International Telecommunication Union

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Radiocommunication Sector of ITU

Report ITU-R M.2241

(11/2011)

Compatibility studies in relation to Resolution 224 in the bands 698-806 MHz and 790-862 MHz

M Series

Mobile, radiodetermination, amateur and related satellite services

International Telecommunication Union

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Note*: This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

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REPORT ITU-R M.2241

Compatibility studies in relation to Resolution 224 in the bands 698-806 MHz AND 790-862 MHz

(2011)

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1 Introduction

1.1 Scope and objective of the Report

The scope of this Report is to provide sharing study results in relation with ITU-R Resolution 224 (taking into account, to the extent practicable, studies performed under Resolution 749 (WRC-07)).

The objective of the sharing studies is to assess the degree of compatibility between IMT systems operating in the frequency bands 790-862 MHz or 698-806 MHz and systems of other services operating in the same or adjacent band. These studies also contain compatibility scenarios involving the mobile service only (between systems with different technical characteristics).

More precisely, this Report addresses the following scenarios:

− Potential interference in the bands 790-862 and 698-806 MHz caused by the co-channel or adjacent channel operation of the broadcasting service[1], the fixed service or other mobile systems, to IMT systems.

− Compatibility between other mobile systems and IMT systems.

− Compatibility between different IMT systems.

This Report also provides guidance to ensure compatibility between the involved services. These guidelines will include interpretation and clarification of appropriate mobile parameters and methodologies to be used for compatibility studies.

1.2 Background

1.2.1 Services allocated on a primary basis in the bands 790-862 and 698-806 MHz

Article 5 of the Radio Regulations details, *inter alia*, the services that are allocated on a primary basis globally or regionally in the 790-862 and 698-806 MHz bands, as well as the corresponding footnotes relevant for the sharing studies of this Report.

1.2.2 GE06 Agreement and the coordination trigger mechanism[2]

In 2006, countries in Region 1 (except Mongolia) and the Islamic Republic of Iran attended a Regional Radiocommunication (RRC-06) Conference for the planning of digital television that led to the adoption of the GE06 Agreement. The GE06 Agreement contains plans for analogue and digital television broadcasting in the frequency bands 174-230 MHz and 470-862 MHz. Under the provisions of the GE06 Agreement, a transition period was set following the Conference during

[1] Studies in this report address the ATSC and DTMB broadcast systems. Studies on other broadcast systems will be included in future revisions to this report.

[2] This information applies to contracting members ofof the GE-06 Agreement.

which the assignments in the analogue Plan shall be protected. For the frequency band 470-862 MHz, this transition period will end on 17 June 2015 at 0001 hours UTC[3].

For Contracting Members to the GE06 Agreement, relevant regulatory and technical provisions of this Agreement address the situation where at least one of the considered services is broadcasting. In addition, the GE06 Agreement contains a Plan for digital TV, a Plan for analogue TV and the List of other primary terrestrial services which covers, *inter alia*, the band 790-862 MHz. However, the GE06 Agreement contains no provision for the coordination of two primary terrestrial services other than broadcasting.

Regarding the protection of digital broadcasting systems, Table AP.1.10 of Appendix 1 to Section I of Annex 4 of the GE06 Agreement contains a trigger field strength of 25 dBμV/m/8 MHz in the frequency range including 790 to 862 MHz for the identification of potentially affected administrations for the protection of the Plan from other primary terrestrial services.

Trigger levels for the protection of mobile service are either based on pre-defined characteristics corresponding to some systems deployed when the GE06 Agreement was developed (e.g. NA type code applying to CDMA) or based on a generic formula (NB type code) which applies generically to cellular mobile systems. The protection criteria is currently calculated based on the notified characteristics of the stations in the mobile service and on the typical values which are provided for the noise figure, the antenna gain, the feeder loss and the man-made noise. These values correspond to certain assumptions and are broadly technology independent.

Each administration has obtained in the GE06 Agreement a certain level of rights in terms of spectrum access with the possibility to use these rights for any services to which the band is allocated. Overall, each administration has the opportunity to negotiate with its neighbours to adapt its rights to spectrum access in this band to the intended deployment.

The GE06 Agreement states that "… Although the determination of the area within which coordination is required is based on technical criteria, it is important to note that it represents a regulatory concept, for the purpose of identifying the area within which detailed evaluations of the interference potential needs to be performed. Hence, the coordination area is not an exclusion zone within which the sharing of frequencies is prohibited, but a means for determining the area within which more detailed calculations need to be performed…"

According to this, the trigger field strength for the cross-border coordination mechanism under the GE06 Agreement is to be used only for regulatory purposes to determine:

- when and with which administrations a coordination is required;
- for which coordination situations detailed evaluations of the interference potential needs to be performed.

The reference equations for calculations are provided for guidance to administrations by the GE06 Agreement. There are also several identified types of mobile services together with system parameters. Administrations can provide exact system parameters for use in bilateral discussions following regulatory identification based on the generic values.

1.2.3 Previous ITU-R studies

ITU-R has undertaken studies in accordance with Resolution 749 (WRC-07). These studies focused on the protection of the broadcasting service, the aeronautical radionavigation service and the fixed service from the mobile service, including IMT, within the band 790-862 MHz for investigating regulatory actions in Regions 1 and 3.

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[3] For details, see the GE-06 Agreement.

The studies carried out under Resolution 749, to a large extent, did not consider the protection of the mobile service including IMT.

1.3 Glossary of terms

3GPP	3rd Generation Partnership Project
ACIR	Adjacent Channel Interference Ratio
ACLR	Adjacent Channel Leakage Ratio
ACS	Adjacent Channel Selectivity
AGC	Automatic Gain Control
APT	Asia Pacific Telecommunity
ARNS	Aeronautical Radio Navigation Service
ATSC	Advanced Television Systems Committee
AWG	APT Wireless Group
AWGN	Additive White Gaussian Noise
BTS	Base Transceiver System
BW	Bandwidth
CDMA	Code Division Multiple Access
CDF	Cumulative Distribution Function
DIMRS	Digital Integrated Mobile Radio Service
DL	Downlink
DTMB	Digital TerrestrialMulti-media Broadcasting
DTV	Digital TeleVision
DTTV	Digital Terrestrial TeleVision
DVB-H	Digital Video Broadcast – Handheld
DVB-T	Digital Video Broadcasting – Terrestrial
e.i.r.p.	Equivalent Isotropically Radiated Power
e.r.p.	Equivalent Radiated Power
E-UTRA	Evolved Universal Terrestrial Radio Access
FDD	Frequency Division Duplex
FTP	File Transfer Protocol
HSPA	High Speed Packet Access
GE06	Geneva Agreement 2006
IMT	International Mobile Telecommunications
I/N	Interference-to-Noise
ISDB-T	Integrated Services Digital Broadcasting Terrestrial
LMR	Land Mobile Radio
LOS	Line-of-Sight

LTE	Long Term Evolution
MCL	Minimum Coupling Loss
MCS	Modulation and Coding Scheme
MS	Mobile Service
NGMN	Next Generation Mobile Networks Alliance (NGMN Alliance)
OFDMA	Orthogonal Frequency Division Multiple Access
OOB	Out-Of-Band
PPDR	Public Protection and Disaster Relief
PRR	Pulse Repetition Rate
RLS	Radio Location System
RRC-06	The Regional Radiocommunication Conference 2006 for the planning of the digital terrestrial broadcasting service in Region 1 (parts of Region 1 situated to the west of meridian 170° E and to the north of parallel 40° S, except the territories of Mongolia) and in the Islamic Republic of Iran, in the frequency bands 174-230 MHz and 470-862 MH
RSBN	РадиотехническаяСистемаБлижнейНавигацииRadiotechnitscheskajaSistemaBlischnejNawigazii, Russian for "Short Range Radio-navigation system"
SECAM	*Séquentiel Couleur Avec Mémoire* French for " Sequential Colour with Memory"
SINR	Signal to Interference Noise Ratio
SNF	System Noise Floor
SLS	System Level Simulation
TD	Time Division
TDD	Time Division Duplex
TP	Throughput
UE	User Equipment
UL	Uplink
WiMAX	Worldwide Interoperability for Microwave Access

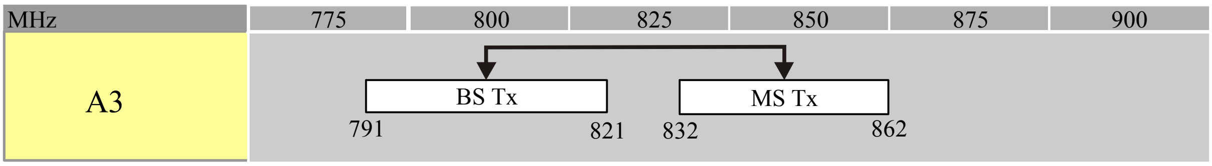
2 Characteristics and parameters of systems in the bands 790-862 and 698-806 MHz

2.1 Applicable IMT frequency arrangements

Seven frequency arrangements are part of the draft revision of Recommendation ITU-R M.1036-3. Four of them have been taken into account in this Report (two based on FDD, one based on TDD, one based on mixed FDD/TDD).

FIGURE 2.1-1

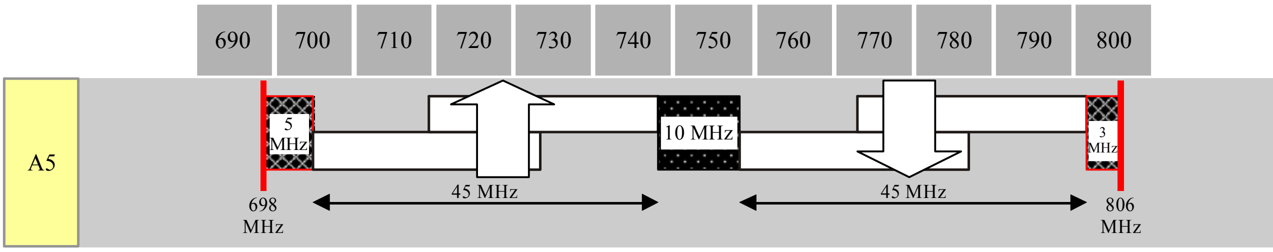
a) CEPT frequency arrangement (referred as A3)



M.1036-02-Ann2

FIGURE 2.1-2

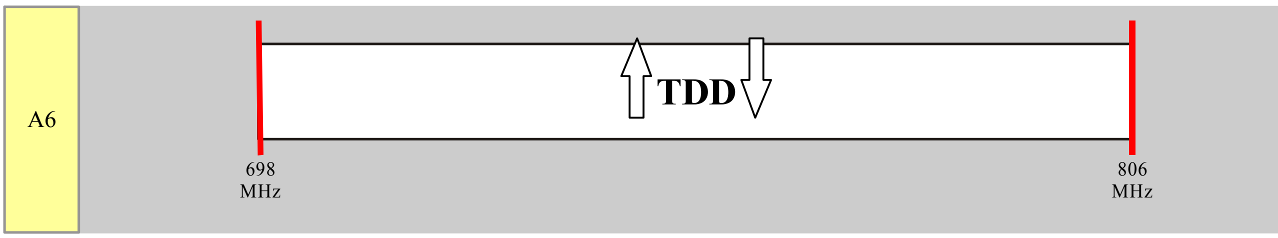
b) APT (Asia Pacific Telecommunity) FDD frequency arrangement (referred as A5)



M.1036-04-Ann2

FIGURE 2.1-3

c) APT TDD frequency arrangement (referred as A6)



M.1036-05-Ann2

2.2 IMT systems parameters

2.2.1 Representative parameters

This section provides generically the parameters of representative IMT systems expected to be deployed in the bands 698-806 MHz and 790-862 MHz

TABLE 2.2.1-1

Parameters of IMT systems in the bands 698-806 MHz and 790-862 MHz

No.	Parameter	Base station	Mobile station
1.	Class of emission		
2.	Modulation parameters	QPSK 16-QAM 64-QAM	QPSK 16-QAM 64-QAM
3.	Duplex mode	FDD/TDD	
4.	Spectral mask of signals, including	-[4]	-[5]
4.1	−3 dB radiation bandwidth	-	-
4.2	−30 dB radiation bandwidth	-	-
4.3	−60 dB radiation bandwidth	-	-
	ACLR (adjacent channel leakage ratio)		
5.	Maximum spectral power density, dB(mW/Hz)	−23	−42.5
6.	Signal bandwidth (MHz)	1.25 MHz, 1.4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz, 20 MHz,	
7.	Transmitter e.i.r.p. (dBm)		
	Maximum transmitter e.i.r.p. (dBm)	55[6]	21 to 23
	Average transmitter e.i.r.p. (dBm)	Deployment dependant	2 (rural) −9 (urban)
8.	Typical height of the transmitting antenna (m)	20 to 30	1.5
9.	Transmitting antenna type (sectorized/omnidirectional)	3 sectors	Omni
10.	Transmitting antenna gain, dBi	15	0
11.	Feeder loss (dB)	3	0
12.	Antenna pattern model	ITU-R F.1336-2[7]	Omni
12.1	– aperture in the horizontal plane at 3 dB (in deg.)	65	NA
12.2	– aperture in the vertical plane at 3 dB (in deg.)	15[8]	NA
12.3	– antenna downtilt	3°	NA
13.	Relative level of side lobes	–20 dB	NA
14.	Power control range (dB)	20	60
15.	Interference criterion I/N in dB	–6	

[4] See 3GPP Document: TS 36 104 v 8.5.0, see section 6.6.3 and TS 36 141 v 8.5.0, see section 6.5.2.1.

[5] See 3GPP Document: TS 36 101 v 8.4.0, see Table 6.6.2.1.1-1 (General E-UTRA spectrum emission mask) and TS 36 521-1 v 8.0.0, see section 6.6.

[6] In particular remote rural areas such as some parts of Russia, the e.i.r.p. value may be higher.

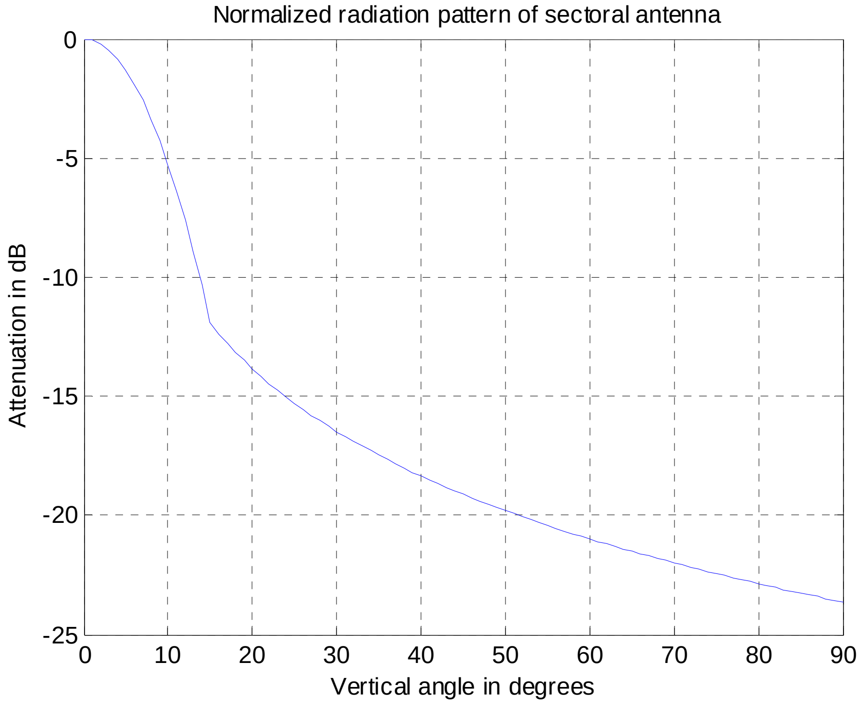
[7] Although this ITU-R Recommendation applies to frequency bands above 1 GHz, it is considered that sectorial antennas operating in the 800 MHz band that employ technology comparable to that used in bands on the order of 1 GHz to 3 GHz should exhibit similar off-axis performance.

[8] This value is derived from Recommendation ITU-R F.1336-2 (recommends 3.3) using an antenna gain of 15 dBi and an horizontal aperture of 65°.

The vertical antenna pattern given in Recommendation ITU-R F.1336-2 shown below was used in this analysis.

FIGURE 2.2.1-1

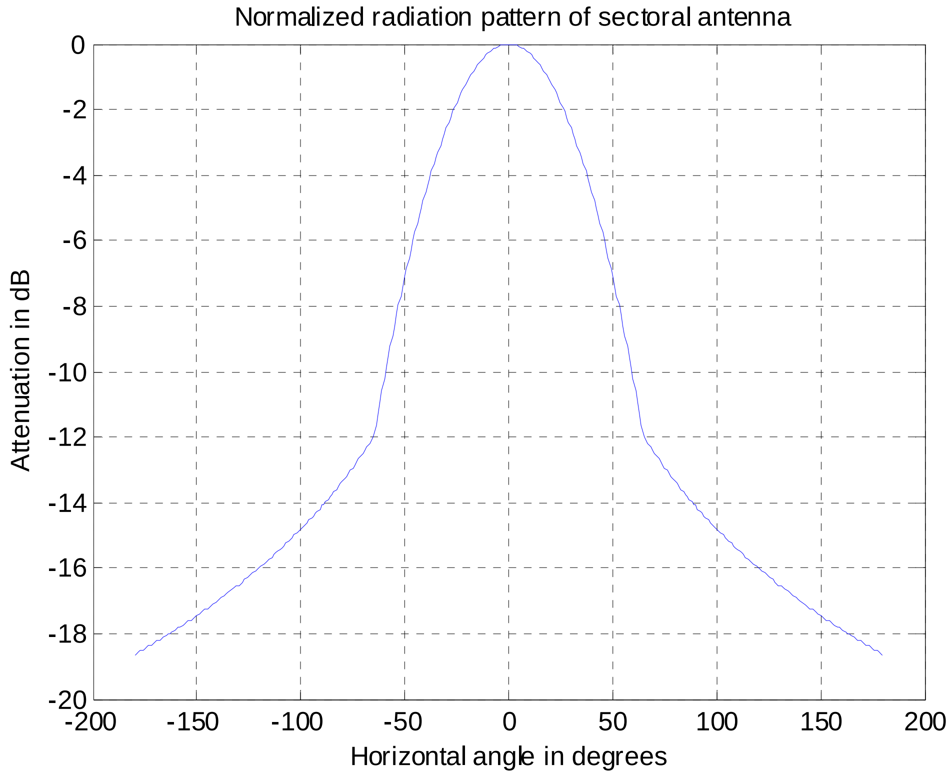
IMT base station vertical antenna pattern



The following figure shows the WiMAX BTS horizontal antenna pattern.

FIGURE 2.2.1-2

WiMAX TDD BTS horizontal antenna pattern



2.2.2 Additional parameters

The following table shows the system parameters of IMT TDD system (WiMAX TDD[9]) which are used in the studies between broadcasting and WiMAX TDD and between PPDR/LMR and WiMAX TDD (see sections 5.1 and 6.2).

[9] Within this document the term WiMAX TDD is synonymous with TDD component of IMT-2000 OFDMA TDD WMAN.

TABLE 2.2.2

Additional IMT parameters

Parameters		WiMAX		Reference
		BTS	MS	
Channel bandwidth		5 MHz, 10 MHz		
System bandwidth (MHz)		4.75, 9.5	4.75, 9.5	
ACLR	Adjacent	45 dB	30 dB	Note for WiMAX TDD[10]
	Non Adjacent	n/a	n/a	
ACS (adjacent channel selectivity)	Adjacent	46 dB	33 dB	Note for WiMAX TDD[11]
	Non Adjacent	n/a	n/a	

The following table shows the IMT system parameters which are used in the interference studies between UE and UE in hotspot scenarios (see sections 3.1 and 4.1). From now on the term “hotspot scenario” will refer to the UE to UE interference studies.

Hotspot radius(m)	25/50[12][13]
Number of interferers in Hotspot, M	2/4
Propagation model	UE-UE：IEEE 802.11 model C[14]

2.2.3 Guidelines to interpret certain mobile parameters

For the compatibility studies in the UHF band the following issues should be considered and used as examples of how to interpret and clarify certain IMT parameters

The inherent element of modern IMT systems is the radio resource management techniques providing flexibility and adaptation for different propagation environments, deployment scenarios and traffic patterns. These techniques define IMT systems performance in the presence of external interference as well as the levels of interference generated by IMT systems to other systems.

10 For WiMAX technology these figures represent typical in-band specifications. For the purposes of the adjacent spectrum block study in section 3.2.1, the consideration of more stringent band edge performance may be appropriate.

11 For WiMAX technology these figures represent typical in-band specifications. For the purposes of the adjacent spectrum block study in section 3.2.1, the consideration of more stringent band edge performance may be appropriate.

12 Comment to AWF UHF Correspondence Group by ETRI KT--comments

13 ECC Report 131, Derivation of a block edge mask (BEM) for terminal stations in the 2.6 GHz frequency band (2 500-2 690 MHz), Dublin, January, 2009

14 NOTE: IEEE 802.11 Model C mode, $L(d) = \begin{cases} L_{FS}(d) & dB \quad d < d_{BP} \\ L_{FS}(d_{BP}) + 35 \log \dfrac{d}{d_{BP}} & dB \quad d \geq d_{BP} \end{cases}$, where L_{FS} is the free space loss, d_{BP} = 0.005 km and d is the UE-UE separation in kilometers. For a UE-UE separation smaller than 5 m, 3 dB of lognormal shadow fading is added, while 4 dB of lognormal shadow fading is added if it is larger than 5 m.

The complexity of these techniques requires system level simulation to be performed using Monte-Carlo methods or even dynamic methods. This section highlights common elements for such studies and it should be noted that techniques described below are interrelated and should be used simultaneously to produce realistic behaviour of IMT system.

2.2.3.1 Power control mechanism for IMT mobile terminals

IMT mobile terminals are using a power control mechanism. This means that the terminals are not emitting at maximum power all the time. In the Monte-Carlo simulation this effect should be modelled explicitly. Power control mechanism varies between IMT standards. Besides that power control is closely interrelated with traffic model and resource allocations scheme. However for the compatibility studies purpose a simplified model of power control is used. For example, LTE system is usually modelled with open loop power control mechanism based only on path loss. In more detailed studies a closed loop power control mechanism could be modelled taking into account scheduler implementation and traffic models which could lead to even smaller values of average transmitting power for IMT terminals.

2.2.3.2 Traffic model for the IMT base stations

For the Monte-Carlo simulations studies usually a full buffered traffic model is assumed, meaning that base stations is always transmitting using all allocated resources. This is usually used to assess the impact of external interference on the maximum potential throughput or to represent the worst case interference scenario in the populated areas.

However in the real networks this is not the case because transmitting 100% time in 100% of frequency resources (in the case of OFDMA) means saturation of the cell and service failure for many of the users. Thus base stations are transmitting only using part of available resources most of the time. For OFDMA systems this translates to transmitting only using part of subcarriers which is equal to part of the maximum power.

Based on throughput results obtained from measurements to date traffic load and corresponding emitted power are usually lower than 50%. This could be used, for example, in cases when interference is aggregated from base station in rural areas where network is deployed to provide coverage rather than capacity. In this report only maximum capacity case is considered.

2.2.3.3 Traffic model for the IMT terminals

For the purpose of compatibility studies full buffered traffic is assumed meaning that users are always ready to transmit when resource is granted by base stations. In Monte-Carlo simulations this translates into constant presence of users transmitting in the uplink direction with the power adjusted by power control algorithm. Such model is used throughout most of the studies related to compatibility of IMT systems within ITU-R.

In the real networks traffic load is not constant and varies significantly during the day and between environments (urban, suburban and rural). For example in the case of traffic model when 2 Mbytes packets from single user are arriving with period of 180 seconds depending on the uplink date rate this would lead to emptying the buffer and inactivity of the user for most of the time. Or from the interference perspective this will lead to significant decrease of interference power up to 10-20 dB when averaged among all users of the network. For other traffic models such as video surveillance and video upload the reduction in average interference will be much smaller, but still below the levels corresponding to full buffered traffic model.

Hence full buffered traffic model might be used for single cell or worst case compatibility studies where the typical traffic models are not known. For statistical (Monte-Carlo) compatibility studies suitable traffic models, taking into account the transmitting activity of stations, would better reflect the situation. An example of that is given in section 2.2.3.7.

2.2.3.4 Scheduling and the number of active users in the downlink

For a full buffered packet traffic model the users in IMT systems are usually multiplex in time domain. In the case of OFDMA systems instead of transmitting in parallel to several users using different frequency blocks the scheduler in the downlink tries to grant all the resources to only one user but for a shorter time. This provides opportunity to minimize control channels traffic to grant resource to more than one user.

This is specifically true for a full buffered traffic model where each user has a traffic to occupy the whole band. For other types of traffic models there could be deviation from the described algorithm.

Thus for the coexistence studies in the downlink only one user is modelled to be active in the cell in the single snapshot.

2.2.3.5 Scheduling and the number of active users in the downlink

For the uplink the scheduler model is mostly the same and is in an effort to grant all resources for one user. However the user equipment is power limited and being located at the edge of cell or in a deep fade conditions it could be impossible to reach base station transmitting using all spectrum resources. In this case user equipment concentrates available transmitter power into a small portion of the channel band to boost uplink link budget. In this case scheduler is able to grant remaining resources to other users in the same time period.

The actual number of transmitting users is highly dependent on the scheduler implementation, traffic model and mobile terminals positions with the cell. For the compatibility studies and a full buffered traffic model usually a simplified algorithm is used when constant number of users is considered to be transmitting simultaneously within one cell. The number of active users is usually in the range 1-5. In a more elaborated studies the number of users could vary based on aforementioned parameters and scheduler implementation.

