

International Telecommunication Union

**ITU-R**  
Radiocommunication Sector of ITU

**Report ITU-R M.2374-0**  
(07/2015)

**Coexistence of two time division duplex  
networks in the 2 300-2 400 MHz band**

**M Series**  
**Mobile, radiodetermination, amateur  
and related satellite services**

**150**  
ITU  
1865-2015



## Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

The regulatory and policy functions of the Radiocommunication Sector are performed by World and Regional Radiocommunication Conferences and Radiocommunication Assemblies supported by Study Groups.

## Policy on Intellectual Property Right (IPR)

ITU-R policy on IPR is described in the Common Patent Policy for ITU-T/ITU-R/ISO/IEC referenced in Annex 1 of Resolution ITU-R 1. Forms to be used for the submission of patent statements and licensing declarations by patent holders are available from <http://www.itu.int/ITU-R/go/patents/en> where the Guidelines for Implementation of the Common Patent Policy for ITU-T/ITU-R/ISO/IEC and the ITU-R patent information database can also be found.

### Series of ITU-R Reports

(Also available online at <http://www.itu.int/publ/R-REP/en>)

Series	Title
<b>BO</b>	Satellite delivery
<b>BR</b>	Recording for production, archival and play-out; film for television
<b>BS</b>	Broadcasting service (sound)
<b>BT</b>	Broadcasting service (television)
<b>F</b>	Fixed service
<b>M</b>	<b>Mobile, radiodetermination, amateur and related satellite services</b>
<b>P</b>	Radiowave propagation
<b>RA</b>	Radio astronomy
<b>RS</b>	Remote sensing systems
<b>S</b>	Fixed-satellite service
<b>SA</b>	Space applications and meteorology
<b>SF</b>	Frequency sharing and coordination between fixed-satellite and fixed service systems
<b>SM</b>	Spectrum management

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

*Electronic Publication*  
Geneva, 2015

© ITU 2015

All rights reserved. No part of this publication may be reproduced, by any means whatsoever, without written permission of ITU.

## REPORT ITU-R M.2374-0

**Coexistence of two time division duplex networks in the 2 300-2 400 MHz band**

(2015)

## TABLE OF CONTENTS

	<i>Page</i>
1 Introduction & Scope.....	2
2 Coexistence modes and interference scenarios for LTE-Advanced TDD operating in adjacent spectrum blocks.....	2
3 Parameters of LTE-Advanced TDD system in the band 2 300-2 400 MHz and propagation models used for interference analysis.....	4
3.1 Deployment-related parameters for LTE-Advanced TDD systems in 2 300-2 400 MHz.....	4
3.2 Specification-related parameters for LTE-Advanced TDD systems in 2 300-2 400 MHz.....	6
3.3 Propagation models used in the interference analysis .....	7
4 Interference analysis .....	7
4.1 BS to BS interference analysis .....	7
4.2 UE-UE interference .....	11
4.3 Synchronization of TDD mobile networks without guard band.....	15
5 Summary of results.....	16
5.1 Summary of BS-BS interference analysis .....	16
5.2 Summary of UE-UE interference analysis .....	16
6 Overall conclusions .....	17
6.1 Measures for coexistence of synchronized LTE-Advanced TDD systems in adjacent channels.....	17
6.2 Measures for coexistence of unsynchronized LTEAdvanced TDD systems in adjacent channels.....	17
Annex 1 Abbreviations .....	19
Annex 2 Propagation models .....	20

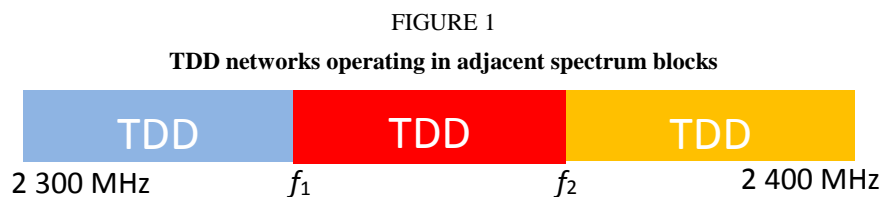
## 1 Introduction & Scope

The band 2 300-2 400 MHz was identified for IMT for Regions 1, 2 and 3 at WRC-07 in accordance with the Footnote **5.384A** in the Radio Regulations, stating that “The bands, or portions of the bands, 1 710-1 885 MHz, 2 300-2 400 MHz and 2 500-2 690 MHz, are identified for use by administrations wishing to implement International Mobile Telecommunications (IMT) in accordance with Resolution **223 (Rev.WRC-07)\***.” The Recommendation ITU-R M.1036 – Frequency arrangements for implementation of the terrestrial component of International Mobile Telecommunications (IMT) in the bands identified for IMT in the Radio Regulations (RR), provides an un-paired arrangement, time division duplex (TDD) for the band 2 300 2 400 MHz. This band is used or is planned to be used for mobile broadband wireless access (BWA) including IMT technologies in a number of countries and there is a need for a study on coexistence of BWA systems, deployed in the same geographical area, using TDD mode in adjacent spectrum blocks in 2 300-2 400 MHz band in order to maximize the additional benefit from harmonized use of the band.

This Report uses the relevant parameters needed in interference studies mentioned in various ITU Recommendations, Reports and 3GPP technical specifications. The parameters assumed in this Report for the BWA including IMT technologies are those of LTE-Advanced TDD; no other IMT radio interfaces e.g. WiMAX have been considered. The interference problems are investigated by deterministic and statistical approaches, for the different scenarios. This report gives technical conclusions regarding the necessary measures to ensure coexistence between operators of LTE-Advanced TDD networks in 2 300-2 400 MHz band.

## 2 Coexistence modes and interference scenarios for LTE-Advanced TDD operating in adjacent spectrum blocks

LTE-Advanced TDD uses unpaired spectrum whereby the same frequency channel is used for transmission and reception, and signals are timed for uplink and downlink. Separation between uplink and downlink occurs in the time domain. TDD allows asymmetry of the uplink and downlink data rates, i.e. number of uplink time slots and downlink time slots in a radio time frame may be different.



NOTE: The above figure is just an example, numbers & sizes of TDD blocks and guard bands between them vary in this band.

