ECC Report 326

Implementation conditions of SRD up to 500 mW in the first RFID interrogator channel centred at 916.3 MHz of the frequency band 915-919.4 MHz

approved 1 October 2021

0 EXECUTIVE SUMMARY

This ECC Report considers the deployment of high-power Short Range Devices (SRDs) of three technologies: Narrowband Networked SRD (NBN), Ultra narrowband (UNB) and Chirped Spread Spectrum (CSS) in the first RFID interrogator channel at 916.3 MHz within the frequency band 915-919.4 MHz.

Two sets of SEAMCAT studies were developed: Each of the three technologies was considered separately in the studies. The interference criterion used for LTE operating below 915 MHz was a 5% of the increase average bitrate loss for the reference base station. The details of the two studies are provided below:

0.1 FIRST STUDY

The first SEAMCAT study considered the first RFID channel at 916.3 MHz together with the contribution from the already available RFID channels at 917.5 MHz and 918.7 MHz. Two scenarios are explored: blocking only of the Mobile/Fixed Communication Network (MFCN) victim receiver and blocking + in-band interference (corresponding to the spurious emissions from the interferers). Attempts to compensate the summation of the spurious emissions are described in section 4. This study also includes blocking and/or in-band interference from devices deployed in the RFID channels two and three (as described in the table below). Various levels of duty-cycle (DC) were simulated for NAP and NN in channel #1.

The results of that study are summarised in Table 30, Table 31, Table 32 and Table 33.

The following table summarises those results and shows the DC applicable to the first RFID channel in order to achieve a throughput loss below 5% on a victim MFCN channel below 915 MHz (if such a value exists, otherwise “None”). The DC is expressed in % of the maximum DC already allowed in RFID channels #2 and #3. i.e. 10%, 2.5% and 1% respectively for the NAP, NN and TN).

Table 1: Summary of results

	Maximum density		Typical density	
NAP & NN DC on channels #2 and #3	DCref (note 1)			Fraction of DCref (note 2)
TN DC	1%	Fraction of TN DCref (note 2)	1%	
NBN (blocking only)	None	None	100% of DCref	100% of DCref
NBN (blocking + spurious)	None	None	None	40% of DCref
CSS (blocking only)	50% of DCref	70% of DCref	100% of DCref	100% of DCref
CSS (blocking + spurious)	None	30% of DCref	100% of DCref	100% of DCref
UNB (blocking only)	100% of DCref	100% of DCref	100% of DCref	100% of DCref
UNB (blocking + spurious)	None	20% of DCref	100% of DCref	100% of DCref

Note: "100% of DCref" means with the DCref, the increase average bitrate loss is below 5%, the "None" means the average bitrate loss is above 5 %. The "x% of DCref" means the DC limit allows being below the 5% of average bitrate loss when the DC on channel #1 is adjusted accordingly.

Note 1: “DCref” is the maximum DC already allowed in channels #2 and #3, i.e. NAP: 10%, NN: 2.5%, TN: 1%
Note 2: "fraction of DCref" means same fraction of DCref as the fraction of NAP DCref used for NAP in channel #1

For typical densities, when only receiver blocking is considered, the average bitrate loss of LTE is below the threshold limit acceptable by LTE BS. Although, when taking into account the spurious level of -36 dBm/100 kHz , some technologies could be deployed with their maximum DC without additional constraints, whereas others may exceed the acceptable threshold. Even in those latter cases, the impact on LTE might be tolerable, recognizing that the real interference impact is expected to be between the value for blocking only and the value with the addition of unwanted emissions when limiting spurious emissions only to transient aspect of spikes.

0.2 SECOND STUDY

The second SEAMCAT study considered alone the first RFID channel at 916.3 MHz with continuous levels of spurious emissions varying from -36 dBm/100 kHz down to -46 dBm/100 kHz. Maximum and typical deployment densities were considered for each technology. Automatic Power Control (APC) was also assumed using realistic parameters.

The second study, found that:

Modelling the spurious emissions (not considering blocking effect) as if they were a level of 10 dB more stringent than the applicable regulatory maximum (-36 dBm/100 kHz), interference causing an increase in average bitrate loss larger than 5% was avoided. Therefore, considering an additional restriction of -29 dBm e.r.p. on aggregate emissions into the victim's 5 MHz receiver, the interference threshold was not overstepped. Reducing the assumed DC for each element of each technology combined with a more relaxed aggregate limit of unwanted emissions below 915 MHz – showed it was possible to determine the points at which the interference threshold is over stepped. The results are summarised in Figure 1.

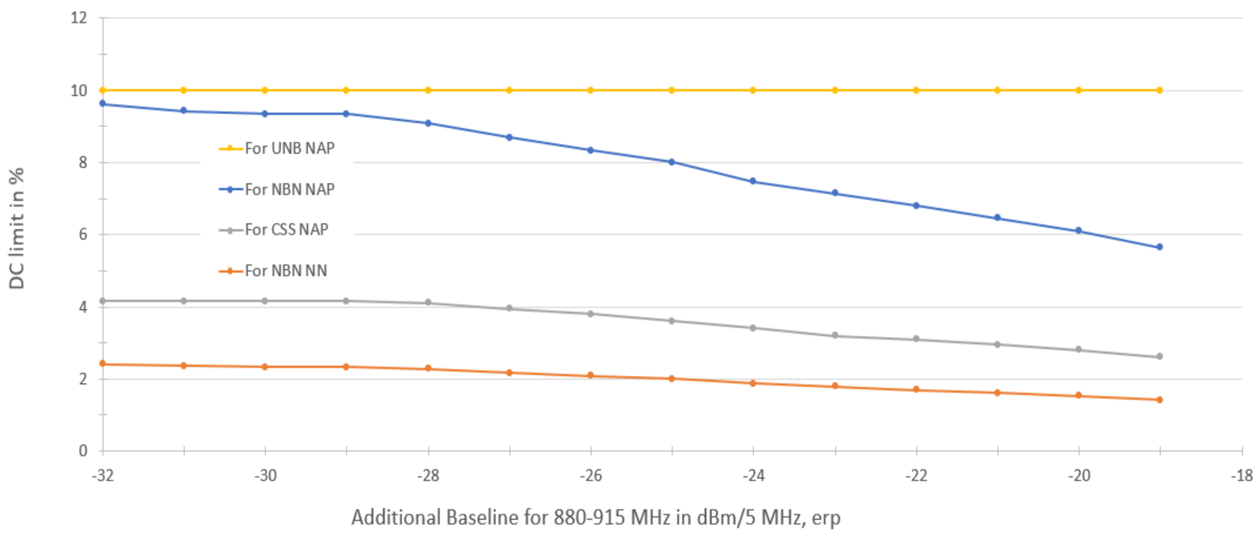

Figure 1: DC limits corresponding to various levels of unwanted emission, for an average bitrate loss below 5% on the victim MFCN

The results in Figure 1 might be interpreted in various ways in order to avoid overstepping the interference threshold, but two examples might be:

- Considering an additional baseline of -19 dBm/5 MHz e.r.p. combined with a DC limited to 2.6% for CSS NAP and 5.7% for NBN NAP and to 1.4% for NN NBN would be necessary, and no DC reduction needed for UNB NAP;
- Considering an additional baseline of -25 dBm e.r.p. into the victim's 5 MHz receiver, combined with a DC limited to 3.6% for CSS NAP and 8% for NBN NAP and to 2% for NN NBN would be necessary, and no DC reduction needed for UNB NAP;
- The -36 dBm/100 kHz general spurious emission limit still applies.

For additional baseline less than about -28 dBm/5 MHz e.r.p., the blocking effect is dominant. Therefore, additional reductions do not bring further improvements on interference.

0.3 GENERAL CONSIDERATIONS

In both studies, simulations assume uniform/constant spurious emissions. However, spurious emissions in real life can encompass not only uniform/constant emissions (such as harmonics) but also transient/rare spikes. Measurements on real equipment could not be provided but it is anticipated that the dominant interference in the field would come from transient aspects of spikes, and therefore the effect from spurious emissions may have been overestimated in the simulations.

From all those results, it can be concluded that the impact of new opportunities in the first RFID channel depends significantly on the deployment scenarios and other assumptions (e.g. with regards to the impact of spurious emissions and deployment density).

It can be noted that some countries use part of the range 915-921 MHz for defence or Governmental systems and/or the range 918-921 MHz for Extended GSM-R. According to ERC Recommendation 70-03, the use of all or part of these bands may be limited or not authorised for SRD in some countries. The situation in these countries is considered by results of co-existence and compatibility studies for Short Range Devices (SRDs) vs Governmental systems and SRD vs GSM-R in ECC Report 200 [7].

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
3G	3rd Generation Mobile
3GPP	3rd Generation Partner Project
5G	5th Generation Mobile
ACS	Adjacent Channel Selectivity
ATPC	Adaptive Transmitting Power Control
BER	Bit Error Rate
BS	Base Station
BW	Bandwidth
CDF	Cumulative Distribution Function
CEPT	European Conference of Postal and Telecommunications Administrations
CSS	Chirp Spread Spectrum
DC	Duty Cycle
DNSRD	Data Networked SRD
ECC	Electronic Communications Committee
EDGE	Enhanced Data rates for Global Evolution
e.i.r.p.	Equivalent Isotopically Radiated Power
e.r.p.	Effective Radiated Power
ETSI	European Telecommunications Standards Institute
E-UTRA	Evolved Universal Terrestrial Radio Access
GSM	Global System for Mobile communications
GSM-R	GSM for Railway
ILT	Interfering Link Transmitter
IMT	International Mobile Telecommunications
I/N	Interference-to-noise ratio
IoT	Internet of Things
ITU-R	International Telecommunication Union – Radio-communication
ISD	Inter site distance
KPI	Key Performance Indicator
LOS	Line of sight
LPWAN	Low-Power Wide-Area Network
LTE	Long Term Evolution
MFCN	Mobile/Fixed Communications Network

Abbreviation	Explanation
MS	Mobile Station
NAP	Network Access Point
NB	Necessary Bandwidth
NBN	Narrowband Networked
NBIoT	Narrowband IoT
NF	Noise Figure
NLOS	Non line of sight
NN	Network Node
NR	New Radio
NR	Noise Rise (e.g. due to adjacent cellular networks in the band)
NSRD	Networked SRD
OCW	Operating channel width
OFDMA	Orthogonal Frequency Division Multiple Access
OFDM	Orthogonal Frequency Division Multiplexing
OoB	Out-of-band
PC	Power control
RB	Resource Block
RBW	Reference bandwidth
RFID	Radio Frequency Identification
RSSI	Received Signal Strength Indicator
Rx	Receiver
SEAMCAT	Spectrum Engineering Advanced Monte Carlo Analysis Tool
SF	Spreading factor
SRD	Short Range Devices
TN	Terminal Node
TR	Technical Report
TS	Technical Specification
TBW	Transmission Bandwidth
Tx	Transmitter Specification
UE	User equipment
UL	Uplink
UMTS	Universal Mobile Telecommunications System
UNB	Ultra NarrowBand
UTRA	Universal Terrestrial Radio Access
WCDMA	Wideband CDMA

1 INTRODUCTION

The aim of this Report is to develop the conditions for implementation of Networked SRDs[1] (NSRD) in the first RFID interrogator channel centred at 916.3 MHz of the frequency band 915-919.4 MHz with regard to possible interference towards Mobile Fixed Communication Networks (MFCNs) operating in the 880-915 MHz.

Such high-power SRDs could be operated with up to 500 mW e.r.p. (with ATPC) and max./avg. duty cycle of 10%/2.5%. These high-power SRD systems may be operated in co-channel with the RFID in the 916.1 - 916.5 MHz.

Possible mitigation measures could include the reduction in maximum transmit power, additional unwanted emission baseline and/or reduction of DC. Based on ECC Recommendation (19)02 [9]. This Report provides additional considerations on spurious emission in the framework of this compatibility study.

For illustration purposes, Figure 2 shows in green colour the frequency range examined in this study for additional 500 mW Network SRD operations in the first interrogator channel. In the same figure, the current regulation according to the ERC Recommendation 70-03 [12] of the frequency band 915-921 MHz, is highlighted in dark blue (for Network SRD) and brown colour (for Governmental, defence and railway systems). It can be noted that some countries use part of the range 915-921 MHz for defence or Governmental systems and/or the range 918-921 MHz for Extended GSM-R. According to ERC Recommendation 70-03, the use of all or part of these bands may be limited or not authorised for SRD in some countries. The situation in these countries is considered by results of co-existence and compatibility studies for Short Range Devices (SRDs) vs Governmental systems and SRD vs GSM-R in ECC Report 200 [7].

The conditions within the band stated in ERC Recommendation 70-03 are summarised in Figure 2.

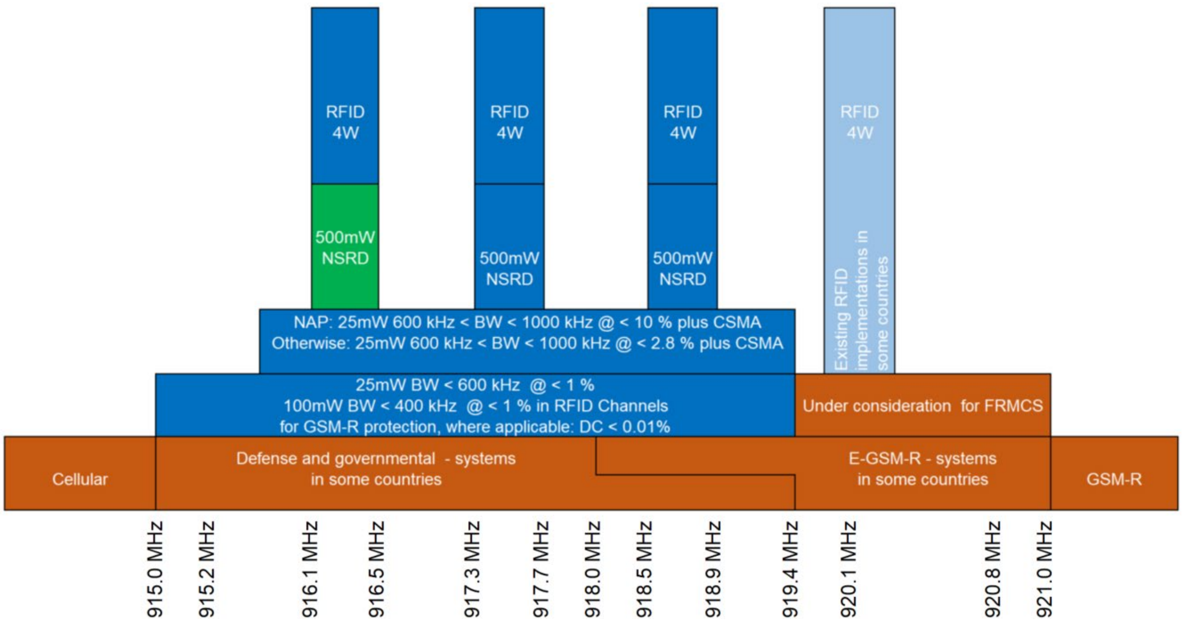

Figure 2: Potential (green) and existing (dark blue) spectrum as defined in the ERC Recommendation 70-03 [12]

Three earlier ECC Reports contain analysis and data that have been cited within this Report:

- ECC Report 200 [7]: Co-existence studies for proposed SRD and RFID applications in the frequency band 870-876 MHz/915-921 MHz;

[1] NSRD refers to devices operating within Data Networks, in which: '[A] network access point in a data network is a fixed terrestrial short range device that acts as a connection point for the other short range devices in the data network to service platforms located outside of that data network. The term data network refers to several short range devices, including the network access point, as network components and to the wireless connections between them' [12]

- ECC Report 246 [13]: Wideband and Higher DC Short Range Devices in 870-875.8 MHz and 915.2- 920.8 MHz (companion to ECC Report 200 [7]);
- ECC Report 261 [14]: Short Range Devices in the frequency range 862-870 MHz.

Three technologies of SRD in data networks of NSRD have been considered in this Report:

- Narrowband Networked (NBN) SRD, as described in ETSI TR 102 886 [4] and conforming to ETSI EN 303 204 [3];
- LPWAN-CSS as described in ETSI TR 103 526 [1] and conforming to ETSI EN 300 220 [11];
- LPWAN-UNB as described in ETSI TR 103 435 [2] and conforming to ETSI EN 300 220.

2 PARAMETERS USED FOR THE CELLULAR SYSTEMS IN 880-915/925-960 MHZ

2.1 TECHNICAL CHARACTERISTICS

The 900 MHz band (880-915/925-960 MHz) is used for GSM (including cellular IoT), 3G and LTE in city centres, urban areas, suburban areas and rural areas as per ECC Decision (06)13 [16].[2]

The 900 MHz cellular band is a band to give coverage to UEs e.g. deep inside buildings (urban/suburban) or providing wide area coverage in rural areas:

- Coverage band: The 900 MHz cellular band is an important band to give coverage in rural, suburban, urban and city centre, being the primary coverage layer in cell edge and deep indoor. The 900 MHz band is the most important of the low bands as due to history/deployment, availability in mobiles and BS infrastructure. Capacity bands (>1 GHz) with typically more than 20 MHz BW available per operator are used as the higher layer in a network;
- Radio systems: The band is used for GSM, IoT, 3G, LTE and in the future for NR and NBIoT. The protection for all of these radio systems needs to be considered. However, this Report studies only the protection of LTE system below 915 MHz;
- Minimum expected bitrate: For users at the cell edge (at CDF < 20%) operators will plan their network to give minimum expected bitrate. Noise rise at the BS from other adjacent services will cause that the coverage range will shrink, and such users will have no cellular service;
- Noise rise in the UL: In cellular networks the UL noise rise in the BS gets constantly monitored and is one of the main Key Performance Indicators (KPIs) for network planners. This is in order to meet regulator/customer coverage and minimum bitrate obligations/expectations. The network is planned to limit inter-system interference and detect possible high noise rise due to adjacent services. In cellular networks UE power control of more than 60 dB will limit possible interference from other networks. The UEs are moving and transmitting just over short time in a network.