2.2.3.6 Indoor outdoor usage of IMT mobile terminals

Power control algorithm behaviour and scheduling decisions are in general dependent on the propagation model as well as on indoor and outdoor usage of IMT mobile terminals related to penetration losses.

Typically more than 50% of the connections in a mobile network are made from indoor locations today and it is assumed that the figure for mobile broadband connections will be more than 70%. For these terminals there will be an additional attenuation in the order of 10-20 dB due to the wall penetration attenuation.

For the compatibility studies it is assumed that at least 50% of the IMT mobile terminals are used indoor. For these terminals an additional attenuation of at least 10 dB should be added due to the wall attenuation.

2.2.3.7 Example on how to take a specific activity factor and output power for IMT mobile terminals into account

IMT mobile terminals are using a power control mechanism. This means that the terminals are not emitting at maximum power all the time. Additionally the user terminal is only transmitting when uploading information meaning that the transmitter is in non-transmit mode most of the time.

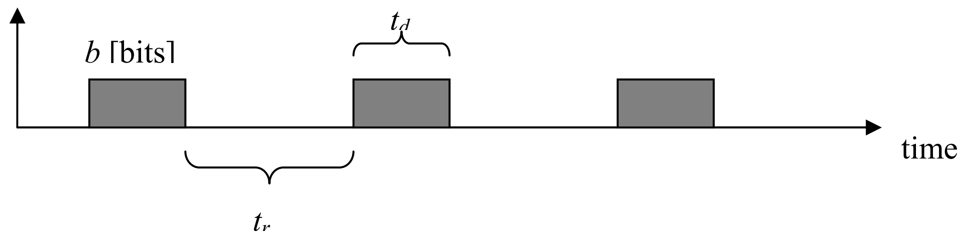
If the aggregated power from IMT mobile terminals should be used for a statistical sharing study it is important to define representative averages and distributions of the output power as well as the activity factor for the user terminals.

Below it is showed how the activity factor for a user terminal at different throughputs could be taken into account when a specific traffic model assumed.

In order to illustrate how the uplink activity factor is linked to the average uplink throughputs and average transmit powers, and thus the technology used, a traffic model from NGMN is used as a starting point. In particular, a FTP model[15] is used, as illustrated in Figure 2.2.3.7.

FIGURE 2.2.3.7

NGMN FTP model



Here packets are arriving at a certain rate and the time between packets, the reading time, is t_r and the time to download a packet is t_d. Each packet is of size b bits. Although these quantities are in general stochastic variables, only their averages are used here in order to simplify the derivation of activity factors and average transmit powers. These means are

$t_r = 180$ s;

$b = 2$ Mbyte = 16.8 Mbit.

Note that for the uplink, 2 Mbytes every three minutes represents a quite heavy load for a user. In addition, the following variables are defined:

- P average power when transmitting (depends on deployment scenario);
- P_a average power over time for an active user (depends on traffic model and P);
- T average throughput when using transmit power P;
- A activity factor (fraction of time transmitting for active user).

The activity factor and average transmit power over time then become

$$A = \frac{t_d}{t_d + t_r} = \frac{b/T}{b/T + t_r} = \frac{1}{1 + t_r \cdot \frac{T}{b}}$$

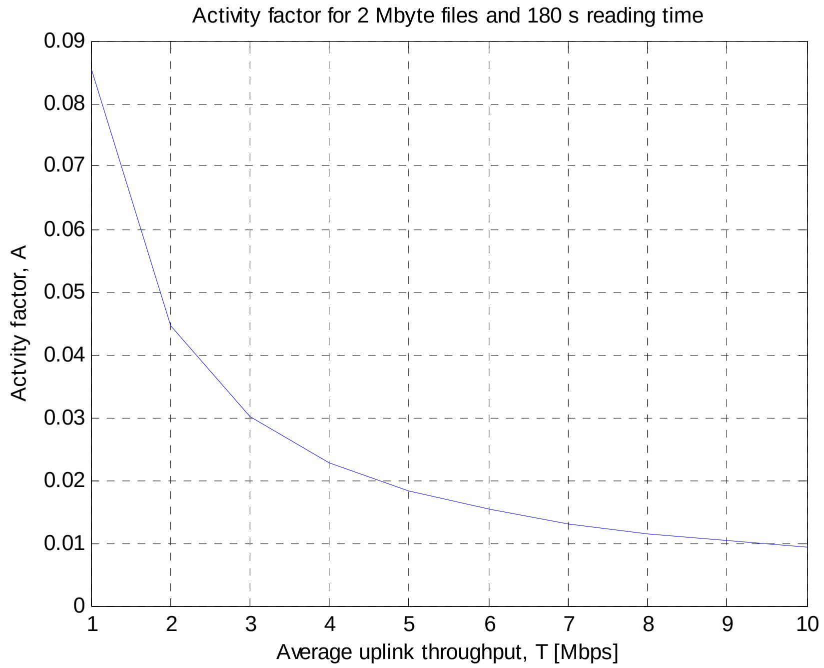
$$P_a = A \cdot P$$

The average power when transmitting, P, and the average throughput, T, can be obtained by measurements in a live network. Figure 1 gives results for the simple calculations for the activity factor for some different average throughputs.

[15] "A White Paper by the NGMN Alliance -- NGMN Radio Access Performance Evaluation Methodology," available at: http://www.ngmn.org/uploads/media/NGMN_Radio_Access_Performance_Evaluation_Methodology.pdf

FIGURE 1

Activity factors for 2 MByte files and 180 s reading time



In order to obtain parameters to be used in a statistical coexistence study, a point on the x-axis is chosen and the corresponding activity factor is then found on the y-axis.

Below is an example on how a specific traffic model and output power can be taken into account to calculate the average power of the user terminals.

If it is assumed that in a LTE network measures an average throughput of 5 Mbps and an average transmit power, P, of 15 dBm is used

– an activity factor of 0.02, corresponding approximately to 4-5 Mbps of uplink throughput;

– an average (over the cell) power when transmitting of P = 15 dBm;

– an average power to be used for each active user, based on the figures above, would then be defined as $P_a = 15 + 10\log_{10}(0.02) = -2$ dBm.

The average transmit power over time for this example then becomes –2 dBm.

2.3 Other mobile systems parameters

2.3.1 Generic parameters of PPDR/LMR

PPDR(public protection and disaster relief) /LMR (land mobile radio)characteristics are mainly extracted from Recommendation ITU-R M.1808. The table below shows the system characteristics which are used in the study between WiMAX TDD and PPDR/LMR. It is noted that a few parameters in this table are taken from existing services in some Asian countries.

TABLE 2.3.1

PPDR/LMR systems characteristics

Base station		**Comments**
Frequency band (MHz)	806-869	
Type of duplex	FDD	
Uplink frequency band	806-824 MHz	
Downlink frequency band	851-869 MHz	
Typical output power (W)	100	Extracted from Rec. ITU-R M.1808. value is needed to calculate the MCL in the scenarios described in section 3.2.1
e.r.p. (dBW)	24	Extracted from Rec. ITU-R M.1808. 10 log (100) + 9 - 5
Channel bandwidth (kHz)	12.5 and 25[16]	
Noise figure (dB)	6	
Antenna gain (dBi)	11	
Antenna height (m)	37.5	
Antenna pattern	Omnidirectional	Assuming Rec. ITU-R F.1336-2
Antenna polarization	Vertical	
Antenna loss (dB)	5	
Mobile station		**Comments**
Output power (W)	Handheld: 5; Vehicular: 30	
e.r.p. (dBW)	Handheld: 5; Vehicular: 14	
Necessary bandwidth (kHz)	11 and 16	
Antenna gain (dBd)	Handheld: –2; Vehicular: 0	
Antenna height (m)	2	
Antenna pattern	Omnidirectional	
Antenna polarization	Vertical	
Antenna loss (dB)	Handheld: 0; Vehicular: 1	
Adjacent channel leakage power	–60 dBc / 8 kHz at 25 kHz from assigned frequency	
Spurious emission		See Rec. ITU-R SM.329
Out of band emission	43 + 10 log(output power) or 70 dBc, less stringent (for spurious emission)	

[16] Channel bandwidth of 16 kHz may apply to analogue systems.

2.3.2 Technology specific parameters of PPDR/LMR

TABLE 2.3.2-1

Typical receiver values of PPDR existing mobile system parameters

	PPDR Technology	
	DIMRS	**Project 25**
Centre frequency 790-862 (MHz)	826	826
Noise figure F (dB)	5	6
Antenna gain G_i (dBi)	15	11
Feeder loss L_F (dB)	3	5
Manmade noise P_o (dB)	0	0

TABLE 2.3.2-2

Transmission and propagation **characteristics of PPDR BTS (see section 5.2)**

	PPDR Technology	
	DIMRS	**Project 25**
Typical transmitter e.i.r.p. (dBm)	47 (per channel)	53 (per channel)
Channel bandwidth (MHz)	0.025/0.0125	
Number of channels per cell	10	10
Antenna gain (dBi)	15	11
Antenna radiation pattern, horizontal plane	three-sector; 65°	Omni
Total composite transmitter e.i.r.p. (dBm)	57	63
Antenna height (m)	20	37.5
Transmit ant. height above average terrain as per RRC-06 Final Acts, Ch 2 to Annex 2 (m)	20	37.5
Receive antenna height as per RRC-06 Final Acts, Ch 2 to Annex 2 (m)	20	37.5

It should be noted that there may be other PPDR/LMR technologies in the band concerned.

2.4 Parameters for broadcasting systems

The list of system characteristics provided below has been based on work carried out under Resolution 749 (WRC-07), the GE06 Agreement, ITU-R Recommendations and Reports as appropriate.

In Regions 1 and 3 the following television systems are in use:

Digital systems:

- DVB-T[17]
- ISDB-T
- DTMB
- ATSC
- DVB-T2
- DVB-H

Analogue systems:

- PAL-G, I
- NTSC/M
- SECAM/D, K

2.4.1 Digital television systems

System parameter values for the ATSC, ISDB-T and DTMB digital television systems are contained in Appendices 1, 3, and 4 of Annex 1 to Recommendation ITU-R BT.1306 and have been reproduced in the following table.

[17] The list of digital systems used in individual countries/administrations can be found in the website of the DVB Project Office. See (http://www.dvb.org/about_dvb/dvb_worldwide/index.xml)

TABLE 2.4.1

Digital television system parameters

System parameter	ATSC	ISDB-T	DTMB
Transmission method	Single carrier	Multiple carrier – Segmented COFDM	Single- and multi-carrier combined systems
Used bandwidth (MHz)	5.38/6.00/7.00 (–3 dB)	Approximately[18] 5.57/6.5/7.4	5.67/6.62/7.56
Channel raster (lower edge of channel (MHz))	6 MHz channel raster	6 MHz channel raster: 470+(n-14)*6[19] 7 MHz and 8 MHz channel raster, see note 20	6/7/8 MHz channel raster
Modulation	8-VSB	DQPSK, QPSK, 16-QAM, 64-QAM	4QAM-NR, 4QAM, 16QAM, 32QAM,64QAM
Code rate	R =2/3 trellis concatenated R=1/2 or R=1/4 trellis	Convolutional code, mother rate 1/2 with 64 states. Puncturing to rate 2/3, 3/4, 5/6, 7/8	0.4(7488, 3008), 0.6(7488, 4512), 0.8(7488, 6016)
Guard interval	n/a	1/4, 1/8, 1/16, 1/32	1/9, 1/6, 1/4
Carrier-to-noise ratio in an AWGN channel	Depending on channel code, 15.19 dB, 9.2 dB, 6.2 dB[(1), (2)]	Depending on modulation and channel code 5.0-23 dB[(4)]	Depending on modulation and channel code. 2.5-22.0 d B

(1) Measured value. After RS decoding, error rate 3×10^{-6}

(2) The *C*/*N* ratios are 9.2 dB for 1/2 rate concatenated trellis coding and 6.2 dB for 1/4 rate concatenated trellis coding.

(3) Simulated with perfect channel estimation, non-hierarchical modes. Error rate before RS decoding 2×10^{-4}, error rate after RS decoding 1×10^{-11}

(4) Measured with prototype receivers. Error rate before RS decoding 2 × 10–4, error rate after RS decoding 1 × 10–^{11}

18 Varies according to Mode, more details are given in Recommendation ITU-R BT.1306.

19 In Japan, "470 + (n-13)*6" is used.

20 The parameters of channel raster depend on the planning of each administration.

2.4.2 Analogue television systems

Characteristics of radiated signals of conventional analogue television systems are contained in Recommendation ITU-R BT.1701.

2.4.3 Broadcasting network characteristics (for both analogue and digital)

The main network characteristics are given in Table 2.4.3-1 with ranges for their values:

TABLE 2.4.3-1

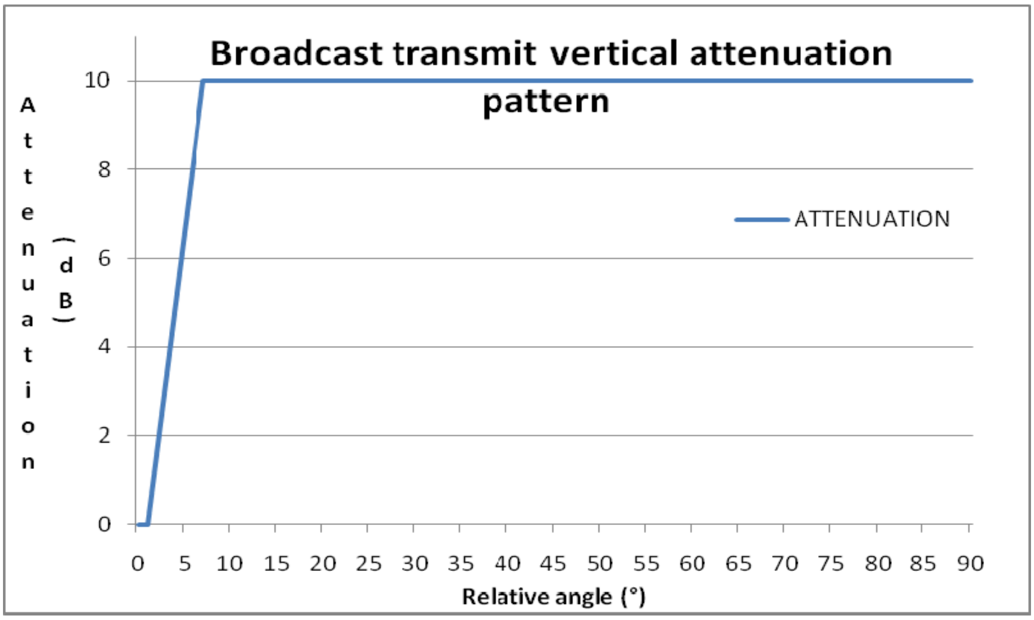
Range of Network characteristics						
	GE06 Digital	**GE06 Analogue**	**Region 2 Digital**	**Region 2 Analogue**	**Region 3 Digital**	**Region 3 Analogue**
Transmitter e.r.p.: (dBW)[21]	From –17 to 53	From –16 to 61	From 47 to 60	From –10 to 67	From –10.9 to 57	From –12.2 to 65.0
Height above ground level (m)[22]	From 2 to 360	From 2 to 320	From 10 to 453	From 12 to 224	From 1 to 481	From 0 to 270
Site altitude (m)	From –999 to 4 507	From –180 to 4 507	From 2 to 451	From –600 to 4 054	From 0 to 2 091	From 0 to 2 036
effective antenna height (m)	From –500 to 2 999	From – 1 207 to 2 200	From 40 to 472	From 0 to 2 168	From –958 to 1 755	From 0 to 1 800
Vertical antenna pattern	See Figure 2.4.3-1					
Polarization	horizontal or vertical or mixed,	horizontal or vertical or mixed	horizontal	horizontal or vertical or mixed	horizontal or vertical or mixed	horizontal or vertical
Downtilt angle (deg.)	From 0 to –1	From 0 to –1	-	-	-	-

[21] Note: within any Region, the maximum transmitter power will be limited by the choice of transmission options for the specific broadcast system in operation.

[22] For high power broadcast transmitters, depending on the associated site altitude and location, there may be legal as well as physical limitations to the minimum antenna height (see ITU-R Recommendation BS.1698).

FIGURE 2.4.3-1

Broadcasting Tx antenna vertical pattern



Broadcast transmitter antenna vertical pattern is given in Figure 2.4.3-1 with reference angle for broadcast transmission is 0°.

TABLE 2.4.3-3

Spectrum mask of DTMB – non-critical case

Relative frequency (DTMB) (MHz)	DTMB Non critical case (dB/8 MHz)
–12	–100
–10.75	–76.9
–9.75	–76.9
–5.75	–74.2
–4.94	–69.9
–3.9	–32.8
+3.9	–32.8
+4.25	–64.9
+5.25	–76.9
+6.25	–76.9
+10.25	–76.9
+12	–100

TABLE 2.4.3-4

Spectrum mask of DTMB – critical case

Relative frequency (DTMB) (MHz)	DTMB critical case (dB/8 MHz)
–12	–120
–6	–95
–4.2	–83
–3.8	–32.8
+3.8	–32.8
+4.2	–83
+6	–95
+12	–120

2.5 Parameters for aeronautical radionavigation systems

The table below contains characteristics of ARNS systems which operate or could operate in the 790-862 MHz frequency band. They are extracted from Recommendation ITU-R M.1830.

TABLE 2.5-1

Technical characteristics of ARNS systems operating in the 790-862 MHz frequency band

Type of station / Characteristics	RSBN	RLS 2 (Type 1)		RLS 2 (Type 2)		RLS 1 (Type 1)	RLS 1 (Type 2)
Application	"Air-to-Ground"	Secondary radars – Type 1 (air traffic control)		Secondary radars – Type 2		Primary radars – Type 1	Primary radars – Type 2
Transmitter characteristics							
Station name	Aircraft transmitter	Ground radar transmitter	Aircraft transponder transmitter	Ground radar transmitter	Aircraft transponder transmitter	Ground radar transmitter	Ground radar transmitter
Maximum effective radiated pulse power (e.r.p.), dBW	30.5	48	35	69.5	34.5	82	82
Pulse power, dBW	27	31	32	40	31	52.5	52.5
Mean power, dBW	0.5	1	14	19.5	10.5	19.5	19.5
Off-duty ratio	447	1 000	63.1	112	112	1 995	1 995
Pulse repetition cycle, ms	2.3	1.3	0.6	1.8	1.8	1.8	1.8
Pulse length, μs	5.1	1.3	8.7	16	16	0.9-2	0.9-2
Necessary emission bandwidth, MHz	3/0.7	4	4	3	8	6	3
Class of emission	P0X/PXX	K0X	K0X	M1X	M1X	P0N	P0N
Operating frequencies (MHz)	772, 776, 780, 784, 788, 792, 796, 800, 804, 808	668	668	835, 836, 837.5	740	833, 835, 836, 858	844, 847, 853, 859
Antenna height, m	0 to 10 000	10	0 to 10 000	10	0 to 10 000	10	10
Maximum antenna gain	3.5	17	3	29.5	3.5	29.5	29.5
Antenna pattern	ND	3 dB beamwidth: vert. pl. = 28° hor. pl. = 4°	ND	3 dB beamwidth: vert. pl. = 45° hor. pl. = 3-5°	ND	3 dB beamwidth: vert. pl. = 45° hor. pl. = 4°	3 dB beamwidth: vert. pl. = 45° hor. pl. = 4°
Direction of the antenna main beam	Lower hemisphere	Azimuth: 0-360° Scan rate: 6 min1	Lower hemisphere	Azimuth: 0-360° Scan rate: 10 min-1	Lower hemisphere	Azimuth: 0-360° Scan rate: 6/10 min-1	Azimuth: 0-360° Scan rate: 6/10 min-1

TABLE 2.5-1 (*end*)

Receiver characteristics							
Station name	Ground radar receiver	Aircraft responder of ground radar	Ground radar receiver	Aircraft responder of ground radar	Ground radar receiver	Ground radar receiver	Ground radar receiver
Antenna height, m	10	10 000	10	10 000	10	10	10
Polarization	Linear, horizontal	Linear, vertical	Linear, vertical	Linear, horizontal	Linear, horizontal	Linear, horizontal	Linear, horizontal
Maximum antenna gain	22	3	17	3	28.4	29.5	29.5
Antenna pattern	3 dB beamwidth: vert. pl. = 50° hor. pl. = 4-5°	ND	3 dB beamwidth: vert. pl. = 28° hor. pl. = 4°	ND	3 dB beamwidth: vert. pl. = 45° hor. pl. = 3-5°	3 dB beamwidth: vert. pl. = 45° hor. pl. = 3-5°	3 dB beamwidth: vert. pl. = 45° hor. pl. = 3-5°
Direction of antenna main beam	Azimuth: 0-360° Scan rate: 100 min^{-1}	Lower hemisphere	Azimuth: 0-360° Scan rate: 6 min^{-1}	Lower hemisphere	Azimuth: 0-360° Scan rate: 10 min^{-1}	Azimuth: 0-360° Scan rate: 6/10 min^{-1}	Azimuth: 0-360° Scan rate: 6/10 min^{-1}
Permissible aggregate co-channel interference field strength provided for the necessary emission bandwidth (from all services), ***E***, dB(μV/m)	42	52/59[1]	29/33[1]	73	24/28[1]	13	13

[1] Two values are given for use in the sharing studies and these values need to be refined following detailed reviews of the results of the studies and should not contradict the GE06 Agreement.

[2] In the case when the interferer has orthogonal polarization in relation to the wanted signal, a polarization discrimination factor of 16 dB should be taken into account when calculating interference. However, it has to be noted that this value is applicable for fixed stations operating in the ARNS and in the mobile service as a mitigation technique during bilateral coordination process.

3 Methodologies and propagation models used to assess compatibility

With respect to interference calculations in the bands 790-862 MHz and 698-806 MHz between IMT systems, on the one hand, and other mobile systems, broadcasting services or fixed services, on the other hand, the use of the prediction methods in Recommendations ITU-R P.1546 and/or ITU-R P.1812 is advised. Recommendation ITU-R P.1546 is a site-general method while Recommendation ITU-R P.1812 is a site-specific method using terrain data.

Concerning the propagation models appropriate for co-existence studies between IMT systems and airborne ARNS stations, the free space propagation model will yield a conservative estimate of (i.e., a lower limit to) the basic transmission loss between the mobile service station and an aircraft. If no further information is available about the path between the mobile service station and an aircraft, the free space model should be used to avoid the possibility of interference. However, it is recognized that the propagation clutter may have a strong influence on the path between airborne and IMT mobile stations, particularly in an urban environment. This would have the consequence of additional propagation loss above free space due to, for example, diffraction over obstacles and/or vegetation.

However, noting involved scenario (i.e., mobile terminals operating at 1.5 m height, the airborne stations operating at altitudes up to 10 000 m, and the distance between two services of up to hundreds of kilometers) it needs to be observed that these additional propagation losses would represent, even in a worst case (i.e., for very deeply obstructed paths), an additional loss of 20 dB (a factor of 0.1 in field strength).

For example, single knife-edge diffraction losses relative to free space rarely exceed 20 dB. Multiple knife-edge diffraction losses, though being more complicated (as measured in dB), are not additive in the number of edges: with grazing incidence on *N* equally separated edges, the additional attenuation factor is $(N+1)^{-1}$. Smooth earth diffraction losses are larger than the knife-edge diffraction losses, but these typically require scenarios in which the mobile service stations are located beyond the combined smooth earth horizon distances, which are quite large for aircraft at operational altitude ceilings.

3.1 Scenarios, methodology and propagation models for compatibility studies between different IMT systems

3.1.1 Scenarios, methodology and propagation models for compatibility studies between LTE TDD and LTE FDD

3.1.1.1 Relevant interference scenarios

This section studies the interference between LTE FDD and TDD systems in the upper UHF band.

In general, the interference scenarios between LTE FDD and LTE TDD include:

– Base station to UE interference (BTS-UE) (Case 1).

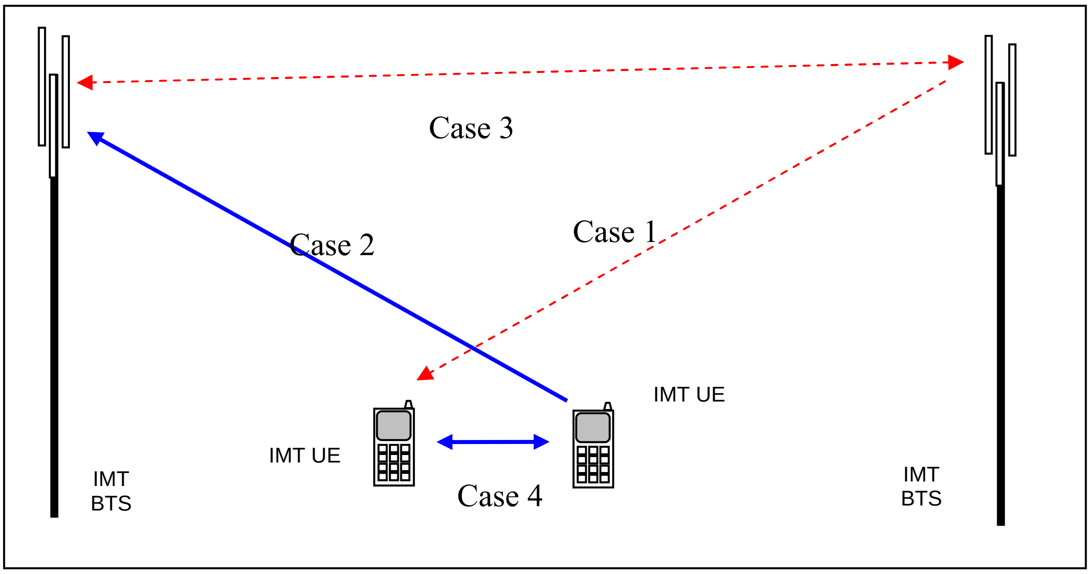
– UE to base station interference (UE-BTS) (Case 2).

