive the IP.

[Reference Document 4-5-6-7/509]

Another set of studies were carried out to test how the results of MC simulations varied for different input parameters (“sensitivity studies”). With respect to other studies based on ”standard” parameters, the probability of interference into fixed DTTB reception increased by a factor of 2 in case that no body loss applies or the UE antenna gain is by 4 dB higher, as well as if 30% of mobile traffic generated from indoor and 70% generated from outdoor. The probability will increase by a factor of 3 if 30% of traffic is generated indoor, 35% is generated outdoor with body loss and an antenna gain of –3 dBi and the remaining 35% is generated outdoor without body loss and an antenna gain of 0 dBi. The studies also concluded that the number of active devices usually is much higher than the number of users triggered this activity, and that the probability of interference increases significantly with the number of active UE. This set of studies indicates that more than 100 000 events should be used in order to get converging/reliable results.

5.2.6 Field Trials

[Reference Document 4-5-6-7/488 and 613]

One field trial study with a particular wireless broadband access system (non-3GPP LTE system) indicated that necessary line-of-sight separation distance ranges from 180 to 995 metres for specified technical parameters in this study (depending from OOBE limit in the range from -56 to -25 dBm/8 MHz and frequency separation) in frequency range until at least 112 MHz (N-14) offset, when no mitigation technique is applied. With a rejection filter at the broadcast receiver antennae input, separation distances decreases from a range of 180 to 995 metres to the range from 38 to 713 m for a 15 dB rejection, and to the range from 22 metres to 703 metres for a 25 dB rejection.

Considering protection ratios for DVB-T2 system interfered with by LTE, it’s shown that to keep the number of households, affected by interference, at a manageable level (lower than 2%), it is necessary to limit user equipment OOBE to the level no higher than -52 dBm/8 MHz or -56 dBm/8 MHz (better, 0.5% households affected), with guard band not less than 9 MHz, 30..40 dB rejection filters and UE maximum power not exceeding 23 dBm.

5.2.7 Measurements

[Reference Document 4-5-6-7/418]

A measurement study showed that the tested DTTB receivers (ACS 62 to 65 dB) behave similarly in the presence of a continuous IMT UE signal, and behaved differently in the presence of a discontinuous (time varying) signal. The IMT UE ACLR tested was between 60 and 70 dB. Modern

DVB-T2 receivers behave better in the presence of a discontinuous IMT UE signal than in the presence of a continuous IMT UE signal, while the performance of DVB-T receivers was reduced by about 20 dB.

The impact of discontinuous IMT UE emissions on DTTB reception can only be efficiently combated by improving DTTB receivers' AGC circuits, including the overall ACS of the receivers. It was confirmed that improving the IMT UE ACLR (i.e. above around 60 dB) does not improve the protection ratio. For these reasons, when determining the IMT UE OOBE limits, only the impact of a continuous IMT UE signal on DTTB reception should be considered.

ANNEX

Model of a wideband distribution amplifier

The I/O characteristics of a non-linear amplifier can be modelled as its series expansion truncated at the 3rd order[36], as follows:

$$V_o = c_1 V_i + c_2 V_i^2 + c_3 V_i^3$$

where:

V_i is the input voltage;

V_o is the output voltage;

c_1 is the amplifier gain;

c_2, c_3 are the 2nd and 3rd order coefficients of the series expansion.

A wideband distribution amplifier can be characterised by means of its maximum gain, nominal output level and corresponding values of 2nd and 3rd order inter-modulation distortion (IMD).

Typically, the nominal output level is given according to DIN 45004B, i.e., as the value corresponding to a 3rd order IMD equal to -54 dB if measured according to the two-carrier method, or -60 dB if measured according to the three-carrier method.

By definition, this nominal output level is referred to two input signals: in a real environment, the output level of each TV channel should be therefore properly reduced according to the following formula, providing the correct amplifier regulation in a condition "before" the introduction of LTE signals:

$$\Delta P = 10 \log (n_c - 1)$$

where n_c is the number of distributed channels.

Once the output level has been properly set (i.e., adjusting the amplifier gain), the I/O characteristic can be simplified as follows:

$$A_o = A_i - k_2 A_i^2 - k_3 A_i^3$$

where

[36] In case of very high input signal levels, a more precise approximation could be achieved with a 5th order model.

$$A = \sqrt{P} = \frac{V}{\sqrt{R}}$$, with R = 75 Ω;

the gain has been normalised to 1.

The coefficients k_2 e k_3 can be calculated on the basis of the 2nd and 3rd order IMD values, according to the following formulas:

$$k_2 = \frac{1}{\sqrt{2}} \cdot 10^{\frac{-(P_{nom} - IMD_2)}{20}}$$

$$k_3 = \frac{2}{3} \cdot 10^{\frac{-(2P_{nom} - IMD_3)}{20}}$$

where:

P_{nom} is the nominal output level, expressed in dBm;

IMD_2 is the 2nd order IMD, expressed in dB;

IMD_3 is the 3rd order IMD, expressed in dB, measured according to the two-carrier method [37].

The described general model is valid for any wideband distribution amplifier.

Different classes of amplifiers, whose market penetration varies from country to country, can be installed in domestic installations, differing in gain and nominal output level:

– **Communal antenna amplifiers**

These amplifiers are widely used in apartment blocks to allow DTT signals received from a single antenna to be boosted sufficiently for distribution to multiple dwellings within the block. Typically these amplifiers are professionally installed and operate close to saturation. The nominal output power of such devices is typically (but not exhaustively) in the range 110-130 dB(µV), and the gain is typically in the range 20-50 dB (adjustable).

– **Masthead amplifiers**

These are small booster amplifiers fitted to the top of the antenna mast and powered by DC injected into the antenna cable, whose purpose is to serve a single house or a small number of apartments. The nominal output power is typically lower than communal antenna amplifiers, i.e., in the range 90-115 dB(µV), and the gain is typically in the range 15-30 dB, often adjustable.

– **Domestic booster amplifiers**

These devices can be installed in attics by the original house builders or by the final user within his apartment. The nominal output power is typically in the range 80-110 dB(µV), and the gain is typically in the range 5-20 dB, fixed or adjustable.

Simulation models

[37] Equal to the 3rd order IMD measured according to the three-carrier method +6 dB.

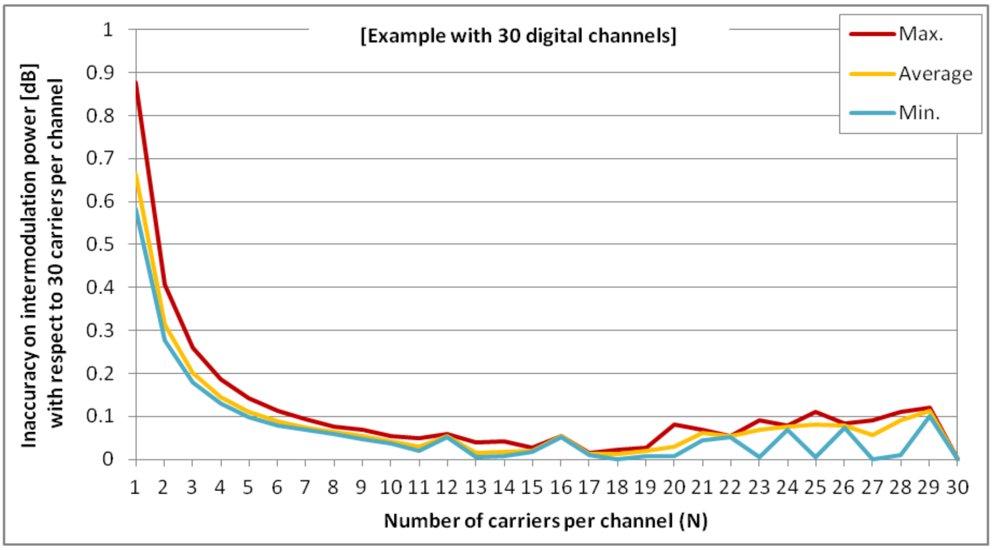
The 2nd order intermodulation products fall at frequencies like $f_1 \pm f_2$ or $2f_1$, while 3rd order intermodulation products fall at frequencies like $f_1 \pm f_2 \pm f_3$, $2f_1 \pm f_2$ or $3f_1$, where f_1, f_2 and f_3 are any of the carriers belonging to the input signals (DVB-T or LTE)[38].

Each of the DVB-T and LTE OFDM signals can be modelled as a number N of equally spaced carriers, distributed within the relevant bandwidth (i.e., 8 MHz for DVB-T channels, 5 or 10 MHz for LTE channels), having a power equal to 1/N of the signal power. The number N has to be chosen as a trade-off between accuracy and simulation time.

As an example, Figure 1 shows the inaccuracy of the calculated intermodulation power as a function of the number N of carriers per channel, determined in a specific case relevant to 30 channels and average intermodulation power equal to -38 dBm.

FIGURE 1

Inaccuracy of the calculated intermodulation power as a function of the number of carriers per channel

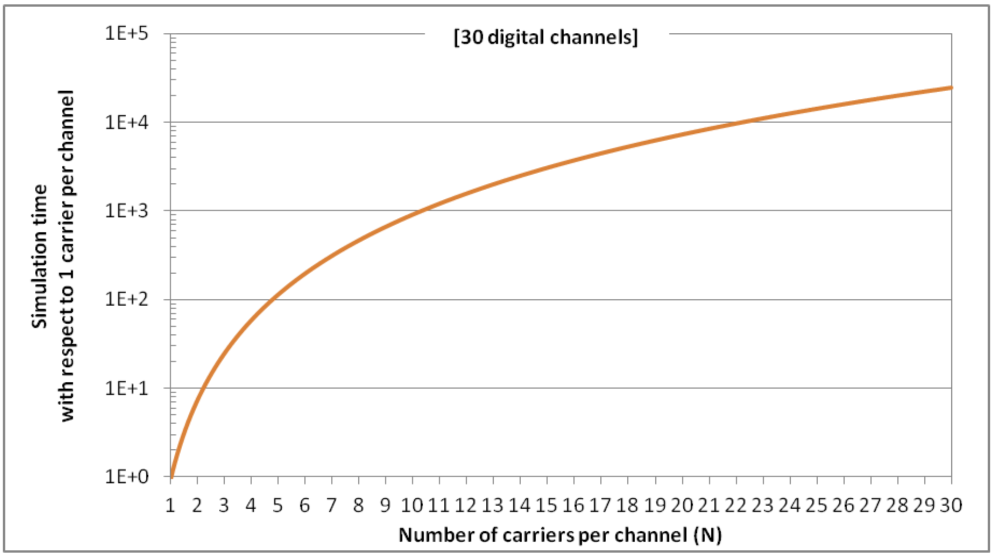


The simulation time increases with the total number of carriers, i.e., the number of distributed channels n_c multiplied by the number N of carriers per channel. Figure 2 shows the estimated simulation time as a function of the number N of carriers per channel, in the case of 30 channels, with respect to the simulation time in case of 1 carrier per channel (set equal to 1).

[38] Considering devices operating in the UHF TV band (i.e. 470-862 MHz), only 3rd order beats at frequencies like $f_1 \pm f_2 \pm f_3$ or $2f_1 - f_2$ can contribute to intermodulation products in the TV signals bandwidth.