The RSSI (Received Signal Strength Indicator) is a KPI (Key Performance Indicator) measurement parameter used in cellular networks (for BSs) to monitor network problems including high noise rise. The RSSI is the total received power (acting like a power meter) which includes:

- ANNEX 1 and 3GPP specifications recommend a noise figure of 5 dB, but some measurements show a noise figure of 2 dB;
- Own cell power in a cell (WCDMA), for 70% cell load ~3 dB;
- Possible interference from other cells and cellular networks in the band (GSM, WCDMA, LTE). Any other interference sources causing additional Noise Rise more than 5 dB will be checked and resolved as it compromises network performance;
- In Figure 3,a screenshot of the measured RSSI for BS sectors in city, urban and suburban network is given. The values in the figure are the mean values over one day. The mean of the minimum and the mean of the maximum measured RSSI values over one day are: $RSSI_{mean,min}$ = -106.6 dBm and $RSSI_{mean,Max.}$ = -101.1 dBm. Similar values have been also reported in Recommendation ITU-R F.1336-4 [22] for urban, suburban and rural environment where also the influence of noise rise on coverage and capacity is discussed. The thermal noise level is -108 dBm for the measurement BW (3.84 MHz), which means the observed NR (Noise Rise) over the day is between 1.4 to 6.9 dB. Considering measurement accuracy and that the numbers include the NF and own-cell power, typically the NR in the network can be expected lower than 2 or 3 dB in average over a day.

[2] Some operators are expected to use 5G-NR in this band. No study has been performed with this RAT in this Report. However the current non-AAS performance requirements from 3GPP are identical between LTE and 5G-NR.

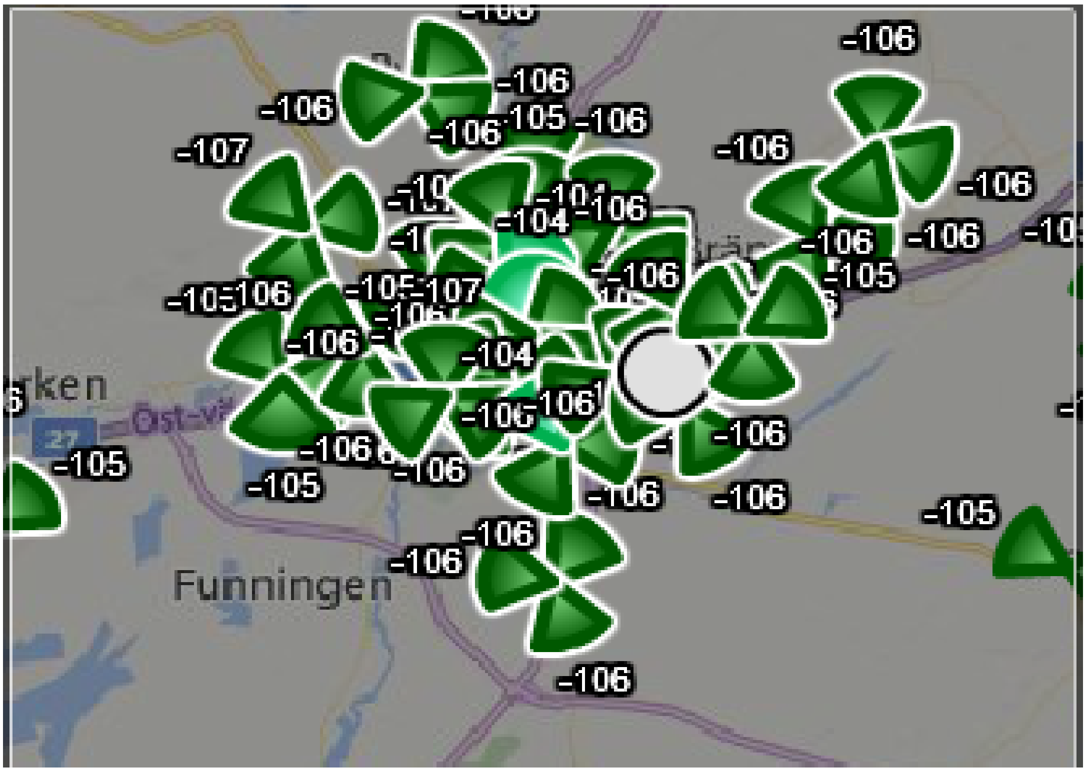

Figure 3: Screenshot of RSSI measurement in Borås (Sweden) including the city centre, urban and suburban area. Covering an area of about 30 km^{2}with 68 BS sectors

2.2 RECEIVER MASK

2.2.1 Unwanted emission and noise rise

In this Report, the interference threshold ($I_{Macro,threshold}$) for macro BS in the 900 MHz band is based on the BS noise limit with a Noise Figure (NF) of 5 dB and Interference-to-Noise ratio protection criterion of I/N = -6 dB Report ITU-R M.2292 [6]:

$$I_{Macro,threshold} = -174 \text{ dBm/Hz} + 10*\log10\,(BW) + NF + I/N \quad (1)$$

For 10 MHz BW, the $I_{Macro,threshold}$ is -105 dBm. For Monte Carlo simulations, the CDF value for interference from adjacent band (SRD operation in 915-925 MHz) should be less than 5% exceeding the $I_{Macro,threshold}$.

2.2.2 Adjacent Channel Selectivity and Blocking

Adjacent Channel Selectivity (ACS) and receiver blocking can cause gain compression and noise rise. In the 3GPP, specification blocking requirements are defined for macro BSs e.g. in 3GPP TS 36.104 [18], table 7.5.1-1 / Table 7.5.1-3 (ACS) as well as in table 7.6.1.1-1 (Blocking). The tables can be related to setting in SEAMCAT for the blocking mask/ACS for one and three UEs for 5 MHz and 10 MHz BW (25/50 RBs).

In ECC Report 310 [19], section 7.2.2, the modelling and implementation of the blocking for SEAMCAT is described.

For the positive values, the blocking response in SEAMCAT can be calculated by the following equation:

$$\begin{aligned} Blocking\ Response &= I_{OOB-STANDARD} - I_{IB-STANDARD}\ (\text{dB}) \\ &= I_{OOB-STANDARD} - N - 10 * \log_{10}\left[10^{\frac{D_{STANDARD}}{10}} - 1\right] \end{aligned} \quad (2)$$

Where:

- $I_{OOB\text{-}STANDARD}$ is the allowed power of an interfering blocking signal as specified by the standard (for $D_{STANDARD}$);
- $I_{IB\text{-}STANDARD}$ is the equivalent in-band interfering signal;
- $D_{STANDARD}$ is the Desensitisation defined by the standard for the blocking specification. For 3GPP cellular systems for reference channel with $D_{STANDARD} = 6\,dB$ it can be obtained $10 * \log_{10}\left[10^{\frac{6}{10}} - 1\right] = 4.74\,dB$;
- N is the noise floor given in dBm. N is derived from the following equation in dB:
  10*log10(kTBW) + NF,
  where k = Boltzmann constant, T = 290 K, BW = Bandwidth, NF = Noise figure.
  For 3GPP cellular system (Thermal noise over 4.5 MHz reference channel): N = -108 dBm + NF.

The typical reception mask to be considered in the studies for an LTE BS operating in the channel 905 - 915 MHz is derived as follows.

The shape of the LTE receiver mask has to be symmetrical. However, within the duplex gap of the E-GSM band / 3GPP band #8, i.e. 915-925 MHz, the effect of the BS duplexer in terms of filtering should be taken into account. From 918.2 MHz, the duplexer of an LTE BS generates an additional filtering of 11 dB for every additional offset of 1 MHz as indicated by the equation (ii) of section 4.1.2.4.1 of the 3GPP TS 45.005 [4]:

ii) -58.7 dBm + MCL + (f-918.2)*11 dB in case of coexistence with UTRA and E-UTRA BS (3)

Where:
F = DL frequency in MHz´, 918.2 ≤ f ≤ 921 and MCL = 67 dB

Thus, the LTE receiver mask is given in Table 2.

Table 2: LTE receiver mask

Frequency	ACS (dB)	Justification
$918.2\,MHz \leq f \leq 920\,MHz$	$48.7 + 11.(f - 918.2)$	In the 915-920 MHz frequency range, the ACS value has to be 48.7 dBm, however according to the equation (ii) in section 4.1.2.4.1 of the 3GPP TS 45.005 from 918.2 MHz to this value is added the slope $11.(f - 918.2)$.
$f = 920\,MHz$	$48.7 + 11.(920 - 918.2) + 9$	The same jump of +9 dB, after 5 MHz, as at 900 MHz.
$f \geq 920\,MHz$	$57.7 + 11.(f - 918.2)$	In the 920-925 MHz frequency range, the ACS value has to be 57.7 dBm, however according to equation (ii) in section 4.1.2.4.1 of the 3GPP TS 45.005 from 918.2 MHz to this value is added the slope $11.(f - 918.2)$.

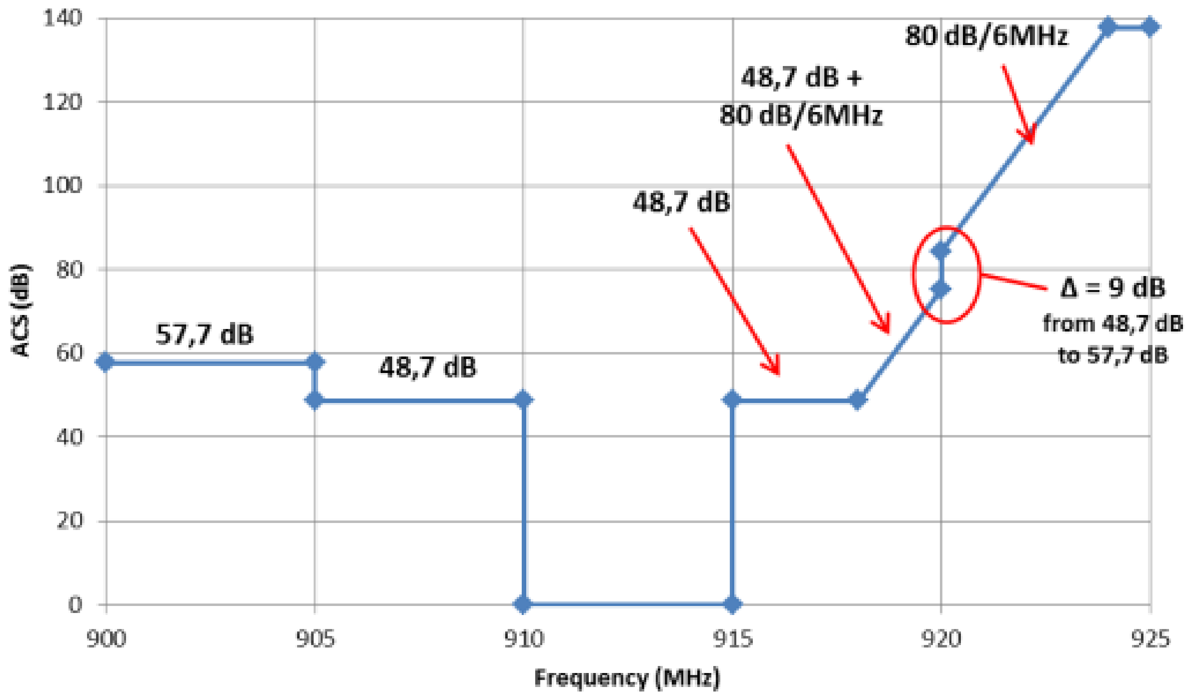

Figure 4: MFCN BS receiver mask, including duplexer effect above 915 MHz

A bandwidth of 5 MHz with single UE in the UL was used in a recent study in the ECC Report 318 [20]. In Table 3 and Table 4 a blocking response for SEAMCAT is given respectively for 5 MHz and 10 MHz BW. For different BWs and number of UEs, the blocking response in general needs to consider that the mask as given in Figure 4 is for 5 MHz BW and one UE. For different BWs and number of UEs, the mask needs to be adjusted with the following equation:

$10*\log_{10}$ (5 MHz /(BW / number of UEs))

Table 3: SEAMCAT Blocking mask table for 5 MHz BW and one UE

MHz	dB
-30	57.7
-7.501	57.7
-7.5	48.7
-2.501	48.7
-2.5	0
2.5	0
2.501	48.7
5.5	48.7
7.5	75.4
7.501	84.4
11.5	137.7
50	137.7

Table 4: SEAMCAT Blocking mask table for 10 MHz BW and one UE

MHz	dB
-30	54.7
-10.001	54.7
-10	45.7
-5.001	45.7
-5	0
5	0
5.001	45.7
8	45.7
10	72.4
10.001	81.4
14	134.7
50	134.7

2.3 ANTENNA

The antenna parameters of LTE 900 MHz are given in ANNEX 1.

2.4 DEPLOYMENT

The simulations are performed using for the LTE system the parameters in ANNEX 1. ANNEX 2 provides a comparison between the LTE parameters listed in the ECC Report 246 [13] and ECC Report 261 [14] against the updated ones.

3 CHARACTERISTICS OF DATA NETWORK SRD IN THE FREQUENCY BAND 915-919.4 MHZ

3.1 INTRODUCTION

The notion of Data Network SRD grasps the various solutions for providing the Internet of things (IoT) connectivity. Studies in this Report regard the following IoT connectivity solutions that are described by ETSI for the use of new spectrum in the frequency band 915-919.4 MHz:

- NBN SRD defined in ETSI TR 102 886 [4] and/or ETSI TR 103 055 [16] and conforming to ETSI EN 303 204 [3];
- LPWAN-CSS system defined in ETSI TR 103 526 [1] and conforming to ETSI EN 300 220 [11];
- LPWAN-UNB systems defined in ETSI TR 103 435 [2] and conforming to ETSI EN 300 220.

Data Networks SRD connect terminal nodes (TN) fitted on the devices to network access points (NAP) which collect the information. The radio links can be one-hop, as in LPWAN-CSS and LPWAN-UNB, or multi-hop, as in NBN SRD. These systems of different technologies expect to provide solutions to similar needs. Hence, some similar parameters and configurations are to be used, in particular to reflect the consistency of all solutions with ETSI EN 300 220 as the antenna heights, indoor/outdoor distribution, and propagation model.

3.2 GENERAL PARAMETERS FOR DATA NETWORK SRD SYSTEM

3.2.1 OOB and spurious emission limits

The ETSI EN 300 220 on Short Range Devices (SRDs) operating in the frequency range 25 MHz to 1 GHz and the ETSI EN 303 204 [3] on the Network Based SRD radio equipment to be used in the 870-876 MHz frequency range with power levels ranging up to 500 mW, define the out-of-band (OOB) and spurious emission limits, which are in accordance with the ERC Recommendation 74-01 [8], respectively as in Figure 5 and Figure 6. For the operating channel width (OCW), 200 kHz can be assumed for the three SRD systems studied in this Report.

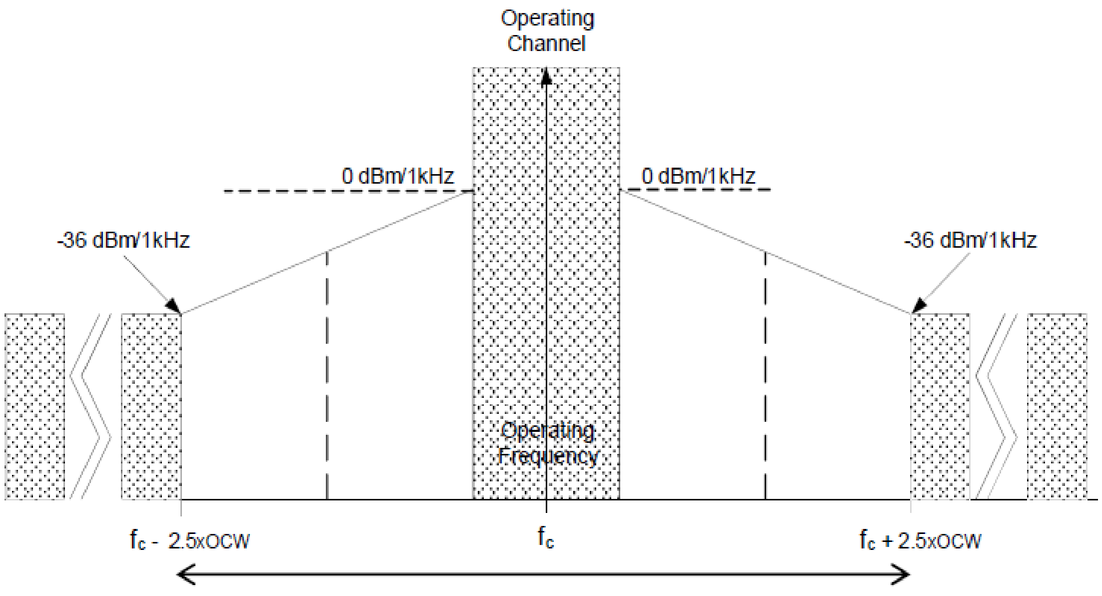

Figure 5: Out-of-band domain for operating channel with Reference bandwidth (RBW)

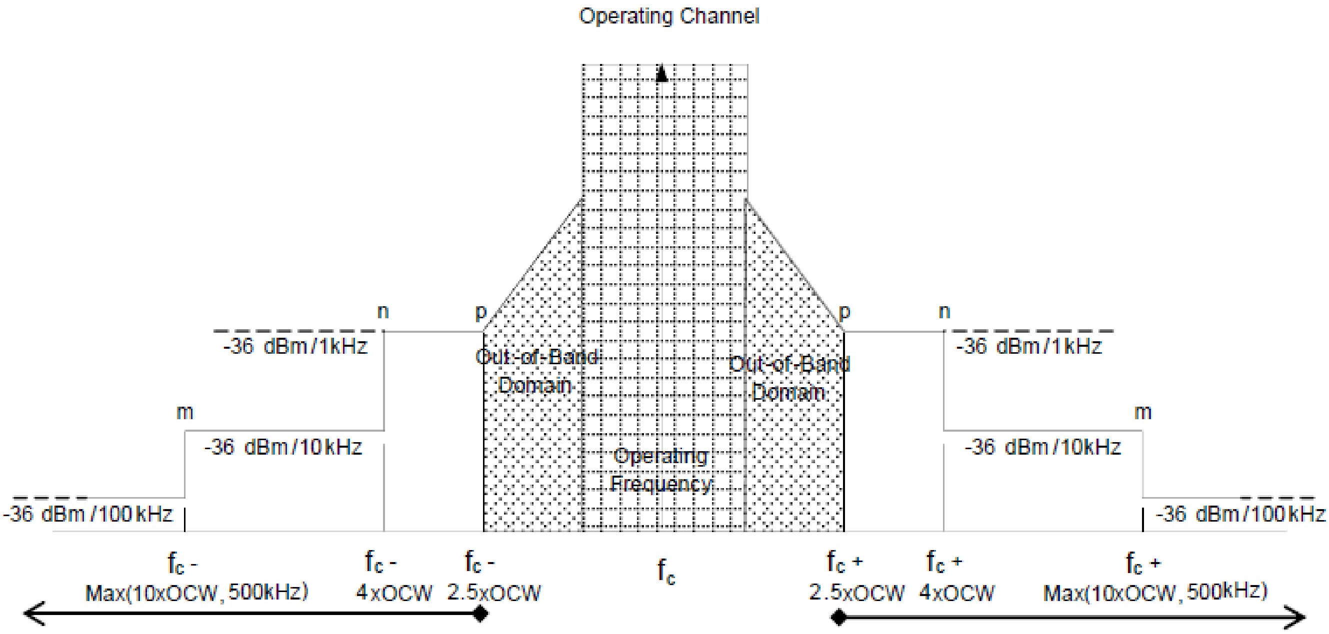

Figure 6: Spectrum mask for unwanted emissions in the spurious domain with RBW

3.2.2 Assumptions used for the simulations for indoor/outdoor ratio

Table 5: Assumptions used in the simulations for the indoor/outdoor ratio of TNs

	Indoor	Outdoor
Scenario1	100%	0%
Scenario 2	30%	70%
Scenario 3	70%	30%

3.3 CHARACTERISTICS OF SRD IN DATA NETWORK

This section contains the characteristics that are specific to each SRD network. Further information on parameters agreed for the three SRD systems studied in this Report can be found in the ECC Report 313 [26].