– Base station to base station interference (BTS-BTS) (Case 3).

– UE to UE interference (UE-UE) (Case 4).

FIGURE 3.1.1.1

Interference scenarios



Deterministic analysis can be used for the interference analysis of Case 3 and Case 4. The Monte-Carlo static simulation is needed for Case 1, Case 2 and Case 4.

3.1.1.2 The MCL between LTE FDD and LTE TDD for compatibility studies

a) The definition and calculation of MCL

Minimum Coupling Loss (MCL) is defined as the minimum distance loss including antenna gain measured between antenna connectors. It is calculated by the expression:

$$MCL = Pathloss - G\_Tx - G\_RX,$$

where

– Pathloss is the path loss between antenna ports;

– G_Tx is the Tx antenna gain;

– G_RX is the Rx antenna gain.

It shows MCL is related to transmit path loss (including antenna ports space, frequency, propagation model) antenna gain and reduction in effective antenna gain due to antenna tilt, antenna misalignment and feeder loss.

b) The MCL assumptions in 3GPP and ITU-R Report

– BS-BS co-site:

In 3GPP TR 25.942, a MCL of 30 dB is considered as the co-sited scenario for Macro BS to Macro BS interference in Section 10.1, some suggestions are described in this section: "The coupling losses between two co-sited base stations are depending on e.g. the deployment scenario and BS antenna gain values. Different deployment scenarios gives rise to a large variation in coupling loss values. However, in order not to have different requirements for different deployment scenarios, it is fruitful to use one value of the minimum coupling loss (MCL) representing all deployment scenarios".

From the last description, 3GPP already notices that different deployment scenarios will produce different MCL requirements; however, 3GPP finally recommends using harmonized MCL values representing all deployment scenarios.

In Report ITU-R M.2030, a MCL of 30 dB is considered as the co-sited scenario for BS to BS interference, while the frequency is 2.6 GHz.

– BS-BS co-area

In 3GPP TR 25.942, MCL of 67 dB is considered as the reference scenario for Macro BS to Macro BS interference for operation in the same geographic area in Sections 10.2.1 and 7.4.1.2.1.3 which is TDD/TDD scenario. MCL of 67 dB is based on that antennas of BSs are Omni-directional, ISD (inter-site distance) is 1 000 meters, distance between BSs of different operators is 288 m Line-of-sight, Tx and Rx antenna gains are 13 dBi, reduction in effective antenna gain due to antenna tilt is 6 dB, frequency is 2 GHz.

Many scenarios of simulation are included in coexistence studies between different systems e.g. TDD/TDD, FDD/FDD, FDD/TDD and UTRA FDD/other radio technologies (see Table 3.1.1.2-1).

TABLE 3.1.1.2-1

Part of macro simulation scenarios in 3GPP TR 25.942

Interfering system	Interfered with system	Simulation frequency	Macro Cell Range	ISD	Antenna Type
UTRA FDD	UTRA FDD	2 000 MHz	667 m	1 000 m	omni
UTRA FDD	UTRA TDD	2 000 MHz	500 m 2 000 m	750 m 3 000 m	omni
UTRA TDD	UTRA TDD	2 000 MHz	667 m	1 000 m	omni
UTRA FDD	GSM/GPRS IS-136 IS-95/1X	850 MHz	1 067 m 2 134 m	1 600 m 3 200 m	sector

It shows that there are several topologies in 2 000 MHz and 850 MHz band. Even in 2 000 MHz band, topology of UTRA FDD and TDD is different from the other two simulation scenarios. However, there is only one MCL value of Macro BS-BS interference for operation in the same geographic area in 3GPP TR 25.942.

Following Table 3.1.1.2-2 is summary of simulation scenarios in 3GPP TR 36.942.

TABLE 3.1.1.2-2

Summary of simulation scenarios in 3GPP TR 36.942

Interfering system	**Interfered with system**	**Simulation frequency**	**Environ ment**	**Cell Range**	**ISD**	**Anten na Type**
10 MHz E-UTRA	10 MHz E-UTRA	2 000 MHz	Urban Area	500 m	750 m	sector
5 MHz E-UTRA	20 MHz E-UTRA	2 000 MHz	Urban Area	500 m	750 m	sector
5 MHz E-UTRA	UTRA	2 000 MHz	Urban Area	500 m	750 m	sector
1.25 MHz E-UTRA	GERAN	900 MHz	Rural Area	2 000 m	3 000 m	sector
20 MHz E-UTRA	UTRA	2 000 MHz	Urban Area	500 m	750 m	sector
1.6 MHz E-UTRA	UTRA 1.6MHz	2 000 MHz	Urban Area	500 m	750 m	sector

It shows that the topologies (considering the ISD and antenna type) in 36.942 are not the same as in 25.942. However, there is no Macro BS-BS MCL value calculated for operation in the same geographic area in 36.942.

– BS-to-UE and UE-to-BS

In 3GPP Recommendations it is homogeneously given a minimum value of 70 dB for macro urban environments, 80 dB for rural macro and 53 dB for micros, irrespective of frequency and systems (e.g, in 3GPP TR 25.816 V8.0.0 for 900 MHz, in 3GPP TR 25.942 for 2 GHz in Sections 5 and 7, and for 850 MHz in Section 7A)

– UE-UE

The acronym FSL is used to represent the term “free space loss”, and is evaluated with the formula

$$FSL = 20 \cdot \log_{10} (4\pi d/\lambda)$$

where d is the propagation distance and λ the radio wavelength.

The MCL value in the UE-to-UE case is calculated as the FSL at a distance of 1 m plus a minimum value for body loss (3GPP TR 25.942 Section 4.2.3, Table 4.2b). In the reference this minimum body loss at 850 MHz is given a value of 2 dB. Then

$$MCL = FSL\ (1\ m) + 2 = 32\ dB$$

b) MCL results

From the previous section the MCL values are reflected in Table 3.1.1.2-3.

TABLE 3.1.1.2-3

MCL Assumption

MCL(including antenna gain)	Assumption	Reference
BTS-BTS	Co-sited: 30 dB; Co-area：67 dB	3GPP 25.942
BTS-UE	70 dB	3GPP 36.942 urban scenarios
UE-UE	32 dB	3GPP 25.942

3.1.1.3 Calculation of ACLR, ACS and ACIR

According to 3GPP TS36.101, TS36.104, the ACLR is the ratio of the filtered mean power centered on the assigned channel frequency to the filtered mean power centered on an adjacent channel frequency. The ACS is the ratio of the receive filter attenuation on the assigned channel frequency to the receive filter attenuation on the adjacent channel(s).

ACLR/ACS is related to not only the bandwidths of the LTE FDD and TDD systems, 5 MHz in this study, but also to the guard-band between two systems. Table 3.1.1.3-1 gives some calculated results of ACLR and ACS under different guard-band situation, following 3GPP TS36.101, TS36.104. In the cases when the ACLR values are not explicitly stated in the mentioned Recommendations, they are calculated as the ratio of interferer maximum transmission power to maximum allowed spurious emissions integrated over the receiver bandwidth. And in the case of ACS values not being explicitly stated, they are calculated with the expression:

$$ACS(dB) \quad = \quad P_{\text{int}}(dBm) - KTBF(dBm) - 10 \cdot \log(10^{M/10} - 1)$$

where F is the receiver noise figure, P_{int} is the out of band blocking interferer level specified in the recommendations and M = 6 dB.

TABLE 3.1.1.3-1

ACLR, ACS of IMT system

Parameters	*ACLR（dB）*			*ACS（dB）*		
Guard-band(MHz)	***0***	***5***	***10***	***0***	***5***	***10***
IMT BTS	*45*	*45*	*62*	*45.7*	*54.7*	*54.7*
IMT UE	*30*	*36*	*42*	*33*	*37.8*	*49.8*

ACIR is defined as the ratio of the power of an adjacent-channel interferer as received at the interfered with receiver, divided by the interference power “experienced” by the interfered with receiver as a result of both transmitter and receiver imperfections. ACIR is a total index to evaluate the interference between two systems. ACIR can be calculated via the following formula:

$$ACIR^{-1} = ACLR^{-1} + ACS^{-1}$$

In Table 3.1.1.3-2 the calculated ACIR values are shown for different interference cases:

TABLE 3.1.1.3-2

ACIR for different interference cases

Parameters	*ACIR（dB）*		
Guard-band(MHz)	***0***	***5***	***10***
Case 1 BTS-UE	***32.7***	***37.0***	***49.6***
Case 2 UE-BTS	***29.9***	***35.9***	***41.8***
Case 3 BTS-BTS	***42.3***	***44.6***	***54.0***
Case 4 UE-UE	***28.2***	***33.8***	***41.3***

3.1.1.4 Propagation models

The following table provides the interference scenarios and the relevant path-loss models applicable for the Monte-Carlo simulation in this study.

TABLE 3.1.1.4

Interference scenarios and relevant path-loss models

Interference scenario	Propagation model	Comments
BTSTx→UERx	Modified Hata	Report ITU-R SM.2028
UETx→ BTSRx	Modified Hata	Report ITU-R SM.2028
UETx→UE Rx macro	H.Xiamodel	3GPP25.942
UETx→UE Rx hot spot	IEEE 802.11 model C	

3.1.1.5 Deterministic analysis

Deterministic analysis can be used to obtain the additional isolation requirement between interferer and interfered equipment, which reflects the worst interference situation.

$$I_{SO} = P_T - MCL - ACIR - I_{\max}$$

I_{SO} : Isolation requirement (dB);

P_T : Transmitter power in its operating band (dBm);

MCL : The minimum isolation including antenna gains measured between antenna ports;

$ACIR$: Adjacent channel interference ratio (dB);

$I_{\max}$: Maximum tolerable interference at the receiver (dBm).

Deterministic analysis can be used for the interference analysis of Case 3 and Case 4.

3.1.1.6 Monte-Carlo simulation

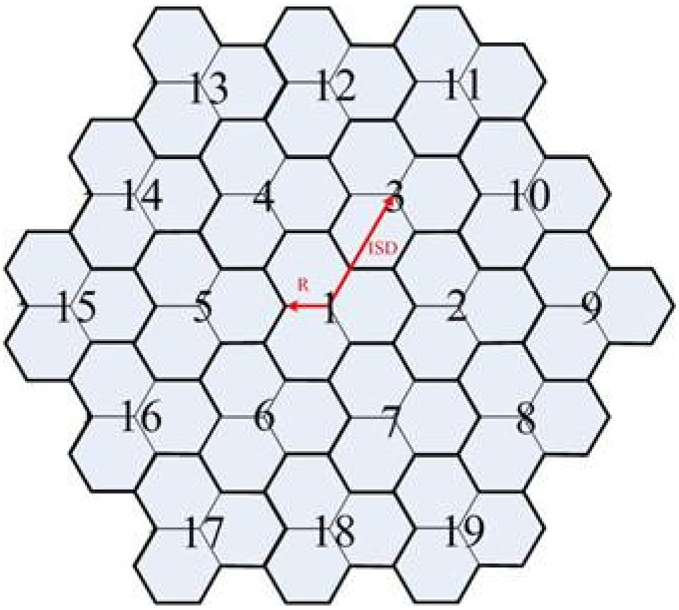
Simulation assumptions for co-existence simulations

1) Topology

It is assumed that both LTE systems are composed of 19 base stations (57 sectors), where the base stations are placed in the middle of 3 sectors. The topology of this scenario is shown in the Figure 3.1.1.6-1. The Wrap-around technique is used to remove the network deployment edge effect.

FIGURE 3.1.1.6-1

The topology of the LTE system

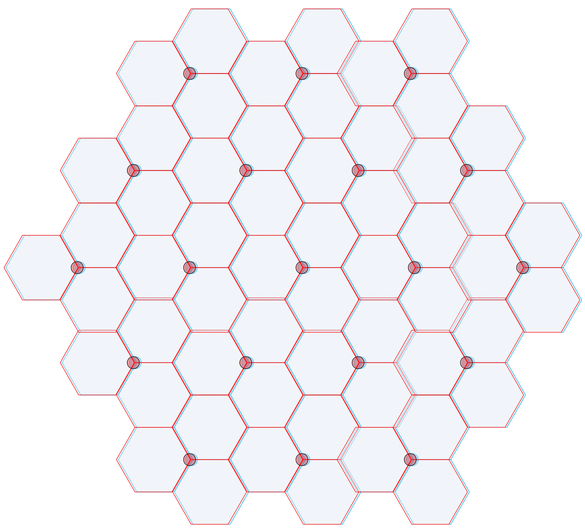


The cell layout of one LTE system is shifted over the other. Two base stations shifting of two operators are considered.

a) Co-sited, where the second system base stations are co-located in the same site of the first system

FIGURE 3.1.1.6-2

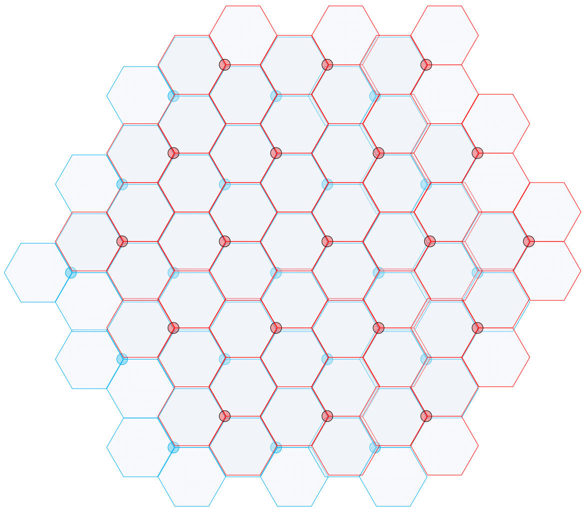
Co-sited scenario



b) Co-area, where the second system base stations are located at the cell border of the first system

FIGURE 3.1.1.6-3

Co-area scenario



2) Scheduler

For LTE FDD and TDD system, Round Robin scheduler is used.

3) Simulated services

When using round robin scheduler, Full buffer traffic service is simulated.

4) ACIR model

For downlink a common ACIR for all frequency resource blocks to calculate inter-system shall be used.

For uplink it is assumed that the ACIR is dominated by the UE ACLR. The ACLR model is referenced to 3GPP 36.942.

5) Power control

There is no power control in LTE system downlink. Fixed power per frequency resource block is assumed.

For LTE system uplink, the following power control equation which refers to 3GPP TR36.942 shall be used for the initial uplink compatibility simulations:

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

Where P_{max} is the maximum transmit power, R_{min} is the minimum power reduction ratio to prevent UEs with good channels to transmit at very low power level, PL is the path loss for the UE and $PL_{x\text{-}ile}$ is the x-percentile path loss (plus shadowing) value. With this power control equation, the x percent of UEs that have the highest pathloss will transmit at P_{max}. Finally, $0<\gamma<=1$ is the balancing factor for UEs with bad channel and UEs with good channel:

The parameter set 1 for power control specified in the Table 5.3 in 3GPP 36.942 is adopted in the simulation (γ=1, $PL_{x\text{-}ile}$ = 115).

6) Protection criterion of LTE system

5% throughput loss of LTE system is regarded as the criterion to judge if the LTE system works properly.

$$TP\_loss = 1 - \frac{TP_{ave-m}}{TP_{ave-s}}$$

where, $TP_{ave\text{-}s}$ is LTE single system average throughout, $TP_{ave\text{-}m}$ is average throughout with interference.

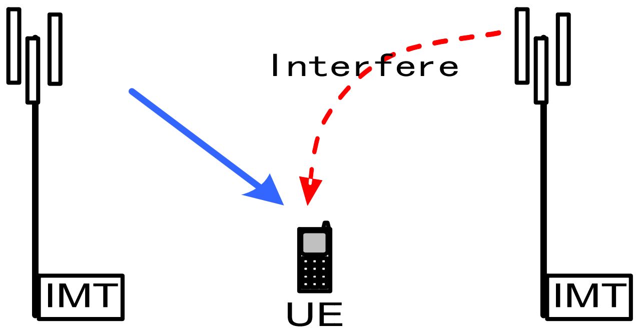
Simulation description

The detailed study content of each case is shown as follows.

Case 1 Downlink of one LTE system interferer downlink of the other LTE system

FIGURE 3.1.1.6-4

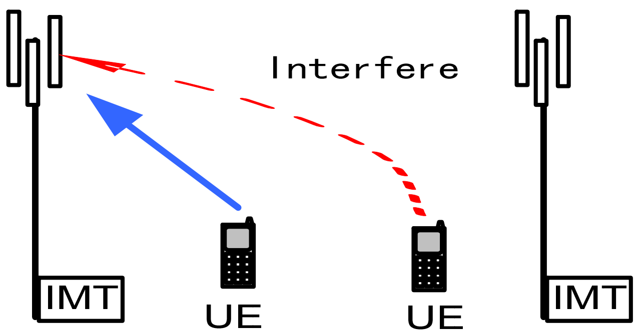
DL->DL scenario



Case 2 Uplink of one LTE system interferer uplink of the other LTE system

FIGURE 3.1.1.6-5

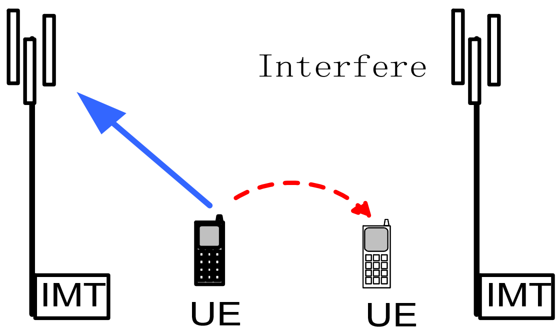
UL->UL scenario



Case 4 Uplink of one LTE system interferer downlink of the other LTE system

FIGURE 3.1.1.6-6

UL->DL scenario



The simulation description is shown as follows.

a) Downlink as interfered with

1) configure system deployment layout and initiate simulation parameter;

2) distribute terminals randomly and uniformly throughout the system area;

3) resource assigned to user randomly, calculate SINR of each user;

4) calculate throughout of user;

5) collect statistics.

b) Uplink as interfered with

1) configure system deployment layout and initiate simulation parameter;

2) distribute terminals randomly and uniformly throughout the system area;

3) select the scheduled UE, set UE transmit power according to the open loop power control algorithm;

4) calculate actual intra/inter system interference to get the actual C/(I+N) and bit rates for each UE;

5) collect statistics

3.1.1.7 Monte-Carlo simulation in hotspot scenario

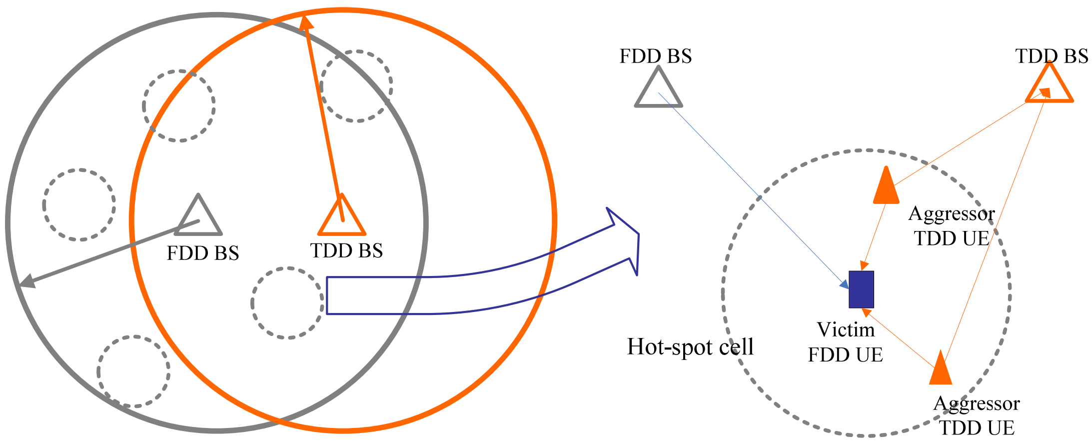
1) Topology

The topology of the LTE FDD and LTE TDD systems is the same than in section 3.1.1.6.1: it is assumed that both LTE systems are composed of 19 base stations (57 sectors), where the base stations are placed in the middle of 3 sectors.

Figure 3-8 depicts the topology of the hotspot interference scenario. The interference calculated is that of a TDD system on an FDD one, and the results are assumed to be valid for the FDD on TDD interference, since both systems share the same baseline system parameters. It is assumed that 2/4 TDD UEs are set within a 25/50 m radius hotspot and the FDD UE is placed in its centre.

FIGURE 3-8

Hotspot interference scenario topology



2) Simulation procedure

Step 1: Configure simulation system; place LTE FDD and LTE TDD BTSs according to the topology of simulation and initiate simulation.

Step 2: Place the interfered with FDD terminals randomly and uniformly within the FDD Macro-cell.

Step 3: Place M TDD terminal interferers at random (uniformly distributed) locations within a hotspot surrounding the FDD terminals.

Step 4: All terminals access to BTSs and resources assigned randomly.

Step 5: Calculate SINR of each interfered terminal:

a) calculate co-channel interference intra-FDD system;

b) calculate adjacent interference from aggressor TDD system;

c) calculate receiver system noise floor.

Step 6: Calculate SINR of each terminal.

Step 7: Calculate throughput of terminals.

Step 8: Collect statistics.

3.2 Scenarios, methodology and propagation models for compatibility studies between IMT systems and other mobile systems

3.2.1 Interference scenarios and propagation models from PPDR/LMR to WiMAX TDD

WiMAX TDD is chosen as an IMT TDD system, and PPDR/LMR is a mobile system. It is assumed that WiMAX TDD is operating at the uppermost channel in the 698-806 MHz band (i.e. in the channel 798-803 MHz, assuming a 3 MHz guard band between WiMAX TDD and PPDR/LMR) and PPDR/LMR is operating above 806 MHz.

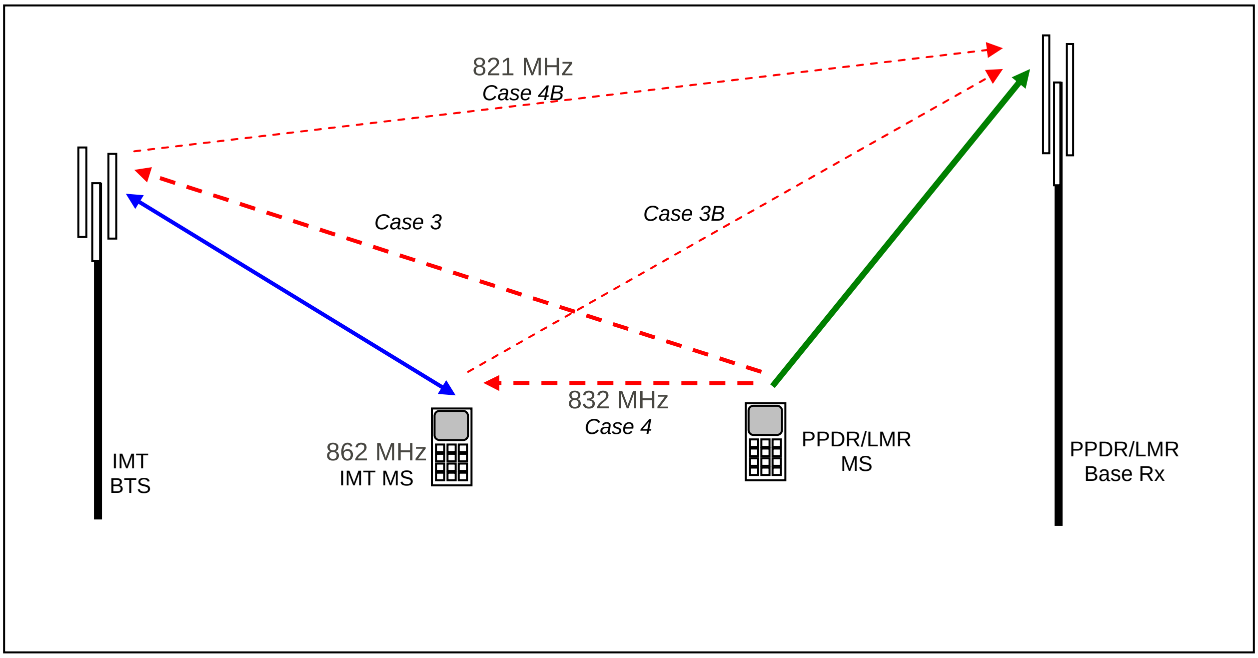
Therefore, only the adjacent band scenario is considered.

The minimum coupling loss (MCL) approach is used. The channel bandwidth of WiMAX TDD is assumed to be 5 MHz in this study. The case of 10 MHz channel bandwidth is anticipated to have similar results.

The following figure shows the interference scenarios between WiMAX TDD and PPDR/LMR systems. Since the scope of this study only considers interference to the IMT system, Case 3 and Case 4 are studied.

FIGURE 3.2.1

Interference Scenarios between PPDR/LMR and WiMAX TDD



The following table provides the interference scenarios and the relevant path-loss models applicable to this study.

TABLE 3.2.1

Interference scenarios and relevant path-loss models

Case	Interference Scenario	Model Adopted	Comments
3	PPDR/LMR MS Tx→ WiMAX BTS Rx	Suburban Modified Hata in Rec. ITU-R SM.2028-1	Mitigated by local clutter and WiMAX BTS RX filtering
4	PPDR/LMR MS Tx→ WiMAX MS Rx	Suburban Modified Hata in Rec. ITU-R SM.2028-1	Mitigated by local clutter

Only the effect of unwanted emissions (the case of spurious emissions) has been taken into account. These emissions are not filtered by the WiMAX TDD receiver since they fall down in the operating receiving band.

