ECC Report 239

Compatibility and sharing studies for BB PPDR systems operating in the 700 MHz range

Approved 30 September 2015

0 EXECUTIVE SUMMARY

The scope of this report is to study the adjacent band compatibility between PPDR systems operating within the 700 MHz frequency band but outside the 2x30 MHz band plan and other applications in the 700 MHz frequency band, i.e. MFCN and SDL in the band 694-790 MHz and DTT below 694 MHz.

The following frequency arrangements for PPDR with a conventional duplex have been studied:

- 2 X 5 MHz (698-703 / 753-758 MHz);
- 2 X 3 MHz (733-736 / 788-791 MHz);
- 2 X 10 MHz (733-743 / 748-758 MHz);
- 2 X (2 X 5) MHz (733-738 / 748-753 MHz and 738-743 / 753-758 MHz).

The report does not consider the compatibility issues with audio PMSE[1]. Also the report does not consider compatibility with DTT usage in the 694-790 MHz band (including in the duplex gap).

0.1 COMPATIBILITY BETWEEN PPDR AND MFCN

The technical specifications of MFCN Base Station (BS) and User Equipment (UE) do not guarantee interference free operation of concurrent networks in adjacent blocks throughout the coverage area. Increasing PPDR UE adjacent selectivity enables the victim PPDR UE to operate in a sparse network when adjacent in frequency to a dense network. Another phenomenon is the 3rd order intermodulation due to DL operations by two different MFCN networks may appear in PPDR band, if this happens, PPDR operator should accept this type of interference.

Compatibility between PPDR UL and SDL (MFCN Supplemental Downlink) depends on the scenario which is targeted. It is feasible for an SDL BS to fulfil the out-of-block power limit defined in ECC/DEC/(15)01 [1] towards PPDR UL in 733-736 MHz, assuming a 15 dBi antenna gain. There is no blocking requirement for PPDR UL Rx in the ECC Decision and thus the PPDR BS Rx filter was not analysed for this scenario. However, it is recognised that the PPDR BS Rx filter is needed.

If the 3GPP minimum requirements for coexistence are to be fulfilled, it is feasible to create SDL Tx and PPDR BS Rx filters with enough rejection. However, the insertion loss in PPDR UL will be higher than standard. In the case of colocation between PPDR and SDL, then more than 2 MHz separation is needed. The exact level of guard-band beyond 2 MHz for site solutions with external filters has not been investigated in this report. Another way to manage colocation may be to rely on different site solutions, e.g. by using appropriate antenna physical separation.

It is shown that PPDR 2x10 MHz in the duplex gap is not feasible.

Compatibility of PPDR 2x(2x5) MHz in the duplex gap with MFCN may be achieved. However, this option suffers from limitations (See more information on the limitations in Section A1.4), such as:

- Severe self-desensitisation of the PPDR UE downlink;
- UE-UE interference;
- Cross-border coordination with SDL.

[1] Compatibility issues with PMSE (wireless microphones) within the guard-band and the duplex gap are covered in ECC Report 221 [13] and CEPT Report 53 [2]**Error! Reference source not found.**.

0.2 COMPATIBILITY BETWEEN PPDR AND DTT

The earlier results of extensive studies on compatibility between MFCN and DTT below 694 MHz are in CEPT Report 53[2] [2]. As a consequence ECC/DEC/(15)01 [1] indicates that the maximum mean unwanted emission power of MFCN UE should be limited to -42dBm/8MHz for protection of fixed DTT reception at 470-694 MHz assuming an MFCN channel of 10 MHz or less and a 9 MHz guard band.

This conclusion was based on the results of a number of compatibility studies looking at MFCN UEs operating within the 703-733 MHz band and the technical feasibility of MFCN UEs implementing appropriate filtering to meet this unwanted emission level.

Studies in this report look at the compatibility between PPDR networks using MFCN LTE-based technologies in the 700 MHz range and DTT below 694 MHz. Studies have shown that the most critical compatibility analysis with DTT Networks is for PPDR UE use in the 698-703 MHz band. These studies also looked at a number of different scenarios with different assumptions looking at PPDR UEs operating within the 698-703 MHz band and the technical feasibility of PPDR UEs implementing appropriate filtering to meet the proposed unwanted emission levels.

Taking into account the results of the studies presented it appears that a reasonable solution would be to recommend unwanted emission levels for PPDR UE of -42 dBm/8 MHz to manage the risk of interference to DTT below 694 MHz. This would provide an adequate level of protection for DTT. The cumulative effect of unwanted emission from both PPDR UEs and MFCN UEs was not studied in this report.

Some studies also show the potential for relaxed values of the unwanted emission levels for PPDR UEs operating in the 698-703 MHz block.

Simulations have shown that UEs with 4 MHz guard band, operating at temperatures above +35°C, may have limitations regarding the technical feasibility of implementing appropriate filtering to meet the unwanted emission limit of -42 dBm/8MHz below 694 MHz.

Taking into account temperature drift and to address the feasibility problems highlighted above for these PPDR UEs to meet the -42 dBm/8 MHz limit a different level can also be considered for such PPDR UEs under extreme environmental conditions for equipment conformance tests. When reviewing these levels the unwanted emission level of a PPDR UE operating in the 698-703 MHz block in extreme environmental conditions for equipment conformance tests should not exceed -30 dBm/8MHz. Measured maximum unwanted emission levels of existing MFCN UEs operating in the 700 MHz band in extreme operating conditions are provided in the studies. The maximum mean in-block power for PPDR terminals is assumed to be 23 dBm to avoid blocking.

The results of co-existence studies when the PPDR system is operating above 733 MHz (in the 700 MHz duplex gap) show that the impact of the PPDR uplink would be lower than the level of impact of MFCN LTE UE on DTT channel 48.

The PPDR Base Station receiver may be subject to interference from DTT transmitters using channel 48 and located in the vicinity. The desensitisation of the PPDR base Station receiver can be significant depending on the distance between the two sites and on the transmission and receiving characteristics.

In that case PPDR Base Station receiver should implement appropriate filtering of DTT in-band emissions. Additionally mitigation techniques would reduce the risk of interference from DTT transmitters using channel 48 into PPDR base station receivers on a case by case basis. Possible mitigation techniques include: down tilting PPDR antenna, fine-tuning antenna orientation and implementing link budget margins by increasing the PPDR network density.

[2] Additional results for threshold levels for MFCN UEs are in the CPM report for AI 1.2 WRC-15

Compatibility between DTT channel 47 and PPDR UL in the band 698-703 MHz was also considered and it was concluded that the situation is comparable (or better) than the situation considered in CEPT Report 53 [2] between DTT channel 48 and MFCN UL in the band 703-733 MHz.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

Abbreviation	Explanation
3GPP	3rd Generation Partnership Project
ACIR	Adjacent Channel Interference Ratio
ACLR	Adjacent Channel Leakage Ratio
ACS	Adjacent Channel Selectivity
AGC	Automatic Gain Control'
BEM	Block Edge Mask
BER	Bit Error Rate
BPP	Band-Pass Filter
BS	Base Station
BW	Band Width
CA	Carrier Aggregation
CDMA	Code Division Multiple Access
CEPT	European Conference of Postal and Telecommunications Administrations
CH	Channel
C/N	Carrier to Noise
DL	Downlink
DMO	Direct Mode Operation
dRSS	Desired Received Signal Strength
DT	De-correlation Time
DTT	Digital Terrestrial Television
DTTB	Digital Terrestrial Television Broadcasting
DVB-T	Digital Video Broadcasting - Terrestrial
EC	European Commission
ECC	Electronic Communications Committee
e.i.r.p.	equivalent isotropically radiated power
eMBMS	evolved Multimedia Broadcast and Multicast Service
ETSI	European Telecommunications Standards Institute
IBE	In-Band Emission
I/N	Interference to Noise
iRSS	Interference Received Signal Strength
ITU-R	International Telecommunication Union - Radiocommunication Sector
LTE	Long Term Evolution

Abbreviation	Explanation
MCL	Minimum Coupling Loss
MFCN	Mobile Fixed Telecommunication Network
MS	Mobile Station
OOBE	Out-of-Band Emission
Oth	Overloading Threshold
PA	Power Amplifier
PIM	Passive Inter-Modulation
PMSE	Programme Making and Special Events
PPDR	Public Protection and Disaster Relief
PR	Protection Ratio
QAM	Quadrature Amplitude Modulation
QEF	Quasi Error Free
QoS	Quality of Service
RB	Resource Block
Rx	Receiver
SAW	Surface Acoustic Wave
SC-FDMA	Single Carrier - Frequency Domain Multiple Access
SDL	Supplemental Downlink
SEAMCAT	Spectrum Engineering Advanced Monte Carlo Analysis Tool
SFP	Subjective Failure Point
SINR	Signal to Interference and Noise Ration
TTI	Transmission Time Interval
TV	Television
TW	Time Window
Tx	Transmitter
UE	User Equipment
UL	Uplink
VoIP	Voice over Internet Protocol
w	With
w/o	Without

1 INTRODUCTION

The PPDR sector and related radio communication matters are an issue of sovereignty of Member States. The PPDR requirements may vary from country to country. This is acknowledged in ECC Report 199 [12], which addresses requirements and spectrum needs for future broadband PPDR service.

In response to the EC Mandate on the 700 MHz frequency band, CEPT Report 53 [2] proposes channelling arrangements for this band. The PPDR service is included in the scope, and it is proposed that

"*The technical parameters (channelling arrangement and common least restrictive technical conditions (BEM) for MFCN in Annex 2 can also be used for the provision of broad band PPDR services within the paired frequency arrangement (703-733 MHz and 758-788 MHz), provided that the implementation is in line with the assumptions made for MFCN networks (including the protection requirements).*

A set of options for broadband PPDR are currently studied by CEPT. These options may be considered for implementation by administrations to respond to spectrum demand for PPDR service on a national level, and include solutions outside the 700 MHz band (e.g. 400 MHz) and/or the possible use of guard band and duplex gap of the 700 MHz with a conventional duplex: for example, the following options are under study 2 X 5 MHz (698-703 / 753-758 MHz), 2 X 3 MHz (733-736 / 788-791 MHz), 2 X 10 MHz (733-743 / 748-758 MHz), 2 X 2 X 5 MHz (733-738 / 748-753 MHz and 738-743 / 753-758 MHz). Different possible PPDR combinations will be evaluated. Direct Mode Operation may be also foreseen."

The scope of this report is to study the adjacent band compatibility between the PPDR systems within the MFCN FDD channelling arrangement (outside the 2x30 MHz band plan) and other applications in the 700 MHz frequency band, i.e. MFCN and DTT below 694 MHz. The report doesn't consider the compatibility issues with audio PMSE[3] or with DTT usage in the 694-790 MHz band (including in the duplex gap).

CEPT Report 53 [2] suggests PPDR usage of the paired frequency arrangement (703-733 and 758-788 MHz) provided that the implementation is in line with the assumptions made for MFCN networks (including the protection requirements thus allowing options for commercial PPDR networks to be implemented or hybrid networks of dedicated/commercial PPDR. . Studies in this ECC Report are covering also vehicle mounted UEs, which were not considered in the CEPT Report 53.

[3] Compatibility issues with PMSE (wireless microphones) within the guard-band and the duplex gap are covered in ECC Report 221 [13] and CEPT Report 53 [2].

2 PPDR NETWORKS

PPDR networks are based on cellular type architecture augmented, where necessary, by vehicle mounted relay stations and direct mode operation, Figure 1. Direct Mode Operation (DMO), device-to-device communications between UEs, is not considered in this ECC report.

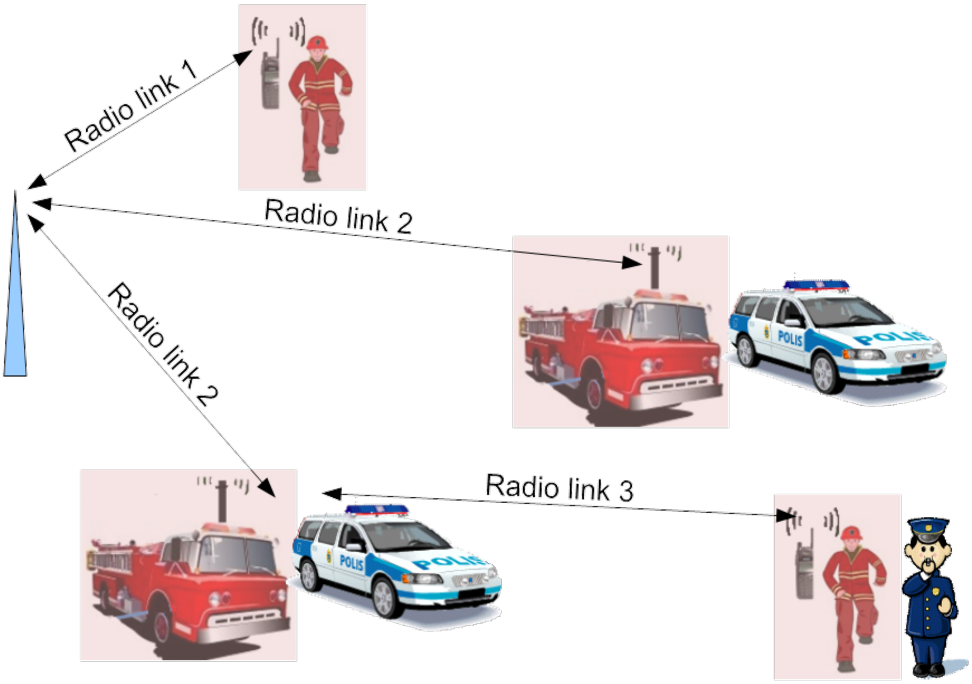


Figure 1: Description of the different radio links of PPDR systems under consideration for coexistence studies at 700 MHz band

2.1 FREQUENCY ARRANGEMENTS

The following PPDR plans are considered in the report:

470-694	694-698	698-703	703-733	733-736	736-753	753-758	758-788	788-791	791-821
DTT		PPDR UL	UPLINK Band #28	PPDR UL		PPDR DL	DOWNLINK Band #28	PPDR DL	DOWNLINK Band #20
	4 MHz	5 MHz	30 MHz	3 MHz	17 MHz	5 MHz	30 MHz	3 MHz	

Figure 2: 2x5 MHz and 2x3 MHz option

470-694	694-698	698-703	703-733	733-738	738-743	743-748	748-753	753-758	758-788	788-791	791-821
DTT			UPLINK Band #28	PPDR UL			PPDR DL		DOWNLINK Band #28		DOWNLINK Band #20
	4 MHz	5 MHz	30 MHz	5 MHz	5 MHz	5 MHz	5 MHz	5 MHz	30 MHz	3 MHz	

Figure 3: 2x10 MHz option

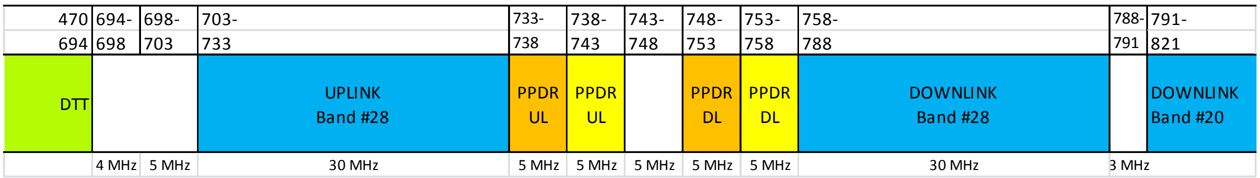


Figure 4: 2x(2x5) MHz option

The document tackles the following compatibility studies:

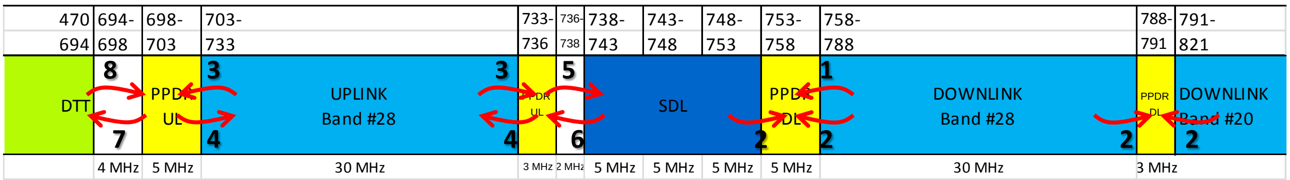


Figure 5: List of compatibility studies

(1) Impact of transmitting MFCN BS (DL) onto receiving PPDR UE (DL)

(2) Cumulative impact of transmitting MFCN BS (DL) onto receiving PPDR UE (DL) when MFCN is both below and above PPDR frequency range

(3) Impact of transmitting MFCN UE (UL) onto receiving PPDR BS (UL)

(4) Impact of transmitting PPDR UE (UL) onto receiving MFCN BS (UL)

(5) Impact of transmitting PPDR UE (UL) onto receiving MFCN UE (SDL)

(6) Impact of transmitting MFCN BS (SDL) onto receiving PPDR BS (UL),

(7) Impact of transmitting PPDR UE (UL) onto DTT reception

(8) Impact of DTT transmitter onto receiving PPDR BS (UL)

Note that compatibility studies for the 2x10 MHz and 2x(2x5) MHz options with MFCN are identical to studies for the 2x5 and 2x3 MHz options. Self-interference of 2x10 MHz and 2x(2x5) MHz options are also discussed in ANNEX 1:.

2.2 PPDR STATISTICS

2.2.1 PPDR activities in The Netherlands

Area studied: the city of Utrecht in The Netherlands.

The numbers on activities are based on the figures in the operational system from the Command & Control room; this are all activities which are registered, variating from big accidents, major events, burglary, steeling in shops, health support with ambulance, patient transport to hospital, car accident, visiting a location for preventive surveillance, surveillance in a shopping street, surveillance by car or foot from a street or curtain area, etc.

Utrecht is the capital and most populous city in the Dutch province of Utrecht. It is located in the eastern corner of the Randstad conurbation, and is the fourth largest city in the Netherlands with a population of 330,772 in 2014.[4]

The area is covered by 39 zip-code areas, the city is divided in 1 km² squares in Figure 6. For each square, the number of households is indicated on the top and number of PPDR activities per year on the bottom.

[4] http://en.wikipedia.org/wiki/Utrecht

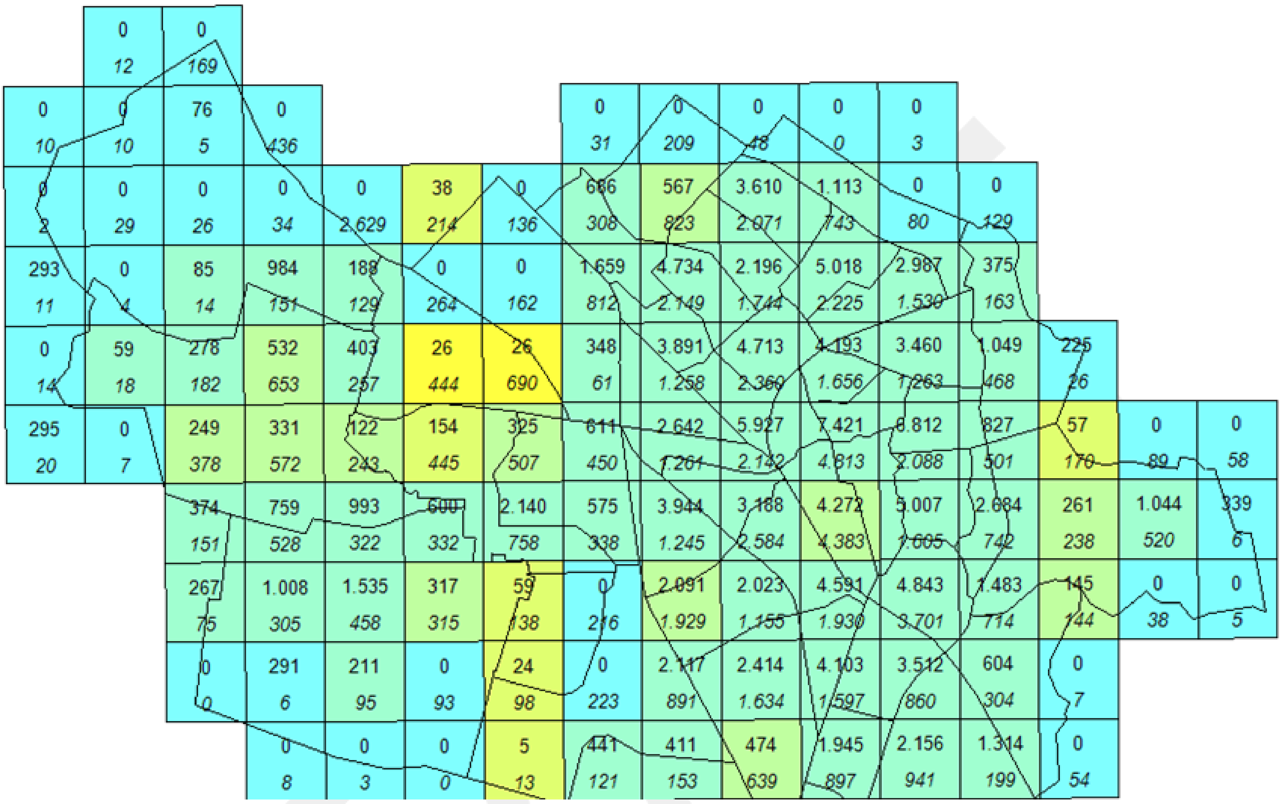


Figure 6: Utrecht city

The worst case in this figure corresponds to about 5000 activities per year and per km² resulting in an average of 14 activities per day where population is about 7500 households per km².

Therefore the number of activities per typical busy hour and per km² is typically less than unity. Equivalently, this corresponds to a probability of 0.46 % of having a PPDR device within a 50 m range from a DTT receiver per hour.

2.2.2 Copenhagen Fire

During 4th quarter of 2014; Copenhagen fire department received 66258 emergency calls; which triggered 1747 emergency responses and 8 persons have been saved from burning buildings.

2.2.3 PPDR staff in France

Table 1 below gives the staff of main security bodies in France and Paris area.

Those are raw figures. In particular, there is no distinction between staff working in offices and staff on the field. Also shifts and off periods are not taken into account. It is estimated that about 5 employees are required for a full time equivalent.

Table 1: PPDR staff in France

	31 December 2013
France	
French population	65 000 000 persons
Gendarmerie	98 000 persons
Police Nationale	143 500 persons
Pompiers	245 000 persons
Ratio	0.75 %
Préfecture police de Paris	
Paris and suburb population	6 800 000 persons
Police	30 000 persons
BSPP	8 500 persons
Others	7 500 persons
Ratio	0.68 %

In addition, security forces use 28190 vehicles throughout the French territory.

2.2.4 Fire brigade in Paris and suburbs

The fire brigade of Paris and suburb is responsible for an area of about 564 km² (excluding sparsely populated areas such as parks, forest and water) and a population of 6.5 million.

In 2012 the brigade treated 491.000 activities; about 3 % of which were fires, 5 % road accidents and 77 % people rescuing.

This gives an average of 2.38 activities per day and per km², where average population density is 11 500 inhabitants per km². Equivalently, this corresponds to probabilities of 0.078 % to have a fire brigade activity within a 50 m range from a DTT receiver per hour.

2.2.5 PPDR statistics in Stockholm

Greater Stockholm covers an area of 6500km² and a population of 2.2 million. Municipality with high population density (>1000 pop/km²) cover an area of 534 km² and 64 % of the total population[5].

[5] http://en.wikipedia.org/wiki/List_of_metropolitan_areas_in_Sweden as on the 30th of May 2015.

In 2014 Police and Fire brigade handled a total of 417500 incidents, although not every incident required a patrol to be sent over.

From the above statistics, we can be reasonably assumed that about 64 % of these incidents (267200) happened in densely populated areas. This gives an average of 0.057 incidents per km² and per hour. Equivalently, this corresponds to probabilities of 0.045 % to have a fire brigade activity within a 50 m range from a DTT receiver per hour.

2.2.6 Conclusion

The statistics given above relate to Police and Fire brigade activities in a number of European cities. These show that the probability of having an incident requiring PPDR activity in any given area is quite low.

The broadband PPDR technology opens various new possibilities, such as face recognition by mobile or fixed cameras, real time automatic number plate recognition (ANPR) and real time tracking of assets (GPS). These possibilities are not covered by the statistics above, which are based on usage of current narrow band systems.

3 TECHNICAL PARAMETERS

3.1 LTE

This section applies to both MFCN and PPDR systems.

3.1.1 LTE BS parameters

Table 2: LTE Wide Area BS, Transmitter characteristics

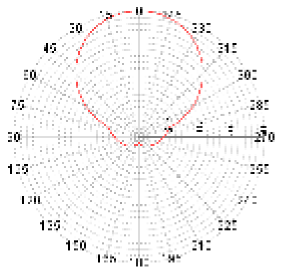
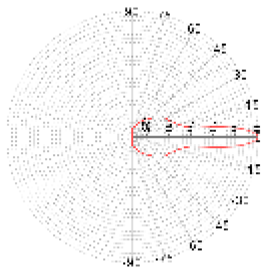
Parameter	Value	Comment
Channel bandwidth	10 / 5 / 3 MHz	
Transmission bandwidth	9 / 4.5 / 2.7 MHz	
ACLR in the 2 first adjacent channels	45 dB	ETSI TS 137 104 [6], Table 6.6.4.1-1
Horizontal antenna pattern		SEAMCAT 4.1.0, Library Antenna, 3GPP Tri-Sector Antenna
Vertical antenna pattern		SEAMCAT 4.1.0, Library Antenna, 3GPP Tri-Sector Antenna
Down-tilt	3°	
Antenna height	30 m	

Table 3: LTE Wide Area BS, Output power per cell

Case	Output power	Comment
Typical	43 dBm/channel	according to ITU-R M.2292
PPDR	45 dBm/channel	

Table 4: LTE Wide Area BS, Receiver characteristics

Parameter	Value		Comment
Channel bandwidth	5 MHz	3 MHz	
Transmission bandwidth	4.5 MHz	2.7 MHz	
Noise figure	5 dB		3GPP TR 36.942 [9], Table 4.6
1st adjacent 3 MHz block			
Blocking level for 1 dB desensitisation		-59.7 dBm	derived from ETSI TS 137 104 [6], Table 7.4.2-1
2nd adjacent 5 MHz block and beyond			
Blocking level for 1 dB desensitisation		-52.9 dBm	derived from ETSI TS 137 104 [6], Table 7.4.1-1

3.1.2 LTE UE parameters

Table 5: LTE UE, Transmitter characteristics

Parameter	Value	Comment
Channel bandwidth	5 / 3 MHz	
Transmission bandwidth	4.5 / 2.7 MHz	
ACLR in the 1st adjacent 5 MHz block	32 dB in 5 MHz	ETSI TS 136 101 [8], Table 6.6.2.3.2-1 (requirement for a UMTS adjacent channel)
ACLR in the 2nd adjacent 5 MHz block	35 dB in 5 MHz	
Maximum transmit power	23 dBm	
Antenna gain	-3 dBi	can be 0 dBi for vehicular devices
Antenna height	1.5 m	can be 2 m for vehicular devices

Table 6: LTE UE, Receiver characteristics

Parameter	Value		Comment
Channel bandwidth	5 MHz	3 MHz	
Transmission bandwidth	4.5 MHz	2.7 MHz	
Noise figure	9 dB		3GPP TR 36.942 [9], Table 4.8
Reference sensitivity	-98.5 dBm	-100.2 dBm	ETSI TS 136 101 [8], Table 7.3.1-1 band #28
ACS	33 dB		ETSI TS 136 101 [8], Table 7.5.1-1 without carrier aggregation

NOTE: Simulation assumptions for PPDR LTE is based in ETSI TS 136 104 [7]. Characteristics included in ETSI TS 137 104 [6] are also in general applicable for PPDR equipment.

3.2 DTT

3.2.1 DTT transmission parameters

Table 7: DTT Tx parameters (ITU-R Report BT.2383)

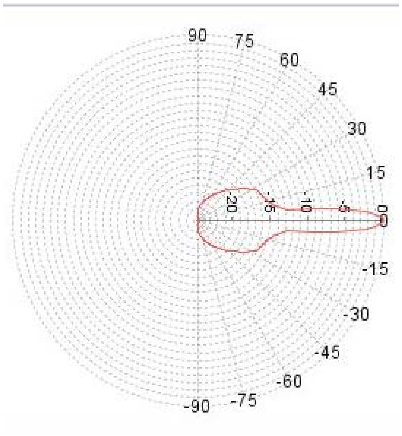
Parameter	Value	Comment
Channel bandwidth	8 MHz	
Transmission bandwidth	7.61 MHz	
Spectrum mask	Table 8	
DTT antenna diagram	Antenna gain (horizontal is omnidirectional and vertical according to diagram on the right)	
DTT Tx Power	85.15 dBm	
DTT Antenna height	300 m	
DTT coverage range	39.5 km	

Table 8: Symmetrical spectrum mask for non-critical and sensitive cases for 8 MHz channels and a 4 kHz measurement bandwidth (Table 3-11 from GE06 agreement)

Relative frequency separation (MHz)	Non critical cases: Relative level (dB)	Critical cases: Relative level (dB)
-12	-110	-120
-6	-85	-95
-4.2	-73	-83
-3.9	-32.8	-32.8
+3.9	-32.8	-32.8
+4.2	-73	-83
+6	-85	-95
+12	-110	-120

3.2.2 DTT rooftop reception parameters

Table 9: DTT receiver parameters for fixed rooftop reception

Parameter	Value	Comment
Channel bandwidth	8 MHz	
Transmission bandwidth	7.61 MHz	
Median field strength	56.7 dBµV/m for a location probability of 95 %, for channel 48	Equivalent to -68.1 dBm at receiver antenna port, refer to Appendix 3.4 of GE06 agreement.
C/(I+N) criterion	21 dB	Table A.3.3-11 from GE06 agreement
ACS (subject to interference by a 5 MHz LTE signal with carrier at 700.5 MHz.)	63 dB for channel 48	Based on measurement results (see ANNEX 2:)
ACS (subject to interference by a 10 MHz LTE signal with carrier at 738 MHz.)	75 dB for channel 48	Based on measurement results (see ANNEX 2:)
Receiving DTT antenna	Directional	see ITU-R Recommendation BT.419-3
DTT Antenna height	10 m	
DTT Tx to Rx propagation model	ITU-R P.1546-4 land	Urban environment Broadcast Digital System

3.2.3 DTT portable reception parameters

Table 10: DTT portable reception parameters

Parameter	Value	Comment
Channel bandwidth	8 MHz	
Transmission bandwidth	7.61 MHz	
Median field strength	85 dBµV/m for a location probability of 95 %, for channel 48	Equivalent to -66.36 dBm at antenna port, refer to Appendix 3.4 of GE06 agreement (reference field strength is given for at 10 m height, outdoor)
C/(I+N) criterion	19 dB	Table A.3.3-11 from GE06 agreement
ACS (subject to interference by a 5 MHz LTE signal with carrier at 700.5 MHz.)	63 dB for channel 48	Based on measurement results (see ANNEX 2:)
ACS (subject to interference by a 10 MHz LTE signal with carrier at 738 MHz.)	75 dB for channel 48	Based on measurement results (see ANNEX 2:)

Parameter	Value	Comment
Receiving DTT antenna	Omnidirectional in the horizontal plan with antenna gain 0 dBd	
DTT Antenna height	1.5 m	Height correction factor from 10 m to 1.5 m is 12 dB
Wall loss	10 dB	For indoors usage

Note: The ACS values in this report are based on measurements that have not considered the intermittent and irregular nature of UE's, therefore the results in this report may not capture the vulnerability of DTT in practice.

4 COMPATIBILITY WITH COMMERCIAL NETWORKS

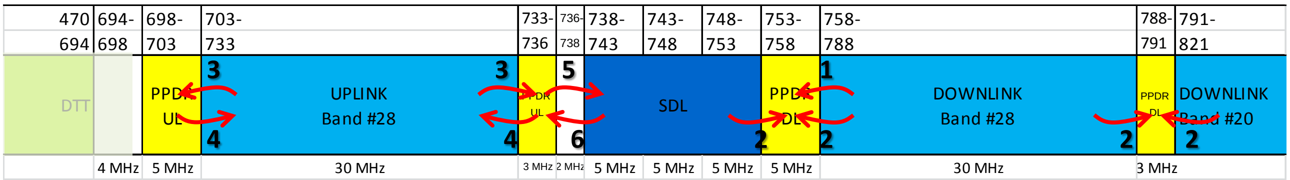


Figure 7: Summary of compatibility studies with commercial LTE networks

(1) Impact of transmitting MFCN BS (DL) onto receiving PPDR UE (DL)

(2) Cumulative impact of transmitting MFCN BS (DL) onto receiving PPDR UE (DL) when MFCN is both below and above PPDR frequency range

(3) Impact of transmitting MFCN UE (UL) onto receiving PPDR BS (UL)

(4) Impact of transmitting PPDR UE (UL) onto receiving MFCN BS (UL)

(5) Impact of transmitting PPDR UE (UL) onto receiving MFCN UE (SDL)

(6) Impact of transmitting MFCN BS (SDL) onto receiving PPDR BS (UL),

4.1 IMPACT OF MFCN BS DL EMISSIONS ONTO PPDR UE DL (NEAR-FAR EFFECT)

Inter-operator interference is mainly due to near-far effect in DL. Near-far effect is a term used to describe the situation where a terminal is located very close to a base station operating in an adjacent frequency block, while simultaneously being located very far from its serving base station. When near-far effect occurs, the interfering signal in an adjacent channel is very strong, while simultaneously the desired signal is very weak. In extreme situations, near-far effect can lead to 'blocking', i.e. the terminal can no longer stay connected to the network.

4.1.1 Throughput loss from 3GPP analysis

3GPP TR 36.942 [9] investigates system scenarios reflecting the environments that LTE is designed to operate in. The studies are fully described in [9] and a summary of these studies is presented thereafter.

In section 7.1.1.2 of the TR [9], the downlink throughput loss due to the coexistence of two adjacent 10 MHz LTE channels is simulated for various ACIR values. The results are shown in Figures 7.2 and 7.3 as well as in Tables 7.2 and 7.3 of the TR [9].

Table 11 below provides the ACIR values when considering LTE BS and PPDR UE adjacent in frequency, as well as the resulting average DL throughput loss and the percentage of users that face a 5% or higher DL throughput loss. Values are provided with and without carrier aggregation (CA)

Table 11: Performance Degradation

	BS ACLR	UE ACS	ACIR	Average DL throughput loss over all users	% of users facing 5% DL throughput loss or higher
w/o CA	45 dB	33 dB	32.7 dB	1 %	~5 %
w/ CA	45 dB	27 dB	26.9 dB	2.5 %	~10 %

Technical parameters defined for MFCN (i.e. BEM) are applicable to PPDR networks (regardless of whether they operate within the MFCN frequency range or in an adjacent dedicated channel) as long as they accept that 5 % (and even 10 % in case of carrier aggregation) of users face a 5 % or higher DL throughput loss.

4.1.2 Baseline analysis

In this study, parameter setting corresponds to a typical case for both the PPDR network and the MFCN network.

This study aims at deriving the statistics of $\frac{C_{PPDR}}{N+I_{MFCN}}$ experienced by PPDR UEs on the DL, and subject to interference from a MFCN in adjacent band. Whenever this ratio, expressed in dB scale, has a value below $-3dB$, the PPDR UE is subject to interference, and cannot properly receive its signal anymore.

Interference power impairing PPDR reception can be broken into two parts: the first part consists of the out of band emissions (ACLR) of the MFCN eNodeB falling into the PPDR band. The second is due to the imperfect rejection (ACS) of adjacent channel at PPDR receiver. The total interfering power is given by the following equation:

$$I_{MFCN} = P_{MFCN} - ACIR$$

$$ACIR = -10 * log10(\frac{1}{10^{\frac{ACS}{10}}} + \frac{1}{10^{\frac{ACLR}{10}}})$$

where P_{MFCN} is the downlink power of the MFCN signal at the antenna port of the victim PPDR UE.

Worst case values of 33 dB for ACS and 45 dB for ACLR are provided in Table 6 and Table 2 respectively, which corresponds to an ACIR value of 32.7 dB. Although these values are believed to be pessimistic compared to real-life devices which have necessarily higher values, they constitute the starting point for the evaluation of the impact of MFCN on PPDR. More realistic values have then been evaluated to assess the sensitivity of the results to these parameters. In the worst case, ACS is the limiting factor. In order to achieve 40 dB ACIR, ACS would need to be improved from 33 dB to 41.6 dB.

Sensitivity study is also carried-out for different values of PPDR cell range. The resulting interference probabilities are summarized in Table 12. Text below gives the details of the assessments as well as the distribution of the received $\frac{C_{PPDR}}{N+I_{MFCN}}$ for a wide range of values.

Interference probability of MFCN DL on PPDR UE is negligible.

Table 12: Interference probability of PPDR subject to MFCN DL interference

		PPDR cell range		
		845 m	715 m	570 m
I_{MFCN}	58 dBm-32.7 dB = 25.3 dBm	0.69 %	0.39 %	0.17 %
	58 dBm-40 dB = 18 dBm	0.12 %	0.05 %	<0.02 %
	58 dBm-45 dB = 13 dBm	0.02 %	<0.02 %	<0.02 %
	58 dBm-55 dB = 3 dBm	<0.02 %	<0.02 %	<0.02 %

In this study the statistics of the received PPDR DL power and MFCN DL interfering power are computed for a user at any arbitrary point. A regular lattice with resolution 10 m is used.

Cell range of MFCN is assumed to be 500 m, in accordance with BT M.2292. Note that this value is also used in 3GPP 36.942 [9].

Three different cell ranges are investigated for the PPDR networks: 845 m, 715 m, 570 m.

It is assumed that BS antennas are 30 m for both PPDR and MFCN networks. Receiving PPDR UE is at 1.5 m height.

The power of PPDR BSs is assumed to be 60 dBm e.i.r.p. while the MFCN eNodeB transmit power is set to the nominal decreased by the ACIR, and the following values are investigated: 25.3, 18, 13 and 3 dBm. For transmitting power of 58 dBm it corresponds to ACIR values of 32.7, 40, 45 and 55 dB.

Both systems use an antenna with diagrams represented in Figure 8, with a 4° down-tilt.

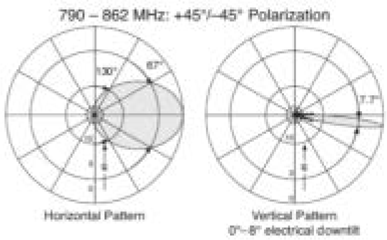


Figure 8: Antenna diagrams

The victim PPDR UE is assumed to be a handheld device with -3 dBi antenna gain, and subject to a 4 dB body loss. Note that these parameters have little impact on the results as both the interfering and useful links are subject to the same values.

Propagation models are extended Hata for both PPDR and MFCN links. MFCN minimum coupling loss is set to 70 dB. Variation for each RF link is set according to the Extended Hata and available in Report ITU-R SM.2028-1 [16].

It is assumed that the victim device is located outdoor and served by the best available base station of the PPDR network while interfered by the strongest received MFCN network.

Results are given in Figure 10 (Figure 9 is a zoom) where it can be seen that the impact of the MFCN DL is very limited.

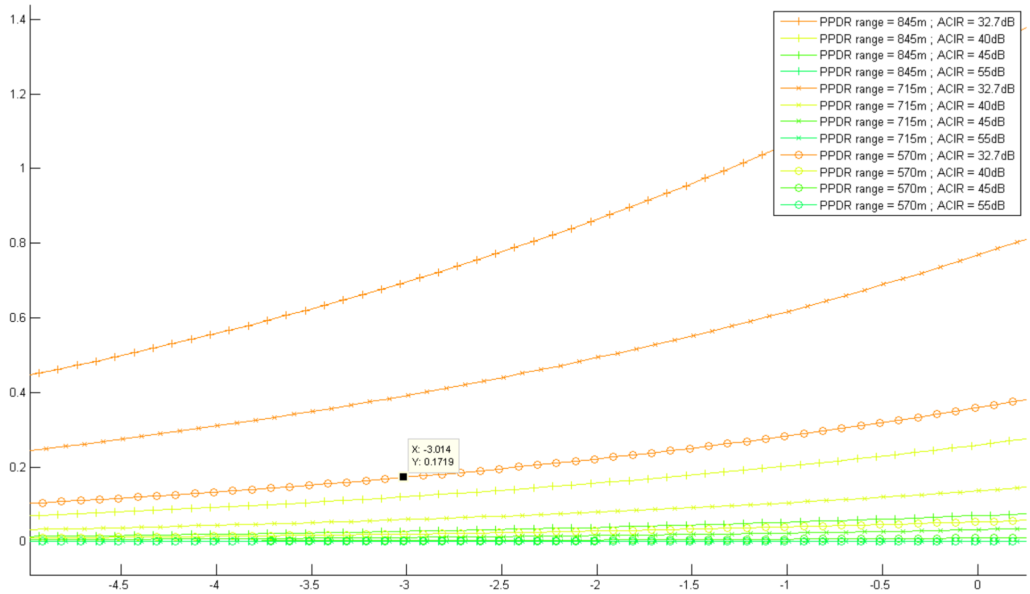
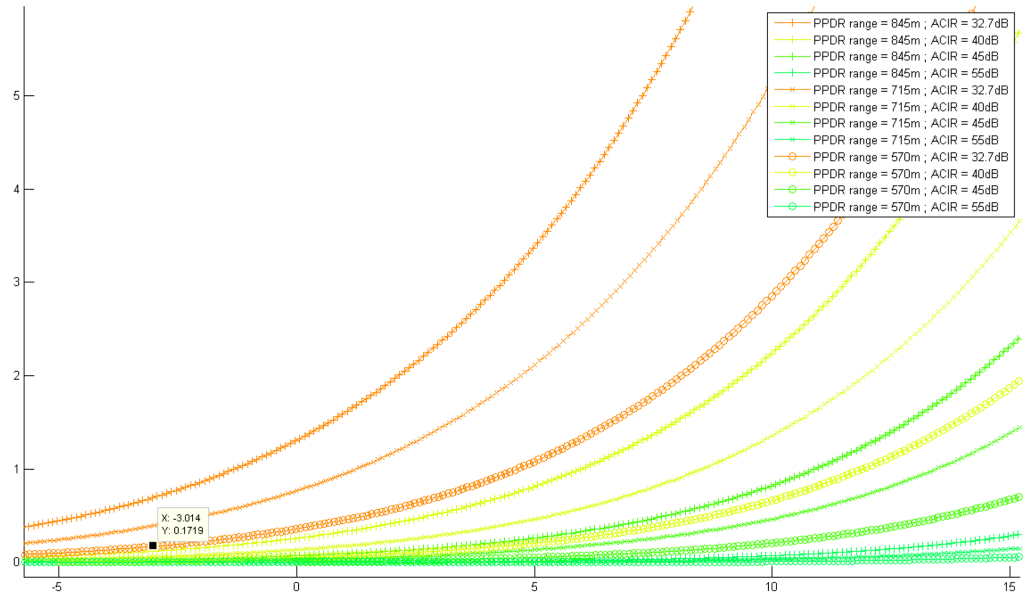


Figure 9: Cumulative distribution function of C/N+I (dB scale) for PPDR DL interfered by MFCN DL (zoom): Y axis is expressed in %



4.1.3 Figure 10: Cumulative distribution function of C/N+I (dB scale) for PPDR DL interfered by MFCN DL Y axis is expressed in dB scaleSensitivity analysis

For this study based on SEAMCAT simulations we investigate a broader range of parameters enabling t the sensitivity of the results to be assessed.

The study considers two LTE networks adjacent in frequency: the victim is a receiving LTE UE operating in a 5 MHz channel and the interferer is a transmitting LTE BS operating in a 10 MHz channel. The main parameters of the reference scenario considered as well as the interference probability due to near far effect are provided in Table 13 below.

In this case we assume a target SINR of -1 dB.

Table 13: Parameters of the central scenario for sensitivity analysis

Victim UE ACS (dB)	Victim network topology		Interfering network topology		Interference probability		
	Cell range (km)	Max e.i.r.p. (dBm)	Cell range (km)	Max e.i.r.p. (dBm)	Unwanted (%)	Blocking (%)	Total (%)
33	0.845	60	0.38	58	0	1.4	1.5

Near-far effect causes UE to operate with a SINR lower than -1 dB with a 1.5 % probability in the central scenario. The 'blocking' (linked to the selectivity of the terminal) is the dominant interference phenomenon, as expected. Even though both networks are deployed with dissimilar topology, the interference probability is not far from being compatible with commercial MFCN QoS (of the order of 1 % or less).

A sensitivity analysis on three parameters, victim BS's e.i.r.p., victim cell range and victim UE's ACS, is performed on the basis of the central scenario.