FIGURE 2

Estimated simulation time as a function of the number of carriers per channel (with respect to 1 carrier per channel, 30 channels)



Also the thermal noise generated inside the in-building distribution system should be included in the simulations. It can be determined on the basis of the typical noise figure of a DVB-T receiver (i.e., 7 dB), applying a further margin to include the active and passive components of the MATV network (i.e., 4 dB).

This model is fully transparent with respect to any interference mitigation device placed in front of it.

APPENDIX 1

[*BNE:*

APPLICABILITY OF MCL approach: Case Studies

The case study submitted in [Document 4-5-6-7/328] show that the MCL zone for a typical suburban area is quite extensive as shown in Figure A.1.1. For the 1 km^2 area shown, the UE will be at a point within 3 dB of the Minimum Coupling Point over 41% of the area, and within 6 dB over 68% of the area.

FIGURE A.1.1

Example showing the proportion of a suburban area where IMT UE equipment would be within 3 dB or 6 dB of the point of MCL for a suburban area

The case study [submitted in Document 4-5-6-7/380] uses Hata and an associated random distribution for the path loss to calculate the locations where an IMT UE operating in a sector located at the edge of DTTB coverage would cause interference to DTTB reception (in other words, it does not assume the UE operates at maximum power or free-space path loss between the UE and DTTB receiver). Further results are expected in subsequent contributions.]

APP1.2 Measurement necessary OOBE levels to protect portable indoor reception

In order to find the upper limit power level for the White Gaussian Noise (WGN) interfering to reception of DVB-T2 over the antenna, which is similar to the interference caused by a IMT-UE transmitting in an adjacent channel, an experiment was set-up. A DVB-T2 signal was transmitted by an antenna, received by a second antenna at a distance of ca. 3 m, connected to a DVB-T2 receiver.

WGN was transmitted over a third antenna positioned at a distance of 1 m, 2 m and 3 m relative to the DVB-T2 reception antenna. The sum signal was fed to a DVB-T2 receiver. All antennas were in a room.

The DVB-T2 link was set to have a 3 dB reserve at 602 MHz. This means that the measurement already contains a significant interference margin, i.e. that the DTT receiver failed around I/N = 0 dB.

For every distance between antennas the WGN-level was increased until some perturbations on the picture transmitted over DVB-T2 were observed (quality criteria Subjective Failure Point (SFP)). Those levels were than corrected to QEF by adding 0.2 dB.

Due to its small dimensions relative to the wavelength transmitted, the LTE-UE antenna pattern will be similar to the omnidirectional antenna used in the measurements.

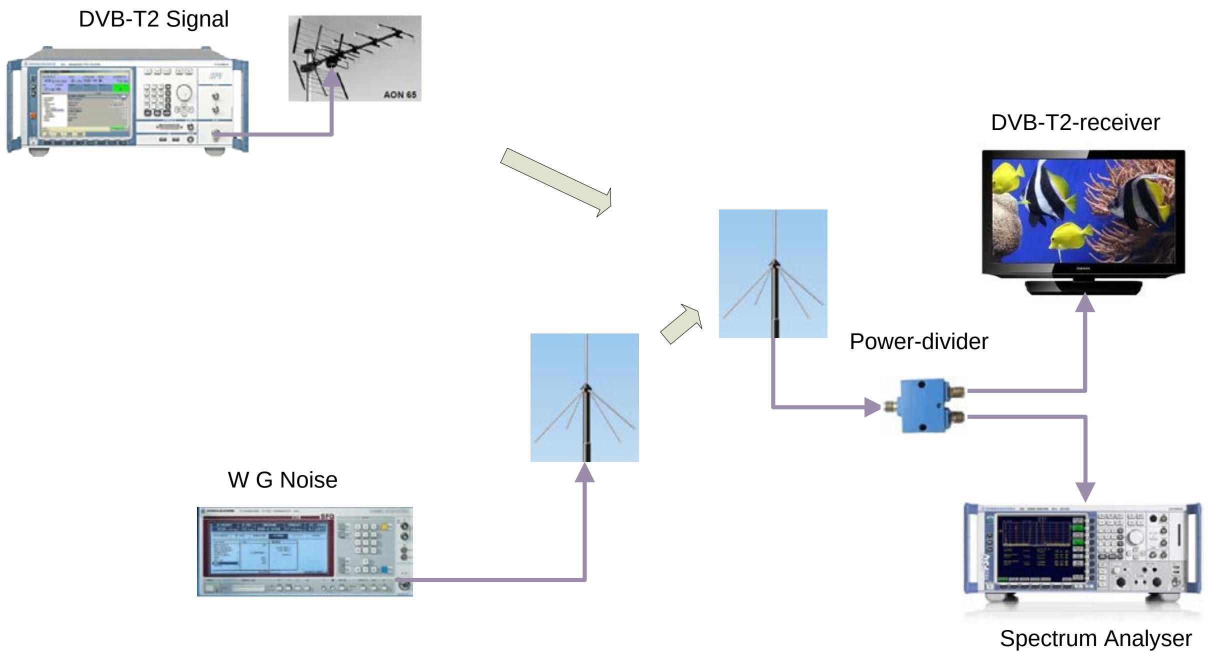
Measurement set-up

The measurement set-up is shown in Figure A.1.2 and consists of:

– DVB-T2 signal generator Rohde & Schwarz SFU set for mode 16k 64QAM 3/4 (C/N = 16 dB);
– DVB-T2 transmitting Yagi-antenna Kathrein AON 65, see Figure A.1.2 [1];
– DVB-T2 receiving ground-plane antenna ThueCom MA560, see Figure A.1.2;
– Humax HD-Fox T2 set-top-box;
– noise generator Rohde & Schwarz SFQ;
– noise transmitting ground-plane antenna ThueCom MA560 see Figure A.1.2;
– signal and Spectrum Analyser Rohde & Schwarz FSW.

FIGURE A.1.2

Measurement Set-up



Results

Setting a DVB-T2 link budget reserve of 3 dB, the maximum allowable WGN power in a bandwidth of 8 MHz that can be transmitted by an omnidirectional antenna (e.i.r.p.), without disturbing the DVB-T2 reception, is:

– at a distance of 1m between antennas: –57.5 dBm;

– at a distance of 2m between antennas: –58.4 dBm;

– at a distance of 3m between antennas: –56.4 dBm.

Assuming that the IMT UE has -3dBi antenna gain, the required OOBE limit to ensure interference free reception under these conditions is around –55 dBm/8 MHz.

At free space propagation the maximum allowable WGN power increases with 6 dB for every doubling of the distance. This is not the case with the measurement results shown here. Further measurements have shown that the propagation loss from transmitting to receiving antenna in the room where the measurements were made is almost unchanged for the distances of 1 metre, 2 metres and 3 metres. This fact is probably due to reflexions from walls, floor and ceiling and is very important, because it happens also with IMT-UE interfering to portable DVB-T2 in buildings.

When the measurements were conducted with a 14 cm brick wall in between the antennas an increase of the allowed noise of just 2.1 dB was measured.

APPENDIX 2

[*MultiAdm 367, 368, 374:*

Example values of active user densities for sensitivity analysis in sharing studies

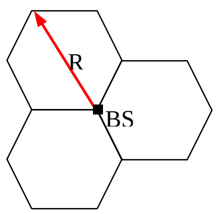
The active user densities presented in Table A.2.1 are calculated for a hexagonal shaped sector of range R, where the sector area is calculated as follows:

$$A_{sector} = \frac{3\sqrt{3}}{8} R^2$$

The active user densities presented in Table A.2.1 are calculated for a hexagonal sector of range R, where the sector area is calculated as follows:

FIGURE A.2.1

Hexagonal three-sector cell



It is understood that an active user equipment (UE) is transmitting. The densities in Table A.2.1 refer therefore to the number of simultaneously transmitting UE.

TABLE A.2.1

Number of active users and the user density in different environments for sensitivity analysis

Number of active UE/Sector emitting simultaneously			
Urban			
IMT sector range (km)	**Sector area (km²)**	**N_active_UE/sector**	**Density (1/km²)**
1	0.649519053	2	3.079201436
		4	6.158402871
		6	9.237604307
		8	12.31680574
		10	15.39600718
Suburban			
IMT sector range (km)	**Sector area (km²)**	**N_active_UE/sector**	**Density (1/km²)**
2	2.598076211	2	0.769800359
		4	1.539600718
		6	2.309401077
		8	3.079201436
Rural			
IMT sector range (km)	**Sector area (km²)**	**N_active_UE/sector**	**Density (1/km²)**
8	41.56921938	2	0.048112522
		4	0.096225045
		6	0.144337567
		8	0.19245009

One distinguishes between the indoor and outdoor active users per cell. In particularly, it is assumed that the ratio of 50%, 70% and 70% should be used to define the number of indoor active users in rural, sub-urban, and urban environments, respectively, [referring to Document 4-5-6-7/49].

APPENDIX 3

Transmit power control

A common model, or emulation, of the behaviour of the LTE power control scheme can be found in [3GPP Technical Report 36.942 V11.0.0, "Radio Frequency (RF) system scenarios"]. It was originally used for 3GPP intra- and inter-system coexistence studies on adjacent channels and it is given by

$$P_t = P_{MAX} \cdot \max\left\{1, \max\left\{R_{MIN}, \left(\frac{CL}{CL_{x-ile}}\right)^{\gamma}\right\}\right\}.$$

Here, P_{tx} is the UE transmit power, P_{MAX} is maximum power, R_{MIN} is used to lower limit the transmit power, *CL* is the coupling loss, CL_{x-ile} is the coupling loss at the x percentile (i.e., x% of UE have path loss less than PL_{x-ile}) and γ is a parameter that shifts the transmit power distribution. With this scheme, 1-x% of the UE transmit with maximum power.

This scheme in much more detail, in [Document JTG 4-5-6-7/242, Annex 2 Attachment 2 Appendix 1B]. The setting of the parameters PL_{x-ile} and γ are very important in order to obtain realistic results, especially the former. Target values for the fraction of UE with full power are proposed in [Document 4-5-6-7/242, Annex 2 Attachment 2 Appendix 1b] but the corresponding value of CL_{x-ile} can differ significantly between scenarios and parameter sets. Therefore, if this scheme is used, or any other for that matter, it is important that reasonable settings are found for precisely the scenario that is being investigated and that generic, or default, values are not used. Otherwise, unrealistically high transmit powers might be obtained.

So as a summary, when the LTE UL transmit power is reduced from the maximum, also the OOB emissions are reduced. The proposed ratio is linear, i.e. 1 dB reduction of OOB emissions for each 1 dB reduction of output power.

The following parameters are used in this study:

– max allowed transmit power = 23 dBm;
– min transmit power = –40 dBm;
– power scaling threshold=0.9;
– balancing factor (0<γ<1))=1.

APPENDIX 4

Measurements and analysis of DVB-T and DVB-T2 protection ratios and adjacent channel selectivity from interference of mobile broadband user equipment operating in adjacent spectrum

DTTB receiver ACS values were derived from the protection ratios given in Recommendations ITU-R BT.1368 and ITU-R BT.2033, for use in sharing studies between DTTB and IMT700.