3.3.1 NBN SRD systems

3.3.1.1 Technology

Technical characteristics taken into account in the studies conducted in this Report for NBN SRD are provided in this section.

The parameters of the NBN technology are based on those used in previous studies, notably ECC Report 200 [7], ECC Report 246 [13] and ECC Report 261 [14] , and consistent with ETSI EN 303 204 [3] Transmitter parameters

Transmission parameters which were considered in ETSI EN 303 204 [3] and ETSI TR 103 055 [16], summarised in the below table, have been used.

Table 6: Emission parameters of up to 500 mW NBN-SRD systems (source ETSI EN 303 204 [3]and ETSI TR 102 886 [5]

	TN Tx (indoor/outdoor)	NN Tx (outdoor)	NAP Tx (outdoor)
Transmitter power (e.r.p.)	27 dBm	27 dBm	27 dBm
Bandwidth	200 kHz	200 kHz	200 kHz

In SEAMCAT, the spectrum emission mask is based on the power at the antenna connector and is relative to the in-block power. The maximum unwanted emission levels, given in Figure 5 and Figure 6, are absolute values. The relative values are based on the transmit power in Table 5 with 27 dBm (e.r.p.) and an antenna gain of 2.15 dBi for NBN-SRD. To study the possible interference onto the cellular UL, the OOB domain and the spurious domain are of interest. The unwanted emission mask is given in Figure 7 and Table 5 with reference to 27 dBm maximum power at the antenna connector. For OCW of 200 kHz, TBW/NB of 200 kHz, f_{low} at 916.1 MHz and f_c at 916.2 MHz. The interest of the mask is for frequencies below 916.1 MHz and possible interference below 915 MHz into the cellular band.

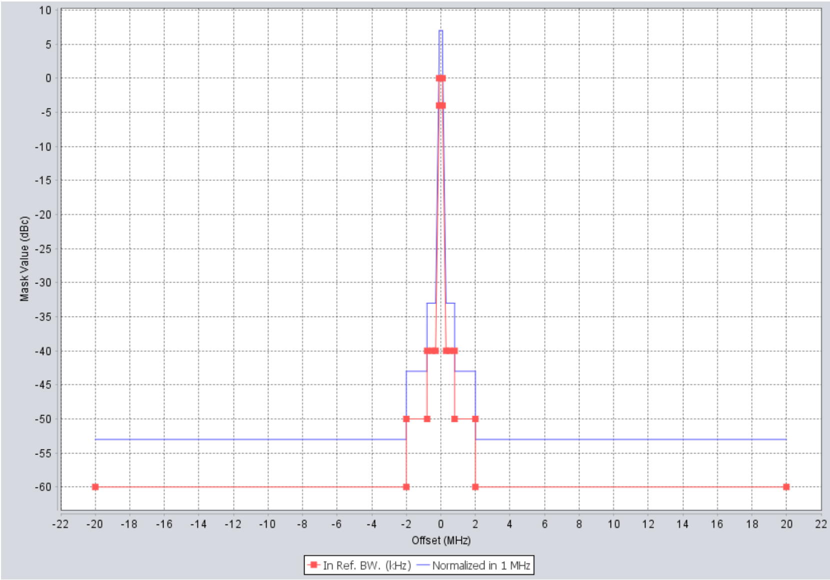

Figure 7: Unwanted emission mask for NBN SRD 27 dBm max. power at the antenna connector and antenna gain of 2.15 dBi. For OCW of 200 kHz and TBW/NB of 200 kHz

Table 7: NBN Emission mask used in study

Frequency offset (MHz)	±0.1	±0.101	±0.3	±0.5	±0.8	±0.801	±2	±2.001	±20
Worst-case mask (dBc)	0	-4	-40	-40	-40	-50	-50	-60	-60
Reference BW (kHz)	200	200	200	200	200	200	200	200	200

Table 8: Unwanted emission for NBN up to 500 mW max. power from ECC Report 261 [14] for -36 dBm/100 kHz spurious emission

Frequency offset (MHz)	-20	-0.5	-0.35	-0.101	-0.1	0.1	0.101	0.35	0.5	20
Worst-case mask (dBc)	-60	-60	-49	-30	0	0	-30	-49	-60	-60
Reference BW (kHz)	200									

3.3.1.2 Receiver sensitivity and ATPC parameter

Table 9: ATPC parameters

Parameter	Value
Sensitivity (dBm)	-95
Receiver bandwidth (kHz)	200
ATPC dynamic range (dB)	20
Step size (dB)	2
ATPC Threshold (dBm)	-89

3.3.1.3 Antenna

The NBN uses an omnidirectional antenna with gain set to: 0 dBi for the end-devices (TN and NN) which are typically deployed at a height of 1.5 m; 3 dBi for NAPs, which are typically deployed outdoors at a height of 7 m. For this Report, 2.15 dBi antenna gain is assumed for NAP, NN and TN NBN devices.

3.3.1.4 Deployment

The 500 mW e.r.p. SRD network elements are deployed as a self-organising mesh network and may operate with conditions summarised in Table 23. In a mesh network, the TN can communicate with TN and NN can communicate with NN; in addition, the NN transmits towards TN and NAP.

The communication between NN to NAP has not been considered in this Report.

Table 10: Expected and observed deployment for NBN-SRD in dense urban environment

Network Element	Max. DC %	Average DC%	Max. Density 1/km^2	Average Density 1/km^2
NAP	10	2.5	10	5
NN	2.5	0.7	90	45
TN	0.1	0.05	1900	950

Table 11: Band deployment assumptions for NBN SRD

Operating band (MHz)	Sub band size (MHz)	Proportion of devices (%)
865-874.4	Min. of 1.4	25-54
915-919.4	1.2 (see note 1)	46-75
Note 1: this assumes 3 x 400 kHz in the RFID interrogator sub-bands are used		

3.3.1.5 Propagation model

The propagation model depends on the environment and antenna heights. The following antenna heights for NBN SRDs are considered:

- NAP: 7 m, NN: 5 m

- TN: 1.5 m

For urban environment, the following two models, as implemented in SEAMCAT, were used:

- Extended Hata for urban above and below rooftop. Assumptions for the min antenna height are 1 to 10 m (e.g. TN) and for maximum antenna height below 30 m (e.g. NAP).). SEAMCAT allows to use BS heights lower than 30 m and uses the following factor for this: b(Hb)=min(0, 20log(Hb/30)), see SEAMCAT Handbook, section A17.3.1 [20]. Below rooftop conditions are assumed if the Tx and Rx antennas are below 10 meters. Below rooftop conditions increase the variation/deviation in the propagation model.
- The Extended Hata SRD is for below rooftop conditions only with antenna heights lower than 3 m and a maximum distance of 300 m (LOS assumption).

From the above and looking in section 3.5 where the maximum distance between the NAP/NN and terminal is estimated for the agreed Rx sensitivity, the following propagation models in SEAMCAT are used for NBN:

- NAP to NN → Extended Hata (with and without variation) for urban below rooftop;
- NN to TN → Extended Hata SRD for urban below rooftop (used in study # 2) and Recommendation ITU-R P.1411 [31] (in study #1);
- NAP/NN/TN to cellular BS → Extended Hata for urban above rooftop.

3.3.2 LPWAN-UNB

3.3.2.1 Technology

LPWAN-UNB specific technical characteristics and deployment scenario considered in the studies are summarised in this section.

3.3.2.2 Transmitter parameters

Table 11 provides the main radio parameters for the transmitters as described in ETSI TR 103 435 [2] .

Table 12: Main transmitter radio parameters (source ETSI TR 103 435 [2])

Parameter	Uplink	Downlink
Tx power per transmitter	Up to 25 mW e.r.p.	Up to 500 mW e.r.p.
Antenna type	omni-directional antenna	omni-directional antenna
Typical signal bandwidth (single carrier)	250 Hz	1 kHz
ATPC	--	Threshold -122 dBm, 30 dB range, step size 1 dB
Single carrier (NAP)	Not defined for UL	Maximum power at antenna connector 260 mW for 5 dBi antenna gain
Multi-carrier (NAP)	Not defined for UL	3 sub-carriers within each RFID channel with Maximum power of 87 mW per carrier at the antenna connector for 5 dBi antenna gain

From ETSI TR 103 435, section 7.1.1.3 [2]: "Multi-carrier operation can be used when the path loss experienced by a single downlink carrier is relatively low and therefore the link can be maintained when the transmit power in the carrier can be reduced significantly below the regulatory maximum". This will influence the usage of single versus 3-carrier operation and the power control operation. In this Report only the single carrier case is used.

The UL and DL signals of LPWAN-UNB have ultra-narrow bandwidth within operating channel width (OCW) of 200 kHz allowed by regulation where the transmission frequency is chosen in this predefined range as shown in Figure 8 (same for DL, but the carrier is 1 kHz).

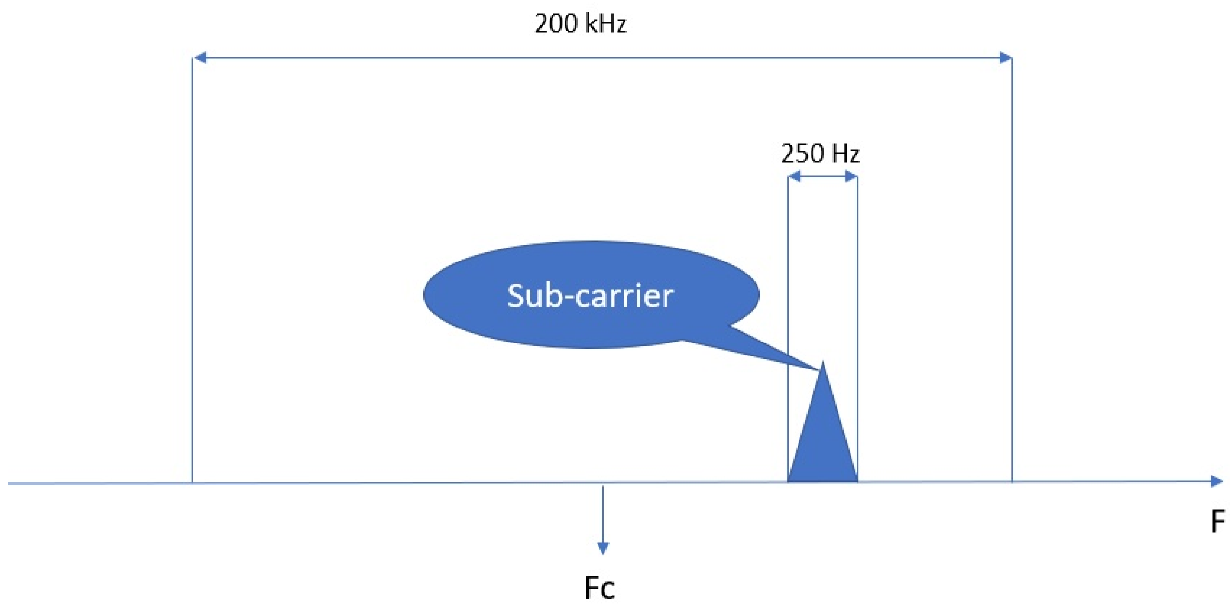

Figure 8: Demonstration of OCW and sub-carrier for UL

a) UL emission masks

The UL emission mask, which is compliant with ETSI EN 300 220-1 [11], proposed for this study is described in Figure 9 and Table 12.

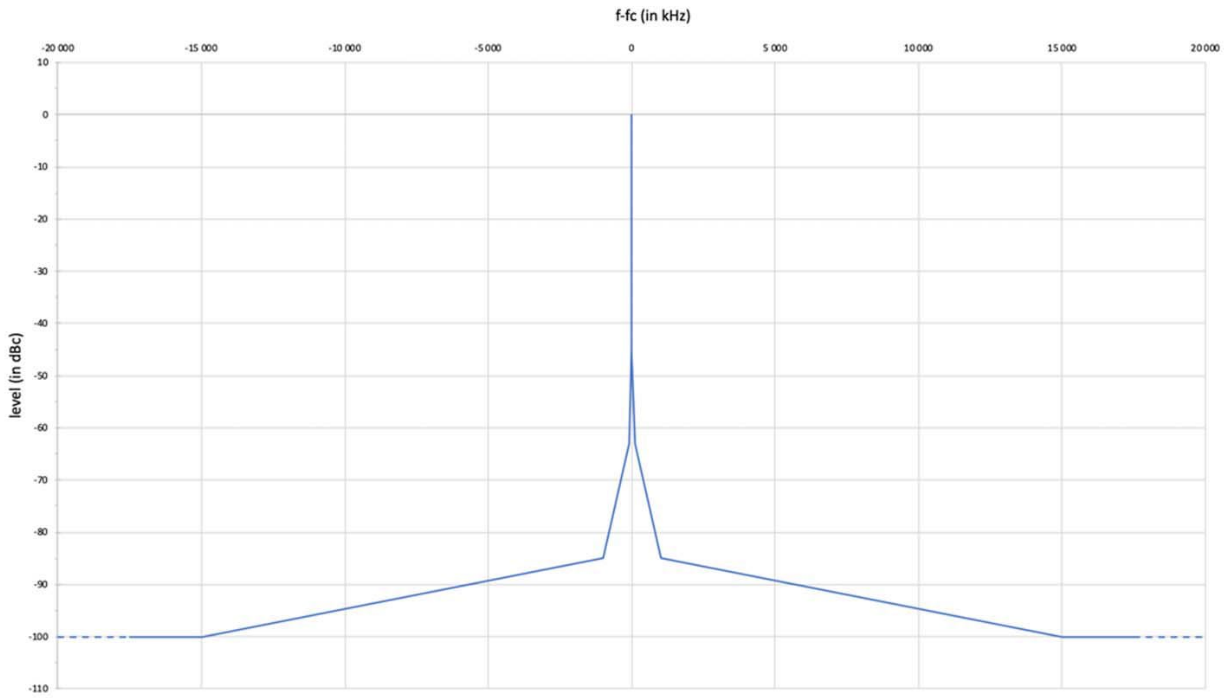

Figure 9: UL emission mask and OOB and spurious emission levels from ETSI TR 103 435 [2] (Reference bandwidth =250 Hz)

Table 13: UL transmission mask values for LPWAN-UNB (Reference bandwidth =250 Hz)

Parameter	Values				
Frequency Offset (kHz)	±0.125	±1	±100	±1000	±15000
Mask (dBc)	0	-45	-63	-85	-85
Ref. Bandwidth (Hz)	250				

b) DL emission mask

DL emission mask provided in ETSI TR 103 435 [2] has been used for this study (see

Figure 10, where it has been compared with ETSI EN 300 220-1 [11] requirements derived for an OCW of 200 kHz).

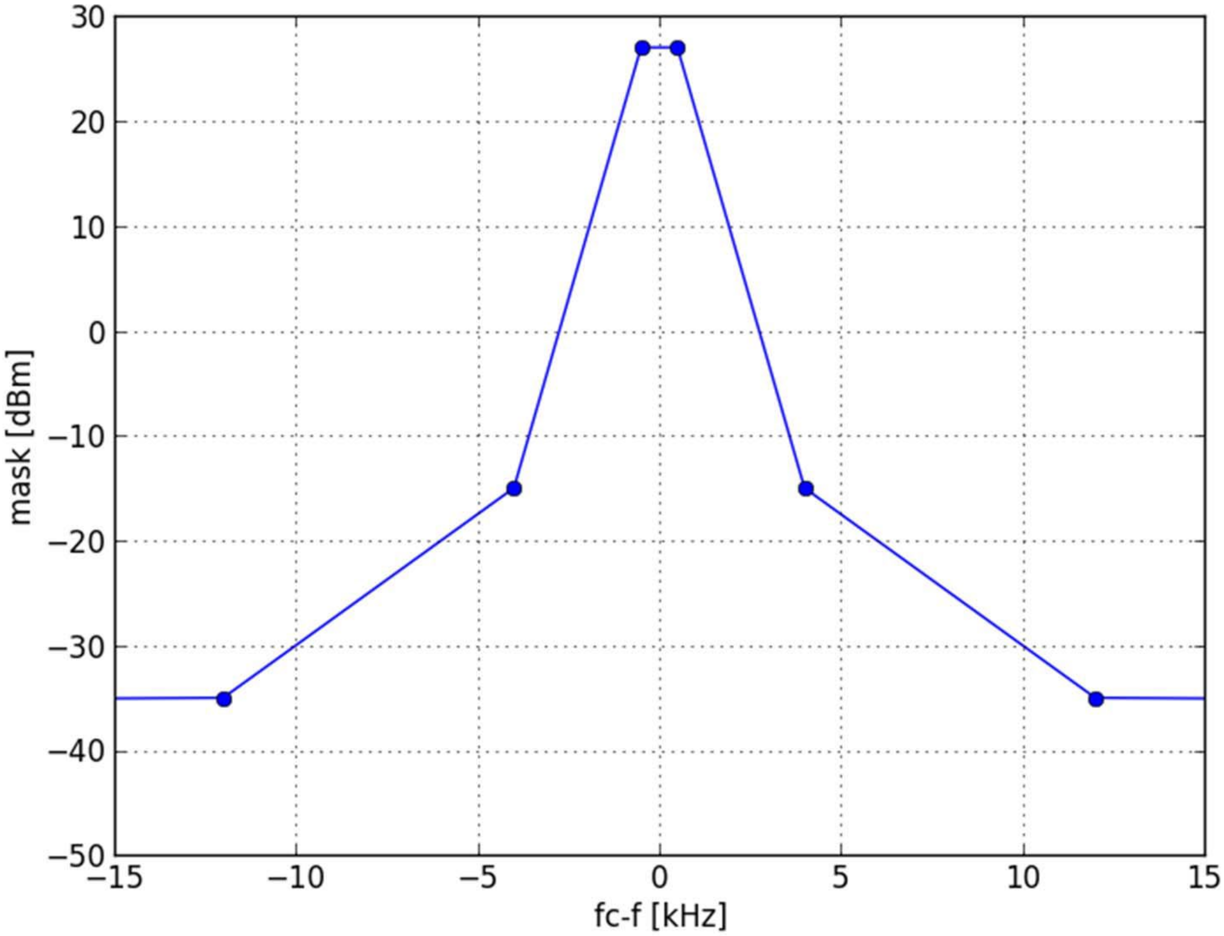

Figure 10: DL emission mask from ETSI TR 103 435 [2] and OOB and spurious emission levels from ETSI EN 300 220-1 (Reference bandwidth =1 kHz)

To study the possible interference towards cellular UL, the OOB band domain and the spurious domain are of interest. The unwanted emission mask is given in Figure 11 and Table 13 with reference to 27 dBm max. power at the antenna connector. For OCW of 200 kHz, TBW/NB of 1 kHz, f_{low} at 916.1 MHz and f_c between 916.1 MHz and 916.3 MHz. The unwanted emission below 915 MHz falling into the cellular band is of main interest in this study.