When more than one TDD system operates in adjacent spectrum blocks and the systems are deployed in the same geographic areas, synchronization of the adjacent TDD networks can prevent cross-cell interference. 3GPP0 [2] has defined “synchronized operation” as “Operation of TDD in two different systems, where no simultaneous uplink and downlink occur”, which means that BSs/ UEs in same geographical area may have to transmit and receive in the same time. More precisely, this means: 1) synchronizing the beginning of the frame (phase synchronization); 2) aligning the frame structure, i.e. configure the length of the frame and the TDD uplink/downlink ratio so that all transmitters stop transmitting before any other starts receiving (the frame length and TDD ratio do not need to be exactly identical provided this condition is met).

When TDD networks operating in adjacent spectrum blocks are unsynchronized, severe interference may occur. Out-of-band and spurious emissions from the transmitter may prevent one or more receivers in an adjacent spectrum block from operating properly. A similar interference situation may arise if a UE in one network is transmitting while UEs using an adjacent spectrum block are receiving.

The table below describes available options for LTE UL/DL configurations as defined in 3GPP TS 36.211. In this table, “D” means DL data transmission, “U” means UL data transmission and “S” signifies a special field, containing DwPTS (down link pilot time slot), GP (guard period) and UpPTS (uplink pilot time slot).

TABLE 1  
LTE-Advanced TDD UL/DL configurations

Uplink/downlink configuration	Downlink-to-uplink switch-point periodicity	Subframe number									
		0	1	2	3	4	5	6	7	8	9
0	5 ms	D	S	U	U	U	D	S	U	U	U
1	5 ms	D	S	U	U	D	D	S	U	U	D
2	5 ms	D	S	U	D	D	D	S	U	D	D
3	10 ms	D	S	U	U	U	D	D	D	D	D
4	10 ms	D	S	U	U	D	D	D	D	D	D
5	10ms	D	S	U	D	D	D	D	D	D	D
6	5 ms	D	S	U	U	U	D	S	U	U	D

The UL/DL configuration chosen by a particular operator will depend upon the relationship between uplink and downlink traffic in a particular geographical area. This asymmetry in UL/DL traffic may depend upon types of services being used by end-users, distribution of users etc. In LTE-Advanced TDD systems operating in adjacent spectrum blocks, interference occurs when UL transmission overlaps DL transmission due to non ideal radio frequency characteristics. A special subframe “S” serves as a switching point between downlink to uplink transmission. It contains three fields – downlink pilot time slot (DwPTS), guard period (GP) and uplink pilot time slot (UpPTS). To address the switching from uplink to downlink transmission, no special subframe is provisioned, but the GP includes the sum of switching times from DL to UL and UL to DL. The switching from UL to DL is achieved by appropriate timing advance at the UE. GP (guard period) may depend upon size of cell and may be different for different operators. The usage of different special subframe format configurations by the operators in adjacent slots will not cause any interference issues.

When LTE-Advanced TDD networks operating in adjacent bands use different UL/DL configurations, interference arises, as illustrated in Fig. 2-1. At the same time, timing synchronization of the frame/sub-frame i.e., full alignment of the frames and sub frames of both adjacent TDD systems is also required, as otherwise there may be interference due to misalignment as shown in Fig. 2-2.

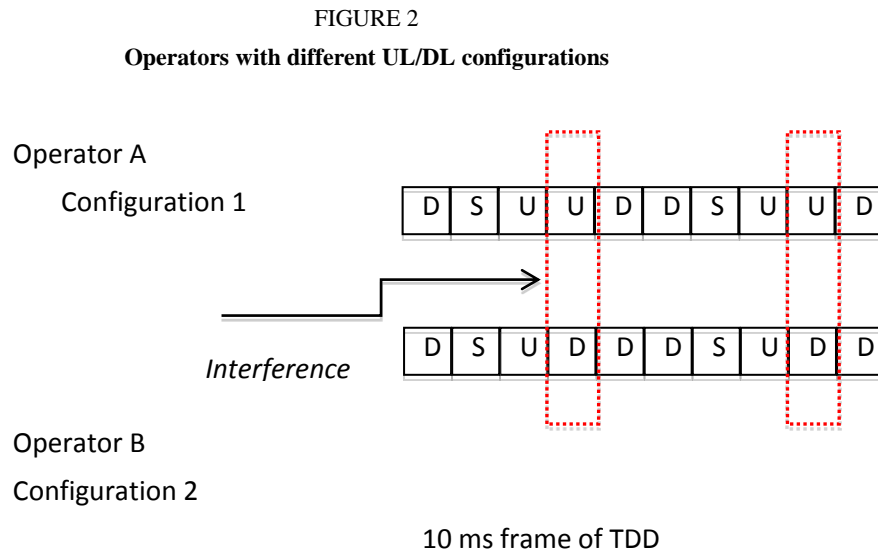
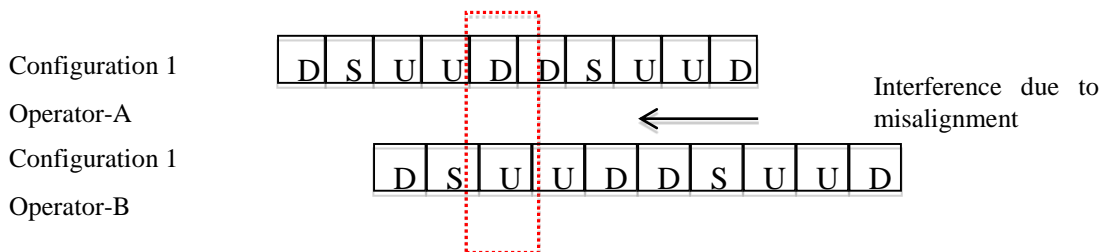


FIGURE 3  
Operators with the same UL/DL configuration but misalignment



In case two TDD networks are unsynchronized, there are four possible scenarios of harmful interference. (1) BS to BS interference: The most critical scenario in case of unsynchronized networks is BS to BS interference, as it is relatively static (i.e. persists for a long period of time) and affects a large number of users. It potentially has an impact on all users of both the systems that interfere with each other; (2 and 3) BS/UE to UE/BS interference: The interference between BS and UE is seen as less critical since the UE and BS have been designed to avoid interference. The interference in this case is equivalent to that between UE and BS in a FDD scenario; (4) UE to UE interference: The UE to UE scenario becomes more random and unpredictable.

