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Compatibility and technical feasibility of coexistence studies for the potential introduction of new terrestrial applications operating in the 2483.5-2500 MHz frequency band with existing services / applications in the same band and adjacent bands

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0 EXECUTIVE SUMMARY

The scope of this Report is to investigate the technical feasibility and coexistence for the potential introduction of new terrestrial applications in the 2483.5-2500 MHz frequency band, sharing with existing radio services / applications in the same band and compatibility with existing services / applications in the adjacent bands. The study considers the impact of a single interferer of the new terrestrial system on other systems.

0.1 COMPATIBILITY WITH MSS IN THE BAND 2483.5-2500 MHZ

Section 4.1 analyses the impact of terrestrial service (TS) in the MSS frequency band 2483.5-2495 MHz on Mobile Satellite System (MSS) receivers operating in the same frequency band. The impact of the proposed TS using 5 MHz and 10 MHz of bandwidth has been studied.

Study between TS using a bandwidth of 5 or 10 MHz and MSS, assuming the median EHata propagation model, gives median separation distances shown below are : Extract from Table 25: MCL Separation distance calculation for 10 MHz TS bandwidth, MSS victim UE, TS interferer and Extract from Table 24: MCL Separation distance calculation for 5 MHz TS bandwidth, MSS victim UE, TS interferer.

Table 1: Extract from Table 25: MCL Separation distance calculation for 10 MHz TS bandwidth, MSS victim UE, TS interferer

Parameter	Units	Outdoor BS	Outdoor UE	Indoor BS	Indoor UE
D EHata (Urban)	km	1.07	0.20	0.09	0.09
D EHata (Suburban)	km	2.38	0.44	0.13	0.13
D EHata (Rural)	km	8.96	1.64	0.47	0.47

Table 2: Extract from Table 26: MCL Separation distance calculation for 5 MHz TS bandwidth, MSS victim UE, TS interferer

Parameter	Units	Outdoor BS	Outdoor UE	Indoor BS	Indoor UE
D EHata (Urban)	km	1.30	0.24	0.09	0.09
D EHata (Suburban)	km	2.90	0.53	0.15	0.15
D EHata (Rural)	km	9.99	2.0	0.58	0.58

This Report considers only the characteristics of an operational MSS system, Globalstar. Other satellite systems have been filed at the ITU BR for use in this band, but these characteristics have not been considered as no other systems are currently active in the band in ITU Region 1.

0.2 COMPATIBILITY WITH POSSIBLE FUTURE RDSS IN THE BAND 2483.5-2500 MHZ

Section 4.2 analyses the impact of terrestrial service (TS) in the MSS frequency band 2483.5-2495 MHz on possible future in-band radio determination satellite navigation systems (RDSS/RNSS).

Study between TS and RDSS operating in the same band, assuming the median EHata Urban propagation model, gives median separation distances between TS systems and the future RDSS receivers as shown below in an extract from Table 32 and Table 35, for TS bandwidth of 10 and 5 MHz, respectively.

Table 3: Extract from Table 37: Separation distance calculation for 10 MHz TS bandwidth, RDSS victim 3 dB Grx, TS interferer BS

RDSS Parameter	Units	Case 1		Case 2	
		Outdoor TS Outdoor RDSS		Indoor TS Outdoor RDSS	
Interferer		TS BS	TS UE	TS BS	TS UE
D EHata (urban)	km	0.9	0.2	0.1	0.1
D EHata (suburban)	km	1.8	0.3	0.1	0.1
D EHata (rural)	km	6.8	1.1	0.3	0.3

Table 4: Extract from Table 38: Separation distance calculation for 5 MHz TS bandwidth, RDSS victim 3 dB Grx, TS interferer BS

RDSSParameter	Units	Case 1		Case 2	
		Outdoor TS Outdoor RDSS		Indoor TS Outdoor RDSS	
Interferer		TS BS	TS UE	TS BS	TS UE
D EHata (urban)	km	1.1	0.2	0.1	0.1
D EHata (suburban)	km	2.2	0.3	0.1	0.1
D EHata (rural)	km	8.3	1.3	0.4	0.4

0.3 COMPATIBILITY WITH MBANS IN THE BAND 2483.5-2500 MHZ

Section 4.3 analyses the impact of terrestrial service (TS) in the MSS frequency band 2483.5-2495 MHz on Medical Body Area Network Systems (MBANS) receivers operating in the same frequency band. It also analyses the impact of MBANS equipment on TS receivers (UE and BS). The impact of the proposed TS using 10 MHz of bandwidth has been studied.

Study between TS systems and MBANS operating in the same band; assuming the median EHata Urban propagation model, gives median physical separation between TS systems and MBANS receivers as shown in Table 5 (for the case where the interferer is the TS BS) and Table 6 (for the case where the interferer is the TS UE). This separation is readily provided by deploying TS systems away from health care facilities, or homes using MBANS equipment. The deployment of the proposed TS in the same building as MBANS equipment has not been studied. TS system using bandwidths of 5 MHz and 15 MHz would need higher and lower separation distances, respectively.

Table 5: Extract from Table 47: MCL Separation distance calculation, MBANS victim, TS interferer BS Outdoor or Indoor

Parameter	Units	Cat. 1 Outdoor TS	Cat. 2 Outdoor TS	Cat. 3 Outdoor TS	Cat. 1 Indoor TS	Cat. 2 Indoor TS	Cat. 3 Indoor TS
D EHata (urban)	km	0.11	0.11	0.14	0.05	0.05	0.05

Table 6: Extract from Table 48: MCL Separation distance calculation, MBANS victim, TS interferer UE Outdoor or Indoor

Parameter	Units	Cat. 1 Outdoor TS	Cat. 2 Outdoor TS	Cat. 3 Outdoor TS	Cat. 1 Indoor TS	Cat. 2 Indoor TS	Cat. 3 Indoor TS
D EHata (urban)	km	0.08	0.08	0.09	0.05	0.05	0.05

0.4 COMPATIBILITY WITH LP-AMI IN THE BAND 2483.5-2500 MHZ

Section 4.4 analyses the impact of terrestrial service (TS) in the MSS frequency band 2483.5–2495 MHz on Low Power Active Medical Implant (LP-AMI) receivers operating in the same frequency band. It also analyses the impact of LP-AMI equipment on TS receivers (UE and BS). The impact of the proposed TS using 10 MHz of bandwidth has been studied.

Study between TS and LP-AMI operating in the same band, assuming the median EHata Urban propagation model gives median physical separation between TS systems and the LP-AMI receivers as shown in Table 7 (for the case where the interferer is the TS BS) and Table 6 (for the case where the interferer is the TS UE). This separation is readily provided by deploying TS systems a away from health care facilities using LP-AMI equipment. The deployment of the proposed TS in the same building as LP-AMI equipment has not been studied. TS system using bandwidths of 5 MHz and 15 MHz would need higher and lower separation distances, respectively.

Table 7: Extract from Table 58: MCL Separation distance calculation, LP-AMI victim, TS interferer BS: MCL Separation distance calculation, LP-AMI victim, TS interferer BS

Parameter	Units	Case 1 Outdoor TS	Case 2 Outdoor TS	Case 1 Indoor TS	Case 2 Indoor TS
D EHata urban	km	0.11	0.06	0.06	0.04

Table 8: Extract from Table 51: Extract from Table 48: MCL Separation distance calculation, MBANS victim, TS interferer UE

Parameter	Units	Case 1 Outdoor TS	Case 2 Outdoor TS	Case 1 Indoor TS	Case 2 Indoor TS
D EHata urban	km	0.08	0.04	0.05	0.01

0.5 COMPATIBILITY WITH PMSE IN THE BAND 2483.5-2500 MHZ

Study between TS and PMSE systems operating in the same band, assuming the median EHata propagation model gives median physical separation between TS systems and the PMSE systems summarized in the following table. The impact of the proposed TS using 10 MHz of bandwidth has been studied. TS system using bandwidths of 5 MHz and 15 MHz would need higher and lower separation distances, respective.

Table 9: MCL separations distances when PMSE and the new terrestrial applications are operated co-frequency (in km)

Victim	Interferer	Separation distances using EHata urban (cases 1 to 4) (km)	Separation distances using free space loss/radio horizon (cases 1 to 4) (km)	Separation distances using EHata urban (cases 5 to 6) (km)	Separation distances using free space loss/radio horizon (cases 5 to 6) (km)
PMSE	Outdoor BS	24.4-28	45	32.7-38	45-332
PMSE	Indoor BS/ Indoor UE	0.5-0.7	16.7-26.9	1.2-5.8	9.3-57.6
PMSE	Outdoor UE	1.9-2.5	37	4.1-22.5	37-324
Outdoor BS	PMSE	0.5-7.7	18.9- 54.3	1.9- 33.6	21.3-332.5
Indoor BS/ Indoor UE	PMSE	0.08-0.31	4.4-70.7	0.19-21.33	27.3-50.4
Outdoor UE	PMSE	0.1-0.6	16.7-45	0.3-24.8	45-103.5

The table above provides the calculated separations distances when PMSE and the new terrestrial applications are operated co-frequency. Considering calculated distances, mitigation techniques may be needed to ensure the coexistence of PMSE and the new terrestrial applications when operated co-frequency.

The analysis considered antenna heights and antenna gains with maximum values resulting in upper limit of the calculated separation distances.

0.6 COMPATIBILITY WITH E-UTRA BAND 7 ABOVE 2500 MHZ

Section 4.6 analyses the impact of terrestrial service (TS) in the frequency band 2483.5-2500 MHz on E-UTRA Band 7 base station (BS) receivers operating in the neighbouring frequencies above 2500 MHz. It also analyses the impact of E-UTRA Band 7 user equipment (UE) on TS receivers (UE and BS).

The study between TS base station and E-UTRA Band 7 base station receiver gives minimum physical separation between the two systems. The median separation distance derived in this study for 5 MHz and 10 MHz TS channels is 970 m for TS outdoor deployment and 51 m for TS indoor deployment. However, the median separation distance for the 15 MHz TS channel is 1100 m for outdoor and 53 m indoor deployment. These separation distances are derived from the median EHata Urban propagation model.

The table shows separation distances for TS BS interferers interfering with E-UTRA BS victim receivers, and E-UTRA UE interferers interfering with TS BS victim receivers. The interference is caused by a combined effect of unwanted emissions from the TS base station and blocking from the E-UTRA base station

However, the separation distances have also been derived for the 95^{th} percentile EHata urban model which will satisfy the interference criterion for at least 95% of the situations. These separation distances are more than 2 km in all the outdoor cases and are given in Table 78, Table 79 and Table 80.

Table 10: Extract from Table 78: Outdoor TS Terrestrial Deployment Separation Distances

Outdoor TS Band-width	interferer TX Parameters	TS BS Interferer Value (m)	E-UTRA UE Interferer Value (m)
5 MHz	Separation distance, EHata urban median 50th percentile (m) Separation distance, EHata urban 95th percentile (m) Separation distance, FSPL (m)	970 2500 3977	96 139 2366
10 MHz	Separation distance, EHata urban median 50th percentile (m) Separation distance, EHata urban 95th percentile (m) Separation distance, FSPL (m)	970 2500 3977	96 139 2366
15 MHz	Separation distance, EHata urban median 50th percentile (m) Separation distance, EHata urban 95th percentile (m) Separation distance, FSPL (m)	1100 2900 4900	96 139 2366

Table 11: Extract from Table 79: Indoor TS Terrestrial Deployment Separation Distances for Combined

Indoor TS Band-width	interferer TX Parameters	TS BS Interferer Value (m)	E-UTRA UE Interferer Value (m)
5 MHz	Separation distance, EHata urban median 50th percentile (m) Separation distance, EHata urban 95th percentile (m) Separation distance, FSPL (m)	51 88 110	56 75 421
10 MHz	Separation distance, EHata urban median 50th percentile (m) Separation distance, EHata urban 95th percentile (m) Separation distance, FSPL (m)	51 88 110	56 75 421
15 MHz	Separation distance, EHata urban median 50th percentile (m) Separation distance, EHata urban 95th percentile (m) Separation distance, FSPL (m)	53 93 135	56 75 421

Table 12: Extract from Table 80 Spurious Emission Separation Distances

Interferer	Victim	Path Loss Model	Separation Distance (m)
TS BS Outdoor	Band 7 BS	EHata urban FSPL	362 1057
TS BS Indoor	Band 7 BS	EHata urban FSPL	87 94
Band 7 UE	TS BS Outdoor 5 MHz	EHata urban FSPL	55 211
Band 7 UE	TS BS Outdoor 10 MHz	EHata urban FSPL	65 472

Interferer	Victim	Path Loss Model	Separation Distance (m)
Band 7 UE	TS BS Outdoor 15 MHz	EHata urban FSPL	68 594
Band 7 UE	TS BS Indoor 5 MHz	EHata urban FSPL	19 19
Band 7 UE	TS BS Indoor 10 MHz	EHata urban FSPL	40 42
Band 7 UE	TS Bs Indoor 15 MHz	EHata urban FSPL	42 53

In urban areas, separation distances calculated using FSPL is an absolute worst-case interference scenario. Separation distances will be less in urban or suburban areas where appropriate propagation using models for those areas are more accurate.

It should be noted that this section has only considered the interference into a non-AAS base station deployed in a macro-urban cell scenario. The co-existence between TS outdoor BS and MFCN(E-UTRA, 5G-NR) Band 7 outdoor small cells, macrocells with AAS antenna, as well as the co-existence between TS indoor BS and MFCN indoor small cells have not been considered.

0.7 COMPATIBILITY WITH ISM/WLAN BELOW 2483.5 MHZ

Interfering RLAN and TS exhibit similar indoor interference characteristics for RLAN receivers as described in 4.7.7.

For outdoor to indoor interference scenarios, greater distances and building entry loss reduce the power levels of the outdoor TS such that the indoor signal levels are similar to the RLAN and indoor TS case.

Since the TS is TDD, there are periodic intervals during which the TS is not transmitting. This may allow another ISM device time to operate even if there is insufficient separation.

As noted in 4.7.7, bluetooth selectivity, narrow bandwidth, and TS unwanted emissions allow it to be much more tolerant of TS than RLAN.

In low noise environments, and where there is low propagation loss, careful consideration during deployment is needed since separation between TS and Radio LAN (RLAN) may be required.

Table 13: Extract from Table 95: MCL and Separation Distance Calculations

TS Location	TS Antenna	Victim	Environment	Separation Distance using EHata urban (m)	Separation Distance using FSPL(m)
Outdoor	Bore sight (+6 dBi)	RLAN	Thermal noise	59	304
			Interference limited	11	11
		Bluetooth	Thermal noise	0.76	0.76
			Interference limited	2.49	2.49
	Side lobe (0 dBi)	RLAN	Thermal noise	52	152
			Interference limited	6	6
		Bluetooth	Thermal noise	0.38	0.38
			Interference limited	2.40	2.40
Indoor	0 dBi	RLAN	Thermal noise	58	571

TS Location	TS Antenna	Victim	Environment	Separation Distance using EHata urban (m)	Separation Distance using FSPL(m)
			Interference limited	10	10
		Bluetooth	Thermal noise	0.68	0.68
			Interference limited	2.46	2.46

0.8 COMPATIBILITY BETWEEN TS AND RLAN/BLE BASED ON MEASUREMENTS

Section 4.8 presents MCL calculations based on laboratory measurement (ANNEX 4). The study shows the calculations of the minimum protection distances between LTE-Systems (BS, UE), as interferer, and BLE/RLAN-Systems, as victims, in Outdoor and Indoor scenarios.

The parameter sensitivities and carrier-to-interference ratios (C/I)dB = (CdB-IdB) for BLE/RLAN are based on the measurement campaign from BNetzA (see the ANNEX 4). The required protection distances are derived considering a realistic and worst case signals from LTE-systems (BS/UE).

For BLE/RLAN, the distances are calculated with different types of interference degrees (grades 1 to 3) and TS power levels. The propagation model is free-space without considering antenna diagram and heights.

- Outdoor case:
  - The results give protection distances for the outdoor case with free space propagation model where the TS (BS/UE) interferes with BLE/RLAN systems that range from 0 m to 48 m. The degree of interference 1 (Interference just begins to be measurable/noticeable), with a worst case signal shape, evokes the largest distances.
- Indoor case
  - In the indoor case, the protection distances are lower because building entry loss (BEL) has been included. If the TS are placed inside the buildings the power levels are much smaller than for outdoor operation. The protection distances vary from 0 m to 12 m. The highest distance is again caused by interference grade 1 with a worst case signal shape.

0.9 COMPATIBILITY WITH RAS OPERATING IN 5 GHZ BAND (2ND HARMONIC OF TS BAND)

The second harmonic band of the TS operating in the 2483.5-2500 MHz band partly falls into the 4950-4990 MHz and 4990–5000 MHz RAS band, in which both, continuum and spectral line observations, are frequently carried out. The single-entry TS worst-case (including UE and without body and clutter losses) compatibility study with respect to the RAS demonstrated that coordination zones of few dozen kilometres up to more than 100 km in certain cases, depending on the local terrain, are necessary. There are several mitigation measures, which would allow devices to be compatible with the RAS even when closer to the RAS sites, such as the consideration of local clutter losses. Furthermore, different UE available from vendors could have different 2nd harmonic emission levels and some devices may have significantly lower output power emission into the RAS band at 5 GHz compared to the spurious emission limit of -30 dBm/MHz. An example for this is shown by the measurement of the 2nd harmonics emission of one particular UE, where the interference emission is 27 dB lower than the limit of -30 dBm defined in ERC Recommendation 74-01 [49] and 3GPP TS 36.104 [10].

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
3GPP	3rd Generation Partnership Project
ACLR	Adjacent Channel Leakage Ratio
ACR	Adjacent Channel Rejection
ACS	Adjacent Channel Selectivity
ALD	Assistive Listening Device
BACL	Beyond Adjacent Channel Leakage
BACLR	Beyond Adjacent Channel Leakage Ratio
BEL	Building Entry Loss
BLE	Bluetooth Low Energy
BS	Base station
C/I	Carrier to interference ratio
Cat	Category
CDMA	Code Division Multiple Access
CEPT	European Conference of Postal and Telecommunications Administrations
D EHata	Separation distance calculated with Extended Hata
DL	Downlink
DUT	Device under test
ECC	Electronic Communications Committee
EHata	Extended Hata
EN	European Norm
E-UTRA	Evolved UMTS Terrestrial Radio Access
FCC	Federal Communications Commission
FFT	Fast Fourier Transform. Method to calculate a spectrum from time records.
FSPL	Free Space Path Loss
iRSS	Interference Received Signal Strength
LP-AMI	Low Power Active Medical Implant
LP-AMI-I	Low Power Active Medical Implant-Implanted
LP-AMI-P	Low Power Active Medical Implant-Peripheral
LTE	Long Term Evolution
MBAN	Medical Body Area Network
MFCN	Mobile Fixed Communication Network

Abbreviation	Explanation
MSS	Mobile Satellite Service
NLOS	Non Line Of Sight
OoB	Out-of-band
OOBE	Out-of-band Emission
pLTE	private Long Term Evolution
PMSE	Programme Making and Special Events
PSD	Power Spectral Density
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RBw	Resolution bandwidth. This is the bandwidth in which a level is measured with a spectrum analyser
RDSS	Radio Determination Satellite Service
RLAN	Radio Local Area Network
RMS	Root Mean Square. If used as a detector, it specifies the average power level in a certain measurement time.
RNSS	Radio Navigation Satellite Service
RX	Receiver
SAB	Services Ancillary to Broadcasting
SAP	Services Ancillary to Programme-making
SNR	Signal to Noise Ratio
TDD	Time Division Duplex
TR	Technical Report
TS	Terrestrial service
TX	Transmitter
UE	User Equipment
UL	Uplink
UMTS	Universal Mobile Telecommunication System
US	United States
USB	Universal Serial Bus

1 INTRODUCTION

The scope of this Report is to investigate the technical feasibility and coexistence for the potential introduction of new terrestrial applications in the 2483.5-2500 MHz frequency band, sharing with existing radio services / applications in the same band and compatibility with existing services / applications adjacent bands.

Existing use to be considered in the studies are in-band Mobile Satellite Services (MSS), in-band MBANS devices, in-band LP-AMI devices, future in-band RDSS, in-band PMSE, radio applications below 2483.5 MHz including licensed and licensed exempt use; radio applications above 2500 MHz (MFCN). Also, the impact of spurious emissions should be considered. Studies should take into account relevant ECC Reports including 149 [1], 150 [2], 165 [3], 201 [4], 219 [5] and CEPT Report 72 [6].

2 FREQUENCY USE AND RELEVANT EC OR ECC DECISIONS AND ECC RECOMMENDATIONS

RR Region 1 Allocation and RR footnotes applicable to CEPT	*European Common Allocation and ECA Footnotes*	*ECC/ERC harmonisation measure*	*Applications*	*Standard*	*Notes*
2483.5 MHz - 2500 MHz					
FIXED MOBILE MOBILE-SATELLITE (SPACE-TO-EARTH) 5.351A RADIODETERMINATION-SATELLITE (SPACE-TO-EARTH) 5.398 Radiolocation 5.398A 5.150 5.399 5.401 5.402	FIXED MOBILE MOBILE-SATELLITE (SPACE-TO-EARTH) 5.351A 5.150 5.399 5.402	ERC/REC 70-03	Active medical implants	EN 301 559	Low Power Active Medical Implants and associated peripherals
			IMT-2000 satellite component		
			ISM		
			Land mobile		Mobile applications
		ERC/REC 70-03	MBANS	EN 303 203	
		ECC/DEC/(09)02	MSS Earth stations	EN 301 441 EN 301 473	
		ERC/REC 25-10	PMSE	EN 302 064	Portable or mobile wireless video and cordless cameras

Figure 1: Frequency band Status in CEPT (ECA Table (ERC Report 25)) [7]

3 PROPOSED NEW TERRESTRIAL SERVICE (TS)

3.1 FREQUENCIES

The proposed new terrestrial service (TS) is based on TDD configuration (3GPP TR 36.791 V16.0.0 (2018-12)) but extended to the band 2483.5-2500 MHz, where BS receive / UE transmit and BS transmit / UE receive on the same frequencies.

It should be noted that 3GPP TR 36.791 is the Federal Communications Commission (FCC) specifications for a terrestrial service in their 2483.5-2495 LTE Band with bandwidths up to 10 MHz for operation in the USA.

3.2 SYSTEM PARAMETERS

The technical characteristics of the 2.4 GHz terrestrial service (TS) are given here below.

Table 14: TS System Parameters-BS Transmit

BS Transmit				
Parameter	**Value**			**Unit**
Frequency Band	2483.5-2500			MHz
Channel Bandwidths	5	10	15	MHz
Power conducted, indoor / outdoor	+20 / +30	+20 / +30	+20 / +30	dBm
Power e.i.r.p., indoor / outdoor	+20 / +36	+20 / +36	+20 / +36	dBm
Out of Band Emission adjacent channel [10], indoor / outdoor (note 1)	-25 / -15	-25 / -15	-25 / -15	dBm
Out of Band Emission, beyond adjacent channel [10], indoor / outdoor	-37	-37	-37	dBm/100 kHz
Spurious emissions [10], (note 2)	-30			dBm/MHz

Note 1: ACLR 45 dB
Note 2: Spurious emissions of -30 dBm/MHz is for Category B specification; The choice of Category A or Category B is defined earlier in TS 36.104, table 4.3-1 [10]. Specifically, the corresponding category is mandatory for the region defined in ITU-R SM.329. In SM.329, clause 3.3: "Category B limits are an example of more stringent spurious domain emission limits than Category A limits. They are based on limits defined and adopted in Europe and used by some other countries."

Table 15: TS System Parameters-BS Receive

BS Receive	
Parameter	**Value**
Frequency Band	2483.5-2500 MHz
Channel Bandwidths	5, 10, 15 MHz
Noise Figure (see Table 75)	5 dB
I/N	-6 dB[12] (note 1)
Note 1: It can be also noted that I/N for TS systems was used for the co-channel cases and when relevant (i.e. LP-AMI, MBANS, PMSE), and the same I/N was used for either base or UE receivers (I/N=-6 dB)	

Table 16: TS System Parameters-UE Transmit

UE Transmit	
Parameter	**Value**
Frequency Band	2483.5-2500 MHz
Channel Bandwidths	5, 10, 15 MHz
Power, conducted, indoor / outdoor	+20 dBm / +24 dBm
Power e.i.r.p., indoor / outdoor	+20 dBm / +24 dBm
Out of Band Emission, adjacent channel, indoor / outdoor	-25 dBm / -21 dBm
Out of Band Emission beyond adjacent channel, indoor / outdoor (note 1)	-40 dBm / -36 dBm
Spurious emissions	-30 dBm/MHz
Note 1: The term “beyond adjacent channel” is an unwanted emission at frequency displacement exceeding the adjacent channel bandwidth. The unwanted emission power is measured in the channel bandwidth of the victim receiver.	

Table 17: TS System Parameters-UE Receive

UE Receive	
Parameter	**Value**
Frequency Band	2483.5-2500 MHz
Channel Bandwidths	5, 10, 15 MHz
ACS [12], 5 MHz / 10 MHz / 15 MHz (note 2)	-65 dBm / -62 dBm / -63 dBm (note 1)
Noise Figure (see Table 75)	9 dB
I/N	-6 dB (note 2)
Note 1: ACS is almost always expressed as a ratio in dB. The new terrestrial service (TS) intends to follow 3GPP specs, and the adjacent channel interference is specified in several ways in 3GPP TS 36.101 and TS 36.104 [10]. Most frequently 3GPP sets limits on adjacent channel blocking and unwanted emissions as an absolute power level in dBm. This is why the tabulated spec is given as an absolute power level, even though it is labelled as ACS Note 2: In [12] section 7.1, page 7-1; it can be also noted that I/N for TS systems was used for the co-channel cases and when relevant (i.e. LP-AMI, MBANS, PMSE), and the same I/N was used for either base or UE receivers (I/N=-6 dB)	

3.3 USE SCENARIO EXAMPLES

The use cases studied are Private LTE Networks (pLTE), which are dedicated, secure LTE networks created for a specific customer, usually a government or enterprise customer, that operates separate and apart from existing macro-cellular networks.

With the Industrial Internet of Things (Industrial IoT) and need for connectivity, there is a demand for pLTE services and networks. One of the main impediments to meeting this demand is the availability of dedicated licensed spectrum to support such services.

The 2483.5-2500 MHz frequency band is suited to meet future wireless connectivity demands in such situations where government and enterprise customers require dedicated spectrum to support their communications needs.

Equipment vendors have been supporters of such pLTE solutions and have developed user equipment that operate on Band 53 in the US.

Government or enterprise customers that has communications needs requiring dedicated, rather than public, spectrum for enhanced throughput and security.

- Utilities (Water, Gas, Electric), smart grid network;
- In mining and minerals, automated remote facilities;
- Oil and gas;
- Ports;
- Smart buildings, security cameras, sensors and alarms wirelessly.

The proposed terrestrial service (TS) with a transmit power e.i.r.p. of up to 4 W for outdoor operation can allow for micro-cells deployment with typical cell radius from 200 m to 1500 m and pico-cells deployment with typical cell radius up to 200 m.

The new terrestrial service (TS) is not envisioned for aeronautical usage, this use case has not been studied.

4 COMPATIBILITY STUDIES FOR THE NEW TERRESTRIAL SERVICE (TS)

According to the allocation of Radio Services in and adjacent to the 2483.5-2500 MHz band various scenarios can be considered.

Existing use to be considered in the studies are in-band Mobile Satellite Services (MSS), in-band MBANS devices, in-band LP-AMI devices, future in-band RDSS, in-band PMSE, radio applications below 2483.5 MHz including licensed and licensed exempt use; radio applications above 2500 MHz (MFCN). Also, the impact of spurious emissions should be considered. Studies should take into account relevant ECC Reports including 149[1], 150 [2], 165 [3], 201 [4], 219 [5] and CEPT Report 72 [6].

4.1 COMPATIBILITY WITH MSS IN THE BAND 2483.5-2500 MHZ

This section analyses the impact of an LTE-based 2.4 GHz terrestrial service (TS) (based on technical details in 3GPP TR 36.791) in the MSS frequency band 2483.5-2500 MHz on incumbent services in the same frequency band. The analysis determines the impact of LTE-based 2.4 GHz terrestrial transmitters on victim co-channel receivers. One service that can share the band is the Mobile Satellite Service (MSS).

The technical characteristics of the 2.4 GHz low power terrestrial service (TS) are given in section 3. The terrestrial service is time division duplex (TDD) with the transmit activity divided between the BS and UE. However, 100% transmit time has been used for the BS and the UE in the calculation. The TS system with 10 MHz bandwidth is analysed here. This exceeds the 1.23 MHz bandwidth for MSS subcarriers, so the interference is calculated based on the power spectral density (PSD) of the TS.

Considering the potential for interference from the MSS downlink into the TS, PFD limits appear in the Radio Regulation, appendix 5, table 5-2 for the band 2483.5-2500 MHz. For low elevation angles, the PFD limit is about 10 dB below the thermal noise floor of the MS receiver. In fact, every practical terrestrial system uses a receiver technology at or near room temperature, approximately 300 degrees Kelvin. They also have noise figures that are greater than 0 dB. The NF used for TS BS is +5 dB. The practical terrestrial system will therefore only receive satellite interference that is more than 10 dB below the value of the noise power spectral density (N0), or I/N ratios lower than -10 dB. In particular, considering Globalstar satellite transmitter system parameters, coexistence between satellite transmitter and TS receiver has not been seen required.

The report considers only the characteristics of an operational MSS system, Globalstar. Other satellite systems have been filed at the ITU BR for use in this band, but their characteristics have not been considered as they are not active within the band at the time of these studies.

4.1.1 MSS system parameters

The technical characteristics of the MSS system are described in Recommendation ITU-R M.1184 [13]. The MSS is a non-GSO system with characteristics in Recommendation ITU-R M.1184. table 4a and table 4b, column D. The MSS system has several components that include ground stations, satellites, and user terminals. The satellite-to-ground link from the satellites to user terminals is the link in the 2483.5 MHz to 2500 MHz band, and will be considered in this paper. The technical characteristics of the MSS interference cases are listed in Table 18.

The protection criteria for interference from IMT to MSS are not defined in ITU-R Recommendations. Recommendation ITU-R S.1432-1 [14] provides the maximum allowable aggregate interference levels into fixed-satellite service (FSS) below 30 GHz. The value of I/N from Recommendation ITU-R S.1432-1 for FSS of -12 dB is used as the I/N for MSS for purposes of this report. Other ECC Reports (i.e. ECC Report 263 [9]) for MSS compatibility with terrestrial services have used different values of I/N for MSS such as -6 dB and -10 dB.

Table 18: Technical characteristics of MSS cases

Case	Description	Range (km)	Transmit Power	Frequencies (GHz)	Interf. Condition	I/N
MSS	Satellite to ground link	1414-4500	0 to 16 dBW e.i.r.p. per CDMA channel	2.4835-2.5	Co-channel	-12 dB (note 1)
Note 1: Recommendation ITU-R S.1432 [14]: extrapolating the line (in Figure 1 of S.1432) to 100% of any month yields an I/N of -12 dB. This I/N corresponds to 6% of a satellite system noise. It can also be noted the interference for a terrestrial service which shares frequencies on a primary basis is equivalent to a single interference entry from another satellite system, according to Recommendations ITU-R S.735 [44] and Recommendation ITU-R S.1323 [45].						

By not adding an extra margin for the apportionment of multiple sources of interferences, the report makes the implicit assumption that the interfering terrestrial service, (TS) will be the main or the sole source of interference into the victim MSS.

MSS equipment can occupy 1.23 MHz CDMA channels in the band 2483.5-2500 MHz depending on the channel assignment as illustrated by Figure 2. The victim receiver is in the user terminal on the ground. The calculation will use an I/N protection criterion of -12 dB for the MSS victim as shown in the last column in Table 18. Interference in the opposite direction is not studied here because the MSS user terminals transmit in a different frequency band at 1.6 GHz.

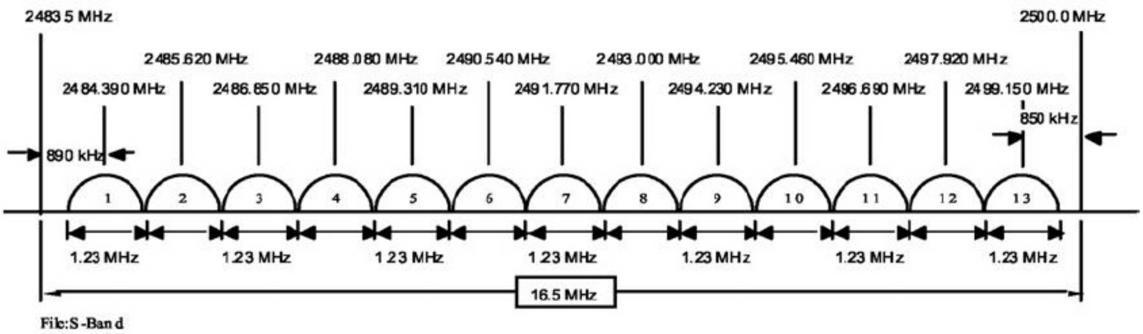

Figure 2: CDMA channels within the downlink satellite-to-user device band

The receiver noise figure for the MSS user terminal is given as 1.8 dB [18] The noise power spectral density, N0, is then determined as follows:

$$N0 = k_B \, T \, F \qquad (1)$$

With:

- N0: noise power (W);
- k_B: Boltzmann's constant 1.3806 x 10-23 (W/Hz/K);
- T: temperature (K);
- F: receiver noise factor;

$$N0 = -112.06 \text{ dBm/MHz; for } T=298°K;\ B= 1\text{MHz; and } F=1.5\ (1.8 \text{ dB}) \qquad (2)$$

4.1.1.1 MSS system parameters

Tables below show selected system parameters from Recommendation ITU-R M.1184 [13], table 4a and table 4b, column D.

Table 19: MSS System Parameters-Transmit (Satellite)

Transmit	
Parameter	**Value**
Frequency	2483.5-2500 MHz
Channel Bandwidth	1.23 MHz (note 1)
Power	+30 to +46 dBm (note 2)
Note 1: The Nyquist criterion for bandwidth requires the receiver bandwidth to be greater than or equal to this chip rate, so the minimum bandwidth would be 1.2288 MHz. This is routinely rounded off to 1.23 MHz or just 1.2 MHz if a consistent value commensurate with other systems is necessary, as in the table 4b in Recommendation ITU-R M.1184. Note 2: The power will vary depending on the traffic load, battery charge status, and satellite antenna beam. The power incident on the ground will also depend on the satellite orbit position relative to receivers on the ground. Since the orbit period is slightly under 2 hours, the power on the ground will also vary dynamically with time. The actual satellite S-band transmit power flux density on the ground is not used in the compatibility calculations, I/N is used instead.	

Table 20: MSS System Parameters-Receive (User Terminal)

Receive	
Parameter	**Value**
Frequency	2483.5-2500 MHz
Channel Bandwidth	1.23 MHz
Reference Sensitivity	-107.7 dBm (note 1)
Noise Figure	1.8 dB (note 2)
I/N protection criterion	-12 dB (note 3)
Note 1: The reference sensitivity is used indirectly in the MCL calculation i.e. the reference sensitivity allows an estimate of the receiver noise figure. Note 2: The noise figure then permits the calculation of N0 in the receiver. Note 3: Recommendation ITU-R S.1432 [14]; This I/N corresponds to 6% of a satellite system noise; thus the interference for a terrestrial service which shares frequencies on a primary basis is equivalent to a single interference entry from another satellite system, according to Recommendation ITU-R S.735 [44] and Recommendation ITU-R S.1323 [45].	

4.1.1.2 MSS antenna parameters

Antenna parameters listed in this section can be found in ITU-R WP5A/1065 (Annex 11)-E (page 214) [19].

Table 21: MSS Antenna Parameters-Transmit (Satellite)

Transmit	
Parameter	**Value**
Type	Sectored
Gain	Various according to the sector

Table 22: MSS Antenna Parameters-Receive (User Terminal)

Receive	
Parameter	**Value**
Type	Omnidirectional
Gain	-0.8 dBi

4.1.2 Scenarios

An example MSS system is shown in Figure 3. The radio link that overlaps the 2483.5 MHz to 2500 MHz is the satellite-to-ground link to the User Terminal. All the other radio links occupy other bands and are not relevant to this study. The victim receiver is in the User Terminal.

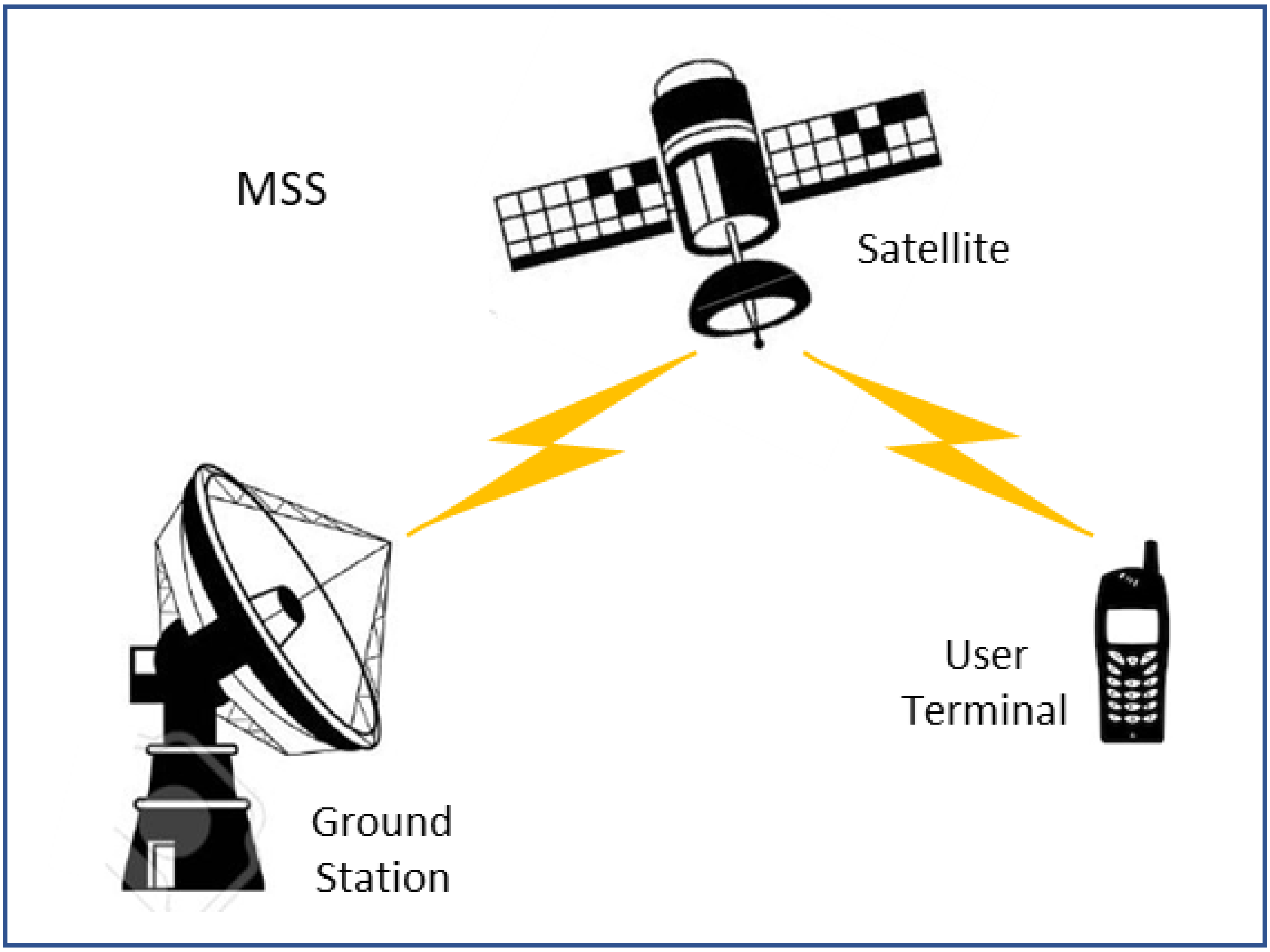

Figure 3: MSS example system components

Interference case to be considered is depicted by the Figure 4

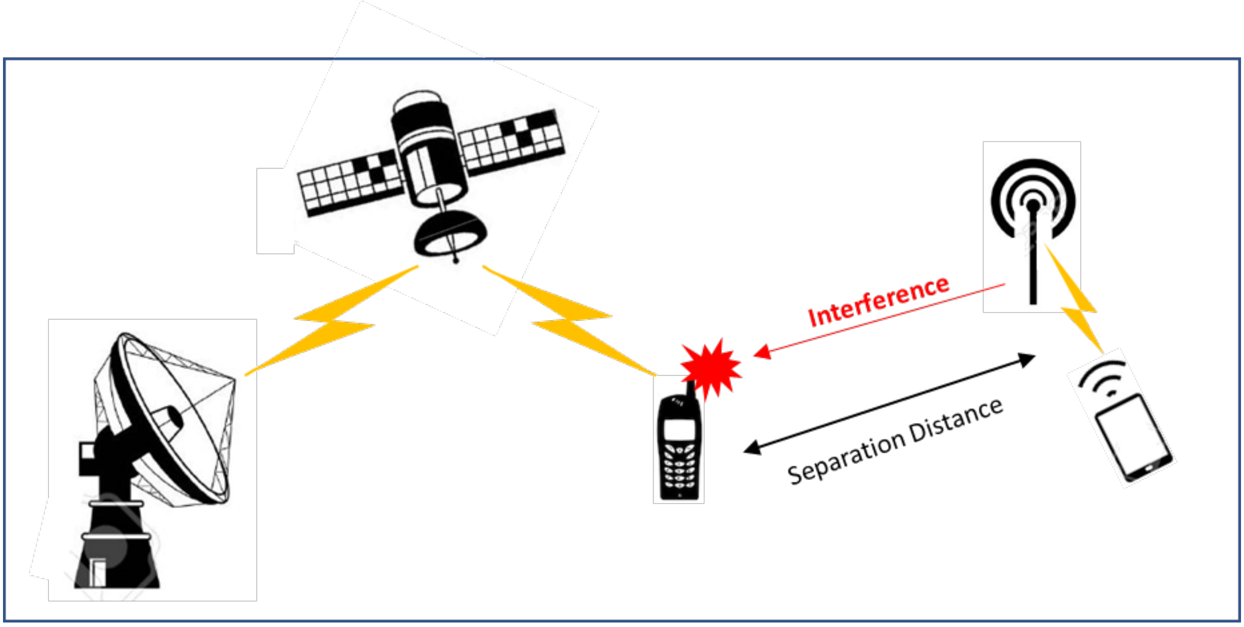

Figure 4: Interference case considered

4.1.3 Study

4.1.3.1 MCL calculations

Minimum coupling loss (MCL) is used for the interference analysis. The MCL calculations are summarised in Table 25. The separation distance is calculated using the EHata path loss model for Urban, Suburban and Rural environments [20]. The path loss depends on the antenna heights of the TS and MSS user terminal.

The transmitted interference power spectral density (PSDtx) is computed in Table 23. The last line gives the total transmitted PSDtx from each TS device and this is used in Table 25 as the starting point for the MCL calculation.

Table 23: TS interference PSD calculation for 10 MHz TS bandwidth

Parameter	Unit	BS (outdoor)	UE (outdoor)	BS (indoor)	UE (indoor)
P	dBm	30.00	24.00	20.00	20.00
GTX	dBi	6.00	0.00	0.00	0.00
hTX	meter	10.00	1.50	1.50	1.50
BW	MHz	10.00	10.00	10.00	10.00
PSDtx	dBm/MHz	26.00	14.00	10.00	10.00

Table 24 TS interference PSD calculation for 5 MHz TS bandwidth

Parameter	Unit	BS (outdoor)	UE (outdoor)	BS (indoor)	UE (indoor)
P	dBm	30	24	20	20
GTX	dBi	6	0	0	0
hTX	meter	10	1,5	1,5	1,5
BW	MHz	5	5	5	5

Parameter	Unit	BS (outdoor)	UE (outdoor)	BS (indoor)	UE (indoor)
PSDtx	dBm/MHz	29.01	17.01	13.01	13.01

Table 25 and Table 26 shows the MCL calculations for the separation distance for the MSS case in Table 18. The separation distance is given on the D line.

The PSD_{interf} in the receiver is computed from the PSDtx power spectral density:

PSD_{interf} = PSDtx-L_{path} + G_{0RX}-BEL and L_{path} = Urban(D), Suburban(D), or Rural(D); (3)

The antenna gain parameters are G_{0RX} for the victim receiver. The G_{0RX} parameter represents the average gain of the omni-directional receive antenna. The BEL parameter is set to 15 dB of attenuation through a single building wall as may apply for an indoor TS system[1].

Table 25: MCL Separation distance calculation for 10 MHz TS bandwidth, MSS victim UE, TS interferer

Parameter	Units	Outdoor BS	Outdoor UE	Indoor BS	Indoor UE
D EHata (Urban)	km	1.07	0.20	0.09	0.09
D EHata (Suburban)	km	2.38	0.44	0.13	0.13
D EHata (Rural)	km	8.96	1.64	0.47	0.47
D FSPL	km	278.70	70.01	7.85	7.85
D horizon	km	18.08	10.10	10.88	10.10
L_{path} (Urban)	dB	149.26	137.26	118.26	118.26
G_{0RX}	dBi	-0.80	-0.80	-0.80	-0.80
BEL	dB	0.00	0.00	15.00	15.00
PSD_{interf}	dBm/MHz	-124.06	-124.06	-124.06	-124.06
N0	dBm/MHz	-112.06	-112.06	-112.06	-112.06
I/N	dB	-12.00	-12.00	-12.00	-12.00

Table 26: MCL Separation distance calculation for 5 MHz TS bandwidth, MSS victim UE, TS interferer

Parameter	Units	Outdoor BS	Outdoor UE	Indoor BS	Indoor UE
D EHata (Urban)	km	1.30	0.24	0.09	0.09
D EHata (Suburban)	km	2.90	0.53	0.15	0.15
D EHata (Rural)	km	9.99	2.00	0.58	0.58
D FSPL	km	393.54	98.85	11.09	11.09
D horizon	km	18.08	10.10	10.88	10.10
L_{path} (Urban)	dB	152.27	140.27	121.27	121.27
G_{0RX}	dBi	-0.80	-0.80	-0.80	-0.80

[1] BEL is set to 15 dB as per 3GPP TR 38.901, section 7.4.3.1 for concrete material

Parameter	Units	Outdoor BS	Outdoor UE	Indoor BS	Indoor UE
BEL	dB	0.00	0.00	15.00	15.00
PSD_{interf}	dBm/MHz	-124.06	-124.06	-124.06	-124.06
N0	dBm/MHz	-112.06	-112.06	-112.06	-112.06
I/N	dB	-12.00	-12.00	-12.00	-12.00

EHata converges to a simple Free Space Path Loss (FSPL) for distances less than 40 meters.

$$\mathrm{FSPL} = 20\log10(4\pi D/\lambda) \quad (4)$$

Where:

- $\lambda = c/f$

When the distance is greater than 100 meters and the base height is 10 m, the EHata path loss for Urban environment is given by

$$\mathrm{EHata} = 42.56 + 35.22\log10(D) \quad (5)$$

For distances in between 40 and 100 meters the path loss is interpolated.

4.1.4 Summary

This section analyses the impact of terrestrial service (TS) in the MSS frequency band 2483.5-2495 MHz on Mobile Satellite System (MSS) receivers operating in the same frequency band. The impact of the proposed TS using 5MHz and 10 MHz of bandwidth has been studied.

Study between TS using a bandwidth of 5 or 10 MHz and MSS, assuming the median EHata propagation model, gives median separation distances shown below in an extract from Table 25 and Table 26.

Table 27: Extract from Table 25: MCL Separation distance calculation for 10 MHz TS bandwidth, MSS victim UE, TS interferer

Parameter	Units	Outdoor BS	Outdoor UE	Indoor BS	Indoor UE
D EHata (Urban)	km	1.07	0.20	0.09	0.09
D EHata (Suburban)	km	2.38	0.44	0.13	0.13
D EHata (Rural)	km	8.96	1.64	0.47	0.47

Table 28: Extract from Table 26: MCL Separation distance calculation for 5 MHz TS bandwidth, MSS victim UE, TS interferer

Parameter	Units	Outdoor BS	Outdoor UE	Indoor BS	Indoor UE
D EHata (Urban)	km	1.30	0.24	0.09	0.09
D EHata (Suburban)	km	2.90	0.53	0.15	0.15
D EHata (Rural)	km	9.99	2.0	0.58	0.58

This Report considers only the characteristics of an operational MSS system, Globalstar. Other satellite systems have been filed at the ITU BR for use in this band, but these characteristics have not been considered as these are not active in this band in ITU Region 1.

4.2 COMPATIBILITY WITH POSSIBLE FUTURE RDSS IN THE BAND 2483.5-2500 MHZ

The upgrading of Radiodetermination Satellite Service (RDSS) in 2483.5-2500 MHz band to primary status on a global basis has been agreed by WRC-12. The approved global primary allocation is intended to facilitate new navigation signals for the future generation of Galileo satellites in subject frequency band. The 2483.5-2500 MHz band, because of its proximity to the mobile service allocations above 2.5 GHz, may offer attractive synergies of radio determination satellite navigation systems (RDSS/RNSS) with terrestrial mobile systems due to improved antenna efficiencies and use of shared hardware not possible with other RDSS bands.

RDSS would also be operated in downlink mode only, so the interference scenario with RDSS is very similar to the scenario with MSS. Another similarity with the MSS case is that RDSS victim receivers are supposed to be operated outdoors only.

It should be noted there is no consideration in the band for tracking applications such as aeronautical “safety-of-life” applications including landing assistance where the integrity requirement for the RDSS signal is greater.

Analysis presented here shows the impact of an LTE-based 2.4 GHz terrestrial service (TS) in the MSS frequency band 2483.5-2495 MHz on a proposed future RDSS incumbent services in the same frequency band. The analysis determines the impact of LTE-based 2.4 GHz terrestrial transmitters on victim co-channel future RDSS receivers.

The technical characteristics of the 2.4 GHz low power terrestrial service (TS) are given in section 3.2. The TS system is time division duplex (TDD) with the transmit activity divided between the BS and UE. However, 100% transmit time has been used for the BS and the UE in the calculation. The uplink and downlink signal powers are averaged to provide a single interference power or power spectral density. The TS system with 5 and 10 MHz of bandwidth is analysed here, in a co-channel configuration.

The analysis is provided with 5 and 10 MHz bandwidth as they have the largest overlap with RDSS and present the highest interference case. The 15 MHz TS system distributes power both above and below the RDSS occupied bandwidth so it also has lower on-channel interference than the 10 MHz case.

4.2.1 RDSS system parameters

This section uses the parameters for proposed RDSS systems given in Recommendation ITU-R M.2082 [42] and ECC Report 150 [1].

The RDSS system characteristics in Recommendation ITU-R M.2082 were based on current Galileo system characteristics given in Recommendation ITU-R M.1787 [17] operating in the band 1559-1610 MHz.

There is no RDSS service thus no satellite in orbit operating in 2483.5-2495 MHz band.

The satellites operating in the band 1559-1610 MHz orbit the earth at an altitude of 23616 km.

The satellites are arranged in three orbital planes with 9 satellites per plane.

An I/N ratio will be used as the interference criterion for future RDSS receivers that may operate in 2483.5-2495 MHz band.

Any RDSS compatibility study would have to consider general-purpose applications where occasional loss of RDSS signal is expected and does not impact overall performance (no extra margin added).

It should be noted there is no consideration in the band for tracking applications such as aeronautical “safety-of-life” applications including landing assistance where the integrity requirement for the RDSS signal is greater. For example, in Recommendation ITU-R M.1903 [15] an “Aeronautical Safety Margin” of at least 6 dB is added when calculating interference. No additional margins are used in this analysis.

Table 29: Technical characteristics of proposed RDSS signal

Case	Description	Range	Transmit Power	Antenna Gain	Frequency	Interf. Condition	I/N
RDSS	Space Station	25239 km	40.5 dBW	13.30 dBic RHCP	2.492 GHz	Co-channel	-6 dB (note 1)
Note 1: see ECC Report 128 [16] and Recommendation ITU-R M.1903 [15]; ECC Report 128 uses 1 dB reduction in C/No in analysis of pseudolite (ground based RNSS transmitters) deployments, and calculates separation distance to “ensure an induced SNR loss of less than 1 dB; Recommendation ITU-R M.1903 [15] says "Therefore, the accepted approach is to define the aggregate interference power density threshold at a level that will not raise the total noise floor by more than 1 dB above the environmental noise floor.”. Noise rise (Nrise) and I/N are connected together by simple formulas (I/N = 10 log10(10exp(0.1 Nrise) – 1)) with 0.97 dB Nrise for -6.0 dB I/N.							

The maximum power flux densities of the RDSS signal are -128 or -129 dB(W/m^2/MHz) depending on the region in Recommendation ITU-R M.2082 [42] and recommended to be -129 dB(W/m^2/MHz) in ECC Report 150 [1]. Satellite RDSS signals are characterised by the ratio C/N0, the ratio of the received signal power to the total thermal noise density at the detector. The minimum received power on the ground for a Galileo signal is -127.25 dBm when a 0 dBi antenna is used in Recommendation ITU-R M.1787 [17].

The Power Spectral Density for two candidate waveforms, BPSK(4) and BOC(1,1), are shown Figure 5. Two other systems are described in ECC Report 150 [1]. A BPSK(1) system with 2 MHz bandwidth and a BPSK(8) system with 16 MHz band are described. The 2 MHz BPSK(1) system performance is comparable to current GPS performance and the 16 MHz BPSK(8) system would just fit within 16.5 MHz band from 2483.5 to 2500 MHz.

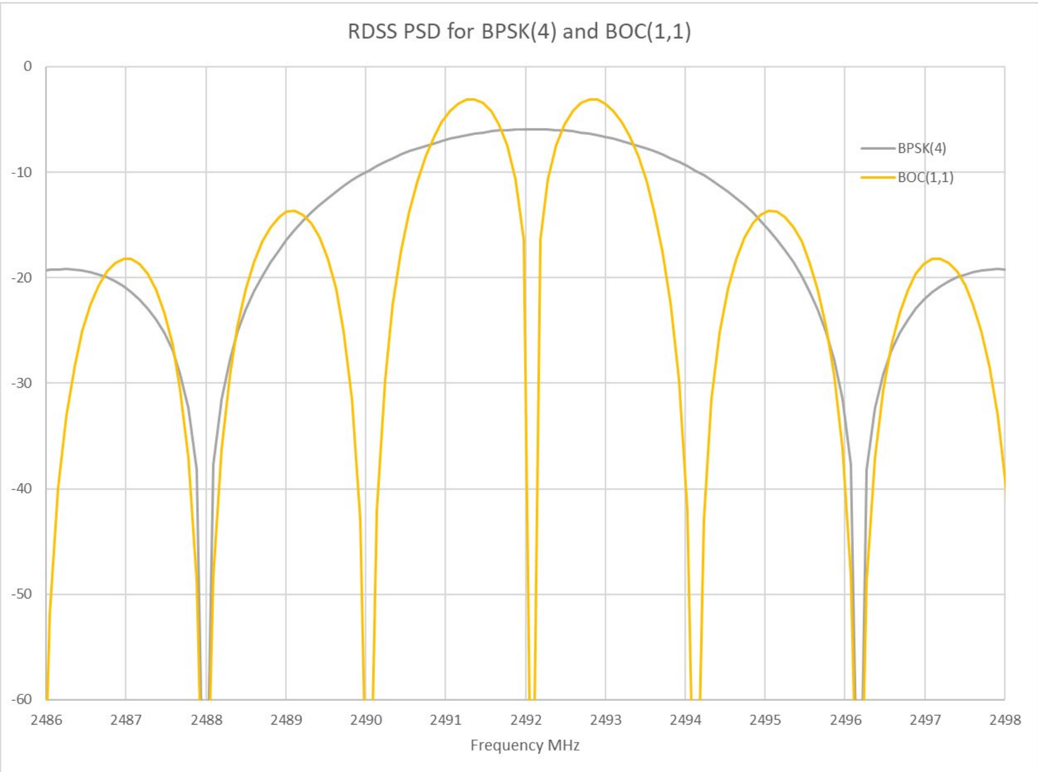

Figure 5: RDSS Example Power Spectral Densities

The bandwidth measured between the first spectral nulls is 8.184 MHz for BPSK(4) and 2.046 MHz for BOC(1,1).

The RDSS receiver noise used in this analysis is 2.2 dB. The noise power, N0, is determined according to 4.1.1:

- N0 = -111.6 dBm/MHz for T=298°K; B=1 MHz; and F=1.66 (or 2.2 dB).

The minimum C/N0 ratio is then found to be when the receiving antenna has 0 dBic gain and the noise temperature is as given. An example calculation of the C/No ratio using the minimum Galileo signal strength and the noise density given above is:

C/N0 = -127.2 – (-171.6) = 44.4 dB.

4.2.1.1 RDSS system parameters

Selected system parameters from ECC Report 150 [1].

Table 30: RDSS Receive Parameters

Parameter	Value
Frequency	2483.5-2500 MHz
Channel Bandwidth	4.092 (BOC(1,1)) or 8.184 MHz (BPSK(4))
Minimum Signal Strength	-127.2 dBm
Noise Figure	2.2 dB

4.2.1.2 RDSS antenna parameters

Table 31: RDSS Receive Antenna Parameters

Parameter	Value
Type	Omnidirectional Hemispherical, RHCP
Gain	0 or 3 dBic

4.2.2 Scenarios

RNSS operating in the band 1559-1610 MHz are shared by multiple RDSS systems (i.e. Galileo, Glonass).

At WRC-12, the 2483.5-2500 MHz band was identified for use by Galileo.

The current and future RDSS systems are assumed to be outdoors.

Each compatibility scenario covers non-aeronautical RDSS receivers with an outdoor and indoor TS base station.

The basic RDSS compatibility scenarios are illustrated in Figure 6 and Figure 7 below.