Protection ratios were tested on thirteen DVB-T/T2 TV receivers, currently available on the market, aiming at getting an insight into the performance of recent DTTB receivers. ACS values of the tested receivers are presented in Table A.4.1. The detailed information on the measurements is provided in the following sections[as well as in Docs. 4-5-6-7/518 and 4-5-6-7/418].

TABLE A.4.1

DVB-T/T2 receivers' adjacent channel selectivity (ACS) Continuous 10 MHz IMT UE transmission; IMT UE ACLR=60 dB; frequency offset=18 MHz	
DTTB Receiver	**ACS (dB)**
Rx1 (DVB-T2)	62
Rx2 (DVB-T2)	72
Rx3 (DVB-T)	62
Rx4 (DVB-T2)	60
Rx5 (DVB-T2)	65
Rx6 (DVB-T)	62
Rx7 (DVB-T2)	72
Rx8 (DVB-T)	72
Rx9 (DVB-T)	62
Rx10 (DVB-T)	54
Rx11 (DVB-T2)*	54
Rx12 (DVB-T2)*	54
Rx13 (DVB-T2)*	54
DVB-T2 average value	62
DVB-T average value	62
* ACLR=53 dB	

Note that the above ACS values were derived from the DDTB receiver protection rations measured in the presence of a continuous IMT UE signal. Since, the impact of discontinuous IMT UE emissions on DTTB reception can only be efficiently combated by improving DTTB receivers' AGC circuits, including the overall ACS of the receivers: improving the ACLR of IMT UE signal does not improve the protection ratio.

MEASUREMENT CAMPAIGN A

MEASUREMENTS AND ANALYSIS OF DVB-T2 PROTECTION RATIOS AND ADJACENT CHANNEL SELECTIVITY FROM INTERFERENCE OF MOBILE BROADBAND USER EQUIPMENT OPERATING IN ADJACENT SPECTRUM

1 Introduction

Measurements have been undertaken of DTT protection ratios in the presence of OOB emissions from a fully loaded 50RB 10 MHz wide LTE UE signal operating with a 9 MHz guard band separation. The interfering UE signal including OOB emissions is derived from RF recordings of a real LTE band 17 UE operating at (704-714 MHz), stimulated from a test set acting as an LTE base station. No allowance for temperature or other worst case component tolerances has been included, so these results can only be considered as typical of this UE.

Protection ratios were tested on three DVB-T2 TV receivers, currently available on the market, containing three different silicon tuners and three different DVB-T2 demodulators in order to obtain the widest coverage of performance. All three receivers are modern designs which are well behaved under time varying interference, although in these tests the interfering signal was of constant power as this gave the higher levels of OOB emissions.

Four test configurations were tested for each receiver:

1) no filtering;

2) with an inline external CH60 filter on the DTT receiver input;

3) with a band pass filter (BPF) on interference source to reduce the UE OOB emissions into CH59;

4) with (2) and (3) together.

Because the inline LTE filter was fixed to filter out interference above CH60, all protection ratio measurements were made with the LTE UE signal centre shifted to 796 MHz instead of 708 MHz. DTT receiver protection ratios are not expected to be substantially different at these two different frequencies as previous studies (ref. 1) have shown. The 9 MHz guard band between the top DTT channel and the UE remains the same.

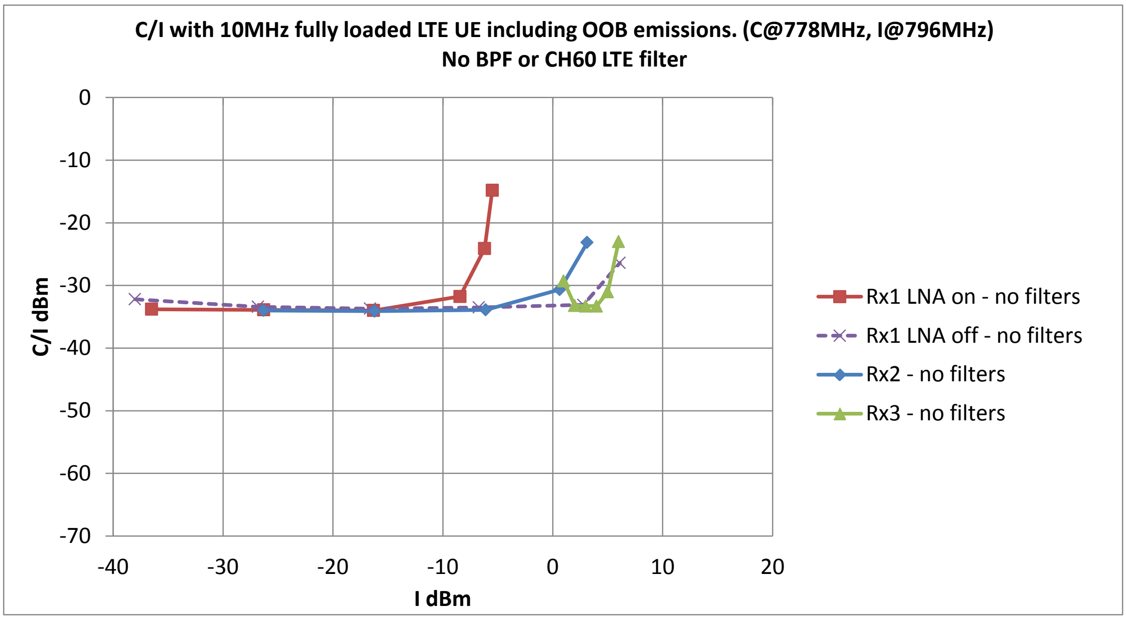
Measurements were also made of the LTE UE ACLR operating with 25RB, 10RB and 1RB in lowest part of the 10 MHz LTE channel. In addition the power of the UE OOB emissions in the 6 MHz band below 695 MHz was measured and compared with the 3GPP specification.

2 Protection ratio results

The non-adjacent channel protection ratio C/I shown in the figures below is the ratio of the power of the wanted DTT signal in CH59 (in 8 MHz BW centred on 778 MHz) to the power of the LTE interferer (in 10 MHz BW centred on 796 MHz).

FIGURE A.4.1

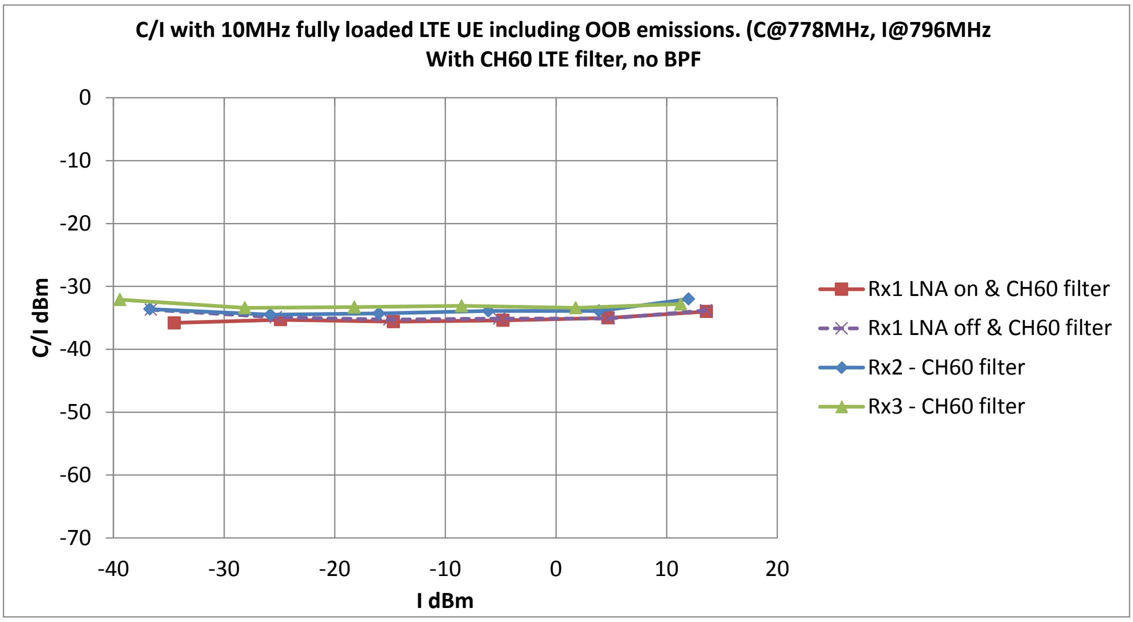
Test configuration 1 – no filtering



In Figure A.4.1 Rx1 has a lower overload threshold because it is configured with a user menu option to turn on an additional low noise amplifier in the front end of the tuner to give greater sensitivity. When turned off it gave the best overload threshold performance – see dashed line in plots.

FIGURE A.4.2

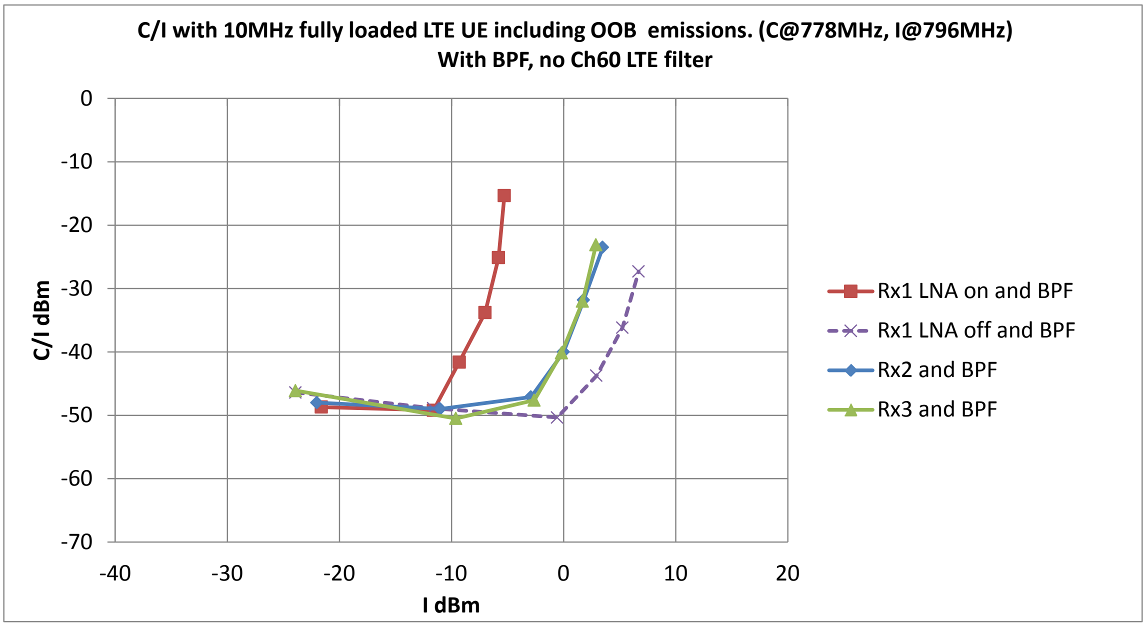
Test configuration 2 – With CH60 filter on the DTT Rx input (no BPF)



Extra DTT receiver filtering in Figure A.4.2 has not changed the protection ratio but has raised the overload threshold point to beyond the test equipment limit of 12 dBm.