### 3 Parameters of LTE-Advanced TDD system in the band 2 300-2 400 MHz and propagation models used for interference analysis

#### 3.1 Deployment-related parameters for LTE-Advanced TDD systems in 2 300-2 400 MHz

Base station and user terminal parameters [1] of LTE-Advanced TDD system are shown in the following table.

TABLE 2

## Deployment-related parameters for LTE-Advanced TDD systems in 2 300-2 400 MHz

	Macro rural	Macro suburban	Macro urban
Cell radius/ Deployment density (for bands between 2 and 3 GHz)	> 2 km (typical figure to be used in sharing studies 4 km)	0.4-2.5 km (typical figure to be used in sharing studies 0.8 km)	0.2-0.8 km (typical figure to be used in sharing studies 0.4 km)
Antenna height	30 m	25 m	20 m
Sectorization	3 sectors	3 sectors	3 sectors
Downtilt	3 degrees	6 degrees	10 degrees
Frequency reuse	1	1	1
Antenna pattern	Recommendation ITU-R F.1336 ( <i>recommends</i> 3.1) $k_a = 0.7$ $k_p = 0.7$ $k_h = 0.7$ $k_v = 0.3$ Horizontal 3 dB beamwidth: 65 degrees Vertical 3 dB beamwidth: determined from the horizontal beamwidth by equations in Recommendation ITU-R F.1336. Vertical beamwidths of actual antennas may also be used when available.		
Antenna polarization	Linear/±45 degrees	Linear/±45 degrees	Linear/±45 degrees
Below rooftop base station antenna deployment	0%	0%	50%
Feeder loss	3 dB	3 dB	3 dB
Maximum base station output power (5/10/20 MHz)	43/46/46 dBm	43/46/46 dBm	43/46/46 dBm
Maximum base station antenna gain	18 dBi	16 dBi	16 dBi
Maximum base station output power/sector (EIRP)	58/61/61 dBm	56/59/59 dBm	56/59/59 dBm
Average base station activity	50%	50%	50%
Average base station power/sector taking into account activity factor	55/58/58 dBm	53/56/56 dBm	53/56/56 dBm

TABLE 3

**Deployment related parameters for LTE Advanced TDD systems UE characteristics  
in 2 300-2 400 MHz**

	Macro rural	Macro suburban	Macro urban
Indoor user terminal usage	50%	70%	70%
Indoor user terminal penetration loss	15 dB	20 dB	20 dB
User terminal density in active mode	0.17/ 5 MHz/km <sup>2</sup>	2.16/ 5 MHz/km <sup>2</sup>	3/5 MHz/km <sup>2</sup>
Maximum user terminal output power	23 dBm	23 dBm	23 dBm
Average user terminal output power	2 dBm	-9 dBm	-9 dBm
Typical antenna gain for user terminals	-3 dBi	-3 dBi	-3 dBi
Body loss	4 dB	4 dB	4 dB

### 3.2 Specification-related parameters for LTE-Advanced TDD systems in 2 300-2 400 MHz

The specification-related parameters used in this study are summarized below.

TABLE 4

**Specification-related parameters used in this study**

	Parameter	Description	Values	Remarks
BS	ACLR	Wide Area BS/	45 dB	Table 6.6.2-1 in [2]
	ACS	Wide Area BS	Interfering signal mean power: -62.6 dBm	Table 7.5.1-3 in [2] and a recalculation of allowed interfering signal (with 1 dB degradation)
UE	ACLR	-	30 dB	Table 6.6.2.3.1-1 in 0 [3]
	ACS	-	33 dB (up to 10 MHz channel bandwidth) 30 dB (BW = 15 MHz) 27 dB (BW = 20 MHz)	Table 7.5.1-1 in [3]



### 3.3 Propagation models used in the interference analysis

The following table summarizes the propagation models applied in this study. The detailed description of each propagation model can be found in Annex 1.

TABLE 5

Transmission scenarios and relevant propagation models

Transmission scenario	Analysis methods	Propagation model	Reference
BS Tx→ BS Rx	Deterministic analysis	P.1546	Recommendation ITU-R P.1546-5 [6]
BS Tx→ UE Rx	Simulation analysis	Modified Hata	Recommendation ITU-R P.1546-5 [6]
UE Tx→ UE Rx	Deterministic analysis	Free space	Recommendation ITU-R P.525-2 [13]
UE Tx→ UE Rx	Simulation analysis	P.1411-7	Recommendation ITU-R P.1411-7 [8]

## 4 Interference analysis

### 4.1 BS to BS interference analysis

The BS to BS case bears the most significant interference when two TDD networks are unsynchronized in adjacent frequency bands. As the interference scenario is static, deterministic analyses were performed to obtain isolation requirement with some MCL assumptions. Besides, the BS to BS interference affected area in absence of additional isolation measure is also evaluated.

#### 4.1.1 Isolation requirement for Macro BS

The isolation requirement for Macro BS is estimated considering the output power of BS, values of ACLR, OOBE, ACS as per specifications in the relevant recommendations. The isolation requirement calculation in this table has not taken into account effects due to propagation environment, antenna characteristics, antenna arrangements, additional RF filtering etc.

