Received: 5 February 2014

Subject: WRC-15 agenda item 1.2

Document 4-5-6-67/417-E
7 February 2014
English only

France

SIMULATION OF POTENTIAL INTERFERENCE FROM IMT UL TO DTT ROOFTOP FIXED RECEPTION FOR DETERMINING IMT TERMINAL OOBE REGULATORY LIMIT

Background:

Joint Task Group 4-5-6-7 developed at its meeting in July 2013 a set of working documents towards items relating to the broadcasting service for WRC-15 agenda item 1.2. Specifically, in order to assess the impact of adjacent band interference from the mobile service into the broadcasting service, several possible calculation methods were proposed. The simulation methods and scenarios/assumptions have been updated based on JTG 4-5-6-7 outputs and new elements received. As work has progressed, updates to the methods and calculations have been proposed. This document also captures the last updates in accordance to discussions which took place in the October 2013 meeting of the JTG 4-5-6-7, and proposes further information on the time aspect in Monte Carlo simulations.

Proposal:

This contribution proposes a method based on statistical Monte Carlo analysis in order to assess LTE uplink interference (i.e. from LTE transmitting user equipment) into Digital Terrestrial Television reception and presents the results of the simulations carried out based on the proposed method. These results also include an assessment of a range of values of OOBE that take into account the time aspect of interference.

Furthermore, some simulations have been done with 500.000 runs in order to increase the accuracy of results.

France invites JTG 4-5-6-7 to consider the following simulations and results when discussing the development of an IMT- UE OOBE limit and to update Attachment 3 of Annex 5 to Document 4-5-6-7/393, in particular with information contained in sections 2.3 and 2.5

Annex : 1

1 Introduction

Joint Task Group 4-5-6-7 is working on the compatibility study between IMT and DTT under WRC-15 agenda item 1.2. One of the objectives is to determine the IMT user equipment (UE) out-of-band emission (OOBE) limit for the protection of DTT reception. This document presents the results of the Monte Carlo simulations carried out with this aim.

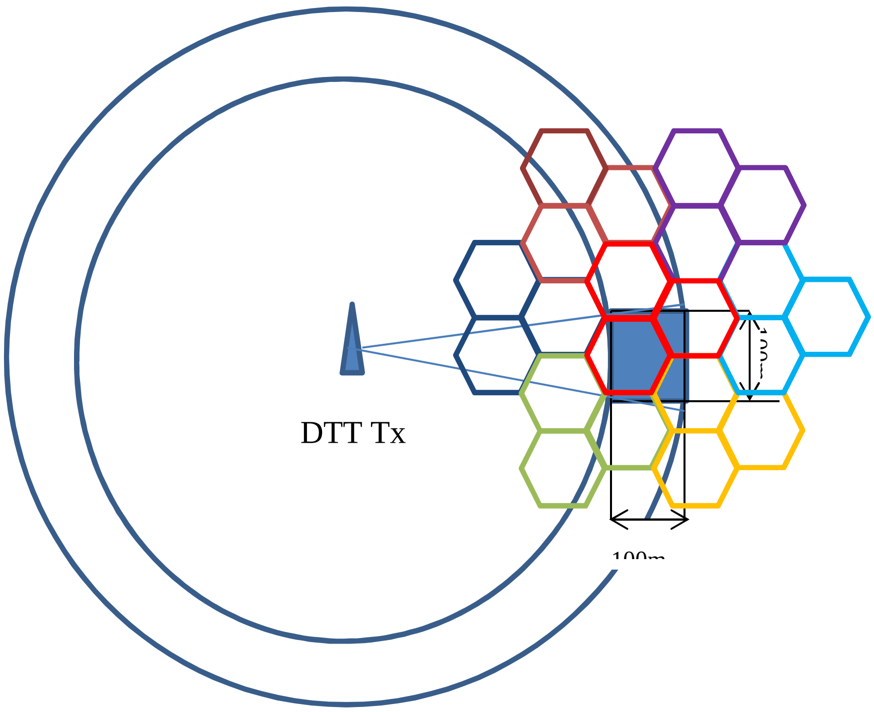
2 Simulation method, assumptions, and results

2.1 Simulation method and scenarios

The Monte Carlo simulation method used in this study is described in detail in Annex 2. A pixel of 100 m x 100 m is placed at DTT coverage edge, at each simulation run (event), DTT receiver location is randomly positioned within this pixel, for each generated DTT receiver point with the pixel, a IMT network cluster of 7 tri-sector sites (21 cells) is created around the DTT victim receiver. Between different simulation runs (events), the relative position between the victim DTT receiver and the reference IMT BS (BS at the centre of the cluster) is randomly generated within the range of cell range (see Figure 1).

FIGURE 1

Simulation scenario



The probability of interference of 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 adjacent channel selectivity (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. Note that further simulations may be required in order to assess the interference impact in the whole DTT coverage area.

2.2 Simulation assumptions

UE OOBE limits are defined for full channel bandwidth occupation in 3GPP specification TS36.101. Both simulations and laboratory measurements have shown that when UE is transmitting in partial band, UE OOBE level is reduced, a correction factor should be applied. The correction factor of UE OOBE from 20 MHz channel to 10 MHz channel is 8 dB. For 10 MHz channel, the correction factor of UE OOBE form 50 RBs to 25 RBs (resource blocks) is 12 dB, while the correction factor for less than 25 RBs is 19 dB.

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

2.3 Simulation results

Simulations are done for urban and rural environments. The simulation results can be found in the excel file hereafter. These simulations have been done for different values for DTT ACS, IMT UE ACLR and OOBE, and different IMT UE densities.