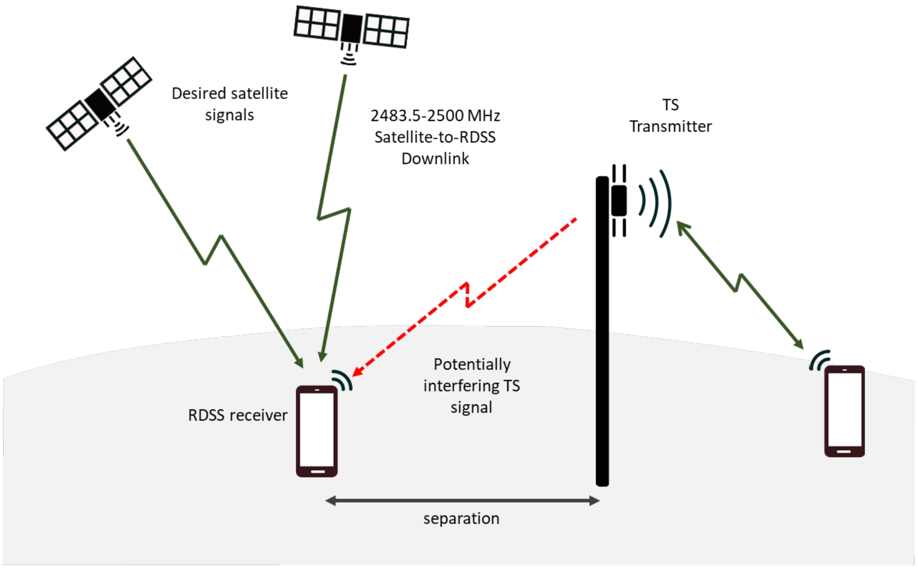

Figure 6: Outdoor TS Base Station and UE device to RDSS receiver

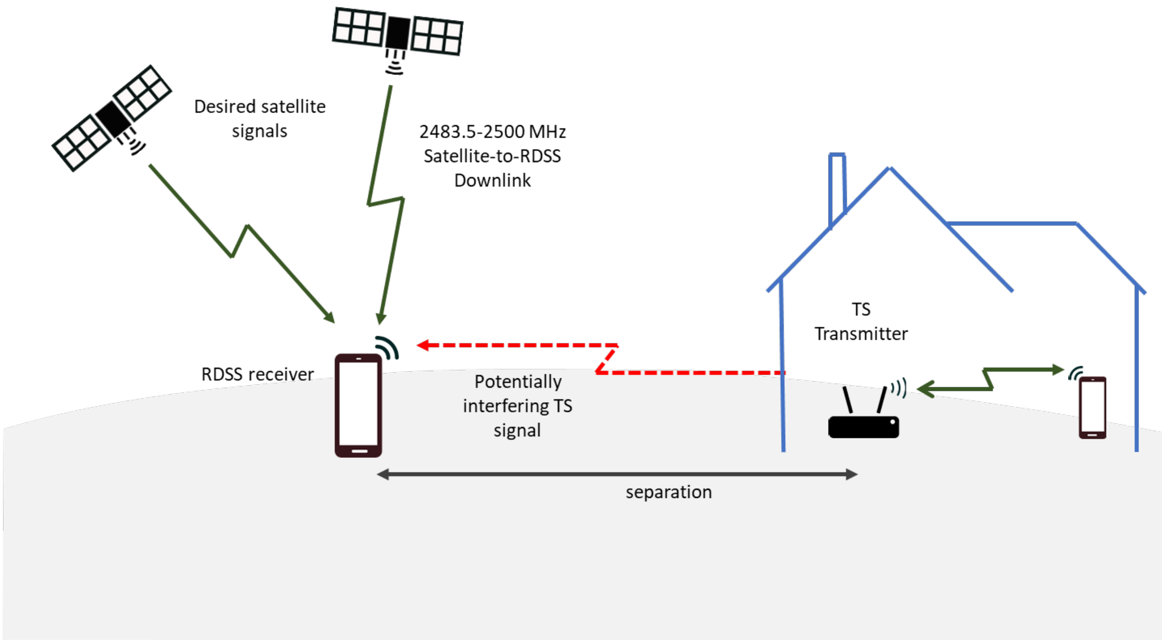

Figure 7: Indoor TS Base Station and UE device to RDSS receiver

4.2.3 Study

The MCL calculations for each of the cases is summarised in the Table 35 and Table 37. The separation distance is calculated from the EHata path loss model for Urban environments [20]. The path loss depends on the antenna heights. The typical antenna heights for TS are congruent with the Urban Environment. The Urban model converges to a Free Space Path Loss (FSPL) model for distances less than 40 m.

Table 32: Interference Cases TS to RDSS

Case	Description
Case 1	Outdoor TS to outdoor RDSS
Case 2	Indoor low-power TS with 15 dB BEL to outdoor RDSS

The transmitted interference power spectral density (PSDtx) is computed in Table 33. The last row in the table gives the total emitted power spectral density.

Table 33: TS interference PSD calculation for 10 MHz TS bandwidth

Parameter	Unit	BS (outdoor)	UE (outdoor)	BS (indoor)	UE (indoor)
P	dBm	30.00	24.00	20.00	20.00
Gtx	dBi	6.00	0.00	0.00	0.00
Htx	meter	10.00	1.50	1.50	1.50
BW	MHz	10.00	10.00	10.00	10.00
PSDtx	dBm/MHz	26.00	14.00	10.00	10.00

Table 34: TS interference PSD calculation for 5 MHz TS bandwidth

Parameter	Unit	BS (outdoor)	UE (outdoor)	BS (indoor)	UE (indoor)
P	dBm	30.00	24.00	20.00	20.00
Gtx	dBi	6.00	0.00	0.00	0.00
Htx	meter	10.00	1.50	1.50	1.50
BW	MHz	5.00	5.00	5.00	5.00
PSDtx	dBm/MHz	29.01	17.01	13.01	13.01

Table 35 to Table 37 show the MCL calculations for the separation distance for each of the RDSS interference for case 1 and 2. The separation distance is given on the D line in each table for each case.

The PSD_{interf} in the receiver is computed from the PSDtx power spectral density:

- PSD_{interf} = PSDtx-L_{path} + G_{0RX} -Lpol-BEL and L_{path} = Urban(D).

The antenna gain parameters are G_{0RX} for the victim receiver. The L_{pol} parameter reflects the polarization loss between the linear polarised LTE signals and the circularly polarised RDSS signals. The value of L_{pol} used here is 1.7 dB which is found in the appendix of Recommendation ITU-R F.1245 [21] for the polarisation loss between linearly polarised fixed service antennas and circularly polarised satellite antennas. However, since the study covers urban propagation and cases where the interferer systems may often not be in the half-beam of the victim antenna, polarisation is supposed to be lost. Hence, separation distances are computed assuming a polarization loss of 0 dB in the urban case, and 1.7 dB in the suburban and rural cases. The G_{0RX} parameter represents the maximum directional gain of the receive antenna. Values of the 3 dB will be used for signals arriving from high elevations and the 0 dB value for signals arriving from low elevations. The BEL parameter is set to 15 dB of attenuation through a single building wall[2].

The MCL separation distance is given below for the case where the RDSS receiver antenna has 0 dB gain. For outdoor case, for a TS system bandwidth of 10 MHz:

- with the urban path loss model the minimum separation distance is 0.7 km;
- with the suburban path loss model the minimum separation distance is 1.5 km;
- with the rural path loss model the minimum separation distance is 5.6 km.

For a TS system bandwidth of 5 MHz:

- with the urban path loss model the minimum separation distance is 0.9 km;
- with the suburban path loss model the minimum separation distance is 1.8 km;
- with the rural path loss model the minimum separation distance is 6.8 km.

[2] BEL is set to 15 dB as per 3GPP TR 38.901, section 7.4.3.1 for concrete material

Table 35: Separation distance calculation for 10 MHz TS bandwidth, RDSS victim 0 dB Grx, TS interferer BS

RDSS Parameter	Units	Case 1		Case 2	
		Outdoor TS Outdoor RDSS		Indoor TS Outdoor RDSS	
Interferer		TS BS	TS UE	TS BS	TS UE
D EHata (urban)	km	0.70	0.10	0.10	0.10
D Ehata (suburban)	km	1.50	0.20	0.10	0.10
D Ehata (rural)	km	5.60	0.90	0.3	0.30
D FSPL (urban)	km	145.30	36.50	4.10	4.10
D FSPL (suburban/rural)	km	120.08	30.16	3.38	3.38
D horizon	km	18.10	10.10	10.90	10.10
L_{path} (urban)	dB	143.60	131.60	112.6	112.6
L_{path} (suburban/rural)	dB	141.96	129.96	110.96	110.96
G_{0rx}	dBic	0.00	0.00	0.00	0.00
POL (urban)	dB	0.00	0.00	0.00	0.00
POL (suburban, rural)	dB	1.70	1.70	1.70	1.70
BEL	dB	0.00	0.00	15.00	15.00
PSD_{interf}	dBm/MHz	-117.60	-117.60	-117.60	-117.60
N0	dBm/MHz	-111.60	-111.60	-111.60	-111.60
I/N	dB	-6.00	-6.00	-6.00	-6.00

Table 36: Separation distance calculation for 5 MHz TS bandwidth, RDSS victim 0 dB Grx, TS interferer BS

RDSS Parameter	Units	Case 1		Case 2	
		Outdoor TS Outdoor RDSS		Indoor TS Outdoor RDSS	
Interferer		TS BS	TS UE	TS BS	TS UE
D Ehata (urban)	km	0.90	0.10	0.10	0.10
D EHata (suburban)	km	1.80	0.30	0.10	0.10
D EHata (rural)	km	6.80	1.10	0.30	0.30
D FSPL (urban)	km	206.53	51.88	5.82	5.82
D FSPL (suburban/rural)	km	169.82	42.66	4.79	4.79
D horizon	km	18.10	10.10	10.90	10.10
L_{path} (urban)	dB	146.67	134.67	115.67	115.67
L_{path} (suburban/rural)	dB	144.97	132.97	113.97	113.97
G0rx	dBic	0.00	0.00	0.00	0.00

RDSS Parameter	Units	Case 1		Case 2	
		Outdoor TS Outdoor RDSS		Indoor TS Outdoor RDSS	
Interferer		TS BS	TS UE	TS BS	TS UE
POL (urban)	dB	0.00	0.00	0.00	0.00
POL (suburban, rural)	dB	1.70	1.70	1.70	1.70
BEL	dB	0.00	0.00	15.00	15.00
PSDinterf	dBm/MHz	-117.66	-117.66	-117.66	-117.66
N0	dBm/MHz	-111,66	-111,66	-111,66	-111,66
I/N	dB	-6.00	-6.00	-6.00	-6.00

When the RDSS receiver has 3 dB of gain the separation distances are given in the following table. The minimum separation distance with the urban path loss model is 0.9 km.

Table 37: Separation distance calculation for 10 MHz TS bandwidth, RDSS victim 3 dB Grx, TS interferer BS

RDSS Parameter	Units	Case 1		Case 2	
		Outdoor TS Outdoor RDSS		Indoor TS Outdoor RDSS	
Interferer		TS BS	TS UE	TS BS	TS UE
D EHata (urban)	km	0.90	0.20	0.10	0.10
D FSPL (suburban/rural)	km	169.62	42.61	4.78	4.78
D horizon	km	18.10	10.10	10.90	10.10
L_{path} (urban)	dB	146.60	134.600	115.60	115.60
L_{path} (suburban/rural)	dB	144.96	132.96	113.96	113.96
G_{0RX}	dBic	3.00	3.00	3.00	3.00
POL (urban)	dB	0.00	0.00	0.00	0.00
POL (suburban, rural)	dB	1.70	1.70	1.70	1.70
BEL	dB	0.00	0.00	15.00	15.00
PSD_{interf}	dBm/MHz	-117.66	-117.66	-117.66	-117.66
N0	dBm/MHz	-111.66	-111.66	-111.66	-111.66
I/N	dB	-6.00	-6.00	-6.00	-6.00

Table 38: Separation distance calculation for 5 MHz TS bandwidth, RDSS victim 3 dB Grx, TS interferer BS

RDSS Parameter	Units	Case 1		Case 2	
		Outdoor TS Outdoor RDSS		Indoor TS Outdoor RDSS	
Interferer		TS BS	TS UE	TS BS	TS UE
D Ehata (urban)	km	1.10	0.20	0.10	0.10
D Ehata (suburban)	km	2.20	0.300	0.10	0.10
D Ehata (rural)	km	8.30	1.30	0.40	0.40
D FSPL (urban)	km	291.74	73.28	8.22	8.22
D FSPL (suburban/rural)	km	243.17	60,25	6.76	6.76
D horizon	km	18.10	10.10	10.90	10.10
L_{path} (urban)	dB	149.67	137.67	118.67	118.67
L_{path} (suburban/rural)	dB	148,09	135.97	116.97	116.97
G0rx	dBic	3.00	3.00	3.00	3.00
POL (urban)	dB	0.00	0.00	0.00	0.00
POL (suburban, rural)	dB	1.70	1.70	1.700	1.70
BEL	dB	0.00	0.00	15.00	15.00
PSD_{interf}	dBm/MHz	-117.66	-117.66	-117.66	-117.66
N0	dBm/MHz	-111.66	-111.66	-111.66	-111.66
I/N	dB	-6.00	-6.00	-6.00	-6.00

4.2.4 MCL calculations

4.2.4.1 Separation distance urban environment

The calculation of Minimum Coupling Loss (MCL) computes a necessary path loss (L_{path}) and a corresponding path distance (D) using the EHata Urban path loss model. It converges to a simple Free Space Path Loss (FSPL) for distances less than 40 meters.

$$\mathrm{FSPL} = 20\log 10(4\pi D/\lambda) \qquad (6)$$

FSPL = 20 log10(4πD/λ)
Where λ=c/f

When the distance is greater than 100 meters and the base height is 10 m, the EHata path loss is given by

$$\mathrm{EHata} = 42.56 + 35.22\log 10(\mathrm{D}) \qquad (7)$$

For distances in between 40 and 100 meters the path loss is interpolated.

4.2.5 Summary

This section analyses the impact of terrestrial service (TS) in the MSS frequency band 2483.5-2495 MHz on possible future in-band radio determination satellite navigation systems (RDSS/RNSS).

Study between TS and RDSS operating in the same band, assuming the median EHata Urban propagation model, gives median separation distances between TS systems and the future RDSS receivers as shown below in an extract from Table 32 and Table 37, for TS bandwidth of 10 and 5 MHz, respectively.

Table 39: Extract from Table 32: Separation distance calculation for 10 MHz TS bandwidth, RDSS victim 3 dB Grx, TS interferer BS

RDSS Parameter	Units	Case 1		Case 2	
		Outdoor TS Outdoor RDSS		Indoor TS Outdoor RDSS	
Interferer		TS BS	TS UE	TS BS	TS UE
D EHata (urban)	km	0.90	0.20	0.10	0.10
D EHata (suburban)	km	1.80	0.30	0.10	0.10
D EHata (rural)	km	6.80	1.10	0.30	0.30

Table 40: Extract from Table 37: Separation distance calculation for 5 MHz TS bandwidth, RDSS victim 3 dB Grx, TS interferer BS

RDSS Parameter	Units	Case 1		Case 2	
		Outdoor TS Outdoor RDSS		Indoor TS Outdoor RDSS	
Interferer		TS BS	TS UE	TS BS	TS UE
D EHata (urban)	km	1.10	0.20	0.10	0.10
D EHata (suburban)	km	2.20	0.30	0.10	0.10
D EHata (rural)	km	8.30	1.30	0.40	0.40

4.3 COMPATIBILITY WITH MBANS IN THE BAND 2483.5-2500 MHZ

A related class of devices authorised to operate at 2483.5-2500 MHz in a number of EU countries is the Medical Body Area Network System (MBANS) devices. MBANS devices include a variety of body-worn (as opposed to implanted) sensors, such as blood pressure and heart rate sensors, which communicate with a nearby hub device to record patient data. As with Low-Power Active Medical Implants (LP-AMIs,) MBANS are SRD-class devices, and are also restricted to indoor use.

This section analyses the impact of an LTE-based 2.4 GHz terrestrial service (TS) in the MSS frequency band 2483.5-2495 MHz on incumbent services in the same frequency band. The analysis determines the impact of LTE-based 2.4 GHz terrestrial transmitters on victim co-channel receivers and vice versa. One service that can share the band is the Medical Body Area Network Systems (MBANS) service.

The technical characteristics of the 2.4 GHz low power terrestrial service (TS) are given in section 3. The terrestrial service is time division duplex (TDD) with the transmit activity divided between the BS and UE. However, 100% transmit time has been used for the BS and the UE in the calculation. The TS system with 10 MHz is analysed here. This exceeds the 3 MHz bandwidth for MBANS, so the interference is calculated with the power spectral density (PSD) of the TS system signals.

4.3.1 MBANS system parameters

This section follows the analysis categories presented in ECC Report 201 [4]. These categories are listed in the table below. MBANS equipment can occupy 3 MHz channels from 2.4 GHz up to 2.5 GHz depending on the deployment. This frequency range overlaps the TS low power terrestrial service in 2483.5-2500 MHz. The calculation will use an I/N ratio of 0 dB for MBANS as shown in the last column in the table below. An I/N ratio of -6 dB is used for TS receivers.

Table 41: Technical characteristics of MBANS categories

+	Description	Range	Transmit Power	Antenna Gain	Duty Cycle	Frequencies (GHz)	Interf. Condition	I/N
1	Health care facility	3 m	0 dBm	0 dBi	10%	2.4-2.5	Co-channel	0 dB (note 1)
2	Home	10 m	13 dBm	0 dBi	2%	2.4-2.5	Co-channel	0 dB
3	Ambulance	3 m	0 dBm	0 dBi	10%	2.4-2.5	Co-channel	0 dB
Note 1: ECC Report 201, table 5 Scenario 3 for example								

The receiver noise figure in ECC Report 201 for MBANS is given as 10 dB. The noise power, N0, is then determined according to 4.1.1:

- N0 = -103.86 dBm for T=298°K; B=1 MHz; and F=10 (or 10 dB).

MBANS is a low power radio system used for the transmission of non-voice data between medical devices for the purposes of monitoring, diagnosing and treating patients by authorised medical personnel. The MBANS consists of one or more on-body wireless sensors to collect simultaneously multiple vital sign parameters. Medical actuator devices can also communicate with a monitoring device placed up to 10 meters from the human body in home categories, or 3 meters for hospital or ambulance categories or deployment.

The three categories of MBANS deployments are list in the table above as health care facilities, homes, and ambulances. These are discussed in the next sub-sections.

4.3.1.1 MBANS Category 1

An example for healthcare facilities (e.g. hospitals) is shown in Figure 8. Several MBANS sensors can be connected to a patient and the data is transmitted between the sensors and an MBANS hub. There can also be multiple patients in a room with separate MBANS hubs. The transmit power is low, usually about 0 dBm, and the range is also low, about 3 meters or less. The duty cycle for the MBANS transmitter is typically 10% for this category.

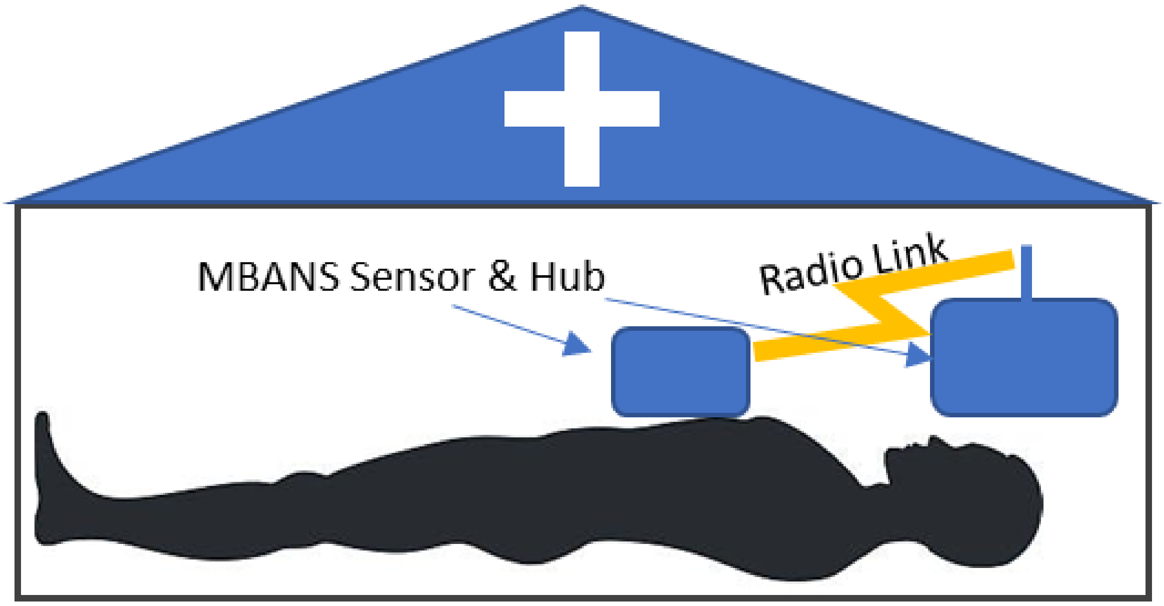

Figure 8: Healthcare MBANS example

4.3.1.2 MBANS Category 2

An example for home deployment of MBANS is shown in Figure 9. The deployment is normally inside a residence. The transmit power level is typically less than 13 dBm and the range is typically up to 10 m. The duty cycle for this category is only 2%.

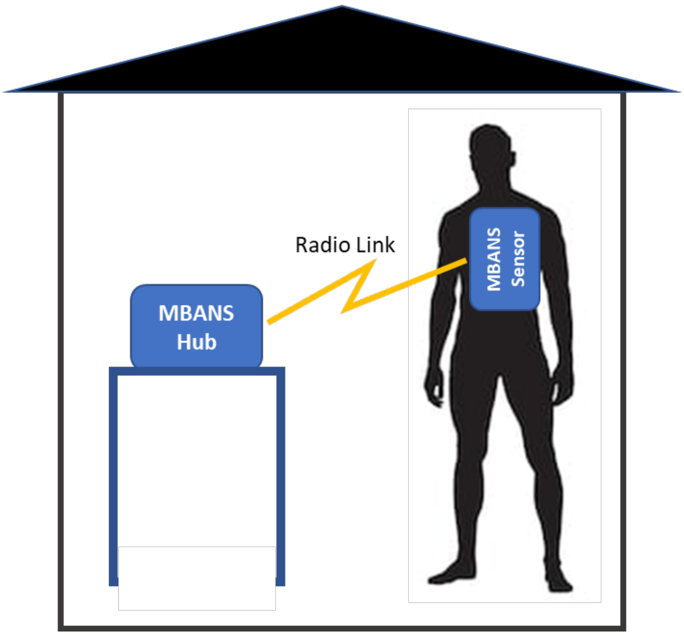

Figure 9: Home MBANS example

4.3.1.3 MBANS Category 3

An example for ambulance deployment of MBANS is shown in Figure 10. The deployment is inside a mobile vehicle with transmit power level less than 0 dBm and range is less than 3 m. MBANS only services a single patient in an ambulance. The duty cycle for this category is 10%.

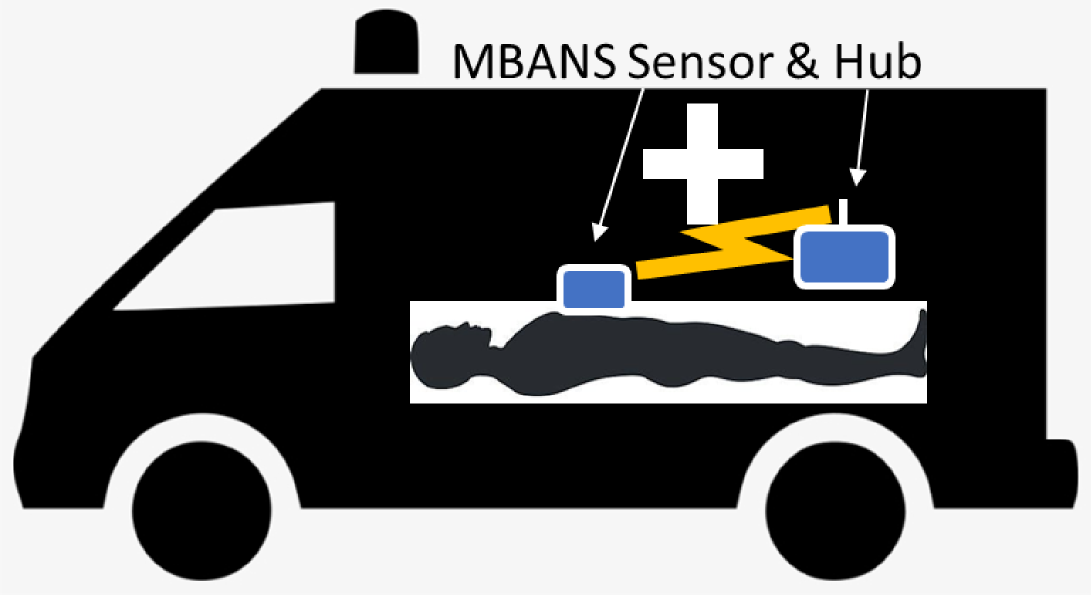

Figure 10: Ambulance MBANS example

4.3.1.4 MBANS system parameters

This is a table of selected system parameters from ECC Report 201 [4].

Table 42: MBANS system parameters-Transmit

Parameter	Value
Frequency	2400-2500 MHz
Channel Bandwidth	3 MHz
Power	0 dBm
ACLR, Block 2, Max / Min	-42 dB / -52 dB
ACLR, Block 3, Max / Min	-45 dB / -55 dB
Spurious emissions, > 1000 MHz, Operating	-30 dBm / MHz

Table 43: MBANS system parameters-Receiver

Parameter	Value
Frequency	2400-2500 MHz
Channel Bandwidth	3 MHz
Reference Sensitivity	-93 dBm to -76 dBm
Noise Figure	10 dB
ACS	30 dB
Blocking	40 dB

4.3.1.5 MBANS antenna parameters

Selected specifications from ECC Report 219 [5].

Table 44: MBANS antenna parameters-Transmit

Parameter	Value
Type	Omnidirectional
Gain	0 dBi

Table 45: MBANS antenna parameters-Receive

Parameter	Value
Type	Omnidirectional
Gain	0 dBi

4.3.2 Scenarios

The interference scenarios to be considered are depicted in Figure 11.

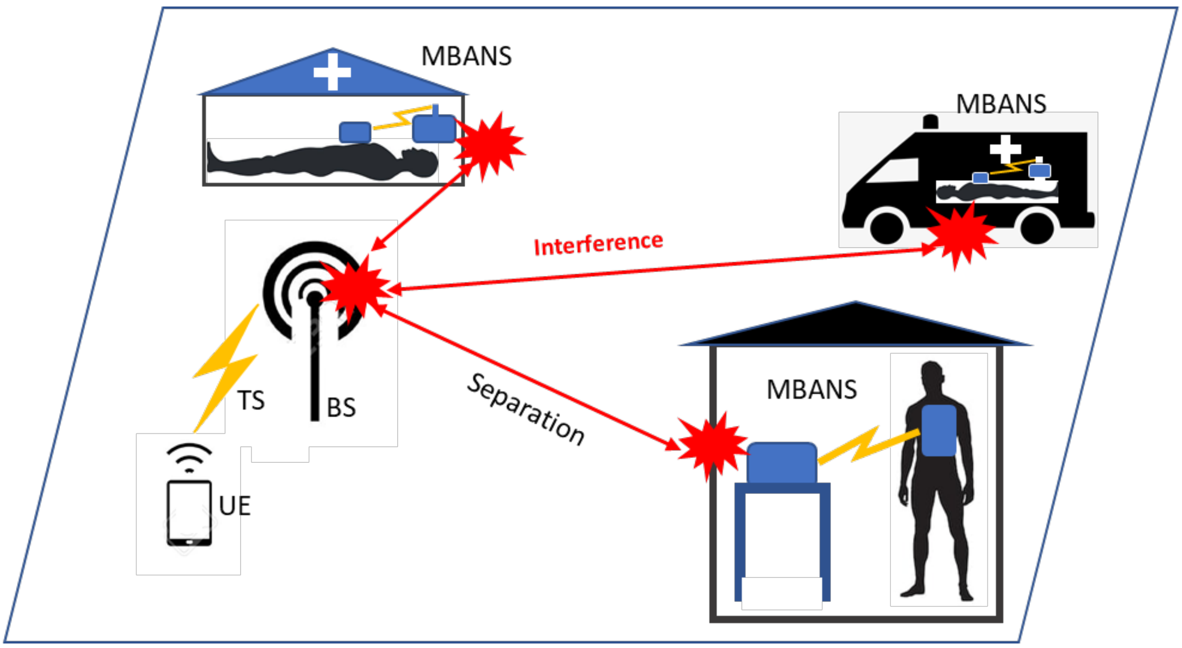

Figure 11: Interference Cases

4.3.3 Study

4.3.3.1 Separation distance urban environment

The MCL calculations for each of the categories is summarised in Table 47 and Table 49. The separation distance is calculated from the EHata path loss model for Urban environments [20]. The path loss depends on the antenna heights. The typical antenna heights for MBANS or TS are congruent with the Urban Environment. The Urban model converges to a Free Space Path Loss (FSPL) model for distances less than 40 m. The model also includes log normal fading.

The transmitted interference power spectral density (PSDtx) is computed in Table 46. The last line in the table gives the total emitted PSDtx.

Table 46: TS interference PSD calculation

Parameter	Unit	BS (outdoor)	UE (outdoor)	BS (indoor)	UE (indoor)
P	dBm	30.00	24.00	20.00	20.00
GTX	dBi	6.00	0.00	0.00	0.00
hTX	meter	10.00	1.50	1.50	1.50
BW	MHz	10.00	10.00	10.00	10.00
PSDtx	dBm/MHz	26.00	14.00	10.00	10.00

Table 47 and Table 49 show the MCL calculations for the separation distance for each of the MBANS cases in Table 41. The separation distance is given on the D line in each table for each category.

The PSD_{interf} in the receiver is computed from the PSDtx power spectral density:

- $PSD_{interf} = PSDtx - L_{path} + G_{0RX} - BEL$ and $L_{path} = Urban(D)$;

The antenna gain parameters are G_{0RX} for the victim receiver, and G0TX for the transmitter. The G_{0RX} parameter represents the maximum directional gain of the receive antenna. The BEL parameter is set to 15 dB of attenuation through a single building wall and 30 dB for two building walls as may apply for an indoor system interfering with another indoor system in a different building[3]. The BEL for the ambulance in category 3 is set to 12 dB.

Table 47: MCL Separation distance calculation, MBANS victim, TS interferer BS

Parameter	Units	Cat. 1 Outdoor TS	Cat. 2 Outdoor TS	Cat. 3 Outdoor TS	Cat. 1 Indoor TS	Cat. 2 Indoor TS	Cat. 3 Indoor TS
D EHata (urban)	km	0.11	0.11	0.14	0.05	0.05	0.05
D FSPL	km	5.31	5.31	7.50	0.15	0.15	0.21
L_{path}	dB	114.86	114.86	117.86	83.86	83.86	86.86
G_{0RX}	dBi	0.00	0.00	0.00	0.00	0.00	0.00
BEL	dB	15.00	15.00	12.00	30.00	30.00	27.00
PSD_{interf}	dBm/MHz	-103.86	-103.86	-103.86	-103.86	-103.86	-103.86
N0	dBm/MHz	-103.86	-103.86	-103.86	-103.86	-103.86	-103.86
I/N	dB	0.00	0.00	0.00	0.00	0.00	0.00

[3] BEL is set to 15 dB as per 3GPP TR 38.901, section 7.4.3.1 for concrete material

Table 48: MCL Separation distance calculation, MBANS victim, TS interferer UE

Parameter	Units	Cat. 1 Outdoor TS	Cat. 2 Outdoor TS	Cat. 3 Outdoor TS	Cat. 1 Indoor TS	Cat. 2 Indoor TS	Cat. 3 Indoor TS
D EHata (urban)	km	0.08	0.08	0.09	0.05	0.05	0.05
D FSPL	km	1.33	1.33	1.88	0.15	0.15	0.21
L_{path}	dB	102.86	102.86	105.86	83.86	83.86	86.86
G_{0RX}	dBi	0.00	0.00	0.00	0.00	0.00	0.00
BEL	dB	15.00	15.00	12.00	30.00	30.00	27.00
PSD_{interf}	dBm/MHz	-103.86	-103.86	-103.86	-103.86	-103.86	-103.86
N0	dBm/MHz	-103.86	-103.86	-103.86	-103.86	-103.86	-103.86
I/N	dB	0.00	0.00	0.00	0.00	0.00	0.00

Table 49: MCL Separation distance calculation, MBANS interferer, TS victim BS or UE

Parameter	Units	Cat. 1 Outdoor TS	Cat. 2 Outdoor TS	Cat. 3 Outdoor TS	Cat. 1 Indoor TS	Cat. 2 Indoor TS	Cat. 3 Indoor TS
P	dBm	0.00	13.00	0.00	0.00	13.00	0.00
G_{0TX}	dBi	0.00	0.00	0.00	0.00	0.00	0.00
BEL	dB	15.00	15.00	12.00	30.00	30.00	27.00
BW	MHz	3.00	3.00	3.00	3.00	3.00	3.00
PSDtx	dBm/MHz	-19.77	-6.77	-16.77	-34.77	-21.77	-31.77
D EHata (urban)	km	0.06	0.07	0.07	0.03	0.04	0.04
D FSPL	km	0.59	2.66	0.84	0.05	0.24	0.07
L_{path}	dB	95.86	108.86	98.86	74.86	87.86	77.86
G_{0RX}	dBi	6.00	6.00	6.00	0.00	0.00	0.00
PSD_{interf}	dBm/MHz	-109.63	-109.63	-109.63	-109.63	-109.63	-109.63
N0	dBm/MHz	-108.86	-108.86	-108.86	-108.86	-108.86	-108.86
I/N	dB	-6.00	-6.00	-6.00	-6.00	-6.00	-6.00
Note: Parameters in the table are shown for TS BS with NF=5 dB. For the TS UE the NF=9 dB, so: N0 will be -104.86 dBm/MHz and PSD_{interf} will be -110.86 dBm/MHz, L_{path} will be 4 dB lower for the TS UE, D EHata will be reduced by a factor of 0.93 for those distances > 0.04 km, D EHata will be reduced by a factor of 0.63 for those distances < 0.04 km since they converge with FSPL, D FSPL will be reduced by a factor of 0.63 since -4 dB = 20 log10(0.63).							

4.3.4 MCL calculations

The calculation of Minimum Coupling Loss (MCL) computes a necessary path loss (L_{path}) and a corresponding path distance (D) using the EHata Urban path loss model.

EHata converges to a simple Free Space Path Loss (FSPL) for distances less than 40 meters.

$$\mathrm{FSPL} = 20\log10(4\pi D/\lambda) \quad (8)$$

where

- λ=c/f

When the distance is greater than 100 meters and the base height is 10 m, the EHata path loss is given by

$$EHata=42.56+35.22\ \log10(D) \quad (9)$$

For distances in between 40 and 100 meters the path loss is interpolated.

4.3.5 Summary

This section analyses the impact of terrestrial service (TS) in the MSS frequency band 2483.5-2495 MHz on Medical Body Area Network Systems (MBANS) receivers operating in the same frequency band. It also analyses the impact of MBANS equipment on TS receivers (UE and BS). The impact of the proposed TS using 10 MHz of bandwidth has been studied.

Study between TS systems and MBANS operating in the same band; assuming the median EHata Urban propagation model, gives median physical separation between TS systems and MBANS receivers summarised in the Tables below. This separation is readily provided by deploying TS systems away from health care facilities, or homes using MBANS equipment. The deployment of the proposed TS in the same building as MBANS equipment has not been studied. TS system using bandwidths of 5 MHz and 15 MHz would need higher and lower separation distances, respectively.

Table 50: Extract from Table 47: MCL Separation distance calculation, MBANS victim, TS interferer BS

Parameter	Units	Cat. 1 Outdoor TS	Cat. 2 Outdoor TS	Cat. 3 Outdoor TS	Cat. 1 IndoorTS	Cat. 2 IndoorTS	Cat. 3 IndoorTS
D EHata (urban)	km	0.11	0.11	0.14	0.05	0.05	0.05

Table 51: Extract from Table 48: MCL Separation distance calculation, MBANS victim, TS interferer UE

Parameter	Units	Cat. 1 Outdoor TS	Cat. 2 Outdoor TS	Cat. 3 Outdoor TS	Cat. 1 IndoorTS	Cat. 2 IndoorTS	Cat. 3 IndoorTS
D EHata (urban)	km	0.08	0.08	0.09	0.05	0.05	0.05

4.4 COMPATIBILITY WITH LP-AMI IN THE BAND 2483.5-2500 MHZ

Within the European Union (EU), the 2483.5-2500 MHz band is also used by a class of devices known as Low Power Active Medical Implants (LP-AMI). LP-AMIs are devices which are implanted in a patient's body, and which have wireless links to nearby peripheral (LP-AMI-P) devices, for the purposes of diagnosing and delivering therapy to individuals with various illnesses. LP-AMI / LP-AMI-P operation is restricted to indoor use. LP-AMI and LP-AMI-P devices belong to a class of devices defined in the EU as Short-Range Devices (SRDs) [22], which are low-power unlicensed devices which may not cause interference to other licensed services, and which are afforded no protection from other devices operating in the same or adjacent frequency bands.

This section analyses the impact of an LTE-based 2.4 GHz terrestrial service (TS) in the MSS frequency band 2483.5-2495 MHz on incumbent services in the same frequency band. The analysis determines the impact of LTE-based 2.4 GHz terrestrial transmitters on victim co-channel receivers and vice versa. One service that can share the band is the Low Power Active Medical Implant (LP-AMI) service.

The technical characteristics of the 2.4 GHz low power terrestrial service (TS) are given in section 3. The terrestrial service is time division duplex (TDD) with the transmit activity divided between the BS and UE. However, 100% transmit time has been used for the BS and the UE in the calculation. The TS system with 10 MHz is analysed here. This exceeds the 3 MHz bandwidth for LP-AMI, so the interference is calculated with the power spectral density (PSD) of the TS system signals.

4.4.1 LP-AMI system parameters

The active medical implant system consists of:

- Devices that are implanted in the body, and
- Peripheral devices, that are used to communicate with implanted devices.

The peripheral device (LP-AMI-P) is operated by a health care professional to exchange data with the implanted device (LP-AMI-D).

These two integral components of the LP-AMI system are linked by the logic of operation whereas LP-AMI-D may transmit only when queried by the stationary LP-AMI-P device. In such manner LP-AMI-P becomes an obligatory controlling device enabling the operation of entire LP-AMI system. And since LP-AMI-P is the professional device that will be connected to mains power supply and used in such indoor environments where diagnostics of patients take place, such as hospital wards, elderly care houses, and medical ambulatories, this would ensure the strict indoor operation of studied LP-AMI systems.

The above described different roles of LP-AMI-P and LP-AMI-D also mean that the role of these two components in sharing studies is different due to the fact, that LP-AMI-P will be the “master” device, i.e. the one which is steering all communications with LP-AMI-D, including sending it instructions to start transmissions and on which channel. LP-AMI-P also features higher and more stable transmitter output power, thanks to its mains electric supply. LP-AMI-P also has an exterior antenna, which compares very favourably against a less efficient micro-antenna of LP-AMI-D which negative gain is worsened by energy loss in body tissues.

The coexistence of LP-AMI with other services using subject bands will be aided by several factors:

LP-AMI-D may be transmitting only when cleared for that by controlling LP-AMI-P device, this will ensure that LP-AMI-Ds will only be transmitting in the indoor environments where LP-AMI-P are installed (hospital wards, elderly care houses, and similar institutions). This certainty of indoor usage will provide necessary mitigation of LP-AMI interference into other users of the subject bands that are used predominantly outdoors (MSS, RDSS).

In addition to the above natural shielding, the LP-AMI-P will be required to employ additional interference mitigation mechanisms such as Listen-Before-Transmit and Adaptive Frequency Selection (LBT/AFS). These mechanisms should be helpful for ensuring coexistence with other radiocommunications services and applications that may be used indoors. Other than aiding coexistence with some other services, the LBT/AFS will be also helpful for ensuring intra-service coexistence of LP-AMI, e.g. in hospital scenarios where more than one LP-AMI system may be used in close proximity to each other.

This section follows the analysis cases presented in ECC Report 149 [1]. These cases are listed in the table below. LP-AMI equipment can occupy 3 MHz channels from 2.4 GHz up to 2.5 GHz depending the deployment. This frequency range overlaps the TS low power terrestrial service in 2483.5-2500 MHz. The calculation will use an I/N ratio of 0 dB for LP-AMI as shown in the last column in the table below. An I/N ratio of -6 dB is used for TS receivers.

Table 52: Technical characteristics of LP-AMI cases

Case	Description	Range	Transmit Power	Antenna Gain	Frequencies	Interf. Condition	I/N
Case 1	AMI-P Peripheral	10 m	10 dBm	0 dBi	2.4835-2.5 GHz	Co-channel	0 dB
Case 2	AMI-D Device	10 m	-30 dBm	0 dBi	-	-	0 dB

The receiver noise figure in ECC Report 149 [1] for LP-AMI is given as 10 dB. The noise power, N0, is determined according to 4.1.1:

- N0 = -103.86 dBm/MHz for T=298°K; B=1 MHz; and F=10 (or 10 dB)

LP-AMI is a low power radio system used for the transmission of data between a peripheral medical device (AMI-P) and an implanted device (AMI-D). In most cases the data is transmitted from the AMI-P to the AMI-D so that the battery of the AMI-D can be conserved. In less frequent cases, the AMI-D can transmit data back to the AMI-P.

4.4.1.1 An example for healthcare facilities

An example for healthcare facilities (e.g. hospitals) is shown in Figure 12. The LP-AMI-P peripheral device is operated by a health care professional to transmit data to the implanted device (LP-AMI-D). The implanted device is battery powered so it operates at a low power to conserve battery energy.

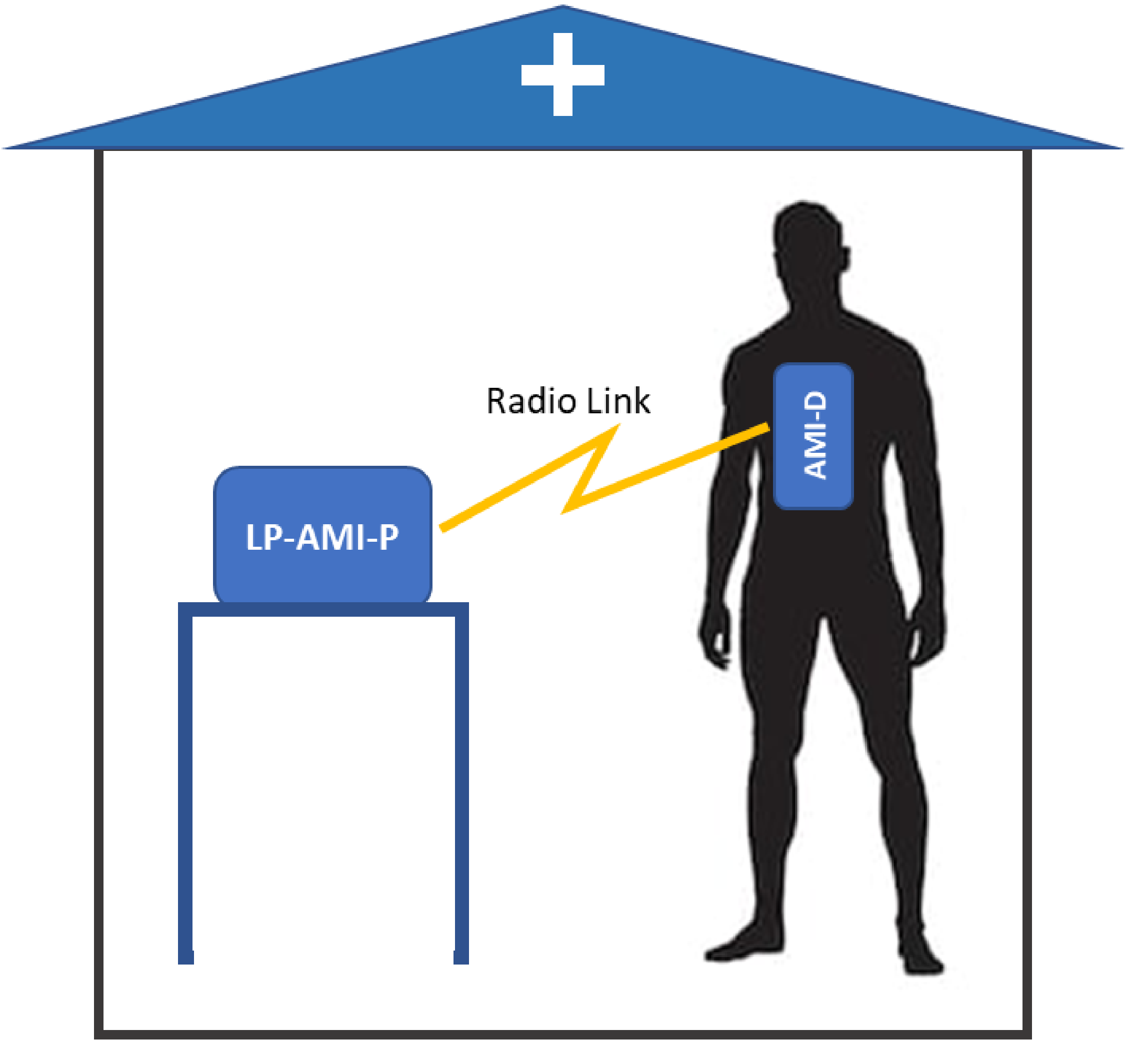

Figure 12: LP-AMI example

4.4.1.2 LP-AMI system parameters

This is a table of selected system parameters from ECC Report 149 [1].

Table 53: LP-AMI system parameters-Transmit

Parameter	Value
Frequency	2400-2500 MHz
Channel Bandwidth	1 MHz
Power, P / D	10 / 0 dBm

Table 54: LP-AMI system parameters-Receive

Parameter	Value
Frequency	2400-2500 MHz
Channel Bandwidth	1 MHz
Reference Sensitivity	-91.9 dBm
Noise Figure	10 dB

4.4.1.3 LP-AMI antenna parameters

Selected specifications from ECC Report 219 [5].

Table 55: LP-AMI antenna parameters-Transmit

Parameter	Value
Type	Omnidirectional
Gain	0 dBi

Table 56: LP-AMI antenna parameters-Receive

Parameter	Value
Type	Omnidirectional
Gain	0 dBi

4.4.2 Scenarios

The interference scenarios to be considered are depicted in Figure 13.

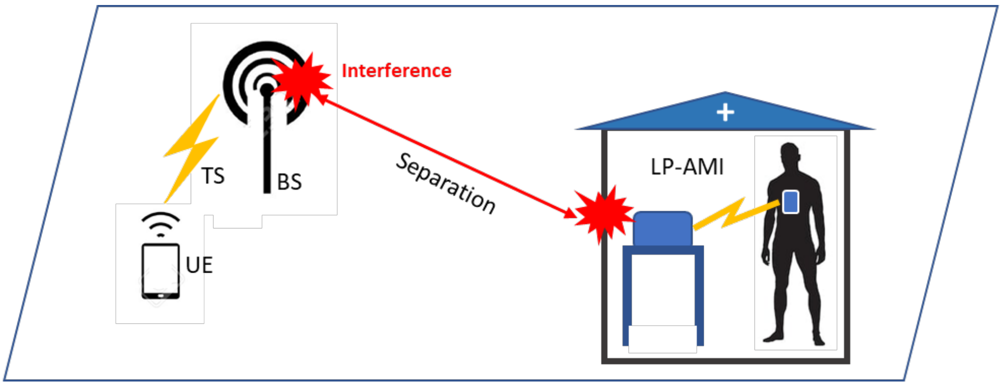

Figure 13: Interference cases

4.4.3 Study

4.4.3.1 Separation distance urban environment

The MCL calculations for each of the cases is summarised in Table 58, Table 59 and Table 60. The separation distance is calculated from the EHata path loss model for Urban environments [20]. The path loss depends on the antenna heights. The typical antenna heights for LP-AMI or TS are congruent with the Urban Environment. The Urban model converges to a Free Space Path Loss (FSPL) model for distances less than 40 m. The model also includes log normal fading.

The transmitted interference power spectral density (PSDtx) is computed in Table 57. The second last line in the table gives the total emitted power spectral density.

Table 57: TS interference PSD calculation

Parameter	Unit	BS (outdoor)	UE (outdoor)	BS (indoor)	UE (indoor)
P	dBm	30.00	24.00	20.00	20.00
GTX	dBi	6.00	0.00	0.00	0.00
hTX	m	10.00	1.50	1.50	1.50
BW	MHz	10.00	10.00	10.00	10.00
PSDtx	dBm/MHz	26.00	14.00	10.00	10.00

Table 58, Table 59 and Table 60 show the MCL calculations for the separation distance for each of the LP-AMI cases in Table 52. The separation distance is given on the D line in each table for each case.

The PSD_{interf} in the receiver is computed from the PSDtx power spectral density:

$$PSD_{interf} = PSDtx - L_{path} + G_{0RX} - BEL \qquad \text{and } L_{path} = Urban(D). \qquad (10)$$

The antenna gain parameters are G_{0RX} for the victim receiver, and G0TX for the transmitter. The G_{0RX} parameter represents the maximum directional gain of the receive antenna. The BEL parameter is set to 15 dB of attenuation through a single building wall and 30 dB for two building walls as may apply for an indoor system interfering with another indoor system in a different building[4].

Table 58: MCL Separation distance calculation, LP-AMI victim, TS interferer BS

Parameter	Units	Case 1 Outdoor TS	Case 2 Outdoor TS	Case 1 Indoor TS	Case 2 Indoor TS
D EHata (urban)	km	0.11	0.06	0.06	0.04
D FSPL	km	5.31	0.24	0.15	0.01
Lpath	dB	114.86	87.86	83.86	56.86
G_{0RX}	dBi	0.00	0.00	0.00	0.00
BEL	dB	15.00	15.00	30.00	30.00
Body Loss	dB	0.00	27.00	0.00	27.00
PSD_{interf}	dBm/MHz	-103.86	-103.86	-103.86	-103.86
N0	dBm/MHz	-103.86	-103.86	-103.86	-103.86
I/N	dB	0.00	0.00	0.00	0.00

Table 59: MCL Separation distance calculation, LP-AMI victim, TS interferer UE

Parameter	Units	Case 1 Outdoor TS	Case 2 Outdoor TS	Case 1 Indoor TS	Case 2 Indoor TS
D EHata (urban)	km	0.08	0.04	0.05	0.01
D FSPL	km	1.33	0.06	0.15	0.01

4 BEL is set to 15 dB as per 3GPP TR 38.901, section 7.4.3.1 for concrete material

Parameter	Units	Case 1 Outdoor TS	Case 2 Outdoor TS	Case 1 Indoor TS	Case 2 Indoor TS
L_{path}	dB	102.86	75.86	83.86	56.86
G_{0RX}	dBi	0.00	0.00	0.00	0.00
BEL	dB	15.00	15.00	30.00	30.00
Body Loss	dB	0.00	27.00	0.00	27.00
PSD_{interf}	dBm/MHz	-103.86	-103.86	-103.86	-103.86
N0	dBm/MHz	-103.86	-103.86	-103.86	-103.86
I/N	dB	0.00	0.00	0.00	0.00

Table 60: MCL Separation distance calculation, LP-AMI interferer, TS victim BS or UE

Parameter	Units	Case 1 Outdoor TS	Case 2 Outdoor TS	Case 1 Indoor TS	Case 2 Indoor TS
P	dBm	10.00	0.00	10.00	0.00
G_{0TX}	dBi	0.00	0.00	0.00	0.00
BEL	dB	15.00	15.00	30.00	30.00
Body Loss	dB	0.00	27.00	0.00	27.00
BW	MHz	1.00	1.00	1.00	1.00
PSDtx	dBm/MHz	-5.00	-42.00	-20.00	-57.00
D EHata (urban)	km	0.09	0.03	0.05	0.00
D FSPL	km	1.88	0.03	0.17	0.00
L_{path}	dB	105.86	68.86	84.86	47.86
G0RX	dBi	6	6	0	0
PSD_{interf}	dBm/MHz	-104.86	-104.86	-104.86	-104.86
N0	dBm/MHz	-108.86	-108.86	-108.86	-108.86
I/N	dB	-6	-6	-6	-6
Note: Parameters from the table are shown for TS BS with NF=5 dB. For the TS UE the NF=9 dB, so: N0 will be -104.86 dBm/MHz and PSD_{interf} will be -110.86 dBm/MHz, L_{path} will be 4 dB lower for the TS UE, D EHata will be reduced by a factor of 0.93 for those distances > 0.04 km, D EHata will be reduced by a factor of 0.63 for those distances < 0.04 km since they converge with FSPL, D FSPL will be reduced by a factor of 0.63 since -4 dB = 20 log10(0.63).					

4.4.4 MCL calculations

The calculation of Minimum Coupling Loss (MCL) computes a necessary path loss (L_{path}) and a corresponding path distance (D) using the EHata Urban path loss model.

EHata converges to a simple Free Space Path Loss (FSPL) for distances less than 40 meters.

$$\mathrm{FSPL} = 20\log10(4\pi D/\lambda) \quad (11)$$

where

- λ=c/f

When the distance is greater than 100 meters and the base height is 10 m, the EHata path loss is given by

$$\mathrm{EHata} = 42.56 + 35.22\,\log10(\mathrm{D}) \quad (12)$$

For distances in between 40 and 100 meters the path loss is interpolated.

4.4.5 Summary

This section analyses the impact of terrestrial service (TS) in the MSS frequency band 2483.5 – 2495 MHz on Low Power Active Medical Implant (LP-AMI) receivers operating in the same frequency band. It also analyses the impact of LP-AMI equipment on TS receivers (UE and BS). The impact of the proposed TS using 10 MHz of bandwidth has been studied.

Study between TS and LP-AMI operating in the same band, assuming the median EHata Urban propagation model gives median physical separation between TS systems and the LP-AMI receivers summarized in the Tables below. This separation is readily provided by deploying TS systems away from health care facilities using LP-AMI equipment. The deployment of the proposed TS in the same building as MBANS equipment has not been studied. TS system using bandwidths of 5 MHz and 15 MHz would need higher and lower separation distances, respectively.

Table 61: Extract from Table 58: MCL Separation distance calculation, LP-AMI victim, TS interferer BS

Parameter	Units	Case 1 Outdoor TS	Case 2 Outdoor TS	Case 1 Indoor TS	Case 2 Indoor TS
D EHata (urban)	km	0.11	0.06	0.06	0.04

Table 62: Extract from Table 59: MCL Separation distance calculation, LP-AMI victim, TS interferer UE

Parameter	Units	Case 1 Outdoor TS	Case 2 Outdoor TS	Case 1 Indoor TS	Case 2 Indoor TS
D EHata (urban)	km	0.08	0.04	0.05	0.01

4.5 COMPATIBILITY WITH PMSE IN THE BAND 2483.5-2500 MHZ

Several administrations already deploy terrestrial services operating in the band 2483.5-2500 MHz, for example, hand-held radio cameras and the associated broadcast auxiliary services used for video programme making and video transmission. These services, also known under the generic term of Programme Making and Special Events (PMSE) applications, are termed Services Ancillary to Broadcasting (SAB) and Services Ancillary to Programme-making (SAP), and have successfully operated in this band for many years without interference from MSS downlink signals.

Typical SAP/SAB broadcast scenarios generally involve wireless cameras which can be hand-held, mounted on a vehicle or in some cases airborne. The signals from these cameras are received by using 4- or 8-way diversity or auto tracking antenna systems. These antenna systems can be mounted on a tripod, vehicle, helicopter, aircraft, mast or other structure, here below referred as SAP/SAB receiver.

This section analyses the impact of an LTE-based 2.4 GHz terrestrial service (TS) in the MSS frequency band 2483.5-2495 MHz on secondary incumbent services in the same frequency band. The analysis determines the impact of TS 2.4 GHz terrestrial transmitters on victim co-channel receivers and vice versa. One service that can share the band is the Programme Making Special Events (PMSE) service.

The technical characteristics of the 2.4 GHz low power terrestrial service are given in section 3. The terrestrial service is time division duplex (TDD) with the transmit activity divided between the BS and

UE. However, 100% transmit time has been used for the BS and the UE in the calculation. The TS system with 10 MHz is analysed here to coincide with the PMSE bandwidth when operated co-frequency.

4.5.1 PMSE System Parameters

This section uses assumptions given in ECC Report 219 [5]. These cases are listed in Table 63 and illustrated in Figure 14 and Figure 15.

Table 63: Technical characteristics of PMSE video links [ECC Report 219, table 2 [5]]

Case	Type of Link	Range	Typical Tx power	Tx antenna gain @ height agl (note 1)	Rx antenna gain @ height agl (note 1)	Frequency range (GHz)
1	Radio Camera Line-of-Sight	< 500 m	20 dBm	0 -3 dBi @1-2 m	3-13 dBi @2-60 m	2-8
2	Radio Camera Non-Line-of-Sight	< 500 m	20 dBm	0 -3 dBi @1-2 m	3-13 dBi @2-60 m	2-3.5
3	Miniature Link	< 200 m	20 dBm	0-3 dBi @ 100 m	3-13 dBi @ 2-60 m	2 -3.5
4	Portable Link	< 2 km	33 dBm	6-14 dBi @ 1-4 m	9-17 dBi @ 2-60 m	2-8 depending on path
5	Mobile vehicular Link (including ground-to-air)	< 10 km	30 dBm	3-9 dBi @1-4 m	10-13 dBi @ 2-60 m 4-9 dBi @150 m-6 km (airborne)	23.5
6	Air to ground Link	< 100 km	36 dBm	3-9 dBi @ 15 m-6 km	17-24 dBi (2 GHz) 34 dBi (7 GHz) @ 2-60 m	<8
Note 1: Typical and maximum value						

PMSE equipment can occupy 8 MHz channels from 2 GHz up to 10 GHz depending the deployment. This frequency range overlaps the TS low power terrestrial service in 2483.5 MHz to 2500 MHz. This report considers the condition for the cases in Table 63 for co-channel sharing such that the 8 MHz channel for PMSE coincides with a 10 MHz TS low power terrestrial deployment. The calculation will use an I/N ratio of -6 dB [5] .

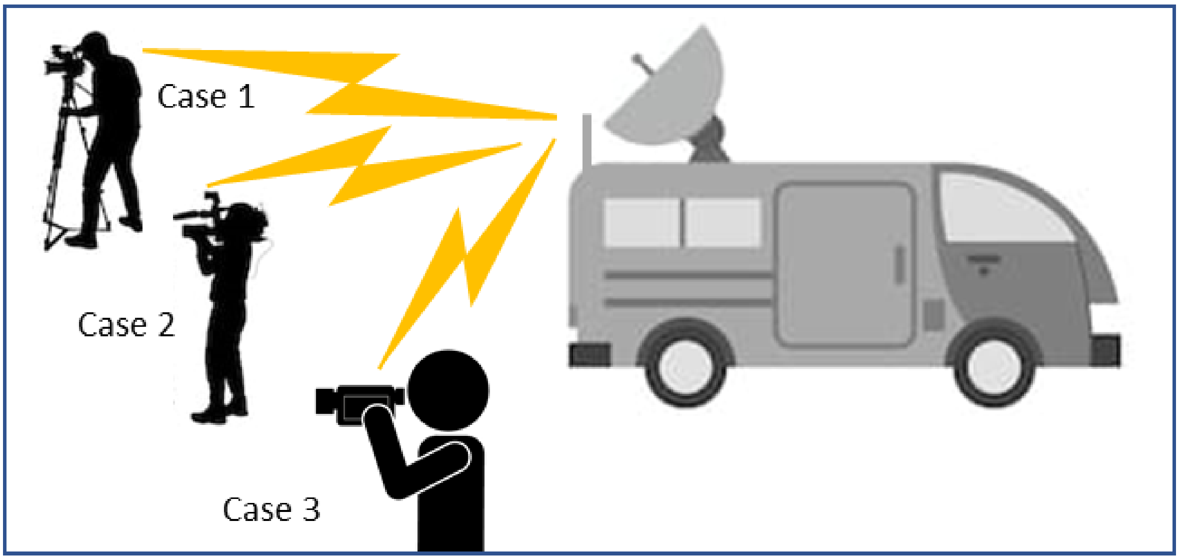

Figure 14: PMSE Cases 1, 2, and 3

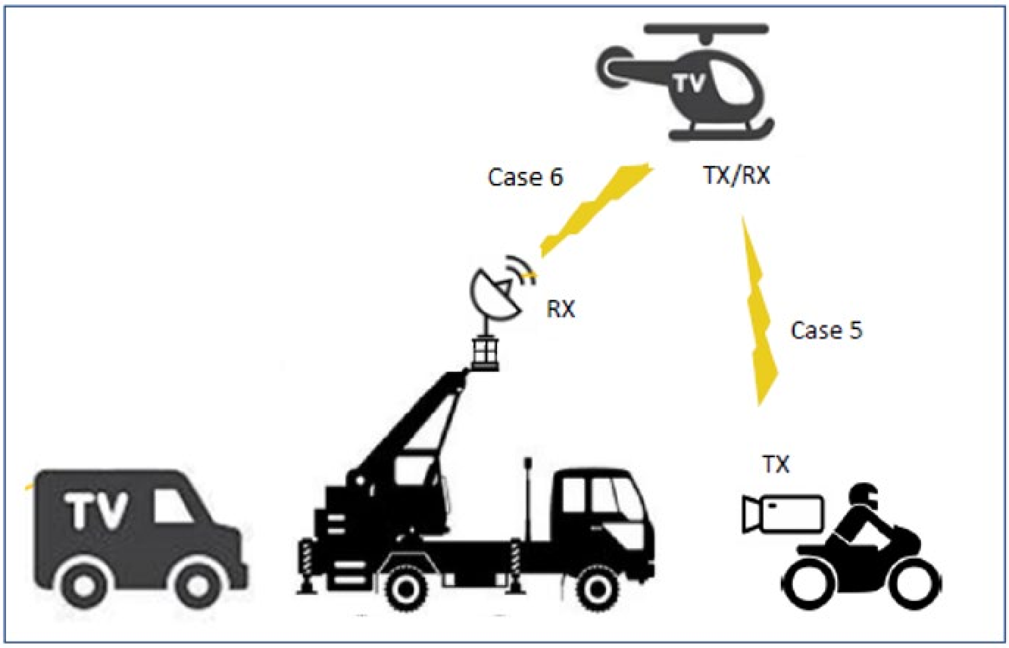

Figure 15: PMSE Cases 5 and 6

The receiver noise figure in Recommendation ITU-R F.1777 [43] for PMSE is given as 2.5 dB for systems deployed a 2.5 GHz and 4 dB for systems deployed at 5 GHz. The noise power, N0, is determined according to 4.1.1:

- N0 = -111.4 dBm/MHz for T=298°K; B=1 MHz; and F=2.5 for system deployed at 2.5 GHz;
- N0 = -109,9 dBm/MHz for T=298°K; B=1 MHz; and 4 dB otherwise

Table 63 shows a large spreading for gain, transmit and receive altitudes.