The following formula shall be used to derive MCL:

$I/N = -6$

$N\text{-}6 = [Pt + Gt]_{\mathbf{PPDR}} + [Gr\ ]_{\mathbf{WiMAX}} - MCL$

$MCL = [Pt + Gt]_{\mathbf{PPDR}} + [Gr\ ]_{\mathbf{WiMAX}} - (N\text{-}6)$ (this formula is valid for co-channel)

In adjacent band :

$MCL_{unwanted} = [P_{unwanted} + Gt]_{\mathbf{PPDR}} + [Gr\ ]_{\mathbf{WiMAX}} - (N\text{-}6)$

$MCL_{blocking} = [Pt + Gt]_{\mathbf{PPDR}} + [Gr - ACS]_{\mathbf{WiMAX}} - (N\text{-}6)$ – not considered in the study.

3.2.2 Interference scenarios and propagation models from PPDR/LMR to LTE FDD and vice versa

3.2.2.1 Introduction

IMT- LTE systems operating in the band 790-862 MHz may interfere to PPDR systems (and vice versa) that are using the same band with different frequency arrangement. *Recognizing* b) of Resolution 224 (Rev.WRC-07) should be duly addressed. "that … parts of the bands 746-806 MHz and 806-862 MHz are used extensively in many countries by various other terrestrial mobile systems and applications, including public protection disaster relief radiocommunications (see Resolution 646 (WRC-03)). This compatibility study includes co-channel interference analysis between IMT-LTE and two major PPDR platforms: Project 25 also known as TIA 102 and DIMRS (Report ITU-R M.2014-1). Further study that would include out of band emissions interference may be needed. This study includes only IMT-LTE with FDD allocation.

3.2.2.2 Frequency arrangement and mutual interference between mobile systems in the 790-862 MHz band

Preliminary draft Recommendation ITU-R M.1036-3 and 3GPP (LTE-3GPP TS 36.101 V10.0.0, band 20) specify new channel arrangements for the IMT-LTE operating in the band 790-862 MHz. The PPDR use Band 10 (Report ITU-R M.2039-2/Table 7) 806-869 MHz. So the IMT-LTE base station (BTS) will experience mutual interference with PPDRs BTS at the 806-862 MHz band. The PPDR in this band are mainly trunk digital radio systems used for dispatch traffic. The main mutual interference is between the BTS downlinks of one system to the BTS uplink of the other system, operating at the same frequencies.

TABLE 3.2.2.2-1

Frequency arrangements in the band 698-960 MHz

Frequency arrangements	Paired arrangements				Un-paired arrangements (e.g. for TDD) (MHz)
	Mobile station transmitter (MHz)	Centre gap (MHz)	Base station transmitter (MHz)	Duplex separation (MHz)	
A3	832-862	11	791-821	41	None

TABLE 3.2.2.2-2 (REPORT ITU-R M.2039-2/TABLE 7)

Band class designations in the 698-862 MHz range

Band class[23]	Transmit frequency band (MHz)	
	Mobile station	Base station
10	806-824 896-901	851-869 935-940

The planned IMT-LTE RF bands for FDD systems are:

BTS transmits at 791-821 MHz; BTS receives at 832-862 MHz.

Total of 2 x 30MHz with transmit to receive separation of 41 MHz.

[23] Only Band class 10 is shown in this Table.

The PPDR at the 806-869 MHz band allocations are:

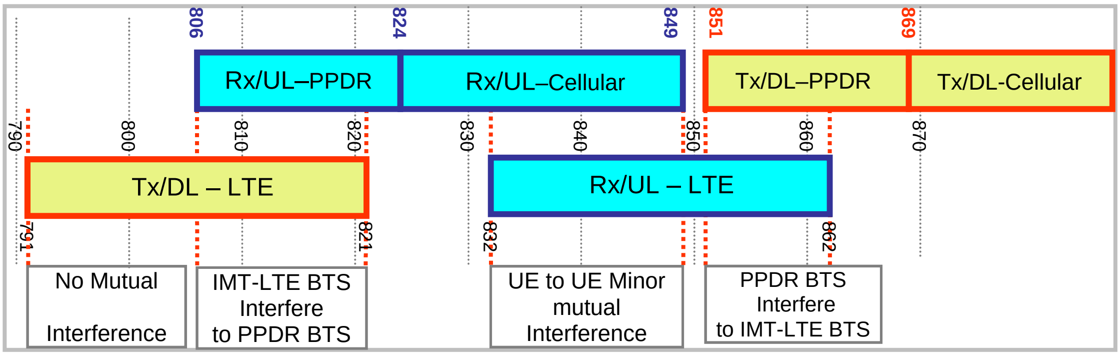
BTS transmits at 851-869 MHz; BTS receives at 806-824 MHz.

Total of 2x 18MHz with transmit to receive separation of 45 MHz.

The result is a mutual interference between BTS transmitters of one system to the BTS receivers of the other systems; see Figure 5.2.2-1; only BTS (Rx and Tx) RF is depicted.

FIGURE 3.2.2.2

IMT-LTE - FDD Co-existence/Interference with PPDR in the band of 790-862 MHz



Scenarios to be considered:

806-821 MHz: IMT-LTE BTS transmitters interfere with PPDR BTS receivers;

851-862 MHz: PPDR BTS transmitters interfere with IMT-LTE BTS receivers;

791-806 MHz and 849-851 MHz: no mutual interference;

832-849 MHz: minor mutual interference from User Equipment (UE) transmitters to other BTS receivers;
821-824 MHz: no mutual interference

Therefore, In this Report only co-channel interference is included. This study includes only IMT with FDD allocation.

PPDR mobile systems use Band 10 (Report ITU-R M.2039-2/Table 7) 806-869 MHz. So, the IMT/LTE base station (BTS) will experience mutual interference with the PPDR system's BTS at the 806-862 MHz band. The PPDR systems in this band are mainly trunk digital radio systems used for PPDR dispatch traffic: Project 25 (APCO) and digital integrated mobile radio system - DIMRS (Report ITU-R M.2014-1). The main mutual interference is between the BTS downlinks of one system to the BTS uplink of the other system, operating at the same frequencies.

3.3 Scenarios, methodology and propagation models for compatibility studies between IMT and broadcasting services

3.3.1 General methodology for compatibility studies between IMT and broadcasting services

This section outlines a number of general approaches that could be used to conduct compatibility studies for IMT being interfered with by the broadcasting service.

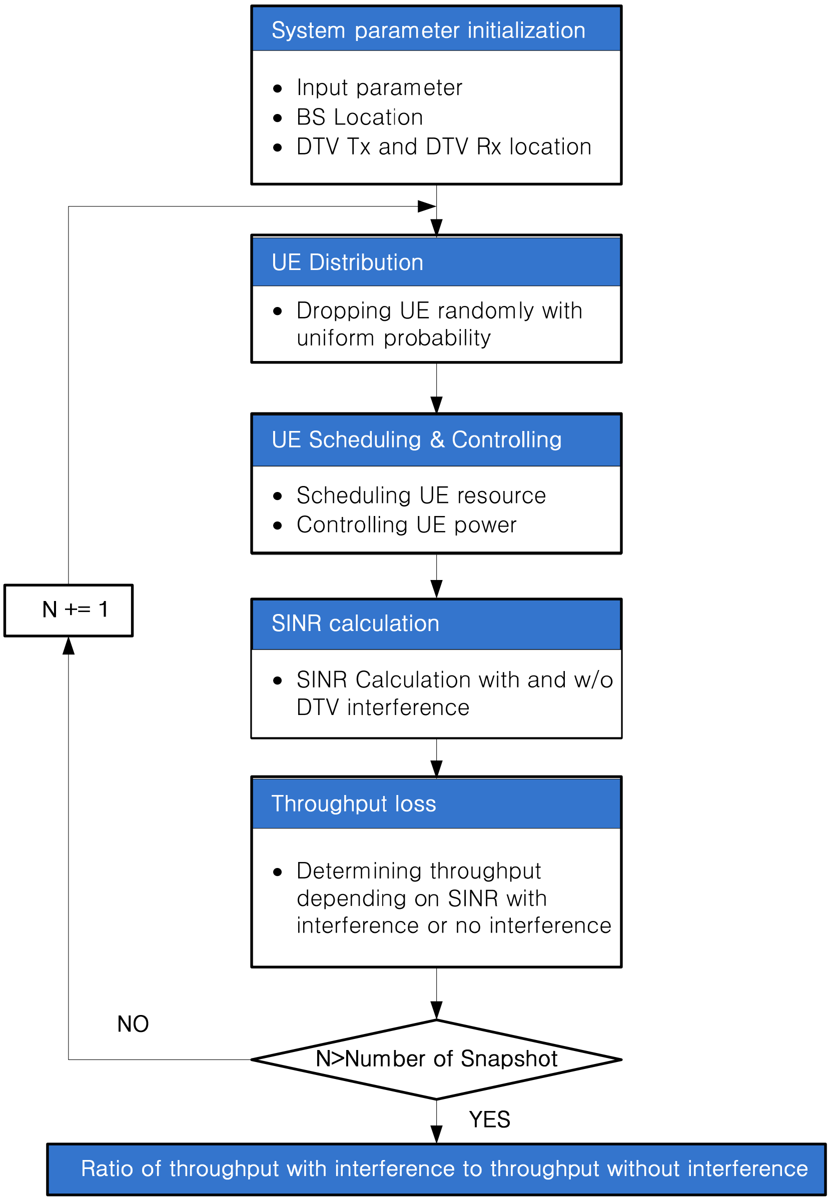
3.3.1.1 Static statistical approach

The static approach is performed by Monte-Carlo system level simulation method with the steps illustrated in Figure 3.3.1.2.

For a given ACIR and isolation distance, system deployment and simulation parameters are configured. For each snapshot, LTE UEs are randomly distributed in the service area, and average throughput of LTE system with the interference from DTV transmitter to LTE receiver or without interference is simulated with several steps, such as: scheduling UE resources, power control (Uplink) or power allocation (Downlink), SINR calculation with or without the interference and determining the throughput. After sufficient times of snapshot, statistical throughput loss with different ACIR and isolation distance of LTE can be obtained.

FIGURE 3.3.1.2

Flowchart of static statistical approach



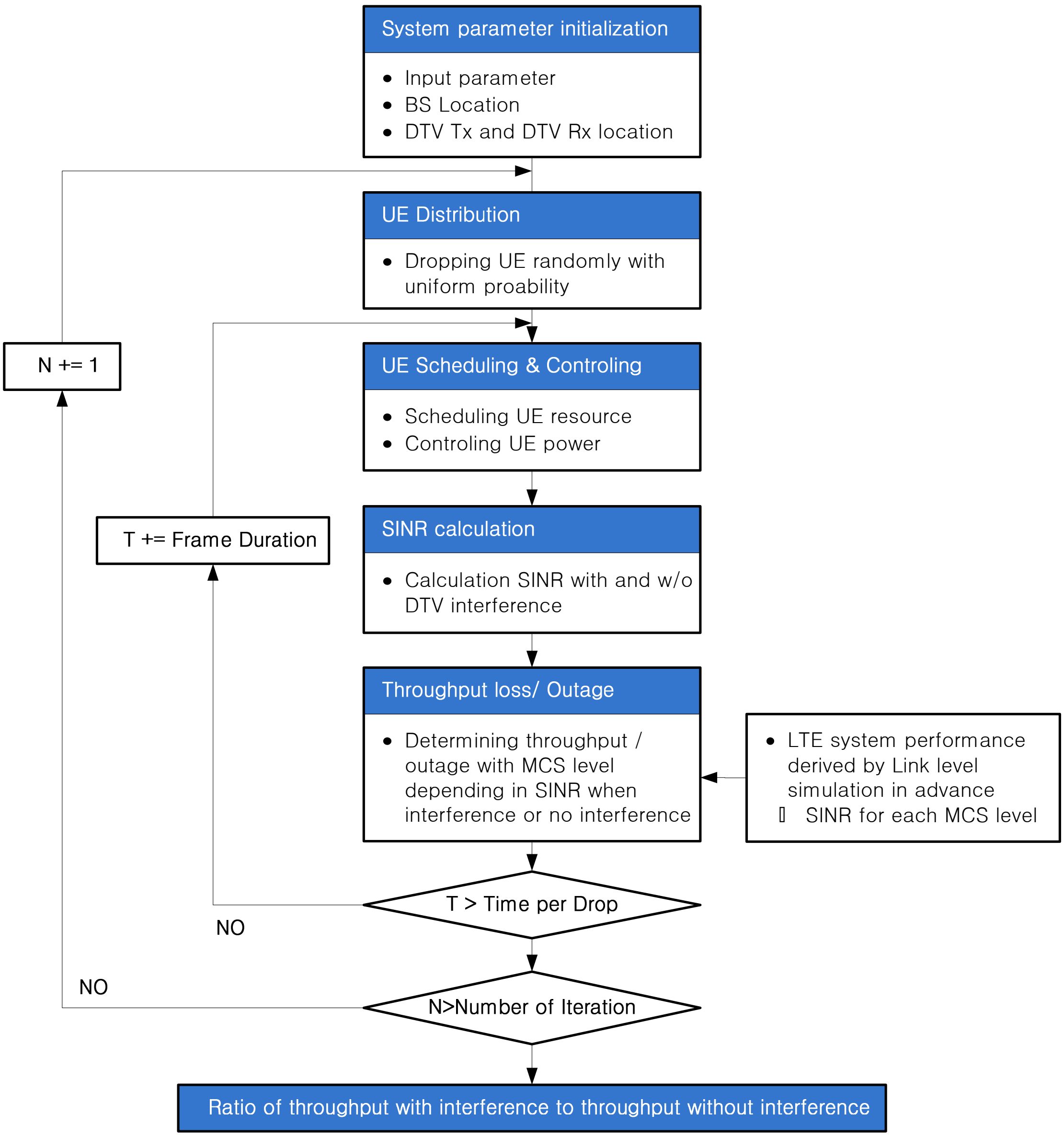
3.3.1.2 Dynamic statistical approach

A statistical approach is performed by mean of system level performance analysis such as system-level simulation (SLS) is performed by step by step as illustrated in Figure 3.3.1.3-1.

The level of interfering signal from DTV transmitter is computed by summation of received power from DTV transmitters to LTE UE which is determined by several factors, such as path loss and antenna discrimination. Once the level of DTV transmitter's interfering signal is determined, SINR (LTE UE desired signal to DTV interference signal ratio) is compared with results for each MCS (modulation and coding scheme) of LTE system which is derived from link level simulation of system. It results in throughput loss or outage of LTE UE. Measuring of throughput loss and outage of LTE system is performed according to the various ACIR values which is combination of ACS of LTE BTS receiver and ACLR of DTV transmitter. Through the sufficient iteration, statistically meaningful throughput loss or outage of LTE UE in uplink is obtained. Also distribution map of outage of LTE UE in uplink due to DTV transmitter will be obtained to find where LTE UE in uplink has the significant performance degradation due to DTV signal.

FIGURE 3.3.1.3-1

Flowchart of dynamic statistical approach

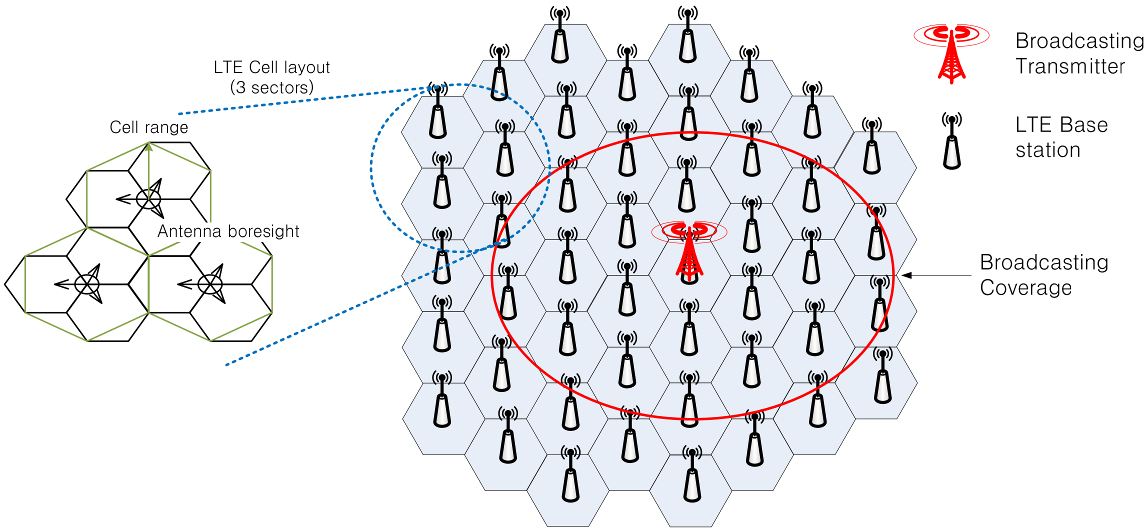


A Monte-Carlo methodology is used to derive the throughput loss or outage of a LTE UE in uplink, and plotted against MCS (modulation and coding scheme) level from SINR (signal-to-interference noise ratio) of LTE system due to DTV transmitter interference.

The DTV transmitter is located in a fixed point. The LTE system configuration is based on an "Urban macro-cell scenario" as defined in Report ITU-R M.2135. Hexagonal LTE cell layout is shown in Figure 3.3.1.3-2 and LTE UEs are randomly dropped and uplink transmit power is applied to LTE UE in uplink scheduling.

FIGURE 3.3.1.3-2

Simulation environment



3.3.2 Compatibility studies between different IMT and broadcast systems

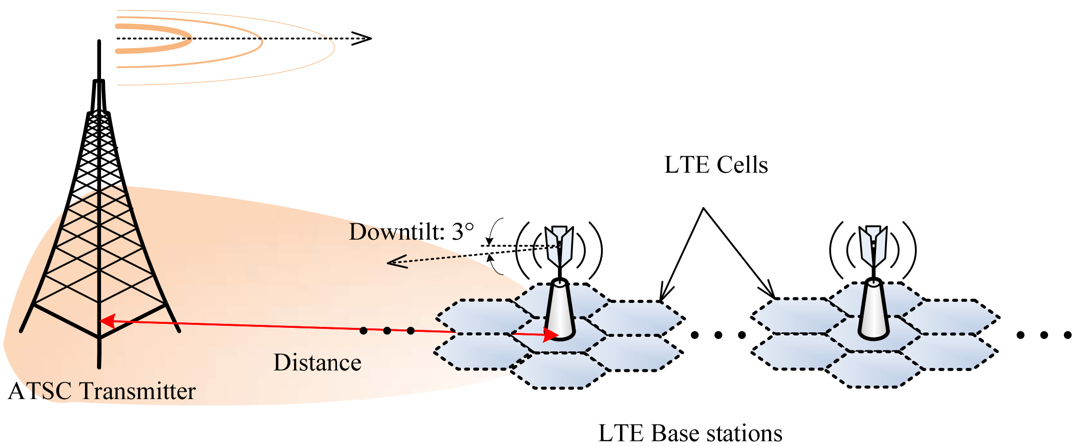
This section outlines a number of specific configurations for the compatibility studies between different IMT and broadcast systems.

3.3.2.1 Compatibility studies between LTE FDD and ATSC

Figure 3.3.2.1-1 describes ATSC transmitter and LTE base stations. LTE cells cover the given whole range with ATSC transmitter as the centre. The antenna direction of ATSC transmitter horizontally looks. LTE BTS receiver is down-tilted with 3 degrees.

FIGURE 3.3.2.1-1

Configuration of ATSC transmitter and LTE BTS



Simulation parameters for ATSC and LTE are summarized in Table 3.3.2.1-1 and path loss model in Table 3.3.2.1-2.

TABLE 3.3.2.1-1

Simulation parameters for LTE and ATSC

Parameters	LTE Value	Remark
Cell layout	Hexagonal grid	
Scenario	Urban Macro	Report ITU-R M.2135
Channel bandwidth	10 MHz*	
Number of UE per km^2	5, 20 UEs	
Inter-site distance	500 m	
Antenna height	30 m	
Antenna vertical pattern	F.1336	ITU-R Recommendation
Antenna downtilt	3 degrees	
Sectorization	3 Sectors	
Duplex method	FDD	
UE max transmit power	23 dBm	
Uplink scheduler	PF	PF factor = 1.2
Uplink power control	Alpha = 0.8	3GPP TS 36.213
Parameters	**ATSC Value**	**Remark**
Transmitter power (eirp)	92.16 dBm	FCC CFR 47. Part 73
Transmitter antenna height	365 m	FCC CFR 47. Part 73
Modulation type	8-VSB	

* 10 MHz channel bandwidth is representative of LTE system deployments applicable to this study.

TABLE 3.3.2.1-2

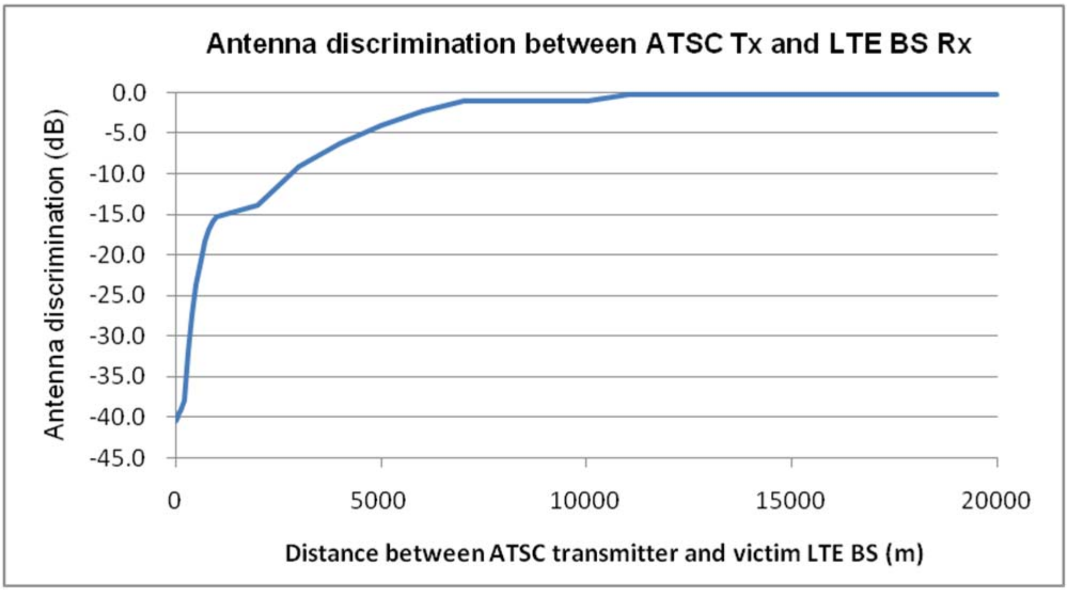
Path loss models for simulation

Path	Model	
LTE UE → LTE BTS	Okumura-Hata model	
DTV transmitter → DTV receivers	Recommendation ITU-R P.1546	

Figure 3.3.2.1-2 shows the attenuation by antenna discrimination due to antenna vertical pattern of ATSC Transmitter and LTE BTS Receiver. LTE base station very close to ATSC transmitter receives the interference attenuated as maximum 40 dB by only antenna discrimination. But, if the distance between both is more than 10 km, the attenuation by antenna discrimination is close to 0 dB.

FIGURE 3.3.2.1-2

The antenna discrimination between ASTC Tx and LTE base station Rx according to the distance



3.3.2.2 Compatibility studies between LTE TDD and DTMB

It is assumed that LTE TDD is operating at the lowermost channel in the 698-806 MHz band and DTMB system is operating at the uppermost channel below 698 MHz. LTE TDD system and DTMB system are operating in the same geographical area.

Compatibility scenarios

For the interference from DTMB system to LTE TDD, the following scenarios can be identified:

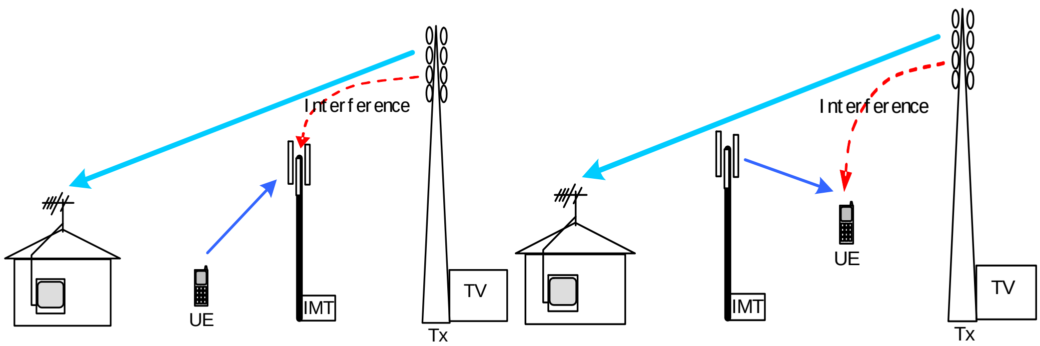
– DTMB transmitter interfering with LTE TDD BTS receiver (Case 1);

– DTMB transmitter interfering with LTE TDD MS receiver (Case 2).

The following figure shows the interference from DTMB system to LTE TDD around the 698 MHz band edge.

FIGURE 3.3.2.5.1

Interference scenarios of Cases 1 and 2



Propagation model

The propagation model used in this study is based on a set of reference parameters, and a prescription (‘algorithm’) for propagation predictions based on an application of the Hata model for short distances (0 km to 0.1 km), Recommendation ITU-R P.1546-3 for long distances (1.0 km to 1 000 km), and a means to interpolate between the predictions at 0.1 km and those at 1.0 km.

$$L(d) = L(0.1) + \frac{[\log(d) - \log(0.1)]}{[\log(1.0) - \log(0.1)]}[L(1.0) - L(0.1)]$$

where L(d) represents the path loss value at the distance of d.