MC Simulation
Results France_JTG.›

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 :

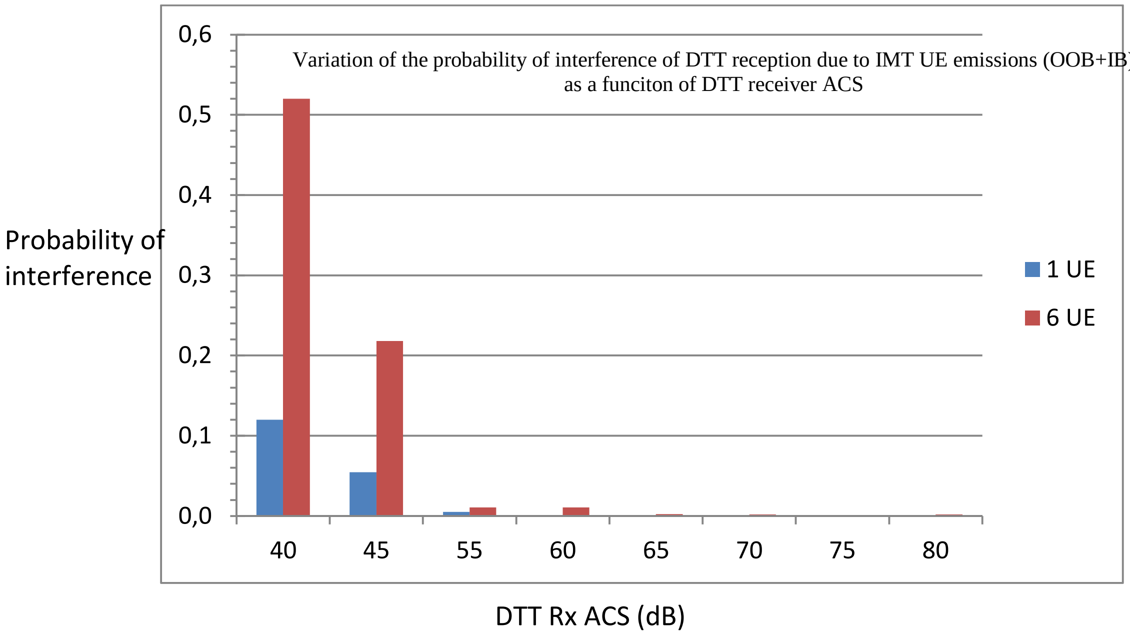
– Number of active UE per sector = 1 and 10;
– ACS = 65 dB;
– ACLR = 63, 65, 67 and 69 dB;
– ACLR correction factor (for 10 UE) = 9 and 19 dB;
– TW = 1800 s (30 min) and 3600 s (60 min);
– DT = 1, 10 and 100 s.

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 2. It can be seen that the probability of interference increases with number of transmitting UEs 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 2

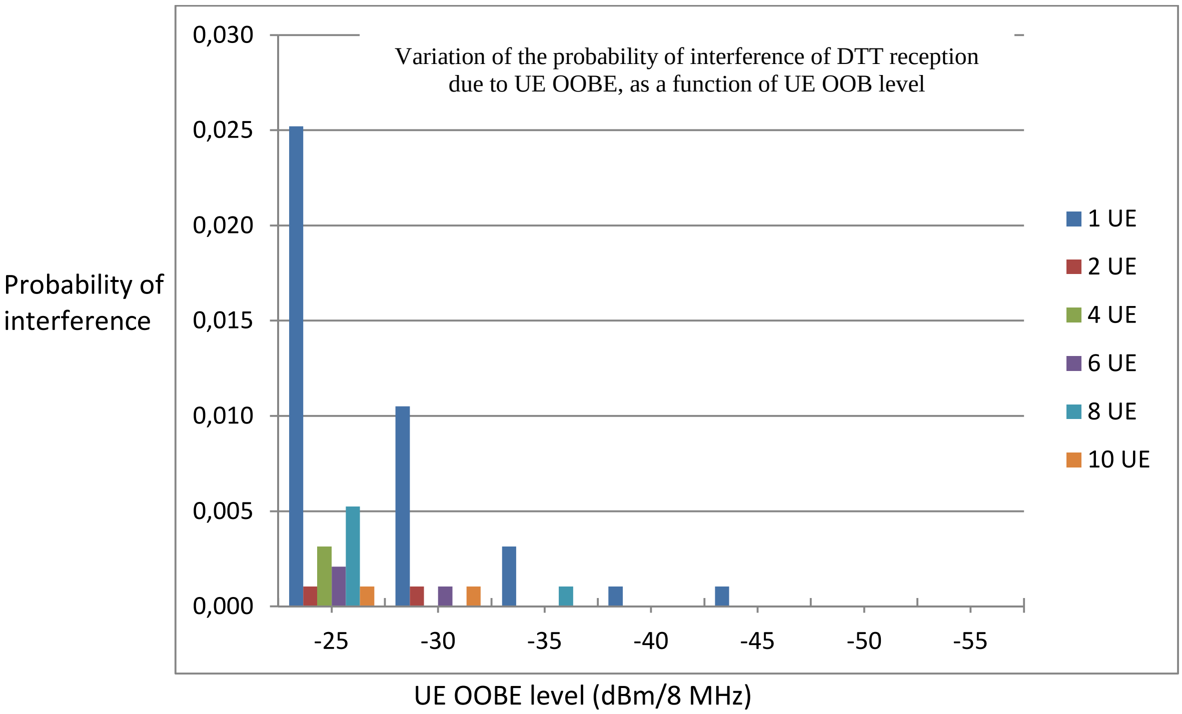
Variation of the probability of interference of DTT reception due to IMT UE emissions (OOB+IB) as a funciton of DTT receiver ACS



The variation of the probability of interference of DTT reception, due to UE OOBE, as a function of UE OOBE is shown in Figure 3. 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% at UE OOBE = –35 dBm/8 MHz.

FIGURE 3

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



As shown in Figure 3, 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), 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).

2.4 Conclusions on the static Monte-Carlo simulations

The results of the simulations carried out for urban and rural environments, within a pixel of 100 m x 100 m, located at DTT coverage edge, lead to the following conclusions:

1) The total probability of interference, including DTT receiver ACS and IMT UE ACLR, is mainly dominated and driven by DTT receiver ACS, except in case of a very low UE density. The probability of interference increases with the decrease of the DTT receiver ACS. It increases also with the increase of the number of active transmitting UEs per cell, but this increase is mainly due to the in-band power of IMT UEs. The second set of simulations for 10 UE made with 500 000 runs confirms this result.

