ECC Report 240

Compatibility studies regarding Broadband PPDR and other radio applications in 410-430 MHz and 450-470 MHz and adjacent bands

Approved 30 September 2015

0 EXECUTIVE SUMMARY

This report aims at analysing the impact of introducing LTE technology for Broadband PPDR (with channel bandwidth of 1.4 MHz, 3 MHz and 5 MHz) within the 410-430 MHz and 450-470 MHz sub-bands based on 3GPP Release 12.

In order to support the identification of additional spectrum for Broadband PPDR, this report has developed a significant number of simulations and analyses to evaluate the impact of introducing LTE technology for PPDR applications within the 410-430 MHz and 450-470 MHz sub-bands. Impact analyses have been conducted for most legacy systems already in operation in those sub-bands and also for most systems in operation in adjacent bands. Additional studies for other legacy systems or specific national scenarios that are not covered in this report may need to be performed. In some countries there are systems which will require special protection.

The impact of PPDR LTE400 system on the legacy systems (TETRA, TETRAPOL, CDMA-PAMR, Analogue FM) rolled out into the 410-430 MHz and 450-470 MHz sub-bands as well as the impact of those systems on LTE400 has been studied. The studies show that based on the 3GPP BS spectrum emission mask minimum requirements LTE400 would cause interference to existing systems. Co-existence, operating within these bands, is possible due to the additional filtering required to fulfil the 3GPP protection of own UL minimum requirement (UE) duplexers to limit the interference at an acceptable level. Indeed such duplexers are needed to ensure both to fulfil the 3GPP minimum requirements and to ensure the correct performance of the LTE400 system itself. This result is valid when considering LTE400 User Equipment transmitting up to 5 W (37 dBm) and two different spectrum masks. Extremely dense legacy networks may impact the uplink capacity of LTE400 system and assuming the LTE400 BS only fulfilling the 3GPP minimum blocking requirements. The LTE duplexers were not considered in the simulations. This will largely decrease such impact. These results are also valid, if the LTE400 system is deployed in the 380-400 MHz sub-band

The results of the theoretical co-existence analyses with DTT demonstrate interferences from the PPDR LTE400 system to DTT reception when the PPDR system is adjacent in the frequency domain to the lower DTT Channel, i.e. Channel 21. Nevertheless, the risk of interference can be reduced by at a set of technical measures including a guard band of up to 3 MHz between DTT and PPDR BSs and an appropriate limit of the corresponding PPDR BS out-of-band emissions. Furthermore additional mitigation measures may be required to solve possible residual interference from PPDR BSs on a case by case basis in a manner similar to the situation between LTE800 and DTT. PPDR400 Base Station OOBE e.i.r.p. levels for protection of DTT above 470 MHz are given in Table 1 below.

Table 1: PPDR 400 Base Station OOBE e.i.r.p. levels for protection of DTT above 470 MHz

Frequency range	Condition on Base station in-block e.i.r.p, P (dBm/cell)	Maximum mean OOBE e.i.r.p (dBm/cell)	Measurement bandwidth
For DTT frequencies above 470 MHz where broadcasting is protected	P ≥ 60	-7	8 MHz
	P < 60	(P – 67)	8 MHz

The conducted Monte-Carlo simulations in this Report have demonstrated limited interferences to DTT for high power UE (37 dBm) with improved ACLR (79 dB, i.e. OOBE of -42 dBm / 8 MHz) in Channel 21.

Local interference analyses and field measurements, where PPDR UEs are operating in the vicinity of DTT, have demonstrated that despite the aforementioned measures and because of the limited DTT receiver selectivity UE using higher powers may still interfere a DTT receiver located in regions / countries where DTT Channel 21 is in use, especially when vertically polarised DTT antennas are used (no orthogonal discrimination between PPDR transmitter and DTT receiver antennas). In case interferences are observed or anticipated, they can be solved locally by a power reduction of PPDR UE through signalling or network planning.

The following values have been identified:

Table 2: PPDR 400 MHz user equipment in-block emission limits for protection of DTT, fixed roof top reception

	UE maximum mean in-block power
Power limit 1 (See Note 1)	23 dBm inside the coverage areas of DTT ch 21 and ch 22
	31 dBm outside the coverage areas of DTT ch 21 and ch 22.
Power limit 2 (see Note 2)	37 dBm

Note 1: Assuming -3 dBi antenna gain for devices implementing this Decision, it matches ECC/DEC/(15)01

Note 2: Refer to Monte Carlo simulations. This can be used in case of DTT transmission is horizontally polarized with antenna polarization discrimination of 16 dB.

In order to limit DTT receiver desensitisation to a level that is comparable to ECC/DEC/(15)01, values for UE ACLR and UE unwanted emission limits are presented in section 3.5.2.2.

Also, PPDR UE blocking capability has to be improved to limit the risk of interference from DTT Channel 21.

Administrations may need to do some further studies to understand the risk of interference for their individual national circumstances. They may also decide that it is appropriate to provide external filters to households in vulnerable DTT areas where there is a risk of interference due to the selectivity of the DTT receivers. This potential solution would not mitigate any risk of interference due to the out-of-band emissions of the handsets.

Compatibility analyses conducted in this report with regards to satellite services have demonstrated that the maximum level of interference is below the level required for space systems relaying 406 MHz emergency signals. This leads to a possible and efficient co-existence between satellites services and BB PPDR in the 400 MHz sub-bands.

The conducted study shows that LTE-based PPDR systems operating in the 420-430 MHz cannot work co-channel with radiolocation radars, because PPDR systems would cause severe desensitisation of radars resulting in wide exclusion zones (more than 400 km). Operation in adjacent band requires exclusion zones of 2.3 km and 3.8 km for airborne and ground radiolocation radars respectively, due to saturation phenomenon which cannot be solved with filtering. Therefore co-located operation of PPDR networks and radiolocation radars is not possible. Out of band emissions of LTE systems falling into radiolocation radars band need to remain below -114 dBm/MHz in order to avoid desensitisation.

Generic compatibility calculations for PPDR activity in the 410-430 MHz band and radio astronomy operating in the 406.1-410 MHz band have shown that physical separation is required between PPDR BS and RAS to achieve compatibility. The calculated exclusion zones can reach up to 90 km based on a spurious emission limit of -36 dBm/100kHz from LTE400 base stations (BS) and can be reduced to 20 km if the spurious emission into the RAS band is limited to -96 dBm/100kHz according to the 3GPP requirement for protection of the base station's own UL band. Separation distances between the UEs and the radio astronomy stations are about 50 km. Adding the terrain profile to the analysis showed that the attenuation from the geographical terrain does not reduce the separation distances.

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
ACIR	Adjacent Channel Interference Ratio
ACLR	Adjacent Channel Leakage Ratio
ACS	Adjacent Channel Selectivity
BB	Broadband
BS	Base Station
BW	Band Width
CDMA	Code Division Multiple Access
CEPT	European Conference of Postal and Telecommunications Administrations
DL	Downlink
DTT	Digital Terrestrial Television
ECC	Electronic Communications Committee
e.i.r.p.	equivalent isotropically radiated Power
ETSI	European Telecommunications Standards Institute
FM	Frequency Modulation
GB	Guard Band
GEO	Geostationary Orbit
GPS	Global Positioning System
ITU-R	International Telecommunication Union - Radiocommunication Sector
LEO	Low Earth Orbit
LP	Location Probability
LTE	Long-Term Evolution
MEO	Medium Earth Orbit
MS	Mobile Station
MSS	Mobile Satellite Service
OOB	Out-of-Band
OOBE	Out-of-Band Emission
Oth	Overloading threshold
PAMR	Public Access Mobile Radio
pI	Probability of Interference
PMR	Private Mobile Radio
PPDR	Public Protection and Disaster Relief
PR	Protection Ratio
QPSK	Quarterly Phase Shift Keying
RB	Resource Block
RES	Radio Equipment and Systems
RF	Radio Frequency
RR	Radio Regulations
Rx	Receiver
SAR	Search And Rescue
SARP	Search And Rescue Processor
SARR	Search And Rescue Repeater
SEAMCAT	Spectrum Engineering Advanced Monte Carlo Analysis Tool

TETRA	Trans-European Trunked Radio
Tx	Transmitter
UE	User Equipment
UHF	Ultra High Frequency
UL	Uplink
WRC	World Radiocommunication Conference

1 INTRODUCTION

ECC Report 218 [3] "Harmonised conditions and spectrum bands for the implementation of future European broadband PPDR systems" indicates frequency bands (410-430/450-470 MHz and 694-790 MHz) for possible use by the PPDR systems.

This report aims at analysing the impact of introducing LTE technology for Broadband PPDR (with channel bandwidth of 1.4 MHz, 3 MHz and 5 MHz) within the 410-430 MHz and 450-470 MHz sub-bands based on 3GPP Release 12. It's made of three main sections. Section 2 is dedicated to general considerations needed to perform co-existences simulations and based on the technical parameters provided in the annexes of this ECC Report. Then Section 3 is dedicated to the impact of PPDR LTE400 systems on most legacy systems already in operation in those sub-bands and also for most systems in operation in adjacent bands. Section 4 is dealing with the impact of most existing systems operating in the same or adjacent bands on PPDR LTE400 systems.

This report aims at analysing the impact of introducing LTE technology based on 3GPP Release 12 for Broadband PPDR (with channel bandwidth of 1.4 MHz, 3 MHz and 5 MHz) within the 410-430 MHz and 450-470 MHz sub-bands.

2 GENERAL CONSIDERATIONS

2.1 PRELIMINARY CONSIDERATIONS FOR SEAMCAT SIMULATIONS

Before discussing the simulations results, some points have to be addressed in order to define the common assumptions.

2.1.1 Anticipated roll-out for Broadband PPDR systems

This report is based on an anticipated roll-out for broadband (LTE technology) wide area networks dedicated to PPDR (Public Protection and Disaster Relief) users, i.e. police forces, fire brigades, emergency services…

The baseline scenario under study is designed to offer outdoor coverage from fixed base stations to car-mounted mobile stations. Both radio parameters and inter-site distance are set to meet a desired level of service availability and protection ratio at cell edge. The following alternative scenarios are also considered:

- network designed for indoor coverage;
- network designed for increased capacity at cell edge;
- use case with increased user density.

Similar approach is used when considering impacts of legacy systems on broadband PPDR systems.

2.1.2 Frequency allocation

As the majority of potential victims are present, the 450-470 MHz sub-band has been considered. The results obtained are also valid for similar systems operating in or adjacent to the 410-430 MHz sub-band. Compatibility of the 410-430 MHz band has also been considered with respect to satellite services, military radars and radio astronomy.

According to harmonisation rules (see ERC Report 25 [4]), uplink band is starting at 450 MHz and downlink band at 460 MHz as illustrated by the following Figure 1.

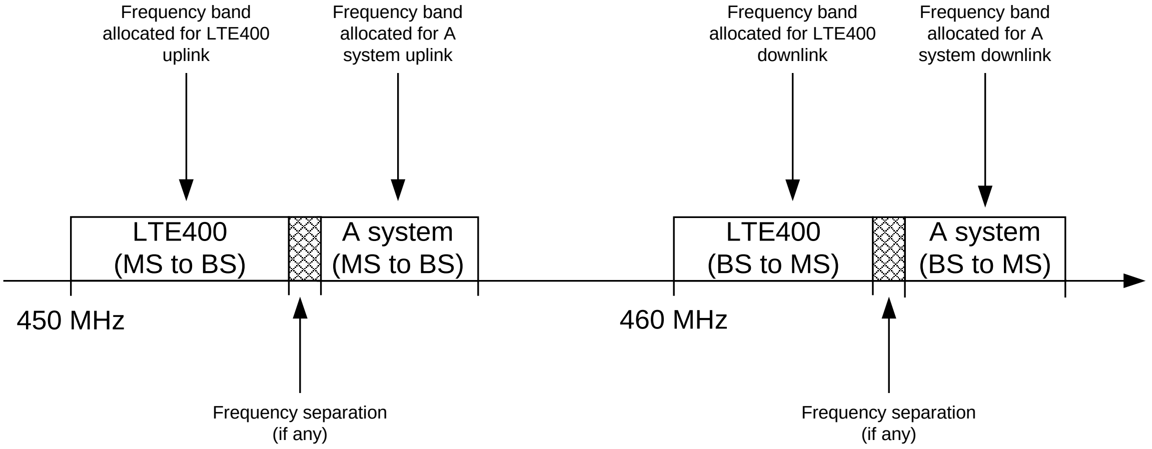

Figure 1: Illustrative frequency allocation of the 450-470 MHz

SEAMCAT simulations have been performed using a 3-MHz allocation for LTE400 system whereas a 2-MHz allocation has been considered for the existing system (Analogue FM, TETRA and TETRAPOL) as illustrated in Figure 1. Depending on the results obtained a frequency guard band could be considered between LTE PPDR and the existing system.

For CDMA-PAMR system, a 1.25 MHz band has been considered (instead of the 2 MHz mentioned above). Depending on the results obtained a frequency guard band could be considered between LTE PPDR and the existing CDMA-PAMR allocation.

The results presented are applicable to any of the 1.4 MHz, 3 MHz and 5 MHz PPDR system variants, provided that apart for the system bandwidth, the radiation characteristics remain similar and in particular that the OOBE and power limit requirements are met.

2.1.3 Propagation environment

As interferer density has been identified as one of the main parameters to be studied, simulations have been limited to the urban environment as this is the environment with the highest user-density.

2.1.4 Cell range and interferer density

In order to define the interferer density, cell range calculations at 450 MHz in an urban environment have been performed using the radio parameters of the different system and the extended Hata propagation model as available within SEAMCAT. For DTT considerations, the cell range has been calculated at 474 MHz (central frequency of Channel 21) using the Recommendation ITU-R P.1546 [5] propagation model.

For the baseline scenario, cell ranges have been calculated in order to guarantee a 75 % confidence level at the cell fringe.

Any mobile system BS antenna height has been set at 30 m and any mobile antenna height has been set at 1.5 m. DTT transmitter antenna height is set to 200 m with the DTT receiver antenna height set to 10 m.

2.1.4.1 LTE400 cell range (3 MHz channel width) and interferer density

The cell range calculation (see details in ANNEX 2:) is based on a base station using three sector configuration. The calculated outdoor LTE cell range in an urban environment for a vehicle mounted 37 dBm e.i.r.p. MS (outdoor reception) using the extended Hata model is 7.5 km (see ANNEX 2:), in this studies this is the base line cell range.

As the main mode of communication used by PPDR users is a group communication mode with a set of users spread all across the cell, LTE400 BS are considered as transmitting all the time at maximum power in order to reach mobile stations at the cell edge. No interference mitigation can be expected from the LTE400 BS power control mechanism.

When the three-sector LTE400 BSs are considered as interferers the density of base stations is defined by:

$$\text{interfererdensity} = \frac{1}{Cell\_Area} = \frac{1}{3\left(\frac{3\sqrt{3}}{2}\left(\frac{Cell\_Range}{2}\right)^2\right)}$$

, where $Cell\_Area$ represents the area of the three hexagonal sectors and $Cell\_Range$ the maximum cell range of a given hexagonal sector, see Figure 2.

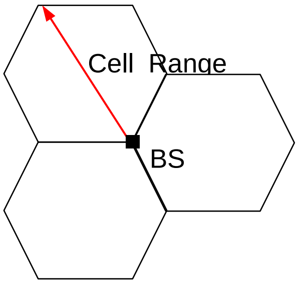

Figure 2: Hexagonal three-sector cell layout

A 7.5 km cell range leads to a value of 0.0091 BS/km² for baseline scenario base station density.

Multiplying the base station density by 4 or by 10 respectively compared to the baseline scenario keeping the BS and mobile station (MS) powers unchanged is equivalent to consider an additional “margin” of 10.5 dB and 17.5 dB respectively at the link budget level whatever the reason of this additional margin (indoor penetration, hand-held-only coverage…).

Base station densities based on BS and MS powers different than those used for baseline scenario have also been used when considering the compatibility between PPDR and DTT. Typical indoor penetration and body loss margins in that frequency range are in the range of 10 dB [12] and 6 dB [13].

When LTE400 MS are considered as interferers, the studies consider 1, 2, 3 and 5 simultaneously transmitting interferers per sector. This is consistent with regard to providing high speed data capability to PPDR users with a 3-MHz LTE (i.e. 15 RB max uplink). This leads to a density from 0.027 to 0.137 MS/km² for the base-line cell range. The number of LTE transmitting users is the ratio of Max subcarriers per Base Station/ Number of subcarriers per mobile (see [16]). Table 3 below presents the various transmitting UE density studied into this report.

Table 3: LTE400 UE Densities

Cell Range (km)	UE per Sector	RB USED PER UE IN A SECTOR	UE/CELL	DENSITY /KM^2
7.5	1	15	3	0.027
7.5	2	7	6	0.055
7.5	3	5	9	0.082
7.5	5	3	15	0.137

The sensitivity analysis on active mobile station density allows dealing with a greater end-user density (emergency situation, dense urban cases…). For the corresponding SEAMCAT simulations, the MS transmission mask is adapted to take into account the fact that the real transmission is made only on 5 RB (when considering 3 MS per sector) and on 3 RB (when considering 5 MS per sector). The mask adaptation results on a homothetic transformation of the frequency axis (OOBE domain) with a ratio corresponding to the RB reduction. When considering a 5-RB transmission, a ratio of 3 is considered (corresponding to the ratio between 15 RBs and 5 RB), the OOBE domain is divided by 3 and the OOBE mask is adapted to fit into this new width. Explicit OOB emission mask is provided in ANNEX 1:.

An increased transmission power for LTE User Equipment (37 dBm instead of 23 or 31 dBm) has been considered in order to enable large coverage by taking advantage of the propagation characteristics of the 400 MHz band. To enable higher UE transmit power the transmission mask can be slightly modified at the edge of the channel with regard to co-existency studies in this Report. Such a modified transmission mask is proposed in ANNEX 1:. When relevant, this report presents the results with 3GPP minimum requirements and proposed modified transmission mask.

When studying the impact on LTE 400 systems, LTE400 BSs are set as for the base line scenario. The number of LTE active users is the ratio of Max subcarriers per Base Station/ Number of subcarriers per mobile (see [16]). In our setup it is 1 transmitting user per sector (3 per BS). The link level data (bitrate mapping) is user selectable and can be modified depending on the simulation to perform. The default values in SEAMCAT are extracted from 3GPP TR 36.942 and were used for the purpose of this Report.

The impact on LTE400 systems is presented using the results delivered by SEAMCAT, i.e. a capacity loss (ratio between the number of unserved users and the total users to be served) and a bit rate loss corresponding to the average degradation of the bit offered to the served users. Those two values are presented for both OFDMA reference cell and system (see on-line SEAMCAT Manual for further details). Please note that for LTE Uplink, a UE can be served with a 0 bit rate, but is not removed from the system. Therefore the capacity loss for LTE Uplink (impact on LTE400 BS) will always be 0 %.

2.1.4.2 TETRA cell range

The calculated TETRA cell range in an urban environment and outdoor reception using the extended Hata model is 5.2 km (see ANNEX 2:).

Then, when TETRA base stations are considered as interferer and the base station density is defined by:

$$\text{interfererdensity} = \frac{1}{Cell\_Area} = \frac{1}{\left(\frac{3\sqrt{3}}{2}(Cell\_Range)^2\right)}$$

, where $Cell\_Area$ represents the area of the hexagonal cell and $Cell\_Range$ the cell range.

The cell range of 5.2 km leads to a base station density of 0.014 BS/km² (base-lie scenario). To cover different network designs, different densities from 0.01 to 0.1 BS/km² are considered into this report

When TETRA MS are considered as interferer, the study will consider 4 simultaneously transmitting interferers per base station. This leads to a density of 0.057 MS/km². To cover different network cases, different densities from 0.05 to 0.2 MS/km² are considered into this report.

2.1.4.3 TETRAPOL cell range

The calculated TETRAPOL cell range in an urban environment and outdoor reception using the extended Hata model is 7.3 km (see ANNEX 2:).

Then, when TETRAPOL base stations are considered as interferer and the base station density is defined by:

$$\text{interfererdensity} = \frac{1}{Cell\_Area} = \frac{1}{\left(\frac{3\sqrt{3}}{2}(Cell\_Range)^2\right)}$$

, where $Cell\_Area$ represents the area of the hexagonal cell and $Cell\_Range$ the maximum cell range.

The cell range of 7.3 km leads to a base station density of 0.007 BS/km² (base-line scenario). To cover different network designs, different densities between 0.007 and 0.1 BS/km² are considered into this report.

When TETRAPOL mobile stations are considered as interferer, the study will consider 4 simultaneously transmitting interferers per base station. This leads to a density of 0.028 MS/km². To cover different network cases, different densities from 0.028 to 0.2 MS/km² are considered into this report.

2.1.4.4 CDMA-PAMR Cell range

The calculated CDMA-PAMR cell range in an urban environment and for outdoor reception using the extended Hata model is 11.1 km. (see ANNEX 2:)

Then, when CDMA-PAMR three-sector base stations are considered as interferers, the base station density is defined by:

$$\text{interfererdensity} = \frac{1}{Cell\_Area} = \frac{1}{3\left(\frac{3\sqrt{3}}{2}\left(\frac{Cell\_Range}{2}\right)^2\right)}$$

, where $Cell\_Area$ represents the area of the three hexagonal sectors and $Cell\_Range$ the maximum cell range of a given hexagonal sector.

The cell range of 11.1 km leads to a base station density of 0.004 BS/km² (base-line scenario). To cover different network designs, different densities between 0.004 and 0.1 BS/km² are considered into this report.

When CDMA-PAMR MS are considered as interferer, the study will consider 4 simultaneously transmitting interferers per sector. This leads to a density of 0.05 MS/km². To cover different network cases, different densities from 0.01 to 0.1 MS/km² are considered into this report.

2.1.4.5 DTT Cell range

The calculated DTT cell range in an urban environment using the Recommendation ITU-R P.1546 [5] propagation model is 40.46 km (see ANNEX 2:)

Then, when DTT transmitters are considered as interferer and the transmitter density is defined by:

$$\text{interfererdensity} = \frac{1}{Cell\_Area} = \frac{1}{\left(\frac{3\sqrt{3}}{2}(Cel\_Range)^2\right)}$$, where $Cell\_Area$ represents the area of the hexagonal cell and $Cell\_Range$ the cell range.

The cell range of 40.46 km leads to a DTT transmitter density of 0.00023 transmitter/km² (base-line scenario). To cover different network designs, different densities between 0.0001 and 0.0005 transmitter/km² are considered into this report.

2.1.4.6 25 kHz Analogue FM cell range

The calculated 25 kHz Analogue FM cell range in an urban environment using the extended Hata model is 7.9 km (Table 102 provides results of calculations of the cell range for 90% confidence level on the cell area).

Then, when 25 kHz Analogue FM BS stations are considered as interferer, the density of interferer is defined by:

$$\text{interfererdensity} = \frac{1}{Cell\_Area} = \frac{1}{\left(\frac{3\sqrt{3}}{2}(Cel\_Range)^2\right)}$$, where $Cell\_Area$ represents the area of the hexagonal cell and $Cell\_Range$ the cell range.

The cell range of 7.9 km leads to a base station density of 0.006 BS/km² (base-line scenario). To cover different network designs, different densities between 0.005 and 0.1 BS/km² are considered into this report.

When 25 analogue kHz FM MS are considered as interferer, the study will consider 20 simultaneously transmitting interferers per cell. This leads to a density of 0.024 MS per km^2. To cover different network cases, different densities from 0.01 to 1 MS/km² are considered into this report

2.2 GENERAL CONSIDERATIONS CONCERNING THE PROTECTION OF THE MSS BAND 406-406.1 MHZ

2.2.1 Background

Resolution 205 (Rev.WRC-12) [6] indicates the following:

"resolves to invite ITU-R

1 to conduct, and complete in time for WRC-15, the appropriate regulatory, technical and operational studies with a view to ensuring the adequate protection of MSS systems in the frequency band 406-406.1 MHz from any emissions that could cause harmful interference (see RR No. 5.267), taking into account the current and future deployment of services in adjacent bands as noted in considering f);

2 to consider whether there is a need for regulatory action, based on the studies carried out under resolves 1, to facilitate the protection of MSS systems in the frequency band 406-406.1 MHz, or whether it is sufficient to include the results of the above studies in appropriate ITU-R Recommendations and/or Reports,

instructs the Director of the Radiocommunication Bureau

1 to include the results of these studies in his Report to WRC-15 for the purposes of considering adequate actions in response to resolves to invite ITU-R above;

2 to organize monitoring programmes in the frequency band 406-406.1 MHz in order to identify the source of any unauthorized emission in that band,"

2.2.2 Purpose of the calculations conducted under agenda item 9.1.1

This Report follows the stated objectives from Resolution 205 (Rev.WRC-12) [6] by studying the emission levels of all present systems in the 390 to 406 MHz and 406.1 to 420 MHz ranges and determining their relative contributions to the interference noise into the Search and Rescue receiver on board the three types of satellites.

1 a LEO (Low Earth Orbit) component with satellites embarking SARP (Search and Rescue Processor) and SARR (Search and Rescue Repeater) instruments on polar sun-synchronized orbit;

2 a GEO (Geostationary Orbit) component with different satellites (MSG, GOES, Insat-3A, Electro and Luch) embarking a SAR (Search and Rescue) repeater;

3 a MEO (Medium Earth Orbit) component with three main radio-navigation systems (GPS, Galileo, Glonass) embarking on their satellites a SAR repeater.

The interference noise sources are assessed in terms of the maximum amount of interference noise that the Search and Rescue receivers on board LEO, MEO and GSO satellites can receive. Once these sources are characterized (usage of a deployment model), they can be applied to an aggregate interference analysis that may be dynamic, in order to assess whether the level resulting from the aggregation of these multiple sources will exceed the maximum aggregate interference level of each kind of satellite receiver.

Each type of instrument on board a specific series of satellite (LEO, MEO, GSO) is characterized by a maximum permissible level of interference usually expressed in power flux density valid for narrow band emissions and wide band emissions.

Therefore, this Report makes reference to the Report developed by the ITU-R [28] concerning the maximum permissible levels of interference, and the current deployment as observed within CEPT countries using narrowband technologies (TETRA, TETRAPOL for instance with 25 kHz, 10 kHz bandwidth). It is to be noted that an extensive questionnaire was launched within CEPT in January 2014 and the results are contained in [29].

3 PPDR IMPACT ON EXISTING SYSTEMS WITHIN THE 410-430 / 450-470 MHz SUB-BANDS AND ADJACENT BANDS

3GPP MS spectrum mask (following a ITU-R recommendation), is used for the compatibility studies between LTE and other systems. An alternative mask, called "proposed mask" in the following section, is proposed in this report to allow coexistence from a regulatory perspective. Both are represented in Figure 3. The specific levels of each mask are included in ANNEX 1:. Note that this current report does not propose to implement the "proposed mask" in the standards but may be used in regulations.

Figure 3: 3GPP MS spectrum mask (blue) and proposed mask (red) for a 37dBm LTE400 UE

3.1 LTE400 IMPACT ON TETRA SYSTEM

For SEAMCAT simulations, frequency allocation has been performed as presented in Figure 4 below. Different interferer densities have been considered around the values calculated in the former section. For each simulation, 100 000 SEAMCAT snapshots have been generated.

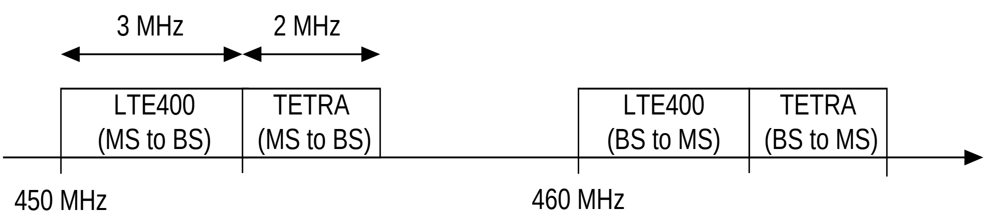

Figure 4: LTE400 on TETRA

3.1.1 LTE400 BS impact on TETRA BS

The three-sector LTE400 BS transmits at 461.5 MHz whereas the TETRA BSs receive signals coming from TETRA MS between 453 and 455 MHz. The victim frequency is randomly chosen (discrete distribution option) in SEAMCAT.

Table 4 below gives the interference probability as calculated using SEAMCAT when combining unwanted emissions and blocking effects. Interference probabilities are given for the LTE400 BS based on 3GPP BS spectrum emission mask minimum requirements, with 25-dB and 30-dB additional attenuation added to the BS spectrum emission mask minimum requirements and protection of own UL minimum requirement

Table 4: LTE400 BS impact on TETRA BS

Interferer Density (LTE400 BS / km²)	Cell Radius (km)	Interference Probability with BS emission mask minimum requirements	Interference Probability with 25 dB additional attenuation compared to the BS emission mask minimum requirement	Interference Probability with 30 dB additional attenuation compared to the BS emission mask minimum requirement	Interference Probability with minimum requirements for protection of BS receiver of own or different BS
0.005	5.06	21.48 %	1.44 %	1.01 %	0.84%
0.0091	3.75	31.71 %	2.55 %	1.87 %	0.82%
0.01	3.58	33.86 %	2.81 %	1.97 %	0.83%
0.02	2.53	48.10 %	5.42 %	4.05 %	0.85%
0.05	1.60	67.41 %	12.30 %	9.36 %	0.85%

The impact of LTE400 BS with Spectrum mask minimum requirements on TETRA BS is significantly high and cannot be considered as acceptable from the operational point of view. The high probability of interference is due to the LTE400 BS 3GPP emission mask together with the favourable propagation conditions (antenna heights and antenna gain). Introducing a further 25 dB (or 30 dB) additional attenuation on the LTE400 BS emission mask within the considered TETRA BS reception band, the interference probability is reduced from 31.71 % to 2.55 % (or 1.87 % respectively) when considering the base-line scenario. The impact of LTE400 BS with 3GPP minimum requirements for protection of BS receiver of own or different BS is less than 1% in all the simulated scenarios. In case TETRA UL is located within the LTE duplex gap, the BS unwanted emissions will be between the BS Spectrum mask and protection of own UL.

Please note that duplexer needed to protect the LTE400 BS reception band and providing 90dB attenuation will also provide attenuation to protect the TETRA BS reception band even in case of dense LTE400 networks.

3.1.2 LTE400 BS impact on TETRA MS

The three-sector LTE400 BS transmits at 461.5 MHz whereas the TETRA MSs receive signals coming from TETRA BS between 463 and 465 MHz. The victim frequency is randomly chosen (discrete distribution option) in SEAMCAT.

Table 5 below gives the interference probability as calculated with SEAMCAT when combining unwanted emissions and blocking effects. Interference probabilities are given for the LTE400 BS 3GPP minimum requirements and with 25-dB or 30-dB additional attenuations to the minimum requirements.

Table 5: LTE400 BS impact on TETRA MS

Interferer Density (LTE400 BS / km²)	Cell Radius (km)	Interference Probability with minimum requirements	Interference Probability with 25 dB additional attenuation	Interference Probability with 30 dB additional attenuation
0.005	5.06	3.13 %	0.34 %	0.23 %
0.0091	3.75	4.29 %	0.48 %	0.28 %
0.01	3.58	4.43 %	0.54 %	0.33 %
0.02	2.53	6.52 %	0.70 %	0.41 %
0.05	1.60	10.41 %	1.14 %	0.62 %

The impact of LTE400 BS on TETRA MS is limited but can be decreased by considering similar additional attenuations than the ones proposed in the previous section. Please note that duplexers needed to protect the LTE400 BS reception band (90 dB attenuation) help to provide necessary attenuation into the TETRA MS reception band.

3.1.3 LTE400 MS impact on TETRA BS

The LTE400 MSs transmit at 451.5 MHz whereas the TETRA BSs receive signals coming from TETRA MS between 453 and 455 MHz. The victim frequency is randomly chosen (discrete distribution option) in SEAMCAT

Table 6 below gives the interference probability as calculated with SEAMCAT when combining unwanted emissions and blocking effects considering 3GPP minimum requirements and a proposed transmission mask consistent with a 37 dBm output power.

Table 6: LTE400 MS impact on TETRA BS

Interferer Density (LTE400 MS / km²)	Interference Probability with minimum requirements	Interference Probability with proposed requirements
0.027	0.78 %	1.57 %
0.082	0.36 %	0.50 %

Interferer Density (LTE400 MS / km²)	Interference Probability with minimum requirements	Interference Probability with proposed requirements
0.137	0.36 %	0.47 %

The impact of LTE400 MS on TETRA BS is limited and acceptable from the operational point of view even when considering modified requirements for high power devices.

3.1.4 LTE400 MS impact on TETRA MS

The LTE400 MSs transmit at 451.5 MHz whereas the TETRA MSs receive signals coming from TETRA BS between 463 and 465 MHz. The victim frequency is randomly chosen (discrete distribution option) in SEAMCAT.

Table 7 below gives the interference probability as defined within SEAMCAT when combining unwanted emissions and blocking effects considering 3GPP spectrum mask minimum requirements. 3GPP also specifies protection of own DL band as a minimum requirement. This is more stringent than the unwanted emission requirement and thus will further reduce the risk of interference and a proposed transmission mask consistent with a 37 dBm output power.

Table 7: LTE400 MS impact on TETRA MS

Interferer Density (LTE400 MS / km²)	Interference Probability with minimum requirements	Interference Probability with proposed requirements
0.027	0.06 %	0.06 %
0.082	0.08 %	0.09 %
0.137	0.16 %	0.16 %

The impact of LTE400 MS on TETRA MS is limited and acceptable from the operational point of view even when considering modified requirements for high power devices.

3.2 LTE400 IMPACT ON ETS300-113-RELATED SYSTEMS

For SEAMCAT simulations, frequency allocation has been performed as presented in Figure 5 below. Different interferer densities have been considered around the values calculated in the former section. For each simulation 100 000 SEAMCAT snapshots have been generated.

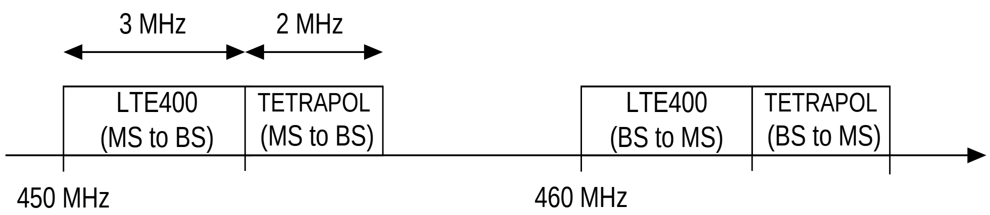

Figure 5: LTE400 on TETRAPOL

3.2.1 LTE400 BS impact on TETRAPOL BS

The three-sector LTE400 BS transmits at 461.5 MHz whereas the TETRAPOL BSs receive signals coming from TETRAPOL MS between 453 and 455 MHz. The victim frequency is randomly chosen (discrete distribution option) in SEAMCAT

Table 8 below gives the interference probability as calculated with SEAMCAT when combining unwanted emissions and blocking effects. Interference probabilities are given for the LTE400 BS spectrum emission mask minimum requirements, with 25-dB or 30-dB additional attenuations to this mask and for protection of BS receiver of own or different BS

Table 8: LTE400 BS impact on TETRAPOL BS

Interferer Density (LTE400 BS / km²)	Cell Radius (km)	Interference Probability with BS emission mask minimum requirements	Interference Probability with 25 dB additional attenuation compared to BS emission mask	Interference Probability with 30 dB additional attenuation compared to BS emission mask	Interference Probability with minimum requirements for protection of BS receiver of own or different BS
0.005	5.06	20.49 %	1.13 %	0.83 %	0.58%
0.0091	3.75	30.66 %	2.25 %	1.48 %	0.58%
0.01	3.58	32.63 %	2.31 %	1.53 %	0.57%
0.02	2.53	47.26 %	4.65 %	3.09 %	0.52%
0.05	1.60	66.31 %	10.80 %	7.51 %	0.55%

The impact of LTE400 BS spectrum emission mask on TETRAPOL BS is significantly high and cannot be considered as acceptable from the operational point of view. The high probability of interference is due to the LTE400 BS emission mask together with the favourable propagation conditions (antenna heights and antenna gain). Introducing a further 25 dB (or 30 dB) additional attenuation on the LTE400 BS emission mask within the considered TETRAPOL BS reception band, the interference probability is reduced from 30.66 % to 2.25 % (or 1.48 % respectively) when considering the base-line scenario. The impact of LTE400 BS with 3GPP minimum requirements for protection of BS receiver of own or different BS is less than 1% in all the simulated scenarios. We note that the allocation of TETRAPOL UL may not fall exactly at the LTE UL operating band frequencies but adjacent. In this case, the LTE BS emissions will be in the same order of magnitude than the minimum requirements.

3.2.2 LTE400 BS impact on TETRAPOL MS

The three-sector LTE400 BS transmits at 461.5 MHz whereas the TETRAPOL MS receive signals coming from TETRAPOL BS between 463 and 465 MHz. The victim frequency is randomly chosen (discrete distribution option) in Table 9 below gives the interference probability as calculated with SEAMCAT when combining unwanted emissions and blocking effects.

Table 9: LTE400 BS impact on TETRAPOL MS

Interferer Density (LTE400 BS / km²)	Cell Radius (km)	Interference Probability with minimum requirements
0.005	5.06	0.32 %
0.0091	3.75	0.61 %
0.01	3.58	0.72 %
0.02	2.53	1.32 %
0.05	1.60	3.34 %

LTE400 BS minimum requirements are already offering a sufficient level of protection with regards to TETRAPOL MS. The highest density cases will benefit from the additional attenuations introduced by the duplexers protecting the LTE400 BS reception band (see above).

3.2.3 LTE400 MS impact on TETRAPOL BS

The LTE400 MS transmit at 451.5 MHz whereas the TETRAPOL BSs receive signals coming from TETRAPOL MS between 453 and 455 MHz. The victim frequency is randomly chosen (discrete distribution option) in SEAMCAT

Table 10 below gives the interference probability as calculated with SEAMCAT when combining unwanted emissions and blocking effects considering 3GPP minimum requirements and a proposed transmission mask consistent with a 37 dBm output power.

Table 10: LTE400 MS impact on TETRAPOL BS

Interferer Density (LTE400 MS / km²)	Interference Probability with minimum requirements	Interference Probability with proposed requirements
0.027	0.80 %	1.52 %
0.082	0.13 %	0.15 %
0.137	0.33 %	0.43 %

The impact of LTE400 MS on TETRAPOL BS is limited and acceptable from the operational point of view even when considering modified requirements for high power devices.

3.2.4 LTE400 MS impact on TETRAPOL MS

The LTE MS transmit at 451.5 MHz whereas the TETRAPOL MS receive signals coming from TETRAPOL BS between 463 and 465 MHz. The victim frequency is randomly chosen (discrete distribution option) in SEAMCAT

Table 11 below gives the interference probability as calculated with SEAMCAT when combining unwanted emissions and blocking effects. The assumed MS emissions is considering 3GPP minimum requirements and a proposed transmission mask consistent with a 37 dBm output power. 3GPP also specifies protection of own DL band as a minimum requirement. This is more stringent than the unwanted emission requirement and thus will further reduce the risk of interference

Table 11: LTE400 MS impact on TETRAPOL MS

Interferer Density (LTE400 MS / km²)	Interference Probability with 3GPP MS spectrum mask minimum requirements	Interference Probability with proposed requirements
0.027	0.05 %	0.05 %
0.082	0.04 %	0.06 %
0.137	0.16 %	0.17 %

The impact of LTE400 MS on TETRAPOL MS is limited and acceptable from the operational point of view even when considering modified requirements for high power devices.

3.3 LTE400 IMPACT ON CDMA-PAMR

For SEAMCAT simulations, frequency allocation has been performed as presented in Figure 6 below. Different interferer densities have been considered around the values calculated in the former section. For each simulation 20 000 SEAMCAT snapshots have been generated.

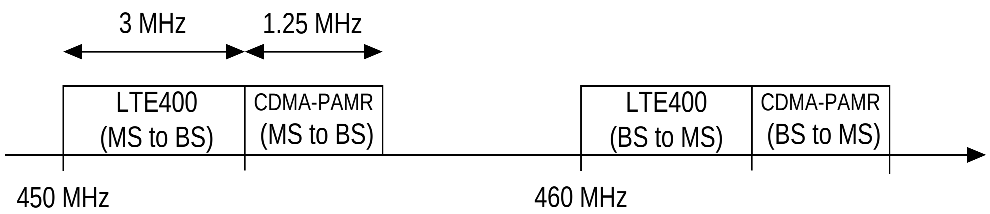

Figure 6: LTE400 on CDMA-PAMR

3.3.1 LTE400 BS impact on a CDMA-PAMR system

The three-sector LTE400 BS transmits at 461.5 MHz whereas the CDMA-PAMR system operates at 453.625 MHz (uplink) and at 463.625 (downlink).

Table 12 below gives the average capacity loss of the CDMA-PAMR system as defined within SEAMCAT. Note that SEAMCAT calculations have been performed using a CDMA-1X link level model as such a model is not available for CDMA-EVDO within SEAMCAT. CDMA-EVDO should offer enhanced performances compared to CDMA-1X.

Interference probabilities are given for the LTE400 BS spectrum emission mask minimum requirements, with 30-dB additional attenuation to the minimum requirements and for the LTE400 BS 3GPP minimum requirements for protection of BS receiver of own or different BS.

Table 12: LTE400 BS impact on CDMA-PAMR system

Interferer density (LTE400 BS / km²)	Cell Radius (km)	With 3GPP spectrum emission mask minimum requirements		With 30 dB additional attenuation compared to 3GPP spectrum emission mask minimum requirements		With minimum requirements for protection of BS receiver of own or different BS	
		System average capacity loss	Reference cell capacity loss	System average capacity loss	Reference cell capacity loss	System average capacity loss	Reference cell capacity loss
CDMA-PAMR Uplink							
0.005	5.06	85.06 %	80.46 %	18.06 %	19.34 %	11.9%	9.8%
0.0091	3.75	92.07 %	81.62 %	23.24 %	19.40 %	10.5%	9.5%
0.02	2.53	89.60 %	94.31 %	29.07 %	24.50 %	10.3%	8.5%
0.05	1.60	99.35 %	99.43 %	32.97 %	36.30 %	9.1%	7.1%
CDMA-PAMR Downlink							
0.005	5.06	7.76 %	0.27 %	7.61 %	0.01 %	N/A	N/A
0.0091	3.75	7.89 %	0.34 %	7.52 %	0.01 %	N/A	N/A
0.02	2.53	7.69 %	0.25 %	7.77 %	0.01 %	N/A	N/A
0.05	1.60	7.56 %	0.15 %	7.61 %	0.00 %	N/A	N/A

The impact of LTE400 BS on CDMA-PAMR Uplink, i.e. on CDMA-PAMR BS, is significantly high and cannot be considered as acceptable from the operational point of view for BS spectrum emission mask. The high probability of interference is due to the LTE400 BS emission mask together with the extremely favourable propagation conditions (antenna heights and antenna gains). By considering 30-dB additional attenuation on the LTE400 BS emission mask within the considered CDMA-PAMR BS reception band, the system capacity loss is reduced from 92.07 % to 23.24 % when considering the base-line scenario. The average capacity loss in the reference cell is reduced from 81.62 % to 19.40 %. It should also be noted that the CDMA-PAMR network uplink noise rise is not significantly increased. For the base-line scenario and 30-dB additional attenuation, its average is increased from 5.53 dB to 5.82 dB, which represents a very limited impact on CDMA-PAMR system. The impact of LTE400 BS with 3GPP minimum requirements for protection of BS receiver of own or different BS varies between 9-11% and 7-10% on the on the system average capacity loss and on reference cell capacity loss, respectively. We note that the allocation of CDMA-PAMR UL may not fall exactly at the LTE UL operating band frequencies but adjacent. In this case, the LTE BS emissions will be in the same order of magnitude than the minimum requirements.

3.3.2 The impact of LTE400 BS on CDMA-PAMR Downlink, i.e. on CDMA-PAMR MS is limited LTE400 MS impact on a CDMA-PAMR system

The LTE400 MSs transmit at 451.5 MHz whereas the CDMA-PAMR system operates at 453.625 MHz (uplink) and at 463.625 (downlink).

Table 13 below gives the average capacity loss of the CDMA-PAMR system as defined within SEAMCAT when considering 3GPP MS spectrum mask minimum requirements and a proposed transmission mask consistent with a 37 dBm output power. 3GPP also specifies protection of own DL band as a minimum requirement. This is more stringent than the unwanted emission requirement and thus will further reduce the risk of interference. Note that SEAMCAT calculations have been performed using a CDMA-1X link level as such a model is not available for CDMA-EVDO within SEAMCAT. CDMA-EVDO should offer enhanced performances compared to CDMA-1X.

Table 13: LTE400 MS impact on CDMA-PAMR system

Interferer density (LTE400 MS / km²)	With minimum requirements		With proposed requirements	
	System average capacity loss	Reference cell capacity loss	System average capacity loss	Reference cell capacity loss
CDMA-PAMR Uplink				
0.027	22.30 %	18.75 %	24.76 %	23.02 %
0.082	18.41 %	16.50 %	19.21 %	18.02 %
0.137	18.77 %	16.49 %	18.45 %	17.55 %
CDMA-PAMR Downlink				
0.027	7.51 %	0.02 %	7.58 %	0.03 %
0.082	7.46 %	0.02 %	7.60 %	0.02 %
0.137	7.57 %	0.03 %	7.49 %	0.02 %

The impact of LTE400 MS on CDMA-PAMR Uplink and Downlink is limited and can be considered as acceptable from the operational point of view. It should also be noted that the CDMA-PAMR network uplink noise rise is not significantly increased for MS spectrum emission mask 3GPP minimum requiremet. For the medium density case, its average is increased from 5.56 dB to 5.69 dB with 3GPP spectrum mask minimum requirements and from 5.56 dB to 5.77 dB with the proposed requirement, which represents a very limited impact on CDMA-PAMR system. The impact is expected to be even lower if the own DL protection requirement is considered.