Table 14: Unwanted emission for LPWAN-UNB NAP with 24 dBm Max. power at the antenna connector and 5 dBi antenna gain. For OCW of 200 kHz and TBW/NB of 1 kHz

Parameter	Values				
Frequency Offset (MHz)	±0.0005	±0.004	±0.012	±1	±20
Mask (dBc)	0	-42	-62	-83	-83
Reference BW (kHz)	1				

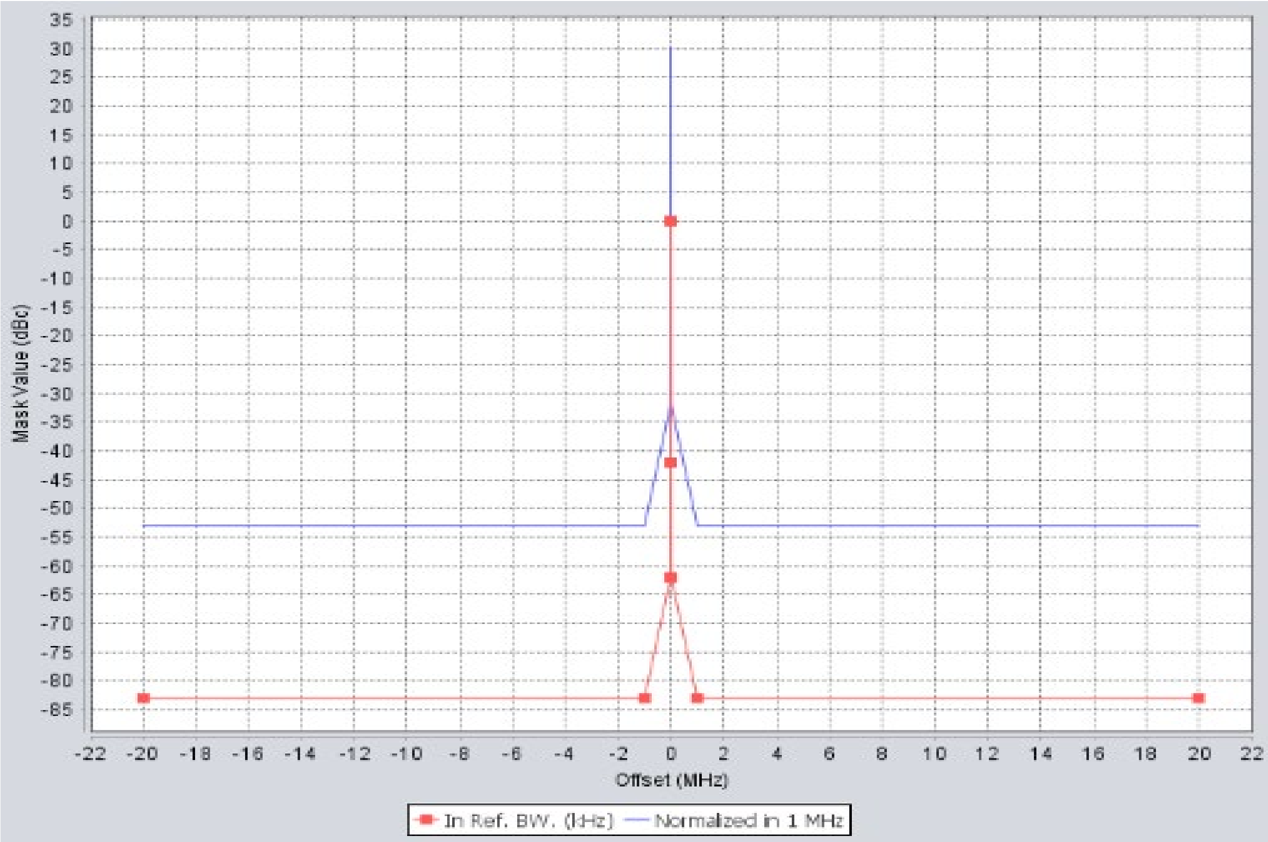

Figure 11: Unwanted emission mask for UNB NAP

3.3.2.3 *ATPC parameters*

For the ATPC configuration in SEAMCAT, the reception parameters mentioned in ECC Report 252, annex 14 [21] (SEAMCAT Handbook) are required.

Table 15: Reception parameters

Parameter	Value	
	TN	NAP
Sensitivity (dBm)	-126	-136
Receiver bandwidth (kHz)	1	0.25

3.3.2.4 Antenna

As mentioned in ETSI TR 103 435 [2], the TNs use omnidirectional antennas with a gain of 0 dBi. The NAPs also use omnidirectional antennas with a maximum gain up to 5 dBi.

3.3.2.5 Deployment

LPWAN-UNB systems have a star topology which consists of TNs and NAPs. The network itself is made of NAPs and a service centre, which connects the LPWAN-UNB system to the internet and/or application servers (see ETSI-TR 103 435 [2]).

The duty cycles considered for LPWAN-UNB shown in Table 15 correspond to the maximum allowed by regulation and to an assumed realistic deployment average.

Table 16: Expected and observed deployment for LPWAN-UNB [30]

Network Element	Max. Density (/km^2)	Average Density (/km^2)	Max. DC%	Average DC%
NAPs	0.1	0.01	10	0.7
Terminals	2000	343	1	0.07

Table 17: Band deployment assumptions for UNB SRDs

Devices	Operating band (MHz)	Proportion of devices (%)
NAP, TN	865-868	25 to 75
NAP, TN	915-919.4	25 to 75

3.3.2.6 Propagation model

The propagation model depends on the environment and antenna heights. The following antenna heights for UNB are considered:

- NAP: 25 m and 7 m;
- TN: 1.5 m.

For urban environment the following two models, as implemented in SEAMCAT, were used

- Extended Hata for Urban above and below roof top. For the min antenna height 1 to 10 m (e.g. TN) and for maximum antenna height below 30 m (e.g. NAP).). SEAMCAT allows to use BS heights lower than 30 m and uses the following factor for this: b(Hb)=min(0, 20log(Hb/30)), see SEAMCAT Handbook, section A17.3.1 [21]. Below roof top conditions are assumed if the Tx and Rx antennas are below 10 metres. Below roof top increases the variation/deviation in the propagation model;
- The Extended Hata SRD is for below roof top only with antenna heights <3 m and max. distance of 300 m (LOS assumption).

From the above and looking in section 3.5 where the maximum distance between the NAP/NN and terminal is estimated for the agreed Rx sensitivity, the following propagation models in SEAMCAT are used for UNB:

- NAP (25 m/7 m) to TN (1.5 m) → Extended Hata for urban above/below rooftop;
- NAP (25 m) to cellular BS (30 m) → Free space as per Recommendation ITU-R P.525 [26];
- NAP (7 m) / TN (1.5 m) to cellular BS (30 m) → Extended Hata for urban above rooftop.

3.3.3 LPWAN-CSS

3.3.3.1 Technology

This section deals with the LPWAN-CSS, it details their characteristics and deployment scheme as considered in the studies.

3.3.3.2 Transmitter parameters

Table 18 presents the transmission parameters of the terminals (TNs) and the NAPs.

Table 18: Transmission parameters for TNs and NAPs

Network Element	TN Tx (indoor)	NAP Tx (outdoor)
ILT transmitter output power (e.r.p.)	Up to 25 mW (with ATPC)-	Up to 500 mW (with ATPC)-
Typical signal bandwidth (single carrier)	125 kHz	125 kHz

For a transmission device powered by up to 500 mW the proposed emission mask is described in Figure 12 whose values are given in Table 19.

Table 19: Transmission mask for LPWAN-SRDs

Parameter	Values				
Frequency Offset (MHz)	±5	±0.5	±0.25	±0.125	±0.0625
Mask (dBc)	-65	-65	-48	-38	0

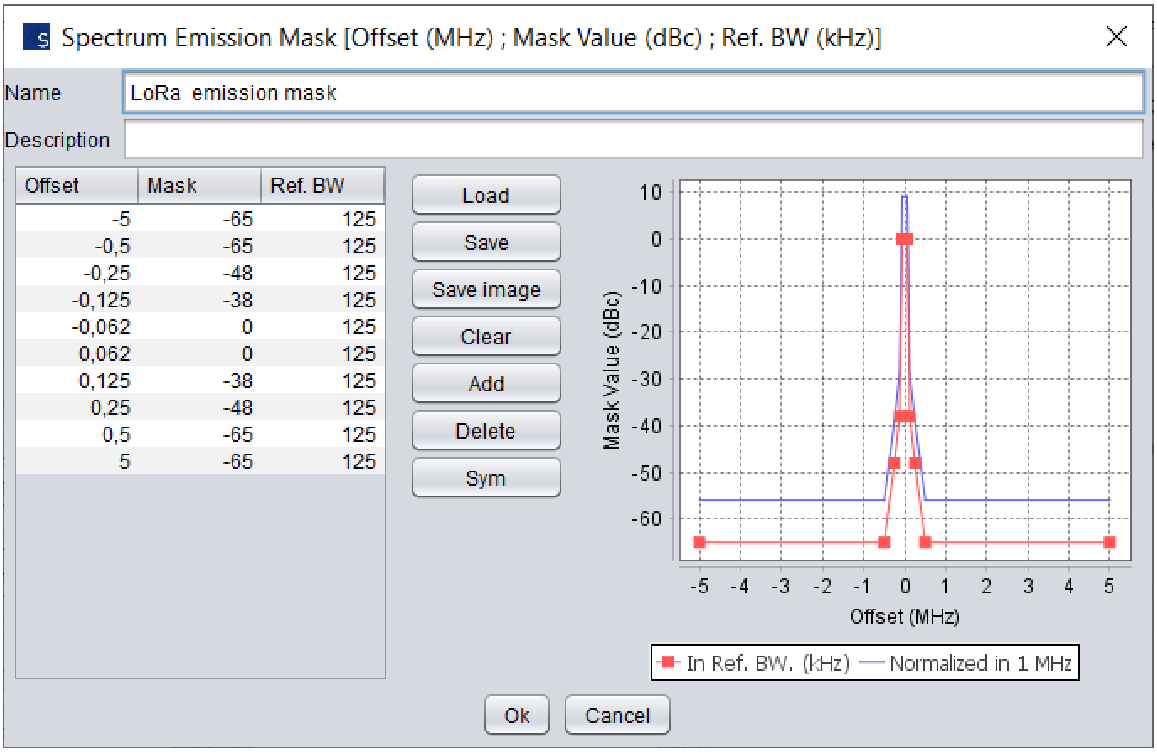

Figure 12: Spectrum emission mask with a 125 kHz measurement bandwidth for LPWAN-CSS (ETSI TR 103 526)

3.3.3.3 ATPC parameters

The sensitivity of CSS SRDs depends on the spreading factor (SF) and ranges from -128 dBm to -141.9 dBm for NAP and from -124 to -137.9 dBm for TN, see ETSI TR 103 526 [1] Section 7.2.4.1. For the study in this Report the TN and NAP sensitivity of -124 and -128 dBm are taken (SF=7), (see section 3.4).

Table 20: Reception parameters

Parameter	Value	
	TN	NAP
Sensitivity (dBm)	-124 to 137.9	-128 to 141.9
Receiver bandwidth (kHz)	125	125
ATPC dynamic range (dB)	14	24
ATPC Threshold (dBm)	-118	-114
Step size	2 dB	3 dB

3.3.3.4 Antenna

The end-device uses an omnidirectional antenna which gain is set to 0 dBi. The gateway uses an omnidirectional antenna with a maximum gain up to 5.5 dBi.

3.3.3.5 Deployment

The LPWAN-CSS system is deployed in a star-of-stars network architecture whereby end-devices are not associated with a specific gateway, but transmit data to multiple gateways within their range with a reception bandwidth of 125 kHz.

Table 21 provides the density and the duty cycle of both the NAPs and the terminals.

Table 21: Excepted and observed deployments for LPWAN-CSS

Equipment	Typical Density	Max. Density	Typical Duty Cycle	Max. Duty Cycle
TN	360/km²	3000/km²	0.007%	0.02%
NAP	0.5/km²	3.5/km²	0.5%	0.7 %

According to the ETSI TR 103 526, figure 7,section 7.2 [1], the DC of TNs depends on the NAP density as shown in Table 22 and Figure 13 below.

Table 22: TN DC as a function of NAP density

NAP density	0	0.5	1	1.5	2	2.5	3	3.5	4
Average time on air (s)	0.24	0.19	0.14	0.1	0.08	0.065	0.06	0.055	0.05
TN DC (%)	0.02	0.0158	0.0117	0.0083	0.0067	0.0054	0.005	0.0046	0.0042

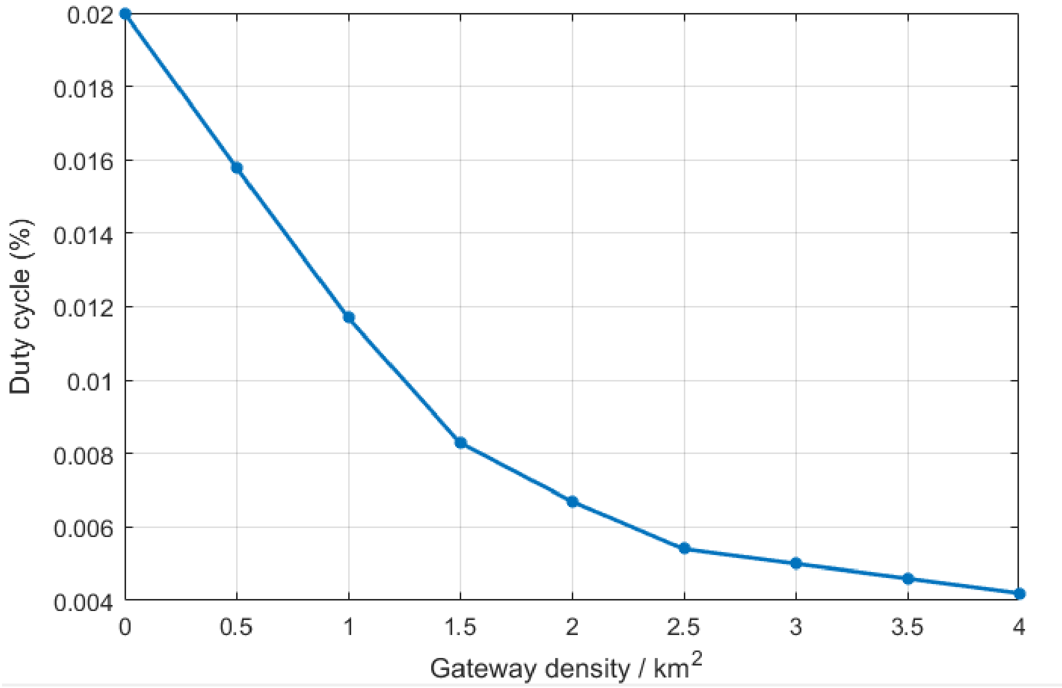

Figure 13: TN DC as a function of NAP density

Table 23: Band deployment assumptions for CSS SRD

Devices	Operating band (MHz)	Proportion of devices (%)
NAP, TN	865-868 MHz	25-75
NAP, TN	915-919.4 MHz	25-75

3.3.3.6 Propagation model

The propagation model depends on the environment and antenna heights. The following antenna height for CSS SRDs are considered:

- NAP: 25 m;
- TN: 1.5 m.

For the urban environment the following two models, as implemented in SEAMCAT, were used:

- Extended Hata for urban above and below rooftop; for the min antenna height 1 to 10 m (e.g. TN) and for maximum antenna height below 30 m (e.g. NAP). SEAMCAT allows to use BS heights lower than 30 m and uses the following factor for this: b(Hb)=min(0, 20log(Hb/30)), see SEAMCAT Handbook, section A17.3.1 [20]. Below rooftop conditions are assumed if the Tx and Rx antennas are below 10 metres. Below rooftop increases the variation/deviation in the propagation model;
- The Extended Hata SRD is for below roof top only with antenna heights lower than 3 m and max distance of 300 m (LOS assumption).

From the above and looking in section 3.5 where the maximum distance between the NAP/NN and terminal is estimated for the agreed Rx sensitivity, the following propagation models in SEAMCAT are used for CSS:

- NAP (25 m) to TN (1.5 m) → Extended Hata for urban above rooftop;
- NAP (25 m) to cellular BS (30 m) → → Free space as per Recommendation ITU-R P.525 [26];
- TN (1.5 m) to cellular BS (30 m) → Extended Hata for urban above rooftop.

3.4 COMPARISON OF SYSTEM PARAMETERS

Table 24 compares some of the most significant parameters among the three systems. These parameters are used in the studies of this Report. The sensitivity depends on the data rate, and in this Report the sensitivity corresponding to the highest data rate is used for the SRD devices.