2) For a given DTT ACS (i.e. ACS=60 dB), the probability of interference of DTT reception, due to UE OOBE is below 0,025% at UE OOBE –25 dBm/8 MHz, it is about 0,01% at UE OOBE –30 dBm/8 MHz. The probability of interference (IP) goes down to 0.003% at UE OOBE level of –35 dBm/8 MHz.

In view of the above results, it can be concluded that, for a given DTT receiver ACS value, a reduction of the OOBE levels for a IMT UE does not improve significatively the overall probability of interference, except in case of a very low UE density (#UE per sector ≤ 2), as it is mostly due to the DTT Receiver ACS.

2.5 Considerations on the time aspect in the assessment of interference

2.5.1 Description

The objective of this section is to reconcile the use of Monte Carlo approach with the need to take into account time element by converting the Interference Probability (IP) into a probability which would better reflect the impact of interference on the TV viewer.

2.5.2 Method of calculation with formulas

If IP is the interference probability 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:

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

Such probability P could be understood as the probability of having a disruption of duration DT (decorrelation time) when watching TV during a given TW (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 between two consecutive network states for one active uplink data user.

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.

Some contributions to the third mobile-DTT correspondence group meeting in October 2013 indicate a TW equal to one hour. The basis for this value could be an average viewing time for a given TV program.

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 signaling). 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.

"Decorrelation" time depends on the services used by the IMT user, but it is felt possible to derive an average "decorrelation" time considering the various IMT services.

2.5.3 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 during 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.

2.5.4 Results

This section provides some calculations for given ACLR and ACS values for different values of DT. The value of TW has been fixed to 1 hour as proposed by some contributions to the mobile-DTT correspondence group in October 2013.

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 1 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 and 70 dB have been chosen for simplification.

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 :

$$PR'(\Delta f) = PR_0 + 10\log(10^{\frac{-ACS}{10}} + 10^{\frac{-ACLR'}{10}}) \qquad (2)$$

Therefore, the values of ACLR = 58 and 68 dB have been chosen.

Also, 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.

Extracting the corresponding cells from the excel table in section *2.3 "Simulation Results"*, and applying equation (1) the following values are obtained:

TABLE 1

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 UEs		**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-03	2.63E-03	6.85E-03	21.8	2.43	0.24	0.12
-40	**63**	2.10E-03	3.68E-03	6.31E-03	20.3	2.24	0.22	0.11
ACS (dB)		**70**						
# active UEs		**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-03	< 5E-04	1.05E-03	3.71	0.37	0.037	0.018
-45	**68**	5.26E-04	< 5E-040	5.26E-04	1.87	0.18	0.018	0.009
-50	**73**	5.26E-04	< 5E-040	5.26E-04	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-04. Further simulations would be needed to improve the accuracy

This table shows the values of Probability (P) of an interference event, which may occur inside the period defined by DT, for an observation time (TW) of one hour. The value of one hour is taken only as an example and is not related with discussions on the QEF criteria.

The results clearly demonstrate the need to balance expected ACS and required ACLR.

In addition, it provides an illustration that lower de-correlation time 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 de-correlation 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: Is it more disruptive to have 4% probability of 1 s of interference or 0.04% probability of 100 s of interference?

Further simulations made with 500 000 runs confirm these results. In addition, these simulations also indicate that, for 10 UE the main contribution to the IP is the UE IB power.

TABLE 2

Simulation results for 500.000 iterations

Study	**FRANCE**			
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 UEs/Sector		1	10	
ACLR correction factor[1] (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

The probability of occurrence of at least one interference from IMT UEs to DTTB receiver during a given Time Window (TW = 30 min or 60 min) are represented in figures 4 to 7, for different number of active UE (1 or 10), different values of Decorrelation Time (DT = 1s, 10s or 100s) and different ACLR correction factors (0dB, 9dB or 19dB).

It is to be noted that, for the case of DT = 1s, 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 considered are very low.