Calculation of equivalent (bandwidth adjusted) ACLR, ACS and ACIR

In the compatibility study of interference from DTMB to TD-LTE, the working channel bandwidth of interferer system and that of interfered with system are different. Therefore, equivalent ACLR, equivalent ACS, and equivalent ACIR are needed. The equivalent ACLR means the adjacent channel leakage ratio from DTMB working channel to TD-LTE working channel. The equivalent ACS means the adjacent channel rejection ratio from DTMB working channel to TD-LTE working channel. The equivalent ACIR is drawn based on:

$$ACIR_{equivalent}{}^{-1} = ACLR_{equivalent}{}^{-1} + ACS_{equivalent}{}^{-1}$$

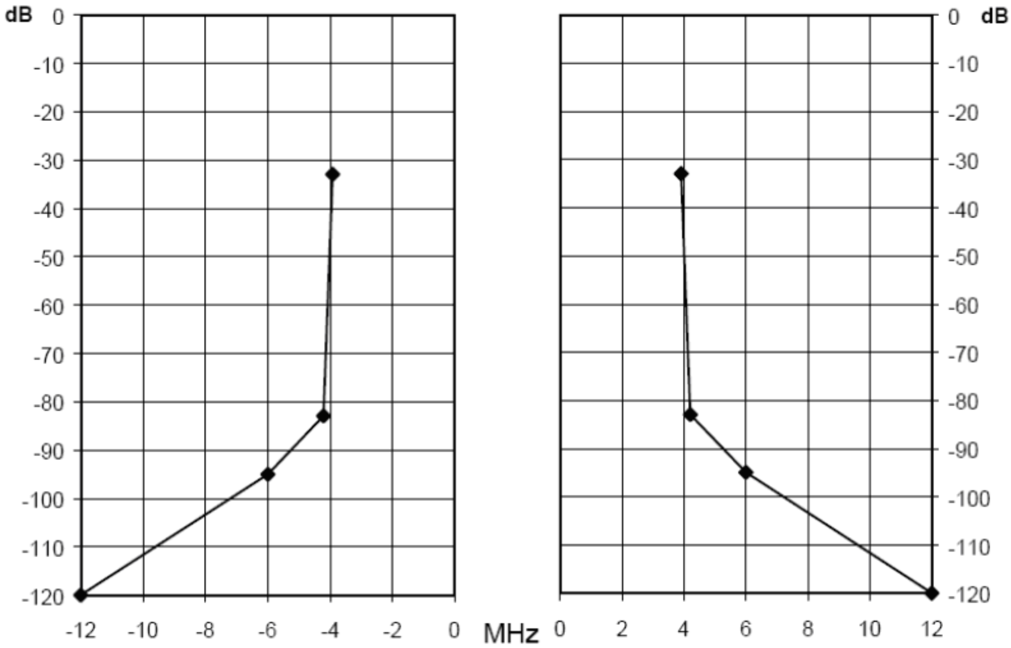
The equivalent ACLR/ACS is related to not only the bandwidths of TD-LTE and DTMB systems but also the guard-band between two systems. This study considers 5 MHz TD-LTE system with occupied bandwidth of 4.5 MHz, and 8 MHz DTMB with occupied bandwidth of 7.6 MHz.

DTMB equivalent ACLR

At present, there is no ACLR value for DTMB in literature. The equivalent ACLR of DTMB from the 7.6 MHz DTMB channel to the adjacent 4.5 MHz TD-LTE channel is calculated through spectrum emission mask of DTMB as illustrated in the figure below, where the transmitting power of DTMB on the assigned channel and the leakage power on adjacent channel(s) can be derived. The calculation considers only the occupied channel bandwidth of DTMB and the occupied channel bandwidth of TD-LTE.

FIGURE 3.3.2.5-2

DTMB spectrum emission mask



DTMB spectrum emission mask can be expressed by the following equation, where Δ f corresponds to x-axis in the figure, and y corresponds to y-axis in the figure.

$$y = \begin{cases} -125.5\Delta f + 444.1 & 3.8MHz \le \Delta f < 4.2MHz \\ -\dfrac{20}{3}\Delta f - 55 & 4.2MHz \le \Delta f \le 6MHz \\ -\dfrac{25}{6}\Delta f - 70 & 6MHz < \Delta f \le 12MHz \\ -120 & \Delta f > 12MHz \end{cases}$$

The calculated equivalent ACLR is presented in Table 3.3.2.5-1

TABLE 3.3.2.5-1

DTMB equivalent ACLR

Parameters	*Equivalent ACLR (dB)*										
Guard-band (MHz)	***0***	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***
DTMB	*61.1*	*67.2*	*71.9*	*76.1*	*80.3*	*84.2*	*87.4*	*89.2*	*89.5*	*89.5*	*89.5*

TD-LTE Equivalent ACS

Referring to material in AWF-9/INP-74 (Rev.2), dated 13 September 2010, for LTE BTS, ACS for 1st adjacent channel = 45 dB; ACS for 2nd adjacent channel = 55 dB; ACS for 3rd adjacent channel = 65 dB. Referring to the same report, for LTE UE, ACS for 1st adjacent channel = 33 dB; ACS for 2nd adjacent channel = 39 dB; ACS for 3rd adjacent channel = 45 dB. Based on the above values and channel bandwidth conversion between TD-LTE and DTMB, the equivalent ACS values in respect of various guard bands can be derived as below.

TABLE 3.3.2.5-2

TD-LTE BTS/UE equivalent ACS

Parameters	*Equivalent ACS (dB)*										
Guard-band (MHz)	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
TD-LTE BTS	*46.8*	*47.6*	*48.7*	*50.2*	*52.6*	*56.8*	*57.6*	*58.7*	*60.0*	*62.1*	*65.0*
TD-LTE UE	*34.4*	*35.0*	*35.8*	*36.9*	*38.4*	*40.4*	*41.0*	*41.8*	*42.7*	*43.8*	*45.0*

Equivalent ACIR

The equivalent ACIR can be calculated by equivalent ACLR and equivalent ACS using the following formula.

$$ACIR^{-1} = ACLR^{-1} + ACS^{-1}$$

TABLE 3.3.2.5-3

Equivalent ACIR for different interference cases

Parameters	*Equivalent ACIR (dB)*										
Guard-band (MHz)	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Case 1	*46.6*	*47.6*	*48.6*	*50.2*	*52.6*	*56.7*	*57.6*	*58.7*	*60.0*	*62.1*	*65.0*
Case 2	*34.4*	*35.0*	*35.8*	*36.9*	*38.4*	*40.4*	*41.0*	*41.8*	*42.7*	*43.8*	*45.0*

Monte-Carlo simulation

A Monte-Carlo method can be used to solve a complicated problem with many variables (represented by a suitable ‘model’) by generating appropriate random numbers representing the ‘model’ parameters.

In the compatibility study, static simulation and Quasi-static simulation are provided for system performance analysis. Throughput loss of the LTE TDD system with each assumed value of Min distance shall be observed. From the results, an additional isolation can be deduced in order to ensure that the throughput loss of IMT system is less than 5%.

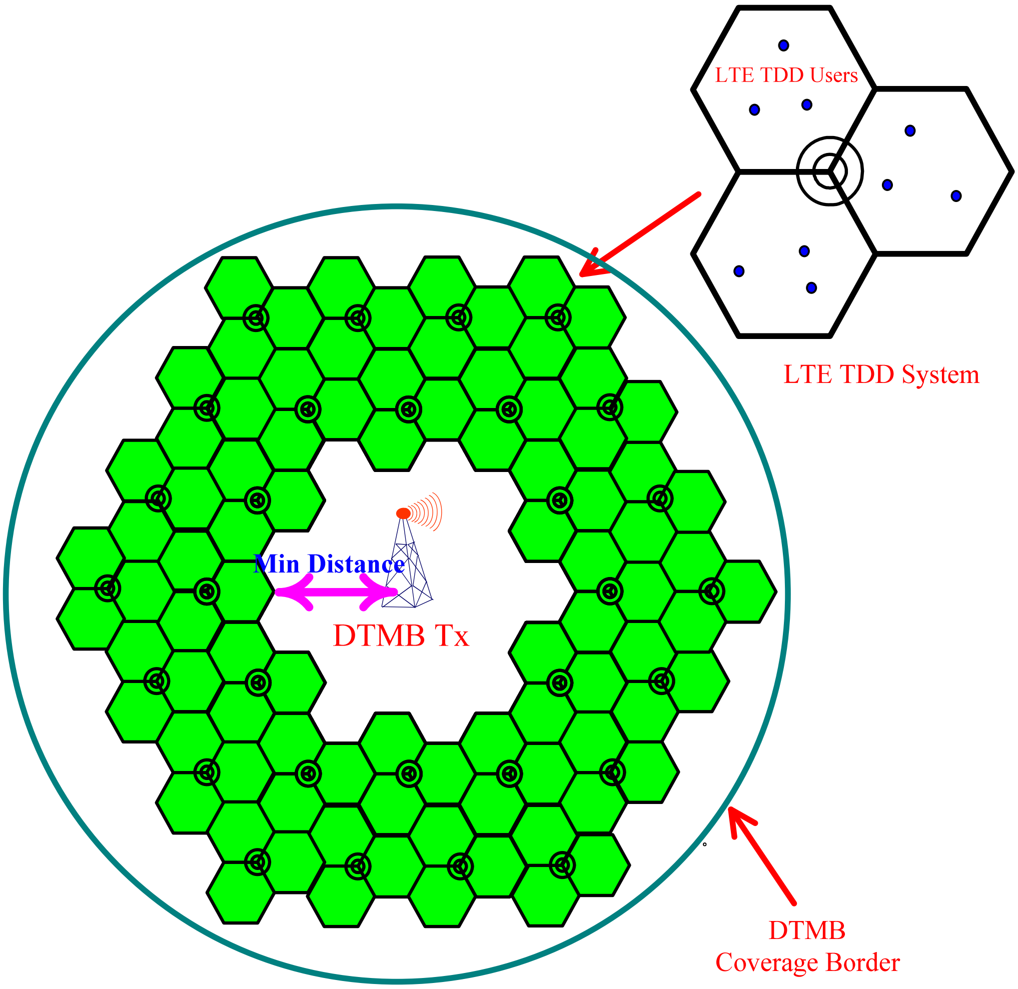
Assumptions of the simulation

1) Topology

As for the network topology, the objective of LTE TDD deployment is for coverage extension. 19-cell tri-sector structure with wrap around of the LTE TDD system layout is deployed. In order to examine the interference from DTMB system to LTE TDD system, DTMB transmitter is located around the central of the LTE TDD topology as shown in the figure below. It is assumed that the distance between DTMB transmitter and interfered BTS is defined as "Min Distance". Different value of Min Distance shall have different impact on the interference from DTMB to LTE TDD system.

FIGURE 3.3.2.5.3

Topology of DTMB system interfering with LTE TDD in the same geographical area



2) Scheduler

For LTE TDD system, Round Robin scheduler is used.

3) Simulated services

For LTE, full buffer traffic packet service is simulated.

4) Protection criterion of LTE TDD

As the DTMB system interferes with LTE TDD system, 5% throughput loss of LTE TDD system is regarded as the criterion to judge if the LTE TDD system works properly.

5) Power control

There is no power control in LTE TDD downlink. Fixed power per frequency resource block is assumed.

For LTE TDD uplink, the following power control equation which refers to 3GPP TR36.942 shall be used for the initial uplink compatibility simulations:

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

Where $P_{\max}$ is the maximum transmit power, $R_{\min}$ is the minimum power reduction ratio to prevent MSs with good channels to transmit at very low power level, PL is the path loss for the MS and $PL_{x\text{-}ile}$ is the x-percentile path loss (plus shadowing) value. With this power control equation, the $x$percent of MSs that have the highest pathloss will transmit at $P_{\max}$. Finally, $0<\gamma<=1$ is the balancing factor for MSs with bad channel and MSs with good channel:

The parameter sets for power control are specified in the following table:

TABLE 3.3.2.5.4

Power Control Algorithm Parameter

Parameter set	Gamma	PLx-ile			
		20 MHz bandwidth	15 MHz bandwidth	10 MHz bandwidth	5 MHz bandwidth
Set 1	1	109	110	112	115
Set 2	0,8	TBD	TBD	129	133

Simulation procedure for DTMB system interfering with LTE TDD in the same geographical area

The main steps of simulation at given ACIR and isolation distance are described as following:

Approach 1, Static simulation

Step 1: Configure system deployment layout according to the different minimum distance between DTMB and LTE BTS in the topology of simulation and simulation parameters.

Step 2: Distribute LTE MSs in the service area with the selected base station deployment.

Step 2.1: Place the specified number of MSs in each sector.

Step 2.2: Calculate the link gains of the intra-system links and the inter-system links, including antenna gain and shadow fading. Each MS chooses its base station based on the strongest signal it receives (or the least loss).

Step 3: Perform schedule, power control for LTE TDD uplink, SINR calculation and throughput loss counting.

Step 4: Repeat Steps 2 to 4 until the number of snap shots is reached.

Approach 2, Quasi-static simulation

Step 1: Configure simulation system, deploy broadcasting transmitter as well as LTE BTSs according to the topology of simulation.

Step 2: Initiate co-existing parameters such as ACIR.

Step 3: Distribute LTE MSs randomly into the cells of broadcasting system and the cells of LTE, and initialize each BTS and MS.

Step 4: Calculate the link gains of the intra-system links and the inter-system links, including path-loss, antenna gain, Doppler fading and shadow fading.

Step 5: Radio resource schedule and management.

Step 6: Calculate the SINR of each link based on signal power, intra-system interference power, and inter-system interference power, and estimate the throughput of LTE system of single snapshot.

Step 7: Update the links of inter-system and intra-system, repeat the steps from 4 to 6 for the next snapshot.

Step 8: Set new positions for LTE MSs and MSs, and repeat the steps from 4 to 7 for the next drop.

Step 9: Collect statistics under certain ACIR, and estimate the throughput loss.

Step 10: Update ACIR, repeat steps from 3 to 9 for the throughput loss under the new value.

3.4 Scenarios, methodology and propagation models for compatibility studies between IMT and Aeronautical Radionavigation Services

The criterion of I/N = –6 dB is commonly used in other sections of this Report to protect IMT systems from non-pulsed interference. For the case of interference from high power pulsed ARNS RADARs other I/N criteria may be used.

3.4.1 Compatibility cases

The following interference cases are studied in this Report.

– Airborne ARNS to MS base stations

– Airborne ARNS to MS user terminals

– ARNS ground stations to MS base stations

– ARNS ground stations to MS user terminals.

The other direction from MS to ARNS has partly been studied in JTG 5-6 and complementary studies are expected to be conducted in WP 5B. For all cases described in this document the worst case scenario has been assumed and the study has been conducted with a deterministic approach i.e. only one interferer at the time has been assumed.

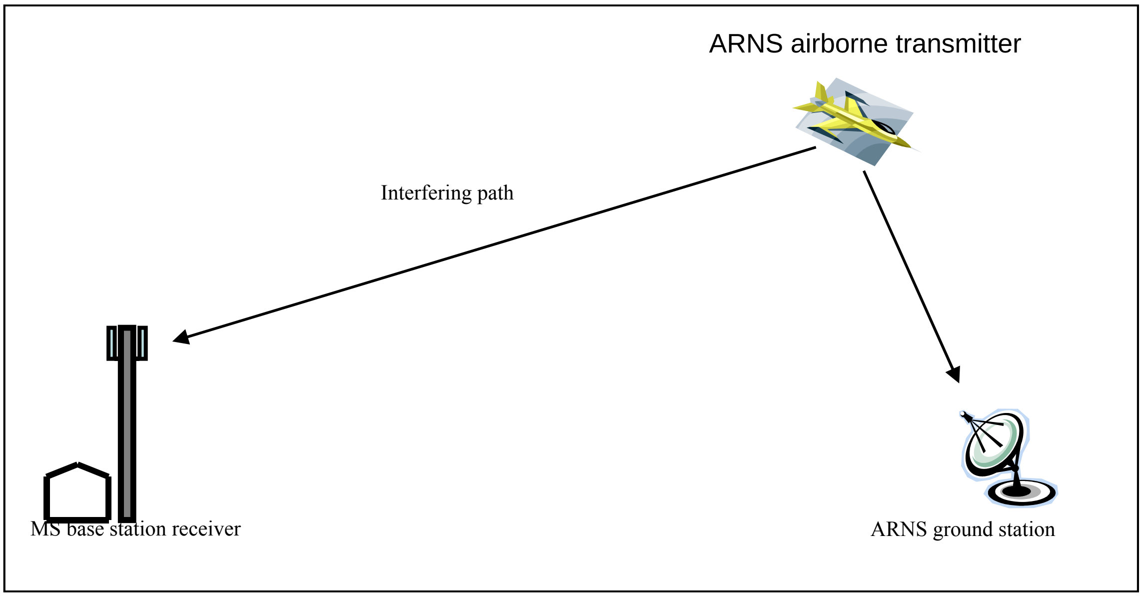
Depending on the mobile usage, TDD, FDD and positioning in the band all scenarios are not applicable for all markets.

3.4.1.1 Case 1 – Airborne ARNS to MS base stations

In this case the ARNS transmitter is located in an airplane which can operate at altitudes up to 10 000 m. The MS receiver antenna is located at 30 m height above the ground and line-of-sight is assumed between the transmitter and receiver antenna, hence free-space propagation could be assumed. Maximum radiated power from the aircraft transmitter is 30-35 dBW e.r.p.

FIGURE 3.4.1.1

Interference case 1 – ARNS airborne transmitter to MS base station

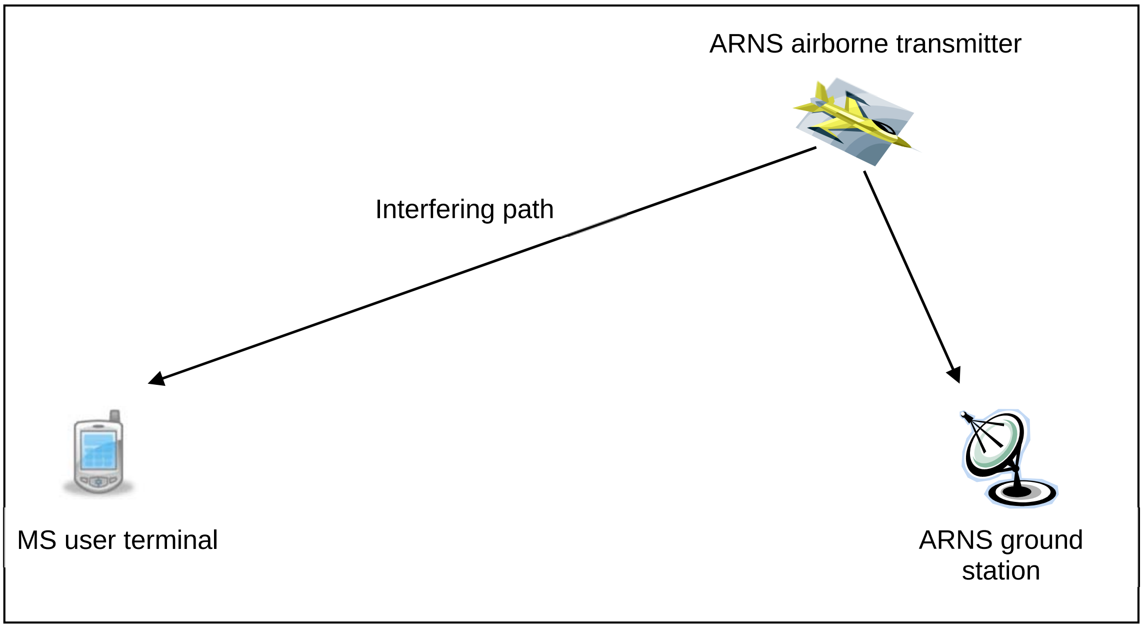


3.4.1.2 Case 2 – Airborne ARNS to MS user terminals

In this case the ARNS transmitter is located in an airplane which can operate at altitudes up to 10 000 m. The MS receiver antenna is located at 1.5 m height above the ground. Both line-of-sight and obstructed scenarios could be assumed. For LOS cases free-space propagation could be used. Maximum radiated power from the aircraft transmitter is 30-35 dBW e.r.p.

FIGURE 3.4.1.2

Interference case 2 – ARNS airborne transmitter to MS user terminal

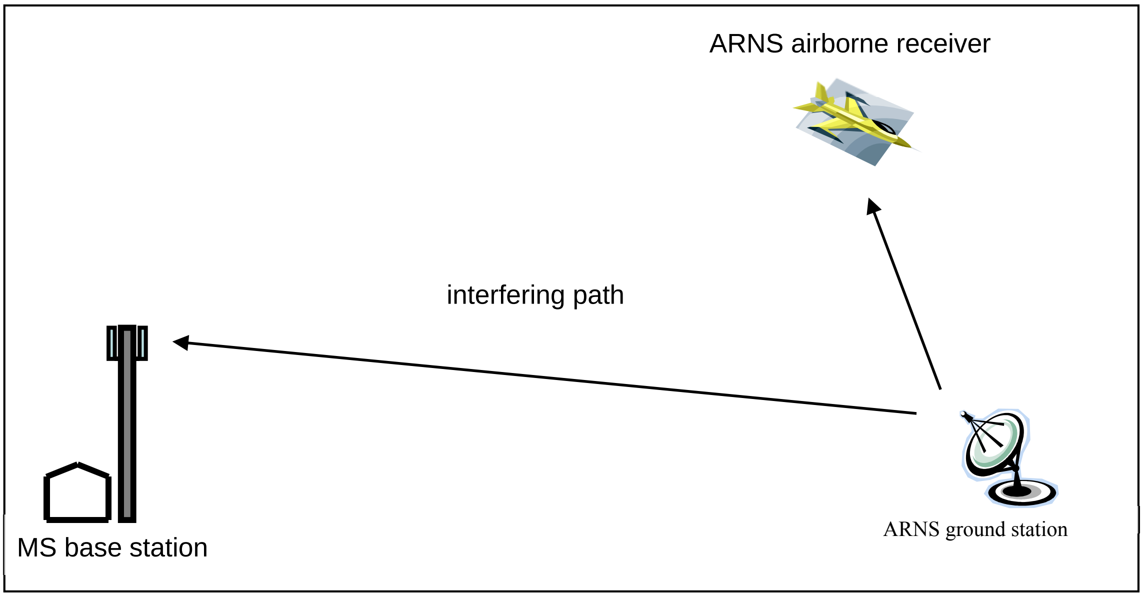


3.4.1.3 Case 3 - ARNS ground stations to MS base stations

In this case the interfering ARNS transmitter antenna is located at 15 m altitude pointing directly to the MS base station antenna which is located at 30 m height above the ground. Propagation model P.1546 could be used to calculate the propagation loss. Maximum radiated power from the ARNS ground transmitter is 48-82 dBWe.r.p.

FIGURE 3.4.1.3

Interference case 3 – ARNS ground stations to MS base stations

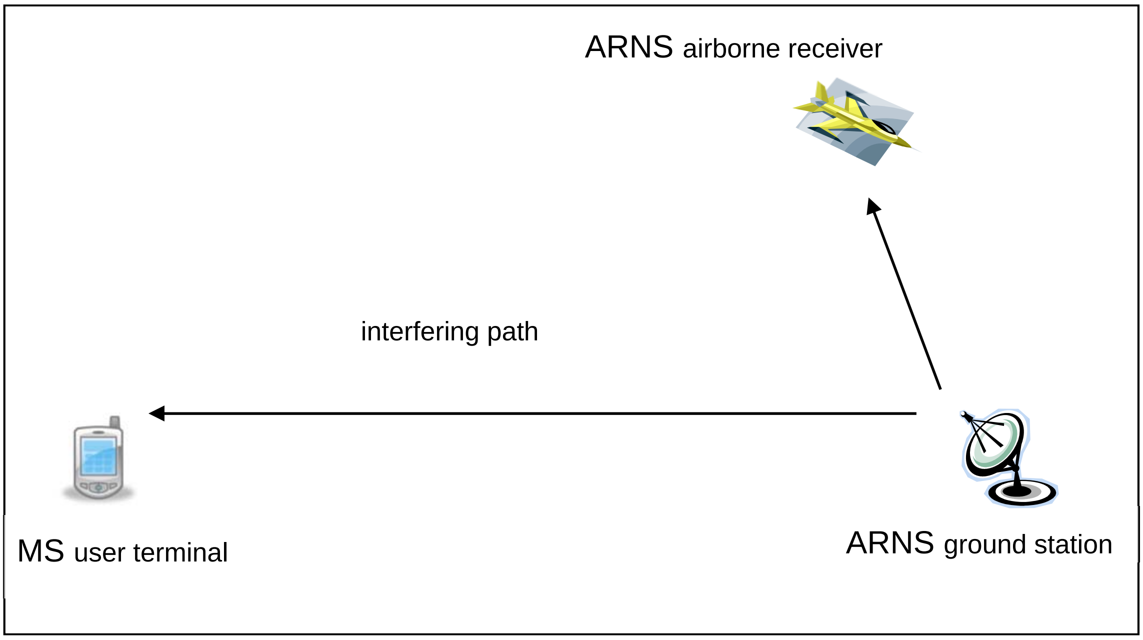


3.4.1.4 Case 4 – ARNS ground stations to MS user terminals

In this case the interfering ARNS transmitter antenna is located at 15 m altitude pointing directly to the MS user terminal antenna which is located at 1.5 m height above the ground. Propagation model P.1546 could be used to calculate the propagation loss. Maximum radiated power from the ARNS ground transmitter is 48-82 dBWe.r.p.