Table 24: Comparison of the most significant parameters for the three different systems

Parameter	NBN	LPWAN-CSS	LPWAN-UNB
Configuration	Mesh	Star	Star
Components	NAP, NN, TN	NAP, TN	NAP, TN
Maximum transmit power (e.r.p.)	500 mW	UL – 25 mW DL – 500 mW	UL – 25 mW DL – 500 mW
Carrier bandwidth	200 kHz	UL - 125 kHz DL - 125 kHz	UL - 250 Hz DL - 1 kHz
Receiver sensitivity	-95 dBm	TN: -124 dBm NAP: -128 dBm (for a spreading factor of SF=7)	TN: -126 dBm NAP: -136 dBm
Antenna height	TN: 1.5 m NN: 5 m NAP: 7 m	TN: 1.5 m NAP: 25 m	TN: 1.5 m NAP: 25 m
Antenna type and gain	Omni-directional antennas TN: 2.15 dBi NN: 2.15 dBi NAP: 2.15 dBi	Omni-directional antennas TN: 0 dBi NAP: 5.5 dBi	Omni-directional antennas TN: 0 dBi NAP: 5 dBi
ATPC: dynamic range, step size and threshold	20 dB, 2 dB, -89 dBm	NAP: 24 dB, 3 dB, -114 dBm TN: 14 dB, 2 dB, -118 dBm	NAP: 30 dB, 1 dB, -122 dBm

3.5 COVERAGE RADIUS FOR SRD DEVICES

For the simulation, the coverage radius for the SRD devices is required. The coverage radius depends on the maximum and average/typical density as given for NAP NBN/NN, NAP UNB and NAP CSS in this Report. For a given density with uniform distribution over a normalised area in the simulation the cell-radius is r0 = 1/sqrt(3*sqrt(3)/2*Density) and the inter-cell distance is ISD = sqrt(3)* r0 for the NAPs/NNs as indicated in Figure 14. The coverage radii with rDL or rUL are expected to be at least greater or equal to r_0 if coverage is given over the whole area.

Table 25: NAP/NN coverage radius for maximum density

	NAP, NN (NBN)	NAP (UNB)	NAP (CSS)
Maximum density per km^2	10/90	0.1	3.5
ISD in km	0.34/0.113	3.4	0.575
Minimum required distance r_0 in km	0.196/0.065	1.96	0.332

Table 26: NAP/NN coverage radius for average density

	NAP, NN (NBN)	NAP (UNB)	NAP (CSS)
Average density per km^2	5/45	0.01	0.5
ISD in km	0.48/0.16	10.75	1.52
Minimum required distance r_0 in km	0.28/0.092	6.2	0.88

The coverage radius is typically the radius of the circle centred at the transmitter, where the received useful signal is higher than the sensitivity of the receiver. This coverage radius determines the area beyond which the receiver cannot produce an output signal with a specific signal-to-noise (S/N) ratio. Hence, its dependence on the maximum pathloss, the sensitivity allowing a specific data-rate, the antenna height. Although it can be observed that the density of the NAP/NN and TN differs by several magnitudes (see for CSS Table 21, UNB Table 16, NBN Table 10).

Table 27: Maximum path loss for receiver sensitivity at high data rates

	NAP/NN/TN NBN	NAP/TN UNB	NAP/TN CSS
Maximum pathloss in DL, dB	126	155	153
Maximum pathloss in UL, dB	126	157	150
NBN: see also ETSI TR 102 886 [4], section B.4.2 [4] on typical operating range for Smart Meter case UNB: see also ETSI TR 103 435 [2] , Chapter 7 Technical information, for single carrier in DL CSS: see also ETSI TR 103 526 [1], section 7.2.4			

In Table 28 the path loss was estimated by using SEAMCAT for an Extended Hata and Extended Hata SRD model for urban environment, below roof, outdoor-to-outdoor and outdoor-to-indoor (with slow-fading, wall loss 20 dB, σ = 5 dB) and taken for CDF at 84% (corresponding to mean + standard deviation). While the extended Hata model assumes that the higher antenna is between 30 and 200 m, the extended Hata SRD model attempts to overcome this constraint by allowing an antenna height lower than 3 m and LOS distances less than 0.3 km. For the calculation in this section, the following assumptions are considered:

- NBN with NAP: 7 m (outdoor), NN 5 m (outdoor) and TN 1.5 m (indoor);
- UNB with NAP: 7 m or 25 m (outdoor) and TN 1.5 m (indoor);
- CSS with NAP: 25 m (outdoor) and TN 1.5 m (indoor).

The four cases below can cover the SRD scenarios.

Table 28: Estimated path loss using in SEAMCAT the Extended Hata and Extended Hata SRD propagation models

	0.1 km	0.2 km	0.3 km	0.5 km	1 km	2 km
NAP (7 m, outdoor) to NN (5 m, outdoor) Extended Hata for urban below rooftop, dB	112	122	127	131	139	150
NN (5 m, outdoor) to TN (1.5 m, indoor) Extended Hata SRD for urban below rooftop, dB	120	130	135	-	-	-
NAP (7 m, outdoor) to TN (1.5 m, indoor) Extended Hata for urban below rooftop, dB	141	153	157	161	169	180
NAP (25 m, outdoor) to TN (1.5 m, indoor) Extended Hata for urban above rooftop, dB	127	137	141	148	159	170

For the coverage radius considering Table 25 to Table 28 (e.i.r.p., sensitivity/data-rate and pathloss), the following coverage radii are considered:

Table 29: Estimated cell radii for NBN, UNB and CSS

Max.Maximum cell radius
▪ NBN: NAP (7 m, outdoor) ↔ NN (5 m, outdoor) with up to 0.25 km ▪ NBN: NN (5 m, outdoor) ↔ TN (1.5 m, indoor) with up to 0.15 km ▪ UNB: NAP (7 m, outdoor) ↔ TN (1.5 m, indoor) with up to 0.3 km For this case the NAP density should be much higher than the one given in Table 10 ▪ UNB: NAP (25 m, outdoor) ↔ TN (1.5 m, indoor) with up to 1 km ▪ CSS: NAP (25 m, outdoor) ↔ TN (1.5 m, indoor) with up to 1 km

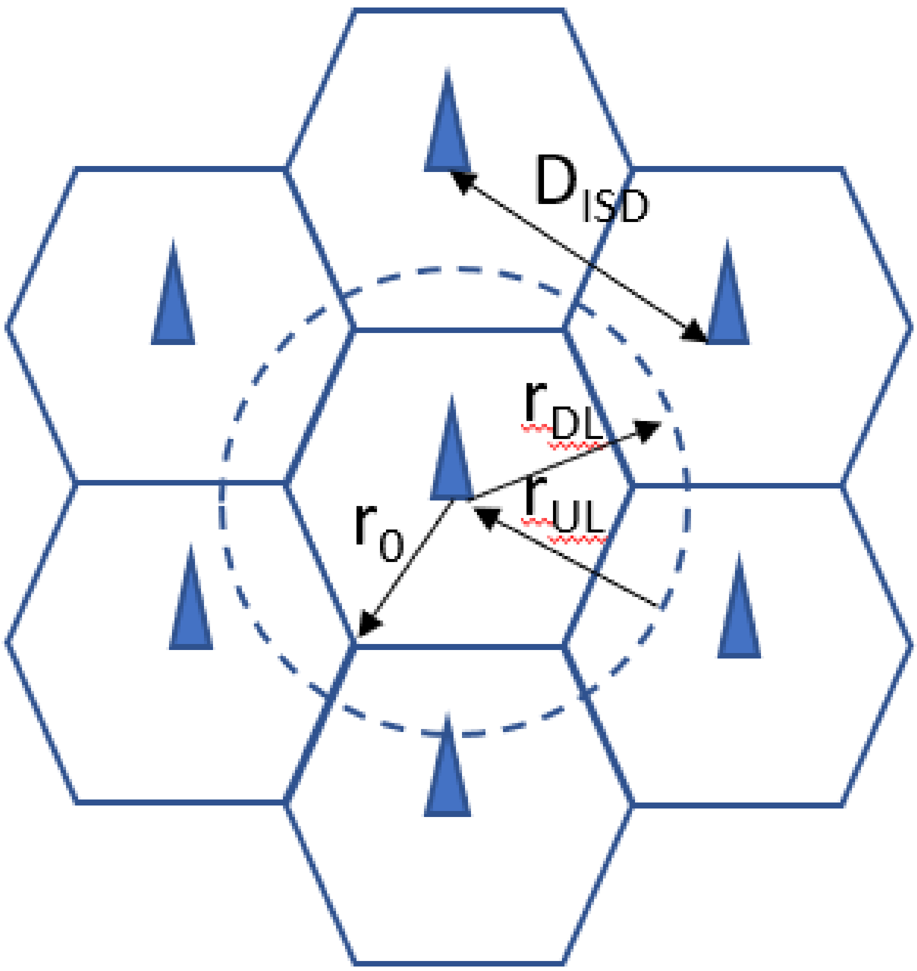

Figure 14: NAP/NN density and expected coverage radius

4 THE UNWANTED EMISSIONS FROM SHORT RANGE DEVICES

In this Report, various studies were performed examining the impact of duty cycle and device density on the compatibility of different networked SRD technologies on cellular systems operating below 915 MHz to evaluate the maximum unwanted emission level for which the increase in average throughput loss in the reference cellular UL will be below 5%. The spurious emission levels of -36 dBm/100 kHz, consistent with ERC Recommendation 74-01 [8], was assumed. Furthermore, as an additional scenario, a further constraint on the envelope of the SRD OOB mask at a level of --19 to -32 /5 MHz e.r.p. for the unwanted emission over the 5 MHz BW of the victim's passband was considered for below 915 MHz.

The spurious emission limits for narrowband systems defined by regulation may exceed those corresponding to the actual unwanted emission for such narrowband devices. ECC Recommendation (19)02 [9] gives guidelines of how to conduct co-existence studies assuming different spurious emission levels if measurement results for such SRD devices are supplied. However, no measurement results were provided in this study for the different SRD devices (NBN, CSS and UNB) operating in the 900 MHz band as this material is not available, but ECC Report 249 [10] shows for various other systems, e.g. DVB-T, DECT, LTE at 800 MHz, etc., such example measurement results.

5 STUDY OF IMPACT ON CELLULAR 880-915 MHZ BAND IN THE UPLINK

5.1 PRINCIPLE OF THE COEXISTENCE STUDY WITH LTE

It is proposed to consider the deployment of the NBN devices between the harmonised 874-874.4 MHz band and respectively the #2 or #3 RFID channels (400 kHz) in the 915-919.4 MHz band. The NBN devices will be spectrally uniformly distributed, with a constant spectral distribution (number of devices/MHz), by having 25% of density per channel considering that the configuration of the 4 channels of 400 kHz offer the capacity for a complete deployment for data network SRD as the three channels only 75%.

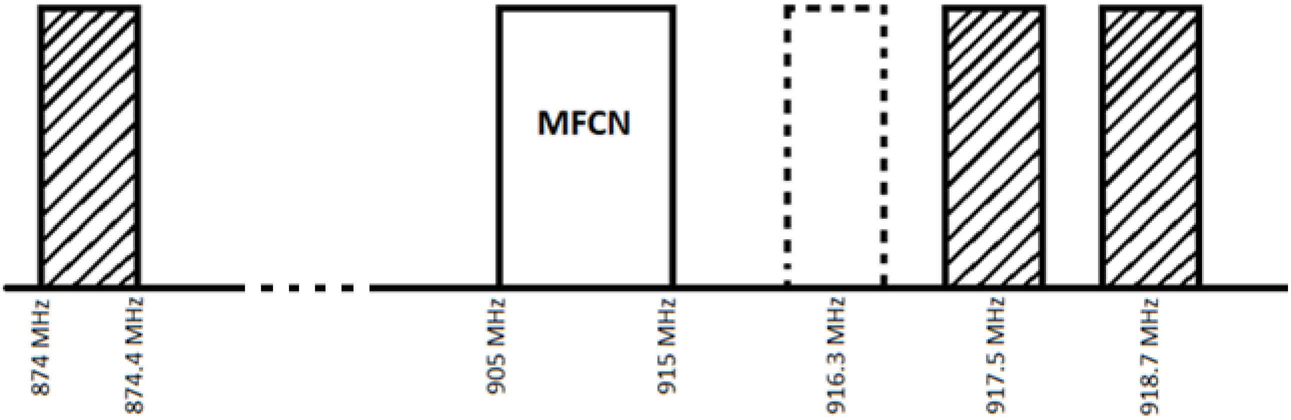

Figure 15: Spectral configuration for the coexistence studies

DC is a parameter that can be considered as .set in a harmonised standard contrary to deployment parameters (antenna height, number and type of devices per km²etc,) and it is then proposed to conduct the following steps.

After, distributing 25% maximum density per channel (#2 and the #3 RFID channels), the remaining 25% of devices into the first RFID channel will be assessed under maximum density assumptions, to determine the DC threshold to be applied to the 1st RFID channel that ensures LTE to be free from harmful interference. Alternative options may also need to be considered such us the reduction of the maximum transmission power in the 1st RFID channel:

- Both the maximum and the average density can be considered in the simulations. For the average density case (i.e. more permissive DC), it should be made explicit that with the identified DC value, interferences to MFCN may happen in areas where the deployment density exceeds the average density.

The portion of density per channel has to be determined so to have a constant spectral distribution (number of devices/MHz). The interference on the LTE from each technology is considered independently.

6 CONCLUSIONS

This ECC Report considers the deployment of high-power Short Range Devices (SRDs) of three technologies: Narrowband Networked SRD (NBN), Ultra narrowband (UNB) and Chirped Spread Spectrum (CSS) in the first RFID interrogator channel at 916.3 MHz within the frequency band 915-919.4 MHz.

Two sets of SEAMCAT simulations were developed: Each of the three technologies was considered separately in the studies. The interference criterion used for LTE operating below 915 MHz was a 5% of the increase of the average bitrate loss for the reference base station. The details of the two studies are provided below:

6.1 FIRST STUDY

The first SEAMCAT study considered the first RFID channel at 916.3 MHz together with the contribution from the already available RFID channels at 917.5 MHz and 918.7 MHz. Two scenarios are explored: blocking only of the Mobile/Fixed Communication Network (MFCN) victim receiver and blocking + in-band interference (corresponding to the spurious emissions from the interferers). Attempts to compensate the summation of the spurious emissions are described in section 4. This study also includes blocking and/or in-band interference from devices deployed in the RFID channels two and three. Various levels of duty-cycle (DC) were simulated for NAP and NN in channel #1.

The results of that study are summarised in Table 30, Table 31, Table 32 and Table 33 below.

In Table 30, the high-power Short Range Devices (SRDs) were simulated with a deployment density set as 25% of the maximum density[3] per RFID channel. The DC is set to the maximum allowed value for high-power SRDs in the two RFID channels in the middle of the band and for 25 mW terminals between RFID channels.

Table 30: Three RFID Channels used for high-power SRDs (max. density)

Duty cycle for high-power SRD in the 2nd and 3rd RFID channels		Max. Duty Cycle						
Duty cycle for 25 mW SRDs		Max. Duty Cycle						
Duty cycle for high-power SRDs in the 1st RFID channel		0% Max. DC	10% Max. DC	20% Max. DC	40% Max. DC	60% Max. DC	80% Max. DC	Max. DC
NBN	Blocking only	4.9	6.1	6.4	7.8	8.2	9.4	9.9
	Blocking + spurious[4]	13.2	14.9	15.3	16.4	19.4	20	21
CSS	Blocking only	4.2	4.5	4.7	4.9	5.1	5.3	5.6
	Blocking + spurious	6.8	6.9	7.1	7.3	7.7	8.2	8.5
UNB	Blocking only	1.2	1.22	1.3	1.36	1.4	1.5	1.6
	Blocking + spurious	19.2	19.8	20.2	20.5	20.9	21.1	21.3

In Table 31, the DC is also set to the maximum allowed value for high-power Short Range Devices (SRDs) in the two RFID channels in the middle of the band, but this time the 25 mW terminals between RFID channels have been simulated with a DC identical to the DC for high-power SRDs in the first RFID channel. This alleviates the effect of 25 mW terminals that are already allowed.

[3] Maximum density as documented by ETSI and/or by the stakeholders

[4] In all those tables, spurious emissions are simulated with -36 dBm/100 kHz and without spurious aggregation as described in ANNEX 3

Table 31: Three RFID Channels used for high-power SRDs (Maximum density)

Duty cycle for high-power SRD in the 2nd and 3rd RFID channels		.Maximum Duty Cycle					
Duty cycle for high-power SRDs in the 1st RFID channel and 25 mW SRDs		10% max	20% max	40% max	60% max	80% max	Max
NBN	Blocking	6.1	6.4	7.8	8.2	9.4	9.9
	Blocking + spurious	14.9	15.3	16.4	19.4	20	21
CSS	Blocking	2.5	3	3.6	4.9	5.1	5.6
	Blocking + spurious	3.9	4.2	5.4	6.4	7.4	8.5
UNB	Blocking	0.3	0.4	0.72	1.1	1.3	1.6
	Blocking + spurious	3.6	4.9	8.9	12.8	16	21.3

In Table 31, the densities described as “typical” by industry stakeholders have been considered for both the terminals and the high-power SRDs with a distribution of 25% of the typical density per RFID channel. The DC is set to the maximum allowed value for high-power SRDs in the two RFID channels in the middle of the band and for 25 mW terminals between RFID channels.

Table 32: 3 RFID Channels used for high-power SRDs (typical density)

Duty cycle for high-power SRD in the 2nd and 3rd RFID channels		Max. Duty Cycle						
Duty cycle for 25 mW SRDs		Max. Duty Cycle						
Duty cycle for high-power SRDs in the 1st RFID channel		0% Max. DC	10% Max. DC	20% Max. DC	40% Max. DC	60% Max. DC	80% Max. DC	Max. DC
NBN	Blocking only	2.7	2.9	3.4	3.7	4.2	4.7	5.1
	Blocking + spurious	7.8	8.1	8.3	8.9	9.6	10.5	11.1
CSS	Blocking only	0.5	0.6	0.69	0.74	0.8	1	1.2
	Blocking + spurious	1.4	1.7	1.8	1.9	2.1	2.3	2.4
UNB	Blocking only	0.16	0.23	0.27	0.3	0.33	0.4	0.42
	Blocking + spurious	4	4.4	4.47	4.52	4.59	4.65	4.7

In Table 32, the typical densities have been considered for both the terminals and the high-power SRDs. However, the DC is set equally in the three RFID channels and also for 25 mwW terminals between RFID channels.