Figure 4

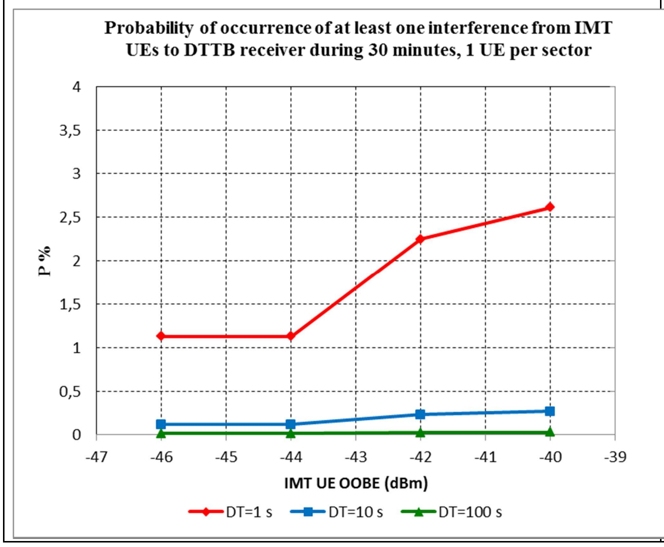


Figure 5

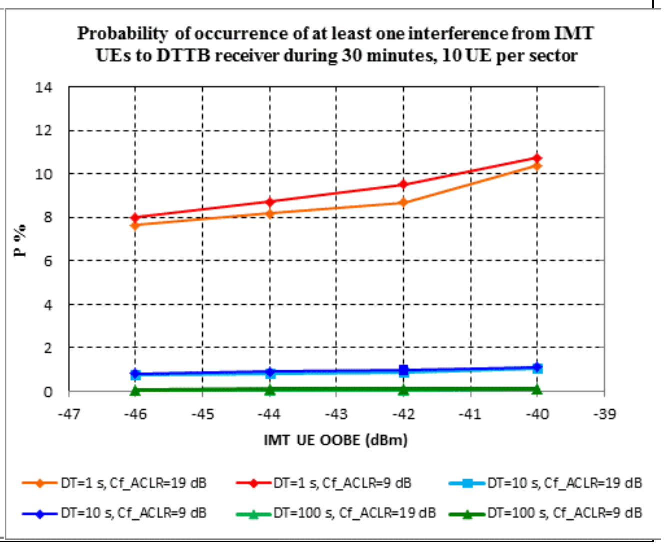


Figure 6

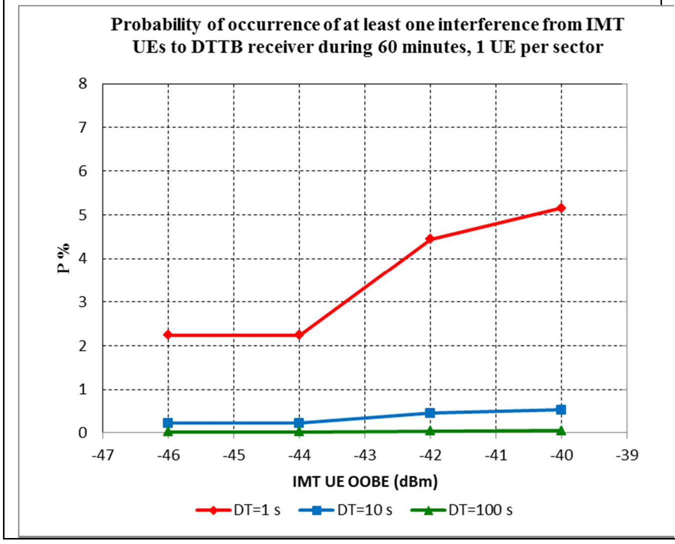
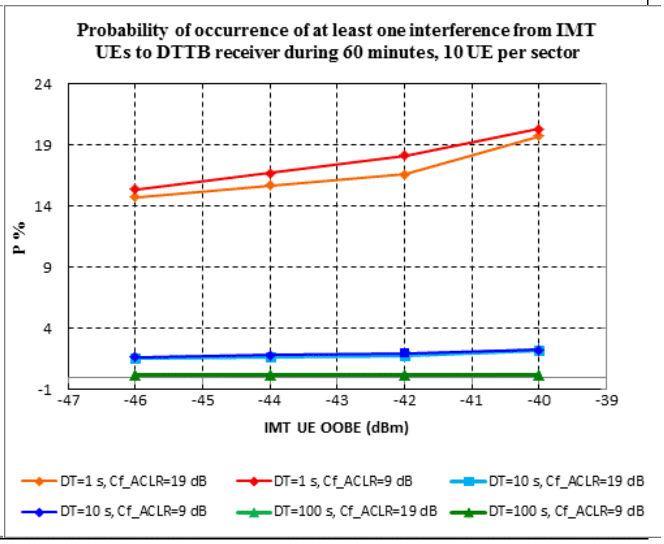


Figure 7



2.6 Conclusions

This study concentrates in the fixed DTT reception. For this study, section 2.4 introduces the conclusions on static Monte-Carlo simulations. Considering also the time element in Monte Carlo simulations presented in Section 2.5, it can be concluded the following :

– It is necessary to choose ACS and ACLR around the same order of magnitude.

– As an example, for a given TW = 3600 seconds, an ACS = 70 dB and ACLR = 63 dB a rough assessment of the probability that an interference for one second decorrelation time occurs in a time window of one hour is less than 4% and the probability that an interference for one hundred second decorrelation time occurs in a time window of one hour is less than 0.04%.

List of Annexes:

Annex 1: Simulation method and DVB-T / IMT system parameters

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

Annex 3: Transmit power control

Annex 4: Examples of DTT and IMT link budgets

Annex 5 : ACS values for DVB-T2

ANNEX 1

Simulation method and DVB-T / IMT system parameters

MONTE CARLO analysis of IMT uplink interference impact on fixed rooftop DTT reception

1 Introduction

This document presents the basic principles of a method using statistical (Monte Carlo) analysis for assessing IMT uplink interference impact on fixed rooftop DTT reception.

2 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 has been extensively used within the CEPT to quantify the probability of interference between cellular mobile systems.

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 (snapshot or event) based on the constructed interference scenario. For each event 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 events.

The probability of interference (p_I) is calculated from the generated data arrays *dRSS* and *iRSS*, based on a given interference criteria threshold (*C/I*, *C/N*, *C/(I+N)* or *(N+I)/I*):

$$p_I=1-p_{NI} \qquad (1)$$

where p_{NI} is the probability of non-interference of the receiver. This probability can be calculated for different interference types (unwanted emissions, blocking, overloading and intermodulation) or combinations of them.

The interference criterion *C/(I+N)* should be used for assessing IMT uplink interference impact on DTT reception. Consequently, p_{NI} is defined as follows:

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

$$= \frac{\sum_{i=1}^{M} 1\left\{\frac{dRSS(i)}{iRSS_{composite}(i)+N} \geq \frac{C}{I+N}\right\}}{M} \qquad (2)$$

where

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

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

L = number of interfering UEs;

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:

$$\Delta p_I = p_{I\_N} - p_{I\_N+I} \quad (3)$$

where

p_{I_N} : p_I in the presence of noise only;

p_{I_N+I} : p_I 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:

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

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 the study presented in this document, we have only evaluated the probability of interference (p_I) of DTT receivers interfered with by IMT UE. This method doesn’t predict any value of what is considered as an acceptable degradation of reception location, and therefore, what is the value of Δp_{RL}. However, it permits to identify the cases where the probability of interference is so low that the impact of moving interference sources on the victim receiver would be negligible.

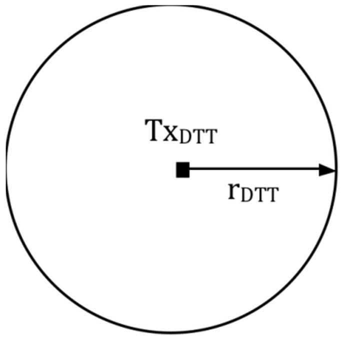
3 Basic geometry and simulation steps

3.1 Geometry

Firstly a DTT coverage area is built up according to the link budget analysis presented in Appendix 1 to Annex 3. The DTT transmitter is placed at the centre of the coverage area as depicted in Figure A.1.1.