TABLE 6

## Isolation requirement for transmitter and receiver

Lable	Parameter	Values			Units	Description
		0	2.5	5		
A	Guardband	0	2.5	5	MHz	
B	Channel bandwidth	20			MHz	
C	BS output power	33			dBm/MHz	46 dBm/ 20 MHz = 33 dBm/MHz (BS transmitting power)
D	ACLR	45			dB	
E	BS OOBE	-12			dBm/MHz	$c - d = -12 \text{ dBm/ MHz}$ (BS output Power) – (ACLR)
F	Noise floor	-109			dBm/MHz	$-174 \text{ dBm/Hz} + 60 +$ $5 \text{ dB}$ BS noise figure 5 dB
G	Maximum allowable OOBE signal level at the receiver	-115			dBm/MHz	$f - 6 \text{ dB}$ $I/N = -6 \text{ dB}$
H	Isolation requirement at the antenna ports at the transmitter side	-103			dB	$g - e$
I	Maximum allowable interfering signal level for adjacent channel selectivity (ACS) or blocking	-69.6	-69.6	-60.6	dBm/MHz	$62.6 \text{ dBm/5MHz} =$ $-69.6 \text{ dBm/MHz}$ Interfering signal level for ACS $53.6 \text{ dBm/5MHz} =$ $-60.6 \text{ dBm/MHz}$ Interfering signal level for blocking requirement under 5 MHz guardband
J	Isolation requirement at the antenna ports the receiver side	102.6	102.6	93.6	dB	$i - c$

Since the same filter is used for both transmitting and receiving for TDD BS, the additional isolation requirement is the maximum value of transmitter and receiver requirements, which is 103 dB.

#### 4.1.1.1 Isolation by additional radio frequency attenuation with different MCL cases

The isolation requirement between unsynchronized BSs needs to be satisfied by additional radio frequency attenuation. The table below presents the isolation requirements with some typical MCL assumptions. Also in the table, some examples are provided to address how one particular MCL is obtained, According to 0 [6], one MCL value could be obtained with various antenna space isolation solutions, e.g., horizontal space isolation, vertical space isolation, or a combination of both.

TABLE 7  
Additional Filter Requirements for different MCL cases

Cases	MCL value (dB)	Examples to obtain certain MCL values	Additional isolation requirement for guardband from 0 to 5 MHz	Equivalent BS radio frequency requirement for each MCL assumption (dBm/MHz)
1	30	For co-location of BSs, MCL of 30 dB can be considered as a typical value for operators who have rather independent deployment between antennas.  According to [5], for example, 0.33m horizontal space separation for 0 dB gain in the direction of the other antenna can achieve 30 dB MCL value.	73	-85
2	50	For co-location of BSs, MCL of 50 dB could normally be achieved by proper BSs deployment between two operators.  According to [5], for example, 3.3 m horizontal space isolation with 0 dB gain in the direction of the other antenna, or 0.5 m vertical space isolation can achieve 50 dB MCL value.	53	-65
3	67	For co-area location of BSs, MCL of 67 dB is considered as the reference scenario for macro BS to macro BS interference for operation in the same geographic area [11].  According to [11], 67 dB could be achieved by around 288 m distance separation between two BSs.	36	-48

As seen from the table above, with an MCL of 50 dB, an additional filter attenuation of 53 dB is needed at the BS, which leads to the BS radio frequency requirement to be -65 dBm/MHz. Further, it may be noted that a decrease in guard band would increase complexity for a BS filter production.

#### 4.1.1.2 Interference affected area by unsynchronized macro BS

This section is to evaluate the interference affected area caused by unsynchronized BSs. As calculated below, without any additional RF improvement, one BS could influence unsynchronized BSs operating in adjacent spectrum block in an area with a radius of. 2.4 to 5.3 km depending on the propagation environment.

TABLE 8  
Interference affected distance by unsynchronized macro BS

Lable	Parameter	Values	Units	Description	
A	Guardband	0   2.5   5	MHz		
H	Isolation requirement at the antenna ports	103	dB	This value is exclusive of antenna gains and feeder loss	
K	Antenna gain assumptions between interfering and interfered BSs (including feeder loss)	20	dB	(16dB–3dB) + (16dB–3dB) –6 dB= 20 dB –6 dB Reduction in effective antenna gain due to antenna tilt, while interfering and interfered antenna horizontal main beams are pointing to each other	
L	Isolation requirement	123	dB	Isolation requirement to determine the separation distance for non-co-located BSs	
M	Affected distance	Urban	2.4	km	Based on 0 [7], with 50% time percentage and 50% location probability
		Suburban	3.9		
		Rural	5.3		

It should be noted that proper site coordination to avoid antenna main beams pointing to each other may largely reduce the affected distance. However, site coordination may not always be guaranteed in realistic network deployment.

#### 4.1.2 Discussion

Interference caused by unsynchronized BSs could be severe and affect a large area of BSs without additional mitigation measures. Additional radio frequency attenuation at the BSs is necessary to mitigate the interference. For example, when an MCL of 50 dB is achieved between BSs in the network deployment, an additional RF attenuation of 53 dB is needed at the BSs, which actually results in a BS radio frequency specification to be –65 dB/MHz. Inevitably, an additional guard band is needed to realize sufficient roll-off of filter to meet the baseline. The precise size of guard band may be chosen so that complexity of the filter is acceptable. Site coordination could be another way to bring down the interference. However, site coordination may not always be realizable in large area and high density network deployments.

## 4.2 UE-UE interference

For UE evaluation, which have locations that are not fixed by the network operators, worst-case locations for the UEs were considered by deterministic analysis, with the UEs transmitting at maximum power. Besides, in order to capture dynamic features such as power control and more realistic user behavior in terms of location, a statistical analysis is necessary to draw the final conclusion, in addition to the more straightforward deterministic analysis [13].

### 4.2.1 Deterministic analysis

This section describes a deterministic approach (i.e., a minimum coupling-loss analysis) for the calculation of the additional isolation requirement for UE to UE interference in an unsynchronized case.

TABLE 9  
Deterministic analysis for UE-UE interference in the worst case

Lable	Parameter	Values			Units	Description
a	Guardband	0	2.5 MHz	5 MHz	MHz	
b	Channel bandwidth	20			MHz	
c	UE maximum output power	10			dBm/MHz	23 dBm/20 MHz =10 dBm/MHz
d	Typical antenna gain for user terminals	-3			dBi	
e	Body loss	4			dB	
f	ACLR	30			dB	
g	ACS	27			dB	
h	ACIR	25.24			dB	
i	UE transmitting emission at the receiving UE	-29.24			dBm/MHz	$c + d + d - e - e - h$
j	Noise floor	-105			dBm/MHz	$-174 \text{ dBm/Hz} + 60 + 9 \text{ dB}$
						UE noise figure 9 dB
k	Allowable interference level at the receiver	-111			dBm/MHz	$f - 6 \text{ dB}$
						$I/N = -6 \text{ dB}$
l	Transmission loss for 1 m	39.87			dB	Free space loss for 1 metre
m	Additional isolation requirement (1 m separation)	41.89			dB	$(i - l) - k$
l	Transmission loss for 2 m	45.89			dB	Free space loss for 2 metres
m	Additional isolation requirement (2 m separation)	35.87			dB	$(i - l) - k$
l	Transmission loss for 3 m	49.41			dB	Free space loss for 3 metres
m	Additional isolation requirement (3 m separation)	32.35			dB	$(i - l) - k$