Table 33: 3 RFID Channels used for high-power SRDs (typical density)

Duty cycle for high-power SRDs in the RFID channels and TN		10% Max. DC	20% Max. DC	40% Max. DC	60% Max. DC	80% Max. DC	Max. DC
NBN	Blocking only	0.6	1.2	2	2.9	4	5.1
	Blocking + spurious	1.2	2.3	4.7	6.7	9.3	11.1
CSS	Blocking only	0.08	0.1	0.4	0.5	0.7	1.2

Duty cycle for high-power SRDs in the RFID channels and TN		10% Max. DC	20% Max. DC	40% Max. DC	60% Max. DC	80% Max. DC	Max. DC
	Blocking + spurious	0.2	0.5	0.8	1.6	1.8	2.4
UNB	Blocking only	0.05	0.08	0.1	0.15	0.18	0.42
UNB	Blocking + spurious	0.8	0.9	1.7	2.8	3.2	4.7

That study found that for typical deployment, the average bitrate loss (reference cell) lay between two simulations assumptions: if blocking only was considered, the average bitrate loss is just below the threshold limit acceptable by LTE BS; if the full -36 dBm/100 kHz emissions in the spurious domain were assumed, then the bitrate loss were found to be below the threshold limit when the DC of all the devices (NAP, NN and TN) is below 40% of maximum DC.

The following table summarises those results and shows the DC applicable to the first RFID channel in order to achieve a throughput loss below 5% on a victim MFCN channel below 915 MHz (if such a value exists, otherwise “None”). The DC is expressed in % of the maximum DC already allowed in RFID channels #2 and #3. i.e., 10%, 2.5% and 1% respectively for the NAP, NN and TN).

Table 34: Summary of results

	Maximum density		Typical density	
NAP & NN DC on channels #2 and #3	DCref (note 1)			Fraction of DCref (note 2)
TN DC	1%	Fraction of TN DCref (note 2)	1%	
NBN (blocking only)	None	None	100% of DCref	100% of DCref
NBN (blocking + spurious)	None	None	None	40% of DCref
CSS (blocking only)	50% of DCref	70% of DCref	100% of DCref	100% of DCref
CSS (blocking + spurious)	None	30% of DCref	100% of DCref	100% of DCref
UNB (blocking only)	100% of DCref	100% of DCref	100% of DCref	100% of DCref
UNB (blocking + spurious)	None	20% of DCref	100% of DCref	100% of DCref

Note: "100% of DCref" means with the DCref, the increase average bitrate loss is below 5%, the "None" means the average bitrate loss is above 5 %. The "x% of DCref" means the DC limit allows being below the 5% of average bitrate loss when the DC on channel #1 is adjusted accordingly.

Note 1 : “DCref” is the maximum DC already allowed in channels #2 and #3, i.e. NAP: 10%, NN: 2.5%, TN: 1%
Note 2 : "fraction of DCref" means same fraction of DCref as the fraction of NAP DCref used for NAP in channel #1

For typical densities, when only receiver blocking is considered, the average bitrate loss of LTE is below the threshold limit acceptable by LTE BS. Although, when taking into account the spurious level of -36 dBm/100 kHz, some technologies could be deployed with their maximum DC without additional constraints, whereas others may exceed the acceptable threshold. Even in those latter cases, the impact on LTE might be tolerable, recognizing that the real interference impact is expected to be between the value for blocking only and the value with the addition of unwanted emissions when limiting spurious emissions only to transient aspect of spikes.

6.2 SECOND STUDY

The second SEAMCAT study considered alone the first RFID channel at 916.3 MHz with continuous levels of spurious emissions varying from -36 dBm/100 kHz down to -46 dBm/100 kHz. Maximum and typical deployment densities were considered for each technology. Automatic Power Control (APC) was also assumed using realistic parameters.

The second study, found that:

- Modelling the spurious emissions (not considering blocking effect) as if they were a level of 10 dB more stringent than the applicable regulatory maximum (-36 dBm/100 kHz), interference causing an increase in average bitrate loss larger than 5% was avoided. Therefore, considering an additional restriction of -29 dBm e.r.p. on aggregate emissions into the victim's 5 MHz receiver, the interference threshold was not overstepped;
- Reducing the assumed DC for each element of each technology combined with a more relaxed aggregate limit of unwanted emissions below 915 MHz showed that it was possible to determine the points at which the interference threshold is overstepped. The results are summarised in Figure 16.

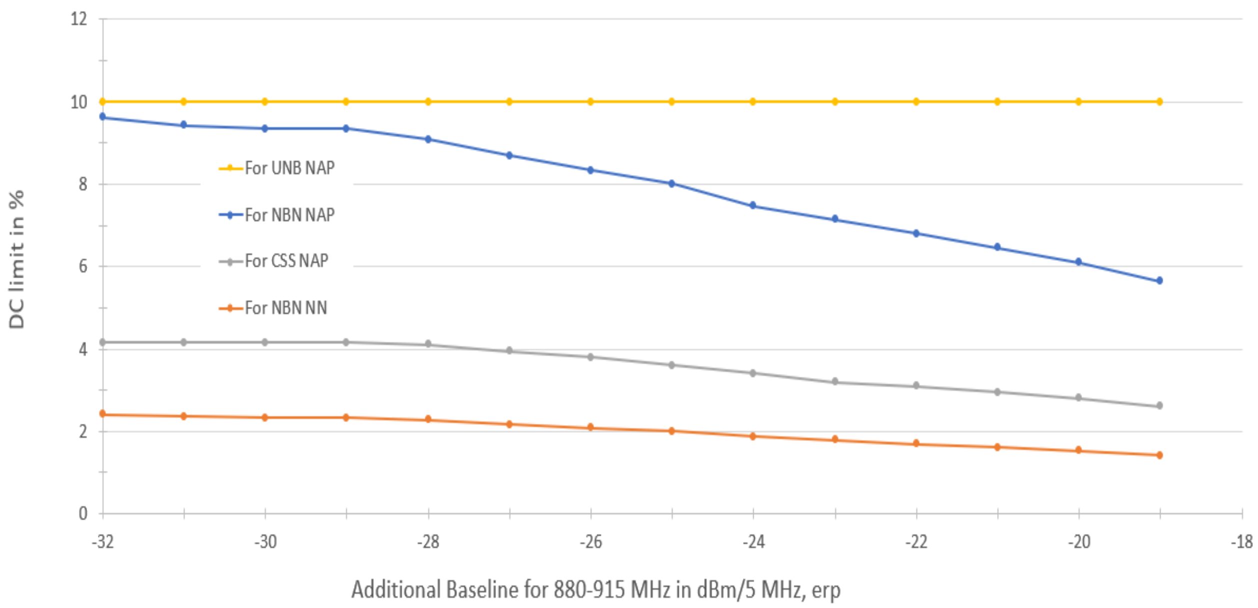

Figure 16: DC limits corresponding to various levels of unwanted emission, for an average bitrate loss below 5% on the victim MFCN

The results in the Figure 16 might be interpreted in various ways in order to avoid overstepping the interference threshold, but two examples might be:

- Considering an additional baseline of -19 dBm/5 MHz e.r.p. combined with a DC limited to 2.6% for CSS NAP and 5.7% for NBN NAP and to 1.4% for NN NBN would be necessary, and no DC reduction needed for UNB NAP;
- Considering an additional baseline of -25 dBm e.r.p. into the victim's 5 MHz receiver, combined with a DC limited to 3.6% for CSS NAP and 8% for NBN NAP and to 2% for NN NBN would be necessary, and no DC reduction needed for UNB NAP
- The -36 dBm/100 kHz general spurious emission limit still applies.

For additional baseline less than about -28 dBm/5 MHz e.r.p., the blocking effect is dominant. Therefore, additional reductions do not bring further improvements on interference.

6.3 GENERAL CONSIDERATIONS

In both studies, simulations assume uniform/constant spurious emissions. However, spurious emissions in real life can encompass not only uniform/constant emissions (such as harmonics) but also transient/rare emissions. Measurements on real equipment could not be provided but it is anticipated that the dominant interference in the field would come from transient aspects of emissions, and therefore the effect from spurious emissions may have been overestimated in the simulations.

From all those results, it can be concluded that the impact of new opportunities in the first RFID channel depends significantly on the deployment scenarios and other assumptions (e.g. with regards to the impact of spurious emissions and deployment density).

ANNEX 1: CHARACTERISTICS OF IMT LTE

The tables below consider the IMT/LTE parameters for co-existence simulations.

Table 35: LTE frequency bands

Frequency Band	Parameters	Units	Value	Reference
900 MHz (FDD)	Uplink band	MHz	880-915	3GPP Band 8 (TS 36.104, table 5.5-1 [18])
	Downlink band	MHz	925-960	

Table 36: The technical parameters of the LTE system

	Para-meters	Units	Base Station (BS)	Reference	Mobile Station (MS)	Reference
Transmitter settings	Maximum transmit power to the antenna input.	dBm	Macro: 43 dBm for 5 MHz channel and 46 dBm for 10 MHz channel Micro: 38 dBm Pico: 24 dBm Home BS: 20 dBm Note 3-1	3GPP TS 36.104, table 6.2-1 [18]	23 Note 3-2	3GPP TS 36.101, table 6.2.2-1) [15]
Local environments - Transmitters	Percentage of transmitters located outdoors	%	Scenario dependant		Scenario dependant Urban: 30%	Report ITU-R M.2292 [6]
	Percentage of transmitters located indoors	%	Scenario dependant		Scenario dependant Urban: 70%	Report ITU-R M.2292
	Parameters	Units	Value		Reference	
	Wall loss (indoor-outdoor) Note 3-3	dB	Rural: 10 Suburban: 15 Urban: 20 Note 3-4			
	Wall loss standard deviation (indoor-outdoor) Note 3-3	dB	5 Note 3-5			
OFDMA UL specific settings for PC	Maximum/Minimum transmit power of MS	dBm	23 / -40		3GPP TS 36.101, table 6.2.2-1 [15]	
	Power scaling threshold		0.9			
	Balancing factor (Gamma)		1 (set 1) 0.8 (set 2) Use set 2 value as default		3GPP TR 36.942 [27]	

	Para-meters	Unit s	Base Station (BS)	Reference	Mobile Station (MS)	Reference
	Coupling loss percentile (CLx-ile/PLx-ile))	dBm	10 MHz bandwidth: 112 (set 1) 129 (set 2) 5 MHz bandwidth: 115 (set 1) 133 (set 2 as default)		3GPP TR 36.942 [27]	
Note 3-1: 46 dBm is the default value for Macro BS in SEAMCAT for this parameter Note 3-2: 24 dBm is the default value in SEAMCAT for this parameter Note 3-3: Wall loss (indoor-indoor) and its standard deviation is dealt with in Table 8 (propagation model) Note 3-4: 10 dB is the default value in SEAMCAT for this parameter Note 3-5: 5 dB is the default value in SEAMCAT for this parameter						

Table 37: SEAMCAT panel

	Parameters	Units	Base Station (BS)	Reference	Mobile Station (MS)	Reference
Receiver Settings	Receiver noise figure	dB	Macro: 5 Micro: 10 Pico: 13 Note 6-1	Report ITU-R M.2292 [6]	9	Report ITU-R M.2292
	Standard desensitisation	dB	6		6	
	Target I/N	dB	-6		-6	
Local environments - Receivers	Percentage of receivers located outdoors	%	Scenario dependant		Scenario dependant Urban: 30%	Report ITU-R M.2292
	Percentage of receivers located indoors	%	Scenario dependant		Scenario dependant Urban: 70%	Report ITU-R M.2292
	Parameters	Units	Value		Reference	
	Wall loss (indoor-outdoor)	dB	See Table 40		See Table 40	
	Wall loss standard deviation (indoor-outdoor)	dB	See Table 40		See Table 40	
Note 6-1: 5 dB is the default value in SEAMCAT for this parameter.						

Table 38: LTE BS Antenna characteristics

Environment	Parameters	Units	Base Station (BS)
Urban	Antenna height	M	30
	Antenna pattern	N/A	Recommendation ITU-R F.1336-4 [22]

Environment	Parameters	Units	Base Station (BS)
			Note 7-1
	Antenna peak gain (including feeder loss)	dBi	15
	Antenna tilt	Degrees	-10…-6 Use -6 as default
Suburban	Antenna height	M	30
	Antenna pattern	N/A	Recommendation ITU-R F.1336-4 [22] Note 7-1
	Antenna peak gain (including feeder loss)	dBi	16
	Antenna tilt	degrees	-6…-3 Use -3 as default
Rural	Antenna height	M	45
	Antenna pattern	N/A	Recommendation ITU-R F.1336-4 [22] Note 7-1
	Antenna peak gain (including feeder loss)	dBi	18
	Antenna tilt	degrees	-3…-1 Use -1 as default
Note 7-1: Using kh = 0.7, kv = 0.3 and kp/ka = 0.7.			

Table 39: LTE MS Antenna characteristics

Parameters	Units	Mobile Station (MS)	Reference
Antenna height	m	1.5	
Antenna pattern		Omni	
Antenna peak gain (including feeder loss)	dBi	-3	Report ITU-R M.2292 [6]
Body Loss	dB	4	Report ITU-R M.2292 [6]

ANNEX 2: COMPARISON BETWEEN LTE PARAMETERS USED IN ECC REPORT 246 AND ECC REPORT 261 AND THOSE IN ANNEX 1

Comparison between SEAMCAT parameters used in ECC Report 246 [13] and ECC Report 261 [14], SEAMCAT five default parameters and parameters in ANNEX 1 to be used in studies.

Table 40: Comparison between different LTE parameters

Parameters	Used in ECC Report 246 and ECC Report 261 (for information)	SEAMCAT 5 default parameters	Parameters in ANNEX 1:
GENERAL SETTINGS			
Max. RB (subcarriers) per BS	48	50	50
Max RB (subcarriers) per MS (Displayed as « Number of RB per MS » in SEAMCAT 5	16	17	17
Handover margin	3	3	3
Minimum coupling loss	70	70	70 (urban/suburban)
System bandwidth	9	10	10
Receiver Noise figure (dB)	5	5	5 (Macro cell)
Resource block bandwidth (Displayed as “Bandwidth of a RB”) in SEAMCAT 5	180	180	180
Receiver blocking attenuation (ACS)	Different from the one used in version 5.		
Standard desensitisation	8	6	6
Target I/N	1	-6	-6
Local environments	No Indoor/outdoor apportionment in SEAMCAT 4	BS: 100% outdoor UE: 70% indoor Wall Loss: 20 dB, standard deviation: deviation:5 dB	70% indoor – 30% outdoor Wall loss: 20 dB urban Wall loss standard deviation: 5 dB
Emission mask	In these Reports, the emission mask is not mentioned		Library mask LTE UE below 1000 MHz
Maximum transmit power to the antenna input. (Displayed as “Max. allowed transmit power of MS”) in SEAMCAT 5	23	23	23
Minimum transmit power of MS	-40	-40	-40

Parameters		Used in ECC Report 246 and ECC Report 261 (for information)	SEAMCAT 5 default parameters	Parameters in ANNEX 1:
Power scaling threshold		0.99	0.9	0.9
Balancing factor		1	0.8	1
Coupling loss percentile		130	129	
OFDMA Capacity -		30	3	DL: 1 UE UL, up to 15 MHz channel bandwidth: 3 UEs UL, 20 MHz channel bandwidth: 6 UEs
Propagation model		Extended Hata	Extended Hata	Extended Hata
	Wall loss indoor-indoor		5	5
	Wall loss std deviation indoor-indoor		10	10
	Loss between adjacent floor		18.3	18.3
	Empirical parameter		0.46	0.46
	Size of the room		4	4
	Height of each floor		3	3
POSITIONING				
Cell layout		2 tiers – 3GPP	2 tiers – 3GPP	2 tiers – 3GPP
Cell radius		0.47 km	1 km	Report ITU-R M 2292 [6], table 2 0.5-5 km (typical 2 km) for macro urban/suburban scenario
System layout		Centre of infinite network – Generate wrap around	Centre of infinite network – No Generate wrap around	Centre of infinite network – Generate wrap around
Mobile antenna height		1.5	1.5	1.5
Mobile antenna gain		0	-7	-3
Body Loss (dB)				4
Base Station antenna height		30	30	30
Base station antenna tilt		-6	-6	-6
Base station antenna peak gain		15	18	18

Parameters	Used in ECC Report 246 and ECC Report 261 (for information)	SEAMCAT 5 default parameters	Parameters in ANNEX 1:
BS antenna pattern	Default Tri-Sector Antenna 3GPP 3 sector Horizontal and Vertical	ITU-R F.1336-4 [22] Note 7-1	ITU-R F.1336-4 [22] Note 7-1 with ka=kp=kh=0.7 and kv=0.3

Table 41: Additional configurations

Parameters	Value	Used in this Report
Cellular grid	Single-cell, 1-tier, 2-tiers tri-sectors 3GPP	Depending on network loading factor as defined in row below
Network loading	For interference studies with 1-tier and 2-tier cellular networks the loading of the network has to be considered as otherwise the results may not reflect realistic network behaviour. The activity factor as given in Report ITU-R M.2292 [6] may be used for randomly selecting x% of BS to randomly transmit or receive.	x = 50%

ANNEX 3: STUDIES

A3.1 STUDY #1

The spurious limit as defined by ERC Recommendation 74-01 [8] covers emission peaks that could be transient. When doing simulations in this study, those emissions, the peaks of the different Short Range Devices (SRDs), have not been aggregated.

In this study, the aggregated interference level in the spurious domain is calculated by adding contributions from all active devices (assuming Max. spurious level per device as given in ERC Recommendation 74-01) and subtracting a value corresponding to 10log10(Number of active devices).