FIGURE A.1.1

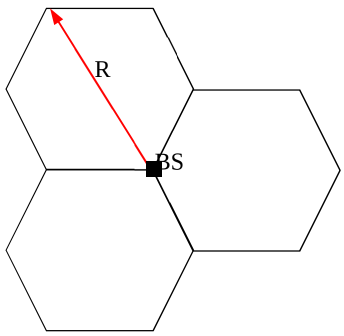
DTT coverage area of radius r_{DTT}



Then, a single frequency IMT cell composed of a single radio site is built up according to the link budget analysis presented in Appendix 2 of Annex 2. The IMT base station (BS) is placed at the centre of the cell. Each IMT cell is composed of three sectors as depicted in Figure A.1.2.

FIGURE A.1.2

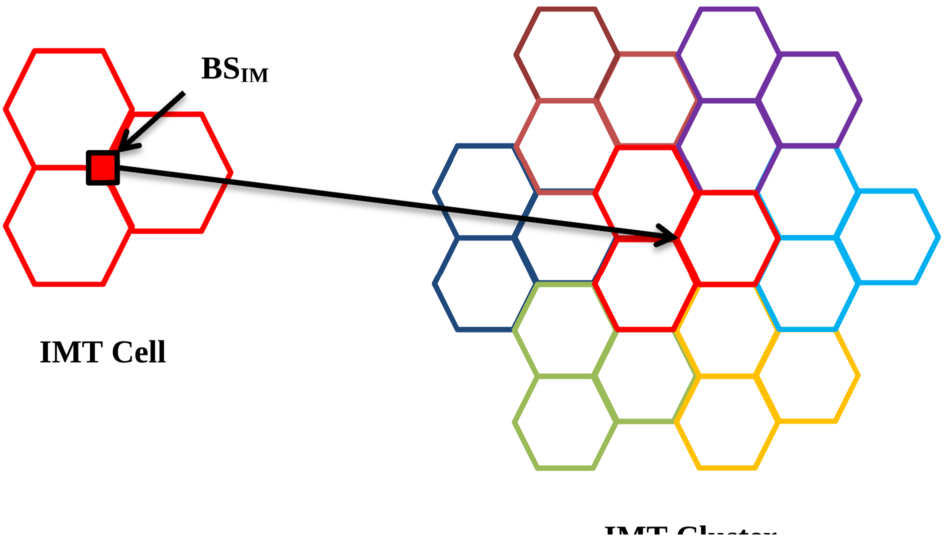
IMT cell: Hexagonal three-sector cell layout (R: cell range)



This IMT cell is repeated to build up a perfectly homogeneous single frequency IMT cluster composed of 7 cells (BS) as depicted in Figure A.1.3. A cluster of size 7 is composed of 21 (7 x 3) hexagonal-shaped sectors.

FIGURE A.1.3

Single frequency IMT cluster



3.2 Simulation steps

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. 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 within a radius of r_{IMT} an IMT cluster is randomly located following a uniform distribution. The cluster position is defined by the position of the central cell's BS position as depicted in Figure A.1.4.

3) The active IMT user equipment (UEs) 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) across *a pixel of 100 m x 100m at the edge of the DTT coverage area as depicted in Figure A.1.5. At least 100 000 events are generated to consider all possible interference cases in this pixel.*

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 adjacent channel selectivities (ACS), as a function of UE out of band emission (OOBE) level or adjacent channel leakage ratio (ACLR). An OOBE correction factor is applied for different UE RBs configurations as described in Tables xx and yy.