3.4 LTE400 IMPACT ON ANALOGUE FM PMR

For SEAMCAT simulations, frequency allocation has been performed as presented in Figure 7 below. Different interferer densities have been considered around the values calculated in the former section. For each simulation, 20 000 SEAMCAT snapshots have been generated.

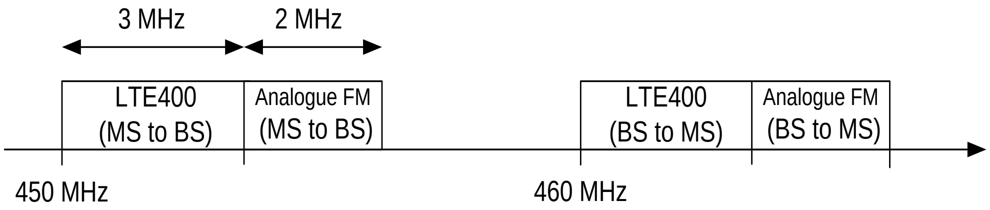

Figure 7: LTE400 on Analogue FM

The results presented below for 25 kHz Analogue FM systems are also valid for other analogue channel widths as those systems are presenting similar technical characteristics (see ANNEX 1:).

3.4.1 LTE400 BS impact on 25 kHz Analogue FM BS

3.4.1.1 Overall assessment

The three-sector LTE400 BS transmit at 461.5 MHz whereas the 25 kHz Analogue FM BSs receive signals coming from 25 kHz Analogue FM MS between 453 and 455 MHz. The victim frequency is randomly chosen (discrete distribution option) in SEAMCAT.

Table 14 below gives the interference probability as calculated with SEAMCAT and combining unwanted emissions and blocking effects. Interference probabilities are given for the LTE400 BS 3GPP spectrum emission mask minimum requirements and, 25 dB or 30 dB additional attenuations to the minimum requirements and for LTE400 BS protection of own UL emission requirement.

Table 14: LTE400 BS impact on 25 kHz Analogue FM BS

Interferer Density (LTE400 BS / km²)	Cell Radius (km)	Interference Probability with 3GPP BS spectrum emission mask minimum requirements	Interference Probability with 25 dB additional attenuation compared to 3GPP BS spectrum emission mask	Interference Probability with 30 dB additional attenuation compared to 3GPP BS spectrum emission mask	Interference Probability with minimum requirements for protection of BS receiver of own or different BS
0.005	5.07	30.44 %	2.37 %	1.04 %	0.26%
0.0091	3.75	41.43 %	3.83 %	2.05 %	0.45%
0.01	3.58	43.53 %	4.12 %	2.28 %	1.21%
0.05	1.60	74.12 %	16.72 %	9.83 %	2.57%

The impact of LTE400 BS with 3GPP spectrum emission mask minimum requirements on 25 kHz Analogue FM BS is significantly high and cannot be considered as acceptable from the operational point of view. The high probability of interference is due to the LTE400 BS emission mask together with the favourable propagation conditions (antenna heights and antenna gain). Introducing a further 25 dB (or 30 dB) additional attenuation on the LTE400 BS emission mask within the 25 kHz Analogue FM BS reception band, the interference probability is reduced from 41.43 % to 3.83 % (or 2.05 % respectively) when considering the base-line scenario. The impact of LTE400 BS with 3GPP minimum requirements for protection of BS receiver of own or different BS is between 0.3 and 2.6 % in all the simulated scenarios. We note that the allocation of analogue FM UL may not fall exactly at the LTE UL operating band frequencies but adjacent. In this case, the LTE BS emissions will be in the same order of magnitude than the minimum requirements.

3.4.1.2 Geographical coordination

Due to limited blocking performance of PMR BSs, PPDR BS may cause performance degradation of the PMR BSs over mean distances of 2.3 km. Therefore deployment of nearby sites will require coordination.

In addition, OOB emissions of PPDR BSs should not exceed -43 dBm/100kHz in the uplink band 450-460 MHz in order to not degrade further the performance of PMR BSs.

3.4.2 LTE400 BS impact on 25 kHz Analogue FM MS

3.4.2.1 Overall assessment

The three-sector LTE400 BS transmits at 461.5 MHz whereas the analogue FM MSs receive signals coming from 25 kHz Analogue FM BS between 463 and 465 MHz. The victim frequency is randomly chosen (discrete distribution option) in SEAMCAT.

Table 15 below gives the interference probability as calculated with SEAMCAT when combining unwanted emissions and blocking effects.

Table 15: LTE400 BS impact on 25 kHz Analogue FM MS

Interferer Density (LTE400 BS / km²)	Cell radius (km)	Interference Probability with minimum requirements
0.005	5.07	0.38 %
0.00912	3,75	0.95 %
0.01	3.58	1.06 %
0.05	1.60	4.76 %

LTE400 BS minimum requirements are already offering a sufficient level of protection with regards to 25 kHz Analogue FM MS. The highest density cases will benefit from the additional attenuations introduced by the duplexers protecting the LTE400 BS reception band (see above).

3.4.2.2 Geographical coordination

Due to limited blocking performance of PMR MSs, PPDR BS may cause performance degradation of the PMR MSs over mean distances of 200 m.

OOB emissions of PPDR BS may also extend the zone up to a mean radius of 2.5 km. In order to ease the coordination process and reduce the number of possible interference cases, OOB emissions of PPDR BS should not exceed -43 dBm/100kHz at frequency offset greater than 1 MHz from PPDR BS band edge. Whenever PPDR and PMR are deployed with smaller offsets, coordination may be required.

3.4.3 LTE400 MS impact on 25 kHz Analogue FM BS

The LTE400 MSs transmit at 451.5 MHz whereas the analogue FM BSs receive signals coming from 25 kHz Analogue FM MS between 453 and 455 MHz. The victim frequency is randomly chosen (discrete distribution option) in SEAMCAT.

Table 16 below gives the interference probability as calculated with SEAMCAT when combining unwanted emissions and blocking effects considering 3GPP minimum requirements and a proposed transmission mask consistent with a 37 dBm output power.

Table 16: LTE400 MS impact on 25 KHz Analogue FM BS

Interferer Density (LTE400 MS / km²)	Interference Probability with minimum requirements	Interference Probability with proposed requirements
0.027	1.46 %	2.87 %
0.082	0.75 %	0.94 %
0.137	1.09 %	0.81 %

The impact of LTE400 MS on 25 kHz Analogue FM BS is limited and acceptable from the operational point of view even when considering modified requirements for high power devices.

3.4.4 LTE400 MS impact on 25 kHz Analogue FM MS

The LTE400 MSs transmit at 451.5 MHz whereas the analogue FM MSs receive signals coming from 25 kHz analogue FM BS between 463 and 465 MHz. The victim frequency is randomly chosen (discrete distribution option) in SEAMCAT.

Table 17 below gives the interference probability as calculated with SEAMCAT when combining unwanted emissions and blocking effects considering 3GPP MS spectrum mask minimum requirements and a proposed transmission mask consistent with a 37 dBm output power. Note that 3GPP also specifies protection of own DL band, which more stringent than the unwanted emission requirement and thus will further reduce the risk of interference.

Table 17: LTE400 MS impact on 25 kHz analogue FM MS

Interferer Density (LTE400 MS / km²)	Interference Probability with minimum requirements	Interference Probability with proposed requirements
0.027	0.01 %	0.00 %
0.082	0.01 %	0.00 %
0.137	0.02 %	0.01 %

The impact of LTE400 MS on 25 kHz Analogue FM MS is limited and acceptable from the operational point of view even when considering modified requirements for high power devices

3.5 LTE400 IMPACT ON DTT RECEPTION

3.5.1 Monte-Carlo simulations (SEAMCAT)

3.5.1.1 Channelling configuration

The starting point channelling configuration studied is depicted in Figure 1 (conventional LTE channelling arrangement). In this configuration the guard band between DDTB lower band edge and PPDR higher band edge is 0 MHz (DTT-PPDR guard band = 0 MHz).

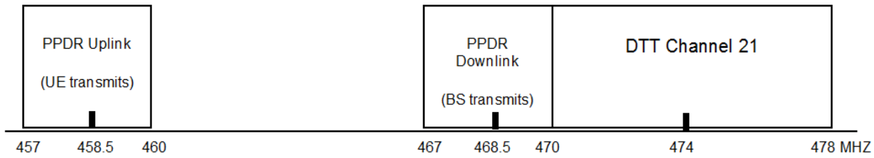

Figure 8: PPDR (LTE) 400 MHz operating in an adjacent band to DTT channel 21 (GB=0 MHz)

Simulations have been carried out across the DTT cell as well as at the DTT cell edge for assessing the potential interference from Broadband PPDR to DTT rooftop fixed reception:

- In case of interference from PPDR BS to DTT reception, DTT- PPDR guard bands (GB) of 0, 1, 2, 3, 4, 5 and 6 MHz were considered. For each guard band, the following BS ACLR values have been used: 42, 52, 60, 67 and 73 dB/8MHz in DTT CH21, with respect to 60 dBm e.i.r.p.;
- In case of interference from PPDR UE to DTT reception, a DTT- PPDR BS guard band of 0 MHz (PPDR UE - DTT GB = 10 MHz) and the following UE ACLR values have been used: 65, 70 and 79 dB/8MHz in DTT CH21, with respect to 37 dBm e.i.r.p..

The reason of the use of this single GB value in the latter case is that at the present time we do not have any knowledge of the variation of DTT receivers ACS beyond a PPDR UE - DTT GB of 10 MHz in the presence of a 3 MHz PPDR (LTE) interfering signal.

3.5.1.2 DTT receiver ACS

The following DTT receiver ACS values have been used in this study, see ANNEX 6:.

Table 18: Measured DTT receiver ACS values

DTT receiver ACS values as a function of PPDR-DTT guard band						
DTT-PPDR GB (MHz)	0	1	2	3	6	10
DTT Rx ACS (dB)	56.3	58.2	57.8	60.8	62.3	65

3.5.1.3 Simulation method (SEAMCAT)

For analysis of the impact of 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 ANNEX 4:.

For LTE MS several different Monte Carlo simulation methods were previously 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 insufficiency of the IP calculation vis-à-vis interference into the broadcasting service and the need to take the time into account when dealing with IMT UE interference. PPDR studies may require similar treatment when dealing with certain aspects of PPDR interference to broadcasting. This is not considered in this study.

A PPDR network cluster of 7 tri-sector sites (21 cells) is considered. The impact of adjacent-channel interference is evaluated, for fixed roof top DTT reception, across the DTT cell as well as at the DTT cell edge, DTT receiver' antennas being directed toward the DTT transmitter. 500 000 – 2 000 000 events have been generated per simulation. The following interference cases are considered:

- Assessment of the probability of interference across the DTT cell:
  - at each simulation run (event), the DTT receiver is randomly positioned, following a uniform polar distribution, within the DTT cell;
  - for each generated DTT receiver point, a PPDR network cluster is generated around the DTT victim receiver. The relative position between the victim DTT receiver and the central PPDR BS is randomly generated, following a uniform polar distribution, within the PPDR cell range;
  - 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 ANNEX 4:.
- Assessment of the probability of interference at the DTT cell edge:
  - a pixel of 100 m x 100 m is positioned at DTT cell edge;
  - at each simulation run (event), DTT receiver location is randomly positioned, following a uniform distribution, within this pixel;
  - for each generated DTT receiver point with the pixel, a PPDR network cluster is generated around the DTT victim receiver. The relative position between the victim DTT receiver and the central PPDR BS is randomly generated, following a uniform polar distribution, within the PPDR cell range (see Figure 49).
  - 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 ANNEX 4:.

The results obtained are presented as probability of interference (pI) to DTT reception, which is location probability degradation (ΔpRL) of DTT reception in the case of interference from PPDR base station and as probability of interference (pI) to DTT reception in the case of interference from PPDR user equipment (see ANNEX 4:).

3.5.1.4 Simulation results: Impact of BB PPDR (LTE) 400 MHz base station on DTT reception (SEAMCAT):

Probability of interference across the DTT cell:

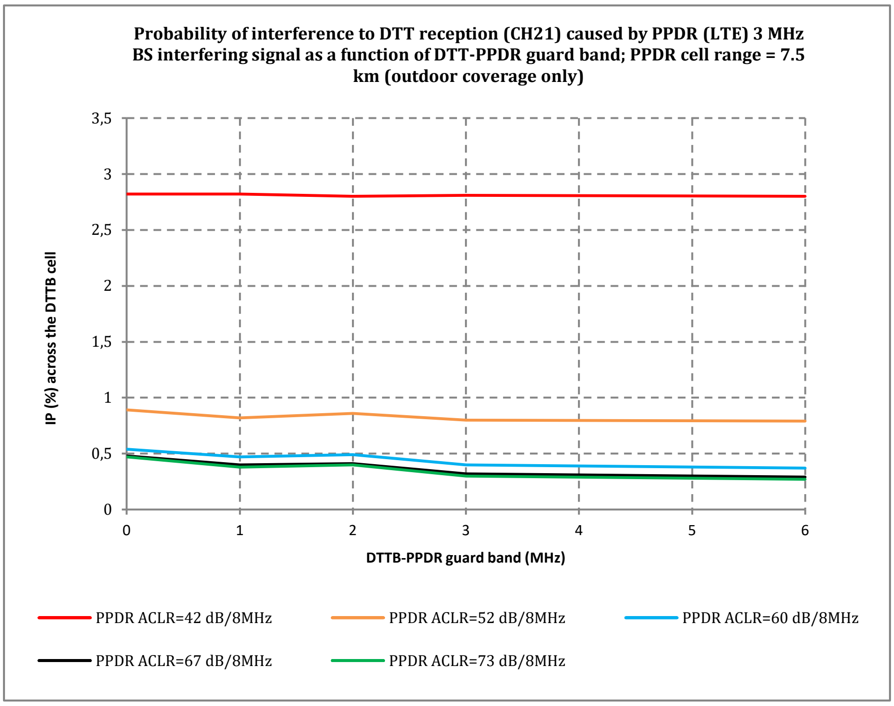

Figure 9: LTE400 BS (e.i.r.p. 60 dBm/3MHz, cell range 7.5 km) impact on DTT reception

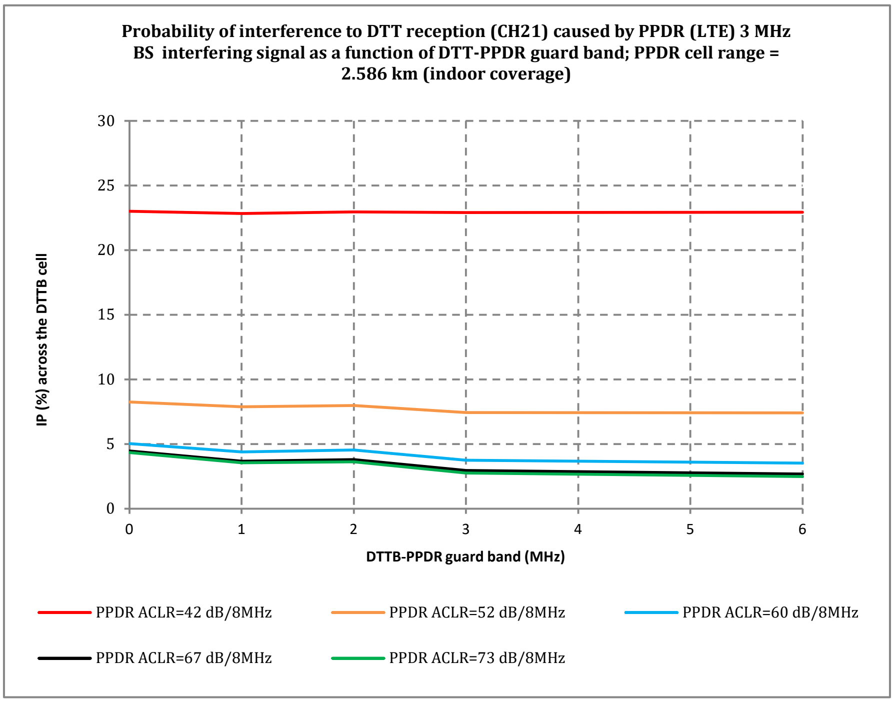

Figure 10: LTE400 BS (e.i.r.p.60 dBm/3MHz, cell range 2.568 km) impact on DTT reception

The above results show that:

- Across the DTT cell, without a guard band, the improvement of PPDR BS ACLR from 42 to 67 dB/8 MHz for LTE400 BS of 60 dBm/3MHz e.i.r.p. reduces:
  - the pI to DTT reception from 2.82 % to 0.48 % in the case of a PPDR cell range of 7.5 km;

  - the pI to DTT reception from 23 % to 4.45 % in the case of a PPDR cell range of 2.586 km.
- As we can see on Figure 11 below, which is a zoom on Figure 9, the limiting factor is the ACS of DTT receiver and therefore the improvement of the ACLR beyond 67 dB does not improve notably the pI to DTT reception.

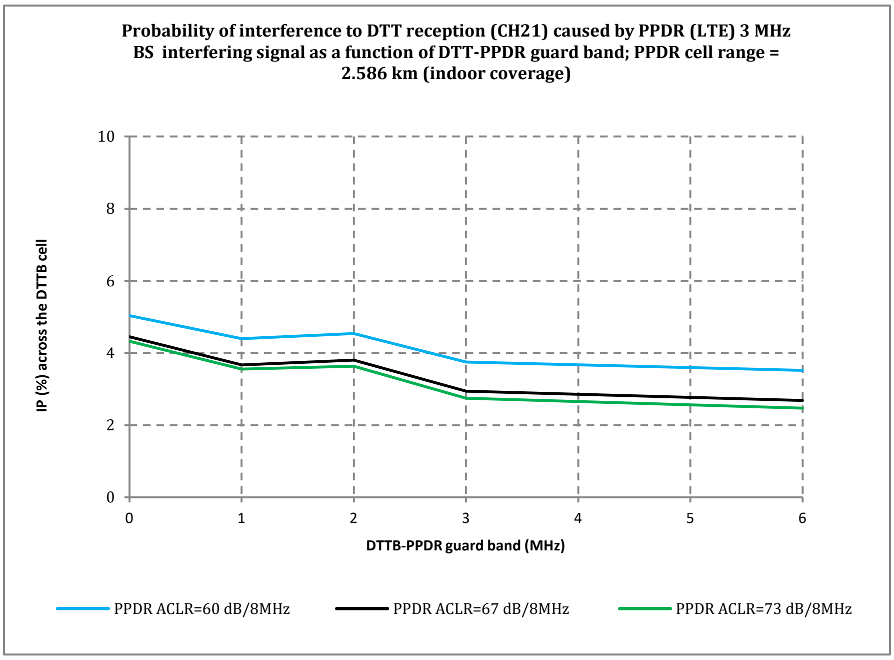

Figure 11: LTE400 BS (e.i.r.p. 60 dBm/3MHz, cell range 2.568 km) impact on DTT reception

With a BS ACLR of 67 dB/8MHz, (assuming e.i.r.p. 60 dBm/3MHz) and over the range of guard bands investigated, from 0 to 6 MHz:

- the pI to DTT reception ranges from 0.48 % to 0.29 % in the case of a PPDR cell range of 7.5 km;
- the pI to DTT reception ranges from 4.45 % to 2.68 % in the case of a PPDR cell range of 2.568 km.

Probability of interference at the DTT cell edge:

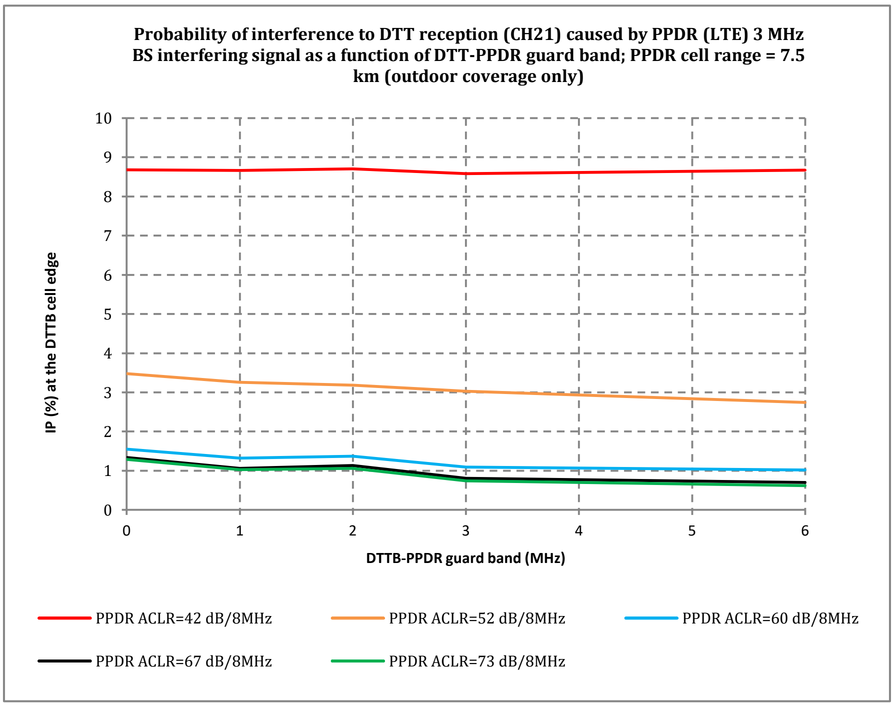

Figure 12: LTE400 BS (e.i.r.p. 60 dBm/3MHz, cell range 7.5 km) impact on DTT reception at DTT cell edge

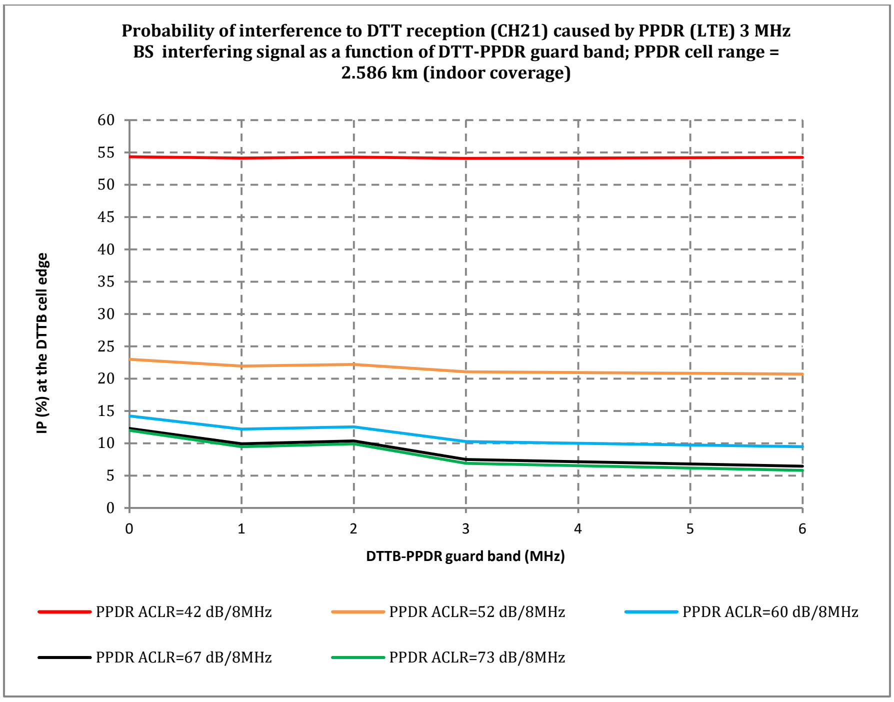

Figure 13: LTE400 BS (e.i.r.p. 60 dBm/3MHz, cell range 2.568 km) impact on DTT reception at DTT cell edge

The above results show that:

- At the DTT cell edge, without a guard band, the improvement of PPDR BS ACLR from 42 to 67 dB/8 MHz for LTE400 BS of 60 dBm/3MHz e.i.r.p. reduces:
  - the pI to DTT reception from 8.68 % to 1.34 % in the case of a PPDR cell range of 7.5 km;
  - the pI to DTT reception from 54.33 % to 12.29 % in the case of a PPDR cell range of 2.586 km.
- As we can see on Figure 14 below, which is a zoom on Figure 12, the limiting factor is the ACS of DTT receiver, and therefore the improvement of the ACLR beyond 67 dB does not improve notably the pI to DTT reception.

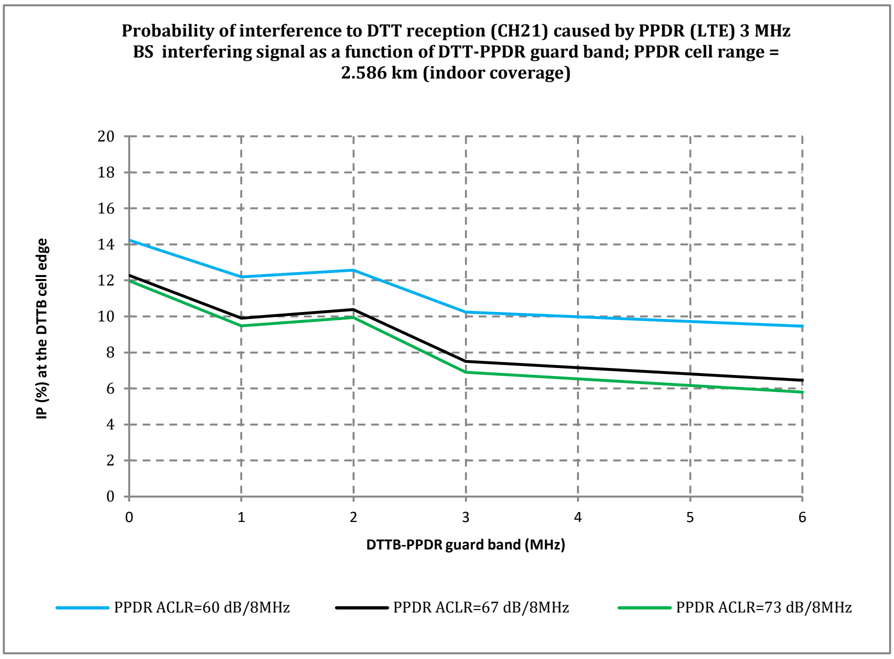

Figure 14: LTE400 BS (e.i.r.p. 60 dBm/3MHz, cell range 2.568 km) impact on DTT reception at DTT cell edge

With a BS ACLR of 67 dB/8 MHz,(assuming e.i.r.p. 60 dBm/3MHz) and over the range of guard bands investigated, from 0 to 6 MHz:

  - the pI to DTT reception ranges from 1.34 % to 0.7 % in case of a PPDR cell range of 7.5 km;

- the pI to DTT reception ranges from 12.29 % to 6.46 % in case of a PPDR cell range of 2.586 km.

The detailed results are provided in ANNEX 8:.

3.5.1.5 Simulation results: Impact of BB PPDR (LTE) 400 MHz user equipment on DTT reception (SEAMCAT):

Probability of interference across the DTT cell

This is the average probability across the DTT cell at any given moment in time. It is not the probability of seeing interference in 1 hour.

The UE density figures used in the following are based on the assumption that the PPDR 400 MHz networks will be mainly used in sparsely populated areas, therefore the density figures include values lower than those assumed for PPDR networks in higher frequency bands (700 MHz), which will be mainly used in densely populated areas.

Table 19: LTE400 MS impact on DTT reception in the DTT cell

Probability of interference to DTT reception across the DTT cell; PPDR 3 MHz UE interfering signals; DTT-PPDR guard band = 0 MHz						
UE e.i.r.p (dBm)	PPDR cell range (km)	N of transmitting UE/sector	UE density(1, 2) ($1/km^2$)	UE ACLR = 65 dB/8MHz	UE ACLR = 70 dB/8MHz	UE ACLR = 79 dB/8MHz
				pI (%)	pI (%)	pI (%)
37	2.586	1	0.23	0.017	0.013	0.012
		3	0.69	0.036	0.033	0.033
		5	1.154	0.06	0.05	0.047
1 It is understood that a transmitting user equipment (UE) is transmitting. Therefore the densities given refer to the number of simultaneously transmitting UEs 2 Indoor / outdoor user equipment = 25% / 75%						

The above results show that:

- Across the DTT cell, without a guard band (PPDR UE-DTT guard band = 10 MHz), for the UE densities of 0.23 and $1.15/km^2$:
  - the pI to DTT reception varies from 0.017 to 0.06 %, in the case of a PPDR UE ACLR of 65 dB/8 MHz;
  - the pI to DTT reception varies from 0.013 to 0.05 %, in the case of with a PPDR UE ACLR of 70 dB/8 MHz;
  - the pI to DTT reception varies from 0.012 to 0.047 %, in the case of a PPDR UE ACLR of 79 dB/8 MHz.
- The improvement of PPDR UE ACLR from 65 to 79 dB/8 MHz reduces:
  - the pI to DTT reception from 0.017 to 0.012 %, in the case of a UE density of $0.23/km^2$;
  - the pI to DTT reception from 0.06 to 0.047 %, in the case of a UE density of $1.15/km^2$.
- The limiting factor being the ACS of DTT receiver, the improvement of the ACLR beyond 79 dB does not improve notably the pI to DTT reception.

Probability of interference at the DTT cell edge'

Table 20: LTE400 MS impact on DTT reception at the DTT cell edge

Probability of interference to DTT reception at the DTT cell edge; PPDR 3 MHz UE interfering signals; DTT-PPDR guard band = 0 MHz						
UE e.i.r.p (dBm)	PPDR cell range (km)	N of transmitting UE/sector	UE density(1, 2) ($1/km^2$)	UE ACLR = 65 dB/8MHz	UE ACLR = 70 dB/8MHz	UE ACLR = 79 dB/8MHz
				pI (%)	pI (%)	pI (%)
37	7.5	1	0.0273	0.0140	0.0065	0.0061

Probability of interference to DTT reception at the DTT cell edge; PPDR 3 MHz UE interfering signals; DTT-PPDR guard band = 0 MHz						
		2	0.0547	0.0154	0.0124	0.0106
		3	0.0821	0.0287	0.0241	0.0210
		5	0.1369	0.0447	0.0401	0.0350
	2.568	1	0.2302	0.0300	0.0298	0.0270
		2	0.4604	0.0701	0.0441	0.0416
		3	0.6907	0.0817	0.0710	0.0673
		5	1.1511	0.1469	0.1075	0.1056

1 It is understood that an transmitting user equipment (UE) is transmitting. Therefore the densities given refer to the number of simultaneously transmitting UEs

2 Indoor / outdoor user equipment =25% / 75%

The above results show that:

- At the DTT cell edge, without a guard band (PPDR UE-DTT guard band = 10 MHz), for the UE densities of 0.02737 and 1.15/km^2:
  - the pI to DTT reception varies from 0.014 to 0.15 %, in the case of a PPDR UE ACLR of 65 dB/8 MHz;
  - the pI to DTT reception varies from 0.0065 to 0.107 %, in the case of with a PPDR UE ACLR of 70 dB/8 MHz;
- the pI to DTT reception varies from 0.006 to 0.106 %, in the case of a PPDR UE ACLR of 79 dB/8 MHz.
- The improvement of PPDR UE ACLR from 65 to 79 dB/8 MHz reduces:
  - the pI to DTT reception from 0.014 to 0.006 %, in the case of a UE density of 0.02737/km^2;
  - the pI to DTT reception from 0.147 to 0.1 %, in the case of a UE density of 1.15/km^2.
- The limiting factor being the ACS of DTT receiver, improvement of the ACLR beyond 79 dB does not improve notably the pI to DTT reception.

For the case of a UE density of 1.15/km^2 an IP of about 0.1 % is found. For comparison, the IP for similar density for PPDR 700 MHz is 0.005 %.

3.5.2 Comparison of LTE UE and PPDR vehicle UE impact on DTT reception

Although the guard band between PPDR UEs and DTT on channel 21 is at least 10 MHz, the implementation margins of DTT reception at cell edge can be degraded at distances up to 100 m from PPDR UEs transmitting with an e.i.r.p. of 37 dBm.

3.5.2.1 MCL Study

An analysis based on Minimum Coupling Loss (MCL) is carried out to study the potential impact of vehicle mounted PPDR 400 MHz UE to DTT fixed roof top reception. For comparison purposes, results for commercial LTE 700 MHz UEs are also provided. Similar frequency separation is foreseen between the UE and the DTT channels for the two systems. More precisely, the minimum frequency separation (channel edge to channel edge) is 9 MHz between LTE UE 700 MHz and DTT channel 48 and it is assumed to be 10 MHz between PPDR 400 MHz UE and DTT channel 21.

The calculations are shown in Table 21 and Figure 15 below.

The high transmit power of the PPDR 400 MHz UE (37 dBm e.i.r.p compared to 20 dBm for the commercial 700MHz LTE UE) and the absence of 4 dB body loss in the case of vehicle mounted PPDR UE increase the potential impact on DTT roof top reception. For the reference geometry corresponding to the minimum coupling loss (22 m horizontal separation distance) the impact in term of C/N degradation of the DTT receiver caused by the considered PPDR UE is 20 dB higher than for commercial LTE UE.

Alternatively, if a similar level of C/N degradation is sought from the PPDR UE and from LTE UE, then the separation distance between the PPDR UE and the DTT roof top antenna in a suburban area should be increased to around 68 m.

Table 21: MCL Comparison between the impact of commercial LTE UE in the 700 MHz band (transmitting at 23 dBm) and PPDR UE in the 400 MHz band (transmitting at 37 dBm) on DTT fixed roof top reception

		DTT fixed reception LTE UE 9 MHz Guard Band	DTT fixed reception PPDR UE high power 10 MHz guard band	DTT fixed reception PPDR UE high power 10 MHz guard band	
Parameter	**Units**	**Value**	**Value**	**Value**	**Comment**
Frequency	MHz	690	474	474	fo
Receiver NF	dB	7.00	7.00	7.00	NF
Thermal noise floor (8MHz)	dBm	-98.17	-98.17	-98.17	Pn = 10log(kTB) + NF + 30
In-block transmit power	dBm/(5MHz)	23.00	37.00	37.00	PTx
Interferer antenna gain	dBi	-3.00	0.00	0.00	GTx
EIRP	**dBm/(5 MHz)**	**20.00**	**37.00**	**37.00**	Pe.i.r.p. = PTx + GTx
Rx Tx horizontal distance	m	22	22	68	d_h separation distance
Tx height	m	1.5	1.5	1.5	h_{Tx}
Rx height	m	10	10	10	h_{Rx}
Path distance	m	23.6	23.6	68.5	$D = sqrt(d_h^2 + (h_{Rx} – h_{Tx})^2)$
Free space attenuation (for information only)	**dB**	**56.67**	**53.41**	**62.67**	LFs
Hata attenuation (suburban) cut off at FS	**dB**	**56.67**	**53.41**	**75.28**	L_{hata}
Rx antenna elevation discrimination gain	dB	0.45	0.45	0.00	G_{Dir}
Rx antenna bore-sight gain (including feeder loss)	dBi	9.15	9.15	9.15	G_{Rx}
Body loss	dB	4	0	0	L_{Body}
Wall Loss	dB	0	0	0	L_{wall}
Total coupling gain	**dB**	**51.97**	**44.71**	**66.13**	$G_{Tot} = L_{hata} + G_{Dir} - G_{Rx} + L_{body} + L_{wall}$
ACS	**dB**	**65.00**	**65.00**	**65.00**	ACS
ACLR	**dB**	**65.00**	**79.00**	**79.00**	ACLR
OOBE (TX)	**dBm/(8 MHz)**	**-42.00**	**-42.00**	**-42.00**	$OOBE = P_{TX}$ - ACLR
ACIR	dB	61.99	64.83	64.83	$-10LOG(10^{(-ACS/10)}+10^{(-ACLR/10)})$
Interference power	**dBm**	**-93.96**	**-72.54**	**-93.96**	$PI = P_{e.i.r.p} - G_{Tot}$ - ACIR
I/N	dB	4.21	25.63	4.21	INR = PI - Pn
Receiver Desensitisation (C/N Degradation)	dB	5.61	25.64	5.60	D=10*log(1+10^(INR/10))

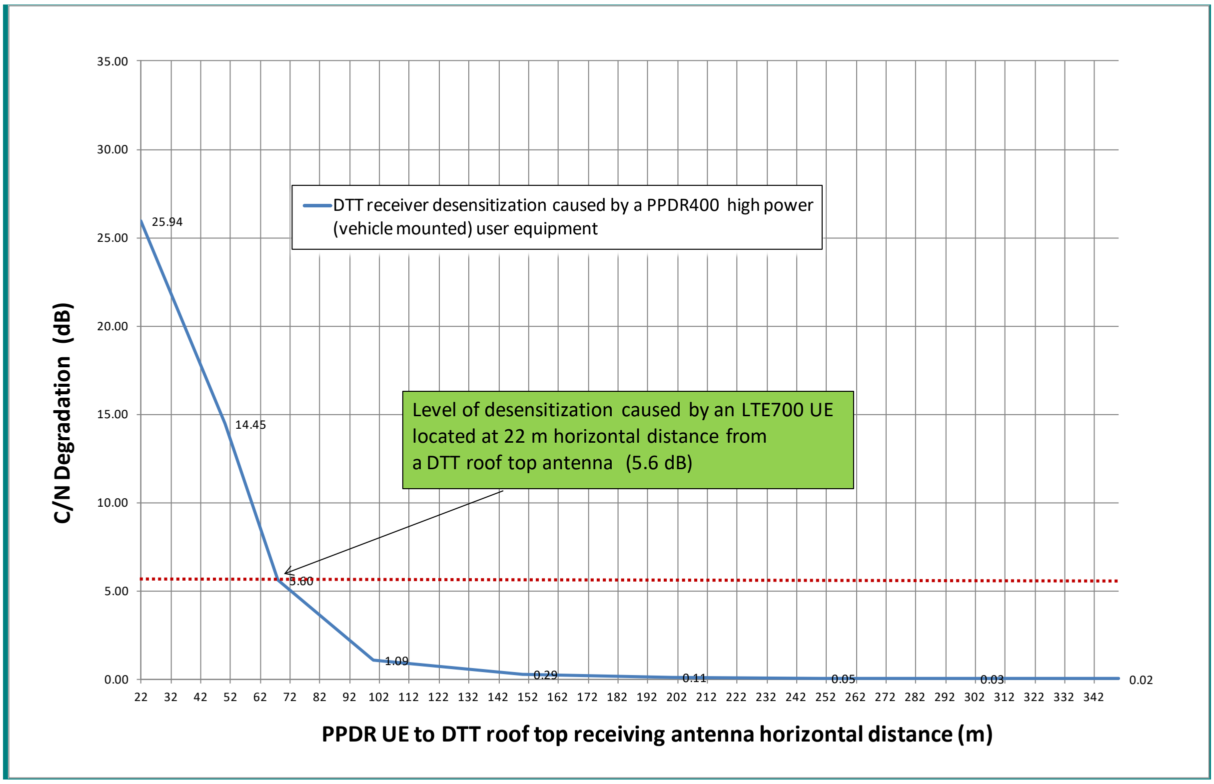

Figure 15: C/N degradation vs horizontal separation distance between LTE UE and DTT reception

Figure 15 shows the DTT Receiver desensitization due to adjacent channel interference from a PPDR high power UE (vehicle mounted) using a channel separated by 10 MHz from a DTT channel, compared to DTT Receiver desensitisation due to adjacent channel interference from an LTE UE (handset) using a channel separated by 9 MHz from a DTT channel (conditions related to the 700 MHz band).

The limiting factor for the compatibility between DTT and PPDR UE in 400 MHz is the DTT ACS performance. To allow for a similar C/N degradation at the DTT receiver input as the C/N degradation generated by a commercial LTE

UE in the 700 MHz band while keeping the DTT ACS performance, the LTE400 PPDR UE (vehicle mounted)transmit power of 37 dBm has to be reduced

3.5.2.2 Conclusions

The high transmit power of the PPDR user equipment generates risk of interference in the DTT channel 21 based on MCL calculations, assuming DTT ACS of 65 dB. The risk of interference is dominated by the DTT RX performance.

As the PPDR user equipment is mobile it would be very difficult to improve this situation by applying mitigation techniques (e.g. external filtering of the DTT receiving installation) on a case by case basis because the position of the PPDR UE cannot be predicted.

A possible way to reduce the risk of interference to the existing DTT receivers would be to reduce the e.i.r.p of the PPDR UE when the UE is operating within a coverage area of DTT channel 21.

Concerning the required Out Of Band Emission (OOBE) limit of the PPDR UE, the same limit as the one specified by the CEPT for the commercial LTE UE, i.e. -42 dBm / 8 MHz in the spectrum used for broadcasting, for a PPDR signal bandwidth of 10 MHz or less, has been assumed in this study.

Table 22 and Table 23 show the parameters for the 400 MHz PPDR UE that would be suitable to limit interference to DTT channel 21 to the same levels as the interference from commercial 700 MHz LTE UE to DTT channel 48. The lower path loss between UE and DTT receive antenna at 400 MHz when compared with 700 MHz results in more onerous restrictions to limit DTT receiver desensitisation to the same levels as 700 MHz commercial UE.

Table 22: LTE400 handheld MS power restrictions to limit DTT receiver desensitisation to the same level as desensitisation due for LTE Commercial UEs within 703-713MHz

	DTT Ch 48	DTT Ch21	DTT Ch22	DTT Ch23 and above
Interferer	LTE UE 703-713	PPDR UE 454-457	PPDR UE 454-457	PPDR UE 454-457
DTT Receiver ACS (dB)	65 [1]	70	75	80
UE Max Power (dBm)	23	23	27	27
UE ACLR (dB)	65	75	75	75
OOBE (dBm / 8 MHz)	-42	-52	-48	-48
Guard Band (MHz)	9	13	21	29
DTT receiver sensitivity degradation (dB)	5.61	3.35	3.72	2.7

Table 23: LTE400 vehicle mounted MS power restrictions to limit DTT receiver desensitisation to the same level as desensitisation due for LTE Commercial UEs within 703-713MHz

	CH 48	DTT Ch21	DTT Ch22	DTT Ch23 and above
Interferer	LTE UE	PPDR UE	PPDR UE	PPDR UE

[1] DTT receiver ACS for the reference situation assuming a 10 MHz LTE service, a 9 MHz guard band, 23 dBm UE transmitter power, -3 dBi UE antenna gain and 4 dB bodyloss as used in ECC Report 53.

	CH 48	DTT Ch21	DTT Ch22	DTT Ch23 and above
	703-713	454-457	454-457	454-457
DTT Receiver ACS (dB)	65 [1]	70	75	80
UE Max Power (dBm)	23	21	26	31
UE ACLR (dB)	65	90	90	100
OOBE (dBm / 8 MHz)	-42	-69	-64	-69
Guard Band (MHz)	9	13	21	29
DTT receiver sensitivity degradation (dB)	5.61	5.82	5.78	5.61

3.5.3 Local interference analysis

3.5.3.1 Minimum coupling loss analysis for PPDR BS interference to DTT

In the previous study, the overall extent of the interference from PPDR to DTT reception has been investigated. The minimum coupling loss analysis complements the previous study highlighting that interference occurs in the vicinity of the BS. Also the study emphasizes on the improvements of receivers ACS and OOB emissions filtering that could solve interference cases.

Table 24 below shows the parameters used to assess the risk of interference from 400 MHz PPDR base stations into DTT reception, using the following criteria:

1. Interference to Noise ratio (I/N) and corresponding degradation in Carrier to Noise ratio (C/N) due to the increase of the overall system noise power. These criteria are relevant with regard to the risk of overloading of transmitting receiving installations, which use wide band amplifiers. These latter are sensitive to the increase of the overall system noise power.