4.1.3.1 Sensitivity to radiated power

Table 14: Impact of e.i.r.p. on interference probability

Victim UE ACS (dB)	Victim network topology		Interfering network topology		Interference probability		
	Cell range (km)	Max e.i.r.p. (dBm)	Cell range (km)	Max e.i.r.p. (dBm)	Unwanted (%)	Blocking (%)	Total (%)
33	0.845	48	0.38	58	1	5.6	5.7
33	0.845	50	0.38	58	0.6	4.4	4.5
33	0.845	52	0.38	58	0.1	3.5	3.5
33	0.845	54	0.38	58	0	2.8	2.9
33	0.845	56	0.38	58	0	2.4	2.4
33	0.845	58	0.38	58	0	2	2
33	0.845	60	0.38	58	0	1.4	1.5
33	0.845	62	0.38	58	0	0.8	0.8
33	0.845	64	0.38	58	0	0.4	0.4
33	0.845	66	0.38	58	0	0	0
33	0.845	68	0.38	58	0	0	0

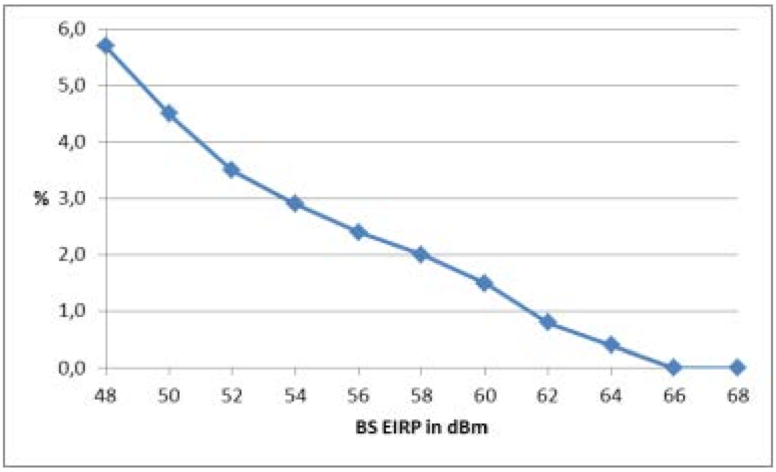


Figure 11: Interference probability on the victim UE according to BS e.i.r.p.
Victim cell range = 0.845 km – Interfering cell range = 0.380 km
Interfering BS e.i.r.p. = 58 dBm/10MHz

4.1.3.2 Sensitivity to network topology

Table 15: Impact of network topology on interference probability

Victim UE ACS (dB)	Victim network topology		Interfering network topology		Interference probability		
	Cell range (km)	Max e.i.r.p. (dBm)	Cell range (km)	Max e.i.r.p. (dBm)	Unwanted (%)	Blocking (%)	Total (%)
33	1.410	60	0.38	58	0	2.7	2.8
33	1.1	60	0.38	58	0	2.5	2.6
33	1	60	0.38	58	0	2.2	2.2
33	0.9	60	0.38	58	0	1.8	1.8
33	0.845	60	0.38	58	0	1.4	1.5
33	0.8	60	0.38	58	0	1.3	1.4
33	0.715	60	0.38	58	0	0.7	0.8
33	0.7	60	0.38	58	0	0.7	0.8
33	0.6	60	0.38	58	0	0.1	0.2
33	0.57	60	0.38	58	0	0	0
33	0.5	60	0.38	58	0	0	0
33	0.4	60	0.38	58	0	0	0
33	0.38	60	0.38	58	0	0	0

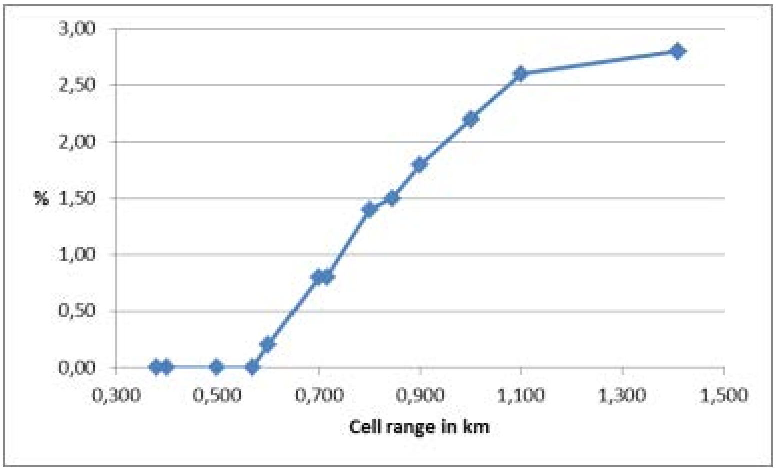


Figure 12: Interference probability on the victim UE according to cell range
Victim BS e.i.r.p. = 60 dBm/5 MHz – Interfering BS e.i.r.p. = 58 dBm/10MHz
Interfering cell range = 0.380 km

4.1.3.3 Sensitivity to UE selectivity

Table 16: Impact of UE selectivity on interference probability

Victim UE ACS (dB)	Victim network topology		Interfering network topology		Interference probability		
	Cell range (km)	Max e.i.r.p. (dBm)	Cell range (km)	Max e.i.r.p. (dBm)	Unwanted (%)	Blocking (%)	Total (%)
33	0.845	60	0.38	58	0	1.4	1.5
35	0.845	60	0.38	58	0	0.8	0.9
37	0.845	60	0.38	58	0	0.3	0.5
39	0.845	60	0.38	58	0	0.2	0.3
41	0.845	60	0.38	58	0	0	0
43	0.845	60	0.38	58	0	0	0
45	0.845	60	0.38	58	0	0	0

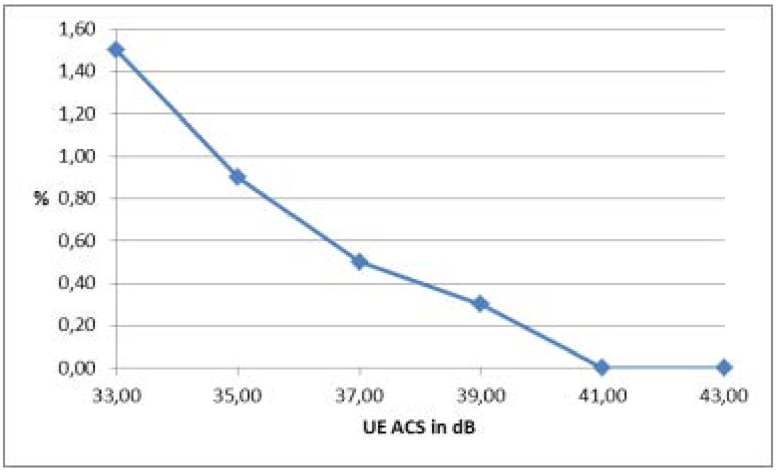


Figure 13: Interference probability on the victim UE according to its ACS
Victim cell range = 0.845 km – Interfering cell range = 0.380 km
Victim BS e.i.r.p. = 60 dBm/5 MHz – Interfering BS e.i.r.p. = 58 dBm/10 MHz

When the PPDR network is in between two MFCN networks, one below and one above the PPDR frequency range, it is expected that interference probability will increase by a factor 2. According to Table 16, this increase can be handled with a further increase of the UE selectivity of 2 dB[6].

4.1.4 Analysis of the intermodulation phenomenon

Inter-operator interference is also due to 3rd order intermodulation products generated inside the terminal due to DL signals in adjacent bands.

Table 17 below shows how the combination of carriers A and C falls into 728-758 MHz frequency range. In consequence, this induces intermodulation products in receiving PPDR UE within the 700 MHz centre gap.

Table 17: Detrimental IM3 from carrier A and C

carrier A (f_{low})		carrier B		carrier C (f_{high})		$IM3_{min} = 2*f_{low}-f_{high}$	
758	768	768	778	778	788	728	758

The combinations of carriers A and B and of carriers B and C, assuming 10 MHz for each carrier, are also given in Table 18 and Table 19 below showing the IM3 falling respectively in the 738-768 MHz range and in the 748-778 MHz range, respectively.

Table 18: Detrimental IM3 from carrier A and B

carrier A (f_{low})		carrier B (f_{high})		carrier C		$IM3_{min} = 2*f_{low}-f_{high}$	
758	768	768	778	778	788	738	768

[6] Table 16 shows that an increase of 2 dB in UE selectivity decreases the interference probability by 2.

Table 19: Detrimental IM3 from carrier B and C

carrier A		carrier B (f_{low})		carrier C (f_{high})		$IM3_{min} = 2*f_{low}-f_{high}$	
758	768	768	778	778	788	748	778

In all the previous cases, IM3 products fall within PPDR DL 753-758 MHz as well as within MFCN/PPDR DL 758-778 MHz. This effect is acceptable from a public commercial perspective. If better intermodulation response rejection is required for BB PPDR UE, more stringent requirements than for commercial equipment will be needed.

4.2 COEXISTENCE OF PPDR UL AND MFCN UL

The system parameters used in the two analyses below are listed in the following tables.

Table 20: MFCN LTE System Parameters (3GPP 36.104 [7], 36.101 [8] and TR 36 942 [9])

	Base Station	UE
Carrier frequency	700 MHz	
Channel bandwidth	10 MHz	
Cell radius	500 m	
Cell layout	Wrap-around 19 tri-sector cells	
Path-loss model	Hata Urban	
Antenna gain and antenna pattern	Maximum gain: 15 dBi Horizontal pattern: $A(\theta) = -\min\left[12\left(\frac{\theta}{\theta_{3dB}}\right)^2, A_m\right]$ θ_{3dB} = 65, Am = 20 dB Vertical pattern: $B(\theta) = -\min\left[12\left(\frac{\beta}{\beta_{3dB}}\right)^2, B_m\right]$ β_{3dB} = 6.2, Bm = 18dB	-3 dBi omni-directional antenna 4 dB body loss
Noise figure	5 dB	9 dB
Max transmit power	43 dBm	23 dBm
Antenna height	30 m	1.5 m
ACLR	45 dB	30 dB
ACS	45 dB	33 dB

Table 21: PPDR LTE System Parameters (3GPP 36.104 [7], 36.101 [8] and TR 36 942 [9])

	Base Station	UE
Carrier frequency	700 MHz	
Channel bandwidth	5 MHz	
Cell radius	845 m, 715 m, 570 m	
Cell layout	Wrap-around 19 tri-sector cells	
Path-loss model	Hata Urban	
Antenna gain and antenna pattern	Maximum gain: 15 dBi Horizontal pattern: $A(\theta) = -\min\left[12\left(\frac{\theta}{\theta_{3dB}}\right)^2, A_m\right]$ θ_{3dB} = 65, Am = 20 dB Vertical pattern: $B(\theta) = -\min\left[12\left(\frac{\beta}{\beta_{3dB}}\right)^2, B_m\right]$ β_{3dB} = 6.2, Bm = 18dB	-3 dBi omni-directional antenna 4 dB body loss
Noise figure	5 dB	9 dB
Max transmit power	45 dBm	23 dBm
Antenna height	30 m	1.5 m
ACLR	45 dB	30 dB
ACS	45 dB	33 dB

4.2.1 Impact of MFCN UL onto PPDR UL

The following Table 22 shows the relative throughput loss of PPDR UL due to UL interference from MFCN UE. Both the average throughput loss and the 5-percentile throughput loss are simulated. Note that for PPDR portables, the antenna gain plus body loss is -7 dBi. Due to uplink power control, the antenna gain does not affect the victim system throughput loss. From the results, we can draw the conclusion that the interference between UL of adjacent systems is within the normal acceptable level for MFCN networks (< 5 %).

Table 22: PPDR UL relative throughput loss due to MFCN UE UL interference (using two different power control setups (see 3GPP TR36.942 [9])

Power control set	PPDR system cell range					
	845 m		715 m		570 m	
	Average	5-percentile	Average	5-percentile	Average	5-percentile
Set 1	1.9 %	2.7 %	1.6 %	2.2 %	1.6 %	1.8 %
Set 2	1.4 %	1.6 %	1.1 %	1.5 %	1.0 %	1.3 %

4.2.2 Impact of PPDR UL onto MFCN UL

The following Table 23 shows the relative throughput loss of MFCN UL due to UL interference from PPDR UE. Both the average throughput loss and the 5-percentile throughput loss are simulated. Note that for PPDR portables, the antenna gain plus body loss is -7 dBi. Due to uplink power control, the antenna gain does not affect the victim system throughput loss. From the results, we can draw the conclusion that the interference between UL of adjacent systems is within the acceptable level (< 5 %).

Table 23: MFCN UL relative throughput loss due to PPDR UE UL interference

Power control set	PPDR system cell range					
	845 m		715 m		570 m	
	Average	5-percentile	Average	5-percentile	Average	5-percentile
Set 1	2.0 %	1.5 %	1.2 %	0.8 %	0.6 %	0.6 %
Set 2	0.9 %	0.7 %	0.5 %	0.5 %	0.3 %	0.3 %

4.3 COEXISTENCE OF PPDR UL AND SDL

The Supplemental Downlink (SDL) option uses 0 up to 4 of the following frequency blocks: 738-743 MHz, 743-748 MHz, 748-753 MHz and 753-758 MHz, as proposed in CEPT Report 53 [2], leaving a minimum of 2MHz guard band between PPDR UL and SDL

4.3.1 Impact of PPDR UL onto SDL, Matlab analysis

This study aims at deriving the statistics of $\frac{C_{SDL}}{N+I_{PPDR}}$ experienced by SDL UEs receiving in the 738-743 MHz block subject to interference from PPDR UEs emitting in 733-736 MHz block.

Interference power impairing PPDR reception can be break into two parts: the first part consists in the out of band emissions (ACLR) of the PPDR UE falling into the SDL block. The second is due to the imperfect rejection (ACS) of adjacent channel of the SDL UE. The total interfering power is given by the following equation:

$$I_{PPDR} = P_{PPDR} - ACIR$$

$$ACIR = -10 * log10(\frac{1}{10^{\frac{ACS}{10}}} + \frac{1}{10^{\frac{ACLR}{10}}})$$

where P_{PPDR} is the uplink power of the PPDR signal at the antenna port of the victim PPDR UE.

ACS value is assumed to be 33 dB and ACLR is set to 30 dB according to Table 6 and Table 5 respectively, which corresponds to an ACIR value of 28.2 dB. Although these values are believed to be pessimistic compared to real-life devices performances which are necessarily higher, they constitute the starting point for the evaluation of the impact of PPDR on SDL. The PPDR UE is assumed to be transmitting at the maximum e.i.r.p. of 20 dBm.

Sensitivity study is carried-out for different number of PPDR users located in the vicinity of the SDL UE. The resulting interference probabilities are summarized in Table 24.

Table 24: SDL interference probability due to PPDR UE UL

PPDR UEs per km²	C/(N+I) experienced by SDL		
	-3	0	5
1	<0.01 %	<0.01 %	0.01 %
2	<0.01 %	<0.01 %	0.02 %
3	<0.01 %	<0.01 %	0.04 %
4	<0.01 %	<0.01 %	0.05 %
5	<0.01 %	<0.01 %	0.06 %

In this study the statistics of the received power for a SDL UE from both its serving BS and potential interfering PPDR UEs are computed. Then the experienced C/(N+I) of the SDL UE is derived. Interferers are located at arbitrary locations on disk around the SDL victim. The area is 1 km² and a regular lattice with resolution 10 m is used.

Cell range of SDL is assumed to be 500 m, in accordance with ITU-R BT M.2292. Note that this value is also used in 3GPP 36.942.

PPDR UE densities ranging from 1 to 5 UEs per km² are investigated for the PPDR networks.

It is assumed that BS antennas are at 30 m a.g.l. for SDL networks and equipped with antennas with diagrams represented in Figure 14, with a 4° down-tilt.

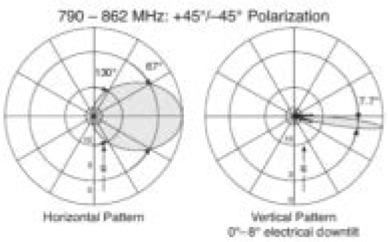


Figure 14: Antenna diagrams

Receiving SDL UE is at 1.5 m height.

The power of SDL BSs is assumed to be 58 dBm e.i.r.p. and PPDR devices are transmitting at 23 dBm and equipped with an omnidirectional antenna with -3 dBi gain and further decreased by an ACIR of about 28 dB.

The victim SDL UE is assumed to be a handheld device with -3 dBi antenna gain, and subject to a 4 dB body loss.

Propagation models are extended Hata for both PPDR and SDL links. Variation for each RF link is set according to the Extended Hata as described in ITU-R Report SM.2028-1 [16].

It is assumed that both the SDL and PPDR UEs are located outdoor.

Results are given in Figure 16 (Figure 15 is a zoom) where it can be seen that the impact of the PPDR UE on the SDL UE is very limited.

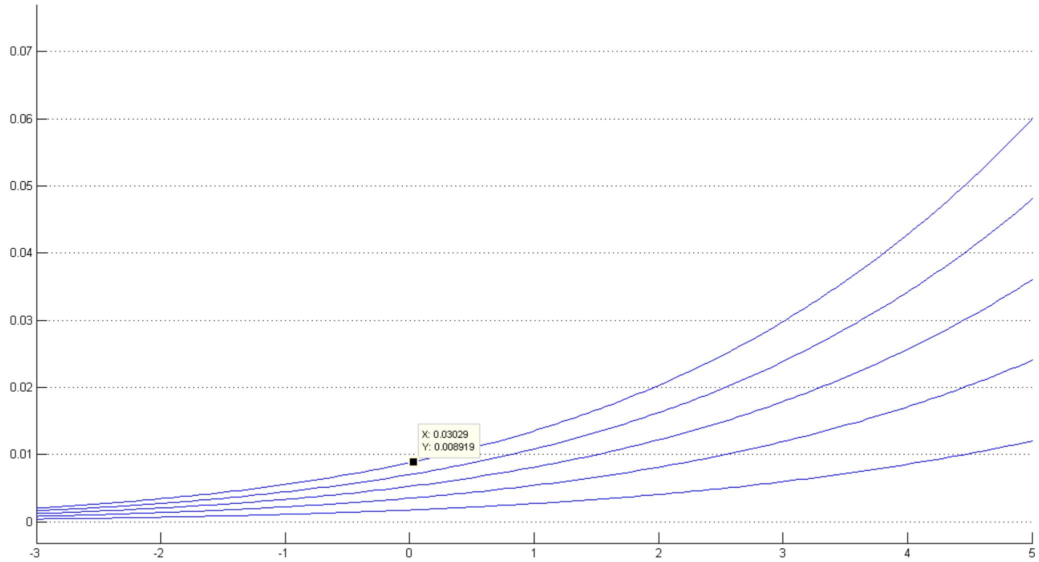


Figure 15: Cumulative distribution function of C/N+I (dB scale) for SDL UE interfered by 1 to 5 PPDR UEs from top to bottom curves (zoom): Y axis is expressed in %

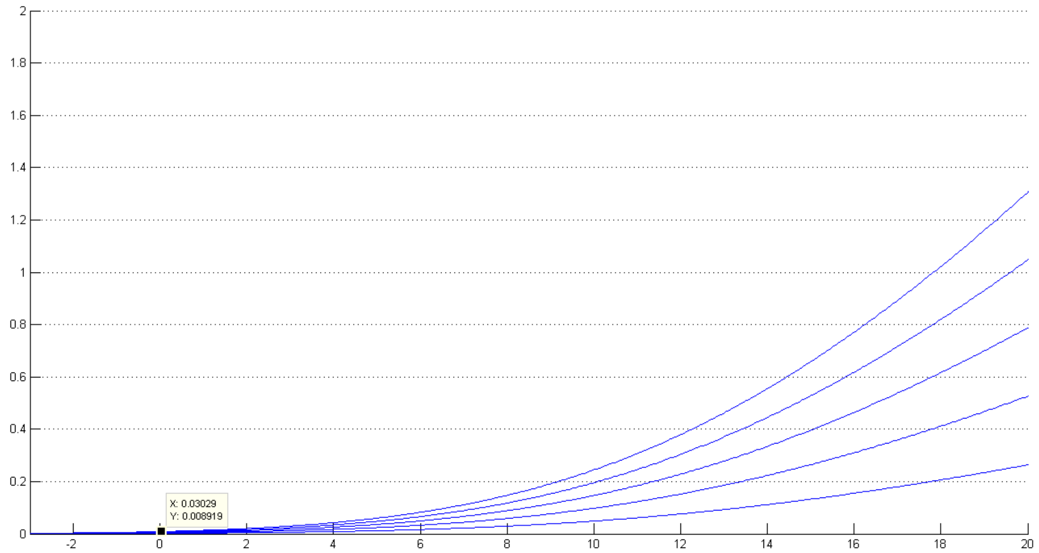


Figure 16: Cumulative distribution function of C/N+I (dB scale) for SDL UE interfered by 1 to 5 PPDR UEs from top to bottom curves: Y axis is expressed in %

4.3.2 Impact of SDL onto PPDR UL

4.3.2.1 Combined impact of blocking and unwanted emissions from BS DL onto PPDR BS:

The aim of this section is to assess the desensitisation of a PPDR base station caused by an interfering LTE base station in adjacent band.

The desensitisation is determined by the following equation:

$$SINR_{target} = \frac{S_{desens}}{N + I_{adj}} = \frac{S_{sens}}{N}$$

Where S_{desens} and S_{sens} are the levels of the wanted signal that allow to reach the target SINR, with and without the interference respectively, and N is the noise floor (thermal noise + noise figure).

I_{adj} denotes the level of interference from the interfering signal at the PPDR base station antenna connector. It is due to the combined effect of the OOBE of the adjacent system and limited selectivity of the PPDR base station receiver.

Desensitisation is given by the following formula:

$$D = \frac{S_{desens}}{S_{sens}} = \frac{N + I_{adj}}{N}$$

The interfering signal is expressed as follows in dB scale:

$$I_{adj} = P_{oobe} + \Delta_{ACS} + 10log10\left(\frac{3}{5}\right) + G + L_{hata}$$

where P_{oobe} is the out-of-band e.i.r.p. of the interfering SDL base station measured in 5 MHz bandwidth and Δ_{ACS} is the increase of the interfering power due to limited PPDR base station selectivity compared to the sole interfering power due to out-of-band emission. G is the antenna gain, including down-tilt (15-1.89 dBi) of the victim PPDR base station, and L_{hata} the path loss between the transmitter and the receiver.

Assuming Δ_{ACS} is equal to 1 dB, sensitivity of base station is -103 dBm (Table 7.2.1-1 of ETSI TS 136 104 [7]), and out-of-band emission of -50 dBm/5MHz e.i.r.p. (Table 3 of ECC/DEC/(15)01 [1]), similar to BEM baseline requirements for the MFCN networks, the desensitisation is shown in Figure 17 as a function of the distance. Extending the baseline requirement of BEM defined for MFCN networks in the uplink blocks to 733-736 MHz ensures a limited impact of out-of-band emissions from SDL base stations to receiving PPDR base station (UL) under the same deployment conditions in terms of coupling loss. It can be seen that desensitisation of the PPDR base station is of about 4 dB at a distance of 50 m from an interfering SDL base station.

It is worth noting that the ACS, for a 3 MHz system, measured in the band of the interfering system is given by the following equation:

$$ACS = ACLR_{dB/5MHz} - 10log10(\frac{3}{5}(10^{\frac{\Delta_{ACS}}{10}} - 1))$$

Assuming Δ_{ACS} is equal to 1 dB:

$$ACS = ACLR_{dB/5MHz} + 8.08$$

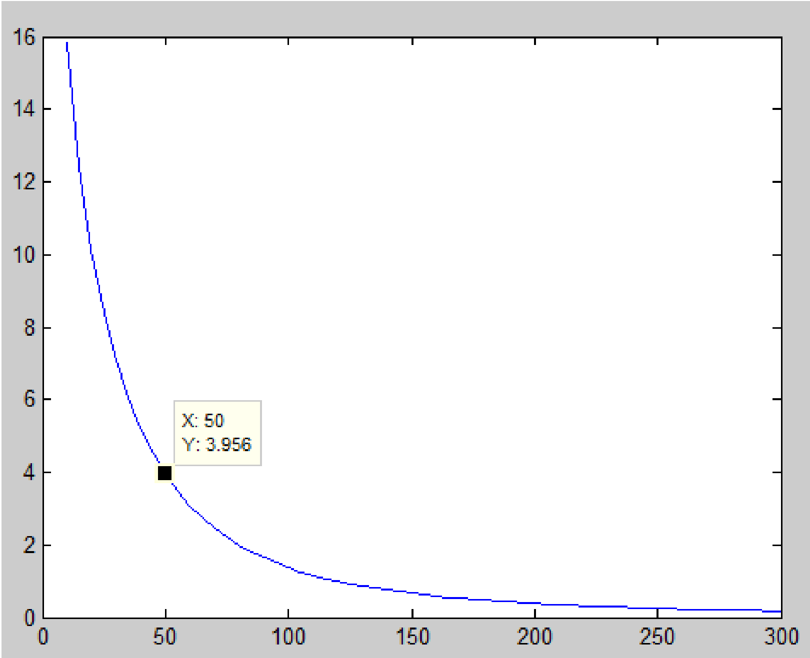


Figure 17: Desensitisation (in dB) as a function of the distance (in m) between victim and interfering BS

Note that the least restrictive requirements for MFCN (i.e. BEM) assume separation distances between base stations of 50 m. Coordination may be required between base stations deployed with less than 50 m separation distance.

Defining LRTC for a target separation distance of less than 50 m would require more stringent BEM, i.e. higher filtering requirements. In some cases, the filtering requirements would demand a guard-band in order to be implementable.

4.3.2.2 Impact of blocking due to SDL emissions onto PPDR BS:

The purpose of this section is to study the coexistence between SDL BS operating in the 700 MHz FDD duplex gap and PPDR BS operating in 733-736 MHz UL / 788-791 MHz DL. The phenomenon considered is the impact of transmitting SDL onto receiving PPDR BS (UL) due to blocking.

Table 25 below provides the wideband blocking levels for an LTE BS operating in a 3 MHz channel, derived from Table 4, for a desensitisation of 1 dB.

Table 25: LTE Wide Area BS, Receiver characteristics for a desensitisation of 1 dB

Parameter	Value
Channel bandwidth	3 MHz
1st adjacent 3 MHz block	
Blocking level for 1 dB desensitisation	-59.7 dBm/3MHz
2nd adjacent 5 MHz block and beyond	
Blocking level for 1 dB desensitisation	-50.7 dBm/5MHz = -52.9 dBm/3MHz

The minimum coupling loss between two BS is assumed to be 67 dB (see section 7.4.1.2.1.3 in 3GPP TR 25.942 [11]) for a scenario on which the BS are coexisting in the same geographical area. This MCL includes the additional loss due the 3° down-tilt of the antennas of the two BS considered.

If the 2x3 MHz option for PPDR is combined with the SDL option, the lowest SDL block that could be envisaged would operate in 738-743 MHz, leaving a 2 MHz guard-band with the PPDR UL band.

For a 3 MHz LTE BS, blocking levels are defined for the first adjacent channel (i.e. 736-739 MHz in that case) and then for the second 5 MHz block (i.e. 741-746 MHz in that case). Nothing is defined for the frequency range 3 to 5 MHz away from the PPDR UL channel edge.

Figure 18 below depicts the situation and shows where the blocking level needs to be determined.

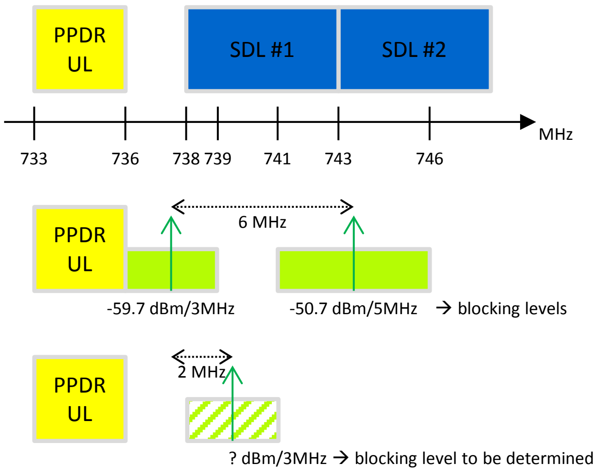


Figure 18: Blocking of PPDR BS due to SDL

There is no information available to determine the blocking level for an interfering signal in 738-743 MHz. Thus, based on the blocking rejection in the first adjacent channel in Table 25, the maximum transmitted power at the SDL BS antenna connector would be:

$$Max\_Tx\_Power = -59.7 + 67 + Additional\_Duplex\_Filtering + 10 \times \log_{10}(5/3) \text{ dBm/5MHz}$$

$$Max\_Tx\_Power = 9.5 + Additional\_Duplex\_Filtering \text{ dBm/5MHz}$$

For instance, in order to let an SDL BS transmit at 43 dBm/5MHz at the antenna connector, an additional filtering of 33.5 dB is required on the PPDR BS receiving chain. Otherwise some mitigation measures may be needed, e.g. a coordination procedure between the SDL operator and the PPDR operator.

4.3.3 PPDR UL and SDL frequency separation

This section analyses different deployment scenarios for PPDR (733-736 MHz UL / 788-791 MHz DL) and SDL (738-743 MHz) from a design perspective.

Scenario 1: Fulfilment of the LRTC in ECC/DEC/(15)01 [1]

Considering a separate SDL BS transmitting unit specifically designed for 738-758 MHz, it is possible to design an internal 10 pole filter providing sufficient rejection to fulfil the LRTC, i.e. -52 dBm/3MHz below 736 MHz, with only 2 MHz guard-band. The LRTC can be translated into an emission level of -67 dBm/3MHz at the SDL BS antenna connector, assuming 15 dBi antenna gain. This may be achieved without unduly increasing the size of the BS equipment. Thus an external filter would not be necessary.

For PPDR BS there is a need for an Rx filter with similar performance as the MFCN BS Tx filter in order to sufficiently increase the selectivity. The feasibility of this filter was not verified.

Scenario 2: Fulfilment of 3GPP requirements for coexistence or colocation between PPDR and SDL

The 3GPP standard requirements for coexistence and colocation are -49 dBm/MHz and -96 dBm/100kHz at the antenna connector, respectively. In addition, blocking rejection of SDL in the coexistence and colocation scenarios are also considered with 1 dB desensitisation. The required filter rejection characteristics also consider attenuation from the receiver chain to reflect a realistic design.

Filter simulations at room temperature are included below. Note that temperature variation also needs to be considered but not shown in these graphs. Figure 19 and Figure 20 show SDL and PPDR UL simulations for a colocation scenario. To be able to fulfil the protection towards PPDR UL according to 3GPP, the lowest 2 MHz of SDL (738-740 MHz) may need to be sacrificed due to high loss or accept to have high performance degradation. The PPDR UL filter also includes high loss across its pass-band.

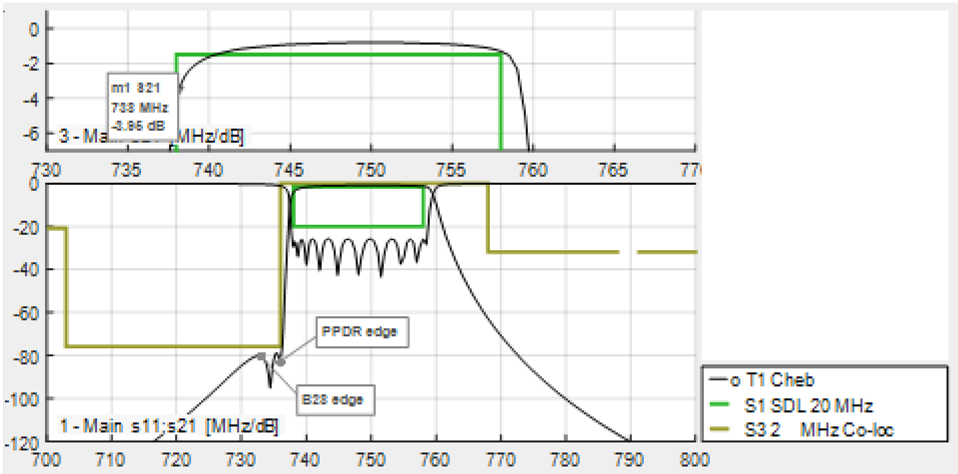


Figure 19: SDL filter simulations for colocation with PPDR UL

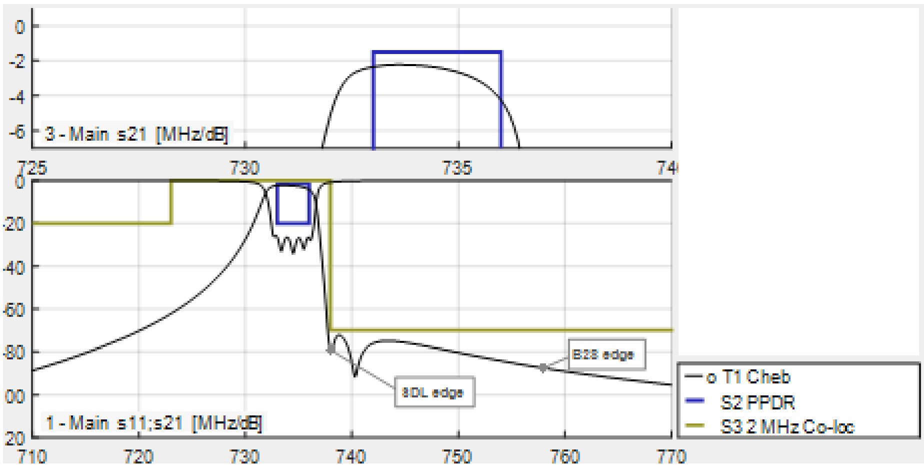


Figure 20: PPDR UL filter simulations for colocation with SDL

The coexistence scenario is slightly easier with 2 MHz offset. However, the expected insertion loss for the PPDR BS Rx filter is higher than 2 dB at the edge, which will affect UL performance.

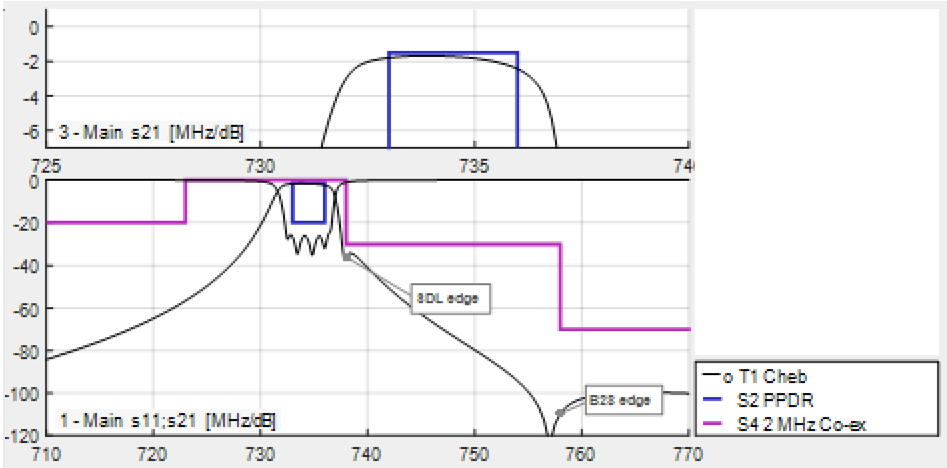


Figure 21: PPDR UL filter simulations for coexistence with SDL

When taking the 3GPP requirements into consideration, coexistence is possible between SDL and PPDR with 2 MHz offset and higher than standard insertion loss for PPDR Rx filter. More than 2 MHz separation between PPDR UL and SDL are needed to allow for colocation. Further simulations show that 5 MHz or larger offset is recommended. The exact level of guard beyond 2 MHz for site solutions with external filters has not been investigated in this report.

Another way to manage colocation may be to rely on different site solutions, e.g. by using appropriate antenna physical separation.

4.4 CONCLUSION

4.4.1 DL to DL (near-far effect) interference

The technical specifications of MFCN networks and terminals do not for every scenario guarantee interference free operation of concurrent networks in adjacent blocks throughout the coverage area.¨

The simulations indicate that near-far effect is dominated by the ‘Blocking’, i.e. insufficient filtering of the interfering BS in-band power by the victim terminal, whereas the unwanted emissions of the LTE BS are always sufficiently reduced to prevent near-far effect.

The simulations indicate that blocking probability due to near-far effect is less than 1 % when networks are deployed with 500 m cell range and 845 m for the MFCN and PPDR network respectively. Conversely, the blocking probability may go beyond 1 % when network topologies are very different. Generally speaking, interference probability between two LTE networks deployed with similar topologies remains in the order of 1% or less.

A limited increase of the terminal selectivity (from 33 to 41 dB) would enable the victim PPDR UE to operate in a sparse network when adjacent in frequency to a dense network. Terminal selectivity may potentially be increased through the introduction of improved sharp filtering that reduces interference from adjacent band.

Another phenomenon in MFCN networks is the 3rd order intermodulation due to DL operations by two different operators. PPDR networks may also be subject to intermodulation interference due to adjacent PPDR or MFCN networks. It should be noted that this level of interference is accepted by commercial networks.

4.4.2 UL to UL interference

The results show that the victim system throughput degradation is less than 5 % when interfering systems are present. Such a degradation level is within the acceptable level per 3GPP report [9] for LTE systems in commercial networks.

4.4.3 SDL to PPDR UL interference

Compatibility between PPDR UL and SDL depends on the scenario which is targeted.

LRTC in ECC/DEC/(15)01 [1] define a maximum e.i.r.p. of -52 dBm/3MHz in the uplink frequencies 733-736 MHz to ensure a limited impact of out-of-band emissions from MFCN BS to receiving PPDR BS (UL) under the same deployment conditions. If LRTC are targeted, it is possible to design an internal filter for SDL BS with only 2 MHz guard-band. This may be achieved without unduly increasing the size of the BS equipment. Thus an external filter would not be necessary.

There is no blocking requirement for PPDR UL Rx in the ECC Decision and thus the PPDR BS Rx filter was not analysed for this scenario. However, it is recognised that the PPDR BS Rx filter is needed.

If the 3GPP minimum requirements for coexistence are to be fulfilled, it is feasible to create SDL Tx and PPDR BS Rx filters with enough rejection. However, the insertion loss in PPDR UL will be higher than standard.

Assuming MFCN and PPDR base stations using standard LTE equipment, the studies show that a minimum of 5 MHz separation is recommended between SDL and PPDR UL if the 3GPP minimum requirements for colocation are to be fulfilled. This means that compatibility is achieved with the upper 3 blocks of harmonized SDL spectrum (7 MHz guard band). If also the lowest SDL block (2 MHz guard band) is to be used together with this PPDR option, additional measures may be needed such as for example additional filtering on the PPDR UL (and possible UL degradation increase), physical antenna separation or applying other regulatory restrictions on the usage in the lowest SDL block. Exactly what measures that would be required, has not been studied.

5 COMPATIBILITY WITH DTT

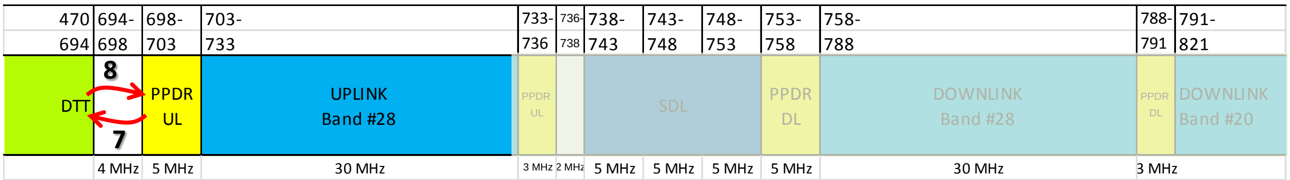


Figure 22: Summary of compatibility studies between PPDR LTE networks and DTT

(7) Impact of transmitting PPDR UE (UL) onto DTT reception

(8) Impact of DTT transmitter onto receiving PPDR BS (UL)

5.1 PPDR VS CHANNEL 47

The frequency separation between the upper edge of DTT channel 47 and the lower edge of PPDR 698-703 MHz uplink channel (12 MHz) is greater than the one between DTT channel 48 and 3GPP band 28[7] (9 MHz). Thus coexistence between PPDR and DTT below 686 MHz is equivalent from radio perspective to – but easier to achieve than – the one between MFCN and DTT below 694 MHz.

It can then be considered that the unwanted emission level of -42 dBm/8MHz required for commercial UEs can be achieved by PPDR UEs in DTT channel 47. Also DTT emissions from channel 47 towards PPDR uplink in the 698-703 MHz band are expected to be somewhat lower than DTT emissions from channel 48 towards Band 28 MFCN UL. Therefore, there is no compatibility study between PPDR and DTT below 686 MHz in this ECC Report.

5.2 PPDR ONTO DTT CHANNEL 48

It is appropriate to consider the potential localised effects to DTT channel 48 by considering minimum coupling loss analysis which gives insight on interference footprint caused by PPDR devices. Minimum coupling loss (MCL) calculations provide the upper bound to potential interference, the variability of LTE UE transmissions in time, location, bandwidth used and transmitted power mean that in most of the cases the interference will be below that what MCL calculations indicate.

Macroscopic compatibility studies assess the chance for DTT receivers to be interfered by PPDR users. This approach allows the technical conditions for PPDR devices to be determined in order to meet an acceptable overall interference probability target.

The amount of interference from PPDR to broadcasting will depend heavily on, amongst other parameters, the deployment scenario, choice of scheduler, and density of active PPDR terminals.

Administrations should remain free, on a national basis, to select protection requirement corresponding to the specific deployment scenario in their country.

Compatibility studies in the present document are conducted for ACLR values between the minimum requirement for LTE UE according to ETSI TS 136 101, i.e. 35 dB ACLR (or equivalent 33 dB/8MHz), see

[7] Band 28 is the LTE 700 MHz band used in Asia-Pacific Telecommunity (APT) countries (703-748 MHz for the uplink, 758-803 MHz for the downlink).

Table 5, and the required ACLR to fulfil -42 dBm/8MHz below 694 MHz (65 dB/8MHz). Additionally, ACLR of 70 dB/8MHz is also included.

Note that the desired level of ACLR can be achieved by different means, including e.g. adequate filtering or partial resource allocation

5.2.1 MCL analysis

It is important for an administration to understand what the localised PPDR interference impact will be on broadcast reception.

Emergency service personnel and vehicles are likely to take the same set of starting routes from and to, for example, a police or ambulance station and have regular patrol routes. Transmissions from PPDR terminals used by emergency service personnel both on foot and from emergency service vehicles have the potential to cause a significant interference problem to residential properties along such routes. In addition there are other situations where it is common for emergency service personnel and vehicles to regularly congregate in certain locations close to residential properties. The following analysis provides a minimum coupling loss assessment so administrations can take a view on the impact such PPDR use may have on broadcast reception.

CEPT Report 53 [2] provides a set of least restrictive technical conditions for harmonised mobile broadband user equipment operating within the 694 – 790 MHz band. It provides a useful reference for the protection of fixed DTT reception from commercial LTE devices by requiring a 9 MHz guard band between the LTE and DTT services and a UE maximum mean unwanted emission power level of -42 dBm / 8 MHz below 694 MHz assuming channel 10 MHz or less and this value has been incorporated in the 3GPP specifications:

- If PPDR mobiles use the frequency band 698 to 703 MHz and the maximum out-of-band emission level is maintained, this will have a greater interference impact on the broadcast service. The greater interference occurs as the selectivity of the DTT receiver will be lower due to the smaller frequency separation[8] (4 MHz) between PPDR user equipment and DTT receivers operating below 694 MHz.
- The equivalent minimum coupling loss calculation for PPDR vehicle mounted user equipment would not include body loss, therefore, if an administration chooses the same ACLR protection level as determined from the harmonisation process to protect Broadcast services, there will be a greater impact from the out-of-band emissions from the vehicle than from a handheld UE.
- On the other hand, there are fewer PPDR devices than commercial devices and their usage may be different, e.g. if their preferred mode is eMBMS, as then, the UE’s are only listening[9].

The following minimum coupling loss calculations give the separation distance needed to protect outdoor roof top DTT receivers from interference from PPDR user equipment operating in the frequency band 698 to 703 MHz. The minimum coupling loss calculations for PPDR UE operating in the MFCN duplex gap indicate a lower risk to DTT reception than that presented by commercial 700 MHz MFCN networks, (Table 32 and Table 33).

In the following minimum coupling loss calculations the UE (handheld and vehicular mounted) is assumed to be using its maximum power of 23 dBm. However the power control feature of the UE will typically reduce the output power unless the PPDR UE is at the edge of the coverage area, as exemplified by the walk test results (see Table 27).

Recommendation ITU-R BT.1895 [17] recommends the use of I/N threshold of -10 dB as a guideline above which compatibility studies on the effect of radiations and emissions from other co-primary applications and services into the broadcasting service should be undertaken.

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[8] A 2 to 4dB drop in the ACS with 4 MHz has been measured with a continuous interfering signal compared to similar tests carried out with 9MHz guard band.

[9] UE’s will still have some background signalling activity, for example in preparation and during handing over to another cell

Table 26 below lists the DTT receiver parameters assumed in this study for fixed rooftop reception.

Table 26: DTT receiver parameters

Parameter	Value	Unit	Source/comment
Noise figure, NF	7	dB	ITU-R Report BT.2383
Noise equivalent bandwidth	7.6	MHz	ITU-R Report BT.2383
Thermal noise (7.6 MHz)	-98.17	dBm	PN = 10log(kTB) + NF
I/N protection criterion	-10	dB	I/N
Target interference power	-108.17	dBm	$P_I = P_N + I/N$

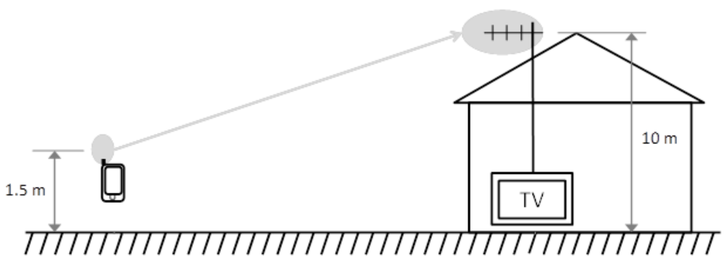

Figure 23 : UE into DTT outdoor roof top geometry

Table 27 presents example UE Tx power from a walk test in urban and suburban environments. ANNEX 5:contains further information on these walk tests. The LTE UE has a power control feature, which makes the UE transmit with maximum power only at the edge of the LTE cell coverage area. Table 27 below shows a range of power levels that a UE used in practice.

Table 27: Summary of LTE walk test results

Area	Band	UE Tx power (dBm)		
		Average	50th percentile	90th percentile
Urban	800 MHz	6	9	18
Suburban cell centre	800 MHz	7	7	19
	1800 MHz	-3	-2	10
Suburban cell edge	800 MHz	16	19	21
	1800 MHz	12	14	22

Table 28: Minimum coupling loss calculation for PPDR UE into DTT outdoor roof top reception

Parameter	Value	Unit	Source/comment
Frequency	700.5	MHz	F
Tx height	1.50	m	h_{Tx}
Rx height	10	m	h_{Rx}
Target interference power	-108.17	dBm	$P_I = P_N + I/N$
ACS	63	dB	
ACLR	65	dB	
ACIR	60.88	dB	
Tx Transmit power	23	dB	P_{Tx}
Rx antenna bore-sight gain[10]	9.15	dB	G_{Rx}
Tx antenna gain	-3	dBi	G_{Tx}
Body loss	4	dB	LBody
Propagation loss	72.44	dB	$L_{FS} = P_{Tx} + G_{Rx} + G_{Tx} - L_{Body} – ACIR - P_I$
Separation distance	113	m	Reference to SEAMCAT Extended Hata for an open environment

Table 29: Minimum coupling loss calculation for relay in vehicles into DTT outdoor roof top reception

Parameter	Value	Unit	Source/comment
Frequency	700.5	MHz	F
Tx height	1.50	m	h_{Tx}
Rx height	10	m	h_{Rx}
Target interference power	-108.17	dBm	$P_I = P_N + I/N$
ACS	63	dB	
ACLR	65	dB	
ACIR	60.88	dB	
Tx Transmit power	23	dB	P_{Tx}
Rx antenna bore-sight gain[11]	9.15	dB	G_{Rx}

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[10] Source document JTG 4-5-6-7/55 also contains feeder loss

Parameter	Value	Unit	Source/comment
Tx antenna gain	0	dBi	G_{Tx}
Body loss	0	dB	L_{Body}
Propagation loss	79.44	dB	$L_{FS} = P_{Tx} + G_{Rx} + G_{Tx} - L_{Body} - ACIR - P_I$
Separation distance	179	m	Reference to SEAMCAT Extended Hata for an open environment

It is possible that the implementation of PPDR in vehicles will use the same transmitter unit as a handheld device, however with an external antenna with improved performance over that used for mobile handsets. Therefore the mobile transmit power could be greater than the maximum e.i.r.p. of 23 dBm anticipated for both UE and vehicle use. Under this circumstance this would increase the size of the potential impact area where DVB-T receivers could be vulnerable to interference.

5.2.1.1 Sensitivity analysis on minimum coupling loss calculations

An administration may consider that it is appropriate to choose another I/N threshold above which compatibility studies on the effect of emissions from PPDR applications into the broadcasting service should be undertaken, compared to that of Recommendation ITU-R BT.1895. For example I/N of -6 dB representing a desensitisation of 1 dB may be considered as providing adequate protection.

It is likely that there will be a range of ACS performance levels of DTT receivers. Tests suggest that the ACS of some poor performing DTT receivers could be 38 dB in the presence of a real signal from a 5 MHz LTE UE that is only 4 MHz away. Note that these receivers may also be at risk of performance degradation when subject to real signals from 10MHz LTE UE signals 9 MHz away, as for the case of MFCN LTE12. Although DTT receiver performance may improve in the future, members of the public may still have receivers that are being sold today. In addition, it may be challenging to design a PPDR UE with an ACLR performance of 65 dB with a guard band of only 4 MHz. Therefore a range of both ACS and ACLR values have been used to calculate the separation distances in Table 30 and Table 31 below.

It is also possible that the system is used in a range of environments, so a range of propagation models representing a number of environments have also been used.

[12] Measurements results in [3] give DVB-T average protection ratio of -26dB for 4MHz guard band with LTE 5MHz system and -23dB for 9MHz guard band with LTE 10MHz system

Table 30: Sensitivity analysis from UE

Parameter changed (only the parameter/s in each line are changed in turn, the remaining parameters are the same as in Table 29)	Valued changed	Separation distance in an open environment, m	Separation distance in an suburban environment, m	Separation distance in an urban environment, m
I/N protection criterion	-6 dB	81	51	48
ACS	60 dB	129	62	56
ACS	55 dB	171	72	62
ACS	50 dB	232	84	69
ACLR	35 dB	614	187	102
ACLR	50 dB	233	84	70
ACLR	60 dB	134	63	56
ACLR	70 dB	104	55	51
ACS / ACLR	38 dB/65 dB	505	154	93

Table 31: Sensitivity analysis from vehicle mounted UEs

Parameter changed (only the parameter/s in each line are changed in turn, the remaining parameters are the same as above, Table 28)	Valued changed	Separation distance in an open environment, m	Separation distance in an suburban environment, m	Separation distance in an urban environment, m
I/N protection criterion	-6 dB	205	64	57
ACS	60 dB	205	69	66
ACS	55 dB	270	79	74
ACS	50 dB	367	93	83
ACLR	35 dB	970	228	161
ACLR	50 dB	369	93	83
ACLR	60 dB	212	70	67
ACLR	70 dB	164	61	61
ACS / ACLR	38 dB/65 dB	798	243	132

5.2.1.2 Estimation of size of vulnerable areas

The point of minimum coupling occurs at a horizontal distance of 22 m from the receive aerial, this is demonstrated in Figure 24 below.