The reason is that each event requires a different approach. WRC rally racing and Formula1 are both about car race events, but for live coverage the RF approach is totally different. WRC rally racing uses a high-altitude fixed wing airplane for relaying the onboard cameras whereas Formula 1 is using multiple receive sites along the track.

Helicopter camera work is carried out between 0 ft. and 500 ft. (0 km to 0.15 km), depending on local regulations for single- or twin-engine helicopters. Using a helicopter as a microwave midpoint flight levels between 1000 ft. and 3000 ft (300 m and 1 km) are normally granted. For larger distances and longer endurance fixed wing airplanes are used and they operate usually between 10000 ft. and 30000 ft (3 km to 9 km). depending on local regulations and available flight levels (i.e., even above the altitudes given in Table 63.

The following figure provides an example of the altitude of a flight when covering an event.

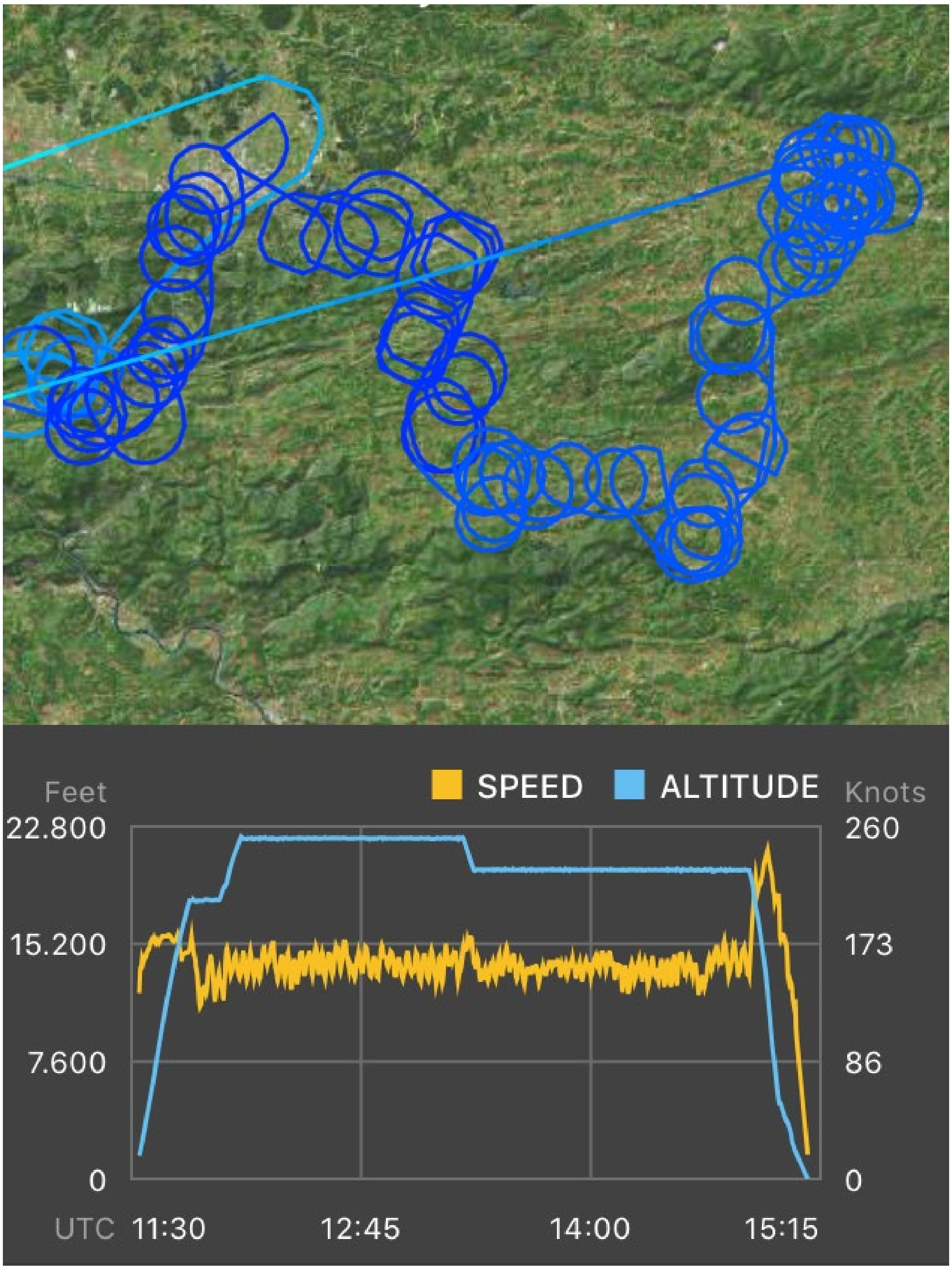

Figure 16: Flight pattern copied from flight radar 24 showing the flightpath at 7km. of a relay airplane during the live coverage of a cycling race)

Depending on the track to cover, reception is done using aerial midpoints or multiple terrestrial receiving sites connected via point to point IP links or via fibre to the television production centre.

Since 2002, broadcasters moved from analogue wireless cameras to digital.

DVB-T(terrestrial) was chosen for modulation in combination with diversity reception for getting the best results in case the transmitter or receiver or both are moving. PMSE is using spatial and polarization diversity in combination with two or more antennas to improve the quality (maximum ratio combining) and reliability of the wireless link (SIMO). The antenna height figures for the wireless camera are typical around 2 meters, however during the honouring at Formula1 or MotoGp the wireless cameras are no longer at ground level but a few meters up. Also, for Golf tournaments wireless cameras on platforms are used which are higher than the figure mentioned in Table 63.

The figure below is showing a terrestrial PMSE receiver setup as for instance used during a Formula 1 or Moto GP race.

For a line-of-sight situation like the downlink from an aircraft, a single receiver in combination with a dish antenna and auto tracker is used (SISO).

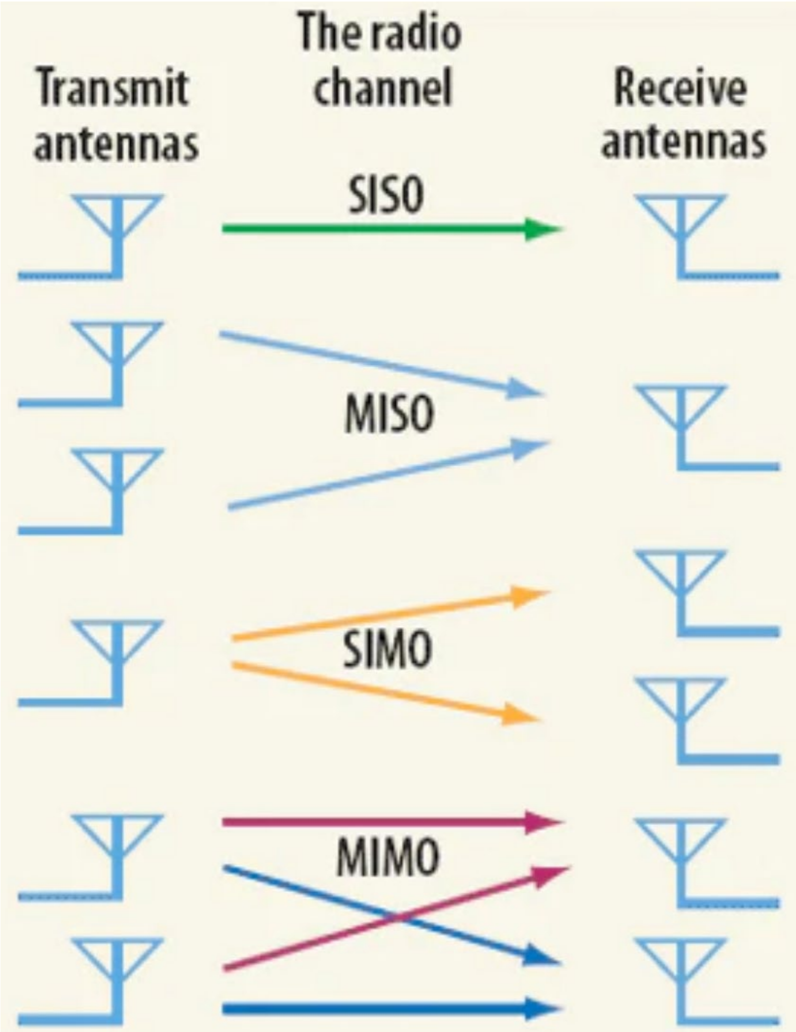

Figure 17: The radio link channel models

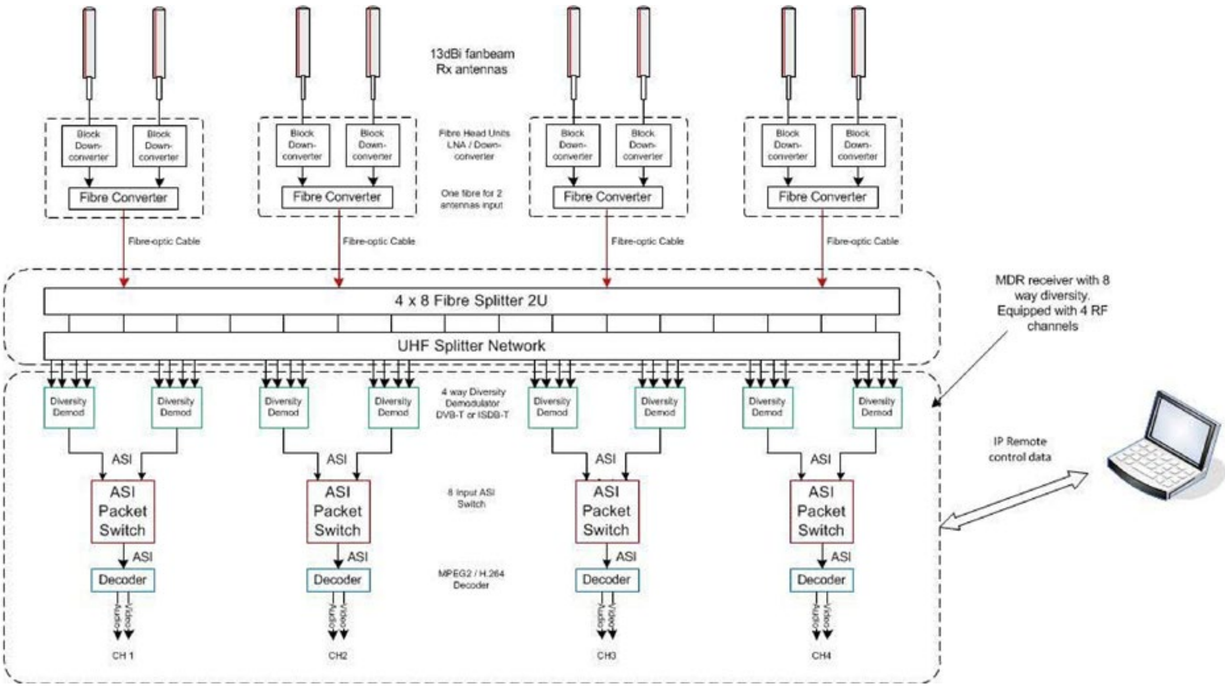

Figure 18: Vislink 8-way diversity PMSE reception system

The figure below is showing an auto tracker which is used for tracking microwave links coming from relay- or camera helicopters or from high altitude relay aircrafts.

Figure 19: Auto-tracker antenna

As an example, the gain as mentioned in Table 63 of 13 dBi. can be achieved using different types of antennas:

- by dish antenna;
- by patch antenna;
- by stacked dipole;
- by helix;
- by yagi.

Depending on the use case and the track to cover, polarization (linear, circular or a combination) and antenna pattern are chosen to achieve the wanted result. Combining antenna patterns by using diversity reception (see Figure 16) will create a virtual new antenna pattern with (in our example) a maximum gain of 13dBi. in multiple directions.

In conclusion, only the main lobe scenarios are considered in this report.

4.5.1.1 PMSE system parameters

This is a table of selected system parameters from ETSI EN 302 064 [23].

Table 64: PMSE system parameters-Transmit

Parameter	Value
Frequency	2000-8000 MHz
Channel Bandwidth	8 MHz
Power	20 to 36 dBm
ACLR, Block 2, Max / Min	-42 dB / -52 dB
ACLR, Block 3, Max / Min	-45 dB / -55 dB
Spurious emissions, > 1000 MHz, Operating	-30 dBm / MHz

Table 65: PMSE system parameters-Receive

Parameter	Value
Frequency	2000-8000 MHz
Channel Bandwidth	8 MHz
Reference Sensitivity	-93 dBm to -76 dBm (see ETSI EN 302 064 [23])
Noise Figure	2.5 dB for Cases 1-6, 4 dB for Case 7
ACS	30 dB
Blocking	40 dB

4.5.2 Scenarios

The interference scenarios to be considered are depicted in Figure 20.

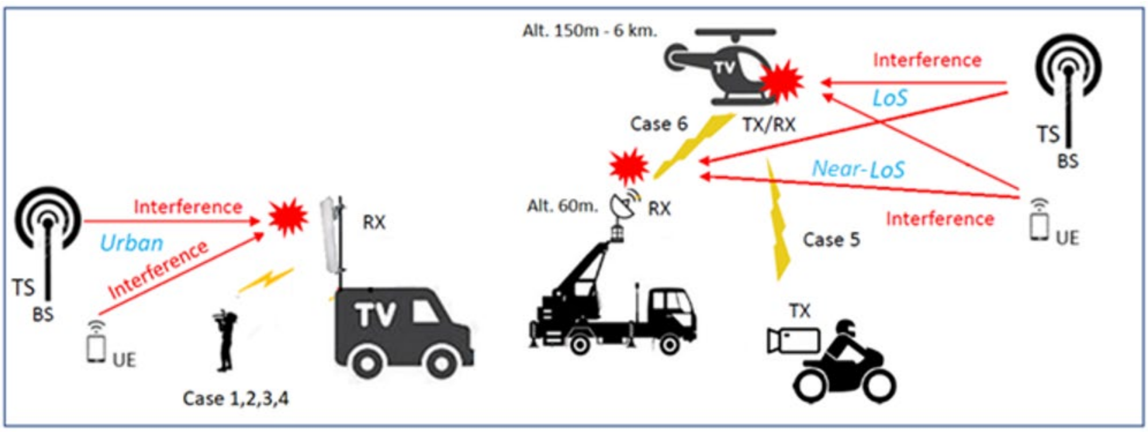

Figure 20: Summary of Interference for PMSE Cases

4.5.3 Study

4.5.3.1 Separation distance urban environment

The MCL calculations for each of the cases is summarise in the tables below. Table 66 calculates the average TS transmitter power spectral density (PSDtx). This result is then used in subsequent tables for PMSE victims. The separation distance is calculated from the EHata path loss model for Urban environments [20] and considering the free space model where applicable.

For the EHata model, the path loss depends on the antenna heights. For the cases where the highest antenna height was below EHata minimum of 30 m, the model was extended to cover the cases of 10 m antenna height (outdoor) or 2 m antenna height (indoor) for the BS and 1.5 m antenna height for the UE independent of the PMSE antenna height.

The EHata model converges to the Free Space Path Loss (FSPL) model for distances less than 40 m. The model also includes log normal fading.

For the PMSE antenna heights, the maximum antenna heights given in Table 63are considered depending on the case and depending on the PMSE situation (receiver or transmitter).

The transmitted interference power spectral density (PSDtx) is computed in Table 66.

Table 66: TS interference PSD calculation

Parameter	Unit	Outdoor BS	Outdoor UE	Indoor BS	Indoor UE
P	dBm	30.00	24.00	20.00	20.00
GTX	dBi	6.00	0.00	0.00	0.00
BW	MHz	10.00	10.00	10.00	10.00
PSD	dBm/MHz	26.00	14.00	10.00	10.00
PSDtx	dBm/MHz	26.00	14.00	10.00	10.00
PSD spurious emissions	dBm/MHz	-30.00	-30.00	-30.00	-30.00

Table 67 and the following tables Table 68, Table 69, Table 70, Table 71 and Table 72 show the MCL calculations for the separation distance for each of the PMSE cases in Table 63.

The D EHata line gives the distance for the EHata urban path loss model, while D FSPL gives the distance for Free Space Path Loss. In many cases the FSPL distance can exceed the distance to the radio horizon, so the radio horizon distance is also tabulated on the bottom line in Table 67 and the following tables Table 68, Table 69, Table 70, Table 71 and Table 72.

The receiver antenna gain parameter is G_{0RX}. The G_{0RX} parameter represents the maximum directional gain of the receiving antenna.

Table 67: MCL Separation distance calculation, along antenna boresight, PMSE victim, outdoor TS interferer BS

Parameter	Unit	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
N0	dBm/MHz	-111.36	-111.36	-111.36	-111.36	-111.36	-111.36
I/N	dB	-6.00	-6.00	-6.00	-6.00	-6.00	-6.00
PSD_{interf}	dBm/MHz	-117.36	-117.36	-117.36	-117.36	-117.36	-117.36
G_{0RX}	dBi	13.00	13.00	13.00	17.00	9.00	24.00
H BS	m	10.00	10.00	10.00	10.00	10.00	10.00

Parameter	Unit	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
H PMSE	m	60.00	60.00	60.00	60.00	6000.00	60.00
L_{path}	dB	156.36	156.36	156.36	160.36	152.36	167.36
D EHata (urban)	km	24.40	24.40	24.40	29.00	32.70 (note 1)	38.00
D FSPL	km	631.00	631.00	631.00	999.40	398.10	2238.90
D horizon	km	45.00	45.00	45.00	45.00	332.50	45.00
Note 1: EHata with maximum antenna height higher than 200m might lead to significant errors (see ECC Rep. 25, Section A.17.3.1).							

For the co-channel case:

- The separation distances extend from 24 km to 38 km assuming the EHata model and the parameters mentioned above;
- Assuming FSPL model the separation distances are from 631 km to 2238 km

The same calculation for the PMSE interferer and outdoor TS victim BS is given in Table 68. The transmitter parameters for cases 1 through 6 use transmitter parameters from ECC Report 219 [5].

Table 68: MCL Separation distance calculation, along antenna boresight, PMSE interferer, outdoor TS victim BS

Parameter	Unit	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
P	dBm	20.00	20.00	20.00	33.00	30.00	36.00
G0TX	dBi	3.00	3.00	3.00	14.00	9.00	9.00
BW	MHz	8.00	8.00	8.00	8.00	8.00	8.00
PSDtx	dBm/MHz	13.97	13.97	13.97	37.97	29.97	35.97
N0	dBm/MHz	-108.86	-108.86	-108.86	-108.86	-108.86	-108.86
I/N	dB	-6.00	-6.00	-6.00	-6.00	-6.00	-6.00
PSD_{interf}	dBm/MHz	-114.86	-114.86	-114.86	-114.86	-114.86	-114.86
G_{0RX}	dBi	6.00	6.00	6.00	6.00	6.00	6.00
H BS	m	10.00	10.00	10.00	10.00	10.00	10.00
H PMSE	m	2.00	2.00	100.00	4.00	1 40	6000.00
L_{path}	dB	134.83	134.83	134.83	158.83	150.83	156.83
D EHata (urban)	km	0.50	0.50	7.70	3.00	1.90	33.60 (note 1)
D FSPL	km	48.30	48.30	49.40	766.20	324.90	665.50
D horizon	km	18.90	18.90	54.30	21.30	21.30	332.50
Note 1: EHata with maximum antenna height higher than 200m might lead to significant errors (see ECC Rep., Section A.17.3.1).							

For the co-channel case:

- The separation distances extend from 0.5 km to 33.6 km assuming the EHata model and the parameters mentioned above;
- Assuming the free space path loss model the separation distances go from 48 km to 766 km.

Table 69 and Table 70 repeat the MCL calculations from the previous two tables, but this time for indoor TS BS deployment. They use the TS power levels from Table 66 for the indoor condition, and they include a 15 dB BEL[5].

Table 69: MCL Separation distance calculation, along antenna boresight, PMSE victim, indoor TS interferer BS

Parameter	Unit	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
N0	dBm/MHz	-111.36	-111.36	-111.36	-111.36	-111.36	-111.36
I/N	dB	-6.00	-6.00	-6.00	-6.00	-6.00	-6.00
PSD_{interf}	dBm/MHz	-117.36	-117.36	-117.36	-117.36	-117.36	-117.36
G_{0RX}	dBi	13.00	13.00	13.00	17.00	9.00	24.00
BEL	dB	15.00	15.00	15.00	15.00	15.00	15.00
H BS	m	2.00	2.00	2.00	2.00	2.00	2.00
H PMSE	m	60.00	60	60	60	6000	60
L_{path}	dB	125.36	125.36	125.36	129.36	121.36	136.36
D EHata	km	0.5	0.5	0.5	0.7	5.8 (note 1)	1.2
D FSPL	km	16.70	16.70	16.70	26.90	9.30	57.60
Note 1: EHata with maximum antenna height higher than 200m might lead to significant errors (see ECC Rep. 25, Section A.17.3.1).							

For the co-channel case:

- The separation distances extend from 0.5 km to 5.8 km assuming the EHata model and the parameters mentioned above;
- Assuming the free space path loss model the separation distances go from 9.3 km to 57.6 km.

The same calculation for the PMSE interferer and indoor TS victim BS is given in Table 70. The transmitter parameters for cases 1 through 6 use transmitter parameters from ECC Report 219 [5].

Table 70: MCL Separation distance calculation, along antenna boresight, PMSE interferer, indoor TS victim BS

Parameter	Unit	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
P	dBm	20.00	20.00	20.00	33.00	30.00	36.00
G0TX	dBi	3.00	3.00	3.00	14.00	9.00	9.00
BW	MHz	8.00	8.00	8.00	8.00	8.00	8.00
PSDtx	dBm/MHz	13.97	13.97	13.97	37.97	29.97	35.97
N0	dBm/MHz	-108.86	-108.86	-108.86	-108.86	-108.86	-108.86
I/N	dB	-6.00	-6.00	-6.00	-6.00	-6.00	-6.00
PSD_{interf}	dBm/MHz	-114.86	-114.86	-114.86	-114.86	-114.86	-114.86
G_{0RX}	dBi	0.00	0.00	0.00	0.00	0.00	0.00.00
BEL	dB	15.00	15.00	15.00	15.00	15.00	15.00.00
H BS	m	2.00	2.00	2.00	2.00	2.00	2.00
H PMSE	m	2.00	2.00	100.00	4.00	4.00	6000.00
L_{path}	dB	113.83	113.83	113.83	137.83	129.83	135.83

[5] BEL is set to 15 dB as per 3GPP TR 38.901, section 7.4.3.1 for concrete material

Parameter	Unit	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
D EHata (urban)	km	0.08	0.08	0.30	0.31	0.19	21.33 (note 1)
D FSPL	km	4.40	4.40	4.40	70.70	27.30	54.40
Note 1: EHata with maximum antenna height higher than 200m might lead to significant errors (see ECC Rep. 25, Section A.17.3.1).							

For the co-channel case:

- The separation distances extend from 0.08 km to 21 km assuming the EHata model and the parameters mentioned above;
- Assuming the free space path loss model the separation distances go from 4.4 km to 70.7 km.

Table 71 and Table 72 repeat the MCL calculations for TS outdoor UE deployment.

Table 71: MCL Separation distance calculation, along antenna boresight, PMSE victim, outdoor TS interferer UE

Parameter	Unit	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
N0	dBm/MHz	-111.36	-111.36	-111.36	-111.36	-111.36	-111.36
I/N	dB	-6.00	-6.00	-6.00	-6.00	-6.00	-6.00
PSD_{interf}	dBm/MHz	-117.36	-117.36	-117.36	-117.36	-117.36	-117.36
G_{0RX}	dBi	13.00	13.00	13.00	17.00	9.00	24.00
H UE	m	1.50	1.50	1.50	1.50	1.50	1.50
H PMSE	m	60.00	60.00	60.00	60.00	6000.00	60.00
L_{path}	dB	144.36	144.36	144.36	148.36	140.36	155.36
D Ehata (urban)	km	1.90	1.90	1.90	2.50	22.50 (note 1)	4.10
D FSPL	km	151.60	151.60	151.60	244.10	96.40	523.30
D horizon	km	37.00	37.00	37.00	37.00	324.50	37.00
.Note 1: Extended Hata with maximum antenna height higher than 200m might lead to significant errors (see ECC Rep. 25, Section A.17.3.1).							

For the co-channel case:

- The separation distances extend from 1.9 km to 22.5 km assuming the EHata model and the parameters mentioned above;
- Assuming the free space path loss model the separation distances go from 151.6 km to 523 km.

Table 72: MCL Separation distance calculation, along antenna boresight, PMSE interferer, outdoor TS victim UE

Parameter	Unit	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
P	dBm	20.00	20.00	20.00	33.00	30.00	36.00
G0TX	dBi	3.00	3.00	3.00	14.00	9.00	9.00
BW	MHz	8.00	8.00	8.00	8.00	8.00	8.00
PSDtx	dBm/MHz	13.97	13.97	13.97	37.97	29.97	35.97
N0	dBm/MHz	-104.86	-104.86	-104.86	-104.86	-104.86	-104.86
I/N	dB	-6.00	-6.00	-6.00	-6.00	-6.00	-6.00
PSD_{interf}	dBm/MHz	-110.86	-110.86	-110.86	-110.86	-110.86	-110.86

Parameter	Unit	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
G_{0RX}	dBi	0.00	0.00	0.00	0.00	0.00	0.00
H UE	m	1.50	1.50	1.50	1.50	1.50	1.50
H PMSE	m	2.00	2.00	100.00	4.00	4.00	6000.00
L_{path}	dB	124.83	124.83	124.83	148.83	140.83	146.83
D Ehata (urban)	km	0.10	0.10	0.60	0.60	0.30	24.80 (note 1)
D FSPL	km	16.70	16.70	16.70	244.10	103.50	206.50
D horizon	km	45.00	45.00	45.00	45.00	332.50	45.00
Note 1: EHata with maximum antenna height higher than 200m might lead to significant errors (see ECC Rep. 25, Section A.17.3.1).							

For the co-channel case:

- The separation distances extend from 0.1 km to 24.8 km assuming the EHata model and the parameters mentioned above;
- Assuming the free space path loss model the separation distances go from 16.7 km to 244 km.

The MCL separation distances along the antenna boresight for PMSE victims from an indoor TS UE interferer, is the same as for the indoor TS BS given in Table 69, since the indoor TS BS and indoor TS UE have the same power levels and antenna gains.

The MCL separation distances along the antenna boresight for indoor TS UE victims from PMSE interferer, is somewhat less than for the indoor TS BS given in Table 70, since the UE receiver noise figure is 4 dB higher than the BS noise figure.

4.5.4 Summary

Study between TS and PMSE systems operating in the same band, assuming the median EHata propagation model, gives median physical separation between TS systems and the PMSE systems summarized in the following table. The impact of the proposed TS using 10 MHz of bandwidth has been studied. TS system using bandwidths of 5 MHz and 15 MHz would need higher and lower separation distances, respectively.

Table 73: MCL separations distances when PMSE and the new terrestrial applications are operated co-frequency

Victim	Interferer	Separation distances using EHata (urban) (cases 1 to 4) (km)	Separation distances using free space loss/radio horizon (cases 1 to 4) (km)	Separation distances using EHata (urban) (cases 5 to 6) (km)	Separation distances using free space loss/radio horizon (cases 5 to 6) (km)
PMSE	Outdoor BS	24.4 to 28	45	32.7 to 38 (note 1)	45 to 332
PMSE	Indoor BS/ Indoor UE	0.5 to 0.7	16.7 to 26.9	1.2 to 5.8 (note 1)	9.3 to 57.6
PMSE	Outdoor UE	1.9 to 2.5	37	4.1 to 22.5 (note 1)	37 to 324

Victim	Interferer	Separation distances using EHata (urban) (cases 1 to 4) (km)	Separation distances using free space loss/radio horizon (cases 1 to 4) (km)	Separation distances using EHata (urban) (cases 5 to 6) (km)	Separation distances using free space loss/radio horizon (cases 5 to 6) (km)
Outdoor BS	PMSE	0.5 to 7.7	18.9 to 54.3	1.9 to 33.6 (note 1)	21.3 to 332.5
Indoor BS/ Indoor UE	PMSE	0.08 to 0.31	4.4 to 70.7	0.19 to 21.33 (note 1)	27.3 to 50.4
Outdoor UE	PMSE	0.1 to 0.6	16.7 to 45	0.3 to 24.8 (note 1)	45 to 103.5
Note 1: EHata with maximum antenna height higher than 200m might lead to significant errors (see ECC Rep. 252, Section A.17.3.1).					

The table above provides the calculated separations distances when PMSE and the new terrestrial applications are operated co-frequency. Considering those distances, mitigation techniques may be needed to ensure the coexistence of PMSE and the new terrestrial applications when operated co-frequency.

The analysis considered antenna heights and antenna gains with maximum values resulting in upper limit of the calculated separation distances.

4.6 COMPATIBILITY WITH E-UTRA BAND 7 ABOVE 2500 MHZ

4.6.1 Introduction

This section analyses the potential impact of proposed terrestrial service (TS) in the 2483.5-2500 MHz frequency band on adjacent E-UTRA Band 7 Uplink (UL) occupying 2500-2570 MHz. The analysis considers on the impact of TS out-of-band (OoB) emission on base station (BS) receiver operation in adjacent Band 7 and the impact of Band 7 BS receiver blocking due to TS in-band emission. This report assumes that the Band 7 systems are based on 3GPP standard LTE, in particular, to BSs deployed in wide-area urban macro-cell systems, which, due to their high antenna elevations and high receive antenna gains, represent the most likely equipment to be impacted by adjacent band transmissions. The analysis in this section has been only conducted for non-AAS base stations.

TS channels are only located in frequencies starting at 2484.0 MHz and extending 5, 10, or 15 MHz up. The top frequencies are 2489 MHz, 2494 MHz, and 2499 MHz for channel bandwidth 5, 10, and 15 MHz respectively. This channel localisation provides at least 1 MHz of frequency separation from Band 7, which starts at 2500 MHz.

The terrestrial service is time division duplex (TDD) with the transmit activity divided between the BS and UE. However, 100% transmit time has been used for the BS and the UE in the MCL calculation.

4.6.2 E-UTRA Band 7 system parameters

4.6.2.1 System parameters for BS and UE

Table 74: E-UTRA Band 7 parameters for BS and UE Transmitter

Parameter	Value			
	Urban Wide-Area Macro BS	UE		
Transmitter Channel bandwidth (MHz)	1.4, 3, 5, 10, 15, 20			
Max Transmit Power (dBm)	No upper limit	23		
ACLR (dB)	45	NA		
OOB emissions		Limit (dBm)	Measurement BW	Δf
		5 MHz Channel		
		-15 -13 -13 -13 -13 -25 -30	30 KHz 1 MHz 1 MHz 1 MHz 1 MHz 1 MHz 1 MHz	±0-1 ±1-2.5 ±2.5-2.8 ±2.8-5 ±5-6 ±6-10 ±15
		Limit (dBm)	Measurement BW	Δf
		10 MHz Channel		
		-18 -13 -13 -13 -13 -13 -25 -30	30 KHz 1 MHz 1 MHz 1 MHz 1 MHz 1 MHz 1 MHz 1 MHz	±0-1 ±1-2.5 ±2.5-2.8 ±2.8-5 ±5-6 ±6-10 ±10-15 ±above 20
		Limit (dBm)	Measurement BW	Δf
		15 MHz Channel		
		-20 -13 -13 -13	30 KHz 1 MHz 1 MHz 1 MHz	±0-1 ±1-2.5 ±2.5-2.8 ±2.8-5

Parameter	Value			
	Urban Wide-Area Macro BS	UE		
		-13 -13 -13 -25 -30	1 MHz 1 MHz 1 MHz 1 MHz 1 MHz	±5-6 ±6-10 ±10-15 ±15-20 ±above 20
		Limit (dBm)	**Measurement BW**	**∆f**
		20 MHz Channel		
		-21 -13 -13 -13 -13 -13 -13 -25 -30	30 KHz 1 MHz 1 MHz 1 MHz 1 MHz 1 MHz 1 MHz 1 MHz 1 MHz	±0-1 ±1-2.5 ±2.5-2.8 ±2.8-5 ±5-6 ±6-10 ±10-15 ±15-20 ±above 20
Antenna pattern	ITU-R F.1336-5 [46]	Omni-directional		
Antenna Gain (dBi)	17	0		
Antenna height (m)	20 (ITU-R M.2292-0 [47])	1.5		

Table 75: E-UTRA Band 7 parameters for BS and UE Receiver

Parameter	Value			
	Urban Wide-Area Macro BS		UE	
Receiver Channel Bandwidth (MHz)	1.4, 3, 5, 10, 15, 20			
Reference Sensitivity (dBm) PREFSENS	Channel BW (MHz)	Limit	Channel BW (MHz)	Limit
	1.4 3 5 10 15 20	-106.8 -103.0 -101.5 -101.5 -101.5 -101.5	1.4 3 5 10 15 20	-101.7 -98.7 -97 -94 -92.2 -91

Parameter	Value			
	Urban Wide-Area Macro BS		UE	
Adjacent Channel Selectivity (ACS)	Channel BW (MHz)	Wanted Signal Mean Power (dBm)	Channel BW (MHz)	ACS (dB)
	1.4 3 5 10 15 20	-95.8 (PREFSENS + 11 dB) -95.0 (PREFSENS + 8 dB) -95.5 (PREFSENS + 6 dB) -95.5 (PREFSENS + 6 dB) -95.5 (PREFSENS + 6 dB) -95.5 (PREFSENS + 6 dB) Interfering Signal Mean Power: -52 dBm.	1.4 MHz 3 MHz 5 MHz 10 MHz 15 MHz 20 MHz	33 33 33 33 30 27
Receiver Noise Figure (dB)	5		9	
Receiver noise power density typical N_{RX} (dBm/MHz)	−109		-113	

The above system parameters for the E-UTRA base station and UE have been taken from 3GPP TS 36.104 [10] and 36.101 [11] respectively.

4.6.2.2 Adjacent Channel Selectivity ACS and Receiver Blocking specifications

The interference in nearby adjacent bands has two components that are described here as unwanted emissions and blocking.

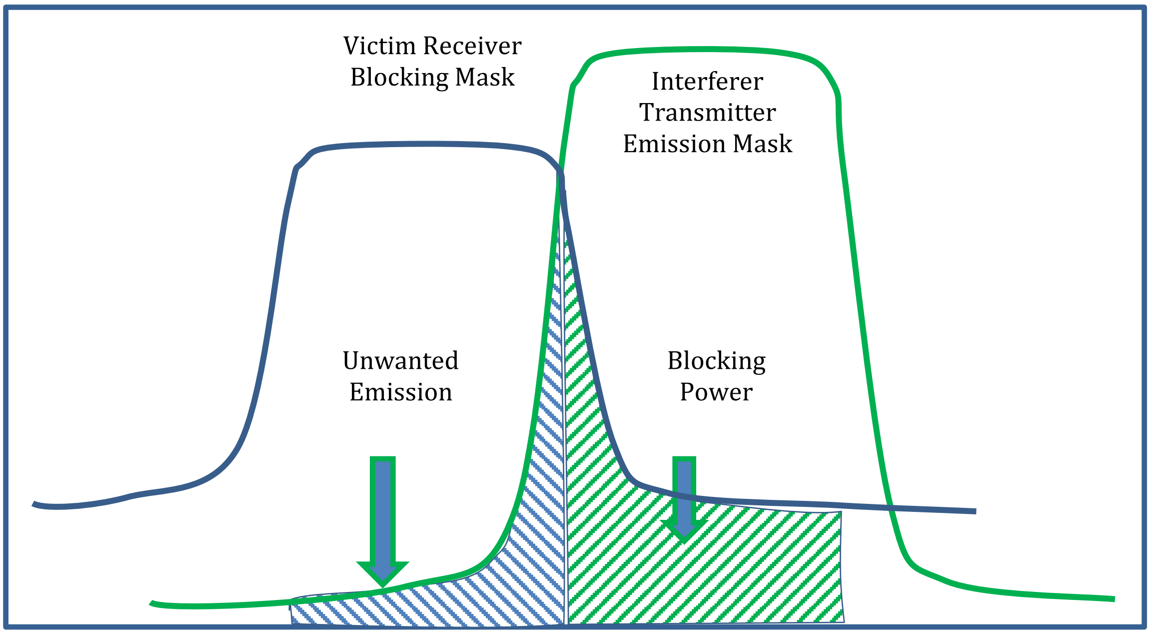

Figure 21: Blocking and unwanted emissions diagram

An interferer transmitter emits power within its occupied channel, and also some attenuated power in adjacent channels. The interferer's power emitted in adjacent channels is an unwanted emission, sometimes described as adjacent channel leakage. The unwanted emission shown in ANNEX 2: is attenuated according to specified performance metrics in the interferer transmitter. The interferer power emitted in the interferer's occupied channel is also incident upon victim receivers, and the victim receiver attenuates that power with filters and other methods. The victim receiver attenuation obtains a performance metric described by a blocking mask, and the attenuated power is called the blocking power in ANNEX 2:.

3GPP TS 36.104 [10] defines Adjacent Channel Selectivity (ACS) requirements for wide-area LTE BS receiver. For BS receiver bandwidths between 5 and 20 MHz, the ACS requirement is the same and is defined for a 5 MHz interfering LTE signal in the Adjacent Channel (AC) region, i.e., offset by approximately 2.5 MHz from the receiver channel edge. The maximum AC average power in this case is -52 dBm[6]. This is power measured at the receiver antenna port, i.e., after the signal has been attenuated by propagation loss and amplified by any receiver antenna gain.

The 3GPP specification also provides blocking requirements for LTE receivers for interfering signals beyond the adjacent channel, but within 20 MHz of the associated band edge [25]. As with the ACS requirement, for receiver bandwidths between 5 and 20 MHz the requirement is the same, and is defined for a 5 MHz interfering LTE signal in the blocking region, i.e. offset by approximately 7.5 MHz from the receiver channel edge. The maximum blocking average power in this case is -43 dBm[7], which is 9 dB greater than the ACS specification.

The LTE wide area BS ACS and In-band blocking characteristics defined in 36.104 [10] are summarised in the below table.

---

[6] The ACS requirement here is specified assuming the receiver is able to meet a 95% throughput requirement with the interfering signal present, with the desired signal at 6 dB above reference sensitivity. Reference sensitivity is also defined by a 95% throughput requirement, so the ACS requirement can be considered as effectively resulting in a 6 dB noise rise or desense at the receiver.

[7] As with the ACS requirement, the blocking requirement here is also specified with a 95% throughput requirement for a desired signal 6 dB above reference sensitivity.

Table 76: E-UTRA BS ACS and In-band blocking levels

Interferer Frequency Range (MHz)	ACS/In-Band Blocking (dBm)	BS Receiver Desensitization (dB)
2495-2500 MHz	-52	6
2480-2495 MHz	-43	6
Below 2480 MHz	-15	6

It should be noted that the above ACS and In-band blocking level are defined for a 6 dB desensitization of the BS receiver. However, in co-existence studies, 1 dB desensitization or lower is considered for the protection of MFCN bands from harmful interference. Hence, the above values of ACS/In-band blocking were recalculated assuming 1 dB desensitization as the highest [ECC Report 165 [3]]. A 1 dB noise rise is equivalent to I/N = -6 dB.For a 6 dB desensitization, the maximum interference experienced by the receiver is Noise_floor + 4.74 dB. Similarly, for a 1 dB desensitization, the maximum interference experienced by the receiver is Noise_floor-5.87 dB. Therefore, the values in Table 76 can be adjusted by 10.5 dB for 1 dB desensitization. The re-calculated values to be considered in this study are shown in Table 77. The tabulated blocking powers therefore obtain a noise rise of 1 dB, or an I/N=-6 dB.

Table 77: Adjusted E-UTRA BS ACS/In-band blocking for 1 dB desensitization

Interferer Frequency Range (MHz)	ACS/In-Band Blocking (dBm)	BS Receiver Desensitization (dB)
2495-2500	-52-10.5=-62.5	1
2480-2495	-43-10.5=-53.5	1
Below 2480 MHz	-15-10.5=-25.5	1

The analysis considers three different bandwidths of the terrestrial service (TS). The three bandwidth are used in 4.6.3.1 and 4.6.3.2 for unwanted emission and blocking calculations, and in 4.6.3.3 for spurious emissions calculations.

4.6.3 MCL analysis of interference from TS BS into E-UTRA Band 7 BS, and interference from E-UTRA Band 7 UE into TS BS

The compatibility scenarios considered in this study are shown below. Figure 22 shows a TS TDD BS transmitter emitting potential interference into an E-UTRA Band 7 BS receiver and Figure 23 shows an E-UTRA FDD UE transmitter emitting potential interference into a TS terrestrial TDD BS receiver. In both cases, the interference power has been computed as a combined effect of unwanted emissions from the TS base station and receiver blocking from the E-UTRA base station.

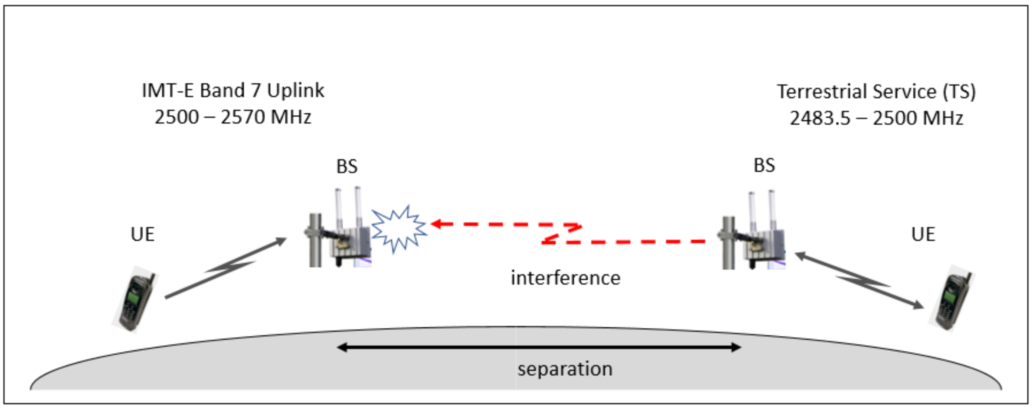

Figure 22: TS interferer with IMT-E (E-UTRA) victim

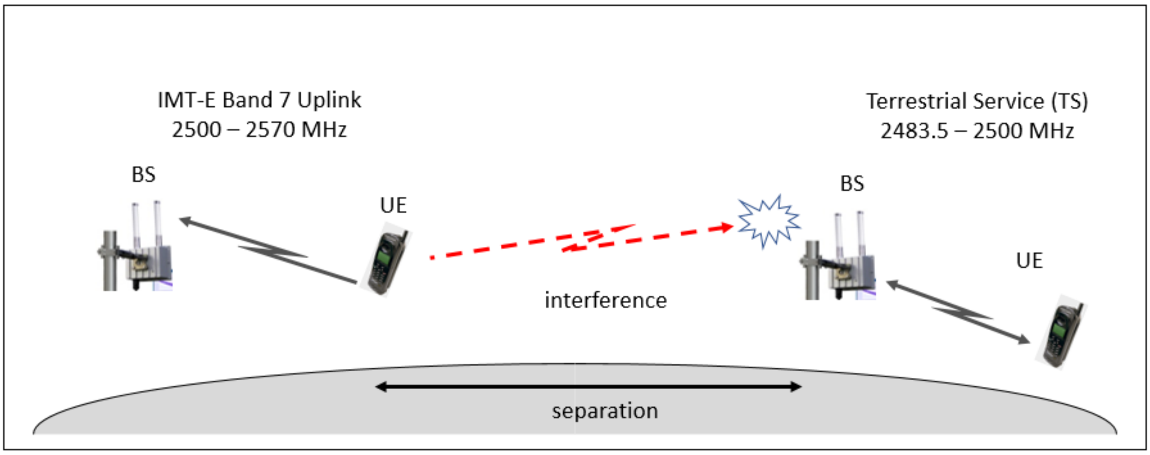

Figure 23 IMT-E (E-UTRA) UE interferer with TS BS victim

The minimum path loss (L_{path}) between an interferer and victim has been derived from the MCL equation under the assumption of a single interferer to satisfy the interference protection criterion of I/N=-6 dB. The derived L_{path} then was transposed into a separation distance using an agreed propagation model. In this study, EHata model for the urban environment has been used to derive the separation distances. Free Space Path Loss (FSPL) has also been considered to provide the worst-case maximum separation distance for conditions with fewer propagation obstacles such as smooth rural terrain or in general direct line-of-sight scenarios.

The details of the MCL calculation can be found in ANNEX 2:.

4.6.3.1 Results of outdoor deployment of terrestrial service

The outdoor deployment of low power terrestrial service (TS) requires physical separation from the Band 7 E-UTRA base station to meet the interference criterion of I/N=-6 dB. The interference is caused by a combined effect of unwanted emissions from the TS base station and blocking from the E-UTRA base station. The separation distances for this combined effect are given in Table 87 for different TS channels.

Table 78: Outdoor TS Terrestrial Deployment Separation Distances (unwanted emissions and blocking)

Outdoor TS Bandwidth	interferer TX Parameters	TS BS Interferer Value	E-UTRA UE Interferer Value
5 MHz	Separation distance, EHata urban median 50th percentile (m) Separation distance, EHata urban 95th percentile (m) Separation distance, FSPL (m)	970 2500 3977	96 139 2366
10 MHz	Separation distance, EHata urban median 50th percentile (m) Separation distance, EHata urban 95th percentile (m) Separation distance, FSPL (m)	970 2500 3977	96 139 2366
15 MHz	Separation distance, EHata urban median 50th percentile (m) Separation distance, EHata 95th percentile (m) Separation distance, FSPL (m)	1100 2900 4900	96 139 2366
Note: I/N = -6 dB in all cases; separation distances are derived for H_{TS}=15 m, $H_{EUTRA-BS}$=20 m, $_{HEUTRA-UE}$=1.5 m			

4.6.3.2 Results of indoor deployment of terrestrial service

Indoor deployment of TS low power terrestrial service (TS) to meet conditions for combined blocking and unwanted emission requires a separation from the Band 7 cell sites shown in the Table 79. The table shows separation distances for TS BS interferers interfering with E-UTRA BS victim receivers, and E-UTRA UE interferers interfering with TS BS victim receivers.

Table 79: Indoor TS Terrestrial Deployment Separation Distances for Combined

Indoor TS Band-width	interferer TX Parameters	TS BS Interferer Value	E-UTRA UE Interferer Value
5 MHz	Separation distance, EHata urban median 50th percentile (m) Separation distance, EHata urban 95th percentile (m) Separation distance, FSPL (m)	51 88 110	56 75 421
10 MHz	Separation distance, EHata urban median 50th percentile (m) Separation distance, EHata urban 95th percentile (m) Separation distance, FSPL (m)	51 88 110	56 75 421
15 MHz	Separation distance, EHata urban median 50th percentile (m) Separation distance, EHata urban 95th percentile (m) Separation distance, FSPL (m)	53 93 135	56 75 421
Note: I/N = -6 dB in all cases; BEL of 15 dB; separation distances are derived for H_{TS}=2m, $H_{EUTRA-BS}$=20 m, $H_{EUTRA-UE}$=1.5 m			

4.6.3.3 Results of Interference due to spurious emissions

Spurious emissions are specified by 3GPP specs, and -30 dBm/MHz for Category B specification[8] is used here for a calculation of the spurious emission power intercepted by a victim receiver. The limits of unwanted emissions in the spurious domain apply at frequencies 10 MHz away from the band edge for BS, the frequency offset for UE depends on the channel bandwidth.

This obtains the separation distances given in the table below.

Table 80 Spurious Emission Separation Distances

Interferer	Victim	Path Loss Model	Separation Distance (m)
TS BS Outdoor	Band 7 BS	EHata (urban) FSPL	362 1057
TS BS Indoor	Band 7 BS	EHata (urban) FSPL	87 94
Band 7 UE	TS BS Outdoor 5 MHz	EHata (urban) FSPL	55 211
Band 7 UE	TS BS Outdoor 10 MHz	EHata(urban) FSPL	65 472
Band 7 UE	TS BS Outdoor 15 MHz	EHata(urban) FSPL	68 594
Band 7 UE	TS BS Indoor 5 MHz	EHata(urban)	19

[8] The relevant section in the 3GPP specs is TS 36.104 section 6.6.4. The 3GPP spec specifically states that either Category A or Category B specs apply. The specs make no distinction between local area base stations, wide area base stations, or any other kind of base station. The choice of Category A or Category B is defined earlier in TS 36.104 Table 4.3-1. Specifically, the corresponding category is mandatory for the region defined in ITU-R SM.329. In SM.329, clause 3.3: “Category B limits are an example of more stringent spurious domain emission limits than Category A limits. They are based on limits defined and adopted in Europe and used by some other countries“

Interferer	Victim	Path Loss Model	Separation Distance (m)
		FSPL	19
Band 7 UE	TS BS Indoor 10 MHz	EHata(urban) FSPL	40 42
Band 7 UE	TS BS Indoor 15 MHz	EHata(urban) FSPL	42 53
Note: I/N = -6 dB in all cases.			

4.6.4 Summary

This section analyses the impact of terrestrial service (TS) in the frequency band 2483.5–2500 MHz on E-UTRA Band 7 base station (BS) receivers operating in the neighbouring frequencies above 2500 MHz It also analyses the impact of E-UTRA Band 7 user equipment (UE) on TS receivers (UE and BS).

The study between TS base station and E-UTRA Band 7 outdoor base station receiver gives minimum physical separation between the two systems. The minimum separation distance - corresponding to the median propagation loss (EHata 50% percentile) - derived in this study for 5 MHz and 10 MHz TS channels is 970 m for TS outdoor deployment and 51 m for TS indoor deployment. However, the median separation distance for the 15 MHz TS channel is 1100 m for outdoor and 53 m indoor deployment. These separation distances are derived from the median EHata Urban propagation model. The calculated separation distances are larger when using FSPL model. However, the separation distances have also been derived for the 95th percentile EHata model which will satisfy the interference criterion for at least 95% of the situations. These separation distances are more than 2 km in all the outdoor cases and are given in Table 78, Table 79 and Table 80.

Table 81: Extract from Table 78: Outdoor TS Terrestrial Deployment Separation Distances

Outdoor TS Bandwidth	interferer TX Parameters	TS BS Interferer Value (m)	E-UTRA UE Interferer Value (m)
5 MHz	Separation distance, EHata (urban) median 50th percentile (m) Separation distance, EHata (urban) 95th percentile (m) Separation distance, FSPL (m)	970 2500 3977	96 139 2366
10 MHz	Separation distance, EHata (urban) median 50th percentile (m) Separation distance, EHata (urban) 95th percentile (m) Separation distance, FSPL (m)	970 2500 3977	96 139 2366
15 MHz	Separation distance, EHata (urban) median 50th percentile (m) Separation distance, EHata (urban) 95th percentile (m) Separation distance, FSPL (m)	1100 2900 4900	96 139 2366

Table 82: Extract from Table 79: Indoor TS Terrestrial Deployment Separation Distances for Combined

Indoor TS Bandwidth	interferer TX Parameters	TS BS Interferer Value (m)	E-UTRA UE Interferer Value (m)
5 MHz	Separation distance, EHata (urban) median 50th percentile (m)	51	56

Indoor TS Bandwidth	interferer TX Parameters	TS BS Interferer Value (m)	E-UTRA UE Interferer Value (m)
	Separation distance, EHata (urban) 95th percentile (m) Separation distance, FSPL (m)	88 110	75 421
10 MHz	Separation distance, EHata (urban) median 50th percentile (m) Separation distance, EHata(urban) 95th percentile (m) Separation distance, FSPL (m)	51 88 110	56 75 421
15 MHz	Separation distance, EHata (urban) median 50th percentile (m) Separation distance, EHata (urban) 95th percentile (m) Separation distance, FSPL (m)	53 93 135	56 75 421

Table 83: Extract from Table 80 Spurious Emission Separation Distances

Interferer	Victim	Path Loss Model	Separation Distance (m)
TS BS Outdoor	Band 7 BS	EHata (urban) FSPL	362 1057
TS BS Indoor	Band 7 BS	EHata(urban) FSPL	87 94
Band 7 UE	TS BS Outdoor 5 MHz	EHata(urban) FSPL	55 211
Band 7 UE	TS BS Outdoor 10 MHz	EHata(urban) FSPL	65 472
Band 7 UE	TS BS Outdoor 15 MHz	EHata(urban) FSPL	68 594
Band 7 UE	TS BS Indoor 5 MHz	EHata(urban) FSPL	19 19
Band 7 UE	TS BS Indoor 10 MHz	EHata (urban) FSPL	40 42
Band 7 UE	TS Bs Indoor 15 MHz	EHata(urban) FSPL	42 53

In urban areas, separation distances calculated using FSPL should be seen as an absolute worst-case interference scenario. Separation distances will be less in urban or suburban areas where appropriate propagation using models for those areas are more accurate.

It should be noted that this section has only considered the interference into a non-AAS base station deployed in a macro-urban cell scenario. The co-existence between TS outdoor BS and MFCN(E-UTRA, 5G-NR) Band 7 outdoor small cells, macrocells with AAS antenna, as well the co-existence between TS indoor BS and MFCN indoor small cells have not been considered.

4.7 COMPATIBILITY WITH ISM/WLAN BELOW 2483.5 MHZ

This section analyses the impact of an LTE-based 2.4 GHz-low power terrestrial service (TS) in the MSS frequency band 2483.5-2495 MHz on portable unlicensed services in the lower adjacent ISM band. The analysis determines the impact of TS 2.4 GHz terrestrial transmitters on victim out of band receivers. The services being considered as victim receivers are RLAN (Wi-Fi) and Bluetooth. Specifically, the closest commonly used channels will be analysed. For RLAN, that is channel 11 while for Bluetooth it is traditional channel 79 or Bluetooth Low Energy (BLE) channel 39. The two Bluetooth channels are at the same frequency, 2480 MHz and are both about 1 MHz in bandwidth. Since BLE 39 is an announcement channel and the only announcement channel relatively free of Wi -Fi, it is considered the most important case and therefore will be referred to throughout as BLE channel 39.

This section draws from ECC Report 244 [25] and 3GPP TR 36.791 [26]. The ISM band is frequently considered congested, and the devices operating in that band must contend with all other users. TR 36.791 shows compatibility in the sense that it produces similar or less interference than do the other ISM users (incumbents). However, TR 36.791 does not use the specifications applicable to CEPT and therefore further assessment is required.

This study examines two methods for assessing interference. First, Minimum Coupling Loss (MCL) and second, Minimum Separation Distance in a similar fashion to Report 244 and relative to incumbent interference level in a similar fashion to TR 36.791.

For RLAN, the victim is channel 11. Therefore, the reference ISM operating channel for comparative interference is RLAN Channel 6 (the next lower clear channel). For BLE channel 39, the comparative interference considered is an RLAN AP operating on Channel 11.

The technical characteristics of the 2.4 GHz low power terrestrial service (TS) are given in section 3. The TS is time division duplex (TDD) with the transmit activity for the BS and UE is assumed to be divided approximately 50%/50% during routine operation. For this analysis the BS is assumed to transmit 100% of the time. The TS system analysed has an allocated bandwidth of 10 MHz and is centred at 2490 MHz.

4.7.1 RLAN and Bluetooth system parameters

4.7.1.1 Relevant specifications

Wi-Fi used for RLANs and Bluetooth are both well-known standard protocols. The relevant technical specifications are as follows:

ETSI EN 300 328, section 4.3.2.2.3 [27] gives the

- RLAN transmission power of +20 dBm e.i.r.p.;
- RLAN maximum Power Density of +10 dBm /MHz e.i.r.p..

IEEE 802.11 [28] gives the RLAN transmit spectral mask (which is similar to the spectrum mask Recommendation ITU-R M.1450-1, figure 1 [29]).

IEEE 802.11 determines that when transmitting in a 20 MHz channel, the transmitted spectrum shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and the maximum of –45 dBr and –53 dBm/MHz at 30 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in IEEE 802.11, figure 20-17. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

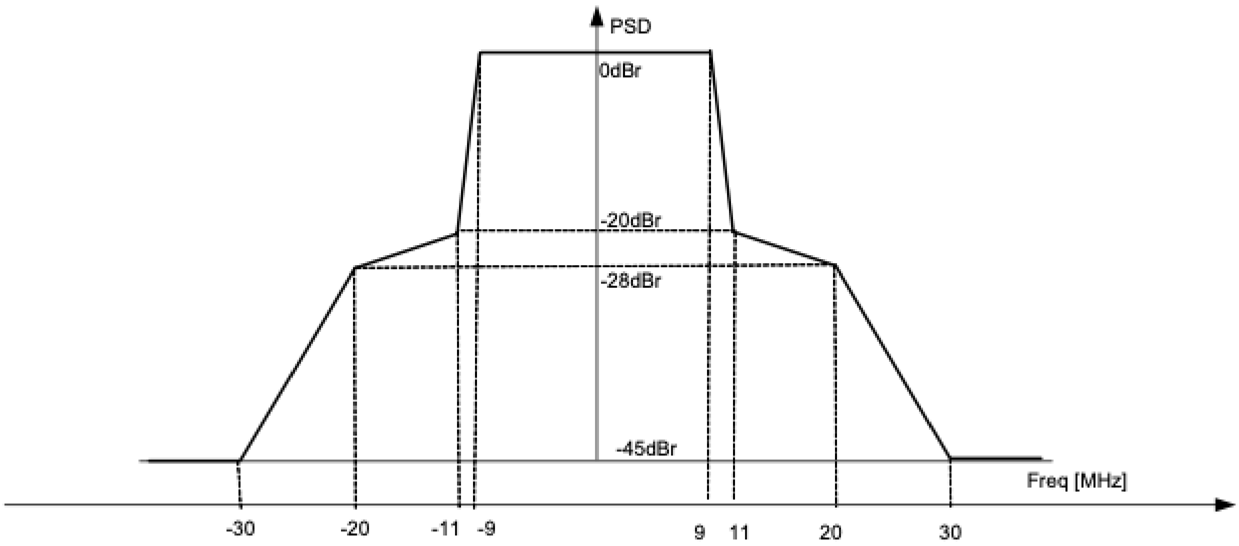

Figure 24: IEEE 802.11 Transmission Spectral Mask

Receiver performance as a function of Modulation is shown in Table 84. Adjacent channel rejection and Minimum sensitivity for 20 and 40 MHz channel spacing is provided. For a 20 MHz channel and 2.4 GHz, the adjacent separation is 25 MHz (Test method for rejection tests raises the desired received signal +3 dB above sensitivity, and then increases the undesired signal until the reference performance is again achieved).