2. Excess of the DTT receiver overloading threshold due to high level of adjacent channel interference.

Table 24: Parameters and formulas used in the MCL analysis (see Figure 16 for the Geometries involved)

Parameter	Units	Value	Notation/Formula
Frequency	MHz	474	f0
DTT Receiver NF	dB	7	NF
DTT Thermal noise floor (8MHz)	dBm	-98.17	P_n = 10log(kTB) + NF + 30
PPDR In-block transmit Power	dBm/(5 MHz)	47	P_{out}
Antenna Gain	dBi	15	$G_{ant(iso)}$
Feeder loss	dB	2	F_{loss}
PPDR e.i.r.p.	dBm/(5 MHz)	60.00	$P_{e.i.r.p} = P_{out} + G_{ant(iso)} - F_{loss}$
GEOMETRIES			
Rx Tx horizontal distance	m	100 to 10000	d_h separation distance
PPDR Tx height	m	30	h_{Tx}

Rx height	m	10	h_{Rx}
Path distance	m	102.0 to 10000	$D = sqrt(d_h^2 + (h_{Rx} – h_{Tx})^2)$
Free space attenuation	dB	66.13 to 105.96	L_{Fs}
Hata attenuation (suburban) cut off at FS	dB	66.13 to 126.98	L_{hata}
Elevation angle for the Tx antenna	degrees	-11.3 to -0.1	$θ_{elev}$
PPDR Tx Tilt	degrees	-3	T_{xtilt}
Tx angle incl. tilt	degrees	-8.3 to +2.9	$T_{angle} = θ_{elev} – T_{xtilt}$
Tx antenna elevation discrimination (real antenna pattern and calculation as in Seamcat) (For information only)	dB	1.0 to 0	G_{TDir}
Tx antenna elevation discrimination (Recommendation ITU-R F.1336 [20])	dB	3.06 to 0.33	G_{TDir}
DTT Rx antenna net gain	dBi	9.15	G_{Rx}
DTT Rx antenna tilt	degrees	0	R_{xtilt}
Rx angle including tilt	degrees	+11.3 to +0.1	$R_{angle} = θ_{elev} + R_{xtilt}$
Rx antenna elevation discrimination	dB	0	G_{RDir}
PPDR Tx / DTT Rx cross polar discrimination	dB	3	G_{Rpol}
Total coupling gain	dB	63.04 to 121.16	$G_{Tot} = Max(L_{FS}; L_{hata})+G_{TDir}-G_{Rx}+G_{RDir}+G_{Rpol}$
Rx ACS	dB	56.3to 65 (see Table 18)	ACS
Tx ACLR	dB	42, 60, 73, 80	ACLR
Tx OOBE (e.i.r.p)	dBm/(8 MHz)	18, 0, -13, -20	$OOBE = P_{e.i.r.p.} - ACLR$
ACIR	dB	51.57 to 76.99	$ACIR = -10LOG(10^{(-ACS/10)}+10^{(-ACLR/10)})$
Interference power	dBm	-54.61 to -138.15	$P_I = P_{e.i.r.p} - G_{Tot} - ACIR$
I/N	dB	43.56 to -39.98	$INR = P_I - P_n$
DTT Receiver Desensitisation(C/N Degradation)	dB	43.56 to 0	D=10*log(1+10^(INR/10)) (See note 2 below)
DTT Receiver Overloading threshold	dBm	-22.00	O_{th}

Interference excess relative to DTT O_{th}	dB	18.96 to -63.16	$Xs_{th} = P_{e.i.r.p} - G_{Tot} - O_{th}$ - additional ACS improvement

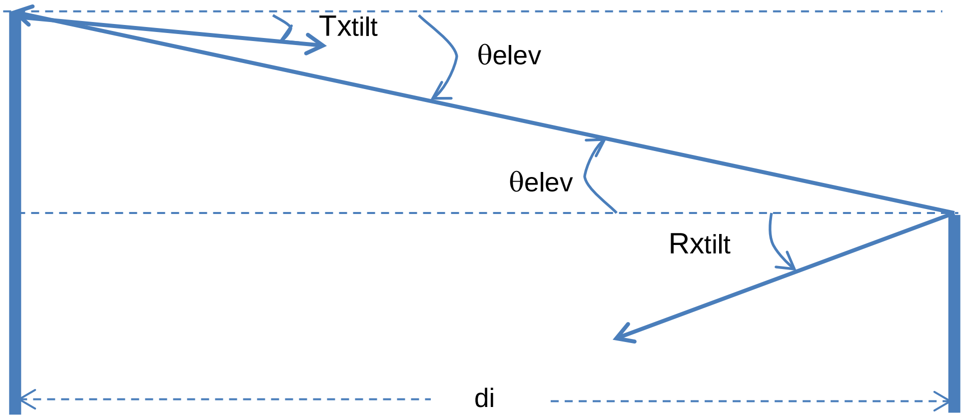

Figure 16: Geometries and related notations

It is assumed that the PPDR BS antenna is in the main lobe DTT receiving antenna.

3.5.3.2 Results

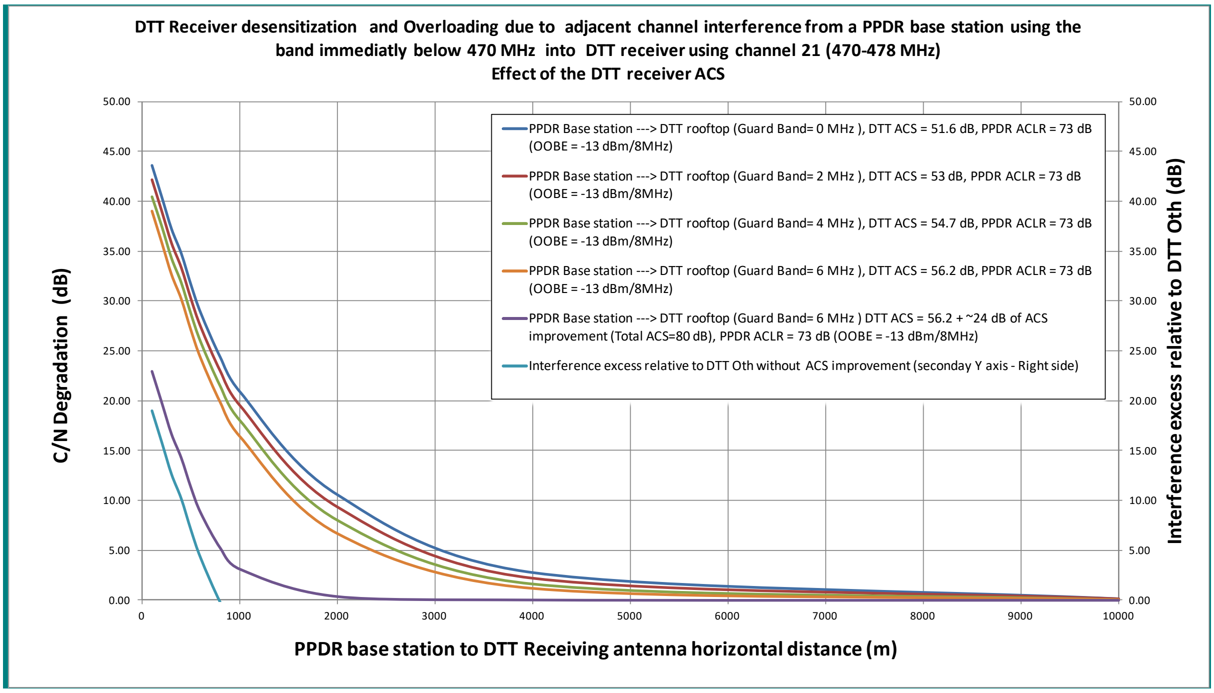

Figure 17: Effect of the DTT receiver ACS on the risk of interference with the considered criteria, OOBE are in terms of e.i.r.p.

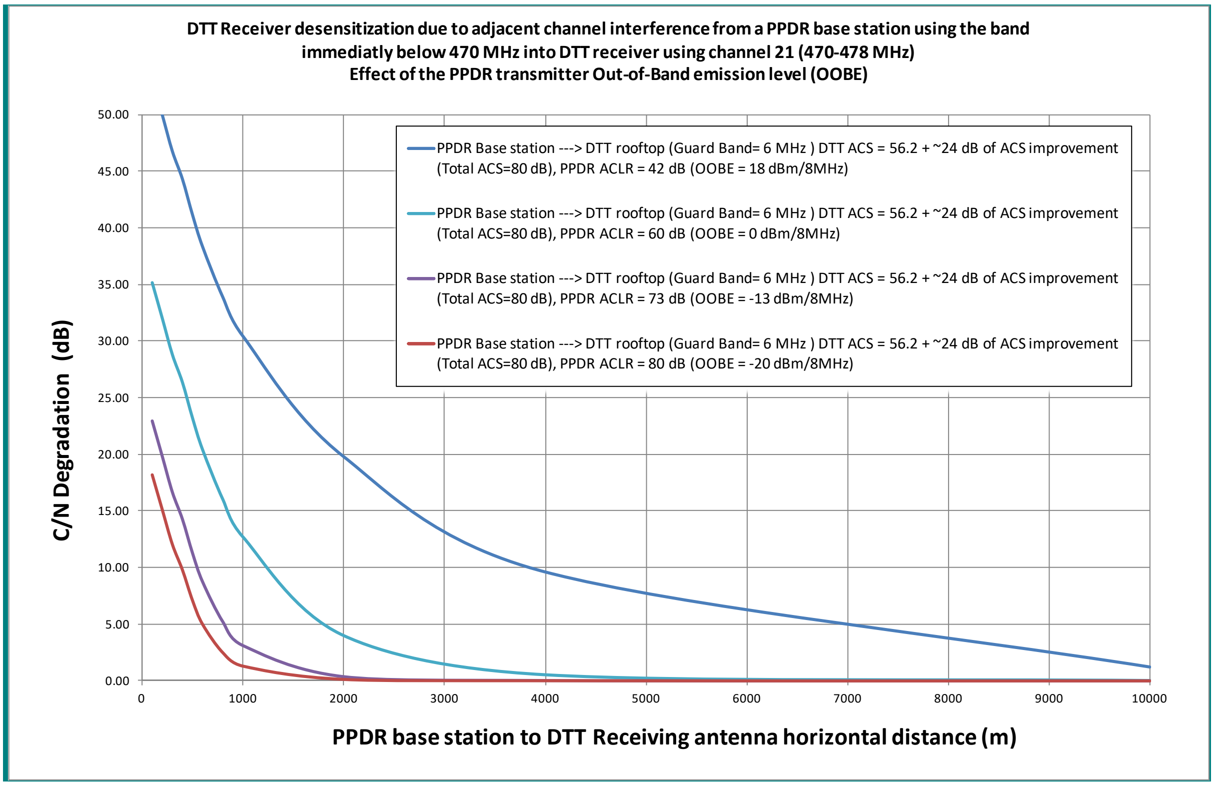

Figure 18: Effect of the PPDR base station e.i.r.p. Out-of-Band emission level on the risk of interference with the considered criteria

3.5.3.3 Analysis and conclusions

1. The risk of interference from PPDR base stations into DTT reception is concentrated around each PPDR base station. This is known and experienced from the 800 MHz LTE implementation where the analysis of the potential of interference is made on a case by case basis (cf. ITU-R Report BT.2301-0(2014) [21]).

2. The curves in Figure 17 above show that the increase of the guard band from 0 to 6 MHz, without significant improvement of the Adjacent Channel Selectivity (ACS) (in future DTT receiver or through additional filtering for the legacy receivers), would not reduce significantly the risk of interference.

3. In order to allow for a guard band of 6 MHz or less, a significant improvement of the DTT receiver ACS (e.g. 24 dB) is required to noticeably reduce the risk (see the related curve in Table 18).

4. The minimum required guard band should consider improvement of the ACS of future DTT receivers as well as cost and size filter design with acceptable performance in DTT channel 21 for legacy receivers. This includes enough rejection of the PPDR channel while not degrading the DTT channel 21 reception (sufficiently low insertion losses).,

5. On the basis that improving the ACS will be required to improve the co-existence and/or to resolve possible interference cases, the level of the OOBE of the PPDR base station Tx will then have a significant impact, as shown in Figure 18. A low OOBE level of the PPDR base station (down to -20 dBm/8 MHz) still improves the protection, while a relaxation of this OOBE level (e.g. to 0 dBm/8 MHz or more) would significantly increase the interference potential. It should be noted that such changes of the OOBE level will have very little effect for the cases with poor ACS values. This is also in line with previous results of studies of LTE 800 MHz.

6. The use of additional filtering at the DTT receiving installation to reject the PPDR channel will prevent overloading of the DTT receivers (Values of Interference excess relative to DTT O_{th} are positive in Figure 17 for distances below 800 m whereas all values for Interference excess become negative when including the 24 dB filter rejection, and therefore do not appear anymore in Figure 18).

7 The studies and experience of the 800 MHz LTE implementation in Europe (with the downlink block starting at 791 MHz while channel 60 ends at 790 MHz), as shown in the CEPT Report 30 [7] (see Executive summary and ANNEX 4:), show that the impact of interference cannot be arbitrarily reduced through a reduction of the BS out-of-block (OoB) emission alone due to finite TV receiver selectivity. They also conclude that other mitigation mechanisms would ultimately be required if the protection is considered insufficient by an administration, e.g. by means of additional measures at the national level.

3.5.3.4 Interference footprint analysis for PPDR UE interference to DTT (non SEAMCAT)

While section 3.5.1 above provides macroscopic assessment of the interference, the footprint analysis in this section provides a 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 analyzed.

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. 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. Monte Carlo simulation is used to calculate IP (probability of interference) 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.

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 19 below.

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.

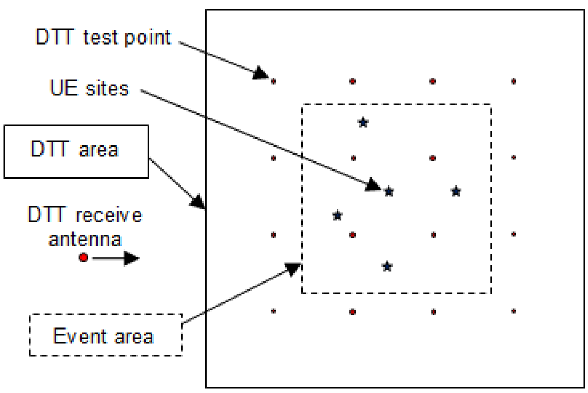

Figure 19: Situation geometry

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.

Parameters

We consider PPDR UEs operating in the 400 MHz band. Two types of UE are considered:

- vehicular PPDR UE units operating at 1.5 m height and with e.i.r.p. levels, 23 dBm, 31 dBm, and 37 dBm, and
- hand held PPDR UE units operating at 1.5 m height and with 20 dBm e.i.r.p..

Table 25: Parameters for the 400 PPDR UE simulations (all calculation made at 474 MHz)

			UE characteristics			DTT characteristics			
e.i.r.p. (dBm)= Tx Power (dBm)+ Antenna Gain (dBi)	H_{tx} (m)	ACLR (dB) for 10 MHz GB DTT/UE 0 MHz GB DTT/BS	ACLR (dB) For 13 MHz GB DTT/UE 3 MHz GB DTT/BS	ACLR (dB) For 16 MHz GB DTT/UE 6 MHz GB DTT/BS	Body loss (dB)	H_{rx} (m)	ACS (dB) for 10 MHz GB DTT/UE 0 MHz GB DTT/BS	ACS (dB) For 13 MHz GB DTT/UE 3 MHz GB DTT/BS	ACS (dB) For 16 MHz GB DTT/UE 6 MHz GB DTT/BS
23 + (-3) = 20	1.5	65	70	75	4	10	65	70	75
23 + (0) = 23	1.5	65	70	75	0	10	65	70	75
31 + (0) = 31	1.5	65	70	75	0	10	65	70	75
37 + (0) = 37	1.5	65	70	75	0	10	65	70	75

Table 26: Parameters for the reference commercial LTE700 UE (all calculation 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 ANNEX 8:.

Results

The detailed results are given in tabular form as well as in diagrammatic form in ANNEX 10:.

The 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 ΔIP% for the three 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 are shown.

Reference case

Reference case: commercial LTE700 UE impact on DTT.

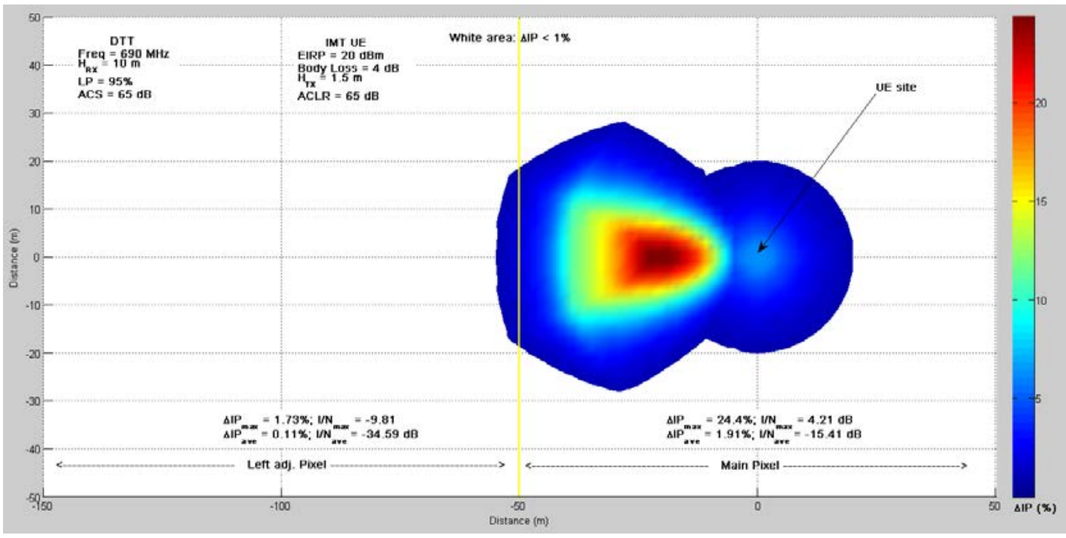

Figure 20: Reference case: commercial LTE700 UE impact on DTT

Table 27: 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. 419 Antenna pattern	
	Main Pixel		Left adjacent Pixel	
	ΔIP (%)	I/N (dB)	ΔIP (%)	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

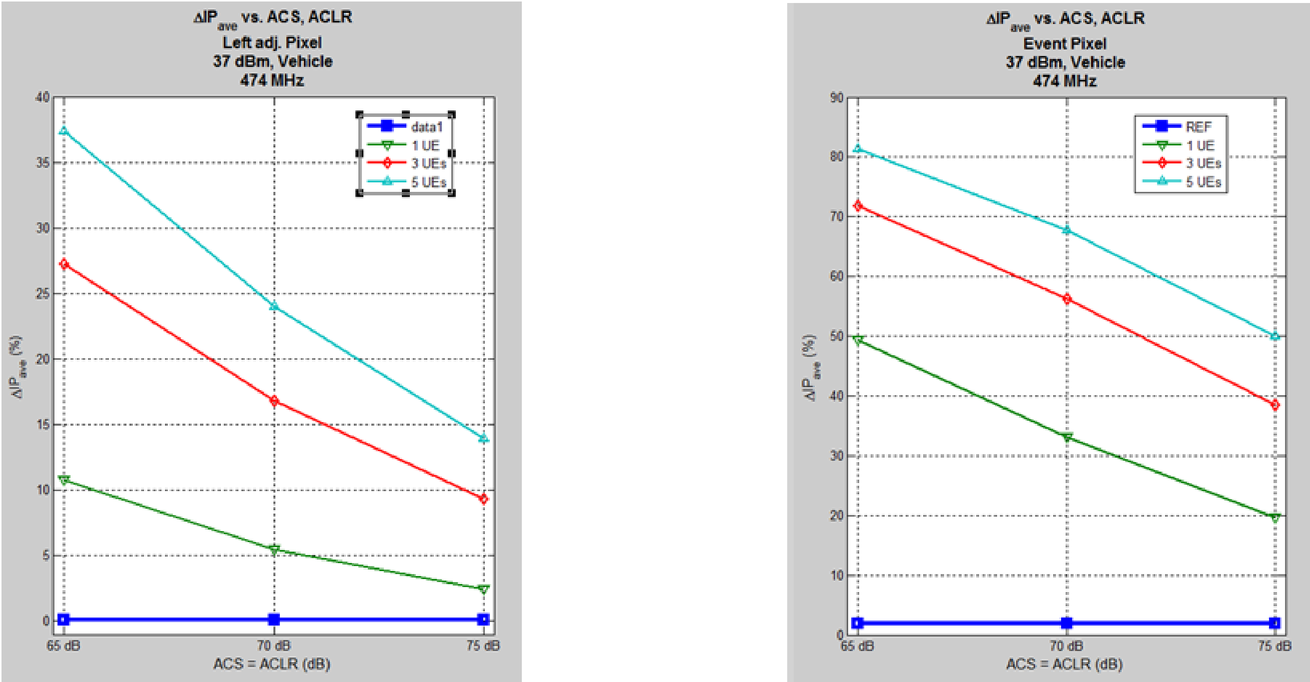

Figure 21: Vehicular PPDR UE, e.i.r.p. = 37 dBm

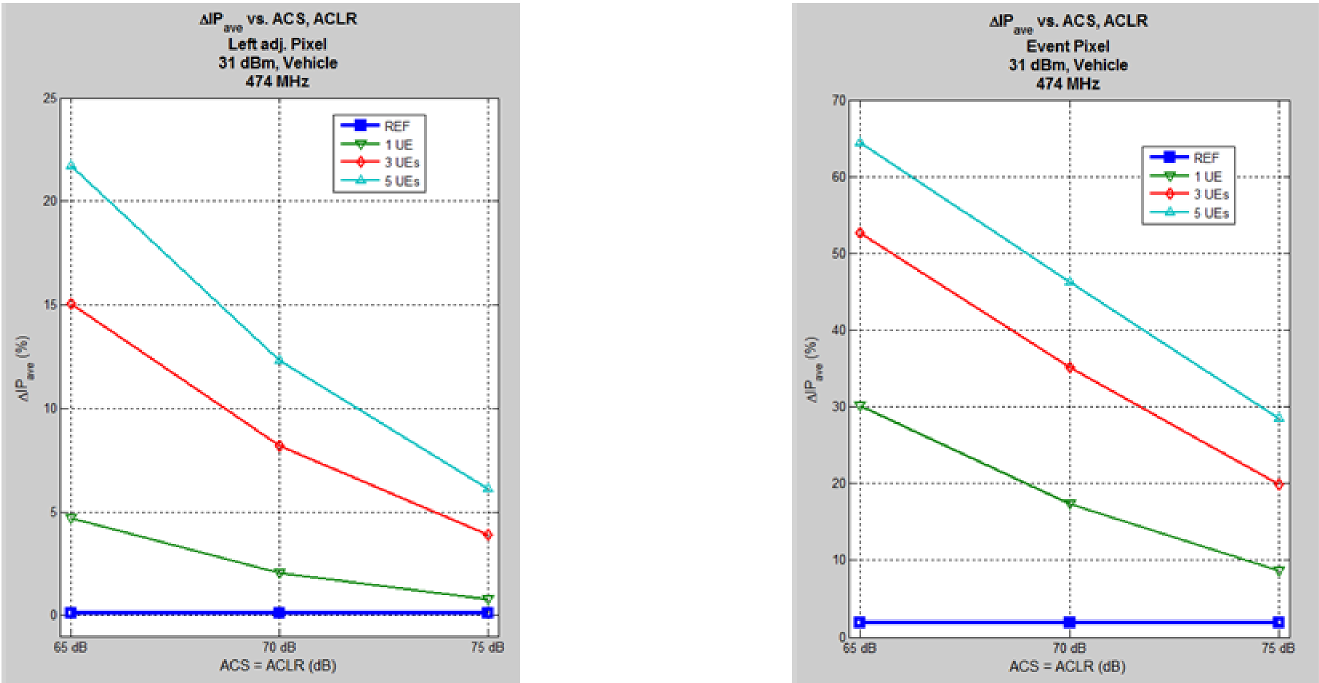

Figure 22: Vehicular PPDR UE, e.i.r.p. = 31 dBm

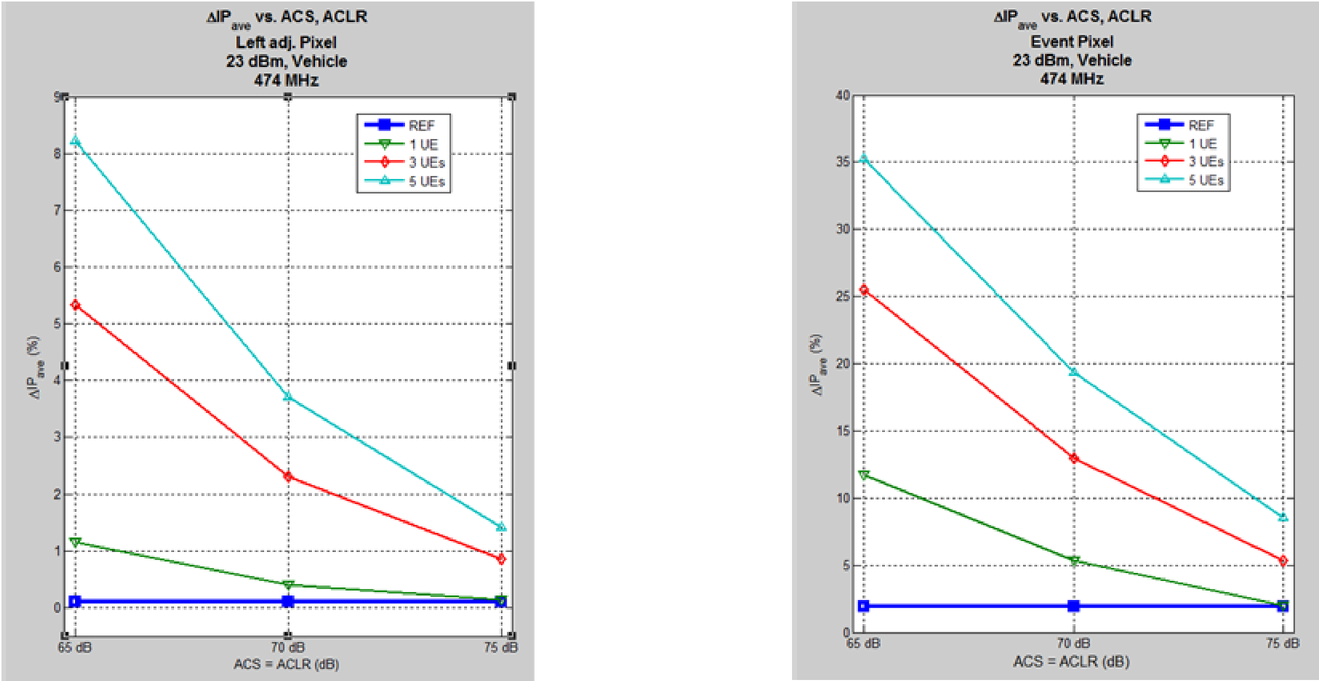

Figure 23: Vehicular PPDR UE, e.i.r.p. = 23 dBm

Comparison tables:

Table 28: Central Event Pixel

Case	ΔIPave (%)	ΔIPave (%)	ΔIPave (%)
Reference commercial LTE 700 UE	1.91 %	1.91 %	1.91 %
PPDR UE case (5 UEs)	GB = 10 MHz ACS = 65 dB = ACLR	GB = 13 MHz ACS = 70 dB = ACLR	GB = 16 MHz ACS = 75 dB = ACLR
e.i.r.p. = 37 dBm (vehicle)	81.38 %	67.68 %	49.98 %
e.i.r.p. = 31 dBm (vehicle)	64.45 %	46.24 %	28.42 %
e.i.r.p. = 23 dBm (vehicle)	35.26 %	19.36 %	8.55 %
Notes: 1- It is assumed that an intervention occurs in close vicinity of the DTT receiver. 2-The case of 5 PPDR UEs is compared to the case of 1 LTE UE. 3- PPDR ACLR is set to 33 dB/8MHz, while LTE UE ACLR is set to 65 dB/8MHz. 4- IP in this case assumed no power control for both systems.			

Table 29: Left Adjacent Pixel

Case	∆IPave (%)	∆IPave (%)	∆IPave (%)
Reference commercial LTE 700 UE	0.110 %	0.110 %	0.110 %
PPDR UE case (5 UEs)	GB=10 MHz (ACS = 65 dB = ACLR)	GB=13 MHz (ACS = 70 dB = ACLR)	GB=16 MHz ACS = 75 dB = ACLR
e.i.r.p. = 37 dBm (vehicle)	37.36 %	24.02 %	13.92 %
e.i.r.p. = 31 dBm (vehicle)	21.73 %	12.31 %	6.11 %
e.i.r.p.= 23 dBm (vehicle)	8.23 %	3.71 %	1.41 %
Notes: 1- It is assumed that an intervention occurs in close vicinity of the DTT receiver. 2-The case of 5 PPDR UEs is compared to the case of 1 LTE UE. 3- PPDR ACLR is set to 33 dB/8MHz, while LTE UE ACLR is set to 65 dB/8MHz. 4- IP in this case assumed no power control for both systems.			

Conclusion

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 analyze the impact of the interference when PPDR UE and DTT receiver are located in the same pixel.

Based on the analysis in this section, we can say that in order to ensure that the LTE system used for PPDR causes similar or smaller interference footprints than that for commercial LTE UE in the 700 MHz band with the agreed technical parameters for LTE 700 [8], the following adjustments can be made:

1. To improve the blocking interference: limitation of the PPDR UE Tx power or increase of guard band below 470MHz or DTT ACS improvement or a combination of the previous ones

2. To improve the unwanted emissions interference: limitation of the OOBE levels in the band above 470 MHz.

3.5.4 Real life experience – Interference from LTE networks to DTT reception in 800MHz band

LTE 800 MHz in France started March 2013. Up to the 2nd of October 2014, for 5936 transmitting LTE 800 MHz BS, 29596 cases of interference to DTT reception were identified (» 5 interferences per BS), which represents interference to 123268 households. All the interference cases were resolved by filtering out the interfering LTE signal with an external filter connected to DTT receiver antenna output. Installations of the filter reduced the DTT receivers' sensitivity by about 2 dB.

The LTE 800 MHz base stations (DL) are operating in a band adjacent to DTT reception with a guard band of 1 MHz. Under the assumption that PPDR (LTE) 400 MHz base stations (DL) would operate in a band adjacent to DTT reception, the real-life interference from LTE 800 MHz networks to DTT reception may provide an insight into the risk of interference from PPDR (LTE) 400 MHz to DTT reception above 470 MHz.

3.5.5 Real life experience – Interference from PMR/PAMR networks to DTT reception in the 400 MHz band

No interference has been reported from PMR/PAMR systems operating in the 400 MHz band to DTT reception on Channel 21 or above in France. The results of the in situ investigations carried out by TDF show that this situation is due to:

- The low density of the active PMR/PAMR transmitters in the band;
- The vertical Tx antenna polarisation used by these transmitters, which guarantees about 14-24 dB protection to DTT reception using horizontal Rx antenna polarisation;
- The narrow bandwidth of the PMR/PAMR signals (12.5 kHz) and the very low IBW/ GB ratio (≤ 0.00625), which guarantee a very high PMR/PAMR ACLR in DTTB CH21 (> 70 dB) and have a very limited overloading effect on active DTTB reception.

Consequently, the fact that no interference has been reported from PMR/PAMR systems operating in the 400 MHz band to DTT reception on Channel 21 cannot call into question the results of the theoretical analyses that show possible interferences from PPDR 400 MHz system (BW = 3 MHz) to DTT reception, which are perfectly in line with the reported real life interference from LTE networks to DTT reception in 800 MHz in France.

3.6 LTE400 IMPACT ON SATELLITE SERVICES

3.6.1 Hypothesis for this study

The following parameters are used for the study.

Concerning LTE systems for MS at 400 MHz, 3 cases of channel bandwidth are considered: 1.4, 3 and 5 MHz. The transmit power equals 37 dBm (7 dBW) with an antenna gain of 0 dBi and they operate just above 410 MHZ (uplink band for transmissions between MS to BS). The transmission bandwidth is up to 5 RB (1 RB = 180 kHz).

For LTE MS, the spurious emissions that fall within the 406 MHz band equal -36 dBm per 100 kHz or -42 dBm per 25 kHz or -72 dBW per 25 kHz. For the channel of 1.4 MHz, only spurious emissions are applicable to this study, since the out of band domain generally extends up to 2.5 the necessary bandwidth, and therefore don't fall within the 406 MHz band.

According to this 250 % extension of the out of band domain, the out of band emissions valid for LTE MS are found in the 406 MHz band only for channel bandwidths of 3 and 5 MHz. Such a value equals -10 dBm per MHz, or -56 dBW per 25 kHz. In those two cases, the spurious domain is located below 406 MHz.

The density of LTE MS used for this study equals 0.023 MS/km^2. It corresponds to a lower bound of the expected density, but the simulation assumes that the LTE is implemented all over Europe.

Concerning LTE systems for BS, 3 cases of channel bandwidth are expected: 1.4, 3 or 5 MHz. The corresponding transmission bandwidths equal 6, 15 or 25 RB (RB = 180 kHz) and the transmit power equals 47 dBm (17 dBW) with an antenna gain of 13 dBi The LTE BS stations operate just above band 420 (downlink band for transmissions between BS to MS). The spurious emissions from LTE BS DL to LTE BS UL protection is -96 dBm/100kHz. Emissions that fall within the 406 MHz band are equal or below -96 dBm per 100 kHz or -102 dBm per 25 kHz or -132 dBW per 25 kHz.

The density of LTE BS is 0.0057/km^2. Concerning the existing narrowband emissions, the following set of typical mobile stations characteristics for a bandwidth of 25 kHz, representative of systems in operation in CEPT countries

- transmit power 12 dBW and 0 dBi antenna gain for mobile stations (every 40 km);
- transmit power 13 dBW and 0 dBi antenna gain for mobile stations (every 50 km);
- transmit power 3 dBW and 0 dBi antenna gain for mobile stations (every 10 km) for a 10 kHz bandwidth.

Above 410 MHz, the dynamic simulations have been conducted using the deployment of both potential future LTE MS systems and the existing narrowband emissions.

Concerning simulations for GSO and MEO, since the corresponding footprint is much larger than Europe, a deployment is considered outside Europe and typical figures such as TETRA transmitters of 5 dBW (antenna of 0 dBi) between 40 km up to 200 km are considered.

3.6.2 Results of simulations for MS LTE deployment above 410 MHz (non SEAMCAT)

a) **LEO satellite**

This simulation corresponds to the case **where new potential LTE deployment has an OOB at 406 MHz of** -56 dBW per 25 kHz. The following curve shows the result of the simulation which computes the cumulative density of the power flux density in dBW/m^2/Hz.

Figure 24: Deployment over CEPT countries for simulations using the LEO satellites

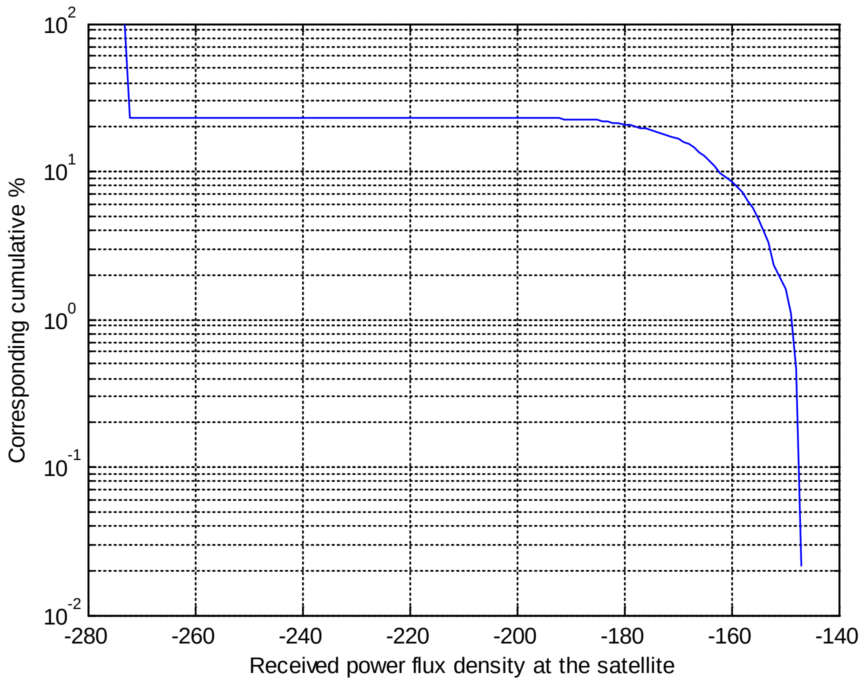

Figure 25: Cumulative density functions of power flux density

The power flux density is –148 dBW/m^2/Hz should all the transmitters are all in operation. Using the maximum permissible levels of interference measured on the SARP instrument (LEO space component) as shown in Table 3-6 in the ITU-R Report, we have the following conclusion for Europe.

Above 410 MHz, in order not to cause interference to the reception of the 406-406.1 MHz band, the maximum permissible required pfd level equals -131 dBW/m^2/Hz. Therefore, above 410 MHz, the filtering pattern on board LEO is sharp enough to eliminate all the unwanted emissions.

b) MEO satellite

This simulation corresponds to the case where new potential LTE deployment has an OOB at 406 MHz of -56 dBW per 25 kHz. The following curve shows the result of the simulation which computes the cumulative density of the power flux density in dBW/m²/Hz.

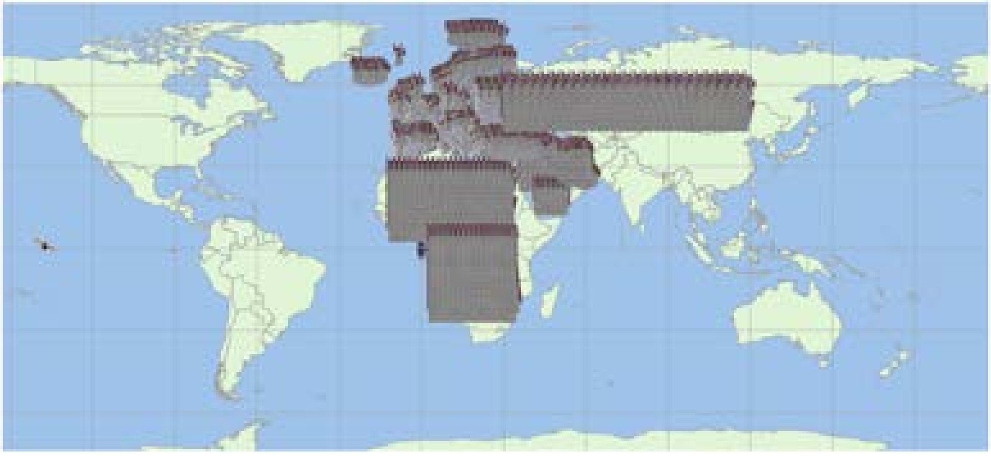

Figure 26: Deployment over CEPT countries for simulations using the MEO satellites

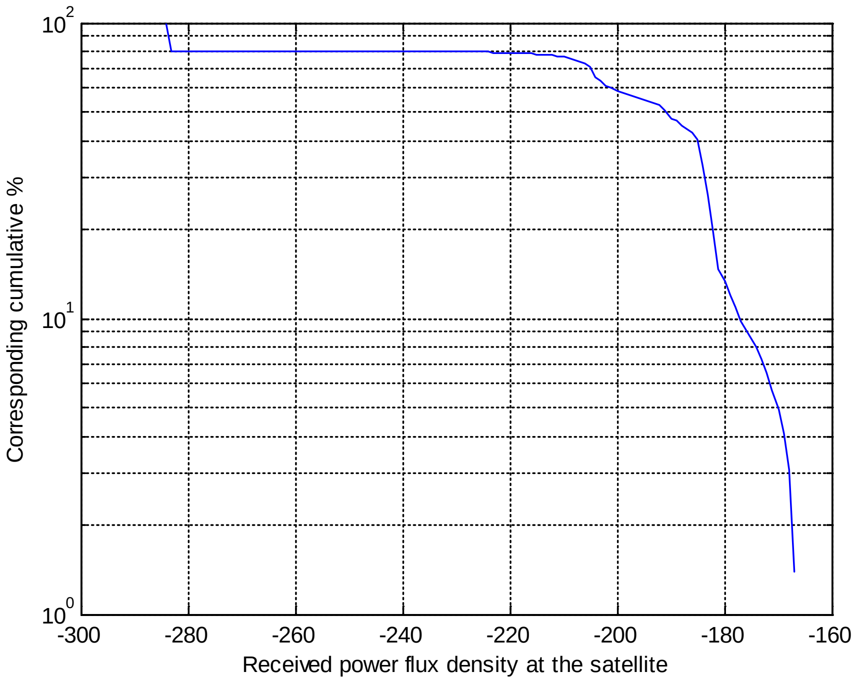

Figure 27: Cumulative density function of power flux density

The power flux density is –168 dBW/m²/Hz should all the transmitters are all in operation. Using the maximum permissible levels of interference measured on the SAR instrument (MEO space component for GALILEO) as shown in Table 3-10 in the ITU-R Report, we have the following conclusion for Europe.

Above 410 MHz, in order not to cause interference to the reception of the 406-406.1 MHz band, the maximum permissible required pfd level equals -157 dBW/m²/Hz. Therefore, above 410 MHz, the filtering pattern is sharp enough to eliminate all the unwanted emissions.

c) **GSO satellite: MSG case**

The power flux density is -181 dBW/m^2/Hz. should all the transmitters are all in operation. Using the maximum permissible levels of interference measured on the SAR instrument (GEO space component for MSG) as shown in Table 3-7 in the ITU-R Report, we have the following conclusion for Europe.

Above 410 MHz, in order not to cause interference to the reception of the 406-406.1 MHz band, the maximum permissible pfd level equals -166 dBW/m^2/Hz. Therefore, above 410 MHz, the filtering pattern is sharp enough to eliminate all the unwanted emissions.

3.6.3 Conclusion¨

The case of the spurious emissions of -132 dBW per 25 kHz has not been simulated, but it is obvious that this value will not cause harmful interference. According to the compatibility analysis as conducted below, it is shown that the maximum permissible pfd level required for every kind of space system relaying 406 MHz emergency signals, is above the pfd level computed from extensive dynamic simulations where both LTE and narrowband transmitters are implemented. Therefore, above 410 MHz, the filtering pattern on board the various kinds of satellites carrying a 406 MHz receiver is sharp enough to eliminate all the unwanted emissions derived from LTE PPDR emissions.

The simulations for BS stations above 420 MHz have not been performed and it can be assumed that these potential new emissions will not cause harmful interference to the reception of the 406-406.1 MHz band.

3.7 LTE400 IMPACT ON MILITARY RADARS

3.7.1 General description of radars and PPDR networks

3.7.1.1 Characteristics and assumptions

Radars characteristics are defined in the Recommendation ITU-R M.1462 [14]. Table 30 below resumes characteristics of the two systems that are taken into account in the budget links.

Table 30: LTE400 and radar parameters

LTE400 PPDR			Military Radars		
	Base Station	Mobile Station		Airborne	Ground
e.i.r.p.	60 dBm	Up to 37 dBm	B_{th}	-108.9 dBm	-109.9 dBm
Channel width	1.4, 3, 5 MHz	1.4, 3, 5 MHz	I/N	-6 dB	- 6 dB
Spurious	-36 dBm / 100 kHz	-36 dBm / 100 kHz	Saturation level[2]	- 15 dBm	-10 dBm
Spurious e.i.r.p.	-11 dBm / MHz	-26 dBm / MHz	G_{RADAR}	22 dBi	38 dBi
G-PPDR	15 dBi	0 dBi	B_{RADAR}	1 MHz	1 MHz
Feeder Loss	2 dB	0 dB			
Polarisation	Linear ±45°		Polarisation	Horizontal	C
tilt	3°				

[2] Saturation level for the radars is applicable, at least, in the whole tuning range 420-450 MHz. Further investigations real characteristics of the radars may imply to consider a wider range.

LTE400 PPDR			Military Radars		
H_e (m)	30 m (50 m)	1.5 m	Flight level	Up to 9000 m	8 m

The assumptions are detailed below:

Considering the difference of polarisation between “Base station emission” and “radar reception”, a mitigation factor of 1.5 dB is taken into account. For Mobile station, without information on polarisation, no mitigation factor is taken into account.

In the case of cohabitation between an airborne and broadband PPDR base station, the antenna tilt of base station (3°) lead to use a decoupling antenna factor (DEC_{ant}), in the link budget. In a first approach, a value of 3 dB can be used in the budget link, as it has been done in ECC Report 172 [25] even if it was not the same frequency range.

Broadband PPDR LTE channel bandwidth is chosen equal to 3 MHz.

Interference criteria radar is respectively:

for saturation : P_{SAT} = -15 dBm

for desensitisation: $P_{ps} = B_{th} + I/N = -108.9 - 6 = -114.9$ dBm/MHz

Propagation model: the Free Space is the most realistic model for a link between an airborne and a ground antenna whose height is equal to 30m. Calculation are realised for F = 430 MHz.

3.7.1.2 Information on operational use of the radars.

420-450 MHz is the tuning range of airborne and ground radars, as described in the Recommendation ITU-R M.1462 [14]. Spectrum agility in this range is an essential requirement to ensure coordination with other systems using this band and to operate in an Electronic Warfare context. Thus, radiolocation systems cannot be limited to some specific frequencies in particular in the 430-440 MHz frequency band where radiolocation is a Primary service.

Airborne radars are used on aeronautical platforms and are daily operating over wide areas (several hundreds of kilometres over land and sea).

Ground radars are transportable systems used to enhance the protection of specific areas. In practice, these radars are co-located with military forces that are operating communication systems derived from current and future PPDR technology. Indeed, military forces are equipped with PPDR systems to interoperate with other governmental actors for national missions. These systems are also used for military operation in addition to hardened tactical communication systems. In this context, it is important to ensure compatibility of future PPDR LTE with radiolocation in 400 MHz.

3.7.2 Study

A Broadband PPDR-LTE network (base station and mobile station) can impact operating radar in several manners. The main cases involved are the following:

- Risk of saturation (blocking);
- Risk of desensitisation in a co-channel scenario;
- Risk of desensitisation in an adjacent channel scenario (out-of-band and spurious).

These three cases are detailed below, according to different scenario.

3.7.2.1 Impact of a PPDR signal on saturation (blocking) of radar receiver.

To avoid radar saturation, the necessary propagation loss can be calculated with the following equation:

Base Station

$$L_{prop} = e.i.r.p._{PPDR\ LTE} - P_{sat} + G_{radar} - DEC_{pol} - DEC_{ant}$$

Mobile Station

$$L_{prop} = e.i.r.p._{PPDR\ LTE} - P_{sat} + G_{radar}$$

Note: Saturation (blocking) can occur, if the potential interferer emits in the tuning range of the radar even though radar is using a “distant” frequency. For example: PPDR BS: 423 MHz, radar 435 MHz. In this case, PPDR BS emission is within the radar tuning range (420-450 MHz) and there is a risk of saturation of the radar depending on the distance between the radar and the base station.

3.7.2.2 Impact of a PPDR signal on desensitisation of radar receiver (co channel scenario in the 420-430 MHz, base station and mobile station).

To avoid radar desensitisation in a co channel scenario, the necessary propagation loss is:

Base Station:

$$L_{prop} = e.i.r.p._{PPDR\ LTE} - P_{ps} + G_{radar} + 10*\log(B_{radar}/B_{PPDR\ LTE}) - DEC_{pol} - DEC_{ant}$$

Mobile Station:

$$L_{prop} = e.i.r.p._{PPDR\ LTE} - P_{ps} + G_{radar} + 10*\log(B_{radar}/B_{PPDR\ LTE})$$

3.7.2.3 Impact of PPDR out of band and spurious on the desensitisation of radar receiver (adjacent channel scenario in the 410-430 MHz or 450-470 MHz, base station).