FIGURE 3.4.1.4

Interference case 4 – ARNS ground stations to MS user terminals

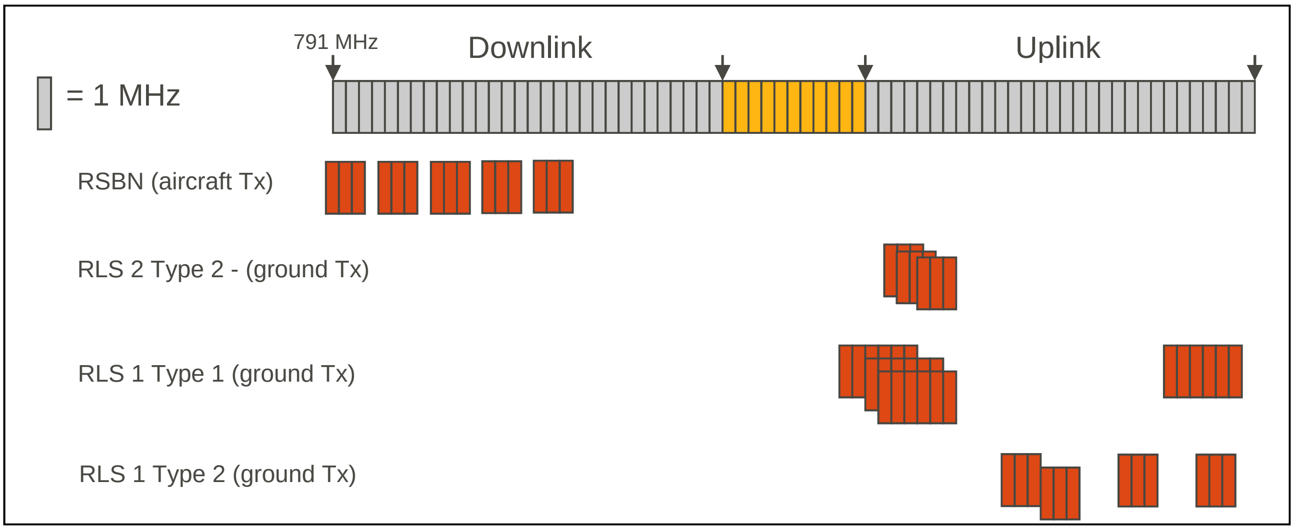


3.4.2 Relevant cases for MS FDD usage in Region 1

If a FDD frequency arrangement according to ECC DEC (09)03 is used not all scenarios above are relevant. Since there will be a frequency separation between the interfering ARNS transmitter and the interfered with MS receiver. From the figure below it can be concluded that only two of the four described interference cases will be relevant for each interference direction.

FIGURE 3.4.2

Relevant interference cases for Region 1 when the ECC REC (09)03 FDD plan is used for MS and Rec. ITU-R M.1830 for ARNS



For the interference direction from ARNS to MS only Cases 2 and 4 will be relevant if the FDD plan is used, hence only these two cases has to be considered.

4 Studies and results of compatibility studies between different IMT systems

4.1 Studies and results of compatibility studies between LTE FDD and LTE TDD

4.1.1 Deterministic analysis results

This section analyses the BTS to BTS interference and UE to UE interference and discusses isolation requirements to limit the impact of the interference.

4.1.1.1 BTS to BTS interference (BTS-BTS)

Two cases are considered: coordinated deployment (co-sited base stations) and covered in the same geographical area (co-area base stations).

Co-sited

One example of computation with 0 MHz guard band:

Item	Description	Units	Value	Reference / comments
A	*Tx emission power*	dBm	43	Interferer
B	Rx channel bandwidth	MHz	5	Interfered with
C	Guard band	MHz	0	
D	Rx Effective LTE carrier occupancy (RxBW)	MHz	4.5	3GPP TS 36.104
	Allowable interference power			
E	Ambient thermal noise floor	dBm/Hz	–174	*man made noise is not considered
F	Receiver noise figure (NF)	dB	5	Ref: TR 36.942
G	System noise floor (SNF)	dBm	–102.5	–174 dBm/Hz + 10*log(Rx_BW_Hz) + NF_dB
H	Allowable Rx sensitivity reduction	dB	1	*I/N = –6 dB*
I	***Allowable interference level at receiver***	**dBm**	**–108.5**	= g + 10*LOG(10^(h/10)-1)
K	MCL	dB	30	
L	ACIR	dB	42.6	
M	***Tx emissions in Rx spectrum block considering ACIR and MCL***	**dBm**	**–29.6**	= a- k- l
N	**Required additional ACIR isolation**	**dB**	**78.9**	= m- i

Co-area

One example of computation with 0 MHz guard band:

Item	Description	Units	Value	Reference / comments
A	***Tx emission power***	dBm	43	Interferer
B	Rx channel bandwidth	MHz	5	Interfered with
C	Guard band	MHz	0	
D	Rx effective LTE carrier occupancy (RxBW)	MHz	4.5	3GPP TS 36.104
	Allowable interference power			
E	Ambient thermal noise floor	dBm/Hz	–174	*man made noise is not considered
F	Receiver noise figure (NF)	dB	5	Ref: TR 36.942
G	System noise floor (SNF)	dBm	–102.5	–174 dBm/Hz + 10*log(Rx_BW_Hz) + NF_dB
H	Allowable Rx sensitivity reduction	dB	1	*I/N = –6 dB*
I	***Allowable interference level at receiver***	**dBm**	**–108.5**	= g + 10*LOG(10^(h/10)-1)
K	MCL	dB	67	
L	ACIR	dB	42.6	
M	***Tx emissions in Rx spectrum block considering ACIR and MCL***	**dBm**	**–66.6**	= a- k- l
N	**Required additional ACIR isolation**	**dB**	**41.9**	= m- i

4.1.1.2 UE to UE interference (UE- UE)

The deterministic analysis found below has been completed with a qualitative discussion of the relevance of the worst case. 1m physical separation is assumed and the max Tx emission power is adopted.

Item	Description	Units	Value	Reference / comments
A	***Tx emission power***	**dBm**	**23**	**Interferer**
B	Rx channel bandwidth	MHz	**5**	**Interfered with**
C	Guard band	MHz	**0**	
D	Rx effective LTE carrier occupancy (RxBW)	MHz	4.5	3GPP TS 36.104
	Allowable interference power			
E	Ambient thermal noise floor	dBm/Hz	–174	*man made is not considered
F	Receiver noise figure (NF)	dB	9	Ref: TR 36.942
G	System noise floor (SNF)	dBm	–98.5	–174 dBm/Hz + 10*log(Rx_BW_Hz) + NF_dB
H	Allowable Rx sensitivity reduction	dB	1	*I/N = –6 dB*
I	***Allowable interference level at receiver***	**dBm**	**–104.5**	= g + 10*LOG(10^(h/10)-1)
K	MCL	dB	32	
L	ACIR	dB	28.5	
M	***Tx emissions in Rx spectrum block considering ACIR and MCL***	**dBm**	**–45.5**	= a- k- l
N	**Required additional ACIR isolation**	**dB**	**67.5**	= m- i

4.1.1.3 Discussions and mitigation methods

The above section provides the interference analysis of BTS to BTS and UE to UE interference and additional isolations needed for successful compatibility. The following techniques can be considered: space isolation and spectrum isolation, etc. The key observations are summarized as following:

– **BTS to BTS interference:**

i) **Co-sited scenario:** If there is no guard band between IMT systems, the additional ACIR isolation requirement is 78.9 dB. If the guard band is 5 MHz, the required additional ACIR isolation requirement is reduced to 76.5 dB. Normally, both space isolation and spectrum isolation, which includes the appropriate RF filter attenuation requirement and the guard-band needed for the filter isolation, could be used. Since an appropriate RF filter for IMT base station might achieve up to 65 dB band-edge roll-off attenuation at 5 MHz, the remaining additional isolation requirement could be achieved by space isolation e.g. through vertical isolation.

Therefore, the additional ACIR isolation requirement for IMT base station may be achieved by a combination of 5 MHz guard-band, appropriate RF filter and space isolation. It should be pointed out that this case is under the assumption of co-sited scenario, which is the worst case in terms of interfering strength.

ii) **Co-area:** If the FDD BTS and TDD BTS are covered in the same geographical area, the additional ACIR isolation is only 41.9 dB with 0 MHz guard band. If the guard band is 5 MHz, the required ACIR isolation requirement is reduced to 39.5 dB. Therefore, the additional ACIR isolation requirement for IMT base station may be achieved by a combination of 5 MHz guard-band and appropriate RF filters which provide 40 dB roll-off at 5 MHz offset.

– **UE to UE interference:**

i) From the above deterministic analysis for a separation distance of 1 m, it can be concluded that an additional isolation is needed. This is the worst case which may occur when two terminals are in close proximity and one of the terminals' transmit power is very high , especially if they are at the border of the coverage area of their base station. Therefore, due to the strong influence of the terminal distribution, the Monte-Carlo simulation results can better show the real scenario in actual network deployment, and the Monte-Carlo method is adopted for analyzing the UE to UE interference scenario.

The deterministic analysis also hints that in a hotspot scenario, where the distance between some terminals might be small, there is a non negligible probability of significant UE to UE interference if no system level mitigation techniques are applied. This hotspot scenario is analysed with a Monte-Carlo simulation and the results of the analysis are shown in section 4.1.2.4.

4.1.2 Monte-Carlo simulation results and analysis

Based on the method above, simulation results are summarized as follows.

4.1.2.1 Case: BTS to UE interference

TABLE 4.1.2.1-1

Average throughput loss

BTS Co-sited						BTS Co-area					
Urban		Suburban		Rural		Urban		suburban		rural	
ACIR (dB)	Ave throughput loss (%)	ACIR (dB)	Ave throughput loss (%)	ACIR (dB)	Ave throughput loss (%)	ACIR (dB)	Ave throughput loss (%)	ACIR (dB)	Ave throughput loss (%)	ACIR (dB)	Ave throughput loss (%)
15	14.7	15	10.1	15	9.8	15	11.7	15	10.7	15	10.6
20	8.1	20	4.8	20	4.6	20	6.5	20	5.7	20	5.7
25	3.8	25	2.1	25	1.9	25	3.3	25	2.8	25	2.9
30	1.6	30	0.8	30	0.7	30	1.5	30	1.2	30	1.4
35	0.6	35	0.3	35	0.2	35	0.6	35	0.5	35	0.6

TABLE 4.1.2.1

25% CDF (cumulative distribution function) throughput loss

BTS Co-sited						BTS Co-area					
Urban		Suburban		Rural		Urban		suburban		rural	
ACIR (dB)	5% CDF throughput loss (%)	ACIR (dB)	5% CDF throughput loss (%)	ACIR (dB)	5% CDF throughput loss (%)	ACIR (dB)	5% CDF throughput loss (%)	ACIR (dB)	5% CDF throughput loss (%)	ACIR (dB)	5% CDF throughput loss (%)
15	38.9	15	24	15	21.4	15	40.7	15	42.2	15	44.5
20	18.3	20	10.2	20	8.2	20	19.2	20	21.6	20	23.2
25	8	25	3.9	25	2.5	25	8.5	25	10	25	11.7
30	2.6	30	1.3	30	1.4	30	3.1	30	4.0	30	5
35	1.0	35	0.3	35	0.1	35	0.9	35	1.3	35	1.9

FIGURE 4.1.2.1-1

5 MHz LTE, Co-sited, average throughput loss

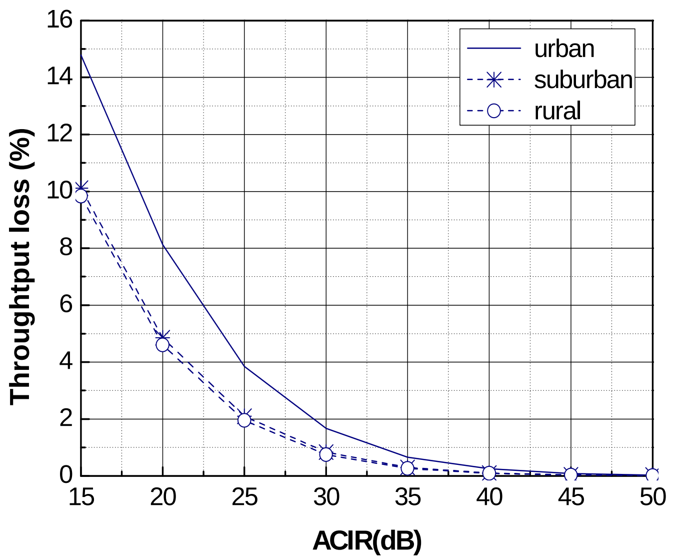


FIGURE 4.1.2.1-2

5 MHz LTE, Co-sited, 5% CDF throughput loss

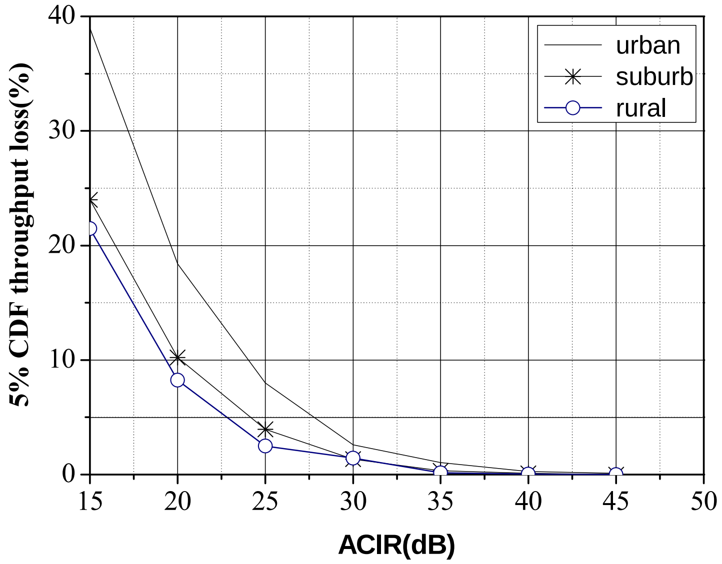


FIGURE 4.1.2.1-3

5 MHz LTE, Co-area, average throughput loss

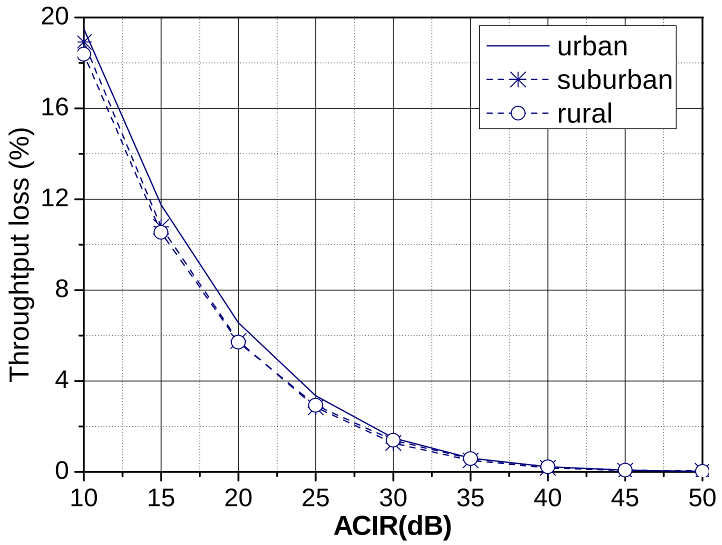
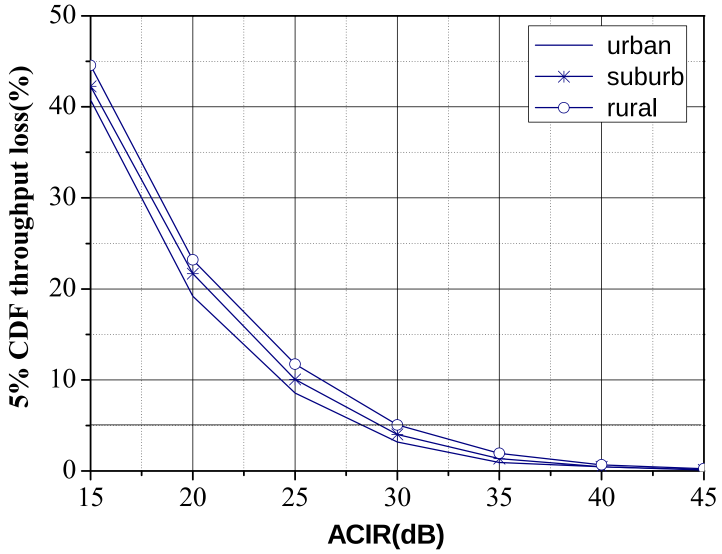


FIGURE 4.1.2.1-4

5 MHz LTE, Co-area, 5% CDF throughput loss



4.1.2.2 Case: UE to BTS interference

TABLE 4.1.2.2-1

Average throughput loss

BTS Co-sited						BTS Co-area					
Urban		Suburban		Rural		Urban		Suburban		rural	
ACIR (dB)	Ave throughput loss (%)	ACIR (dB)	Ave throughput loss (%)	ACIR (dB)	Ave throughput loss (%)	ACIR (dB)	Ave throughput loss (%)	ACIR (dB)	Ave throughput loss (%)	ACIR (dB)	Ave throughput loss (%)
10	23.1	10	10.5	10	8.0	10	26.1	10	15.6	10	13.6
15	13.8	15	5.0	15	3.6	15	16.4	15	8.6	15	7.4
20	7.7	20	2.2	20	1.5	20	10.0	20	4.4	20	3.7
25	4.0	25	0.9	25	0.6	25	5.6	25	2.1	25	1.7
30	1.9	30	0.3	30	0.2	30	2.8	30	0.9	30	0.7
35	0.8	35	0.1	35	0.1	35	1.3	35	0.3	35	0.3

TABLE 4.1.2.2-2

5% CDF throughput loss

BTS Co-sited						BTS Co-area					
Urban		Suburban		Rural		Urban		Suburban		rural	
ACIR (dB)	5% CDF throughput loss (%)	ACIR (dB)	5% CDF throughput loss (%)	ACIR (dB)	5% CDF throughput loss (%)	ACIR (dB)	5% CDF throughput loss (%)	ACIR (dB)	5% CDF throughput loss (%)	ACIR (dB)	5% CDF throughput loss (%)
10	73.4	10	22.8	10	17.7	10	100	10	51.8	10	49.4
15	37.5	15	9.2	15	6.5	15	61.4	15	22.8	15	22.2
20	16.7	20	3.3	20	2.3	20	28.2	20	9.0	20	8.1
25	7.6	25	1.4	25	0.7	25	11.1	25	3.7	25	2.8
30	2.8	30	0.7	30	0.3	30	3.3	30	1.2	30	0.7

FIGURE 4.1.2.2-1

5 MHz LTE, Co-sited, average throughput loss

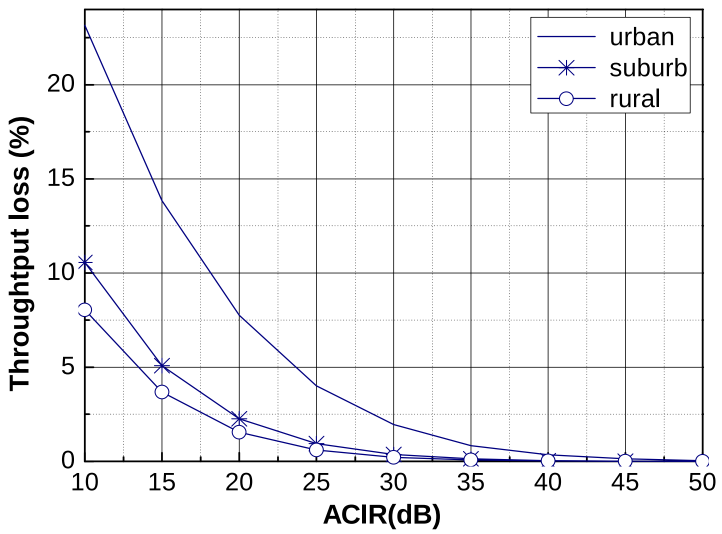


FIGURE 4.1.2.2-2

5 MHz LTE, Co-sited, 5% CDF throughput loss

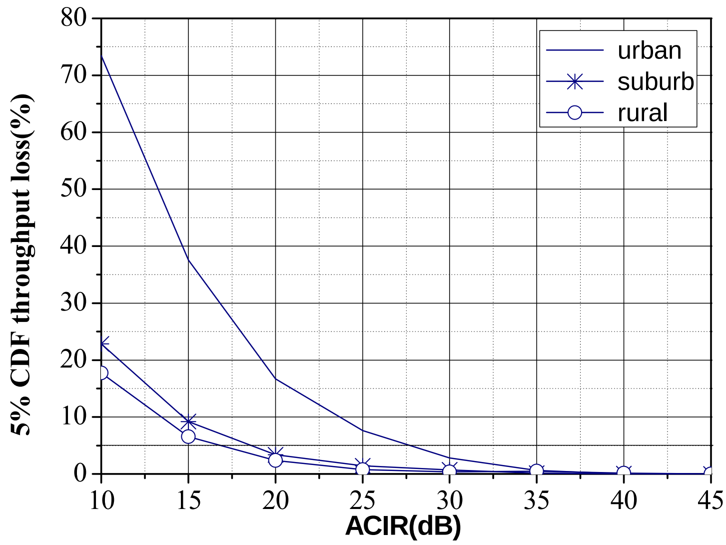


FIGURE 4.1.2.2-3

5 MHz LTE, Co-area, average throughput loss

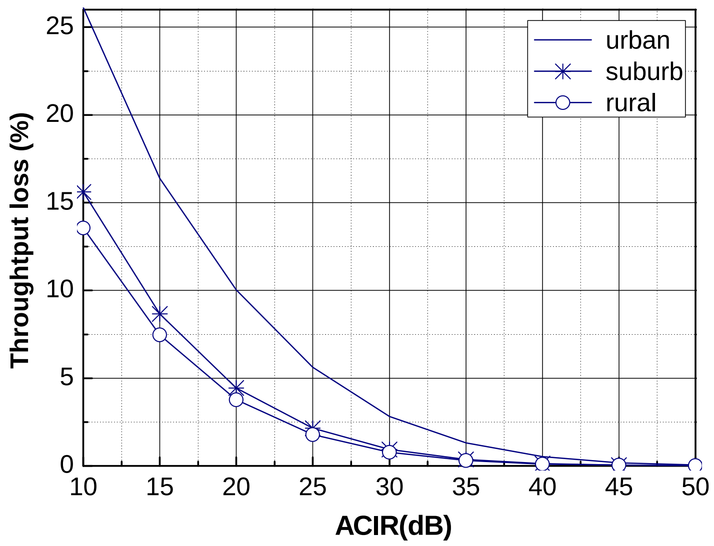
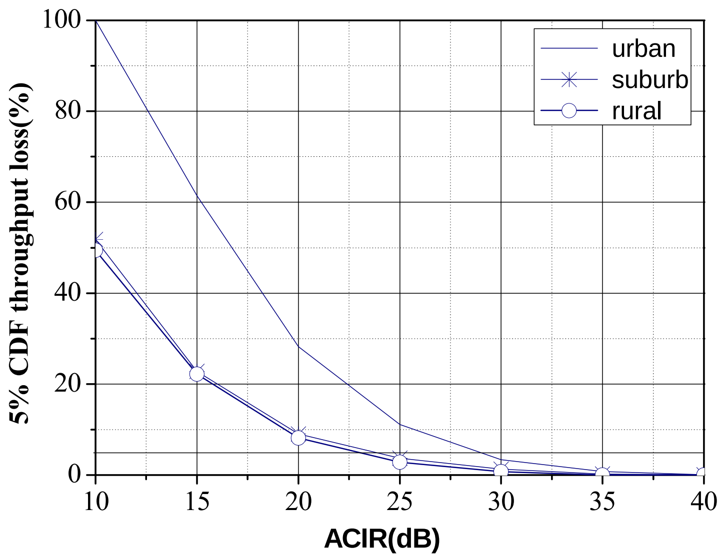


FIGURE 4.1.2.2-4

5 MHz LTE, Co-area, 5% CDF throughput loss



4.1.2.3 Case: UE to UE interference in macro cell

Lower than 0.1 % in all cases of Average and 5% CDF (cumulative distribution function) throughput loss.