Table 84: IEEE 802.11 Receiver Specifications

Modulation	Coding rate	Adjacent channel rejection (dB)	Nonadjacent channel rejection (dB)	Minimum sensitivity (20 MHz channel spacing (dBm)	Minimum sensitivity (40 MHz channel spacing (dBm)
BPSK	½	16	32	-82	-79
QPSK	½	13	29	-79	-76
QPSK	3/4	11	27	-77	-74
16-QAM	½	8	24	-74	-71
16-QAM	3/4	4	20	-70	-67
64-QAM	2/3	0	16	-66	-63
64-QAM	3/4	-1	15	-65	-62
64-QAM	5/6	-2	14	-64	-61

The website https://www.gnswireless.com/info/signal-to-noise-ratio-snr gives a table of Required SNR for the various Modulation and Coding Schemes.

Table 85: Wi-Fi SNR Required

Index	Modulation	Coding rate	Required SNR (dB)
0	BPSK	½	5
1	QPSK	½	7.5

Index	Modulation	Coding rate	Required SNR (dB)
2	QPSK	3/4	10
3	16-QAM	½	12.5
4	16-QAM	3/4	15
5	64-QAM	2/3	17.5
6	64-QAM	3/4	20

The website https://en.wikipedia.org/wiki/List_of_WLAN_channels#2.4_GHz_(802.11b/g/n/ax) list the Wi-Fi- channels. Of interest are channels 6 and 11 with centre frequencies of 2437 and 2662 MHz.

4.7.1.2 Bluetooth system parameters

Selected specifications from TR 36.791 [31], ETSI ES 202 131 [30] and calculated values for Bluetooth system parameters are shown in Table 86.

Table 86: Bluetooth system parameters

Parameter	Value	Units
BLE channel 39 carrier frequency	2480	MHz
BLE channel 39 channel bandwidth	1	MHz
BLE channel 39 data rate	1	Mbit/s
BLE channel 39 TX power	-26	dBm
Bluetooth Signal-to-Interference required 1 Mbps rate (GFSK, 0.1% BER)	11	dB
Bluetooth Sensitivity specification (note 1)	-70	dBm
Bluetooth Sensitivity typical (note 2)	-95	dBm
Bluetooth blocking or desense	40	dB
BLE blocking and desense + Signal to Interference	51	dB
Bluetooth delta signal over sensitivity	+3	dB
Ratio of Interferer to Victim noise floor	54	dB
Expressed as PSD	54	dB/MHz

Note 1: The Bluetooth SIG < https://www.bluetooth.com/blog/3-key-factors-that-determinethe-range-of-bluetooth/ > indicates that although the specified sensitivity ranges from -70 to -82 dBm depending on the PHY, typical implementations achieve -95 dBm or better

Note 2: The Bluetooth SIG < https://www.bluetooth.com/blog/3-key-factors-that-determinethe-range-of-bluetooth/ > indicates typical implementations achieve -95 dBm or better.

4.7.1.3 RLAN system parameters

Selected specifications from 802.11 [28] and calculated results for RLAN system parameters are shown in Table 87.

Table 87: RLAN system parameters

Parameter	Value	Units
RLAN AP channel 11 carrier centre frequency	2462	MHz
RLAN AP transmit power	20	dBm

Parameter	Value	Units
RLAN occupied BS	20	MHz
RLAN PSD (typical)	7.0	dBm/MHz
RLAN OOBE at BLE 39	-26.2	dBr
RLAN AP leakage power at 2480 MHz	-19.2	dBm/MHz
RLAN transmit power to BLE noise ratio	-39.2	dB
RLAN Ch 6 OOBE integrated over channel 11	-17.5	dBr
RLAN Ch 6 leakage power into channel 11	-10.5	dBm/MHz
RLAN Ch 6 transmit power to Channel 11	-30.5	dB

4.7.1.4 Extra considerations for compatibility with ALD and Cochlear implants using BLE

Background

Assistive Listening Devices (ALD) are hearing aids with radio conductivity. From the 1990s, VHF usually in the 169-174 MHz band where in use especially in education to provide a flat playing field for hearing impaired children however the spectrum was not harmonised and thus use was limited to education and in some cases links to TV or radio audio. In recent years the universal availability of the 2.4 GHz band has largely replace the VHF units with the added advantage of linking to mobile phones, music players PCs etc.

Cochlear implants13 consist of a surgical implant connected to the auditory nerves and an external part which is held in place by a magnet and either linked to an associated ALD as shown below or communications combined in the external. 2.4 GHz unit.

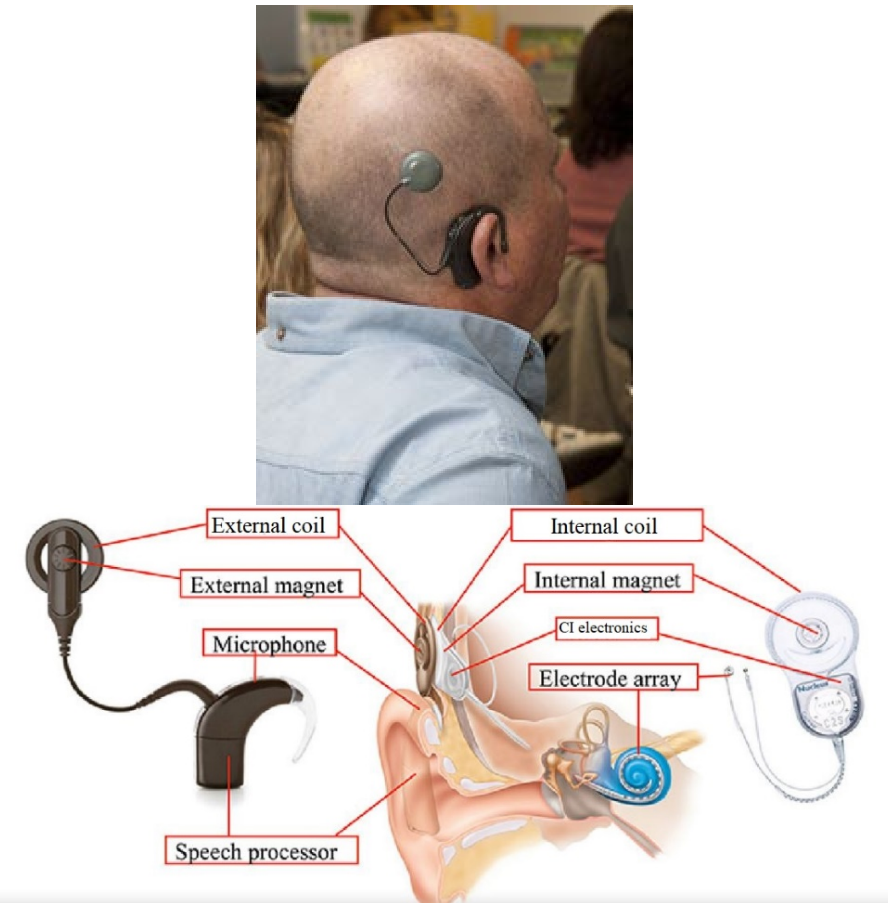

Figure 25: Typical Cochlear implant

Older 2.4 GHz Systems

ALDs have a single button cell battery which initially precluded the integration of Bluetooth into or attached to the ALD due to battery consumption. A chest worn unit identified as the media gateway in Figure 26 with rechargeable battery translated the Bluetooth received audio into an inductive loop which connected to the ALDs.

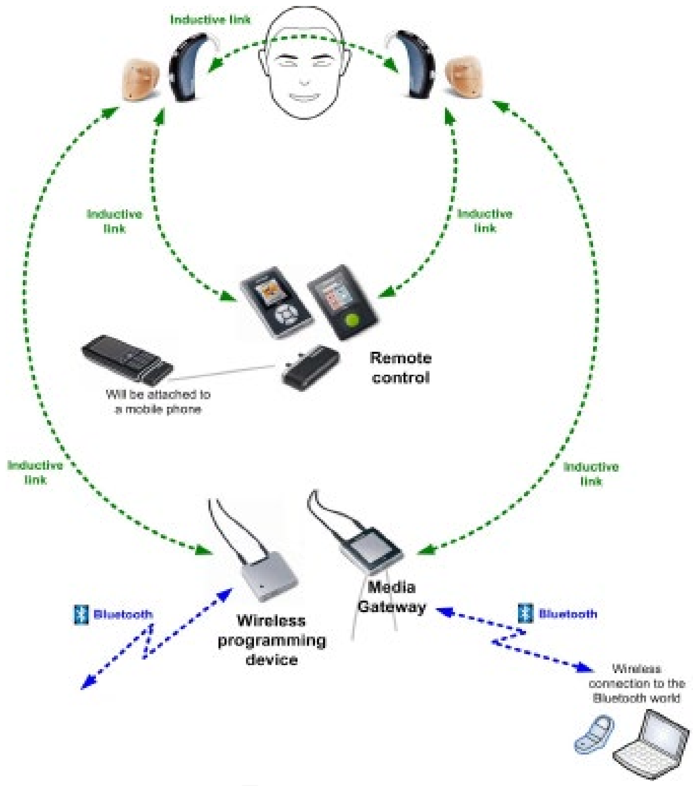

Figure 26: ALD using inductive neck loop

Current Systems

With the reduction of the current required to operate a Bluetooth chip, integration into the over the ear ALDs has taken place since 2015. Figure 17 shows a typical unit, where two ALDs are in use there will be Bluetooth conductivity in both units. Within educational establishments these Bluetooth enabled ALDs are complemented with a teachers Bluetooth microphone.

Figure 27: ALD with built in 2.4 GHz communications

Use in the 2400-2483 MHz band

For the purpose of communication links both ALD and Cochlear implants use similar systems dependant on manufacturer and objective i.e. some manufacturers use the Apple system some BLE and many are proprietary chips. Prime use is linking to mobile phones, PCs and TV.

Bluetooth parameters are appropriate for most characteristics; however, a number of the propriety chips have a sensitivity of -95 or better.

Interaction with the proposed system in 2483-2500 MHz

It is reasonable to suppose that the proposed mobile system units will be used close to the ear and in some cases may physically touch the ALD or Cochlear devices.

Summary

From the information above, there are two scenarios:

1 The 2.4 GHz communication identified in Figure 26: In this case it is unlikely that any interference will be generated by a proposed mobile phone.

2 In the case of current systems and Cochlear implants using integrated 2.4 GHz communication, when the proposed mobile system handset is held against the ear: the ability of ALD or cochlear implants to reject interference from some 4 W maximum TDD signals when being used by an ALD/Cochlear user or being adjacent to a user might have a lower probability of success. The TDD of the signal is an additional issue, as the system will not have time to adjust to it before it switches.

Physical testing will be required to assess the severity of interference.

4.7.2 Derived parameters

In the next sections the noise figure (NF), selectivity, and unwanted emission will be examined. The NF among other aspects helps to determine the amount of noise that the victim receives within its receiver bandwidth.

The role of victim selectivity and interferer out of band emission is explained in the next section.

4.7.3 Blocking (selectivity) vs Unwanted Emissions

An interferer interferes with the Victim through either its intended or unwanted emissions as shown in the following figure. The limitation of the receiver selectivity or other mechanisms may be adversely affected by the interferer’s intended signal which is referred to as blocking. Alternatively, some of the Interferer’s unwanted emissions fall within the Victim receive bandwidth and limit performance. Both mechanisms must be considered. A composite of these (worst case if the separate results are significantly different or combined) can be determined for comparing between systems or for the determination of expected compatibility.

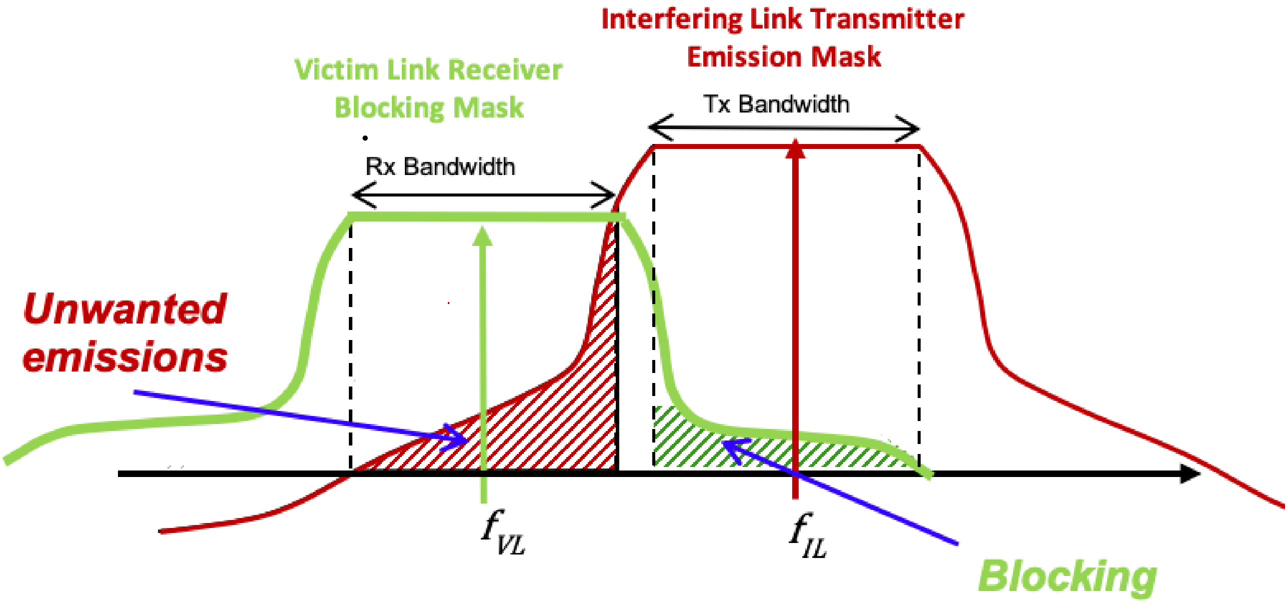

Figure 28: Blocking and Unwanted Emissions

4.7.4 Noise Figure

For this analysis, the NF for each of the victims of interest is required.

4.7.4.1 RLAN

IEEE does not specify the required device Noise Figure (NF), but by subtracting the required SNR column in Table 85 to the respective Sensitivity in .

Table 84 as shown below in Table 88 the assumed effective noise floor level can be determined to be at about -86 dBm. Other devices may perform better and other specifications may be stricter such as EN 302 571 which is 3-5 dB more restrictive than 802.11. In Table 85, Texas Instruments[9] indicates a noise floor -94 dBm for one of their offerings. Since kTB in 22 MHz is -100.6 dBm, the RLAN NF ranges roughly from 6.5 dB to 14.7 dB.

Table 88: RLAN NF derived from Sensitivity Specification

Index	Modulation	Coding	Required SNR (dB)	Sensitivity (dBm)	Required SNR -Sensitivity (dBm)
0	BPSK	1/2	5.0	-82	87.0
1	QPSK	1/2	7.5	-79	86.5
2	QPSK	3/4	10.0	-77	87.0
3	16-QAM	1/2	12.5	-74	86.5
4	16-QAM	3/4	15.0	-70	85.0
5	64-QAM	2/3	17.5	-66	83.5
6	64-QAM	3/4	20.0	-65	85.0
				Minimum:	83.5

[9] Texas Instruments, The Effects of Adjacent Channel Rejection and Adjacent Channel Interference on 802.11 WLAN Performance, SPLY005 – November 2003 http://www.ti.com/pdfs/bcg/80211_acr_wp.pdf

Index	Modulation	Coding	Required SNR (dB)	Sensitivity (dBm)	Required SNR -Sensitivity (dBm)
kTB	-100.6	dBm		Average:	85.9
NF	14.7	dB		Maximum:	87.0

For this analysis, an intermediate value of 9 dB RLAN NF will be used.

4.7.5 Selectivity

For this analysis, each of the victim's ability to withstand a strong adjacent channel interferer is required to be analysed. The various mechanisms for blocking and desense are considered. Blocking and desense mechanisms combined will be referred to as the victim's selectivity as a measure of the victim to filter or reject the interferer strong, adjacent channel intended signal.

4.7.5.1 RLAN

IEEE does not specify the receiver selectivity for 802.11 devices but specifies selectivity in a manner similar to RLAN NF described above. A measure of selectivity in Table 89 below is obtained by adding the required SNR, the Adjacent Channel Rejection, and the 3 dB increase in power due to the test specification detailed above. This methodology may be conservative for several reasons, for example, in the TS to RLAN case the TS has a narrower bandwidth with a centre frequency offset of 2490-2462 = 28 MHz which is greater than the 25 MHz offset used in the specification. There may also be additional ISM band filtering. This conservative approach is noted, but not expected to exhibit a large difference in interference and so will not be addressed directly in the analysis. The adjacent channel selectivity is seen to be about 23 dB (ranging from 20.5 to 24 with average 22.875).

Table 89: RLAN Selectivity derived from Adjacent Channel Rejection Specification

Index	Modulation	Coding	Required SNR (dB)	Adjacent Channel Rejection (dB)	SNR+ACR+3 (dB)
0	BPSK	1/2	5.0	16	24.0
1	QPSK	1/2	7.5	13	23.5
2	QPSK	3/4	10.0	11	24.0
3	16-QAM	1/2	12.5	8	23.5
4	16-QAM	3/4	15.0	4	22.0
5	64-QAM	2/3	17.5	0	20.5
6	64-QAM	3/4	20.0	-1	22.0
				Minimum:	20.5
				Average:	**22.9**
				Maximum:	24.0

For this analysis, a compromise value of a 23 dB RLAN selectivity will be used.

4.7.5.2 BLE

Bluetooth does not specify selectivity but has a single number for Blocking and Desense of 40 dB, so the calculation is straightforward as a required SNR of 11 dB is added to the 3 dB specified as part of desense test-plus-effective selectivity in 11 + 3 + 40 = 54 dB.

For this analysis, 54 dB BLE selectivity will be used.

4.7.6 Unwanted Emissions

For unwanted emissions, each combination of interferer and victim is considered. There are four device pairings that need to be considered. The Interferers are the TS and RLAN while the Victims are RLAN (on channel 11) and BLE (on channel 39). In this section, the differences between the TS indoor/outdoor power nor antenna gain is not needed to be considered, as the relative level between the Interferer's desired and undesired powers are the same in all three cases. Thus, Unwanted Emissions can be systematically approached by first looking at the interferer's unwanted emissions and normalizing to 1 MHz bandwidth.

4.7.6.1 TS

The Transmit power and TS Adjacent Channel Unwanted Emission is given for the indoor and outdoor devices is given in section 3. However, each of the devices have the same relative levels as shown in Table 90. This analysis approach is also used in the Beyond Adjacent Channel Unwanted Emissions.

The two victims of the TS however are at different centre frequencies and have different bandwidths.

BLE channel 39 is at 2480 MHz and therefore has an offset of 10 MHz from the TS. The ACL is in a 10 MHz measurement bandwidth. Since the BLE is 1 MHz (vs TS of 10) and centred at the TS adjacent channel centre, it is conservative to use the TS ACLR adjusted for the bandwidth.

RLAN channel 11 is separated further from TS at 2462 MHz (offset of 28 MHz). Therefore, the Beyond Adjacent Channel Leakage (BACL/BACLR) is used. In this case the RLAN bandwidth used is 20 MHz.

Table 90: TS ACLR Calculation

	Indoor	Side Lobe Outdoor (0 dBi)	Bore Sight Outdoor (6 dBi)
Transmit e.i.r.p. (dBm)	20	30	36
Adjacent Channel (Note 1) Unwanted Emissions (dBm)	-25	-15	-9 (note 2) (e.i.r.p.)
ACLR (dB/10 MHz)	-45	-45	-45
ACLR (dB/MHz)	-55		
Victim:	Bluetooth		
Bandwidth	1 MHz		
Victim received unwanted power to interferer transmit power ratio (dB)	-55		
Beyond Adjacent Channel (Note 3) Unwanted Emissions (dBm)	-40	-30	-24 (note 4) (e.i.r.p.)
Beyond Adjacent Channel Leakage Ratio (dB/10 MHz)	-60	-60	-60
Beyond Adjacent Channel Leakage Ratio (dB/MHz)	-70		
Victim:	RLAN		
Bandwidth	20 MHz		
Victim received unwanted power to interferer transmit power ratio (dB)	-57		
Note 1: The victim bandwidth and frequency separation must be determined for each situation values Note 2: From TS system parameters section, with the outdoor gain adjacent channel implied from the other Note 3: The victim bandwidth and frequency separation must be determined for each situation values Note 4: From TS system parameters section, with the outdoor gain adjacent channel implied from the other			

For this analysis for unwanted TS emissions, -55 dB will be used for TS on BLE and -57 dB for TS on RLAN.

4.7.6.2 RLAN

To determine the unwanted emissions with an RLAN as the interferer and either RLAN or Bluetooth as the victim, the emission mask of Figure 24 is used with the expanded illustration in Figure 29.

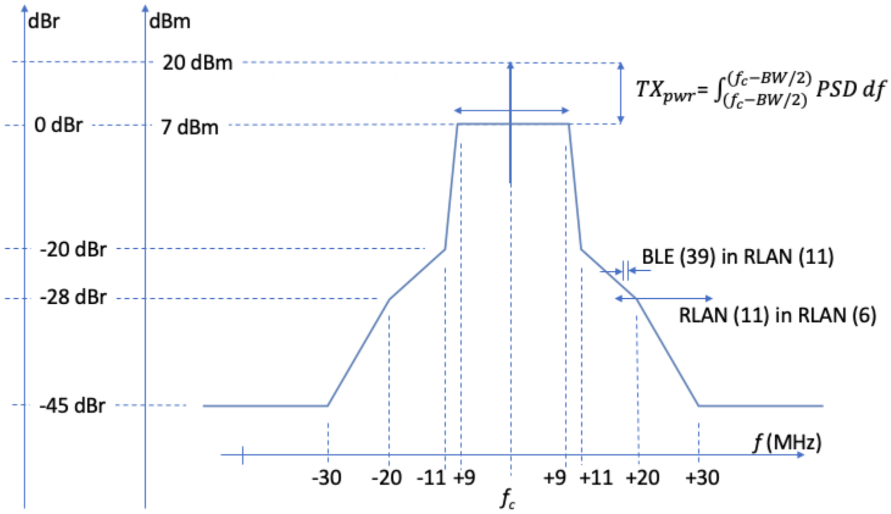

Figure 29: RLAN Transmission Mask with Unwanted Regions

For BLE the separation is 2480 MHz – 2462 MHz = 18 MHz and the bandwidth is 1 MHz. Therefore, the bandwidth is narrow enough to justify determining the value at 18 MHz offset which is -26.2 dBr (integration over 18 +/- 0.5 MHz differs by less the 0.01 dB). Due to the +20 dBm transmit power and +7 dBm PSD as shown in the figure above, the transmit power is at +13 dBr. Therefore, the ratio between the transmit power and the amount of power in the BLE bandwidth is -39.2 dB.

The RLAN case, however, is different. The Channel 6 interferer is at 2437 MHz and victim is still at 2462 MHz resulting in a 25 MHz offset with +/- 10 MHz receive bandwidth. This requires the integration of the offset from 15 to 35 MHz (i.e., three segments). Doing so results is -17.5 dBr (whereas the point at 25 MHz offset is -36.5 dBr – this is due to both the wider bandwidth and the inclusion of frequencies with less offset). The same offset between Power Spectral Density (PSD) and carrier power is needed for BLE applies here, so the ratio between the transmit power and the amount of power in the victim RLAN bandwidth is -30.5 dB as shown in Table 87.

For this analysis for unwanted RLAN emissions, -39.2 dB will be used for RLAN to BLE and -30.5 dB for RLAN to RLAN.

4.7.7 Limiting Mechanism

To determine if either the Transmitter Unwanted Emissions (i.e., Out of Band Emissions (OOBE)) or Desense and Blocking as shown in Figure 28 above are the limiting factor requires comparison of each of the four scenarios as shown in Table 91 below.

Table 91: Composite Tolerance to Strong OOB Signal

Interferer Victim	TS RLAN	TS BLE	RLAN RLAN	RLAN BLE
Unwanted Emissions (dB)	-57	-55	-30.5	-39.2
RX Selectivity (dB)	-23	-54	-23	-54
Composite (dB)	-23	-51	-23	-39

In the above table, the TS to BLE scenario shows a nearly equal affect from both mechanisms and so the composite is the power sum combined. All other combinations were strongly dominated by one or the other mechanism. The composite values have been rounded to the nearest dB.

By examination, it is evident that the Channel 11 RLAN Victim will perform about the same, whether the Interferer is a TS or an RLAN operating on channel 6, if the signal levels are similar.

Also, by examination, it is evident that the BLE channel 39 Victim will perform much better against a potential TS interferer compared to RLAN channel 11 interferer, for similar power levels, as there is 12 dB delta in composite performance.

4.7.8 Victim Thermal Noise

Since $kT = -173.86\ dBm$, the noise floor in consideration of NF and thermal is as follows.

Table 92: Victim Thermal Noise

Victim	RLAN
NF (dB)	9
kT (dBm)	-173.86
Bandwidth (MHz)	20
10 $\log_{10}$ (bandwidth) (dB)	73
Victim noise level (dBm)	-91.86

4.7.9 Propagation parameters

In the analyses of the interference cases, both FSPL and EHata are presented.

For the scenario outdoor to outdoor interference, path loss is the same below 40 m. Between 0.04 and 0.1 km, the Enhanced HATA model[10] linearly interpolates (on a dB-log scale). Beyond 0.1 km, there are various scenarios and parameters. The parameter values used are given in the following table. The parameters are described in the SEAMCAT[11] [20] manual, section A17.3.1. This analysis employs the outdoor à indoor model which adds one external building wall. The typical Building Entry Loss (BEL) of 15 dB was selected as representative of buildings with lower BEL loss[12].

Table 93: Enhanced HATA parameters

Parameter	Value
Environment	Urban
Frequency (MHz)	2437-2490
Hm (m) for RLAN/BLE	1.5
Hb (m) for TS BS Outdoor	10
Hb (m) for TS BS Indoor	1.5
Alpha (all distances are well under 20 km)	1
External Wall loss (dB)	15

10 Enhanced Hata model has been further extended by extrapolating the model to permit 10 meter antenna heights (see ANNEX 2:)

11 In this Report SEAMCAT tool has not been used for performing studies, but reference is used to SEAMCAT Handbook relating to explaining propagation model used in calculations

12 BEL is set to 15 dB as per 3GPP TR 38.901, section 7.4.3.1 for concrete material

Parameter	Value
Internal Wall loss (dB)	5
Room size (m)	4

This analysis also requires an internal to internal propagation model. For this scenario, E-HATA is used as defined in SEAMCAT manual in section A 17.3.3 [20]. Other assumptions for this scenario are: same building, same floor, and an added linear 5 dB of loss for every 4 m of distance. The interference of the complete system is calculated using FSPL and 10 m separation for all the scenarios.

4.7.10 Scenarios

The ISM band is congested such that in many cases the desired operating range of the system is not set by the thermal noise of the receiver, but by the interference of other interferers (interference limited). Since common guidance for RLAN indoor coverage is to have about 10 m separation between devices, this section will determine the Minimum Coupling Loss (MCL) in the two conditions where 1) there is no additional interference, and 2) where there is a competing RLAN AP transmitting on the nearest clear channel, at +20 dBm power and at 10 m distance. These assumptions lead to the analysis scenarios in Table 94.

Table 94: Analysis Scenarios

TS Location	TS Antenna	Victim	Environment	Case #
Outdoor	Bore sight (+6 dBi)	RLAN	Thermal noise	1
			Interference limited	2
		Bluetooth	Thermal noise	3
			Interference limited	4
	Side lobe (0 dBi)	RLAN	Thermal noise	5
			Interference limited	6
		Bluetooth	Thermal noise	7
			Interference limited	8
Indoor	0 dBi	RLAN	Thermal noise	9
			Interference limited	10
		Bluetooth	Thermal noise	11
			Interference limited	12

The cases are shown in the following figures.

Figure 30 shows cases 1-8 where the Outdoor TS has either 0 or 6 dBi gain, the Victim is either RLAN or Bluetooth, and there is or is not a competing RLAN device limiting the victim N+I floor. The distance between the competing RLAN device to the victim (d_c) is fixed at 10 m and calculated as FSPL for the competing system interference levels. In a user environment this level will vary widely by device and place as well as time. This arrangement is not uncommon and was selected to show the comparative performance of a TS to a competing RLAN.

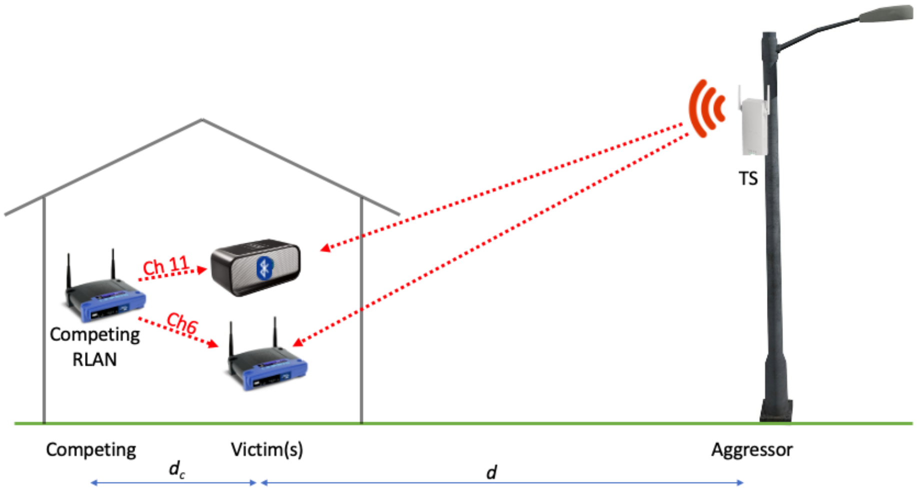

Figure 30: Outdoor TS to Indoor ISM devices

Figure 31 shows cases 9-12 where the Indoor TS has 0 dBi gain, the Victim is either RLAN or Bluetooth, and there is or is not a competing RLAN device limiting the victim N+I floor. The distance between the competing RLAN device to the victim (d_c) is fixed at 10 m and calculated as FSPL to determine the competing system interference levels. In a user environment this level will vary widely by device and place as well as time. This arrangement is not uncommon and was selected to show the comparative performance of a TS to a competing RLAN.

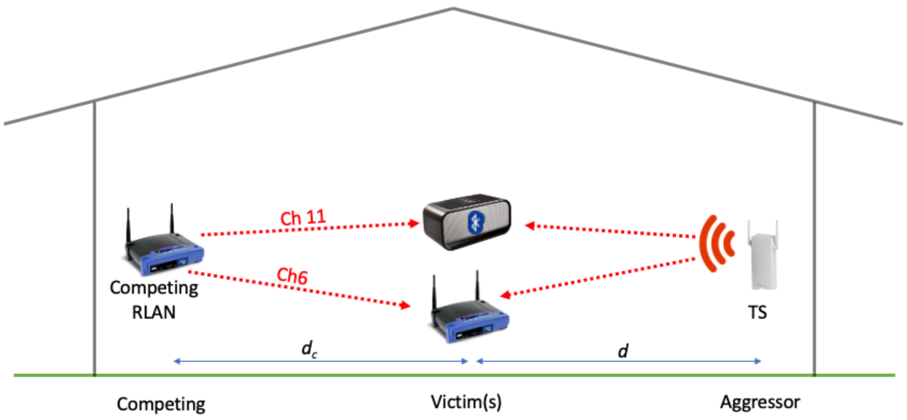

Figure 31: Indoor TS to Indoor ISM devices

4.7.11 Study

Since the separation distances between interferer and victim will generally be short, the FSPL will be used as well as Enhanced HATA. The equation for FSPL is given by:

$$FSPL\ (dB\ ) = 20\ Log_{10}\left(\frac{4\pi d}{\lambda}\right) - (G_T + G_R); \qquad (13)$$

Where:

- λ, d are in the same units.

In all cases the receiver gain assumed to be 0 dBi, the transmit gain is either 0 or 6 dBi, and distance units will be expressed in meters. Therefore, the path loss equation may be simplified as:

$$FSPL\ (dB) = \ 40.37 + 20\ Log_{10}(\ d\ ) - G_T\ ; \qquad (14)$$

Where:

- d in expressed in meters.

For the 10 m separation of a competing system, the loss is therefore 60.37 dB. The table below presents the scenarios and the resulting MCL and Separation Distance. The parameters used for Enhanced HATA were given above in Table 93.

Table 95: MCL and Separation Distance Calculations with RLAN (MSD)

Parameter	Unit	1	2	5	6	9	10
P	dBm	30.00	30.00	30.00	30.00.00	20.00	20.00
GTX	dBi	6.00	6.00	0.00	0.00	0.00	0.00
Composite	dB	-23.00	-23.00	-23.00	-23.00	-23.00	-23.00
BEL	dB	-15.00	-15.00	-15.00	-15.00	0.00	0.00
Hm	m	1.50	1.50	1.50	1.50	1.50	1.50
Hb	m	10.00	10.00	10.00	10.00	1.50	1.50
Noise Floor (note 1)	dBm	-92.00	-63.40	-92.00	-63.40	-92.00	-63.40
MCL	dB	90.00	61.40	84.00	55.40	89.00	60.40
Separation distance (FSPL)	m	304.00	11.00	152.00	6.00	271.00	10.00
EHata (urban)	m	59.00	11.00	52.00	6.00	58.00	10.00
Note 1: Thermal Noise for cases 1, 5, 9 and Thermal Noise + Interference of other interferers for cases 2, 6, 10; interference of other interferers (interference limited) is computed from a competing RLAN AP transmitting on the nearest clear channel, at +20 dBm power and at 10 m distance.							

Table 96: MCL and Separation Distance calculation with Bluetooth (noise limited).

Parameter	Unit	Case		
		3	7	11
		BS outdoor	BS outdoor side-lobe	BS indoor
Ptx	dBm	30.00	30.00	20.00
Gtx	dBi	6.00	0.00	0.00
Grx	dBi	0.00	0.00	0.00
BEL	dB	15.00	15.00	0.00
Composite	dB	51.00	51.00	51.00
B TX	MHz	10.00	10.00	10.00
B RX	MHz	1.00	1.00	1.00
Ptx in RX band	dBm	20.00	20.00	10.00
I max	dBm	-40.00	-46.00	-41.00
C	dBm	-67.00	-67.00	-67.00
T(C/I)	dB	11.00	11.00	11.00
MCL	dB	38.00	32.00	37.00
d_FSPL	m	0.76	0.38	0.68

		Case		
D_EHata (urban)	m	0.76	0.38	0.68

Table 97: MCL and Separation Distance calculation with Bluetooth (interference limited)

Parameter	Unit	Case		
		4	8	12
		BS outdoor	BS outdoor side-lobe	BS indoor
Ptx	dBm	30.00	30.00	20.00
Gtx	dBi	6.00	0.00	0.00
Grx	dBi	0.00	0.00	0.00
BEL	dB	15.00	15.00	0.00
Composite	dB	51.00	51.00	51.00
B TX	MHz	10.00	10.00	10.00
B RX	MHz	1.00	1.00	1.00
Ptx in RX band	dBm	20.00	20.00	10.00
I max	dBm	-40.00	-46.00	-41.00
Ptx RLAN	dBm	20.00	20.00	20.00
B TX RLAN	MHz	20	20	20
Distance	m	10.00	10.00	10.00
Composite	dB	39.00	39.00	39.00
Added interf	dBm	-30.14	-30.14	-30.14
I max + RLAN interf	dBm	-29.71	-30.03	-29.80
C	dBm	-67.00	-67.00	-67.00
T(C/I)	dB	11.00	11.00	11.00
MCL	dB	48.29	47.97	48.20
d_FSPL	m	2.49	2.40	2.46
D_EHata (urban)	m	2.49	2.40	2.46

4.7.12 TDD compatibility with RLAN and Bluetooth

The TS is an LTE TDD system and so there is the possibility that RLAN and Bluetooth would be able to complete a transmission in between the TX portions of the frame.

For RLAN that has been considered in various publications, for instance TR 36.791 indicates the possibility in section 6.5.5.2 of that paper and further presents test results in section 6.5.5.5 of that paper. Additionally, the 802.11 MTU is 2304 bytes [13] and would commonly have a dwell time well under the RX portion of the LTE TDD frame.

[13] https://networkengineering.stackexchange.com/questions/32970/what-is-the-802-11-mtu

For Bluetooth TR 36.791 indicates the possibility in section 6.5.5.4 of that paper. Further, the Bluetooth slots[14] are short, 375 micro-second, where a new hop frequency is used for each transmission slot; thus, a given Bluetooth transmission slot is short compared to the RX portion of a TDD LTE frame.

4.7.13 Summary

Interfering RLAN and TS exhibit similar indoor interference characteristics for RLAN receivers, as described in 4.7.7.

For outdoor to indoor interference scenarios, greater distances and building entry loss reduce the power levels of the outdoor TS such that the indoor signal levels are similar to the RLAN and indoor TS case.

Since the TS is TDD, there are periodic intervals during which the TS is not transmitting. This may allow another ISM device time to operate even if there is insufficient separation.

As noted in in 4.7.7, Bluetooth selectivity, narrow bandwidth, and TS unwanted emissions allow it to be much more tolerant of TS than RLAN.

In low noise environments, and where there is low propagation loss, careful consideration during deployment is needed since separation between TS and RLAN may be required.

Table 98: Extract from Table 95: MCL and Separation Distance Calculations

TS Location	TS Antenna	Victim	Environment	Separation Distance using EHata urban (m)	Separation Distance using FPSL (m)
Outdoor	Bore sight (+6 dBi)	RLAN	Thermal noise	59.00	304.00
			Interference limited	11.00	11.00
		Bluetooth	Thermal noise	0.76	0.76
			Interference limited	2.49	2.49
	Side lobe (0 dBi)	RLAN	Thermal noise	52.00	152.00
			Interference limited	6.00	6.00
		Bluetooth	Thermal noise	0.38	0.38
			Interference limited	2.40	2.40
Indoor	0 dBi	RLAN	Thermal noise	58.00	571.00
			Interference limited	10.00	10.00
		Bluetooth	Thermal noise	0.68	0.68
			Interference limited	2.46	2.46

4.8 CALCULATIONS OF MINIMUM PROTECTION DISTANCES BASED ON THE MEASUREMENT CAMPAIGN BETWEEN BLUETOOTH-/RLAN SYSTEMS AND LTE-SYSTEMS IN OUTDOOR AND INDOOR SCENARIOS

4.8.1 Introduction

This document describes the calculations of minimum protection distances for outdoor/indoor scenarios between New Terrestrial Systems (TS), as interferer, and Bluetooth (BLE)/Radio Local Area Network (RLAN) systems as victims. The parameters sensitivities and protection

[14] https://www.asee.org/documents/zones/zone1/2008/student/ASEE12008_0017_paper.pdf

ratios (carrier-to-interference ratio = (C/I) = C-I) are the results of the measurement campaign of the BNetzA, which are described in ANNEX 4. These parameters are median values. All the other parameter, i.e. power, antenna gain, are as defined in this report – see chapter 3.2. The protection distances were calculated for different interference levels:

- Grade 1: Interference just begins to be measurable/noticeable;
- Grade 2: Connection is severely interfered and would probably not be used;
- Grade 3: Total or near total loss of performance, or connection loss.

4.8.2 Scenario BLE/RLAN-systems interfered by TS (LTE-Systems)

There are 3 types of scenarios:

- BLE/RLAN (victims) and TS (BS/UE, interferer) outside buildings;
- BLE/RLAN (victims) inside buildings and TS (BS/UE, interferer) outside buildings;
- BLE/RLAN (victims) inside buildings and TS (BS/UE, interferer) inside buildings.

4.8.3 System parameter

Table 99: Input parameters

Parameter	Unit	Value	Reference
Sensitivity Rx BLE	dBm	-89 (median)	ANNEX 4:
Sensitivity Rx RLAN	dBm	-61 (median)	ANNEX 4:
Measured protection ratio BLE $(C/I)_{dB} = (C_{dB} - I_{dB})$	dB	-53 up to -63 (median)	ANNEX 4:
Measured protection ratio RLAN $(C/I)_{dB} = (C_{dB} - I_{dB})$	dB	-22 up to -39 (median)	ANNEX 4:
$P_{TS,BS}$	dBm	20 (indoor) / 30 (outdoor)	Table 14
$P_{TS,UE}$	dBm	20 (indoor) / 24 (outdoor)	Table 16
$Antenna\ gain\ BS$ $G_{TS,BS}$	dB	6	Table 14
$Antenna\ gain\ UE$ $G_{TS,UE}$	dB	0	Table 16
$P_{TS,BS}\ (e.i.r.p.)$	dBm	36 / 30	Table 14
$P_{TS,UE}\ (e.i.r.p.)$	dBm	20	Table 16
Bandwidth B_{TS}	MHz	10	Table 14
Frequency band	MHz	2483.5 - 2500	Table 14, Table 12

In this table, the system parameters are collected that are used in the following calculations. The BLE/RLAN parameters (sensitivities, carrier-to-interference ratios) are those of the systems tested in the measurement campaign from BNetzA (see ANNEX 4:). All the other parameters, i.e. power, antenna gain, bandwidths, are as defined in this report – see chapter 3.2.

4.8.4 Propagation model

4.8.4.1 Free-Space Attenuation

The free-space propagation is a fundamental reference for radio-engineering. The basic calculation of the free-space attenuation is provided in Recommendation ITU-R P.525. The basic transmission loss is referred to free-space attenuation between isotropic antennas and is a function of the frequency and the distance between the isotropic antennas.

$$L_{fs} = 32.45 + 20log_{10}\left({}^{d}/_{km}\right) + 20log_{10}\left({}^{f}/_{MHz}\right) \tag{15}$$

$$^{d}/_{km} = 10^{\left(L_{fs}-32,45-20log_{10}\left({}^{f}/_{MHz}\right)\right)/20} \tag{16}$$

Noting that the free space attenuation is independent of the antenna heights and is depending only on the frequency and direct radio path considered, i.e. no multi-path propagation is addressed.

4.8.4.2 Recommendation ITU-R P.2109 on building entry loss

This Recommendation provides a method for estimating building entry loss at frequencies between about 80 MHz and 100 GHz. The method is not site-specific, and is primarily intended for use in sharing and compatibility studies. This is a rather new Recommendation, adopted in 2017.

The penetration loss at 2490 MHz is about 13 dB for traditional houses and 33 dB for thermally efficient houses. The chosen value is 15 dB.

4.8.5 MCL analysis

The interference on RLAN-/Bluetooth systems in outdoor/indoor case is determined with MCL methodology for a worst-case and realistic signal shape. The parameter for RLAN-/Bluetooth systems are based on measurement campaign from BNetzA (see ANNEX 4:). The basic transmission loss is free-space L_{fs} and for TS bandwidth from $B_{TS} = 10\,MHz$ can be determined by

$$L_{fs} = \frac{P_{TS,x}}{B_{TS}} + G_{TS,x} - BEL - \frac{I_{BLE,RLAN}}{B_{TS}} \tag{17}$$

The parameter $C_{BLE,RLAN} = Wanted\ level = sensitivity + \ 3\ dB\ or\ 10\ dB;\ (C-I)_{dB} = \left({}^{C}/_{I}\right)_{dB}$ of interference criteria for BLE/RLAN systems $I_{BLE,RLAN}$ are given from measurement campaign (ANNEX 4:) is calculated by

$$\frac{I_{BLE,RLAN}}{B_{TS}} = \frac{C_{BLE,RLAN}}{B_{BLE,RLAN}} - \left(\frac{C_{BLE,RLAN}}{B_{BLE,RLAN}} - \frac{I_{BLE,RLAN}}{B_{TS}}\right) \tag{18}$$

Where:

- $L_{fs} = Basic\ transmission\ loss\ (free - space);$
- $P_{TS,x} = Transmitted\ power\ for\ Tx\ terrestrial\ system\ (x = BS, UE) in\ dBm;$
- $TS = Terrestrial\ systems;$
- $x = Base\ station\ (BS), User\ equipment\ (UE);$
- $B_{TS} = Bandwidth\ for\ Terrestrial\ systems\ in\ MHz;$
- $G_{TS,x} = Antenna\ gain\ for\ TS\ (x = BS, UE)\ in\ dB;$

- $BEL = Building\ entry\ loss\ in\ dB;$
- $I_{BLE,RLAN} = Interference\ criteria\ (LTE\ level\ ) for\ Rx\ Bluetooth\ (BLE) or\ RLAN\ systems;$
- $B_{BLE,RLAN} = Bandwith\ of\ Bluetooth\ (BLE)\ or\ RLAN\ systems\ in\ MHz;$
- $C_{BLE,RLAN} = Wanted\ level = sensitivity + 10\ dB\ or\ 3\ dB\ for\ Rx\ BLE\ or\ RLAN\ systems\ in\ dBm\ ;$
- $\left({}^{C}/_{I}\right)_{dB} = (C - I)_{dB} = Protection\ ratio\ (Carrier - to - Interference\ ratio)\ in\ dB.$

4.8.6 Summary Results

Table 100: Summary of separation distances for outdoor scenarios TS interfere with BLE/RLAN. Calculations are done with propgation model in Recommendation ITU-R. P.525

Scenario Outdoor	Distance [m] of Interference grade 1* (median)	Distance [m] of Interference grade 2* (median)	Distance [m] of Interference grade 3* (median)
BS,*realistic* interfere with RLAN/BLE	3.8 to 34	4.3 to 15.2	2.4 to 9.6
BS,*worst case* interfere with RLAN/BLE	6 to 48	5.4 to 19.1	2.4 to 13.5
UE,*realistic* interfere with RLAN/BLE	2.1 to 8.5	1.7 to 3.4	0.8 to 1.7
UE,*worst case* interfere with RLAN/BLE	2.4 to 34	1.7 to 15.2	0 to 1.9
*Grade 1: Interference just begins to be measurable/noticeable *Grade 2: Connection is severely interfered and would probably not be used *Grade 3: Total or near total loss of performance, or connection loss			

Table 101: Summary of separation distances for indoor scenarios TS interfere with BLE/RLAN. Calculations are done with propgation model in Recommendation ITU-R. P.525

Scenario Indoor	Distance [m] of Interference grade 1* (median)	Distance [m] of Interference grade 2* (median)	Distance [m] of Interference grade 3* (median)
BS,*realistic* interfere with RLAN/BLE	0.7 to 6	0.8 to 2.7	0.4 to 1.7
BS,*worst case* interfere with RLAN/BLE	1.1 to 8.5	1 to 3.4	0.4 to 2.4
UE,*realistic* interfere with RLAN/BLE	0.4 to 5.4	0.3 to 2.1	0.1 to 1.1
UE,*worst case* interfere with RLAN/BLE	0.4 to 12	0.3 to 6	0 to 1.1
*Grade 1: Interference just begins to be measurable/noticeable *Grade 2: Connection is severely interfered and would probably not be used *Grade 3: Total or near total loss of performance, or connection loss			

4.8.7 Detailed Summary Results

Table 102: Summary of the results BLE/RLAN – outdoor scenarios (C = Wanted level = sensitivity + 3 dB). Calculations are done with propgation model in Recommendation ITU-R. P.525

Scenario Outdoor	Power e.i.r.p [dBm]	Distance [m] of Interference grade 1 (median)	Distance [m] of Interference grade 2 (median)	Distance [m] of Interference grade 3 (median)
BS,*realistic* interfere with BLE,*y*	36	17.0	15.2	9.6
BS,*worst case* interfere with BLE,*y*	36	21.5	19.1	13.5
BS,*realistic* interfere with BLE,*y*	30	8.5	7.6	4.8
BS,*worst case* interfere with BLE,*y*	30	10.8	9.6	6.8
UE,*realistic* interfere with BLE,*y*	24	3.8	3.4	1.7
UE,*worst case* interfere with BLE,*y*	24	4.3	3.8	1.7
BS,*realistic* interfere with RLAN,*z*	36	34.0	13.5	6.8
BS,*worst case* interfere with RLAN,*z*	36	48.0	17.0	6.8
BS,*realistic* interfere with RLAN,*z*	30	17.0	6.8	3.4
BS,*worst case* interfere with RLAN,*z*	30	24.1	8.5	3.4
UE,*realistic* interfere with RLAN,*z*	24	8.5	2.4	0.8
UE,*worst case* interfere with RLAN,*z*	24	34.0	15.2	1.9
y = Audio streaming, Mouse control, Device control *z = Data transmission, Device control*				

Table 103: Summary of the results BLE/RLAN – outdoor scenarios (C = Wanted level = sensitivity + 10 dB). Calculationtions are done with propgation model in IT-R. P.525

Scenario Outdoor	Power e.i.r.p [dBm]	Distance [m] of Interference grade 1 (median)	Distance [m] of Interference grade 2 (median)	Distance [m] of Interference grade 3 (median)
BS,*realistic* interfere with BLE,*y*	36	7.6	8.5	6.8
BS,*worst case* interfere with BLE,*y*	36	12.1	10.8	6.8
BS,*realistic* interfere with BLE,*y*	30	3.8	4.3	3.4
BS,*worst case* interfere with BLE,*y*	30	6.0	5.4	3.4
UE,*realistic* interfere with BLE,*y*	24	2.1	1.7	1.0
UE,*worst case* interfere with BLE,*y*	24	2.4	1.7	0.0
BS,*realistic* interfere with RLAN,*z*	36	19.1	9.6	4.8
BS,*worst case* interfere with RLAN,*z*	36	19.1	12.1	4.8
BS,*realistic* interfere with RLAN,*z*	30	9.6	4.8	2.4
BS,*worst case* interfere with RLAN,*z*	30	9.6	6.0	2.4
UE,*realistic* interfere with RLAN,*z*	24	4.3	1.9	0.8
UE,*worst case* interfere with RLAN,*z*	24	19.1	9.6	0.0
y = Audio streaming, Mouse control, Device control *z = Data transmission, Device control*				

Table 104: Summary of the results BLE/RLAN – indoor scenarios (C = Wanted level = sensitivity + 3 dB). Calculationtions are done with propgation model in IT-R. P.525

Scenario Indoor	Power e.i.r.p [dBm]	BEL	Distance [m] of Interference grade 1 (median)	Distance [m] of Interference grade 2 (median)	Distance [m] of Interference grade 3 (median)
BS,*realistic* interfere with BLE,*y*	36	15	3.0	2.7	1.7
BS,*worst case* interfere with BLE,*y*	36	15	3.8	3.4	2.4
BS,*realistic* interfere with BLE,*y*	30	15	1.5	1.4	0.9
BS,*worst case* interfere with BLE,*y*	30	15	1.9	1.7	1.2
BS,*realistic* interfere with BLE,*y (Inside Building)*	20	0	2.7	2.4	1.5
BS,*worst case* interfere with BLE,*y (Inside Building)*	20	0	3.4	3.0	2.1
UE,*realistic* interfere with BLE,*y*	24	15	0.7	0.6	0.3
UE,*worst case* interfere with BLE,*y*	24	15	0.8	0.7	0.3
UE,*realistic* interfere with BLE,*y (Inside Building)*	20	0	2.4	2.1	1.1
UE,*worst case* interfere with BLE,*y (Inside Building)*	20	0	2.7	2.4	1.1
BS,*realistic* interfere with RLAN,*z*	36	15	6.0	2.4	1.2
BS,*worst case* interfere with RLAN,*z*	36	15	8.5	3.0	1.2
BS,*realistic* interfere with RLAN,*z*	30	15	3.0	1.2	0.6
BS,*worst case* interfere with RLAN,*z*	30	15	4.3	1.5	0.6
BS,*realistic* interfere with RLAN,*z (Inside Building)*	20	0	5.4	2.1	1.1
BS,*worst case* interfere with RLAN,*z (Inside Building)*	20	0	7.6	2.7	1.1
UE,*realistic* interfere with RLAN,*z*	24	15	1.5	0.4	0.1
UE,*worst case* interfere with RLAN,*z*	24	15	6.0	2.7	0.3
UE,*realistic* interfere with RLAN,*z (Inside Building)*	20	0	5.4	1.5	0.5
UE,*worst case* interfere with RLAN,*z Inside Building)*	20	0	21.5	9.6	1.2

Table 105: Summary of the results BLE/RLAN – indoor scenarios (C = Wanted level = sensitivity + 10 dB) Calculationtions are done with propgation model in IT-R. P.525

Scenario Indoor	Power e.i.r.p [dBm]	BEL	Distance [m] of Interference grade 1 (median)	Distance [m] of Interference grade 2 (median)	Distance [m] of Interference grade 3 (median)
BS,*realistic* interfere with BLE,*y*	36	15	1.4	1.5	1.2
BS,*worst case* interfere with BLE,*y*	36	15	2.1	1.9	1.2
BS,*realistic* interfere with BLE,*y*	30	15	0.7	0.8	0.6
BS,*worst case* interfere with BLE,*y*	30	15	1.1	1.0	0.6
BS,*realistic* interfere with BLE,*y (Inside Building)*	20	0	1.2	1.4	1.1

Scenario Indoor	Power e.i.r.p [dBm]	BEL	Distance [m] of Interference grade 1 (median)	Distance [m] of Interference grade 2 (median)	Distance [m] of Interference grade 3 (median)
BS,*worst case* interfere with BLE,*y (Inside Building)*	20	0	1.9	1.7	1.1
UE,*realistic* interfere with BLE,*y*	24	15	0.4	0.3	0.2
UE,*worst case* interfere with BLE,*y*	24	15	0.4	0.3	0.0
UE,*realistic* interfere with BLE,*y (Inside Building)*	20	0	1.4	1.1	0.6
UE,*worst case* interfere with BLE,*y (Inside Building)*	20	0	1.5	1.1	0.5
BS,*realistic* interfere with RLAN,*z*	36	15	3.4	1.7	0.9
BS,*worst case* interfere with RLAN,*z*	36	15	3.4	2.1	0.9
BS,*realistic* interfere with RLAN,*z*	30	15	1.7	0.9	0.4
BS,*worst case* interfere with RLAN,*z*	30	15	1.7	1.1	0.4
BS,*realistic* interfere with RLAN,*z (Inside Building)*	20	0	3.0	1.5	0.8
BS,*worst case* interfere with RLAN,*z (Inside Building)*	20	0	3.0	1.9	0.8
UE,*realistic* interfere with RLAN,*z*	24	15	0.8	0.3	0.1
UE,*worst case* interfere with RLAN,*z*	24	15	3.4	1.7	0.0
UE,*realistic* interfere with RLAN,*z (Inside Building)*	20	0	2.7	1.2	0.5
UE,*worst case* interfere with RLAN,*z Inside Building)*	20	0	12.1	6.0	0.9

4.8.8 Summary

The study shows the calculations of the minimum protection distances between LTE-Systems (BS, UE), as interferer, and BLE/RLAN-Systems, as victims, in Outdoor and Indoor scenarios.

The parameter sensitivities and carrier-to-interference ratios (C/I)dB = (CdB-IdB) for BLE/RLAN are based on the measurement campaign from BNetzA (see the ANNEX 4:). The required protection distances are derived considering a realistic and worst case signals from LTE-systems (BS/UE).

For BLE/RLAN, the distances are calculated with different types of interference degrees (grades 1 to 3) and TS power levels. The propagation model is free-space without considering antenna diagram and heights.

- Outdoor case
  - The results give protection distances for the outdoor case with free space propagation model where the TS (BS/UE) interferes with BLE/RLAN systems that range from *0 m to 48 m*. The degree of interference 1 (Interference just begins to be measurable/noticeable), with a worst case signal shape, evokes the largest distances.
- Indoor case
  - In the indoor case, the protection distances are lower because building entry loss (BEL) has been included. If the TS are placed inside the buildings the power levels are much smaller than for outdoor operation. The protection distances vary from *0 m to 12 m*. The highest distance is again caused by interference grade 1 with a worst case signal shape.

4.9 COMPATIBILITY WITH RADIO ASTRONOMY SERVICES

4.9.1 Introduction

The frequency range 4950-5000 MHz is extremely important to the RAS for continuum observations, both in single-dish mode and with VLBI. A large variety of astronomical objects can be studied, for example galaxies and their active cores (powered by super-massive black holes), super-nova remnants, pulsars, and so on.

Table 106 lists CEPT countries with radio astronomy stations operating in both frequency ranges 4950 - 990 MHz and 4990-5000 MHz.

Table 106: List of CEPT countries with RAS stations operating in the frequency band 4950-5000 MHz

RAS station	Country	Geographic longitude	Geographic latitude	Altitude above sea level (m)
Nancay	France	02° 11′ 50″	47° 22′ 24″	150
Effelsberg	Germany	06° 53′ 01.0″	50° 31′ 29.4″	369
Wettzell		12° 52′ 38″	49° 08′ 42″	611
Medicina	Italy	11° 38′ 49″	44° 31′ 15″	28
Noto		14° 59′ 20″	36° 52′ 33″	90
Sardinia		09° 14′ 42″	39° 29′ 34″	600
Irbene	Latvia	21º51'18"	57º33'13"	16
Westerbork	Netherlands	06° 36′ 15″	52° 55′ 01″	16
Badary	Russia	102° 14′ 00″	51° 46′ 10″	832
Svetloe		29° 46′ 54″	60° 31′ 56″	80
Sao Zelenchukskaya		43° 47′ 15″	41° 34′ 00″	970
Yebes	Spain	– 03° 05′ 13″	40° 31′ 28.8″	980
Onsala	Sweden	11° 55′ 04″	57° 23′ 35″	18
Bleien	Switzerland	08° 06′ 43.3″	47° 20′ 23.7″	469
Jodrell Bank	UK	-02° 18′ 26″	53° 14′ 10″	78

The second harmonic band of LTE-based terrestrial services UEs operating in 2483.5–2500 MHz partly falls into the 4950-4990 and 4990–5000 MHz RAS band, in which both, continuum and spectral line observations, are frequently carried out. The lower part (4950-4990 MHz) has a secondary allocation, while 4990-5000 MHz is a primary band. Furthermore, RR No. 5.149 [33] applies, which urges administrations "to take all practicable steps to protect the radio astronomy service from harmful interference" in both bands. Power threshold levels needed to protect a RAS station are defined in Recommendation ITU-R RA.769-2 [34]. According to ECC Report 249 [1] (their Figs. 9 and 10), one of the measured LTE800 UE devices produced second harmonics in the 1600 MHz band, with broad-band emissions of about -35 dBm/MHz. It is possible that LTE2500 UEs could produce similar features at 5 GHz and thus the regulatory limit of –30 dBm/MHz for spurious emissions as defined in Recommendation ITU-R SM.329 [10] was deemed to be appropriate for the study of compatibility with the RAS. However spurious emission limits of –40 and –50 dBm/MHz were also investigated for comparison. It is noted that in the RR [33], there is also footnote No. 5.402 which is about second harmonic emission into the RAS band.

The compatibility with RAS and terrestrial UEs is studied in the following for the single-interferer scenario. Both, the generic (i.e., flat-Earth) and site-specific (i.e., accounting for terrain heights around real observatories) cases are of interest.

4.9.2 RAS technical parameters

Threshold levels for interference detrimental to RAS observations are listed in Table 107; they are based on Recommendation ITU-R RA.769-2.