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 A.1.4

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

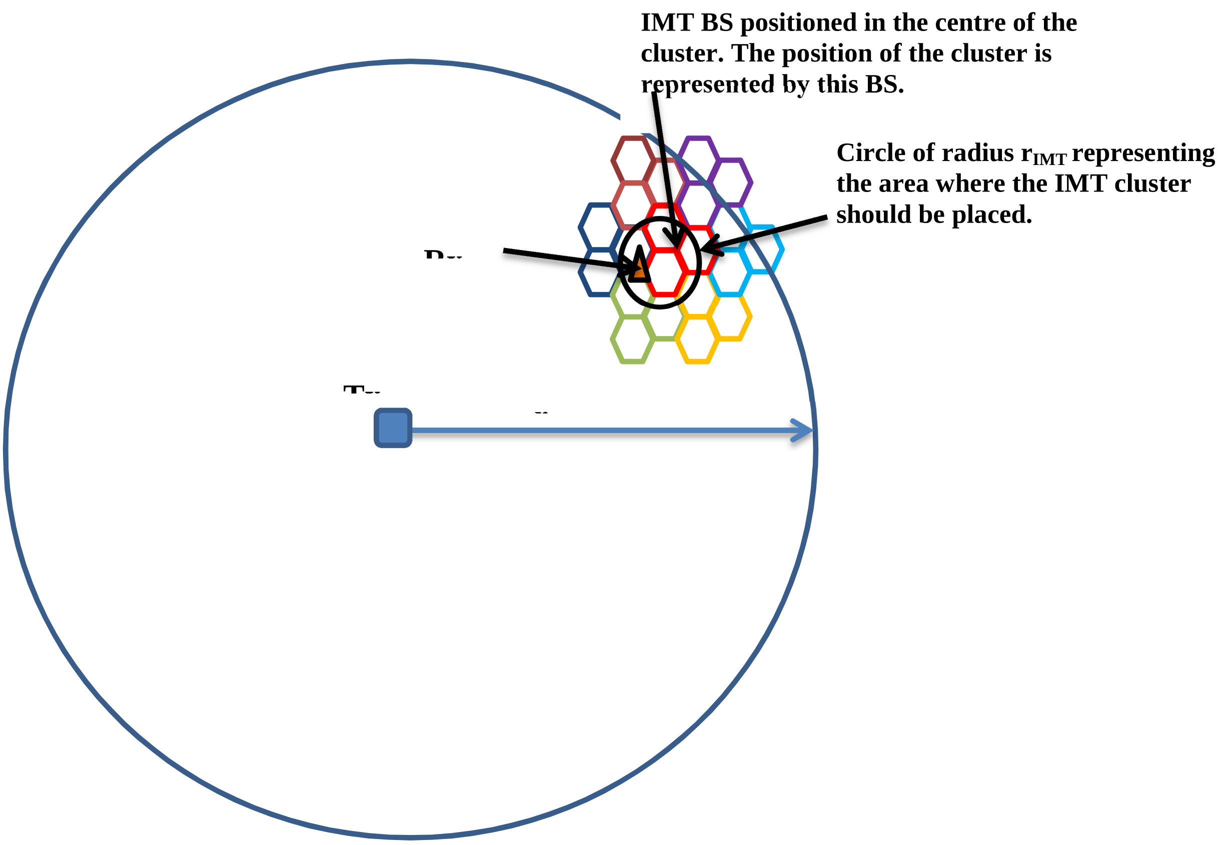
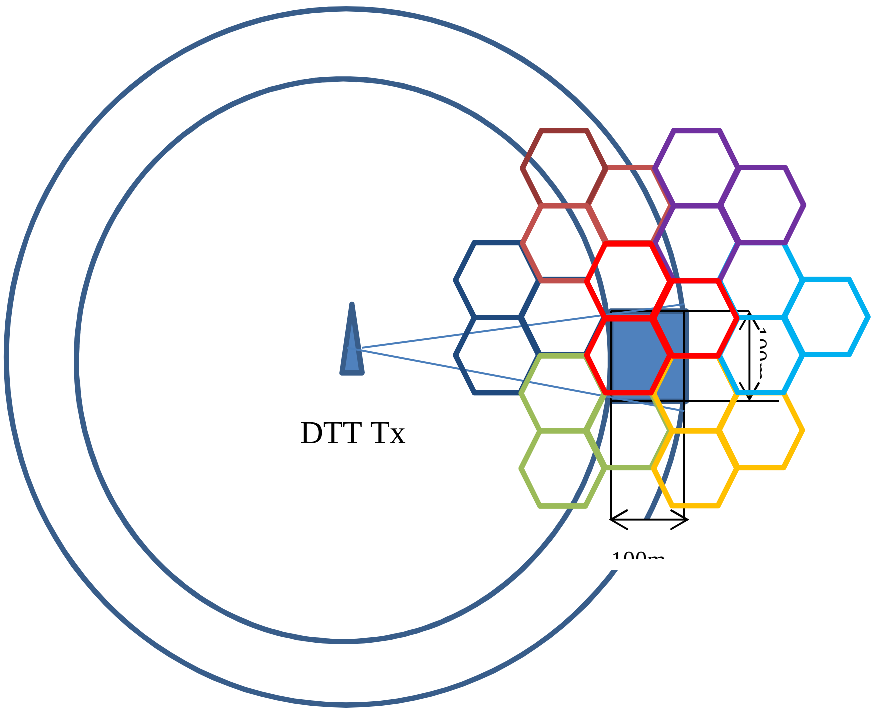


FIGURE A.1.5

Edge of the DTT coverage area



4 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 ($\boldsymbol{p_I}$) that may results in Monte Carlo simulation. The tables can be extended beyond a $\boldsymbol{p_I}$ of 0.0105%

TABLE A.1.1

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 95000 events, across a *pixel of 100 m x 100 m, only 10 interference cases were predicted.*

5 Input assumptions for the broadcasting and mobile services

This study has been carried out only for fixed outdoor DTT reception mode in urban as well as in rural environments. The system parameters used are presented in Tables A.1.2 and A.1.3.

TABLE A.1.2

DTT system parameters for fixed outdoor reception

DTT receiver parameters for fixed roof top antenna in urban and rural environments		
Parameter	**Value**	**Source**[1]
Frequency (MHz)	690	Document 4-5-6-7/126
Channel BW (MHz)	8	
Environment	Urban and rural	
Antenna height (m)	10	Document 4-5-6-7/126
Antenna gain including losses (dBi)	9.15	Derived from the parameter values given in Document 4-5-6-7/126
Antenna pattern	See Rec. ITU-R BT.419	Document 4-5-6-7/126
Antenna polarisation discrimination (dB) vis-à-vis IMT UT	0	
Modulation scheme	64 QAM (CR=2/3, GI=1/32)	
3 dB BW (MHz)	7.6	Document 4-5-6-7/126
Noise floor (dBm)	-98.17	Derived from the parameter values given in Document 4-5-6-7/126
C/N (dB)	21	Document 4-5-6-7/126
P_{min}(dBm) at the receiver input	-77.17	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	Derived from the parameter values given in Document 4-5-6-7/126
Receiver ACS (dB)	40, 45, 50, 55, 60, 70 and 80	
Protection criterion	C/(I+N) = 21 dB	

1 See also Document 4-5-6-7/55.

TABLE A.1.3

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	Document 4-5-6-7/49
ACLR[2]	48, 53 ,58 ,63 ,68 ,73 and 78	
Transmit power control parameters	See Annex 2	
IMT BS parameters		
Cell ranges: Urban Rural	 1 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 10 to Rec. ITU-R F.1336	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.

[2] Reference OOBE (dBm) level is defined for full resource allocation (50 RB) to a single UE

TABLE A.1.4

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 A.1.5

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 eirp = 23 dBm; OOBE for 1 active UE = -25 dBm		
Number of active UEs 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

ANNEX 2

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

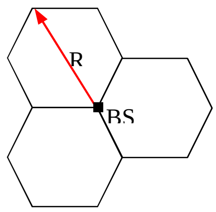
The active user densities presented in Table A.2.1 are calculated for a hexagonal shaped sector of range R, where the sector area is calculated as follows:

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

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



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 UEs.

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 (km^2)**	**N_active_UE/sector**	**Density ($1/km^2$)**
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 (km^2)**	**N_active_UE/sector**	**Density ($1/km^2$)**
2	2.598076211	2	0.769800359
		4	1.539600718
		6	2.309401077
		8	3.079201436
Rural			
IMT sector range (km)	**Sector area (km^2)**	**N_active_UE/sector**	**Density ($1/km^2$)**
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.