FIGURE 4.1.2.3-1

5 MHz LTE, Co-sited, average throughput loss

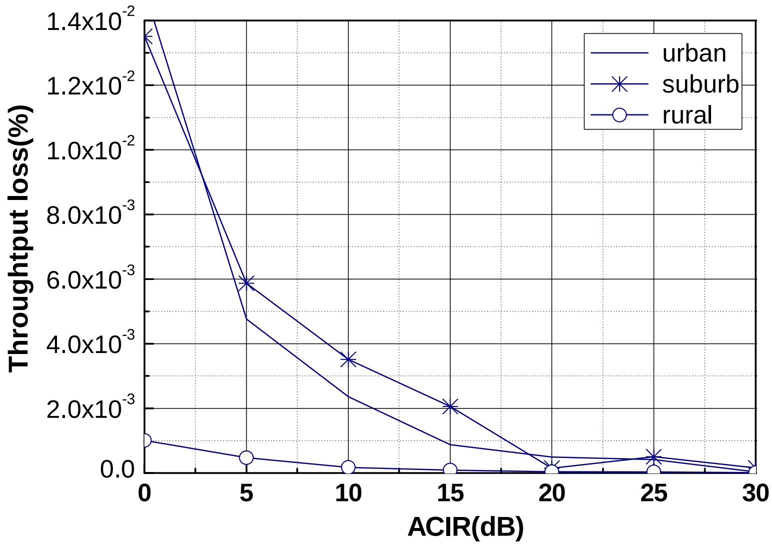


FIGURE 4.1.2.3-2

5 MHz LTE, Co-sited, 5% CDF throughput loss

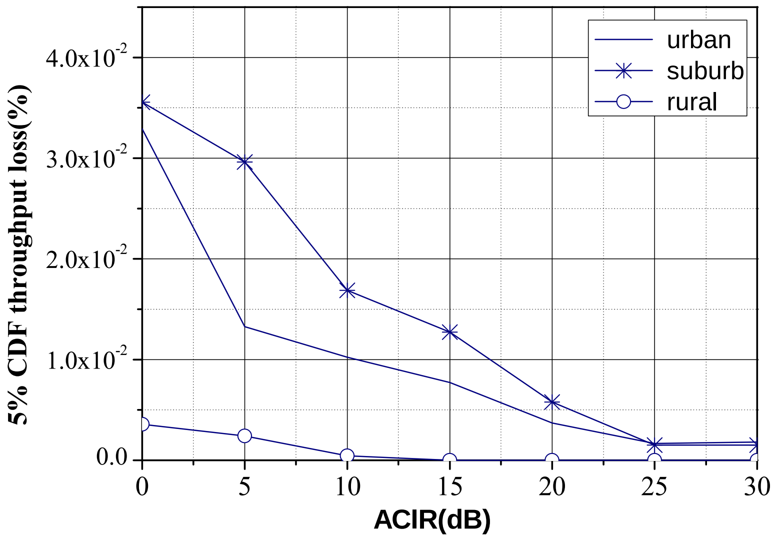


FIGURE 4.1.2.3-3

5 MHz LTE, Co-area, average throughput loss

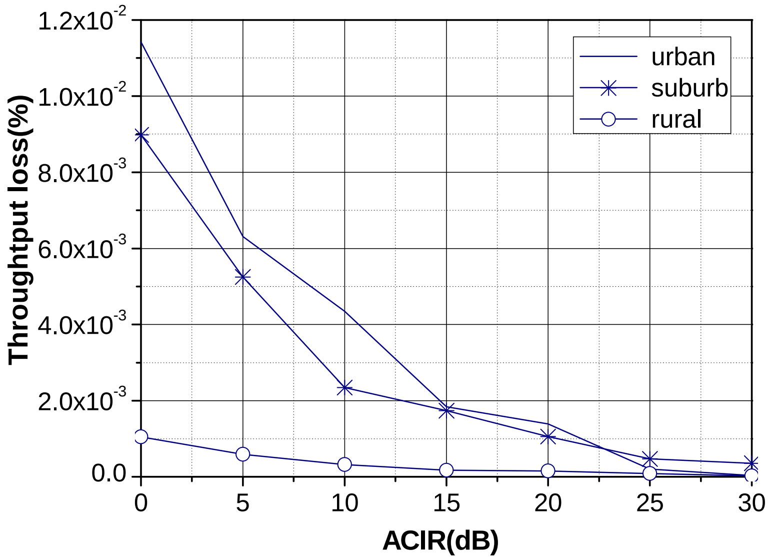
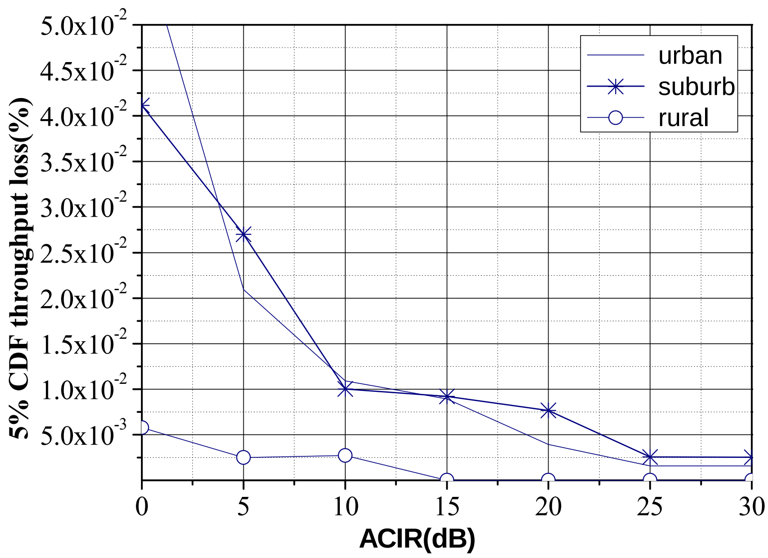


FIGURE 4.1.2.3-4

5 MHz LTE, Co-area, 5% CDF throughput loss



4.1.2.4 Case: UE to UE interference in hotspot scenario

TABLE 4-5

Average throughput loss

25 m hotspot radius				50 m hotspot radius			
BTS Co-sited		BTS Co-area		BTS Co-sited		BTS Co-area	
ACIR (dB)	Avg. throughput loss (%)	ACIR (dB)	Avg. throughput loss (%)	ACIR (dB)	Avg. throughput loss (%)	ACIR (dB)	Avg. throughput loss (%)
10	8.7	10	9.7	10	5	10	5
15	7	15	7.2	15	3.1	15	3.1
17.5	4.8	17.5	5.	20	1.9	20	1.9
20	3.75	20	3.8	25	1	25	1
25	2.5	25	2.5	30	0.8	30	0.8

TABLE 4-6

5% CDF throughput loss

25 m hotspot radius				50 m hotspot radius			
BTS Co-sited		BTS Co-area		BTS Co-sited		BTS Co-area	
ACIR (dB)	5% CDF throughput loss (%)	ACIR (dB)	5% CDF throughput loss (%)	ACIR (dB)	5% CDF throughput loss (%)	ACIR (dB)	5% CDF throughput loss (%)
15	14.7	15	11.7	10	28	10	28
20	32	20	33	15	15.6	15	15.4
25	10	25	10	20	9.8	20	9.6
30	5	30	5	25	5	25	5
35	0.6	35	0.6	30	2.7	30	2.5

FIGURE 4-14

25 m hotspot radius, average throughput loss

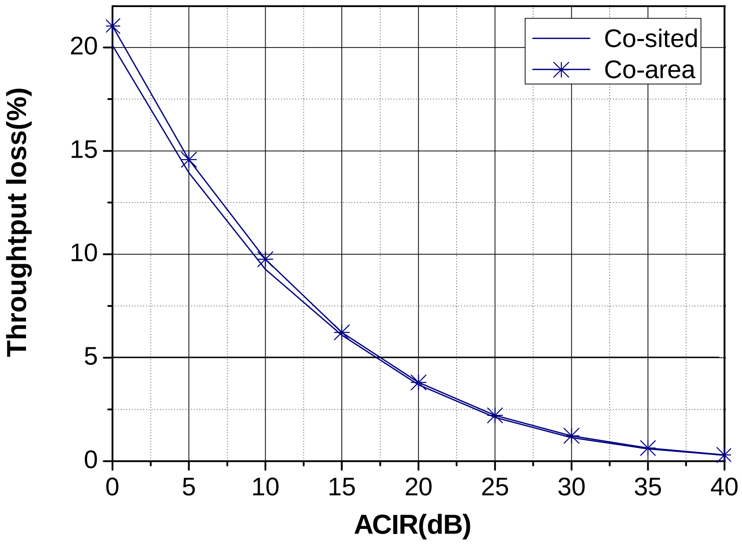


FIGURE 4-15

25 m hotspot radius, 5% CDF throughput loss

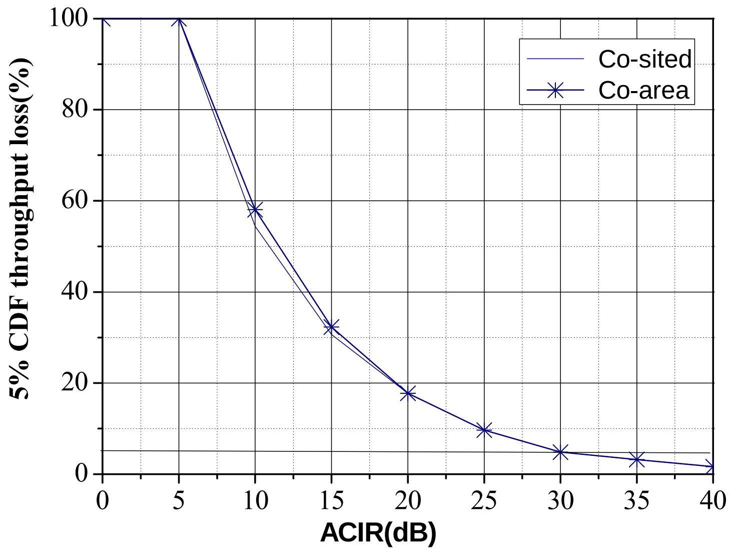


FIGURE 4-16

50 m hotspot radius, average throughput loss

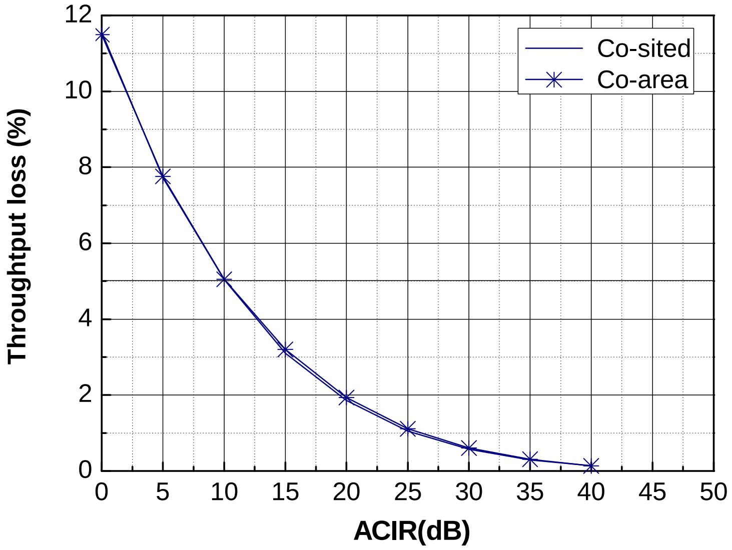
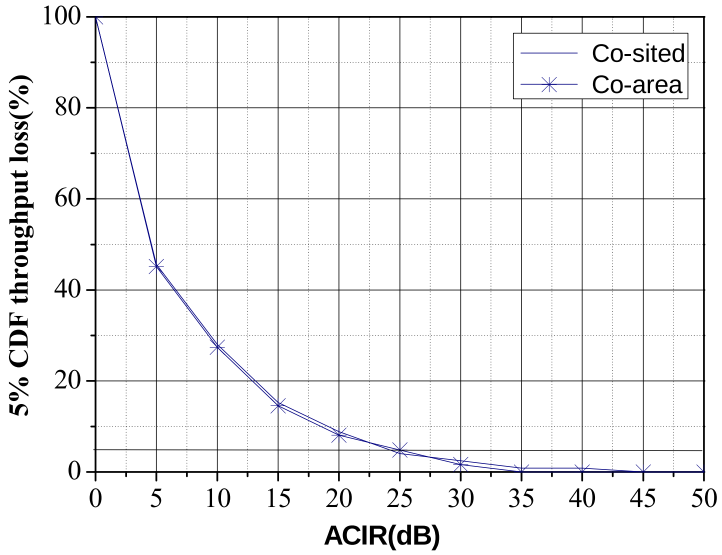


FIGURE 4-17

50 m hotspot radius, 5% CDF throughput loss



4.2 Summary

The above section provides the interference analysis of BTS to UE, UE to BTS and UE to UE interference and additional isolations needed for successful compatibility. The key observations are summarized as following:

BTS to UE interference

According to Tables 4-1 and 4-2, the throughput loss will decrease with the increase of ACIR. When the ACIR value is small, the 5% CDF (the edge use) throughput loss is far greater than the system average. As ACIR gradually increases, the 5% CDF throughput loss gets closely to the average value. The simulation results show that in all scenarios the requirements of an average throughput loss <5% are met when ACIR is 25 dB, and the 5% CDF throughput loss <5% when ACIR is 31 dB. These ACIR conditions are met even with a 0 MHz guard band, ACIR = 32.7 dB, with a small margin, and with an ample margin, ACIR = 37 dB, when the guard band is 5 MHz.

UE to BTS interference

According to Tables 4-3 and 4-4, with the increase of ACIR, the throughput loss will decrease, and the 5% CDF throughput loss gets closely to the average value. The interference is more severe in the urban scenario, where the requirements of an average throughput loss <5% are met when ACIR is 26 dB, and, the 5% CDF throughput loss <5% when ACIR is 29 dB in both co-sited and co-area scenarios. These ACIR conditions are met both with 0 and 5 MHz guard bands, with ACIR values of 29.9 and 35.9 dB, respectively.

UE to UE interference in macro-cell

According to Figure 4-10 to Figure 4-13, it is shown that, in macro networks and with urban, suburban and rural user densities, interference among UEs is negligible.

UE to UE interference in hotspot

According to Tables 4-5 and 4-6, the interference among UEs in hotspots is more severe, i.e., the throughput loss is higher in the hotspot scenario than in macro-cells. The effect of the interference is also more severe in the case of smaller hotspot radius: for a 25 m radius the requirement of an average throughput loss < 5% is met when ACIR is 17.5 dB, and that of a 5 % CDF throughput loss < 5% when ACIR is 30 dB, in both co-sited and co-area scenarios. With 0 MHz guard band, ACIR = 28.2 dB, the ACIR condition of 5 % CDF users is not met. However, both ACIR conditions are met with a 5 MHz guard band, ACIR = 33.8 dB with 3.8 dB margin.

Based on review of the foregoing study results, the common mitigation methods are proposed hereby.

TABLE 4.2

The additional isolation and mitigation options between IMT system in UHF band

Scenarios	Additional isolation(dB)	Mitigation options
BTS to UE	-	
UE to BTS	-	
UE to UE	1.8 (hotspot)	5 MHz guard band
BTS to BTS	78.9(Co-sited) 41.9(Co-area)	**Co-site:** 5 MHz guard band With appropriate RF filter about 65 dB band-edge roll-off attenuation at 5 MHz at IMT BTS. With space isolation e.g. through vertical isolation. **Co-area:** 5 MHz guard band With appropriate RF filter about 40 dB band-edge roll-off attenuation at 5 MHz at IMT BTS

According to the results and analysis, LTE FDD and TDD systems using 5 MHz channels can coexist successfully in adjacent bands with a combination of 5 MHz guard-band, appropriate RF filters and some additional mitigation methods in the engineering field.

5 Compatibility studies between different IMT systems and other mobile systems

5.1 interference impact from PPDR/LMR mobile station to WiMAX

5.1.1 MCL requirement

MCL is determined to make sure that the interfered with receiver does not experience unacceptable interference with protection criteria of "I/N = –6 dB". The following table provides the MCL requirement results for different interference scenarios. Antenna gains in both Tx and Rx have not been taken into account.

The blocking effect is not considered in this study.

Guard band of 3 MHz from 803 to 806 MHz is assumed in this section. It should be noted that this guard clearly appears in the IMT FDD frequency arrangement A5 but not in the IMT TDD frequency arrangement.

Case 3 (see figure 3.2.1): PPDR/LMR MS Tx→ WiMAX BTS Rx

Case 4 (see figure 3.2.1): PPDR/LMR MS Tx→ WiMAX MS Rx

The MCL Requirements for

LMR MS Tx→WiMAX BTS Rx case 3 equal 89 dB

LMR MS Tx→WiMAX MS Rx case 4 equal 86 dB

5.1.2 Distance separation

TABLE 5.1.2-1

Case 3 path-loss requirement

4A: LMR MS Tx→WiMAX BTS Rx		**Path-loss requirement in dB (spurious emission)**	**Distance separation in km or additional isolation in dB**
Analogue 12.5 kHz	Handheld	101.2	0.42 km or 20.0 dB
	Vehicular	102.2	0.44 km or 21.0 dB
Analogue 16 kHz	Handheld	101.2	0.42 km or 20.0 dB
	Vehicular	102.2	0.44 km or 21.0 dB
Analogue 25 kHz	Handheld	101.2	0.42 km or 20.0 dB
	Vehicular	102.2	0.44 km or 21.0 dB
Digital 12.5 kHz	Handheld	101.2	0.42 km or 20.0 dB
	Vehicular	102.2	0.44 km or 21.0 dB
Digital 25 kHz	Handheld	101.2	0.42 km or 20.0 dB
	Vehicular	102.2	0.44 km or 21.0 dB

TABLE 5.1.2-2

Case 4 path-loss requirement

3B: LMR MS Tx→WiMAX MS Rx		**Path-loss requirement in dB (spurious emission)**	**Distance separation in km or additional isolation in dB**
Analogue 12.5 kHz	Handheld	86.2	0.06 km or 35.6 dB
	Vehicular	87.2	0.06 km or 36.6 dB
Analogue 16 kHz	Handheld	86.2	0.06 km or 35.6 dB
	Vehicular	87.2	0.06 km or 36.6 dB
Analogue 25 kHz	Handheld	86.2	0.06 km or 35.6 dB
	Vehicular	87.2	0.06 km or 36.6 dB
Digital 12.5 kHz	Handheld	86.2	0.06 km or 35.6 dB
	Vehicular	87.2	0.06 km or 36.6 dB
Digital 25 kHz	Handheld	86.2	0.06 km or 35.6 dB
	Vehicular	87.2	0.06 km or 36.6 dB

5.1.3 Discussion and mitigation techniques

In this study, worst case scenario is assumed

– Tx at its maximum power.

– Out-of-band emission or spurious emission just meets the least requirement.

However, in the reality, MS does not transmit at its maximum power for most of the time. Out-of-band emission and spurious emission are likely better than the least requirements.

Case 3: PPDR/LMR MS Tx→WiMAX BTS Rx

Combination of physical separation and additional RF filtering can meet the requirement for limiting the interference from PPDR/LMR MS Tx to WiMAX BTS Rx to an acceptable level.

Case 4: PPDR/LMR MS Tx→WiMAX MS Rx

Combination of physical separation and additional RF filtering can meet the requirement for limiting the interference from PPDR/LMR MS Tx to WiMAX MS Rx to an acceptable level.

5.1.4 Summary

Statistically the probability of WiMAX MS and PPDR/LMR MS are in the most adjacent channels and are in the close proximity is very small. Assuming there are 20 WiMAX TDD 5 MHz channels and 560 PPDR/LMR channels, the probability of WiMAX MS being in the upper most channels and PPDR/LMR MS being in one of the lowest 100 channels is about 0.9%. Another point is that due to TDD and OFDMA technology WiMAX MS does not transmit all the time. So, the severe interference of this scenario only happens with very low probability.

5.2 Protection of LTE base stations (BTS) from PPDR base stations and vice versa in the 790-862 MHz band in Region 1

5.2.1 Protection of LTE and PPDR base stations based on I/N = –6 dB

5.2.1.1 Field-strength levels for the protection of BTS receivers

The following formula is taken from Recommendation ITU-R-M.1767:

Field strength (dB(μV/m)) = $-37 + F + I/N - G_i + L_f + 10 \times \log (B_i) + P_o + 20 \times \log f + I/N$

where:

F: receiver noise figure of the mobile service base or mobile station receivers (dB);

B_i: the BW of the terrestrial interfering stations (MHz); for 790-862 MHz, use Bi = 5 MHz;

G_i: the receiver antenna gain of the station in the mobile service (dBi);

L_F: antenna cable feeder loss (dB);

f: centre frequency of the interfering station (MHz);

P_o: man-made noise (dB) (typical value is 1 dB for the VHF band and 0 dB for the UHF band);

I/N: criterion of interference to land mobile receiver system noise ratio (dB), Rec. ITU-R M.1767. I/N = −6 dB is equivalent to 1 dB increase of the base station receiver noise floor.

Recommendation ITU-R M.1767 provides typical values of F, G_i, L_F and P_o.

The receiver thermal noise power KTBF at non-loss isotropic antenna for a bandwidth BW = 5 MHz and Noise Figure (F) of 5 dB equals −114+7 +5 = **−102 dBm**; and −**108 dBm**, for I/N –6 dB; these are the power levels at the BTS receiver input, to protect the IMT-LTE, DIMRS and Project 25, for 5 MHz[24] reference signal. To include Gi(dBi) = 15 and LF(dB) = 3, we get power protection level Pr = −108 dBm-12 dB = **−120 dBm**.

The conversion of the field strength (dBμV/m) to power (dBm) assuming an Isotropic Antenna is given by:

$$P_r = \frac{E^2 \, g\lambda^2}{Z_0 4\pi} = \frac{E^2 g c^2}{480\pi^2 f^2}$$; P(dBm)= E(dBμV/m) - 77.21 - 20Log f (MHz).

Table 5.2.1 provides typical values of the parameters and calculation results, when applying the above equations to derive field-strength values, to protect a BTS receivers at RF 790-862 MHz.

TABLE 5.2.1.1-1

IMT-LTE and PPDR parameters to derive the field strength protecting base stations

	IMT--LTE BTS,[25]	**DIMRS**	**Project 25**
Center Frequency 790-862 (MHz)	826	826	
F (dB)	5	5	6
G_i (dBi)	15	15	11
L_F (dB)	3	3	5
Bi (MHz)	5	5	
P_o (dB)	0	0	
$F - G_i + L_F + P_o$	−7	−7	**0**
Power on Isotropic antenna (dBm)	**−120**	**−120**	**−113**
Field strength (dBμV/m);	**15**	**15**	**22**

5.2.1.2 Assumptions needed to derive protection distance

This section provides assumptions to derive distances to protect LTE base stations from PPDR base stations and vice versa in the 790-862 MHz band.

[24] The sensitivity is derived from the Rx bandwidth BW; a smaller BW is compensated by getting only part of the 5 MHz interfering signal; so the real receiver BW is disregarded in calculating interference.

[25] Attachment 2 "Generic set of parameters for IMT in the band 790-862 MHz to be used for sharing studies called for under WRC-12 Agenda item 1.17".

When calculating propagation loss, it is necessary to take into consideration terrestrial landscape (see also RRC06-Chapter 2 to Annex 2). Typical characteristics of IMT BTS and PPDR BTS transmitters, which are used for the study on sharing the band 790-862 MHz between radio services, are specified in Table 5.2.4.3.

- **Time variability**

The propagation curves represent the field-strength values exceeded for 50%, 10% and 1% of time. This estimation is based on 10% of time curves for land zone and 20% for pure warm-sea.

- **Aggregation of interference from base stations**

In this study aggregation of 1 for Project 25 and 10 transmitters for DIMRS and LTE is considered.

- **Characteristics of IMT-LTE and PPDR to estimate the protection distance**

Table 5.2.1.2-1 specifies the parameters needed to calculate the distance to protect BTS receiver interfered from BTS transmitter of different system.

TABLE 5.2.1.2-1

Characteristics to estimate protection distances between IMT-LTE and PPDR

MS system type	**IMT-LTE**	**DIMRS**	**Project 25**
Typical transmitter e.i.r.p. (dBm)	55	47 (per channel)	53 (per channel)
Channel bandwidth (MHz)	5	0.025	
Number of channels per cell	1	10	10
Antenna gain(dBi)	15	15	11
Antenna radiation pattern, horizontal plane	Three-sector; 65°	Three-sector; 65°	Omni
Total composite transmitter e.i.r.p. (dBm)	55	57	63
Antenna height (m)	20	20	37.5
% of locations	50		
Terrain type between member states - per RRC06-FinalAct–ch2 to Annex 2	Warm sea- Zone 4; Land – Zone 1		
Transmit Ant. height above average terrain per RRC06-FinalAct–ch2 to Ann 2 (m)	20	20	37.5
Receive antenna height per RRC06-FinalAct–ch2 to Annex 2 (m)	20	20	37.5
Number of transmitter sites aggregation	10	10	1

5.2.1.3 Distances to protect IMT-LTE BTS receivers from PPDR BTS transmitters

The protections distances are derived from the field strengths of section 5.2.1.1.

TABLE 5.2.1.3-1

Distances to protect IMT-LTE BTS receivers from PPDR BTS transmitters

	Protection of IMT-LTE	
PPDR system	DIMRS	Project25
Field strength dB (μV/m)	15	
Warm sea Zone 4 (km)	385	360
Land Zone 1 (km)	195	170
Affected sub band (MHz)	851-862	

5.2.1.4 Distances to protect PPDR BTS receivers from IMT-LTE BTS transmitters

The protections distances are derived from the field strengths of section 5.2.1.1.

TABLE 5.2.1.4-1

Distances to protect PPDR BTS receivers from IMT-LTE BTS transmitters

	Protection of PPDR	
PPDR type	DIMRS	Project25
Field strength dB (μV/m)	15	22
Warm sea Zone 4 (Km)	360	350
Land Zone 1 (Km)	175	170
Affected sub band (MHz)	806-821	

5.2.2 Distances estimated based on CEPT ECC Rec(11)04

In section 5.2.1,the protection distances were estimated using the field strength of 15 dBμV/m/5 MHz for IMT-LTE & DIMRS, 22 dBμV/m/5 MHz for Project25 at the base station antenna height (20 m for IMT-LTE & DIMRS, 37.5 m for Project25) with a 10 dB aggregation factor for IMT-LTE & DIMRS, which might be considered as conservative in some cases.

Recommendation ECC(11)04 recommends the following field strength for the cross-border operation between TDD MFCN(mobile fix communication network) systems and between TDD MFCN and FDD MFCN systems in the frequency band 790-862 MHz.

Stations of MFCN systems may be operated without bilateral agreement if the mean field strength of each carrier produced by the base station does not exceed a value of 15 dBμV/m/5 MHz at 10% time, 50% of locations at 3 metres above ground level at the borderline.

Using the system parameters given in Table 5.2.1.2-1 and the field strength recommended in Recommendation ECC(11)04, the distances between IMT-LTE and DIMRS/Project25 are calculated with the propagation model taken Recommendation ITU-R P.1546 (10% time and 50% locations); the results are summarised in Tables 5.2.2-1 and 5.2.2-2.