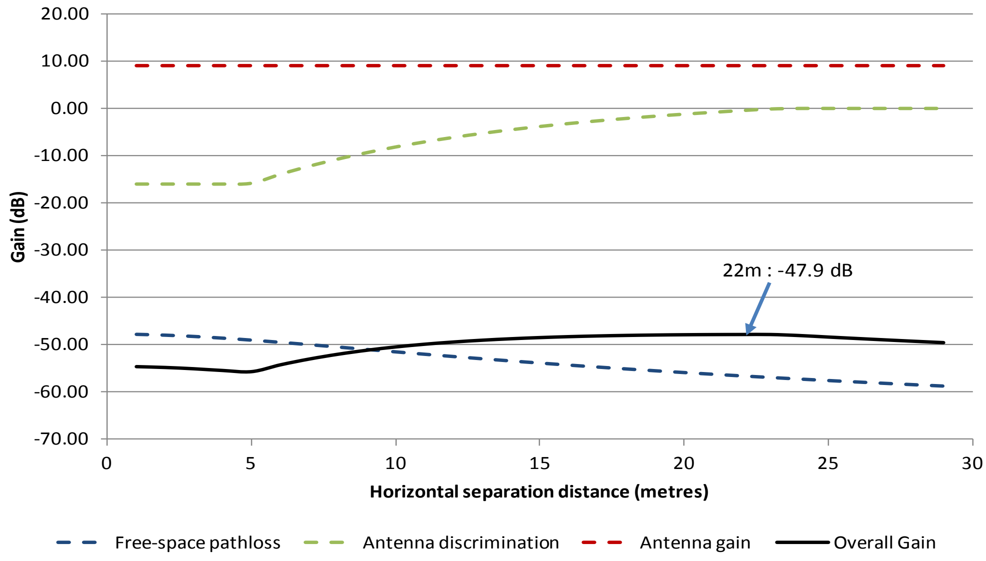
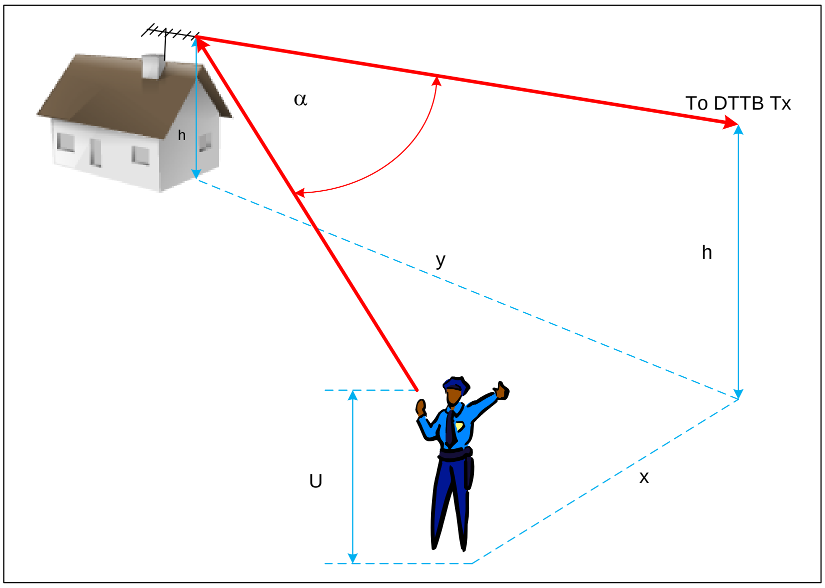


Figure 24: Coupling Loss plotted against Horizontal Separation

As it is unlikely that a UE will be located exactly 22 m from a receive aerial there is a need to test the sensitivity of the minimum coupling method by considering what the probability is that a receiver will be within 3 dB, 6 dB etc. of the worst case location.

By looking at values within 3 dB, 6 dB etc. of the minimum coupling loss value we will no longer be considering a point but rather will be looking at an area; a footprint. Each DTT receiving aerial will have associated with it a footprint within which a UE is within 3 dB, 6 dB etc. of the minimum coupling value.

The footprint associated with each receive aerial can be calculated based on the ITU-R BT.419 receiving aerial pattern. The directivity of the DTT receiving aerial based on angle α as shown in Figure 25.



h = height of receive aerial, 10 m

y = distance along y-axis to UE

x = distance along x-axis to UE

U = height of UE, 1.5 m

α = angle used to calculate receive aerial directivity

Figure 25: Geometry for calculating DTT receive aerial footprint

Given the geometry shown in Figure 25, the assumptions about receiving aerial gain and pattern and moving the UE over an area around the DTT receive aerial, the locations where a UE is within 1 dB, 2 dB, 3dB etc. of the minimum coupling value can be calculated and plotted, see Figure 26.

within 6 dB = 42m
within 5 dB = 36m
within 4 dB = 30m
within 3 dB =25m
within 2 dB = 19m
within 1 dB = 13m

y metres

x metres	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
0	6.7	6.7	6.9	7.2	7.6	7.8	6.4	5.1	4.1	3.3	2.6	2.0	1.6	1.2	0.9	0.6	0.5	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.2	0.5
1	6.7	6.8	7.0	7.2	7.6	7.9	6.5	5.3	4.2	3.4	2.7	2.1	1.7	1.3	1.0	0.7	0.5	0.4	0.3	0.2	0.1	0.1	0.1	0.1	0.2	0.5
2	6.9	7.0	7.1	7.4	7.7	8.2	6.8	5.6	4.6	3.7	3.0	2.4	1.9	1.5	1.2	1.0	0.8	0.6	0.5	0.4	0.3	0.3	0.2	0.2	0.2	0.6
3	7.2	7.2	7.4	7.7	8.0	8.4	7.3	6.1	5.1	4.2	3.5	2.9	2.4	2.0	1.6	1.4	1.1	1.0	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.6
4	7.6	7.6	7.7	8.0	8.3	8.6	8.0	6.8	5.8	4.9	4.1	3.5	3.0	2.5	2.2	1.9	1.6	1.4	1.3	1.1	1.0	1.0	0.9	0.9	0.9	0.9
5	8.0	8.0	8.2	8.4	8.6	9.0	8.8	7.6	6.6	5.7	4.9	4.2	3.7	3.2	2.8	2.5	2.2	2.0	1.8	1.7	1.6	1.5	1.4	1.3	1.3	1.3
6	8.4	8.5	8.6	8.8	9.0	9.3	9.7	8.5	7.4	6.5	5.7	5.1	4.5	4.0	3.6	3.2	2.9	2.7	2.5	2.3	2.2	2.0	1.9	1.9	1.8	1.8
7	8.9	9.0	9.1	9.2	9.5	9.7	10.1	9.4	8.4	7.5	6.6	6.0	5.3	4.8	4.4	4.0	3.7	3.4	3.2	3.0	2.8	2.7	2.6	2.5	2.4	2.3
8	9.4	9.5	9.6	9.7	9.9	10.2	10.5	10.4	9.3	8.4	7.6	6.9	6.3	5.7	5.2	4.8	4.5	4.2	3.9	3.7	3.5	3.3	3.2	3.1	3.0	2.9
9	10.0	10.0	10.1	10.2	10.4	10.6	10.9	11.2	10.3	9.4	8.6	7.8	7.2	6.6	6.1	5.7	5.3	5.0	4.7	4.4	4.2	4.0	3.9	3.8	3.6	3.5
10	10.5	10.5	10.6	10.7	10.8	11.0	11.3	11.5	11.3	10.4	9.5	8.8	8.1	7.5	7.0	6.6	6.2	5.8	5.5	5.2	5.0	4.8	4.6	4.4	4.3	4.2
11	11.0	11.0	11.0	11.2	11.3	11.5	11.7	11.9	12.2	11.3	10.5	9.7	9.1	8.5	7.9	7.4	7.0	6.6	6.3	6.0	5.8	5.5	5.3	5.1	5.0	4.9
12	11.4	11.5	11.5	11.6	11.8	11.9	12.1	12.3	12.6	12.2	11.4	10.7	10.0	9.4	8.8	8.3	7.9	7.5	7.1	6.8	6.5	6.3	6.1	5.9	5.7	5.5
13	11.9	11.9	12.0	12.1	12.2	12.4	12.5	12.7	12.9	13.1	12.3	11.6	10.9	10.3	9.7	9.2	8.7	8.3	7.9	7.6	7.3	7.0	6.8	6.6	6.4	6.2
14	12.4	12.4	12.4	12.5	12.6	12.8	12.9	13.1	13.3	13.5	13.2	12.4	11.8	11.1	10.6	10.0	9.6	9.1	8.7	8.4	8.1	7.8	7.5	7.3	7.1	6.9
15	12.8	12.8	12.9	13.0	13.1	13.2	13.3	13.5	13.7	13.9	14.0	13.3	12.6	12.0	11.4	10.9	10.4	9.9	9.5	9.2	8.8	8.5	8.3	8.0	7.8	7.6

x metres	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
0	0.8	1.1	1.4	1.7	2.0	2.2	2.5	2.7	3.0	3.2	3.5	3.7	3.9	4.1	4.3	4.5	4.7	4.9	5.1	5.3	5.5	5.7	5.9	6.0	6.2
1	0.8	1.1	1.4	1.7	2.0	2.2	2.5	2.8	3.0	3.2	3.5	3.7	3.9	4.1	4.3	4.5	4.7	4.9	5.1	5.3	5.5	5.7	5.9	6.0	6.2
2	0.9	1.2	1.4	1.7	2.0	2.3	2.5	2.8	3.0	3.2	3.5	3.7	3.9	4.1	4.3	4.5	4.7	4.9	5.1	5.3	5.5	5.7	5.9	6.0	6.2
3	0.9	1.2	1.5	1.7	2.0	2.3	2.5	2.8	3.0	3.3	3.5	3.7	3.9	4.1	4.4	4.6	4.8	5.0	5.1	5.3	5.5	5.7	5.9	6.0	6.2
4	0.9	1.2	1.5	1.8	2.0	2.3	2.6	2.8	3.0	3.3	3.5	3.7	4.0	4.2	4.4	4.6	4.8	5.0	5.2	5.3	5.5	5.7	5.9	6.1	6.2
5	1.3	1.3	1.5	1.8	2.1	2.3	2.6	2.8	3.1	3.3	3.5	3.8	4.0	4.2	4.4	4.6	4.8	5.0	5.2	5.4	5.5	5.7	5.9	6.1	6.2
6	1.8	1.8	1.8	1.9	2.1	2.4	2.6	2.9	3.1	3.3	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0	5.2	5.4	5.6	5.7	5.9	6.1	6.3
7	2.3	2.3	2.3	2.2	2.3	2.4	2.7	2.9	3.2	3.4	3.6	3.8	4.0	4.3	4.5	4.7	4.9	5.0	5.2	5.4	5.6	5.8	5.9	6.1	6.3
8	2.9	2.8	2.8	2.8	2.8	2.8	2.8	3.0	3.2	3.4	3.7	3.9	4.1	4.3	4.5	4.7	4.9	5.1	5.3	5.4	5.6	5.8	6.0	6.1	6.3
9	3.5	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.5	3.7	3.9	4.1	4.3	4.5	4.7	4.9	5.1	5.3	5.5	5.7	5.8	6.0	6.2	6.3
10	4.1	4.0	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.8	4.0	4.2	4.4	4.6	4.8	5.0	5.2	5.3	5.5	5.7	5.9	6.0	6.2	6.4
11	4.7	4.6	4.6	4.5	4.4	4.4	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.4	4.6	4.8	5.0	5.2	5.4	5.6	5.7	5.9	6.1	6.2	6.4
12	5.4	5.3	5.2	5.1	5.0	5.0	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.9	5.1	5.2	5.4	5.6	5.8	5.9	6.1	6.3	6.4
13	6.1	5.9	5.8	5.7	5.6	5.5	5.5	5.4	5.4	5.3	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.3	5.5	5.7	5.8	6.0	6.2	6.3	6.5
14	6.7	6.6	6.4	6.3	6.2	6.1	6.1	6.0	5.9	5.9	5.8	5.8	5.8	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.9	6.0	6.2	6.4	6.5
15	7.4	7.2	7.1	7.0	6.8	6.7	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.2	6.2	6.2	6.1	6.1	6.1	6.1	6.2	6.4	6.6

Figure 26: Increase in coupling loss (dB) relative to the minimum value

Though the point of minimum coupling loss occurs at 22 m, the area (footprint) in which the coupling loss is within 6 dB of the minimum coupling loss value extends from 7 m to 48 m from the DTT receive aerial covering an area of 1150 m^2.

This calculated footprint based on the Recommendation ITU-R BT.419 antenna is very similar to measurements of coupling loss (gain) of an actual receive aerial, measured by wandering around in the area in-front of an antenna and logging the measured signal level, Figure 27.

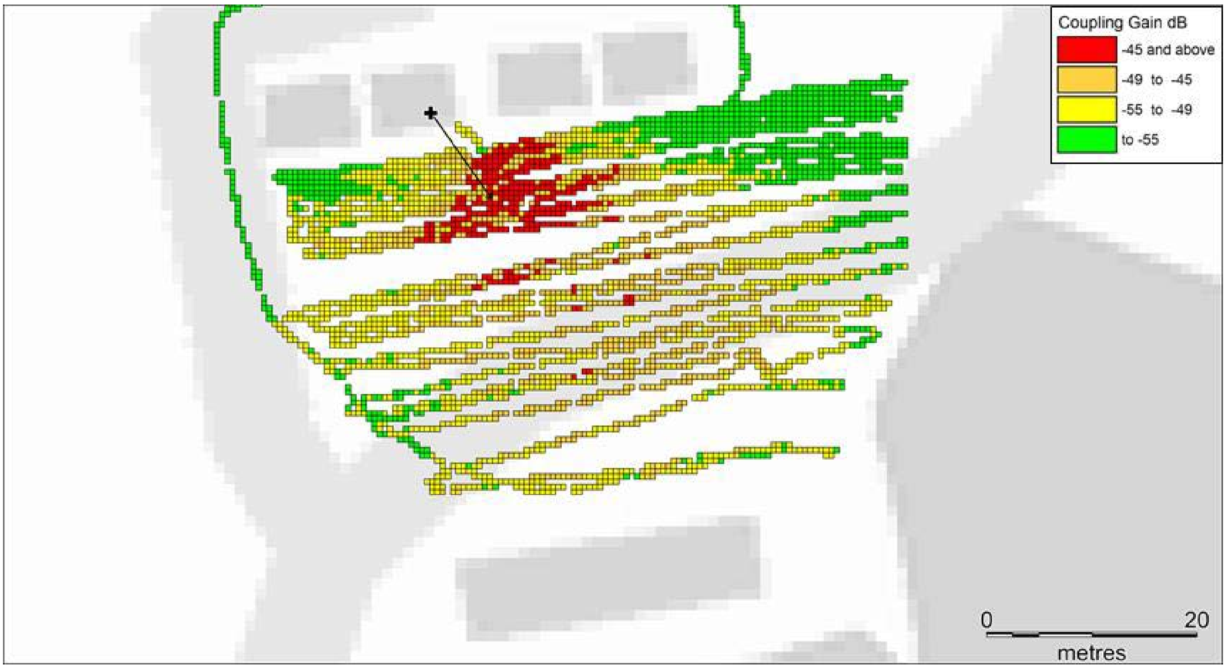


Figure 27: Measured coupling gain - Heat Map at 554 MHz of a contract TV receive aerial mounted 8.7 m a.g.l.

The footprint can be applied to each DTT receive aerial in an area to calculate both the proportion of the area that falls within X dB of the value of minimum coupling loss and as PPDR UE are likely to be located in roads the proportion of road within X dB of the value of minimum coupling loss.

This exercise has been carried out for a sample 1 km^2 area in a typical suburban area within the United Kingdom, Figure 28. The mapping of the same area is shown in Figure 29 with dots showing the centroid of each building (address point).

Figure 28: Sample United Kingdom Suburban area

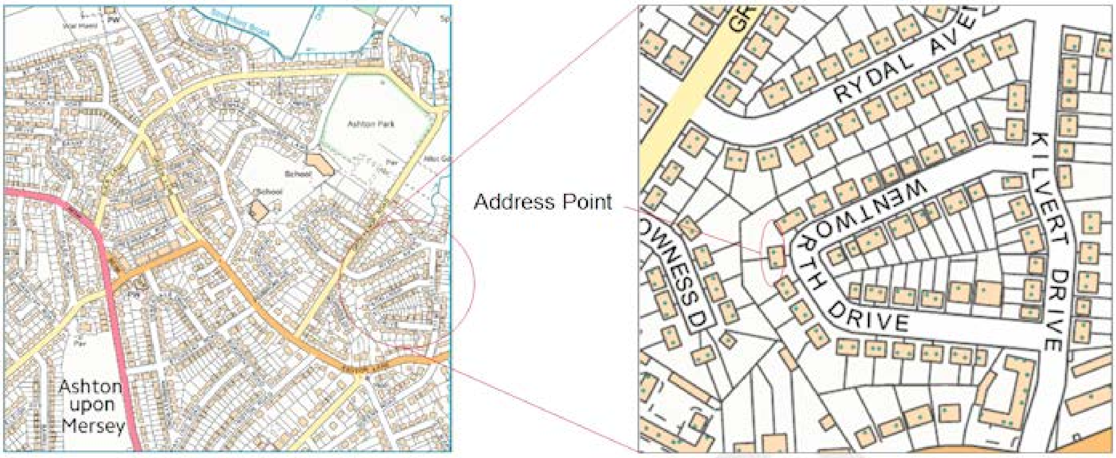


Figure 29: Mapping of the sample suburban area showing individual locations[13]

The sample area contains 2039 individual locations (buildings or houses), which corresponds to a population of about 5,000 people.

Locating the footprint at each of the centroids (address points), Figure 30, allows the area that is within for example 3 dB or 6 dB of the minimum coupling loss, after accounting for overlaps, to be calculated.

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[13] © Crown copyright and database rights 2013 Ordnance Survey 100039117

Figure 30: Sample suburban area mapping with 3 dB and 6 dB minimum coupling footprints overlaid

For the 1 km^2 area shown, 0.4075 km^2 falls within the 3 dB footprint and 0.6835 km^2 within the 6 dB footprint. From this we can conclude that the percentage of the area that a UE will be within 3 dB of the point of minimum coupling loss is 41 % and within 6 dB is 68 %.

In the sample about 10 % of the 1 km^2 area, are locations where UE activity will be low, i.e. these are fields, allotments and to some extent parks. If these areas are excluded (or are given a lower weighting) then the percentage of the area that a UE will be within 3 dB is 45 % and within 6 dB is 75 %.

The proportion of road within 6 dB of the point of minimum coupling loss of a receiving aerial is 87 %.

Whilst the sample used for the calculations is a specific case in the UK, it is typical of the distribution of houses in suburban areas in Europe and as such these should have similar proportions of their area within 3 dB and 6 dB of the minimum coupling loss value.

The minimum coupling loss analysis suggests that there may be a large number of households using the DTT service that are potentially vulnerable to interference. The extent of interference being a function of DTT wanted signal level and UE operating power. It should be noted that interference to any specific DTT receiver at channel 48 would only occur whilst the PPDR is in the immediate vicinity and is transmitting. For properties located along routes regularly taken by emergency service vehicles or personnel such interference may occur more often depending also on other factors like propagation conditions etc.

5.2.1.3 DTT receiver desensitisation analysis

The unwanted emission limits for commercial 700 MHz LTE UE were set on the basis of the need to;

- manage the risk of interference between mobile use and the broadcasting service below 694 MHz,
- being technically feasible from the point of view of practical implementation of IMT terminal, and to
- achieve global harmonization of mobile terminals.

The unwanted emission limit for LTE 700 MHz UE set in CEPT Report 53 [2], results in a degradation of DTT receiver sensitivity, for fixed reception, of 5.4 dB (I/N = 4.0 dB). This level of interference to DTT is 10 dB above the levels used in CEPT Report 30 (I/N = -6 dB), which tackles compatibility studies between commercial LTE 800 MHz networks and DTT.

Table 32: Comparison of potential DTT desensitisation between commercial hand-held MFCN and PPDR (UEs transmitting at maximum power)

Parameter	Unit	Commercial MFCN 9 MHz guard band	PPDR UE 4 MHz guard band				PPDR UE 39 MHz Guard Band
ACS	dB	65.0	63.0	63.0	63.0	63	75.0
UE TX power	dBm	23	23	23	23	23	23
ACLR	dB	65.0	65.0	60.0	50.0	33	75.0
Unwanted emission (Tx)	dBm /5 MHz	-42.0	-42.0	-37.0	-27.0	-10	-52.0
Interference power at 22 m horizontal separation	dBm /5 MHz	-94.2	-93.0	-90.3	-81.9	-65.0	-104.0
I/N	dB	3.9	5.2	7.8	16.3	33.2	-5.8
Receiver desensitisation, C/N	dB	5.4	6.3	8.5	16.4	33.2	1.0

Table 33: Comparison of potential DTT desensitisation between commercial MFCN and PPDR vehicle mounted UEs transmitting at maximum power

Parameter	Unit	Commercial MFCN 9 MHz guard band	PPDR vehicular UE 4 MHz guard band				39 MHz guard band
ACS	dB	65.0	63.0	63.0	63.0	63.0	75.0
UE TX power	dBm	23	23	23	23	23	23
ACLR	dB	65.0	65.0	60.0	50.0	33.0	75.0
Unwanted emission (Tx)	dBm/5MHz	-42.0	-42.0	-37.0	-27.0	-10.0	-52.0
Interference power at 22 m horizontal separation	dBm/5MHz	-94.2	-86.0	-83.3	-74.9	-57.9	-96.9
I/N	dB	3.9	12.2	14.8	23.3	40.3	1.3
Receiver desensitisation, C/N	dB	5.4	12.4	15.0	23.3	40.3	3.7

Operating PPDR in the guard band between DTT channel 48 and commercial LTE leads to increased desensitisation compared to commercial LTE, assuming PPDR UE:s transmitting at the power of 23 dBm and the same separation between interfered receiver and interferer. The main reason for the difference in interference levels are due to the assumption that higher e.i.r.p. is used for PPDR vehicular terminals compared to handheld. Ensuring the same level of desensitisation from a PPDR UE as from a commercial LTE UE would require improvement of the PPDR UE ACLR and/or reduction of the transmit power of the

PPDR UE. This comparison between desensitisation from PPDR within 698-703 MHz towards channel 48 and desensitisation from MFCN above 703 MHz towards channel 48 is taking into account only frequency separation between PPDR and MFCN networks towards channel 48.

5.2.1.4 Summary of minimum coupling loss analysis

The minimum coupling loss analysis suggests that there may be a large number of households using the DTT service that are potentially vulnerable to interference. The extent of interference being a function of DTT wanted signal level and UE operating power. It should be noted that interference to any specific DTT receiver at channel 48 would only occur whilst the PPDR is in the immediate vicinity and is transmitting. For properties located along routes regularly taken by emergency service vehicles or personnel such interference may occur more often depending also on other factors like propagation conditions etc.

5.2.2 Coverage area analysis based on MCL desensitisation

This study analyses the difference in DTT coverage area that is susceptible to interference from PPDR vehicle mounted terminal compared to MFCN 700 MHz terminal.

METHODOLOGY

The wanted signal level (50 % time) at 10 m a.g.l. for a generic transmitter on channel 48 (Table 34) has been calculated using 1546.

Table 34: Parameters of generic DTT station

Station	e.i.r.p. (dBm)	Antenna height (m a.g.l.)	Site Height (m a.o.d.)
HP Tx	85.15	300	300

Table 35: Parameters used for the simulation

Parameter	Value
E.i.R.P.	See Table 1
DTT antenna	A generic 24 lambda antenna with 1 degree downtilt[14]
DTT receive antenna height	10m a.g.l.
Propagation Model	1546-5
DTT Minimum Field Strength	45.5 dBµV/m

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14 $E(\theta) = abs\left(\frac{Sin\Psi}{\Psi}\right)$ where $\Psi = \pi A Sin(\theta - \beta)$ and

A = the antenna vertical aperture in wavelengths

β = the beam tilt radians below the horizontal.

To allow for null fill the value of E(θ) should not go below the value of 0.15 for the first null, 0.1 for the second null and 0.05 for third null and beyond

Parameter	Value
Location Variation	5.5 dB
Location availability	95 %
Correction for Location availability	9 dB
DTT Field Strength for 95% locations served	54.5 dBµV/m
DTT receiver ACS (PPDR 698 – 703 MHz)	63 dB
DTT receiver ACS (PPDR 703 – 713 MHz)	65 dB

Table 36: DTT receiver desensitisation

Interfering Device	DTT receiver desensitisation
PPDR Vehicle mounted UE Unwanted emissions = -30 dBm/8MHz	20.65 dB
Hand held MFCN UE Unwanted emissions = -42 dBm/8MHz	5.61 dB

Locations susceptible to interference are considered as those where the median wanted DTT field strength (Ewanted) level minus the receiver desensitisation (DesensMCL), derived through MCL, is less than the minimum field strength required to serve 95 % of locations (Emed).

$$Loc_{suscetible}\ \{(E_{wanted} - Desens_{MCL}) < E_{med}\}$$

As a UE is unlikely to be located exactly at the point of minimum coupling, the result therefore only shows the areas where the desensitisation may have an impact (on average). The calculation is only applied in areas that are served, i.e. where the DTT wanted level exceeds 54.5 dBµV/m.

It should be noted that other sources of interference are not considered as part of this analysis.

RESULTS

Figure 31below shows the area susceptible to PPDR 700 MHz vehicle mounted terminal stations.

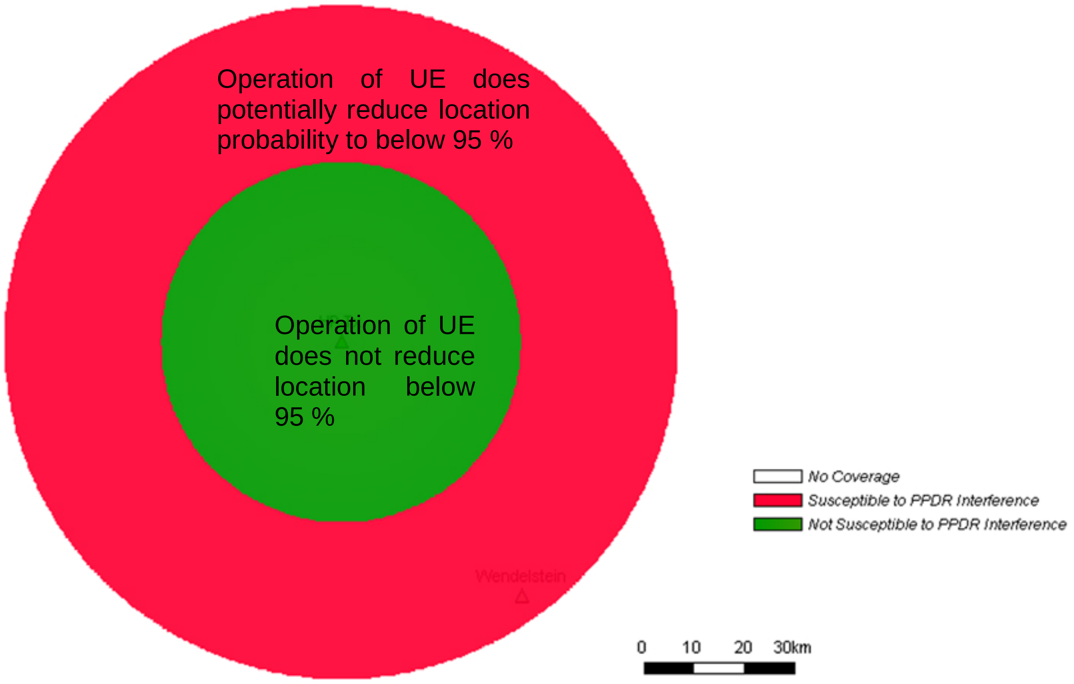

Figure 31: Area susceptible to PPDR 700 MHz vehicle mounted terminal stations

Figure 32 below shows the area susceptible to MFCN 700 MHz terminal stations.

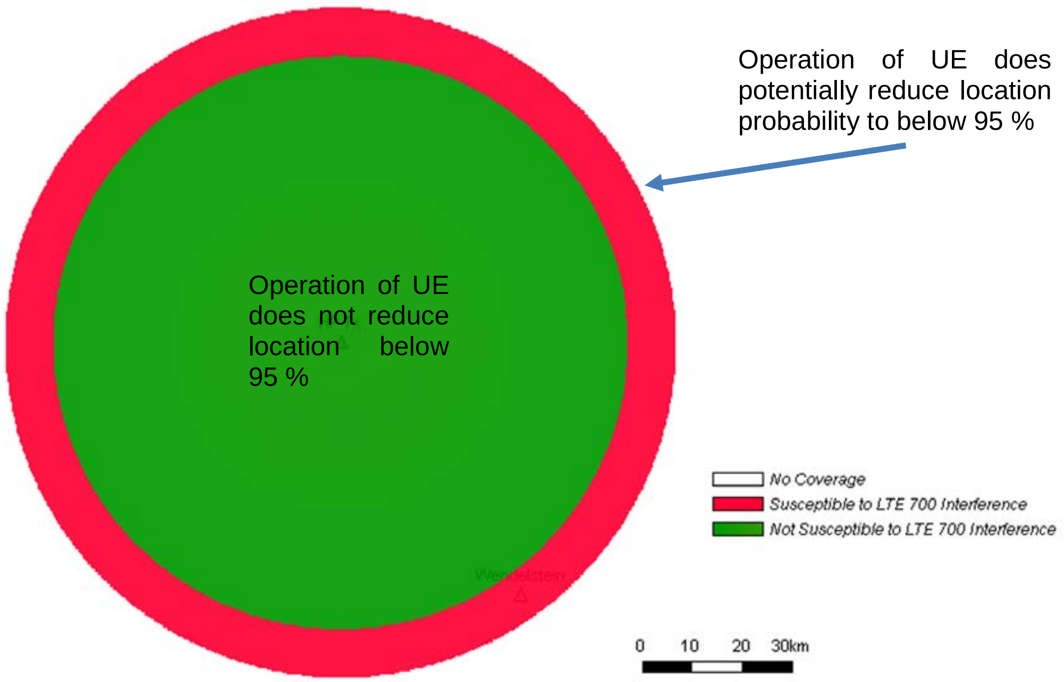

Figure 32: Area susceptible to MFCN 700 MHz terminal stations.

The area potentially susceptible to interference from PPDR UE is greater than that for MFCN UE, the lower PPDR user density will mitigate the impact.

5.2.3 Monte Carlo analysis using SEAMCAT, method I:

5.2.3.1 Macroscopic compatibility study for PPDR UE into DTT, baseline scenario

This methodology is based on SEAMCAT simulations with a time component added in order to reflect interventions, the arrival and departure of vehicles and personnel at an incident which is a characteristic of PPDR.

In this scenario, both the PPDR agents and the vehicles are connected to the infrastructure for day to day operations as shown in Figure 33. The locations of vehicles and agents are assumed independent.

Figure 33: Baseline scenario

Table 37: Baseline scenario parameters

PPDR devices	Value	Note
Terminal distribution	Uniform	Day to day operation.
Indoor (%)/Outdoor mix (%)	25/75	
Vehicle mounted density	37.5 % of total device density	
ACLR (dB/8MHz)	35, 50, 55, 58, 60, 62, 65, 70	
Power control	Yes	Max allowed Tx power = 23 dBm; Min Tx power = -40 dBm;
Note: Missing parameters are in accordance with section 3.		

Interfering system is a 2x5 MHz FDD PPDR (LTE) operating in the lower 700 MHz sub-band (698-703 MHz). A duplex spacing of 55 MHz is assumed. Indoor coverage PPDR network (targeting vehicular and UE terminals), with a BS e.i.r.p of 60 dBm and a UE e.i.r.p of up to 23 dBm, have been studied. A PPDR cell of 0.845 km has been used in simulations. Simulations assume a constant ACLR. In real LTE networks, the UEs are allocated with different numbers of RBs and also in different positions within the carrier. The ACLR increases with the offset towards the victim system. The PPDR link budget resulting in the above cell range is presented in ANNEX 5:.

Table 38: Baseline scenario parameters

PPDR devices	Value	Note
Terminal distribution	Uniform	Day to day operation.
Indoor (%)/Outdoor mix (%)	25/75	
Vehicle mounted density	37.5 % of total device density	
ACLR (dB/8MHz)	35, 50, 55, 58, 60, 62, 65, 70	
Power control	Yes	Max allowed Tx power = 23 dBm; Min Tx power = -40 dBm;
Note: Missing parameters are in accordance with section 3.		

Within this cell range, the UE density has been varied from 1 to 10.78. It is assumed that the UE density about 1 UE/km^2 represents a typical busy period, not a quiet period or a major event. In a major event the user densities may increase locally by factor of ten (see ANNEX 6:).

Table 39: UE density

PPDR Urban: BS power = 56 dBm e.i.r.p.; UE power = 23 dBm e.i.r.p.			
Sector range (km)	Sector area (km^2)	N_active_UE/sector	Density (1/km^2)
0.845	0.464	0.464	1
		1	2.156
		2	4.312
		3	6.469
		5	10.781

The starting point channelling configuration studied is depicted in Figure 34 (conventional LTE channelling arrangement). In this configuration the guard band between DTTB higher band edge and PPDR lower band edge is 4 MHz (DTTB-PPDR guard band = 4 MHz).

Table 40: UE density

PPDR Urban: BS power = 60 dBm e.i.r.p.; UE power = 23 dBm e.i.r.p.			
Sector range (km)	Sector area (km^2)	N_active_UE/sector	Density (1/km^2)
0.845	0.464	0.464	1
		1	2.156
		2	4.312
		3	6.469
		5	10.781

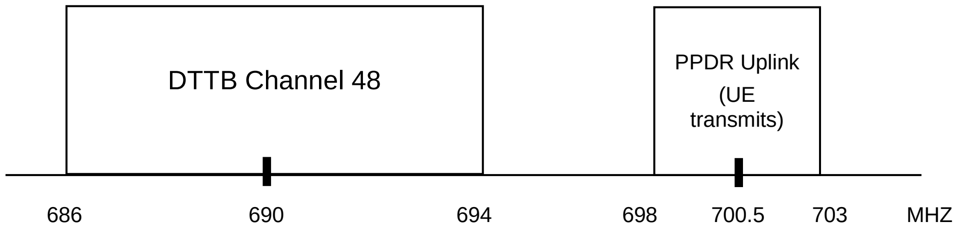

Figure 34: PPDR (LTE) 700 MHz operating in an adjacent band to DTTB channel 48 (guard band = 4 MHz)

The simulations have been carried out at the DTTB cell edge for assessing the potential interference from Broadband PPDR to DTTB reception. The following UE ACLR values have been used: 33, 50, 55, 58, 60, 62, 65 and 70 dB/8MHz in DTT CH48, with respect to 23 dBm e.i.r.p. The DTTB receiver ACS used is 63 dB

Note that the results of this study can be generalised to PPDR (LTE) 3 and 1.4 MHz channel bandwidths. The PPDR system parameters used are given in Table 95 in Section A5.2.

The Monte Carlo simulation method used in this study has been used within CEPT to determine the OOBE emission limits of LTE 800 MHz base stations in the UHF broadcasting band. The method is summarised in this section and is described in detail in Section A5.1. Several different Monte Carlo simulation methods were used to determine the OOBE emission limits of LTE800 and LTE 700 User equipment. Studies conducted for ITU-R/JTG 4-5-6-7 as well as for CPG/PTD have already recognized the inadequacies of the IP calculation vis-à-vis interference into the broadcasting service and the need for taking the time and movement of the UE into account when dealing with IMT UE interference.

An attempt to take the time aspect into account is proposed later in this section by modelling the appearance and disappearance of interfering sources during a given period of time but without considering their movement.

A PPDR network cluster of 7 tri-sector sites (21 cells) is considered. The impact of adjacent-channel interference is evaluated, for DTTB reception, at the DTTB cell edge, receivers' antennas being directed toward the DTT transmitter. 500 000 – 2 000 000 events have been generated per simulation to consider all possible interference cases for a given interference scenario.

Assessment of the probability of interference:

- a pixel of 100 m x 100 m is positioned at DTTB cell edge;
- at each simulation run (event), DTTB receiver location is randomly positioned, following a uniform distribution, within this pixel;
- for each generated DTTB receiver point with the pixel, a PPDR network cluster is generated around the DTTB victim receiver. The relative position between the victim DTTB receiver and the central PPDR BS is randomly generated, following a uniform polar distribution, within the PPDR cell range (see Figure 83).
- the above steps are repeated for each generated event;
- the probability of interference (pI) is calculated after the completion of a simulation as described in A5.1.

The results obtained are presented as probability of interference (pI) to DTTB reception (see A5.1) and then extended to take time into account.

During the first step, the instantaneous interference probability for a DTT user located at the cell edge of the DTT coverage area is derived (DTT cell edge, defined as the area where received field strength is smaller than the minimum median field strength +3 dB, represents approximately 3.7 % of the covered population in mainland France).

Because typical criteria for broadcasting compatibility studies is based on one uncorrected error per hour, the results are extended to take account of a viewing time of an hour, assuming a pure birth and death process for the interferers.

This simplifying assumption is suitable to model interfering sources that do not move at the same time as they are actively transmitting data over the network. Interfering sources may appear, disappear and re-appear at uncorrelated locations, but do not transmit data while moving. Because it is difficult to simulate transmitting while moving interference sources, a discussion is provided below in order to enable a qualitative assessment of the interference in this case.

Without loss of generality and splitting the time in "N" small time intervals, the probability that an interference occurs at least once over a given time window, in this case corresponding to one hour of TV viewing, is the probability of being subject to interference in at least one time interval.

If the time intervals are small enough the probability of being interfered in one such time interval is given by the instantaneous interference probability.

The probability that interference occurs over the time window (TW) is therefore given by:

$$P_{qef} = 1 - P(\overline{IP_1} \cap \ldots \cap \overline{IP_N})$$

Where $\overline{IP_k}$ is the random value that models the absence of interference in the k^{th} time interval. If the time intervals are large enough so that the network states in each time interval are not correlated, then the right hand side of the equation can be rewritten as follows.

$$P_{qef} = 1 - \left(1 - P(IP_1)\right) \times \ldots \times \left(1 - P(IP_N)\right)$$

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

Where N is the number of network state changes during the time window (TW).

Therefore, there is a trade-off for the choice of the time interval. Here, the duration of the time interval is called "De-correlation time (DT)". DT depends on the UE density and the services used by the latter as well as their mobility. For a given service and UE density:

- Time interval has to be short enough so that the network state does not change during the time interval;
- Time interval has to be large enough so that the consecutive network states are de-correlated.

Chosen on the basis of the above conditions the time interval represents the DT between two consecutive network states.

For the case of a PPDR network, this means that there is only one transmitting UE at an intervention and it does not change its position (no new network state). Each of the interventions is at different places (new network state).

Because network state does not change until a UE arrives or leaves the network, time interval is linked to the time constants involved in the birth and death process of the UEs. We assume in the following that time interval duration is chosen as the inverse of the mean arrival rate of the UEs.

As a typical modelling approach for communication network, it is assumed that the PPDR system can be appropriately modelled using a M/M/∞ Markov chain, following Kendall's notation.

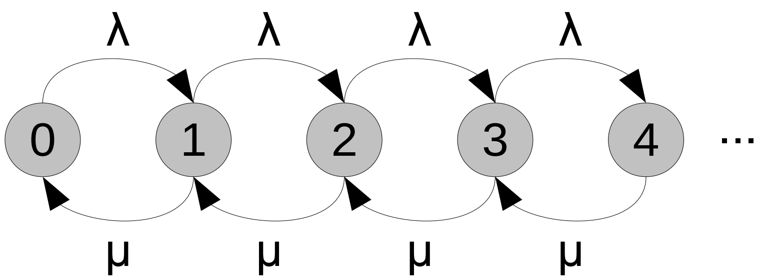

Figure 35: Markov chain

A result of Markov chain theory is that the average number of users in the system is given by:

$$K = \frac{\lambda}{\mu}$$

Where λ is the mean arrival rate and μ is the mean termination rate of active sessions.

Because PPDR users may be transmitting from the intervention area during the whole duration of the intervention, μ is calculated using mean duration of an intervention $T_{intervention}$ as follows:

$$\mu = \frac{1}{T_{intervention}}$$

The de-correlation time is given by:

$$DT = \frac{1}{K\mu} = \frac{1}{\lambda}$$

Assuming that the intervention duration is typically of the order of twenty minutes; the following parameters can be derived:

Table 41: Intervention time intervals

	K: active users per km²	DT=1/λ: inter-arrival rate (min)	Viewing time (min)	N: time intervals (N=VT/DT)
Typical busy hour	1	20	60	3
	2.1	9.52	60	6.3
	4.3	4.65	60	12.9
	6.4	3.12	60	19.2
Major event	10.8	1.85	60	32.34

5.2.3.2 Results for DTT rooftop reception at cell edge

Table 42: Probability of interference to DTTB reception

Probability of interference to DTTB reception at the DTTB cell edge; PPDR 5 MHz UE interfering signals								
DTT-PPDR guard band =4 MHz; DTTB CH48 and ACS=63 dB								
UE density(1)	UE ACLR = 33	UE ACLR = 50	UE ACLR = 55	UE ACLR = 58	UE ACLR = 60	UE ACLR = 62	UE ACLR = 65	UE ACLR = 70
(1/km^2)	dB/8 MHz(2)	dB/8 MHz	dB/8 MHz	dB/8 MHz	dB/8 MHz	dB/8 MHz	dB/8 MHz	dB/8 MHz
	pI (%)	pI (%)	pI (%)	pI (%)	pI (%)	pI (%)	pI (%)	pI (%)
1	0.432(3)	0.060(3)	0.032(3)	0.019(3)	0.011(3)	0.009(3)	0.005(3)	0.006(3)
2.15622803	0.718	0.081	0.04	0.025	0.016	0.013	0.009	0.008
4.31245606	1.251	0.12	0.055	0.037	0.026	0.021	0.017	0.011
6.46868409	1.821	0.189	0.082	0.048	0.036	0.029	0.019	0.017
10.7811401	2.869	0.288	0.125	0.077	0.058	0.046	0.035	0.023
(1) It is understood that an active user equipment (UE) is transmitting. Therefore the densities given refer to the number of simultaneously transmitting UEs								
(2) ACLR in DTTB CH48								
(3) For information only - values derived by extrapolation based on the pI obtained for UE densities of 2.216 and 4.312/km^2								

Table 43: Probability of interference to DTTB reception

Probability of interference to DTTB reception at the DTTB cell edge; PPDR 5 MHz UE interfering signals;								
DTT-PPDR guard band =4 MHz; DTTB CH48 and ACS=63 dB								
UE density(1)	UE ACLR = 33	UE ACLR = 50	UE ACLR = 55	UE ACLR = 58	UE ACLR = 60	UE ACLR = 62	UE ACLR = 65	UE ACLR = 70
(1/km^2)	dB/8 MHz(2)	dB/8 MHz	dB/8 MHz	dB/8 MHz	dB/8 MHz	dB/8 MHz	dB/8 MHz	dB/8 MHz
	pI (%)	pI (%)	pI (%)	pI (%)	pI (%)	pI (%)	pI (%)	pI (%)
1	0.432(3)	0.060(3)	0.032(3)	0.019(3)	0.011(3)	0.009(3)	0.005 (3)	0.006 (3)
2.15622803	0.718	0.081	0.04	0.025	0.016	0.013	0.009	0.008
4.31245606	1.251	0.12	0.055	0.037	0.026	0.021	0.017	0.011

Probability of interference to DTTB reception at the DTTB cell edge; PPDR 5 MHz UE interfering signals;								
6.46868409	1.821	0.189	0.082	0.048	0.036	0.029	0.019	0.017
10.7811401	2.869	0.288	0.125	0.077	0.058	0.046	0.035	0.023

Table 44: Probability of interference over one hour viewing time

	K: active users per km²	Probability that an interference occurs over one hour viewing time							
		ACLR 33dB	ACLR 50dB	ACLR 55dB	ACLR 58dB	ACLR 60dB	ACLR 62dB	ACLR 65dB	ACLR 70dB
Typical busy hour	1	1.29 %	0.18 %	0.10 %	0.06 %	0.03 %	0.03 %	0.01 %	0.02 %
	2.1	4.44 %	0.51 %	0.25 %	0.16 %	0.10 %	0.08 %	0.06 %	0.05 %
	4.3	14.99 %	1.54 %	0.71 %	0.48 %	0.33 %	0.27 %	0.22 %	0.14 %
	6.4	29.73 %	3.57 %	1.56 %	0.92 %	0.69 %	0.56 %	0.36 %	0.33 %
Major event	10.8	60.99 %	8.91 %	3.96 %	2.46 %	1.86 %	1.48 %	1.13 %	0.74 %

It can be seen from the previous result analysing interference for the case of interventions that ACLR values of 50 dB and lower may lead to very high probability in case of major events. ACLR values of 60 dB and higher gives a probability level of less than 5 %.

Discussion on the fact that moving sources of interference are not modelled:

- The movement pattern of PPDR UEs is unknown
- In case of low network traffic from interventions, day to day operations / patrols have more available bandwidth which is used for background PPDR traffic.
- For sporadic transmission of heavy data leading to heavy network loading for typical duration of about 10 s, e.g. high quality picture reporting of 10 Mb, assuming a typical pedestrian speed of 4 km/h, the interference source is similar to the case of instantaneous interference source. This case of intervention is therefore appropriately modelled by the above describe methodology.
- For regular transmission of small data bursts, such as GPS reporting or phone calls, the transmission would typically require a limited amount of RBs per burst. Therefore unwanted emissions are expected to be limited and power control to limit blocking.

5.2.3.3 Results for DTT indoor reception at cell edge

In the following, we investigate the case of portable reception for DTT receiver located indoor and planned according to RPC 2 configuration from GE06 agreement.

According to extended Hata models, two distinct cases may occur for a PPDR interfering with a DTT receiver located indoor:

The PPDR UE is located outdoor, in this case, typical Hata extended model applies, with additional building entry loss and variation increased by the wall loss variation;

The PPDR UE is located indoor. In this case, the PPDR UE and the DTT receiver are either in the same building or not, following a given probability specified by Hata Model.

Detailed equations can be found in Report ITU-R SM.2028-1.

Assuming median outdoor to indoor wall loss of 11 dB with standard deviation of 6 dB, the interference probability, derived from SEAMCAT simulations with 1.000.000 events are given in Table 45 below.

Table 45: Probability of interference to DTTB indoor reception at the DTTB cell edge; PPDR 5 MHz UE interfering signals indoor/outdoor

Probability of interference to DTTB indoor reception at the DTTB cell edge; PPDR 5 MHz UE interfering signals indoor/outdoor				
DTT-PPDR guard band = 4 MHz; DTTB CH48 and ACS = 63 dB				
UE density(1)	UE ACLR = 55	UE ACLR = 58	UE ACLR = 60	UE ACLR = 62
(1/km^2)	dB/8MHz	dB/8MHz	dB/8MHz	dB/8MHz
	pI (%)	pI (%)	pI (%)	pI (%)
2.15622803	0.0135/0.0180	0.0094/0.0129	0.0087/0.0078	0.0075/0.0073
10.7811401	0.0583/0.0778	0.039/0.0515	0.0362/0.0385	0.0244/0.0299
1. It is understood that an active user equipment (UE) is transmitting. Therefore the densities given refer to the number of simultaneously transmitting UEs				
2. ACLR in DTTB CH48				

As it can be seen from the previous tables, interference to indoor DTT reception is less severe than for the case of fixed rooftop reception. Therefore criteria applying for protection of fixed rooftop reception are also applicable to indoor reception. Note that this result is applicable only to PPDR like services. In the case of commercial LTE UEs, location of interference sources and victim DTT may be correlated, e.g. a commercial user may be using a LTE device while watching DTT.

5.2.3.4 Macroscopic compatibility study for PPDR UE into DTT, relay in vehicles scenario

One or two vehicles are deployed for operation to a given location with a crew of up to 10 people equipped with handsets.