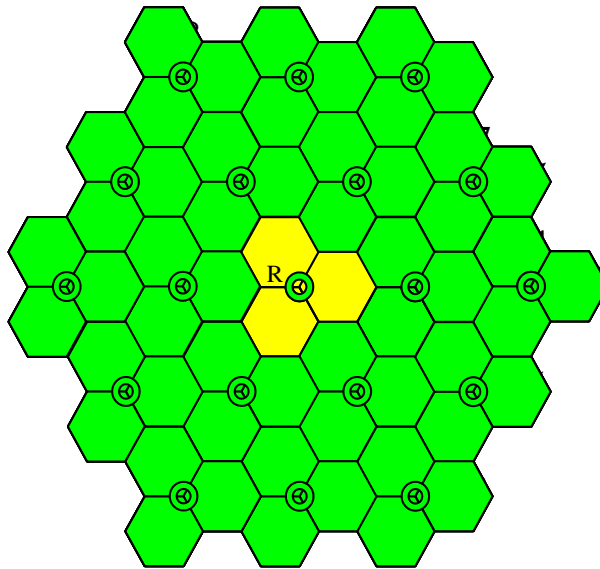
## 4.2.2 Simulation analysis

### 4.2.2.1 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 wrap-around technique is applied. Co-siting, where the BSs of one system are co-located in the same sites of the other system, is considered in this study.

FIGURE 4  
Topology of one LTE system



#### 2) Scheduler

In the simulation, a round robin scheduler is used.

#### 3) Simulated services

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

#### 4) ACIR model

For uplink it is assumed that the ACIR is dominated by the UE ACLR. The ACLR model is referenced from [4].

#### 5) Power control

For the LTE system uplink, the following power control equation which refers from [4] shall be used for the 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:

$P_{max}$ : maximum transmit power

$R_{min}$ : minimum power reduction ratio to prevent UEs with good channels to transmit at very low power level

$PL$ : path loss for the UE

$PL_{x-ile}$ : 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,  $0 < \gamma \leq 1$  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 [4] is adopted in the simulation ( $\gamma = 1$ ,  $PL_{x-ile} = 115$ ).

6) User density

According to [1], the active user density applied in this simulation are 0.17/5 MHz/km<sup>2</sup> for macro rural, 2.16/5 MHz/km<sup>2</sup> for macro suburban, 3/5 MHz/km<sup>2</sup> for macro urban.

7) Protection criterion

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

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

where,  $TP_{ave-s}$  is the single system average throughput,  $TP_{ave-m}$  is the average throughput with interference.

#### 4.2.2.2 Simulation procedure

Step 1 Configure two LTE TDD systems deployment and initiate simulation parameter; the interfering system is set as uplink transmission and the victim system is set as downlink transmission;

Step 2 Distribute UEs of each system under certain density assumption and distribute UEs randomly and uniformly throughout the system area;

Step 3 Perform UE power control;

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

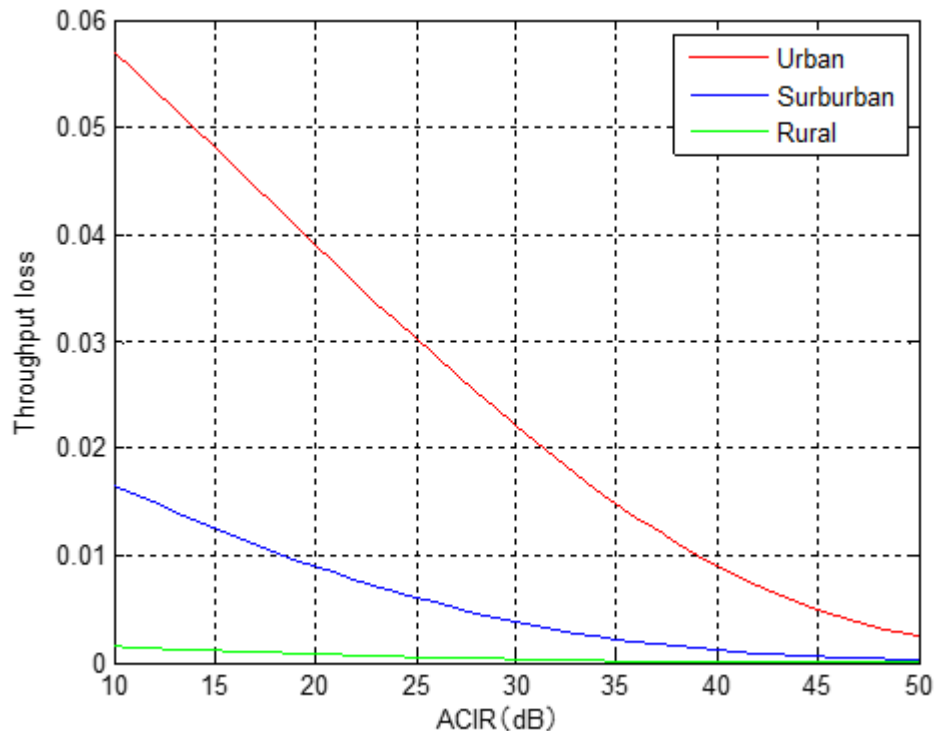
Step 5 Calculate the SINR of each link based on signal power, intra-system interference power, inter-system interference power and link gains, and calculate throughput of downlink of the victim system;

Step 6 Repeat 2 to 5 to collect statistical values.

### 4.2.2.3 Simulation results

FIGURE 5

Monte-Carlo simulation results for UEs uniformly distributed in macro networks and with Urban, Sub-urban and Rural user densities assumptions [1]



According to the Monte-Carlo simulation results, it is shown that when UEs are uniformly distributed in macro networks and with certain active user densities assumptions [1], interference from UEs to UEs in unsynchronized mode is almost negligible under current 3GPP specifications [3].