In this study only the case of continuum RAS observations is considered. For the RAS station an isotropic antenna with a gain of 0 dBi (see Recommendation ITU-R RA.1513-2 [35]) is assumed. This considers that the chance that the interference is received by the main lobe of the antenna is low, but that it is almost impossible to predict the actual side-lobe gain, as the RAS pointing position is quasi-random with time (as different astronomical sources are observed). Therefore, for the typical gain towards the horizon, i.e., for compatibility studies vs. terrestrial services, the total average over the pattern (which is about 0 dBi) is usually employed. Note also that according to Recommendation ITU-R SA.509 [36] the level of 0 dBi is usually exceeded within about 19° from boresight.

The Rx height of the RAS station will depend on each case study. For this compatibility study three different scenarios are studied: Effelsberg 100-m RT (Germany) assuming 53 m height, Yebes 40-m RT (Spain) assuming 23 m height and Sardinia 64-m RT (Italy) with 33 m height.

Table 107: RAS thresholds (4990-5000 MHz, continuum and VLBI mode)

RAS allocation status	RAS protection criteria according to Recommendation ITU-R. RA.769-2		
	Parameter	Power entering receiver	Spectral PFD
Primary allocation RR No. 5.149, 5.402 Broadband (note 1, note 2)	Continuum measurements	-207 dB(W/10 MHz)	-241 dB(W/m2 Hz)
	VLBI measurements	-165 dB(W/10 MHz)	-200 dB(W/m2 Hz)
	Antenna noise temp. (K)	12	
	Receiver noise temp. (K)	10	

Note 1: RR. No 5.402 states “Administrations are urged to take all practicable steps to prevent harmful interference to the radio astronomy service from emissions in the 2483.5-2500 MHz band, especially those caused by second-harmonic radiation that would fall into the 4990-5000 MHz band allocated to the radio astronomy service worldwide.”

Note 2: The term “Broadband” corresponds to “continuum” observations (see Table 1 of Recommendation ITU-R RA.769-2 [34]) and “narrowband” to “spectral line” observations (see Table 2 of Recommendation ITU-R RA.769-2) respectively. Both in-band emissions in these RAS bands and emissions from outside these RAS bands falling into them should remain below the thresholds for detrimental interference given in Recommendation ITU-R RA.769-2, subject to Recommendation ITU-R RA.1513 [35] which provides with 2% data loss to the RAS due to interference by all stations of one service, and with an aggregate data loss of 5% in any band from all services.

Some radio telescopes are operating almost exclusively in VLBI mode today. For them, less strict thresholds would theoretically apply (see Table 107). However, it must be pointed out that pure VLBI stations still need to perform calibration measurements, which are usually performed in total-power mode. The priorities of research for individual RAS stations change with time, adapting to the progress of science. It is therefore not appropriate to assume that the proportion of VLBI to continuum work will stay the same. Increasing threshold levels for such stations will impair their function as multi-purpose scientific instruments and restrict the future freedom of choice for their research topics.

4.9.3 IMT technical parameters

The LTE-based TS UEs technical parameters used for this study (Table 108) were mainly adopted from Table 16 (Section 3.2) of this Report. As the compatibility study is carrying on the second harmonic emissions, the regulatory spurious emissions spectral power level of –30 dBm/MHz is assumed as the power transmitted by the UE. Since standard cell-phone equipment is employed, the Tx antennas can be assumed to be omni-directional with a gain of 0 dBi. UE devices are assumed to be on the ground so 1.5 m height is chosen for this study. Second harmonics from channel bandwidths with 5 and 10 MHz partially fall into the secondary allocation RAS band (4950-4900 MHz) while 15 MHz bandwidth channel partially falls into both, the primary and secondary RAS band.

Table 108: LTE-based technical parameters for user equipment (UE)

UE Transmitter	
Parameter	**Value**
Frequency Band	2483.5–2500 MHz
Channel Bandwidths	5, 10, 15 MHz
Spurious emissions	–30 dBm/MHz

4.9.4 Propagation models

Path propagation was calculated according to the model in Recommendation ITU-R P.452-16 [37], using a "time percent" parameter of 2% (for single-interferer scenarios), a temperature of 20°C and 1013 hPa. As the compatibility study is carried out as a worst-case analysis, neither clutter or body loss at the Tx end point of the propagation path is taken into account. Other investigations, which also looked at aggregation effects of a full cell phone network, often come to results, in which the aggregated separation distances are somewhat larger than the single-interferer results, even when they include these additional losses and other effects such as power control mechanisms.

4.9.5 Single interferer study

4.9.5.1 Generic case

For the generic analysis, terrain heights have been set to zero (amsl). In Figure 32, the resulting margin (i.e., the difference between RAS threshold levels and received emission) is displayed (red). A negative margin means that the threshold is exceeded, which leads to data loss at the observatory.

It can be seen that the necessary separation distance is around 50 km when assuming a spurious emission level of –30 dBm/MHz. The situation is less problematic for spurious emission power of the order of –50 dBm/MHz, leading to separation distances of at most 25 km. ANNEX 5: reports about second harmonics measurements of LTE user equipment from one vendor that shows a power spectral density of -57 dBm/MHz at 5 GHz. For such a device, a separation distance of 17 km would suffice.

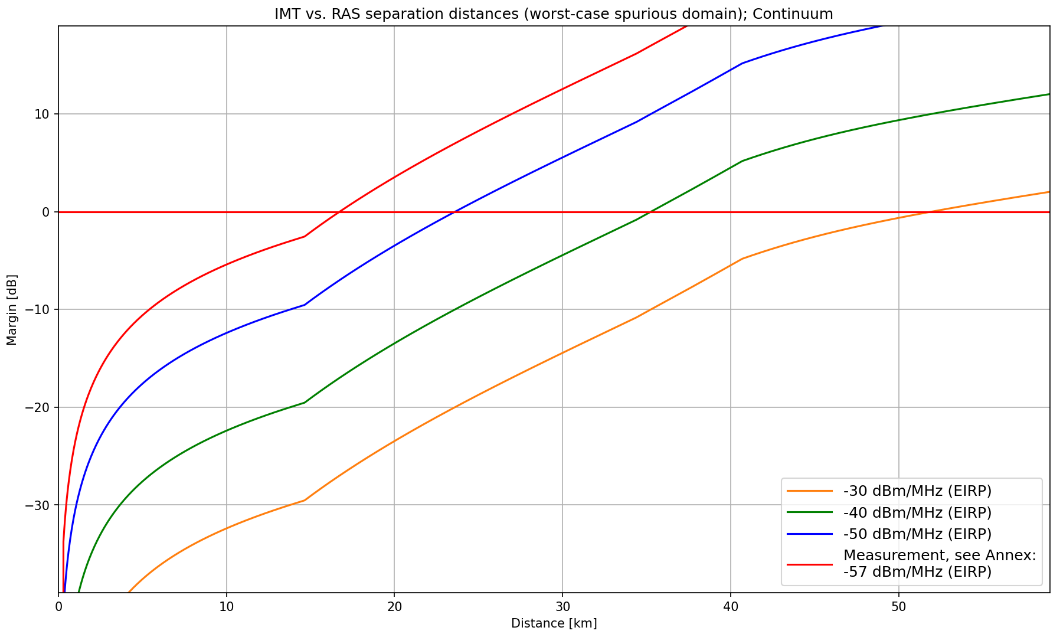

Figure 32: Margin vs. distance for the single-interferer generic case (4990-5000 MHz, continuum mode)

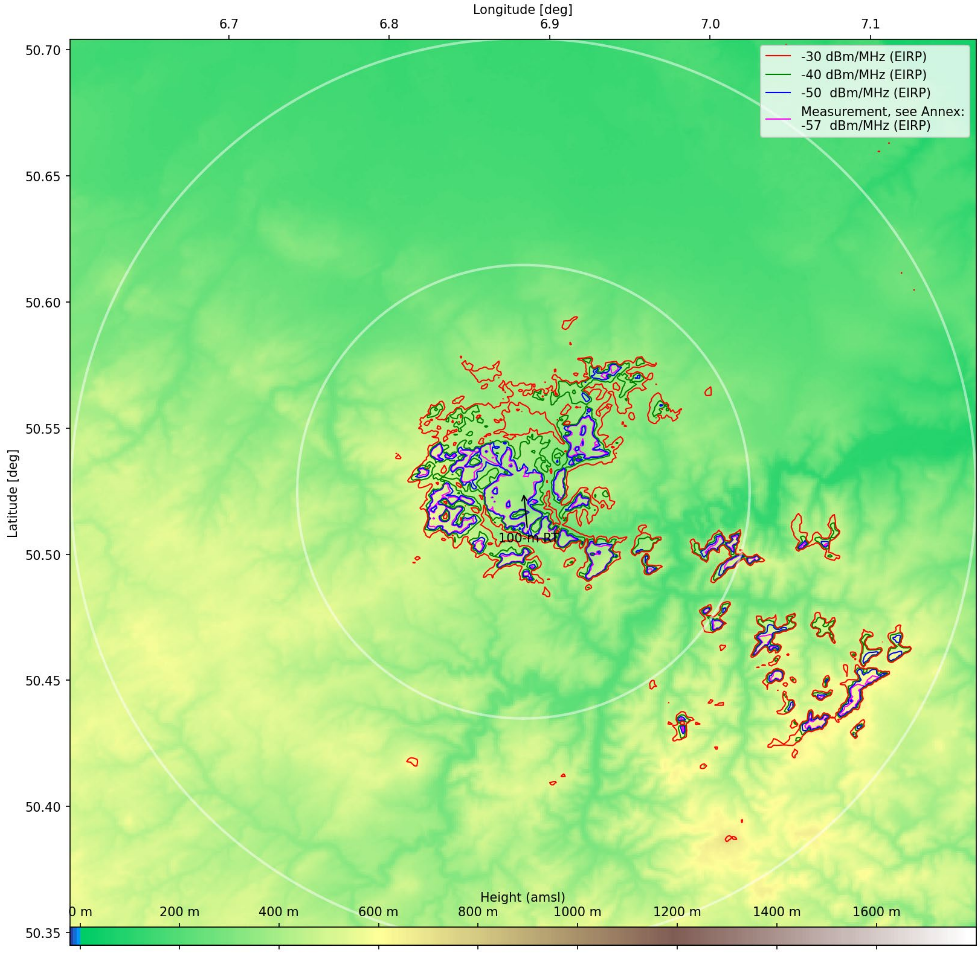

Figure 33:Coordination zones for the single-interferer Effelsberg case (4990-5000 MHz, continuum mode, UE at 1.5-m height) based on measurement results

4.9.5.2 Site-specific cases

The generic case study in the previous section assumes a flat-Earth scenario, i.e., zero terrain height around the RAS station. Some of the European radio telescopes are located in rather mountainous environments and it can be expected that hill or mountain tops can provide some level of additional interference shielding. Therefore, for three European observatories case studies have been carried out, which take the local environment into account, in particular the topographical situation. These three locations are the following, Effelsberg 100-m radio telescope in Germany, Yebes 40-m radio telescope in Spain and the 64-m Sardinia radio telescope in Italy. Since information about the expected deployment densities in the area around these three RAS stations was not previously provided, only a single-interferer worst-case study is performed.

As for the generic case, three spurious emission power levels were considered (i.e., –30 dBm/MHz, which is the regulatory limit and –40 dBm/MHz and –50 dBm/MHz). This allows to compare how the coordination zone sizes change when the power level is decreased. The three maps for the different RAS stations are shown in Figure 34 to Figure 36. The contours show the coordination zone areas. The white circles mark distances from the RAS station in steps of 50 km radius. It is important to point out that the coordination zones do not exclude cell phone operations. There are several mitigation measures, which could be used to allow operation within the zones. For example, clutter loss could be accounted for, if it can be guaranteed that it applies under all circumstances in a given area. Other options would be to use less bandwidth for the carriers or reduce the Tx power depending on the location.

The measurements of one LTE user device, which are reported about in Annex 5, demonstrated that the 2nd harmonics emissions at 5 GHz of this UE had a power spectral density of -57 dBm/MHz. For comparison, Fig. 36 shows a zoom-in of the Effelsberg station map, with an additional contour. The difference to the -50 dBm/MHz contour line is marginal, which is why the results for the other two RAS stations are omitted.

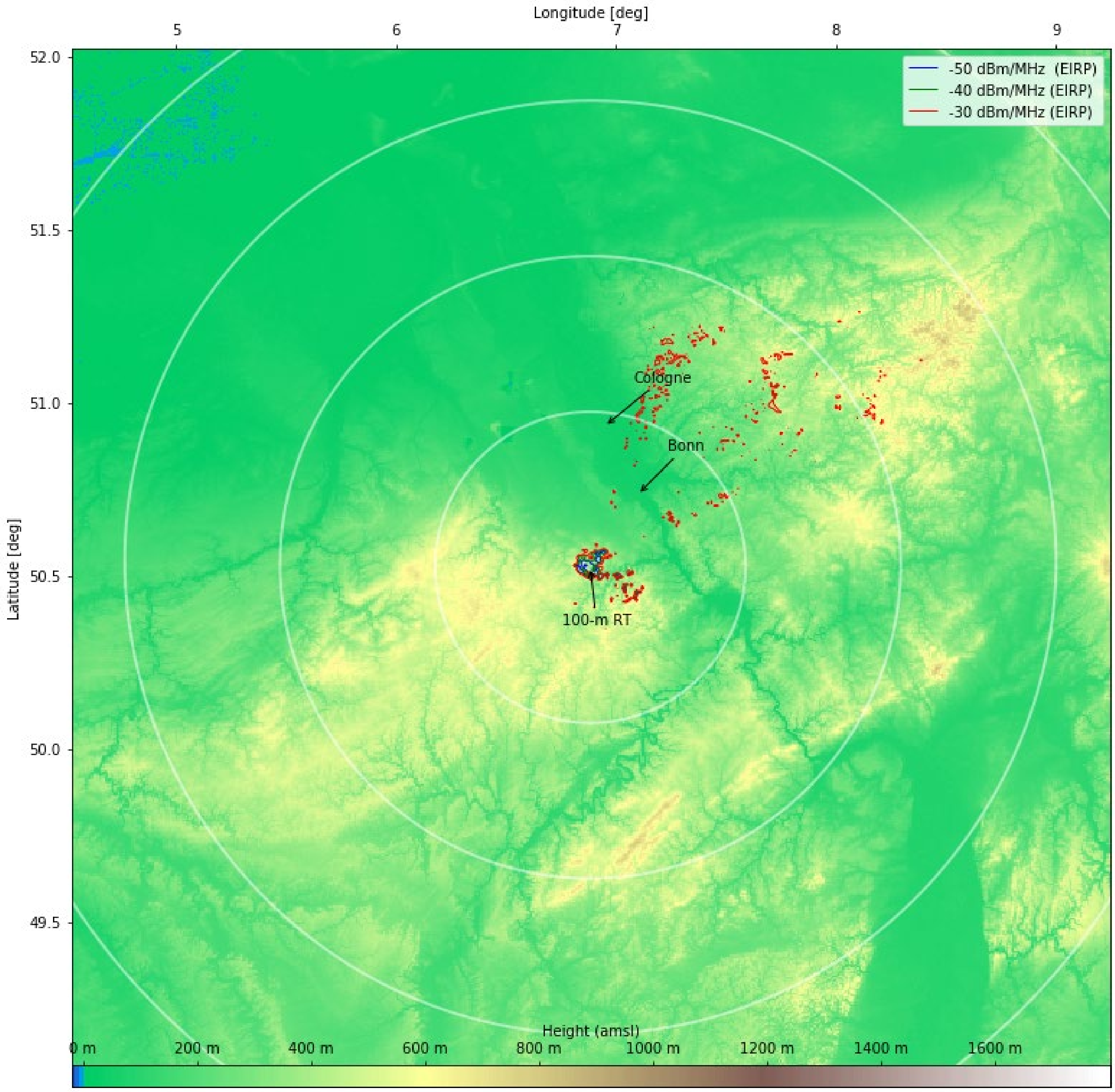

Figure 34: Coordination zones for the single-interferer Effelsberg case (4990-5000 MHz, continuum mode, UE at 1.5-m height) for various levels of spurious emission (–30/–40/–50 dBm/MHz)

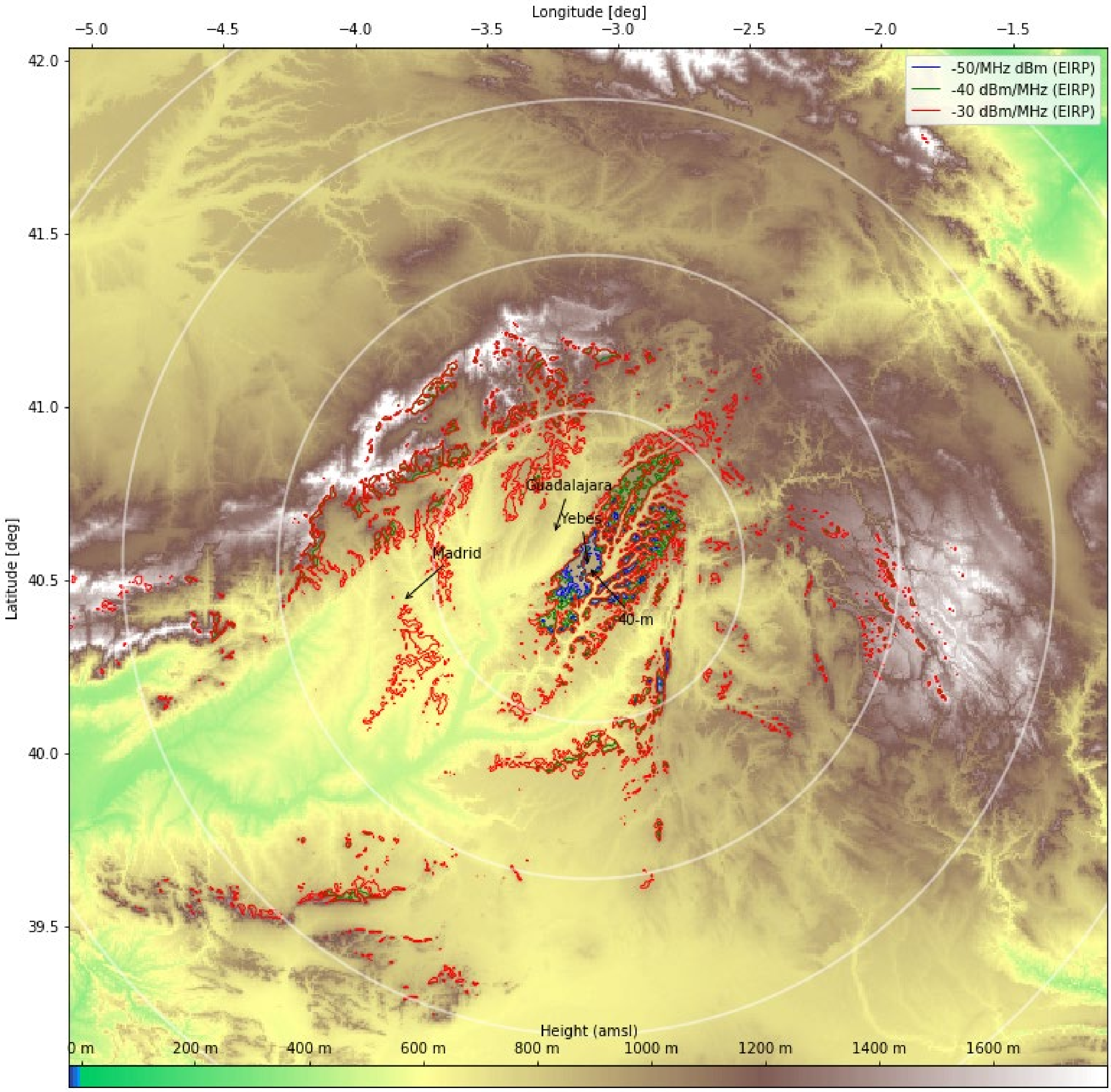

Figure 35: Coordination zones for the single-interferer Yebes case (4990-5000 MHz, continuum mode, UE at 1.5-m height) for various levels of spurious emission (–30/–40/–50 dBm/MHz)

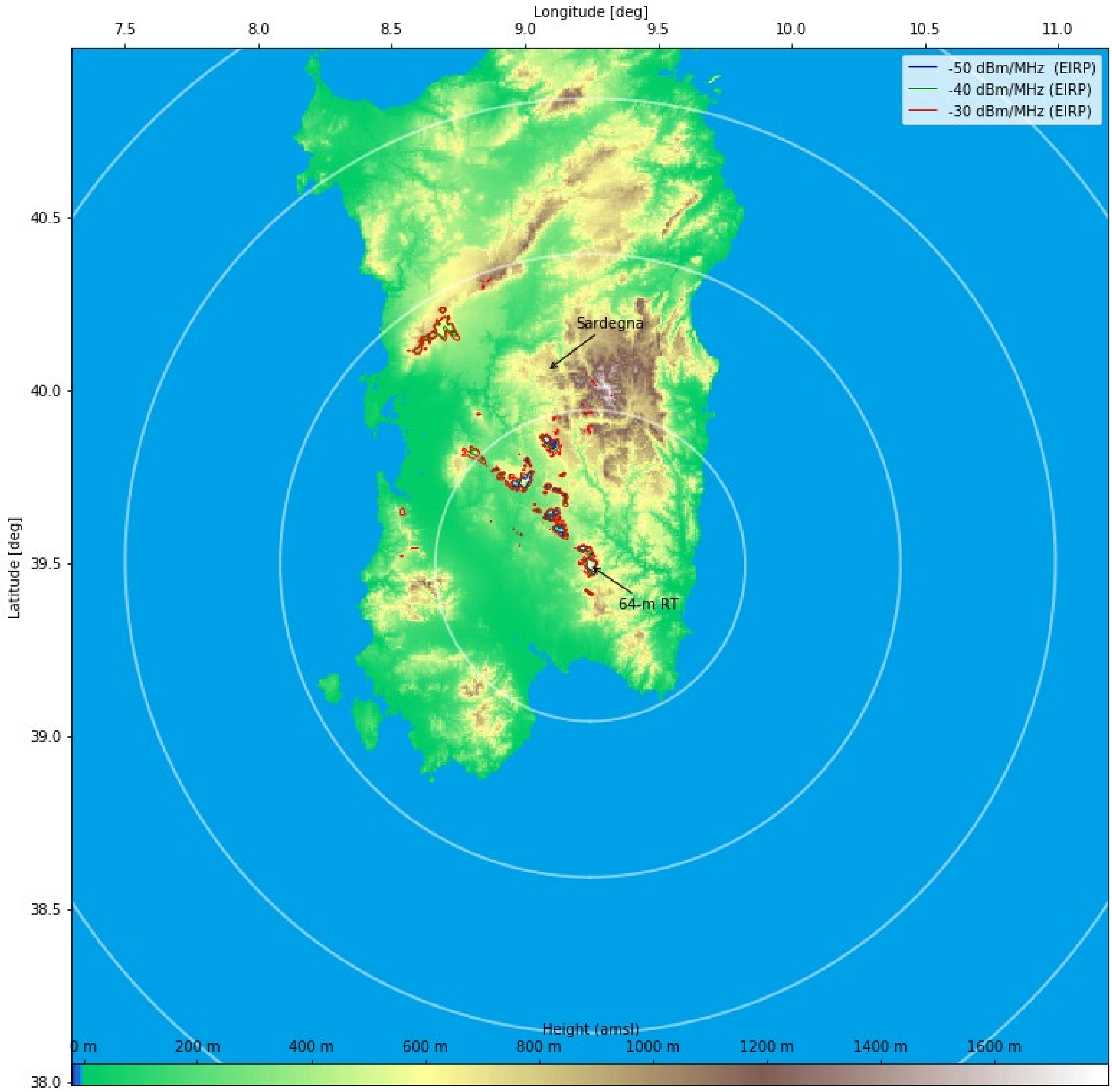

Figure 36: Coordination zones for the single-interferer Sardegna case (4990-5000 MHz, continuum mode, UE at 1.5-m height) for various levels of spurious emission (–30/–40/–50 dBm/MHz)

4.9.6 Summary

The second harmonic band of the TS operating in the 2483.5-2500 MHz band partly falls into the 4950-4990 and 4990–5000 MHz RAS band, in which both, continuum and spectral line observations, are frequently carried out. The single-entry TS worst-case (including UE) compatibility study with respect to the RAS demonstrated that coordination zones of few dozens of kilometres up to more than 100 km in certain cases, depending on the local terrain, are necessary. There are several mitigation measures, which would allow devices to be compatible with the RAS even when closer to the RAS sites, such as the consideration of local clutter losses. Furthermore, different UE available from vendors could have different 2nd harmonic emission levels and some devices may have significantly lower output power emission into the RAS band at 5 GHz compared to the spurious emission limit of -30 dBm/MHz. An example for this is shown by the measurement of the 2nd harmonics emission of one particular UE – see annex 5 – where the interference emission is 27 dB lower than the limit of -30 dBm defined in ERC Recommendation 74-01 [49] and 3GPP TS 36.104 [10].

5 CONCLUSIONS

The scope of this Report is to investigate the technical feasibility and coexistence for the potential introduction of new terrestrial applications in the 2483.5-2500 MHz frequency band, sharing with existing radio services / applications in the same band and compatibility with existing services / applications adjacent bands.

5.1 COMPATIBILITY WITH MSS IN THE BAND 2483.5-2500 MHZ

Section 4.1 analyses the impact of terrestrial service (TS) in the MSS frequency band 2483.5-2495 MHz on Mobile Satellite System (MSS) receivers operating in the same frequency band. Only the impact of the proposed TS using 5MHz and 10 MHz of bandwidth has been studied.

Study between TS using a bandwidth of 5 or 10 MHz and MSS, assuming the median EHata propagation model, gives median separation distances shown below in an extract from Table 25 and Table 26.

Table 109: Extract from Table 22: MCL Separation distance calculation, MSS victim UE, TS interferer

Parameter	Units	Outdoor BS	Outdoor UE	Indoor BS	Indoor UE
D EHata (Urban)	km	1.07	0.20	0.09	0.09
D EHata (Suburban)	km	2.38	0.44	0.13	0.13
D EHata (Rural)	km	8.96	1.64	0.47	0.47

Table 110: Extract from Table 24: MCL Separation distance calculation for 5 MHz TS bandwidth, MSS victim UE, TS interferer

Parameter	Units	Outdoor BS	Outdoor UE	Indoor BS	Indoor UE
D EHata (Urban)	km	1.30	0.24	0.09	0.09
D EHata (Suburban)	km	2.90	0.53	0.15	0.15
D EHata (Rural)	km	9.99	2.0	0.58	0.58

In the absence of any obstacle, the separation distance when the TS system is deployed outdoor is given by the radio horizon. This Report considers only the characteristics of an operational MSS system, Globalstar. Other satellite systems have been filed at the ITU BR for use in this band, but these characteristics have not been considered.

5.2 COMPATIBILITY WITH POSSIBLE FUTURE RDSS IN THE BAND 2483.5-2500 MHZ

Section 4.2 Section analyses the impact of terrestrial service (TS) in the MSS frequency band 2483.5-2495 MHz on possible future in-band RDSS radio navigation systems.

Study between TS and RDSS operating in the same band , assuming the median EHata Urban propagation model, gives median separation distances between TS systems and the future RDSS receivers as shown below in an extract from Table 32 and Table 35, for TS bandwidth of 10 and 5 MHz, respectively.

Table 111: Extract from Table 32: Separation distance calculation for 10 MHz TS bandwidth, RDSS victim 3 dB Grx, TS interferer BS

RDSS Parameter	Units	Case 1		Case 2	
		Outdoor TS Outdoor RDSS		Indoor TS Outdoor RDSS	
Interferer		TS BS	TS UE	TS BS	TS UE
D EHata (urban)	km	0.9	0.2	0.1	0.1
D EHata (suburban)	km	1.8	0.3	0.1	0.1
D EHata (rural)	km	6.8	1.1	0.3	0.3

Table 112: Extract from Table 37: Separation distance calculation for 5 MHz TS bandwidth, RDSS victim 3 dB Grx, TS interferer BS

RDSS Parameter	Units	Case 1		Case 2	
		Outdoor TS Outdoor RDSS		Indoor TS Outdoor RDSS	
Interferer		TS BS	TS UE	TS BS	TS UE
D EHata (urban)	km	1.1	0.2	0.1	0.1
D EHata (suburban)	km	2.2	0.3	0.1	0.1
D EHata (rural)	km	8.3	1.3	0.4	0.4

In the absence of any obstacle, the separation distance when the TS system is deployed outdoor is given by the radio horizon.

5.3 COMPATIBILITY WITH MBANS IN THE BAND 2483.5-2500 MHZ

Section 4.3 analyses the impact of terrestrial service (TS) in the MSS frequency band 2483.5–2495 MHz on Medical Body Area Network Systems (MBANS) receivers operating in the same frequency band. It also analyses the impact of MBANS equipment on TS receivers (UE and BS).

Only the impact of the proposed TS using 10 MHz of bandwidth has been studied.

Study between TS systems and MBANS operating in the same band; assuming the median EHata Urban propagation model, gives median physical separation between TS systems and MBANS receivers summarized in the Tables below. This separation is readily provided by deploying TS systems a small distance away from health care facilities, or homes using MBANS equipment. The deployment of the proposed TS in the same building as MBANS equipment has not been studied, and might lead to impracticable separation distances. TS system using bandwidths of 5 MHz and 15 MHz would need higher and lower separation distances, respectively.

Table 113: Extract from Table 47: MCL Separation distance calculation, MBANS victim, TS interferer BS

Parameter	Units	Cat. 1 Outdoor TS	Cat. 2 Outdoor TS	Cat. 3 Outdoor TS	Cat. 1 Indoor TS	Cat. 2 Indoor TS	Cat. 3 Indoor TS
D EHata (urban)	km	0.11	0.11	0.14	0.05	0.05	0.05
D FSPL	km	5.31	5.31	7.50	0.15	0.15	0.21

Table 114: Extract from Table 48: MCL Separation distance calculation, MBANS victim, TS interferer UE

Parameter	Units	Cat. 1 Outdoor TS	Cat. 2 Outdoor TS	Cat. 3 Outdoor TS	Cat. 1 Indoor TS	Cat. 2 Indoor TS	Cat. 3 Indoor TS
D EHata (urban)	km	0.08	0.08	0.09	0.05	0.05	0.05
D FSPL	km	1.33	1.33	1.88	0.15	0.15	0.21

5.4 COMPATIBILITY WITH LP-AMI IN THE BAND 2483.5-2500 MHZ

Section 4.4 analyses the impact of terrestrial service (TS) in the MSS frequency band 2483.5-2495 MHz on Low Power Active Medical Implant (LP-AMI) receivers operating in the same frequency band. It also analyses the impact of LP-AMI equipment on TS receivers (UE and BS).

Only the impact of the proposed TS using 10 MHz of bandwidth has been studied.

Study between TS and LP-AMI operating in the same band, assuming the median EHata Urban propagation model gives median physical separation between TS systems and the LP-AMI receivers summarized in the Tables below. This separation is readily provided by deploying TS systems a small distance away from health care facilities using LP-AMI equipment. The deployment of the proposed TS in the same building as MBANS equipment has not been studied, and might lead to impracticable separation distances. TS system using bandwidths of 5 MHz and 15 MHz would need higher and lower separation distances, respectively.

Table 115: Extract from Table 58: MCL Separation distance calculation, LP-AMI victim, TS interferer BS

Parameter	Units	Case 1 Outdoor TS	Case 2 Outdoor TS	Case 1 Indoor TS	Case 2 Indoor TS
D EHata (urban)	km	0.11	0.06	0.06	0.04

Table 116: Extract from Table 59: MCL Separation distance calculation, LP-AMI victim, TS interferer UE

Parameter	Units	Case 1 Outdoor TS	Case 2 Outdoor TS	Case 1 Indoor TS	Case 2 Indoor TS
D EHata (urban)	km	0.08	0.04	0.05	0.01

5.5 COMPATIBILITY WITH PMSE IN THE BAND 2483.5-2500 MHZ

Study between TS and PMSE systems operating in the same band , assuming the median EHata propagation model, gives median physical separation between TS systems and the PMSE systems summarized in the following table. Only the impact of the proposed TS using 10 MHz of bandwidth has been studied. TS system using bandwidths of 5 MHz and 15 MHz would need higher and lower separation distances, respectively.

Table 117: Extract from Table 73: MCL separations distances when PMSE and the new terrestrial applications are operated co-frequency

Victim	Interferer	Separation distances using EHata urban (cases 1 to 4) (km)	Separation distances using free space loss/radio horizon (cases 1 to 4) (km)	Separation distances using EHata urban (cases 5 to 6) (km)	Separation distances using free space loss/radio horizon (cases 5 to 6) (km)
PMSE	Outdoor BS	24.4-28	45	32.7-38	45-332
PMSE	Indoor BS/ Indoor UE	0.5-0.7	16.7-26.9	1.2-5.8	9.3-57.6
PMSE	Outdoor UE	1.9-2.5	37	4.1-22.5	37-324
Outdoor BS	PMSE	0.5-7.7	18.9- 54.3	1.9-33.6	21.3-332.5
Indoor BS/ Indoor UE	PMSE	0.08-0.31	4.4-70.7	0.19-21.33	27.3-50.4
Outdoor UE	PMSE	0.1-0.6	16.7-45	0.3-24.8	45-103.5

The table above provides the calculated separations distances when PMSE and the new terrestrial applications are operated co-frequency. Considering those distances, it is expected that mitigation techniques would be needed to ensure the coexistence of PMSE and the new terrestrial applications when operated co-frequency.

The analysis considered antenna heights and antenna gains with maximum values resulting in upper limit of the calculated separation distances.

5.6 COMPATIBILITY WITH E-UTRA BAND 7 ABOVE 2500 MHZ

Section 4.6 analyses the impact of terrestrial service (TS) in the frequency band 2483.5–2500 MHz on E-UTRA Band 7 base station (BS) receivers operating in the neighbouring frequencies above 2500 MHz. It also analyses the impact of E-UTRA Band 7 user equipment (UE) on TS receivers (UE and BS).

The study between TS base station and E-UTRA Band 7 base station receiver gives minimum physical separation between the two systems. The median separation distance derived in this study for 5 MHz and 10 MHz TS channels is 970 m for TS outdoor deployment and 51 m for TS indoor deployment. However, the median separation distance for the 15 MHz TS channel is 1100 m for outdoor and 53 m indoor deployment. These separation distances are derived from the median EHata Urban propagation model.

However, the separation distances have also been derived for the 95th percentile EHata model which will satisfy the interference criterion for at least 95% of the situations. These separation distances are more than 2 km in all the outdoor cases and are given in Table 78, Table 79 and Table 80.

Table 118: Extract from Table 78: Outdoor TS Terrestrial Deployment Separation Distances

Outdoor TS Band-width	interferer TX Parameters	TS BS Interferer Value	E-UTRA UE Interferer Value
5 MHz	Separation distance, EHata urban median (m) Separation distance, EHata urban 95th percentile (m) Separation distance, FSPL (m)	970 2500 3977	96 139 2366
10 MHz	Separation distance, EHata urban median (m) Separation distance, EHata urban 95th percentile (m) Separation distance, FSPL (m)	970 2500 3977	96 139 2366
15 MHz	Separation distance, EHata urban median (m) Separation distance, EHata urban 95th percentile (m) Separation distance, FSPL (m)	1100 2900 4900	96 139 2366

Table 119: Extract from Table 79: Indoor TS Terrestrial Deployment Separation Distances for Combined

Indoor TS Bandwidth	interferer TX Parameters	TS BS Interferer Value	E-UTRA UE Interferer Value
5 MHz	Separation distance, EHata urban median (m) Separation distance, EHata urban 95th percentile (m) Separation distance, FSPL (m)	51 88 110	56 75 421
10 MHz	Separation distance, EHata urban median (m) Separation distance, EHata urban 95th percentile (m) Separation distance, FSPL (m)	51 88 110	56 75 421
15 MHz	Separation distance, EHata urban median (m) Separation distance, EHata urban 95th percentile (m) Separation distance, FSPL (m)	53 93 135	56 75 421

Table 120: Extract from Table 80 Spurious Emission Separation Distances

Interferer	Victim	Path Loss Model	Separation Distance (m)
TS BS Outdoor	Band 7 BS	EHata urban FSPL	362 1057
TS BS Indoor	Band 7 BS	EHata urban FSPL	87 94
Band 7 UE	TS BS Outdoor 5 MHz	EHata urban FSPL	55 211
Band 7 UE	TS BS Outdoor 10 MHz	EHata urban FSPL	65 472
Band 7 UE	TS BS Outdoor 15 MHz	EHata urban FSPL	68 594
Band 7 UE	TS BS Indoor 5 MHz	EHata urban FSPL	19 19

Interferer	Victim	Path Loss Model	Separation Distance (m)
Band 7 UE	TS BS Indoor 10 MHz	EHata urban FSPL	40 42
Band 7 UE	TS Bs Indoor 15 MHz	EHata urban FSPL	42 53

In urban areas, separation distances calculated using FSPL should be seen as an absolute worst-case interference scenario. Separation distances will be less in urban or suburban areas where appropriate propagation using models for those areas are more accurate.

It should be noted that this section has only considered the interference into a non-AAS base station deployed in a macro-urban cell scenario.

5.7 COMPATIBILITY WITH ISM/WLAN BELOW 2483.5 MHZ

Interfering RLAN and TS exhibit similar indoor interference characteristics for RLAN receivers, as described in 4.7.7.

For outdoor to indoor interference scenarios, greater distances and building entry loss reduce the power levels of the outdoor TS such that the indoor signal levels are similar to the RLAN and indoor TS case.

Since the TS is TDD, there are periodic intervals during which the TS is not transmitting. This may allow another ISM device time to operate even if there is insufficient separation.

As noted in in 4.7.7, Bluetooth selectivity, narrow bandwidth, and TS unwanted emissions allow it to be much more tolerant of TS than RLAN.

In low noise environments, and where there is low propagation loss, careful consideration during deployment is needed since separation between TS and RLAN may be required.

Table 121: Extract from Table 95: MCL and Separation Distance Calculations

TS Location	TS Antenna	Victim	Environment	Separation Distance using EHata urban (m)	Separation Distance using FSPL (m)
Outdoor	Boresight (+6 dBi)	RLAN	Thermal noise	59	304
			Interference limited	11	11
		Bluetooth	Thermal noise	0.76	0.76
			Interference limited	2.49	2.49
	Side lobe (0 dBi)	RLAN	Thermal noise	52	152
			Interference limited	6	6
		Bluetooth	Thermal noise	0.38	0.38
			Interference limited	2.40	2.40
Indoor	0 dBi	RLAN	Thermal noise	58	571
			Interference limited	10	10
		Bluetooth	Thermal noise	0.68	0.68
			Interference limited	2.46	2.46

5.8 COMPATIBILITY BETWEEN TS AND RLAN/BLE BASED ON MEASUREMENTS

Section 4.8 present MCL calculations based on laboratory measurement (ANNEX 4:). The study shows the calculations of the minimum protection distances between LTE-Systems (BS, UE), as interferer, and BLE/RLAN-Systems, as victims, in Outdoor and Indoor scenarios.

The parameter sensitivities and carrier-to-interference ratios (C/I)dB = (CdB-IdB) for BLE/RLAN are based on the measurement campaign from BNetzA (see the ANNEX 4:). The required protection distances are derived considering a realistic and worst case signals from LTE-systems (BS/UE).

For BLE/RLAN, the distances are calculated with different types of interference degrees (grades 1 to 3) and TS power levels. The propagation model is free-space without considering antenna diagram and heights.

- Outdoor case
  - The results give protection distances for the outdoor case with free space propagation model where the TS (BS/UE) interferes with BLE/RLAN systems that range from 0 m to 48 m. The degree of interference 1 (Interference just begins to be measurable/noticeable), with a worst case signal shape, evokes the largest distances.
- Indoor case
  - In the indoor case, the protection distances are lower because building entry loss (BEL) has been included. If the TS are placed inside the buildings the power levels are much smaller than for outdoor operation. The protection distances vary from 0 m to 12 m. The highest distance is again caused by interference grade 1 with a worst case signal shape.

5.9 COMPATIBILITY WITH RAS OPERATING IN 5 GHZ BAND (SECOND HARMONIC OF TS BAND)

The second harmonic band of the TS operating in the 2483.5-2500 MHz band partly falls into the 4950-4990 and 4990-5000 MHz RAS band, in which both, continuum and spectral line observations, are frequently carried out. The single-entry TS worst-case (including UE) compatibility study with respect to the RAS demonstrated that coordination zones of few dozens of kilometres up to more than 100 km in certain cases, depending on the local terrain, are necessary. There are several mitigation measures, which would allow devices to be compatible with the RAS even when closer to the RAS sites, such as the consideration of local clutter losses. Furthermore, different UE available from vendors could have different 2nd harmonic emission levels and some devices may have significantly lower output power emission into the RAS band at 5 GHz compared to the spurious emission limit of -30 dBm/MHz.

ANNEX 1: EXTENDED HATA PROPAGATION MODEL OUT OF RANGE ANTENNA HEIGHTS

A1.1 INTRODUCTION

This annex is about the effects of the TS (Terrestrial System) base station antenna height parameter. The EHata model constrains mobile antenna heights to the range 1...10 meters, and base antenna heights to the range 30..200 meters. There is a gap between 10 meters and 30 meters such that the EHata model becomes invalid if any antenna height falls in the gap.

With regards to SEAMCAT calculation of the EHata model, the valid ranges identified by COST 231 [15] based on the original work of Okumura and Hata are also applied. If the user specifies input parameters, which are out of range, SEAMCAT gives a consistency warning relating to validity of implementation of the propagation model and the loss is calculated by applying height correction factors as described in the SEAMCAT documentation [16].

A1.2 PROPOSED SOLUTION

In the simulation, the calculated results include some antenna heights in the range of 10 meters or 30 meters, depending on whether the TS antenna is the higher, or the lower antenna, in the path loss calculation.

The problem with the EHata model for base station heights of 10 meters remains for some co-channel cases with low antenna heights, such as ISM, PMSE, MBANS, LP-AMI, RDSS, and MSS. Many of these cases already fall under 0.1 km separation distance so they are already converging to FSPL, which works for any antenna height. A few remaining cases can exist for both the interferer and victim antenna height under 10 meters, with separation distance greater than 0.1 km. The proposed solution for those cases is to extrapolate the EHata model to permit base heights down to 10 meters. This extrapolation is small and within the range supported by Okumura’s measurements [38] and also Recommendation ITU-R P.1546 [39].

A1.3 EXTENDED HATA AND EXTRAPOLATED HATA MODEL

The Hata model was derived from data collected by Okumura and published in 1968. The Hata model was subsequently published in 1980. The Hata model simplified the calculations of path loss so that they became widely used and later extended by COST 231 and still later incorporated into SEAMCAT. The original Okumura data included base station heights as low as 20 meters as shown in Figure 37. The Hata formulas extend down to 20 meters without incurring any significant distortions. Some discussions of the Okumura data and the Hata model are published by Garry Hess [40] and John Seybold [41]. Okumura published a gain factor for the base height that is shown in Figure 37. The Figure shows base height gain factors relative to a 200-meter reference value, for base heights from 20 meters to 1000 meters, and path lengths (d parameter) from 1 km to 100 km.

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15 https://op.europa.eu/en/publication-detail/-/publication/f2f42003-4028-4496-af95-beaa38fd475ff

16 https://wiki.cept.org/display/SH/A17.3.1+Outdoor-outdoor+propagation.

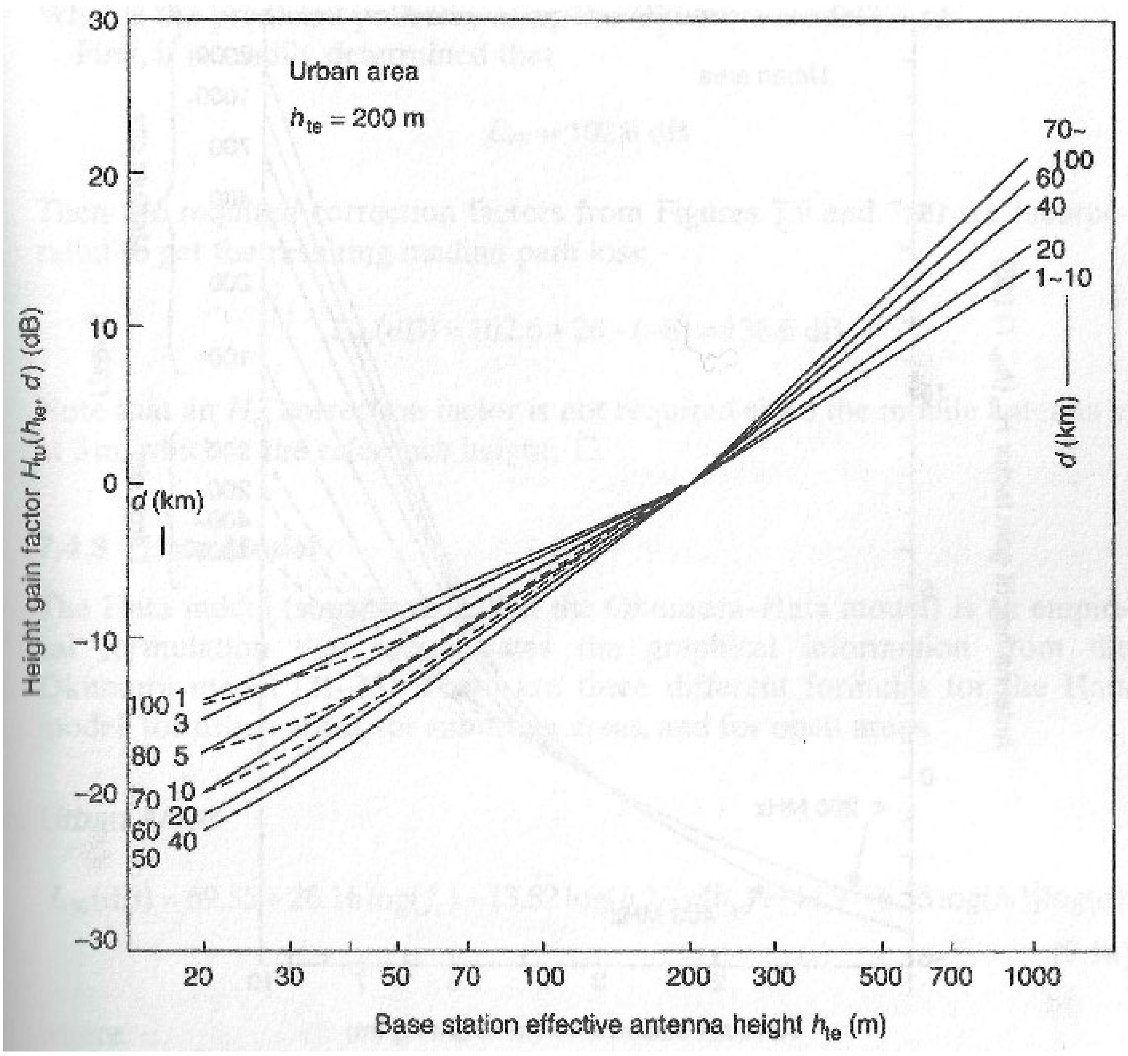

Figure 37: Okumura Gain Factor for Base Height from Seybold

Extrapolating the EHata model to permit 10-meter antenna heights is a simple linear extension of the model parameters. The discussion by Garry Hess includes software to calculate the Hata model without the limits imposed by COST 231 and SEAMCAT. The Hess software permits a straight-line extrapolation of the base height gain factor down to 10 meters as shown in Figure 38. Figure 38 can be compared with Figure 37 to show that the Hata model follows the Okumura data well.

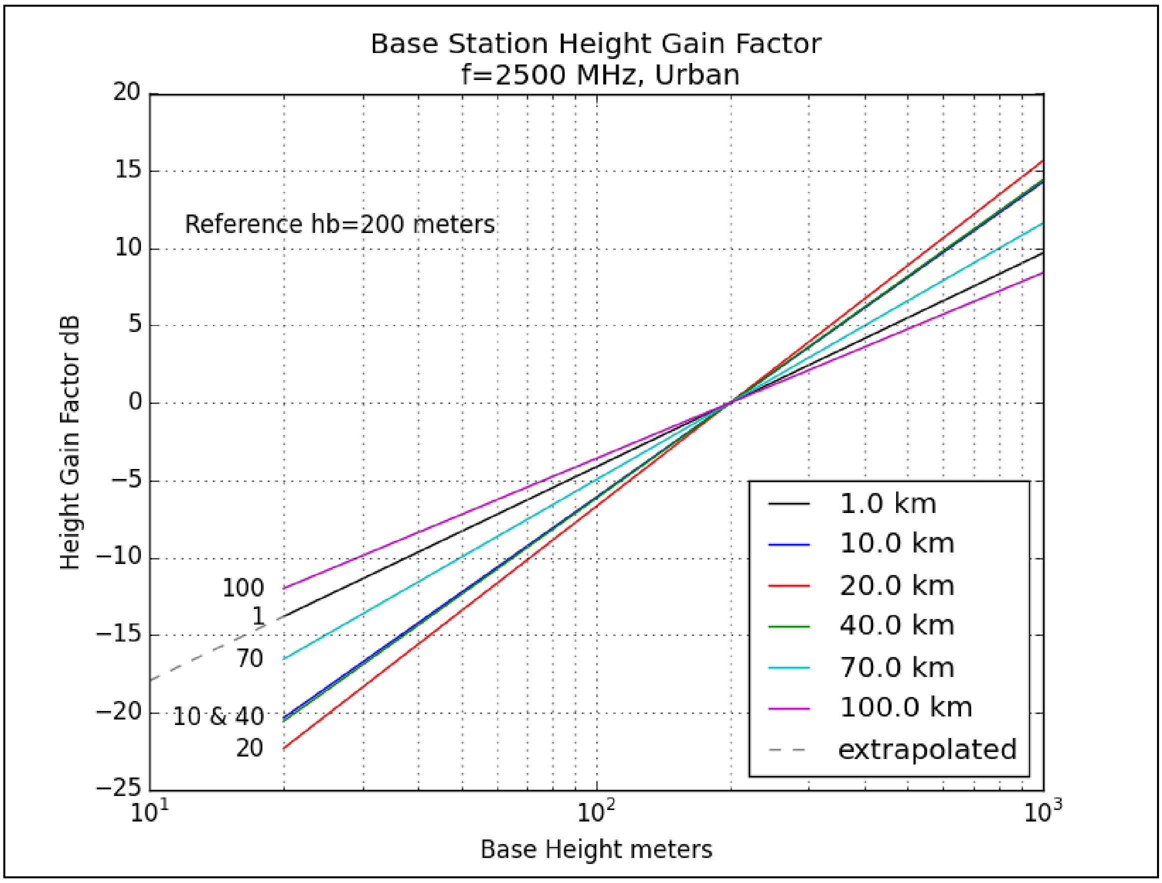

Figure 38: Hata Base Height Gain Factor

Extrapolated values for the base height gain factor for d=1 km are conveniently tabulated in the table below.

Table 122: Base Height Gain Factors

Base Height	Gain Factor	Delta
10 m	-18.0 dB	-6.6 dB
15 m	-15.5 dB	-4.1 dB
20 m	-13.8 dB	-2.4 dB
30	-11.4 dB	0.0 dB

A1.4 RECOMMENDATION ITU-R P.1546 PATH LOSS

Recommendation ITU-R P.1546 [39] also provides a graphical method to predict path loss. The graph for median path loss at 2000 MHz is shown in the below figure. The figure shows path loss for base antenna heights from 10 meters to 1200 meters. At a distance of 1 km, the difference between base height of 10 meters and 37.5 meters is 5 dB. This is in close agreement with values in Table 122. Recommendation ITU-R P.1546 states the similarity of results with the Hata model in Annex 8: “This Recommendation produces similar results to the Okumura-Hata method for distances up to 10 km, h2 = H2 = 1.5 m, R = 15.”

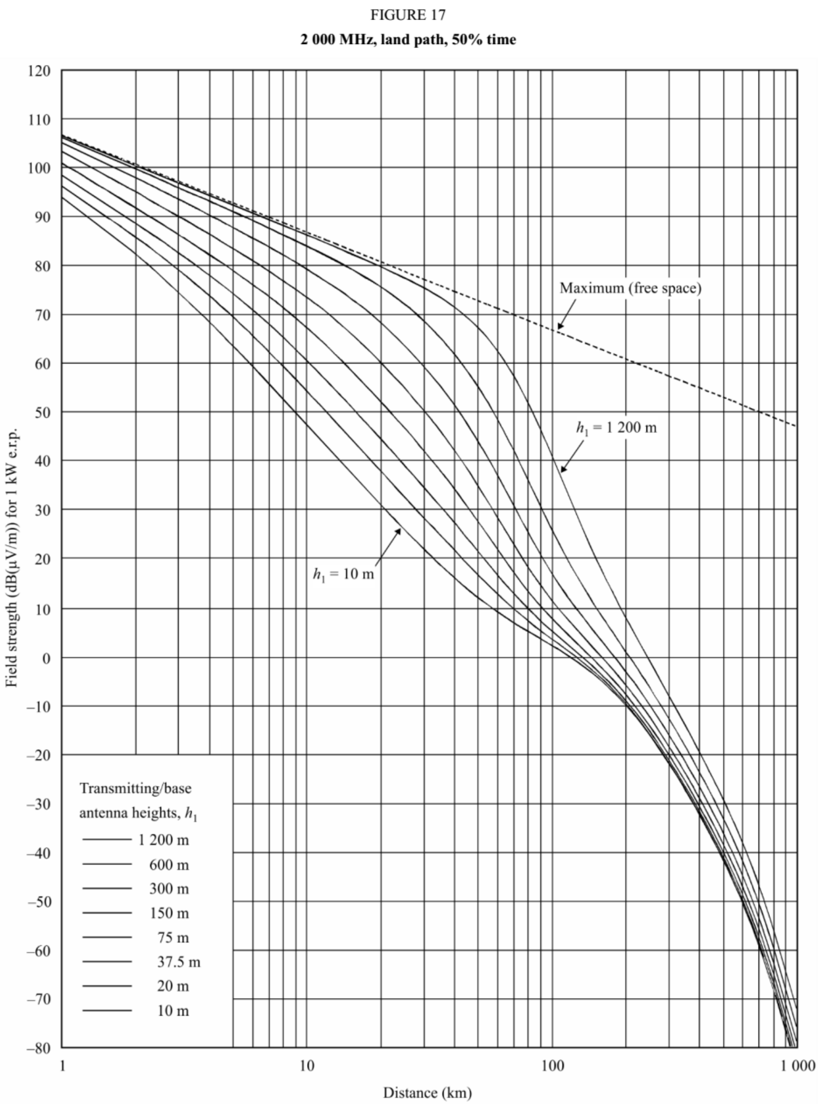

Figure 39: Recommendation ITU-R P.1546 Field Strength for Various Antenna Heights

A1.5 EFFECTS OF ANTENNA HEIGHT CHANGE TO 10 METERS

The effect for co-channel services (ISM, PMSE, MBANS, LP-AMI, RDSS, and MSS) should be to reduce interference, so the separation distances should decrease. The customary EHata model is invalid in some of those cases since they might have both the interferer and the victim antenna heights at 10 meters or less, and the MCL path length is greater than 0.1 km. An extrapolated version of the EHata model permits an MCL calculation without the limitations.

A1.6 CONCLUSION

Interference for PMSE, MBANS, LP-AMI, MSS, RDSS, and ISM – would not be accurate with hTX=10 meters if a higher antenna at 30 meters was substituted, but in most cases the interference should be less than the calculated value(s) with the higher antenna. A better calculation uses the extrapolated EHata model for antenna heights less than 30 meters.

Solution implemented in this Report:

For– PMSE, MBANS, LP-AMI, MSS, RDSS, and ISM –an extrapolation was applied down to hTX=10 meters that reduced interference by about 6.6 dB as given in Table 122.

ANNEX 2: COMPATIBILITY WITH E-UTRA BAND 7 ABOVE 2500 MHZ, COMBINED INTERFERENCE CALCULATION FOR BLOCKING, ADJACENT CHANNEL, AND UNWANTED EMISSIONS

This annex describes the approach of computing MCL (Minimum Coupling Loss) for combined interference from Blocking, Adjacent Channel Selectivity (ACS), and Unwanted Emissions. The specific interference scenario under consideration is for emissions from a TS aggressor transmitter just below 2.5 GHz into an E-UTRA victim receiver with 5 MHz channel bandwidth just above 2.5 GHz.

The 3GPP TS 36.104 [10] contains the technical specifications for E-UTRA BS. The E-UTRA BS receiver's ACS and blocking levels have been given in sections 7.5 and 7.6 [10], respectively. These levels are provided for compliance testing and are valid for 6 dB desensitization ($D_{Standard}$). However, this compatibility study considers 1 dB desensitization (D_{Target}). Hence, the translation of ACS and blocking levels for the D_{Target}=1 dB are given in Table 123 below and has also been explained in section 4.6.2.

Table 123: E-UTRA BS (5 MHz channel) ACS and Blocking Levels

Interferer Frequency Range	Level	I/N	Receiver Desensitization
2495-2500 MHz	-52.0 dBm -62.5 dBm	+4.5 dB -6.0 dB	6 dB 1 dB
2480-2495 MHz	-43.0 dBm -53.5 dBm	+4.5 dB -6.0 dB	6 dB 1 dB
Below 2480 MHz	-15.0 dBm -25.5 dBm	+4.5 dB -6.0 dB	6 dB 1 dB

For the MCL calculations, blocking response of the receiver's filter is required. The section below derives the blocking response.

A2.1 BLOCKING RESPONSE

The Receiver's Blocking response is defined as the receiver filter attenuation of signal outside of receiver's band/channel [SEAMCAT, page 303 [20]]:

$$\text{Blocking Response} = \text{IOOB} - \text{STANDARD} - \text{IIB} - \text{STANDARD} \quad (19)$$

In the above table, level is the mean value of out-of-band interference ($I_{OOB\text{-}STANDARD}$) signal level but doesn't provide the actual level of interference it causes in-band ($I_{IB\text{-}STANDRD}$). However, $I_{IB\text{-}STANDRD}$ can be calculated from the receiver's noise floor. A blocking response of the receiver filter can thus be derived as below.

Since,

$$D_{linear} = (n+i)/n \quad (20)$$

Where:

- i = in-band Interference (linear);
- n = noise floor (linear).

$I_{IB\text{-}STANDARD}$ can be derived from (20) and is given as:

$$\text{DdB} = 10 * \log10[(n+i)/n] \quad (21)$$

Substitute (21) in (1), the result is,

$$IIB - STANDARD = N + 10 * \log10[10^{\wedge}(DdB/10) - 1] \quad (22)$$

$$\text{Blocking Response} = I_{OOB\text{-}STANDARD} - N - 10*\log_{10}[10^{\wedge}(D_{dB}/10) - 1] \quad (23)$$

Considering, Noise Figure = 5 dB, Receiver BW = 5 MHz and $I_{OOB\text{-}STANDARD}$ = -52 dBm (ACS level)

Blocking Response = -52 – (-102) – 10*log10(10^(6/10)-1)

Blocking Response = 45.25 dB

This is the blocking response of the receiver filter for the ACS region up to ±5 MHz frequency offset from the band edge.

Similarly, blocking response for the frequency offsets between ±5 MHz and ±20 MHz offset can be derived as below.

Considering, Noise Figure = 5 dB, Receiver BW = 5 MHz and $I_{OOB\text{-}STANDARD}$ = -43 dBm (blocking level)

Blocking Response = -43 – (-102) – 10*log10(10^(6/10)-1)

Blocking Response = 54.25 dB

This is the blocking response of the receiver filter for the blocking region up to ±20 MHz frequency offset from the band edge.