When arrived at the theatre of operations, the estimated duration of operations lasts for 1 hour in average.

Part of the crew gets out of the vehicles. The crew remains in the direct vicinity of the vehicle, within a hexagonal area with side length 100 m, either indoor or outdoor.

During the intervention, the crew member’s remain always connected together. They communicate with the PPDR cellular infrastructure, if necessary, via the vehicle, i.e. the vehicle acts as a relay between the handsets and the PPDR cellular infrastructure.

There is no nearby intervention occurring at the same time in the same location area: interference from other PPDR vehicles/crews can be neglected.

PPDR vehicles and handsets implement LTE technology. The zone of intervention thus constitutes an isolated pico-cell of 100 m radius, backhauled to the PPDR infrastructure by the vehicle via a LTE radio link. The backhaul network has a cell range of 845 m.

The vehicles are equipped with roof top antenna and LTE terminal equipment (Tx power class: 23 dBm).

Handsets are equipped with standard omnidirectional handset antenna and LTE terminal equipment which nominal transmit power is 10 dBm (it can be extended to 23 dBm in extreme indoor conditions or outdoor strong attenuator between handset and vehicle).

The frequency allocation is as follows: only handsets are operated in the 698-703 MHz (see Figure 37).

Handsets to vehicle radio links: carrier frequency = 700.5 MHz, bandwidth = 5 MHz.

Vehicles to PPDR infrastructure: 733-736 MHz frequency band, bandwidth = 3 MHz.

DL frequencies are operated in the paired bands (respectively: 753-758 MHz for vehicle to handsets radio links, 788-791 MHz for PPDR infrastructure to vehicles radio links).

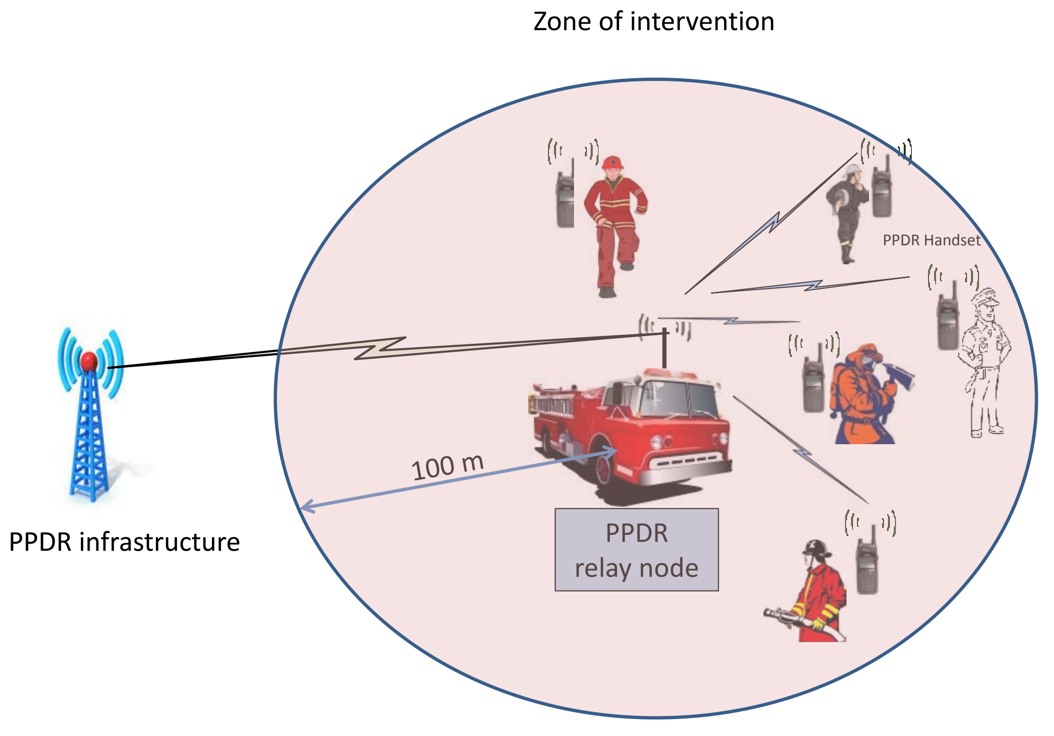

Figure 36: PPDR deployment scenario

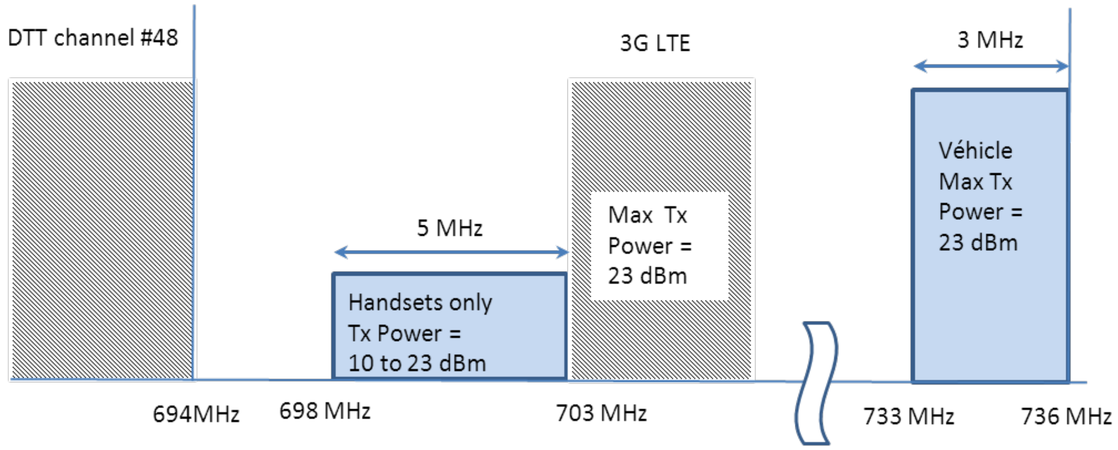

Figure 37: Frequency allocation

The PPDR zone of intervention (the PPDR isolated cell) is in the vicinity of a DTT receiver.

The DTT receiver is located in a pixel of 100 m x 100 m of the DTT coverage edge.

Two DTT configurations are evaluated:

- Fixed rooftop reception: DTT receiver antenna is a fixed house rooftop antenna, thus located outdoor.
- Portable indoor reception: DTT receiver is located indoor.

The PPDR vehicle is located outdoor. In order to fit with worst case conditions, the present study focuses on PPDR handset outdoor deployment (indoor is considered in a 2nd step thus the victim DTT receiver does not benefit from building attenuation).

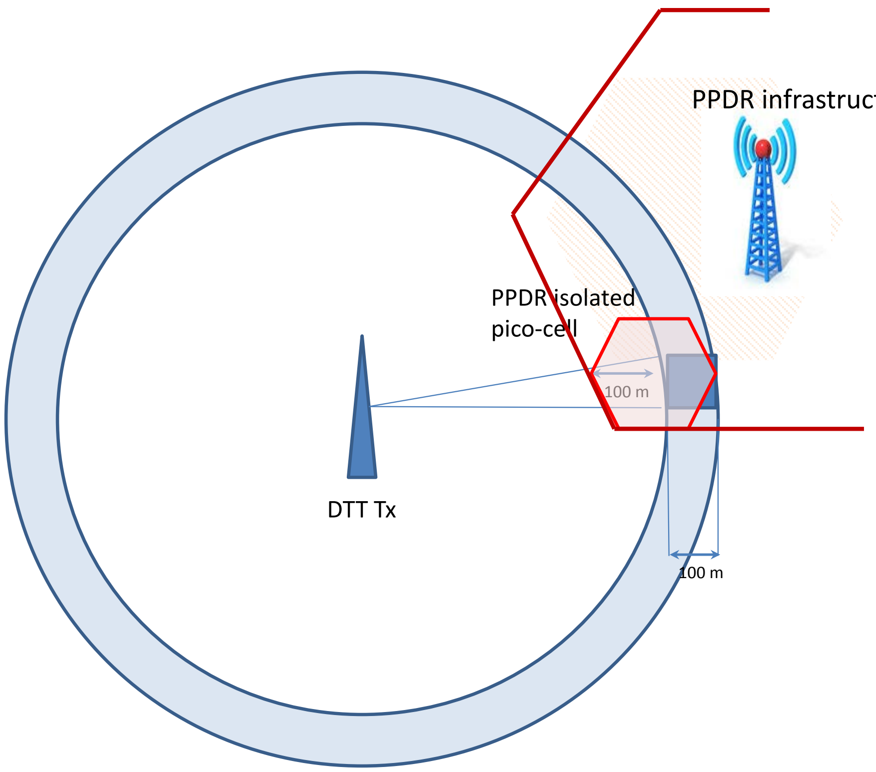

Figure 38: PPDR interferers around DTT receiver

Both PPDR vehicle and handsets have been modelled in the Monte Carlo simulations in urban environment. Both implement LTE technology.

The vehicles are equipped with rooftop omnidirectional antenna. Handsets are equipped with standard omnidirectional antenna.

Table 46: PPDR vehicle parameters

PPDR vehicle parameters	
Number of active receivers	1, outdoor location
Rx Centre frequency (for relaying)	700.5 MHz
Rx Channel BW (for relaying)	5 MHz
Antenna height	2 m
Antenna pattern	Omnidirectional
Feeder loss	1.5 dB
Antenna gain	0 dBi
Noise figure	9 dB

Table 47: PPDR handset parameters

PPDR handset parameters	
Nb of active transmitters	10 within a 100 m * 100 m intervention zone
Indoor/Outdoor mix	25 % indoor, 75 % outdoor
Tx Centre frequency	700.5 MHz
Channel BW	5 MHz
Number of resource blocks/UE	5
Effective bandwidth	900 kHz
Antenna height	1.5 m
Antenna pattern	Omnidirectional
Antenna gain	-3 dBi
Body losses	4 dB
Average building entry loss	11 dB
Max Tx power	10 dBm for outdoor handsets, 23 dBm for indoor handsets
Max e.i.r.p.	7 dBm for outdoor handsets, 20 dBm for indoor handsets
ACLR in channel 48	60, 65 and 70 dB/8 MHz

Simulations have been run with 400 000 events. Interference criteria is C/(N+I).

5.2.3.5 Results for rooftop reception

Table 48: Probability of interference to DTTB reception at DTTB cell edge

Probability of interference to DTTB reception at the DTTB cell edge; PPDR 5 MHz UE interfering signals;					
DTT-PPDR guard band = 4 MHz; DTTB CH48 and ACS = 63 dB					
UE density(1)	UE ACLR = 55	UE ACLR = 58	UE ACLR = 60	UE ACLR = 62	UE ACLR = 65
(UE/intervention)	dB/8MHz	dB/8MHz	dB/8MHz	dB/8MHz	dB/8MHz
	pI (%)	pI (%)	pI (%)	pI (%)	pI (%)
8	0.0635	0.0375	0.0266	0.019	0.0131
12	0.127	0.0756	0.0527	0.039	0.0294
1. It is understood that an active user equipment (UE) is transmitting. Therefore the densities given refer to the number of simultaneously transmitting UEs					
2. ACLR in DTTB CH48					

5.2.3.6 Results for indoor reception

Table 49: Probability of interference to DTTB indoor reception at DTTB cell edge

Probability of interference to DTTB indoor reception at the DTTB cell edge; PPDR 5 MHz UE interfering signals indoor/outdoor;					
DTT-PPDR guard band = 4 MHz; DTTB CH48 and ACS = 63 dB					
UE density(1)	UE ACLR = 55	UE ACLR = 58	UE ACLR = 60	UE ACLR = 62	UE ACLR = 65
(1/km2)	dB/8MHz	dB/8MHz	dB/8MHz	dB/8MHz	dB/8MHz
	pI (%)	pI (%)	pI (%)	pI (%)	pI (%)
8	0.135/0.013	0.097/0.009	0.077/0.006	0.066/0.003	0.057/0.003
12	0.263/0.023	0.188/0.015	0.158/0.012	0.128/0.009	0.105/0.006
1. It is understood that an active user equipment (UE) is transmitting. Therefore the densities given refer to the number of simultaneously transmitting UEs					
2. ACLR in DTTB CH48					

5.2.4 Monte Carlo analysis using SEAMCAT, method II

This scenario was simulated using SEAMCAT with the following assumptions, see Figure 39 below. It represents a realistic scenario:

- A receiving DTT antenna is dropped randomly within the DTT coverage area, y = 39.5 km;

- PPDR handheld UEs and PPDR vehicle mounted UEs are dropped randomly within a distance from the receiving DTT antenna, x = 50 m. This corresponds to a number of users active at the event;
- The UEs use power control.

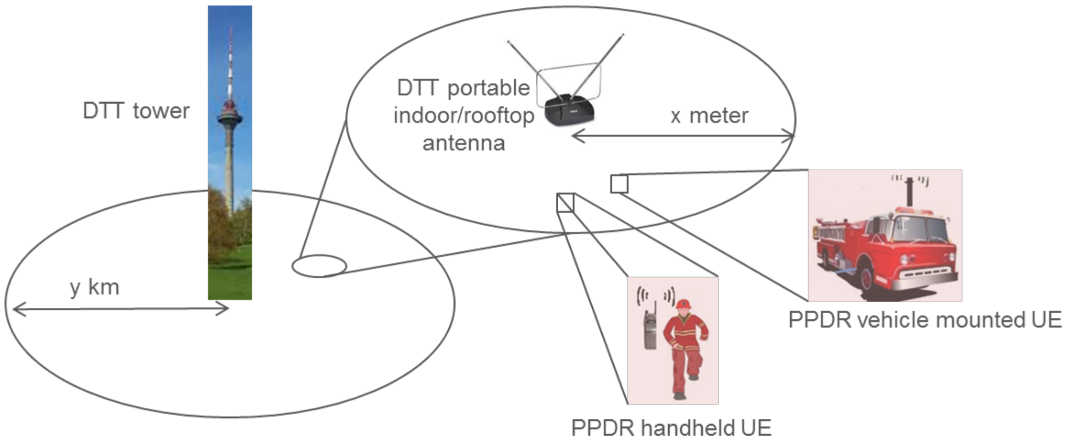

Figure 39: Set-up of PPDR interference to DTT (SEAMCAT simulations, method II)

The interference probabilities are given below for various ACLR values, where the minimum follows the ETSI standard.

The Table 50 below includes the probability of interference from a LTE PPDR UE within 698-703 MHz into channel 48. 5 RBs are allocated for each device, e.g. 5 RBs are allocated on the 1 device scenario, while transmissions occupy 25 RBs in the 5 devices case. In addition, the 5 RBs transmissions are randomly allocated within the channel bandwidth. For example, the 5 RBs transmissions for the 1 device scenario are randomly placed within the LTE carrier (always adjacent).

As a simplification, the ACLR is constant independent of position of UL RBs within the E-UTRA channel. In a real scenario, the ACLR increases with the offset from the UL allocation. Thus, emissions below 694 MHz from a 5 RBs allocation at the highest frequencies of the carrier will be lower than those from a 5 RBs transmission at the lowest frequencies.

Table 50: Interference probability for PPDR handheld UE interfering DTT rooftop reception

UE ACLR (dB/8 MHz)	CHANNEL 48		
	Number of handheld devices		
	1 device	2 devices	5 devices
35	11.9 %	21.66 %	38.95 %
50	1.69 %	3.30 %	7.41 %
60	0.33 %	0.81 %	1.80 %
65	0.16 %	0.46 %	0.90 %
70	0.13 %	0.31 %	0.74 %

The probability of interference is around 11 % (1 device), 21 % (2 devices) and 39 % (5 devices) for channel 48, when the UEs fulfil the ACLR requirement according to the ETSI Harmonized Standard. This probability decreases below 5 % for an ACLR of 50 dB or larger for the most common PPDR use case of 1 device as well as for the 2 devices scenario. The later reflects an incident, which can happen at occasions. Further ACLR improvement does not decrease the probability of interference considerably.

For the less common scenario of 5 active devices, the probability of interference is above 5 % for ACLR of 50 dB.

5.2.5 Monte Carlo analysis (non-SEAMCAT), method III

The footprint analysis in this section provides detailed information about local interference effects when it is assumed that interferers and victims are located in close vicinity. For broadcast protection purposes, the local interference effects are important and need to be analysed. The analysis in this chapter assumes UEs transmitting at maximum power, while it is recognized that LTE networks use power control and thus a UE will transmit at different power depending on the distance to its serving cell. In addition, a constant ACLR is assumed, while in practice ACLR will be equal or lower than the simulated value depending on the UL RB allocation and position.

In this section we consider the UE's local interference structure and extent in detail, using the characteristics of PPDR UEs transmitting at maximum output power as the calculation basis. Monte Carlo simulation is used to calculate IP resulting when PPDR UEs are located in close vicinity (about 100 m) of the victim DTT receiver.

We also consider the local interference effects of multiple PPDR UEs operating in a limited area for an extended period of time, for example in the case of an 'emergency event'. In this case, the emergency vehicles arrive on the scene and are considered stationary during the course of the event.

This analysis enables comparison between the effect of a PPDR UE and that of a commercial LTE UE to ensure that no LTE system causes greater interference footprint than for commercial LTE UE in the 700 band.

5.2.5.1 Model and method

MC simulations are carried out to determine the extent of interference near an 'event' where a number of PPDR UEs are used in a limited area.

The geometry of the situation is shown schematically in Figure 40.

The large square represents the area where interference is to be calculated. It has dimensions 100 m x 100 m. The small points within the large square represent the grid of points at which the interference calculations are to be carried out. DTT receiving antennas at the points are located at 10 m height and are assumed to be pointing towards the right.

At the center of the large square is a smaller, dashed-line square having dimensions 50 m x 50 m, which represents the 'event' area. The small stars within the small square represent the interfering UEs. During the course of the simulations the UEs will have random positions within the small square.

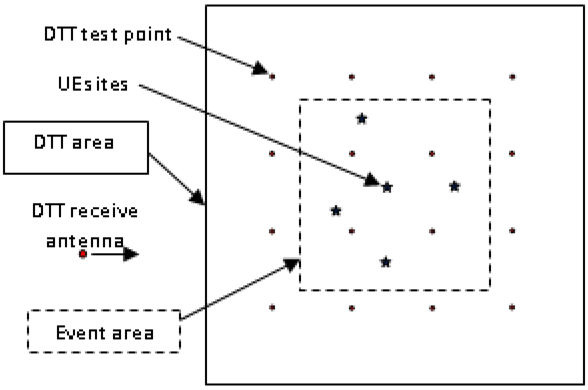

Figure 40: Geometry of the situation

The calculation area (100 m x 100 m) is assumed to correspond to the DTT coverage edge, i.e., location probability, LP = 95 % in the presence of noise only; this is taken to mean that the interference probability, IP, at each point is IPN = 5 %. For the present calculations, the DTT reception points were placed in a grid at regular 2 m intervals. The UEs, from trial to trial were placed randomly within the central 50 m x 50 m 'event' area.

For each DTT point, 100 000 000 simulations were carried out. The wanted DTT signal and the interfering UE signals follow a Gaussian distribution with σDTT = 5.5 dB and σUE calculated according to the Hata propagation model, respectively.

In the presence of UE interference, the interference probability, IP(N+UE), is calculated at each DTT point taking into account noise and UE interference, power summed. The increased interference is given by the difference: ΔIP = IP(N+UE) - IPN.

The ΔIP is a proxy value that is used to measure the interference footprint. Then matching the ΔIP with a one obtained from a reference case ensures that the interference footprints are similar.

5.2.5.2 Parameters

We consider PPDR UEs operating in the 700 MHz band with 5 MHz bandwidth. Two types of UE are considered (Table 51):

- vehicular PPDR UE units operating at 1.5 m height and with e.i.r.p. level of 23 dBm and
- hand held PPDR UE units operating at 1.5 m height and with 20 dBm e.i.r.p.

Table 51: The parameters for the 700 PPDR UE simulation (all calculation are made at 690 MHz)

		UE characteristics				DTT characteristics	
e.i.r.p. (dBm)= Tx Power (dBm)+ Antenna Gain (dBi)	H_{tx} (m)	ACLR (dB) for 4 MHz GB DTT/UE	ACLR (dB) for 39 MHz GB DTT/UE	Body loss (dB)	H_{rx} (m)	ACS (dB) for 4 MHz GB DTT/UE	ACS (dB) for 39 MHz GB DTT/UE
23 + (-3) = 20	1.5	33	85	4	10	63	75
23 + (0) = 23	1.5	33	85	0	10	63	75

Table 52: The parameters for the reference commercial LTE700 UE (calculation are made at 690 MHz)

e.i.r.p. (dBm)	Htx (m)	ACLR (dB) for 9 MHz GB DTT/UE	Body loss (dB)	Hrx (m)	ACS (dB) for 9 MHz GB DTT/UE
23 + (-3) = 20	1.5	65	4	10	65

The complete set of parameters is given in Table 53 and Table 54

Table 53: DTT receiver parameters

DTT receiver parameters	
Antenna height	10 m
Antenna gain	9.15 dB
Antenna pattern	Rec. ITU-R BT.419
Frequency	690 MHz
Noise	-98.17 dBm
C/N	21 dB
Co-channel protection ratio	21 dB
Location probability	95 %
Gaussian Propagation	σDTT = 5.5 dB
ACS	See Table 51

Table 54: PPDR UE parameters

PPDR UE parameters	
Bandwidth	5 MHz
Antenna height (omni-directional)	1.5 m
e.i.r.p.	20, 23 dBm
Body loss	0, 4 dB
Propagation model	Hata
ACLR	see Table 51

5.2.5.3 Results

he calculations are made for 1 active UE up to 5 active UEs, respectively. In the MC simulations, the UEs were placed randomly inside the dashed central square (50 m x 50 m).

The pixel has dimensions 100 m x 100 m. Only the points having ΔIP ≥ 1 % are shown as coloured; the remaining points with ΔIP < 1 % are white.

The results for the 100 m x 100 m pixel adjacent to and situated at the left of the considered pixel are also listed as this pixel is also affected due to the DTT antenna orientation considered in the simulations.

For each considered e.i.r.p of the PPDR UE the curves representing the ∆IP% for the two guard bands (indicated using the corresponding ACLR) are shown for both the left adjacent pixel and the event pixel. The curves corresponding to 1 up to 5 User Equipment is shown.

5.2.5.4 Reference case

Reference case: commercial LTE700 UE impact on DTT.

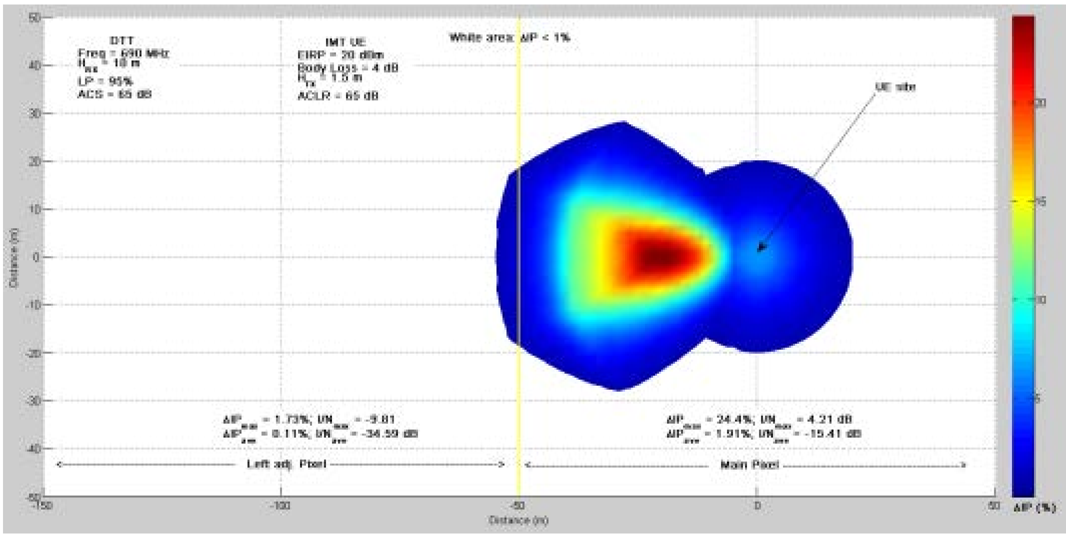

Figure 41: LTE UE impact on DTT (main pixel and left adjacent pixel)

Table 55: Reference

Reference				
e.i.r.p. = 20 dBm	ACLR = 65 dB	Body loss = 4 dB	Handheld @ 1.5 m	
DTT coverage edge (LP = 95 %)	ACS = 65 dB	Fixed DTT reception @ 10 m	Rec. ITU-R BT.419 Antenna pattern	
	Main Pixel		Left adj. Pixel	
	∆IP (%)	I/N (dB)	∆IP (%)	I/N (dB)
Maximum	24.36 %	4.21 dB	1.73 %	-9.81 dB
Average	1.91 %	-15.41 dB	0.11 %	-34.59 dB

Vehicular PPDR UE, e.i.r.p. = 23 dBm

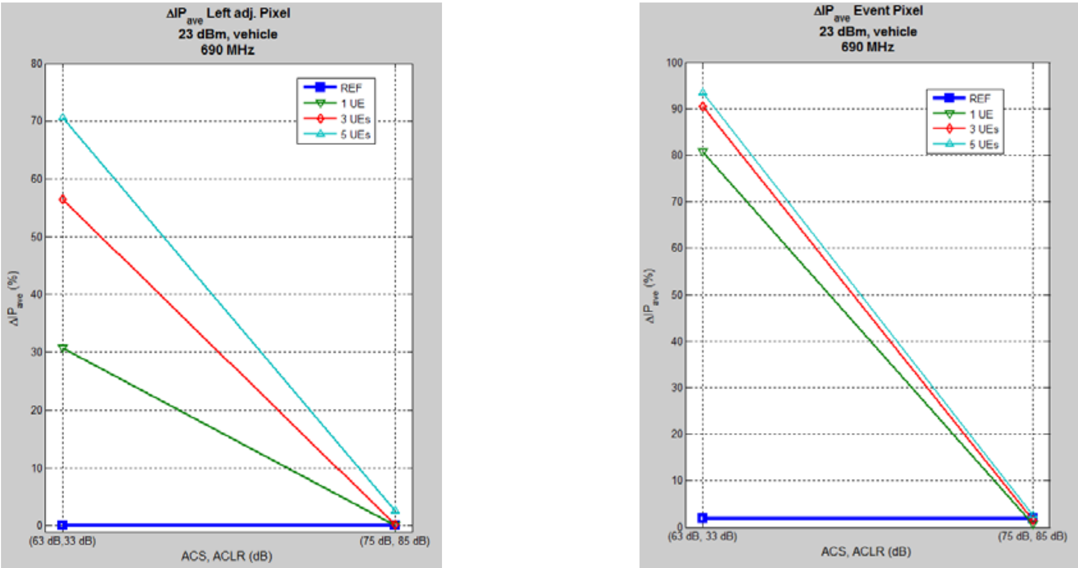

Figure 42: e.i.r.p. = 23 dBm (vehicle mounted)

Table 56: Vehicular, e.i.r.p. = 23 dBm

Vehicular, e.i.r.p. = 23 dBm				
	GB = 4 MHz ACS = 63 dB, ACLR = 33 dB		GB = 39 MHz ACS = 75 dB, ACLR = 85 dB	
# UEs	∆IPave Central pixel	∆IPave Left adj. Pixel	∆IPave Central pixel	∆IPave Left adj. pixel
1	80.65 %	30.68 %	0.557 %	0.030 %
3	90.45 %	56.46 %	1.530 %	0.217 %
5	93.51 %	70.54 %	2.540 %	0.364 %

Hand-held PPDR UE, e.i.r.p. = 20 dBm

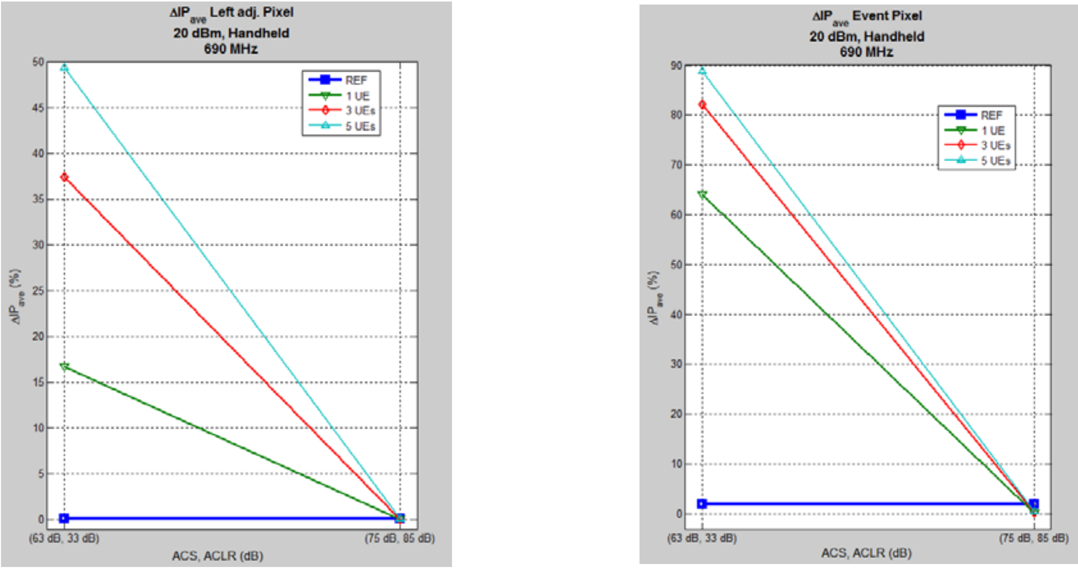

Figure 43: e.i.r.p. = 20 dBm (hand-held)

Table 57: Handheld, e.i.r.p. = 20 dBm (Body loss = 4 dB)

Handheld, e.i.r.p. = 20 dBm (Body loss = 4 dB)				
	GB = 4 MHz ACS = 63 dB, ACLR = 33 dB		GB = 39 MHz ACS = 75 dB, ACLR = 85 dB	
# UEs	∆IPave Central pixel	∆IPave Left adj. Pixel	∆IPave Central pixel	∆IPave Left adj. pixel
1	64.06 %	16.73 %	0.109 %	0.006 %
3	82.13 %	37.36 %	0.302 %	0.042 %
5	88.80 %	49.29 %	0.505 %	0.071 %

5.2.5.5 Comparison tables:

Table 58: Event Pixel

Case	∆IP (%)	∆IP (%)
Reference commercial LTE 700 UE	1.91 %	1.91 %
PPDR UE case (5 UEs)	GB = 4 MHz	GB = 39 MHz
e.i.r.p. = 23 dBm (vehicular)	93.51 %	2.54 %
e.i.r.p. = 20 dBm (handheld)	88.80 %	0.505 %
Note 1: It is assumed that an intervention occurs in close vicinity of the DTT		

Case	∆IP (%)	∆IP (%)
receiver. Note 2: The case of 5 PPDR UEs is compared to the case of 1 LTE UE. Note 3: PPDR ACLR is set to 33 dB/8 MHz, while LTE UE ACLR is set to 65 dB/8MHz. Note 4: IP in this case assumed no power control for both systems.		

Table 59: Left Adjacent Pixel

Case	∆IP (%)	∆IP (%)
Reference commercial LTE 700 UE	0.11 %	0.11 %
PPDR UE case (5 UEs)	GB = 4 MHz	GB = 39 MHz
e.i.r.p. = 23 dBm (vehicular)	70.54 %	0.364 %
e.i.r.p.= 20 dBm (handheld)	49.29 %	0.071 %
Note 1: It is assumed that an intervention occurs in close vicinity of the DTT receiver. Note 2: The case of 5 PPDR UEs is compared to the case of 1 LTE UE. Note 3: PPDR ACLR is set to 33 dB/8 MHz, while LTE UE ACLR is set to 65 dB/8MHz. Note 4: IP in this case assumed no power control for both systems.		

5.2.5.6 Conclusions

MC simulations have been carried out to analyse in detail the increased interference to DTT reception caused by PPDR UE located in close vicinity of a DTT receiver and transmitting in an adjacent channel assuming minimum requirements from 3GPP specification. The increase was calculated as the increase in interference probability, ∆IP, compared to noise only. In addition to the detailed point-wise results displayed pictorially, averages, ∆IPave, over small areas have also been calculated and provided in Tables.

These simulations cover also the case of an "emergency event" which is specific to PPDR.

Local interference information, say within an area the size of a pixel, is necessary to have in order to analyse impact of the interference when PPDR UE and DTT receiver are located in the same pixel.

The comparison between the effect of a PPDR UE and that of a commercial LTE UE shows the following:

For the option with the PPDR uplink in the 700 MHz guard band, i.e. in 698-703 MHz, corresponding to 4 MHz of guard band with regard to channel DTT 48, the ∆IP values in the event pixel are 93.51 % and 88.8 % for the vehicular and the handheld UE respectively, assuming 5 simultaneous operating UEs in the event area transmitting at full power and fulfilling minimum ACLR requirement of 33 dB from 3GPP specification. These exceed by far the reference value for 1 commercial LTE handheld UE with ACLR 65 dB, which is 1.91 %. Even with one UE operating, the reference value is largely exceeded.

For the same conditions, the ∆IP in the left adjacent pixel is 70.54 % and 49.29 % for the vehicular and the handheld UE respectively, compared to the reference value which is 0.11 %. Same conclusion is for only one operating UE.

For the option with the PPDR uplink in the 700 MHz duplex gap, i.e. in 733-738 MHz, corresponding to 39 MHz of guard band with regard to DTT channel 48, the ∆IP values in the event pixel are 2.54 % and 0.51 % for the vehicular and the handheld UE respectively. They are close to the reference value for the commercial LTE handheld UE which is 1.91 %. If we consider 1 or 3 UEs in the event pixel, these values will both become less than the reference value.

The same observation applies to the left adjacent pixel, with ∆IP values of 0.36 % and 0.07 % for the vehicular and the handheld UE respectively, which are close to the reference value for the commercial LTE handheld UE which is 0.11 %.

Based on the analysis in this section, we can say that in order to ensure that the LTE system used for PPDR causes similar interference footprints compared to commercial LTE UE in the 700 band with the agreed technical parameters for LTE 700 [2], the same out-of-band emissions are needed. Additionally, reduction of the in-band emissions would compensate for the DTT ACS performance at a smaller frequency separation. The assessment of the required reduction is made using the MCL method in section 5.2.1

5.2.6 PPDR UE ASPECTS

5.2.7 Economies of scale for PPDR

In ECC Report 199 [12], it is mentioned that

"For economies of scale a technical solution should be based on a widely used technology. Therefore LTE is taken as a working assumption. A common technology brings the advantage of improving international cooperation. Disaster Relief (DR) could benefit from this in particular as a global interoperable solution is useful in improving the delivery of mutual aid."

Further, in ECC Report 218, it is stated that

"To bring the cost down to an acceptable level for both mobile broad band network infrastructure and end user terminal equipment for Public Safety one should try to leverage on commercial mobile broadband technology. This could give a substantial economy of scale if PPDR (Public Protection and Disaster Relief) requirements can be adopted by the commercial technology standard without too many and huge modifications. This is valid both for network infrastructure as well as for end user radio terminal equipment."

The extracted text clearly notes the benefit for the PPDR service to make use of existing technology, in particular LTE, as well as existing equipment. The DTT protection level below 694 MHz is a key factor which will determine if this is possible.

5.2.8 Impact of DTT requirements in the LTE UE implementation

UE duplexers covering the spectrum 703-733/753-788 MHz can currently supply enough rejection to fulfil -42 dBm/8MHz below 694 MHz. This emission level is then ensured at 9 MHz frequency offset for a filter passband of 2x30 MHz.

Following the statements referred in section 5.2.7, it would be beneficial to reuse these filters for PPDR by downshifting 5 MHz. -42 dBm/8MHz can then be ensured below 689 MHz.

Figure 44 shows the UE emissions of a 5 MHz E-UTRA carrier (full and 1 RB allocation) after PA (power amplifier) and a shifted version of different Band 28 duplexers. The duplexer has been designed to cover 703-733/758-788 MHz and supplies enough rejection to fulfill -42 dBm/8MHz below 694 MHz for a 10 MHz E-UTRA carrier. Temperature drift of around 1 MHz also needs to be considered.

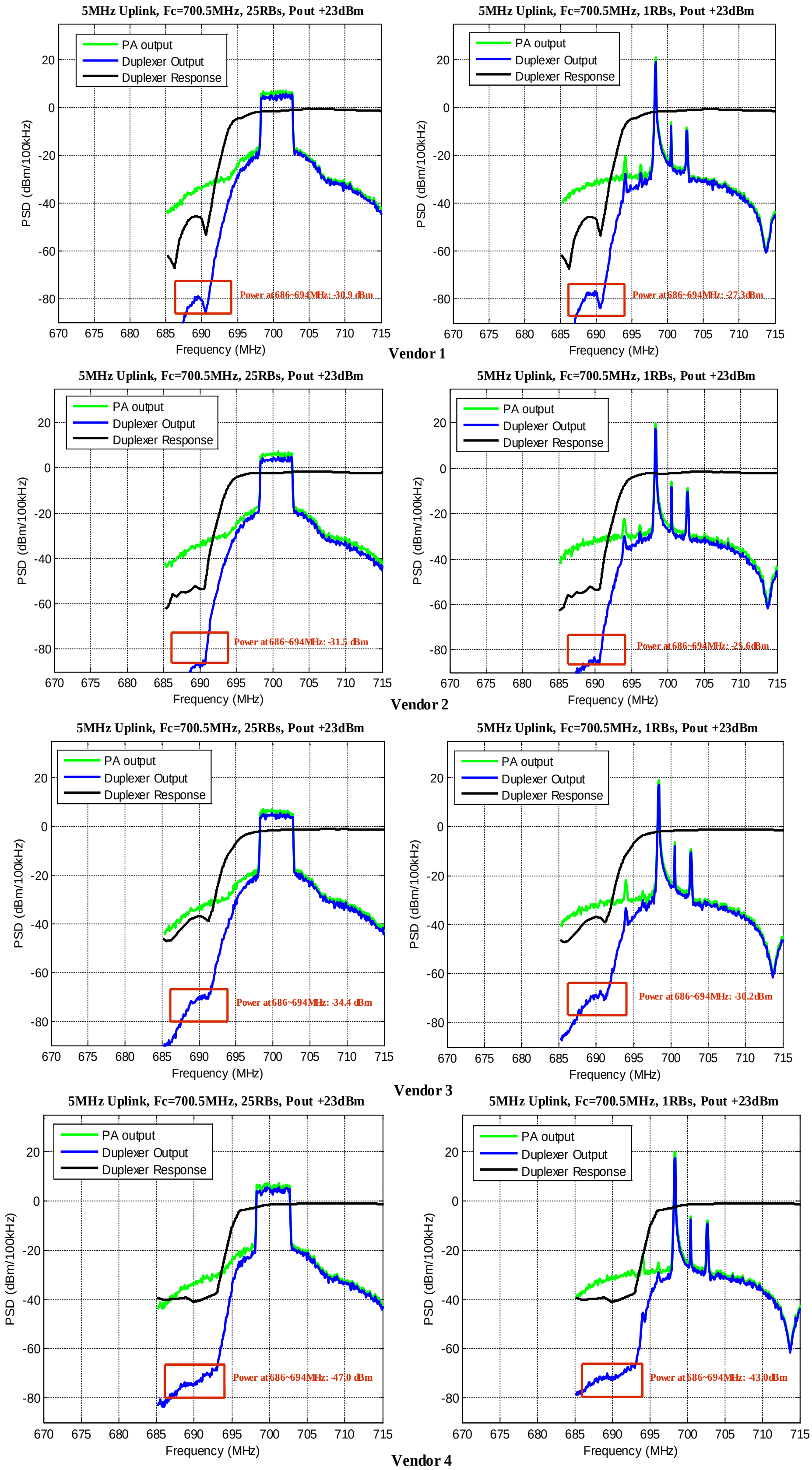

Figure 44: UE out-of-band emissions for 5 MHz E-UTRA after PA and UL filter (30 MHz) from different vendors at room temperature (left and right figures represent of 1 RB and full allocation, respectively)

The Table 60 below summarizes the Out-of-band emissions without temperature drift and with temperature drift from a E-UTRA 5 MHz carrier between 686-694 MHz

Table 60: Out-of-band emission to DTT frequency from 5 MHz LTE

	#RBs	Emission to DTT channel 48 (dBm/8MHz)	
		At room temperature	At extreme temperatures
Vendor 1	25RB	-30.9 dBm	-26.1 dBm
	1RB	-27.3 dBm	-22.7 dBm
Vendor 2	25RB	-31.5 dBm	-25.4 dBm
	1RB	-25.6 dBm	-21.3 dBm
Vendor 3	25RB	-34.4 dBm	-29.3 dBm
	1RB	-30.2 dBm	-24.5 dBm
Vendor 4	25RB	-47.0 dBm	-35.4 dBm
	1RB	-43.0 dBm	-30.5 dBm

From the results, we can observe that 1 RB emissions is the worst case scenario. This needs to be considered when setting the requirements. However, in a real deployment scenario, UEs will be allocated with different number of RBs and thus emissions will always be lower than this value. In addition, simulations show emissions at maximum output power while power control is used in LTE. This will further reduce the out-of-band emissions. Also ETC (Extreme temperature conditions are defined in the standards)) need to be accounted for the minimum requirement, while extreme conditions will not occur in a typical scenario and emissions will be lower.

The highest emissions from a 5 MHz E-UTRA carrier without and with temperature drift are given by Vendor 2. These are about -25 dBm/8 MHz and -21 dBm/8 MHz, respectively. The lowest emissions are achieved by Vendor 4, being -43 dBm/8 MHz and -30.5 dBm/8 MHz without and with temperature drift. These results indicate that the lowest feasible minimum OOBE level that can be achieved considering the temperature range devices are required to work across is -30 dBm/8 MHz.

The shift in frequency of filter response due to temperature drift is downward (increasing hence the OOBE level in the lower band compared to the situation at normal temperature) only for higher temperatures.

5.3 DTT CHANNEL 48 ONTO PPDR

5.3.1 MCL analysis of DTT Tx interference onto PPDR UL

Table 61 and Table 62 (with attached explanatory Figure 45) and Figure 46 below show the variation of the PPDR receiver desensitisation (at the PPDR base station) for a range of horizontal distances separating the PPDR base station from the DTT transmitter.

Two cases were considered:

1 High power DTT transmitter (200 kW ERP, 200 m height above ground level) using channel 48.

2 Medium power DTT transmitter (5 kW ERP, 75 m height above ground level) using channel 48.

The calculations assume that the ACLR of the DTT transmitter and the ACS of the PPDR base station receiver are both equal to 70 dB for the considered guard band of 4 MHz.