FIGURE A.4.3

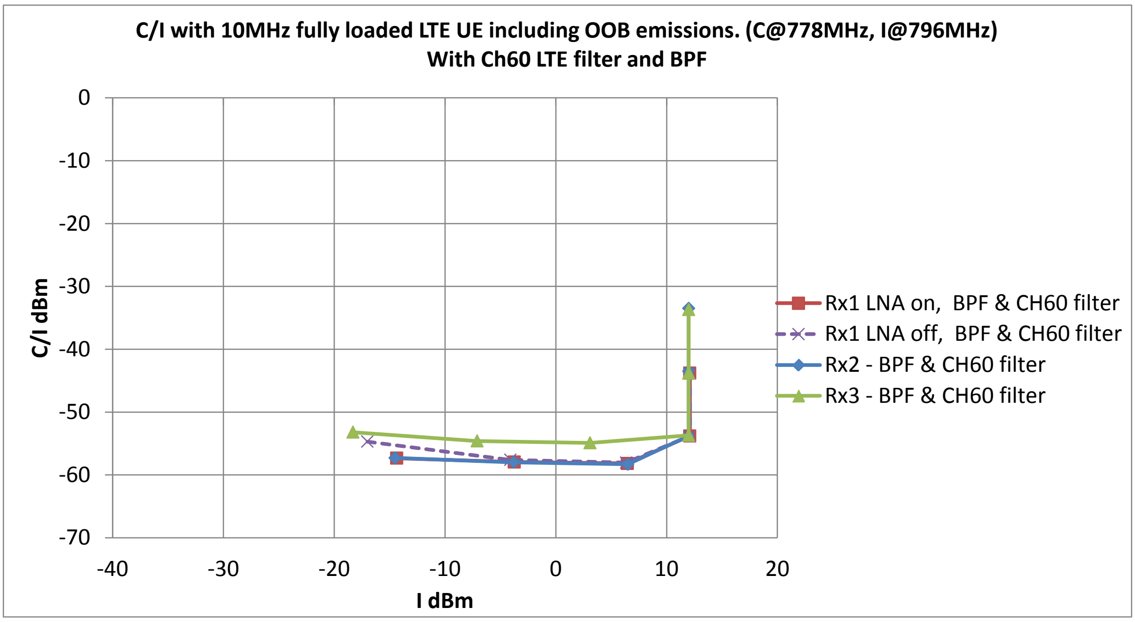
With BPF on interference source to reduce the UE OOB emissions into CH59



Note the improvement in protection ratio in Figure A.4.3 due to reducing the UE OOB with the BPF, and similar overload thresholds to the no filter case.

FIGURE A.4.4

With BPF on interference source to reduce the UE OOB emissions into CH59, and CH60 filter



Note the protection ratio improves further and the overload threshold improves when filtering on the UE OOB and DTT RX is applied. The overload threshold was greater than the 12 dBm limit of the test setup as shown in the figure.

The protection ratio measurements show that protection ratio performance of the TV sets in a channel 9 MHz away from the LTE UE operating at full load, is limited by the UE OOB emissions. Applying additional DTT receiver filtering does not help (Figure A.4.2) until the UE OOB emissions are also reduced (Figure A.4.3). The best performance for protection ratio and overload threshold is realised when additional filtering is added to both the UE OOB and the DTT Rx (Figure A.4.4).

3 Measurement of PR_0 with flat and sloping co-channel noise

The wanted signal was fixed at –40 dBm.

PR_0 with flat noise co-channel interference was measured using the built in AWGN generator in the DVB-T2 modulator.

To measure PR_0 with coloured noise co-channel interference, the section of the CH59 spectrum was extracted in Matlab to create a separate ARB interference test signal suitable for co-channel tests, so that the result would not be influenced by a high power adjacent interferer. The results of the co-channel interference tests are shown in Table A.4.2.

TABLE A.4.2

Co-channel PR_0 Results for DVB-T2

Receiver	Ch59 sloped OOB emissions	AWGN flat noise
Rx1	18.0	18.8
Rx2	17.8	18.8
Rx3	18.7	19.2

4 Calculated receiver ACS

The minimum ACS was calculated using the measurement tolerances listed above and the sloped OOB emissions PR_0 values in Table A.4.2 and is shown in the following figures. Note the 12 dBm limit of the signal generator limits the ACS in the cases where the LTE CH60 filter is used in each figure.

The values of ACS at the three lowest interference levels (before overload starts to degrade ACS) for each test configuration were averaged for each test configuration as shown in Table A.4.3.

TABLE A.4.3

Summary of receiver ACS dB (before overload occurs)

Test configuration	Rx1 LNA off ACS dB	Rx1 LNA on ACS dB	Rx2 ACS dB	Rx3 ACS dB	Mean ACS dB
1 no filters	53.57	55.32	54.47	54.15	54.4
2 – CH60 filter	58.03	63.58	54.81	54.79	57.8
3 – BPF to reduce UE OOB	66.19	64.04	65.42	66.44	65.5
4 – BPF + CH60 filter	77.60	79.75	78.91	73.89	77.5

5 Results and conclusions from measurements

The measured UE fulfilled the 3GPP OOB emission specification with a significant margin, but this is only a typical measurement result on a single UE which does not allow for temperature variation or extremes of component tolerance which the 3GPP mask needs to take into account.

The results show the effects of filtering as follows:

– Without any filtering, DTT protection ratios on these receivers are dominated by the UE OOB emissions.

– Adding filtering to the UE to reduce the OOB emissions by 23.5 dB across the DTT channel resulted in better DTT protection ratios (by approximately 15 dB).

– Increasing the DTT receiver selectivity by 26.4 dB through the addition of the inline filter has no effect on protection ratio unless the UE OOB emissions are also reduced.

– A further 4 to 8 dB improvement in DTT protection ratio is achieved when both the UE OOB emissions are reduced by 23.5 dB and the DTT receiver selectivity increased by 26.4 dB.

– The overload threshold was increased when the inline filter was added to the receiver and it was not possible to overload any of the receivers with the maximum 12 dBm interference level available with the test equipment used.

– The receiver performance results were quite similar with the main difference being overload threshold, where one receiver with a user enabled LNA showed a slightly lower overload threshold when the LNA was enabled as might be expected.

In the case of the UE operating with 25RB, 10RB and 1RB, the measured ACLRs with a 9 MHz guard band were 7-10 dB greater than in the fully loaded 50RB case, and were not studied further due to time limitations.

In addition, the absolute power of the UE in the 6 MHz band below 695 MHz was measured and compared with the 3GPP specification. This was measured as –32.7 dBm/6 MHz @ 695 MHz which is well below the 3GPP specification (rel 12) of –26.2 dBm/6 MHz for 662-694 MHz for band 28.

These results show that existing external inline filter technology can be used to improve the DTT selectivity in the locations where it is needed. External filtering rather than internal TV filtering has the advantage that it allows the reception of other TV services via cable at higher UHF frequencies with the same tuner, and avoids additional insertion loss where the filter is not needed. It should be noted that these measurements were made on a single UE sample.

MEASUREMENT CAMPAIGN B

MEASUREMENTS FOR ASSESSING THE IMPACT OF OOBE AS WELL AS SHORT PULSE INTERFERENCES FROM IMT USER EQUIPMENT TO DTTB RECEPTION

1 Introduction

This report presents the results of the measurements carried out on ten different DTTB receivers (DVB-T and DVB-T2 receivers), currently available on the European market, for assessing the impact of short pulse interferences from IMT (LTE) user equipment to DTTB reception on channel 48. It aims at providing information to assist sharing studies for the co-existence of DTTB broadcasting with IMT user equipment.

2 Results and conclusions from measurements

Measurement results show that:

1) In the presence of a discontinuous IMT UE signal, modern DVB-T2 receivers have behaved well, while the performance of DVB-T receivers was reduced by about 20 dB compared to their performances in the presence of a continuous IMT UE signal.

2) Reducing the IMT UE OOBE level from –37 dBm (UE ACLR=60 dB) to –47 dBm

(UE ACLR=70 dB):

– has no notable improvement on DVB-T2 receivers’ protection ratios for a given receiver ACS;

– has improved DVB-T receivers’ protection ratios by 11 dB when the ACS is improved by an external filter.

3) The inline external CH48 BPF filter on the DTTB receiver input has restored the DVB-T receivers’ performance to normal. That is it has improved the receivers PR to their values in the presence of a continuous IMT UE signal. For the DVB-T2 receivers, their performance has become better than the performance obtained in the presence of a continuous IMT UE signal by about 30 dB.

Moreover, the filter has improved the receivers Oth by more than 15 dB irrespective of receiver type.

The conclusions drawn from the results of the measurements are summarized below:

– The tested DTTB receivers have behaved very similarly in the presence of a continuous IMT UE signal, while they have behaved very differently one from the other in the presence of a discontinuous (time varying) IMT UE signal. The ACS of the DTTB receivers tested are in the range of 62 to 65 dB.

– Modern DVB-T2 receivers are behaving well in the presence of a discontinuous interfering signal. Actually, the modern DVB-T2 receivers tested have behaved better in the presence of a discontinuous IMT UE signal than in the presence of a continuous IMT UE signal, while the performance of DVB-T receivers was reduced by about 20 dB.

– The impact of discontinuous IMT UE emissions on DTTB reception can only be efficiently combated by improving DTTB receivers' AGC circuits, including the overall ACS of the receivers: improving the ACLR of IMT UE signal does not improve the protection ratio.

– The values of ACLR and ACS should be similar in magnitude for obtaining the best performance in reduction and filtering of out of band emissions.

– For the protection of the broadcasting service, the ACLR of IMT UE signal should be fixed by taking into account the impact of a continuous IMT UE signal on DTTB reception as well as the implementation cost of IMT UE filtering.

Measurement results are summarised in Tables A.4.4 and A.4.5.