Hence, the blocking mask for EUTRA BS can be diagrammatically shown as:

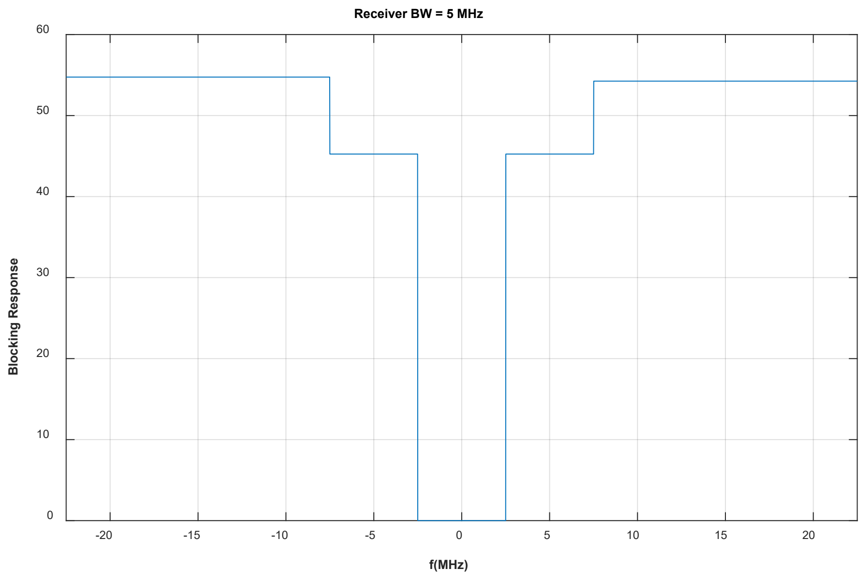

Figure 40: Blocking response of E-UTRA BS receiver with 5 MHz channel BW

The above blocking response derivation has been calculated for the receiver channel width of 5 MHz. Also, the receiver filter attenuations are provided with positive signs.

It should be noted that LTE 5 MHz channel has an occupied channel bandwidth of 4.5 MHz, but with the MTC-IoT and Guard band NB-IoT, the effective channel bandwidth to be protected is considered as 5 MHz.

A2.2 OUT-OF-BAND (OOB) UNWANTED EMISSIONS

The OOB unwanted emissions for the TS system transmitter are given in report section 4.6.2, Table 74 and are summarised in tables below.

Table 124: OOB unwanted emissions for TS transmitter of 5 MHz and 10 MHz channel

	5 MHz	10 MHz
Unwanted emissions in E-UTRA Rx band (2500-2505 MHz)	-37 dBm/100 KHz -20 dBm/5 MHz	-37 dBm/100 KHz -20 dBm/5 MHz

Table 125: OOB unwanted emissions for TS transmitter of 15 MHz channel

	15 MHz
Unwanted emissions in E-UTRA Rx band (2500-2504 MHz)	$-30dBm - \frac{7}{5}\left(\frac{f\_offset}{MHz} - 0.05\right)dB$ /100 kHz -19.78 dBm/4 MHz
Unwanted emissions in E-UTRA Rx band (2504-2505 MHz)	-37dBm/100 kHz -27 dBm/MHz
Effective Unwanted emissions in E-UTRA Rx band (2500-2505 MHz)	-19 dBm/5 MHz

A2.3 MCL CALCULATIONS – BLOCKING AND UNWANTED EMISSIONS

Case 1: 5 MHz and 10 MHz TS channels

The 5 MHz and 10 MHz TS channels fall into the blocking region of the E-UTRA receiver. This corresponds to a 54.25 dB blocking response as described in section A2.1.

The MCL equation for combined effects of blocking and OOB unwanted emissions can be written as:

$$[(P.tx - Blocking\_Response(Blocking\ level))lin + (P.txunwanted)lin]dB + G.tx - Lpath + G.rx \leq 10.log10(KTB) + NF + I/N \quad (24)$$

$$Lpath \geq [(P.tx - Blocking\_Response(Blocking\ level))lin + (P.txunwanted)lin]dB + G.tx + G.rx - (10.log10(KTB) + NF + I/N \quad (25)$$

The Calculated L_{path} using equation (25) and corresponding separation distance is given in the below table below. and corresponding separation distance is given in the below table below. The Calculated L_{path} using equation (25) and corresponding separation distance is given in the below table below. The Calculated L_{path} using equation (25) and corresponding separation distance is given in the below table below. and corresponding separation distance is given in the below table below.

Table 126: Calculated L_{path} and separation distance for TS transmitter (5 and 10 MHz) and E-UTRA BS (5 MHz)

	5 MHz	10 MHz
Outdoor TS P.tx (dBm)	30	30
Outdoor TS $P.tx_{unwanted}$ (dBm)	-20	-20
Blocking_Response(Blocking level) (dB)	54.25	54.25
Outdoor TS G.tx (dBi)	6	6
E-UTRA BS G.rx (dBi)	17	17
NF (dB)	5	5
I/N (dB)	-6	-6
Nth=10.log10(KTB) (dB)	-107	-107
L_{path} (dB)	112.4	112.4
Separation distance EHata Median (m)	970	970
Separation distance EHata 95th percentile (m)	2500	2500
Separation distance FSPL (m)	3977	3977
Note: EHata propagation model has a log-normal distribution, L+Tσ, where, L is the median propagation loss corresponding to the 50th percentile probability and σ is the standard deviation for slow fading. To be sure that L_{path} will provide the interference protection of I/N=-6 dB for at least 95th percentile probability in time or space, a value of 1.65*σ (σ=9 dB, d>0.6) should be added to the median value. Hence, the separation distance provided in the table above corresponds the 95th percentile probability [ITU-R SM.2028-2 [48]].		

Therefore, in this case study for TS 5 MHz and 10 MHz channels, to satisfy the interference criterion of I/N= - 6 dB, at least a pathloss of 112.4dB is required. This is equivalent to a separation distances of 970 m, 2500 m and 3977 m for EHata median (50th percentile), EHata 95th percentile and Free-Space propagation models respectively. The typical MFCN macro-cell range is 400 meters in the urban area. The coexistence between TS and MFCN small-cell is not considered in this study.

Note: The above separation distances are derived for H_{TS}=15 m and H_{EUTRA}=20 m.

Case 2: 15 MHz TS channel

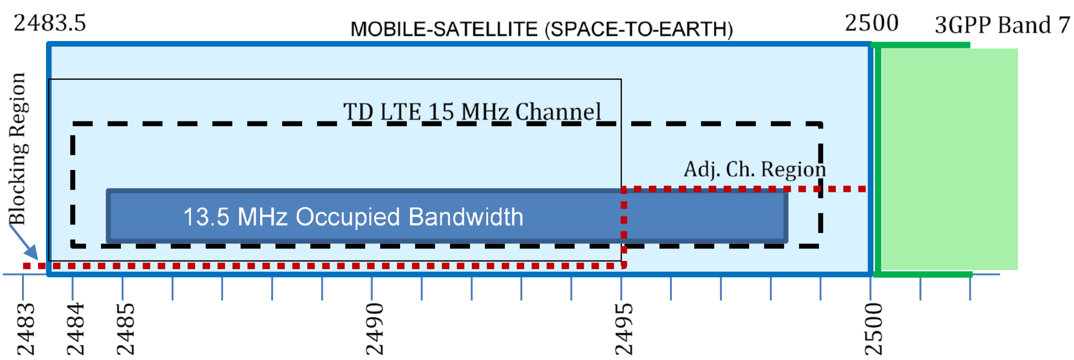

Figure 41: The blocking response of E-UTRA 5 MHz channel in the TS 15 MHz channel

The 15 MHz TS channel overlaps majorly with the Blocking level region and partly with the ACS region of the E-UTRA receiver. If TS transmitter distributes power uniformly over the 13.5 MHz OBW, the corresponding MCL equation can be written as:

$$(P.tx + 10.\log10(10/13.5) - Blocking\_Response(Blocking\ level))lin + (P.tx + 10.\log10(3.5/13.5) - Blocking\_Response(ACS\ level))lin + (P.txunwanted)lin]dB + G.tx - Lpath + G.rx \leq 10.\log10(KTB) + NF + I/N \quad (26)$$

[

$$Lpath \geq [(P.tx + 10.\log10(10/13.5) - Blocking\_Response(Blocking\ level))lin + (P.tx + 10.\log10(3.5/13.5) - Blocking\_Response(ACS\ level))lin + (P.txunwanted)lin]dB + G.tx + G.rx - (10.\log10(KTB) + NF + I/N) \quad (27)$$

The Calculated L_{path} using equation (27) and corresponding separation distance is given in Table 127.

Table 127: Calculated L_{path} and separation distance for TS transmitter (15 MHz) and E-UTRA BS (5 MHz)

	15 MHz
Outdoor TS P.tx (dBm)	30
Outdoor TS $P.tx_{unwanted}$ (dBm)	-19
Blocking_Response(Blocking level) (dB)	54.25
Blocking_Response(ACS level) (dB)	45.25
Outdoor TS G.tx (dBi)	6
E-UTRA BS G.rx (dBi)	17
NF (dB)	5
I/N (dB)	-6
Nth=10.log10(KTB) (dB)	-107
L_{path} (dB)	114.5
Separation distance EHata Median (m)	1100
Separation distance EHata 95th percentile (m)	2900
Separation distance FSPL (m)	4900
Note: EHATA propagation model has a log-normal distribution, L+Tσ, where, L is the median propagation loss corresponds to the 50th percentile probability and σ is the standard deviation for slow fading. To be sure that L_{path} will provide the interference protection of I/N=-6 dB for at least 95th percentile probability in time or space, a value of 1.65*9dB (σ=9 dB, d>0.6) should be added to the median value. Hence, the separation distance provided in the table above reflects the 95th percentile probability [ITU-R SM.2028-2 [48]].	

Therefore, in this case study for TS 15 MHz channel, to satisfy the interference criterion of I/N=-6 dB at least a pathloss of 114.5dB is required. This is equivalent to a separation distances of 1110 meters, 2900 m and 4900 m for EHata median (50th percentile), EHata 95th percentile and Free-Space propagation models respectively. The typical MFCN macro-cell range is 400 meters in the urban area. The coexistence between TS and MFCN small-cell is not considered in this study.

Note: The above separation distances are derived for H_{TS}=15 m and H_{EUTRA}=20 m.

ANNEX 3: RECORDED VIDEO CAMERA OPERATION IN THE FREQUENCY BAND 2483.5-2500 MHZ

According to the information available, the competent authority coordinated 14 wireless cameras in the 2030-2490 MHz frequency range for the observed event production [in Hamburg, Germany]. In Figure 42 and Figure 43, the frequency coordination is marked as a red background bar. The light blue background bar marks the ISM frequency range 2400-2483.5 MHz.

Figure 42 shows a camera frequency usage above the ISM range:

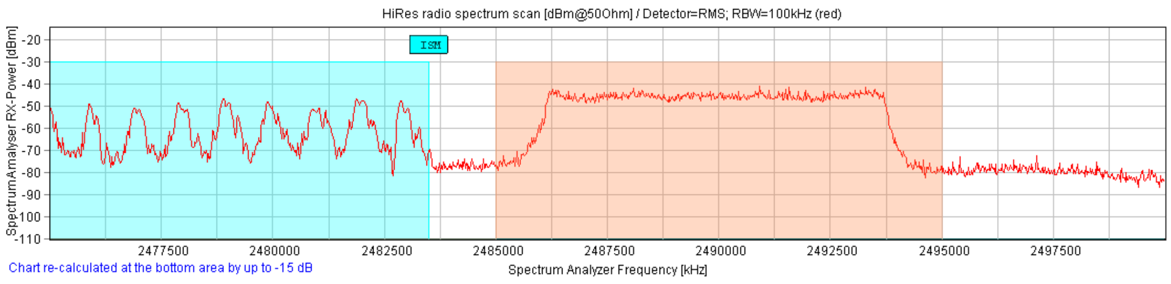

Figure 42: Aggregated spectrum usage in the frequency domain of a video camera

Figure 43 shows that the video signal was transmitted over a long period of time in a 100% duty cycle. This is a different use of spectrum than below in the ISM band.

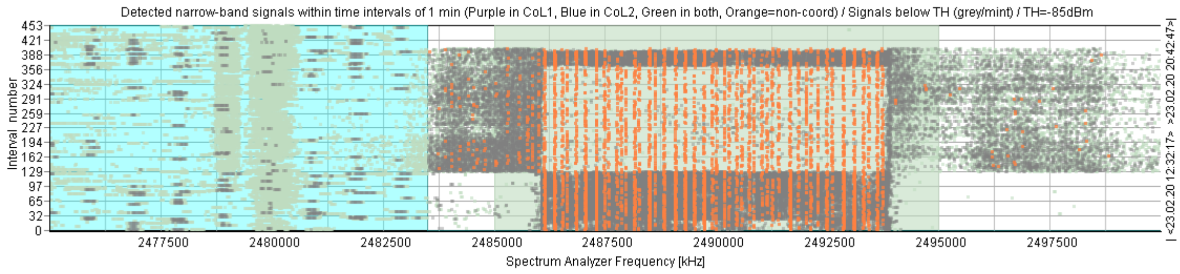

Figure 43: Frequency usage of a video camera in time domain, 5-minute time blocks

ANNEX 4: PROTECTION RATIO MEASUREMENTS LTE 2400 (INTERFERER) VS. BLUETOOTH AND RLAN (VICTIMS)

A4.1 SUMMARY OF MEASUREMENTS

To support CEPT Report 325 on the coexistence between LTE 2400 and RLAN/Bluetooth in the ISM band 2400–2483.5 MHz, the Federal Network Agency (BNetzA) of Germany has conducted a measurement campaign to assess the required protection ratios needed by Bluetooth/RLAN when exposed to an LTE interferer on 2489 MHz.

33 Bluetooth and 29 RLAN devices of different applications, representing the current market, have been measured. The interfering signals have been taken from an LTE base station and user equipment currently being sold on the US market. While the unwanted emissions of real LTE equipment are usually well below the mandatory limits specified by 3GPP, additional signals were used in the measurements that were formed to just fulfil these requirements. Although practically unrealistic, regarding the interference potential to neighbouring radio services, these signals represent the worst possible case.

The measurements have shown the following results and findings:

- There is a significant spread of both sensitivity and protection ratios between different devices. Nevertheless, the results may be regarded as representative;
- The medium required protection ratio (protecting 50% of the devices) were around -55 to -60 dB for Bluetooth, and -30 dB for RLAN;
- The protection ratios showed no significant dependency on the unwanted LTE emissions in the ISM band, with the exception of the worst case signal from LTE user equipment;
- At the point of failure, the receivers are still in a linear state at wanted signal levels up to 25 dB above their sensitivity. The acquired protection ratios can therefore be applied to a wide range of wanted signal levels for compatibility studies.

The current document describes the above-mentioned measurements and their results in detail. Intra-service interference (RLAN vs. RLAN and Bluetooth vs. Bluetooth) is not considered in this report because this would require a completely separate investigation and is outside the scope of these measurements.

A4.2 INTRODUCTION AND BACKGROUND

The CEPT currently considers the introduction of an LTE based radio network in the frequency range 2483.5 to 2495 MHz. This band is immediately adjacent to the unlicensed ISM band from 2400 to 2483.5 MHz where mainly Radio LAN (RLAN) and Bluetooth (BLE) applications are operated.

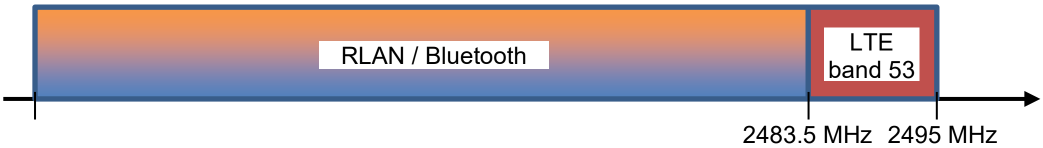

Figure 44: Frequency band allocations

To assess the compatibility between these radio services, the necessary protection ratios were measured.

The measurements took place between December 2020 and January 2021 in the laboratory of the Radio Monitoring Station Munich of the Federal Network Agency (BNetzA).

This annex describes in detail the measurement process, setup and findings.

A4.3 FREQUENCY ARRANGEMENTS

To accommodate LTE signals with a bandwidth of 10 MHz, 3GPP band 53 allows for only one channel. In addition, this band is designed for Time Division Duplex (TDD), base stations (BS) and user equipment (UE) operate on the same frequency.

Prior to the measurements, it was agreed to select 2489 MHz as the centre frequency for the interfering LTE signals.

Bluetooth devices select a hopping sequence themselves, which cannot be altered by the user. The highest Bluetooth channel is 2480 MHz, which is used more or less frequently, depending on the current hopping sequence.

RLAN devices may be set to a fixed channel. For these measurements, it was agreed to use channel 11 with its centre frequency of 2462 MHz.

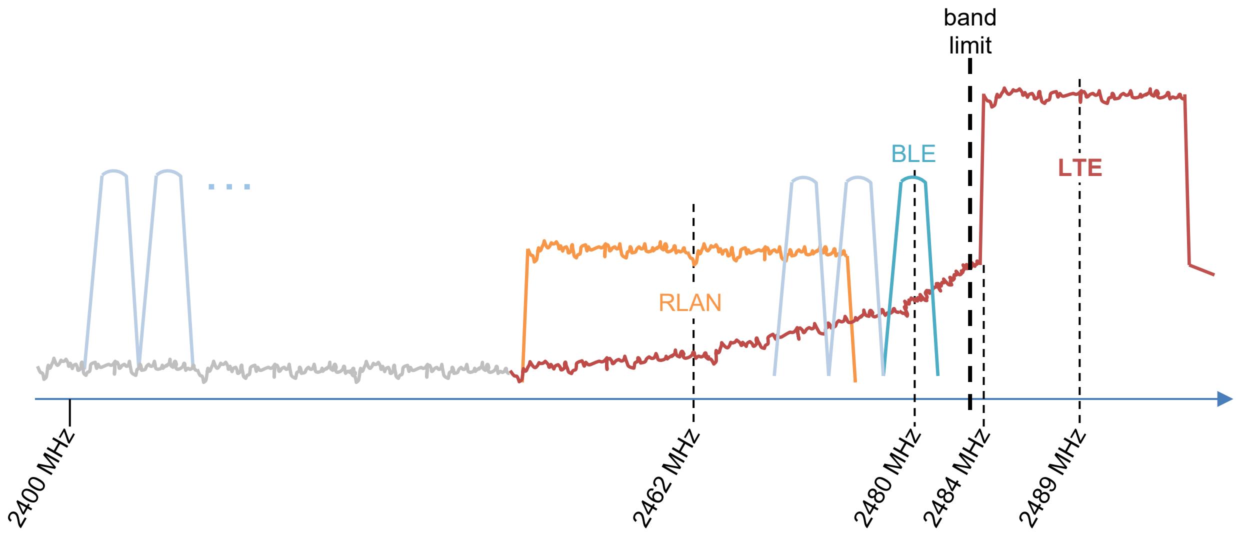

Figure 45: Frequency arrangement

A4.4 WANTED SIGNALS

General

The wanted signal was generated by a matching device (hereafter called “server”), according to the respective application. The direction from the server to the DUT is regarded as the “downlink”. The opposite direction from the DUT back to the server is referred to as “uplink”. Downlink and uplink signals were split up within the measurement setup. This enabled the uplink level to be adjusted independently from the downlink level. The uplink level was set to a fixed value ensuring that the server received sufficient signal strength at all times. Only the downlink level was adjusted according to the measurement situation. This downlink level at the input of the DUT is called “wanted signal level”.

The C/I measurements were conducted at the following three wanted signal levels:

- 3 dB above the sensitivity of the DUT (“low level”);
- 10 dB above the sensitivity of the DUT (“medium level”);
- 25 dB above the sensitivity of the DUT (“high level”).

The reason for measuring at different wanted signal levels is to determine which effect in the BLE/RLAN receiver is dominating:

- If the receiver is in its linear operating state, the C/I is independent of the wanted signal level and can therefore also be applied in compatibility studies to other levels than measured. The interference is dominated by the unwanted LTE emissions inside the wanted channel;

- If the receiver is overloaded by the high LTE level next to the wanted channel, the C/I should drop with raising wanted signal level (i. e. the unwanted signal level stays constant).

All levels in this report are RMS levels measured during the burst only ("average burst level"), and in the whole respective signal bandwidth (Bluetooth: 1 MHz, RLAN: 20 MHz). No bandwidth correction must therefore be applied when using the results for compatibility studies.

Bluetooth

Bluetooth devices negotiate a frequency hopping sequence. The selected sequence may alter the probability of the selected channels according to occurring interferences and implementation in the DUT. As a consequence, the results of C/I measurements with interferers that affect only part of the Bluetooth spectrum may not always be exactly reproducible and comparable, especially for the following reasons:

- When experiencing frequency-selective interference, some BLE devices re-negotiate the hopping sequence, leaving out the most interfered channels;
- After a connection loss, the hopping sequence is changed, resulting in a different probability of using the higher and lower channels;
- Some BLE devices restrict the hopping sequence to a few channels only. They may be on the upper or on the lower end of the available spectrum.

Since the user cannot influence the hopping sequence, no consideration was taken in these measurements concerning possible effects on the results.

All Bluetooth levels are given as average burst levels (RMS during the burst) in 1 MHz bandwidth.

RLAN

RLAN devices may be operated in auto frequency selection or in fixed frequency mode. To allow direct comparison of results, all measurements were taken with a fixed setting of channel 11, corresponding to a centre frequency of 2462 MHz.

Almost all RLAN devices currently on the market support the RLAN standard IEEE 802.11g, most of them support also IEEE 802.11n. The Standard 802.11n allows for a bandwidth of 40 MHz whereas 802.11g is limited to a bandwidth of 20 MHz. Again, to allow comparison between results, all devices were forced to use only 20 MHz wide channels, which is possible in both standards.

All RLAN levels are given as average burst levels (RMS during the burst) in 20 MHz bandwidth.

A4.5 INTERFERING LTE SIGNALS

The LTE signals used as interferers were initially taken from a setup consisting of a real base station and an USB LTE modem as user equipment. The base station was connected via a computer simulating the backbone network to the internet. The USB dongle was operated in a laptop computer.

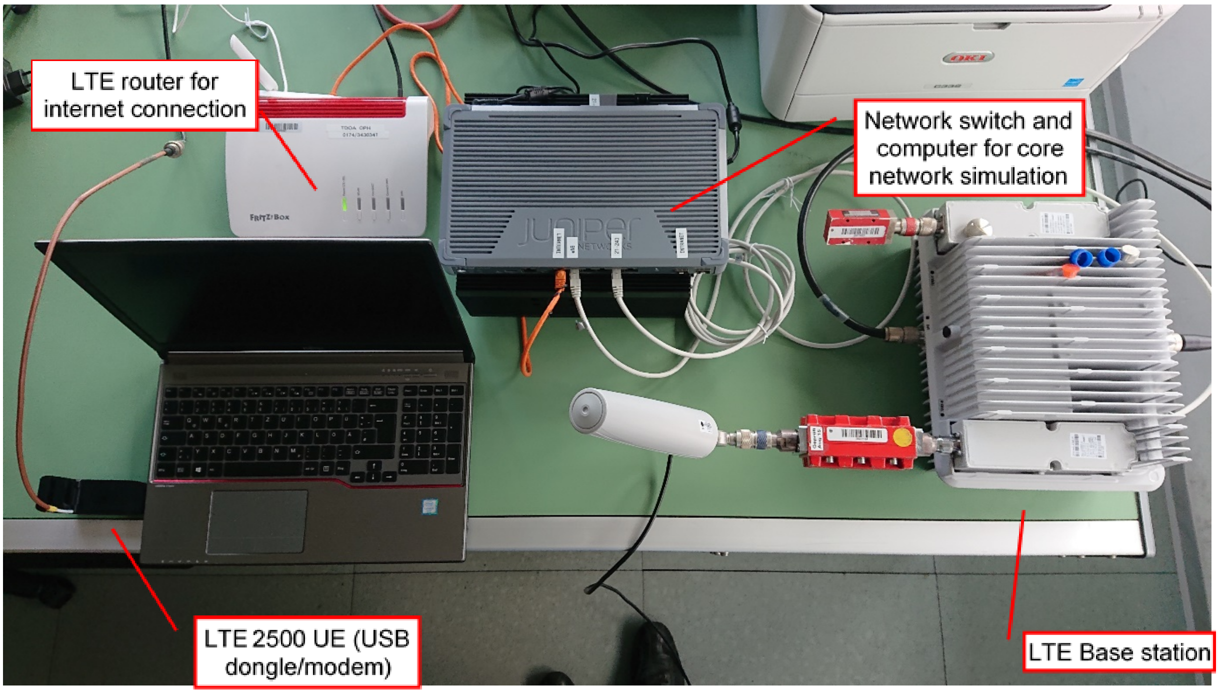

Figure 46: Illustration of the LTE BS and UE

The following parameters of the LTE signals were used:

- Centre frequency: 2489 MHz;
- Bandwidth: 10 MHz;
- DL/UL ratio: 1:1;
- Transmit power BS: 30 dBm;
- Transmit Power UE: 23 dBm.

Prior to the measurements, the agreed centre frequency was 2490 MHz and the BS transmit power was 36 dBm. However, the base station supplied for the measurements could not be configured to these parameters.

Since the test configuration represents an adjacent band situation between wanted and interfering signals, the out-of-band (OoB) emissions from the LTE devices have a significant influence on the protection ratios. For the C/I measurements, conformance with OoB and spurious limits in the relevant ETSI standards were assumed. The sources for these limits are:

- ETSI TS 136.104, Table 6.6.3.2A-3 for BS;
- ETSI TS 136.101, Table 6.6.2.1.1-1 for UE.

Special care was therefore taken to determine the unwanted LTE emission levels in the BLE/RLAN band.

Furthermore, outdoor operations with a local area BS were assumed.

Because the maximum unwanted emissions only occur when the station transmits all OFDM carriers with full power, the measurements were taken during a file download/upload between the Laptop and the internet.

The sideband emissions of the BS were recorded with the following setup:

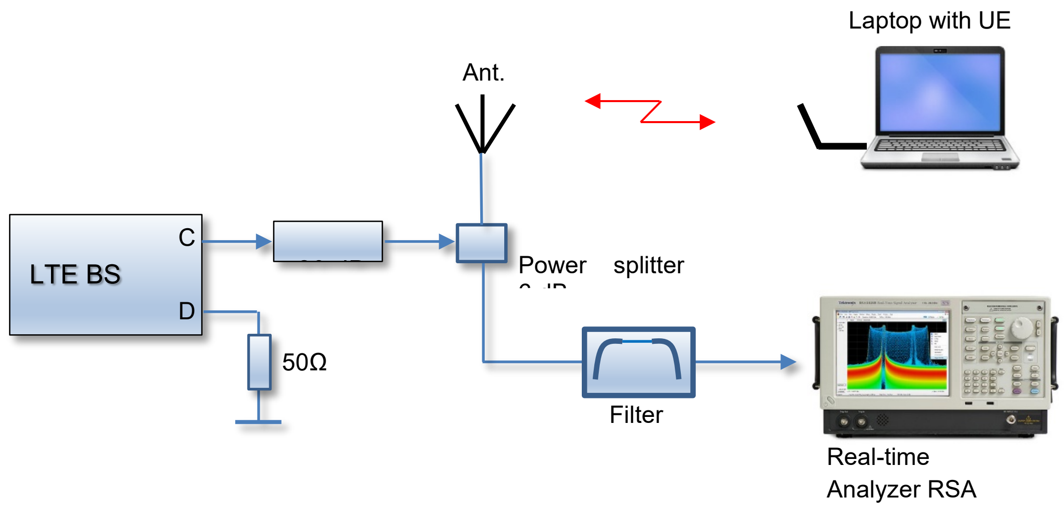

Figure 47: Block diagram of the setup to record the LTE BS spectrum

The filter was a band pass tuned to pass the lower sideband range while suppressing the main LTE emission. This is necessary because the level difference of the low sideband emissions and the main LTE signal exceeds the dynamic range of the analyser. The filter allows sensitive measurement of the sideband emissions without overloading the analyser. The frequency response curve of the filter is recorded in a separate measurement with a sweeping signal generator and is later added to the measurement of the LTE signal.

The real-time analyser records the I/Q data of a full LTE frame with 10 ms duration. Then, the analysis time is limited to a downlink burst (without rise/fall times) and the resulting RMS spectrum is calculated via FFT algorithms.

The following figure shows the display of the analyser during an example sideband measurement.

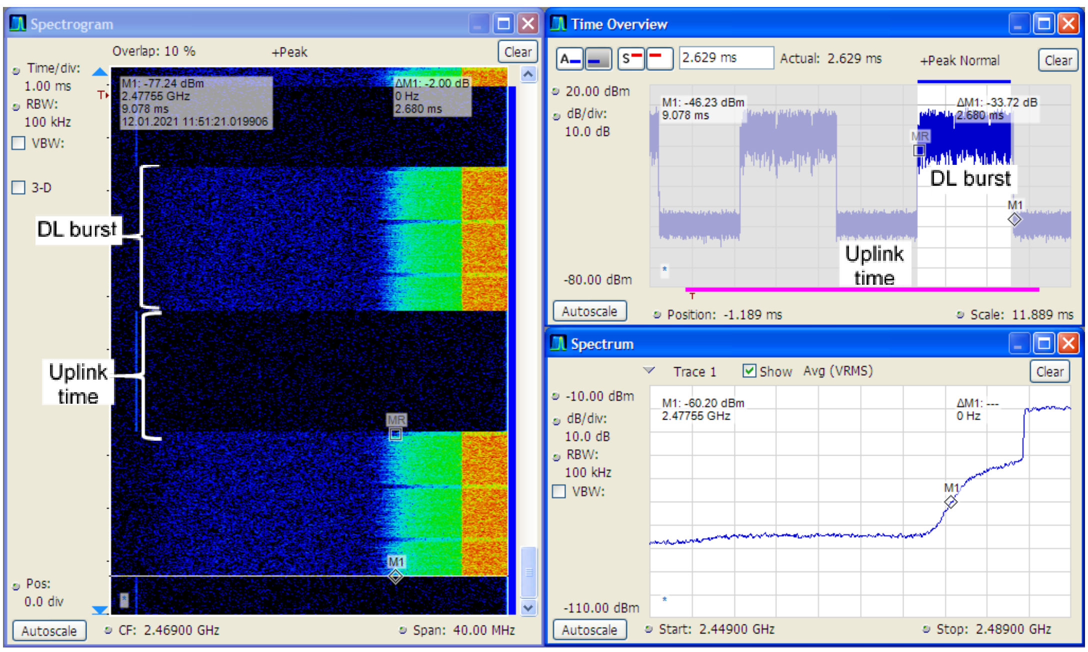

Figure 48: Sample real time analyser display in the sideband measurements[17]

17 Left: spectrogram. X: frequency, Y: time. Levels are shown in colours (temperature scale) Upper right: amplitude vs. time. Unshaded (blue bar on top) is the selected analysis time. Lower right: RMS spectrum, averaged over the selected analysis time.

The following figure shows the result of the BS sideband measurement. Since the base station was designed for the US market, the relevant FCC limit, also contained in 3GPP TR 36.791, is also shown for information. The FCC mask is defined in a reference bandwidth of 1 MHz. Note that the limit line from TS 36.104 [10] is defined in varying reference bandwidths. In the graph their levels are converted to a common bandwidth of 100 kHz.

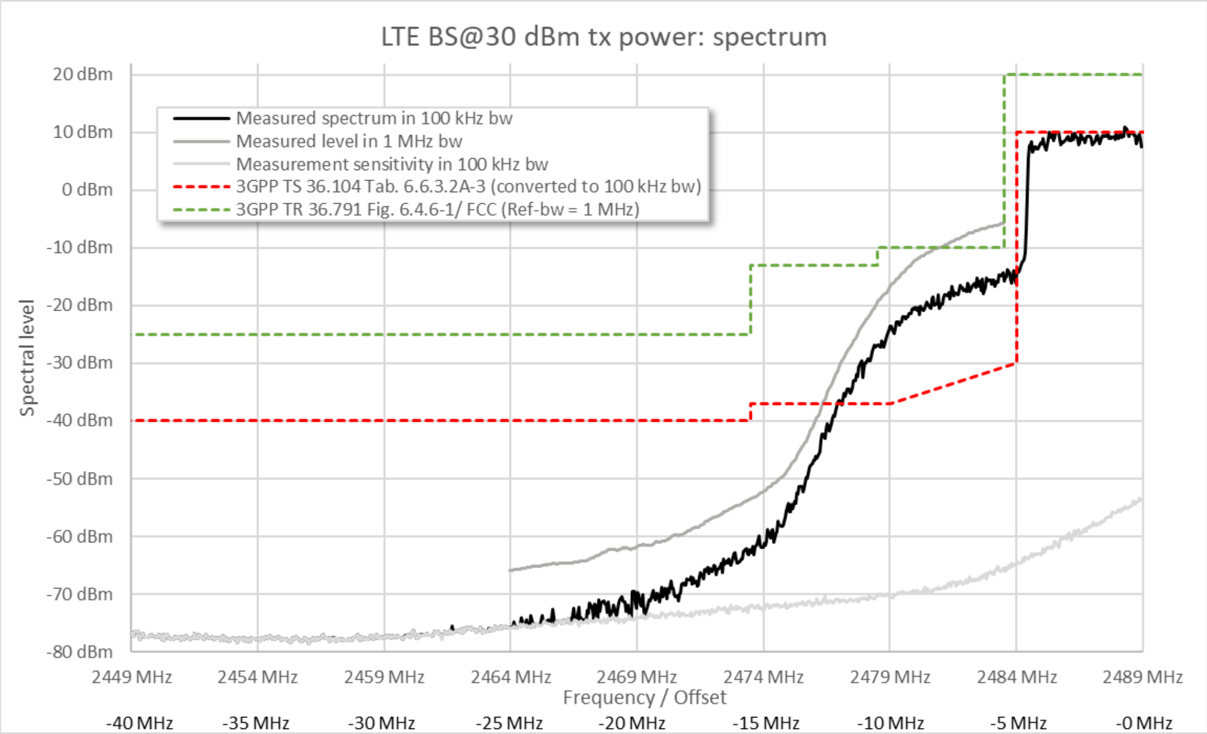

Figure 49: Measured BS sideband spectrum and limit lines

It can be seen that the emissions from the BS exceed the limits of 3GPP TS 36.104 [10] down to 2479 MHz considerably and even exceed the FCC limits slightly down to 2483.5 MHz.

The UE applies transmit power control. Therefore, for measurements of the UE unwanted emissions, the Laptop with the UE and the BS were placed in separate rooms in order to stipulate the maximum power.

The sideband emissions of the UE were recorded with the following setup:

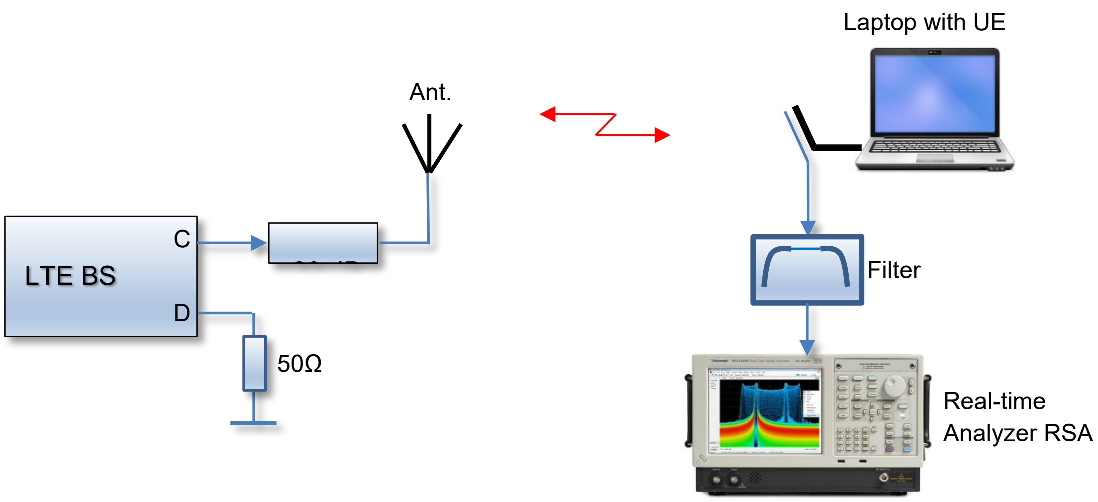

Figure 50: Block diagram of the stup to record the LTE UE spectrum

Since the UE had no external antenna connector, its signal was picked up by an open RF wire attached directly to the UE antenna. Because only relative level recordings were done, it was not necessary to obtain the absolute Tx level.

The measurement process was the same as described above for the BS. Limiting the analysis time to the relevant burst only (see Figure 48) prevents any influences from emissions in the opposite direction and separates uplink and downlink completely.

The following figure shows the result of the UE sideband measurement. For the European Market, the limit from 3GPP TR 36.101 would apply. Its levels were converted to a common reference bandwidth of 100 kHz. The levels of the measured spectrum were referenced to a total transmit power of 23 dBm. Again, the FCC limit is also shown for reference. Since this limit is defined in a reference bandwidth of 1 MHz, it is also converted to 100 kHz bandwidth.

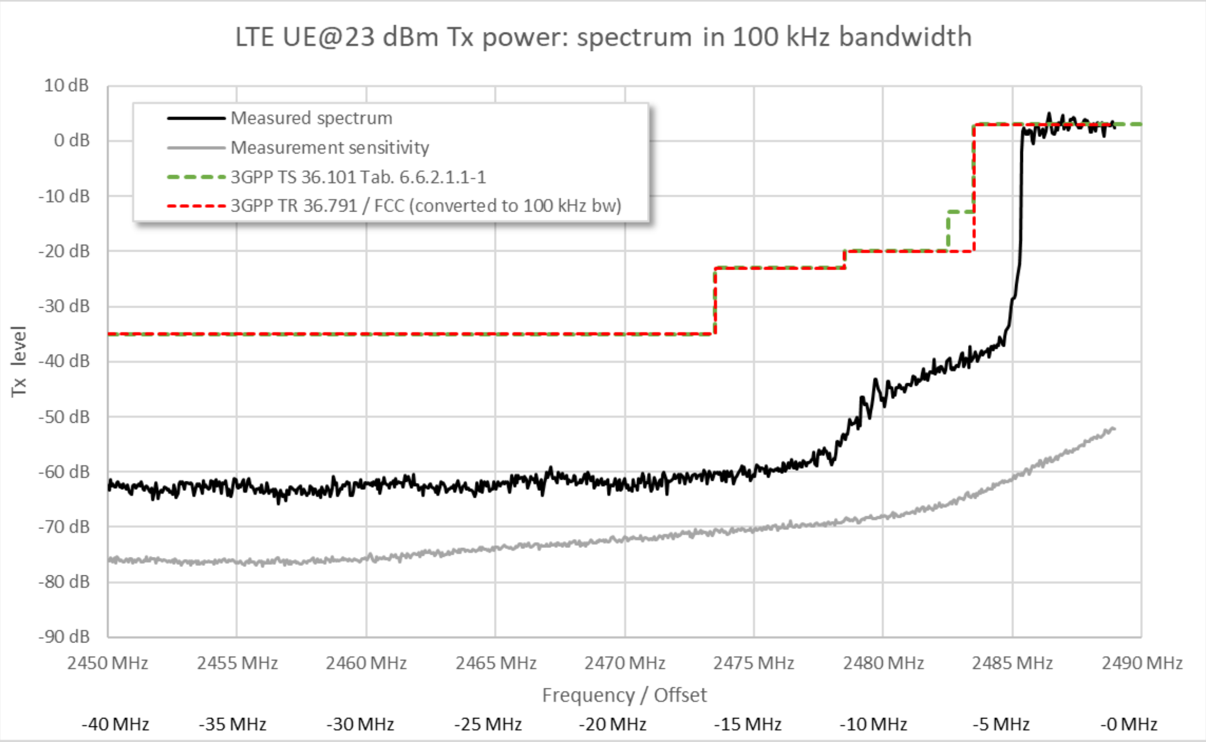

Figure 51: Measured UE sideband spectrum and limit lines

The sideband emissions of the UE were always considerably below the limits. Note that the UE did not use the full bandwidth, even during maximum upload speed.

For the following, mostly practical reasons, the LTE signals from BS and UE could not directly be used for the C/I measurements:

- The BS spectrum exceeds the European limit, which could cause unrealistically high interference potential;
- The UE does not have an external antenna connector, preventing a linear pickup of the signal over the whole frequency range of interest;
- Measurements are only possible during constant upload/download of data, requiring internet access;
- Separation of uplink and downlink signals to investigate only one direction is extremely difficult to realise;
- The sideband emissions of the available UE and BS, although typical, only represent one particular device and not the worst possible case

For the above reasons, the I/Q data of BS and UE signals were recorded for the duration of a full LTE frame (10 ms). They were then separated into different frequency regions by means of a self-developed software. This software also allows changing the levels of the different sideband ranges. The resulting spectral parts are then combined together to form a total spectrum. This allows “forming” the sideband spectrum as required. During time slots where the opposite device sends (DL slot for the UE and UL slot for the BS), the transmitters are switched completely off. This suppresses the residual broadband noise that is present during the active slot (see Figure 48) where this noise can be seen during the uplink time only). The above-mentioned adjustment of the sideband emissions was therefore only applied to the transmission bursts, whereas in the remaining time all emissions were set to zero. Details of this process are described in ANNEX 1:.

The resulting spectra were loaded into a signal generator and used for the C/I measurements. This allows full control over level and frequency of the interfering signals.

As seen in many other public mobile radio systems, the typical level of OoB emissions, and especially of spurious emissions is often far below the 3GPP limits. Although this results in typically lower interference potential to neighbouring radio services, there may (theoretically) also be devices whose unwanted emissions are as high as the limits allow.

To assess the influence of the sideband emission levels on the C/I for BLE and RLAN, two different signals were measured:

- A signal that closely matches the sideband emissions of the available real BS and UE. These signals are herein called “Realistic”;
- A signal with unwanted emissions just meeting the requirements of the European 3GPP masks. For the BS the OoB emissions next to the LTE channel were reduced to match the European 3GPP mask, assuming manufacturers would supply base stations sold in Europe to meet this requirement. These signals are herein called “Worst Case”.

So, all measurements were made with four separate interfering LTE signals:

- BS Realistic;
- BS Worst Case;
- UE Realistic;
- UE Worst Case.

The following figures show the generated BS and UE signals used for the C/I measurements. They are shown in relative levels, referenced to 100 kHz bandwidth and normalized to the spectral in-band level in 100 kHz bandwidth.

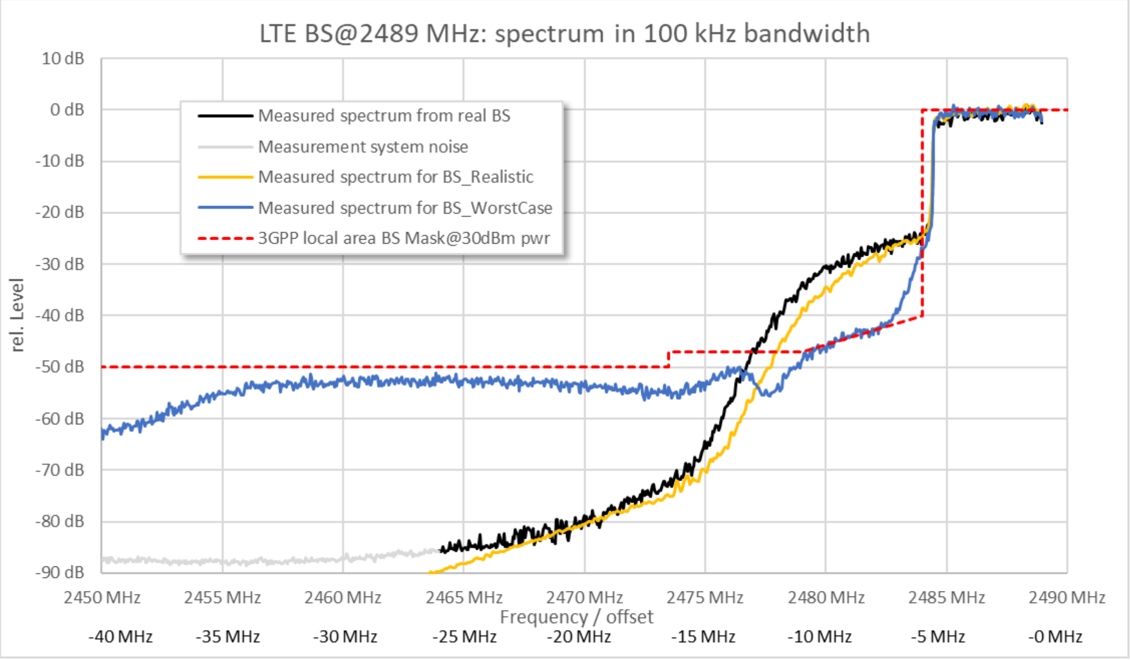

Figure 52: Sideband emissions of LTE BS signals

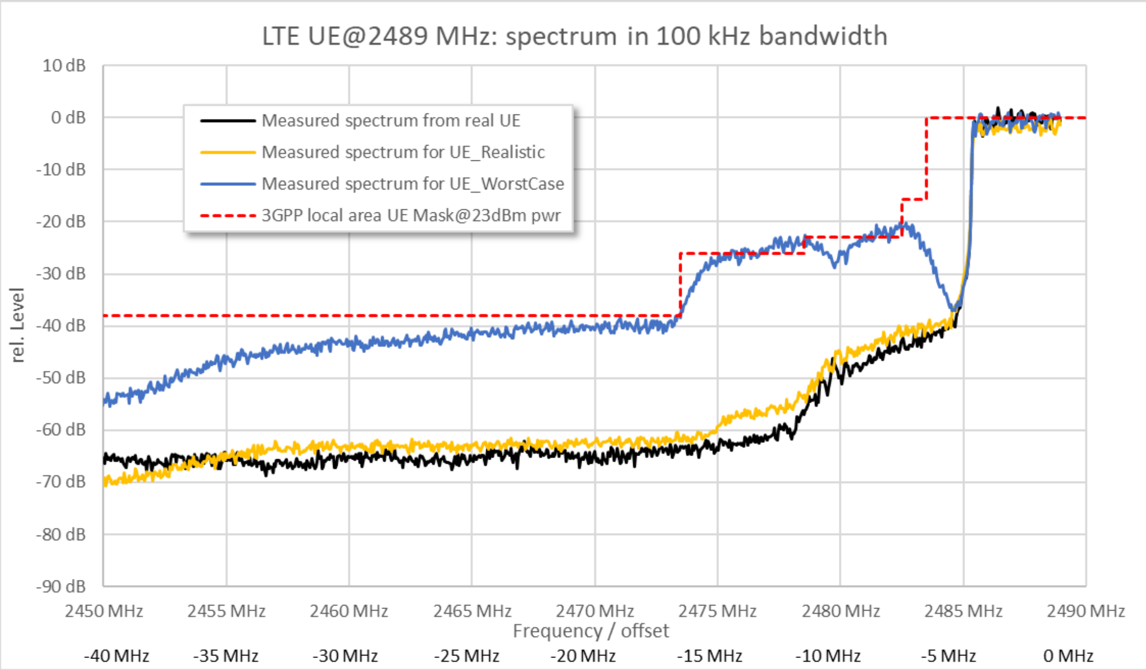

Figure 53: Sideband emissions of LTE UE signals

To suppress the residual noise from the signal generator and achieve the low sideband levels below 2475 MHz, an external band pass filter was inserted after the signal generator for the LTE BS Realistic signal.

Unless stated otherwise, all LTE levels in the following sections are RMS levels during the burst (AV-burst), measured in 10 MHz bandwidth.

A4.6 FAILURE CRITERIA

General

The measurements were taken from the view of a user operating the BLE/RLAN equipment. Since most DUTs, especially Bluetooth devices, have no internal point to objectively measure the performance, the criteria whether a connection is interfered or not had to be somewhat subjective. However, the failure criteria defined were aimed to provide a comparison throughout different applications as far as possible. Whenever the device or application allowed, an objective method of performance assessment was used.

To allow assessment of the margin between no interference and total connection loss, the C/I were measured at three different grades of interference. Because BLE/RLAN is used for completely different purposes, the actual failure criteria depend on the application and are described in the following subsections. As a general guideline, the interference grades were defined as follows:

- Grade 1: Interference just begins to be measurable/noticeable;
- Grade 2: Connection is severely interfered and would probably not be used;
- Grade 3: Total or near total loss of performance, or connection loss.

Bluetooth

Depending on the application, the following failure criteria and interference grades were used for Bluetooth devices.

<u>For BT audio devices:</u>

Aural listening to a 1 kHz sine tone that was transmitted by the server via loudspeaker. The three interference grades were:

1 First occurrence of audio drops within an observation period of at least 10 sec.

2 Heavily distorted audio, so that no one would listen to it

3 Total or near total loss of audio. At least several seconds of muted audio.

Failure criterion for BT mouse application:

A computer mouse (pointing device) was slowly moved along a straight line. The corresponding mouse cursor movements on the DUT's screen were observed. The moving distance (top to bottom) of the mouse was marked in an undistorted situation. When BLE packets get lost, the mouse cursor does not move the whole way from top to bottom although the mouse was moved the previously specified distance. Interference grades were:

1 Mouse does not quite move to the top of the screen (First packets lost)

2 Mouse moves only about half way to the top (half of the packets lost)

3 Mouse freezes or nearly no mouse movements detectable

Failure criteria for smart home appliances:

Continuously triggering a switching function such as altering temperature or locking/unlocking a door lock and observing the reaction on the control app and/or DUT. The interference grades were:

1 First noticeable delay in command reaction

2 Long command reaction or not all commands are executed

3 No execution of commands any more or loss of connection

RLAN

Depending on the application, the following failure criteria and interference grades were used for RLAN devices.

Failure criteria for RLAN data connections:

Transferring 16 parallel data streams by the software “iPerf3” from the server to the DUT and measuring the total throughput. The three interference grades were:

1 First measurable degradation of data rate below the maximum possible for the DUT

2 Half of the maximum possible data rate

3 Total or near total loss of throughput

Failure criteria for RLAN device control:

Repeatedly issuing commands to the device and observing its reaction. Examples: Skipping audio files in a play list, rotating a surveillance camera. The three interference grades were:

1 First reduction of device control, picture freezes or short delay in reaction from DUT.

2 Severe loss of device control, long picture freezes or long delays in DUT reaction

3 Total or near total loss of reaction from DUT

A4.7 LIST OF MEASURED DEVICES

General

A total of 34 Bluetooth and 29 RLAN devices were acquired for the measurements. Devices supporting both Bluetooth and RLAN were measured separately in both categories. For confidentiality reasons, the actual device brand and type are not stated in this report. Instead, each DUT is given a running number, preceded by a “B” for Bluetooth, and “W” for RLAN devices.

For different individual reasons (e. g. setup problems/requirements, too low sensitivity, driver issues), some devices could not be measured. This is the reason why not all running numbers may appear in the measurement results.

The selection of DUTs was oriented along the following aspects:

- Covering a wide spread of applications, but emphasizing on the most common application
- Covering different manufacturers, if possible different chipsets

Devices of the following categories were measured:

Table 128: Categories of evaluated DUTs

Bluetooth	RLAN
Audio Video Receiver (AVR)	Audio Video Receiver (AVR)
BLE doorlock	Digital camera
BLE thermostat	DSL WiFi router
DAB radio with BLE	Laptop PC
Fitness tracker	LTE WiFi router
Laptop PC	Smartphone
Networked LED lamp	USB Wi-Fi adapter
Networked LED luminaire	Wi-Fi surveillance camera
Smartphone	Wireless speaker
Soundbar with BLE	
Wireless ear buds	
Wireless headphones	
Wireless speaker	

It is believed that the selection for both radio services can be regarded as representative.

Bluetooth

The following list contains the selected Bluetooth devices. The sensitivity values were measured according to section A4.8 below

Table 129: Bluetooth devices selected for the measurements

Rx B	Application	BLE standard	ext. Ant.	Chip	Sensitivity
1	Audio streaming	?	-	Mediatek Sun Module	-94 dBm
2	Audio streaming	BLE4.2 / A2DP / SBC	-	?	-78 dBm
3	Audio streaming	BLE3.0	-	?	-89 dBm
4	Device control	BLE 5.0	-	?	-100 dBm
5	Audio streaming	BLE 5.0 / A2DP / SBC	-	?	-94 dBm
6	Mouse control	BLE 4.0	-	Qualcomm Snapdragon 400 (MSM8930)	-84 dBm
7	Audio streaming	?	-	?	-88 dBm
8	Mouse control	?	-	Intel® Dual Band Wireless-AC8260	-82 dBm
9	Device control	?	-	?	-89 dBm
10	Audio streaming	BLE 4.0	-	?	-86 dBm
11	Audio streaming	?	-	?	-83 dBm
12	Audio streaming	BLE 4.0 A2DP/AVRCP	-	?	-
13	Audio streaming	BLE 5.0 / A2DP / AVRCP / HFP / HSP	-	?	-91 dBm
14	Device control	?	-	?	-
15	Audio streaming	BLE 4.1	-	?	-87 dBm
16	Audio streaming	BLE 5.0 A2DP, AVRCP, HSP, HFP	-	?	-95 dBm
17	Mouse control	BLE 4.1	-	Qualcomm Snapdragon 805 APQ8084 Pro	-
18	Device control	?	-	?	-91 dBm
19	Audio streaming	?	-	?	-91 dBm

Rx B	Application	BLE standard	ext. Ant.	Chip	Sensitivity
20	Audio streaming	BLE 5.0	-	?	-91 dBm
21	Audio streaming	BLE 2.1 / A2DP / SBC	-	?	-79 dBm
22	Audio streaming	BLE 4.2 / A2DP/ AVRCP/ SBC	x	Broadcom Lego Module	-83 dBm
23	Device control	?	-	?	-88 dBm
24	Audio streaming	BLE 5.0 / A2DP / AVRCP	-	?	-92 dBm
25	Mouse control	BLE 4.0	-	Qualcomm Snapdragon 800 MSM8974	-
26	Audio streaming	BLE 5.0	-	Qualcomm APTX	-86 dBm
27	Audio streaming	?	-	?	-97 dBm
28	Mouse control	BLE5.0	-	Qualcomm Snapdragon 845 (SDM845)	-86 dBm
29	Audio streaming	?	-	?	-87 dBm
30	Device control	?	-	?	-87 dBm
31	Audio streaming		-	?	-91 dBm
32	Audio streaming	BLE 5.0 / SPP / A2DP / HFP / AVRCP / HSP	-	?	-92 dBm
33	Mouse control	BLE 5.0 / A2DP / aptX HD / LE	-	HiSilicon Kirin 980	-88 dBm

It is assumed that most Bluetooth applications are audio streaming applications (head-/earphones, wireless speakers, BLE radios), followed by Bluetooth mice for computers, tablets and smartphones.

Figure 54: Evaluated Bluetooth devices

RLAN

The following list contains the selected RLAN devices. The sensitivity values were measured according to section A4.8 below.

Table 130: RLAN devices selected for the measurements

Rx W	Application	Wi-Fi Standard	External antenna	Chip	Sensitivity	Data rate (note 1)
1	Data transfer	802.11n/g/b/a/ac	-	Qualcomm Snapdragon 845 (SDM845)	-52 dBm	40 Mbit/s
2	Data transfer	802.11n/g/b/a/ac	-	Qualcomm Atheros QCA9985+QCA9984	-63 dBm	20 Mbit/s
3	Data transfer	802.11n/g/b/a/ac	-	?	-	
4	Data transfer	802.11b/g/n	-	Realtek RTL8192CE	-57 dBm	25 Mbit/s
5	Data transfer	802.11n/ac	-	Qualcomm IPQ4019+QCA9984	-71 dBm	45 Mbit/s
6	(various)	802.11n/g/b	-	?	-	
7	Data transfer	802.11b/g/n	-	?	-56 dBm	25 Mbit/s
8	Data transfer	802.11n/g/b/a/ac	x	?	-73 dBm	20/45 Mbit/s
9	Data transfer	802.11n/g/b/a/ac	-	Broadcom BCM43526	-63 dBm	45 Mbit/s
10	Data transfer	802.11ac/ax	x	?	-59 dBm	20 Mbit/s
11	Device control	802.11n/g/b/a/ac	-	Mediatek Sun Module	-88 dBm	
12	Data transfer	802.11n/g/b/a/ac	x	?	-67 dBm	35 Mbit/s
13	Data transfer	802.11n/g/b/a/ac	-	?	-74 dBm	35 Mbit/s
14	Data transfer	802.11 b/g	x	Realtek RTL8187L	-75 dBm	20 Mbit/s
15	Data transfer	802.11n/g/b	-	Qualcomm Snapdragon 400 (MSM8930)	-	
16	Data transfer	802.11n/g/b/a/ac	-	Intel® Dual Band Wireless-AC8260	-67 dBm	45 Mbit/s
17	Device control	802.11n/g/b/a	x	Broadcom Lego Module	-84 dBm	
18	Data transfer	802.11n/g/b/a/ac/ax	-	?	-49 dBm	40 Mbit/s

Rx W	Application	Wi-Fi Standard	External antenna	Chip	Sensitivity	Data rate (note 1)
19	Data transfer	802.11n/g/b/a	x	Ralink RT2770F	-70 dBm	
20	Data transfer	802.11n/g/b/a/ac	-	Qualcomm Snapdragon 800 MSM8974	-41 dBm	40 Mbit/s
21	Data transfer	802.11n/g/b/a/u/ac/ax/ab	x	MediaTek MT7915DAN + MediaTek MT7975DN	-58 dBm	40 Mbit/s
22	Data transfer	802.11n/g/b/a/ac	-	Qualcomm Snapdragon 805 APQ8084 Pro	-51 dBm	35 Mbit/s
23	Data transfer	802.11n/g/b/a/ac	-	Realtek RTL8812BU	-58 dBm	45 Mbit/s
24	Data transfer	802.11b/g/n/ac	-	?	-69 dBm	40 Mbit/s
25	Device control	802.11b/g/n	-	?	-	
26	Device control	802.11n/g/b/a	-	?	-88 dBm	
27	Device control	802.11b/g	-	?	-81 dBm	
28	Data transfer	802.11n/g/b/a/ac	-	HiSilicon Kirin 980	-55 dBm	35 Mbit/s
29	Data transfer	802.11n/g/b/a/ac	-	Qualcomm	-58 dBm	45 Mbit/s
Note 1: This is the maximum throughput measured for data transfer devices, rounded down to the next 5 Mbit/s.						

It is assumed that most RLAN applications are used for user data transmission (providing network access to mobile devices).

Figure 55: Evaluated RLAN devices

Although RLAN devices such as wireless speakers and receivers are configured as media clients and transmit audio, the audio quality cannot be used as a performance criterion, because they transfer the whole file to be played at the beginning of the playing process and then play out from an internal buffer. Lost RLAN packets therefore only result in a longer transfer time, unnoticed by the user. The RLAN performance was therefore measured by repeatedly skipping files in a pre-defined play list and observe the delay in reaction.

A4.8 SENSITIVITY MEASUREMENTS

General

The sensitivity of each DUT was measured prior to the C/I measurements. Depending on whether the DUT has an external antenna connector, the measurement setup according to Figure 58 or Figure 60 was used. The LTE signal was switched off during these measurements at all times.

First, the maximum performance was noted by supplying sufficient wanted signal level. Then, this signal level was slowly reduced until the first grade of the pre-defined failure criterion (see Section A4.6) was reached. A wanted level 1 dB above this point was recorded as the DUT's sensitivity.

Bluetooth

The following figure shows the measured sensitivity of the selected Bluetooth devices.