To avoid radar desensitization in an adjacent channel scenario (i.e. PPDR spurious emission), the necessary propagation loss is the following:

Base Station:

$$L_{prop} = e.i.r.p._{unwanted\ em\ PPDR} - P_{ps} + G_{radar} - DEC_{pol} - DEC_{ant}$$

Mobile Station:

$$L_{prop} = e.i.r.p._{unwanted\ em\ PPDR} - P_{ps} + G_{radar}$$

3.7.3 Results

3.7.3.1 PPDR Impact on aeronautical radiolocation systems within the 410-430 / 450-470 MHz sub-bands and adjacent bands.

Saturation (blocking) in the 420-430 MHz frequency range

BS-PPDR → airborne radar

To avoid radar saturation, the necessary propagation loss is the following:

$$L_{prop} = e.i.r.p._{PPDR} - P_{sat} + G_{radar} - DEC_{pol} - DEC_{ant}$$

$$L_{prop} = 60 - (-15) + 22 - 1.5 - 3 = 92.5\ dB$$

Attenuation of 92.5 dB corresponds to a distance of 2.3 km, with free space propagation model.

MS-PPDR → airborne radar

To avoid radar saturation, the necessary propagation loss is the following:

$$L_{prop} = e.i.r.p._{PPDR} - P_{sat} + G_{radar}$$

$$L_{prop} = 37 - (-15) + 22 = 74 \text{ dB}$$

Attenuation of 74 dB corresponds to a distance of 280 m, with free space propagation model.

Desensitisation

Co channel scenario in the 420-430 MHz.

Base station:

To avoid radar desensitization in a co channel scenario, the necessary propagation loss is the following:

$$L_{prop} = e.i.r.p._{PPDR} - P_{ps} + G_{radar} + 10*\log(B_{radar}/B_{LTE}) - DEC_{pol} - DEC_{ant}$$

$$L_{prop} = 60 - (-114,9) +22- 4.7 -1,5 - 3 = 187.7 \text{ dB}$$

Attenuation of 187.7 dB corresponds to a very important distance with free space propagation loss. It is noted that radio electric line of sight is equal to 410 km for a 9000 m airborne altitude (315 km for 5000 m, and 250 km for 3000 m).

Note: Another calculation is realised taking into account propagation model with MNT. With an assumption of 2 broadband PPDR-LTE base stations located in Marseille and Cannes, the impact of broadband PPDR LTE is calculated for 3 altitudes of airborne:

These results illustrate zones in which airborne radar desensitization criteria is exceeded.

Mobile station:

To avoid radar desensitization in a co channel scenario, the necessary propagation loss is the following:

$$L_{prop} = e.i.r.p._{LTE} - P_{ps} + G_{radar} + 10*\log(B_{radar}/B_{LTE})$$

$$L_{prop} = 37 - (-114.9) + 22 - 4.7 = 169.2 \text{ dB}$$

Attenuation of 169.2 dB corresponds to a very important distance (several hundred kilometres) with free space propagation model.

Impact of BS PPDR unwanted emission on the airborne radar receiver.

Out-of-Band: To avoid radar desensitization in an adjacent channel scenario (i.e. PPDR out-of-band), the necessary propagation loss is the following:

The case of an adjacent channel with F_c = 4 MHz is calculated below: out-of-band emission limit is given in

Table 68 (ANNEX 1:) and is equal to

O-O-B (Fc =4 MHz) = -5 dBm - 10/3 * (Delta Fc – 1.5) dB= -5 – 8.3
= -13.3 dBm (in 100 kHz), i.e. -3.3 dBm (in 1 MHz)

$$L_{prop} = e.i.r.p._{unwanted\ em\ PPDR} - P_{ps} + G_{radar} - DEC_{pol} - DEC_{ant}$$

$$L_{prop} = (-3.3 + 13) - (-114.9) + 22 -1.5 -3 = 142.1 \text{ dB}$$

Attenuation of 143.5 dB corresponds to a distance larger than 500 km with free space propagation model, assuming worst case emission mask at 4MHz offset from LTE specification.

Spurious: to avoid radar desensitization in an adjacent channel scenario (i.e. PPDR spurious emission), the necessary propagation loss is the following:

$$L_{prop} = e.i.r.p._{unwanted\ em\ PPDR} - P_{ps} + G_{radar} - DEC_{ant}$$

$$L_{prop} = (-26 + 13) - (-114.9) + 22 -3 = 120.9 \text{ dB}$$

Attenuation of 120.9 dB corresponds to a distance equal to 61 km with free space propagation model, assuming worst case general spurious emissions from LTE specification.

If it is assumed a protection distance for the radar of 1 km, spurious level should be 35 dB lower than present level.

If it is assumed a protection distance for the radar of 3 km, spurious level should be 25 dB lower than present level.

If the radar is within LTE UL spectrum band, the applicable spurious emissions are -96 dBm/100kHz. This emission level is also reached if the radar allocation is below LTE UL

$$L_{prop} = e.i.r.p._{unwanted\ em\ PPDR} - P_{ps} + G_{radar} - DEC_{ant}$$

$$L_{prop} = (-86 + 13) - (-114.9) + 22 -3 = 41.9 \text{ dB}$$

Impact of MS PPDR unwanted emission on the airborne radar receiver.

Out-of-Band: To avoid radar desensitisation in an adjacent channel scenario (i.e. PPDR out-of-band), the necessary propagation loss is the following:

For F_c = 4 MHz, level of Out-of-band is equal to -10 dBm (in 1 MHz)

$$L_{prop} = e.i.r.p._{unwanted\ em\ PPDR} - P_{ps} + G_{radar}$$

$$L_{prop} = (-10 + 0) - (-114.9) + 22 = 126.9 \text{ dB}$$

Attenuation of 126.9 dB corresponds to a distance larger than 120 km with free space propagation model, assuming worst case emission mask at 4MHz offset from LTE specification.

Spurious: to avoid radar desensitisation in an adjacent channel scenario (i.e. PPDR spurious emission), the necessary propagation loss is the following:

$$L_{prop} = e.i.r.p_{.unwanted\ em\ PPDR} - P_{ps} + G_{radar}$$

$$L_{prop} = (- 26 + 0) - (- 114.9) + 22 = 110.9 \text{ dB}$$

Attenuation of 100.9 dB corresponds to a distance equal to 20 km with free space propagation model, assuming worst case general spurious emissions from LTE specification.

If the radar is within LTE DL spectrum band, the applicable spurious emissions are -50dBm/MHz. This emission level is also reached if the radar allocation is below LTE DL

$$L_{prop} = e.i.r.p._{unwanted\ em\ PPDR} - P_{ps} + G_{radar}$$

$$L_{prop} = (-50 + 0) - (-114.9) + 22 = 86.9 \text{ dB}$$

3.7.3.2 PPDR Impact on ground radar within the 410-430 / 450-470 MHz sub-bands and adjacent bands.

This chapter evaluates coexistence between ground radar and PPDR 400 LTE. Recommendation ITU-R M.1465 [18] describes ground radar that is very close to radar used by French military and reception characteristics (Table 30) remain relevant for this study.

Interference criteria for ground radar are respectively:

for saturation : P_{SAT} = -10 dBm;

for desensitisation: $P_{ps} = B_{th} + I/N = -109.9 - 6 = -115.9$ dBm/MHz

Saturation in the 420-430 MHz frequency range

PPDR Base station → ground radar:

To avoid radar saturation, the necessary propagation loss is the following:

$$L_{prop} = e.i.r.p_{\ PPDR} - P_{sat} + G_{radar} - DEC_{pol} - DEC_{ant}$$

$$L_{prop} = 60 - (-10) + 38.5 - 1.5 - 3 = 104 \text{ dB}$$

Attenuation of 104 dB corresponds to a distance of 3.8 km with EPM73 model[3].

PPDR Mobile station → ground radar

To avoid radar saturation, the necessary propagation loss is the following:

$$L_{prop} = e.i.r.p_{\ .\ PPDR} - P_{sat} + G_{radar}$$

$$L_{prop} = 37 - (-10) + 38.5 = 85.5 \text{ dB}$$

Attenuation of 85.5 dB corresponds to a distance of 560 m with EPM73 model.

Desensitisation

Co channel scenario in the 420-430 MHz

PPDR Base station → ground radar:

To avoid radar desensitisation in a co channel scenario, the necessary propagation loss is the following:

$$L_{prop} = e.i.r.p_{\ PPDR\ LTE} - P_{ps} + G_{radar} + 10*\log(B_{radar}/B_{LTE}) - DEC_{pol} - DEC_{ant}$$

$$L_{prop} = 60 - (-115.9) + 38.5 - 4.7 - 1.5 - 3 = 205.2 \text{ dB}$$

Attenuation of 205.2 dB corresponds to a distance of 230 km with EPM73 model, assuming worst case OOBE from LTE specification.

PPDR Mobile station → ground radar:

3 EPM73 is an empirical propagation model that takes into account antenna heights in the calculation of the distance). EPM 73 is more appropriate than free space in this case of “ground to ground” link. This model has been used in the study “broadband wireless Systems usage in 2300-2400 MHz” (See ECC Report 172).

To avoid radar desensitisation in a co-channel scenario, the necessary propagation loss is the following:

$$L_{prop} = e.i.r.p._{LTE} - P_{ps} + G_{radar} + 10*\log(B_{radar}/B_{LTE})$$

$$L_{prop} = 37 - (-115.9) + 38.5 - 4.7 = 186.7 \text{ dB}$$

Attenuation of 186.7 dB corresponds to a distance of 110 km with EPM73 model, assuming worst case OOBE from LTE specification.

<u>Impact of PPDR unwanted emission on the ground radar receiver.</u>

PPDR Base station → ground radar:

Out-of-Band: To avoid radar desensitisation in an adjacent channel scenario (i.e. PPDR out-of-band), the necessary propagation loss is the following:

The case of an adjacent channel with Fc = 4 MHz is calculated below, out-of-band emission limit is given in Table 68 (ANNEX 1:) and equal to -5 dBm -10/3* (Delta Fc – 1.5) dB

O-O-B (F_c =4 MHz) = -5 dBm -10/3* (Delta F_c – 1.5) dB= -5 -8,3
= -13.3 dBm (in 100 kHz), i.e. -3.3 dBm (in 1 MHz)

$$L_{prop} = e.i.r.p._{unwanted\ em\ PPDR} - P_{ps} + G_{radar} - DEC_{pol} - DEC_{ant}$$

$$L_{prop} = (-3.3+13) - (-115,9) + 38.5 - 1.5 - 3 = 159.6 \text{ dB}$$

Attenuation of 159.6 dB corresponds to a distance of 57 km with EPM73 model, assuming worst case emission mask at 4MHz offset from LTE specification.

Spurious: to avoid radar desensitisation in an adjacent channel scenario (i.e. PPDR spurious emission), the necessary propagation loss is the following:

$$L_{prop} = e.i.r.p_{\ unwanted\ em\ PPDR} - P_{ps} + G_{radar} - DEC_{pol} - DEC_{ant}$$

$$L_{prop} = (-26 + 13) - (-115.9) + 38.5 - 1.5 - 3 = 136.9 \text{ dB}$$

Attenuation of 136.9 dB corresponds to a distance of 30 km with EPM73 model, assuming worst case general spurious emissions from LTE specification.

If it is assumed 1 km protection distance around the radar, spurious level should be 45 dB lower than present level.

If it is assumed 3 km protection distance around the radar, spurious level should be 35 dB lower than present level.

If the ground radar is within LTE UL spectrum band, the applicable spurious emissions is -96 dBm/100kHz. This emission level is also reached if the ground radar allocation is below LTE UL

$$L_{prop} = e.i.r.p_{\ unwanted\ em\ PPDR} - P_{ps} + G_{radar} - DEC_{pol} - DEC_{ant}$$

$$L_{prop} = (-86 + 13) - (-115.9) + 38.5 - 1.5 - 3 = 76.9 \text{ dB}$$

PPDR Mobile station → ground radar:

Out-of-Band: To avoid radar desensitisation in an adjacent channel scenario (i.e. PPDR out-of-band), the necessary propagation loss is the following:

For F_c = 4 MHz, level of Out-of-band is equal to -10 dBm (in 1 MHz)

$$L_{prop} = e.i.r.p_{\ unwanted\ em\ PPDR} - P_{ps} + G_{radar}$$

$$L_{prop} = (-10+0) - (-115.9) + 38.5 = 144.4 \text{ dB}$$

Attenuation of 144.4 dB corresponds to a distance of 22.5 km with EPM73 model, assuming worst case emission mask at 4MHz offset from LTE specification.

Spurious: to avoid radar desensitisation in an adjacent channel scenario (i.e. PPDR spurious emission), the necessary propagation loss is the following:

$$L_{prop} = e.i.r.p._{\text{unwanted em PPDR}} - P_{ps} + G_{radar}$$

$$L_{prop} = (-26+0) - (-115.9) +38.5 = 128.4 \text{ dB}$$

Attenuation of 128.4 dB corresponds to a distance of 7 km with EPM73 model, assuming worst case general spurious emissions from LTE specification.

If it is assumed 1km protection distance around the radar, spurious level should be 30 dB lower than present level.

If it is assumed 3km protection distance around the radar, spurious level should be 15 dB lower than present level.

The tables below gives a synthesis of the different cases studied for the ground radar.

If the radar is within LTE DL spectrum band, the applicable spurious emissions are -50dBm/MHz. This emission level is also reached if the radar allocation is below LTE DL

$$L_{prop} = e.i.r.p._{\text{unwanted em PPDR}} - P_{ps} + G_{radar}$$

$$L_{prop} = (-50+0) - (-115.9) +38.5 = 104.2 \text{ dB}$$

3.7.3.3 Reduction of exclusion zones due to desensitisation by the mean of filtering

Saturation cannot be solved by filtering of LTE OOB emissions; therefore the exclusion zones cannot be reduced.

In this section we derive the appropriate reduction of LTE OOB emissions that do not increase the size of the exclusion zones further than the size of exclusion zones due to saturation.

Indeed, mitigation technics such as implementation of additional filtering on both PPDR BSs and UEs could be used to achieve these LTE OOB emissions reductions. In the paragraphs below necessary attenuation compared to LTE technical specification (additional filtering) is evaluated.

Airborne radar

To avoid radar saturation, the necessary propagation loss is 92.5 dB.

$$L_{prop} = e.i.r.p._{\text{PPDR}} - P_{sat} + G_{radar} - DEC_{pol} - DEC_{ant}$$

$$L_{prop} = 60 - (-15) + 22 - 1.5 - 3 = 92.5 \text{ dB, i.e. 2.3 km with free space propagation model}$$

So, to avoid radar desensitisation at this distance (i.e. for this propagation attenuation value), maximum PPDR e.i.r.p. unwanted emission level can be calculated as follows:

$$L_{prop} = e.i.r.p._{\text{unwanted em PPDR}} - P_{ps} + G_{radar} - DEC_{pol} - DEC_{ant}$$

$$L_{prop} = e.i.r.p._{\text{unwanted em PPDR}} - (-114{,}9) +22 -1.5 - 3 = 92.5 \text{ dB}$$

$$e.i.r.p._{\text{unwanted em PPDR}} = (-114{,}9) - 22 + 1.5 + 3 + 92.5 \text{ dB}$$

$$e.i.r.p._{\text{unwanted em PPDR}} = -39.9 \text{ dBm/MHz}$$

By applying a 3 dB margin to this unwanted e.i.r.p., it is assumed that LTE OOB emissions do not increase further the total interfering power, and therefore the exclusion zone remains unchanged.

For a 2.3 km separation distance, Table 31 below gives the necessary additional filtering to apply on LTE Base Station specification (worst case values):

Table 31: Necessary additional filtering to apply on LTE Base Station specification (worst case values)

delta F_c		OOB e.i.r.p.	limit	Necessary attenuation
from 1.55 to 4.55 MHz	0 dBm/MHz (delta 3.05 MHz)	13 dBm/MHz	-42.9 dBm	55.9 dB
from 4.55 to 7.55 MHz	-5 dBm/MHz	8 dBm/MHz		50.9 dB
from 7.55 to 10 MHz	-6 dBm/MHz	7 dBm/MHz		49.9 dB
delta F_c		Spurious e.i.r.p.	Limit	Necessary attenuation
> 10 MHz	-36 dBm/100kHz	-13 dBm/MHz	-42.9 dBm	29.9 dB
Within or below LTE UL spectrum	-96 dBm/100kHz	-73 dBm/MHz	-42.9 dBm	0 dB

Ground radar

To avoid radar saturation, the necessary propagation loss is 104 dB:

$$L_{prop} = e.i.r.p._{PPDR} - P_{sat} + G_{radar} - DEC_{pol} - DEC_{ant}$$

L_{prop} = 60 - (-10) + 38.5 - 1.5 - 3 = 104 dB, i.e. 3.8 km with EPM73 propagation model.

So, to avoid radar desensitisation at this distance (i.e. for this propagation attenuation value), maximum PPDR e.i.r.p. unwanted emission level can be calculated as follows:

$$L_{prop} = e.i.r.p._{unwanted\ em\ PPDR} - P_{ps} + G_{radar} - DEC_{pol} - DEC_{ant}$$

$$L_{prop} = e.i.r.p._{unwanted\ em\ PPDR} - (-115.9) + 38.5 - 1.5 - 3 = 104 \text{ dB}$$

$$e.i.r.p._{unwanted\ em\ PPDR} = (-115.9) - 38.5 + 1.5 + 3 + 104 \text{ dB}$$

$$e.i.r.p._{unwanted\ em\ PPDR} = -45.9 \text{ dBm/MHz}$$

By applying a 3 dB margin to this unwanted e.i.r.p., it is assumed that LTE OOB emissions do not increase further the total interfering power, and therefore the exclusion zone remains unchanged.

For a 3.8 km separation distance, Table 32 below gives the necessary additional filtering to apply on LTE specification (worst case values):

Table 32: Necessary additional filtering to apply on LTE specification (worst case values)

delta F_c		OOB e.i.r.p.	limit	Necessary attenuation
from 1.55 to 4.55 MHz	0 dBm/MHz (delta	13 dBm/MHz		61.9 dB

delta F_c		OOB e.i.r.p.	limit	Necessary attenuation
	3.05 MHz)		-48.9 dBm	
from 4.55 to 7.55 MHz	-5 dBm/MHz	8 dBm/MHz		56.9 dB
from 7.55 to 10 MHz	-6 dBm/MHz	7 dBm/MHz		55.9 dB
delta F_c		Spurious e.i.r.p.	limit	Necessary attenuation
> 10MHz	-36dBm/100kHz	-13 dBm/MHz	-48.9 dBm	35.9 dB
Within or below LTE UL spectrum	-96 dBm/100kHz	-73 dBm/MHz	-48.9 dBm	0 dB

3.7.4 Conclusion.

3.7.4.1 Summary of the study.

Results show that impact of PPDR-LTE (base station and mobile station) on ground and airborne radar can be very important and can cause harmful interference:

In a co channel scenario, the risk of interference from PPDR base stations into radar reception is concentrated on radar desensitisation, while risk of saturation is not null but less important.

In an adjacent scenario, the impact is lower than in co channel scenario but spurious level cannot insure cohabitation without interference. This also means that out-of-band emissions can cause interference on radar receiver.

Table 33 and Table 34 below gives a synthesis of the different cases studied:

Table 33: Synthesis of the different cases studied for Airborne Radar

Airborne Radar Saturation		
PPDR LTE400 interferer	BS Co-Channel	MS Co-Channel
Necessary attenuation	92.5 dB	74 dB
Corresponding Distance (Free Space condition)	2.3 km	280 m

Table 34: Attenuation and corresponding separation distances, derived from worst case values taken from LTE specification and without additional filtering

Airborne Radar Desensitisation				
PPDR LTE400 interferer	BS Co-Channel	BS Out-of-Band	BS Spurious	BS within or below LTE UL
Necessary attenuation	187.7 dB	142.1 dB	120.9 dB	41.9 dB
Corresponding Distance (Free Space condition)	>> 500 km	> 500 km	61 km	< 10 km

Airborne Radar Desensitisation				
Airborne Radar Desensitisation				
PPDR LTE400 interferer	MS Co-channel	MS Out-of-band	MS Spurious	MS within or above LTE DL
Necessary attenuation	169.2 dB	126.9 dB	110.9 dB	86.9 dB
Corresponding Distance (Free Space condition)	>> 500 km	120 km	20 km	1 km

The following Table 35 and Table 36 below gives a synthesis of the different cases studied for the ground radar:

Table 35: Synthesis of the different cases studied for the ground radar

Ground Radar Saturation (Hr = 8m)		
PPDR LTE400 interferer	BS	MS
Necessary attenuation	104 dB	85.5 dB
Corresponding Distance (Free Space condition)	8.8 km	1000 m
Corresponding Distance (EPM73*, H_{BS} = 30 m, H_{MS} = 1.5 m)	3.8 km	560 m

Table 36: Attenuation and corresponding separation distances, derived from worst case values taken from LTE specification and without additional filtering

Ground Radar Desensitisation (Hr = 8m)				
PPDR LTE400 interferer	BS Co-Channel	BS Out-of-Band	BS Spurious	BS within or below LTE UL
Necessary attenuation	205.2 dB	159.6 dB	136.9 dB	76.9
Corresponding Distance (Free Space condition)	>> 500 km	>500 km	390 km	0.3 km
Corresponding Distance (EPM73*, H_{BS} = 30 m, H_{MS} = 1.5 m)	230 km	57 km	30 km	
Ground Radar Desensitisation (Hr = 8m)				
PPDR LTE400 interferer	MS Co-channel	MS Out-of-band	MS Spurious	MS within or above LTE DL
Necessary attenuation	186.7 dB	144.4 dB	128.4 dB	104.2 dB
Corresponding Distance (Free Space condition)	>> 500 km	>500 km	146 km	9 km

Ground Radar Desensitisation (Hr = 8m)				
Corresponding Distance (EPM73*, H_{BS} = 30 m, H_{MS} = 1.5 m)	110 km	22.5 km	7 km	

*: EPM73 is an empirical propagation model that takes into account antenna heights in the calculation of the distance). EPM73 is more appropriate than free space in this case of "ground to ground" link. This model has been used in the study "broadband wireless Systems usage in 2300-2400MHz" (See ECC Report 172 [25]).

Based on the result of this study, it can be concluded that PPDR-LTE base station general spurious level reduced by at least 35 dB would ensure co-existence. Note that PPDR DL emissions for own UL protection is 60dB below the general spurious emission requirement.

It is noted that no cumulative effect of the mobile stations has been carried out in the study.

3.8 IMPACT ON RADIO ASTRONOMY AT 406.1 - 410 MHz

The impact of LTE400 activities in the 410-430 MHz band on RAS in the 406.1- 410 MHz band is studied with the consideration of emission from base stations (BS) and user equipment (UE). The MCL calculations are performed for single and aggregate emitters, first assuming a flat terrain for radio astronomy stations. In a further step, the terrain profiles of two radio astronomy stations namely, Effelsberg in Germany and Westerbork in the Netherlands, are implemented in the analysis to include the effect of the attenuation from the geographical terrain on the propagation calculations around these observatories.

List of Radio Astronomy stations in Europe using the frequency band 406.1-410 MHz is in ANNEX 10:

3.8.1 Study parameters

The LTE400 parameters used for this study, as listed in Table 37.

Recommendation ITU-R RA.769-2 [19] provides threshold levels of -203 dBW (or -173 dBm) for interference detrimental to the RAS for the band 406.1- 410 MHz. The receiver antenna gain is assumed 0 dBi and the typical height of the receiver is taken to be 50 m.

Table 37: LTE400 and RAS parameters

LTE400			RAS Station
	Base Station	User Equipment	
e.i.r.p.	47 dBm	37 dBm	
Center frequency	421.5 MHz	411.5 MHz	408 MHz
Bandwidth	2.7 MHz	2.7 MHz	3.9 MHz
Spurious power	-36 dBm/100 kHz Note	10 dBm/MHz	
RAS protection level			-173 dBm
Antenna gain	13 dBi	0 dBi	0 dBi
Feeder Loss	2 dBm	0 dBm	
Deployment density	0.0057 km^2	0.023 km^2	
Duty cycle	100 %	100 %	
Height (m)	30 m	1.5 m	50 m

LTE400	RAS Station
Note : -96dBm/100kHz is the 3GPP requirement for protection of own UL band. BS emissions are expected to be equal or lower than this level at the RAS frequencies due to rejection from the TX filter.	

3.8.2 Results for flat terrain

The results of the compatibility study for flat terrain profile are summarised in Table 38 and Figure 28. For the analysis, the propagation model P.452-15, including free space, smooth earth diffraction, troposcatter, and ground clutter attenuations was selected. The atmospheric attenuation was assumed 0.0 dB/km.

In the case of a single base station emitting at a direct line of sight on a RAS station (i.e., the worst case scenario, the obtained MCL is 165.8 dB, which translates to a separation distance of 94 km, assuming the spurious emissions level of -36dBm/100kHz towards RAS. In the aggregation study (considering 36dBm/100kHz towards RAS) with a deployment density of 0.0057 km2, an MCL of 152.8 dB or alternatively a separation distance of 89 km is obtained.

A BS needs to fulfil the protection criteria of its own UL frequencies, which will require a TX filter. The UL protection level is -96dBm/100kHz. It is likely that the filter will maintain a similar level of attenuation in the RAS band and thus depending on the actual level of spurious emissions. The size of the exclusion zone can be reduced down to around 20km if the emissions within RAS are -96dBm/100kHz.

Table 38: LTE400-RAS compatibility results assuming flat terrain (assuming -36dBm/100kHz spurious emissions within RAS frequencies)

	LTE400 PPDR Base Station		Mobile Station	
	Single Interferer	Aggregate Interference	Single Interferer	Aggregate Interference
Spurious emissions in 406.1-410 MHz	-37.1 dBW		-32 dBW	
Protection Level	-202.9 dBW	-202.9 dBW	-202.9 dBW	-202.9 dBW
MCL	165.8 dB	152.8 dB	170.8 dB	170.8 dB
Mean power received by RAS station in 406.1-410 MHz		-145.6 dBW		-150.0 dBW,
Separation distance	94 km	--	38 km	56 km
Required reduction in spurious emissions	28 dB	--	74 dB	53 dB
Spurious emission limit	-101 dBm/MHz	-68.3 dBm/MHz	-82 dBm/MHz	-62.5 dBm/MHz

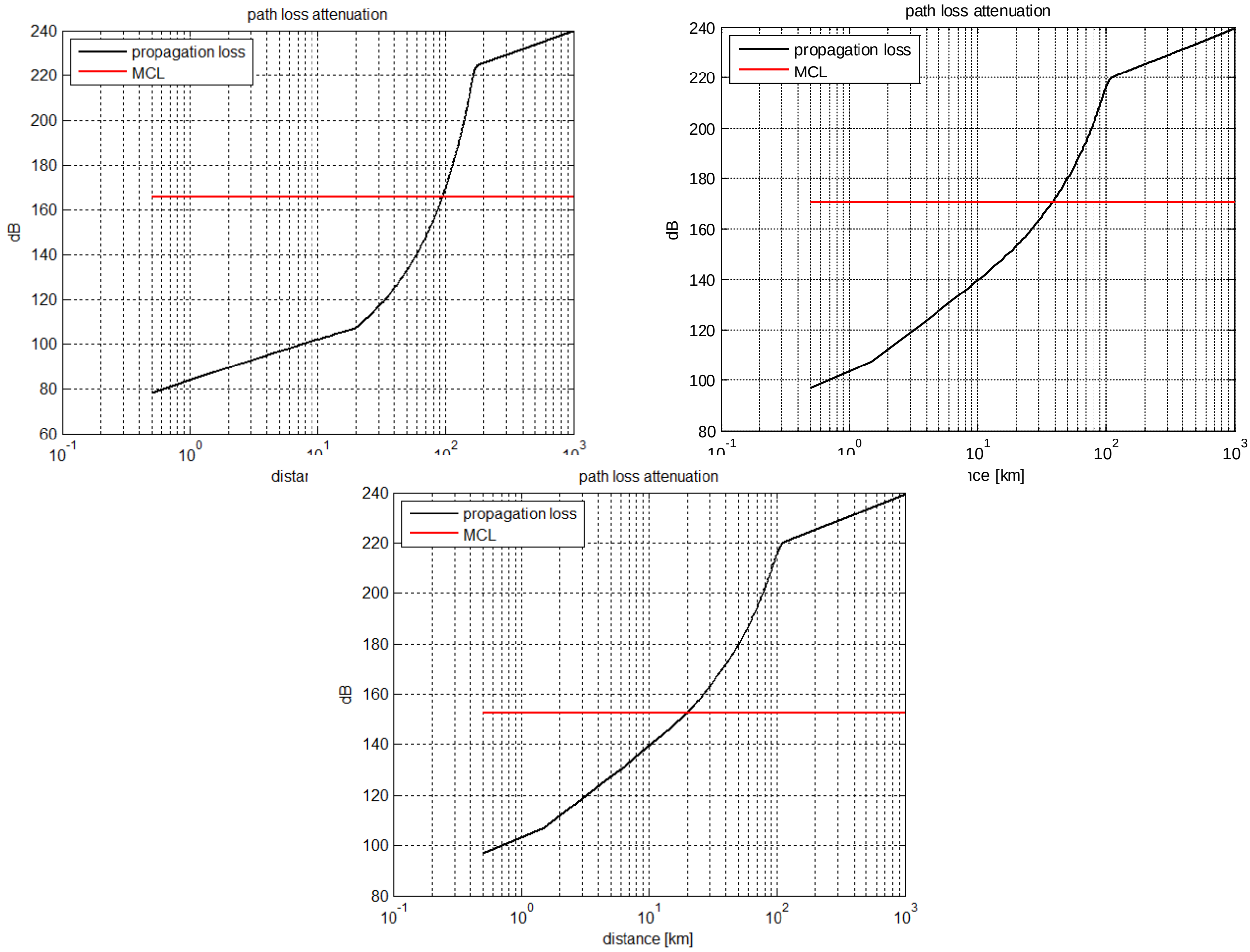

Figure 28: Path loss attenuation graphs for spurious emission from LTE400 BS (left) fulfilling -36 dBm/100kHz emissions within the RAS frequencies and UE (right) depicting the required separation distances from a radio telescope assuming a flat terrain profile

3.8.3 Case studies for radio telescopes Effelsberg and Westerbork using terrain profiles (assuming -36 dBm/100kHz spurious emissions within RAS frequencies)

For a more realistic assessment, the terrain profiles at a resolution of 0.55 km x 0.93 km around two radio astronomy telescopes, Effelsberg in Germany and Westerbork in the Netherlands, were incorporated in the MCL calculations. Monte Carlo simulations were performed with 2038 trials for 368 devices within an area of 254.2 km x 254.2 km. For the case study of base stations around the Effelsberg radio telescope, the mean aggregate power received is -172.8 dBW although it can exceed up to -138.5 dBW in of 2 % of the measurements. Based on the mean aggregate power levels the radius of the exclusion zone for Effelsberg becomes 88 km. However, taking into account that the data-loss due to exceeding power levels should not occur in more than 2 % of the measurements, this radius increases to 102 km.

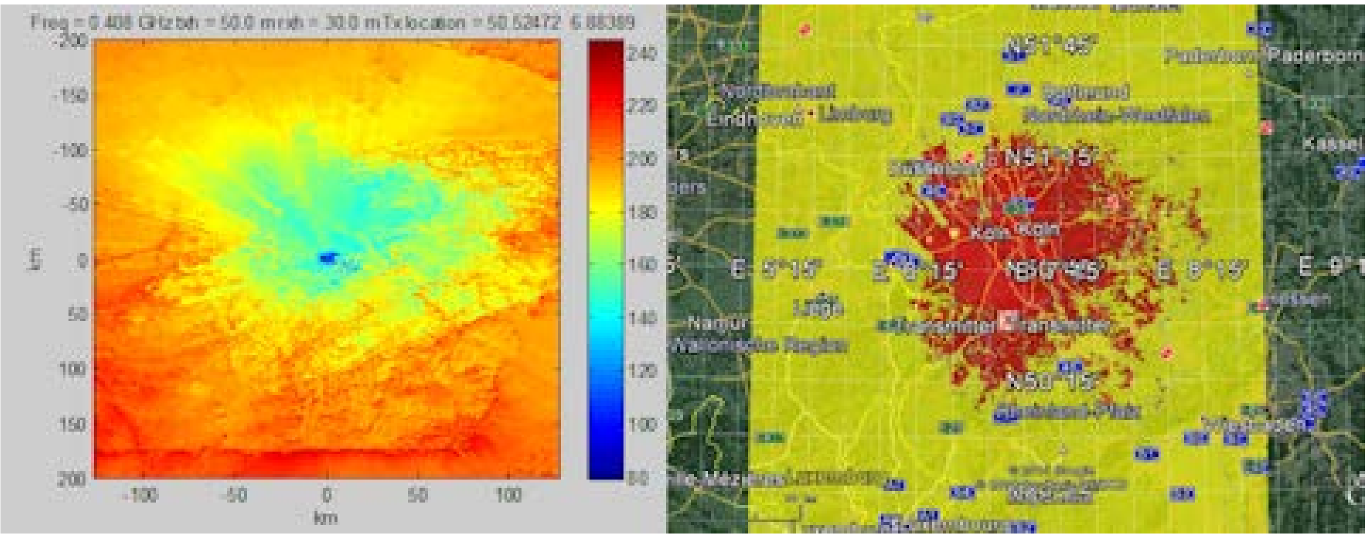

Figure 29: Attenuation map for Effelsberg based on terrain profile analysis for LTE400 base stations (left) and the map for the exclusion zone based on MCL calculations (right)

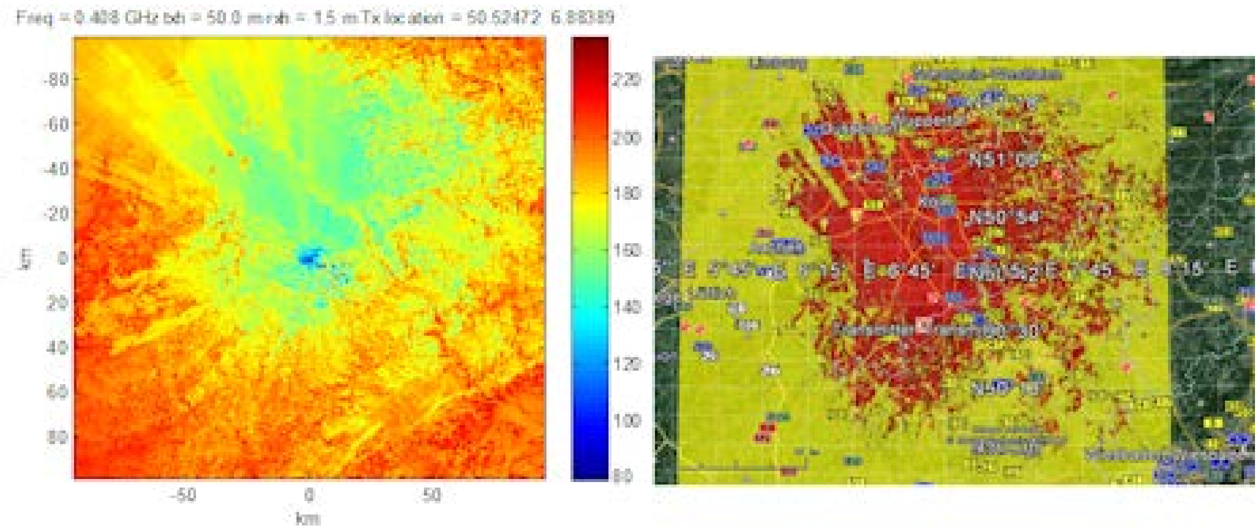

Figure 30: Same as Figure 29, but for user equipment

The Monte Carlo simulations for user equipment were performed with 1000 trials for 834 devices within an area of 190 km x 190 km. For a mean aggregate power of -170.4 dBW the radius of the exclusion zone becomes 88 km and can increase up to more than 95 km when the aggregate power reaches -139.9 dBW with a 2 % probability. Figure 31 shows the calculated exclusion zones around Effelsberg on attenuation plots.

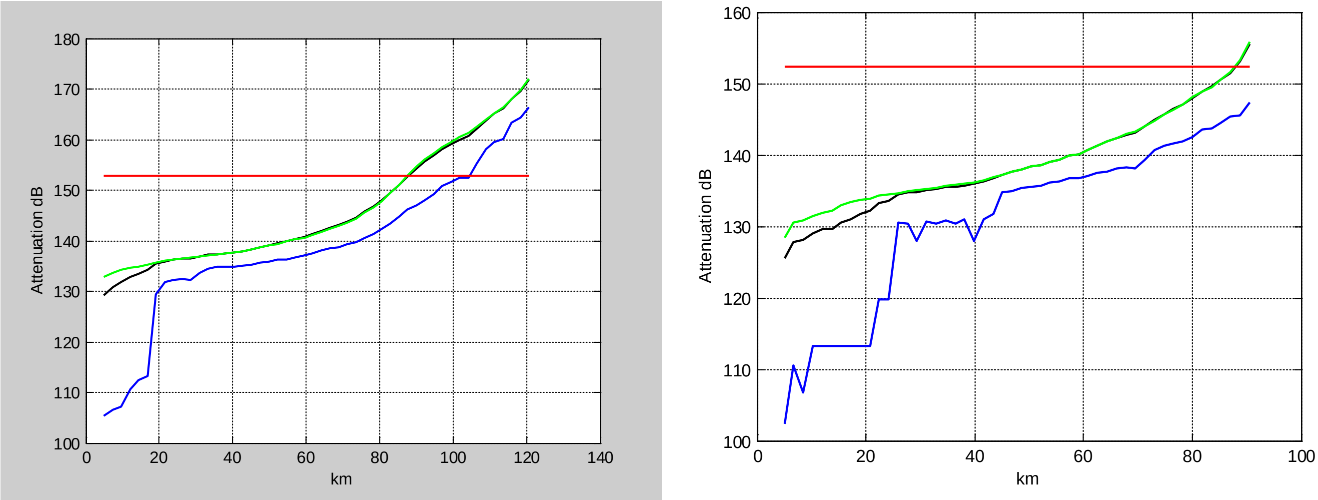

Figure 31: Attenuation plots showing the required radii for exclusion zones around Effelsberg including terrain profile analysis for LTE400 base stations (left) and the user equipment (right). The green curves show the attenuation based on mean aggregate emission levels. The blue curves show the attenuation when the power levels exceed the mean level by no more than 2% of the time

The attenuation maps and the size of exclusion zones for Westerbork are displayed in Figure 32, Figure 33 and Figure 34. In the case of base stations, the mean aggregate power received is -146.3 dBW and can exceed up to -137.4 dBW with a probability of 2 %. Based on the mean aggregate power levels the radius of the exclusion zone for Westerbork becomes 92 km, while considering the restriction in a data-loss of 2 % due to exceeding power levels this radius increases to 94 km. For the user equipment a mean aggregate power of -150.2 dBW leads to a radius of more than 90 km for the exclusion zone and can increase further when the aggregate power reaches -131.5 dBW with a 2 % probability.

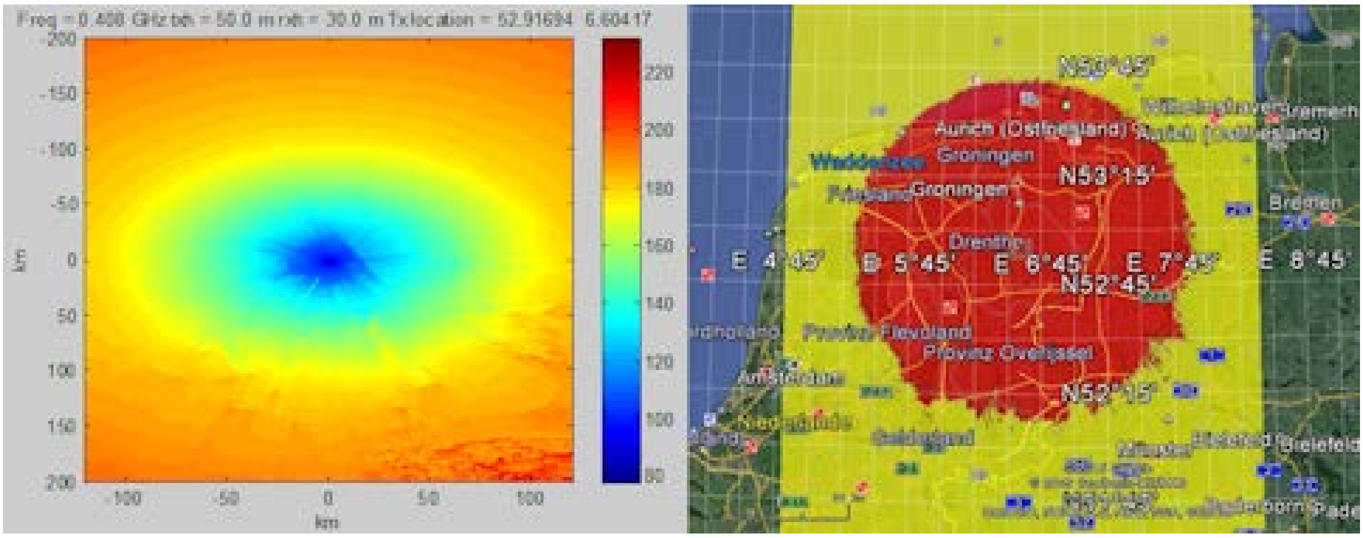

Figure 32: Attenuation map for Westerbork based on terrain profile analysis for LTE400 base stations (left) and the map for the exclusion zone based on MCL calculations (right)

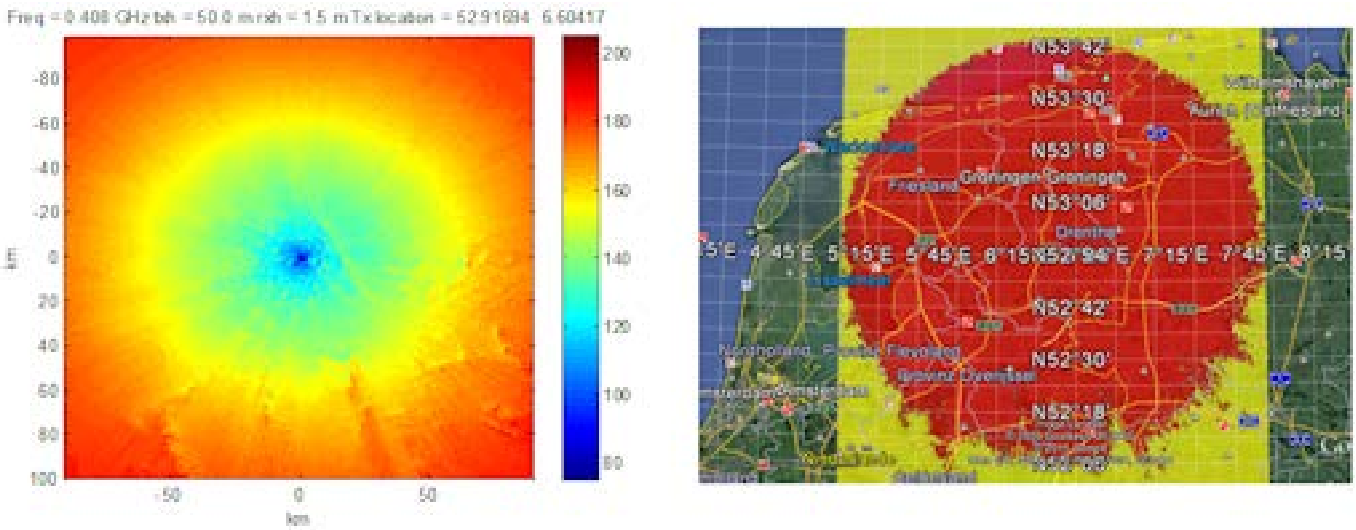

Figure 33: Same as Figure 32, but for user equipment

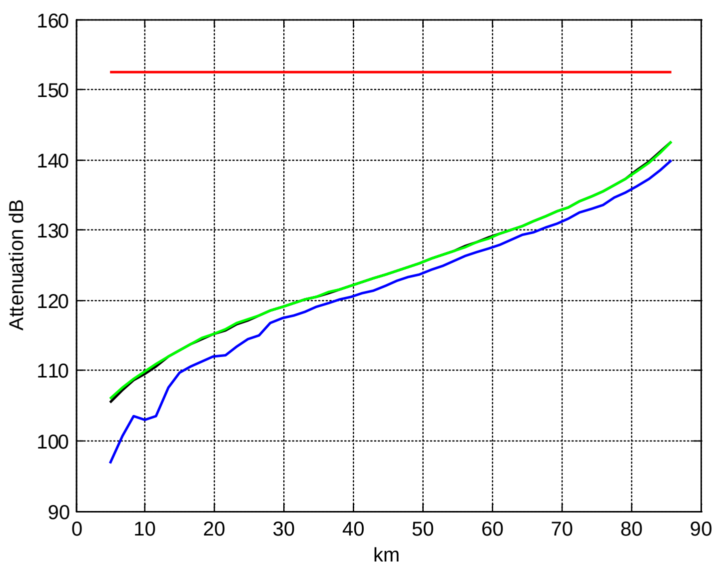

Figure 34: same as Figure 31, but for the Westerbork radio observatory in the Netherlands

3.8.4 Conclusion

Generic compatibility calculations for PPDR activity in the 410 – 430 MHz band and radio astronomy operating in the 406.1 – 410 MHz band have shown that compatibility is difficult to achieve. Separation distances of the order of 90 km between LTE400 base stations and radio astronomy stations are required. if the BS spurious emissions are -36 dBm/100kHz at these frequencies. However, LTE defines -96 dBm/100kHz UL band protection, which requires a TX filter implementation. This TX filter is expected to perform equal or better at the RAS frequencies, which translates into a reduction of the separation distance to around 20 km for a spurious emission level of -96 dBm/100kHz.The operational bandwidth for the user equipment falls directly adjacent to the RAS band and therefore results in a high level of unwanted emissions into this band. The required separation distance from the UEs is about 50 km. Moreover, adding the terrain profile to the analysis showed that the attenuation from the geographical terrain does not reduce the separation distances.