TABLE A.4.4

DVB-T2 receivers' average protection ratios			
Average ACS without filter = 65 dB, Average ACS with CH48 BPF = 98 dB			
Continuous Tx ACLR=60 No Filter	**Continuous Tx, ACLR=60 CH48 BPF**	**Continuous Tx, ACLR=70 No Filter**	**Continuous Tx, ACLR=70, CH48 BPF**
Average PR (dB)	Average PR (dB)	Average PR (dB)	Average PR (dB)
-42	-43	-45	-54
Average Oth (dBm)	Average Oth (dBm)	Average Oth (dBm)	Average Oth (dBm)
-3	NR	-3	NR
DVB-T2 receivers			
Average ACS without filter = 65 dB, Average ACS with CH48 BPF = 98 dB			
Discontinuous Tx, ACLR=60 No Filter	**Discontinuous Tx, ACLR=60 CH48 BPF**	**Discontinuous Tx, ACLR=70 No Filter**	**Discontinuous Tx, ACLR=70, CH48 BPF**
Average PR (dB)	Average PR (dB)	Average PR (dB)	Average PR (dB)
-49	-70	-50	-72
Average Oth (dBm)	Average Oth (dBm)	Average Oth (dBm)	Average Oth (dBm)
NR	NR	NR	NR

TABLE A.4.5

DVB-T receivers' average protection ratios			
Average ACS without filter = 62 dB, Average ACS with CH48 BPF = 95 dB			
Continuous Tx ACLR=60	**Continuous Tx, ACLR=60 CH48 BPF**	**Continuous Tx, ACLR=70**	**Continuous Tx, ACLR=70, CH48 BPF**
Average PR (dB)	Average PR (dB)	Average PR (dB)	Average PR (dB)
-40	-41	-43	-54
Average Oth (dBm)	Average Oth (dBm)	Average Oth (dBm)	Average Oth (dBm)
-2	NR	-2	NR
DVB-T receivers			
Average ACS without filter = 62 dB, Average ACS with CH48 BPF = 95 dB			
Discontinuous Tx ACLR=60	**Discontinuous Tx, ACLR=60 CH48 BPF**	**Discontinuous Tx, ACLR=70**	**Discontinuous Tx, ACLR=70, CH48 BPF**
Average PR (dB)	Average PR (dB)	Average PR (dB)	Average PR (dB)
-22	-42	-23	-53
Average Oth (dBm)	Average Oth (dBm)	Average Oth (dBm)	Average Oth (dBm)
-5	NR	-4	NR

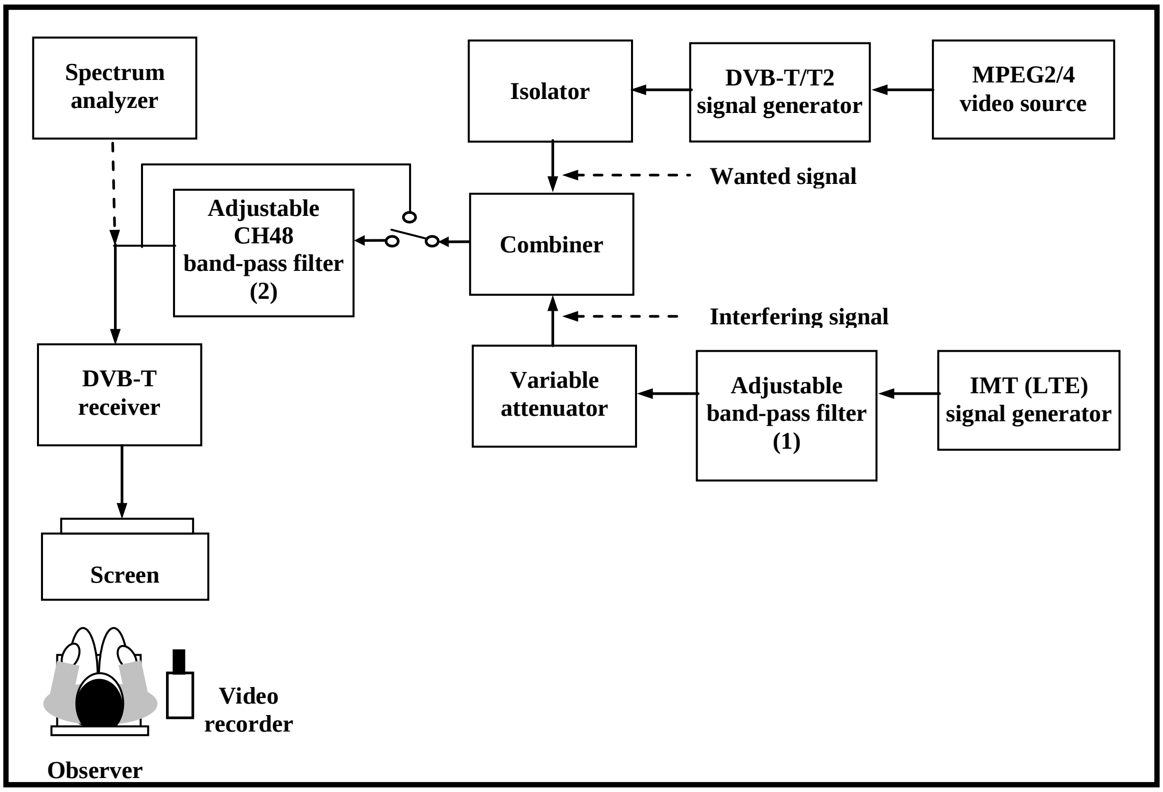
3 Measurement methodology and system parameters

3.1 Test set-up used

The test setup for protection ratio and overloading threshold measurements is depicted in Figure A.4.5.

FIGURE A.4.5

Measurements set-up



An adjustable band-pass filter (1) was inserted between the interfering signal generator and the combiner. The objective of this filter is to eliminate the wideband noise generated by the interfering signal generator and adjust the interfering signal to the correct interference transmission mask and ACLR values. An isolator was also inserted between the DVB-T signal generator and the combiner to keep the power from the interfering signal generator returning to the DVB-T signal generator output.

A CH48 BPF (2) has been used to reduce the UE in band (IB) emissions falling into DTTB CH48 and consequently to identify the predominate component of the interfering UE emissions, which are composed of UE IB and OOB emissions, on the DTTB reception.

3.2 Wanted signal levels

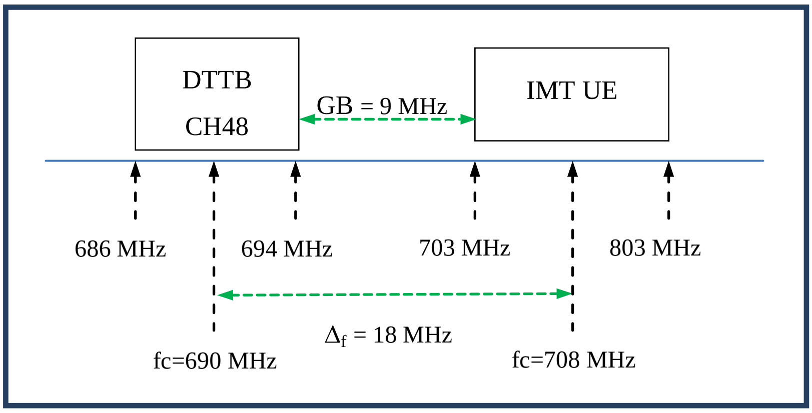
Protection ratios (PR) and overloading thresholds (Oth) of a receiver are derived from its C(I) curves. The measurements have been carried out by using different DVB-T/T2 wanted signal levels to cover the range from weakest to strongest signals: –70, –60, –50 ,–40, –30 and –20 dBm. At low wanted signal levels the protection ratio limit is usually reached before the overloading threshold. Therefore it is necessary to use higher wanted signal levels to reach the onset of overload.

3.3 Frequency offsets between IMT UE interfering signal and DTTB wanted signal

A single frequency offset has been used (18 MHz) aiming at limiting the number of measurement to be carried out. This frequency offset corresponds to a guard band (GB) of 9 MHz between DTTB centred at 690 MHz and the IMT UE signal centred at 708 MHz as shown in Figure A.4.6.

FIGURE A.4.6

Frequency offsets between IMT UE and DTTB signals



3.4 Generation of the IMT uplink signal

The uplink signal can vary considerably in both the time and frequency domains depending upon the traffic loading required. In the frequency domain the number of RBs allocated for each SC-FDMA symbol can vary rapidly. Maximum number of RBs is 50. In the time domain, there can be long periods where the UE does not transmit at all, leading to an irregular pulse like power profile. The minimum duration of UE transmission time interval is 1 ms (1 TTI), while the duration of a basic radio frame is 10 ms (10 TTI).

In this measurement campaign three different UE transmission modes have been used:

– Continuous transmission (TM1);

– Discontinuous transmission (TM2) with: UE signal maximum transmission duration = 1 ms, transmission period = 1 s;

– Discontinuous transmission (TM3) with: UE signal maximum transmission duration = 1 ms, transmission period = 5 s.

The UE generator output power was fixed to 20.83 dBm. Two different ACLR values, 60 and 70 dB, have been used in measurements. These ACLR values were obtained by means of an inline band pass filter (BPF) on UE signal generator. They correspond respectively to -37 and -47 dBm/8 MHz, for an IMT UE maximum transmit power of 23 dBm, in case of full uplink resource allocation (50 RBs).

3.5 Failure point assessment method

The SFP method was used in this measurement campaign. The PR for the wanted DVB-T signal is a value of wanted-to-unwanted signal ratio at the receiver input, for a picture quality where no more than one error is visible in the picture for an average observation time of 20 seconds.

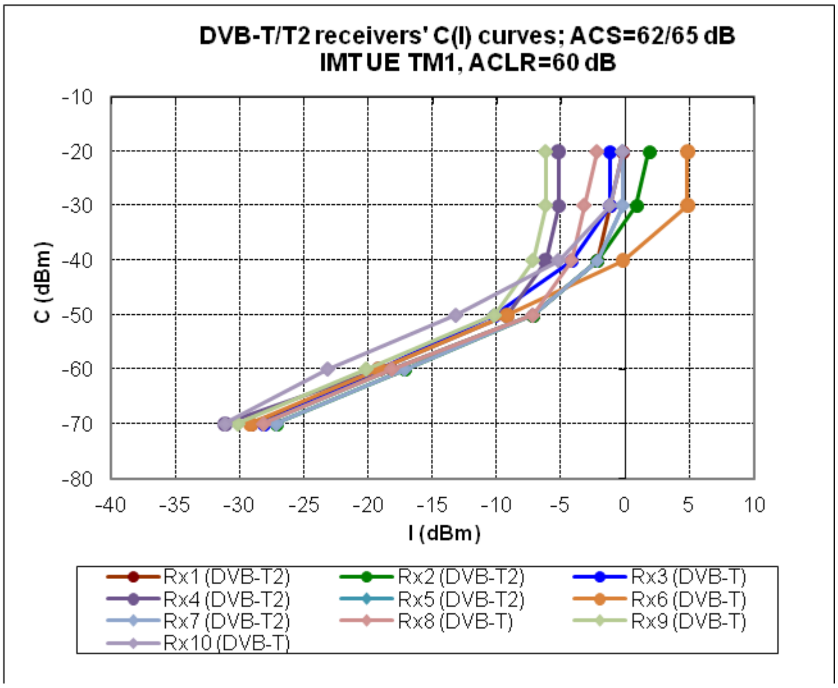
The adjustment of the wanted and unwanted signal levels has been done in steps of 1 dB.

3.6 Method for determining protection ratios and overloading thresholds

It should be stressed that the protection ratios are generally considered and used as independent of the wanted signal level. That is C(I) is supposed to be a linear function with unity slope (a straight line with unity slope). The protection ratio of the receiver is obtained by subtracting I from C(I) at any point on this line and can be used for all wanted signal levels.
However, in most cases the protection ratios of wideband TV receivers vary as a function of the wanted signal level. Consequently, C(I) is not a straight line with unity slope with some variation with the interfering signal strength. Nevertheless, for interfering signals below the overloading threshold such C(I) curves can always be approximated by a straight line with unity slope with an acceptable error. This is the method used for determining PR and O_{th} method. It is described in detail in Report ITU-R BT.2215.

FIGURE A.4.7

DTTB receivers' C(I) curves



A CH48 BPF has been used to reduce the UE in band (IB) emissions falling into DTTB CH48 and consequently to identify the predominate component of the interfering UE emissions, which are composed of UE IB and OOB emissions, on the DTTB reception.