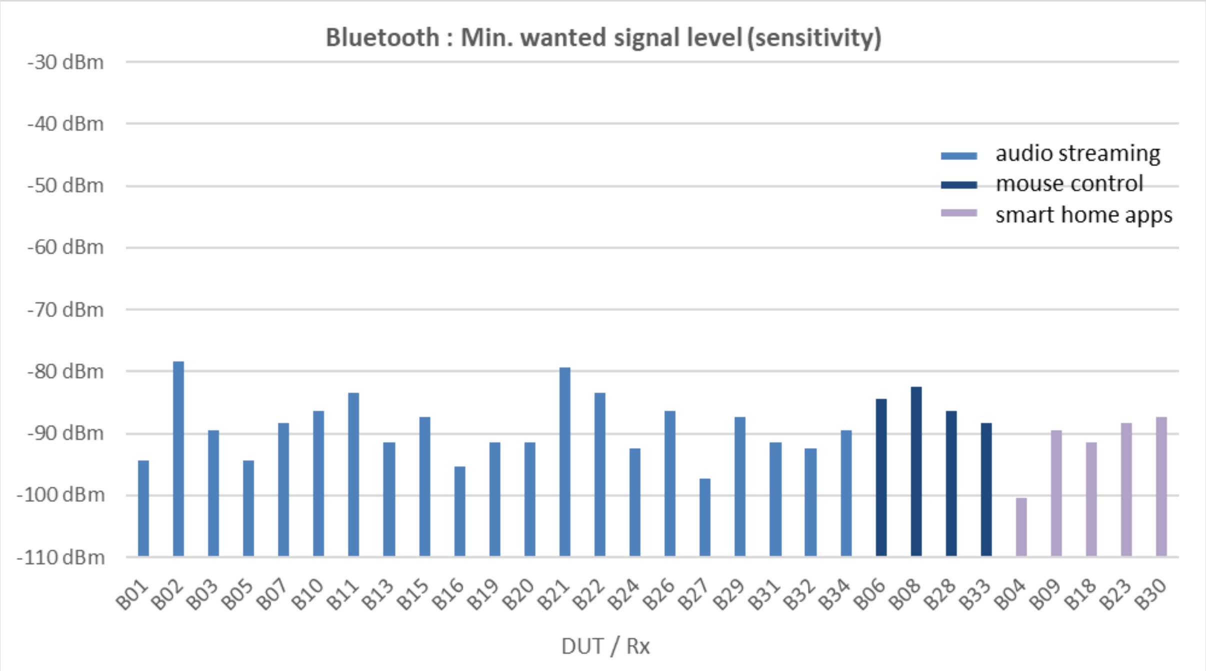

Figure 56: Measured sensitivity of the selected Bluetooth devices

It can be seen that, although the devices are used for different applications, the sensitivities do not show a general difference.

The following table contains statistical values from these measurements.

Table 131: Measured sensitivity of selected Bluetooth devices

Parameter	Value
Maximum level (poorest sensitivity)	-78 dBm
Upper decile (10% are less sensitive)	-83 dBm
Median (50% of DUTs are higher, 50% lower)	**-89 dBm**
Lower decile (10% of DUTs are more sensitive)	-95 dBm
Minimum level (best sensitivity)	-100 dBm

RLAN

The following figure shows the measured sensitivity of the selected RLAN devices.

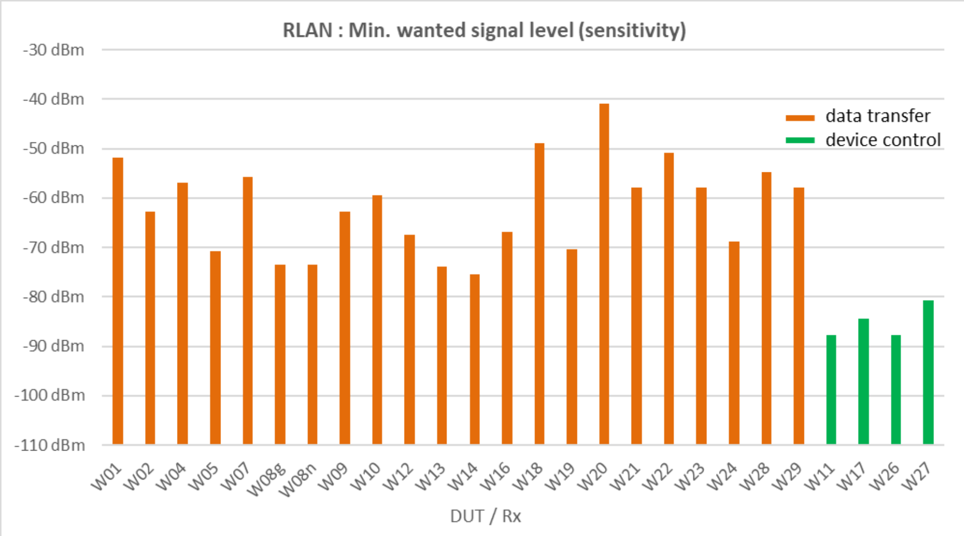

Figure 57: Measured sensitivity of the selected RLAN devices

It can be seen that the sensitivity of the devices used for data transfer generally require more signal level than the devices for remote control. It was therefore decided not to combine the results of both categories in the evaluation processes.

Furthermore, even the sensitivity of the data transfer devices varied considerably. However, this is mainly due to software implementation of the higher OSI layers, rather than properties of the RF unit. Since C/I measurements were always performed at a wanted signal level that is a certain amount of dB above the respective sensitivity, they are comparable between all devices for the same application.

The following table contains statistical values for the data transfer devices only.

Table 132: Measured sensitivity of selected RLAN data transfer devices

Parameter	Value
Maximum level (poorest sensitivity)	-41 dBm
Upper decile (10% are less sensitive)	-51 dBm
Median (50% of DUTs are higher, 50% lower)	**-61 dBm**
Lower decile (10% of DUTs are more sensitive)	-73 dBm
Minimum level (best sensitivity)	-75 dBm

The sensitivity of the DUTs for RLAN device control ranged between -81 dBm and -88 dBm.

A4.9 PROTECTION RATIO MEASUREMENTS

Measurement Setup

The setup used for the C/I measurements depends on whether the DUT has an external antenna connector. Devices with a built-in antenna, such as most BLE devices, had to be measured in a G-TEM cell, which establishes a stable RF field around the DUT.

The following setup was used for the C/I measurements of DUTs with built-in antennas, shown on the example of a BLE headset as DUT and a smartphone as “server”.

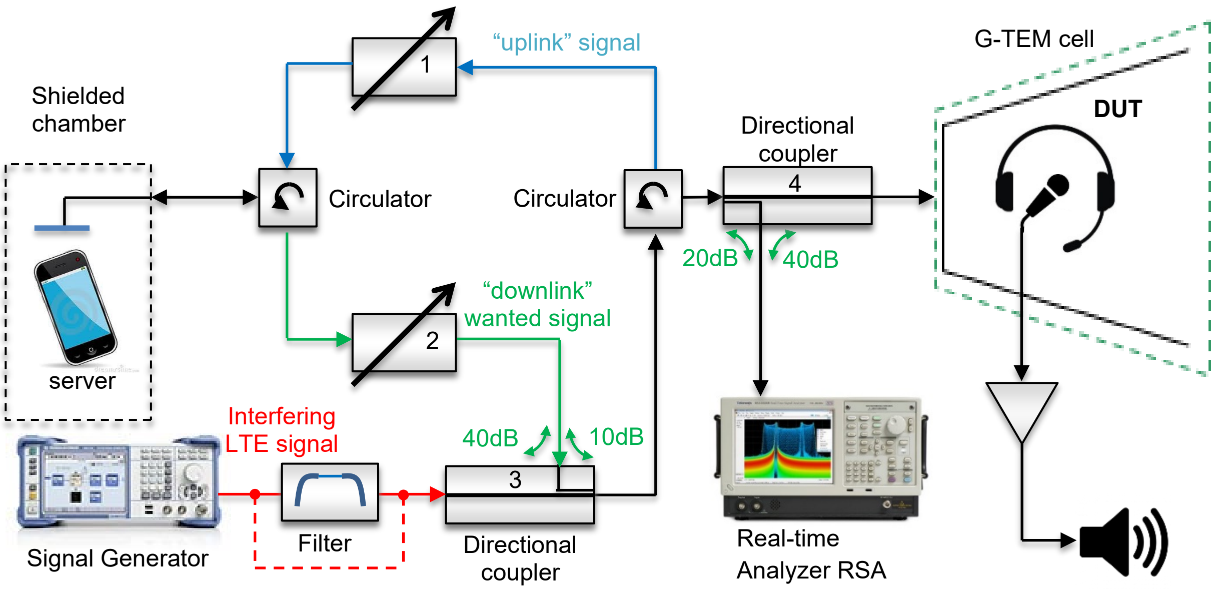

Figure 58: Block diagram of the setup used for C/I measurements of devices with built-in antennas

It was necessary to place the server inside a shielded chamber in a neighbouring room to prevent the RF signal to bypass the wired setup over the air.

The band pass filter after the LTE signal generator was only switched on for the BS Realistic signal in order to sufficiently suppress any wideband noise in the BLE/RLAN channel.

By means of the variable attenuator “1” it was ensured that the uplink level at the server input was always well above that device’s sensitivity. Together with the use of the directional coupler “3” it was ensured that the interfering signal only affects the DUT while the direction to server was always operating without interference.

The various attenuations of the setup were measured beforehand with a signal generator instead of the server.

The free space attenuation of the TEM cell was also measured beforehand with a calibrated antenna instead of the DUT. It was determined to be 28 dB. This attenuation limited the maximum applicable signal levels for both wanted and LTE signals. Devices with built-in antennas could therefore not be measured at sensitivity + 25 dB (high level).

An antenna gain of 0 dBi was assumed for all DUTs.

Wanted and unwanted signal levels were measured with the real-time analyser as described in A4.1, and converted into levels at the DUT input using the known attenuation of the TEM cell and directional coupler “4”.

The following figure illustrates the setup described above, with the example of a BLE mouse control

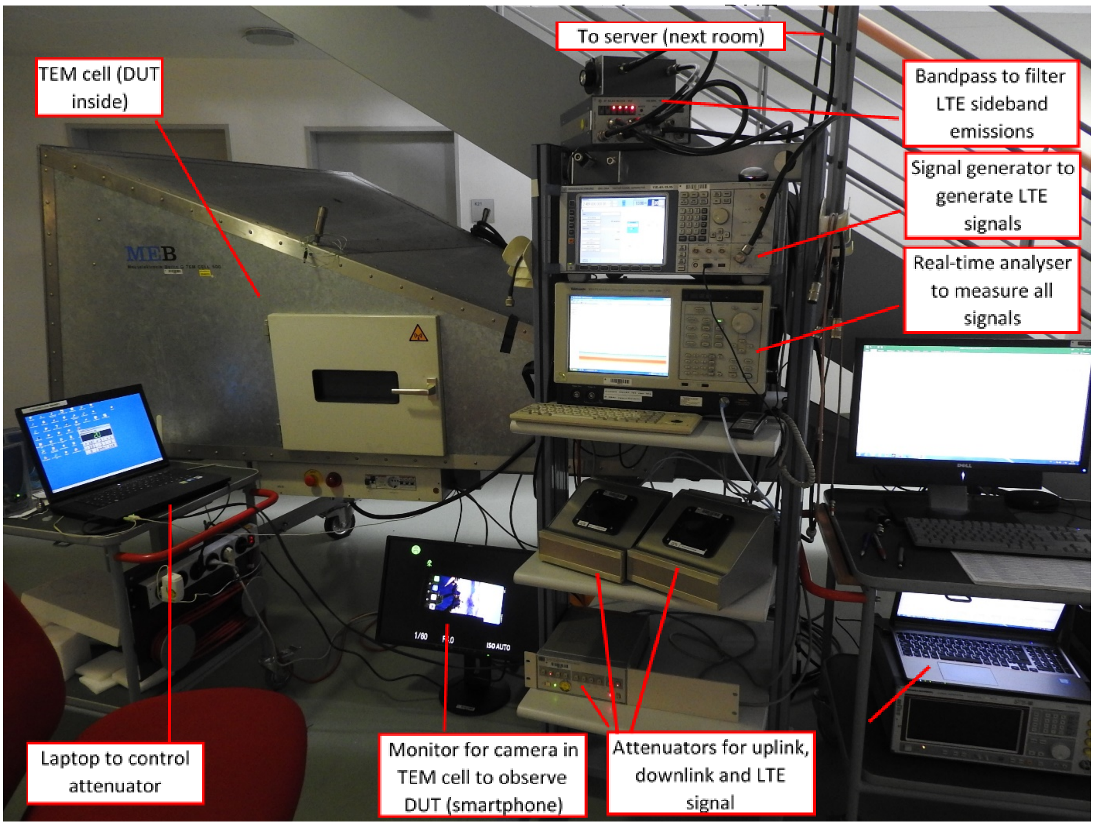

Figure 59: Illustration of the measurement setup for devices with built-in antennas (example: BLE mouse control)

The following setup was used for the C/I measurements of DUTs with external antenna connectors, shown on the example of a Wi-Fi router as DUT and an access point as "server".

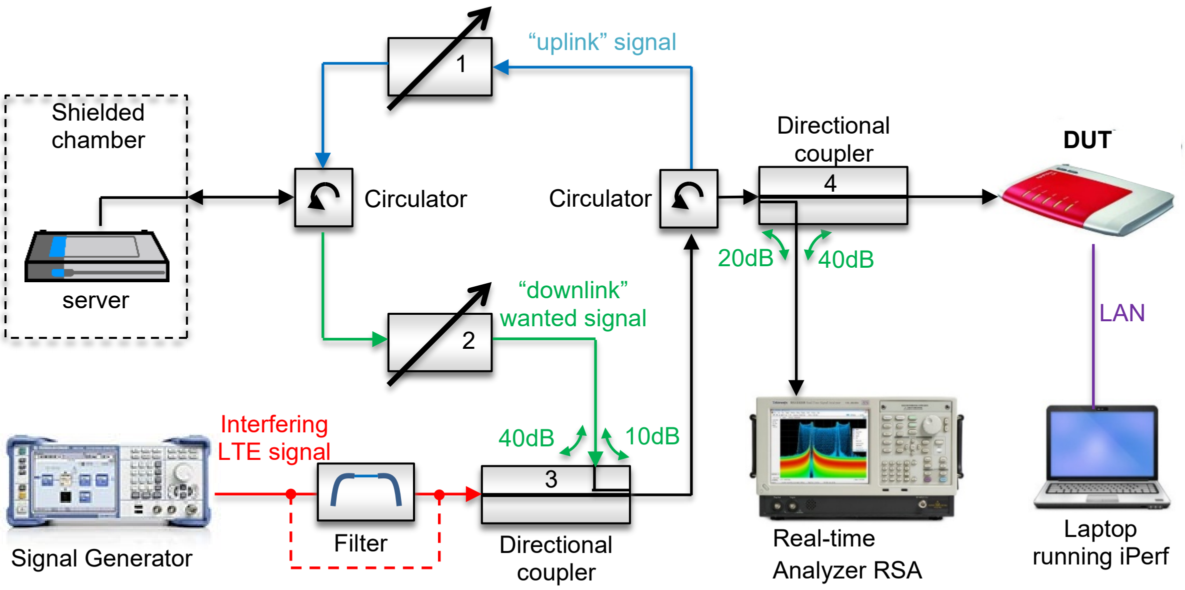

Figure 60: Block diagram of the setup used for C/I measurements of devices with external antenna connectors

The following figure illustrates the setup described above, with the example of a USB Wi-Fi Adaptor as DUT.

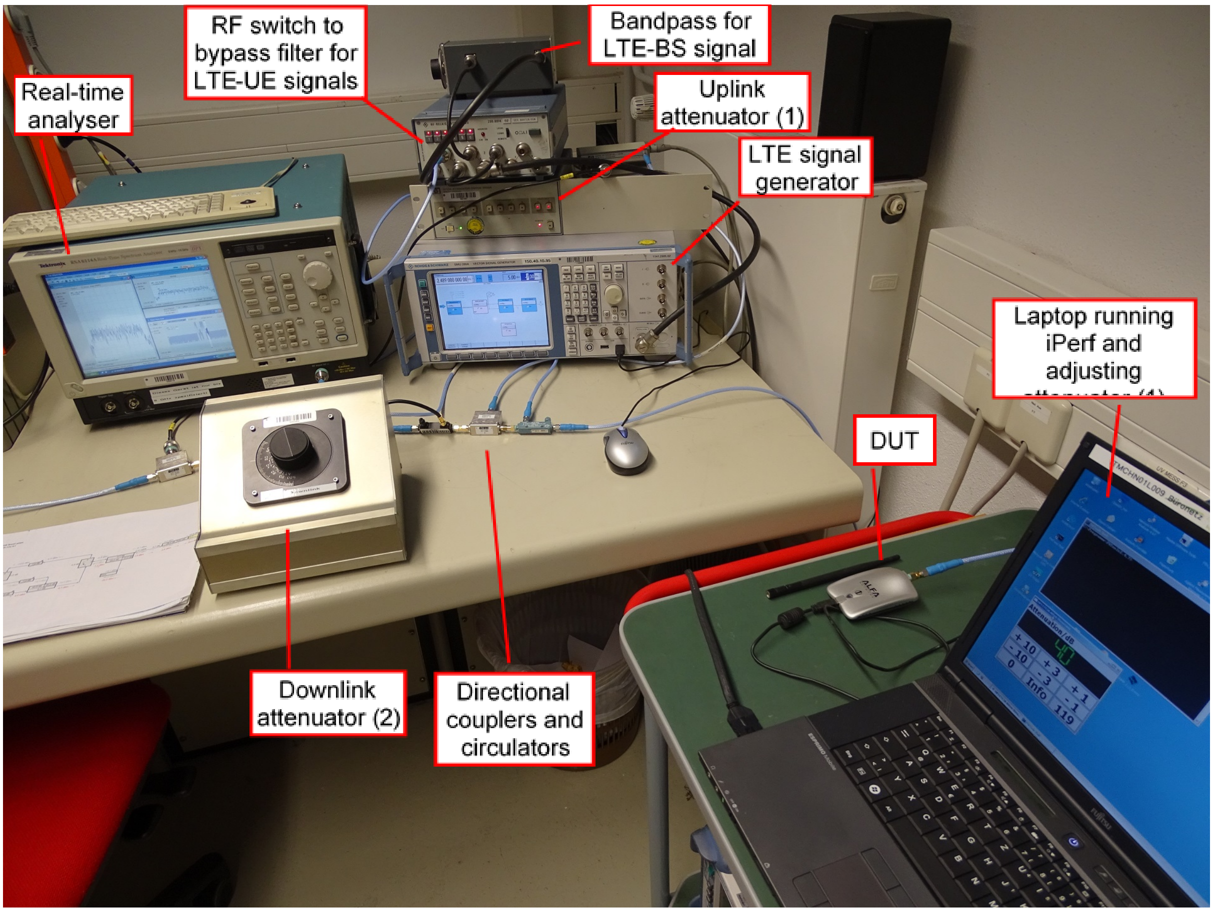

Figure 61: Illustration of the measurement setup for devices with external antennas (example: USB Wi-Fi Adaptor)

Measurement Procedure

RLAN data transfer devices were configured as master/server or slave/client depending on device type. The server was an access point (D-Link DAP 1665) supporting all modes.

For DUTs with built-in antennas, the optimum position and orientation of the DUT inside the TEM was determined first. This was done by measuring and maximising the level of the return (uplink) packets during an active connection. This assumes that the DUTs use the same antenna for transmission and reception. Fine adjustments were then made without interfering signal by gradually lowering the wanted downlink level and observing the performance.

After determination of the sensitivity (see section A4.8), the wanted signal level was adjusted either 3, 10 or 25 dB above the individual sensitivity.

Then, the interfering LTE signal was introduced and its level was gradually increased until the respective interference grade was reached. The difference of wanted level – LTE level was recorded as the C/I.

In some situations and for some DUTs, the point of failure could not be reached due to the limited maximum power from the LTE signal generator. In these cases, the C/I could not be determined.

As mentioned earlier, both levels are given as average burst levels (RMS during the burst) over the whole signal bandwidth (BLE: 1 MHz, RLAN: 20 MHz, LTE: 10 MHz).

Results for Bluetooth

The following considerations and observations are important to note in order to fully understand the measurement results.

- BLE audio devices are generally easier to interfere than for example BLE home appliance devices because even some lost packets lead to drop-outs in the audio. A heater thermostat simply re-transmits lost packets, and only a considerable amount of lost packets will lead to a noticeable delay in reaction. Nevertheless, the failure criteria were selected in a way that allows reasonable comparison between devices for different applications;
- The wanted signal level was measured on one BLE channel in the centre of the band around 2450 MHz. However, due to the aerial coupling of the server device the generated level of the channels from 2402 and 2480 MHz was slightly different. To determine a possible correction, the server level was once measured on each of the 80 channels, linearly averaged and compared with the level measured on 2450 MHz. By coincidence, the difference in our measurement setup was less than 1 dB;
- Once a connection between server and DUT is lost due to interference, the hopping sequence after reconnection is different. Whereas most BLE audio devices always use all available channels, the sequence for BLE home appliances and mouse control is often limited to a few channels only. Hence, the interference effect depends on whether the used BLE channels are more to the lower or to the higher end of the ISM frequency band. This fact may limit the reproducibility of the C/I measurements for those devices;
- Once a device detects interference on some of the used channels, the hopping sequence may be changed in order to use only channels that are less interfered. This leads to the fact that the noticeable interference disappears after a few seconds, although the interfering level remains constant. However, again after some time, the devices try to re-use the interfered channels causing the interfering effect to appear again. This effect was counted as “interfered”;
- Due to the attenuation of the TEM cell, the maximum DUT input level of both wanted and LTE signal was limited. Therefore, C/I measurements at a wanted level of sensitivity + 25 dB was only possible for Rx B22 which was the only BLE device with external antenna connector.

The following graphs show the results of the BLE C/I measurements, grouped by interfering LTE signal. The first three figures in each group show the dependence on the interference grade. The fourth figure in each group shows a statistical evaluation of the C/I depending on the wanted signal level, for the interference grade 2 (heavily interfered).

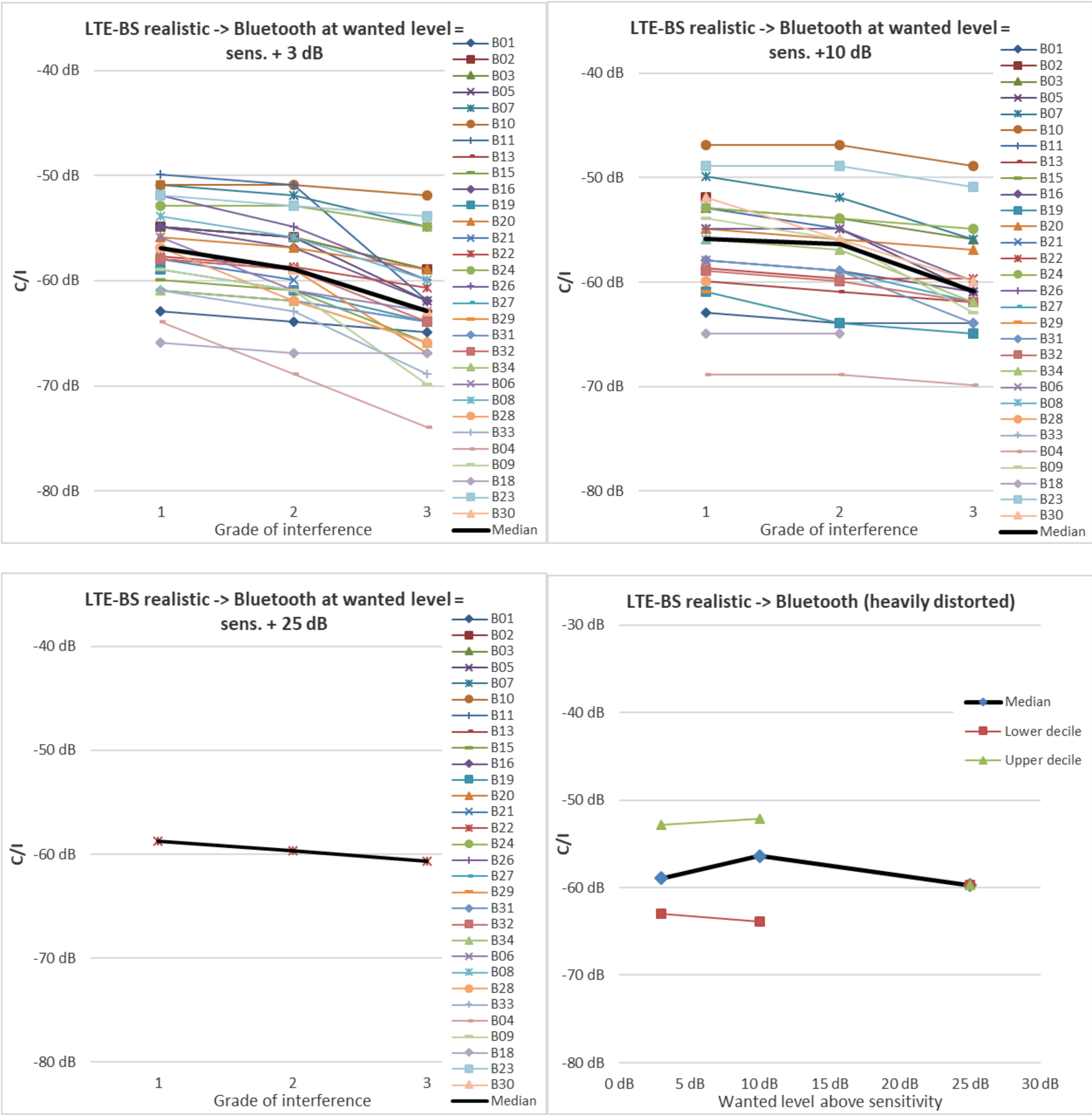

Figure 62: C/I for BLE devices exposed to LTE BS realistic interferer

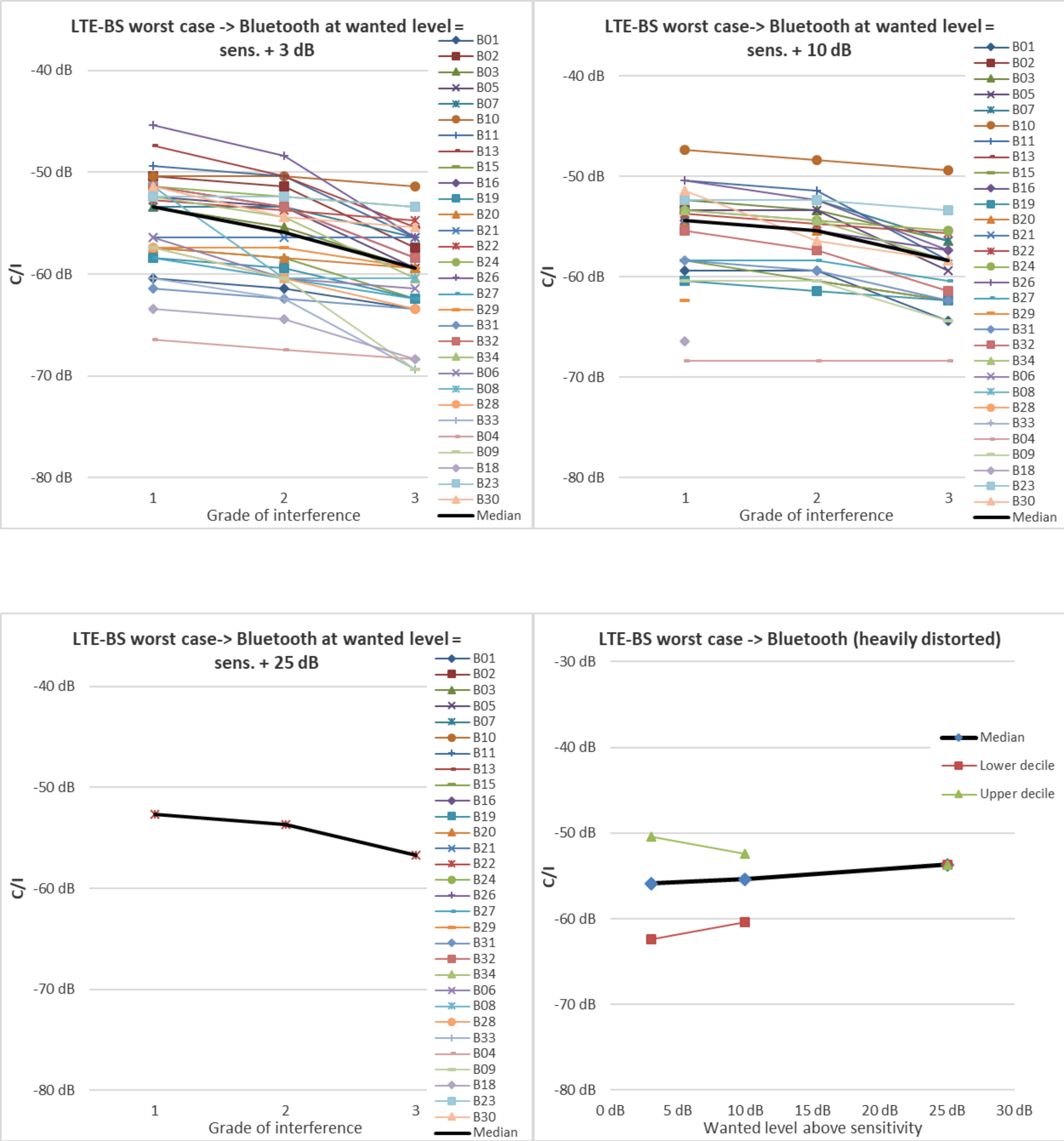

Figure 63: C/I for BLE devices exposed to LTE BS worst case interferer

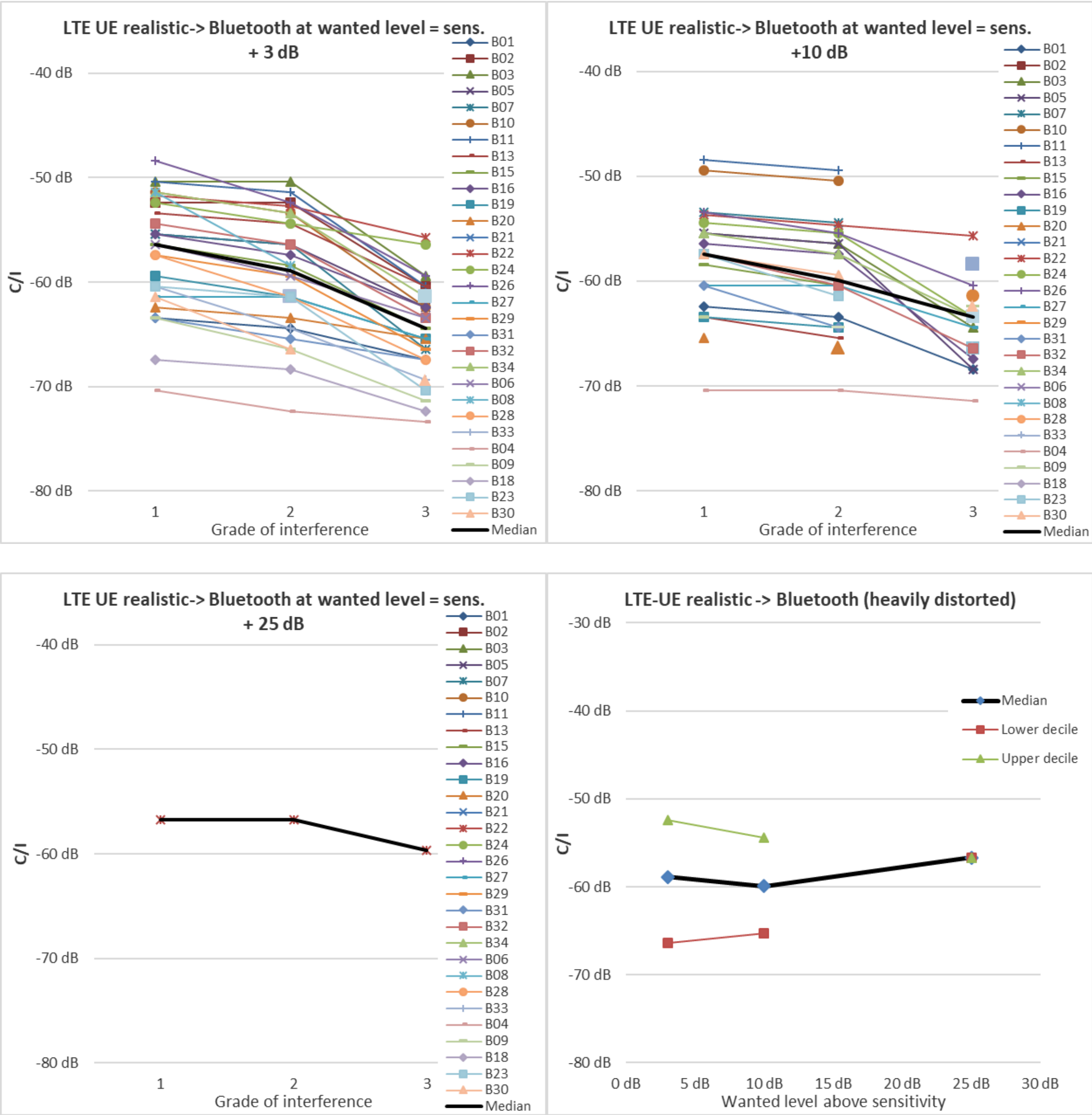

Figure 64: C/I for BLE devices exposed to LTE UE realistic interferer

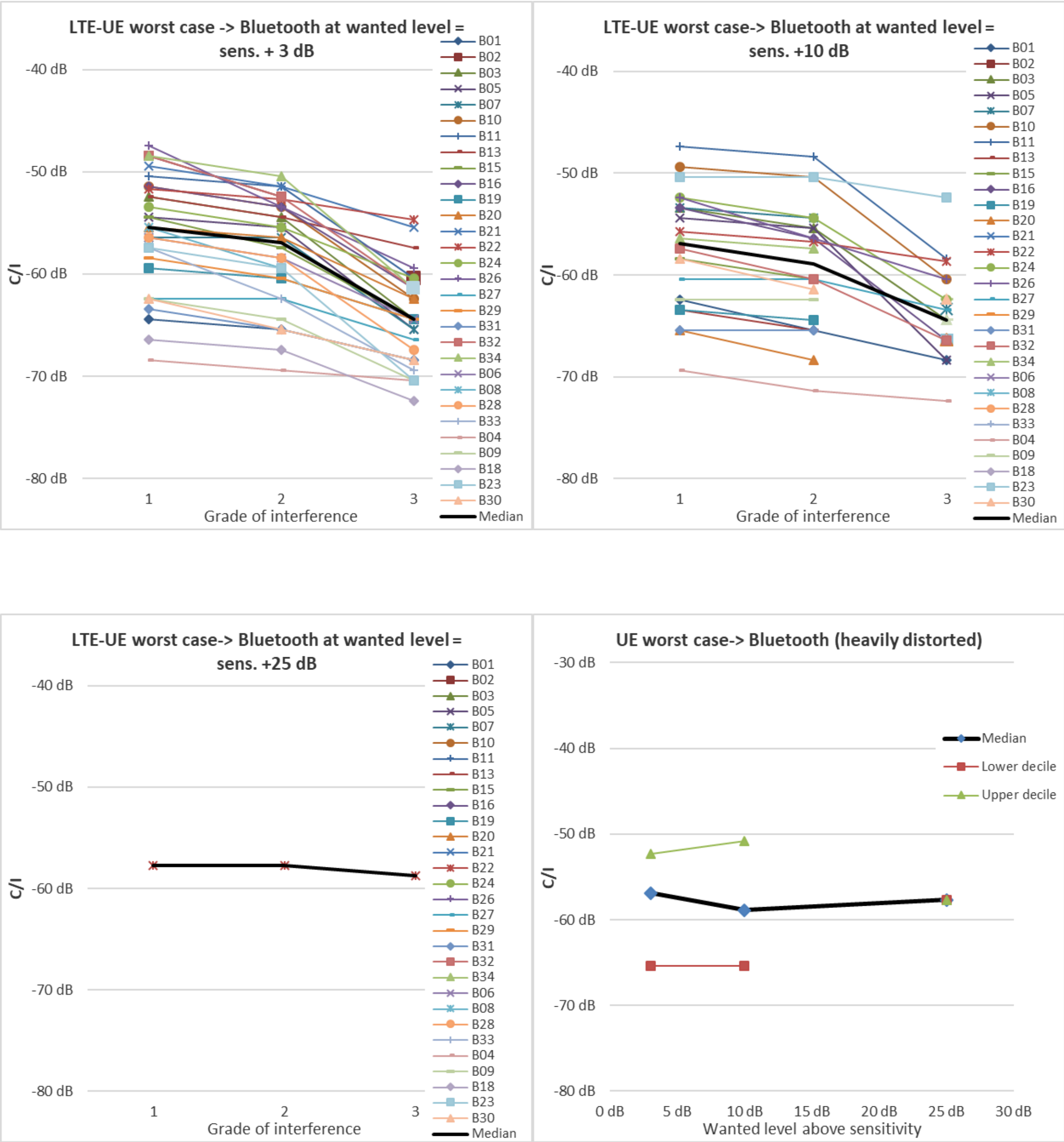

Figure 65: C/I for BLE devices exposed to LTE UE worst case interferer

Observations:

- The C/I of the measured BLE devices show a considerable spread by as much as 20 to 25 dB;
- The C/I of BLE audio devices are generally in the same range as those of mouse control and smart home applications;
- The receivers are generally not overloaded in situations with signal levels of up to 25 dB above sensitivity. This can be seen in the fourth figure of each group above where the C/I is largely independent of the wanted signal level (note that the value for sensitivity + 25 dB could only be derived from one DUT).

The detailed results are shown in tabular form in ANNEX 2:, together with a list of device-specific observations and remarks that may help in the interpretation of outliers.

Results for RLAN

The following considerations and observations are important to note in order to fully understand the measurement results.

- Once a connection between server and DUT is lost due to interference, many of the data transfer devices did not recover to maximum throughput. A total connection loss had to be forced in some cases to re-establish the full data rate.
- For data transfer devices, at some points of C/I the data rate drops in steps. This is due to re-negotiation of modulation and/or coding. Once a lower modulation was established, some devices refused to re-negotiate higher modulation/coding even after interference was taken away. In these cases a reset of the connection had to be forced.
- Optimum position and orientation of the DUTs inside the TEM cell was determined by measuring the level of the return ack-packets. All DUTs were positioned in a way that maximum return packet level was achieved. However, positioning for RLAN DUTs was much less critical than for BT devices. This may be due to the fact that most RLAN devices use multiple antennas in different orientation.
- The sensitivity of different DUTs varied considerably by more than 45 dB. However, it can be assumed that this is due to software implementation, specific application, and – for data transfer devices –version of the 802.11 protocol providing maximum throughput, rather than the receiver hardware.
- Some access points limited the throughput for one data stream. iPerf was therefore configured to set up 16 parallel data streams. The specified data rate is the sum of all 16 streams.
- Maximum data rates for data transfer devices varied even without interference. Therefore they were rounded to the next lower 5 Mbit/s.
- DUTs used to (remotely) control other devices were found to be significantly less susceptive to interference, compared with data transfer devices. This is because device control only requires successful transmission of a few packets and is therefore not a real-time application. Failure to receive packets results in re-transmission of them, which usually takes place very quickly, thereby not causing noticeable performance degradation. RLAN connections between cameras and computers/smartphones also fall in this category. Although transmission of the live picture is usually also supported, the majority of the transmitted data is in the reverse direction (uplink, the DUT sends) which is not interfered.

Because RLAN data transfer devices are generally more critical in terms of interference susceptibility than device control, it was decided not to mix up these two applications in the evaluation process.

The following graphs show the results of the C/I measurements for RLAN data devices only, grouped by interfering LTE signal. The first three figures in each group show the dependence on the interference grade. The fourth figure in each group shows a statistical evaluation of the C/I depending on the wanted signal level, for the interference grade 2 (heavily interfered). This interference grade, being reduced to half the maximum data rate, will be noticed by almost all users and can therefore be recommended for coordination purposes.

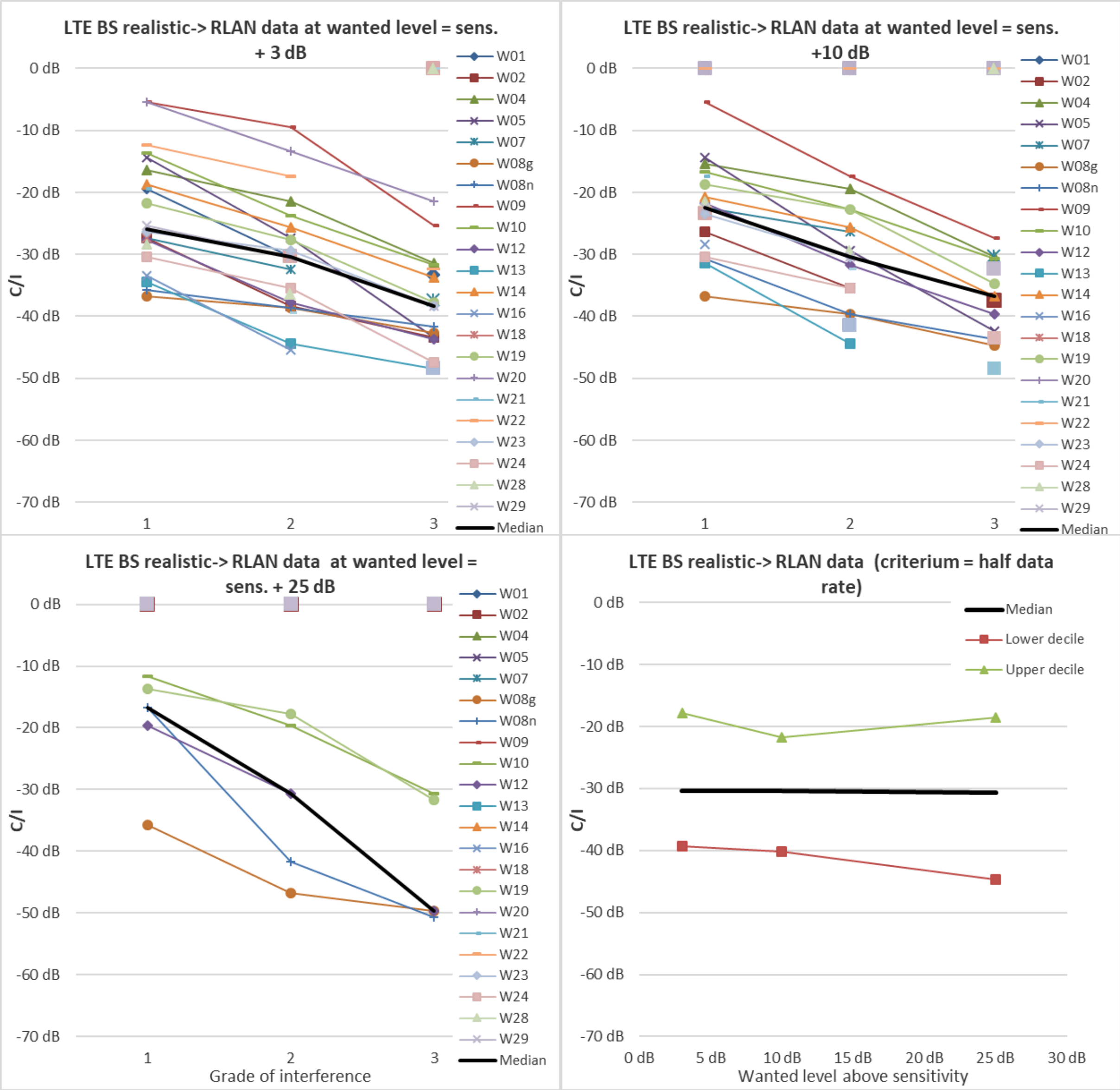

Figure 66: C/I for RLAN data transfer devices exposed to LTE BS realistic interferer

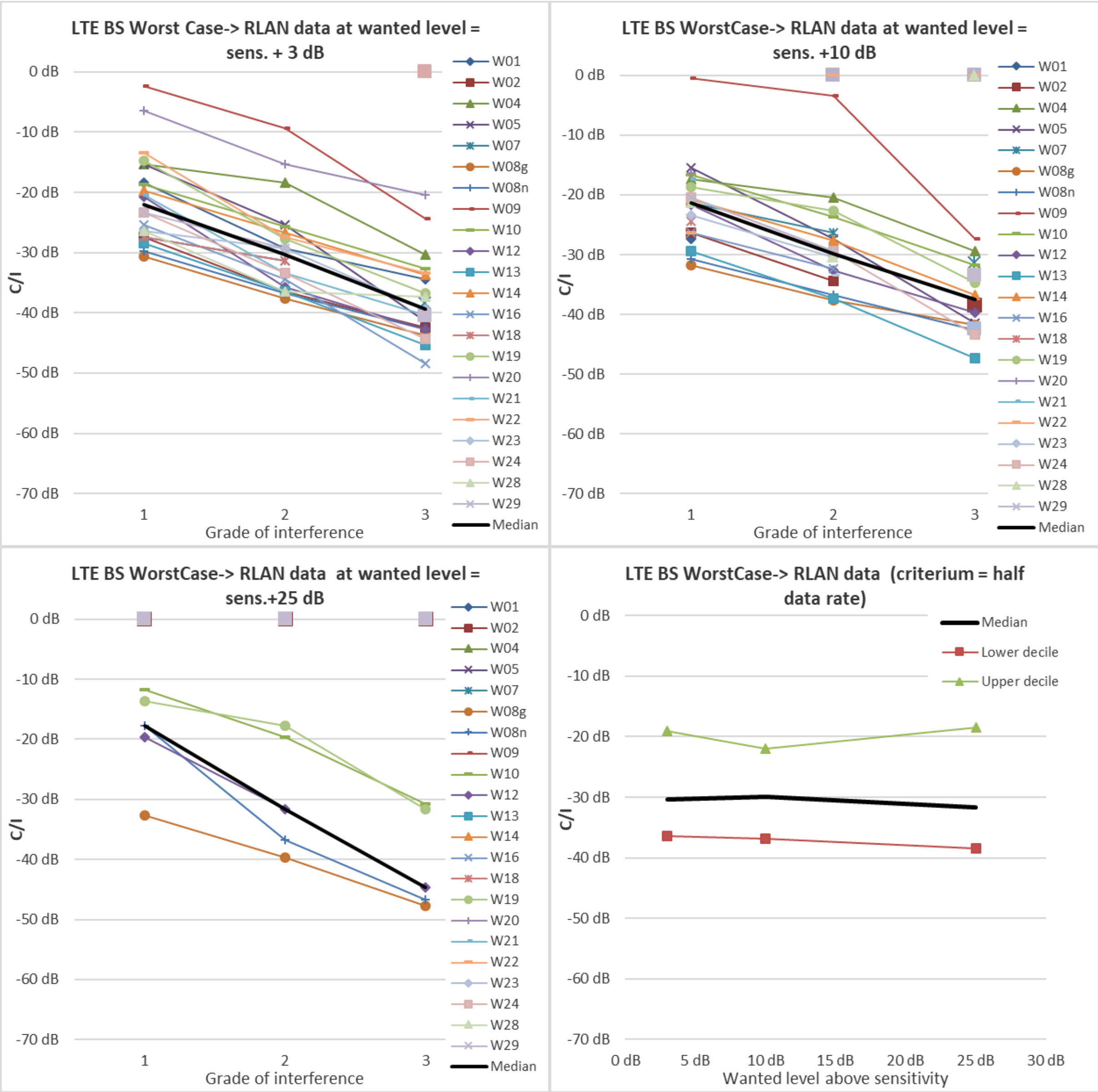

Figure 67: C/I for RLAN data transfer devices exposed to LTE BS worst case interferer

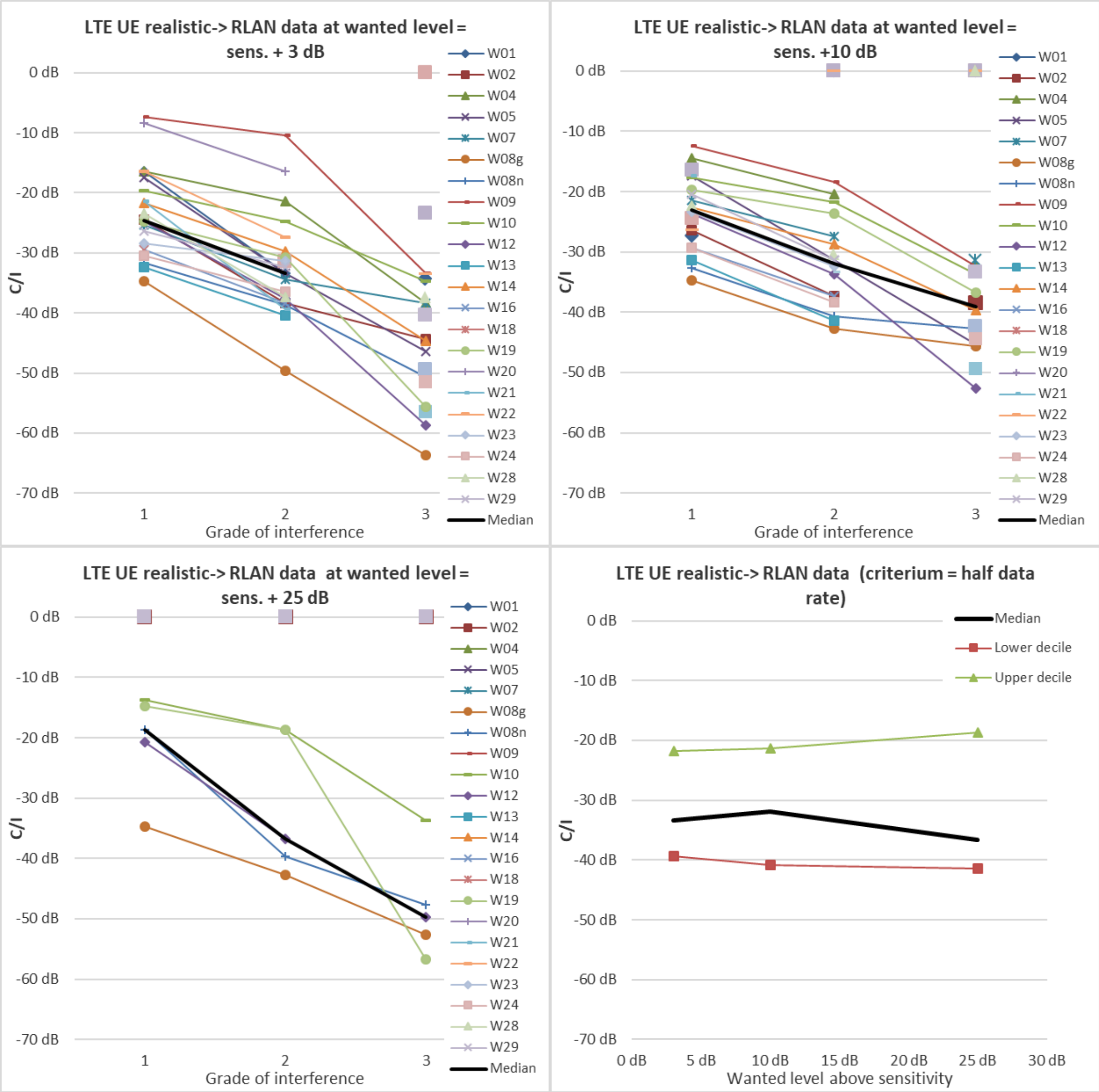

Figure 68: C/I for RLAN data transfer devices exposed to LTE UE realistic interferer

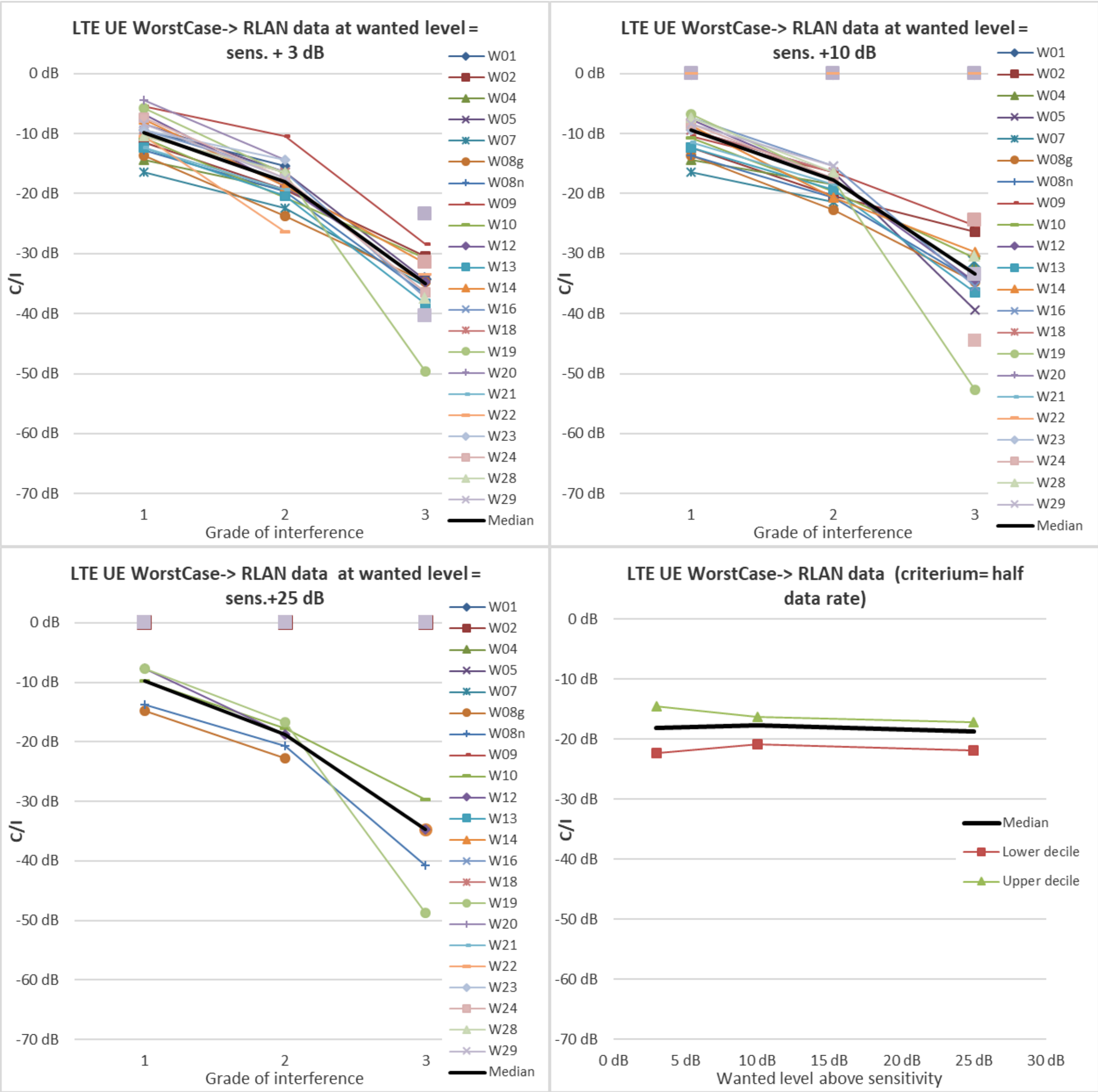

Figure 69: C/I for RLAN data transfer devices exposed to LTE UE worst case interferer

Observations:

Even when exposed to an LTE Realistic interferer which has nearly no unwanted emissions inside the RLAN channel, the devices are not overloaded up to a wanted level of 25 dB above sensitivity. The C/I is independent of the wanted signal level (see first part of the figure above).

The C/I values vary considerably by as much as 45 dB between DUTs, especially when exposed to LTE signals with low unwanted emissions inside the RLAN channel (BS realistic and UE realistic).

There is as much as 45 dB variation between first occurrence of interference and total loss of data transfer, the median difference being around 20 dB. This is significantly different from the "1 / 0 behaviour" observed on some other digital radio services.

The detailed results of all tested RLAN DUTs (including those for device control) are shown in tabular form in ANNEX 3:, together with a list of device-specific observations and remarks that may help in the interpretation of outliers.

A4.10 CONCLUSION

Measuring the C/I of burst radio systems when exposed to also burst, but unsynchronized, interfering signals such as in this campaign is very complex and may lead to extreme variations in the results. Furthermore, when the frequency selection of the victim service is arbitrary and/or reactive to interference as applied in Bluetooth, the obtained results may not always be exactly reproducible. Together with the large variation of BLE and RLAN devices and applications on the market, this makes it necessary to measure a large number of devices in order to obtain statistically relevant results.

The current measurements have shown extremely large variations in both sensitivity and C/I values. Assuming that the physical RF properties of the receivers is somewhat equal, the reasons for these differences may rather be among the following:

- Antenna design (mismatch, size, number, orientation) for devices with built-in antennas
- Software implementation (negotiation with the server about speed, modulation, coding, FEC, and frequency hopping sequence for BLE)
- Specific application served by the device (audio or data transmission, remote device control etc.)

Nevertheless, it is believed that that the selection of measured devices for both services can be regarded as being representative.

The C/I results have shown no general dependency on the wanted signal level between 3 and 25 dB above sensitivity. This means that the receivers are still operating in their linear state and for compatibility studies the C/I results can be applied to any wanted signal level in the tested range.

For a median wanted signal level and the interference grade 2 (heavily distorted or half data rate), the following table shows the median results of the C/I measurements.

Table 133: Summary of median C/I values for interference grade 2

LTE signal	C/I Bluetooth	C/I RLAN (data transfer)
BS realistic	- 56 dB	- 30 dB
BS worst case	- 55 dB	- 30 dB
UE realistic	- 60 dB	- 32 dB
UE worst case	- 59 dB	- 16 dB

The intention of using the “worst case” LTE signals with unwanted emissions always reaching the limits was to show the influence of these emissions inside the wanted frequency channel/band vs. the interfering effect created by the high LTE level outside the receive band. It is noted that the unwanted emission level of real LTE devices in the ISM band will most probably be well below these limits and rather be in the range of the tested “realistic” signals. With the exception of the UE worst case signal interfering with Bluetooth, the measurements have shown that the influence of the unwanted emissions in the ISM band is not dominant. The reason why the C/I values for both BS signals are very similar may be the controversial effect of the sideband emissions of the worst case signal below 2475 MHz being higher and the OoB emissions of the realistic signal being lower.

A4.11 ADDENDUM: LTE SIGNAL GENERATION

The signal from the base station and the user terminal were conditioned to meet two separate requirements each:

- Worst case scenario: the spurious emissions were tailored to meet the spectrum emission mask limits;
- Realistic scenario: the spurious emissions were left as they are, only the levels at an offset of 15 MHz and more from the centre frequency were reduced.

For that, the signals were conditioned by a gated equalizer in the digital domain by dedicated (Python-)scripts, reusing elements of prior digital signal processing activities. The schematic is given below.