TABLE 5.2.2-1

Estimated distances to border (Land) based on the field strength in ECC Rec(11)04

	Distance based on single base station (BTS)	Distance based on aggregate base stations (BTS's)
Distance from LTE BS to Borderline (km)	30	55
Distance from Project25 BS to Borderline (km)	57	57
Distance from DIMRS BS to Borderline (km)	33	60

TABLE 5.2.2-2

Estimated distances between systems (Land) based on the field strength in ECC Rec(11)04

	Distance based on single base station (BTS)	Distance based on aggregate base stations (BTS's)
Distance between LTE and Project25 (km)	87	112
Distance between LTE and DIMRS (km)	63	115

These distances are different from those in the section 5.2.1due to the different calculation method.

In a sea area, where the borderline between two neighboring countries is not clearly defined, the ECC REC(11)04 may not be applicable without mutual agreement.

In the case of warm sea area, the distances presented in the previous sections (5.2.1.3-1 and 5.2.1.4-1) may be considered.

5.3 Mitigation techniques

The following techniques can be considered:

– Lowering antenna heights (effective, above ground level and above sea level) and/or down tilting the BTS antenna.

– Splitting the frequency bands into preferential frequencies, where operation on the non-preferential frequencies may be interfered. For instance, splitting the 2x30 MHz into two equal 2x15 MHz bands, where IMT LTE will be preferential at the lower RF band, 791-806/832-847 MHz, and PPDR will be preferential at the upper RF band, 806-821/847-862 MHz.

6 Compatibility studies between IMT and broadcast services

6.1 Result of statistical approach for compatibility study between LTE and ATSC in UHF band

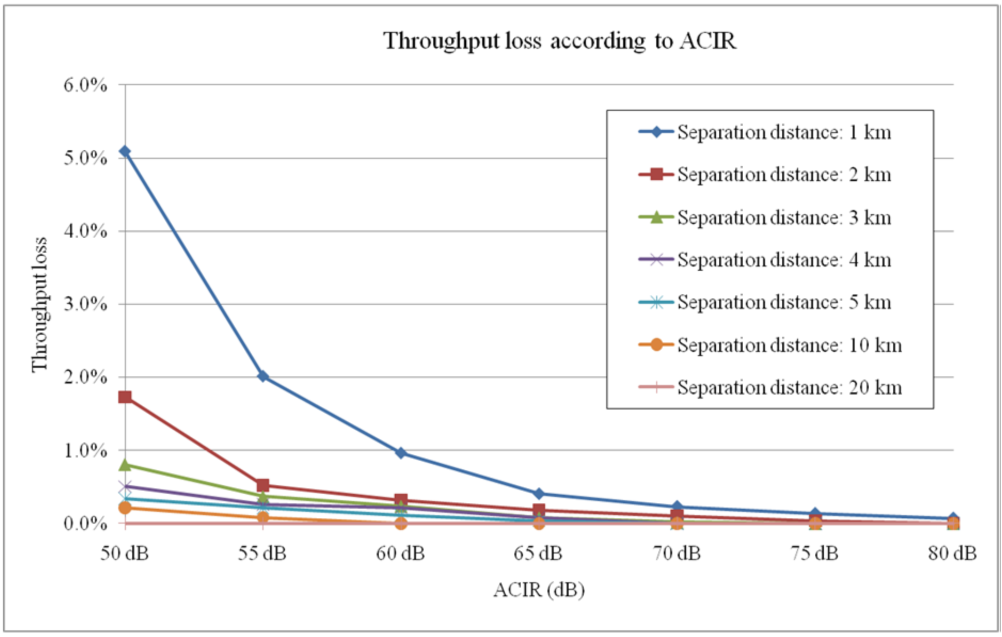
6.1.1 Simulation results

This simulation derives the throughput loss of LTE cells at a given distance from an ATSC transmitter.

Figure 6.1.1-1 shows the throughput loss of a LTE BTS caused by an ATSC transmitter for given separation distances for different values of the ACIR.

FIGURE 6.1.1-1

Throughput loss of LTE Cells at the given distance from ATSC transmitter according to ACIR



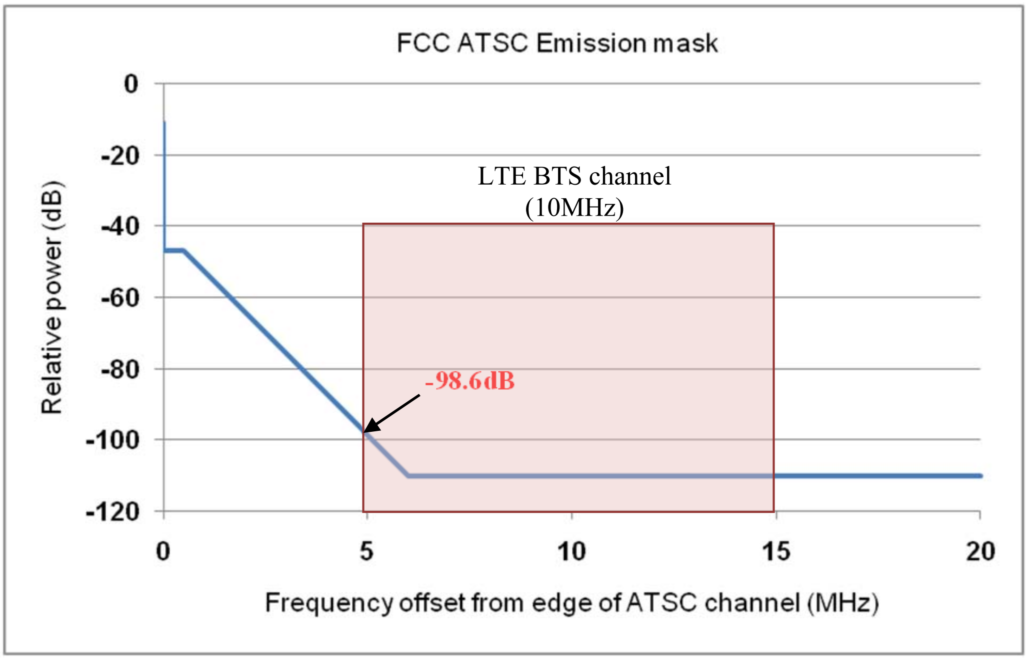
The largest performance degradation of the LTE downlink due to an ATSC transmitter is caused with a separation distance of 1 km. The throughput loss of the LTE cell within the range of 1 km separated from the ATSC transmitter is 2% with a 55 dB value for the ACIR. But the throughput loss of the LTE cell within the range of more than 2 km separated from the ATSC transmitter is less than 1% with a 55 dB ACIR. Specially, when the ACIR is more than 80 dB or the separation distance with an ACIR above 50 dB is more than 20 km, the ATSC transmitter does not cause a significant performance degradation of the LTE uplink.

The ACLR and ACS values for the LTE system are defined in the 3GPP LTE base station standards. The ATSC standard A64 was used for the ATSC system. The ACIR for the ATSC standard was calculated as given below.

The emission mask of the ATSC transmitter is described in Figure 6.1.1-2. The attenuation of the ATSC transmitter at 5 MHz frequency offset from the LTE BTS channel is –98.6 dB. The ACLR of the ATSC transmitter at 10 MHz offset from the LTE BTS channel is calculated as –104 dB by integrating the curve given in Figure 6.1.1-2 below.

FIGURE 6.1.1-2

The antenna discrimination between ATSC Tx and LTE base station Rx according to the distance



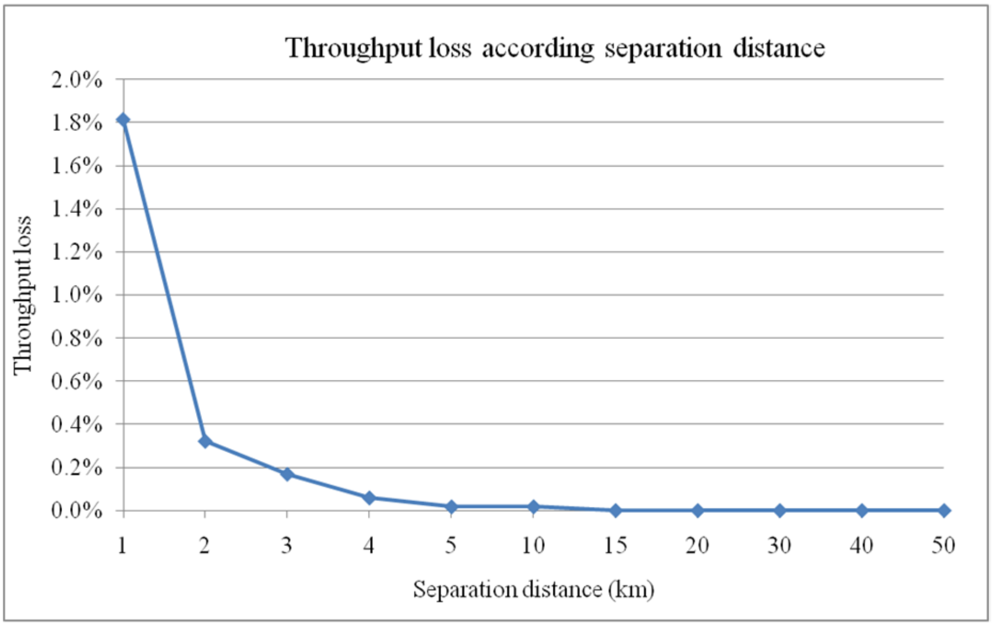
The ACS of the LTE UE to the adjacent LTE channel with the same channel bandwidth is defined as 46 dB in 3GPP TS 36.104. If it is assumed that the 5 MHz frequency offset guarantees 10 dB more than that of 3GPP specification, the ACS of the LTE BTS to the ATSC channel at 5 MHz frequency offset to the LTE channel is 56 dB. The ACIR from a ATSC transmitter to a LTE BTS receiver is 56 dB with a 104 dB ACLR value for the ATSC transmitter and 56 dB ACS for the LTE BTS receiver.

Figure 6.1.1-3 shows the throughput loss for the LTE system based on ACLR and ACS values defined in the 3GPP standards (ACIR = 56 dB) as a function of the separation distance between an ATSC transmitter and a LTE BTS. When the LTE BTS is separated from the ATSC transmitter by 1 km, the throughput loss of the LTE uplink is less than 2%. When the separation distance between the ATSC transmitter and the LTE BTS is 15 km or more, the LTE BTS shows no performance degradation due to the ATSC transmitter.

FIGURE 6.1.1-3

Throughput loss of a LTE system based on ACLR and ACS values defined in the

3GPP LTE standards (ACIR = 56 dB)



6.1.2 Summary

This section introduce a methodology to analyze the realistic interference from an ATSC transmitter to LTE UE and addressed how much performance degradation of the LTE uplink the ATSC transmitter causes. It is concluded that these results can be utilized as a good example to assess how much performance degradation an ATSC transmitter causes based on the ATSC and LTE standards, "how close to the ATSC transmitter the performance degradation of the LTE BTS occurs , and so on.

6.2 Compatibility studies results on DTMB system interfering with LTE TDD in the same geographical area

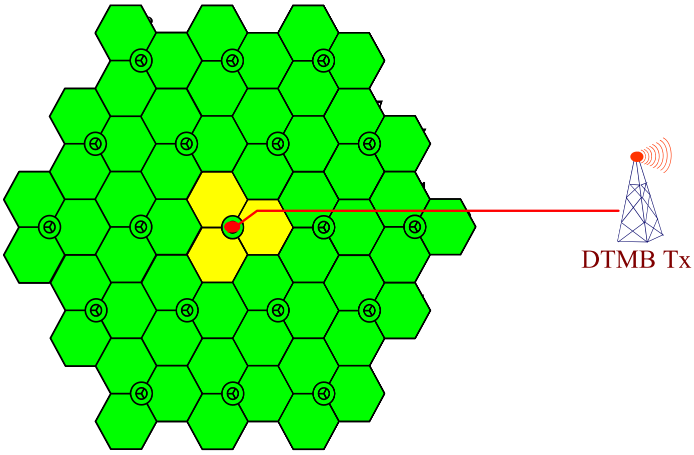
6.2.2 Simulation results

6.2.2.1 Simulation results by static statistical approach

This section provides simulation results via static statistical approach as presented in section 3.3.1.2. In the following simulation, the DTMB Tx is co-located with the central LTE BS as indicated in Figure 6.2.2.1.

FIGURE 6.2.2.1

Network topology indicating the location of DTMB Tx



6.2.2.1.1 Static statistical results for Case 1

FIGURE 6.2.2.1.1

Throughput loss of LTE TDD system under various ACIR in urban/rural environments as DTMB transmitter interfering with LTE TDD BS receiver via static statistical approach

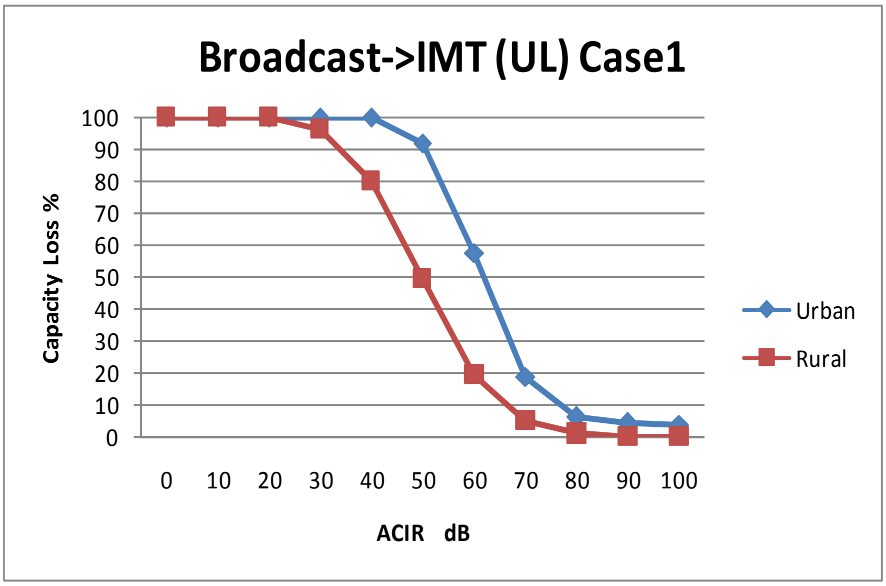


Figure 6.2.2.1.1 illustrates the overall capacity loss of the LTE TDD system for various ACIR values in urban/rural environments when the DTMB transmitter is interfering with LTE TDD BS receiver. To meet the criterion that the LTE TDD throughput loss does not exceed 5%, the ACIR values should not be less than 85 dB for the urban environment and should not be less than 71 dB for the rural environment.

6.2.2.1.2 Static simulation results for Case 2

FIGURE 6.2.2.1.2

Throughput loss of LTE TDD system under various ACIR in urban/rural environments as DTMB transmitter interfering with LTE TDD MS receiver via static statistical approach

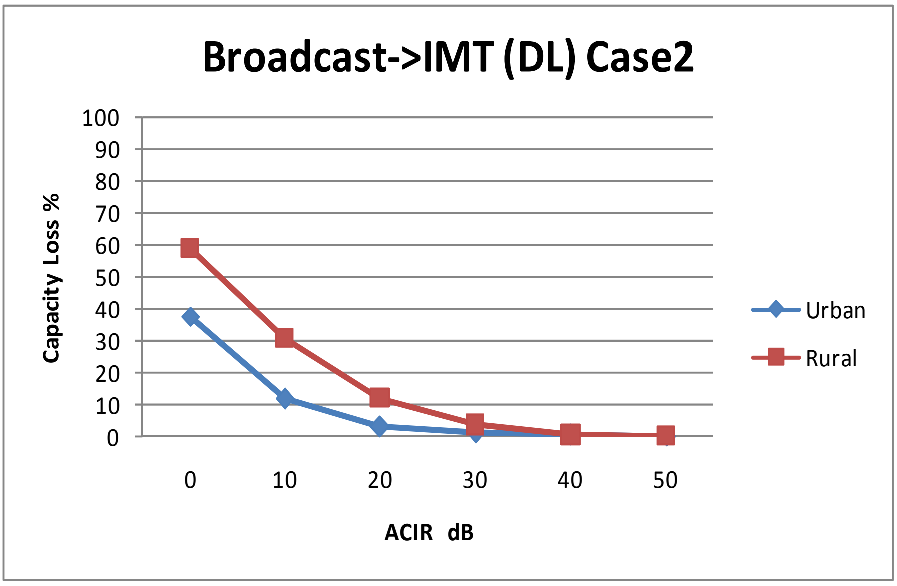


Figure 6.2.2.1.2 illustrates the overall throughput loss of the LTE TDD system under various ACIR in urban/rural environments when the DTMB transmitter interferes with the LTE TDD MS receiver. The horizontal minimum distance between the DTMB Tx and the LTE UE in the simulation is set as 30 m. To meet the criterion that the LTE TDD throughput loss does not exceed 5%, the ACIR values should not be less than 18 dB for the urban scenario and should not be less than 28 dB for rural scenario.

6.2.2.1.3 Remarks

The additional isolation values are calculated below based on the static simulation results above and the equivalent ACS, ACLR values in section 3.3.2.5.3.

TABLE 6.2.2.1.3-1

Additional isolation requirement for Case 1

Guard Band (MHz)	Urban		Rural	
	Additional equivalent ACLR requirement (dB)	Additional equivalent ACS requirement (dB)	Additional equivalent ACLR requirement (dB)	Additional equivalent ACS requirement (dB)
0 MHz	23.93	38.25	9.93	24.25
1 MHz	17.82	37.4	3.82	23.4
2 MHz	13.06	36.35	0	22.35
3 MHz	8.89	34.82	0	20.82
4 MHz	0	32.39	0	18.39
5 MHz	0	28.25	0	14.25
6 MHz	0	27.4	0	13.4
7 MHz	0	26.35	0	12.35
8 MHz	0	24.96	0	10.96
9 MHz	0	22.89	0	8.89
10 MHz	0	20	0	6

TABLE 6.2.2.1.3-2

Additional isolation requirement for Case 2

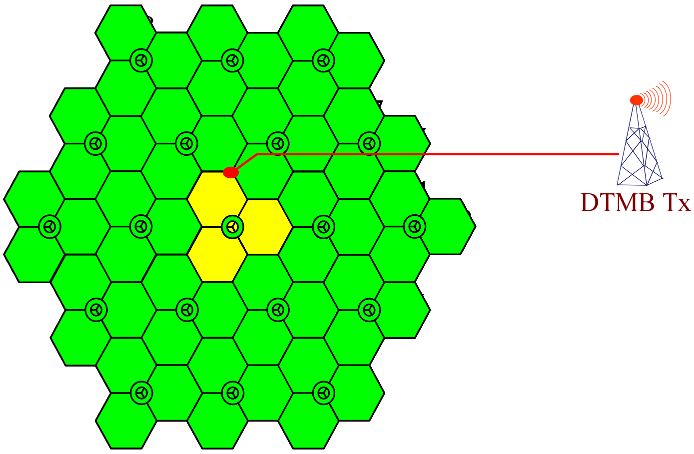
Guard Band (MHz)	Urban		Rural	
	Additional equivalent ACLR requirement (dB)	Additional equivalent ACS requirement (dB)	Additional equivalent ACLR requirement (dB)	Additional equivalent ACS requirement (dB)
0 MHz	0	0	0	0

6.2.2.2 Simulation results by dynamic statistical approach

This section provides simulation results via the dynamic statistical approach as presented in Section 3.3.1.3. In the following simulation, the DTMB Tx is located at the cell border of the central LTE BS and two adjacent BSs as indicated in Figure 6.2.2.2.

FIGURE 6.2.2.2

Network topology indicating the location of DTMB Tx



6.2.2.2.1 Dynamic statistical results for Case 1

FIGURE 6.2.2.2.1

Throughput loss of LTE TDD system under various ACIR in urban/rural environments as DTMB transmitter interfering with LTE TDD BS receiver via dynamic statistical approach

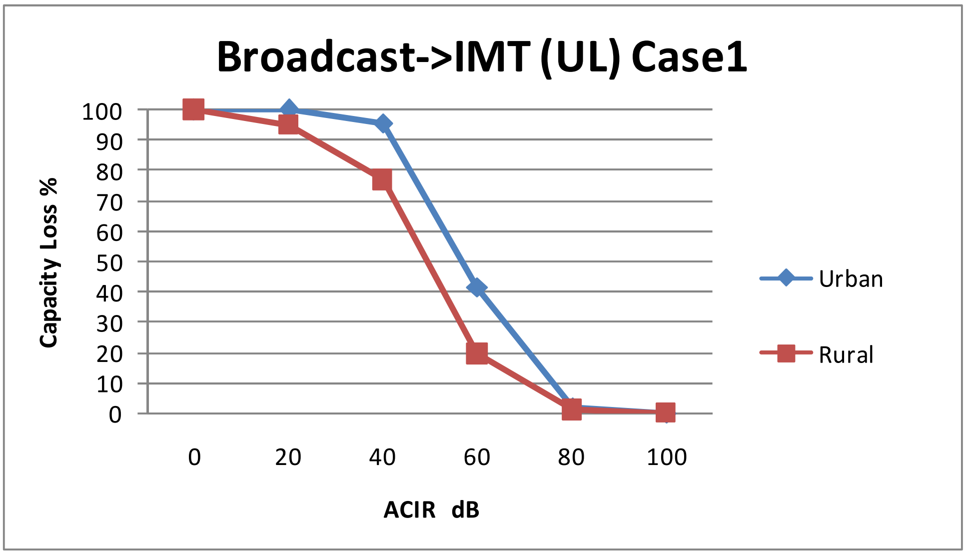


Figure 6.4.2.2.1 illustrates the overall throughput loss of the LTE TDD system under various ACIR in urban/rural environments when the DTMB transmitter interferes with LTE TDD BS receiver. To meet the criterion that the LTE TDD throughput loss does not exceed 5%, the ACIR values should not be less than 79 dB for urban environment and should not be less than 75 dB for rural environment.

6.2.2.2.2 Dynamic statistical results for Case 2

FIGURE 6.2.2.2.2

Throughput loss of LTE TDD system under various ACIR in urban/rural environments as DTMB transmitter interfering with LTE TDD MS receiver via dynamic statistical approach

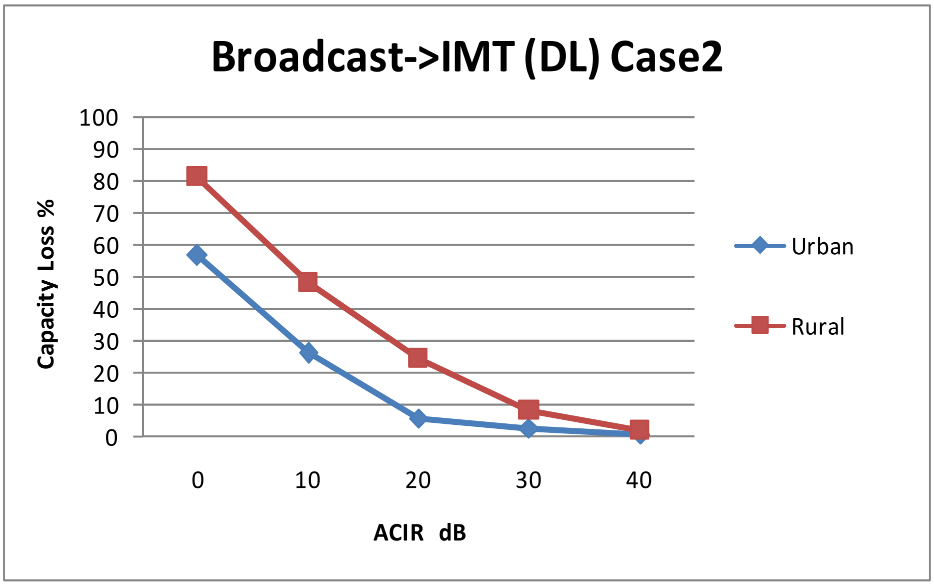


Figure 6.2.2.2.2 illustrates the overall throughput loss of the LTE TDD system under various ACIR in urban/rural environments when the DTMB transmitter interferes with the LTE TDD MS receiver. The horizontal minimum distance between the DTMB Tx and LTE UE in the simulation is set as 30 m. To meet the criterion that the LTE TDD throughput loss does not exceed 5%, the ACIR values should not be less than 21 dB for urban environment and should not be less than 35 dB for rural environment.

6.2.2.2.3 Remarks

The dynamic simulation results above show that additional ACLR/ACS isolation may be needed to meet the requirements of coexistence between the two systems under certain scenarios. The additional isolation values are calculated below based on the simulation results above and the equivalent ACS, ACLR values in section 3.3.2.5.3.

Case 1: DTMB transmitter interfering with LTE TDD BS receiver

Case 1	Urban		Rural	
Guard-band (MHz)	Additional equivalent ACLR requirement (dB)	Additional equivalent ACS requirement (dB)	Additional equivalent ACLR requirement (dB)	Additional equivalent ACS requirement (dB)
0	17.9	32.2	13.9	28.2
1	11.8	31.4	7.8	27.4
2	7.1	30.3	3.1	26.3
3	2.9	28.8	0	24.8
4	0	26.4	0	22.4
5	0	22.2	0	18.2
6	0	21.4	0	17.4
7	0	20.3	0	16.3
8	0	19	0	15
9	0	16.9	0	12.9
10	0	14	0	10

Case 2: DTMB transmitter interfering with LTE TDD MS receiver

Case2	Urban		Rural	
Guard-band (MHz)	Additional equivalent ACLR requirement (dB)	Additional equivalent ACS requirement (dB)	Additional equivalent ACLR requirement (dB)	Additional equivalent ACS requirement (dB)
0	0	0	0	0.6
1	0	0	0	0

____