Measurements were carried out in two steps, for UE $ACLR_{CH48}$= 60 and 70 dB, with full IMT UE resource allocation (50 RBs):

1 C(I) of the DTTB receiver under test were measured for UE TM1, without and with an inline external CH48 BPF filter on the DTTB receiver input;

2 C(I) of the DTTB receiver under test were measured for UE TM2 and TM3, without and with an inline external CH48 BPF filter on the DTTB receiver input;

The objective of these measurements is to evaluate the impact of the UE OOBE and IBE on DTTB PR and Oth respectively in case of a continuous (Step 1) as well as in case of a discontinuous (Step 2) IMT UE emission.

The IMT UE signal was attenuated by CH48 BPF by 36 dB (see Annex 3). The insertion loss of the filter over DTTB channel 48 was 3 dB. Consequently, the effective ACS improvement of DTTB receivers by the filter was about 33 dB.

The measured C(I) curves have been post processed, according to the method described in Report ITU-R BT.2215, in order to determine the PR and Oth of the tested DTTB receivers. The results obtained are presented in the following sections.

4 Measurement results

4.1 Calculated DVB-T/T2 receiver ACS

TABLE A.4.6

Calculated DVB-T/T2 receivers' adjacent channel selectivity Continuous IMT UE transmission, UE ACLR=60 dB		
DTTB Receiver	**ACS without CH48 filter (dB)**	**ACS with CH48 filter (dB)**
Rx1 (DVB-T2)	62	95
Rx2 (DVB-T2)	72	105
Rx3 (DVB-T)	62	95
Rx4 (DVB-T2)	60	93
Rx5 (DVB-T2)	65	98
Rx6 (DVB-T)	62	95
Rx7 (DVB-T2)	72	105
Rx8 (DVB-T)	72	105
Rx9 (DVB-T)	62	95
Rx10 (DVB-T)	54	87
DVB-T2 average value	65	98
DVB-T average value	62	95

The receiver ACS has been calculated by the following equation:

$$ACS(dB) = -10\log(10^{(PR-PR_0)/10} - 10^{-ACLR/10})$$

where:

ACLR: Adjacent channel leakage ratio of the generated IMT UE signal;

PR: Measured adjacent channel protection ratio;

PR_0: Measured co-channel protection ratio (f_i-f_w = 0 MHz);

where:

$\mathbf{f_i}$ is the centre frequency of the interfering signal; and

$\mathbf{f_w}$ is the centre frequency of the wanted signal.

4.2 Calculated DVB-T/T2 receiver protection ratios (PR)

TABLE A.4.7

DVB-T/T2 receivers' PR and Oth without CH48 BPF (ACS=62/65 dB) Continuous IMT UE transmission, UE ACLR=60 dB		
DTTB Receiver	**RP (dB)**	**Oth (dBm)**
Rx1 (DVB-T2)	-41	-2
Rx2 (DVB-T2)	-43	-2
Rx3 (DVB-T)	-40	-4
Rx4 (DVB-T2)	-39	-6
Rx5 (DVB-T2)	-42	-2
Rx6 (DVB-T)	-41	5
Rx7 (DVB-T2)	-43	-2
Rx8 (DVB-T)	-42	-4
Rx9 (DVB-T)	-40	-7
Rx10 (DVB-T)	-35	-1
Average value (DVB-T2)	-41.6	-2,8
Average value (DVB-T)	-39.6	-2,2

TABLE A.4.8

DVB-T/T2 receivers' PR and Oth with CH48 BPF (ACS=95/98 dB) Continuous IMT UE transmission, UE ACLR=60 dB		
DTTB Receiver	**RP (dB)**	**Oth (dBm)**
Rx1 (DVB-T2)	-44	NR
Rx2 (DVB-T2)	-44	NR
Rx3 (DVB-T)	-41	NR
Rx4 (DVB-T2)	-41	NR
Rx5 (DVB-T2)	-43	NR
Rx6 (DVB-T)	-43	NR
Rx7 (DVB-T2)	-43	NR
Rx8 (DVB-T)	-42	NR
Rx9 (DVB-T)	-41	NR
Rx10 (DVB-T)	-37	NR
Average value (DVB-T2)	-43	NR
Average value (DVB-T)	-40.8	NR
NR: Oth not reached at maximum IMT UE level at the receiver input (13.8 dBm)		

TABLE A.4.9

DVB-T/T2 receivers' PR and Oth without CH48 BPF (ACS=62/65 dB) Discontinuous IMT UE transmission, UE ACLR=60 dB		
DTTB Receiver	**RP (dB)**	**Oth (dBm)**
Rx1 (DVB-T2)	-30/-59[1]	NR
Rx2 (DVB-T2)	-60	NR
Rx3 (DVB-T)	-23	-5
Rx4 (DVB-T2)	-30[2]	NR
Rx5 (DVB-T2)	-56[3]	NR
Rx6 (DVB-T)	-26[4]	NR
Rx7 (DVB-T2)	-33/-63[5]	NR
Rx8 (DVB-T)	-25	-5
Rx9 (DVB-T)	-12	NR
Rx10 (DVB-T)	-23	-4
Average value (DVB-T2)	-49[6]	NR
Average value (DVB-T)	-22	-5
NR: not reached at maximum IMT UE level at the receiver input (13.8 dBm) 1. With hysteresis at C=-40 dBm 2. -72 dB at C≥-60 dBm 3. Interference only at C=-70 dBm (PR=-56), no interference for C>-70 dBm at maximum IMT UE level (13.8 dBm) at the receiver input 4. PR=-36 dB with break at C=-40 dBm 5. With hysteresis at C=-60 dBm 6. Rx1 and Rx7 were excluded (first generation DVB-T2 receivers from the same manufacturer)		

TABLE A.4.10

DVB-T/T2 receivers' PR and Oth with CH48 BPF (ACS=95/98 dB) Discontinuous IMT UE transmission, UE ACLR=60 dB		
DTTB Receiver	**RP (dB)**	**Oth (dBm)**
Rx1 (DVB-T2)	-71	NR
Rx2 (DVB-T2)	-73	NR
Rx3 (DVB-T)	-41	NR
Rx4 (DVB-T2)	-64	NR
Rx5 (DVB-T2)	-68	NR
Rx6 (DVB-T)	-41	NR
Rx7 (DVB-T2)	-72	NR
Rx8 (DVB-T)	-43	NR
Rx9 (DVB-T)	-42	NR
Rx10 (DVB-T)	-42	NR
Average value (DVB-T2)	-69.6	NR
Average value (DVB-T)	-41.8	NR

NR: Oth not reached at maximum IMT UE level at the receiver input (13.8 dBm)
Note: Rx1 and Rx7 from the same manufacturer

TABLE A.4.11

DVB-T/T2 receivers' PR and Oth without CH48 BPF (ACS=6265 dB) Continuous IMT UE transmission, UE ACLR=70 dB		
DTTB Receiver	**RP (dB)**	**Oth (dBm)**
Rx1 (DVB-T2)	-45	-2
Rx2 (DVB-T2)	-47	-2
Rx3 (DVB-T)	-47	-3
Rx4 (DVB-T2)	-40	-6
Rx5 (DVB-T2)	-46	-2
Rx6 (DVB-T)	-42	3
Rx7 (DVB-T2)	-46	-1
Rx8 (DVB-T)	-47	-4
Rx9 (DVB-T)	-42	-7
Rx10 (DVB-T)	-38	-1
Average value (DVB-T2)	-44.8	-2.6
Average value (DVB-T)	-43.2	-2.4

TABLE A.4.12

DVB-T/T2 receivers' PR and Oth with CH48 BPF (ACS=95/98 dB) Continuous IMT UE transmission, UE ACLR=70 dB		
DTTB Receiver	**RP (dB)**	**Oth (dBm)**
Rx1 (DVB-T2)	-54	NR
Rx2 (DVB-T2)	-54	NR
Rx3 (DVB-T)	-53	NR
Rx4 (DVB-T2)	-54	NR
Rx5 (DVB-T2)	-54	NR
Rx6 (DVB-T)	-54	NR
Rx7 (DVB-T2)	-54	NR
Rx8 (DVB-T)	-54	NR
Rx9 (DVB-T)	-54	NR
Rx10 (DVB-T)	-53	NR
Average value (DVB-T2)	-54	NR
Average value (DVB-T)	-53.6	NR
NR: Oth not reached at maximum IMT UE level at the receiver input (10.4 dBm)		

TABLE A.4.13

DVB-T/T2 receivers' PR and Oth without CH48 BPF (ACS=62/65 dB) Discontinuous IMT UE transmission, UE ACLR=70 dB		
DTTB Receiver	**RP (dB)**	**Oth (dBm)**
Rx1 (DVB-T2)	-55	NR
Rx2 (DVB-T2)	-64	NR
Rx3 (DVB-T)	-23	-5
Rx4 (DVB-T2)	-31[1]	NR
Rx5 (DVB-T2)	-56[2]	NR
Rx6 (DVB-T)	-26	NR
Rx7 (DVB-T2)	-65	NR
Rx8 (DVB-T)	-31	-4
Rx9 (DVB-T)	-12	NR
Rx10 (DVB-T)	-24	-4
Average value (DVB-T2)	-50[3]	NR
Average value (DVB-T)	-23	-4.3
NR: not reached at maximum IMT UE level at the receiver input (10.4 dBm) 1. -72 dB at C≥-60 dBm 2. Interference only at C=-70 dBm (PR=-56), no interference for C>-70 dBm at maximum IMT UE level (10.4 dBm) at the receiver input 3. Rx1 and Rx7 were excluded (first generation DVB-T2 receivers from the same manufacturer)		

TABLE A.4.14

DVB-T/T2 receivers' PR and Oth with CH48 BPF (ACS=95/98 dB) Discontinuous IMT UE transmission, UE ACLR=70 dB		
DTTB Receiver	**RP (dB)**	**Oth (dBm)**
Rx1 (DVB-T2)	-73	NR
Rx2 (DVB-T2)	-74	NR
Rx3 (DVB-T)	-54	NR
Rx4 (DVB-T2)	-67	NR
Rx5 (DVB-T2)	-71	NR
Rx6 (DVB-T)	-53	NR
Rx7 (DVB-T2)	-74	NR
Rx8 (DVB-T)	-54	NR
Rx9 (DVB-T)	-53	NR
Rx10 (DVB-T)	-53	NR
Average value (DVB-T2)	-71.8	NR
Average value (DVB-T)	-53.4	NR
NR: Oth not reached at maximum IMT UE level at the receiver input (10.4 dBm)		

Note: Rx1 and Rx7 from the same manufacturer

APPENDIX 5

Transmit Power Control

Two cases are considered:

– The UE power is constant and equal to the maximum (P_{max} =23 dBm);

– The UE power is subject to transmit power control (TPC).

The TPC algorithm is given by

$$P_t = P_{\max} \times \min\left\{1, \max\left[R_{\min}, \left(\frac{CL}{CL_{x-ile}}\right)^{\gamma}\right]\right\} \quad (linear)$$

$$P_t = P_{\max} + \min\left\{0, \max\left[P_{\min} - P_{\max}, \gamma(CL - CL_{x-ile,})\right]\right\} \quad (dB)$$

Note that R_{min} = P_{min}/P_{max} (linear), or in dB, R_{min} = P_{min} – P_{max} (e.g. = -40 – 23 = -63 dB).