4 IMPACT OF EXISTING SYSTEMS WITHIN THE 410-430 / 450-470 MHZ SUB-BANDS AND ADJACENT BANDS ON BROADBAND PPDR SYSTEMS

4.1 TETRA IMPACT ON LTE400 SYSTEM

For SEAMCAT simulations, frequency allocation has been performed as presented in Figure 35 below. Different interferer densities have been considered around the values calculated in the former section. For each simulation, 100 000 SEAMCAT snapshots have been generated.

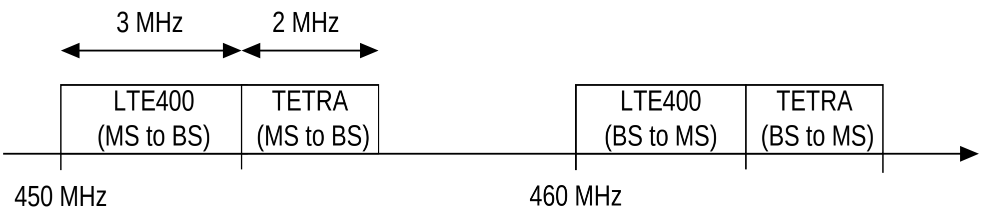

Figure 35: TETRA on LTE400

4.1.1 TETRA BS impact on LTE400 BS

The TETRA BS transmit signals to TETRA MS between 463 and 465 MHz whereas the three-sector LTE400 BS receive signals coming from LTE400 MS at 451.5 MHz. Interfering link frequency is randomly chosen (discrete distribution option) in SEAMCAT.

Table 39 below gives the average capacity loss and bit rate loss for OFDMA system as defined within SEAMCAT for an LTE400 BS fulfilling the 3GPP out-of-band blocking minimum requirements.

Table 39: TETRA BS impact on LTE400 BS

Interferer Density (TETRA BS / km²)	Cell Range (km)	OFDMA System		OFDMA Reference Cell	
		Capacity Loss	Bitrate Loss	Capacity Loss	Bitrate Loss
0.01	6.2	0.00 %	1.93%	0.00 %	1.88 %
0.014	5.2	0.00 %	2.68 %	0.00 %	2.63 %
0.05	2.77	0.00 %	8.89 %	0.00 %	8.73 %
0.1	1.96	0.00 %	16.09 %	0.00 %	15.93%

LTE FDD BS implements duplexers for performance purpose. The UL filter will provide at least 90dB of attenuation against its own DL band. This rejection will also apply against TETRA blockers, decreasing the risk of interference in the above table further,

4.1.2 TETRA BS impact on LTE400 MS

The TETRA BS transmit signals to TETRA MS between 463 and 465 MHz whereas the LTE400 MS receive signals from the three-sector LTE400 BS at 461.5 MHz. Interfering link frequency is randomly chosen (discrete distribution option) in SEAMCAT.

Table 40 below gives the average capacity loss and bit rate loss for OFDMA system as defined within SEAMCAT.

Table 40: TETRA BS impact on LTE400 MS

Interferer Density (TETRA BS / km²)	Cell Range (km)	OFDMA System		OFDMA Reference Cell	
		Capacity Loss	Bitrate Loss	Capacity Loss	Bitrate Loss
0.01	6.2	0.32 %	1.43 %	0.33 %	1.56 %
0.014	5.2	0.32 %	1.38 %	0.32 %	1.55 %
0.05	2.77	0.18 %	1.06 %	0.18 %	1.19 %
0.1	1.96	0.11 %	0.89 %	0.12 %	0.95 %

4.1.3 TETRA MS impact on LTE400 BS

The TETRA MS transmit signals to TETRA BS between 453 and 455 MHz whereas the three-sector LTE400 BS receives signals coming from LTE400 MS at 451.5 MHz. Interfering link frequency is randomly chosen (discrete distribution option) in SEAMCAT.

Table 41 below gives the average capacity loss and bit rate loss for OFDMA system as defined within SEAMCAT.

Table 41: TETRA MS impact on LTE400 BS

Interferer Density (TETRA MS / km²)	OFDMA System		OFDMA Reference Cell	
	Capacity Loss	Bitrate Loss	Capacity Loss	Bitrate Loss
0.05	0.00 %	0.22 %	0.00 %	0.22 %
0.057	0.00 %	0.27 %	0.00 %	0.26 %
0.1	0.00 %	0.46 %	0.00 %	0.44 %
0.2	0.00 %	0.88 %	0.00 %	0.88 %

4.1.4 TETRA MS impact on LTE400 MS

The TETRA MS transmit signals to TETRA BS between 453 and 455 MHz whereas the LTE400 MS receives signals coming from LTE400 BS at 461.5 MHz. Interfering link frequency is randomly chosen (discrete distribution option) in SEAMCAT.

Table 42 below gives the average capacity loss and bit rate loss for OFDMA system as defined within SEAMCAT for an LTE400 MS fulfilling the 3GPP in-band blocking minimum requirements.

Table 42: TETRA MS impact on LTE400 MS

Interferer Density (TETRA MS / km²)	OFDMA System		OFDMA Reference Cell	
	Capacity Loss	Bitrate Loss	Capacity Loss	Bitrate Loss
0.05	0.03 %	0.07 %	0.04 %	0.07 %
0.057	0.04 %	0.07 %	0.04 %	0.08 %
0.1	0.04 %	0.07 %	0.04 %	0.08 %
0.2	0.03 %	0.05 %	0.03 %	0.06 %

LTE FDD MS implements duplexers for performance purpose. The DL filter will provide around 45dB of attenuation against its own UL band. This rejection will also apply against TETRA blockers, decreasing the risk of interference in the above Table 42 further,

4.1.5 Analysis

The four former tables show that the impact of TETRA systems on LTE-based broadband PPDR systems is very limited. The only case showing significant level of probability of interferences corresponds to a very dense TETRA network (BS-BS coexistence), assuming the LTE400 BS only fulfilling the 3GPP blocking minimum requirements. In real networks, LTE BS implements duplexers, which improves the blocking performance. This was not considered in the simulations In addition, in the case, the TETRA BS density is almost ten times greater than for the baseline scenario; this can be considered as an exceptional case to be managed as such.

4.2 TETRAPOL IMPACT ON LTE400 SYSTEM

For SEAMCAT simulations, frequency allocation has been performed as presented in Figure 36 below. Different interferer densities have been considered around the values calculated in the former section. For each simulation, 100 000 SEAMCAT snapshots have been generated.

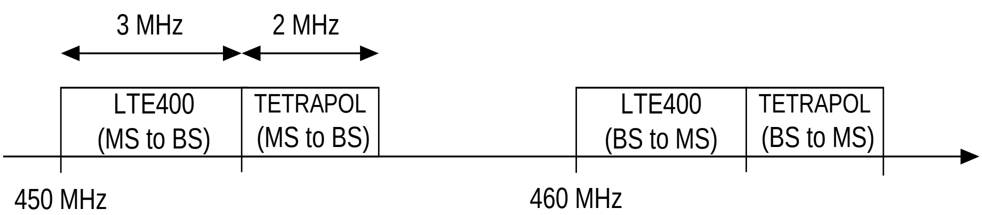

Figure 36: TETRAPOL on LTE400

4.2.1 TETRAPOL BS impact on LTE400 BS

The TETRAPOL BS transmits signals to TETRAPOL MS between 463 and 465 MHz whereas the three-sector LTE400 BS receive signals coming from LTE400 MS at 451.5 MHz. Interfering link frequency is randomly chosen (discrete distribution option) in SEAMCAT.

Table 43 below gives the average capacity loss and bit rate loss for OFDMA system as defined within SEAMCAT for an LTE400 BS fulfilling the 3GPP out-of-band blocking minimum requirements.

Table 43: TETRAPOL BS impact on LTE400 BS

Interferer Density (TETRAPOL BS / km²)	Cell Range (km)	OFDMA System		OFDMA Reference Cell	
		Capacity Loss	Bitrate Loss	Capacity Loss	Bitrate Loss
0.007	7.3	0.00 %	0.91 %	0.00 %	0.91 %
0.01	6.2	0.00 %	1.30 %	0.00 %	1.28 %
0.05	2.77	0.00 %	6.12 %	0.00 %	6.05 %
0.1	1.96	0.00 %	11.43 %	0.00 %	11.31 %

LTE FDD BS implements duplexers for performance purpose. The UL filter will provide at least 90 dB of attenuation against its own DL band. This rejection will also apply against TETRAPOL blockers, decreasing the risk of interference in the above Table 43 further,

4.2.2 TETRAPOL BS impact on LTE400 MS

The TETRAPOL BS transmits signals to TETRAPOL MS between 463 and 465 MHz whereas the LTE400 MS receives signals from the LTE400 BS at 461.5 MHz. Interfering link frequency is randomly chosen (discrete distribution option) in SEAMCAT.

Table 44 below gives the average capacity loss and bit rate loss for OFDMA system as defined within SEAMCAT.

Table 44: TETRAPOL BS impact on LTE400 MS

Interferer Density (TETRAPOL BS / km²)	Cell Range (km)	OFDMA System		OFDMA Reference Cell	
		Capacity Loss	Bitrate Loss	Capacity Loss	Bitrate Loss
0.007	7.3	0.27 %	1.06 %	0.27 %	1.04 %
0.01	6.2	0.25 %	1.12 %	0.25 %	1.26 %
0.05	2.77	0.15 %	0.81 %	0.16 %	0.93 %
0.1	1.96	0.09 %	0.66 %	0.10 %	0.73 %

4.2.3 TETRAPOL MS impact on LTE400 BS

The TETRAPOL MS transmit signals to TETRAPOL BS between 453 and 455 MHz whereas the three-sector LTE400 BS receives signals coming from LTE400 MS at 451.5 MHz. Interfering link frequency is randomly chosen (discrete distribution option) in SEAMCAT.

Table 45 below gives the average capacity loss and bit rate loss for OFDMA system as defined within SEAMCAT.

Table 45: TETRAPOL MS impact on LTE400 BS

Interferer Density (TETRAPOL MS / km²)	OFDMA System		OFDMA Reference Cell	
	Capacity Loss	Bitrate Loss	Capacity Loss	Bitrate Loss
0.028	0.00 %	0.03 %	0.00 %	0.03 %
0.05	0.00 %	0.04 %	0.00 %	0.04 %
0.1	0.00 %	0.08 %	0.00 %	0.09 %
0.2	0.00 %	0.15 %	0.00 %	0.16 %

4.2.4 TETRAPOL MS impact on LTE400 MS

The TETRAPOL MS transmit signals to TETRAPOL BS between 453 and 455 MHz whereas the LTE400 MS receives signals coming from LTE400 BS at 461.5 MHz. Interfering link frequency is randomly chosen (discrete distribution option) in SEAMCAT.

Table 46 below gives the average capacity loss and bit rate loss for OFDMA system as defined within SEAMCAT for an LTE400 MS fulfilling the 3GPP in-band blocking minimum requirements.

Table 46: TETRAPOL MS impact on LTE400 MS

Interferer Density (TETRAPOL MS / km²)	OFDMA System		OFDMA Reference Cell	
	Capacity Loss	Bitrate Loss	Capacity Loss	Bitrate Loss
0.028	0.01 %	0.01 %	0.01 %	0.01 %
0.05	0.01 %	0.02 %	0.01 %	0.02 %
0.1	0.01 %	0.01 %	0.01 %	0.01 %
0.2	0.00 %	0.01 %	0.00 %	0.01 %

LTE FDD MS implements duplexers for performance purpose. The DL filter will provide around 45 dB of attenuation against its own UL band. This rejection will also apply against TETRAPOL blockers, decreasing the risk of interference in the above Table 46 further,

4.2.5 Analysis

Table 43, Table 44, Table 45 and Table 46 show that the impact of TETRAPOL systems on LTE-based broadband PPDR systems is very limited. The only case showing a significant level of probability of interferences a very dense TETRAPOL network (BS-BS coexistence), assuming the LTE400 BS only fulfilling the 3GPP blocking minimum requirements. In real networks, LTE BS implements duplexers, which improves the blocking performance. This was not considered in the simulations In addition,in this case, the TETRAPOL BS density is more than ten times greater than the baseline scenario; this can be considered as an exceptional case to be managed as such.

4.3 CDMA-PAMR IMPACT ON LTE400 SYSTEM

For SEAMCAT simulations, frequency allocation has been performed as presented in Figure 37 below. Different interferer densities have been considered around the values calculated in the former section. For each simulation, 20 000 SEAMCAT snapshots have been generated.

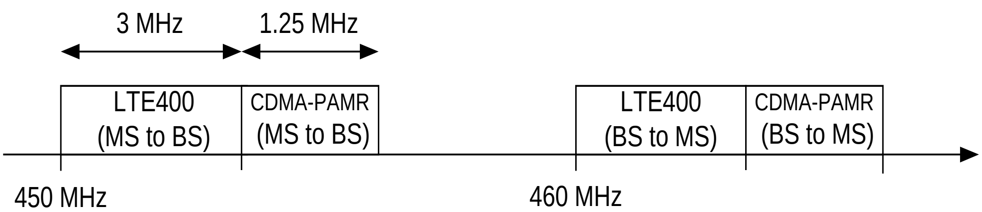

Figure 37: CDMA-PAMR on LTE400

4.3.1 CDMA-PAMR BS impact on LTE400 BS

The CDMA-PAMR BS transmits signals to CDMA-PAMR MS at 463.625 MHz whereas the three-sector LTE400 BS receives signals coming from LTE400 MS at 451.5 MHz.

Table 47 below gives the average capacity loss and bit rate loss for OFDMA system as defined within SEAMCAT for an LTE400 BS fulfilling the 3GPP out-of-band blocking minimum requirements.

Table 47: CDMA-PAMR BS impact on LTE400 BS

Interferer Density (CDMA-PAMR BS / km²)	Cell Range (km)	OFDMA System		OFDMA Reference Cell	
		Capacity Loss	Bitrate Loss	Capacity Loss	Bitrate Loss
0.004	11.1	0.00 %	0.36 %	0.00 %	0.07 %
0.01	7.16	0.00 %	0.84 %	0.00 %	0.16 %
0.1	2.27	0.00 %	5.78 %	0.00 %	1.58 %

LTE FDD BS implements duplexers for performance purpose. The UL filter will provide at least 90dB of attenuation against its own DL band. This rejection will also apply against CDMA PAMR blockers, decreasing the risk of interference in the above Table 47 further, ‘

4.3.2 CDMA-PAMR BS impact on LTE400 MS

The CDMA-PAMR BS transmits signals to CDMA-PAMR MS at 463.625 MHz whereas the LTE400 MS receives signals from the LTE400 BS at 461.5 MHz.

Table 48 below gives the average capacity loss and bit rate loss for OFDMA system as defined within SEAMCAT.

Table 48: CDMA-PAMR BS impact on LTE400 MS

Interferer Density (CDMA-PAMR BS / km²)	Cell range (km)	OFDMA System		OFDMA Reference Cell	
		Capacity Loss	Bitrate Loss	Capacity Loss	Bitrate Loss
0.004	11.1	0.05 %	0.23 %	0.04 %	0.25 %
0.01	7.16	0.13 %	0.49 %	0.10 %	0.61 %
0.1	2.27	0.04	0.46 %	0.08 %	1.05 %

4.3.3 CDMA-PAMR MS impact on LTE400 BS

The CDMA-PAMR MS transmit signals to CDMA-PAMR BS at 453.625 MHz whereas the three-sector LTE400 BS receives signals coming from LTE400 MS at 451.5 MHz.

Table 49 below gives the average capacity loss and bit rate loss for OFDMA system as defined within SEAMCAT.

Table 49: CDMA-PAMR MS impact on LTE400 BS

Interferer Density (CDMA-PAMR MS / km²)	OFDMA System		OFDMA Reference Cell	
	Capacity Loss	Bitrate Loss	Capacity Loss	Bitrate Loss
0.01	0 %	0.19 %	0 %	0.17 %
0.05	0 %	0.34 %	0 %	0.36 %
0.1	0 %	0.40 %	0 %	0.43 %

4.3.4 CDMA-PAMR MS impact on LTE400 MS

The CDMA-PAMR MS transmit signals to CDMA-PAMR BS at 453.625 MHz whereas the LTE400 MS receives signals coming from LTE400 BS at 461.5 MHz.

Table 50 below gives the average capacity loss and bit rate loss for OFDMA system as defined within SEAMCAT for an LTE400 MS fulfilling the 3GPP in-band blocking minimum requirements.

Table 50: CDMA-PAMR MS impact on LTE400 MS

Interferer Density (CDMA-PAMR MS / km²)	OFDMA System		OFDMA Reference Cell	
	Capacity Loss	Bitrate Loss	Capacity Loss	Bitrate Loss
0.01	0 %	0.09 %	0 %	0.12 %
0.05	0 %	0;08 %	0 %	0.10 %
0.1	0.04 %	0.07 %	0.06 %	0.10 %

LTE FDD MS implements duplexers for performance purpose. The DL filter will provide around 45 dB of attenuation against its own UL band. This rejection will also apply against CDMA-PAMR blockers, decreasing the risk of interference in the above Table 50 further,

4.3.5 Analysis

Table 47, Table 48, Table 49 and Table 50 show that the impact of CDMA-PAMR systems on LTE-based broadband PPDR systems is very limited. The only case showing some bit rate loss corresponds to a very dense CDMA-PAMR network (BS density more than twenty times greater than the baseline scenario),BS-BS coexistence, assuming the LTE400 BS only fulfilling the 3GPP blocking minimum requirements. In real networks, LTE BS implements duplexers, which improves the blocking performance. This was not considered in the simulations

4.4 25 KHZ ANALOGUE FM IMPACT ON LTE400 SYSTEM

For SEAMCAT simulations, frequency allocation has been used as presented in Figure 38 below. Different interferer densities have been considered around the values calculated in the former section. For each simulation, 20 000 SEAMCAT snapshots have been generated.

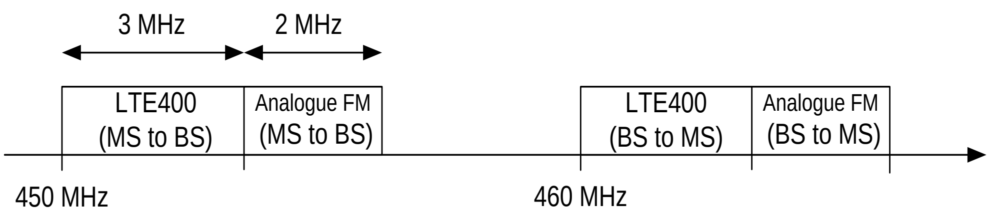

Figure 38: 25 kHz Analogue FM on LTE400

4.4.1 25 kHz Analogue FM BS impact on LTE400 BS

The 25 kHz Analogue FM BS transmits signals to 25 KHz Analogue FM MS between 463 and 465 MHz whereas the three-sector LTE400 BS receives signal coming LTE400 MS at 451.5 MHz. Interfering link is randomly chosen (discrete distribution option) in SEAMCAT.

Table 51 below gives the average capacity loss and bitrate loss for OFDMA system as defined within SEAMCAT for an LTE400 BS fulfilling the 3GPP out-of-band blocking minimum requirements..

Table 51: Analogue FM BS impact on LTE400 BS

Interferer Density (25 kHz Analogue FM BS / km²)	Cell range (km)	OFDMA System		OFDMA Reference Cell	
		Capacity Loss	Bitrate Loss	Capacity Loss	Bitrate Loss
0.005	8.77	0.00 %	0.95 %	0.00 %	0.89 %
0.01	6.20	0.00 %	1.85 %	0.00 %	1.79 %
0.02	4.39	0.00 %	3.55 %	0.00 %	3.45 %
0.05	2.77	0.00 %	8.54 %	0.00 %	8.48 %
0.1	1.96	0.00 %	15.5 %	0.00 %	15.49 %

LTE FDD BS implements duplexers for performance purpose. The UL filter will provide at least 90 dB of attenuation against its own DL band. This rejection will also apply against analogue FM blockers, decreasing the risk of interference in the above Table 51 further,

4.4.2 25 kHz Analogue FM BS on LTE400 MS

The 25 kHz Analogue FM BS transmits signals to 25 kHz Analogue FM MS between 463 and 465 MHz whereas the LTE400 MS receives signal coming LTE400 BS at 461.5 MHz. Interfering link is randomly chosen (discrete distribution option) in SEAMCAT.

Table 52 below gives the average capacity loss and bit rate loss for OFDMA system as defined within SEAMCAT.

Table 52: Analogue FM BS impact on LTE400 MS

Interferer Density (25 kHz Analogue FM BS / km²)	Cell range (km)	OFDMA System		OFDMA Reference Cell	
		Capacity Loss	Bitrate Loss	Capacity Loss	Bitrate Loss
0.005	8.77	0.25 %	1.01 %	0.22 %	1.11 %
0.01	6.20	0.38 %	1.56 %	0.47 %	1.86 %
0.02	4.39	0.46 %	2.03 %	0.42 %	2.03 %
0.05	2.77	0.46 %	2.09 %	0.48 %	2.27 %
0.1	1.96	0.36 %	1.91 %	0.36 %	2.19 %

4.4.3 25 kHz Analogue FM MS on LTE400 BS

The 25 KHz Analogue FM MS transmit signals to 25 kHz Analogue BS between 453 and 455 MHz whereas the three-sector LTE400 BS receives signals coming from LTE400 MS at 451.5 MHz. Interfering link frequency is randomly chosen (discrete distribution option) in SEAMCAT.

Table 53 below gives the average capacity loss and bit rate loss for OFDMA system as defined within SEAMCAT.

Table 53: 25 kHz Analogue FM MS impact on LTE400 BS

Interferer Density (25 kHz Analogue MS / km²)	OFDMA System		OFDMA Reference Cell	
	Capacity Loss	Bitrate Loss	Capacity Loss	Bitrate Loss
0.01	0.00 %	0.02 %	0.00 %	0.03 %
0.05	0.00 %	0.12 %	0.00 %	0.12 %
0.1	0.00 %	0.25 %	0.00 %	0.25 %
0.2	0.00 %	0.45 %	0.00 %	0.42 %
0.5	0.00 %	1.14 %	0.00 %	1.12 %
1	0.00 %	2.20 %	0.00 %	2.21 %

4.4.4 25 kHz Analogue FM MS on LTE400 MS

The 25 kHz Analogue FM MS transmit signals to 25 kHz Analogue FM BS between 453 and 455 MHz whereas the LTE400 MS receives signals coming from LTE400 BS at 461.5 MHz. Interfering link frequency is randomly chosen (discrete distribution option) in SEAMCAT.

Table 54 below gives the average capacity loss and bit rate loss for OFDMA system as defined within SEAMCAT for an LTE400 MS fulfilling the 3GPP in-band blocking minimum requirements.

Table 54: 25 kHz Analogue FM MS impact on LTE400 MS

Interferer Density (25 kHz Analogue MS / km²)	OFDMA System		OFDMA Reference Cell	
	Capacity Loss	Bitrate Loss	Capacity Loss	Bitrate Loss
0.01	0.02 %	0.07 %	0.05 %	0.11 %
0.05	0.13 %	0.38 %	0.12 %	0.41 %
0.1	0.32 %	0.83 %	0.39 %	0.99 %
0.2	0.36 %	1.00 %	0.40 %	1.11 %
0.5	0.37 %	0.87 %	0.30 %	0.86 %
1	0.24 %	0.66 %	0.28 %	0.72 %

LTE FDD MS implements duplexers for performance purpose. The DL filter will provide around 45 dB of attenuation against its own UL band. This rejection will also apply against analogue FM blockers, decreasing the risk of interference in the above Table 54 further,

4.4.5 Analysis

Table 51, Table 52, Table 53 and Table 54 show that the impact of Analogue FM systems on LTE-based broadband PPDR systems is very limited. The only case showing some bit rate loss corresponds to a very dense Analogue FM network (BS density more than twenty times greater than the baseline scenario, BS-BS coexistence), assuming the LTE400 BS only fulfilling the 3GPP blocking minimum requirements. In real networks, LTE BS implements duplexers, which improves the blocking performance. This was not considered in the simulations

The results presented here for 25 kHz Analogue FM systems are also valid for other analogue channel widths as those systems are presenting similar technical characteristics.

4.5 DTT IMPACT ON LTE400 (SEAMCAT CALCULATIONS)

For those SEAMCAT simulations, frequency allocation has been performed as presented in Figure 39 below, this may be updated according to the results of the previous studies, especially the results of the reverse study (LTE400 impact on DTT). Different interferer densities have been considered around the values calculated in the former sections. For each simulation 20 000 SEAMCAT snapshots have been generated.

Figure 39: DTT (Channel 21) on DTT

4.5.1 DTT transmitter impact on LTE400 BS

The DTT transmitter transmits at 474 MHz whereas the three-sector LTE400 BS receives signals from LTE400 MS at 458.5 MHz.

Table 55 below gives the interference probability as defined within SEAMCAT and calculated for both unwanted and blocking interferences, for an LTE400 BS fulfilling the 3GPP out-of-band blocking minimum requirements.

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Table 55: DTT transmitter impact on LTE400 BS

Interferer Density (DTT transmitter / km²)	DTT Cell Range (km)	OFDMA System		OFDMA Reference Cell	
		Capacity Loss	Bitrate Loss	Capacity Loss	Bitrate Loss
0.0001	62.04	0 %	5.94 %	0 %	5.96 %
0.00023	40.46	0 %	11.89 %	0 %	11.82 %
0.0005	27.74	0 %	18.92 %	0 %	18.35 %

LTE FDD BS implements duplexers for performance purpose. The UL filter will provide at least 90 dB of attenuation against its own DL band. This rejection will also apply against DTT blockers, decreasing the risk of interference in the above Table 55 further,

4.5.2 DTT transmitter impact on LTE400 MS

The DTT transmitter transmits at 474 MHz whereas LTE400 MS receive signals from LTE400 BS at 468.5 MHz.

Table 56 below gives the interference probability as defined within SEAMCAT and calculated for both unwanted and blocking interferences.

Table 56: DTT transmitter impact on LTE400 MS

LTE MS with blocking minimum requirements					
Interferer Density (DTT transmitter / km²)	DTT Cell Range (km)	OFDMA System		OFDMA Reference Cell	
		Capacity Loss	Bitrate Loss	Capacity Loss	Bitrate Loss
0.00023	40.46	7.70 %	22.56 %	7.60 %	24.31 %
LTE MS with enhanced blocking requirements (30 dB)					
Interferer Density (DTT transmitter / km²)	DTT Cell Range (km)	OFDMA System		OFDMA Reference Cell	
		Capacity Loss	Bitrate Loss	Capacity Loss	Bitrate Loss
0.0001	62.04	0.08 %	0.62 %	0.09 %	0.69 %
0.00023	40.46	0.15 %	1.33 %	0.15 %	1.52 %
0.0005	27.74	0.38 %	2.62 %	0.42 %	3.10 %

4.5.3 Analysis

According to Table 55 and Table 56, the impact of DTT on LTE400 base stations may become an issue in case of dense DTT networks where channel 21 is in use especially close to the transmitter. The BS duplexer capability was not included in the simulations. Including it will improve the compatibility between DTT and LTE BS LTE400 An improvement of the MS blocking capability (33.7 dB as defined into 3GPP documentation) by 30dB can improve the DTT impact in this scenario.

5 CONCLUSION

This report aims at analysing the impact of introducing LTE technology for Broadband PPDR (with channel bandwidth of 1.4 MHz, 3 MHz and 5 MHz) within the 410-430 MHz and 450-470 MHz sub-bands based on 3GPP Release 12.

In order to support the identification of additional spectrum for Broadband PPDR, this report has developed a significant number of simulations and analyses to evaluate the impact of introducing LTE technology for PPDR applications within the 410-430 MHz and 450-470 MHz sub-bands. Impact analyses have been conducted for most legacy systems already in operation in those sub-bands and also for most systems in operation in adjacent bands. Additional studies for other legacy systems or specific national scenarios that are not covered in this report may need to be performed. In some countries there are systems which will require special protection.

The impact of PPDR LTE400 system on the legacy systems (TETRA, TETRAPOL, CDMA-PAMR, Analogue FM) rolled out into the 410-430 MHz and 450-470 MHz sub-bands as well as the impact of those systems on LTE400 has been studied. The studies show that based on the 3GPP BS spectrum emission mask minimum requirements LTE400 would cause interference to existing systems. Co-existence, operating within these bands, is possible due to the additional filtering required to fulfil the 3GPP protection of own UL minimum requirement (UE) duplexers to limit the interference at an acceptable level. Indeed such duplexers are needed to ensure both to fulfil the 3GPP minimum requirements and to ensure the correct performance of the LTE400 system itself. This result is valid when considering LTE400 User Equipment transmitting up to 5 W (37 dBm) and two different spectrum masks . Extremely dense legacy networks may impact the uplink capacity of LTE400 system and assuming the LTE400 BS only fulfilling the 3GPP minimum blocking requirements. The LTE duplexers were not considered in the simulations. This will largely decrease such impact. These results are also valid, if the LTE400 system is deployed in the 380-400 MHz sub-band

The results of the theoretical co-existence analyses with DTT demonstrate interferences from the PPDR LTE400 system to DTT reception when the PPDR system is adjacent in the frequency domain to the lower DTT Channel, i.e. Channel 21. Nevertheless, the risk of interference can be reduced by at a set of technical measures including a guard band of up to 3 MHz between DTT and PPDR BSs and an appropriate limit of the corresponding PPDR BS out-of-band emissions. Furthermore additional mitigation measures may be required to solve possible residual interference from PPDR BSs on a case by case basis in a manner similar to the situation between LTE800 and DTT. PPDR400 Base Station OOBE e.i.r.p. levels for protection of DTT above 470 MHz are given in Table 1 below.

Table 57: PPDR 400 Base Station OOBE e.i.r.p. levels for protection of DTT above 470 MHz

Frequency range	Condition on Base station in-block e.i.r.p, P (dBm/cell)	Maximum mean OOBE e.i.r.p (dBm/cell)	Measurement bandwidth
For DTT frequencies above 470 MHz where broadcasting is protected	$P \geq 60$	-7	8 MHz
	$P < 60$	$(P - 67)$	8 MHz

The conducted Monte-Carlo simulations in this Report have demonstrated limited interferences to DTT for high power UE (37 dBm) with improved ACLR (79 dB, i.e. OOBE of -42 dBm / 8 MHz) in Channel 21.

Local interference analyses and field measurements, where PPDR UEs are operating in the vicinity of DTT, have demonstrated that despite the aforementioned measures and because of the limited DTT receiver selectivity UE using higher powers may still interfere a DTT receiver located in regions / countries where DTT Channel 21 is in use, especially when vertically polarised DTT antennas are used (no orthogonal discrimination between PPDR transmitter and DTT receiver antennas). In case interferences are observed or anticipated, they can be solved locally by a power reduction of PPDR UE through signalling or network planning.

The following values have been identified:

Table 58: PPDR 400 MHz user equipment in-block emission limits for protection of DTT, fixed roof top reception

	UE maximum mean in-block power
Power limit 1 (See Note 1)	23 dBm inside the coverage areas of DTT ch 21 and ch 22
	31 dBm outside the coverage areas of DTT ch 21 and ch 22.
Power limit 2 (see Note 2)	37 dBm

Note 1: Assuming -3 dBi antenna gain for devices implementing this Decision, it matches ECC/DEC/(15)01
Note 2: Refer to Monte Carlo simulations. This can be used in case of DTT transmission is horizontally polarised with antenna polarisation discrimination of 16 dB.

In order to limit DTT receiver desensitisation to a level that is comparable to ECC/DEC/(15)01, values for UE ACLR and UE unwanted emission limits are presented in section 3.5.2.2.

Also, PPDR UE blocking capability has to be improved to limit the risk of interference from DTT Channel 21.

Administrations may need to do some further studies to understand the risk of interference for their individual national circumstances. They may also decide that it is appropriate to provide external filters to households in vulnerable DTT areas where there is a risk of interference due to the selectivity of the DTT receivers. This potential solution would not mitigate any risk of interference due to the out-of-band emissions of the handsets.

Compatibility analyses conducted in this report with regards to satellite services have demonstrated that the maximum level of interference is below the level required for space systems relaying 406 MHz emergency signals. This leads to a possible and efficient co-existence between satellites services and BB PPDR in the 400 MHz sub-bands.

The conducted study shows that LTE-based PPDR systems operating in the 420-430 MHz cannot work co-channel with radiolocation radars, because PPDR systems would cause severe desensitisation of radars resulting in wide exclusion zones (more than 400 km). Operation in adjacent band requires exclusion zones of 2.3 km and 3.8 km for airborne and ground radiolocation radars respectively, due to saturation phenomenon which cannot be solved with filtering. Therefore co-located operation of PPDR networks and radiolocation radars is not possible. Out of band emissions of LTE systems falling into radiolocation radars band need to remain below -114 dBm/MHz in order to avoid desensitisation.

Generic compatibility calculations for PPDR activity in the 410-430 MHz band and radio astronomy operating in the 406.1-410 MHz band have shown that physical separation is required between PPDR BS and RAS to achieve compatibility. The calculated exclusion zones can reach up to 90 km based on a spurious emission limit of -36 dBm/100kHz from LTE400 base stations (BS) and can be reduced to 20 km if the spurious emission into the RAS band is limited to -96 dBm/100kHz according to the 3GPP requirement for protection of the base station’s own UL band. Separation distances between the UEs and the radio astronomy stations are about 50 km. Adding the terrain profile to the analysis showed that the attenuation from the geographical terrain does not reduce the separation distances.

ANNEX 1: TECHNICAL PARAMETERS

A1.1 LTE400

The following tables provide technical information regarding LTE400 mobile and base stations. Those values are derived from existing 3GPP LTE frequency bands leveraging the recent introduction of band 31 (452.5-457.5 / 462.5-467.5 MHz). Reference documents are:

- 3GPP TS 36.101 v12.5.0 (2014-09); 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception (Release 12);
- 3GPP TS 36.104 v12.5.0 (2014-09) ; 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception (Release 12)

Table 59: System Parameters for LTE400

Parameters	Mobile Station	Base Station
Channel Width	1.4, 3 or 5 MHz	1.4, 3 or 5 MHz
Transmit Power	Up to 37 dBm (1)	47 dBm (2)
Transmission Bandwidth	Up to 5 RB at cell edge (1 RB = 180 kHz)	6, 15 or 25 RB (1 RB = 180 kHz)
Antenna Height	1.5 m	30 m
Antenna Gain	0 dBi	13 dBi (3)
Reference Sensitivity (QPSK)	-99, -95.7, -93.5 dBm (From Table 7.3.1-1. in TS 36.101)	-106.8, -103,-101.5 dBm (From Table 7.2.1-1 in TS 36.104)
Power Control Characteristic	See ANNEX 6:	Not used

(1): Only two power classes are defined within 3GPP TS 36.101: 23 dBm (for any band except Band 14) or 31 dBm (for Band 31). In order to keep the same number of radio sites for legacy PPDR systems, car-mounted mobiles are considered as capable to transmit up to 37 dBm. SEAMCAT simulations consider only outdoor devices.

(2) Considering two power amplifiers

(3) Typical directive antenna (15 dBi) including cable loss (2 dBi). Kathrein product datasheet (742 242) used to created SEAMCAT antenna patterns.

Table 60: BB PPDR (LTE) system parameters for BS and UE

PPDR BS and UE parameters	
PPDR BS parameters	
Parameter	Value
Center frequency (MHz),for a DTT-PPDR guard band = 0 MHz	468.5
Channel BW (MHz)	3
Maximum number of resource blocs (RBs)	15
Antenna height (m)	30
Frequency reuse	1
Power (dBm)	47

PPDR BS and UE parameters	
Antenna gain (dBi)	13 (15 dBi - 2 dB cable loss)
e.i.r.p. (dBm) = Power + Antenna gain	60
Antenna pattern/Number of sectors	Directional/3
ACLR (dB/8MHz) in DTT channel 21	42, 52, 60, 67 and 73
Cell ranges for vehicle/ helmet mounted terminals coverage (km)	7.5 and 2.586
PPDR UE parameters	
Parameter	Value
Center frequency (MHz)	458.5
Channel BW (MHz)	3
Maximum number of RBs / Number of RBs used in simulations	15 / 5
Antenna height (m)	1.5
Power (dBm)	37
Antenna gain for vehicle/helmet mounted terminals (dBi)	0
e.i.r.p. (dBm) = Power + Antenna gain	37
Body loss for vehicle/ helmet mounted terminals (dB)	0 / 4
Antenna pattern	Omni-directional
Average density of UE (UE/km^2)	See Table 3
Distribution of transmitting UE (% indoors / % outdoors) in urban scenario	25/75
ACLR (dB/8 MHz) in DTT Channel 21	60, 65 and 79
Transmit power control parameters	See ANNEX 5: for parameters

[1] 468.5, 467.5, 466.5, 465.5 and 462.5 respectively for DTT-PPDR guard bands of 0, 1, 2, 3 and 6 MHz guard bands

Table 61: LTE400 MS emission limits (From Table 6.6.2.1.1-1 in TS 36.101 [9])

Delta fOOB (MHz)	Channel width			Measurement bandwidth
	1.4 MHz	3 MHz	5 MHz	
± 0-1	-10 dBm	-13 dBm	-15 dBm	30 kHz
± 1-2.5	-10 dBm	-10 dBm	-10 dBm	1 MHz
± 2.5-2.8	-25 dBm	-10 dBm	-10 dBm	1 MHz
± 2.8-5		-10 dBm	-10 dBm	1 MHz
± 5-6		-25 dBm	-13 dBm	1 MHz
± 6-10			-25 dBm	1 MHz

Table 62: LTE400-3 MHz MS emission limits when transmission is limited to 3 or 5 RBs

Delta fOOB (MHz)	3 RB	Delta fOOB (MHz)	5 RB	Measurement bandwidth
± 0 - 0.2	-13 dBm	± 0 - 0.333	-13 dBm	30 kHz
± 0.2 – 1	-10 dBm	± 0.333 – 1.666	-10 dBm	1 MHz
±1 - 1.2	-25 dBm	± 1.666 – 2	-25 dBm	1 MHz

Table 63: LTE400 MS emission limits for 37 dBm UE

Delta fOOB (MHz)	Channel width			Measurement bandwidth
	1.4 MHz	3 MHz	5 MHz	
± 0-1	-7 dBm	-7 dBm	-9 dBm	30 kHz
± 1-1.8	-7 dBm	-7 dBm	-7 dBm	1 MHz
± 1.8-2.5	-10 dBm	-7 dBm	-7 dBm	1 MHz
± 2.5-2.8	-25 dBm	-10 dBm	-10 dBm	1 MHz
± 2.8-5		-10 dBm	-10 dBm	1 MHz
± 5-6		-25 dBm	-13 dBm	1 MHz
± 6-10			-25 dBm	1 MHz

Table 64: LTE400-3 MHz MS emission limits for 37 dBm UE when transmission is limited to 3 or 5 RBs

Delta fOOB (MHz)	3 RB	Delta fOOB (MHz)	5 RB	Measurement bandwidth
± 0 - 0.2	-7 dBm	± 0 - 0.333	-7 dBm	30 kHz
± 0.2 - 0.5	-7 dBm	± 0.333 – 0.833	-7 dBm	1 MHz
± 0.5 – 1	-10 dBm	± 0.833 – 1.666	-10 dBm	1 MHz
±1 - 1.2	-25 dBm	± 1.666 – 2	-25 dBm	1 MHz

Figure 40: Comparison between proposed mask and 3GPP minimum requirements

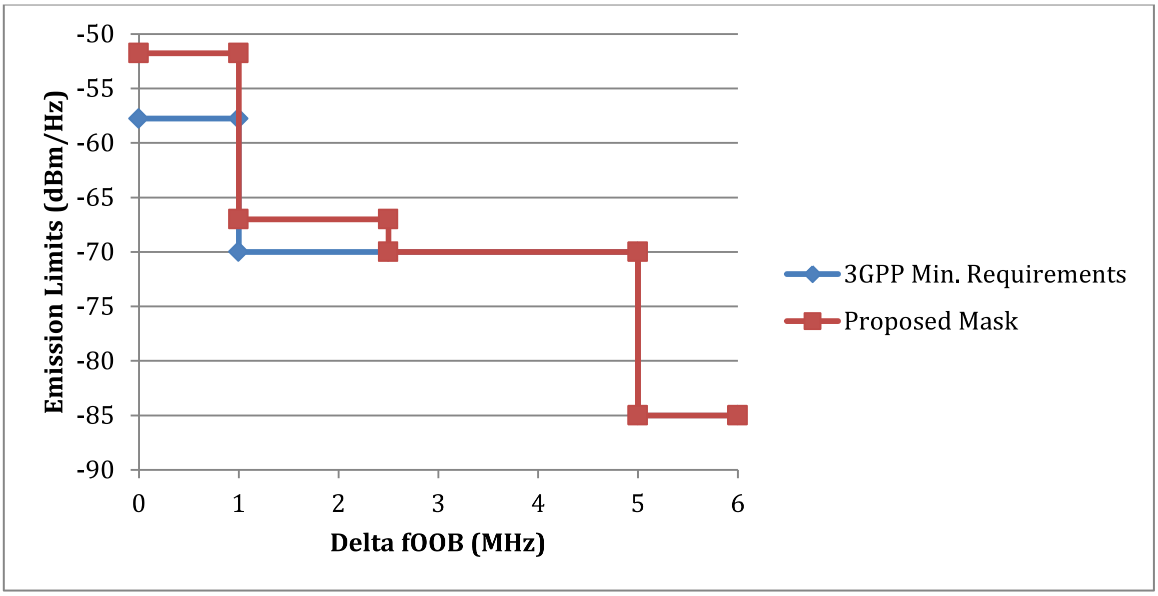

Table 65: LTE400 MS spurious emissions limits (From Table 6.6.3.1-2 in TS 36.101 [9])

Frequency range outside the out of band domain	Maximum level	Measurement bandwidth
9 kHz ≤ f < 150 kHz	- 36 dBm	1 kHz
150 kHz ≤ f < 30 MHz	- 36 dBm	10 kHz
30 MHz ≤ f < 1000 MHz	- 36 dBm	100 kHz
1 GHz ≤ f < 12.75 GHz	- 30 dBm	1 MHz

Table 66: UE Spurious emissions limits for protection of own UE receiver for 3GPP Band 31 (From Table 6.6.3.2-1 in TS 36.101 [9])

E-UTRA Band	Spurious emission						
	Protected band	Frequency range (MHz)			Maximum Level (dBm)	MBW (MHz)	Note
31	E-UTRA Band 1, 5, 7, 8, 20, 22, 26, 27, 28, 31, 32, 33, 34, 38, 40, 42, 43	FDL_low	-	FDL_high	-50	1	
	E-UTRA Band 3	FDL_low	-	FDL_high	-50	1	2

Note: Band 31 UL emissions towards Band 31 own RX is -50dBm/MHz. The same requirement applies for UE UL emissions to protect own RX

Table 67 : LTE400 MS receiver blocking values (From Tables 7.3.1-1, 7.6.1.1-1 and 7.6.1.1-2 in TS 36.101 [9])

	Channel width		
	1.4 MHz	3 MHz	5 MHz
P_{wanted}	-93 dBm	-89.7 dBm	-87.5 dBm
$P_{unwanted}$	-56 dBm	-56 dBm	-56 dBm
Blocking capability	37 dB	33.7 dB	31.5 dB

Table 68: LTE400 BS emission limits (From Tables 6.6.3.2.1-1, 6.6.3.2.1-2 and 6.6.3.2.1-3 in TS 36.104 [10])

Channel width	Delta Fc (MHz)	OOB emissions	Measurement bandwidth
1.4 MHz	0.7 to 2.1	-1 dBm -10/1.4 * (Delta F_c – 0.7) dB	100 kHz
	2.1 to 3.5	-11 dBm	100 kHz
	3.5 to 9.95	-16 dBm	100 kHz
3 MHz	1.5 to 4.5	-5 dBm -10/3* (Delta F_c – 1.5) dB	100 kHz
	4.5 to 7.5	-15 dBm	100 kHz
	7.5 to 9.995	-16 dBm	100 kHz
5 MHz	2.5 to 7.5	-7 dBm -7/5* (Delta F_c – 2.5) dB	100 kHz
	7.5 to 9.95	-14 dBm	100 kHz

Table 69 : LTE400 BS spurious emissions limits (From Table 6.6.4.1.2.1-1. in TS 36.104 [10])

Frequency range outside the out of band domain	Maximum level	Measurement bandwidth
9 kHz ≤ f < 150 kHz	- 36 dBm	1 kHz
150 kHz ≤ f < 30 MHz	- 36 dBm	10 kHz
30 MHz ≤ f < 1000 MHz	- 36 dBm	100 kHz
1 GHz ≤ f < 12.75 GHz	- 30 dBm	1 MHz

Table 70 : LTE400 BS spurious emissions limits (From Table 6.6.4.1.2.1-1. in TS 36.104 [10])

Frequency range outside the out of band domain	Maximum level	Measurement bandwidth
9 kHz ≤ f < 150 kHz	- 36 dBm	1 kHz
150 kHz ≤ f < 30 MHz	- 36 dBm	10 kHz
30 MHz ≤ f < 1000 MHz	- 36 dBm	100 kHz
1 GHz ≤ f < 12.75 GHz	- 30 dBm	1 MHz

Table 71: BS Spurious emissions limits for protection of own BS receiver (From Table 6.6.4.2-1 in TS 36.104 [10])

	Frequency range	Maximum Level	Measurement Bandwidth	Note
Wide Area BS	FUL_low – FUL_high	-96 dBm	100 kHz	

Table 72 : LTE400 BS blocking values (From Tables 7.2.1-1 and 7.6.1.1-1. in TS 36.104 [10])

	Channel width		
	1.4 MHz	3 MHz	5 MHz
P_{wanted}	-100.8 dBm	-97 dBm	-95.5 dBm
$P_{unwanted}$	-15 dBm	-15 dBm	-15 dBm
Blocking Capability	85.8 dB	82 dB	80.5 dB

A1.2 TETRA

The ETSI standard ETS 300 392-2 [17] has been used to obtain most of the TETRA system parameters. This standard is titled ‘Radio Equipment and Systems (RES); Trans-European Trunked Radio (TETRA); Voice plus Data (V+D); Part 2: Air Interface (AI)’. Those parameters which cannot be obtained from the standard are assumed values believed to accurately model operational TETRA systems. Following Tables list all of the parameters required by the Monte Carlo simulation to model a TETRA system.