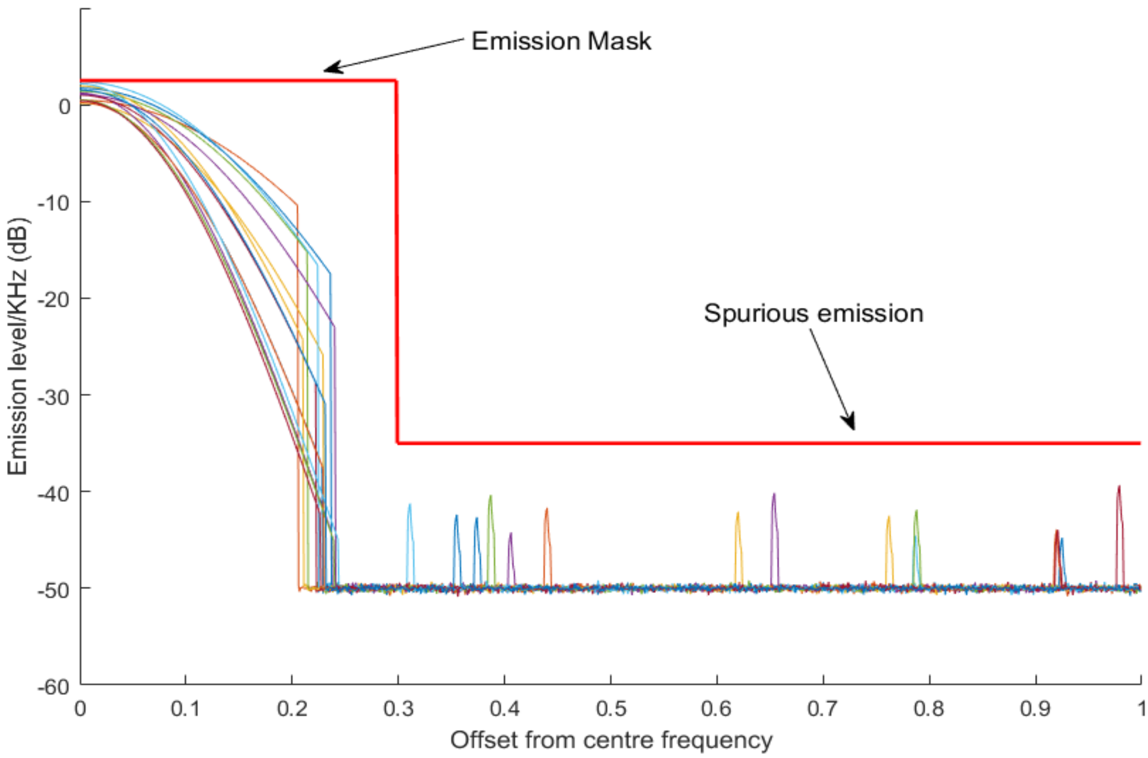

Figure 17

In this study, the aggregated interference level in the spurious domain is calculated by adding contributions from all active devices (assuming max. spurious level per device) and subtracting a value corresponding to 10log10(Number of active devices). The first study is on the co-existence between each of the three technologies NBN, LPWAN-CSS and LPWAN-UNB and LTE base stations below 915 MHz, in accordance with the agreed approach which is to determine the DC max. of 500 mW in the 1st RFID channel, under the assumption of a uniform distribution of Short Range Devices (SRDs) (constant number of SRDs/MHz).

The simulations were carried out according to the approach defined in section 5.1 which is used to determine the maximum DC of 500 mW in the 1st RFID channel, for a uniform distribution of SRDs (constant number of SRDs/MHz). The automatic power control was used for both NBN and CSS technology.

A3.1.1 NBN deployment scenarios

In the first scenario, a distribution of 25% of the maximum density per channel on the second and third RFID channels was considered respectively on 917.5 MHz and 918.7 MHz.

The propagation models used for simulations are Extended Hata with and without environment variation and Recommendation ITU-R P.1411-10 [25] without variation. In order to determine the impact of each of two types of interferences (blocking and unwanted emissions), the blocking interference was first simulated by setting a perfect NBN emission mask i.e. by ignoring unwanted and spurious emissions. This result on blocking gives us an idea of a lower bound of interferences due to receiver characteristics of the victim LTE systems.

The considered unwanted emissions mask for NBN system is based on -36 dBm/100 kHz spurious limit. The interferences results are given in Table 40 for information.

In the second scenario, 25% of the maximum density is distributed on each of the three RFID channels; the DC is set at its maximum on the second and the third RFID channels and will only be adjusted on the first RFID channel.

Table 42: Average bitrate loss in the ref cell (%) in the case three RFID Channels used for high-power SRDs

DC on each of the three RFID channel	Propagation models	Blocking only (for information)	-36 dBm/100 kHz (with spurious aggregation, for information)	-36 dBm/100 kHz (without spurious aggregation)
Max DC	(1)	16.3	33.4	29.4
	(2)	10.4	25.7	21.4
	(3)	9.9	25.2	21
80% max DC	(1)	15	31.5	27
	(2)	9.7	24.3	20.2
	(3)	9.4	23.9	20
60% max DC	(1)	13.8	29.5	25.7
	(2)	8.4	22.3	19.8
	(3)	8.2	21.9	19.4
40% Max DC	(1)	12.1	28.5	23.3
	(2)	8.3	20.9	17.2
	(3)	7.8	20.1	16.4
20% Max DC	(1)	11.3	25	23.1
	(2)	6.8	19.5	16
	(3)	6.4	19.3	15.3
Propagation models: (1) Extended Hata with variations (2) Extended Hata without variations (3) ITU-R P.1411 [25] (TN-NN) and extended Hata (NN-NAP) without variation				

Table 43: Interference brought by the addition of the first RFID for high power SRDs compared to its non-use

DC: (2nd and 3rd RFID channel)	DC: (1st RFID channel)	Propagation model	Blocking only (for information)	-36 dBm/100 kHz (with spurious aggregation, for information)	-36 dBm/100 kHz (without spurious aggregation)
max DC	0% max DC	(1)	5.8	24.3	18
		(2)	5.6	18.4	14.7
		(3)	4.9	16.2	13.2
	20% max DC	(1)	11.3 (+5.5)	25 (+0.7)	23.1 (+5.1)
		(2)	6.8 (+1.2)	19.5 (+1.1)	16 (+1.3)
		(3)	6.4 (+1.5)	19.3 (+3.1)	15.3 (+2.1)
	40% max DC	(1)	12.1 (+6.3)	28.5 (+4.2)	23.3 (+5.3)
		(2)	8.3 (+2.7)	20.9 (+2.5)	17.2 (+2.5)
		(3)	7.8 (+2.9)	20.1 (+3.9)	16.4 (+3.2)
	60% max DC	(1)	13.8 (+8.0)	29.5 (+5.2)	25.7 (+7.7)
		(2)	8.4 (+2.8)	22.3 (+3.9)	19.8 (+5.1)
		(3)	8.2 (+3.3)	21.9 (+5.7)	19.4 (+6.2)
	80% max DC	(1)	15 (+9.2)	31.5 (+7.2)	27 (+9.0)
		(2)	9.7 (+4.1)	24.3 (+5.9)	20.2 (+5.5)
		(3)	9.4 (+4.5)	23.9 (+7.7)	20 (+6.8)
	Max DC	(1)	16.3 (+10.5)	33.4 (+9.1)	29.4 (+11.4)
		(2)	10.4 (+4.8)	25.7 (+7.3)	21.4 (+6.7)
		(3)	9.9 (+5.0)	25.2 (+9.0)	21 (+7.8)

Propagation models:
(1) Extended Hata with variations
(2) Extended Hata without variations
(3) ITU-R P.1411 [25] (TN-NN) and extended Hata (NN-NAP) without variation

A3.1.2 LPWAN UBN deployment scenarios

In the first scenario, the high-power Short Range Devices (SRDs) are distributed over the second and third RFID channels respectively on 917.5 MHz and 918.7 MHz with 25% of the max density per channel and for the terminals a distribution of 75% of the max density was considered. The interferences results are given in Table 54 in Annex 3.

In the second scenario, high-power SRDs with 25% of the max. density is added to the first RFID channel; the DC is set at its maximum for the high-power SRDs on the second and the third RFID channels and is only be adjusted for high-power SRDs on the first RFID channel and for 25 mW terminals.

Table 44: Average bitrate loss in the ref cell (%) three RFID Channels used for high-power SRDs

DC: NAP (2nd and 3rd RFID channel)	DC: NAP (1st RFID channel)	DC TN (1st RFID channel)	Propagation model	Blocking only (for information)	-36 dBm/100 kHz (with spurious aggregation, for information)
Max DC (10%)	Max=10%	Max=1%	(1)	7.4	44.7
			(2)	1.6	29.1
	80% Max. DC	80% Max. DC	(1)	6.1	39.1
			(2)	1.3	23.7
	60% Max. DC	60% Max. DC	(1)	4.8	31.6
			(2)	1.1	18.7
	40% Max. DC	40% Max. DC	(1)	3.1	22.9
			(2)	0.72	13.7
	20% Max. DC	20% Max. DC	(1)	1.9	11.5
			(2)	0.4	7.6
	10% Max. DC	10% Max. DC	(1)	1.1	7.5
			(2)	0.3	3.9
Propagation models: (1) Extended Hata with variations (2) Extended Hata without variations					

By adding the high-power Short Range Devices (SRDs) devices (NAP) to the first RFID channel with the maximum DC (10%), the resulting adjacent band impact on LTE Uplink below 915 MHz leads to an increase of the probability of average bitrate loss from 19.2% up to 20.5%.

Co-existence could be ensured when decreasing the DC of high-power SRDs on the 1st RFID channel and the DC of terminals by 80% (i.e. allowing 20% of the currently allowed DC on other RFID channels) by not exceeding an average bitrate loss in the LTE ref cell threshold of 5%.

Table 43 evaluates the percentage of interference brought by the addition of the first RFID channel for high-power SRD compared to its non-use.

Table 45: The variation in the average bitrate loss increase (%) brought by the addition of the first RFID for high-power SRDs compared to its non-use

DC: NAP (2nd and 3rd RFID channel)	DC: TN (1st RFID channel)	DC: NAP (1st RFID channel)	Propagation model	Increase for Blocking only (for information) (%)	Increase for -36 dBm/100 kHz (with spurious aggregation, for information) (%)	Increase for -36 dBm/100 kHz (without spurious aggregation) (%)
Max DC (10%)	Max. DC = 1%	Max. DC = 0% (reference)	(1)	5.9	43.3	36.5
			(2)	0.95	28.5	19.2
		10% Max. DC	(1)	+0.2	+0.8	+1.9
			(2)	+0.05	+0.9	+0.6
		20% Max. DC	(1)	+0.4	+2.2	+2.8
			(2)	+1.05	+1.6	+1
		40% Max. DC	(1)	+0.9	+3.1	+3.6
			(2)	+2.05	+1.8	+1.3
		60% Max. DC	(1)	+1.1	+3.8	+4.2
			(2)	+0.45	+2.1	+1.7
		80% Max. DC	(1)	+1.2	+5.2	+5.1
			(2)	+0.55	+2.5	+1.9
Propagation models: (1) Extended Hata with variations (2) Extended Hata without variations						

A3.1.3 PWAN-CSS deployment scenarios

In the first scenario, the high-power Short Range Devices (SRDs) are distributed over the second and third RFID channels respectively on 917.5 MHz and 918.7 MHz with 25% of the maximum density per channel and for the terminals a distribution of 75% of the maximum density was considered. The interferences results are given in Table 54.

In the second scenario, high-power SRDs with 25% of the maximum density is added to the first RFID channel; the DC is set at its maximum for the high-power SRDs (10%) on the second and third RFID channels and is only be adjusted for high-power SRDs on the first RFID channel and for 25 mW terminals.

Table 46: Average bitrate loss in the ref cell (%) in the case of 3 RFID Channels used for high-power SRDs

DC: NAP (2nd and 3rd RFID channel)	DC TN (1st RFID channel)	Propagation model	Blocking only (for information)	-36 dBm/100 kHz (with spurious aggregation, for information)	-36 dBm/100 kHz (without spurious aggregation)
Max DC (10%)	Max=1%	(1)	11.9	26.1	16.7
		(2)	5.6	14.3	8.2
	80% Max. DC	(1)	10.7	23	13.9
		(2)	5.1	13	7.4
	60% Max. DC	(1)	9.1	19.8	12.2
		(2)	4.9	11	6.4
	40% Max. DC	(1)	7.1	15.5	9.6
		(2)	3.6	8.6	5.4
	20% Max. DC	(1)	5.7	11.7	7.7
		(2)	3	7.3	4.2
	10% Max. DC	(1)	4.9	10.3	6.7
		(2)	2.5	6.4	3.9
Propagation models : (1) Extended Hata with variations (2) Extended Hata without variations					

By adding the high Short Range Devices (SRDs) devices (NAP) to the first RFID channel with the maximum DC, the resulting adjacent band impact to LTE uplink below 915 MHz in terms of probability of bitrate loss would be increased from 6% up to 8%.

Co-existence could be ensured only when decreasing the DC of high- power SRDs on the 1st RFID channel and the DC of terminal by at least 60% (i.e. allowing 40% of the currently allowed DC on other RFID channels) which remains beyond DC envisaged on the markets.

The following table evaluates the delta average bitrate loss (%) brought by the addition of the first RFID channel for high-power SRD compared to its non-use.

Table 47: Increase in the average bitrate loss (%) brought by the addition of the first RFID for high-power SRDs compared to its non-use

DC: NAP (2nd and 3rd RFID channel)	DC: TN (1st RFID channel)	DC: NAP (1st RFID channel)	Propagation model	Blocking only (for information)	-36 dBm/100 kHz (with spurious aggregation, for information)	-36 dBm/100 kHz (without spurious aggregation)
Max DC (10%)	Max DC = 1 %	Max. DC = 0%	(1)	8.9	23.3	13.9
			(2)	4.2	12.4	6.8
		10% max DC	(1)	+0.8	+5.8	+5.8
			(2)	+0.3	+5.5	+0.1
		20% max DC	(1)	+1	+7.5	+8.7
			(2)	+0.5	+5.6	+0.3
		40% max DC	(1)	+1.2	+7.9	+10.9
			(2)	+0.7	+5.7	+0.5
		60% max DC	(1)	+1.8	+9.2	+11.1
			(2)	+0.9	+6.4	+0.9
		80% max DC	(1)	+2.7	+10.4	+12
			(2)	+1.1	+6.9	+1.5
Propagation models : (1) Extended Hata with variations (2) Extended Hata without variations						

A3.2 STUDY #2

A3.2.1 500 mW Short Range Devices

A3.2.1.1 Short Range Devices parameters

The simulation considers separately each of the three technologies by considering only the high-power SRDs devices with up to 500 mW e.r.p. max output power per device (NBN-SRD, LPWAN-UNB and LPWAN-CSS) deployed in the first RFID channel centred at 916.3 MHz. These high-power SRD devices are anticipated to operate in parallel to existing RFID systems in the 916.1-916.5 MHz channel. For the interference study towards the UL cellular band (880-915 MHz) the minimum separation to the lower band edge of the RFID channels is 1.1 MHz. The spurious emission domain applies for these SRD devices (UNB, CSS) and the maximum power allowed value per device is -36 dBm/100 kHz below 915 MHz, see ERC Recommendation 74-01 [8], ECC Recommendation (19)02 [9] or relevant ETSI harmonised standards [3], [11]. For NBN part of the unwanted emission into the cellular band is in the OOB domain. Furthermore, the spurious emission level is:

- Per device and independent of number of carriers;
- At the antenna connector;
- Independent of the actual operating channel power;
- From ECC Recommendation (19)02 [9] recommends 2 says: "that assumptions of unwanted emissions levels used in sharing and compatibility studies should in the first case be based on conformance limits defined in EC/ECC Recommendations/Decisions and ETSI Harmonised Standards if available".;
- In the SEAMCAT simulation with Power Control (PC), the spurious emission is linearly reduced with the output power in logarithmic scale. This may be partly true as in reality it depends on the OOB domain, actual operating channel BW and the frequency separation between interferer and victim.
- The 916.1-916.5 MHz channel in this study may have a potential higher risk to cause interference to the cellular uplink compared to the other two channels further away;
- It is further noted that the specific mask for spurious domain with 200 kHz OCW may fall into the cellular UL with -36 dBm/100 kHz from 914.1 MHz to 915 MHz (see Figure 6).

A3.2.2 Cellular 900 MHz band

A3.2.2.1 Cellular background

The 900 MHz cellular band is a coverage band to give coverage to UEs e.g. deep inside buildings (urban/suburban) or providing wide area coverage in rural areas. BSs will be not deployed on the same grid as for capacity bands, e.g. for 1800 or 2100 MHz bands. Network planners design the 900 MHz network for noise limited operation (small co-channel interference) in opposite to interference limited case. In urban/suburban areas the network takes advantages of different layers with capacity/coverage bands to handle UE traffic. Therefore for this study the interference threshold ($I_{Macro,threshold}$) for macro BS in the 900 MHz band should be based on the BS noise limit with Noise Figure (NF) = 5 dB, Interference-to-Noise protection criteria of I/N = - 6 dB [6] and Noise Rise (NR) of 2 dB due to adjacent cellular networks in the band (see section 2.1):

$$I_{Macro,threshold} = -174 \text{ dBm/Hz} + 10 \cdot \log10(BWHz) + NF + I/N + NR \quad (4)$$

For 4.5 MHz BW, the $I_{Macro,threshold}$ = -106.5 dBm. For the BS, antenna height and antenna gain and tilt typical parameters for suburban/urban areas are (see Report ITU-R M.2292 [6] and ANNEX 2):

- Antenna gain 17 dBi (16 to 18 dBi typically);
- Feeder loss 1 dB (0.5 to 2 dB typically), usually Low Noise Amplifier is used close to antenna for UL;
- Antenna height and downtilt are respectively 30 meters and 6 degrees.

Table 48: LTE/New Radio network information

Parameter	Values	Comment
Radio system	GSM (cellular IoT), 3G, LTE and NR with different BWs	LTE and NR with OFDMA UL or IMT-2020 UL macro modules in SEAMCAT with 5 MHz BW
Environment	Rural, suburban, urban, dedicated indoor	Suburban and urban macro deployment above rooftop
Cell radius	Report ITU-R M.2292 [5] typical 2 km for suburban/urban for <1 GHz bands. This corresponds in SEAMCAT to 1 km cell radius	1 km cell radius in SEAMCAT
CDF acceptable %	Noise rise and throughput loss	<5% exceeding the $I_{Macro,threshold}$ <5% BER increase for cell edge throughput

A3.2.3 MCL result for Networked SRD/NAP to cellular BS

Minimum Coupling Loss (MCL) can be used for an outdoor scenario where both SRD NAP/NN and cellular BS are located in fixed locations. The MCL calculation below focuses on the outdoor NAPs with the following cases

- Case 1: SRD NBN/NN NAP with height outdoor 7 and 5 metres;
- Case 2: SRD UNB NAP with height outdoor 7 and 25 metres;
- Case 3: SRD CSS NAP with height outdoor 25 metres.

The MCL calculation below only considers the cellular BS blocking aspect and assumes that SRD transmits with its maximum power. SRD power control and duty cycle are considered in the A3.2.4 below for the Monte Carlo simulations.