Similarly, CL/$CL_{x\text{-}ile}$ gives CL – $CL_{x\text{-}ile}$ when expressed in dB.

Here, P_{tx} is the UE transmit power, P_{max} is maximum power, R_{min} is used to lower limit the transmit power, *CL* is the coupling loss, $CL_{x\text{-}ile}$ is the coupling loss at the x percentile (i.e., x% of UE have path loss less than $CL_{x\text{-}ile}$ and γ is a parameter that shifts the transmit power distribution. With this scheme, 1-x% of the UE transmit with maximum power.

CL is the 'coupling loss'; the interpretation of CL is important in determining the relevant value of P_t when using TPC.

Here CL is interpreted as follows:

$$CL = PL_p + <\sigma_{PL}> + B_{loss} - G_{UE} - G_{BS} + D_{BS} + WL + <\sigma_{WL}>$$

where

PL_p	is the propagation path-loss;
$<\sigma_{PL}>$	is the statistical deviation of the propagated power ($<\sigma_{PL}>$ can be positive or negative);
B_{loss}	is the UE body loss, e.g. 4 dB;
G_{UE}	is the UE antenna gain, e.g. -3 dB;
G_{BS}	is the base station antenna gain (e.g. 12 dB);
D_{BS}	is the base station receive antenna discrimination (e.g. according to Rec. ITU-R F.1336;
WL	is the wall penetration loss (e.g., 11 dB) if indoor outdoor calculations are required;
$<\sigma_{WL}>$	is the statistical deviation of the wall loss ($<\sigma_{WL}>$ can be positive or negative).

This is done because these elements encompass all 'coupling losses' between the UE transmitter and the base station receiver.

APPENDIX 6

Example calculations to derive IMT UE OOB limits using ΔRLP Monte Carlo simulations

1 Introduction

Studies have been carried out to determine minimum necessary UE OOB limits in order to protect fixed DTT reception.

These studies have been carried out using the Monte Carlo (MC) methodology as described in [Document JTG 4-5-6-7/172] to determine the degradation of the reception location probability (Δ_{RLP}) for DVB-T2 reception at the DTT coverage edge.

The Monte Carlo simulations were carried out for random UE operating within a 19 sector mobile network, with 23 base stations, as shown in [Figure 1].

The DTT pixels were taken to be randomly placed within the central sector of [Figure 1]; thus the results will represent an intermediate case and not be worst-case, because of the averaging effect when placing the pixel randomly within the mobile sector.

The parameters used are those specified in various [JTG 4-5-6-7 documents] – the explicit values of the parameters used in this study are listed in Appendix 7.

2 Results

An urban mobile network has been considered, with a 1 kilometre cell radius.

The simulations are carried out for DTT ACS = 65 dB, 70 dB and 75 dB, respectively. For each value of ACS, six values of OOB (and ACLR) are investigated.

One set of simulations are carried out assuming that 1 UE is active at any given time in each sector using the respective values of OOB.

Three sets of simulations are carried out assuming that 10 UE are active at any given time in each sector, using the respective values of OOB, OOB - 9 dB and OOB - 19 dB for the three sets.

Three different UE indoor-outdoor scenarios have been considered with ratios:

indoor/outdoor = 0%/100%, 14%/86% and 30%100%, respectively.

As prescribed by the JTG 4-5-6-7, $CL_{x\text{-}ile}$ = 122 dB is used for all simulations. In each case, the corresponding values of the mean UE transmit power, and the percentage of UE using maximum transmit power (23 dBm) in the simulations is given.

The results are presented below in tabular form for DVB-T2. They present the impact in terms of degradation in location probability calculated as described in previous [EBU inputs to the JTG 4-5-6-7, e.g. in Document 4-5-6-7/382]. As explained in these previous inputs, [the EBU] does not support using the IP (interference probability) alone as a measure of assessing interference, as it is only an intermediate result on the way to the correct parameter which is Δ_{RLP} (degradation in location probability). It has been however incorporated in the present results only for the sake of comparison with the results of others studies.

R.1 ACS = 65 dB

Three indoor-outdoor scenarios are considered. Indoor/outdoor: 0% / 100%, 14% / 86%, 30% / 70%.

R.1.1 ACS = 65 dB, 100% outdoor UE, 0% indoor UE

$\%_{Power\_max}$ = 1.2%; $UE_{power-ave}$ = 8.1 dBm; CL_{x-ile} = 122 dB; DTT antenna random from pixel to pixel									
		1 UE (OOB)		10 UE (OOB)		10 UE (OOB – 9)		10 UE (OOB – 19)	
OOB (dBm)	ACLR (dB)	Δ_{RLP} (%)	IP (%)	Δ_{RLP} (%)	IP (%)	Δ_{RLP} (%)	IP (%)	Δ_{RLP} (%)	IP (%)
-40	63	5.599	0.007485	24.091	0.075925	11.952	0.036466	10.207	0.031134
-42	65	4.305	0.005879	19.318	0.059614	11.260	0.034284	10.127	0.030915
-44	67	3.473	0.004834	16.006	0.049064	10.809	0.032904	10.079	0.030777
-46	69	2.934	0.004163	13.857	0.042298	10.505	0.032031	10.047	0.030689
-48	71	2.621	0.003735	12.427	0.037988	10.318	0.031483	10.029	0.030634
-50	73	2.433	0.003465	11.561	0.035251	10.207	0.031134	10.021	0.030599

R.1.2 ACS = 65 dB, 86% outdoor UE, 14% indoor UE

$\%_{Power\_max}$ = 5.1%;$UE_{power-ave}$ = 9.2 dBmCL_{x-ile} = 122 dB; DTT antenna random from pixel to pixel									
		1 UE (OOB)		10 UE (OOB)		10 UE (OOB – 9)		10 UE (OOB – 19)	
OOB (dBm)	ACLR (dB)	Δ_{RLP} (%)	IP (%)	Δ_{RLP} (%)	IP (%)	Δ_{RLP} (%)	IP (%)	Δ_{RLP} (%)	IP (%)
-40	63	5.463	0.006750	24.368	0.069397	12.143	0.033361	10.344	0.028480
-42	65	4.191	0.005254	19.571	0.054495	11.410	0.031371	10.275	0.028279
-44	67	3.387	0.004300	16.237	0.044863	10.964	0.030103	10.230	0.028152
-46	69	2.858	0.003686	14.066	0.038694	10.653	0.029305	10.206	0.028072
-48	71	2.560	0.003298	12.614	0.034758	10.471	0.028800	10.185	0.028022
-50	73	2.380	0.003053	11.731	0.032252	10.344	0.028480	10.177	0.027989

R.1.3 ACS = 65 dB, 30% outdoor UE, 70% indoor UE

$\%_{Power\_max}$ = 20.9%;$UE_{power-ave}$ = 13.7dBm; CL_{x-ile} = 122 dB; DTT antenna random from pixel to pixel									
		1 UE (OOB)		10 UE (OOB)		10 UE (OOB – 9)		10 UE (OOB – 19)	
OOB (dBm)	ACLR (dB)	Δ_{RLP} (%)	IP (%)	Δ_{RLP} (%)	IP (%)	Δ_{RLP} (%)	IP (%)	Δ_{RLP} (%)	IP (%)
-40	63	4.633	0.005945	24.731	0.063118	12.323	0.030781	10.542	0.026358
-42	65	3.564	0.004644	19.877	0.049819	11.615	0.028977	10.469	0.026176
-44	67	2.854	0.003806	16.530	0.041169	11.163	0.027832	10.412	0.026060
-46	69	2.449	0.003272	14.308	0.035605	10.858	0.027107	10.380	0.025987
-48	71	2.190	0.002934	12.846	0.032042	10.661	0.026646	10.359	0.025941
-50	73	2.058	0.002719	11.933	0.029777	10.542	0.026358	10.349	0.025912

R.2 ACS = 70 dB

Three indoor-outdoor scenarios are considered. Indoor/outdoor: 0% / 100%, 14% / 86%, 30% / 70%.

R.2.1 ACS = 70 dB, 100% outdoor UE, 0% indoor UE

%$_{Power\_max}$ = 1.2%; UE$_{power-ave}$ = 8.1 dBm; CL$_{x-ile}$ = 122 dB; DTT antenna random from pixel to pixel									
		1 UE (OOB)		10 UE (OOB)		10 UE (OOB – 9)		10 UE (OOB – 19)	
OOB (dBm)	ACLR (dB)	Δ_{RLP} (%)	IP (%)	Δ_{RLP} (%)	IP (%)	Δ_{RLP} (%)	IP (%)	Δ_{RLP} (%)	IP (%)
-40	63	4.105	0.005602	18.449	0.056807	5.198	0.015893	3.337	0.010380
-42	65	2.759	0.003924	13.053	0.039904	4.445	0.013633	3.252	0.010152
-44	67	2.022	0.002846	9.502	0.028957	3.974	0.012207	3.197	0.010010
-46	69	1.530	0.002156	7.232	0.021942	3.651	0.011304	3.171	0.009920
-48	71	1.204	0.001712	5.750	0.017474	3.465	0.010737	3.139	0.009864
-50	73	1.012	0.001431	4.764	0.014638	3.337	0.010380	3.127	0.009828

R.2.2 ACS = 70 dB, 86% outdoor UE, 14% indoor UE

%$_{Power\_max}$ = 5.1%; UE$_{power-ave}$ = 9.2 dBm; CL$_{x-ile}$ = 122 dB; DTT antenna random from pixel to pixel									
		1 UE (OOB)		10 UE (OOB)		10 UE (OOB – 9)		10 UE (OOB – 19)	
OOB (dBm)	ACLR (dB)	Δ_{RLP} (%)	IP (%)	Δ_{RLP} (%)	IP (%)	Δ_{RLP} (%)	IP (%)	Δ_{RLP} (%)	IP (%)
-40	63	3.988	0.005000	18.679	0.051934	5.292	0.014541	3.394	0.009502
-42	65	2.681	0.003470	13.241	0.036502	4.504	0.012483	3.310	0.009293
-44	67	1.969	0.002500	9.628	0.026490	4.040	0.011178	3.252	0.009162
-46	69	1.495	0.001888	7.343	0.020070	3.709	0.010355	3.216	0.009079
-48	71	1.169	0.001499	5.836	0.015984	3.516	0.009834	3.197	0.009027
-50	73	0.987	0.001254	4.824	0.013394	3.394	0.009502	3.185	0.008993

R.2.3 ACS = 70 dB, 30% outdoor UE, 70% indoor UE

%$_{Power\_max}$ = 20.9%;UE$_{power-ave}$ = 13.7dBm; CL$_{x-ile}$ = 122 dB; DTT antenna random from pixel to pixel									
		1 UE (OOB)		10 UE (OOB)		10 UE (OOB – 9)		10 UE (OOB – 19)	
OOB (dBm)	ACLR (dB)	Δ_{RLP} (%)	IP (%)	Δ_{RLP} (%)	IP (%)	Δ_{RLP} (%)	IP (%)	Δ_{RLP} (%)	IP (%)
-40	63	3.380	0.004423	18.998	0.047522	5.382	0.013597	3.462	0.008914
-42	65	2.313	0.003083	13.494	0.033621	4.580	0.011685	3.381	0.008719
-44	67	1.710	0.002228	9.803	0.024550	4.125	0.010475	3.327	0.008596
-46	69	1.269	0.001678	7.470	0.018689	3.795	0.009705	3.290	0.008518
-48	71	1.009	0.001333	5.951	0.014927	3.587	0.009222	3.268	0.008469
-50	73	0.850	0.001116	4.911	0.012530	3.462	0.008914	3.252	0.008437

R.3 ACS = 75 dB

Three indoor-outdoor scenarios are considered. Indoor/outdoor: 0% / 100%, 14% / 86%, 30% / 70%.