Table 73: System parameters for TETRA

Parameters	Mobile Station	Base Station
Channel spacing	25 kHz	25 kHz
Transmit Power	30, 35 or 40 dBm	40 dBm
Receiver Bandwidth	18 kHz	18 kHz
Antenna Height	1.5 m	30 m
Antenna Gain	0 dBi	9 dBi
Receiver Sensitivity	-103 dBm	-106 dBm
Receiver Protection Ratio	19 dB	19 dB
TDMA Users / Carrier	4	4
Power Control Characteristic	5 dB steps to a minimum of 15 dBm	Not used

Table 74: Unwanted emissions for the TETRA System (measurement bandwidth of 18 kHz)

Frequency Offset	30 dBm Mobile Station	35 dBm Mobile Station	40 dBm Mobile Station	40 dBm Base Station
25 kHz	- 30 dBm	- 25 dBm	- 20 dBm	- 20 dBm
50 kHz	- 36 dBm	- 35 dBm	- 30 dBm	- 30 dBm
75 kHz	- 36 dBm	- 35 dBm	- 30 dBm	- 30 dBm
100 - 250 kHz	- 45 dBm	- 43 dBm	- 40 dBm	- 40 dBm
250 – 500 kHz	- 50 dBm	- 48 dBm	- 45 dBm	- 45 dBm
500 kHz – frb	- 50 dBm	- 50 dBm	- 50 dBm	- 50 dBm
Greater than frb	- 70 dBm	- 65 dBm	- 60 dBm	- 60 dBm
At frequency offsets less than 100 kHz no limit tighter than - 36 dBm shall apply At frequency offsets equal to and greater than 100 kHz no limit tighter than - 70 dBm shall apply				

Table 75: Receiver blocking values for the TETRA System

Frequency Offset	30, 35, 40 dBm Mobile Station	40 dBm Base Station
50 – 100 kHz	-40 dBm	-40 dBm
100 – 200 kHz	-35 dBm	-35 dBm
200 – 500 kHz	-30 dBm	-30 dBm
> 500 kHz	-25 dBm	-25 dBm

A1.3 TETRAPOL

TETRAPOL parameters have been obtained from the TETRAPOL's publicly available specification and are reflecting ETS300-113 related radio systems.

Table 76: System parameters for TETRAPOL

Parameters	Mobile Station	Base Station
Channel spacing	10 or 12.5 kHz	10 or 12.5 kHz
Transmit Power	33 dBm	38 dBm
Receiver Bandwidth	8 kHz	8 kHz
Antenna Height	1.5 m	30 m
Antenna Gain	0 dBi	9 dBi
Receiver Sensitivity	-111 dBm	-113 dBm
Receiver Protection Ratio	15 dB	15 dB
TDMA Users / Carrier	4	4
Power Control Characteristic	2 dB steps to a minimum of 21 dBm	Not used

Table 77 : Receiver blocking for the TETRAPOL system (MS and BS)

Frequency Offset	Blocking
13.5 – 25 kHz	-65 dBm
25 – 40 kHz	-55 dBm
40 – 100 kHz	-50 dBm
100 – 150 kHz	-40 dBm
150 – 500 kHz	-35 dBm
> 500 kHz	-25 dBm

Table 78 : Unwanted emissions (dBm) for the TETRAPOL system (in 8 kHz bandwidth)

Frequency Offset	Mobile Station	Base Station
8.5 - 21 kHz	Max (p-60,-36)	Max (p-60,-36)
21 – 25 kHz	Max (p-70,-36)	Max (p-70,-36)
25 – 40 kHz	p – 70	p - 70
40 – 100 kHz	p – 75	p – 75
100 – 150 kHz	p – 85	p - 85
150 – 500 kHz	p – 90	p – 95
Greater than 500 kHz	p – 100	p - 105
In the corresponding receiving band	-80	-100

(1): where p represents the transmission power expressed in dBm.

A1.4 ANALOGUE FM PMR

A1.4.1 25 kHz Analogue FM PMR

The ETSI standards ETS 300 086 [23] and ETS 300 113 [24] have been used to obtain information regarding 25 kHz FM system parameters. Other parameters are assumed values believed to accurately model operational FM systems. Following Tables list all of the parameters required by the Monte Carlo simulation to model a 25 kHz FM system.

Table 79: Parameters assumed for the 25 kHz FM PMR systems

Parameter	Mobile Station	BS
Channel Spacing	25 kHz	25 kHz
Transmit Power	37 dBm	44 dBm
Receiver Bandwidth	15 kHz	15 kHz
Antenna Height	1.5 m	30 m
Antenna Gain	0 dBi	9 dBi
Transmitting Interferer Density Range	Variable	Variable
Receiver Sensitivity	-107 dBm / -117 dBm (1)	-110 dBm / -120 dBm (1)
Receiver Protection Ratio	17 dB	17 dB
Power Control Characteristic	Not used.	Not used

(1): The first values were taken from ECC Report 099 [11]; the second ones were in this report following guidance received from ETSI ERM.

Table 80: Unwanted emissions for the 25 kHz FM PMR systems (measurement bandwidth of 18 kHz)

Frequency Offset	Mobile Station	BS
25 kHz	- 33 dBm	- 26 dBm
100 - 250 kHz	- 53 dBm	- 46 dBm
250 - 500 kHz	- 60 dBm	- 53 dBm
500 kHz - 1 MHz	- 64 dBm	- 57 dBm
1 MHz - 10 MHz	- 69 dBm	- 62 dBm
> 10 MHz	- 71 dBm	- 64 dBm
Linear interpolation (in dB) is used between 25 kHz and 100 kHz		

Table 81: Receiver blocking values for the 25 kHz FM PMR systems

Frequency Offset	Mobile Station	BS
Any frequency	- 23 dBm	- 23 dBm

A1.4.2 20 kHz Analogue FM PMR

The ETSI standards ETS 300 086 [23] and ETS 300 113 [24] have been used to obtain information regarding 20 kHz FM system parameters. Other parameters are assumed values believed to accurately model operational FM systems. Table 82,

Table 83 and Table 84 list all of the parameters required by the Monte Carlo simulation to model a 20 kHz FM system.

Table 82: Parameters assumed for the 20 kHz FM PMR systems

Parameter	Mobile Station	BS
Channel Spacing	20 kHz	20 kHz
Transmit Power	37 dBm	44 dBm
Receiver Bandwidth	12 kHz	12 kHz
Antenna Height	1.5 m	30 m
Antenna Gain	0 dBi	9 dBi
Transmitting Interferer Density Range	Variable	Variable
Receiver Sensitivity	- 107 dBm	- 110 dBm
Receiver Protection Ratio	17 dB	17 dB
Power Control Characteristic	Not used	Not used

Table 83: Unwanted emissions for the 20 kHz FM PMR systems (measurement bandwidth of 12 kHz)

Frequency Offset	Mobile Station	BS
20 kHz	- 33 dBm	- 26 dBm
100 - 250 kHz	- 53 dBm	- 46 dBm
250 - 500 kHz	- 60 dBm	- 53 dBm
500 kHz - 1 MHz	- 64 dBm	- 57 dBm
1 MHz - 10 MHz	- 69 dBm	- 62 dBm
> 10 MHz	- 71 dBm	- 64 dBm
Linear interpolation (in dB) is used between 20 kHz and 100 kHz		

Table 84: Receiver blocking values for the 20 kHz FM PMR systems

Frequency Offset	Mobile Station	BS
any frequency	- 23 dBm	- 23 dBm

A1.4.3 12.5 kHz Analogue FM PMR

The ETSI standards ETS 300 086 [23] and ETS 300 113 [24] have been used to obtain information regarding 12.5 kHz FM system parameters. Other parameters are assumed values believed to accurately model operational FM systems. Following Tables list all of the parameters required by the Monte Carlo simulation to model a 12.5 kHz FM system.

Table 85: Parameters assumed for the 12.5 kHz FM PMR systems

Parameter	Mobile Station	BS
Channel Spacing	12.5 kHz	12.5 kHz
Transmit Power	37 dBm	44 dBm
Receiver Bandwidth	8 kHz	8 kHz
Antenna Height	1.5 m	30 m

Parameter	Mobile Station	BS
Antenna Gain	0 dBi	9 dBi
Transmitting Interferer Density Range	Variable	Variable
Receiver Sensitivity	-107 dBm*	-110 dBm*
Receiver Protection Ratio	21 dB	21 dB
Power Control Characteristic	Not used	Not used

*those numbers for receiver sensitivity were taken from ECC Report 099 [11] and have been modified for the purpose of this Report to -117 dBm for MS and -120 dBm for BS

Table 86: Unwanted emissions for the 12.5 kHz FM PMR systems (measurement bandwidth of 8 kHz)

Frequency Offset	Mobile Station	BS
12.5 kHz	- 23 dBm	- 16 dBm
100 – 250 kHz	- 43 dBm	- 36 dBm
250 – 500 kHz	- 60 dBm	- 53 dBm
500 kHz - 1 MHz	- 64 dBm	- 57 dBm
1 MHz – 10 MHz	- 69 dBm	- 62 dBm
> 10 MHz	- 71 dBm	- 64 dBm
Linear interpolation (in dB) is used between 12.5 kHz and 100 kHz		

Table 87: Receiver blocking values for the 12.5 kHz FM PMR systems

Frequency Offset	Mobile Station	BS
Any frequency	- 23 dBm	- 23 dBm

A1.5 CDMA-PAMR

Table 88 : System parameters for the CDMA PAMR systems

Parameters	Mobile Station	Base Station
Channel spacing	1250 kHz	1250 kHz
Transmit Power	23 dBm	42 dBm
Receiver Bandwidth	1250 kHz	1250 kHz
Antenna Height	1.5 m	30 m
Antenna Gain	0 dBi	15 dBi (1)
Receiver Sensitivity	-121 dBm	-126 dBm
Interference introduced by own CDMA transmitters over thermal noise	5 to 15 dB 12 dB maximum at the cell edge of the regular cell	3 to 6 dB 3 dB at medium loaded cell
Power Control Characteristic	Used at SEAMCAT simulation	No Power Control on DL

(1) Kathrein product datasheet (741 516) used to created SEAMCAT antenna patterns

Table 89 : Receiver blocking values for the CDMA PAMR systems

Frequency Offset	Mobile Station	Base Station
Greater than 900 kHz	-30 dBm	-21 dBm

Table 90 : Unwanted emissions for the CDMA PAMR systems

	Frequency Offset	Mobile Station	Base Station	Measurement Bandwidth
	0.75 MHz	N.A.	p – 45	30 kHz
(1):	0.885 MHz	p – 47	p – 60	30 kHz
	1.98 MHz	p – 67	p – 65	30 kHz
	4 MHz	p – 82	p – 75	30 kHz
	6 MHz	p – 74	p – 76	100 kHz
	12 MHz	p – 74	p – 85	100 kHz

where p represents the transmission power expressed in dBm.

A1.6 DTT

A1.6.1 DTT Transmission

Table 91: DTT system parameters for transmission

Transmitter parameters	
Parameter	Value (1)
System	DVB-T2
Frequency (MHz)	474
Channel BW (MHz)	8
Antenna height (m)	200 / 75
Effective Antenna Height	300 / 150
Antenna pattern	Horizontal: omni-directional Vertical: 24λ / 16λ aperture (1)
Down Tilt	1° / none
e.r.p. (kW)	200 / 5
Spectrum Mask	Recommendation ITU-R BT.1206-2 Critical Mask [26] (GE06)

1 If two values are given, the first one refers to a high power DTT transmitter, the second to a medium power DTT transmitter.

2

$$E(\theta) = abs\left(\frac{Sin\Psi}{\Psi}\right)$$

where

$\Psi = \pi\, A Sin(\theta - \beta)$; and

Transmitter parameters
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 shown in Table below: Null fill values to be applied to vertical radiation patterns

	Limit on E(θ)
First null	0.15
Second null	0.1

A1.6.2 DTT reception

Table 92 : DTT system parameters for fixed outdoor reception

DTT receiver parameters for fixed roof top antenna in urban environment	
Parameter	Value
Frequency (MHz)	474
Channel BW (MHz)	8
Antenna height (m)	10
Antenna gain including losses (dBi)	9.15
Antenna pattern	See Recommendation ITU-R BT.419 [22]
Antenna polarisation discrimination (dB) vis-à-vis PPDR BS/UE	3 / 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	47.87
Pmed (dBm) at the receiver input	-68.12
Emed (dBµV/m) at 10 m above the ground, for Ploc = 95 %	53.46
Receiver ACS (dB)	51.6, 52.4, 53, 53.9, 54.7, 55.4, 56.2 and 65 (1) (1)
Protection criteria	C/(I+N) = 21 dB and Oth=-22 dBm(2)
1 For DTT-PPDR guard bands of 0, 1, 2, 3, 4, 5, 6 and 10 MHz 2 Average value recorded by TDF in real life LTE 800 MHz roll out in France	

A1.7 DTT ACS VALUES USED IN THE STUDIES

The DTTB receiver ACS presented in Figure 41 and Table 93 were determined by measurements on ten different brand new DTTB receivers (6 DVB-T and 4 DVB-T/T2 receivers) sold on the European market. They were calculated from the measured protection ratios.

A limited number of measurements have also been carried out with a 5 MHz PPDR (LTE) signal aiming at comparing the DTTB receiver ACS determined respectively in the presence of a 3 and 5 MHz interfering PPDR signal.

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

The ACS of the DTTB receivers tested varies from 56 to 62.4 dB as a function of DTTB-PPDR guard band varying from 0 to 6 MHz.

The ACS of the DVB-T receivers improves by about 5 dB if the DTTB-PPDR guard band is increased from 0 to 3 MHz, while the improvement is only about 1 dB if the guard band is increased from 3 MHz to 6 MHz.

The ACS of the DVB-T2 receivers improves by about 3 dB if the DTTB-PPDR guard band is increased from 0 to 3 MHz. The same order of improvement is obtained if the guard band is increased from 3 MHz to 6 MHz.

The average ACS of the DVB-T/T2 receivers improves by 4.4 dB if the DTTB-PPDR guard band is increased from 0 to 3 MHz, while the improvement is only about 1.5 dB if the guard band is increased from 3 MHz to 6 MHz.

For the same DTTB-PPDR guard band, the ACS of the DVB-T/T2 receivers in the presence of a PPDR signal having a bandwidth of 5 MHz seems to be similar to their ACS in the presence of a PPDR signal having a bandwidth of 3 MHz.

From the above facts, we may conclude that a DTTB-PPDR guard band of 3 MHz is the most appropriate guard band for minimising the interference from 3 MHz PPDR (LTE) 400 MHz to DTTB reception above 470 MHz, while keeping the unused spectrum fairly low (see also Figure 41).

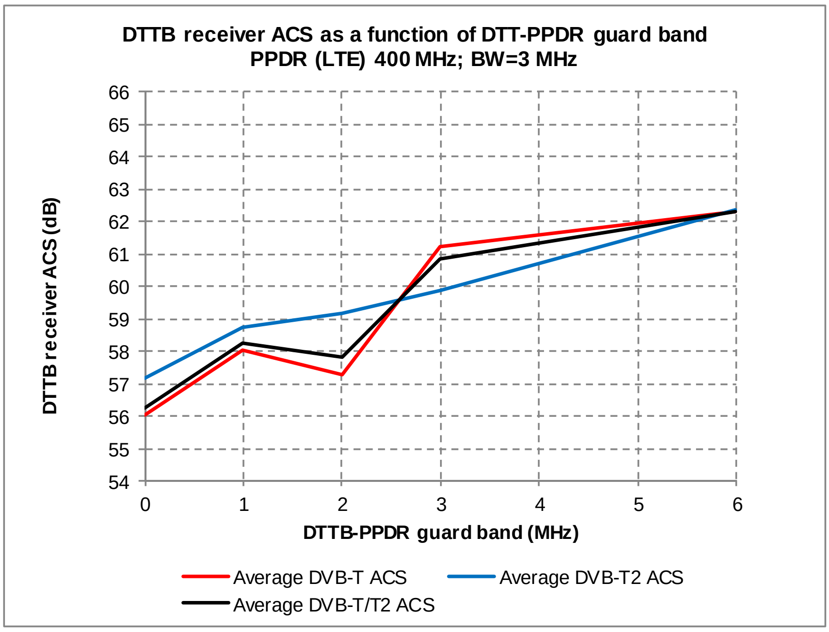

Figure 41: DTTB ACS values determined by measurements on ten different brand new DTTB receivers

Table 93: DTT ACS values used in the simulations

DTTB receiver ACS as a function of DTT-PPDR guard band PPDR (LTE) 400 MHz; BW=3/5 MHz		
DTTB-PPDR guard band (MHz)	PPDR BS ACLR in DTTB CH 21 (dB/8MHz)*	Average DVB-T/T2 ACSN (dB)
0	68	56.3
1	73	58.2
2	75	57.8
3	78	60.8
6	>80	62.3
* For ACLR values greater than 69 dB the OOBE level of the PPDR BS signal does not have any impact on the calculated ACS value		

The receiver ACS value 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.

A1.7.1 DTT ACS measured for 12.5 MHz guard band

The ACS for 10 DVB-T2 receivers was measured.

The following DVB-T2 parameters were used

Table 94: System parameters

DTTB system parameters		
Parameter	Value	Comments
Centre frequency (MHz)	474	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	-70, -60, -50, -40, -30 and -	In order to properly determine

DTTB system parameters		
levels used (dBm)	20	the PR
Parameter	Value	Comments
Frequency (MHz)	▪ 452.5 – 457.5 MHz	All RB active
Modulation	SC-FDMA	
ACLR into DTTB CH 48 (dBm/8MHz)	> 100 dB	
Transmission mode	Continuous	

A1.7.1.1 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.

A1.7.1.2 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 100 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.

A1.7.1.3 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.

A1.7.1.4 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.

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

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

The following results were obtained:

Table 95: Median ACS (dB)

	Median ACS (dB)
	452.5-457.5 MHz
RX1	72
RX2	67
RX3	80
RX4	67
RX5	70
RX6	66
RX7	68
RX8	68
RX9	70
RX10	67
Average	69.5

ANNEX 2: CELL RANGE CALCULATIONS

Detailed cell range calculations for the systems studied in this report are presented in the following tables.

A2.1 LTE400 CELL RANGE (3 MHZ CHANNEL WIDTH)

Table 96: LTE400 path loss calculation

Downlink/Uplink Path loss	
Downlink Path loss:	
BS TX Power (dBm)	47
BS antenna gain (dBi)	13
MS antenna gain (dBi)	0
MS sensitivity (dBm)	-95.7
Downlink available path loss (dB)	155.7
Uplink Path loss:	
MS TX Power (dBm)	37
MS antenna gain (dBi)	0
BS antenna gain (dBi)	13
BS target sensitivity (dBm) – 5 RB	-107.7
Uplink available path loss (dB)	157.7
LTE 400 Cell Range @ 450 MHz	
Balanced path loss (dB)	15.7
Cell range for 75% confidence level at the cell edge (km)	7.5

Table 97: Examples of LTE400 cell range calculation (Outdoor coverage only)

Link budgets for urban environment - Outdoor coverage only						
PPDR parameters		Uplink		Downlink		
		UE (QPSK) > BS (QPSK)	Link	BS (QPSK) > UE (QPSK)	Link	Notes
Center frequency	MHz	458.5	UE	468.5	BS	
Channel BW	MHz	3.00	UE	3.00	BS	
Noise power (Pn)	dBm	-108.77	BS	-96.70	UE	P_n(dBm) = F + 10log(k*T*B*10^6) + 30
SNIR at cell-edge	dB	1	BS	1	UE	
Receiver sensitivity (Rx P_{min})	dBm	-107.77	BS	-95.70	UE	See 3GPP TS 36.104 V12.3.0 (2014-03) [10] and 3GPP TS 36.101 V12.3.0 (2014-03) [9]
Cell-edge coverage probability	%	75		75		For 90 % cell coverage probability

Link budgets for urban environment - Outdoor coverage only						
Gaussian confidence factor for cell-edge coverage probability	%	0.67		0.67		
Shadowing loss standard deviation (σ)	dB	8.50		8.50		
Building entry loss standard deviation (σ_w)	dB	0.00		0.00		
Total loss standard deviation (σ_T)	dB	8.50		8.50		$s_T = SQRT(\sigma^2 + \sigma_w^2)$
Loss margin (L_m)	75 %	5.73		5.73		Lm = μ 75% * σ_T
Rx P_{mean}	dBm	-102.04	BS	-89.97	UE	Rx P_{mean} = Rx P_{min} + L_m
Transmitter power (P_{tx})	dBm	37.00	UE	47.00	BS	
P_{tx} e.i.r.p.	dBm	37.00	UE	60.00	BS	
Antenna height	m	1.50	UE	30.00	BS	
Cable loss (L_{cable})	dB	0.00	UE	0.00	BS	
Antenna gain (G_{iso})	dBi	0.00	UE	13.00	BS	
G_{iso}-L_{cable}	dBi	13.00	BS	0.00	UE	
Average building entry loss (L_{wall})	dB	0.00		0.00		
Typical body loss	dB	0.00		0.00		
Max allowed path loss (L_{pmax})	dB	152.04	UE	149.97	BS	Lp = e.i.r.p.+(G_{iso}-L_{cable}) - L_{wall} - L_{body} -P_{mean}
IMT BS cell range calculated by Extended Hata model	km			7.5	rPPDR	Urban: cell range calculated from DL L_{pmax}

Table 98: Examples of LTE400 cell range calculation (Indoor & Outdoor coverage only)

Link budgets for urban environment – Indoor & outdoor coverage						
PPDR parameters		Uplink		Downlink		
		UE (QPSK) >BS (QPSK)	Link	BS (QPSK) >UE (QPSK)	Link	Notes
Centre frequency	MHz	458.5	UE	468.5	BS	
Channel BW	MHz	3.00	UE	3.00	BS	
Noise power (Pn)	dBm	-108.77	BS	-96.70	UE	P_n(dBm) = F + 10log(k*T*B*10^6) + 30
SNIR at cell-edge	dB	1	BS	1	UE	
Receiver sensitivity (Rx P_{min})	dBm	-107.77	BS	-95.70	UE	See 3GPP TS 36.104 V12.3.0 (2014-03) [10] and 3GPP TS 36.101

Link budgets for urban environment – Indoor & outdoor coverage						
						V12.3.0 (2014-03) [9]
Cell-edge coverage probability	%	75		75		For 90 % cell coverage probability
Gaussian confidence factor for cell-edge coverage probability	%	0.67		0.67		
Shadowing loss standard deviation (σ)	dB	8.50		8.50		
Building entry loss standard deviation (σ_w)	dB	6.00		6.00		
Total loss standard deviation (σ_T)	dB	10.40		10.40		s_T = SQRT($\sigma^2 + \sigma_w{}^2$)
Loss margin (L_m)	75 %	7.02		7.02		L_m = μ75% * σ_T
Rx P_{mean}	dBm	-100.76	BS	-88.68	UE	Rx P_{mean} = Rx P_{min} + L_m
Transmitter power (Ptx)	dBm	37.00	UE	47.00	BS	
P_{tx} e.i.r.p.	dBm	37.00	UE	60.00	BS	
Antenna height	m	1.50	UE	30.00	BS	
Cable loss (L_{cable})	dB	0.00	UE	2.00	BS	
Antenna gain (G_{iso})	dBi	0.00	UE	15.00	BS	
G_{iso}-L_{cable}	dBi	13.00	BS	0.00	UE	
Average building entry loss (L_{wall})	dB	11.00		11.00		
Typical body loss	dB	4.00		4.00		
Max allowed path loss (Lpmax)	dB	135.76	UE	133.68	BS	Lp = e.i.r.p. + (G_{iso} - L_{cable}) - L_{wall} - L_{body} - P_{mean}
IMT BS cell range calculated by Extended Hata model	km			2.568	r_{PPDR}	Urban: cell range calculated from DL L_{pmax}

A2.2 TETRA CELL RANGE

Table 99: TETRA cell range calculation

Downlink/uplink path loss	
Downlink path loss	
BS TX Power (dBm)	40
BS antenna gain (dBi)	9
MS antenna gain (dBi)	0
MS sensitivity (dBm)	-103

Downlink/uplink path loss	
Downlink available path loss (dB)	152
Uplink path loss	
MS TX Power (dBm)	35
MS antenna gain (dBi)	0
BS antenna gain (dBi)	9
BS dynamic sensitivity (dBm)	-106
Uplink available path loss (dB)	150
TETRA Cell Range @ 450 MHz	
Balanced path loss	150
Cell range for 75 % confidence level at the cell edge (km)	5.2

A2.3 TETRAPOL CELL RANGE

Table 100: TETRAPOL cell range calculation

Downlink/uplink path loss	
Downlink path loss	
BS TX Power (dBm)	38
BS antenna gain (dBi)	9
MS antenna gain (dBi)	0
MS sensitivity (dBm)	-111
Downlink available path loss (dB)	158
Uplink path loss	
MS TX Power (dBm)	33
MS antenna gain (dBi)	0
BS antenna gain (dBi)	9
BS dynamic sensitivity (dBm)	-113
Uplink available path loss (dB)	155
TETRAPOL Cell Range @ 450 MHz	
Balanced path loss	155
Cell range for 75 % confidence level at the cell edge (km)	7.3

A2.4 CDMA-PAMR CELL RANGE

Table 101: CDMA-PAMR cell range calculation

Downlink/uplink path loss	
Limiting Uplink path loss	
MS TX Power (dBm)	23
MS antenna gain (dBi)	0
BS sensitivity (dBm)	-126
BS antenna gain (dBi)	15
BS feeder loss	2
Soft Hand-Off Gain (dB)	4
Receiver Interference Margin	4
Diversity Gain	3
Uplink available path loss (dB)	161
CDMA-PAMR Cell Range @ 450 MHz	
Cell range for 75 % confidence level in the cell area (km)	11.1

A2.5 25 KHZ ANALOGUE FM CELL RANGE

Table 102: 25 kHz Analogue FM cell range calculation

Downlink/uplink path loss	
Downlink path loss	
BS TX Power (dBm)	44
BS antenna gain (dBi)	9
MS antenna gain (dBi)	0
MS sensitivity (dBm)	-117
Downlink available path loss (dB)	160
Uplink path loss	
MS TX Power (dBm)	37
MS antenna gain (dBi)	0
BS antenna gain (dBi)	9
BS dynamic sensitivity (dBm)	-120
Uplink available path loss (dB)	166
TETRAPOL Cell Range @ 450 MHz	
Balanced path loss	160
Cell range for 75 % confidence level at the cell edge (km)	7.9

A2.6 DTT CELL RANGE

Table 103: An example of DTT cell range calculation

DTT parameters	Unit	Urban (High power transmitter)	Notes
Center frequency	MHz	474.00	Channel 48
Channel BW	MHz	8.00	
Effective BW	MHz	7.6	
Noise figure (F)	dB	7	
Boltzmann's constant (k)	Ws/K	$1.38*10^{-23}$	
Absolute temperature (T)	K	290	
Noise power (P_n)	dBm	-98.17	Pn(dBm) = F + 10log(k*T*B*106) + 30
SNR at cell-edge	dB	21	
Receiver sensitivity (P_{min})	dBm	-77.17	$P_{min} = P_n(dBm) + SNR(dB)$
Cell-edge coverage probability	%	95	
Gaussian confidence factor for cell-edge coverage probability of 95% (µ95%)	%	1.64	
Shadowing loss standard deviation (σ)	dB	5.50	
Building entry loss standard deviation (σw)	dB	0.00	
Total loss standard deviation (σT)	dB	5.50	$sT = SQRT(\sigma^2 + \sigma w^2)$
Loss margin (L_m)	95 %	9.05	Lm = µ 95% * σT
P_{mean} (95%)	dBm	-68.12	$P_{mean} = P_{min} + L_m$
Minimum field strength	dBµV/m	53.46	
e.i.r.p.	dBm	85.15	
Antenna height	m	200.00	
Cable loss (L_{cable})	dB	3.00	
Antenna gain (G_{iso})	dBi	12.15	
G_{iso}-L_{cable}	dBi	9.15	
Average indoor user terminal penetration loss (L_{wall})	dB	0.00	
Max allowed path loss (L_p)	dB	162.42	L_p = e.i.r.p. + $(G_{iso} - L_{cable}) - L_{wall} - L_{body} - P_{mean}$
DTT coverage radii calculated by ITU-R P.1546 [5] propagation model	km	40.46	Urban

ANNEX 3: ANALYSIS OF INTER SITE DISTANCE IN TETRA NETWORKS IN GREAT BRITAIN

A3.1 INTRODUCTION

To better understand typical PPDR network deployments, using information in Ofcom's database[4] on the location and operating power of TETRA sites in Great Britain, site spacing and the distribution of operating powers has been assessed.

A3.2 ANALYSIS

The Ofcom database lists 3663 TETRA sites within Great Britain, an area of 229,848 km^2, which equates to a site density of 0.016 sites/km^2.

Using Delaunay triangulation and applying a 20 kilometre limit to reduce edge effects the inter site distance of TETRA base stations has been calculated, Figure 42. For Great Britain the median inter site distance is 8 km, Figure 43and Figure 44.

To assess the potential spacing of PPDR sites in metropolitan areas[5], the existing TETRA site spacing in Greater London, West Midlands, Liverpool, Manchester, Bradford, Leeds and surrounding towns, Newcastle and Sunderland has been calculated. These areas contain 486 TETRA sites and cover an area of 8722 km^2; a site density of 0.056 sites/km^2. The median inter site distance in these metropolitan areas is 4.5 km, Figure 45 and Figure 46.

The radiated power of TETRA stations in Great Britain is shown in Figure 47.

A3.3 DISCUSSION

For practical reasons UK TETRA networks employ a mixture of omni-directional and directional base station antennas. Actual cell site deployment is much denser than is being assumed in present interference studies,

Table 104: Comparison of TETRA site density in Great Britain with the study assumptions

	Site Density Urban	Site density as % of GB
GB TETRA	0.056 sites/km^2	100 %
Study TETRA	0.014 sites/km^2	25 %
Study TETRA POL	0.007 sites/km^2	12.5 %

This may in part be due to the service availability in Great Britain being higher than that assumed in interference studies.

The higher network density of deployments in Great Britain if reflected in PPDR LTE deployments would lead to higher levels of interference than indicated by current assumptions.

A review of radiated powers shows that in general higher powers are used in built up areas, these also being the areas with the highest site density. Different approaches have been adopted in England, Wales and Scotland to deployment of TETRA sites in rural areas.

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4 http://sitefinder.ofcom.org.uk/ It should be noted that though the database was last updated in May 2012 so information on some networks may be out of date, TETRA network roll out was complete by 2012.

5 OS OpenData Boundary-Line

A3.4 RECOMMENDATION

Calculations of interference from PPDR networks to other services should reflect actual network deployments. Assuming LTE site density remains the same as existing PPDR networks then; cell site deployment should assume omni-directional as well as sectored deployments

For assessing interference an Inter Site Distance of 4.5 km for omni-directional deployments in metropolitan areas should be used which equates to a cell radius of 2.6 km where omni-directional base station antenna are deployed

A3.5 CONCLUSION

Parameters being used for assessing interference are not representative of actual deployment in the UK and consequently may underestimate interference

1 Inter Site Distance

Figure 42: Calculation of Inter Site Distance using Delaunay triangulation of Tetra site locations in Great Britain

2 Distribution of Site spacing

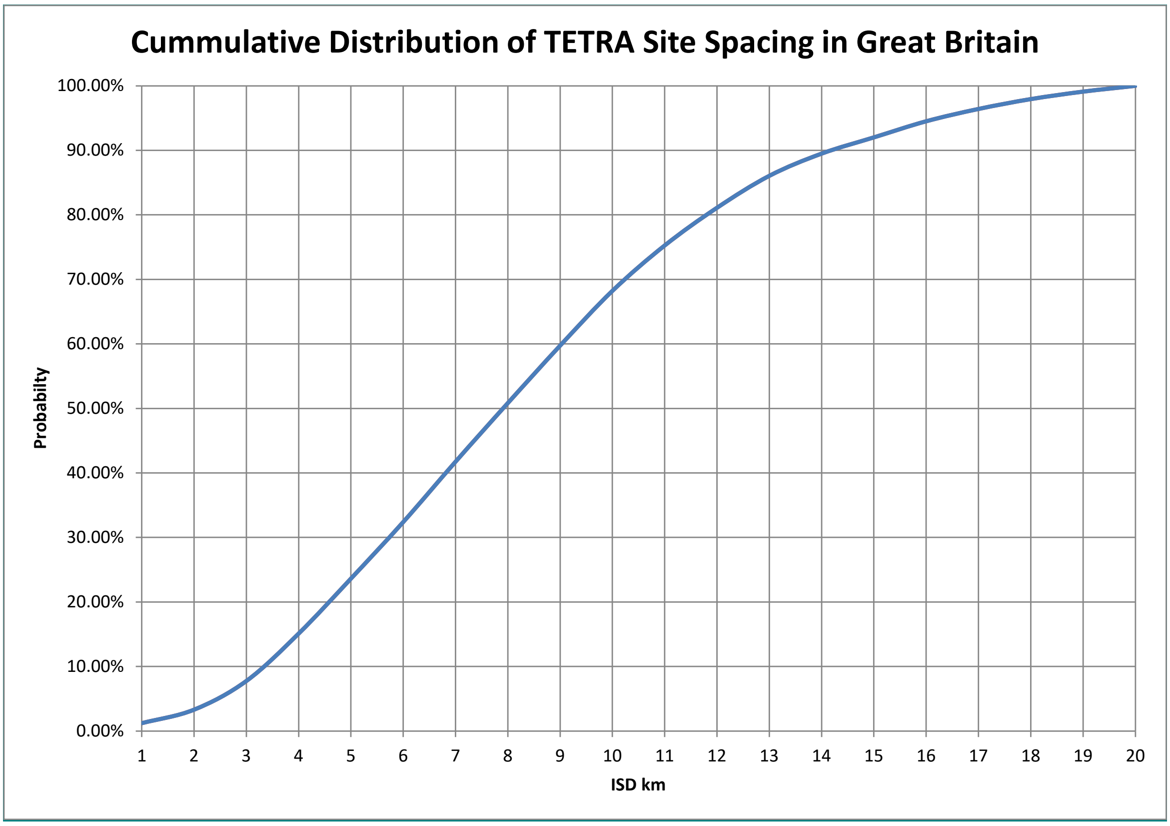

Figure 43: Cumulative Distribution of TETRA inter site distances in Great Britain

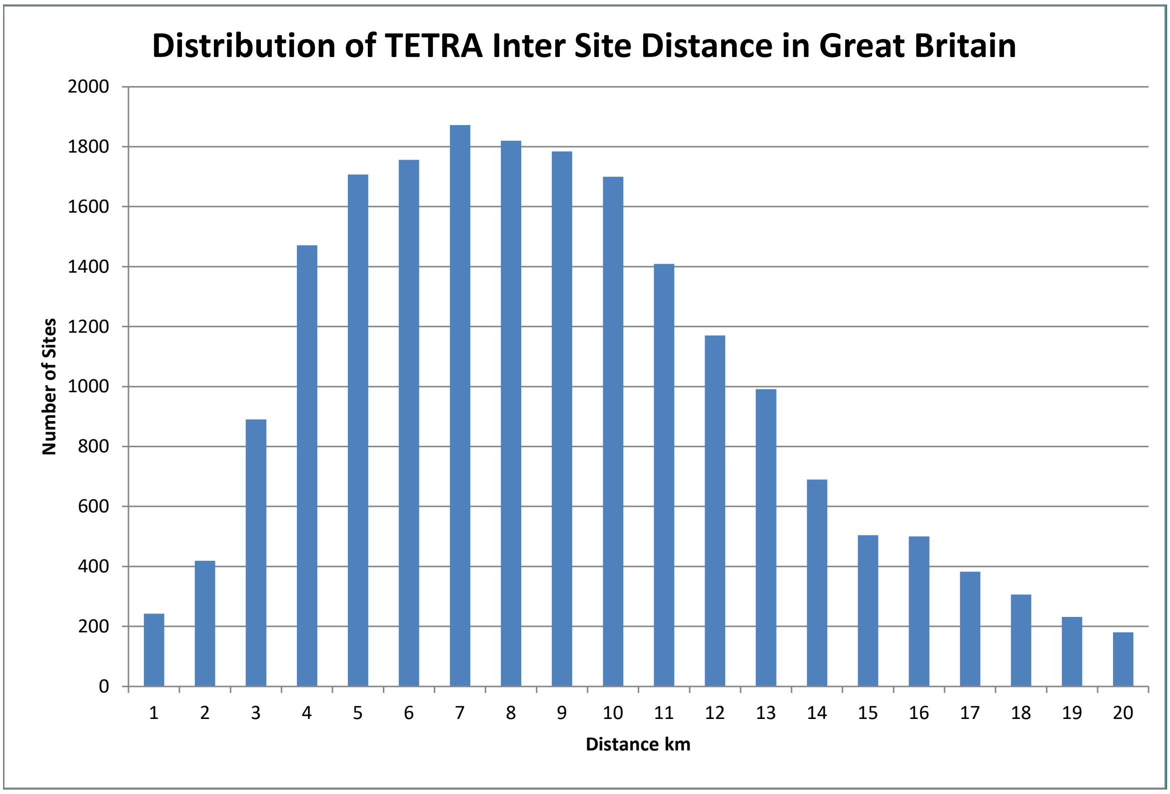

Figure 44: Distribution of TETRA inter site distances in Great Britain

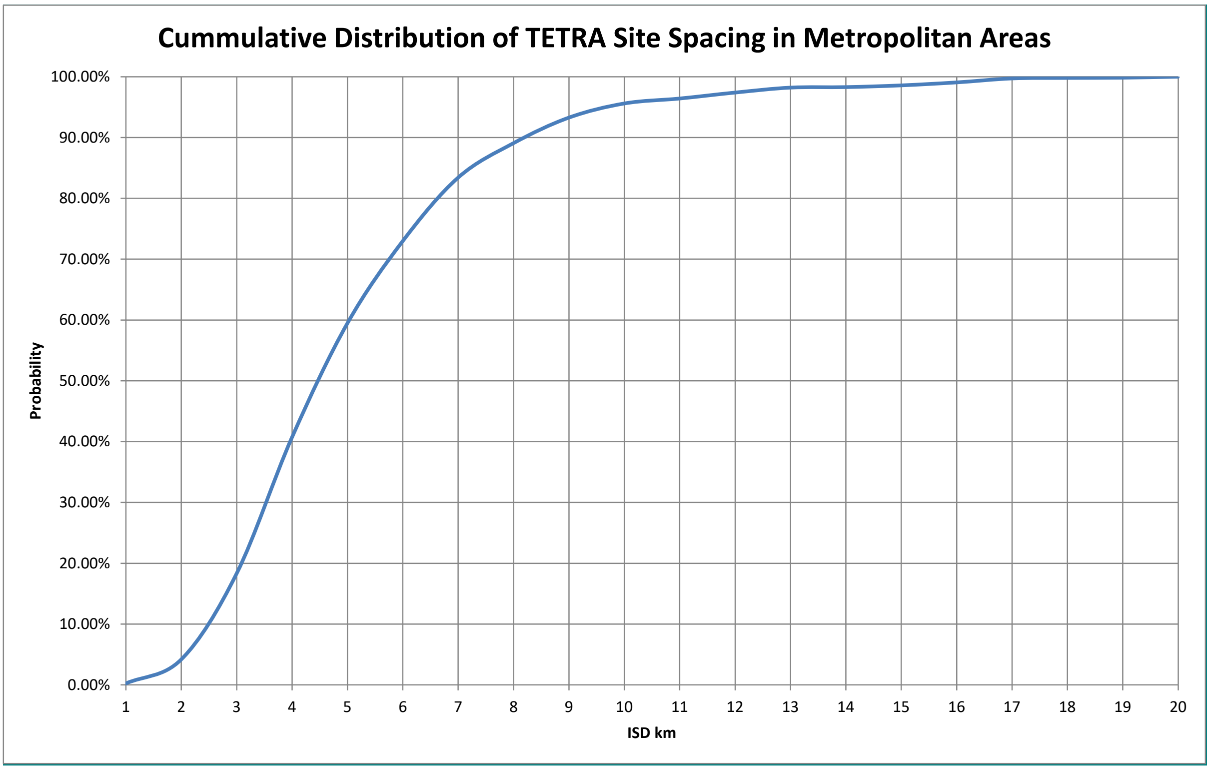

Figure 45: Cumulative Distribution of TETRA inter site distances in Metropolitan Areas

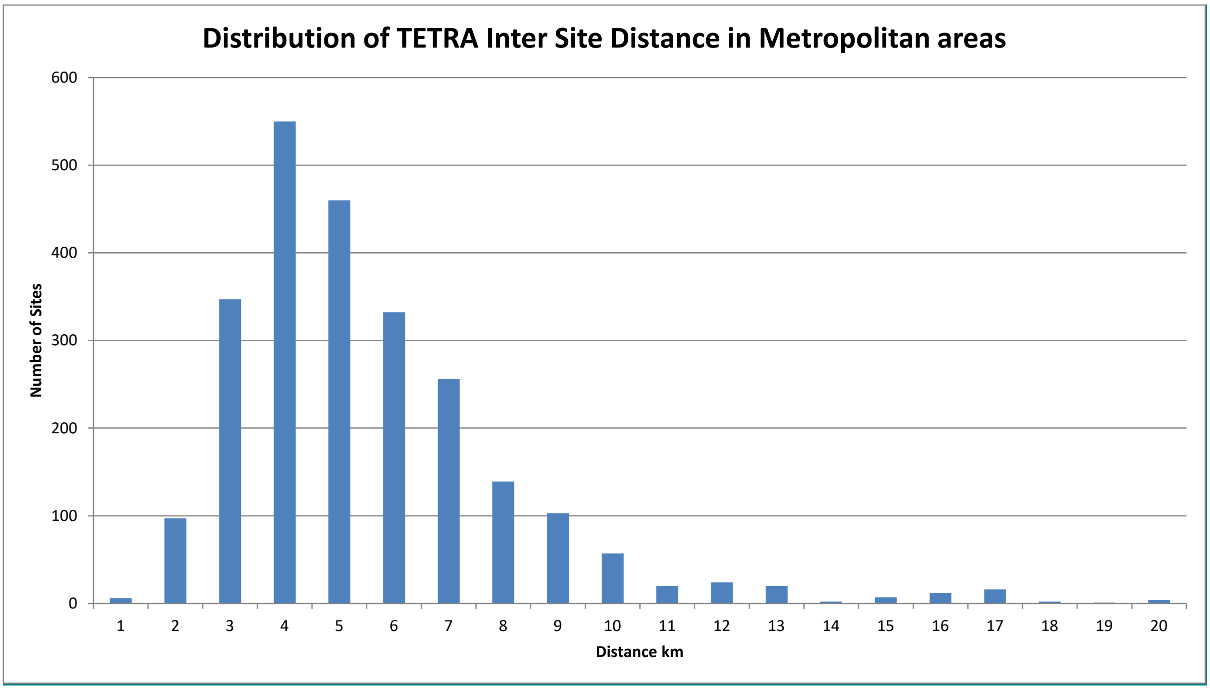

Figure 46: Distribution of TETRA inter site distances in Metropolitan areas

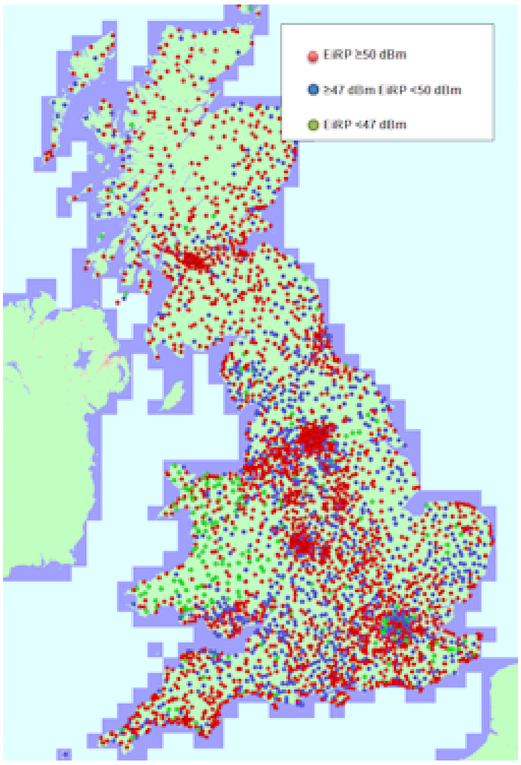

Figure 47: TETRA site e.i.r.p.