### 4.2.3 Hot spot area interference analysis

ECC Report 131 studied interference from TDD terminals in 3GPP band class 38 to FDD terminals in 3GPP band class 7. According to this report, the examined interference scenario is a macro-cellular urban network, where victim UEs are always located at the centre of a very densely populated hot-spot of interferers. The hot-spot scenario consists of an average of 2 simultaneously transmitting interferers in a 5 MHz block within a 25 m hot-spot. It was shown by the simulation that, taking into account the probability of collision between victim and interferer packets, when the out-of-band emissions of UE transmitter comply with a requirement of  $-22.5$  dBm/MHz, the impact of UE to UE interference is likely to be very limited. This result also applies to interference between adjacent unsynchronized TDD UEs. The RF requirement of  $-22.5$  dBm/ MHz means that an additional isolation requirement of about 7.5 dB (considering a basic ACIR of 25 dB) may be required to prevent interference in some densely populated hot-spot areas.



#### 4.2.4 Discussion

MCL analysis and simulations reflect two different aspects of UE to UE interference. On one hand, the MCL analysis shows that in a worst-case scenario where UEs are in close proximity and the interferer uses high power, there may be considerable interference from one UE to another, exceeding the interference limit by 30 - 40 dB. The MCL analysis does not account for the occurrence likelihood of close proximity between UEs, the usage of maximum power, Radio Block allocation, etc.

On the other hand, Monte Carlo simulations reflect the statistical aspects of the interference from one TDD network to another. Simulations of macro cells with homogeneous distributions of UEs show that the interference for such a scenario will be very low. However, simulations of interference experienced in a hot spot, with a high density of interfering UEs, indicate that an additional isolation of about 7 dB may be necessary to guarantee interference free operation, which leads to the UE RF requirement to be  $-22.5$  dBm/MHz. It should further be noted that the results are sensitive to the network assumptions. At the same time, new UE RF requirements would lead to a new band definition, and it may not be easily realized due to UE's internationally roaming nature.

#### 4.3 Synchronization of TDD mobile networks without guard band

In the case of two LTE-Advanced TDD systems operating in the adjacent spectrum blocks, one way to avoid all BS-BS and UE-UE interference without using a guard band and specific filtering is by maintaining the same timing resource for BS. Network synchronization is the most efficient way to realize TDD network coexistence in terms of maximization of spectrum utilization rate and avoids the need of additional filters.

*For achieving synchronization, when two TDD networks are operating in same geographic area, according to ECC-Report 216 on practical guidance on TDD network synchronization [12], all base stations that may interfere with each other (both within one operators network and between operators in the same frequency band) need to implement a common reference phase clock and configure compatible frame structures. GNSS, IEEE 1588 v2, and Over the air synchronization techniques are currently available for transmitting a reference phase/time clock.*

In order to deploy synchronised TDD networks in a multi-operator context (without guard bands), agreement needs to be reached on:

- A common phase clock reference and accuracy/performance constraints;

- A common UL/DL configuration ratio. For instance, considering latency aspects and asymmetry of traffic on DL side, configurations 1 & 2 are more preferable in case of higher requirements on delays and more traffic on downlink than uplink. Adjacent operators will require having same UL/DL configuration in one contiguous area e.g. 1:3 in urban area, 2:2 in rural area. However this will restrict flexibility of individual operators to choose a configuration as per its requirement. This ratio needs to be the same at the same time i.e. if at a later stage, both operators in adjacent spectrum blocks change to a different configuration but both with the same configuration, it can be done. National administrations need to decide on the possibility of implementation as per requirement and feasibility.

- Reliability of the reference clock and protection mechanism have to be ensured and/or a procedure when losing this reference clock has to be defined.

## 5 Summary of results

### 5.1 Summary of BS-BS interference analysis

The most critical interference scenario in unsynchronized TDD networks is BS to BS interference. This type of interference is relatively static and can affect a large area of services if no additional interference mitigation measures are used. Measures such as additional filtering, guard bands and site coordination can be used to ensure coexistence. The results of the BS-BS interference scenario analysis show that

- The additional isolation requirement to be obtained from propagation environment, antenna characteristics, antenna arrangements, additional RF filtering etc. is 103 dB. Isolation by additional filters may be dependent upon the MCL case, as discussed earlier, and may range from 36-73 dB. For example, when an MCL of 50 dB is achieved between BSs in the network deployment, an additional RF attenuation of 53 dB is needed at the TDD BSs operating in adjacent spectrum blocks.
- Without any additional RF improvement, one BS could influence the unsynchronized BSs operating in the adjacent spectrum block in an area with a radius of 2.4 to 5.3 km depending on the propagation environment. Proper site coordination may reduce the affected distance to some extent. However, site coordination may not always be guaranteed in realistic network deployment.
- In case of inter-operator synchronized LTE-Advanced TDD networks operating in adjacent channels, isolation requirements may be met without guard band, additional filter or additional site coordination.

In summary, if inter-operator networks are not synchronized, additional radio frequency attenuation at the BSs is necessary to mitigate the interference either by site coordination or by additional filters with appropriate guard band.

### 5.2 Summary of UE-UE interference analysis

The impact of UE-UE interference depends upon transmit power, resource allocation and proximity of the interfering UE. UE-UE interference may occur when victim and interferer UEs are in close proximity, active and both are in cell edge coverage conditions e.g. in conference rooms, crowded locations, railway stations, shopping malls, stadiums etc. The size of the affected area depends on the interfering UE transmit power, path loss, data rate and propagation environment. The results of the analysis of UE-UE interference scenarios show that:

- MCL analysis shows that in a worst-case scenario there may be interference in the order of 30-40 dB. However, the MCL analysis does not account for the occurrence likelihood of close proximity between UEs, the usage of maximum power, Radio Block allocation, etc. and simulation analysis is required to reflect the statistical aspects of the interference. UE-UE simulation analysis shows that the interference for such a scenario will be very low.
- UE to UE interference is relatively random and unpredictable. For most cases, interference between UEs is negligible under the common UE RF requirement defined in 3GPP [3].
- In some extreme hot-spot cases interference may occur. An additional isolation requirement of a few dB may be beneficial to reduce interference in some densely populated hot-spot areas. New UE RF requirements would lead to a new band definition, and it may not be easily realized due to UE's internationally roaming nature.