Table 61 - High power DTT transmitter (200 kW ERP, 200 m height above ground level) using channel 48

Parameter	Units	Value	Value	Value	Value	Value	Value	Value	Comment
Frequency	MHz	700.5	700.5	700.5	700.5	700.5	700.5	700.5	fo
Receiver NF	dB	4	4	4	4	4	4	4	NF
Thermal noise floor (5MHz)	dBm	-103.44	-103.44	-103.44	-103.44	-103.44	-103.44	-103.44	Pn = 10log(kTB) + NF + 30
In-block transmit ERP	dBm/(8 MHz)	83	83	83	83	83	83	83	$P_{e.r.p}$
ERP to EIRP	dBi	2.15	2.15	2.15	2.15	2.15	2.15	2.15	C_{iso}
EIRP	**dBm/(10 MHz)**	**85.15**	**85.15**	**85.15**	**85.15**	**85.15**	**85.15**	**85.15**	$P_{e.i.r.p} = P_{e.r.p}+C_{iso}$
Rx Tx horizontal distance	km	1	2	4	6	10	14	20	d_h separation distance
Tx height	m	200	200	200	200	200	200	200	h_{Tx}
Rx height	m	20	20	20	20	20	20	20	h_{Rx}
Path distance	km	1.01607	2.00808	4.00405	6.00270	10.00162	14.00116	20.00081	D = sqrt(d_h^2 + (h_{Rx} – h_{Tx})^2)
Free space attenuation	**dB**	**89.49**	**95.40**	**101.40**	**104.92**	**109.35**	**112.27**	**115.37**	LFs
Hata attenuation (suburban) cut off at FS	**dB**	**89.49**	**95.40**	**101.40**	**104.92**	**109.35**	**112.27**	**115.37**	Lhata
Elevation angle	degrees	10.2	5.1	2.6	1.7	1	0.7	0.5	θ_{elev}
Tx Tilt	degrees	1	1	1	1	1	1	1	T_{xtilt}
Tx angle incl tilt	degrees	9.2	4.1	1.6	0.7	0	-0.3	-0.5	$T_{angle} = \theta_{elev} - T_{xtilt}$
Tx antenna elevation discrimination	dB	20	11.7	3	0.7	0	0	0	G_{TDir}
Rx antenna bore-sight gain	dBi	15	15	15	15	15	15	15	G_{Rx}
Rx tilt	degrees	4	4	4	4	4	4	4	R_{xtilt}
Rx angle including tilt	degrees	14.2	9.1	6.6	5.7	5	4.7	4.5	$R_{angle} = \theta_{elev} + R_{xtilt}$
Rx antenna elevation discrimination	dB	12.8	12.3	11.6	11.2	10.9	10.7	10.5	G_{RDir}
Total coupling gain	**dB**	**107.29**	**104.40**	**101.00**	**101.82**	**105.25**	**107.97**	**110.87**	G_{Tot} = Max(L_{FS}; Lhata)+G_{TDir}-G_{Rx}+G_{RDir}
ACS	**dB**	**70**	**70**	**70**	**70**	**70**	**70**	**70**	ACS
ACLR	**dB**	**70**	**70**	**70**	**70**	**70**	**70**	**70**	ACLR
OOBE (e.i.r.p)	**dBm/(5 MHz)**	**13.00**	**13.00**	**13.00**	**13.00**	**13.00**	**13.00**	**13.00**	OOBE = P_{EIRP} - ACLR
ACIR	dB	66.99	66.99	66.99	66.99	66.99	66.99	66.99	ACIR = -10LOG($10^{(-ACS/10)}+10^{(-ACLR/10)}$)
Interference power	**dBm**	**-89.13**	**-86.24**	**-82.84**	**-83.65**	**-87.09**	**-89.81**	**-92.71**	PI = $P_{e.i.r.p}$ - G_{Tot} - ACIR
I/N	dB	14.32	17.20	20.61	19.79	16.35	13.63	10.74	INR = PI - Pn
Receiver Desensitisation (C/N Degradation)	dB	**14.48**	**17.28**	**20.64**	**19.83**	**16.45**	**13.82**	**11.09**	D=10*log(1+10^(INR/10))

Table 62 - Medium power DTT transmitter (5 kW ERP, 75 m height above ground level) using channel 48

Parameter	Units	Value	Value	Value	Value	Value	Value	Value	Comment
Frequency	MHz	700.5	700.5	700.5	700.5	700.5	700.5	700.5	fo
Receiver NF	dB	4	4	4	4	4	4	4	NF
Thermal noise floor (5MHz)	dBm	-103.44	-103.44	-103.44	-103.44	-103.44	-103.44	-103.44	Pn = 10log(kTB) + NF + 30
In-block transmit ERP	dBm/(8 MHz)	67	67	67	67	67	67	67	$P_{e.r.p}$
ERP to EIRP	dBi	2.15	2.15	2.15	2.15	2.15	2.15	2.15	C_{iso}
EIRP	**dBm/(8 MHz)**	**69.15**	**69.15**	**69.15**	**69.15**	**69.15**	**69.15**	**69.15**	$P_{e.i.r.p} = P_{e.r.p}+C_{iso}$
Rx Tx horizontal distance	km	1	2	4	6	10	14	20	d_h separation distance
Tx height	m	75	75	75	75	75	75	75	h_{Tx}
Rx height	m	20	20	20	20	20	20	20	h_{Rx}
Path distance	km	1.00151	2.00076	4.00038	6.00025	10.00015	14.00011	20.00008	D = sqrt(d_h^2 + (h_{Rx} – h_{Tx})^2)
Free space attenuation	**dB**	**89.36**	**95.37**	**101.39**	**104.91**	**109.35**	**112.27**	**115.37**	LFs
Hata attenuation (suburban) cut off at FS	**dB**	**89.36**	**95.37**	**101.39**	**107.60**	**114.90**	**119.60**	**129.70**	Lhata
Elevation angle	degrees	3.1	1.6	0.8	0.5	0.3	0.2	0.2	θ_{elev}
Tx Tilt	degrees	0	0	0	0	0	0	0	T_{xtilt}
Tx angle incl tilt	degrees	3.1	1.6	0.8	0.5	0.3	0.2	0.2	$T_{angle} = \theta_{elev} - T_{xtilt}$
Tx antenna elevation discrimination	dB	0	0	0	0	0	0	0	G_{TDir}
Rx antenna bore-sight gain	dBi	15	15	15	15	15	15	15	G_{Rx}
Rx tilt	degrees	4	4	4	4	4	4	4	R_{xtilt}
Rx angle including tilt	degrees	7.1	5.6	4.8	4.5	4.3	4.2	4.2	$R_{angle} = \theta_{elev} + R_{xtilt}$
Rx antenna elevation discrimination	dB	11.8	11.2	10.7	10.5	10.4	10.3	10.3	G_{RDir}
Total coupling gain	**dB**	**86.16**	**91.57**	**97.09**	**103.10**	**110.30**	**114.90**	**125.00**	G_{Tot} = Max(L_{FS}; Lhata)+G_{TDir}-G_{Rx}+G_{RDir}
ACS	**dB**	**70**	**70**	**70**	**70**	**70**	**70**	**70**	ACS
ACLR	**dB**	**70**	**70**	**70**	**70**	**70**	**70**	**70**	ACLR
OOBE (e.i.r.p)	**dBm/(5 MHz)**	**-3.00**	**-3.00**	**-3.00**	**-3.00**	**-3.00**	**-3.00**	**-3.00**	OOBE = P_{EIRP} - ACLR
ACIR	dB	66.99	66.99	66.99	66.99	66.99	66.99	66.99	ACIR = -10LOG($10^{(-ACS/10)}+10^{(-ACLR/10)}$)
Interference power	**dBm**	**-84.00**	**-89.41**	**-94.93**	**-100.94**	**-108.14**	**-112.74**	**-122.84**	PI = $P_{e.i.r.p}$ - G_{Tot} - ACIR
I/N	dB	19.44	14.03	8.51	2.50	-4.70	-9.30	-19.40	INR = PI - Pn
Receiver Desensitisation (C/N Degradation)	dB	**19.49**	**14.20**	**9.09**	**4.44**	**1.27**	**0.48**	**0.05**	D=10*log(1+10^(INR/10))

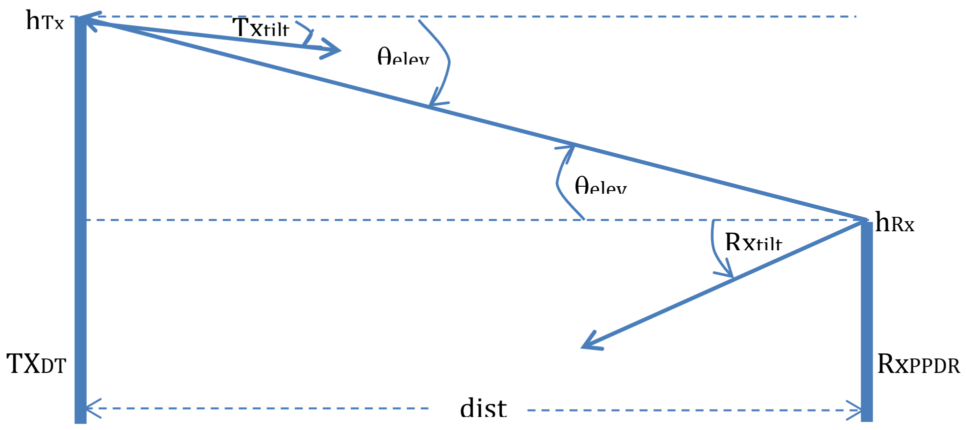

Figure 45: Geometry used to calculate the respective antenna discriminations in Table 61 and Table 62

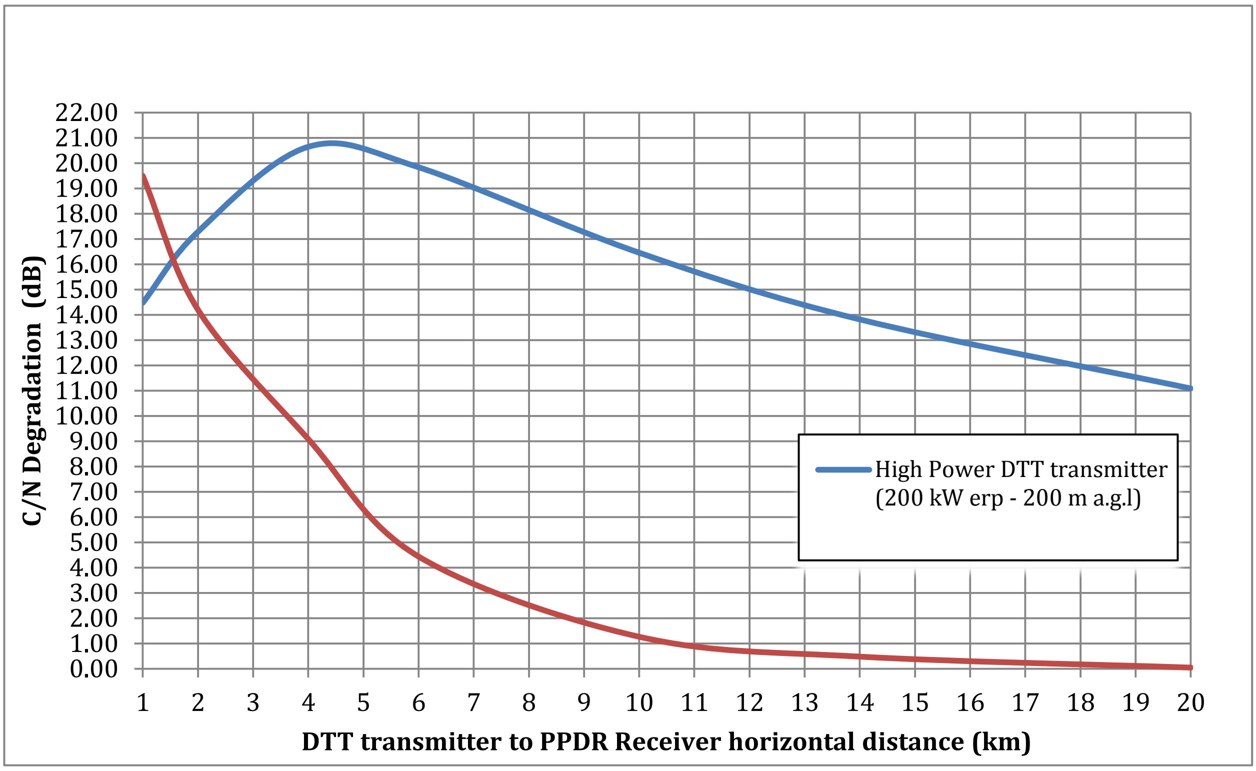

Figure 46 - Receiver desensitisation of a PPDR base station using the band 698-703 MHz due to DTT transmission in CH48 (ACS=ACLR=70 dB)

The results above show that a significant desensitisation (up to 21 dB) would occur to the PPDR BS receiver due to the DTT adjacent channel interference for the considered levels of ACLR of the DTT transmitter and the ACS of the PPDR BS receiver (both equal to 70 dB).

Referring to the curves in Figure 46, the highest desensitisation level occurs at distances between 4 and 5 km from a high power DTT transmitter and below 1 km from a medium power DTT transmitter. The variation of the desensitisation with the distance and between the two cases of high and medium power DTT transmitters is due to the combined effect of the vertical antenna pattern of the DTT transmitter and the PPDR Base station.

Improving this situation would be subject to the feasibility of improving both the DTT ACLR and the PPDR ACS while keeping the two systems separated with only 4 MHz of guard band. Appropriate engineering practices (site selection and densification, tilting, etc.) could also reduce the impact to a satisfactory level.

5.3.2 Potential impact analysis (generic)

5.3.2.1 Desensitisation of PPDR uplink 698 – 703 MHz by DTT ch48

This study looks at the the upper 10 RB (701 - 703 MHz) its desensitisation due to DTT out-of-band emissions. The calculations have been done at 50 % time.

METHODOLOGY

The signal level at 30 m a.g.l. for one main station that uses channels 48 (Table 63) has been calculated. Calculations are to the centre of a 200 m pixel and have been carried out at 50 % using ITU-R P.1546-5 .From these calculations the potential desensitisation of PPDR base stations has been derived assuming the values in Table 64.

The potential desensitisation due to the DTT station is analysed, to eliminate desensitisation due to insufficient LTE base station receiver ACS, the base station receiver ACS has been assumed to be very high, i.e.> 100 dB.

The LTE base station antenna system (15 dBi gain) is assumed to be slant polarised, so offers 3 dB cross polar discrimination. The VRP of the base station antenna is taken in to account in the calculations in a simplified way, i.e. 3 dB is subtracted from the received power

Table 63: Generic Main Stations modelled

Station	e.i.r.p. (dBm)	Antenna height (m a.g.l.)	Effective Height (m)
HP TX	85.2	300	300

Table 64: Parameters used for the simulation

Parameter	Value
e.i.r.p.	See Table 63
ACLR of DTT ch48 transmitter (701 – 703 MHz)	82.4 dB (based on GE06 non-critical mask)
DTT antenna	A generic 24 lambda antenna with 1 degree downtilit[15]

15 $E(\theta) = abs\left(\frac{Sin\Psi}{\Psi}\right)$ where $\Psi = \pi A Sin(\theta - \beta)$ and

A = the antenna vertical aperture in wavelengths

Parameter	Value
Propagation Model	ITU-r P.1546-5
LTE base station antenna	Horizontal omni, vertical simplified (3 dB)
Gain of LTE base station antenna system	15 dBi
LTE base station height	30 m a.g.l.
Polarisation discrimination	3 dB
LTE reference sensitivity (10 RB)	-106.4 dBm
LTE receiver ACS	>100 dB

LTE receiver desensitisation has been calculated as follows,

$$D_{sens} = 10\ LOG_{10}\left[1 + 10^{\wedge\left(\frac{I-N}{10}\right)}\right]$$

Where;

I = the interfering DTT signal at the LTE receiver dBm

N = LTE Receiver reference sensitivity in the case of the 10 RB -106.4 dBm

Dsens = the desensitisation of the LTE receiver in dB

β = the beam tilt radians below the horizontal.

To allow for null fill the value of E(θ) should not go below the value of 0.15 for the first null, 0.1 for the second null and 0.05 for third null and beyond

RESULTS

The following Figure 47shows the extent of the desensitisation for the upper 10 RB.

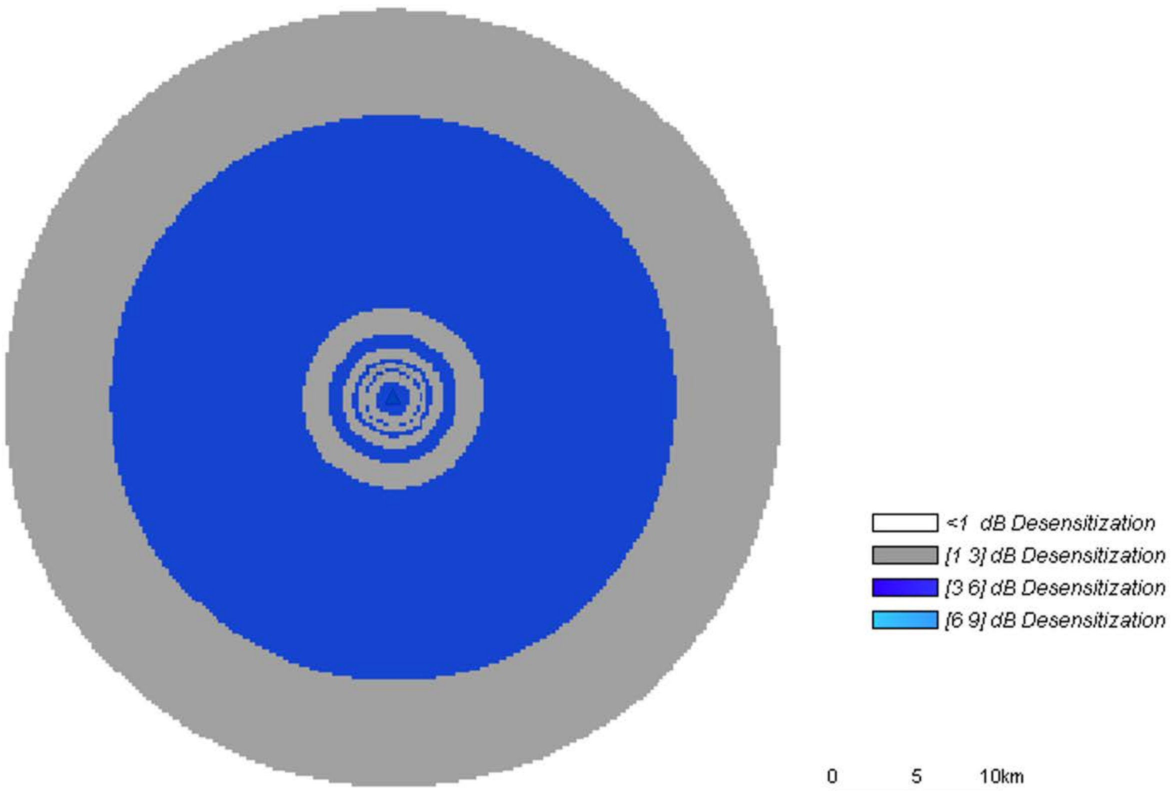

Figure 47: desensitisation for the upper 10 RB

For the lowest 5 RBs (698 - 699 MHz) the simulation results would show about 11dB higher desensitisation. The scheduling algorithm, however, may provide some mitigation through selecting the best RB's for uplink transmissions.

5.3.2.2 Blocking of PPDR uplink 698 – 703 MHz by DTT ch48

This study provides information on the extent of potential PPDR receiver desensitisation and the additional filtering required from a BS only fulfilling the 3GPP minimum requirements to limit blocking due to DTT transmissions with e.i.r.p. of 85 dBm in ch48 at different separation distances

The calculations have been done at 50 % time.

METHODOLOGY

The signal level at 30 m a.g.l. for one main station that uses channels 48 (Table 65) has been calculated. Calculations are to the centre of a 200 m pixel and have been carried out at 50 % using ITU-R P.1546-5. From these calculations the potential desensitisation of PPDR base stations has been derived assuming the values in Table 66.

The LTE base station antenna system (15 dBi gain) is assumed to be slant polarised, so offers 3 dB cross polar discrimination. The VRP of the base station antenna is taken in to account in the calculations in a simplified way, i.e. 3 dB is subtracted from the received power.

Table 65: Generic Main Stations modelled

Station	e.i.r.p. (dBm)	Antenna height (m a.g.l.)	Effective Height (m)
HP TX	85.2	300	300

Table 66: Parameters used for the simulation

Parameter	Value
e.i.r.p.	See Table 65
DTT antenna	A generic 24 lambda antenna with 1 degree downtilit[16]
DTT ACLR	>100 dB
Propagation Model	ITU-r P.1546-5
LTE base station antenna	Horizontal omni, vertical simplified (3 dB)
Gain of LTE base station antenna system	15 dBi
LTE base station height	30 m a.g.l.
Polarisation discrimination	3 dB
LTE reference sensitivity (25 RB)	-101.5 dBm
Blocking level for 1 dB desensitisation **2nd adjacent 5 MHz block and beyond**	-52.9 dBm

LTE receiver blocking has been calculated as follows,

$$Filtering = FS - \left(BlockingLevel + 77.12 + 20Log_{10}(F_{MHz})\right) + G_{BS} - X_{pol} - VRP_{BS}$$

where:

Filtering = Additional BS filtering (dB) required to limit desensitisation to 1 dB assuming a BS only fulfilling the minimum 3GPP blocking requirements

FS = Predicted DTT field strength in (dBµV/m)

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16 $E(\theta) = abs\left(\frac{Sin\Psi}{\Psi}\right)$ where $\Psi = \pi A Sin(\theta - \beta)$ and

A = the antenna vertical aperture in wavelengths

β = the beam tilt radians below the horizontal.

To allow for null fill the value of E(θ) should not go below the value of 0.15 for the first null, 0.1 for the second null and 0.05 for third null and beyond

GBS = Gain of the base station antenna system (dBi)

Xpol = Base station polarisation discrimination relative to DTT (dB)

VRPBS = Base station vertical pattern discrimination at the reception location (dB)

RESULTS

The following Figure 48 shows the extent of the blocking.

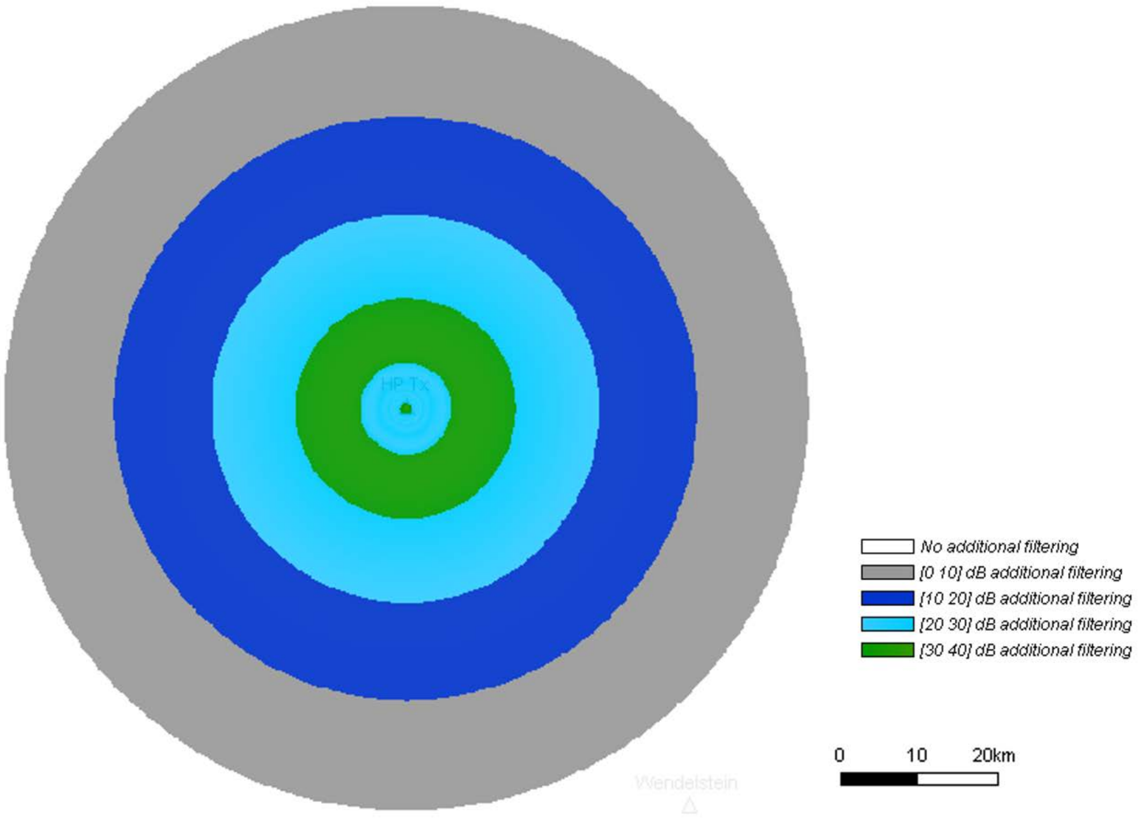

Figure 48: Blocking of PPDR base station

RESULTS

The study shows that the PPDR base station (compliant with 3GPP RX blocking minimum requirements) can be impacted by blocking for more than 20 km distance from a high power DTT transmitter. This however, can be mitigated by improving rejection of the base stations.

5.3.3 Monte Carlo analysis

This scenario was simulated using SEAMCAT with the following assumptions, see Figure 49.

- A PPDR BS is randomly dropped within the DTT coverage area, y = 39.5 km;
- DTT transmits at maximum power (53 dBW), antenna height is 300 m;
- DTT spectrum emission mask is non-critical case (GE06);
- BS horizontal antenna diagram: omnidirectional corresponding to an average value for a 3-sector site using 18 dBi BS sector antennas, i.e. 15 dBi;
- BS vertical antenna diagram: vertical gain according to an 18 dBi BS sector antenna;
- BS better than in the ETSI Harmonised Standard and enough to reject the DTT blocking signals.

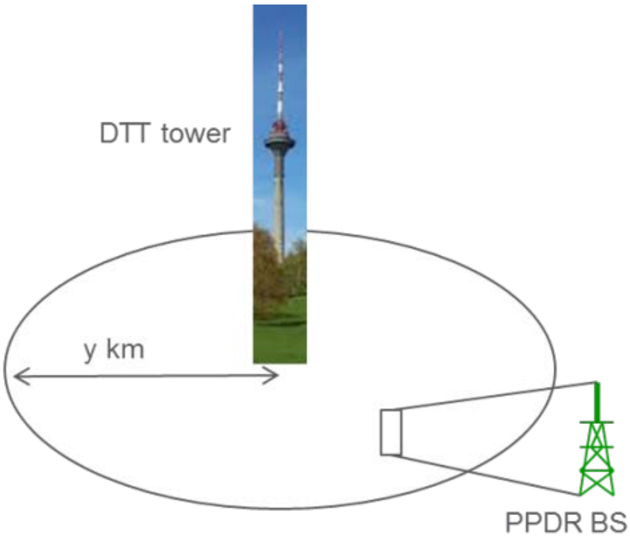

Figure 49: Set-up of DTT interference to PPDR (SEAMCAT simulations)

The results in the Table 67 below include the impact of channel 47 and 48 out-of-band emissions into a PPDR BS receiving within 698-703 MHz. The simulations assume a blocking rejection from an LTE BS better than in the ETSI Harmonised Standards and enough to reject the DTT blocking signals. The assumed ACLR is 69 dB and 79 dB from channel 48 and 47, respectively (these ACLR value correspond roughly to the non-critical spectrum mask for DTT transmitters as defined in the GE-06 agreement). The used criteria to calculate desensitisation is I/N > -6 dB, corresponding to 1 dB desensitisation. It can be seen that the probability of this desensitisation for a PPDR 700 base station randomly located inside the DTT coverage area is approximately 50 % from channel 48 and 24 % from channel 47 for DTT e.i.r.p. of 53 dBW.

Table 67: Probability of desensitisation of PPDR BS > 1 dB (only out-of-band emissions)

	BS receiving at 698-703 MHz
Channel 47	23.81 %
Channel 48	49.97 %

For DTT transmitters with lower e.i.r.p. this probability of 1 dB desensitisation for PPDR BS will be lower. It will also be lower for DTT transmitters using critical spectrum mask defined in the GE-06 agreement (which would roughly give 10 dB lower out-of-band emission levels than the non-critical spectrum mask at the considered frequency offsets). As an example, if the critical-spectrum mask was used on the DTT transmitter considered above with 53 dBW e.i.r.p., the probability of 1 dB desensitisation would be reduced from around 50 % to around 24 %.

The risk of desensitisation from channels below channel 47 will be lower than the values in Table 67 above.

Mitigation techniques are needed to reduce the risk of interference from DTT transmitters into PPDR base station receivers on a case by case basis.

Possible mitigation techniques include: down tilting PPDR antenna, fine-tuning antenna orientation and implementing link budget margins by increasing the PPDR network density.

5.3.4 Case study, PPDR BS deployment in France

Minimum coupling loss analysis shows that DTT transmitter may impact receiving PPDR base stations at distances beyond 20 km.

In this study, the sensitivity level of the upper 10 RB (701 - 703 MHz) of the base station, is compared with the interfering power level coming from high power DTT transmitters. Interference levels surrounding ten DTT high power transmitters located in France mainland are evaluated and compared with the sensitivity level of a 5 MHz PPDR BS centred on 700.5 MHz.

Figure 50: DTT transmitters under study

The transmitters have among the biggest e.i.r.p.s of the French DTT network. e.i.r.p.s are represented in the Figure 51 below.

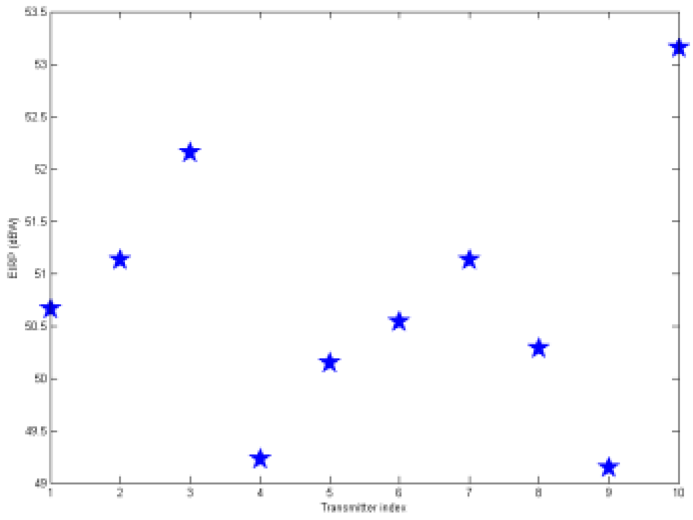

Figure 51: e.i.r.p.s of the transmitters under study

The sensitivity of a 5 MHz LTE base station is given by Table 7.2.1-1 of 3GPP 136.104. PPDR antenna gain is assumed to be 15 dBi gain and a 3° down tilt isolation, resulting in an overall 13.1 dBi.

The DTT transmitters are simulated according to e.i.r.p.s used on the field, as well as real 3D antenna diagrams. The OOBE level is set according to the non-critical spectrum emission mask from Table 3-11 of the GE06 agreement. For instance, sensitive case has OOBE 10 dB lower than the non-sensitive case The use of cross-polarisation at the PPDR BS antenna is expected to improve the situation a further 3dB.

The interfering field strength is derived according to the following formula:

$$I_{DTT} = e.i.r.p._{DTT} - ACLR_{DTT} + G_{DTT} - L_{FD} + G_{PPDR}$$

Interference to the 10 highest RBs (701 - 703 MHz) of the PPDR system is assessed. RBs in the upper-side of the band benefit from lower interference due to the increased frequency separation and hence better DTT ACLR. This hypothesis improves the simulation results by about 11 dB compared to the use of the lowest 5 RBs (698 - 699 MHz), assuming that UEs experiencing close to sensitivity propagation conditions would be scheduled on best available RBs.

Table 68: Parameters used for the simulation

Parameter	Value
e.i.r.p.	Real value of the transmitter
ACLR_DTT	82.36dB in 10RBs
G_DTT	Real antenna diagram
L_1546	According to Fresnel Deygout propagation model
G_PPDR	15 - 1.89 = 13.1 dBi

Table 69: Parameters used for the simulation

Parameter	Value
e.i.r.p.	Real value of the transmitter
ACLR_DTT	82.36dB in 10RBs
G_DTT	Real antenna diagram
L_FD	According to Fresnel Deygout propagation model
G_PPDR	15 - 1.89 = 13.1 dBi

The following maps compare the interfering power to the sensitivity of a base station for ten high power DTT transmitters. More formally, in dB scale:

$$X(x,y) = I_{DTT}(x,y) - S_{sens}$$

From this map, the desensitisation can be derived as follows:

$$\frac{S_{desens}}{S_{sens}} = 10log10(1 + 10^{X(x,y)/10}10^{SINR/10})$$

Where SINR is the target SINR threshold and S_{sens}.the sensitivity of the PPDR BS over ten RBs is equal to -106.4dBm.

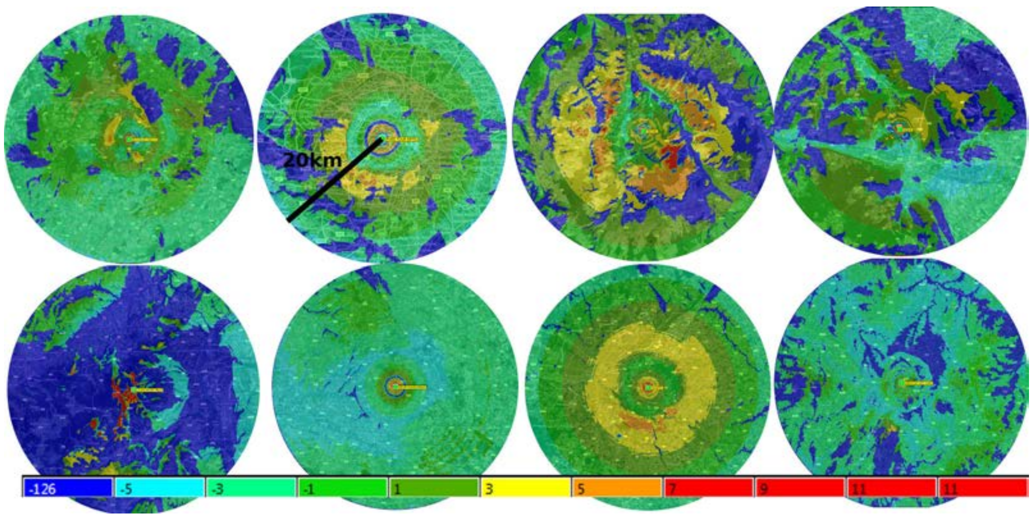

Figure 52: Interfering power divided by sensitivity (dB scale) in the vicinity of 8 DTT transmitter sites assuming channel 48 is used

In most cases, the interfering field strength to the top 10 RB is no more than 1 dB above the sensitivity level within 5km of the DTT site. Assuming a target SINR of 1 dB, the desensitisation rarely exceeds 4 dB within 5km of the DTT site but, depending on the configuration of the DTT site, ERP, antenna height and pattern and the terrain higher levels of desensitisation to the highest 10 RB may occur at greater distances. Also it should be noted that desensitisation of the RB closer to the DTT service will be higher.

However, care should be taken when deploying a PPDR site in the vicinity of a DTT transmitter that uses channel 48. It is suggested to carry-out measurements before deploying sites.

There are approximately 70 DTT transmitters operating at ERP higher than 37 dBW in France. Assuming that 6 multiplex would be deployed after the 700 MHz band release, it is estimated that about 15 sites could use channel 48. It is worth noting that most of high power transmitters in France are located in sparsely populated areas.

In the case where possible locations for the PPDR base station are limited, possible mitigation techniques include, amongst others, down-tilting PPDR antenna, fine-tuning antenna orientation, improving link budget margins by increasing the network density.

6 CONCLUSIONS

6.1 COMPATIBILITY BETWEEN PPDR AND MFCN

The technical specifications of MFCN Base Station (BS) and User Equipment (UE) do not guarantee interference free operation of concurrent networks in adjacent blocks throughout the coverage area. Increasing PPDR UE adjacent selectivity enables the victim PPDR UE to operate in a sparse network when adjacent in frequency to a dense network. Another phenomenon is the 3rd order intermodulation due to DL operations by two different MFCN networks may appear in PPDR band, if this happens, PPDR operator should accept this type of interference.

Compatibility between PPDR UL and SDL (MFCN Supplemental Downlink) depends on the scenario which is targeted. It is feasible for an SDL BS to fulfil the out-of-block power limit defined in ECC/DEC/(15)01 [1] towards PPDR UL in 733-736 MHz, assuming a 15 dBi antenna gain. There is no blocking requirement for PPDR UL Rx in the ECC Decision and thus the PPDR BS Rx filter was not analysed for this scenario. However, it is recognised that the PPDR BS Rx filter is needed.

If the 3GPP minimum requirements for coexistence are to be fulfilled, it is feasible to create SDL Tx and PPDR BS Rx filters with enough rejection. However, the insertion loss in PPDR UL will be higher than standard. In the case of colocation between PPDR and SDL, then more than 2 MHz separation is needed. The exact level of guard-band beyond 2 MHz for site solutions with external filters has not been investigated in this report. Another way to manage colocation may be to rely on different site solutions, e.g. by using appropriate antenna physical separation.

It is shown that PPDR 2x10 MHz in the duplex gap is not feasible.

Compatibility of PPDR 2x(2x5) MHz in the duplex gap with MFCN may be achieved. However, this option suffers from limitations (See more information on the limitations in Section A1.4), such as:

- Severe self-desensitisation of the PPDR UE downlink;
- UE-UE interference;
- Cross-border coordination with SDL.

6.2 COMPATIBILITY BETWEEN PPDR AND DTT

The earlier results of extensive studies on compatibility between MFCN and DTT below 694 MHz are in CEPT Report 53[17] [2]. As a consequence ECC/DEC/(15)01 [1] indicates that the maximum mean unwanted emission power of MFCN UE should be limited to -42dBm/8MHz for protection of fixed DTT reception at 470-694 MHz assuming an MFCN channel of 10 MHz or less and a 9 MHz guard band.

This conclusion was based on the results of a number of compatibility studies looking at MFCN UEs operating within the 703-733 MHz band and the technical feasibility of MFCN UEs implementing appropriate filtering to meet this unwanted emission level.

Studies in this report look at the compatibility between PPDR networks using MFCN LTE-based technologies in the 700 MHz range and DTT below 694 MHz. Studies have shown that the most critical compatibility analysis with DTT Networks is for PPDR UE use in the 698-703 MHz band. These studies also looked at a number of different scenarios with different assumptions looking at PPDR UEs operating within the 698-703 MHz band and the technical feasibility of PPDR UEs implementing appropriate filtering to meet the proposed unwanted emission levels.

[17] Additional results for threshold levels for MFCN UEs are in the CPM report for AI 1.2 WRC-15

Taking into account the results of the studies presented it appears that a reasonable solution would be to recommend unwanted emission levels for PPDR UE of -42 dBm/8 MHz to manage the risk of interference to DTT below 694 MHz. This would provide an adequate level of protection for DTT. The cumulative effect of unwanted emission from both PPDR UEs and MFCN UEs was not studied in this report.

Some studies also show the potential for relaxed values of the unwanted emission levels for PPDR UEs operating in the 698-703 MHz block.

Simulations have shown that UEs with 4 MHz guard band, operating at temperatures above +35°C, may have limitations regarding the technical feasibility of implementing appropriate filtering to meet the unwanted emission limit of -42 dBm/8MHz below 694 MHz.

Taking into account temperature drift and to address the feasibility problems highlighted above for these PPDR UEs to meet the -42 dBm/8 MHz limit a different level can also be considered for such PPDR UEs under extreme environmental conditions for equipment conformance tests. When reviewing these levels the unwanted emission level of a PPDR UE operating in the 698-703 MHz block in extreme environmental conditions for equipment conformance tests should not exceed -30 dBm/8MHz. Measured maximum unwanted emission levels of existing MFCN UEs operating in the 700 MHz band in extreme operating conditions are provided in the studies. The maximum mean in-block power for PPDR terminals is assumed to be 23 dBm to avoid blocking.

The results of co-existence studies when the PPDR system is operating above 733 MHz (in the 700 MHz duplex gap) show that the impact of the PPDR uplink would be lower than the level of impact of MFCN LTE UE on DTT channel 48.

The PPDR Base Station receiver may be subject to interference from DTT transmitters using channel 48 and located in the vicinity. The desensitisation of the PPDR base Station receiver can be significant depending on the distance between the two sites and on the transmission and receiving characteristics.

In that case PPDR Base Station receiver should implement appropriate filtering of DTT in-band emissions. Additionally mitigation techniques would reduce the risk of interference from DTT transmitters using channel 48 into PPDR base station receivers on a case by case basis. Possible mitigation techniques include: down tilting PPDR antenna, fine-tuning antenna orientation and implementing link budget margins by increasing the PPDR network density.

Compatibility between DTT channel 47 and PPDR UL in the band 698-703 MHz was also considered and it was concluded that the situation is comparable (or better) than the situation considered in CEPT Report 53 [2] between DTT channel 48 and MFCN UL in the band 703-733 MHz.

ANNEX 1: DISCUSSION ON SELF-INTERFERENCE OF 2X10 MHz AND 2X(2X5) MHz OPTIONS

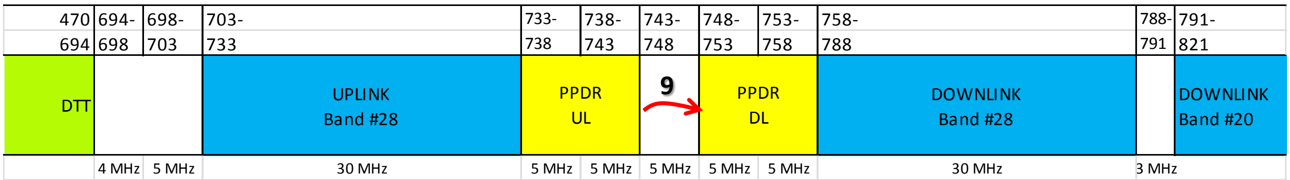

Figure 53: Summary of self-interference study for the 2x10 MHz option

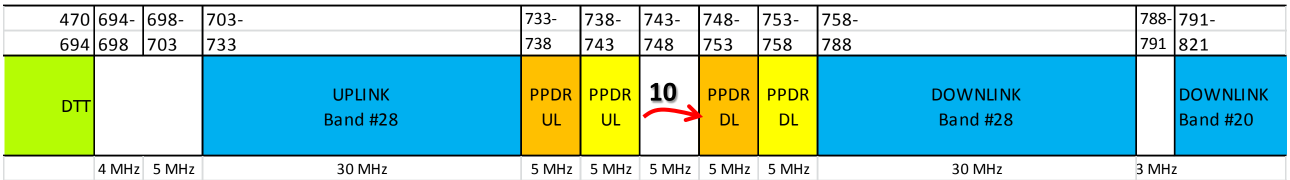

Figure 54: Summary of self-interference study for the 2x(2x5) MHz option

(9) Self interference of PPDR UE and impact of transmitting PPDR UE (UL) onto another receiving PPDR UE (DL)

(10) Impact of transmitting PPDR UE (UL) onto another receiving PPDR UE (DL)

A1.1 2X10 MHz OPTION

The 2x10 MHz configuration of PPDR is technically not feasible, because the 3rd order PIM products will largely degrade the reference sensitivity and the duplexer is difficult to development with only a 5 MHz duplex gap.

In this document, we only consider the impact of self- interference caused by the transmitter OOB emissions (shown in red) into the receiver chain resulting in a reduction of receive sensitivity or self-desensitisation.

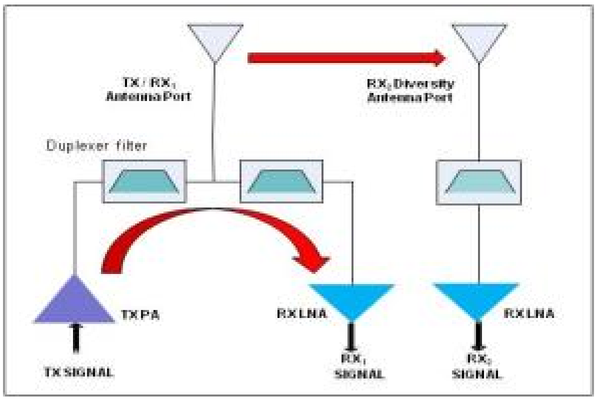

Figure 55: FDD self –interference (Tx OOB emission into Rx path)

As part of this analysis we explore the transmitter OOB emissions level expected for a 700 MHz devices and the required Tx to Rx duplexer filter isolation needed to mitigate the impact of self-interference due to these OOB emissions. We also comment on the impact on system performance in terms of cell search measurements (which are needed for handover) due to this high level of receiver self-interference.

A1.1.1 Tx OOB emission

With a LTE channel bandwidth of 10 MHz and a 5 MHz duplex gap it is expected that there will be considerable leakage of the transmitted signal OOB emission into the adjacent spectrum. From the 3GPP specification [8] the following OOB emissions are specified at the antenna port is copied below.

Table 70: ETSI TS 136 101 [8] Table 6.6.2.1.1-1: General E-UTRA UL spectrum emission mask

Spectrum emission limit (dBm) / Channel bandwidth							
ΔfOOB (MHz)	1.4 MHz	3.0 MHz	5 MHz	10 MHz	15 MHz	20 MHz	Measurement bandwidth
± 0-1	-10	-13	-15	-18	-20	-21	30 kHz
± 1-2.5	-10	-10	-10	-10	-10	-10	1 MHz
± 2.5-2.8	-25	-10	-10	-10	-10	-10	1 MHz
± 2.8-5		-10	-10	-10	-10	-10	1 MHz
± 5-6		-25	-13	-13	-13	-13	1 MHz
± 6-10			-25	-13	-13	-13	1 MHz
± 10-15				-25	-13	-13	1 MHz
± 15-20					-25	-13	1 MHz
± 20-25						-25	1 MHz

Note ΔfOOB = Δ Frequency of Out Of Band emission

From the above Table 70 we observe that the emission into the adjacent spectrum channel is -13 dBm/MHz or -3 dB/10MHz. Now the required Rx sensitivity, RX_{SENS} is about -94 dBm/9 MHz, so we need the duplex RF filter to provide better than 91 dB (94 - 3 dB) of filter attenuation of the Tx OOB emission so as to not degrade the Rx sensitivity or RX_{SENS} by 3 dB. So, filter isolation needs to be greater than 91 dB to avoid this 3 dB performance degradation.

A1.1.2 Duplex RF filter

Typically a handset SAW filter as used in the 700/800 MHz band will provide a filter attenuation of 45 dB isolation. So in this case 46 dB+ of isolation is missing. However, this required level value of isolation (45 dB) assumes the Tx channel has a reasonable frequency offset relative to the receiver channel and there is a sufficient duplex gap to account for SAW filter, temperature drift and mechanical/variation tolerance.

However, with only a 5 MHz duplex gap and a small Tx to Rx channel spacing, we could expect a significant lower value of isolation than 45 dB due to filter drift and mechanical variance as shown below in Figure 56.

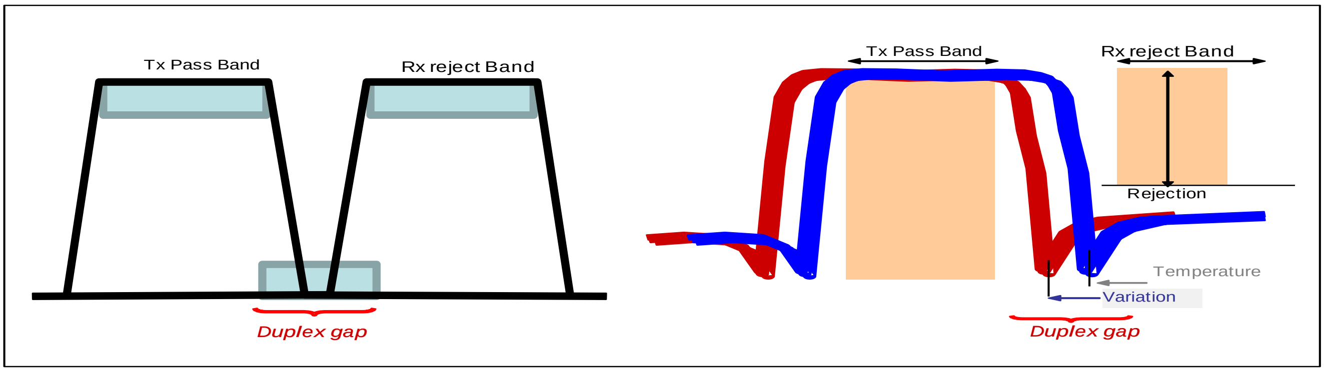

Figure 56: FDD self–interference (duplex RF performance)

A1.1.3 Tx OOB emission + Duplex RF filter

In Figure 57 below we have provided some PA simulations for a 3GPP band 13 devices, which operates in the 700 MHz band to study the Tx OOB emission into the Rx channel taking into account the proposed band plan. We have also investigated the results of any duplexer filter mitigation taking into account real 700 MHz filter data. The results show that the duplex filter provides little or no reduction of the PA OOB emission into the Rx channel. This analysis points to the fact that shows a duplex gap of 20 MHz similar to other 3GPP 700 MHz bands is needed rather than the 5 MHz proposed.

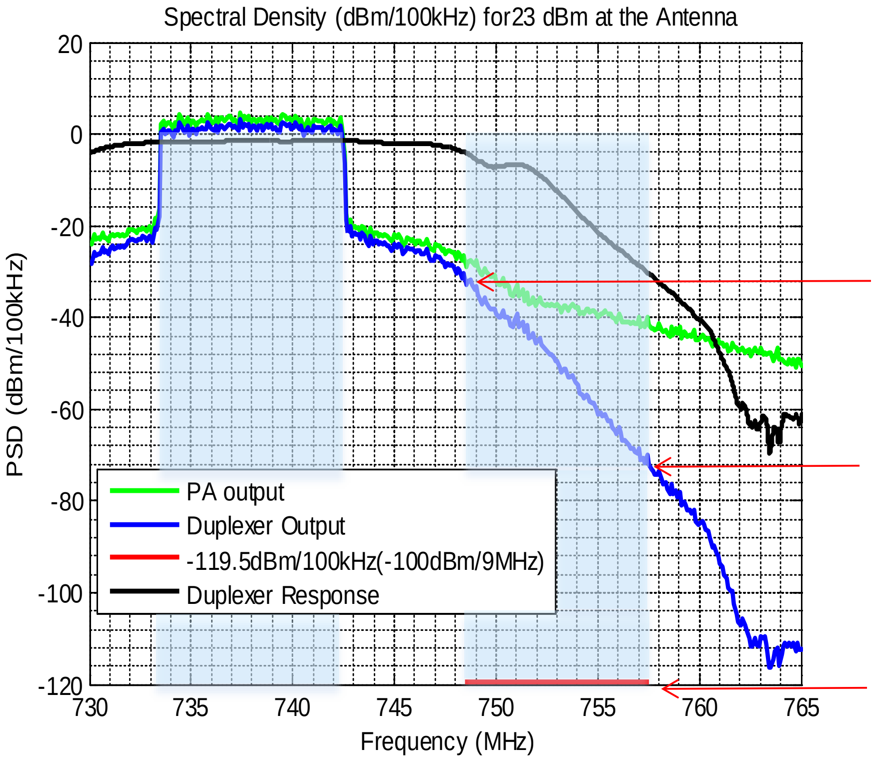

Figure 57: FDD self–interference (Tx OOB + Duplex RF filter)

A1.1.4 TX OOB emission mitigation

Since Tx OOB emission scale with channel bandwidth, one way of reducing the Tx OOB emission would be to restrict the UL transmission configuration or number of transmitted UL resource block (RB) so as not to self-interfere or desensitize the Rx channel.

For example, if we compare the channel bandwidth, Rx - Tx channel spacing and the duplex gap for the 3GPP 700 MHz and 400 MHz band we note that all these bands would need to restrict the transmitted resource block allocation in order not to self-interfere or desensitize its own receiver to meet the specified Rx sensitivity in [8]. For example taking the case of B14 which is 2 X 10 MHz band operating in the 700 MHz we note the UL will need to be restricted to 15 RB out of the maximum allowed of 100 RB to meet the specified Rx sensitivity. Another example would be B31 (450 MHz), which has only a 5 MHz duplex gap, the maximum channel bandwidth is limited to 5 MHz and even then the number of transmitted RB would be limited to 5.

EUTRA Operating Band	Uplink (UL) band UE transmit FUL_low – FUL_high			Downlink (DL) band UE receive FDL_low–FDL_high			Duplex Mode	UL BW MHz	DL BW MHz	RX-TX spacing MHz	Duplex gap MHz	E-UTRA band / channel bandwidth			
												1.4 MHz	3 MHz	5 MHz	10 MHz
13	777	–	787	746	–	756	FDD	10	10	31	21			20 [1]	20 [1]
14	788	–	798	758	–	768	FDD	10	10	30	20			15 [1]	15 [1]
31	452.5	–	457.5	462.5	–	467.5	FDD	5	5	10	5	6	5 [1]	5 [1]	
SE(14)125	733	–	743	748	–	758	FDD	10	10	15	5			1-2 [1]	1-2 [1]

Note: [1] number of RB for RFSEN

Figure 58: Reduction in UL capacity to meet the Rx RFSEN requirements

Concerning the Tx - Rx spacing and duplex gap either B13 or B31 and therefore the number of UL resources blocks would need to be limited to a value of around 1-2 RB in order to maintain the RX_{SENS} value, assuming we have 45 dB of duplex isolation (noting the previous comment it is impossible to achieve this value due to filter performance, and therefore desensitize would still be observed with this small allocation).