ANNEX 4: SIMULATION METHOD FOR IMPACT ON DTT

A4.1 INTRODUCTION

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

A4.2 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):

$$pI=1-pNI \qquad (1)$$

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 DTT 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 ∆pRL 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 usage of PPDR network is rather static, when PPDR UEs are 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, 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 DTT receivers interfered with by PPDR UE. This method doesn't predict what the value of ∆pRL is. 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.

A4.3 BASIC GEOMETRY AND SIMULATION STEPS

A4.3.1 Geometry

Firstly a DTT coverage area is built up according to the link budget analysis presented in A2.6. The DTT transmitter is placed at the centre of the coverage area as depicted in Figure 48.

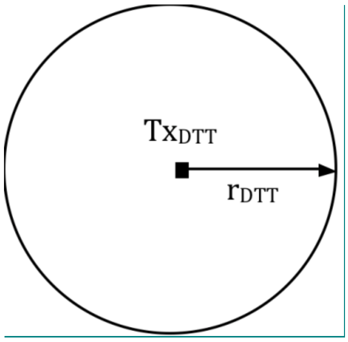

Figure 48: DTT coverage area of radius rDTT

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 49.

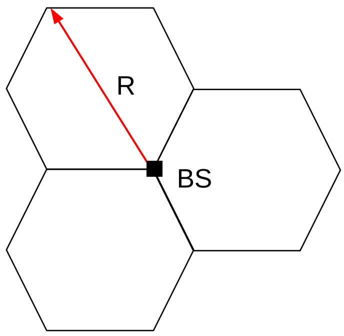

Figure 49: Hexagonal three-sector cell layout (R: cell range)

This PPDR cell is repeated to build up a perfectly homogeneous single frequency PPDR cluster composed of 7 cells (BS) as depicted in Figure 50. A cluster of size 7 is composed of 21 (7 x 3) hexagonal-shaped sectors.

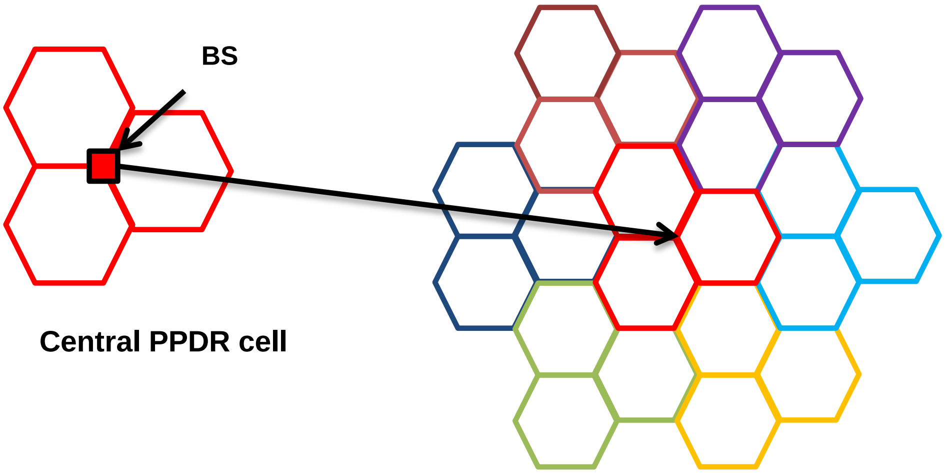

Figure 50: Single frequency PPDR cluster

A4.3.2 Simulation steps

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

1. The DTT receiver is randomly positioned, following a uniform polar distribution, in the DTT cell or in a pixel of 100 m x 100 m at the edge of the DTT cell as depicted in Figure 51. The azimuth orientation of the TV receiver antenna is directed toward the DTT transmitter in case of fixed rooftop reception.

2. Around the DTT receiver within a radius of 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 52.

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.

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

6 ΔpRL is calculated according to equation (5) (note used in the case of interference from PPDR UE to DTT reception).

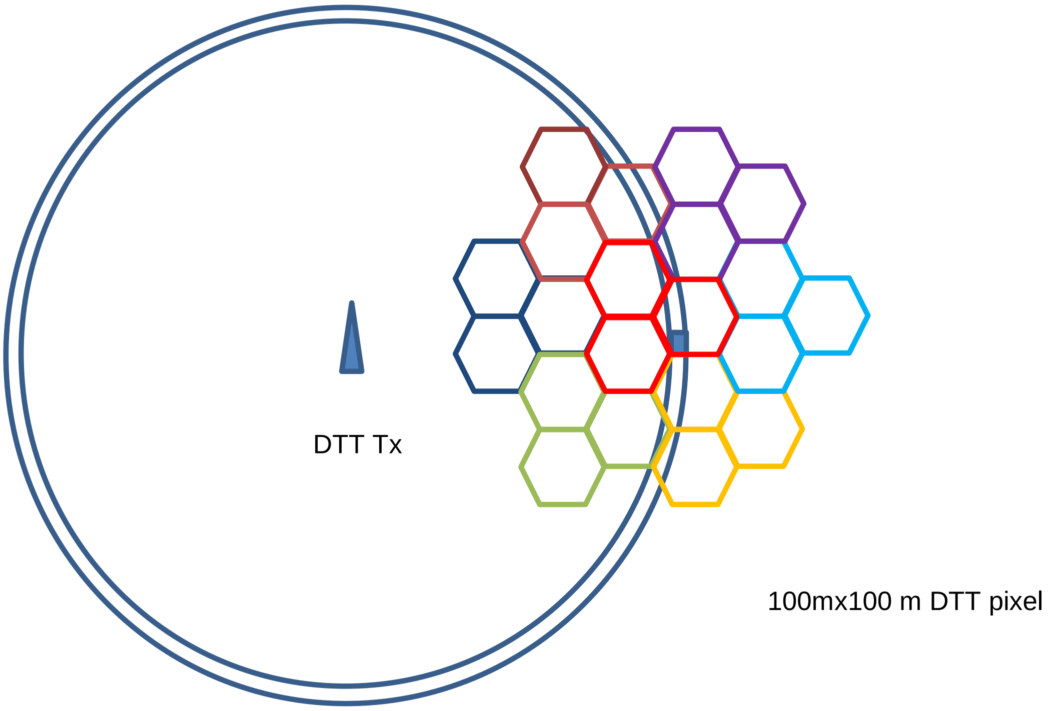

Figure 51: Edge of the DTT coverage area

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

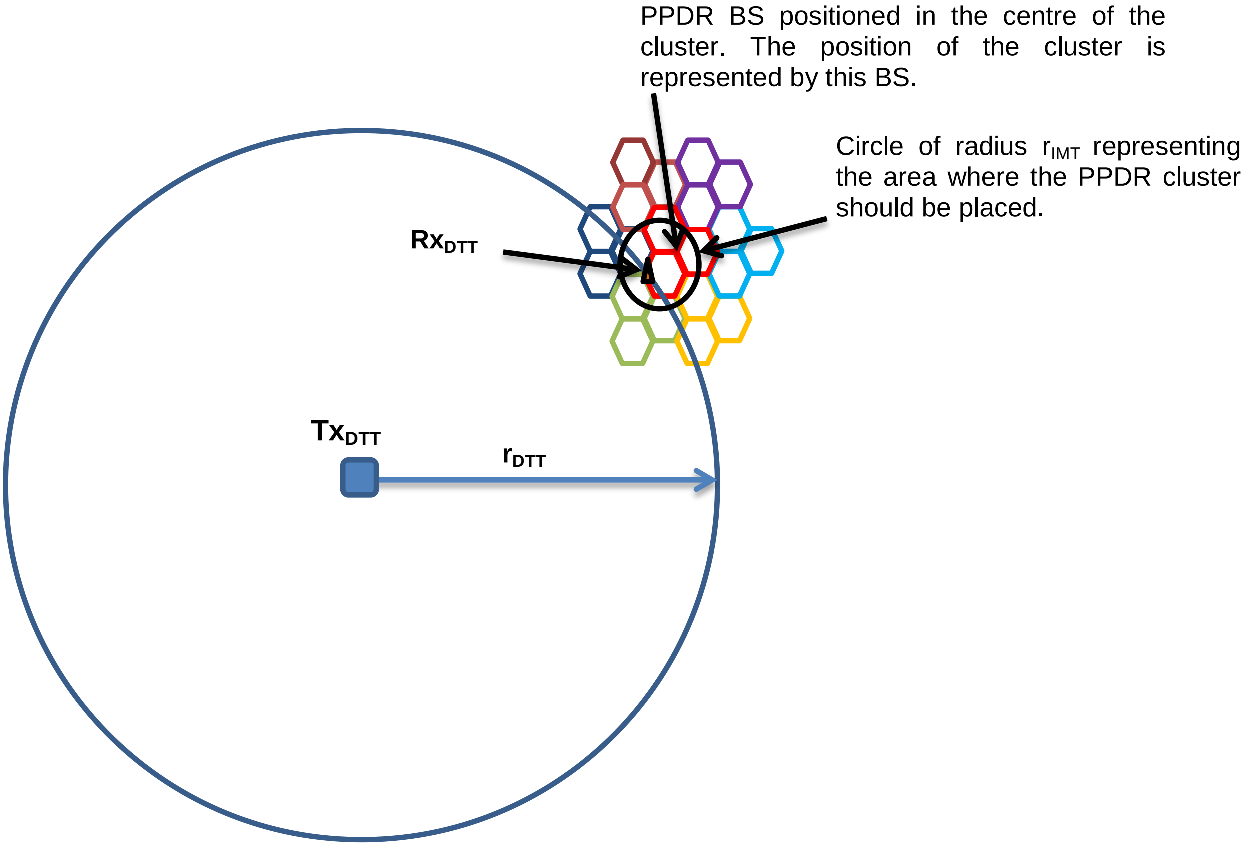

Figure 52: Position of PPDR cluster around DTT receiver

ANNEX 5: TRANSMIT POWER CONTROL

A common model, or emulation, of the behaviour of the LTE power control scheme can be found in 3GPP Technical Report 36.942 V11.0.0, “Radio Frequency (RF) system scenarios” [27]. 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 transmits with maximum power.

This scheme in much more detail, in [15] The setting of the parameters PL_{x-ile} and γ are very important in order to obtain realistic results, especially the former. Target values for the fraction of UEs with full power are proposed in [15] but the corresponding value of CL_{x-ile} can differ significantly between scenarios and parameter sets. Therefore, if this scheme is used, or any other for that matter, it is important that reasonable settings are found for precisely the scenario that is being investigated and that generic, or default, values are not used. Otherwise, unrealistically high transmit powers might be obtained.

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

The following parameters are used in this study:

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

ANNEX 6: SIMULATION RESULTS

A6.1 THE PROBABILITY OF INTERFERENCE ACROSS THE DTT CELL

Table 105: Impact of PPDR (LTE) 400 MHz base station on DTT reception (PPDR outdoor coverage only)

Probability of interference to DTT reception across the DTT cell; PPDR 3 MHz BS interfering signals; PPDR cell range = 7.5 km (outdoor coverage)						
		ACLRPPDR (dB/8MHz)	ACLRPPDR (dB/8MHz)	ACLRPPDR (dB/8MHz)	ACLRPPDR (dB/8MHz)	ACLRPPDR (dB/8MHz)
		42	52	60	67	73
DTT-PPDR guard band (MHz)	ACSDTT (dB)	IP (%)	IP (%)	IP (%)	IP (%)	IP (%)
0	56.3	2.82	0.89	0.54	0.48	0.47
1	58.2	2.82	0.82	0.47	0.4	0.38
2	57.8	2.8	0.86	0.49	0.41	0.4
3	60.8	2.81	0.8	0.4	0.32	0.3
6	62.3	2.8	0.79	0.37	0.29	0.27

Table 106: Impact of PPDR (LTE) 400 MHz base station on DTT reception (PPDR indoor coverage)

Probability of interference to DTT reception across the DTT cell; PPDR 3 MHz BS interfering signals; PPDR cell range = 2.568 km (indoor coverage)						
		ACLRPPDR (dB/8MHz)	ACLRPPDR (dB/8MHz)	ACLRPPDR (dB/8MHz)	ACLRPPDR (dB/8MHz)	ACLRPPDR (dB/8MHz)
		42	52	60	67	73
DTT-PPDR guard band (MHz)	ACSDTT (dB)	IP (%)	IP (%)	IP (%)	IP (%)	IP (%)
0	56.3	23	8.25	5.04	4.45	4.33
1	58.2	22,82	7.87	4.4	3.67	3.55
2	57.8	22,96	7.97	4.54	3.8	3.63
3	60.8	22,9	7.44	3.75	2.94	2.75
6	62.3	22,92	7.42	3.52	2.68	2.47

A6.2 THE PROBABILITY OF INTERFERENCE AT THE DTT CELL EDGE

Table 107: Impact of PPDR (LTE) 400 MHz base station on DTT reception (PPDR outdoor coverage only)

Probability of interference to DTT reception at the DTT cell edge; PPDR 3 MHz BS interfering signals; PPDR cell range = 7.5 km (outdoor coverage)						
		ACLRPPDR (dB/8MHz)	ACLRPPDR (dB/8MHz)	ACLRPPDR (dB/8MHz)	ACLRPPDR (dB/8MHz)	ACLRPPDR (dB/8MHz)
		42	52	60	67	73
DTT-PPDR guard band (MHz)	ACSDTT (dB)	IP (%)	IP (%)	IP (%)	IP (%)	IP (%)
0	56.3	8.68	3.48	1.55	1.34	1.29
1	58.2	8.66	3.26	1.32	1.06	1.03
2	57.8	8.7	3.18	1.37	1.13	1.06
3	60.8	8.58	3.03	1.09	0.81	0.74
6	62.3	8.67	2.74	1.02	0.7	0.62

Table 108: Impact of PPDR (LTE) 400 MHz base station on DTT reception (PPDR indoor coverage)

Probability of interference to DTT reception at the DTT cell edge; PPDR 3 MHz BS interfering signals; PPDR cell range = 2.568 km (indoor coverage)						
		ACLRPPDR (dB/8MHz)	ACLRPPDR (dB/8MHz)	ACLRPPDR (dB/8MHz)	ACLRPPDR (dB/8MHz)	ACLRPPDR (dB/8MHz)
		42	52	60	67	73
DTT-PPDR guard band (MHz)	ACSDTT (dB)	IP (%)	IP (%)	IP (%)	IP (%)	IP (%)
0	56.3	54.33	22.98	14.23	12.29	11.99
1	58.2	54.13	21.96	12.2	9.91	9.48
2	57.8	54.28	22.17	12.56	10.38	9.93
3	60.8	54.06	21.04	10.24	7.5	6.9
6	62.3	54.2	20.71	9.46	6.46	5.8

ANNEX 7: REAL-LIFE INTERFERENCE FROM LTE800 TO DTT

A7.1 INTRODUCTION

Some CEPT administrations see some possibilities of making limited parts of the 400 MHz sub-bands (410-430 MHz or 450-470 MHz band or both) available in the future, or long-term future, for Broadband (BB) PPDR LTE networks. Channel bandwidths from 1 to 5 MHz seem to be more appropriate [7]. If this happens, BB PPDR (LTE) may operate adjacent to the UHF broadcasting band, without any guard band, as shown in Figure 53.

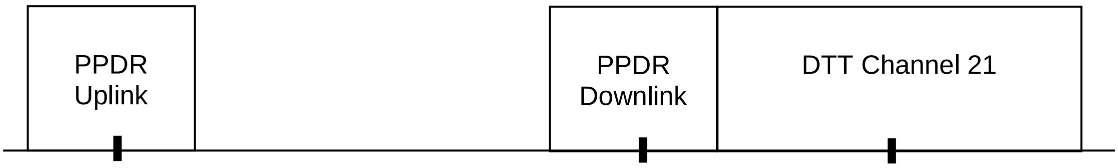

Figure 53: PPDR (LTE) 400 MHz operating in an adjacent band to DTT channel 21.

Under this assumption, based on a conventional mobile channelling arrangement, PPDR 400 MHz base stations (UL) will operate in an adjacent band to DTT reception. This configuration is quite similar to the LTE 800 MHz networks where LTE base stations (UL) are operating in an adjacent band to DTT reception with a guard band of 1 MHz between broadcasting band edge at 790 MHz and LTE downlink band edge at 791 MHz.

It is then legitimate to be interested in the impact of existing LTE 800 MHz networks on DTT reception to better assess the possible impact of PPDR 400 MHz networks to DTT reception.

This document presents a short report on the real-life interference from LTE 800 MHz networks to DTT rooftop fixed reception in France

A7.2 LTE 800 MHz ROLL-OUT

LTE 800 MHz roll-out is underway in France since March 2013. The information presented in the following section on the number of interference from LTE 800 MHz to DTT reception dated from 2 October 2014[6]. The concerned roll-out has been carried out by the three main French mobile network operators and was urban predominated. It included only 5936 base stations (BS). The total number of BS needed for full national coverage is estimated to be about 30000 for the three network operators.

A7.3 ACCOUNTING OF INTERFERENCE FROM LTE 800 MHz TO DTT RECEPTION

A7.3.1 Number of interference

Table 109: Number of interferences to DTT reception

Real-life interference from LTE 800 MHz to DTT reception in France Number of transmitting three sectorial base stations (BS) = 5936; Urban predominated roll-out		
Number of interference		
DTT reception mode	Number of interference to DTT reception	Estimated number of interference to households
Individual aerial reception[1]	21790	21790

[6] Information provided by “Comité LTE 800 MHz” and presented in this document with the permission of ANFR (Agence National des Frequences)

Real-life interference from LTE 800 MHz to DTT reception in France Number of transmitting three sectorial base stations (BS) = 5936; Urban predominated roll-out		
Communal aerial reception[2]	7806	101478
Total number of interference	29596	123268
Average number of interference per BS	≈ 5	≈ 21
[1] An individual aerial reception is when a single TV aerial feeds a single household. [2] It is assumed that a common aerial feeds on average 13 households		

A7.3.2 Interference ranges

Table 110: Interference distance between LTE800 BS transmitter and DTT reception

Real-life interference from LTE 800 MHz to DTT reception in France Number of transmitting three sectorial base stations (BS) = 5936; Urban predominated roll-out	
Interference distance*	
Max distance (m)	5770
Average distance (m)	582
Median distance (m)	487
Standard deviation (m)	423
* Distance between the victim DTT receiver and the interfering BS transmitter	

A7.4 CONCLUSION

Real-life experience of the roll-out of LTE 800 MHz networks in France shows that LTE base stations, operating in an adjacent band to DTT reception, cause harmful interference to the latter, despite a guard band of 1 MHz between DTT band edge at 790 MHz and LTE downlink band edge at 791 MHz. This has been observed since the beginning of the roll in France. Indeed, this interference is limited and can be resolved, case by case, by mitigation techniques; mainly by filtering out the interfering LTE signal by an external filter connected to DTT receiver antenna output.

Actually, up to now, for 5936 active LTE 800 MHz BS, 29596 interferences to DTT reception were identified (≈ 5 interferences per BS), which represents interference to 123268 households. All the interference cases were resolved by filtering. However, such operations cost time and money.

Consequently, it is sensible to conclude that PPDR (LTE) 400 MHz networks operating in an adjacent band to DTT reception at 470 MHz would cause harmful interference to DTT reception. Even if this interference was limited, it would be quite difficult to resolve it due to the interference caused to DTT reception by commercial LTE networks. Filtering the interferences coming simultaneously from the upper and lower adjacent bands to the UHF broadcasting band, with an acceptable insertion loss for DTT receivers, will be a challenge for RF filter manufacturers, unless a guard band is used between PPDR (LTE) 400 MHz and DTT.

A reasonable guard band will permit to improve PPDR ACLR as well as DTT receiver ACS and consequently to reduce the probability of interference to DTT reception caused by PPDR 400 MHz networks. Moreover, the guard band will surely ease the development of RF mitigation filters.

ANNEX 8: DETAILED PARAMETERS AND RESULTS OF THE LOCAL INTERFERENCE PROBABILITY ANALYSIS FOR PPDR UE INTERFERENCE TO DTT

A8.1 COMPLETE SET OF PARAMETERS

The complete set of parameters is given in Table 111 and Table 112.

Table 111: DTT receiver parameters

DTT receiver parameters	
Antenna height	10 m
Antenna gain	9.15 dB
Antenna pattern	Rec. 419
Frequency	474 MHz for the PPDR 400 impact calculation And 690 MHz for the commercial LTE 700 impact calculation
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 93

Table 112: PPDR UE parameters

PPDR UE parameters	
Bandwidth	3 MHz
Antenna height (omni-directional)	1.5m
e.i.r.p.	23, 31, 37 dBm
Body loss	0, 4 dB
Propagation model	Hata
ACLR	See Table 60

A8.2 RESULTS

The results are given below in tabular form as well as in diagrammatic form.

The diagrams are presented in sets of 3, corresponding to 1, 3 and 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.

A8.2.1 Reference case: commercial LTE700 UE impact on DTT

Table 113: Reference case: commercial LTE700 UE impact on DTT

DTT reference receiver parameters	
Antenna height	10 m
Antenna gain	9.15 dB
Antenna pattern	Rec. 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	65 dB

Table 114: PPDR reference UE parameters

PPDR reference UE parameters	
Antenna height (omni-directional)	1.5 m
e.i.r.p.	20 dBm (= 23 - 3)
Frequency	~ 470 MHz
Body loss	4 dB
Propagation model	Hata
ACLR	65 dB

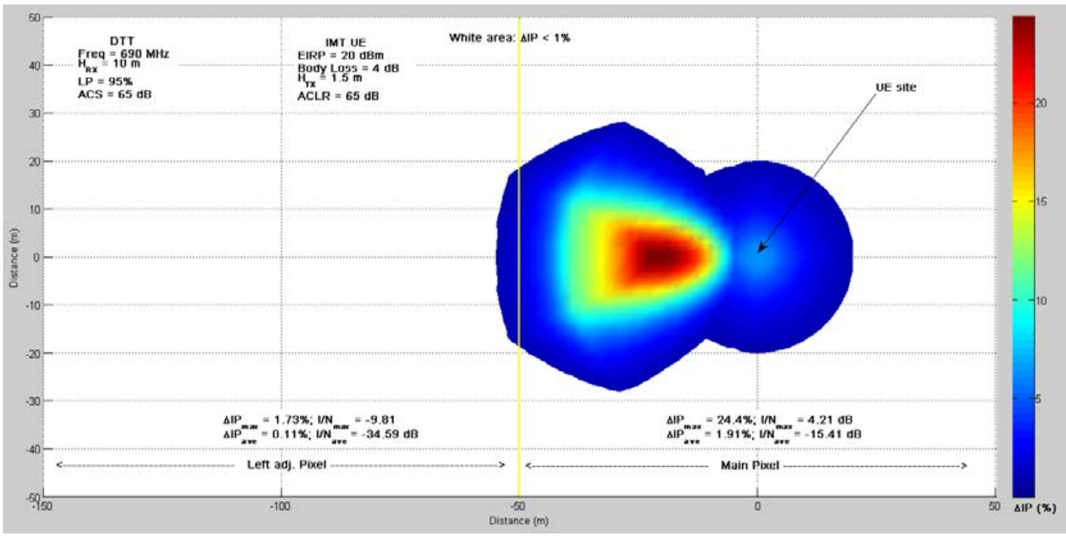

Figure 54: Interference footprint for commercial LTE700 UE impact on DTT

Table 115: 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. 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

A8.2.2 Vehicular PPDR UE, e.i.r.p. = 37 dBm

A8.2.2.1 ACS = 65 dB = ACLR

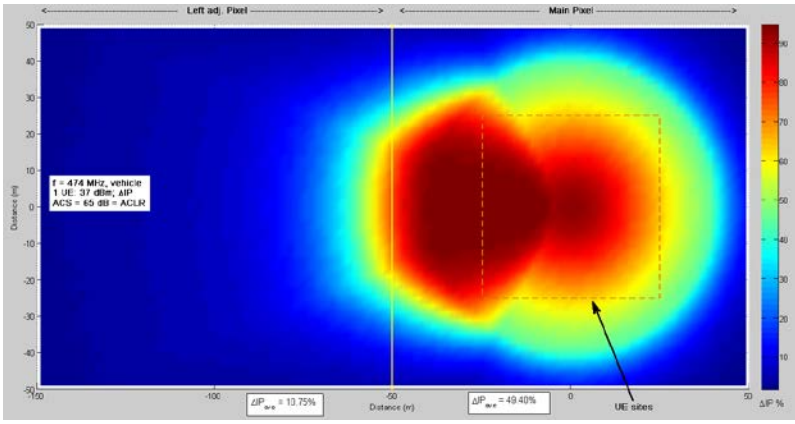

Figure 55: 1 UE @ 37 dBm, ACS = 65 dB = ACLR

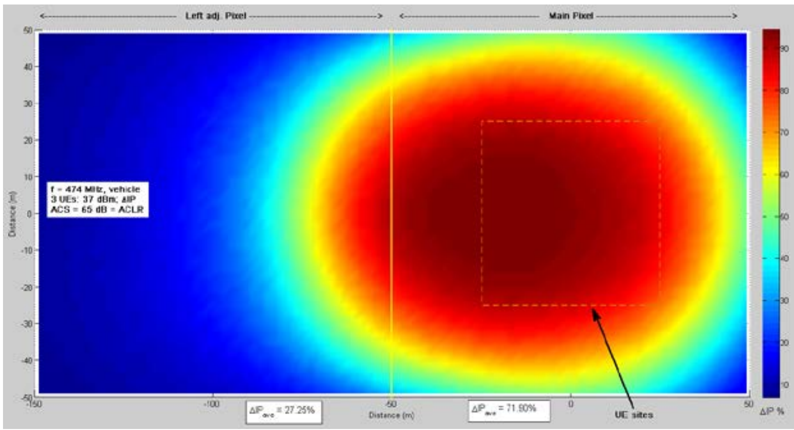

Figure 56: 3 UEs @ 37 dBm, ACS = 65 dB = ACLR

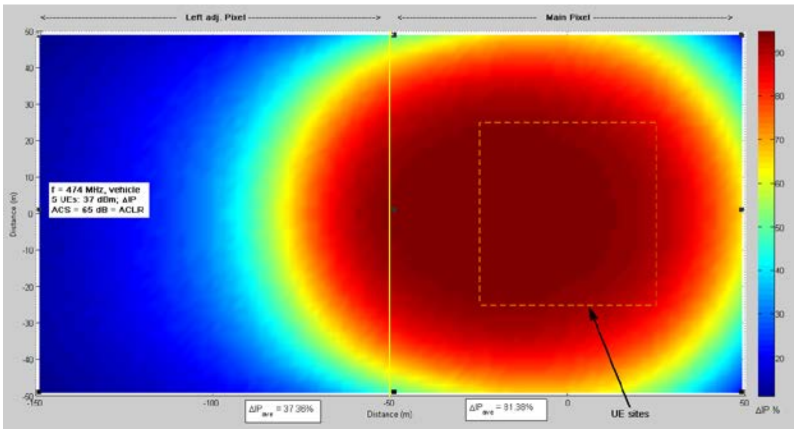

Figure 57: 5 UEs @ 37 dBm, ACS = 65 dB = ACLR

A8.2.2.2 ACS = 70 dB = ACLR

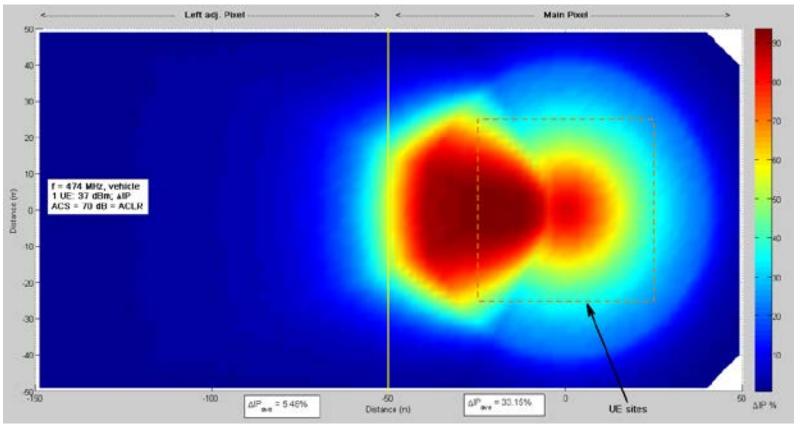

Figure 58: 1 UE @ 37 dBm, ACS = 70 dB = ACLR

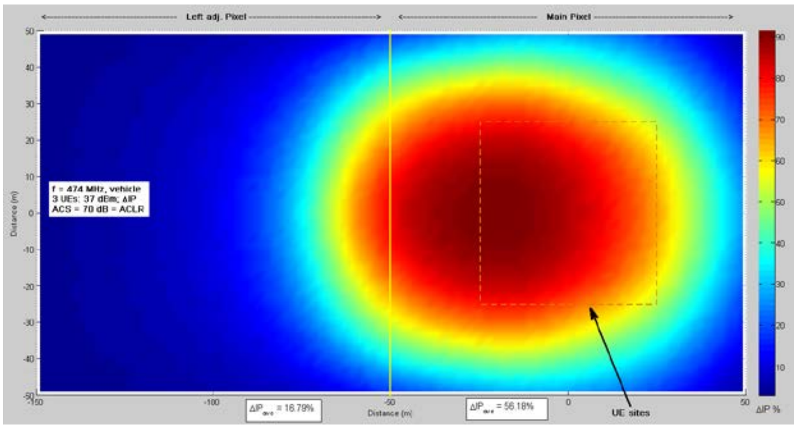

Figure 59: 3 UEs @ 37 dBm, ACS = 70dB = ACLR

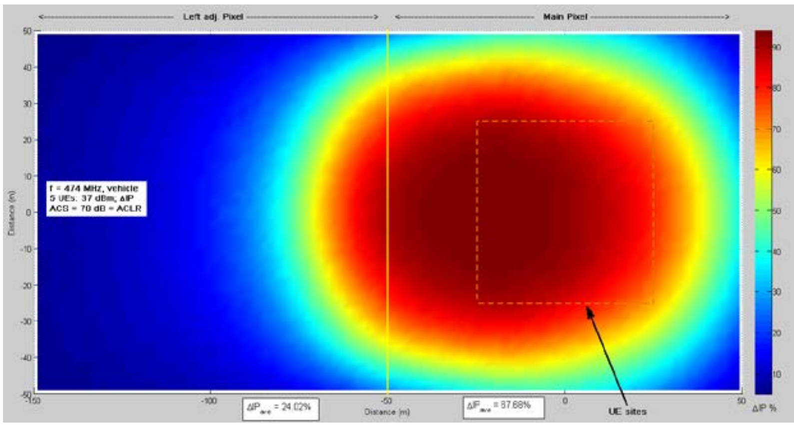

Figure 60: 5 UEs @ 37 dBm, ACS = 70 dB = ACLR

A8.2.2.3 ACS = 75 dB = ACLR

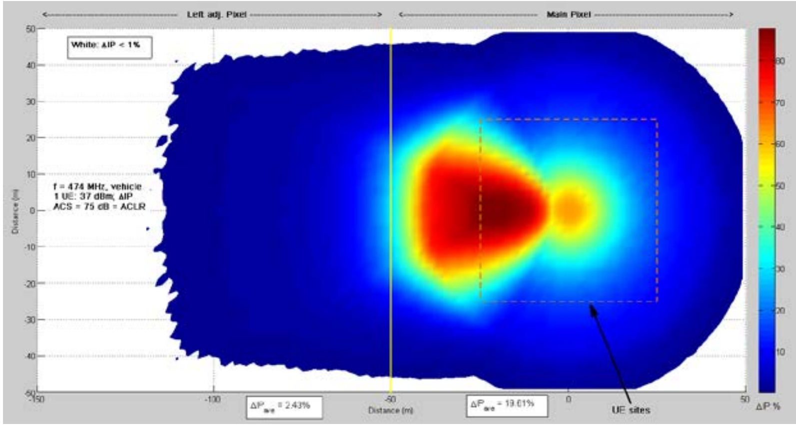

Figure 61: 1 UE @ 37 dBm, ACS = 75 dB = ACLR

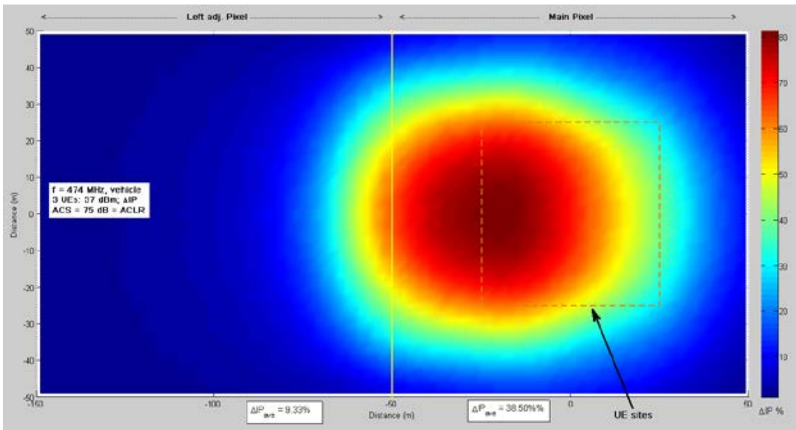

Figure 62: 3 UEs @ 37 dBm, ACS = 75 dB = ACLR

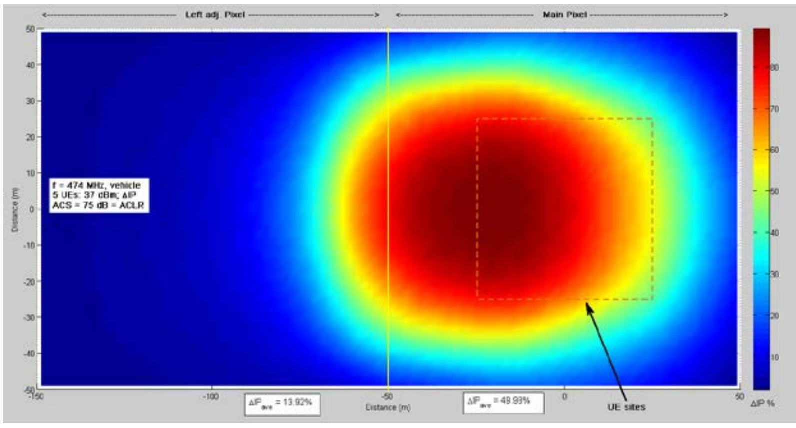

Figure 63: 5 UEs @ 37 dBm, ACS = 75 dB = ACLR

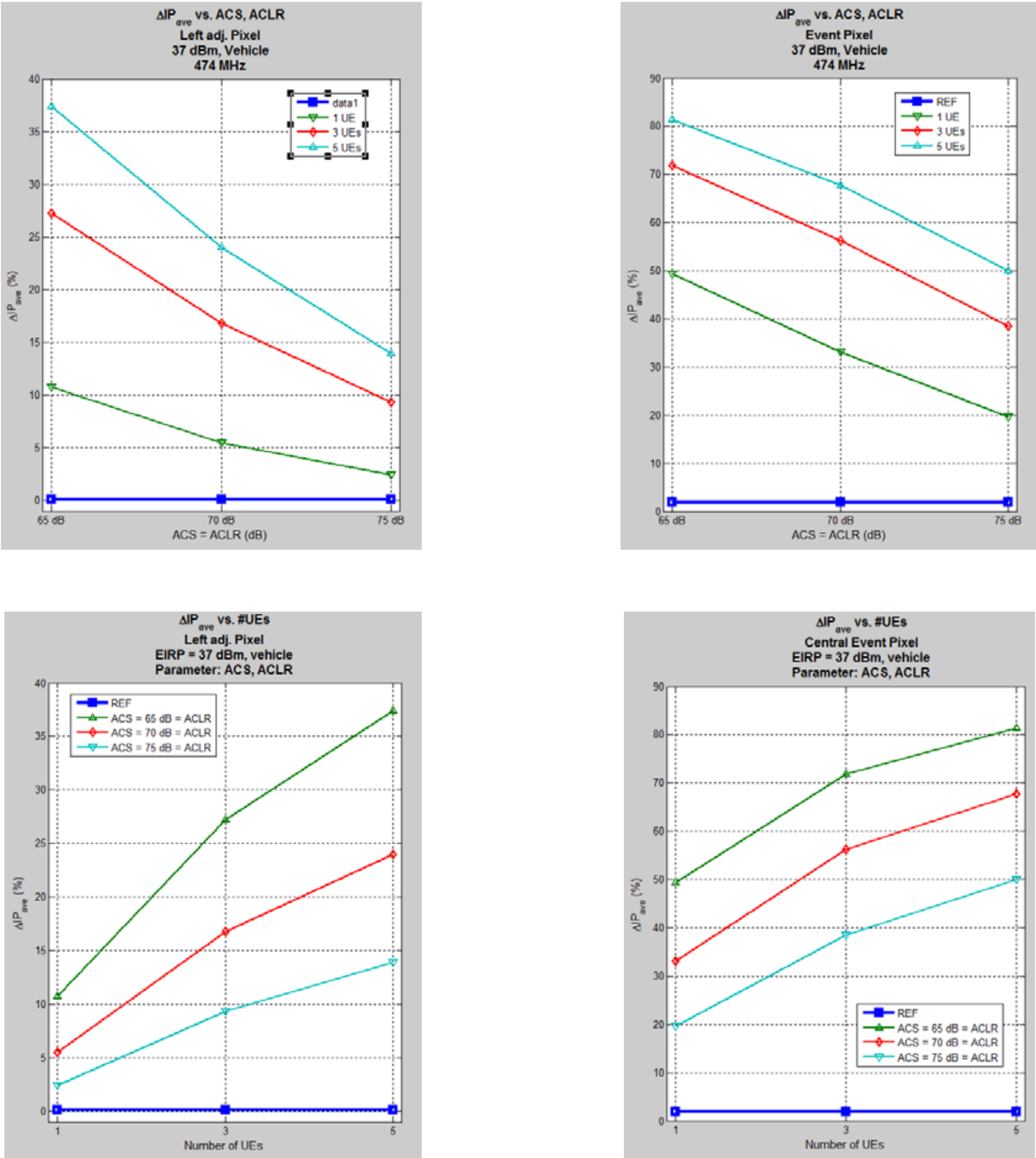

Figure 64: e.i.r.p. = 37 dBm (vehicle mounted)

Table 116: Vehicular, e.i.r.p. = 37 dBm

Vehicular, e.i.r.p. = 37 dBm						
	ACS = 65 dB = ACLR		ACS = 70 dB = ACLR		ACS = 75 dB = ACLR	
	GB = 10 MHz	GB=10 MHz	GB=13MHz	GB=13MHz	GB=16MHz	GB=16MHz
# UEs	ΔIPave Central pixel	ΔIPave Left adj. pixel	ΔIPave Central pixel	ΔIPave Left adj. pixel	ΔIPave Central pixel	Left adj. pixel
1	49.40%	10.75%	33.15%	5.48%	19.61%	2.43%
3	71.90%	27.25%	56.18%	16.79%	38.50%	9.33%
5	81.38%	37.36%	67.68%	24.02%	49.98%	13.92%