In summary, the analysis indicates that interference may occur when UEs are in close proximity but for most scenarios this interference will occur rarely. For UEs, additional filters are not a realistic means for reducing interference.

## 6 Overall conclusions

When LTE-Advanced TDD networks are operating in adjacent channels with insufficient guard band and without inter-operator network synchronization, severe interference is observed in the analysis. In case interference between adjacent LTE-Advanced TDD network operators is not addressed, it may impact the performance of the network in terms of peak data rate, latency etc. For coexistence, measures, which may be required to be taken are given below.

### 6.1 Measures for coexistence of synchronized LTE-Advanced TDD systems in adjacent channels

Two LTE-Advanced TDD systems can coexist in adjacent spectrum blocks in 2 300-2 400 MHz without a guard band and also without additional filter requirements than the present requirements of ACLR, ACS, OOBE in accordance with current relevant specifications, if the networks of the concerned operators are synchronized with same time source and have same UL/DL configuration. Network synchronization is the most efficient way to realize TDD network coexistence in terms of maximization of spectrum utilization rate and prevention of additional requirements on filters.

- Inter-operator synchronization of LTE-Advanced TDD systems is not part of this study, however, the matter has been studied and reports of various regional organization e.g. ECC 0 [9], and APT [14] are available. For synchronization, the same timing resource is required to be used by networks for BS Frame/Phase synchronization. There may be various options of implementing synchronization e.g. GNSS, IEEE 1588, Over the air synchronization for indoor base station etc. or a combination of these.
- The requirement of using the same UL/DL configuration for concerned operators for coexistence reasons may restrict flexibility of individual operators to choose from available options of UL/DL configurations. However, Configurations 1 & 2 may be more preferable options in case of higher requirements on delays and more traffic on downlink than uplink.

### 6.2 Measures for coexistence of unsynchronized LTE-Advanced TDD systems in adjacent channels

#### 6.2.1 BS –BS coexistence in case of unsynchronized LTE-Advanced TDD systems:

Unsynchronized LTE-Advanced TDD systems may co-exist in adjacent spectrum blocks by applying one or more of the following measures to reduce interference between base stations:

- **Frequency separation:** Interference into the networks of adjacent operators may be decreased by introducing guard bands. In this report it is not studied in detail how large such a guard band would need to be, though it is clear from previous studies (Reports ITU-R M.2146 0 [12], and ITU-R M.2113 0 [15]) that if this is used as a stand-alone solution, a large amount of spectrum would remain unused.
- **Additional filtering and appropriate guard band:** Additional filters may substantially reduce interference by decreasing the unwanted emissions from the transmitter and improving the selectivity on the receiver side. A guard band between spectrum used by adjacent operators is then necessary to allow for sufficient filter roll-off. The required size of such a guard band would depend on the necessary additional isolation and the ability of the filter. According to the analysis in this report, such filters would need to provide additional isolation in the range 36-73 dB, depending on the interference scenario (propagation environment and isolation available because of other considerations than the filter e.g. site-coordination, antenna characteristics).
- **Co-ordination among network operators:** Site engineering techniques such as transmitter antenna tilting, selection of antenna direction and careful deployment planning may reduce

interference. However, it could be very difficult to implement practically as different operators may have different user distribution patterns, growth patterns, business and operational plans.

- **A combination of the above**

### 6.2.2 UE –UE coexistence in case of unsynchronized LTE-Advanced TDD systems:

The analysis indicates that interference may occur when the UEs are in close proximity but that for most scenarios this interference will occur rarely. For UEs, additional filters are not a realistic means for reducing interference.

## References

- [1] Report ITU-R M.2292-0 – Characteristics of terrestrial IMT-Advanced systems for frequency sharing/interference analyses.
- [2] 3GPP TS 36.104: 3rd Generation Partnership Project; Technical Specification Group Radio Access Networks; Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception (Release 9).
- [3] 3GPP TS 36.101: 3rd Generation Partnership Project; Technical Specification Group Radio Access Networks; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception (Release 9).
- [4] 3GPP TS 36.942: 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Frequency (RF) system scenarios (Release 11).
- [5] Report ITU-R M.2244 – Isolation between antennas of IMT base stations in the land mobile service.
- [6] Recommendation ITU-R P.1546-5 (09/2013) – Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3 000 MHz.
- [7] Report ITU-R SM.2028-1 – Monte Carlo simulation methodology for the use in sharing and compatibility studies between different radio services or systems
- [8] Recommendation ITU-R P.1411-7 (09/2013) – Propagation data and prediction methods for the planning of short-range outdoor radiocommunication systems and radio local area networks in the frequency range 300 MHz to 100 GHz.
- [9] ECC Report 216 (August 2014) Practical guidance for TDD networks synchronization.
- [10] 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) (January, 2009).
- [11] 3GPP TR 25.942 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Radio Frequency (RF) system scenarios (Release 12)
- [12] Report ITU-R M.2146 (05/2009) – Coexistence between IMT-2000 CDMA-DS and IMT-2000 OFDMA TDD WMAN in the 2 500-2 690 MHz band operating in adjacent bands in the same area

- [13] Recommendation ITU-R P.525-2 (1978-1982-1994) with editorial amendments in year 2000 – Calculation of free space attenuation
- [14] APT Report on Network Synchronization Technologies in Radio Access Networks for IMT TDD systems No. APT/AWG/REP-60 Edition: March 2015
- [15] Report ITU-R M.2113-1 (2008-12) – Sharing studies in the 2 500- 2 690 MHz band between IMT-2000 and fixed broadband wireless access systems including nomadic applications in same geographical area

## **Annex 1**

### **Abbreviations**

ACI	Adjacent channel interference
ACS	Adjacent channel selectivity
CPE	Customer premises equipment
DL	Down-link
DwPTS	Down-link pilot time slot
LTE	Long term evolution
MCL	Minimum coupling loss
MIMO	Multiple input multiple output
OOBE	Out of band emission
TDD	Time division duplex
UE	User equipment
UL	Up-link
UpPTS	Up-link pilot time slot