ANNEX 3

Transmit power control

A common model, or emulation, of the behavior 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 UEs 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 UEs transmit with maximum power.

This scheme in much more detail, in [Document 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 UEs 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 is 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.;

ANNEX 4

Examples of DVB-T and IMT link budgets

TABLE A.4.1

DVB-T link budget for fixed roof top reception

DVB-T link budget for fixed roof top reception at 10 m Single transmitter case (Assignments)				
DVB-T parameters		**Downlink all environments (Medium power transmitter)**	**Downlink all environments (High power transmitter)**	**Notes**
Center frequency	MHz	690.00	690.00	Channel 48
Channel BW	MHz	8.00	8.00	See Doc. 4-5-6-7/55
Effective BW	MHz	7.6	7.6	See Doc. 4-5-6-7/55
Noise figure (F)	dB	7	7	See Doc. 4-5-6-7/55
Boltzmann's constant (k)	Ws/K	1.38E-23	1.38E-23	
Absolute temperature (T)	K	290	290	
Noise power (P_n)	dBm	-98.16	-98.16	P_n(dBm) = F+10log(k*T*B*10^6)+30
SNR at cell-edge	dB	21	21	See Doc. 4-5-6-7/55
Receiver sensitivity (P_{min})	dBm	-77.17	-77.17	P_{min} = P_n(dBm) +SNR(dB)
Cell-edge coverage probability	%	95	95	See Doc. 4-5-6-7/55
Gaussian confidence factor for cell-edge coverage probability of 95% ($\mu_{95\%}$)	%	1.645	1.645	
Shadowing loss standard deviation (σ)	dB	5.50	5.50	See Annex 5 of Doc. 4-5-6-7/113 and Doc. 5-6/180
Building entry loss standard deviation (σ_w)	dB	0.00	0.00	
Total loss standard deviation (σ_T)	dB	5.50	5.50	$s_T = SQRT(\sigma^2 + \sigma_w^2)$
Loss margin (L_m)	95%	9.05	9.05	$L_m = \mu_{95\%} * \sigma_T$
P_{mean} (95%)	dBm	-68.12	-68.12	$P_{mean} = P_{min} + L_m$
Minimum median field strength	dBµV/m	56.72	56.72	See Doc. 4-5-6-7/55
e.i.r.p.	dBm	69.15	85.15	5 and 200 kW ERP respectively, see Doc. 4-5-6-7/55
Antenna height	m	150.00	300.00	See Doc. 4-5-6-7/55
Cable loss (L_{cable})	dB	4.00	4.00	See Doc. 4-5-6-7/55
Antenna gain (G_{iso})	dBi	13.15	13.15	See Doc. 4-5-6-7/55
G_{iso}-L_{cable}	dBi	9.15	9.15	
Average building entry loss (L_{wall})	dB	0.00	0.00	
Max allowed path loss (L_{pmax})	dB	146.42	162.42	L_{pmax} = e.i.r.p. + (G_{iso}-L_{cable}) - L_{wall} -L_{body} -P_{mean}
DVB-T coverage radii calculated by ITU-R P.1546 propagation model	km	12.62	39.5	Urban
	km	32.11	70.53	Suburban
	km	32.11	70.53	Rural

TABLE A.4.2

Example of IMT link budget for macro urban/suburban scenario

IMT (LTE) link budget for macro urban and suburban scenarios						
IMT parameters		**Uplink**		**Downlink**		
		UE (QPSK) > BS (QPSK)	**Link**	**BS (QPSK) > UE (QPSK)**	**Link**	**Comment**
Center frequency	MHz	703.00	UE	758.00	BS	
Channel BW	MHz	10.00	UE	10.00	BS	See Doc. 4-5-6-7/49
Number of RB used		1	UE	50	BS	
RB BW	MHz	0.18	UE	0.18	BS	
Effective BW	MHz	0.18	UE	9	BS	
Noise factor (F)	dB	5	BS	9	UT	See Doc. 4-5-6-7/49
Boltzmann's constant (k)	Ws/K	1.38E-23		1.38E-23		
Absolute temperature (T)	K	290		290		
Noise power (P_n)	dBm	-116.42	BS	-95.43	UE	P_n(dBm) = $F+10\log(k*T*B*10^6)+30$
SNIR at cell-edge	dB	0.9	BS	0.9	UE	
Link throughput at cell-edge (per RB)	kbps	83	UE	6249	BS	
Receiver sensitivity (P_{min})	dBm	-115.52	BS	-94.53	UE	For UE receiver sensitivity : P_{min} = Pn(dBm) +SNR(dB) Rx_sens=-101,5 dBm for Effective BW = 4.5 MHz (25 RB), see 3GPP TS 36.104 v.11.1.0, § 7.2 and see 3GPP TS 36.101 v.11.1.0, § 7.3
Cell-edge coverage probability	%	82		82		Commonly used values provided by BS manufacturers
Gaussian confidence factor for cell-edge coverage probability of 82% ($\mu_{82\%}$)		0.92		0.92		
Shadowing loss standard deviation (σ)	dB	5.50		5.50		See Annex 5 of Doc. 4-5-6-7/113 and Doc. 5-6/180
Building entry loss standard deviation (σ_w)	dB	6.00		6.00		See Annex 5 of Doc. 4-5-6-7/113 and Rec. ITU-R P.1812
Total loss standard deviation (σ_T)	dB	8.14		8.14		$s_T = SQRT(\sigma^2 + \sigma_w{}^2)$
Loss margin (L_m)	82%	7.45		7.45		$L_m = \mu_{82\%} * \sigma_T$
P_{mean} (82%)	dBm	-108.07	BS	-87.08	UE	$P_{mean} = P_{min} + L_m$
e.i.r.p.	dBm	20.00	UE	56.00	BS	See Doc. 4-5-6-7/49 23 dBm + (-3 dB)
Antenna height	m	1.50	UE	30.00	BS	See Doc. 4-5-6-7/49
Cable loss (L_{cable})	dB	0.00	UE	3.00	BS	See Doc. 4-5-6-7/49