This restriction in UL RB allocation and the consequential impact on the RX_{SENS} value will be significant for PPDR operation, as:

Many studies have shown for PPDR systems (unlike commercial systems) there is an acute need for increased UL capacity and therefore a band plan which would require a restriction on the UL capacity would be a significant limitation.

Coverage is a key component for PS systems and therefore Rx desensitize with a 1-2 RB transmitter allocation would be a problem as this allocation is normally used to derive the edge of cell coverage for speech (VOIP) services.

With such a high level of self-interference or desensitisation even for very small UL RB allocation this would have an negative impact on the number of base stations cells ‘visible’ during cell search since the cell search performance/ sensitivity would be masked by the self-interference noise from its own transmitter. This problem would be more acute since the probability of transmitting more than 1-2 resources block remains fairly high. In this case the degradation in cell search measurements would not be negligible and would have an impact on handover performance and lead to an increased rate of drop call performance.

A1.2 SUMMARY

The combination of narrow duplex gap (5 MHz) and large channel bandwidth (5/10 MHz) will require an extremely high Tx - Rx duplex filter isolation to avoid self-interference. It will be difficult, if not impossible, to achieve the required level Tx - Rx duplex isolation in a SAW filter used for handset application.

A possible restriction in UL RB allocation to mitigate the self-interference (to avoid the degradation in receiver sensitivity) will be a significant disadvantage for PPDR operation for the following reasons:

CEPT studies have shown for PS systems (unlike commercial systems) that there often is an acute need for increased UL capacity from the scene of incident, and therefore a band plan which would require a restriction on the UL capacity would be working counter to the requirements.

Coverage is a key element for PPDR systems and therefore Rx desensitisation with some 1-2 RB would be a problem as these small allocations are typically used to derive the edge of cell coverage performance for speech (VOIP) services.

A high level of self-interference or desensitisation even for very small UL RB allocations would have a negative impact on the number of base stations cells ‘visible’ during cell search, since the cell search performance/ sensitivity would be masked by the self-interference noise from its own transmitter. In this case the degradation in cell search measurements would have a negative impact on handover performance and drop call performance.

A1.3 2X(2X5) MHz OPTION

For this configuration, the PPDR devices (BTS or Terminal) may be technically feasible since it alleviates the PIM effect, but, the feasibility is achieved at the expense of high cost and network deployment complexity. The high cost is mainly from the improving output power of Power Amplifier which caused by high insertion loss of duplexer. Different PPDR devices (BTS or Terminal) with separate (2*5 MHz) will be needed for option 2*(2*5 MHz). And this is similar to two PPDR networks.

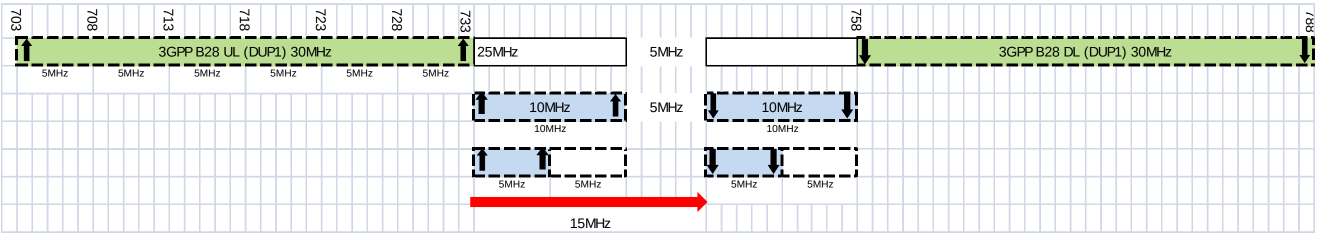

Figure 59: 2x(2x5) MHz option

Deploying 2x5 MHz as shown above will not loosen filter requirements much.

The Tx duplex filter does not provide any attenuation with a 5 MHz duplex gap due to temperature and mechanical tolerance.

Tx to Rx spacing is still unchanged as 15 MHz and the Tx OOB will still be an issue.

The only benefit is a slight reduction in PA noise at the Rx frequency. However as shown below for both cases (10 MHz and 5 MHz) the noise entering into the Rx channel is still significant.

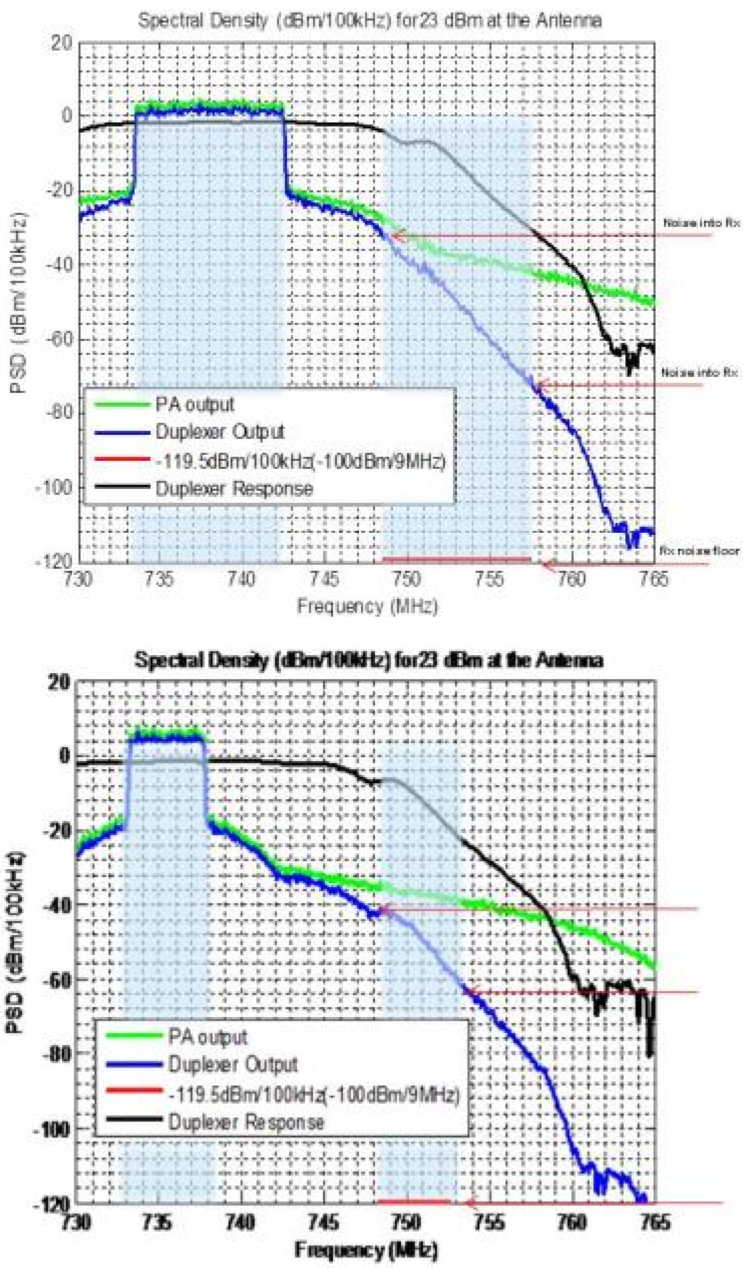

Figure 60: FDD self–interference (Tx OOB + Duplex RF filter)

This problem is quite similar to other 3GPP bands where there is an insufficient Tx - Rx spacing. For example, we consider the 3GPP specification for PPDR B14, even with a 20 MHz duplex gap the UL resource has to be limited to 15 RB in the 3GPP specification to meet the reference Rx sensitivity in the example shown below.

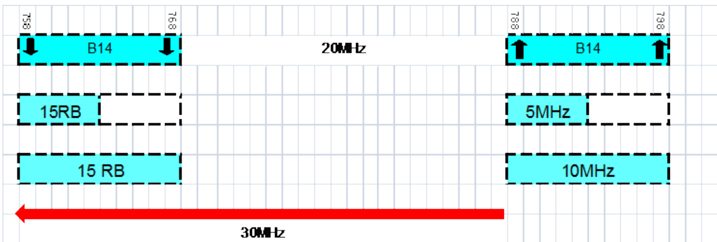

Figure 61: 3GPP band #14 for Public Safety

EUTRA Operating Band	Uplink (UL) band UE transmit FUL_low – FUL_high	Downlink (DL) band UE receive FDL_low–FDL_high	Duplex Mode
13	777 – 787	746 – 756	FDD
14	788 – 798	758 – 768	FDD
31	452.5 – 457.5	462.5 – 467.5	FDD
SE(14)125	733 – 743	748 – 758	FDD

UL BW	DL BW	RX-TX spacing	Duplex gap
MHz	MHz	MHz	MHz
10	10	31	21
10	10	30	20
5	5	10	5
10	10	15	5

E-UTRA band / channel bandwidth			
1.4 MHz	3 MHz	5 MHz	10 MHz
		20 [1]	20 [1]
		15 [1]	15 [1]
6	5 [1]	5 [1]	
		1-2 [1]	1-2 [1]
Note: [1] number of RB for RFSEN			

Figure 62: reduction in UL capacity to meet the Rx RFSEN requirements

Another issue that would be useful to indicate at this point is that UE to UE coexistence would still be a problem as there is no duplex filter mitigation. Consequently this problem is same for both 5 and 10 MHz channel bandwidth as show below.

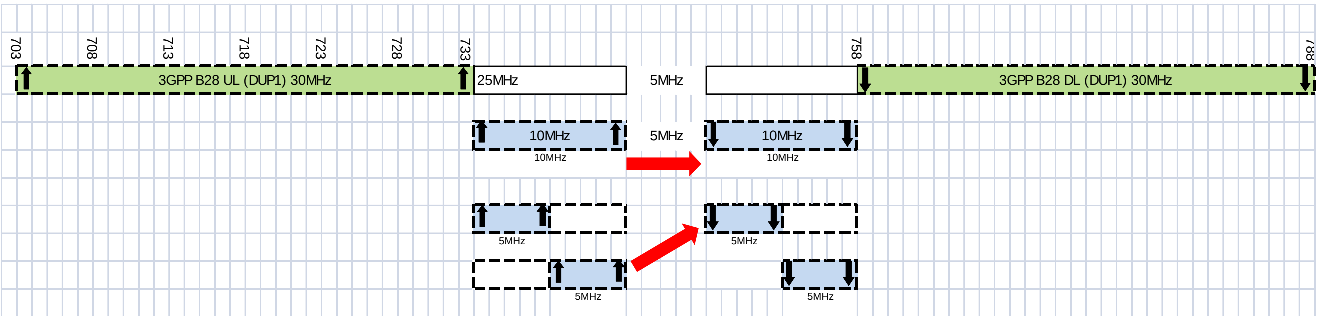

Figure 63: UE to UE coexistence

A1.4 LIMITATIONS OF 2X2X5 MHz OPTION

A channelling arrangement of 2x2x5 MHz in the duplex gap has also been studied. This option suffers from several limitations:

- Severe self-desensitisation of the PPDR UE downlink: Typical duplex filters technologies would not provide sufficient rejection, therefore specific technology developments are still to be investigated. Also, carrier aggregation between the two blocks is not possible.
- UE-UE interference: When transmitting in the top UL block, a UE interfere the UEs that use the lowest DL block nearby. Therefore, UEs on the same intervention would need to use only the same block. However, it is unclear how to prevent nearby UEs to use different blocks. Technical feasibility is questionable. Furthermore, this would limit usable bandwidth to 5 MHz at each intervention. Additionally, self-desensitisation still remains an issue.
- Cross-border coordination: The upper UL block uses frequencies 738-743 MHz that may be used by SDL by administrations wishing to deploy supplemental downlink in the duplex gap. Cross-Border interference may arise over distance of 100 km for land paths and 600 km for cold sea paths.

A1.4.1 Severe self-desensitisation of the PPDR UE downlink

Sensitivity level for a LTE UE is -98.5 dBm according to specification. Maximum Tx power of a UE is 23 dBm. Typical attenuation of duplex filter of the order of 40 dB and OOB emissions at the output of the power amplifier with a Tx-Rx separation of 15 MHz are of the order of -30 dBm/5 MHz.

Overall OOB emissions falling into the downlink is therefore of the order of -70 dBm/5MHz (without taking into account allowance for variations).

The OOB level from the UE transmitter at the input of the UE's own Rx chain is well above the sensitivity level. Therefore filters with performance similar to the filters of commercial LTE UEs do not provide enough rejection to avoid self-desensitisation. Note that this also requires the use of two different duplex filters for each block that cannot be used at the same time. Therefore carrier aggregation is not possible.

A parallel can be made with the 3GPP band 20. In band 20, despite operating on the 4th adjacent channel, the reference sensitivity level is set fairly high (see Table 7.3.1-1) and can only be fulfilled with a narrow transmission bandwidth (20 RBs, i.e. less than 5 MHz Tx BW, see Table 7.3.1-2). Only UEs with 5 MHz BW, i.e. operating in 8th 'adjacent channel' do not have restriction on the UL bandwidth to achieve maximum sensitivity.

A1.4.2 Inter UE desensitisation

Sensitivity level for a LTE UE is -98.5 dBm according to specification. Assuming similar OOB emissions performance between the top UL block and the lowest DL block (5 MHz gap) as for the MFCN to DTT channel 48 requirements (9 MHz gap), the OOB emissions is -42 dBm/8 MHz, which corresponds to -44 dBm/5 MHz.

This is 54.5dB above sensitivity level.

Using extended Hata model, 54.2 dB corresponds to a separation distance of 17 m. This separation distance is an issue for the case of PPDR intervention where UEs are located nearby.

A1.4.3 Cross-border coordination

The upper UL block uses frequencies 738-743 MHz that may be used by SDL by administrations wishing to deploy supplemental downlink in the duplex gap.

Assuming a SDL base station e.i.r.p. of 62 dBm, and PPDR antenna gain 12 dB; the interfering power falling into the PPDR UL block is between -103.6 and -101.6 dBm at distance 100 km for antenna heights respectively 20 and 37.5 m according to ITU-R P.1546 for land path at 1 % of the time.

Interfering power is -102.6 dBm at distance 600 km for cold sea paths.

PPDR UL BS sensitivity is -101.5 dBm. Therefore there is a risk of cross-border interference over large distances when SDL face PPDR uplink.

ANNEX 2: ACS MEASUREMENTS OF DTT RECEIVERS

A2.1 FIRST SET OF MEASUREMENTS

A2.1.1 Introduction

This annex presents the results of the measurements carried out on nine different DTTB receivers (DVB-T and DVB-T2 receivers), sold on the European market a few years ago, to determine their protection ratios and overloading thresholds in the presence of a 5 MHz PPDR (LTE) interfering signal. The measurements were carried out with a PPDR-DDTB frequency offset of 10.5 MHz corresponding to a 4 MHz guard band between DTTB and PPDR UE. The ACS of the receivers was derived from the measured protection ratios [1],[4].

The average PR and ACS of the DTTB receivers was also compared with their average PR and ACS derived in the presence of a 10 MHz LTE UE signal with a LTE-DDTB frequency offset of 15.5 MHz corresponding to a 9 MHz guard band between DTTB and LTE UE.

The annex provides information to assist compatibility studies for the co-existence of DTTB broadcasting with PPDR 700 MHz user equipment (UE).

A2.1.2 Measurement results and conclusions

The following conclusions have been drawn from the results of the measurements:

The tested DTTB receivers behaved very similarly in the presence of a continuous PPDR UE signal, while they have behaved very differently, one from the other, in the presence of a discontinuous (time varying) PPDR UE signal. In the presence of a continuous PPDR UE signal the average PR of the DTTB receivers tested was -43 dB, PR measured with a PPDR UE ACLR of 65 dB/8 MHz.

Modern DVB-T2 receivers behave well in the presence of a discontinuous interfering signal. The DVB-T2 receivers tested behaved better in the presence of a discontinuous PPDR UE signal than in the presence of a continuous PPDR UE signal, while the protection ratio of DVB-T receivers was degraded on average by about 18 dB.

The average ACS of the DTTB receivers tested was 63 dB with a DTTB-PPDR guard band of 4 MHz. This ACS is similar to 65 dB measured with the same receivers in the presence of a 10 MHz LTE UE signal with a LTE-DDTB guard band of 9 MHz

The impact of discontinuous PPDR UE emissions on DTTB reception can be mitigated by improving DTTB receivers' AGC circuits, including the overall ACS of the receivers.

Table 71: Comparison of DTTB (C48) PR and ACS measured in the presence of a 5 MHz PPDR UE interfering signal with those measured in the presence of a 10 MHz LTE UE signal in the 700 MHz band(1)

Comparison of DTTB (C48) PR and ACS measured in the presence of a 5 MHz PPDR UE interfering signal with those measured in the presence of a 10 MHz LTE UE signal in the 700 MHz band(1)				
PPDR UE 700 ACLR (dB/8MHz)	BW (MHz)	DTTB-PPDR UE guard band (MHz)	Average DTTB PR (dB)	Average DTTB ACS (dB)

Comparison of DTTB (C48) PR and ACS measured in the presence of a 5 MHz PPDR UE interfering signal with those measured in the presence of a 10 MHz LTE UE signal in the 700 MHz band(1)				
65	5	4	-43	63(2)
LTE UE 700 ACLR (dB/8MHz)	BW (MHz)	DTTB-PPDR UE guard band (MHz)	Average DTTB PR (dB)	Average DTTB ACS (dB)
60	10	9	-41	65(3)
70	10	9	-45	63
(1) see Doc. CPG-PTD(14)044 (2) Normalised ACS to be used with C/(I+N) = 21 dB (see Annex A2.1.6) (3) ACS value used with C/(I+N) = 21 dB in PTD compatibility studies				

A2.1.3 Measurement methodology and system parameters

A2.1.3.1 Test set-up used

The test setup for protection ratio and overloading threshold measurements is depicted below.

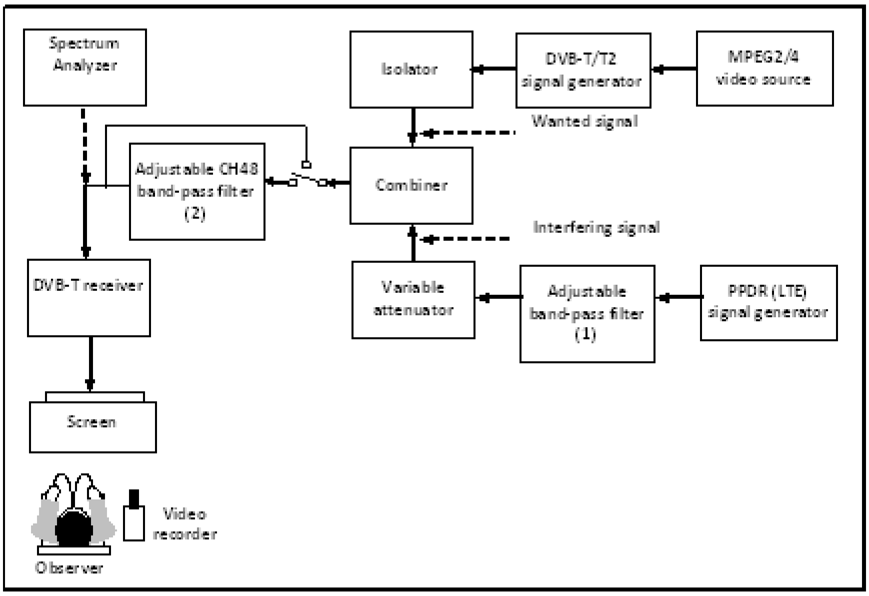

Figure 64: Test set up

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

A CH48 BPF (2) has been used to reduce the UE in band (IB) emissions and consequently to identify the predominate component of the interfering UE emissions, which are composed of UE IB and OOB emissions, on the DTTB reception. Further details on this filter can be found in section A2.1.3.5.

A2.1.3.2 System parameters

Table 72: DTTB system parameters

DTTB system parameters		
Parameter	Value	Comments
Centre frequency (MHz)	690	Channel 48
Channel raster (MHz)	8 MHz	
DVB-T: Modulation : FFTsize: Coding rate: Guard interval: Throughput per multiplex: Specified C/N (dB):	 64 QAM 8k ext 3/4 1/8 (112 µs) 24.882 Mbps 18	 Configuration used in France Gaussian channel
DVB-T2: Modulation : FFTsize: Coding rate: Guard interval: Pilot profile: # OFDM symbols /Frame: Throughput per multiplex: Specified C/N (dB):	 256 QAM 32k ext 3/5 1/16 (224 µs) PP4 62 33.177 Mbps 18 dB	 Gaussian channel
Content	HD video streams	
Measured average receiver sensitivity (dBm)	-80	
Wanted signal levels used (dBm)	-70, -60, -50, -40, -30 and -20	In order to properly determine the PR and Oth
PPDR UE parameters		
Parameter	Value	Comments
Centre frequency (MHz)	700.5	
Channel raster (MHz)	5	
Modulation	SC-FDMA	
Number of RBs used	20	
Max UE power (dBm)	23	17.3 dBm was used for tests
OOBE in DTTB CH 48 (dBm/8MHz)	-42	UE ACLR_CH48 = 65 with full PPDR UE resource allocation (50 RBs)
Transmission mode	Continuous and	

DTTB system parameters		
	discontinuous (burst)	
Maximum transmission duration (s)	0.001	1 Transmission time interval (TTI)
Transmission period (s)	1 and 5	
1UE ACLR_CH48 (dB) = UE IBE power (dBm/5MHz) measured at 700.5 MHz- UE OOBE power (dBm/8MHz) measured at 690 MHz		

A2.1.3.3 Wanted signal levels

Protection ratios (PR) and overloading thresholds (Oth) of a receiver are derived from its C(I) curves. The measurements have been carried out by using different DVB-T/T2 wanted signal levels to cover the range from weakest to strongest signals: -70, -60, -50 ,-40, -30 and -20 dBm. At low wanted signal levels the protection ratio limit is usually reached before the overloading threshold. Therefore it is necessary to use higher wanted signal levels to reach the onset of overload.[4]

A2.1.3.4 Frequency offsets between PPDR UE interfering signal and DTTB wanted signal

A frequency offset of 10.5 MHz has been used. This frequency offset corresponds to a guard band (GB) of 4 MHz between DTTB centered at 690 MHz and the PPDR UE signal centered at 700.5 MHz.

A2.1.3.5 Generation of the LTE uplink signal

The uplink signal can vary considerably in both the time and frequency domains depending upon the traffic loading required. In the frequency domain the number of RBs allocated for each SC-FDMA symbol can vary rapidly. Maximum number of RBs is 25. In the time domain, there can be long periods where the UE does not transmit at all, leading to an irregular pulse like power profile. The minimum duration of UE transmission time interval is 1ms (1 TTI), while the duration of a basic radio frame is 10 ms (10 TTI).

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

- Continuous transmission (TM1);
- Discontinuous transmission (TM2) with: UE signal maximum transmission duration = 1 ms, transmission period = 1 s;
- Discontinuous transmission (TM3) with: UE signal maximum transmission duration = 1 ms, transmission period = 5 s.

The discontinuous signals here were used to demonstrate certain interference effects.

The UE generator output power was fixed to 17.27 dBm, corresponding to a signal level of 9.5 dBm at the DTTB receiver input. An ACLR values of 65 dB, corresponding to an OOBE level of -42 dBm/8MHz in DTT channel 48 for a maximum UE power of 23 dBm, has been used in measurements. This ACLR values were obtained by means of an adjustable band-pass filter (1) on UE signal generator.

The spectrum of PPDR UE TM1 signal having an ACLR of 65 dB is shown in Figure 65, while the time domain characteristics of PPDR UE TM2 are showing in Figure 66 and Figure 67.

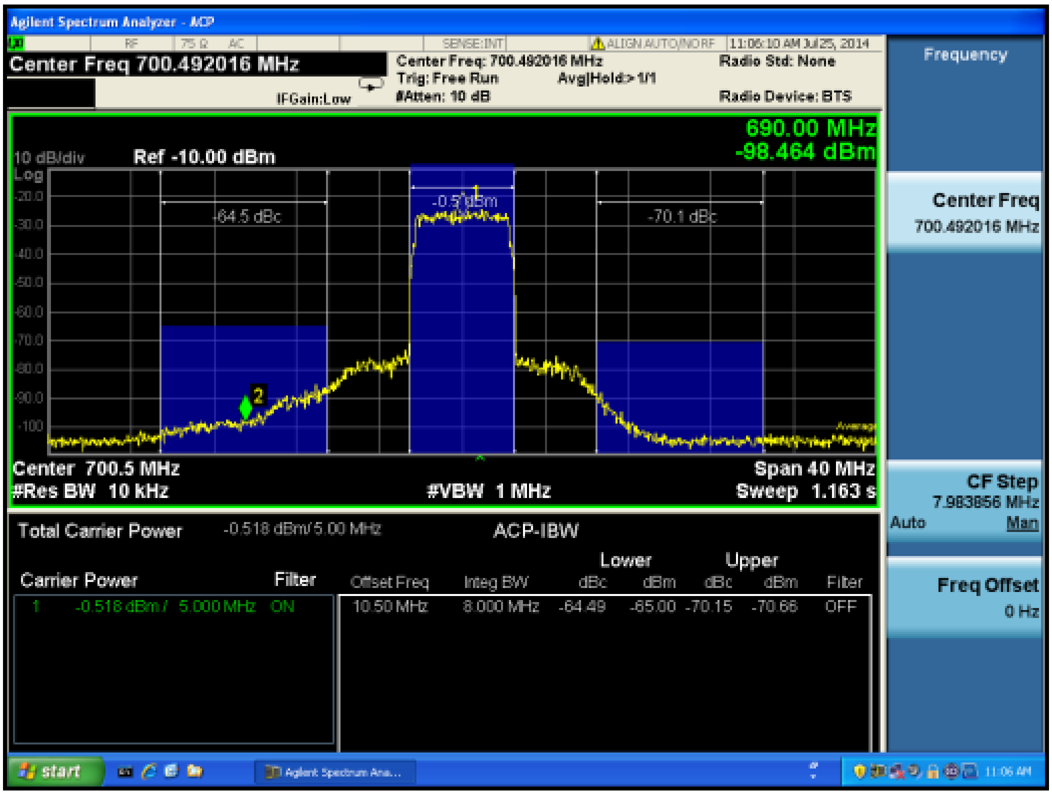

Figure 65: Spectrum of PPDR UE signal having an ACLR of 65 dB

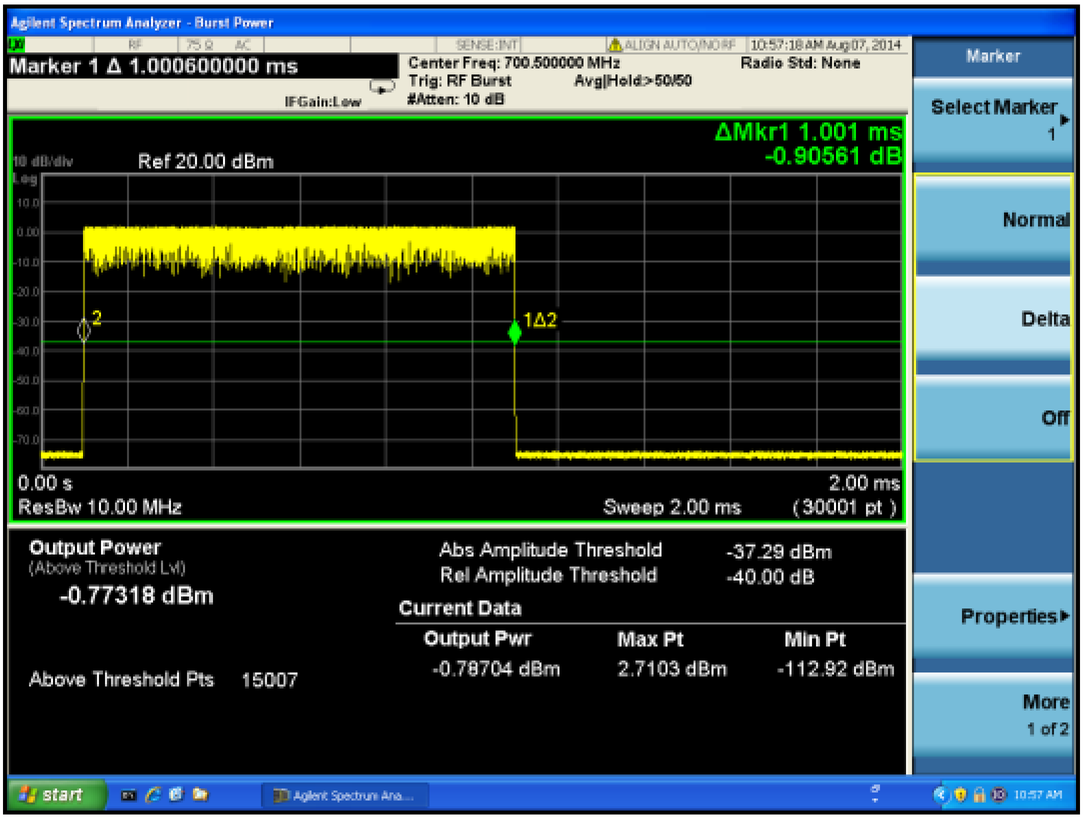

Figure 66: PPDR UE TM2 signal in the time domain (details of one pulse)

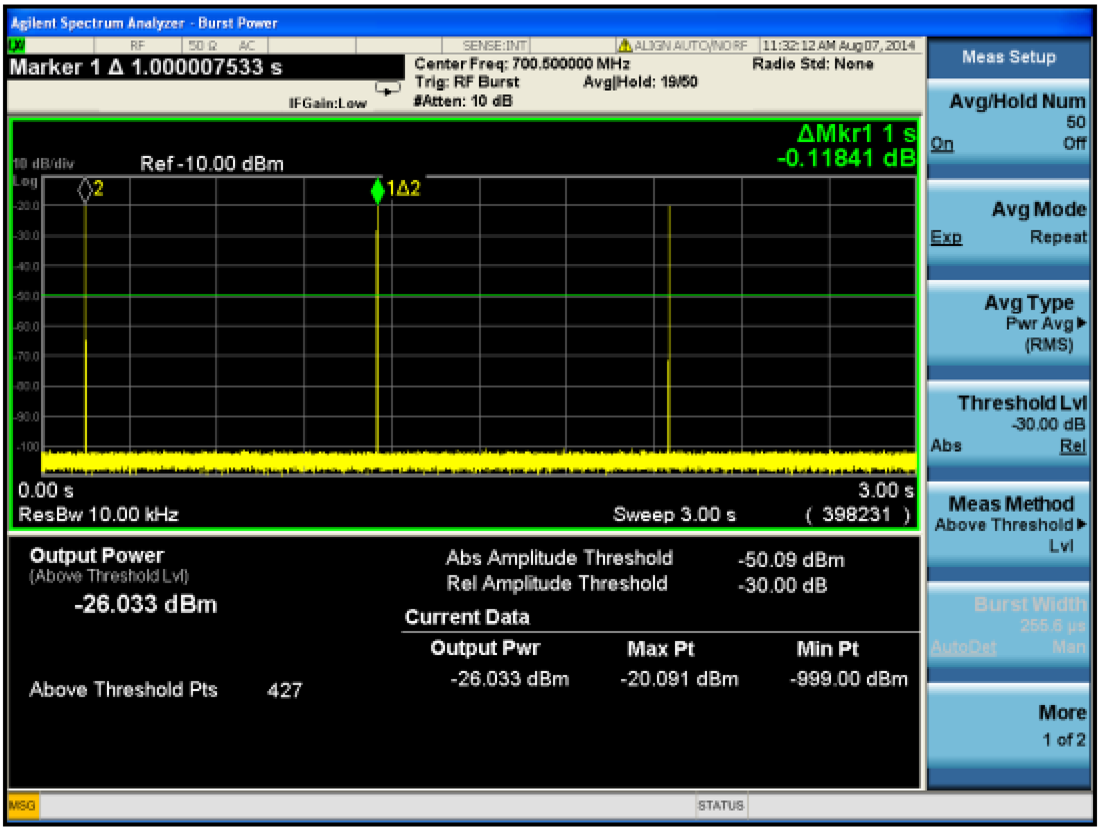

Figure 67: PPDR UE TM2 signal in the time domain (details of several pulses)

A2.1.4 Failure point assessment method

The protection ratios for the DTTB system can be based on:

- a target BER of 2x10–4 measured between the inner and outer codes, before Reed-Solomon decoding. This corresponds to a quasi-error-free (QEF) picture quality with the BER < 1x10–11 at the input of the MPEG-2 demultiplexer
- the SFP (subjective failure point) in case of domestic receivers, since it is not be possible to measure the BER. The PR for the wanted DTTB signal is a value of wanted-to-unwanted signal ratio at the receiver input, for a picture quality where no more than one error is visible in the picture for an average observation time of 20 s (see Recommendation ITU-R BT.1368 [5]).

The SFP method was used in this measurement campaign. The adjustment of the wanted and unwanted signal levels has been done in steps of 1 dB.

A2.1.5 Method for determining protection ratios and overloading thresholds

It should be stressed that the protection ratios are generally considered and used as independent of the wanted signal level. That is C(I) is supposed to be a linear function with unity slope (a straight line with unity slope). The protection ratio of the receiver is obtained by subtracting I from C(I) at any point on this line and can be used for all wanted signal levels.

However, in most cases the protection ratios of wideband TV receivers vary as a function of the wanted signal level. Consequently, C(I) is not a straight line with unity slope with some variation with the interfering signal strength. Nevertheless, for interfering signals below the overloading threshold such C(I) curves can always be approximated by a straight line with unity slope with an acceptable error. This is the method used for determining PR and Oth method. It is described in detail in Report ITU-R BT.2215 [15].

Measurements were carried out in two steps, for an UE ACLR_CH48 = 65 dB, with full PPDR UE resource allocation (20 RBs):

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

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

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

The PPDR UE signal was attenuated by CH48 BPF by 29 dB. The insertion loss of the filter over DTTB channel 48 was 2 dB. Consequently, the effective ACS improvement of DTTB receivers by the filter was about 27 dB. The frequency domain response of the filter is shown below.

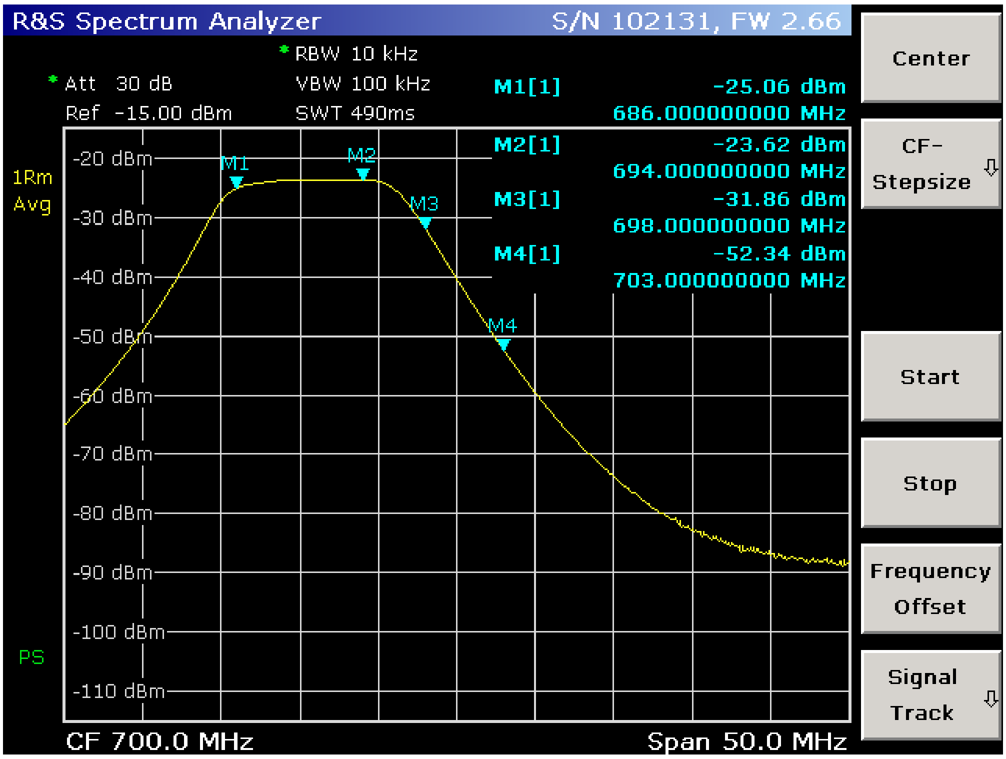

Figure 68: Frequency domain response of CH48 BPF centered at 690 MHz

A2.1.6 Receiver Adjacent Channel Selectivity

Victim receiver adjacent channel selectivity (ACS) derived from its protection ratios (PR) and interfering signal adjacent channel leakage ratio (ACLR), can be used with the protection criterion $C/(I_{co\text{-}ch}+N)$ to assess the compatibility between the victim system and the interfering system. The advantage of using ACS (always with $C/(I_{co\text{-}ch}+N)$ and ACLR) over using PR is that it permits to assess not only the impact of the interfering signal on the victim receiver, as can be done by PR, but also the impact of the interfering signal OOBE and in band emissions (IBE) independently one from the other on the victim receiver. This can be easily understood from the following equation:

$$\frac{1}{ACIR} = \frac{1}{ACS} + \frac{1}{ACLR}$$

where, $ACIR=PR_{co\text{-}ch} - PR_{adj\text{-}ch}$, PR measured in the presence of the interfering signal.

The receiver ACS can be calculated by the following equation:

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

or $ACS_N(dB) = -10\log(10^{(PR_{adj}-(C/N))/10} - 10^{-ACLR/10})$, ACSN is called normalised ACS.

Note that ACS as derived above is not the victim receiver filter attenuation at a given frequency offset; it is the overall response of the receiver to the interfering signal, which depends on the receiver filter attenuation, automatic gain control (ACG), demodulation and detection as well as error control coding performances of the receiver. Consequently, ACS of a receiver should be used cautiously in compatibility studies for the following reasons:

- An ACS value of a receiver derived from the measured PR and ACLR may not be very accurate due to measurement errors and the sensitivity of the above equations to measurement errors. Higher the ACLR, higher the accuracy of the ACS derived from the measurements.
- The ACS values of a receiver derived from the PR and ACLR measured respectively in the presence of two interfering signal having different bandwidths cannot be compared unless the receiver's co-channel PR ($PR_{co\text{-}ch}$) measured is identical in both cases. Nevertheless, a relevant comparison is always possible between the normalised ACS (ACSN) values.
- The ACS values of a receiver derived from the PR and ACLR, measured in the presence of an interfering signal having a smaller bandwidth than the victim system bandwidth, cannot be used with the protection criteria $C/(I_{co\text{-}ch}+N)$ or $PR_{co\text{-}ch}$ defined for intra-service interference if the $PR_{co\text{-}ch}$ measured in the presence of the interfering signal is lower that the intra-service $PR_{co\text{-}ch}$.

The last point is clarified in the following Table 73 based on the measurement results presented in this document:

Table 73: DTT-PPDR compatibility assessment in the presence of an adjacent band interfering PPDR signal. Assesment based on the measured DTT PRadj and DTT intra-service C/N criterion used respectively with ACS and ACSN

DTT-PPDR compatibility assessment in the presence of an adjacent band interfering PPDR signal. Assesment based on the measured DTT PRadj and DTT intra-service C/N criterion used respectively with ACS and ACSN						
DTTB receiver	DTTB-DTTB $PR_{co\text{-}ch}$ = DTT C/N (dB)	DTTB-PPDR (5 MHz) $PR_{co\text{-}ch}$ (dB)	DTTB-PPDR PR_{adj} (dB)	PPDR ACLR (dB)	DTTB ACS (dB)	DTTB ACSN (dB)
Rx1	17	15	-44	65	60	63
Compatibility assessment based on the measured DTTB-PPDR adjacent channel PR (-44 dB)						
C (dBm)	Iadj (dBm)	C/Iadj(dB)	Interference	Comments		
-70	-27	-43	Non, C/I>PR_{adj}	Correct assessment		
Compatibility assessment based on the measured DTTB intra-service $PR_{co\text{-}ch}$= C/N =17 dB; DTTB ACS = 60 dB						
C (dBm)	I_{adj} (dBm)	$I_{in\text{-}band}$ (dBm)	I_{OOBE} (dBm)	I_{total} at the receiver input	C/I (dB)	Interference
-70	-27	-87.00	-92	-85.807	15.807	Yes, C/I<C/N ; Incorrect

DTT-PPDR compatibility assessment in the presence of an adjacent band interfering PPDR signal. Assesment based on the measured DTT PRadj and DTT intra-service C/N criterion used respectively with ACS and ACSN						
						assessment
Compatibility assessment based on the measured DTTB intra-service PRco-ch = C/N =17 dB; DTTB ACSN = 63 dB						
C (dBm)	I_{adj} (dBm)	$I_{in\text{-}band}$ (dBm)	I_{OOBE} (dBm)	I_{total} at the receiver input	C/I (dB)	Interference
-70	-27	-90.00	-92	-87.876	17.876	No, C/I>C/N ; Correct assessment

The ACSN of the tested DTTB receivers, derived from the measurement results are presented in Table 74.

Table 74: Calculated DVB-T/T2 receivers' adjacent channel selectivity. Continuous PPDR UE transmission, UE ACLR=65 dB

Calculated DVB-T/T2 receivers' adjacent channel selectivity. Continuous PPDR UE transmission, UE ACLR=65 dB		
DTTB Receiver	ACSN without CH48 filter (dB)	ACSN with CH48 filter (dB)
Rx1 (DVB-T2)	63	90
Rx2 (DVB-T2)	67	94
Rx3 (DVB-T)	65	92
Rx4 (DVB-T2)	59	86
Rx5 (DVB-T2)	60	87
Rx6 (DVB-T)	67	94
Rx7 (DVB-T2)	62	89
Rx8 (DVB-T)	63	90
Rx10 (DVB-T)	60	87
Average value	63	90

A2.2 MEASUREMENT RESULTS

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

A2.2.1 DTTB receivers PR and Oth values in the presence of a continuous PPDR UE signal (TM1)

The C(I) curves of the DTTB receivers tested in the presence of an PPDR UE TM1 signal are shown in Figure 69 and Figure 70, while their PR and Oth, are presented in Table 75 and

Table 76.

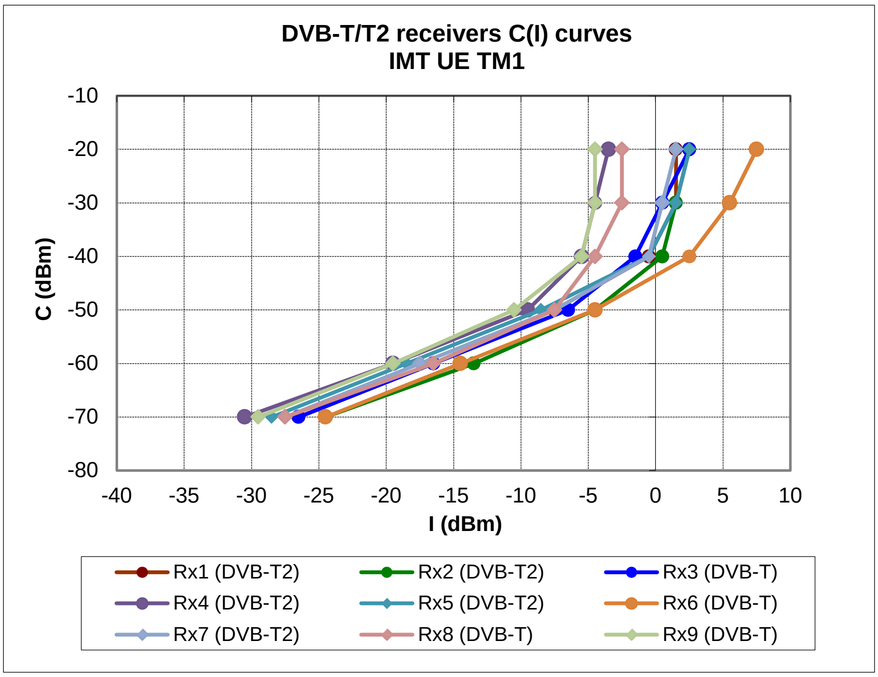

Figure 69: DVB-T/T2 receivers C(I) curves IMT UE TM1

Table 75: DVB-T/T2 receivers' PR and Oth without CH48 BPF (ACSN=63 dB). Continuous PPDR UE transmission, UE ACLR=65 dB

DVB-T/T2 receivers' PR and Oth without CH48 BPF (ACSN=63 dB) Continuous PPDR UE transmission, UE ACLR=65 dB		
DTTB Receiver	RP (dB)	Oth (dBm)
Rx1 (DVB-T2)	-44	2
Rx2 (DVB-T2)	-46	2
Rx3 (DVB-T)	-44	1
Rx4 (DVB-T2)	-40	-5
Rx5 (DVB-T2)	-42	2
Rx6 (DVB-T)	-46	6
Rx7 (DVB-T2)	-43	1
Rx8 (DVB-T)	-43	-3
Rx9 (DVB-T)	-41	-5
Average value (DVB-T2)	-43	0
Average value (DVB-T)	-44	0
Average value	-43	0

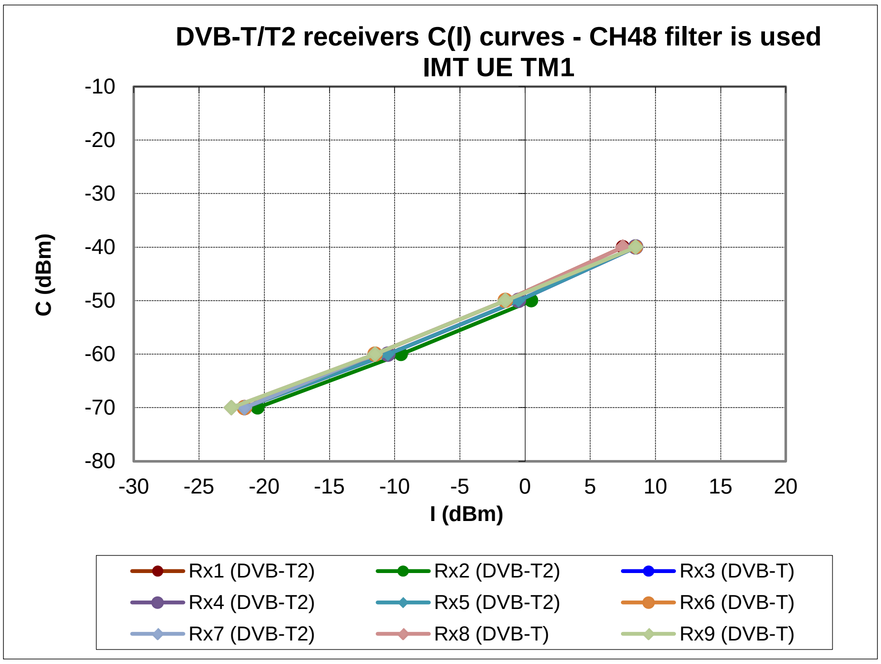

Figure 70: DVB-T/T2 receivers C(I) curves - CH48 filter is used IMT UE TM1

Table 76: DVB-T/T2 receivers' PR and Oth with CH48 BPF (ACSN=93 dB). Continuous PPDR UE transmission, UE ACLR=65 dB

DVB-T/T2 receivers' PR and Oth with CH48 BPF (ACSN=93 dB) Continuous PPDR UE transmission, UE ACLR=65 dB		
DTTB Receiver	RP (dB)	Oth (dBm)
Rx1 (DVB-T2)	-49	NR
Rx2 (DVB-T2)	-50	NR
Rx3 (DVB-T)	-49	NR
Rx4 (DVB-T2)	-49	NR
Rx5 (DVB-T2)	-49	NR
Rx6 (DVB-T)	-49	NR
Rx7 (DVB-T2)	-49	NR
Rx8 (DVB-T)	-49	NR
Rx9 (DVB-T)	-48	NR
Average value (DVB-T2)	-49	NR
Average value (DVB-T)	-49	NR
Average value	-49	NR
NR: Oth not reached at maximum IMT UE level at the receiver input (9.5 dBm)		

A2.2.2 DTTB receivers PR and Oth in the presence of a discontinuous PPDR UE signal (TM2/TM3)

The C(I) curves of the DTTB receivers tested in the presence of an PPDR UE TM2 signal are shown in Figure 71 and Figure 72, while their PR and Oth, are presented in Table 77 and Table 78.