R.3.1 ACS = 75 dB, 100% outdoor UE, 0% indoor UE

$\%_{Power\_max}$ = 1.2%; $UE_{power\text{-}ave}$ = 8.1 dBm; $CL_{x\text{-}ile}$ = 122 dB; DTT antenna random from pixel to pixel									
		1 UE (OOB)		10 UE (OOB)		10 UE (OOB – 9)		10 UE (OOB – 19)	
OOB (dBm)	ACLR (dB)	Δ_{RLP} (%)	IP (%)	Δ_{RLP} (%)	IP (%)	Δ_{RLP} (%)	IP (%)	Δ_{RLP} (%)	IP (%)
-40	63	3.603	0.004989	16.523	0.050618	2.936	0.009253	1.1860	0.003672
-42	65	2.316	0.003295	11.009	0.033516	2.221	0.006972	1.1010	0.003441
-44	67	1.571	0.002206	7.408	0.022447	1.801	0.005530	1.0640	0.003298
-46	69	1.055	0.001502	5.001	0.015354	1.505	0.004616	1.0390	0.003206
-48	71	0.758	0.001059	3.495	0.010839	1.311	0.004037	1.0250	0.003149
-50	73	0.600	0.000780	2.529	0.007982	1.186	0.003672	1.0160	0.003113

R.3.2 ACS = 75 dB, 86% outdoor UE, 14% indoor UE

$\%_{Power\_max}$ = 5.1%; $UE_{power\text{-}ave}$ = 9.2 dBm; $CL_{x\text{-}ile}$ = 122 dB; DTT antenna random from pixel to pixel									
		1 UE (OOB)		10 UE (OOB)		10 UE (OOB – 9)		10 UE (OOB – 19)	
OOB (dBm)	ACLR (dB)	Δ_{RLP} (%)	IP (%)	Δ_{RLP} (%)	IP (%)	Δ_{RLP} (%)	IP (%)	Δ_{RLP} (%)	IP (%)
-40	63	3.502	0.004440	16.731	0.046283	2.984	0.008464	1.207	0.003359
-42	65	2.255	0.002899	11.168	0.030663	2.247	0.006372	1.119	0.003150
-44	67	1.529	0.001932	7.495	0.020531	1.834	0.005049	1.077	0.003018
-46	69	1.034	0.001315	5.085	0.014048	1.528	0.004216	1.055	0.002935
-48	71	0.746	0.000926	3.551	0.009929	1.333	0.003690	1.038	0.002882
-50	73	0.588	0.000681	2.564	0.007300	1.207	0.003359	1.026	0.002848

R.3.3 ACS = 75 dB, 30% outdoor UE, 70% indoor UE

$\%_{Power\_max}$ = 20.9%; $UE_{power\text{-}ave}$ = 13.7 dBm; $CL_{x\text{-}ile}$ = 122 dB; DTT antenna random from pixel to pixel									
		1 UE (OOB)		10 UE (OOB)		10 UE (OOB – 9)		10 UE (OOB – 19)	
OOB (dBm)	ACLR (dB)	Δ_{RLP} (%)	IP (%)	Δ_{RLP} (%)	IP (%)	Δ_{RLP} (%)	IP (%)	Δ_{RLP} (%)	IP (%)
-40	63	2.960	0.003930	17.018	0.003930	3.039	0.007946	1.234	0.003178
-42	65	1.962	0.002583	11.360	0.002583	2.291	0.006003	1.146	0.002981
-44	67	1.300	0.001718	7.629	0.001718	1.860	0.004768	1.097	0.002855
-46	69	0.895	0.001171	5.186	0.001171	1.554	0.003985	1.069	0.002776
-48	71	0.660	0.000825	3.626	0.000825	1.362	0.003491	1.055	0.002726

-50	73	0.522	0.000607	2.617	0.000607	1.234	0.003178	1.044	0.002694

3 Conclusions

These further calculations show that in order to reach, or approach as much as possible, the target of 1% degradation of location probability (Δ_{RLP}) it is required to have both ACS of the DTT receiver and ACLR of the IMT user equipment in the range 70 dB to 75 dB. This corresponds to out-of-band emission levels of the IMT user equipment in the range –47 dBm/8 MHz to -52 dBm/8 MHz.

Based on these calculations, [the EBU] maintain the proposals for out of band emission limits of LTE UE operating in the 700 MHz band with 10 MHz channel bandwidth [as given in Document 4-5-6-7/382].

APPENDIX 7

Parameters used in the study

19 sectors (see the [Figure ###1###])

23 Base stations

UE density

1 UE/sector (with full OOB levels)

10 UE/sector (with full and reduced OOB levels: -9 dB, -19 dB)

200 000 events per simulation

An event consists of the random placement of {1 or 10} UE within each sector, and the random placement of the pixel (and 100 000 DTTs within the pixel) within the central sector (but at a fixed position within the sector is a few cases)

TPC

$P_{UE} = P_{max} – \min\{0, \mathrm{Max}[R_{min}, (CL – CL_{x\text{-}ile})^{\gamma}]\}$, where

$P_{max} = 23$ dBm, $R_{min} = -63$ dB, $CL_{x\text{-}ile} = 122$ dB, $\gamma = 1$

Urban environment

Sector range = 1 km

DTT

Fixed reception (95% location probability at coverage edge)

DVB-T sensitivity: -77.17 dBm; PR = 21 dB

DVB-T2 sensitivity: -79.07 dBm; PR = 20 dB

1 pixel per event; 100 000 DTT sites per pixel

Height = 10 m

$Gain_{DTT}$ = 9.15 dBi

DTT antenna randomly directed for each event (but pointed always to the right or left in a few cases)

Recommendation ITU-R BT.419 for DTT antenna discrimination (max of vertical and horizontal discrimination)

Base station

Height = 30 m

$Gain_{BS}$ = 15 dBi, feeder loss = 3 dB

Recommendation ITU-R F.1336 for tri-sector BS antenna discrimination

Tilt = 3°

UE

Height = 1.5 m

$e.i.r.p._{max}$ = 23 dBm, $e.i.r.p._{min}$ = -40 dBm

Body loss = 4 dB

Indoor losses

11 dB wall loss, 6 dB Gaussian standard distribution

UE Indoor/outdoor ratio

0% / 100%

14% / 86%

70% / 30%

Protection ratios

Co-channel: 21 dB

ACS = 65 dB, 70 dB

OOB = - 40 dBm, -42 dBm, -44 dBm, -46 dBm, -48 dBm, -50 dBm

ACLR = 63 dB, 65 dB, 67 dB, 69 dB, 71 dB, 73 dB

Results:

Δ_{RLP} (with 1 error per hour ≡ interference for ≥ 0.028% of the events)

IP (interference probability for 1 event)

APPENDIX 8

Summary of results of experience on initial deployment of IMT networks in the 800 MHz band in France

Introduction

The aim of this appendix is to share experience on the deployment of mobile service LTE networks, and the impact of LTE downlinks on fixed roof-top DTT reception below 790 MHz in France. Note that the fixed DTT reception "chain" means a roof-top antenna, an amplifier system (in some cases), a passive cable and a TV receiver. Portable and mobile DTT receptions are not under consideration in this paper.

Based on the work carried out in Europe, a mechanism to address the potential interference from IMT base station to fixed DTT reception has been put in place in France:

– Mobile operators have the obligation to implement on all base stations filtering characteristics called "Case A/channel 60" of base station BEM out-of-block e.i.r.p. limits over frequencies below 790 MHz (see Annex, part B, table 4 of European Commission decision 2010/267/EU[39]).
– In addition, mobile operators in the 800 MHz have the obligation:
  – to solve interference of TV installation receiving broadcasting stations assigned before the LTE deployment;
  – to provide the French TV viewers a common interface to complain in case of interference, and to help mobile operators to identify quickly where and which operator should intervene, ANFR is managing a call centre for interference to DTT reception and also collects the information provided by mobile operators in the 800 MHz band (eg, base station deployment and base station putting into service information).

Moreover, information is provided (i.e. the phone number of the call centre mentioned above) through different means to local professional aerial installers, apartment block administrators, local authority and TV viewers before base stations are put into service.

Analysis of the cause of interference

The vast majority of reported interference cases that have been observed so far on fixed DTT reception were caused by LTE base station provoking DTT saturation (active systems like amplifiers or DTT television / set-top box). Saturation means that usually all TV channels are interfered.

Summary of interference situation

During the period from 1st November 2012 to 31st December 2013, 2 605 LTE base stations have been put into service in the 800 MHz band, in particular in urban areas, and there have been 7 570 reported cases of interference to fixed DTT receiving installations, domestic or community aerial (some interference may not have resulted in claims from TV viewers).

39 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:117:0095:0101:en:PDF.

The number of interference cases per base station is very dependent on the local conditions of TV reception. In areas where the TV signal is weak, TV viewers are likely to have installed an amplifier and have a higher risk of being interfered with.

It has been observed that the median interference distance between the base station and the TV reception installation is about 330 metres with an interference distance in 99% of cases below 1.3 kilometres, with one case reported at 3.5 kilometres (hilly terrain).

Mitigation measures taken to resolve interference situations

Every interference case due to the deployment of LTE base stations in the 800 MHz band onto the fixed roof-top DTT reception has been resolved by the introduction of a LTE 800 filter, either head-end filters (if active systems like amplifiers are present between the roof-top antenna and the television /set-top box) or user filters. The specifications of these filters have been defined by the administration, taking into account studies conducted with the help of stakeholders (broadcasters and the 800 MHz mobile operators). An industrial label could help consumers and professional aerial installers to identify efficient filters.

Summary

In view of the information detailed above according to the present experience, the following can be summarized about the interference situation between LTE base stations downlinks and fixed roof-top DTT reception in adjacent band both within France:

– for the 800 MHz band, the distance between the interfering IMT base station and the fixed roof-top DTT receiving location is in 99% of cases below 1.3 kilometres, with one case reported at 3.5 kilometres (hilly terrain).;

– for the 800 MHz band, almost all reported interference cases that have been observed so far on fixed roof-top DTT reception were caused by LTE base station provoking DTT saturation (active systems like amplifiers or DTT television / set-top box) and all had been resolved by the introduction of an LTE 800 filter (either head-end filters or user filters). The administration and operators have been able to manage successfully this kind of interference;

– at 700 MHz, assuming the deployment of IMT although a greater frequency separation between the mobile downlinks and the highest DTT channel 48 (cf. 700 MHz channelling options under consideration) may have a limited beneficial impact on DTT saturation effects, administration and stakeholders will have some knowledge of fixed roof-top TV receiving installations which could be interfered, based on the 800 MHz experience. The 800 MHz experience does not provide relevant information about the interference from mobile uplink to DTT reception.