A8.2.3 Vehicular PPDR UE, e.i.r.p. = 31 dBm

A8.2.3.1 ACS = 65 dB = ACLR

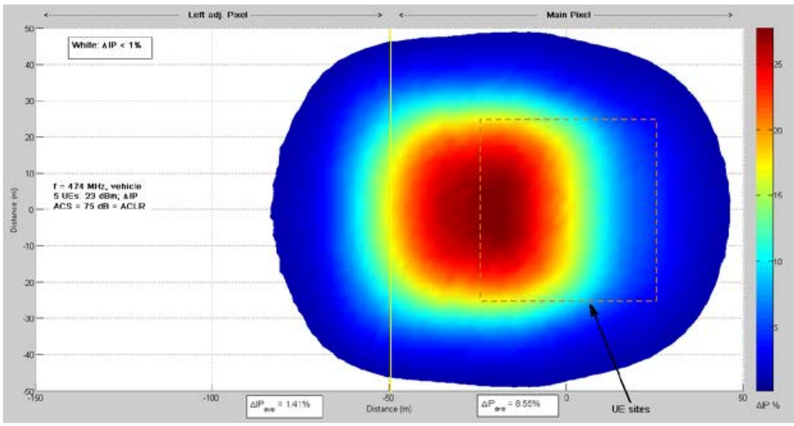

Figure 65: 1 UE @ 31 dBm, ACS = 65 dB = ACLR

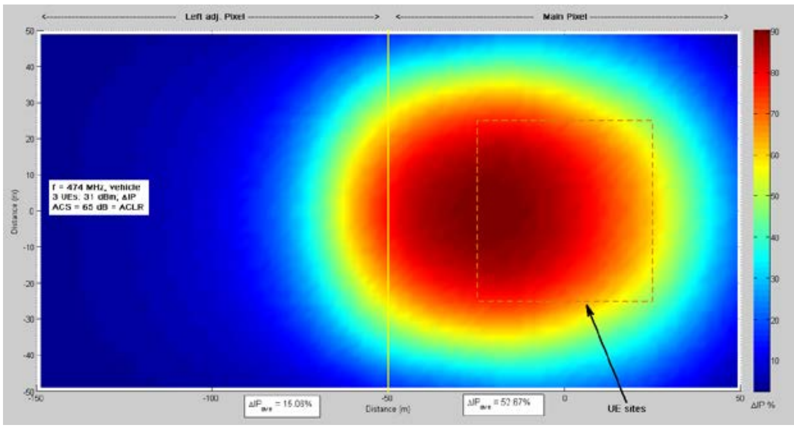

Figure 66: 3 UEs @ 31 dBm, ACS = 65 dB = ACLR

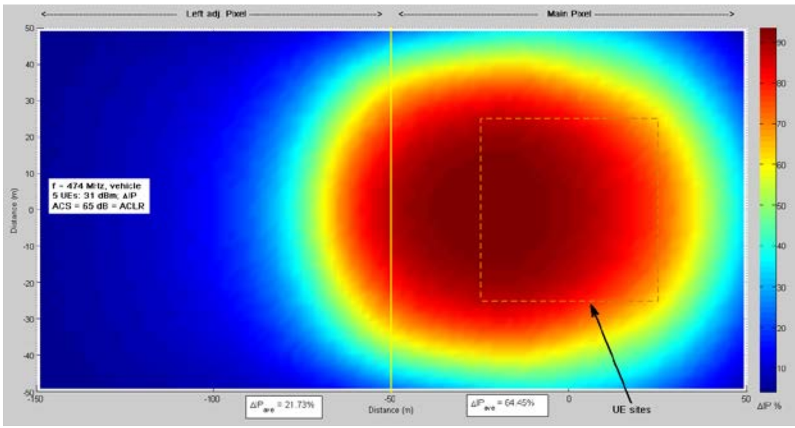

Figure 67: 5 UEs @ 31 dBm, ACS = 65 dB = ACLR

A8.2.3.2 ACS = 70 dB = ACLR

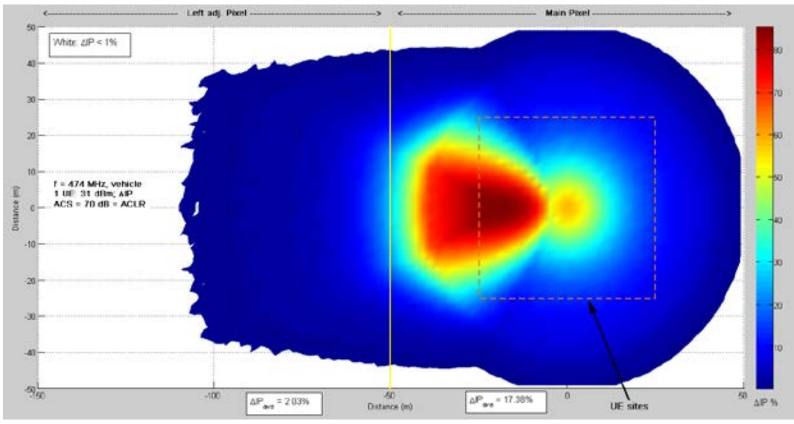

Figure 68: 1 UE @ 31 dBm, ACS = 70 dB = ACLR

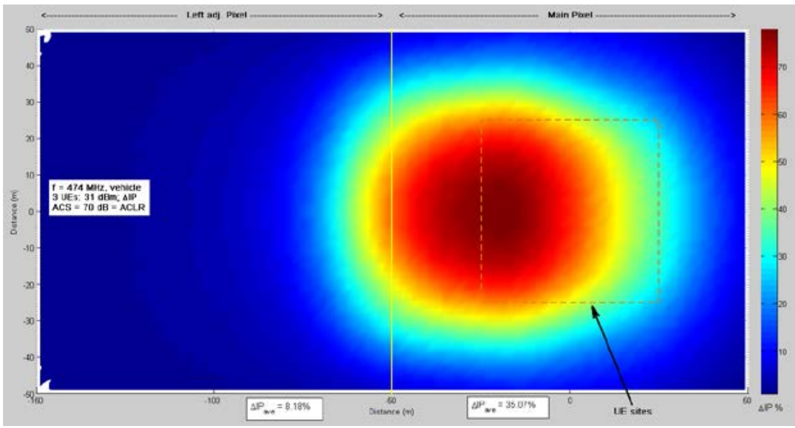

Figure 69: 3 UEs @ 31 dBm, ACS = 70 dB = ACLR

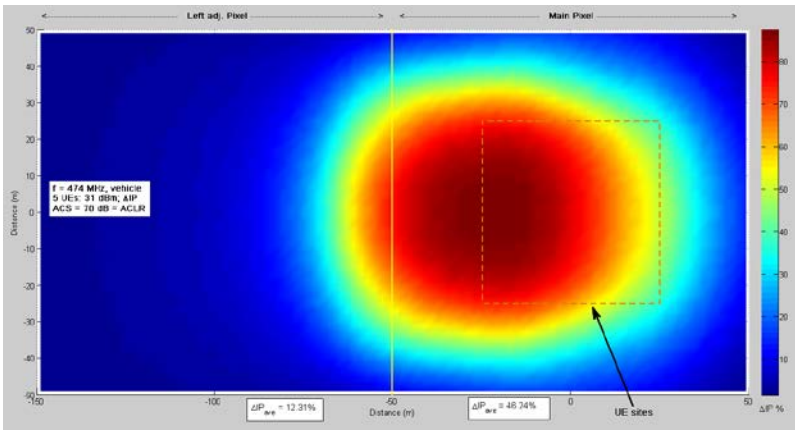

Figure 70: 5 UEs @ 31 dBm, ACS = 70 dB = ACLR

A8.2.3.3 ACS = 75 dB = ACLR

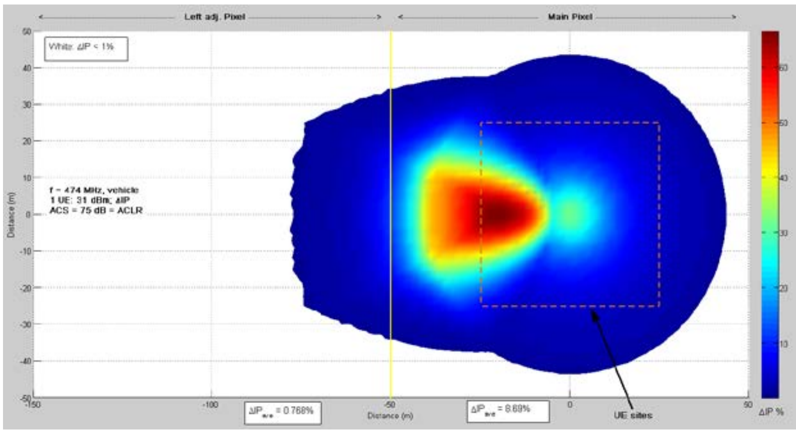

Figure 71: 1 UE @ 31 dBm, ACS = 75 dB = ACLR

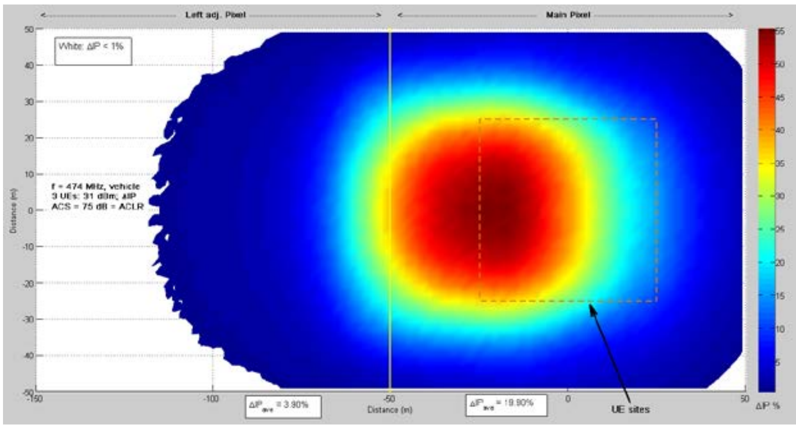

Figure 72: 3 UEs @ 31 dBm, ACS = 75 dB = ACLR

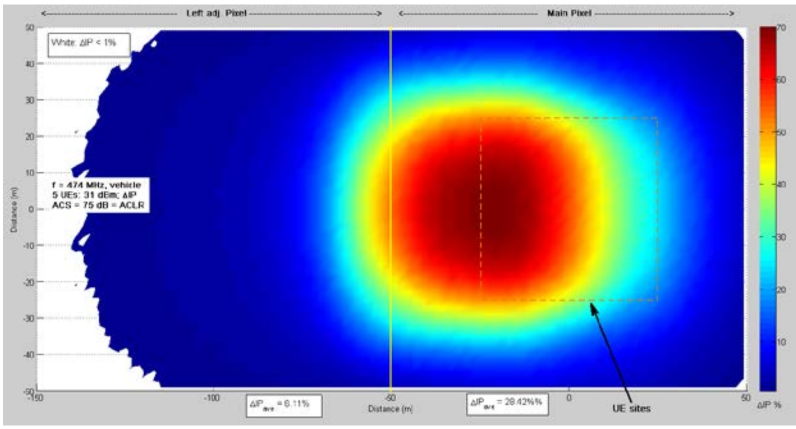

Figure 73: 5 UEs @ 31 dBm, ACS = 75 dB = ACLR

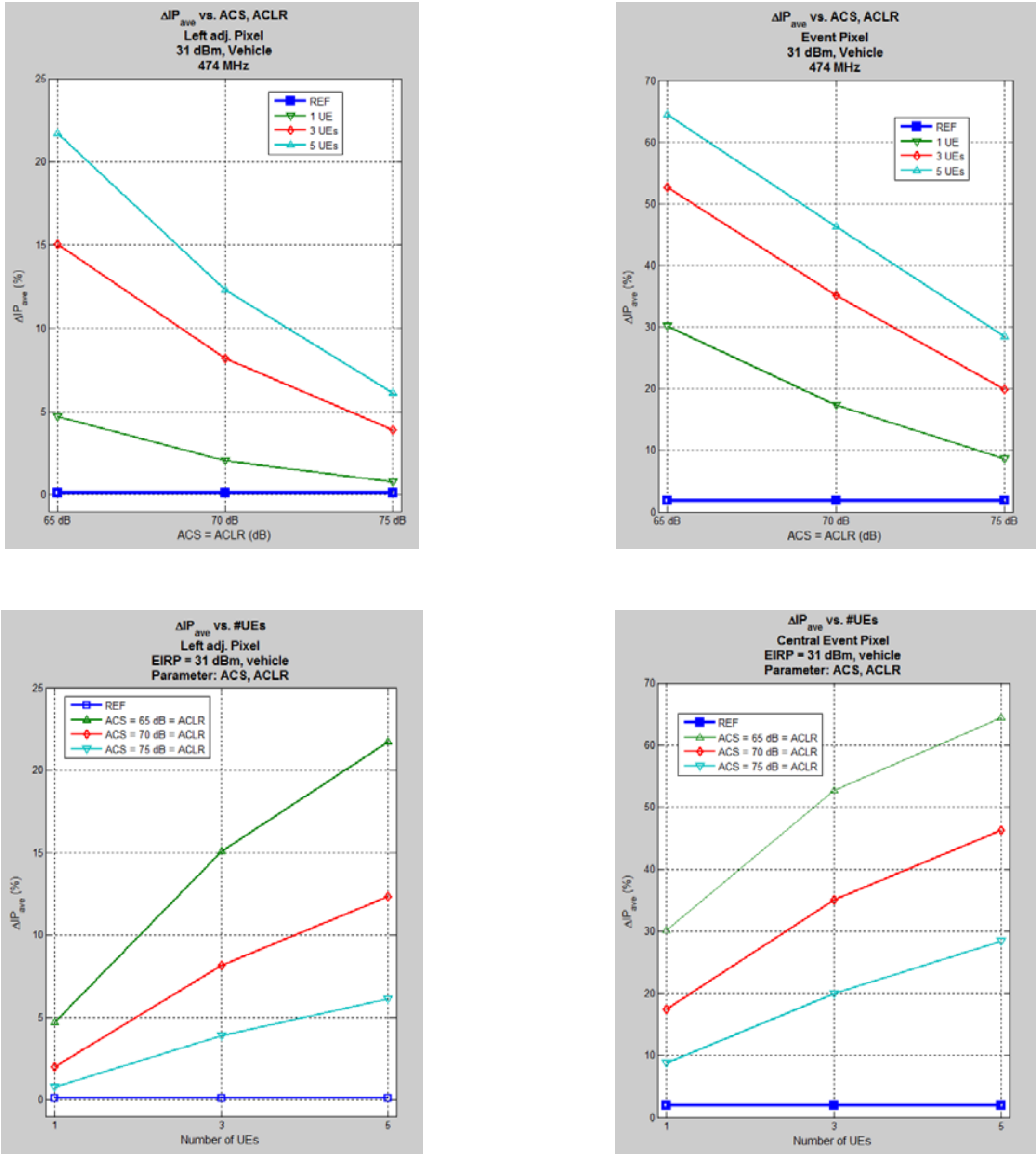

Figure 74: e.i.r.p. = 31 dBm (vehicle mounted)

Table 117: Vehicular, e.i.r.p. = 31 dBm

Vehicular, e.i.r.p. = 31 dBm						
	ACS = 65 dB = ACLR		ACS = 70 dB = ACLR		ACS = 75 dB = ACLR	
	GB = 10 MHz	GB=10 MHz	GB=13MHz	GB=13MHz	GB=16MHz	GB=16MHz
# UEs	ΔIPave Central pixel	ΔIPave Left adj. pixel	ΔIPave Central pixel	ΔIPave Left adj. pixel	ΔIPave Central pixel	Left adj. Pixel
1	30.15%	4.71%	17.38%	2.03%	8.69%	0.768%
3	52.67%	15.06%	35.07%	8.18%	19.90%	3.90%
5	64.45%	21.73%	46.24%	12.31%	28.42%	6.11%

A8.2.4 Vehicular PPDR UE, e.i.r.p. = 23 dBm

A8.2.4.1 ACS = 65 dB = ACLR

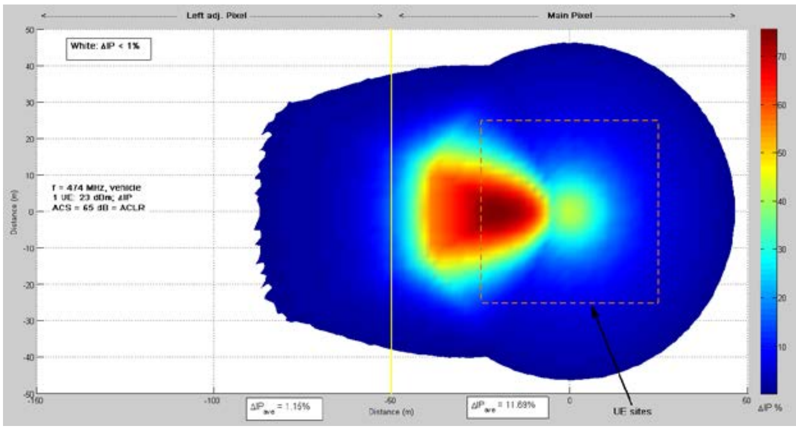

Figure 75: 1 UE @ 23 dBm, ACS = 65 dB = ACLR

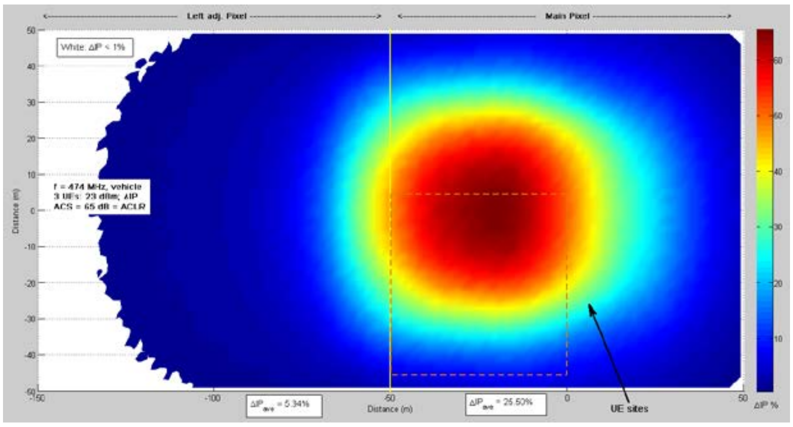

Figure 76: 3 UEs @ 23 dBm, ACS = 65 dB = ACLR

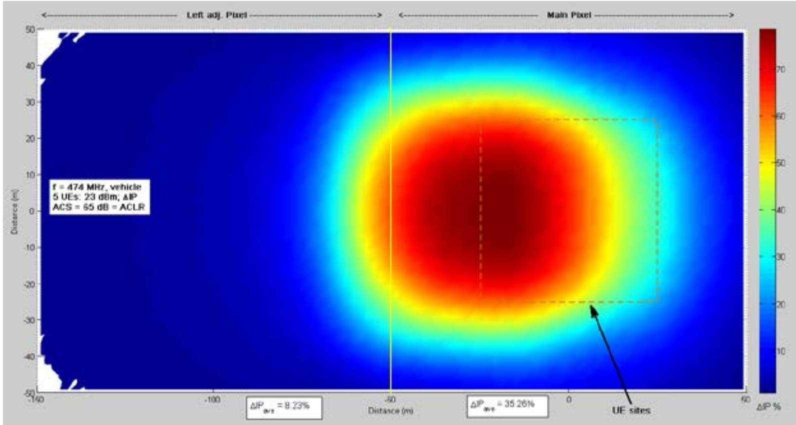

Figure 77: 5 UEs @ 23 dBm, ACS = 65 dB = ACLR

A8.2.4.2 ACS = 70 dB = ACLR

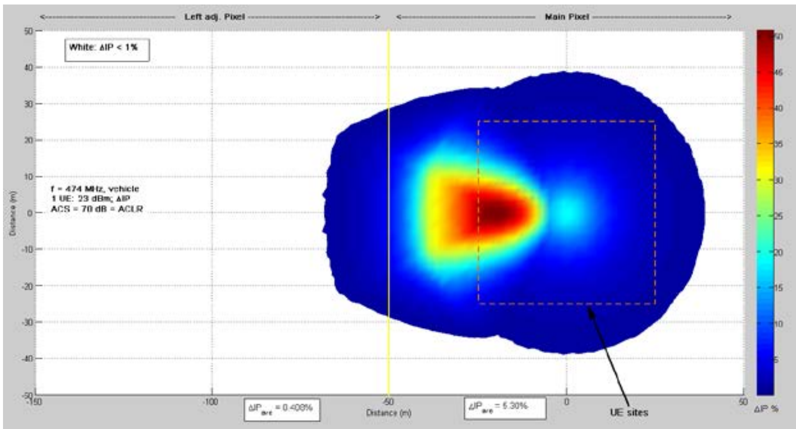

Figure 78: 1 UE @ 23 dBm, ACS = 70 dB = ACLR

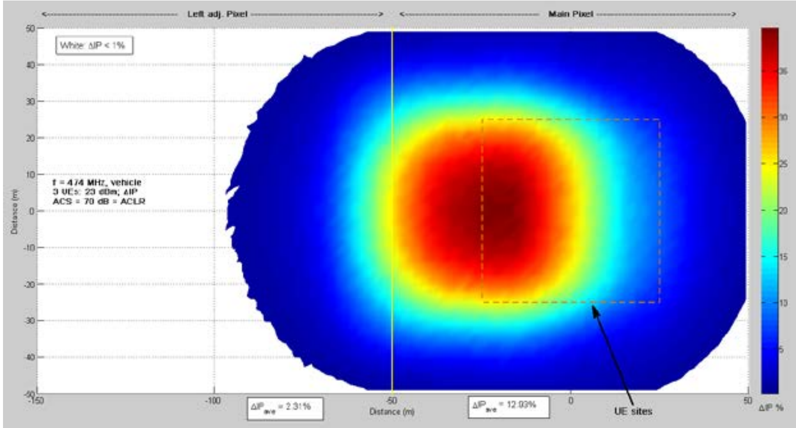

Figure 79: 3 UEs @ 23 dBm, ACS = 70 dB = ACLR

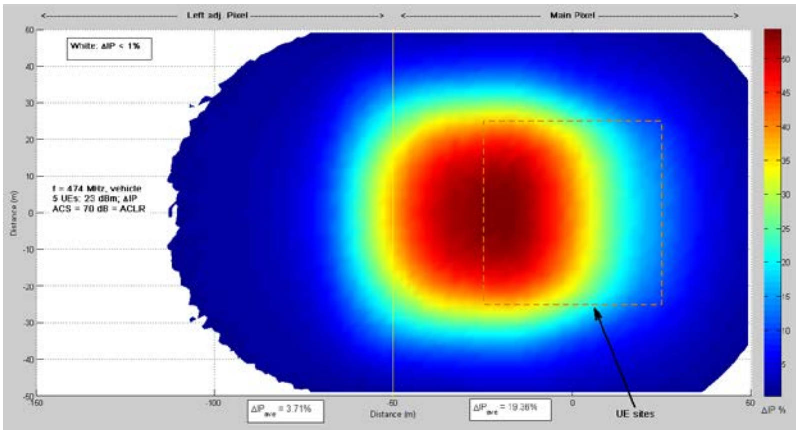

Figure 80: 5 UEs @ 23 dBm, ACS = 70 dB = ACLR

A8.2.4.3 ACS = 75 dB = ACLR

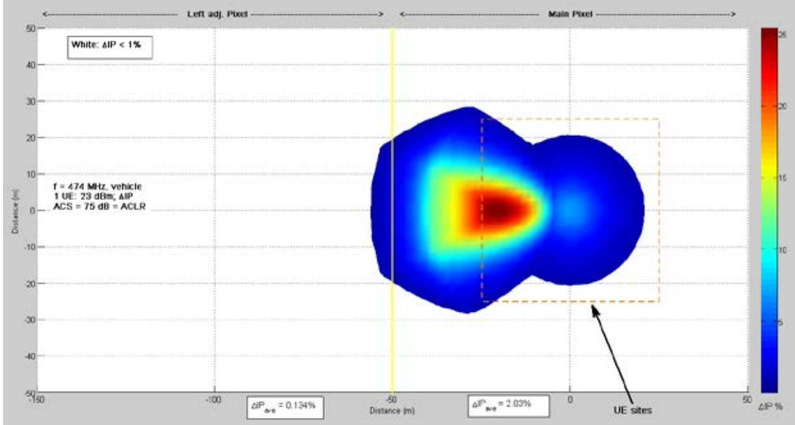

Figure 81: 1 UE @ 23 dBm, ACS = 75 dB = ACLR

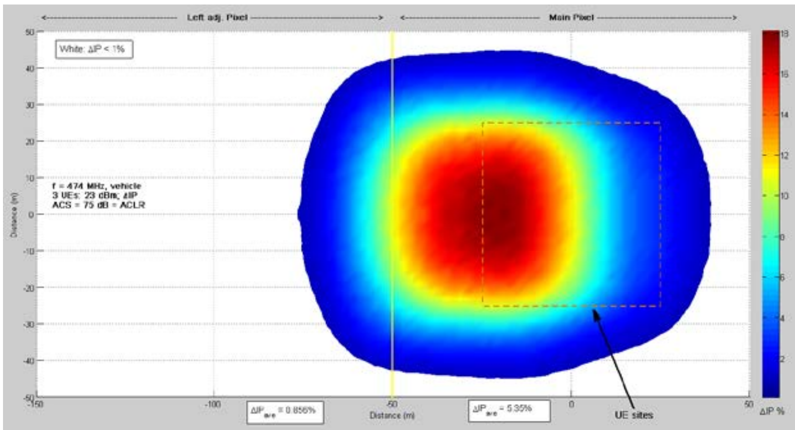

Figure 82: 3 UEs @ 23 dBm, ACS = 75 dB = ACLR

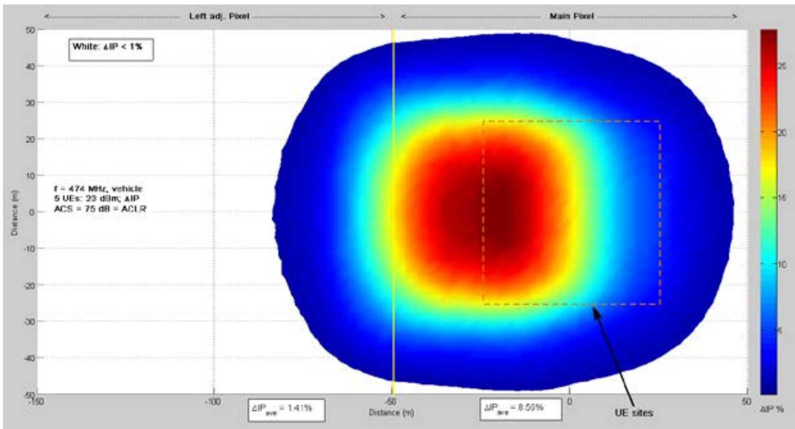

Figure 83: 5 UEs @ 23 dBm, ACS = 75 dB = ACLR

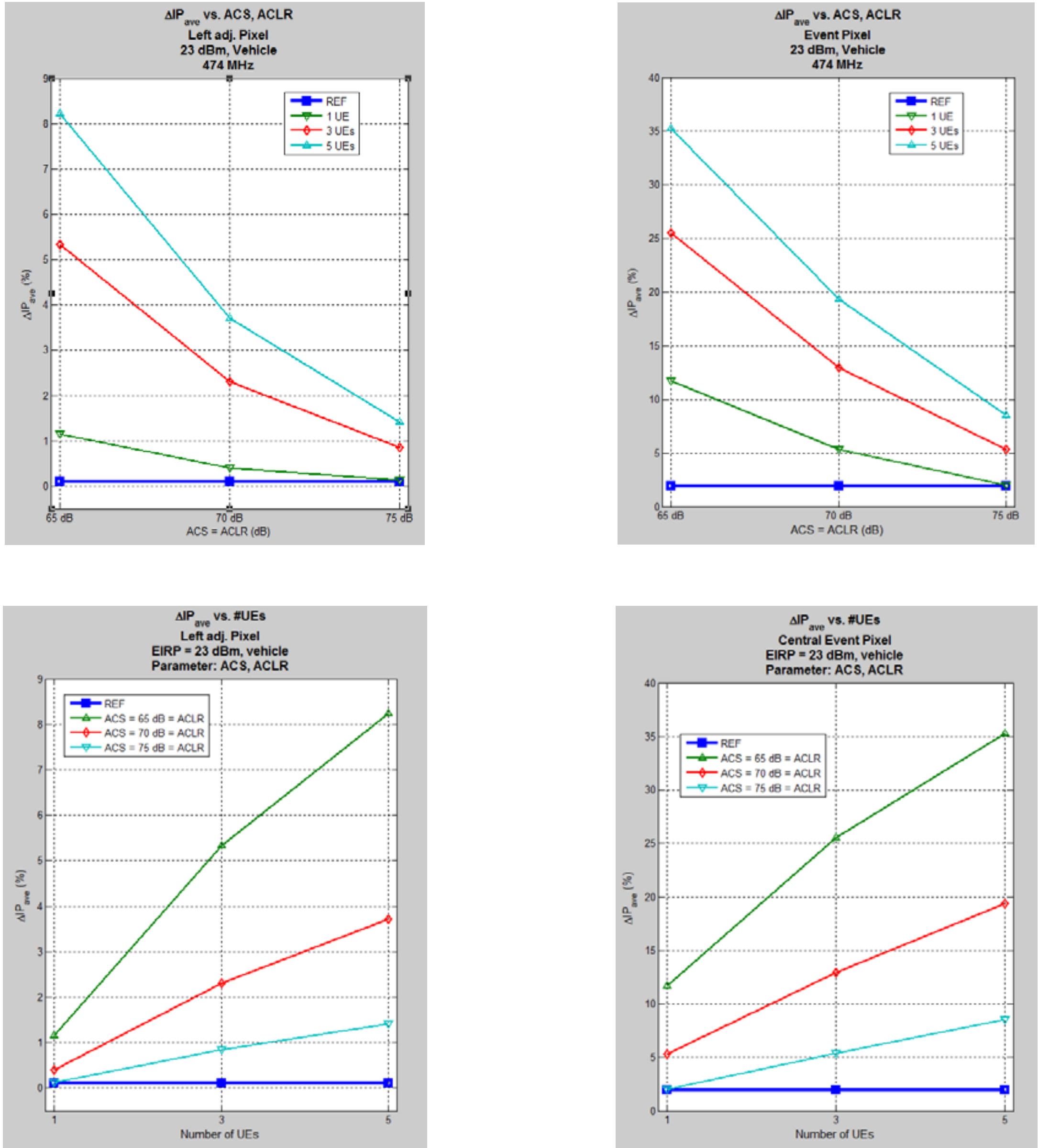

Figure 84: e.i.r.p. = 23 dBm (vehicle mounted)

Table 118: Vehicular, e.i.r.p. = 23 dBm

Vehicular, e.i.r.p. = 23 dBm						
	ACS = 65 dB = ACLR		ACS = 70 dB = ACLR		ACS = 75 dB = ACLR	
	GB = 10 MHz	GB=10 MHz	GB=13MHz	GB=13MHz	GB=16MHz	GB=16MHz
# UEs	ΔIPave Central pixel	ΔIPave Left adj. Pixel	ΔIPave Central pixel	ΔIPave Left adj. pixel	ΔIPave Central pixel	Left adj. Pixel
1	11.69%	1.15%	5.30%	0.408%	2.03%	0.134%
3	25.50%	5.34%	12.93%	2.31%	5.35%	0.856%
5	35.26%	8.23%	19.36%	3.71%	8.55%	1.41%

A8.3 COMPARISON TABLES

Table 119: Event Pixel

Case	ΔIP (%)	ΔIP (%)	ΔIP (%)
Reference commercial LTE 700 UE	1.91%	1.91%	1.91%
PPDR UE case (5 UEs)	GB=10 MHz	GB=13 MHz	GB=16MHz
e.i.r.p. = 37 dBm (vehicle)	81.38%	67.68%	49.98%
e.i.r.p. = 31 dBm (vehicle)	64.45%	46.24%	28.42%
e.i.r.p. = 23 dBm (vehicle)	35.26%	19.36%	8.55%
Notes: 1- It is assumed that an intervention occurs in close vicinity of the DTT receiver. 2- The case of 5 PPDR UEs is compared to the case of 1 LTE UE. 3- PPDR ACLR is set to 33 dB/8MHz, while LTE UE ACLR is set to 65dB/8MHz. 4- IP in this case assumed no power control for both systems.			

Table 120: Left Adjacent Pixel

Case	ΔIP (%)	ΔIP (%)	ΔIP (%)
Reference commercial LTE 700 UE	0.11%	0.11%	0.11%
PPDR UE case (5 UEs)	GB=10 MHz	GB=13 MHz	GB=16MHz
e.i.r.p. = 37 dBm (vehicle)	37.36%	24.02%	13.92%
e.i.r.p. = 31 dBm (vehicle)	21.73%	12.31%	6.11%
e.i.r.p. = 23 dBm (vehicle)	8.23%	3.71%	1.41%
Notes: 1- It is assumed that an intervention occurs in close vicinity of the DTT receiver. 2- The case of 5 PPDR UEs is compared to the case of 1 LTE UE. 3- PPDR ACLR is set to 33 dB/8MHz, while LTE UE ACLR is set to 65dB/8MHz. 4- IP in this case assumed no power control for both systems.			

ANNEX 9: REAL-LIFE INTERFERENCE FROM EXISTING PMR/PAMR TO DTT

A9.1 INTRODUCTION

Some CEPT administrations see some possibilities of making limited parts of the 400 MHz sub-bands (410-430 MHz or 450-470 MHz band or both) available in the future, or long-term future, for Broadband (BB) PPDR LTE networks. Channel bandwidths from 1 to 5 MHz seem to be more appropriate [8]. If this happens, BB PPDR (LTE) may operate adjacent to the UHF broadcasting band, without any guard band, as shown in Figure 85.

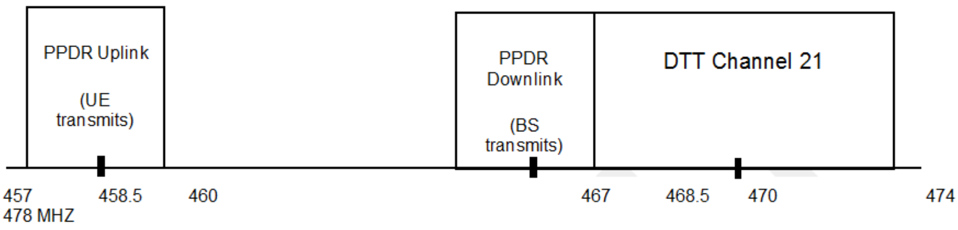

Figure 85: Possible operation of PPDR (LTE) 400 MHz adjacent to DTT channel 21 without guard band.

Under this assumption, based on a conventional mobile channelling arrangement, PPDR 400 MHz base stations (DL) will operate in an adjacent band to DTTB reception. This configuration is quite similar to the LTE 800 MHz networks where LTE base stations (DL) are operating in an adjacent band to DTTB reception with a guard band of 1 MHz between broadcasting band edge at 790 MHz and LTE downlink band edge at 791 MHz. Thus, it is legitimate to conclude that without an appropriate guard band, PPDR 400 MHz BS will cause interference to DTTB reception above 470 MHz.

In fact, LTE 800 MHz roll-out is underway in France since March 2013. Until the 2nd of October 2014, for 7579 transmitting LTE 800 MHz BS, 30377 interferences to DTTB reception were identified (5.4 interferences per BS), which represents interference to 163861 households. All the interference cases were resolved by filtering out the interfering LTE signal by an external filter connected to DTTB receiver antenna output, which implicitly reduced the DTTB receivers' sensitivity by about 2 dB.

Despite of the above fact, one administration and a member of industry, by referring to FM questionnaire (see FM49(14)003rev2), have concluded that:

"As highlighted by the recent FM questionnaire, this band is heavily used across Europe but no administration has reported interferences on DTT Channel 21 due to those systems that are presenting similar transmission features (for both mobile and base stations) than BB PPDR systems. This is highlighting that the theoretical analyses are potentially too pessimistic leading to too conservative mitigation solutions."

However, this conclusion is doubtful since it is in contradiction with the LTE 800 MHz - DTTB real-life experience reported in France. Consequently, it was felt by TDF that in situ investigations were necessary to understand why "no administration has reported interferences from the existing PMR/PAMR systems to DTTB reception on Channel 21". The investigations carried out by TDF are limited to France.

A9.2 INVENTORY OF THE EXISTING PMR/PAMR IN FRANCE

The inventory of the PMR/PAMR Tx/BS in the band 430-470, recorded in the French national data base, is presented in Table 121. The distributions of the most important PMR/PAMR are depicted in Figure 86.

Table 121: PMR/PAMR Tx/BS in the band 430-470 recorded in the French national data base

PMR/PAMR Tx/BS in the band 430-470 recorded in the France			
Type of application	State	Power ranges (W)	Number of Tx/BS
Système de COMmunication MARitime	Active	NA	2
Système de COMmunication TERrestre	Active	NA	127
FH	Active	NA	35
FH ABI (On site paging)	Active	60	680
FH LR	Active	NA	2
SAT	Active	NA	4
SAT GEO	Active	NA	2
Fixe service (Orange)	Active	NA	942
PMR	Active	1-25-40	4806
PMR (railway network signalling)	Active	1-25-40	6910
TETRA	Active	3 à 50	28
Total number of Tx/BS			13741
NA: Information not available			

Figure 86: Distributions of the Railway PMR network (signalling) in France

A9.3 IN SITU INVENTORY AND PMR/PAMR/DTTB COMPATIBILITY MEASUREMENTS IN THE 400 MHZ BAND IN FRANCE

Based on the information provided in French national data base, an in situ inventory has been and compatibility measurements have been carried out in the 400 MHz band:

- to identify the PMR emissions adjacent and non-adjacent to DTTB channel 21;
- to measure their impact on DTTB reception on channel 21 or below.

18 different PMR/PAMR Tx/BS (radio sites) were identified in DTTB service areas where the reception on channel 21 or 22 was ensured. Each of these radio sites was visited by TDF measurement teams aiming at identifying the PMR emissions adjacent and non-adjacent to DTTB channel 21 and measuring their impact on DTTB reception on channel 21 or 22. An example of the investigated PMR/PAMR radio sites are depicted in Figure 87.

Investigations showed that:

- the 400 MHz band was underused by PMR/PAMR systems. In fact, the majority of the private PMR BS recorded as active were not operating. It was supposed that private PMR systems failed to compete with commercial mobile networks like GSM, UMTS and LTE.
- the cellular mobile systems TETRAPOL were deployed below 400 MHz. The upper part of the band was only partially used by very old systems like On site paging or Railway network signalling. All these systems were narrow band systems with an effective BW of 12.5 kHz.
- in the case of the Railway network signalling system, which is one of the most important PMR networks in France, all the Tx antennas were pointing toward the railways, thus rarely toward the householders' rooftop DTT receiver antennas (see Figure 87);
- nearly all PMR/PAMR Tx/BS were using vertically polarised transmission antennas resulting in a V/H antenna discrimination of up to 23 dB;
- it was not possible to measure the ACLR of the PMR/PAMR signals in DTTB CH21 due to the very low PMR(PAMR) BW/DTT-PMR(PAMR) GB ratio (≤ 0.0125). We will call this ratio "IBW/GB" ratio;
- the narrow band PMR/PAMR signals had no notable overloading effect on active DTTB reception.

The results of the investigations are summarised in Table 122 and Table 123

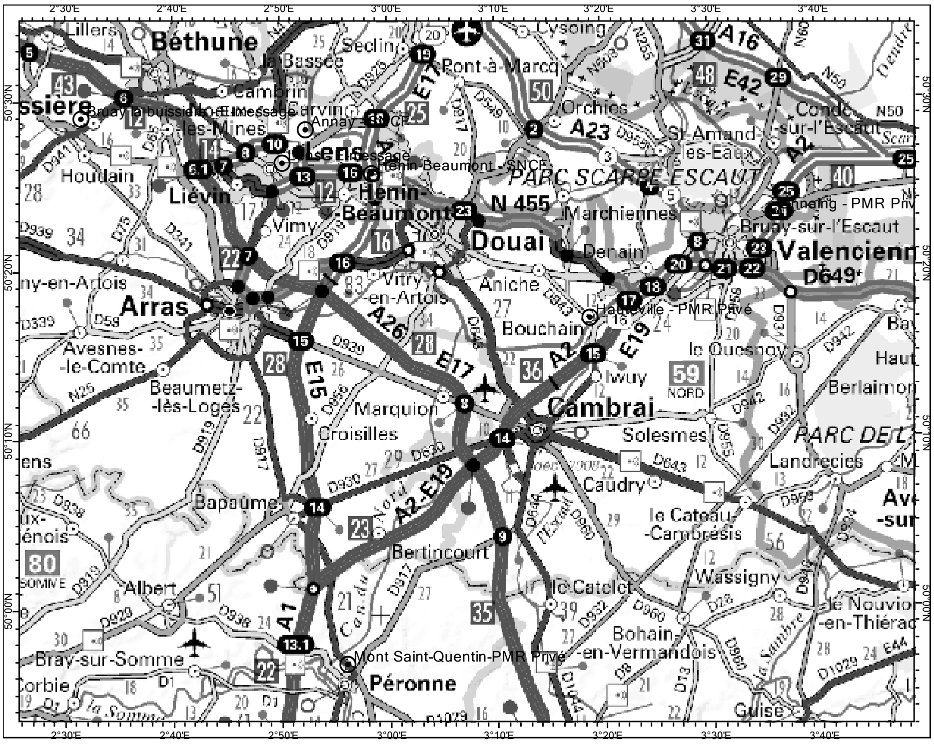

Figure 87: Some of the investigated PMR/PAMR radio sites

Table 122: In situ identification of the PMR/PAMR systems operation in the 400 MHz band in France

Site number	Station ID – ANFR database	Type of Application/state	Effective BW (kHz)	e.i.r.p. (dBm)	Antenna Height (m)	Antenna polar/directivity
City of Lille 1 (Bruay)	645 555	On-site paging /Active	12.5	NA	≈20	V/Omni
2 (Lens)	61 931	On-site paging /Active	12.5	NA	≈30	V/Direct
3 (Annay)	171 381	PMR*/Active	12.5	NA	≈15	V/Direct
4 (Henin)	171 379	PMR*/Active	12.5	NA	≈15	V/Direct
5 (Onnaing)	786 689	PMR/Not active	NA	NA	≈20	V/Omni
6 (Haute Ville)	739 224	PMR/Not active	NA	NA	≈20	V/Omni
7 (Mont Saint Quentin)	372 857	PMR/Not active	NA	NA	≈25	V/Omni
City of Nancy 8 (Secteur Gare)	1 022 144	PMR/Not active	NA	NA	≈35	V/Omni
9 (Secteur Gare)	1 022 143	PMR/Not active	NA	NA	≈35	V/Omni
10 (Villers-les-Nancy)	774 999	PMR/ active	12.5	NA	≈45	V/Omni
11 (Champigneulles)	171 030	PMR*/Not active	NA	NA	≈15	V/Omni
City of Mulhouse 12 (Cernay)	517 634	Fixe Service/Not active	NA	NA	≈16	V/Direct
13 (Bollwiller)	329 088	Fixe Service/Not active	NA	NA	≈11	V/Direct
14 (Lutterbach)	144 766	PMR/Not active	NA	NA	≈21	V/Omni
City of Nancy 15 (Clairieux)	NA	PMR**/active	12.5	NA	≈25	Cross polar/Directional
16 (Ludres)	NA	PMR**/active	12.5	NA	≈22	Cross polar/Directional
17 (Etoile)	NA	PMR**/active	12.5	NA	≈70	V/Omni
18 (Scy-Chazelles)	NA	PMR**/active	12.5	NA	≈25	V/Directional
	*Railway network signalling ** TETRA/TETRAPOL Base Station in the 390-395 MHz frequency band NA: Information not available					

Table 123: In situ on-site paging/DDTB compatibility measurements results (Note that the maximum active antenna gain used in France is about 25 dB)

Site number	Modulation	Estimated (1) Tx/BS e.i.r.p. (dBm)	DTT fc (MHz)	GB(2) (MHz)	Tx/BS ACLR(3) (dB)	Antenna discrim(4) (dB)	Dsep (5) (m)	C (dBm)	I (dBm)	Passive antenna reception(6)	Active antenna reception (Nom GAmp ≈20/22 dB) (7)	Active antenna reception (Max GAmp ≈28/30 dB)	GAmp reduction due to Tx/BS frequency (dB)
										Is there Interference?	Is there Interference?	Is there Interference?	
1	AM(8)	56	474	3.8	> 70	24	116	-22	-27	No	No	No	0
2	AM(8)	52	474	3.8	> 70	16	243	-27	-31	No	No	No	0
3	FM	48	474	2	> 70	23	160	-29	-39	No	No	Yes	0
10	AM	49	474	2.5	> 70	14	200	-27	-30	No	No	Yes	0
15	GMSK	47	482	91.4	> 70	20	329	-50	-43	No	No	No	18
16	GSMK	50	482	89.2	> 70	0	108	-31	-10	No	No	Yes	16
17	GMSK	50	482	90.3	> 70	21	322	-41	-41	No	No	No	16
18	GMSK	48	490	99.2	> 70	18	1074	-57	-52	No	No	No	16

1 Power estimated by means of a vertically polarised professional log periodic antenna

2 Guard band between DTTB Rx and interfering signal

3 Rough estimation; not measurable, OOBE level below spectrum analyser noise floor measured or estimated in DTTB CH21

4 V/H or back lobe antenna discrimination. Note that the average orthogonal polarization (V/H) discrimination of the commercial TV antennas varies from 22 to 25 dB (see [22])

5 Horizontal physical separation between Tx/BS and DTTB Rx

6 PR=-38 dB; Oth=-10 dBm, for GB= 1 MHz

7 Oth=-20 dBm for GB = 1 MHz; Oth=-12 dBm for 9 ≤GB ≤ 25 MHz; -10 for 49 ≤GB ≤ 137 MHz (GAmp=23 dB) / Oth=-26 dBm for GB = 1 MHz; Oth=-20 dBm for GB ≥ 9 MHz (GAmp=29 dB). DDTB Rx + mast amplifier Oth defined in the presence of a 10 MHz LTE 800 MHz BS interfering signal

8 Sporadic transmission

A9.4 CONCLUSION

No interference has been reported from PMR/PAMR systems operating in the 400 MHz band to DTT reception on Channel 21 or above in France. The results of the in situ investigations carried out show that this situation is explained by:

- The low density of the active PMR/PAMR transmitters in the band;
- The vertical Tx antenna polarisation used by these transmitters, which guarantees about 14-24 dB protection to DTT reception using horizontal Rx antenna polarisation;
- The narrow bandwidth of the PMR/PAMR signals (12.5 kHz) and the very low IBW/ GB ratio (≤ 0.00625), which guarantee a very high PMR/PAMR ACLR in DTTB CH21 (> 70 dB) and have a very limited overloading effect on active DTTB reception.

Consequently, the fact that no interference has been reported from PMR/PAMR systems operating in the 400 MHz band to DTT reception on Channel 21 in Europe cannot call into question the results of the theoretical analyses that show possible interferences from PPDR 400 MHz system (BW = 3 MHz) to DTT reception, which are perfectly in line with the reported real life interference from LTE networks to DTT reception in 800 MHz in France.

ANNEX 10: RADIO ASTRONOMY STATIONS IN EUROPE USING THE BAND 406.1-410 MHz

Table 124: Radio astronomy stations in Europe using the band 406.1-410 MHz

Observatory	Administration	Coordinates	Elevation (m AMSL)
Effelsberg	Germany	06° 53’00” E, 50° 31’32” N	369
e-callisto solar network		Germany, Italy, Belgium, Ireland, Finland, Czech Republic	
Westerbork	Netherlands	06° 36’15” E, 52° 55’01” N	16
Ondrejov	Czech Republic	14° 46’58” E, 49° 54’48” N	533
Lustbühel	Austria	15° 29’34” E, 47° 04’03” N	483
Humain	Belgium	05°15’19” E, 50° 11’31” N	293
Metsähovi	Finland	24°23’35” E, 60°13’04” N	61
Nançay	France	02° 11’50” E, 47° 22’24” N	150
Medicina	Italy	11° 38’49” E, 44° 31’14” N	28
Noto	Italy	14° 59’20” E, 36° 52’33” N	90
Sardinia	Italy	09° 14’42” E, 39° 29’34” N	600
Kraków	Poland	19° 49’36” E, 50° 03’18” N	314
Espiunca	Portugal	-08° 13’52” E, 40° 59’57” N	205
Bleien	Switzerland	08° 06’44” E, 47° 20’26” N	469
Cambridge	United Kingdom	00° 02’20” E, 52° 09’59” N	24
Darnhall	United Kingdom	-02° 32’03” E, 53° 09’22” N	47
Defford	United Kingdom	-02° 08’35” E, 52° 06’01” N	25
Jodrell Bank	United Kingdom	-02° 18’26” E, 53° 14’10” N	78
Pickmere	United Kingdom	-02° 26’38” E, 53° 17’18” N	35

Observatory	Administration	Coordinates	Elevation (m AMSL)
Knockin	United Kingdom	-02^{o} 59’45” E, 52^{o} 47’24” N	66

ANNEX 11: LIST OF REFERENCES

[1] ECC Decision (08)05 The harmonisation of frequency bands for the implementation of digital Public Protection and Disaster Relief (PPDR) radio applications in bands within the 380-470 MHz range

[2] ECC Decision (15)01 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)

[3] ECC Report 218 Harmonised conditions and spectrum bands for the implementation of future European broadband PPDR systems

[4] ERC Report 25 The European table of frequency allocations and applications in the frequency range 8.3 kHz to 3000 GHz

[5] Recommendation ITU-R P.1546 Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3000 MHz

[6] Resolution 205 (Rev.WRC-12) Protection of the systems operating in the mobile-satellite service in the band 406-406.1 MHz

[7] CEPT Report 30 The identification of common and minimal (least restrictive) technical conditions for 790 - 862 MHz for the digital dividend in the European Union

[8] CEPT Report 53 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

[9] 3GPP TS 36.101 for LTE400 Mobile stations

[10] 3GPP TS 36.104 for LTE400 Base stations

[11] ECC Report 099 TETRA Enhanced Data Services (TEDS): Impact on existing PMR/PAMR and Air Ground Air (AGA) systems in the 400 MHz band

[12] Recommendation ITU-R P.2040: Effects of building materials and structures on radiowave propagation above about 100 MHz

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[14] Recommendation ITU-R M.1462: Characteristics of and protection criteria for radars operating in the radiolocation service in the frequency range 420-450 MHz

[15] SEAMCAT OFDMA UL power control: http://tractool.seamcat.org/wiki/Manual/Scenario/OFDMA#OFDMAULpowercontrol

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[18] Recommendation ITU-R M.1465 Characteristics of and protection criteria for radars operating in the radiodetermination service in the frequency band 3100-3700 MHz

[19] Recommendation ITU-R RA.769-2 Protection criteria used for radio astronomical measurements

[20] Recommendation ITU-R F.1336 Reference radiation patterns of omnidirectional, sectoral and other antennas for the fixed and mobile service for use in sharing studies in the frequency range from 400 MHz to about 70 GHz

[21] ITU-R Report BT.2301-0(2014) National field reports on the introduction of IMT in the bands with co-primary allocation to the broadcasting and the mobile services.

[22] Recommendation ITU-R BT.419 Directivity and polarization discrimination of antennas in the reception of television broadcasting

[23] ETSI standard ETS 300 086 Technical characteristics and test conditions for radio equipment with an internal or external RF connector intended primarily for analogue speech

[24] ETSI standard ETS 300113 Technical characteristics and test conditions for radio equipment intended for the transmission of data (and speech) and having an antenna connector

[25] ECC Report 172 Broadband Wireless Systems Usage in 2300-2400 MHz

[26] Recommendation ITU-R BT.1206-2 Spectrum limit masks for digital terrestrial television broadcasting

[27] 3GPP Technical Report 36.942 V11.0.0, “Radio Frequency (RF) system scenarios”

[28] Report ITU-R M.2359 – Protection of the 406-406.1 MHz band http://www.itu.int/pub/R-REP-M.2359

[29] Summary of replies to the FM49 questionnaire on the European availability of the 400 MHz range for BB PPDR LTE networks