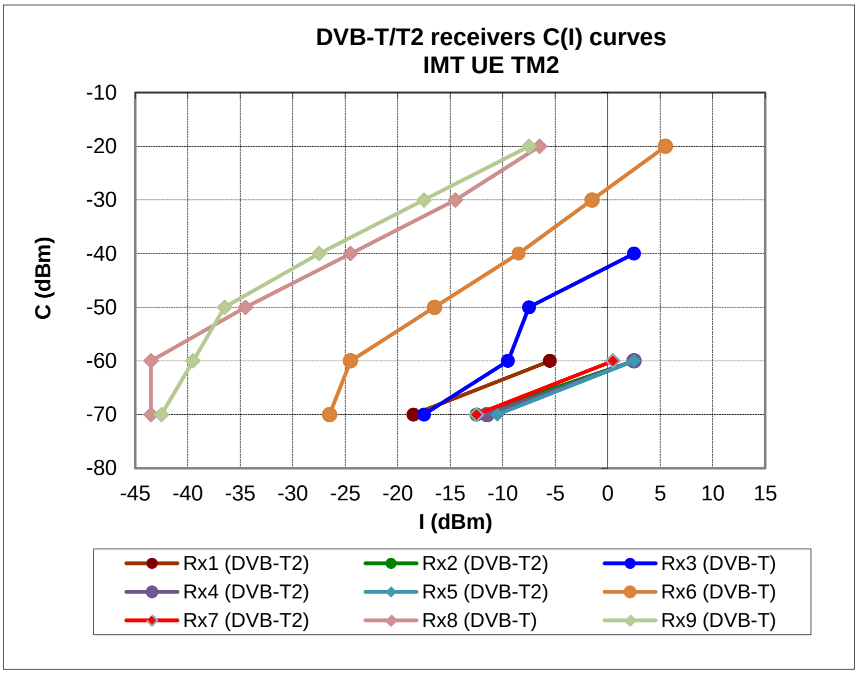

Figure 71: DVB-T/T2 receivers C(I) curves IMT UE TM2

Table 77: DVB-T/T2 receivers' PR and Oth without CH48 BPF (ACS=64 dB). Discontinuons PPDR UE transmission, UE ACLR=65 dB

DVB-T/T2 receivers' PR and Oth without CH48 BPF (ACS=64 dB) Discontinuons PPDR UE transmission, UE ACLR=65 dB		
DTTB Receiver	RP (dB)	Oth (dBm)
Rx1 (DVB-T2)	-53	NR
Rx2 (DVB-T2)	-60	NR
Rx3 (DVB-T)	-43	NR
Rx4 (DVB-T2)	-61	NR
Rx5 (DVB-T2)	-61	-1
Rx6 (DVB-T)	-32	NR
Rx7 (DVB-T2)	-59	NR
Rx8 (DVB-T)	-17	NR
Rx9 (DVB-T)	-13	NR
Average value (DVB-T2)	-59	NR
Average value (DVB-T)	-26	NR

DVB-T/T2 receivers' PR and Oth without CH48 BPF (ACS=64 dB) Discontinuons PPDR UE transmission, UE ACLR=65 dB		
Average value	-44	NR
NR: Oth not reached at maximum IMT UE level at the receiver input (9.5 dBm)		

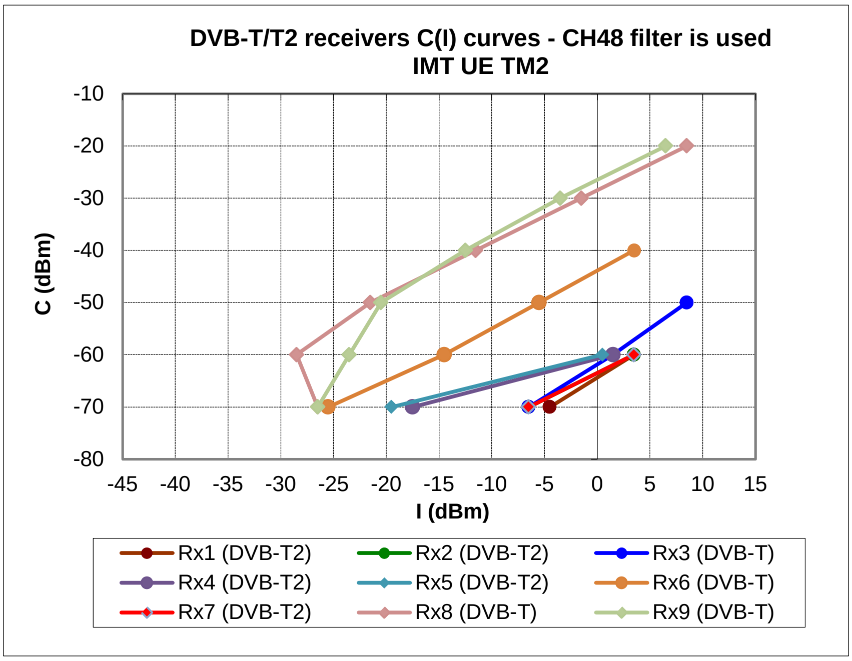

Figure 72: DVB-T/T2 receivers C(I) curves - CH48 filter is used IMT UE TM2

Table 78: DVB-T/T2 receivers' PR and Oth with CH48 BPF (ACS=93 dB). Discontinuous PPDR UE transmission, UE ACLR=65 dB

DVB-T/T2 receivers' PR and Oth with CH48 BPF (ACS=93 dB) Discontinuous PPDR UE transmission, UE ACLR=65 dB		
DTTB Receiver	RP (dB)	Oth (dBm)
Rx1 (DVB-T2)	-65	NR
Rx2 (DVB-T2)	-64	NR
Rx3 (DVB-T)	-60	NR
Rx4 (DVB-T2)	-58	NR
Rx5 (DVB-T2)	-56	NR
Rx6 (DVB-T)	-45	NR
Rx7 (DVB-T2)	-64	NR
Rx8 (DVB-T)	-29	NR

DVB-T/T2 receivers' PR and Oth with CH48 BPF (ACS=93 dB) Discontinuous PPDR UE transmission, UE ACLR=65 dB		
Rx9 (DVB-T)	-28	NR
Average value (DVB-T2)	-61	NR
Average value (DVB-T)	-41	NR
Average value	-52	NR
NR: Oth not reached at maximum IMT UE level at the receiver input (9.5 dBm)		

Measurement results show that:

- In the presence of a continuous LTE UE signal (TM1):
  - The tested DTTB receivers have behaved very similarly. The average PR and Oth of the receivers were respectively -43 dB and 0 dBm.
  - The inline external CH48 BPF filter on the DTTB receiver input has improved the PR of the receivers on average by about 6 dB and their Oth by 10.
- In the presence of thediscontinuous LTE UE signal (TM2/TM3):
  - The tested DTTB receivers have behaved very differently one from the other in the presence of a discontinuous PPDR UE signal (TM2/TM3). DVB-T2 receivers have behaved better in the presence of a discontinuous PPDR UE signal than in the presence of a continuous PPDR UE signal (TM1). On the other hand, the PRs of DVB-T receivers (Rx6, Rx8 and Rx9) were degraded respectively by 17, 32 and 35 dB. Note that Rx3 is a DVB-T2&T receiver which was used in T mode.
  - Concerning the overloading phenomenon most of the tested DTTB receivers have behaved better in the presence of a discontinuous PPDR UE signal than in the presence of a continuous PPDR UE signal. Actually, Oth was not reached at the maximum IMT UE level (9.5 dBm) at the input of the tested receivers.

- The inline external CH48 BPF filter on the DTTB receiver input:
  - improved the receivers' PR by 15 dB, but failed to fully restore the DVB-T receivers' performance to their performance in the presence of a continuous LTE UE signal (PR improved to -41 dB instead of -44 dB);
  - improved the DVB-T2 receivers' performance beyond their performance in the presence of a continuous PPDR UE signal (PR = -61 dB instead of -43 dB, 18 dB improvement).

Table 79: DVB-T receivers' average protection ratios

DVB-T receivers' average protection ratios	
Average ACS without filter = 64 dB, Average ACS with CH48 BPF = 91 dB Continuous UE Tx, ACLR = 65	
Without CH48 filter	With CH48 filter
Average PR (dB)	Average PR (dB)
-44	-49
Average Oth (dBm)	Average Oth (dBm)
0	NR (<9.5 dBm)
Average ACS without filter = 64 dB, Average ACS with CH48 BPF = 91 dB	

DVB-T receivers' average protection ratios	
Discontinuous UE Tx, ACLR = 65	
Without CH48 filter	With CH48 filter
Average PR (dB)	Average PR (dB)
-26	-41
Average Oth (dBm)	Average Oth (dBm)
NR (<9.5 dBm)	NR (<9.5 dBm)

Table 80: DVB-T2 receivers' average protection ratios

DVB-T2 receivers' average protection ratios	
Average ACS without filter = 62 dB, Average ACS with CH48 BPF = 89 dB Continuous UE Tx, ACLR=65	
Without CH48 filter	With CH48 filter
Average PR (dB)	Average PR (dB)
-43	-49
Average Oth (dBm)	Average Oth (dBm)
0	NR (<9.5 dBm)
Average ACS without filter = 62 dB, Average ACS with CH48 BPF = 89 dB Discontinuous UE Tx, ACLR = 65	
Without CH48 filter	With CH48 filter
Average PR (dB)	Average PR (dB)
-59	-61
Average Oth (dBm)	Average Oth (dBm)
NR (<9.5 dBm)	NR (<9.5 dBm)

A2.2.3 Comparison of the impact of a PPDR UE 5 MHz and a LTE UE 10 MHz signals on DTTB reception

A2.2.3.1 Continuous PPDR UE transmission (TM1)

Table 81: DVB-T/T2 receivers' PR without CH48 BPF. Continuous PPDR UE transmission

DVB-T/T2 receivers' PR without CH48 BPF Continuous PPDR UE transmission			
DTTB Receiver	RP (dB) LTE 10 MHz, OOBE = -37 dBm Guard band = 9 MHz*	RP (dB) PPDR 5 MHz, OOBE = -42 dBm Guard band = 4 MHz	RP (dB) LTE 10 MHz, OOBE = -47 dBm Guard band = 9 MHz*
Rx1 (DVB-T2)	-41	-44	-45
Rx2 (DVB-T2)	-43	-46	-47
Rx3 (DVB-T)	-40	-44	-47
Rx4 (DVB-T2)	-39	-40	-40
Rx5 (DVB-T2)	-42	-42	-46
Rx6 (DVB-T)	-41	-46	-42
Rx7 (DVB-T2)	-43	-43	-46
Rx8 (DVB-T)	-42	-43	-47
Rx9 (DVB-T)	-40	-41	-42
Average PR (DVB-T2)	-42	-43	-45
Average PR (DVB-T)	-41	-44	-45
* see Doc. CPG-PTD(14)044			

Table 82: DVB-T/T2 receivers' Oth without CH48 BPF. Continuous IMT UE transmission

DVB-T/T2 receivers' Oth without CH48 BPF Continuous IMT UE transmission			
DTTB Receiver	Oth (dBm) LTE 10 MHz, OOBE = -37 dBm Guard band = 9 MHz*	Oth (dBm) PPDR 5 MHz, OOBE = -42 dBm Guard band = 4 MHz	Oth (dBm) LTE 10 MHz, OOBE = -47 dBm Guard band = 9 MHz*
Rx1 (DVB-T2)	-2	2	-2
Rx2 (DVB-T2)	-2	2	-2
Rx3 (DVB-T)	-4	1	-3
Rx4 (DVB-T2)	-6	-5	-6

DVB-T/T2 receivers' Oth without CH48 BPF Continuous IMT UE transmission			
Rx5 (DVB-T2)	-2	2	-2
Rx6 (DVB-T)	5	6	3
Rx7 (DVB-T2)	-2	1	-1
Rx8 (DVB-T)	-4	-3	-4
Rx9 (DVB-T)	-7	-5	-7
Average PR (DVB-T2)	-3	0	-3
Average PR (DVB-T)	-3	0	-3
* see Doc. CPG-PTD(14)044			

Table 83: DVB-T/T2 receivers' PR with CH48 BPF. Continuous IMT UE transmission

DVB-T/T2 receivers' PR with CH48 BPF Continuous IMT UE transmission			
DTTB Receiver	RP (dB) LTE 10 MHz, OOBE = -37 dBm Guard band = 9 MHz*	RP (dB) PPDR 5 MHz, OOBE = -42 dBm Guard band = 4 MHz	RP (dB) LTE 10 MHz, OOBE = -47 dBm Guard band = 9 MHz*
Rx1 (DVB-T2)	-44	-49	-54
Rx2 (DVB-T2)	-44	-50	-54
Rx3 (DVB-T)	-41	-49	-53
Rx4 (DVB-T2)	-41	-49	-54
Rx5 (DVB-T2)	-43	-49	-54
Rx6 (DVB-T)	-43	-49	-54
Rx7 (DVB-T2)	-43	-49	-54
Rx8 (DVB-T)	-42	-49	-54
Rx9 (DVB-T)	-41	-48	-54
Average PR (DVB-T2)	-43	-49	-54
Average PR (DVB-T)	-42	-49	-54
* see Doc. CPG-PTD(14)044			

Table 84: DVB-T/T2 receivers' Oth with CH48 BPF. Continuous IMT UE transmission

DVB-T/T2 receivers' Oth with CH48 BPF Continuous IMT UE transmission			
DTTB Receiver	Oth (dBm) LTE 10 MHz, OOBE = -37 dBm Guard band = 9 MHz*	Oth (dBm) PPDR 5 MHz, OOBE = -42 dBm Guard band = 4 MHz	Oth (dBm) LTE 10 MHz, OOBE = -47 dBm Guard band = 9 MHz*
Rx1 (DVB-T2)	NR	NR	NR
Rx2 (DVB-T2)	NR	NR	NR
Rx3 (DVB-T)	NR	NR	NR
Rx4 (DVB-T2)	NR	NR	NR
Rx5 (DVB-T2)	NR	NR	NR
Rx6 (DVB-T)	NR	NR	NR
Rx7 (DVB-T2)	NR	NR	NR
Rx8 (DVB-T)	NR	NR	NR
Rx9 (DVB-T)	NR	NR	NR
Average PR (DVB-T2)	NR	NR	NR
Average PR (DVB-T)	NR	NR	NR
* see Doc. CPG-PTD(14)044			

A2.2.3.2 Discontinuous PPDR UE transmission (TM1/TM2)

Table 85: DVB-T/T2 receivers' PR without BPF filter Discontinuous IMT UE transmission

DVB-T/T2 receivers' PR without BPF filter Discontinuous IMT UE transmission			
DTTB Receiver	RP (dB) LTE 10 MHz, OOBE = -37 dBm Guard band = 9 MHz*	RP (dB) PPDR 5 MHz, OOBE = -42 dBm Guard band = 4 MHz	RP (dB) LTE 10 MHz, OOBE = -47 dBm Guard band = 9 MHz*
Rx1 (DVB-T2)	-30/-59	-53	-55
Rx2 (DVB-T2)	-60	-60	-64
Rx3 (DVB-T)	-23	-43	-23
Rx4 (DVB-T2)	-30	-61	-31
Rx5 (DVB-T2)	-56	-61	-562
Rx6 (DVB-T)	-26	-32	-26
Rx7 (DVB-T2)	-33/-63	-59	-65

DVB-T/T2 receivers' PR without BPF filter Discontinuous IMT UE transmission			
Rx8 (DVB-T)	-25	-17	-31
Rx9 (DVB-T)	-12	-13	-12
Average PR (DVB-T2)	-49	-59	-50
Average PR (DVB-T)	-22	-26	-23
* see Doc. CPG-PTD(14)044			

Table 86: DVB-T/T2 receivers' Oth without BPF filter. Discontinuous IMT UE transmission

DVB-T/T2 receivers' Oth without BPF filter Discontinuous IMT UE transmission			
DTTB Receiver	Oth (dBm) LTE 10 MHz, OOBE = -37 dBm Guard band = 9 MHz*	Oth (dBm) PPDR 5 MHz, OOBE = -42 dBm Guard band = 4 MHz	Oth (dBm) LTE 10 MHz, OOBE = -47 dBm Guard band = 9 MHz*
Rx1 (DVB-T2)	NR	NR	NR
Rx2 (DVB-T2)	NR	NR	NR
Rx3 (DVB-T)	-5	NR	-5
Rx4 (DVB-T2)	NR	NR	NR
Rx5 (DVB-T2)	NR	NR	NR
Rx6 (DVB-T)	NR	NR	NR
Rx7 (DVB-T2)	NR	NR	NR
Rx8 (DVB-T)	-5	NR	-4
Rx9 (DVB-T)	NR	NR	NR
Average PR (DVB-T2)	NR	NR	NR
Average PR (DVB-T)	-5	NR	-5
* see Doc. CPG-PTD(14)044			

Table 87: DVB-T/T2 receivers' PR with BPF filter. Discontinuous IMT UE transmission

DVB-T/T2 receivers' PR with BPF filter Discontinuous IMT UE transmission			
DTTB Receiver	RP (dB) LTE 10 MHz, OOBE = -37 dBm Guard band = 9 MHz*	RP (dB) PPDR 5 MHz, OOBE = -42 dBm Guard band = 4 MHz	RP (dB) LTE 10 MHz, OOBE = -47 dBm Guard band = 9 MHz*
Rx1 (DVB-T2)	-71	-65	-73
Rx2 (DVB-T2)	-73	-64	-74
Rx3 (DVB-T)	-41	-60	-54
Rx4 (DVB-T2)	-64	-58	-67
Rx5 (DVB-T2)	-68	-56	-71
Rx6 (DVB-T)	-41	-45	-53
Rx7 (DVB-T2)	-72	-64	-74
Rx8 (DVB-T)	-43	-29	-54
Rx9 (DVB-T)	-42	-28	-53
Average PR (DVB-T2)	-70	-61	-72
Average PR (DVB-T)	-42	-41	-53
* see Doc. CPG-PTD(14)044			

Table 88: DVB-T/T2 receivers' Oth with BPF filter. Discontinuous IMT UE transmission

DVB-T/T2 receivers' Oth with BPF filter Discontinuous IMT UE transmission			
DTTB Receiver	Oth (dBm) LTE 10 MHz, OOBE = -37 dBm Guard band = 9 MHz*	Oth (dBm) PPDR 5 MHz, OOBE = -42 dBm Guard band = 4 MHz	Oth (dBm) LTE 10 MHz, OOBE = -47 dBm Guard band = 9 MHz*
Rx1 (DVB-T2)	NR	NR	NR
Rx2 (DVB-T2)	NR	NR	NR
Rx3 (DVB-T)	NR	NR	NR
Rx4 (DVB-T2)	NR	NR	NR
Rx5 (DVB-T2)	NR	NR	NR
Rx6 (DVB-T)	NR	NR	NR
Rx7 (DVB-T2)	NR	NR	NR

DVB-T/T2 receivers' Oth with BPF filter Discontinuous IMT UE transmission			
Rx8 (DVB-T)	NR	NR	NR
Rx9 (DVB-T)	NR	NR	NR
Average PR (DVB-T2)	NR	NR	NR
Average PR (DVB-T)	NR	NR	NR
* see Doc. CPG-PTD(14)044			

A2.3 SECOND SET OF MEASUREMENTS

The ACS for 10 DVB-T2 receivers was measured.

Three cases were analysed:

- PPDR LTE in 698-703 MHz;
- Commercial LTE in 703-713 MHz;
- PPDR LTE in 733-743 MHz.

The DVB-T2 signal was placed in CH48.

The measurements used the following setup:

From measuring the C/I with a DVB-T2 signal ranging from -70 dBm to -20 dBm the ACS was derived.

The following results were obtained:

Table 89: Median ACS (dB)

	Median ACS (dB)		
	698-703 MHz	703-713 MHz	733-743 MHz
Rx1	64	60	86
Rx2	61	67	72
Rx3	62	74	79
Rx4	63	67	70
Rx5	64	66	83
Rx6	62	66	72
Rx7	64	68	73
Rx8	64	67	70
Rx9	66	69	72
Rx10	63	66	71
Average	63	67	75

The impact from PPDR LTE in 698-703 MHz would be 4 dB worse when commercial LTE in 703-713 MHz. It would also be 12 dB worse compared to its implementation above 733 MHz.

The following figure shows the setup that was used.

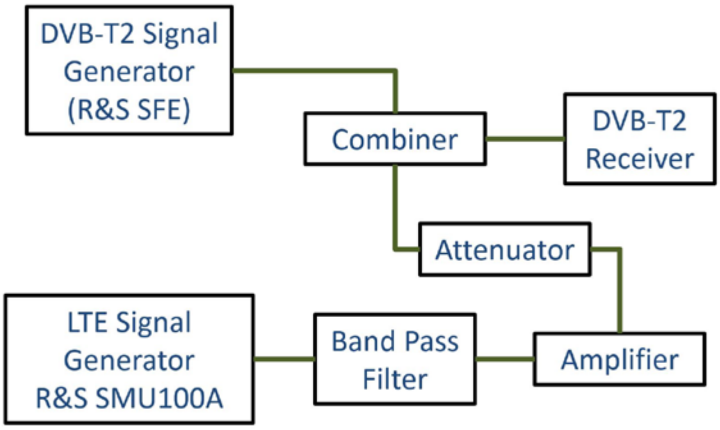

Figure 73: Test setup

The following DVB-T2 parameters were used

Table 90: System parameters

DTTB system parameters		
Parameter	Value	Comments
Centre frequency (MHz)	690	Channel 48
Channel raster (MHz)	8 MHz	
DVB-T2: Modulation : FFTsize: Coding rate: Guard interval: Pilot profile: Throughput per multiplex: Minimum C/N (dB):	 256 QAM 32k ext 2/3 1/128 PP7 40.2 Mbps 18 dB	Measured (Gaussian channel)
Content	SD video streams	
Wanted signal levels used (dBm)	-70, -60, -50, -40, -30 and -20	In order to properly determine the PR
Parameter	Value	Comments
Centre frequency (MHz)	3 cases: ▪ PPDR LTE in 698-703 MHz	All RB active

DTTB system parameters		
	▪ Commercial LTE in 703-713 MHz ▪ PPDR LTE in 733-743 MHz	
Modulation	SC-FDMA	
ACLR into DTTB CH 48 (dBm/8MHz)	> 90 dB	
Transmission mode	Continuous	

A2.3.1.1 Wanted signal levels

Protection ratios (PR) of a receiver are derived from its C(I) curves. The measurements have been carried out by using different DVB-T/T2 wanted signal levels to cover the range from weakest to strongest signals: -70, -60, -50 ,-40, -30 and -20 dBm. At low wanted signal levels the protection ratio limit is usually reached before the overloading threshold. However, overloading is not necessary to asses when determining receiver ACS from PRs.

A2.3.1.2 Generation of the LTE uplink signal

The UE generator output power was fixed to -33 dBm. A power amplifier was used to achieve a signal power level of 10 dBm. A band pass filter ensuring an ACLR better than 90 dB was also added to the signal chain. This was followed by an attenuator which was used to determine the maximum acceptable interference level without picture impairments.

A2.3.1.3 Failure point assessment method

The protection ratios for the DTTB system was be based on:

- the SFP (subjective failure point) in case of domestic receivers, since it is not be possible to measure the BER. The PR for the wanted DTTB signal is a value of wanted-to-unwanted signal ratio at the receiver input, for a picture quality where no more than one error is visible in the picture for an average observation time of 20 s. For DVB-T2, the values measured on the basis of SFP are within 0.2 dB of QEF.

The SFP method was used in this measurement campaign. The adjustment of the wanted and unwanted signal levels has been done in steps of 1 dB. The necessary correction to QEF was not performed since the result would not change noticeably.

A2.3.1.4 Calculation of receiver ACS

The test setup ensured that the impact of the LTE ACLR (>20 dB better than the ACS) was always negligible, a simplified calculation can be performed.

$$ACS = C/N_{\min} - PR$$

ANNEX 3: MEASUREMENT OF DTT EQUIPMENT WITH A REAL EMISSION FROM AN LTE UE

A3.1 METHODOLOGY

The following test signal created from a LTE UE was used to test a set of three DVB-T and DVB-T2 receivers. The National Instruments PXIe-1075 replicated the measured 5MHz LTE signal onto the frequency range 698-703 MHz. This signal has been chosen to be representative of an interfering signal that would be emitted by a PPDR UE in practice. The LTE signal was recorded the while the UE uploaded files to an FTP server. DTT receivers can be susceptible to bursty signals. The signal used is in these measurements is likely to test the ACG of the DTT receivers more than a continuous signal or from a very regular intermittent signal.

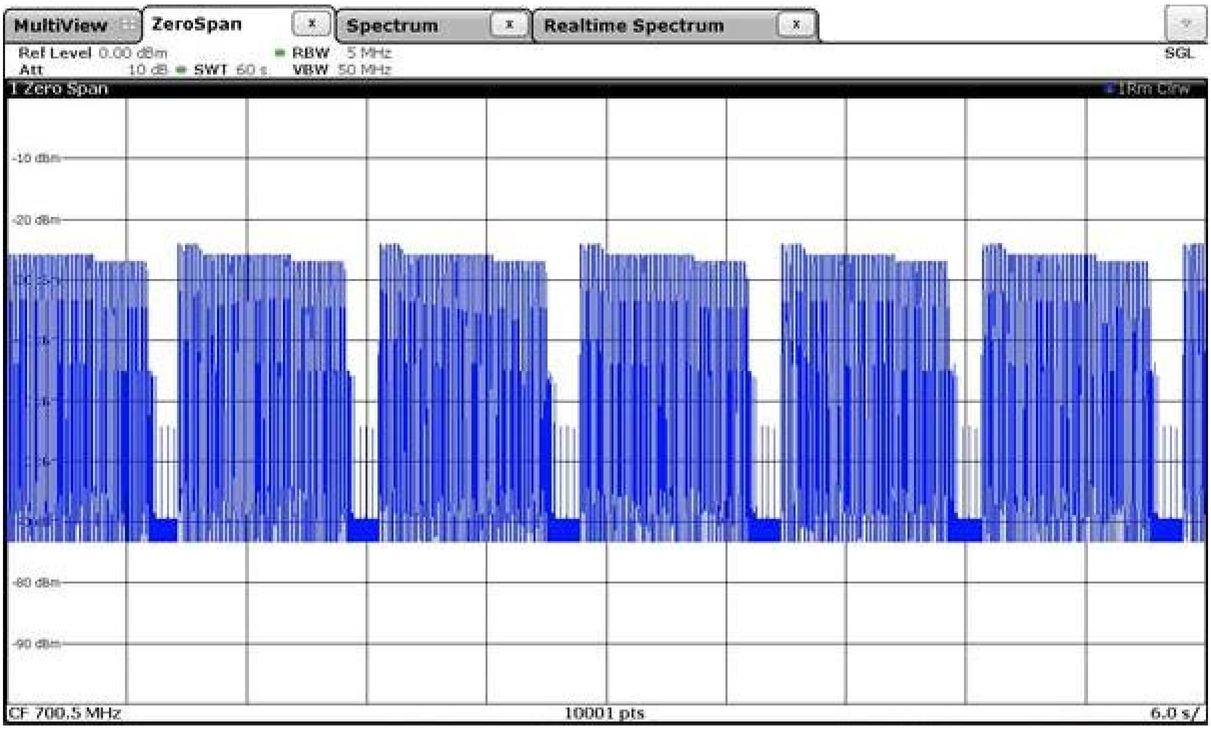

Figure 74 : Representative of an interfering signal from PPDR UE

This interfering source emission was then used to test the DTT receivers at four wanted signal levels of -40 dBm, -50 dBm, -60 dBm and -70 dBm. The wanted signal used for DVB-T was 64QAM, code rate 2/3, DFT size 8k and guard interval 1/32. The wanted signal used for DVB-T2 was 256 QAM, code rate 3/5, DFT size 32k and guard interval 1/16.

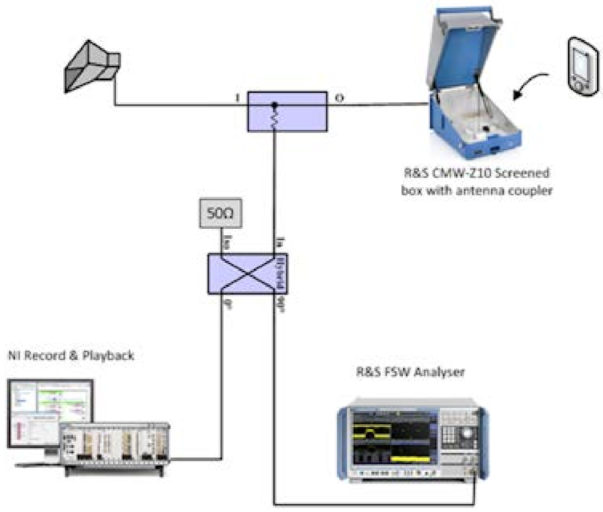

Figure 75: Test set-up

For the frequency offset Δf the adjacent channel selectivity (ACS) of the receiver is calculated from the measured protection ratio at the offset (PR(Δf)), the co-channel protection ratio PR0 and the ACLR of the interference signal generator:

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

The protection ratios varied for the three different receivers at the different wanted signal levels.

The ACLR of the LTE signal was calculated as 48.87 dB. Note that this ACLR value prevents measuring ACS values of the order of 48 dB and higher. This is reflected by the missing results as "NR" in the tables in section A3.2 below.

The protection ratios measured can be seen in Figure 76 and Figure 77 below.

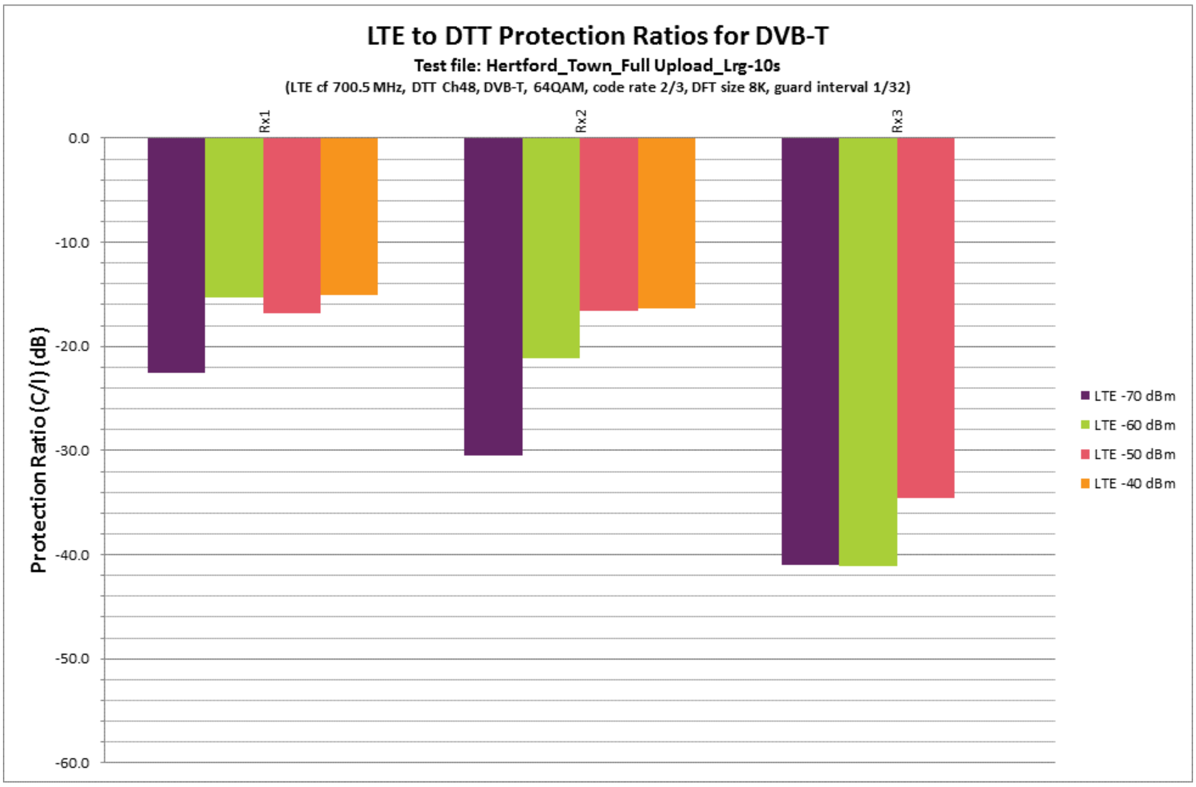

Figure 76: Protection ratios for DVB-T

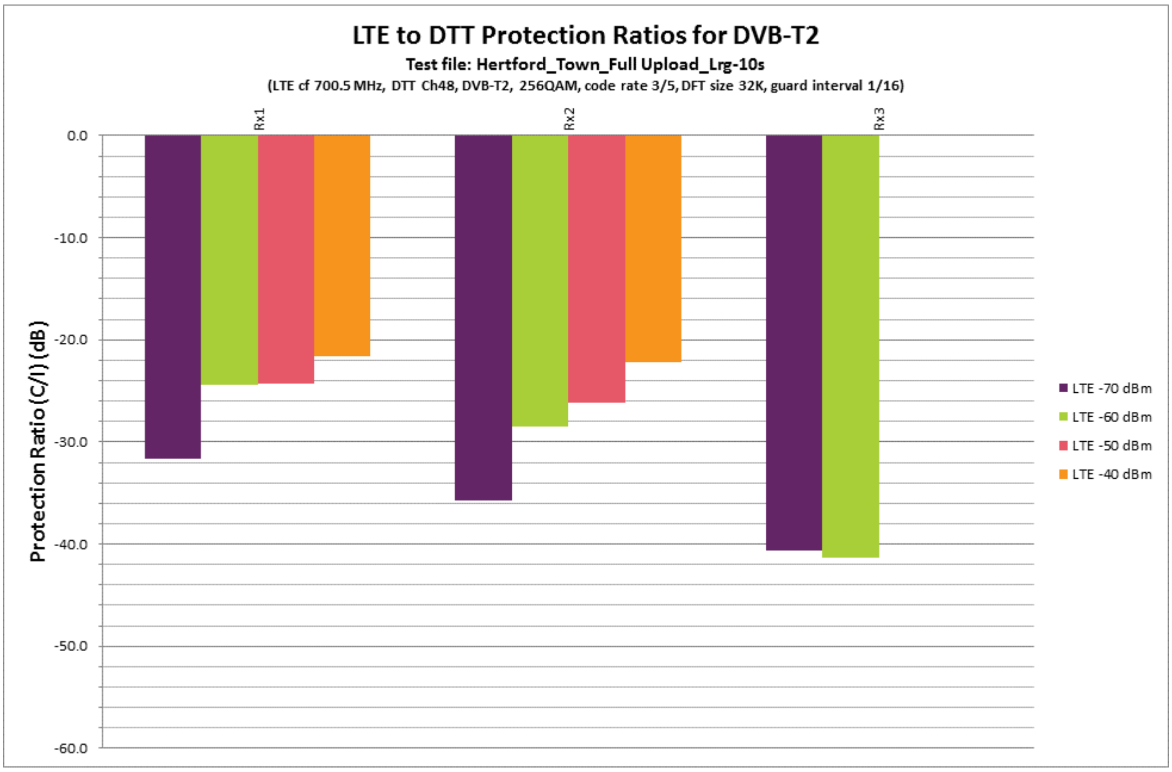

Figure 77: Protection ratios for DVB-T2

These protection ratios with the ACLR value of the LTE UE to calculate a range of ACS values.

A3.2 RESULTS

Table 91 : Results for Rx1

Wanted DTT power at receiver (dBm/8MHz)	ACS	
	DVB-T	DVB-T2
-70	37	39
-60	31	31
-50	33	31
-40	31	28

Table 92: Results for Rx2

Wanted DTT power at receiver (dBm/8MHz)	ACS	
	DVB-T	DVB-T2
-70	44	NR
-60	36	48
-50	30	46
-40	32	41

Table 93: Results for Rx3

Wanted DTT power at receiver (dBm/8MHz)	ACS	
	DVB-T	DVB-T2
-70	NR	53
-60	NR	59
-50	NR	NR
-40	NR	NR

A3.3 CONCLUSIONS OF MEASUREMENTS RESULTS

The average ACS was found to be 38 dB. All the estimated ACS values are lower than the assumed value of 63 dB that has been used for many of the studies in this report. This suggests that there is equipment in the market that performs worse than the assumed ACS of 63 dB.

ANNEX 4: MEASUREMENTS OF LTE UE TX POWER AND BEHAVIOUR OF THE POWER CONTROL ALGORITHM

A4.1 LTE DRIVE TEST

The document presents measurement of an LTE network carried-out in dense urban environment on a commercial network.

Handsets were placed inside a car, behind the shield as shown below.

Figure 78: Example of handsets placed inside a car

Two people sited in the front.

The vehicle was also equipped with a scanner with a deported antenna on the roof of the vehicle.

Measurement path is shown in Figure 79 below together with the relevant base stations as declared by the operator on the date of the measurements. It is worth noting that network deployment was in early stage and therefore site density is rather low and cell edge propagation conditions were experienced in large part of the measurement path.

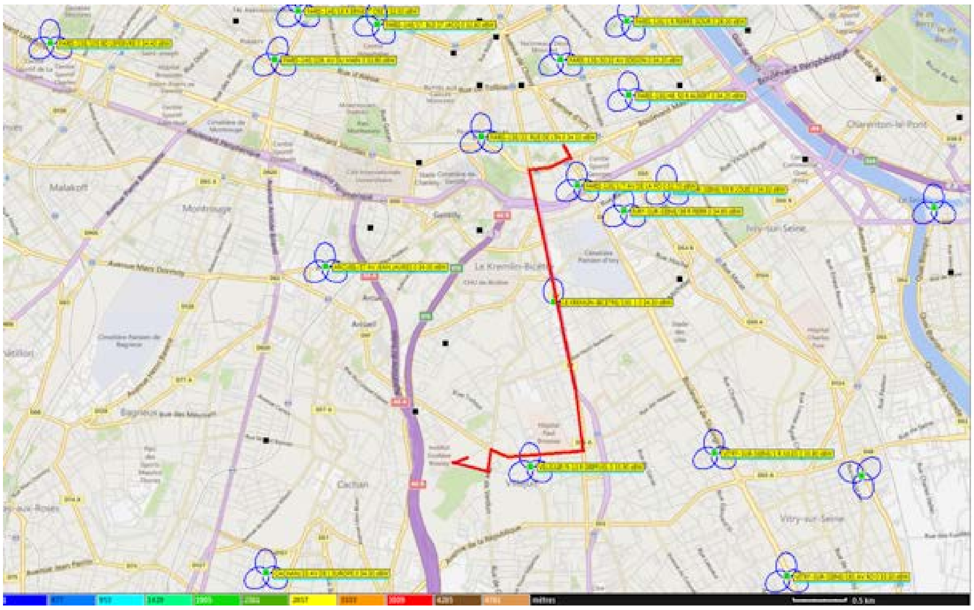

Figure 79: Measurement path (red) together with LTE 800MHz base stations declared by the target MNO. Base stations declared activated prior to measurement campaign in green

A4.2 UE TX POWER

Devices were set to upload 1 MB files via FTP, interleaved with 2 seconds pauses. Upload rate was limited to about 128 kbps.

UE transmit power together with the received signal strength of base the serving cell were recorded. The Figure 80 below shows the UE Tx power plot as a function of the RSRP (Reference Signal Received Power). Because the two measurements are asynchronous, the RSRP values have been first interpolated at transmit power measurement timestamps.

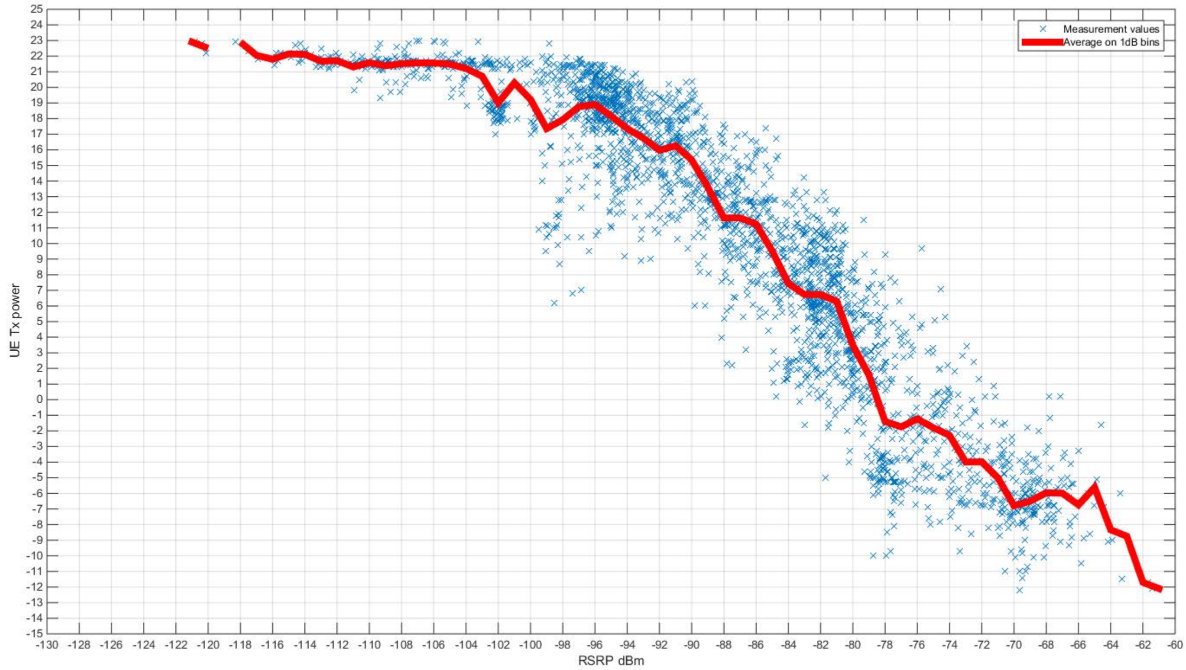

Figure 80: UE Tx power as a function of RSRP

Figure 80 clearly shows that the power control algorithm adapts the power of the device depending on the path loss to base station. Therefore, vehicle mounted devices, with better antenna gains and experiencing better propagation channel, will actually transmit at lower power than handsets.

Using the modified Hata model in urban environment, the median received RSRP at cell edge for a PPDR vehicle mounted device is -87.8 dBm assuming a cell range of 845m for a base stations transmitting at 60 dBm e.i.r.p. and pilot boost at 0 dB.

A4.3 RSRP AT CAR-ROOF LEVEL

The following Figure 81 gives the difference between RSRP experienced by the mobile UE located in the car and the measured RSRP by the scanner which antenna is on the car roof. As it can be seen, the received power is in average 19 dB better on the car roof. This is partly explained by the difference in antenna gain, assumed to be -3 dBi for the handset and peak gain 3.5dBi for the scanner.

Vehicle mounted devices experience better link budgets than handheld devices located within the vehicle.

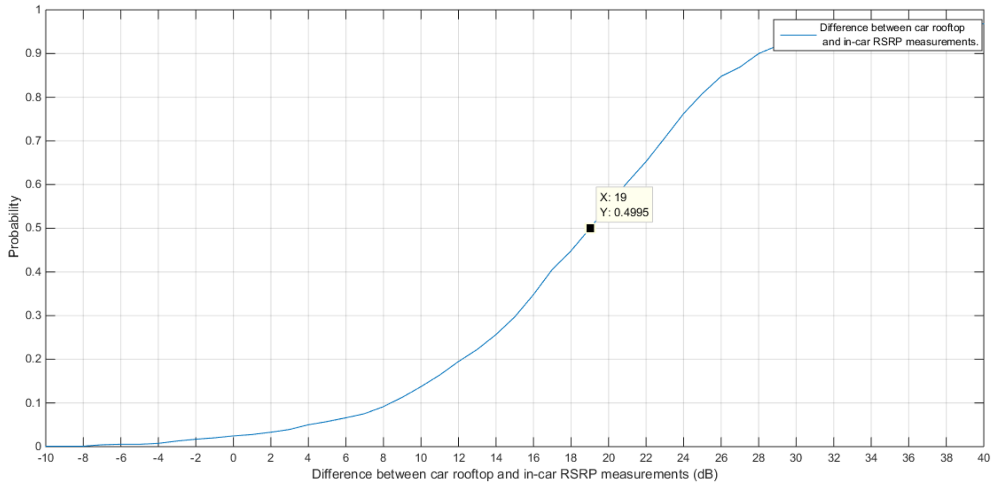

Figure 81: CDF of difference (dB) between RSRP measured by the scanner (car roof) and by the handheld UE (in car)

ANNEX 5: SIMULATION METHOD FOR IMPACT ON DTT (MONTE-CARLO)

A5.1 SIMULATION METHOD

A5.1.1 Introduction

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

A5.1.2 Principles of the Monte Carlo method

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

The Monte Carlo method permits to model a large range of radio systems and to simulate various interference scenarios. The Monte Carlo method has been extensively used within the CEPT to quantify the probability of interference between cellular mobile systems.

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

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

pI=1-pNI (1)

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

The interference criterion C/(I+N) should be used for assessing PPDR uplink interference impact on DTTB reception. Consequently, pNI is defined as follows:

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

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

where

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

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

L = number of interfering UEs;

M = number of events where dRSS>sens.

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

$$\Delta pI = pI\_N - pI\_N{+}I \qquad (3)$$

where

pI_N : pI in the presence of noise only;

pI_N+I : pI in the presence of noise and interference.

In case of a fixed source of interference (e.g. PPDR base station), the reception location probability (pRL) is calculated as follows:

$$pRL=1-pI \qquad (4)$$

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

$$\Delta pRL = pRL\_N - pRL\_N{+}I \qquad (5)$$

where

pRL_N : pRL in the presence of noise only;

pRL_N+I : pRL in the presence of noise and interference.

In case of a moving source of interference (e.g. current commercial LTE user equipment), calculation of ΔpRL may not be so straight forward. Consequently, moving source of interference (time element) should be taken into account by converting the probability of interference (pI) into a probability which would better reflect the impact of interference on the TV viewer. This can be done by calculating the cumulative probability of interference in a given time window.

However, the nature of PPDR network is rather static, as PPDR UEs are usually located around some house blocks or streets due to a police or firemen intervention or an event. For this reason, the value of IP has its own meaning, and there might be no need to derive what would be the cumulative probability of interference. Moreover, during an event or intervention, the PPDR UE will be mostly used for data transmission, which means a long session time while a given PPDR UE is sending data.

In the study presented in this document, we have only assessed the pI to DTTB receivers interfered with by PPDR UE. This method doesn’t predict what is the value of ΔpRL. However, it permits to identify the cases where the probability of interference is so low that the impact of PPDR UE on the victim receiver would be negligible.

A5.1.3 Basic geometry and simulation steps

A5.1.3.1 Geometry

The DTTB transmitter is placed at the centre of the coverage area as depicted in Figure 82.

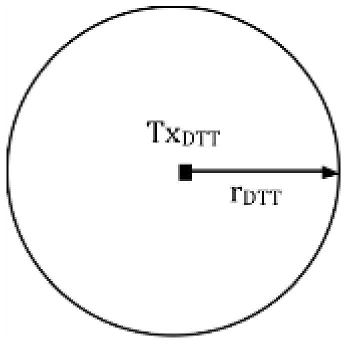

Figure 82 DTTB coverage area of radius rDTTB

The PPDR base station (BS) is placed at the centre of the cell. Each PPDR cell is composed of three sectors as depicted in Figure 83.