Antenna gain (G_{iso})	dBi	-3.00	UE	15.00	BS	See Doc. 4-5-6-7/49
G_{iso}-L_{cable}	dBi	12.00	BS	-3.00	UE	
Average building entry loss (L_{wall})	dB	11.00		11.00		See Annex 5 of Doc. 4-5-6-7/113 and Rec. ITU-R P.1812
Typical body loss	dB	4.00		4.00		See Doc. 4-5-6-7/49
Max allowed path loss (L_{pmax})	dB	125.07		125.08		L_p = e.i.r.p. +(G_{iso}-L_{cable}) - L_{wall} -L_{body} -P_{mean}
IMT BS cell radius calculated by Extended Hata model (r_{IMT})	km	1.089 (1 km is used in simulations)			r_{IMT}	Urban: cell radius calculated from UL L_{pmax}
	km	2			r_{IMT}	Suburban: cell radius calculated from UL L_{pmax}

TABLE A.4.3

Example of IMT link budget for macro rural scenario

IMT (LTE) link budget for macro rural scenario						
IMT parameters		**Uplink**		**Downlink**		
		UE (QPSK) > BS (QPSK)	**Link**	**BS (QPSK) > UE (QPSK)**	**Link**	**Notes**
Center frequency	MHz	703.00	UE	758.00	BS	
Channel BW	MHz	10.00	UE	10.00	BS	
Number of RB used		1	UE	50	BS	
RB BW	MHz	0.18	UE	0.18	BS	
Effective BW	MHz	0.18	UE	9	BS	
Noise factor (F)	dB	5	BS	9	UE	See Doc. 4-5-6-7/49
Boltzmann's constant (k)	Ws/K	1.38E-23		1.38E-23		
Absolute temperature (T)	K	290		290		
Noise power (P_n)	dBm	-116.42	BS	-95.43	UE	P_n(dBm) = F+10log(k*T*B*10^6)+30
SNIR at cell-edge	dB	0.9	BS	0.9	UE	
Link throughput at cell-edge	kbps	83	UE	6249	BS	
Receiver sensitivity (P_{min})	dBm	-115.52	BS	-94.53	UE	P_{min} = Pn(dBm) +SNR(dB) Rx_sens=101,5 dBm for Effective BW = 4.5 MHz (25 RB), see 3GPP TS 36.104 v.11.1.0, § 7.2 and see 3GPP TS 36.101 v.11.1.0, § 7.3
Cell-edge coverage probability	%	70		70		Commonly used values provided by BS manufacturers
Gaussian confidence factor for cell-edge coverage probability of 70% ($\mu_{70\%}$)		0.52		0.52		
Shadowing loss standard deviation (σ)	dB	5.50		5.50		See Annex 5 of Doc. 4-5-6-7/113 and Doc. 5-6/180
Building entry loss standard deviation (σ_w)	dB	6.00		6.00		See Annex 5 of Doc. 4-5-6-7/113 and Rec. ITU-R P.1812
Total loss standard deviation (σ_T)	dB	8.14		8.14		s_T = SQRT($\sigma^2 + \sigma_w^2$)
Loss margin (L_m)	70%	4.27		4.27		$L_m = \mu_{70\%} * \sigma_T$
P_{mean} (70%)	dBm	-111.25	BS	-90.26	UE	$P_{mean} = P_{min} + L_m$
e.i.r.p.	dBm	20.00	UE	56.00	BS	See Doc. 4-5-6-7/49 23 dBm + (–3 dB)
Antenna height	m	1.50	UE	30.00	BS	See Doc. 4-5-6-7/49
Cable loss (L_{cable})	dB	0.00	UE	3.00	BS	See Doc. 4-5-6-7/49
Antenna gain (G_{iso})	dBi	-3.00	UE	15.00	BS	See Doc. 4-5-6-7/49
G_{iso}-L_{cable}	dBi	12.00	BS	-3.00	UE	

Average building entry loss (L_{wall})	dB	11.00		11.00		See Annex 5 of Doc. 4-5-6-7/113 and Rec. ITU-R P.1812
Typical body loss	dB	4.00		4.00		See Doc. 4-5-6-7/49
Max allowed path loss (L_{pmax})	dB	128.25		128.26		L_p = e.i.r.p. +(G_{iso}-L_{cable}) - L_{wall} -L_{body} -P_{mean}
IMT BS cell radius calculated by Extended Hata model (r_{IMT})	km	8.09 (8 km is used in simulations)			r_{IMT}	Rural: cell radius calculated from UL L_{pmax}

ANNEX 5

ACS values for DVB-T2

TABLE A.5.1

Derived ACS values for silicon tuners from the un-corrected protection ratios (dB) for a DVBT-2 signal interfered with by an LTE UE signal in adjacent channels for silicon tuners in Table 3

(as in document 4-5-6-7/185 Table 5)

Channel offset N **8 MHz channels/ (centre frequency offset)**	**1 Mbit/s UE** **traffic loading** **Signal generator ACLR = 100 dB all offsets**		**10 Mbit/s UE** **traffic loading** **Signal generator ACLR = 100 dB all offsets**		**20 Mbit/s UE** **traffic loading** **Signal generator ACLR =** **67.8 dB (N+1)** **80.4 dB (N+2)** **100 dB (N+3 to N+9)**	
	ACS Percentile **dB**		**ACS Percentile** **dB**		**ACS Percentile** **dB**	
	50th	**90th**	**50th**	**90th**	**50th**	**90th**
1/(10)	55.0	38.0	60.0	58.0	60.8	58.5
2 (18)	60.0	43.0	66.0	64.0	66.2	62.1
3 (26)	63.0	45.0	67.0	64.0	69.0	63.0
4 (34)	65.0	55.0	67.0	64.0	71.0	64.0
5 (42)	66.0	56.0	67.0	63.0	73.0	65.0
6 (50)	69.0	57.0	68.0	62.0	71.0	64.0
7 (58)	69.0	60.0	68.0	63.0	72.0	63.0
8 (66)	69.0	60.0	68.0	61.0	73.0	64.0
9 (74)	69.0	62.0	68.0	62.0	73.0	66.0

____