## Annex 2

### Propagation models

#### Propagation model for BS-UE

Modified Hata model [6] is used for BS to UE transmission in the simulation analysis. The parameters have the following meanings:

- $L$ : median propagation loss (dB)
- $f$ : frequency (MHz)
- $H_m$ :  $\min\{h_1, h_2\} = 1.5\text{m}$  in this study
- $H_b$ :  $\max\{h_1, h_2\} = 20\text{m}$  in this study
- $d$ : distance (km), preferably less than 100 km

Case 1:  $d \leq 0.04$  km

$$L = 32.4 + 20 \log(f) + 10 \log(d^2 + (H_b - H_m)^2 / 10^6)$$

Case 2:  $d \geq 0.1$  km

$$a(H_m) = (1.1 \log(f) - 0.7) H_m - (1.56 \log(f) - 0.8)$$

$$\alpha = \begin{cases} 1 & \text{for } d \leq 20 \text{ km} \\ 1 + \left(0.14 + 1.87 \times 10^{-4} f + 1.07 \times 10^{-3} H_b\right) \left(\log \frac{d}{20}\right)^{0.8} & \text{for } 20 \text{ km} < d \leq 100 \text{ km} \end{cases}$$

Sub-case 1: Urban

2 000 MHz  $< f \leq$  3 000 MHz

$$L = 46.3 + 33.9 \log(2000) + 10 \log(f / 2000) - 13.82 \log(30) + [44.9 - 6.55 \log(30)] \log(d) - a(H_m)$$

Sub-case 2: Suburban

$$L = L(\text{urban}) - 12.3$$

Sub-case 3: Open area

$$L = L(\text{urban}) - 32.5$$

Case 3:  $0.04$  km  $< d <$   $0.1$  km

$$L = L(0.04) + \frac{[\log(d) - \log(0.04)]}{[\log(0.1) - \log(0.04)]} [L(0.1) - L(0.04)]$$

When  $L$  is below the free space attenuation for the same distance, the free space attenuation should be used instead.

#### Propagation models for UE-UE

In order to evaluate the interference between a mobile station and a mobile station, models for propagation between terminals located from below roof-top height to near street level in § 4.3 of Recommendation ITU-R P.1411-7 [8] is applied in this report.

The parameters required are the frequency  $f$  (MHz) and the distance between the terminals  $d$  (m).

Step 1: Calculate the median value of the line-of-sight loss:

$$L_{LoS}^{median}(d) = 32.45 + 20 \log_{10} f + 20 \log_{10}(d/1\,000)$$

Step 2: For the required location percentage,  $p$  (%), calculate the LoS location correction:

$$\Delta L_{LoS}(p) = 1.5624\sigma \left( \sqrt{-2 \ln(1-p/100)} - 1.1774 \right) \quad \text{with } \sigma = 7 \text{ dB}$$

Alternatively, values of the LoS correction for  $p = 1, 10, 50, 90$  and  $99\%$  are given in Table 8.

Step 3: Add the LoS location correction to the median value of LoS loss:

$$L_{LoS}(d, p) = L_{LoS}^{median}(d) + \Delta L_{LoS}(p)$$

Step 4: Calculate the median value of the NLoS loss:

$$L_{NLoS}^{median}(d) = 9.5 + 45 \log_{10} f + 40 \log_{10}(d/1\,000) + L_{urban}$$

$L_{urban}$  depends on the urban category and is 0 dB for suburban, 6.8 dB for urban and 2.3 dB for dense urban/high-rise.

Step 5: For the required location percentage,  $p$  (%), add the NLoS location correction:

$$\Delta L_{NLoS}(p) = \sigma N^{-1}(p/100) \quad \text{with } \sigma = 7 \text{ dB}$$

$N^{-1}(\cdot)$  is the inverse normal cumulative distribution function. An approximation to this function, good for  $p$  between 1 and 99% is given by the location variability function  $Qi(x)$  of Recommendation ITU-R P.1546. In this study,  $p = 50$  is applied, and values of the NLoS location correction for  $p = 50\%$  are given in Table 8.

TABLE 10

LoS and NLoS location variability corrections

p (%)	$\Delta L_{LoS}$ (dB)	$\Delta L_{NLoS}$ (dB)	dLoS (m)
1	-11.3	-16.3	976
10	-7.9	-9.0	276
50	0.0	0.0	44
90	10.6	9.0	16
99	20.3	16.3	10

Step 6: Add the NLoS location correction to the median value of NLoS loss:

$$L_{NLoS}(d, p) = L_{NLoS}^{median}(d) + \Delta L_{NLoS}(p)$$

*Step 7:* For the required location percentage,  $p$  (%), calculate the distance  $d_{LoS}$  for which the LoS fraction  $F_{LoS}$  equals  $p$ :

$$d_{LoS}(p) = 212[\log_{10}(p/100)]^2 - 64 \log_{10}(p/100) \quad \text{if } p < 45$$

$$d_{LoS}(p) = 79.2 - 70(p/100) \quad \text{otherwise}$$

Values of  $d_{LoS}$  for  $p = 1, 10, 50, 90$  and  $99\%$  are given in Table 8.

*Step 8:* The path loss at the distance  $d$  is then given as:

- a) If  $d < d_{LoS}$ , then  $L(d, p) = L_{LoS}(d, p)$
- b) If  $d > d_{LoS} + w$ , then  $L(d, p) = L_{NLoS}(d, p)$
- c) Otherwise linearly interpolate between the values  $L_{LoS}(d_{LoS}, p)$  and  $L_{NLoS}(d_{LoS} + w, p)$ :

$$L_{LoS} = L_{LoS}(d_{LoS}, p)$$

$$L_{NLoS} = L_{NLoS}(d_{LoS} + w, p)$$

$$L(d, p) = L_{LoS} + (L_{NLoS} - L_{LoS})(d - d_{LoS})/w$$

The width  $w$  is introduced to provide a transition region between the LoS and NLoS regions. This transition region is seen in the data and typically has a width of  $w = 20$  m.

---