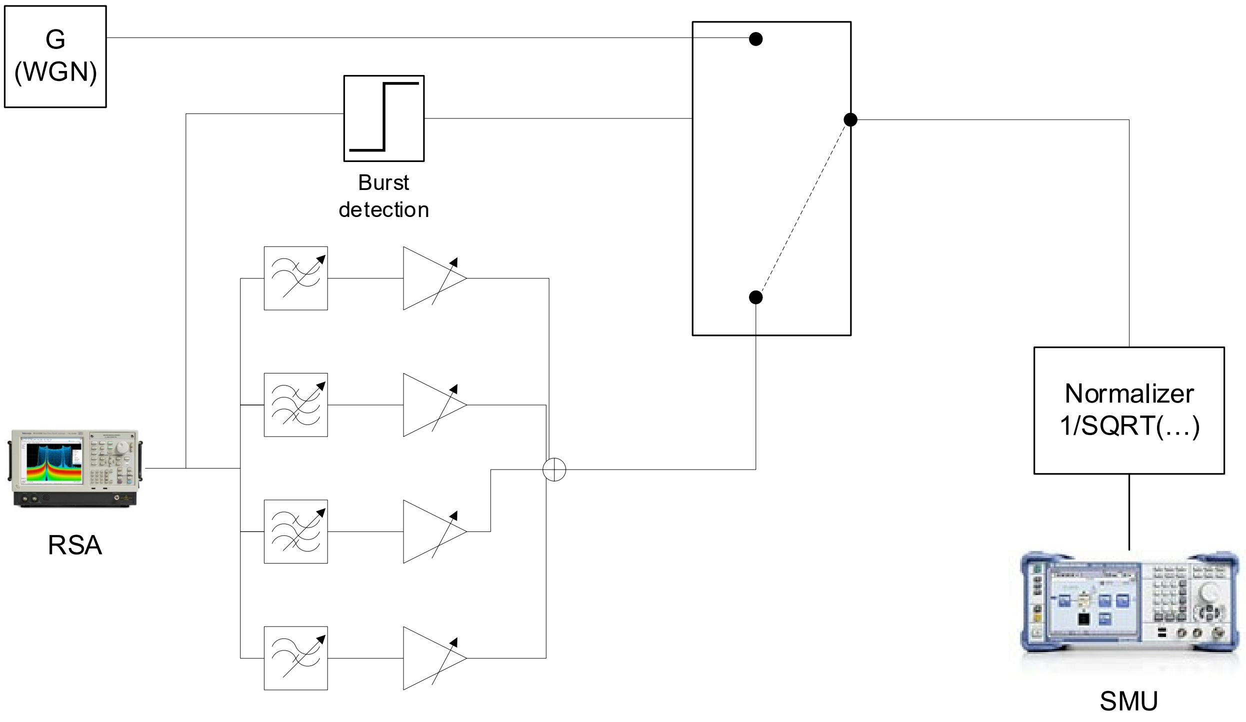

Figure 70 -: signal conditioner schematic

From each transmitter, the signal was sampled by the real-time spectrum analyser (RSA) on its centre frequency with a sampling rate of 75 MS/s for one frame (10 ms).

The conditioner consists of the following sections:

- a white noise generator to fill the time between the transmitter's burst period;
- a burst detector for discrimination of samples to be sent to output;
- a filter bank consisting of as many low pass / high pass / band pass stages as required by the steps in the spectral emission mask. All filters can be configured freely and are followed by an adjustable amplifier;
- a normalizer to scale the final signal's peak level to 0 dB; using as much of the generator's dynamic range as possible.

The white noise generator is levelled in such a way that the signal is below the noise in the recorded 'no-signal' times. Sending a constant stream of zeros into the generators IQ-DAC leads inevitably to an unwanted DC-signal, what was avoided this way.

The burst discriminator rated the average power of the samples around a specific sample (regarding samples from the past and future relative to the sample of interest). If the power was above a fixed threshold, a burst was detected. The discriminator's output was used to switch the signal path between the white-noise generator and the filter bank as indicated in Figure 7173.

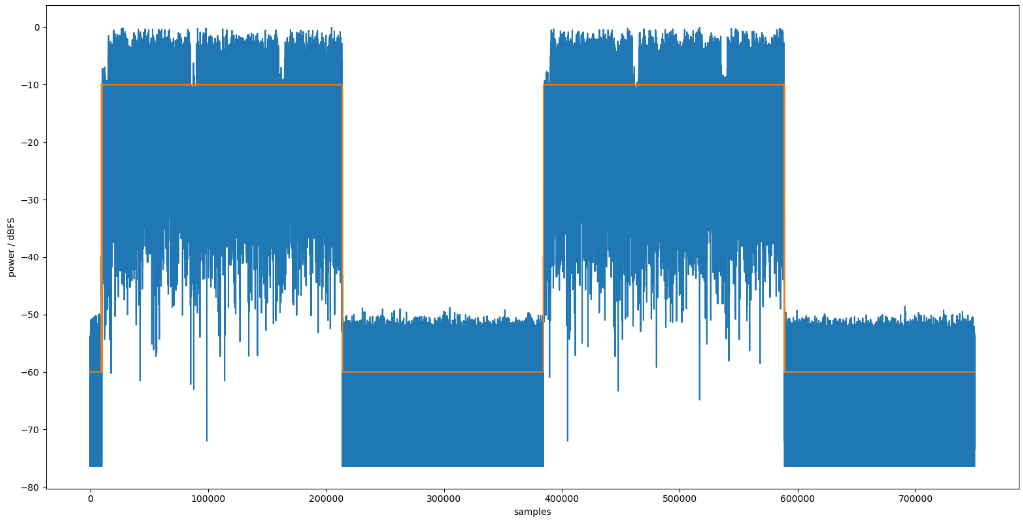

Figure 71: Signal power vs. time and burst discriminator output

The filters were chosen to be 127 taps long FIR-filters with a Chebyshev design each. This allows for a controlled passband / stopband ripple along with quite sharp filter edges independent of the desired filter's response (low pass / band pass). The group delay and phase shift due to filtering is identical for all filtered bands, since all filters have the same length and the same tapering window. This keeps the spurious emissions in sync to the main emissions.

An example of the filters frequency response is given in the following figure. The desired 3 dB-frequencies for both the low pass filters and high pass filters were 10 MHz; 5 MHz and 15 MHz for the band pass filter.

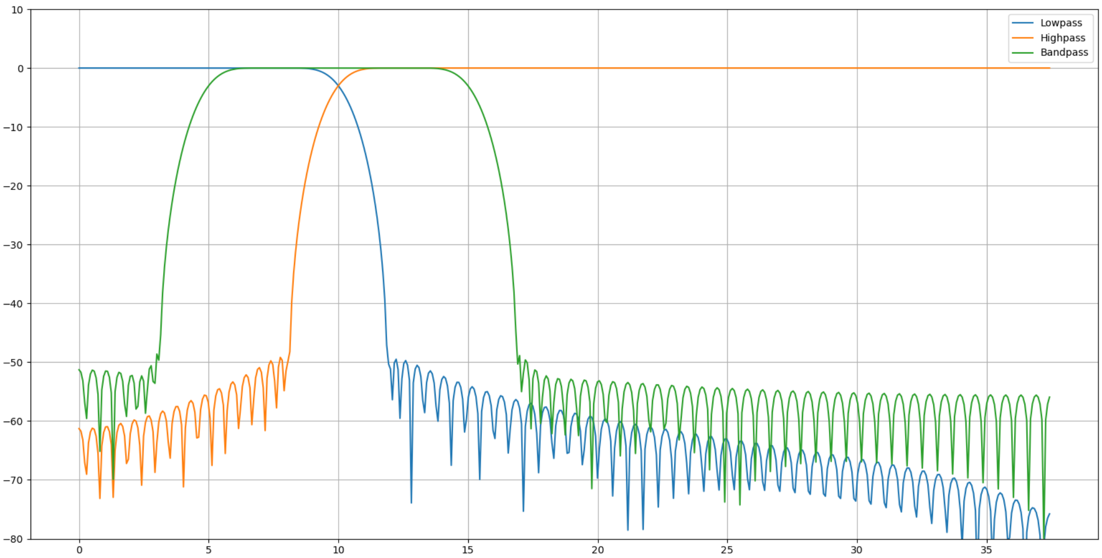

Figure 72: frequency response of the 3 basic filter types used in the equalizer (x-axis: frequency in MHz; y-axis: attenuation in dB)

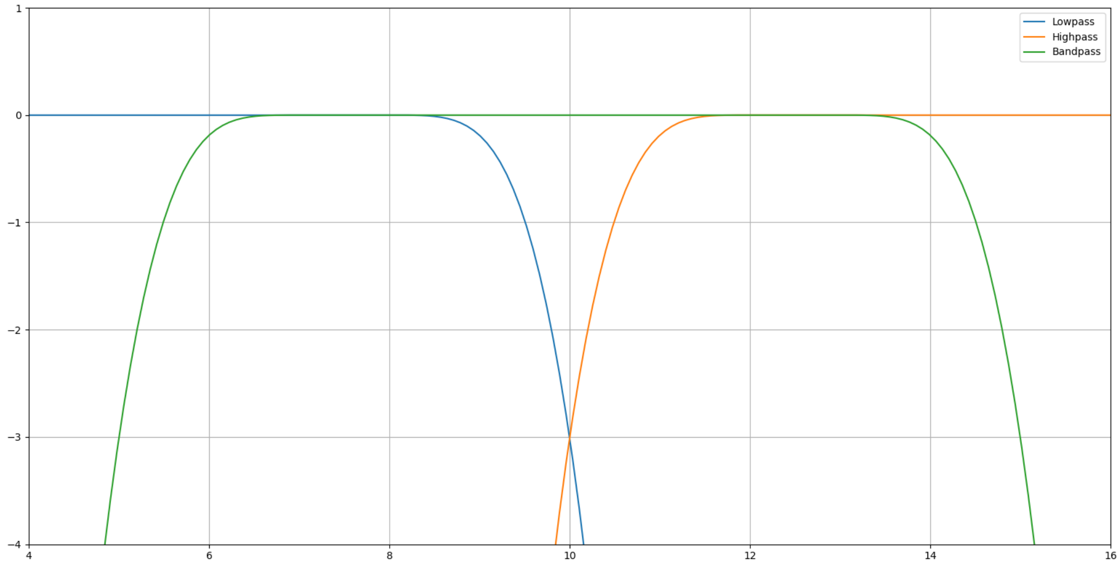

Figure 73: frequency response of the 3 basic filter types used in the equalizer (x-axis: frequency in MHz; y-axis: attenuation in dB); zoomed

A4.12 ADDENDUM: DETAILED MEASUREMENT RESULTS FOR BLUETOOTH

LTE signal: BS Realistic

Table 134: Measured C/I values for Bluetooth devices exposed to LTE BS realistic signals.
Green: C/I is better than indicated, i. e. device could not be interfered at the given C/I

		Wanted level (C) = sens. + 3 dB				Wanted level (C) = sens. + 10 dB			Wanted level (C) = sens. +25 dB		
Rx	Application	Sensitivity	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I
B01	Audio streaming	-94 dBm	-63 dB	-64 dB	-65 dB	-63 dB	-64 dB	-64 dB			
B02	Audio streaming	-78 dBm	-55 dB	-56 dB	-59 dB	-52 dB					
B03	Audio streaming	-89 dBm	-55 dB	-56 dB	-59 dB	-53 dB	-54 dB	-56 dB			
B05	Audio streaming	-94 dBm	-55 dB	-56 dB	-62 dB	-55 dB	-55 dB	-61 dB			
B07	Audio streaming	-88 dBm	-51 dB	-52 dB	-55 dB	-50 dB	-52 dB	-56 dB			
B10	Audio streaming	-86 dBm	-51 dB	-51 dB	-52 dB	-47 dB	-47 dB	-49 dB			
B11	Audio streaming	-83 dBm	-50 dB	-51 dB	-62 dB	-53 dB	-55 dB				
B13	Audio streaming	-91 dBm	-58 dB	-59 dB	-63 dB	-60 dB	-61 dB	-62 dB			
B15	Audio streaming	-87 dBm	-60 dB	-61 dB	-66 dB	-61 dB					
B16	Audio streaming	-95 dBm	-55 dB	-57 dB	-62 dB	-58 dB	-59 dB	-61 dB			
B19	Audio streaming	-91 dBm	-59 dB	-61 dB	-64 dB	-61 dB	-64 dB	-65 dB			
B20	Audio streaming	-91 dBm	-56 dB	-57 dB	-59 dB	-55 dB	-56 dB	-57 dB			

			Wanted level (C) = sens. + 3 dB				Wanted level (C) = sens. + 3 dB				Wanted level (C) = sens. + 3 dB		
Rx	Application	Sensitivity	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I		Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I		Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I
B21	Audio streaming	-79 dBm	-58 dB	-60 dB			-53 dB						
B22	Audio streaming	-83 dBm	-58 dB	-59 dB	-61 dB		-59 dB	-60 dB	-60 dB		-59 dB	-60 dB	-61 dB
B24	Audio streaming	-92 dBm	-53 dB	-53 dB	-55 dB		-53 dB	-54 dB	-55 dB				
B26	Audio streaming	-86 dBm	-52 dB	-55 dB	-60 dB		-55 dB	-55 dB	-60 dB				
B27	Audio streaming	-97 dBm	-61 dB	-62 dB	-64 dB		-58 dB	-59 dB	-62 dB				
B29	Audio streaming	-87 dBm	-57 dB	-59 dB	-67 dB		-61 dB						
B31	Audio streaming	-91 dBm	-61 dB	-62 dB	-64 dB		-58 dB	-59 dB	-64 dB				
B32	Audio streaming	-92 dBm	-58 dB	-59 dB	-64 dB		-59 dB	-60 dB	-62 dB				
B34	Audio streaming	-89 dBm	-61 dB	-62 dB	-66 dB		-56 dB	-57 dB	-62 dB				
B06	Mouse control	-84 dBm	-56 dB	-61 dB	-63 dB		-58 dB						
B08	Mouse control	-82 dBm	-54 dB	-56 dB	-60 dB		-56 dB						
B28	Mouse control	-86 dBm	-57 dB	-62 dB	-66 dB		-60 dB						
B33	Mouse control	-88 dBm	-61 dB	-63 dB	-69 dB								
B04	Smart home/dev. Ctrl.	-100 dBm	-64 dB	-69 dB	-74 dB		-69 dB	-69 dB	-70 dB				
B09	Smart home/dev. Ctrl.	-89 dBm	-59 dB	-61 dB	-70 dB		-54 dB	-56 dB	-63 dB				

			Wanted level (C) = sens. + 3 dB			Wanted level (C) = sens. + 10 dB			Wanted level (C) = sens. +25 dB		
Rx	Application	Sensi tivity	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I
B18	Smart home/dev. Ctrl.	-91 dBm	-66 dB	-67 dB	-67 dB	-65 dB	-65 dB				
B23	Smart home/dev. Ctrl.	-88 dBm	-52 dB	-53 dB	-54 dB	-49 dB	-49 dB	-51 dB			
B30	Smart home/dev. Ctrl.	-87 dBm	-57 dB	-59 dB	-63 dB	-52 dB	-56 dB	-60 dB			
Median	(all)	-89 dBm	-57 dB	-59 dB	-63 dB	-56 dB	-56 dB	-61 dB	-59 dB	-60 dB	-61 dB
Lower decile	(all)	-95 dBm	-61 dB	-63 dB	-67 dB	-61 dB	-64 dB	-64 dB	-59 dB	-60 dB	-61 dB
Upper decile	(all)	-83 dBm	-52 dB	-53 dB	-55 dB	-52 dB	-52 dB	-55 dB	-59 dB	-60 dB	-61 dB

LTE signal: BS Worst Case

Table 135: Measured C/I values for Bluetooth devices exposed to LTE BS Worst Case signals.
Green: C/I is better than indicated, i. e. device could not be interfered at the given C/I

			Wanted level (C) = sens. + 3 dB			Wanted level (C) = sens. + 10 dB			Wanted level (C) = sens. +25 dB		
Rx	Application	Sensitivity	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I
B01	Audio streaming	-94 dBm	-60 dB	-61 dB	-63 dB	-59 dB	-59 dB	-64 dB	0 dB	0 dB	0 dB
B02	Audio streaming	-78 dBm	-50 dB	-51 dB	-57 dB	-53 dB					
B03	Audio streaming	-89 dBm	-53 dB	-55 dB	-59 dB	-52 dB	-53 dB	-56 dB			
B05	Audio streaming	-94 dBm	-52 dB	-53 dB	-59 dB	-53 dB	-53 dB	-59 dB			
B07	Audio streaming	-88 dBm	-53 dB	-53 dB	-56 dB	-52 dB	-52 dB	-56 dB			
B10	Audio streaming	-86 dBm	-50 dB	-50 dB	-51 dB	-47 dB	-48 dB	-49 dB			
B11	Audio streaming	-83 dBm	-49 dB	-50 dB	-56 dB	-50 dB	-51 dB	-58 dB			
B13	Audio streaming	-91 dBm	-47 dB	-50 dB	-55 dB	-60 dB	-60 dB	-62 dB			
B15	Audio streaming	-87 dBm	-57 dB	-58 dB	-62 dB	-58 dB	-60 dB	-62 dB			
B16	Audio streaming	-95 dBm	-51 dB	-53 dB	-58 dB	-54 dB	-55 dB	-57 dB			
B19	Audio streaming	-91 dBm	-58 dB	-59 dB	-62 dB	-60 dB	-61 dB	-62 dB			
B20	Audio streaming	-91 dBm	-57 dB	-58 dB	-59 dB	-54 dB	-55 dB	-58 dB			

			Wanted level (C) = sens. + 3 dB				Wanted level (C) = sens. + 10 dB				Wanted level (C) = sens. + 25 dB		
Rx	Application	Sensitivity	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I		Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I		Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I
B21	Audio streaming	-79 dBm	-56 dB	-56 dB	-56 dB		-54 dB						
B22	Audio streaming	-83 dBm	-53 dB	-54 dB	-55 dB		-54 dB	-55 dB	-56 dB		-53 dB	-54 dB	-57 dB
B24	Audio streaming	-92 dBm	-51 dB	-52 dB	-53 dB		-53 dB	-54 dB	-55 dB				
B26	Audio streaming	-86 dBm	-45 dB	-48 dB	-56 dB		-50 dB	-52 dB	-57 dB				
B27	Audio streaming	-97 dBm	-58 dB	-60 dB	-62 dB		-58 dB	-58 dB	-60 dB				
B29	Audio streaming	-87 dBm	-57 dB	-57 dB	-59 dB		-62 dB						
B31	Audio streaming	-91 dBm	-61 dB	-62 dB	-63 dB		-58 dB	-59 dB	-62 dB		0 dB	0 dB	0 dB
B32	Audio streaming	-92 dBm	-51 dB	-53 dB	-58 dB		-55 dB	-57 dB	-61 dB				
B34	Audio streaming	-89 dBm	-52 dB	-54 dB	-60 dB		-53 dB	-54 dB	-58 dB				
B06	Mouse control	-84 dBm	-56 dB	-60 dB	-61 dB								
B08	Mouse control	-79 dBm	-51 dB	-60 dB	-60 dB								
B28	Mouse control	-86 dBm	-57 dB	-60 dB	-63 dB								
B33	Mouse control	-88 dBm	-60 dB	-62 dB	-69 dB								
B04	Smart home/dev. Ctrl.	-100 dBm	-66 dB	-67 dB	-68 dB		-68 dB	-68 dB	-68 dB				

			Wanted level (C) = sens. + 3 dB				Wanted level (C) = sens. + 10 dB				Wanted level (C) = sens. + 25 dB		
Rx	Application	Sensitivity	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I		Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I		Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I
B09	Smart home/dev. Ctrl.	-89 dBm	-57 dB	-60 dB	-69 dB		-60 dB	-60 dB	-64 dB				
B18	Smart home/dev. Ctrl.	-91 dBm	-63 dB	-64 dB	-68 dB		-66 dB						
B23	Smart home/dev. Ctrl.	-88 dBm	-52 dB	-52 dB	-53 dB		-52 dB	-52 dB	-53 dB				
B30	Smart home/dev. Ctrl.	-87 dBm	-51 dB	-54 dB	-55 dB		-51 dB	-56 dB	-58 dB				
Median	(all)	-89 dBm	-53 dB	-56 dB	-59 dB		-54 dB	-55 dB	-58 dB		-53 dB	-54 dB	-57 dB
Lower decile	(all)	-95 dBm	-61 dB	-62 dB	-68 dB		-61 dB	-60 dB	-64 dB		-53 dB	-54 dB	-57 dB
Upper decile	(all)	-83 dBm	-50 dB	-50 dB	-55 dB		-51 dB	-52 dB	-55 dB		-53 dB	-54 dB	-57 dB

LTE signal: UE Realistic

Table 136: Measured C/I values for Bluetooth devices exposed to LTE UE realistic signals.
Green: C/I is better than indicated, i. e. device could not be interfered at the given C/I

			Wanted level (C) = sens. + 3 dB				Wanted level (C) = sens. + 10 dB				Wanted level (C) = sens. +25 dB		
Rx	Application	Sensitivity	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I		Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I		Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I
B01	Audio streaming	-94 dBm	-63 dB	-64 dB	-67 dB		-62 dB	-63 dB	-68 dB		0 dB	0 dB	0 dB
B02	Audio streaming	-78 dBm	-52 dB	-52 dB	-60 dB								
B03	Audio streaming	-89 dBm	-50 dB	-50 dB	-59 dB		-55 dB	-56 dB	-64 dB				
B05	Audio streaming	-94 dBm	-55 dB	-56 dB	-62 dB		-55 dB	-56 dB	-68 dB				
B07	Audio streaming	-88 dBm	-55 dB	-56 dB	-66 dB		-53 dB	-54 dB	-63 dB				
B10	Audio streaming	-86 dBm	-51 dB	-53 dB	-62 dB		-49 dB	-50 dB	-61 dB				
B11	Audio streaming	-83 dBm	-50 dB	-51 dB	-60 dB		-48 dB	-49 dB	-58 dB				
B13	Audio streaming	-91 dBm	-53 dB	-54 dB	-60 dB		-63 dB	-65 dB					
B15	Audio streaming	-87 dBm	-56 dB	-58 dB	-64 dB		-58 dB	-60 dB	-62 dB				
B16	Audio streaming	-95 dBm	-55 dB	-57 dB	-62 dB		-56 dB	-57 dB	-67 dB				
B19	Audio streaming	-91 dBm	-59 dB	-61 dB	-65 dB		-63 dB	-64 dB	-66 dB				
B20	Audio streaming	-91 dBm	-62 dB	-63 dB	-65 dB		-65 dB	-66 dB					

			Wanted level (C) = sens. + 3 dB			Wanted level (C) = sens. + 10 dB			Wanted level (C) = sens. +25 dB		
Rx	Application	Sensitivity	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I
B21	Audio streaming	-79 dBm	-60 dB	-61 dB							
B22	Audio streaming	-83 dBm	-52 dB	-53 dB	-56 dB	-54 dB	-55 dB	-56 dB	-57 dB	-57 dB	-60 dB
B24	Audio streaming	-92 dBm	-52 dB	-54 dB	-56 dB	-54 dB	-55 dB	-63 dB			
B26	Audio streaming	-86 dBm	-48 dB	-52 dB	-59 dB	-53 dB	-55 dB	-60 dB			
B27	Audio streaming	-97 dBm	-61 dB	-61 dB	-65 dB	-60 dB	-60 dB	-64 dB			
B29	Audio streaming	-87 dBm	-57 dB	-59 dB	-66 dB						
B31	Audio streaming	-91 dBm	-63 dB	-65 dB	-67 dB	-60 dB	-64 dB	-66 dB	0 dB	0 dB	0 dB
B32	Audio streaming	-92 dBm	-54 dB	-56 dB	-63 dB	-57 dB	-60 dB	-66 dB			
B34	Audio streaming	-89 dBm	-51 dB	-53 dB	-61 dB	-55 dB	-57 dB	-63 dB			
B06	Mouse control	-84 dBm	-56 dB	-59 dB	-63 dB						
B08	Mouse control	-79 dBm	-51 dB	-58 dB	-61 dB						
B28	Mouse control	-86 dBm	-57 dB	-61 dB	-67 dB						
B33	Mouse control	-88 dBm	-60 dB	-64 dB	-69 dB						

			Wanted level (C) = sens. + 3 dB				Wanted level (C) = sens. + 10 dB				Wanted level (C) = sens. +25 dB		
Rx	Application	Sensitivity	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I		Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I		Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I
B04	Smart home/dev. Ctrl.	-100 dBm	-70 dB	-72 dB	-73 dB		-70 dB	-70 dB	-71 dB				
B09	Smart home/dev. Ctrl.	-89 dBm	-63 dB	-66 dB	-71 dB		-63 dB	-64 dB					
B18	Smart home/dev. Ctrl.	-91 dBm	-67 dB	-68 dB	-72 dB								
B23	Smart home/dev. Ctrl.	-88 dBm	-60 dB	-61 dB	-70 dB		-57 dB	-61 dB	-63 dB				
B30	Smart home/dev. Ctrl.	-87 dBm	-61 dB	-66 dB	-69 dB		-57 dB	-59 dB	-62 dB				
Median	(all)	-89 dBm	-56 dB	-59 dB	-64 dB		-57 dB	-60 dB	-63 dB		-57 dB	-57 dB	-60 dB
Lower decile	(all)	-95 dBm	-63 dB	-66 dB	-71 dB		-63 dB	-65 dB	-68 dB		-57 dB	-57 dB	-60 dB
Upper decile	(all)	-83 dBm	-51 dB	-52 dB	-59 dB		-53 dB	-54 dB	-60 dB		-57 dB	-57 dB	-60 dB

LTE signal: UE Worst Case

Table 137: Measured C/I values for Bluetooth devices exposed to LTE UE Worst Case signals.
Green: C/I is better than indicated, i. e. device could not be interfered at the given C/I

			Wanted level (C) = sens. + 3 dB			Wanted level (C) = sens. + 10 dB			Wanted level (C) = sens. +25 dB		
Rx	Application	Sensitivity	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I
B01	Audio streaming	-94 dBm	-64 dB	-65 dB	-68 dB	-62 dB	-65 dB	-68 dB	0 dB	0 dB	0 dB
B02	Audio streaming	-78 dBm	-48 dB	-52 dB	-60 dB						
B03	Audio streaming	-89 dBm	-52 dB	-54 dB	-64 dB	-53 dB	-55 dB	-64 dB			
B05	Audio streaming	-94 dBm	-54 dB	-55 dB	-65 dB	-54 dB	-55 dB	-68 dB			
B07	Audio streaming	-88 dBm	-56 dB	-56 dB	-65 dB	-53 dB	-54 dB	-63 dB			
B10	Audio streaming	-86 dBm	-51 dB	-53 dB	-62 dB	-49 dB	-50 dB	-60 dB			
B11	Audio streaming	-83 dBm	-50 dB	-51 dB	-60 dB	-47 dB	-48 dB	-58 dB			
B13	Audio streaming	-91 dBm	-52 dB	-54 dB	-57 dB	-63 dB	-65 dB	-66 dB			
B15	Audio streaming	-87 dBm	-54 dB	-57 dB	-64 dB	-58 dB	-60 dB	-62 dB			
B16	Audio streaming	-95 dBm	-51 dB	-53 dB	-61 dB	-53 dB	-56 dB	-66 dB			
B19	Audio streaming	-91 dBm	-59 dB	-60 dB	-64 dB	-63 dB	-64 dB	-66 dB			
B20	Audio streaming	-91 dBm	-55 dB	-56 dB	-62 dB	-65 dB	-68 dB	-66 dB			

			Wanted level (C) = sens. + 3 dB			Wanted level (C) = sens. + 10 dB			Wanted level (C) = sens. +25 dB		
Rx	Application	Sensitivity	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I
B21	Audio streaming	-79 dBm	-49 dB	-51 dB	-55 dB						
B22	Audio streaming	-83 dBm	-52 dB	-53 dB	-55 dB	-56 dB	-57 dB	-59 dB	-58 dB	-58 dB	-59 dB
B24	Audio streaming	-92 dBm	-53 dB	-55 dB	-60 dB	-52 dB	-54 dB	-62 dB			
B26	Audio streaming	-86 dBm	-47 dB	-53 dB	-59 dB	-52 dB	-56 dB	-60 dB			
B27	Audio streaming	-97 dBm	-62 dB	-62 dB	-66 dB	-60 dB	-60 dB	-63 dB			
B29	Audio streaming	-87 dBm	-58 dB	-60 dB	-64 dB						
B31	Audio streaming	-91 dBm	-63 dB	-65 dB	-68 dB	-65 dB	-65 dB	-66 dB	0 dB	0 dB	0 dB
B32	Audio streaming	-92 dBm	-48 dB	-52 dB	-61 dB	-57 dB	-60 dB	-66 dB			
B34	Audio streaming	-89 dBm	-48 dB	-50 dB	-61 dB	-56 dB	-57 dB	-64 dB			
B06	Mouse control	-84 dBm	-56 dB	-58 dB	-64 dB						
B08	Mouse control	-79 dBm	-55 dB	-59 dB	-61 dB						
B28	Mouse control	-86 dBm	-56 dB	-58 dB	-67 dB						
B33	Mouse control	-88 dBm	-57 dB	-62 dB	-69 dB						
B04	Smart home/dev. Ctrl.	-100 dBm	-68 dB	-69 dB	-70 dB	-69 dB	-71 dB	-72 dB			

			Wanted level (C) = sens. + 3 dB				Wanted level (C) = sens. + 10 dB				Wanted level (C) = sens. +25 dB		
Rx	Application	Sensitivity	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I		Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I		Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I
B09	Smart home/dev. Ctrl.	-89 dBm	-62 dB	-64 dB	-70 dB		-62 dB	-62 dB	-64 dB				
B18	Smart home/dev. Ctrl.	-91 dBm	-66 dB	-67 dB	-72 dB								
B23	Smart home/dev. Ctrl.	-88 dBm	-57 dB	-59 dB	-70 dB		-50 dB	-50 dB	-52 dB				
B30	Smart home/dev. Ctrl.	-87 dBm	-62 dB	-65 dB	-68 dB		-58 dB	-61 dB	-62 dB				
Median	(all)	-89 dBm	-55 dB	-57 dB	-64 dB		-57 dB	-59 dB	-64 dB		-58 dB	-58 dB	-59 dB
Lower decile	(all)	-95 dBm	-64 dB	-65 dB	-70 dB		-65 dB	-65 dB	-68 dB		-58 dB	-58 dB	-59 dB
Upper decile	(all)	-83 dBm	-48 dB	-52 dB	-59 dB		-51 dB	-51 dB	-59 dB		-58 dB	-58 dB	-59 dB

Table 138: Device-specific issues and remarks

Rx	Remark
B04	Criteria was switching of display in the camera
B06	Tested with mouse movement
B12	Not possible to establish a Bluetooth connection with any device, possibly a fault-> not measured
B12	Device was faulty and not able to establish Bluetooth connections-> not measured.
B14	Device only configurable with active internet connection -> not measured
B17	Mouse movement unreliable even without interference -> not measured
B25	Mouse function not supported (Android version is too old) -> not measured
B30	Uses different hopping sequence after connection loss, results of two consecutive measurements not always equal

A4.13 ADDENDUM: DETAILED MEASUREMENT RESULTS FOR RLAN

LTE signal: BS Realistic

Table 139: Measured C/I values for RLAN data transfer devices exposed to LTE BS realistic signals.
Green: C/I is better than indicated, i. e. device could not be interfered at the given C/I

			Wanted level = sens. + 3 dB			Wanted level = sens. + 10 dB			Wanted level = sens. + 25 dB		
Rx	Application	Sensitivity	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I
W01	Data transfer	-52 dBm	-19 dB	-30 dB	-33 dB						
W02	Data transfer	-63 dBm	-27 dB	-38 dB	-43 dB	-26 dB	-35 dB	-37 dB			
W04	Data transfer	-57 dBm	-16 dB	-21 dB	-31 dB	-15 dB	-19 dB	-30 dB			
W05	Data transfer	-71 dBm	-14 dB	-27 dB	-43 dB	-14 dB	-29 dB	-42 dB			
W07	Data transfer	-56 dBm	-27 dB	-32 dB	-37 dB	-22 dB	-26 dB	-30 dB			
W08g	Data transfer	-73 dBm	-37 dB	-39 dB	-43 dB	-37 dB	-40 dB	-45 dB	-36 dB	-47 dB	-50 dB
W08n	Data transfer	-73 dBm	-36 dB	-39 dB	-42 dB	-31 dB	-40 dB	-44 dB	-17 dB	-42 dB	-51 dB
W09	Data transfer	-63 dBm	-5 dB	-9 dB	-25 dB	-5 dB	-17 dB	-27 dB			
W10	Data transfer	-59 dBm	-14 dB	-24 dB	-32 dB	-17 dB	-23 dB	-31 dB	-12 dB	-20 dB	-31 dB
W12	Data transfer	-67 dBm	-28 dB	-38 dB	-44 dB	-22 dB	-32 dB	-40 dB	-20 dB	-31 dB	-50 dB
W13	Data transfer	-74 dBm	-34 dB	-44 dB	-48 dB	-31 dB	-44 dB	-48 dB			

			Wanted level = sens. + 3 dB			Wanted level = sens. + 10 dB			Wanted level = sens. + 25 dB		
Rx	Application	Sensitivity	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I
W14	Data transfer	-75 dBm	-19 dB	-26 dB	-34 dB	-21 dB	-26 dB	-37 dB			
W16	Data transfer	-67 dBm	-33 dB	-45 dB	-48 dB	-28 dB	-41 dB				
W18	Data transfer	-49 dBm	-27 dB	-30 dB		-23 dB					
W19	Data transfer	-70 dBm	-22 dB	-28 dB	-38 dB	-19 dB	-23 dB	-35 dB	-14 dB	-18 dB	-32 dB
W20	Data transfer	-41 dBm	-5 dB	-13 dB	-21 dB				0 dB	0 dB	0 dB
W21	Data transfer	-58 dBm	-19 dB	-39 dB		-17 dB	-32 dB				
W22	Data transfer	-51 dBm	-12 dB	-17 dB	-32 dB						
W23	Data transfer	-58 dBm	-26 dB	-29 dB	-38 dB	-23 dB	-30 dB	-32 dB			
W24	Data transfer	-69 dBm	-30 dB	-35 dB	-47 dB	-30 dB	-35 dB	-43 dB			
W28	Data transfer	-55 dBm	-28 dB	-36 dB		-21 dB	-29 dB				
W29	Data transfer	-58 dBm	-25 dB	-30 dB	-38 dB	-22 dB	-30 dB	-32 dB			
Median	(all)	-61 dBm	-26 dB	-30 dB	-38 dB	-22 dB	-30 dB	-37 dB	-17 dB	-31 dB	-50 dB
Lower decile	(all)	-73 dBm	-34 dB	-39 dB	-48 dB	-31 dB	-40 dB	-44 dB	-29 dB	-45 dB	-50 dB
Upper decile	(all)	-51 dBm	-13 dB	-18 dB	-30 dB	-15 dB	-22 dB	-30 dB	-13 dB	-19 dB	-31 dB

Table 140: Measured C/I values for RLAN remote control DUTs exposed to LTE BS realistic signals.
Green: C/I is better than indicated, i. e. device could not be interfered at the given C/I

			Wanted level = sens. + 3 dB				Wanted level = sens. + 10 dB				Wanted level = sens. + 25 dB		
Rx	Application	Sensitivity	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I		Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I		Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I
W11	device control	-88 dBm	-47 dB	-50 dB	-49 dB		-49 dB	-51 dB	-52 dB				
W17	device control	-84 dBm	-47 dB	-48 dB	-49 dB		-41 dB	-42 dB	-45 dB		-44 dB	-47 dB	-48 dB
W26	device control	-88 dBm	-48 dB	-52 dB	-50 dB		-51 dB	-50 dB	-51 dB				
W27	device control	-81 dBm	-62 dB				-55 dB				0 dB	0 dB	0 dB

LTE signal: BS Worst Case

Table 141: Measured C/I values for RLAN data transfer DUTs exposed to LTE BS Worst Case signals.
Green: C/I is better than indicated, i. e. device could not be interfered at the given C/I

			Wanted level = sens. + 3 dB				Wanted level = sens. + 10 dB				Wanted level = sens. + 25 dB		
Rx	Application	Sensitivity	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I		Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I		Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I
W01	Data transfer	-52 dBm	-18 dB	-29 dB	-34 dB		-27 dB						
W02	Data transfer	-63 dBm	-27 dB	-36 dB	-42 dB		-26 dB	-34 dB	-38 dB				
W04	Data transfer	-57 dBm	-15 dB	-18 dB	-30 dB		-17 dB	-20 dB	-29 dB				
W05	Data transfer	-71 dBm	-15 dB	-25 dB	-41 dB		-15 dB	-27 dB	-41 dB				
W07	Data transfer	-56 dBm	-27 dB	-31 dB	-38 dB		-21 dB	-26 dB	-31 dB				
W08g	Data transfer	-73 dBm	-31 dB	-38 dB	-44 dB		-32 dB	-38 dB	-42 dB		-33 dB	-40 dB	-48 dB
W08n	Data transfer	-73 dBm	-30 dB	-37 dB	-43 dB		-31 dB	-37 dB	-43 dB		-18 dB	-37 dB	-47 dB
W09	Data transfer	-63 dBm	-2 dB	-9 dB	-24 dB		0 dB	-3 dB	-27 dB				
W10	Data transfer	-59 dBm	-19 dB	-26 dB	-33 dB		-17 dB	-24 dB	-32 dB		-12 dB	-20 dB	-31 dB
W12	Data transfer	-67 dBm	-21 dB	-36 dB	-43 dB		-22 dB	-33 dB	-40 dB		-20 dB	-32 dB	-45 dB
W13	Data transfer	-74 dBm	-28 dB	-36 dB	-45 dB		-29 dB	-37 dB	-47 dB				
W14	Data transfer	-75 dBm	-20 dB	-27 dB	-34 dB		-21 dB	-28 dB	-37 dB				

			Wanted level = sens. + 3 dB				Wanted level = sens. + 10 dB				Wanted level = sens. + 25 dB		
Rx	Application	Sensitivity	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I		Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I		Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I
W16	Data transfer	-67 dBm	-25 dB	-34 dB	-48 dB		-26 dB	-32 dB	-42 dB				
W18	Data transfer	-49 dBm	-27 dB	-31 dB			-24 dB						
W19	Data transfer	-70 dBm	-15 dB	-28 dB	-37 dB		-19 dB	-23 dB	-35 dB		-14 dB	-18 dB	-32 dB
W20	Data transfer	-41 dBm	-6 dB	-15 dB	-20 dB		-16 dB						
W21	Data transfer	-58 dBm	-20 dB	-33 dB	-40 dB		-17 dB	-33 dB					
W22	Data transfer	-51 dBm	-13 dB	-27 dB	-33 dB		-26 dB						
W23	Data transfer	-58 dBm	-26 dB	-29 dB	-39 dB		-23 dB	-30 dB	-33 dB				
W24	Data transfer	-69 dBm	-23 dB	-33 dB	-44 dB		-20 dB	-29 dB	-43 dB				
W28	Data transfer	-55 dBm	-26 dB	-36 dB	-37 dB		-21 dB	-30 dB					
W29	Data transfer	-58 dBm	-23 dB	-29 dB	-40 dB		-20 dB	-29 dB	-33 dB				
Median	(all)	-61 dBm	-22 dB	-30 dB	-39 dB		-21 dB	-30 dB	-38 dB		-18 dB	-32 dB	-45 dB
Lower decile	(all)	-73 dBm	-28 dB	-36 dB	-44 dB		-29 dB	-37 dB	-43 dB		-28 dB	-39 dB	-47 dB
Upper decile	(all)	-51 dBm	-14 dB	-19 dB	-30 dB		-16 dB	-22 dB	-30 dB		-13 dB	-19 dB	-31 dB

Table 142: Measured C/I values for RLAN device control DUTs exposed to LTE BS Worst Case signals.
Green: C/I is better than indicated, i. e. device could not be interfered at the given C/I

			Wanted level = sens. + 3 dB				Wanted level = sens. + 10 dB				Wanted level = sens. + 25 dB		
Rx	Application	Sensitivity	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I		Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I			Interference Grade 2: C/I	Interference Grade 3: C/I
W11	Device control	-88 dBm	-41 dB	-44 dB	-56 dB		-42 dB	-45 dB	-47 dB				
W17	Device control	-84 dBm	-38 dB	-45 dB	-49 dB		-45 dB	-47 dB	-50 dB		-40 dB	-42 dB	-42 dB
W26	Device control	-88 dBm	-47 dB	-51 dB	-53 dB		-49 dB	-52 dB	-53 dB				
W27	Device control	-81 dBm	-57 dB	-61 dB	-63 dB		-56 dB						

LTE signal: UE Realistic

Table 143: Measured C/I values for RLAN data transfer devices exposed to LTE UE realistic signals.
Green: C/I is better than indicated, i. e. device could not be interfered at the given C/I

			Wanted level = sens. + 3 dB				Wanted level = sens. + 10 dB				Wanted level = sens. + 25 dB		
Rx	Application	Sensitivity	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I		Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I		Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I
W01	Data transfer	-52 dBm	-16 dB	-33 dB	-34 dB		-27 dB						
W02	Data transfer	-63 dBm	-24 dB	-38 dB	-44 dB		-26 dB	-37 dB	-38 dB				
W04	Data transfer	-57 dBm	-16 dB	-21 dB	-38 dB		-14 dB	-20 dB	-32 dB				
W05	Data transfer	-71 dBm	-17 dB	-33 dB	-46 dB		-17 dB	-31 dB	-45 dB				
W07	Data transfer	-56 dBm	-25 dB	-34 dB	-38 dB		-21 dB	-27 dB	-31 dB				
W08g	Data transfer	-73 dBm	-35 dB	-50 dB	-64 dB		-35 dB	-43 dB	-46 dB		-35 dB	-43 dB	-53 dB
W08n	Data transfer	-73 dBm	-32 dB	-39 dB	-51 dB		-33 dB	-41 dB	-43 dB		-19 dB	-40 dB	-48 dB
W09	Data transfer	-63 dBm	-7 dB	-10 dB	-33 dB		-12 dB	-18 dB	-32 dB				
W10	Data transfer	-59 dBm	-20 dB	-25 dB	-35 dB		-18 dB	-22 dB	-34 dB		-14 dB	-19 dB	-34 dB
W12	Data transfer	-67 dBm	-25 dB	-38 dB	-59 dB		-24 dB	-34 dB	-53 dB		-21 dB	-37 dB	-50 dB
W13	Data transfer	-74 dBm	-32 dB	-40 dB	-56 dB		-31 dB	-41 dB	-49 dB				
W14	Data transfer	-75 dBm	-22 dB	-30 dB	-45 dB		-23 dB	-29 dB	-40 dB				

			Wanted level = sens. + 3 dB				Wanted level = sens. + 10 dB				Wanted level = sens. + 25 dB		
W16	Data transfer	-67 dBm	-29 dB	-38 dB	-49 dB		-29 dB	-37 dB	-42 dB				
W18	Data transfer	-49 dBm	-29 dB	-31 dB			-24 dB						
W19	Data transfer	-70 dBm	-25 dB	-31 dB	-56 dB		-20 dB	-24 dB	-37 dB		-15 dB	-19 dB	-57 dB
W20	Data transfer	-41 dBm	-8 dB	-16 dB	-23 dB		-16 dB						
W21	Data transfer	-58 dBm	-21 dB	-39 dB	-40 dB		-17 dB	-33 dB					
W22	Data transfer	-51 dBm	-16 dB	-27 dB	-33 dB		-26 dB						
W23	Data transfer	-58 dBm	-28 dB	-31 dB	-40 dB		-23 dB	-32 dB	-33 dB				
W24	Data transfer	-69 dBm	-30 dB	-36 dB	-51 dB		-29 dB	-38 dB	-44 dB				
W28	Data transfer	-55 dBm	-23 dB	-37 dB	-37 dB		-22 dB	-30 dB					
W29	Data transfer	-58 dBm	-26 dB	-32 dB	-40 dB		-20 dB	-31 dB	-33 dB				
Median	(all)	-61 dBm	-25 dB	-33 dB	-40 dB		-23 dB	-32 dB	-39 dB		-19 dB	-37 dB	-50 dB
Lower decile	(all)	-73 dBm	-32 dB	-39 dB	-56 dB		-31 dB	-41 dB	-48 dB		-29 dB	-42 dB	-55 dB
Upper decile	(all)	-51 dBm	-16 dB	-22 dB	-33 dB		-17 dB	-21 dB	-32 dB		-14 dB	-19 dB	-39 dB

Table 144 Measured C/I values for RLAN device control DUTs exposed to LTE UE realistic signals.
Green: C/I is better than indicated, i. e. device could not be interfered at the given C/I

			Wanted level = sens. + 3 dB				Wanted level = sens. + 3 dB				Wanted level = sens. + 25 dB		
Rx	Application	Sensitivity	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I		Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I		Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I
W11	Device control	-88 dBm	-43 dB	-50 dB	-53 dB		-47 dB	-50 dB	-56 dB				
W17	Device control	-84 dBm	-40 dB	-51 dB	-53 dB		-50 dB	-54 dB	-56 dB		-47 dB	-51 dB	-54 dB
W26	Device control	-88 dBm	-54 dB	-55 dB	-58 dB		-51 dB	-54 dB	-60 dB				
W27	Device control	-81 dBm	-62 dB	-63 dB			-56 dB						

LTE signal: UE Worst Case

Table 145: Measured C/I values for RLAN data transfer DUTs exposed to LTE UE Worst Case signals. Green: C/I is better than indicated, i. e. device could not be interfered at the given C/I

Rx	Application	Sensitivity	Wanted level = sens. + 3 dB			Wanted level = sens. + 10 dB			Wanted level = sens. + 25 dB		
			Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I
W01	Data transfer	-52 dBm	-9 dB	-15 dB	-34 dB						
W02	Data transfer	-63 dBm	-11 dB	-19 dB	-30 dB	-12 dB	-20 dB	-26 dB			
W04	Data transfer	-57 dBm	-14 dB	-19 dB	-39 dB	-14 dB	-18 dB	-32 dB			
W05	Data transfer	-71 dBm	-8 dB	-16 dB	-34 dB	-9 dB	-16 dB	-39 dB			
W07	Data transfer	-56 dBm	-16 dB	-22 dB	-35 dB	-16 dB	-21 dB	-31 dB			
W08g	Data transfer	-73 dBm	-14 dB	-24 dB	-35 dB	-14 dB	-23 dB	-35 dB	-15 dB	-23 dB	-35 dB
W08n	Data transfer	-73 dBm	-13 dB	-20 dB	-37 dB	-14 dB	-21 dB	-35 dB	-14 dB	-21 dB	-41 dB
W09	Data transfer	-63 dBm	-5 dB	-10 dB	-28 dB	-10 dB	-16 dB	-25 dB			
W10	Data transfer	-59 dBm	-11 dB	-21 dB	-31 dB	-11 dB	-20 dB	-31 dB	-10 dB	-18 dB	-30 dB
W12	Data transfer	-67 dBm	-7 dB	-19 dB	-35 dB	-8 dB	-18 dB	-35 dB	-8 dB	-19 dB	-35 dB
W13	Data transfer	-74 dBm	-12 dB	-20 dB	-38 dB	-12 dB	-19 dB	-36 dB			
W14	Data transfer	-75 dBm	-8 dB	-19 dB	-32 dB	-9 dB	-21 dB	-30 dB			
W16	Data transfer	-67 dBm	-9 dB	-16 dB	-37 dB	-7 dB	-15 dB	-35 dB			
W18	Data transfer	-49 dBm	-10 dB	-16 dB	-31 dB	-9 dB	-16 dB	-24 dB			
W19	Data transfer	-70 dBm	-6 dB	-17 dB	-50 dB	-7 dB	-18 dB	-53 dB	-8 dB	-17 dB	-49 dB
W20	Data transfer	-41 dBm	-4 dB	-14 dB	-23 dB						
W21	Data transfer	-58 dBm	-12 dB	-19 dB	-40 dB	-11 dB	-18 dB	-33 dB			
W22	Data transfer	-51 dBm	-10 dB	-26 dB	-33 dB						
W23	Data transfer	-58 dBm	-9 dB	-14 dB	-40 dB	-9 dB	-17 dB	-33 dB			

Rx	Application	Sensitivity	Wanted level = sens. + 3 dB			Wanted level = sens. + 10 dB			Wanted level = sens. + 25 dB		
			Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I
W24	Data transfer	-69 dBm	-7 dB	-17 dB	-36 dB	-8 dB	-17 dB	-44 dB			
W28	Data transfer	-55 dBm	-10 dB	-16 dB	-37 dB	-7 dB	-16 dB	-30 dB			
W29	Data transfer	-58 dBm	-8 dB	-17 dB	-40 dB	-8 dB	-15 dB	-33 dB			
Median	(all)	-61 dBm	-10 dB	-18 dB	-35 dB	-9 dB	-18 dB	-33 dB	-10 dB	-19 dB	-35 dB
Lower decile	(all)	-73 dBm	-14 dB	-22 dB	-40 dB	-14 dB	-21 dB	-40 dB	-14 dB	-22 dB	-46 dB
Upper decile	(all)	-51 dBm	-6 dB	-15 dB	-30 dB	-7 dB	-16 dB	-26 dB	-8 dB	-17 dB	-32 dB

Table 146: Measured C/I values for RLAN device control DUTs exposed to LTE UE Worst Case signals.
Green: C/I is better than indicated, i. e. device could not be interfered at the given C/I

Rx	Application	Sensitivity	Wanted level = sens. + 3 dB			Wanted level = sens. + 10 dB			Wanted level = sens. + 25 dB		
			Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I	Interference Grade 1: C/I	Interference Grade 2: C/I	Interference Grade 3: C/I
W11	Device control	-88 dBm	-29 dB	-32 dB	-36 dB	-36 dB	-52 dB	-54 dB			
W17	Device control	-84 dBm	-28 dB	-30 dB	-33 dB	-34 dB	-32 dB	-56 dB	-35 dB	-44 dB	-49 dB
W26	Device control	-88 dBm	-35 dB	-65 dB	-38 dB	-40 dB	-40 dB	-43 dB			
W27	Device control	-81 dBm	-62 dB	-63 dB		-56 dB					

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Table 147: Device-specific issues and remarks for RLAN DUTs

Rx	Remark
W03	Requires another device of the same brand to configure, ->not measured.
W06	Device only configurable with active internet connection, -> not measured
W07	Practically equal to W04
W08	Very accurate and reproducible results -> measured in both 802.11g and 802.11n modes.
W09	Driver issue, connection is lost after some time, extremely unreliable in measurement, and extremely sensitive to interference
W10	Bug in firmware causes device to ignore channel setting when fastest modes are enabled, -> measured with limitation to 54 Mbit/s (gross) in driver software
W11	Device buffers audio, therefore operated by constantly skipping takes in a play list and measurement of delay in reaction
W12	Max. data rate of 45 Mbit/s only possible at very high levels, and only for short times, -> measured at 35 Mbit/s
W13	Extremely high sensitivity
W14	Device changes transmit power depending on receive power and S/N. -> not measured at high wanted level because of unstable data rate
W15	iPerf not installable -> not measured
W17	Device buffers audio, therefore operated by constantly skipping takes in a play list and measurement of delay in reaction
W18	Surprisingly poor sensitivity
W25	Device not able to connect to a PC via an access point –> not measured
W26	Unreliable behaviour, picture update hangs even without interference, -> measurement during camera rotation
W27	Returns to 802.11b when interfered, therefore extremely immune to interference

A4.14 ADDENDUM: MEASUREMENT EQUIPMENT

Table 148: List of measurement equipment used No

	Type	Model	Inv. No.
1	Vector signal generator	R&S SMU200A	11006937
2	Real-time analyser	Tektronix RSA6114	12009118
3	Attenuator 20 dB 50W	Spinner BN745364	5012184
4	Adjustable attenuator 0-99 dB	HP 11713A	5012881
5	Adjustable attenuator 6-60 dB	Weinschel 940-60-33	16003451 / 52
6	Terminator 50 Ohm	Spinner BN527712	5012184
7	Relais Matrix	R&S PSU	5012714
8	Directional coupler 10 dB	Cernex CDC02081020T	12009146
9	Directional coupler 20 dB	UMCC DC-L000-20S	11006959
10	Circulator	DiTom 3DC2040	70000086
11	Power divider 6 dB	Suhner 4901.17.A	12009439
12	Variable band pass filter 2%	Trtithic 5VF1500/3000-3-50	5013289
13	Variable band pass filter 5%	Trilithic 3VF2000/4000-5-50	11008536
14	G-TEM Cell	MEB G-TEM Cell 500	11008551
15	Laptop computer	Fujitsu Lifebook E756	75668163
16	RLAN access point	D-Link DAP 1665	-
17	Bluetooth mouse	i-tec MW243	-

ANNEX 5: MEASUREMENTS OF THE 2ND HARMONIC OF AN LTE 2400 USER EQUIPMENT

A5.1 SUMMARY OF MEASUREMENTS

To support calculations of compatibility between LTE2400 (3GPP band 53) and the Radio Astronomy Service in the band 4950–5000 MHz, the harmonic level of a typical LTE2400 user equipment (UE) was measured.

The result was that the level on the harmonic frequency 4978 MHz was attenuated by about 67 dB relative to the in-band spectral power. Assuming a transmit power of the UE of 20 dBm in 10 MHz bandwidth, and further assuming omnidirectional characteristics of the transmit antenna on both wanted and harmonic frequency, this relates to a TRP on the harmonic frequency of **-57 dBm/MHz** which is 27 dB below the limit defined in ECC/REC 74/01 and 3GPP TS 36.104.

A5.2 INTRODUCTION AND BACKGROUND

In support of CEPT Report 345 concerning the compatibility of an LTE system in the frequency range 2483.5 to 2495 MHz, the level of a selected user equipment (UE) on the second harmonic frequency (4976 MHz) was tentatively measured.

The results may be included in the CEPT Report 325 to help in the assessment of realistic attenuations of the UE harmonic level in the 5 GHz band for compatibility studies.

A5.3 MEASUREMENT SETUP

The selected LTE2400 user equipment was a USB modem operated in a laptop computer.

The following relevant RF parameters were set in the LTE system:

- Centre frequency: 2489 MHz
- Bandwidth (channel width): 10 MHz
- Duplex scheme: TDD
- Downlink/uplink ratio: 1:1
- Transmit power of the UE: 20 dBm
- UE antenna gain: 0 dBi (assumed)

The harmonic emissions of the UE were measured in a suitable environment with the following setup:

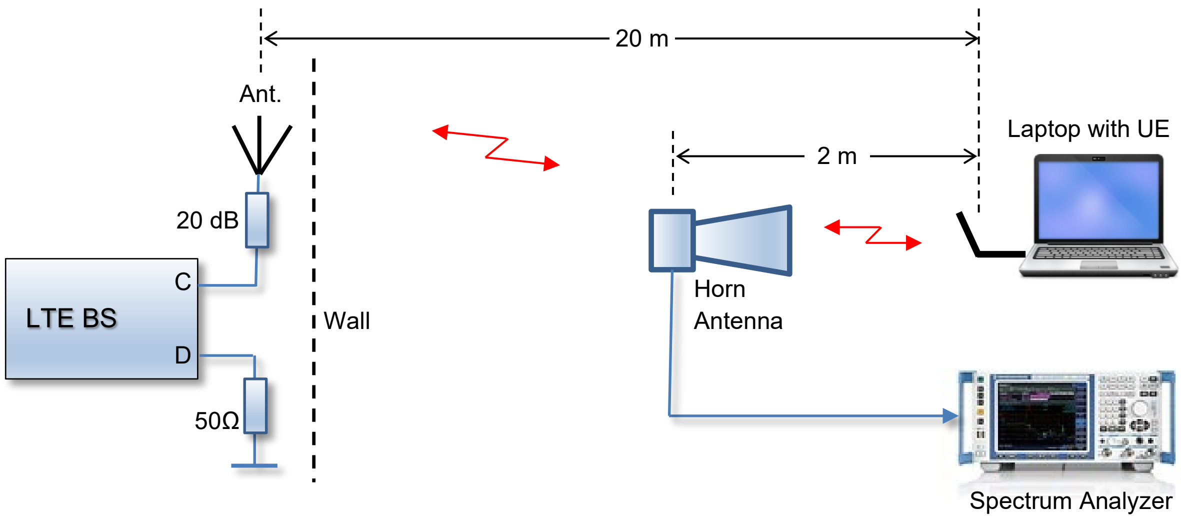

Figure 74: Block diagram of the setup to measure the UE harmonics

The LTE base station was attenuated by 20 dB and operated behind a wall/shielded window to ensure that the UE receives a low downlink level and stipulate the maximum transmit power on the uplink.

A wanted connection between Laptop and Internet was established and a large file was uploaded using the whole capacity of the LTE cell.

Wanted and harmonic levels were measured with a pyramidal horn antenna. The measurement settings of the spectrum analyser were as follows:

- Centre frequency: 2489 MHz / 4978 MHz
- RBw: 1 MHz
- Span: Zero (time domain)
- Sweep time: 10 ms (1 LTE frame)
- Trigger: Video
- Measurement mode: Time domain power (limited to the UL burst time only)
- Detector: RMS

The trigger level was set high enough to be fired at uplink bursts only. The integration time of the RMS detector was set to 2.1 ms, which is the length of one uplink burst.

The above setting ensured that the average burst power of the uplink was measured.

By using the antenna factor of the horn antenna, the power levels can be converted to field strengths. Although the setup cannot determine the TRP directly, it allows assessing the attenuation of the harmonics relative to the on-channel level. Assuming a lossless omnidirectional antenna for the UE, and a transmit power of 20 dBm, this harmonic attenuation can be used to tentatively determine the TRP on the harmonic frequency.

A5.4 MEASUREMENT RESULTS

The measurement in 2 m distance revealed the following results:

Table 149: Measured LTE levels and calculated field strengths in 2 m measurement distance

Parameter	F = 2489 MHz	F = 4978 MHz
Measured level	-21 dBm/MHz	< -81 dBm/MHz (note 1)
Gain Horn antenna	3 dBi	9 dBi
Antenna factor	35.1 dB/m	35.1 dB/m
Field strength	121.1 dBµV/m	< 61.1 dBµV/m
Note 1: This is the level of the analyser noise. Harmonic emissions could not be detected down to this level		

The transmit power of the UE is assumed to be +20 dBm in 10 MHz bandwidth which relates to 20 dBm + 10*log(1 MHz / 10 MHz) = +10 dBm/MHz bandwidth.

This value creates the measured field strength of 121.1 dBµV/m at the horn antenna in 2 m distance. The harmonic emissions on 4978 MHz are measured to be less than 61.1 dBµV/m with means they are attenuated by more than 60 dB.

Assuming omnidirectional antenna pattern for both wanted and harmonic frequencies, the resulting TRP on 4978 MHz is then less than 10 dBm/MHz – 61 dB = -51 dBm/MHz which is well below the limit of -30 dBm/MHz defined in ECC/REC 74/01 and 3GPP TS 36.104.

Because the level of the harmonic emission measured in 2 m distance was below the analyser noise, a second measurement in only 1 m distance was made. This test revealed the following results:

Table 150: Measured LTE levels and calculated field strengths in 2 m measurement distance

Parameter	F = 2489 MHz	F = 4978 MHz
Measured level	-16 dBm/MHz	-79 dBm/MHz
Analyser noise level	-78 dBm/MHz	-81 dBm/MHz
LTE level at horn antenna	-16 dBm/MHz	-83.3 dBm/MHz
Gain Horn antenna	3 dBi	9 dBi
Antenna factor	35.1 dB/m	35.1 dB/m
Field strength	126.1 dBµV/m	58.8 dBµV/m

The LTE level at the horn antenna can be calculated by cancellation of the analyser noise according to the following formula (using linear units):

$$P_{LTE} = P_{meas} - P_{sys} \tag{28}$$

With

- P_{meas} = measured receive level
- P_{LTE} = Level of the LTE signal
- P_{sys} = Analyser noise level

With the same assumptions and calculations as above, this second measurement results in an attenuation of the emissions on the harmonic frequency by 126.1 – 58.8 = 67.3 dB which correlates to an estimated TRP of +10 dBm/MHz – 67.3 dBm/MHz = **-57.3 dBm/MHz** on 4978 MHz.

A5.5 ADDENDUM: MEASUREMENT EQUIPMENT

Table 151: List of measurement equipment used

No	Type	Model	Inv. No.
1	Spectrum Analyser	R&S ESPI7	11006934
2	Horn antenna	Watkins & Johnson WJ48430	5012877

ANNEX 6: LIST OF REFERENCES

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