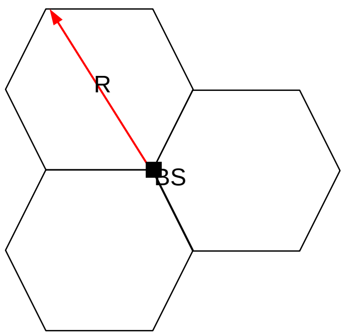

Figure 83: PPDR cell: Hexagonal three-sector cell layout (R: cell range)

This PPDR cell is repeated to build up a perfectly homogeneous single frequency PPDR cluster composed of 7 cells (BS) as depicted in Figure 84. A cluster of size 7 is composed of 21 (7 x 3) hexagonal-shaped sectors.

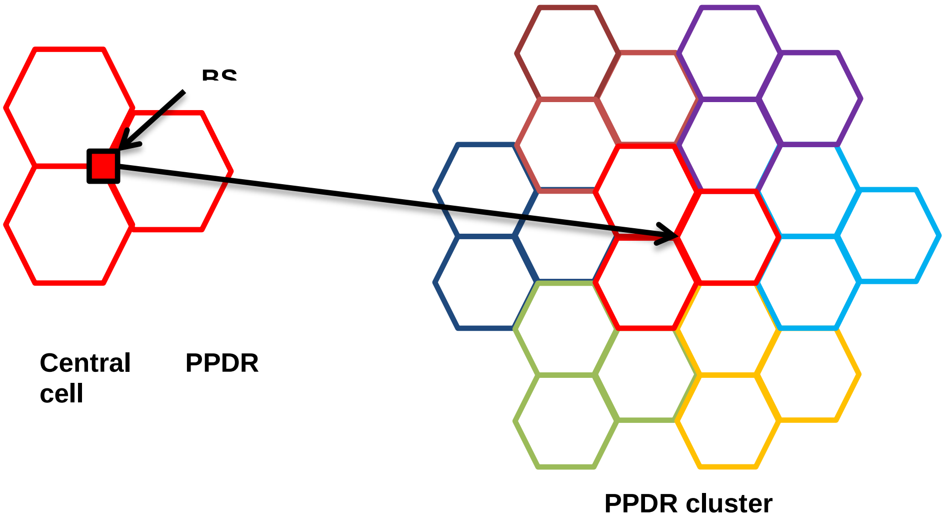

Figure 84: Single frequency PPDR cluster

A5.1.3.2 Simulation steps

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

1 The DTTB receiver is randomly positioned, following a uniform polar distribution, in the DTTB cell or in a *pixel of 100 m x 100 m at the edge of the DTTB cell as depicted in* Figure 85 The azimuth orientation of the TV receiver antenna is directed toward the DTTB transmitter in case of fixed rooftop reception.

2 Around the DTTB receiver within a radius of rPPDR a PPDR cluster is randomly positioned following a uniform angular distribution. The position of the cluster is defined by the position of the central cell's BS as depicted in Figure 86.

3 The active PPDR user equipment (UE) is randomly positioned, following a uniform distribution, within each cell of the PPDR cluster.

4 The probability of interference (pI) is calculated according to equations (1) and (2). *500 000 - 2 000 000 events are generated to consider all possible interference cases in this pixel.*

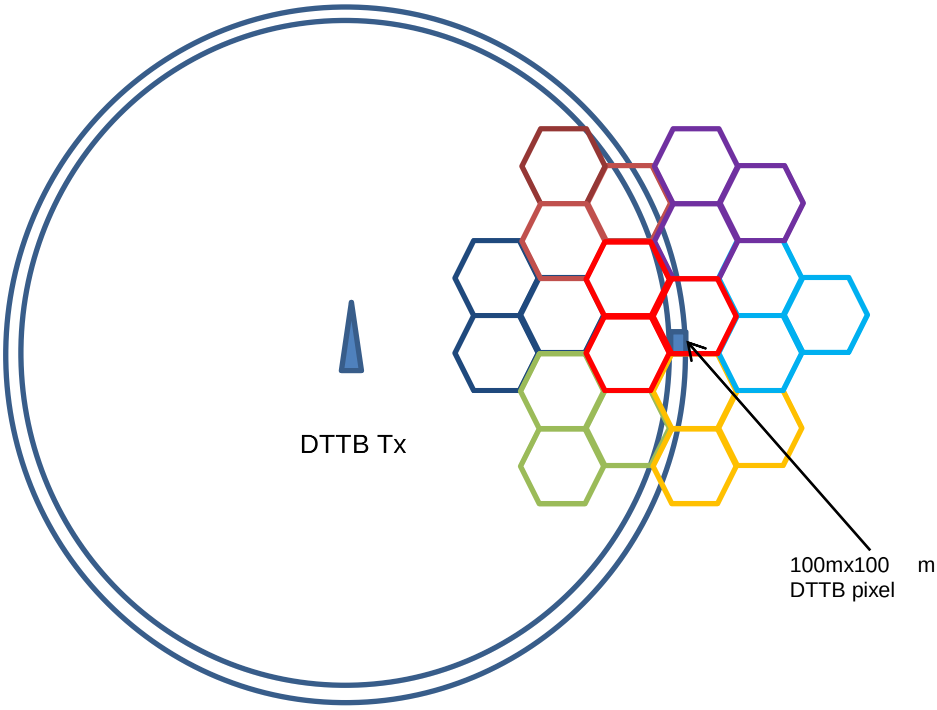

Figure 85: Edge of the DTTB coverage area

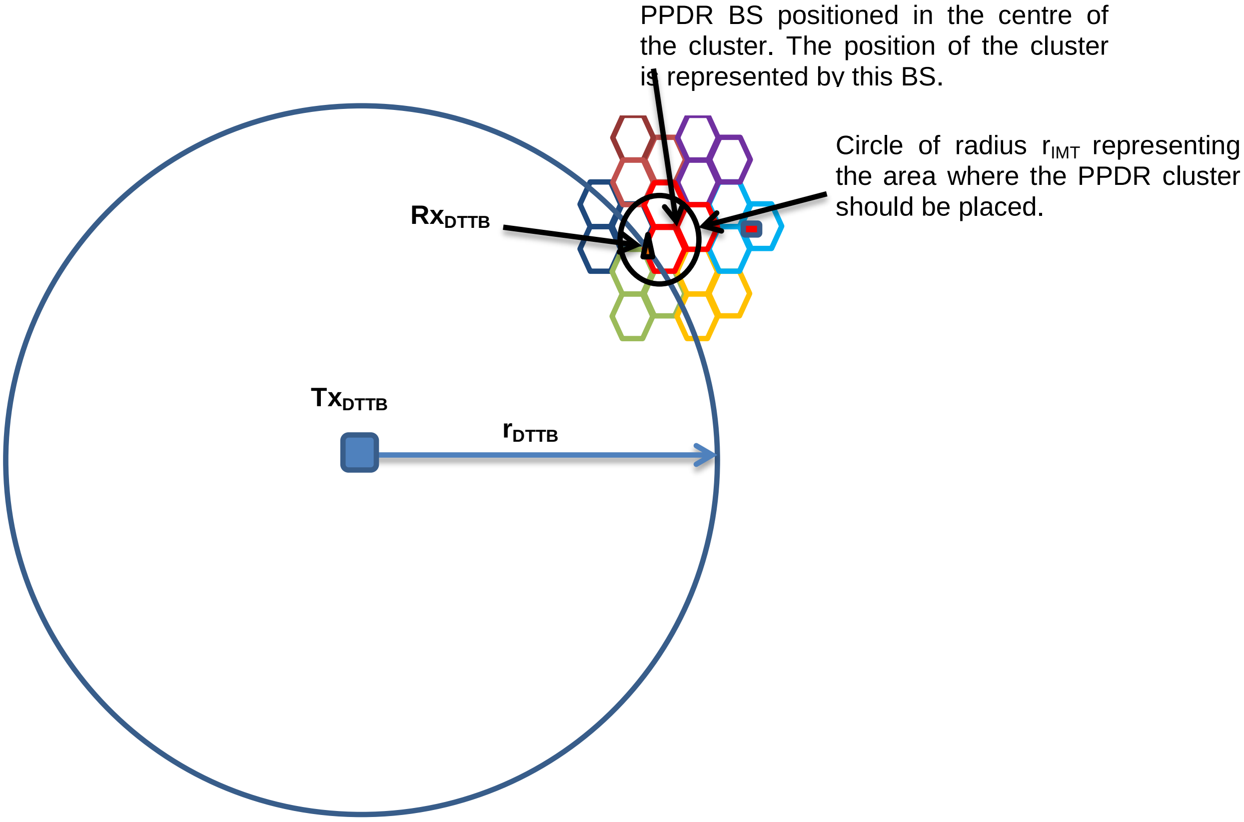

Figure 86: Position of the PPDR cluster around the victim DTTB receiver (a single Monte Carlo event)

A5.2 DTTB AND BROADBAND PPDR (LTE) 700 MHz SYSTEM PARAMETERS

Table 94: DTTB system parameters for fixed outdoor reception

DTTB receiver parameters for fixed roof top antenna in urban environments	
Parameter	Value
Frequency (MHz)	690
Channel BW (MHz)	8
Antenna height (m)	10
Antenna gain including losses (dBi)	9.15
Antenna pattern	See Rec. ITU-R BT.419
Antenna polarisation discrimination (dB) vis-à-vis PPDR UE	0
Modulation scheme (other modulation schemes may be used in different countries)	64 QAM (CR=2/3. GI=1/32)
3 dB BW (MHz)	7.6
Noise floor (dBm)	-98.17
C/N (dB)	21
Pmin(dBm) at the receiver input	-77.17
Emin (dBµV/m) at 10 m above the ground	
Pmed (dBm) at the receiver input	-68.12
Emed (dBµV/m) at 10 m above the ground, for Ploc = 95 %	56.72
Receiver ACS (dB)	63 (1)
Protection criteria	C/(I+N) = 21 dB and Oth= -22 dBm(2)
1 Measured ACS value	

Table 95 Broadband PPDR (LTE) 700 MHz system parameters for base station and user equipment

PPDR BS parameters	
Parameter	Value
Center frequency (MHz)	755.5 (1)
Channel BW (MHz)	5
Maximum number of resource blocs (RBs)	25
Antenna height (m)	30
Frequency reuse	1
Power (dBm)	44
Antenna gain (dBi)	12 (15 dBi - 3 dB cable loss)
e.i.r.p. (dBm) = Power + Antenna gain	56
Antenna pattern/Number of sectors	Directional/3
Cell range for vehicle/ handheld coverage (km)	0.845
PPDR UE parameters	
Parameter	Value
Center frequency (MHz)	700.5
Channel BW (MHz)	5
Maximum number of RBs	25
Antenna height (m)	1.5
Power (dBm)	23
Antenna gain for vehicle/handheld terminals (dBi)	0/-3
e.i.r.p. (dBm) = Power + Antenna gain (vehicle/handheld)	23/20
Body loss for vehicle/ handheld terminals (dB)	0 / 4
Antenna pattern	Omni-directional
Average density of UE (UE/km2)	See Table 37
Distribution of active UE (%indoors / %outdoors) in urban scenario	25/75
Distribution of vehicular terminals (% of total number of terminals)	37.5
ACLR (dB/8MHZ) in DTTB channel 48	33, 50, 60, 65 and 70
Transmit power control parameters	See Annex A5.4
1 For PPDR-DTTB guard band of 4 MHz	

A5.3 CALCULATION OF ACTIVE USER DENSITIES IN A HEXAGONAL BASE STATION SECTOR

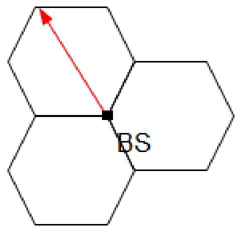

Figure 87: Hexagonal tree sector cell

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

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

A5.4 TRANSMIT POWER CONTROL

A common model, or emulation, of the behaviour of the LTE power control scheme can be found in [9]. It was originally used for 3GPP intra- and inter-system coexistence studies on adjacent channels and it is given by:

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

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

The setting of the parameters PL_{x-ile} and γ are very important in order to obtain realistic results, especially the former. The corresponding value of CL_{x-ile} can differ significantly between scenarios and parameter sets. Therefore, if this scheme is used, or any other for that matter, it is important that reasonable settings are found for precisely the scenario that is being investigated and that generic, or default, values are not used. Otherwise, unrealistically high transmit powers might be obtained.

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

The following parameters are used in this study:

- Max allowed transmit power = 37 dBm;
- Min transmit power = -40 dBm;
- Power scaling threshold = 0.9;
- Balancing factor (0<γ<1)) = 1.;

A5.5 EXAMPLES OF DVB-T AND PPDR (LTE) 700 MHz LINK BUDGETS

Table 96: DVB-T link budget for fixed roof top reception

DVB-T link budget for fixed roof top reception			
DVB-T parameters		Downlink urban (High power transmitter)	Notes
Center frequency	MHz	690.00	Channel 48
Channel BW	MHz	8.00	
Effective BW	MHz	7.6	
Noise figure (F)	dB	7	
Boltzmann's constant (k)	Ws/K	1.38E-23	
Absolute temperature (T)	K	290	
Noise power (Pn)	dBm	-98.17	Pn(dBm) = F + 10log(k*T*B*106) + 30
SNR at cell-edge	dB	21	
Receiver sensitivity (Pmin)	dBm	-77.17	Pmin = Pn(dBm) + SNR(dB)
Cell-edge coverage probability	%	95	
Gaussian confidence factor for cell-edge coverage probability of 95% (µ95%)	%	1.64	
Shadowing loss standard deviation (ơ)	dB	5.50	
Building entry loss standard deviation (ơw)	dB	0.00	
Total loss standard deviation (ơT)	dB	5.50	sT = SQRT(□2 + □w
Loss margin (Lm)	95%	9.05	Lm = µ95% * □T
Pmean (95%)	dBm	-68.12	Pmean = Pmin + Lm
Minimum field strength	dBµV/m	56.72	
e.i.r.p.	dBm	85.15	
Antenna height	m	300.00	
Cable loss (Lcable)	dB	4.00	
Antenna gain (Giso)	dBi	13.15	
Giso-Lcable	dBi	9.15	

DVB-T link budget for fixed roof top reception			
Max allowed path loss (Lp)	dB	162.42	Lp = e.i.r.p. + (Giso-Lcable) - Lwall-Pmean
DVB-T coverage radius calculated by ITU-R P.1546	km	39.5	Urban

Table 97: Example of LTE700 PPDR link budget for urban environment - indoor coverage

PPDR (LTE) 700 MHz link budget for macro cell scenario						
PPDR parameters		Uplink		Downlink		
		UE (QPSK) > BS (QPSK)	Link	BS (QPSK) > UE (QPSK)	Link	Notes
Center frequency	MHz	700.5	UE	755.5	BS	
Channel BW	MHz	5.00	UE	5.00	BS	
Number of RB used		5	UE	25	BS	
RB BW	MHz	0.18	UE	0.18	BS	
Effective BW	MHz	0.9	UE	4.5	BS	
Noise figure (F)	dB	5	BS	9	UE	
Boltzmann's constant (k)	Ws/K	1.38E-23		1.38E-23		
Absolute temperature (T)	K	290		290		
Noise power (Pn)	dBm	-109.43	BS	-98.44	UE	Pn(dBm) = F + 10log(k*T*B*106) + 30
SNIR at cell-edge	dB	0.9	BS	0.9	UE	Including 3 dB Noise rise
Link throughput at cell-edge	kbps	417	UE	3124	BS	See 3GPP TR 36 942 V11.0.0 (2012-10) [9]
Receiver sensitivity (Rx Pmin)	dBm	-108.53	BS	-97.54	UE	Rx Pmin = Pn + SNIR
Cell-edge coverage probability	%	70		70		
Gaussian confidence factor for cell-edge coverage probability	%	0.52		0.52		
Shadowing loss standard deviation (σ)	dB	5.50		5.50		
Building entry loss standard deviation (σw)	dB	6.00		6.00		See Table 6 of Recommendation ITU-R

PPDR (LTE) 700 MHz link budget for macro cell scenario						
						P.1812 [10]
Total loss standard deviation (σT)	dB	8.14		8.14		sT = SQRT(σ2 + σw2)
Loss margin (Lm)	70%	4.27		4.27		Lm = σ70% * □T
Rx Pmean	dBm	-104.26	BS	-93.27	UE	Rx Pmean = Rx Pmin + Lm
Transmitter power (Ptx)	dBm	23.00	UE	44.00	BS	
Ptx e.i.r.p.	dBm	20.00	UE	56.00	BS	
Antenna height	m	1.50	UE	30.00	BS	
Cable loss (Lcable)	dB	0.00	UE	3.00	BS	
Antenna gain (Giso)	dBi	-3.00	UE	15.00	BS	
Giso-Lcable	dBi	12.00	BS	-3.00	UE	
Average building entry loss (Lwall)	dB	11.00		11.00		See Table 6 of Recommendation ITU-R P.1812 [10]
Typical body loss	dB	4.00		4.00		
Max allowed path loss (Lpmax)	dB	121.26	UE	131.27	BS	Lp = e.i.r.p.+ (Giso - Lcable) - Lwall - Lbody - Pmean
IMT BS cell range calculated by Extended Hata model	km	0.845			rPPDR	Urban cell range calculated from unbalanced UL Lpmax

Table 98: Example of link budget for PPDR vehicle receptions

PPDR parameters		Uplink
Center frequency	MHz	700.5
Channel BW	MHz	5.00
Number of RB used		5
RB BW	MHz	0.18
Effective BW	MHz	0.9
Noise figure (F)	dB	5
Boltzmann's constant (k)	Ws/K	1.38E-23
Absolute temperature (T)	K	290
Noise power (Pn)	dBm	-109.43
SNIR at cell-edge	dB	10

PPDR parameters		Uplink
Receiver sensitivity (Rx Pmin)	dBm	-99.43
Cell-edge coverage probability	%	70
Gaussian confidence factor for cell-edge coverage probability	%	0.52
Shadowing loss standard deviation (σ)	dB	9.00
Building entry loss standard deviation (σw)	dB	0.00
Total loss standard deviation (σT)	dB	9.00
Loss margin (Lm)	75%	4.72
Rx Pmean	dBm	-94.71
Transmitter power (Ptx)	dBm	23.00
Ptx e.i.r.p.	dBm	23.00
Antenna height	m	2
Cable loss (Lcable)	dB	0.00
Antenna gain (Giso)	dBi	0.00
Giso - Lcable	dBi	12.00
Average building entry loss (Lwall)	dB	0.00
Typical body loss	dB	0.00
Max allowed path loss (Lpmax)	dB	129.71
Extended Hata path loss for cell range 845 m.	dB	119.9
Extended Hata path loss for cell range 715 m.	dB	117.4
Extended Hata path loss for cell range 570 m.	dB	113.9

A5.6 AVERAGE ACTIVE USER DENSITIES FOR PPDR UE

The densities of the active users in a PPDR cell for different environments are listed in Table 99. The assumption is that these figures are to represent a typical busy period, not for a quiet period or a major event. In a major event it is assumed the user densities may increase locally by a factor of ten.

Table 99: Active PPDR user equipment densities (number of UE/km^2)

	Urban	Suburban	Rural
UK (London area)	1.76	0.118	0.014
Germany	0.377	0.066	0.0165
Denmark	0.63	0.051	0.01
AVERAGE	0.92	0.078	0.014

One distinguishes also between the indoor and outdoor active users per cell. In particularly, it is assumed that the ratio of 50 %, 70 % and 70 % should be used to define the number of indoor active users in commercial networks in rural, sub-urban and urban environments, respectively. PPDR users are less likely to be within buildings when using their UEs. In particularly, the following envisaged distribution of PPDR users is to be used in calculations: 75 % outdoors (out of which ~50 % will be transmitting from a car and 50 % using a handheld terminal), 20 % in PPDR offices, 5 % in residential buildings) for urban and suburban cases. For rural cases, 90 % of outdoor usage is expected to be from car radios.

For the specific simulations presented in the main body of the document, the assumption is that 75 % of the UEs are outdoor on a vehicle installation, whilst 25 % of them are indoor.

ANNEX 6: MEASUREMENT OF LTE MOBILE DEVICE TRANSMIT POWER

A series of walk tests were carried out in a dense urban and two suburban scenarios in the UK[18] using a Rohde and Schwarz FreeRider system. The suburban areas consisted of both good (cell centre) and poor (cell edge) coverage areas that were identified using mobile operators' coverage checkers and field measurements of signal strength and signal quality.

During the walk test, our methodology was to successively run a testing pattern consisting of: an HTTP download; Ping; HTTP browsing; and FTP upload, with 5 seconds pause in between each data task.

Measurements were taken on two networks in different bands – one in 800 MHz and one in 1800 MHz.

The resulting distributions of the transmit power as reported by the handset are presented in Figure 88 and summarised in Figure 89 and Table 100.

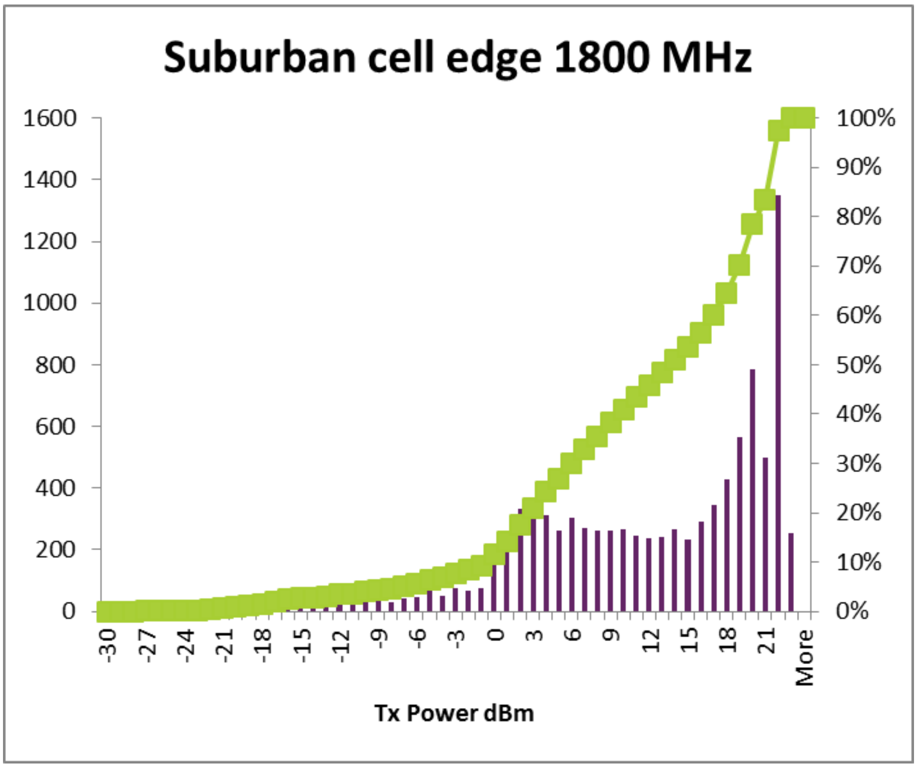

Figure 88: Suburban cell edge 1800 MHz mobile device transmit power distribution

18 http://stakeholders.ofcom.org.uk/binaries/consultations/pssr-2014/updated-analysis.pdf

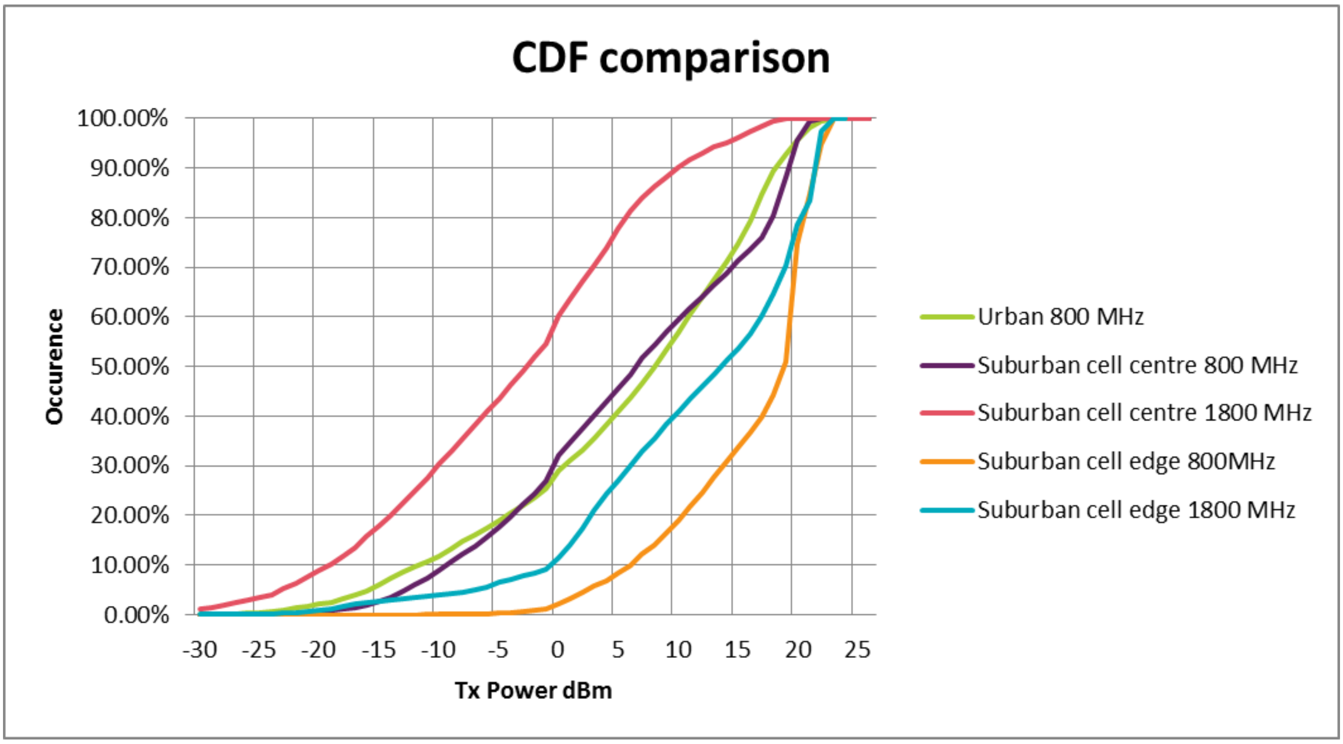

Figure 89: Suburban cell edge 1800 MHz mobile device transmit power distribution

Table 100: Summary of walk test results

Area	Band	UE Tx power (dBm)		
		Average	50th percentile	90th percentile
Urban	800 MHz	6	9	18
Suburban cell centre	800 MHz	7	7	19
	1800 MHz	-3	-2	10
Suburban cell edge	800 MHz	16	19	21
	1800 MHz	12	14	22

We have found no relationship between transmit power level and frequency band, although it is difficult to draw any firm conclusions on this as there are a number of unknown factors to consider, such as possible different network deployment configurations in these areas.

ANNEX 7: MEASUREMENTS OF OOB EMISSION WITH 4 MHz & 5 MHZ GUARD BANDS AND WITH CURRENT FILTER

The OOB emission measurements are based on 4 scenarios. 2 scenarios are based on a 4 MHz guard band, and, 2 scenarios are based on a 5 MHz guard band. For each scenario, these are 1 RB or 25 RBs.

In all scenarios, the channel is based on 5 MHz bandwidth.

In addition, we have not duplexer based on the 2*5 MHz (698-703 MHz & 753-758 MHz) band plan, thus the test conditions are based on the band 28 duplexer.

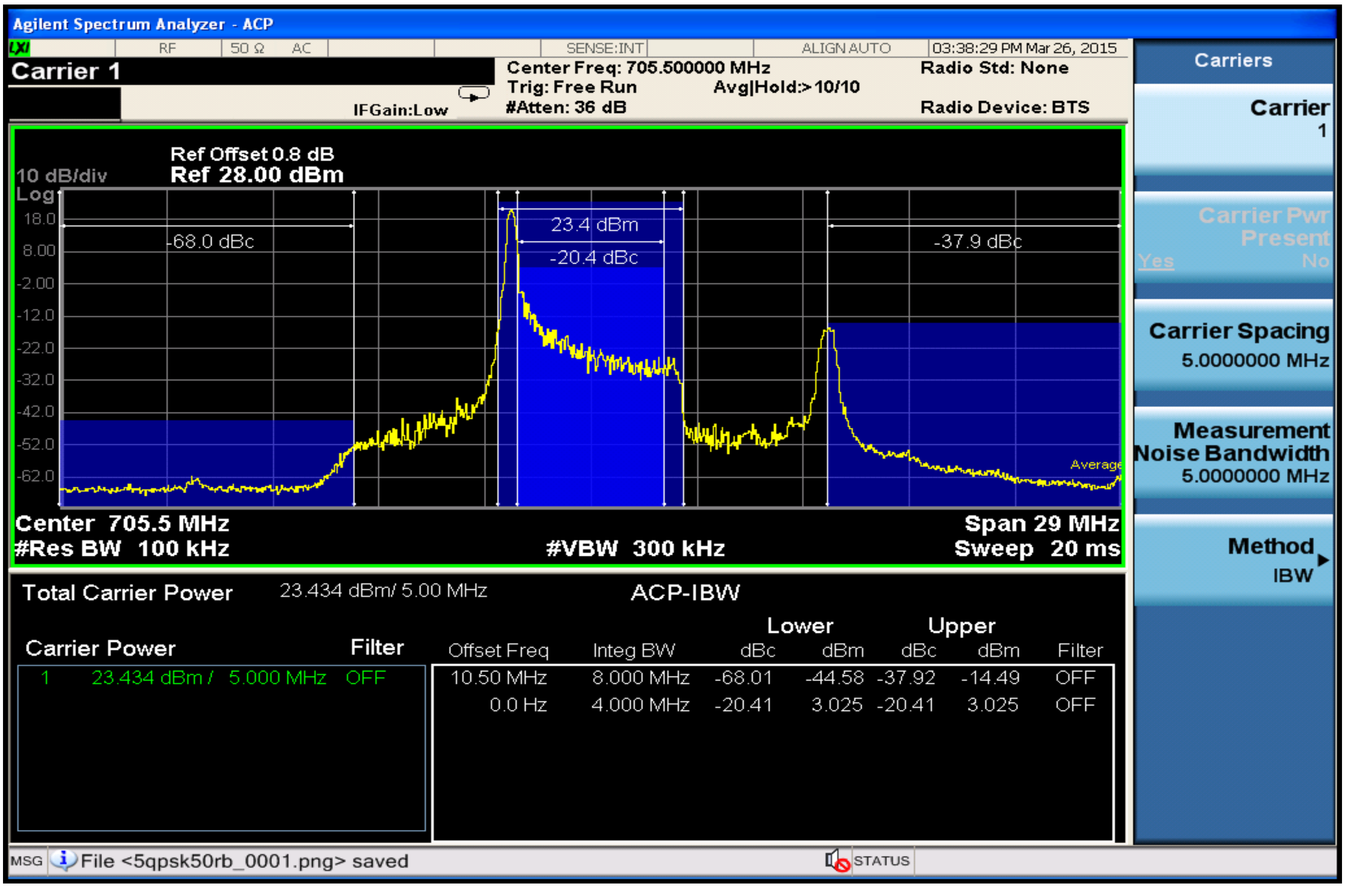

Figure 90: 4 MHz guard band with 1 RB in 5 MHz channelling

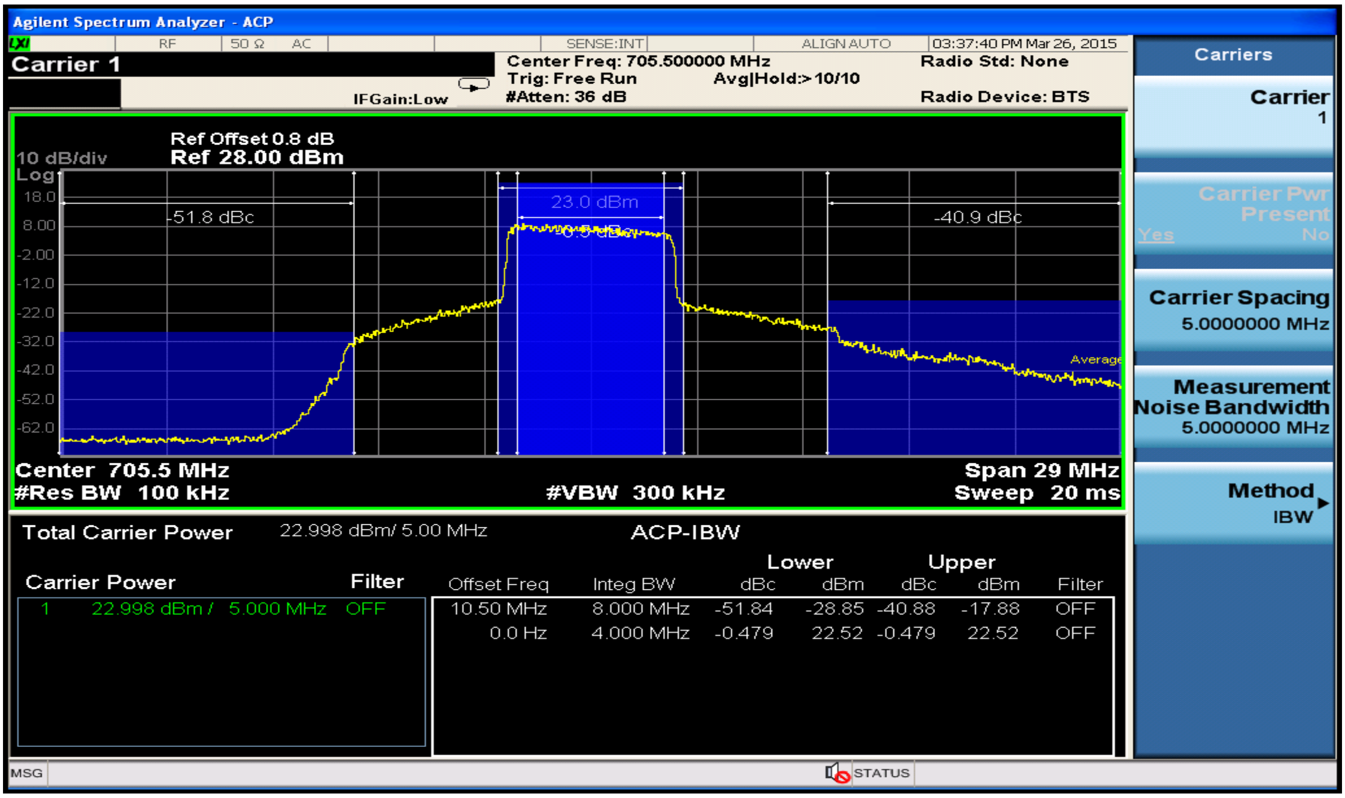

Figure 91: 4 MHz guard band with 25 RBs in 5 MHz channelling

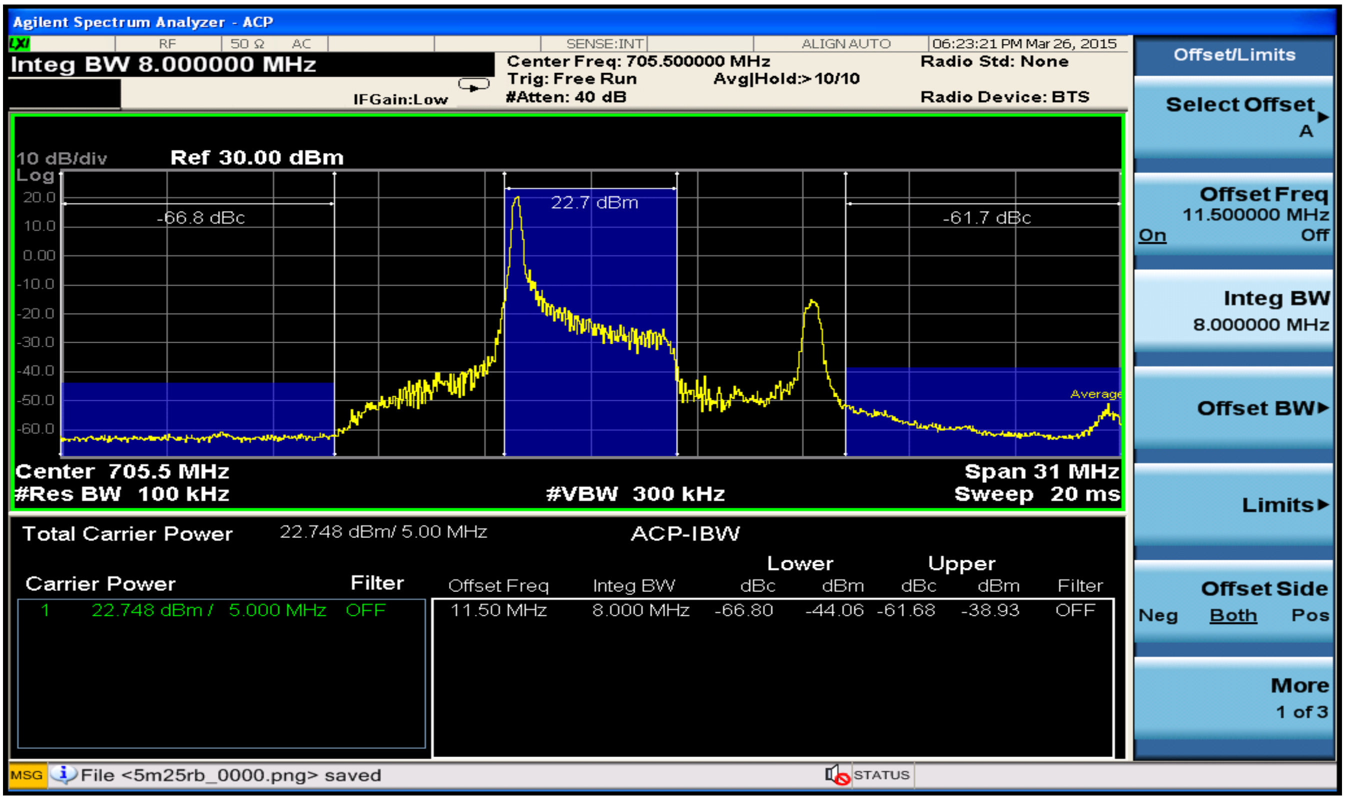

Figure 92: 5 MHz guard band with 1 RB in 5 MHz channelling

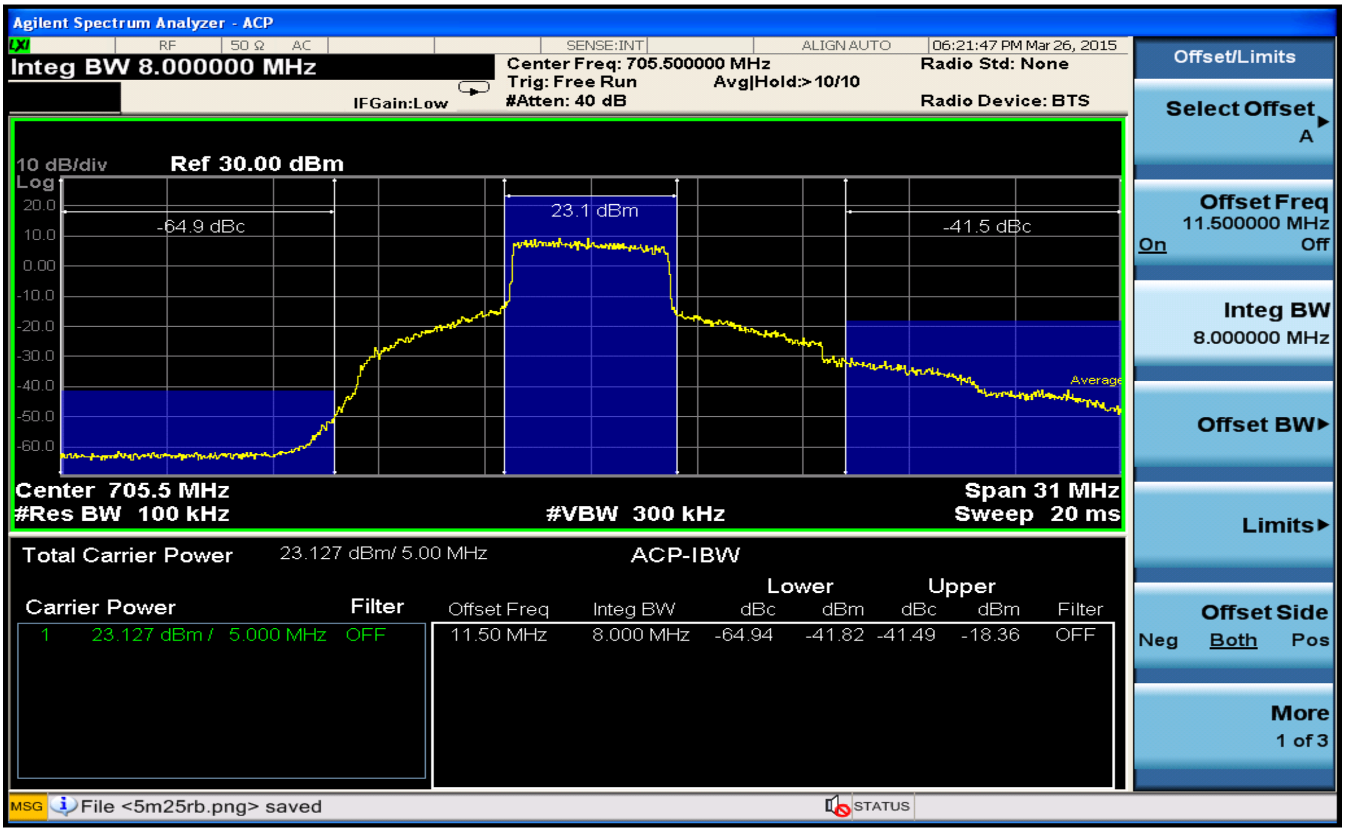

Figure 93: 5 MHz guard band with 25 RB in 5 MHz channelling

A7.1 SUMMARY

Assuming 4 MHz guard band, test OOB performance for the LTE waveform of 5 MHz, 1 RB or full RBs (25), antenna Output Power, and measured OOB in 8MHz (691-699 MHz) is:

Table 101: Test OOB performance for the LTE waveform of 5 MHz, assuming 4 MHz guard band

BW	RB	Mod	Pout	691-699 MHz noise
5	1	QPSK	23.4 dBm	-44.5 dBm
5	25	QPSK	23 dBm	-28.8 dBm

Thus, the -25 dBm/8MHz OOB for LTE 5MHz BW could be meet, but we need some margins e.g. temperature and process effect.

Assuming 5 MHz offset, test OOB performance is:

Table 102: Test OOB performance for the LTE waveform of 5 MHz, assuming 5 MHz guard band

BW	RB	Mod	Pout	690-698 MHz noise
5	1	QPSK	22.75 dBm	-44.06 dBm
5	25	QPSK	23.1 dBm	-41.82 dBm

The -25 dBm/8MHz OOB can be assumed. The OOB up to and around -42 dBm/8 dBm could be assumed, if there are some additional margins (e.g. temperature ...).

A7.2 CONCLUSION

The use of the band 698-703 MHz by PPDR/PMR terminal shall be taking into account that:

- The OOB emission of -25 dBm/8MHz below 694 MHz could be assumed with 4 MHz guard band. Some margins should be add, thus a tolerance of +-2 dB should be added in the table of terminal parameters.
- 5 MHz would be required if OOB emission of -42 dBm/8MHz should be reached.

There are several other factors to take into account to evaluate protection of TV receiver:

- In real life and in general, UEs use only a part of the RBs in the 698-703 MHz band
- Improve the future filters of mobile service in the 698-703 MHz band compared to readily built filters that achieve -25 dBm/8 MHz,
- If the TV channel (686-694 MHz) is not used, the guard band will be 4 + 8 = 12 MHz. This will be enough to get an OOB emission of -42 dBm/8MHz below 686 MHz

ANNEX 8: OTHER FACTORS ON PPDR TO BE CONSIDERED

The following section provides some pointers for administrations to consider in assessing the potential impact to DTT services

The LEWP/RCEG matrix attached to the ECC Report 199 [12] estimates that the spectrum required for future applications and services for PPDR ranges between 4.37 – 26.87 MHz for uplink and 1.52 – 20.35 MHz for downlink. This indicates that there is a level of uncertainty over the future demand for PPDR mobile services and indicates that there could be a high demand for uplink services, administrations need to consider their own likely circumstances when considering the analysis and results in this report.

There are some PPDR applications that may require low level usage of the network, for example eMBMS, as then the UE's are only listening, although UE's will still have some background signalling activity in preparation and during handing over to another cell. There could be other innovations such as body-worn video[19] which could prove very useful in the future; however there are some uncertainties about the extent of its adoption.

It could be envisaged that in the future, administrations with a dedicated PPDR network may choose to allow additional organisations to have access to the network. It may be that other non-Emergency Services support organisations will require interoperability with Emergency Services for public safety operational purposes, for example with Road Safety, Utilities, etc. Therefore there may be more users of the PPDR mobile service than are presently envisaged.[20]

Administrations need to consider whether emergency service personnel and vehicles will most likely take the same set of starting routes from and to a main station or have regular patrol routes. Transmissions form PPDR terminals used by emergency service personnel both on foot and from emergency service vehicles have the potential to cause an interference problem to residential properties along such a route. In addition there may be other situations where it is common for emergency service personnel and vehicles to regularly take common routes and or to congregate in certain locations close to residential properties.

If PPDR networks are designed to provide indoor coverage and typically the UE is used outdoors there may be a lower risk of interference due to the UE's typically using a lower transmit power as the UE would not be at the edge of the cell. If however, the PPDR network is designed for outdoor use, then there may be additional risks of interference to TV sets in some circumstances for example indoor use, due to the UE having to transmit at a higher power to reach the base station.

An administration may decide that it is appropriate to place a licence requirement for the power of the vehicular PPDR UE to be limited in parts of DTT channel 48 coverage areas that have been identified as at risk of interference.

[19] http://www.bapcojournal.com/news/fullstory.php/aid/2665

[20] For example, in the UK there is a Sharers list of more than 1000 organizations that have requested to use the current dedicated PPDR network. It is understood that other administrations have also allowed additional sharers on the current PPDR network.

ANNEX 9: LIST OF REFERENCE

[1] ECC Decision (15)01 on Harmonised technical conditions for mobile/fixed communications networks (MFCN) in the band 694-790 MHz including a paired frequency arrangement (Frequency Division Duplex 2x30 MHz) and an optional unpaired frequency arrangement (Supplemental Downlink); version of March 2015

[2] CEPT Report 53: Report A from CEPT to the European Commission in response to the Mandate “to develop harmonised technical conditions for the 694-790 MHz ('700 MHz') frequency band in the EU for the provision of wireless broadband and other uses in support of EU spectrum policy objectives”; version of November 2014

[3] DVB-T system characteristics: Recommendation ITU-R BT.1306, ETSI EN 300 744;

[4] DVB-T2 system characteristics: Recommendation ITU-R BT.1877, ETSI EN 302 755;

[5] Planning criteria, including protection ratios, for digital terrestrial television services in the VHF/UHF bands: Recommendation ITU-R BT.1368.

[6] ETSI TS 137 104: E-UTRA, UTRA and GSM/EDGE; Multi-Standard Radio (MSR) Base Station (BS) radio transmission and reception

[7] ETSI TS 136 104 Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception

[8] ETSI TS 136 101: E-UTRA; User Equipment (UE) radio transmission and reception

[9] 3GPP TR 36.942: E-UTRA; Radio Frequency (RF) system scenarios

[10] Recommendation ITU-R P.1812 A path-specific propagation prediction method for point-to-area terrestrial services in the VHF and UHF bands

[11] 3GPP TR 25.942: UTRA; Radio Frequency (RF) system scenarios

[12] ECC Report 199: User requirements and spectrum needs for future European broadband PPDR systems (Wide Area Networks); version of May 2013

[13] ECC Report 221: Adjacent band compatibility between MFCN and PMSE audio applications in the 700 MHz frequency band; version of September 2014

[14] SEAMCAT OFDMA UL power control: http://tractool.seamcat.org/wiki/Manual/Scenario/OFDMA#OFDMAULpowercontrol

[15] Report ITU-R BT.2215-4 Measurements of protection ratios and overload thresholds for broadcast receivers

[16] Report ITU-R SM.2028-1 Monte Carlo simulation methodology for the use in sharing and compatibility studies between different radio services or systems

[17] Recommendation ITU-R BT.1895