Table 49: LTE system parameters

Victim Characteristics	Units	LTE macro BS
Operating Centre Frequency	MHz	912.5
Receiver channel Bandwidth	MHz	5
Receiver transmission BW	MHz	4.5 (25 RBs)
Receiver Noise Figure (NF)	dB	5
Receiver Antenna Height	m	30
Receiver Antenna Gain	dBi	15
Receiver thermal Noise (kTB)	dBm	-108
Noise Floor (kTB+NF)	dBm	-103
I/N objective	dB	-6
Antenna gain Δh BS correction factor	dB	< 2 dB, for > ~0.1km distance
Blocking response	dB	48.7 dB (915 to 918 MHz)

Table 50: NBN SRD system parameters

Interferer's Characteristics	Units	NBN NAP/NN	CSS NAP	UNB NAP
Operating Frequency	MHz	916.1–916.5		
Transmit Power	dBm	27	23.65	24.15
Antenna Gain	dBi	2.15	5.5	5
Bandwidth	kHz	200	125	1
Antenna Height	m	5 and 7	25	7 and 25

From the above the MCL without the antenna gain correction factor can be calculated with the following equation:

$$MCL = (Pint + Gint + (Gvict - G\Delta h)) - (Blocking\ Response + Noise\ Floor + I/N) \quad (5)$$

which gives a MCL of: ~102 dB.

From Figure 18, it can be seen that for the MCL the minimum separation distance for the SRD NAP/NN to the cellular BS:

- SRD with 25 m antenna height is 3.3 km (free space LOS propagation model ITU-R P.525);
- SRD with 7 m height is 0.5 km (Extended Hata NLOS model);
- SRD with 5 m height is 0.36 km (Extended Hata NLOS model).

In the simulation below, the BS-to-BS distance for the cellular network in urban environment is assumed equal to 3 km. From this it can be understood that SRD NAP heights at 25 m will have a high likelihood to cause problems to cellular network.

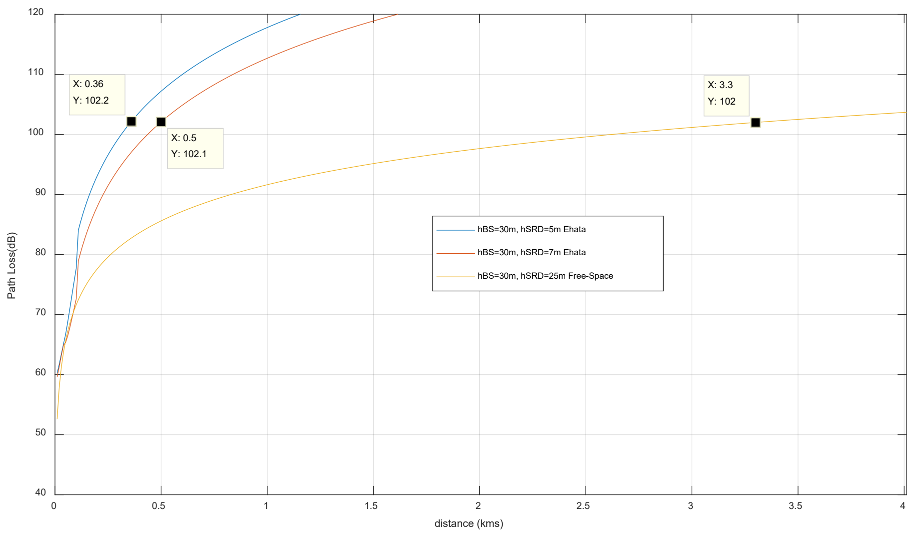

Figure 18: Propagation loss between cellular BS (30 m) and SRD NAP (NN at different heights for LOS and NLOS

A3.2.4 Monte Carlo simulation with SEAMCAT

Figure 19 shows the principle of the Monte Carlo simulation scenario for possible Networked SRD interference towards cellular BS site. The number of active SRD devices is calculated for a simulation radius of ~3 km which corresponds to an area of 28.3 km². For the cellular network, the cell radius is 1 km in SEAMCAT which means a BS-to-BS distance of 3 km.

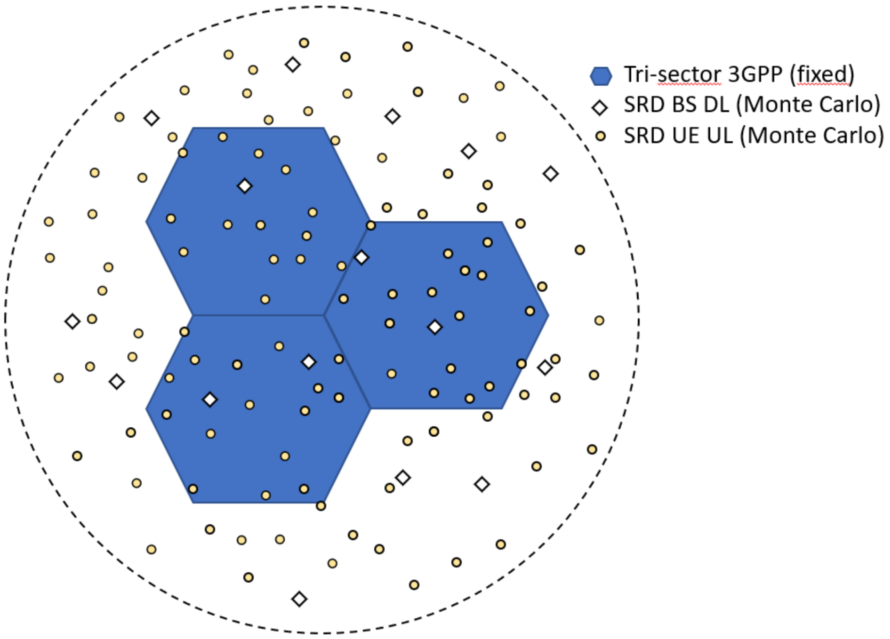

Figure 19: Principal sketch of the simulation scenario with cellular BS victim and SRDs as interferer

A3.2.4.1 SEAMCAT simulation configuration

For the cellular system, the following settings as given in the below table are used in SEAMCAT for the results as discussed in the section below.

Table 51: SEAMCAT settings used for cellular system with justification

SEAMCAT setting	Comments
OFDMA UL_F:(0, 1) GHz_BW_Urban_Macro	Used in previous studies.
BW, number of UEs per sector in the UL	In SEAMCAT the blocking mask if combined with duplex filter cannot be set correctly for e.g. three UEs. This is as SEAMCAT applies the blocking response relative to the centre sub-carrier. Hence, the number of RBs per MS needs to be equal to that by BS. In this simulation 5 MHz BW and one UE per sector in the UL per snapshot is used. This follows also what has been done in recent RMR900 work, see [33].
UE antenna gain and bodyloss	0 dBi is used and no body loss considered
Antenna peak envelope	For single sector consider peak envelope [39]

Table 52: SEAMCAT settings used for SRD

SEAMCAT setting	Justification / Comments
Transmitter density and DC	Transmitter density and DC are given for LPWAN-CSS, LPWAN-UNB and NBN in Table 21, Table 16 and Table 10.

SEAMCAT setting	Justification / Comments
ILT to VLR position and number of active transmitters	Uniform distribution of the active ILT. The number of active ILT determines the ILT simulation area as a function of the transmitter density and DC Number of active BS = Simulation area * DC * Tx Density The simulation radius should be > 2*cellular cell radius.
Variations enabled	For propagation model and wall loss model.

A3.2.4.2 SEAMCAT information message with consistency warning

The following information message will be displayed when running the SEAMCAT file:

- Propagation model used and antenna height. The Extended Hata for Urban above and below roof top is used. Below roof top if the Tx and Rx antennas below 10 metres. The deviation of the model pathloss estimation depends on the use above or below roof top (See SEAMCAT Handbook [33], annex 17) for further information. SEAMCAT allows to use BS heights lower than 30 m and uses the following factor for this:

  b(Hb)=min(0, 20log(Hb/30)) , (see SEAMCAT Handbook, section A17.3.1 [21]);
- Propagation model extended Hata SRD with antenna heights above 3 m is outside the scope of the model and might cause inaccurate results.

A3.2.4.3 Monte Carlo simulation results

Monte Carlo simulations for cellular macro urban as victim with SRD NBN, LPWAN-UNB and LPWAN- CSS as an interferer are done for the two-corner cases:

- Average expected deployment case for average DC and average density;
- Maximum expected deployment case for Max. DC and Max. density;
- For TN with 70% indoor and 30% outdoor. The maximum and average estimated densities for each SRD technology are given for NBN in Table 9, LPWAN-UNB in Table 15 and LPWAN-CSS in Table 26. Each SRD technology was studied separately. One-quarter of the given maximum density values are used in the simulation to account for the possible spreading of the devices over the three RFID channels and in the band below 915 MHz. For the spurious emission, the -36 dBm/100 kHz is used;
- It is assumed in the simulation results below that the unwanted emission is reduced relative to the Max. output power (in logarithmic scale) for which the unwanted emission mask is implemented. Power control for NAP/NN and TN for NBN and CSS SRD. For UNB TN such power control seems to be not implemented;
- For the SRD cell radii, the values as given in Table 28 are used;
- For SRD e.r.p., antenna gain, antenna height, channel BW and receiver sensitivity the values in Table 23 are used.

A3.2.5 For NBN SRD

The results below are for NBN SRD for NAP, NN and TN. The simulation does not consider the case of TNs to act as NNs which would change the Max. DC from 0.1% to 2.5%. The simulation does also not consider the NN to NAP transmission but the NN to TN is considered with 2.5% DC, the maximum DC for NN is 2.5%. In the below tables the mean values for interference increase and average throughput loss due to possible interference and blocking from SRD NBN are given. For the density a quarter of the maximum and of the average densities as given in Table 9 are used:

It can be summarised:

- The result for 30% or 70% TN indoor does not differ too much and this is as the interference is mainly coming from the NN and NAP which are 100% outdoor and at higher heights than the TNs;
- It can be seen from the interference results that the interference is due to both unwanted emission and blocking by exceeding the BS threshold limit. For 1/4 of the max density and max DC, the unwanted

emission is although dominant. For 1/4 of the average density and average DC the mean interference level is below the acceptable BS threshold limit;

- Enabling power control improves the situation for both the unwanted emission and blocking. For 1/4 of the Max. density and Max. DC, the average bitrate loss is still above 5%.

Table 53: Interference in cellular UL due to unwanted emission and blocking from NBN for 70% indoor and 30% outdoor terminal case

		Interference in dBm over $I_{Macro,threshold}$ = -107 dBm		
		Unwanted emissions	ACS/blocking	Total
		Mean	Mean	Mean
Without PC	1/4 of Max. Density and Max. DC	-98	-103	-95
	1/4 of Avg. Density and Avg. DC	-115	-120	-114
With PC	1/4 Max. Density and Max. DC	-109	-115	-107
	1/4 of Avg. Density and Avg. DC	-128	-133	-127

Table 54: Interference in cellular UL due to unwanted emission and blocking from NBN for 30% indoor and 70% outdoor terminal case

		Interference increase in dBm over $I_{Macro,threshold}$ = -107 dBm		
		Unwanted emissions	ACS/blocking	Total
		Mean	Mean	Mean
Without PC	1/4 of Max. Density Max. DC	-98	-103	-96
	1/4 of Avg. Density Avg. DC	-115	-120	-113
With PC	1/4 of Max. Density Max. DC	-110	-115	-109
	1/4 of Avg. Density Avg. DC	-128	-135	-127

Table 55: Average Bitrate loss in reference cell for interference (unwanted and blocking) from NBN, for 70%/30% and 30%/70% indoor/outdoor terminal cases

		Throughput loss in %	
		TN 70% indoor and 30% outdoor	TN 30% indoor and 70% outdoor
		Mean	Mean
Without PC	1/4 of Max. Density with Max. DC	34%	35%
	1/4 of Avg. Density with Avg. DC	4.9%	5.9%
With PC	1/4 of Max. Density with Max. DC	10.3%	9%
	1/4 of Avg. Density with Avg. DC	1.3%	1.2%

A3.2.6 For LPWAN-UNB SRD

The results below are for UNB SRD for NAP with 25 metres height and TN at 1.5 m height. For the 7 m NAP height, the interference can be expected to be less towards the cellular BS compared to the 25 m antenna height under the same assumptions. In the tables below the mean value for interference (unwanted emissions and blocking) and throughput loss from SRD LPWAN-UNB is given. For the LPWAN-UNB system power control (PC) seems to be not possible. For the density, a quarter of the maximum, as given in Table 16, are used in the simulation. The 1/4 of average NAP density was not considered. The average density and average DC from the results show no problem for LPWAN-UNB with interference towards cellular UL as shown below.

From the results, the following can be summarised:

- The result for 30% or 70% indoor TN differs as the TN unwanted emission is the main reason for the high interference and throughput loss. The NAP (density*DC = 0.25 for max/max) is negligible compared to the TN (density*DC = 500 for max./max.);
- The high medium throughput loss with above 17% is due to the unwanted emission of the TN. The TN and NAP do not seem to allow for power control;
- It is expected that PC in the TN would be similar to the case for NBN or CSS to help to improve interference situation;
- Blocking from NAP due to the antenna height of 25 m can still be a problem even if PC is used, see section 5.3.3 (MCL analysis).

Table 56: Interference increase in cellular UL due to unwanted emission and blocking from UNB for 70% indoor and 30% outdoor terminal case

		Interference increase in dBm over $I_{Macro,threshold}$ = -107 dBm		
		Unwanted emissions	ACS/blocking	Total
		Mean	Mean	Mean
Without PC	1/4 of Max. Density with Max. DC	-106	-118	-106
	1/4 of Avg. Density with Avg. DC	-146	-156	-146
With PC NAP	1/4 of Max. Density with Max. DC	N.A	N.A	N.A
	1/4 of Avg. Density with Avg. DC	N.A	N.A	N.A

Table 57: Interference increase in cellular UL due to unwanted emission and blocking from UNB for 30% indoor and 70% outdoor terminal case

		Interference increase in dBm over $I_{Macro,threshold}$ = -107 dBm		
		Unwanted emissions	ACS/blocking	Total
		Mean	Mean	Mean
Without PC	1/4 of Max. Density with Max. DC	-101	-113	-100
	1/4 of Avg. Density with Avg. DC	-140	-151	-139
With PC NAP	1/4 of Max. Density with Max. DC	N.A	N.A	N.A
	1/4 of Avg. Density with Avg. DC	N.A	N.A	N.A

Table 58: Average Bitrate loss in reference cell for interference and blocking from UNB, for 70%/30% and 30%/70% indoor/outdoor terminal cases

		Throughput loss in %	
		TN 70% indoor and 30% outdoor	TN 30% indoor and 70% outdoor
		Mean	Mean
Without PC	1/4 of Max. Density with Max. DC	13%	23%
	1/4 of Avg. Density with Avg. DC	0.2%	0.3%
With PC NAP	1/4 of Max. Density with Max. DC	N.A	N.A
	1/4 of Avg. Density with Avg. DC	N.A	N.A

A3.2.6.1 LPWAN-CSS SRD

The results below are for CSS SRD for NAP with 25 metres height and TN at 1.5 m height. In the tables below the mean values for interference (unwanted emissions and blocking) increase and throughput loss from SRD LPWAN-CSS are given. A density 1/4 of the maximum and average densities as given in Table 20 are used in the simulation.

From the results, the following can be summarised:

- For 1/4 of the average density and average DC the mean interference level is well below the BS threshold level and therefore the increase in average bitrate loss in the reference cell of the cellular system in SEAMCAT is negligible;
- For 1/4 of the Max. density and Max. DC, the NAP is the dominant factor for the unwanted emissions and blocking interferences in the results with and without PC. Both equally contribute to the interference at the BS;
- Power control helps to decrease the unwanted emission/blocking for 30 and 70% indoor TN scenario but as expected is more effective for the 70% TN outdoor case;
- Blocking from NAP due to the antenna height of 25 m can still be a problem even if PC is used, see section A3.2.3.

Table 59: Interference increase in cellular UL due to unwanted emission and blocking from CSS for 70% indoor and 30% outdoor terminal case

		Interference increase indBm over $I_{Macro,threshold}$ = -107 dBm		
		Unwanted emissions	ACS/blocking	Total
		Mean	Mean	Mean
Without PC	1/4 of Max. Density with Max. DC	-102	-102	-99
	1/4 of Avg. Density with Avg. DC	-143	-144	-140
With PC	1/4 of Max. Density with Max. DC	-108	-108	-105
	1/4 of Avg. Density with Avg. DC	-152	-152	-149

Table 60: Interference increase in cellular UL due to unwanted emission and blocking from CSS for 30% indoor and 70% outdoor terminal case

		Interference increase in dBm over $I_{Macro,threshold}$ = -107 dBm		
		Unwanted emissions	ACS/blocking	Total
		Mean	Mean	Mean
Without PC	1/4 of Max. Density with Max. DC	-101	-101	-98
	1/4 of Avg. Density with Avg. DC	-143	-143	-141
With PC	1/4 of Max. Density with Max. DC	-112	-110	-107
	1/4 of Avg. Density with Avg. DC	-156	-156	-153

Table 61: Increase in the average in the average Bitrate loss in reference cell for interference and blocking from CSS, for 70%/30% and 30%/70% indoor/outdoor terminal cases

		Throughput loss in %	
		TN 70% indoor and 30% outdoor	TN 30% indoor and 70% outdoor
		Mean	Mean
Without PC	1/4 of Max. Density with Max. DC	26%	30%
	1/4 of Avg. Density with Avg. DC	0.3%	0.3%
With PC	1/4 of Max. Density with Max. DC	14%	11%
	1/4 of Avg. Density with Avg. DC	0.1%	<0.1%

A3.2.6.2 Additional baseline to protect cellular UL below 915 MHz

The maximum spurious emission level from Short Range Devices (SRDs) in order to have the possible increase in average throughput loss less than 5% in the cellular UL is investigated in this section. Using the simulation as outlined in the sections above with the following settings:

- 1/4 of maximum density and maximum duty cycle and for TN with 70% indoor;

- Considering just 1st RFID channel (1.1 MHz offset to cellular uplink band-edge to band-edge) and each SRD system (NBN, UNB and CSS) considered separate in the results;
- With APC enabled beside for UNB as APC is not defined. With PC enabled for NAP and TN means the unwanted emission gets reduced relative with transmit output power in logarithmic scale;
- Ignoring the effect of blocking

It is found in general that the main contributors of the spurious emission effect from CSS, UNB and NBN SRD are:

- For CSS, the NAP (500 mW) is the main contributor to the unwanted emission effect. This is due to the NAP antenna height and additional wall loss for TN (25 mW) even if the DC*density ratio for the TN is higher than for the NAP;
- For UNB, the TN (25 mW) is the main contributor for the spurious emission effect as the NAP (500 mW) density is very low;
- For NBN, the NAP and NN (500 mW) both contribute to the unwanted emission effect while TNs (500 mW) have more limited contributions. This is due to the NAP and NN densities.

It is found that if the model of the spurious emission of the SRD systems is reduced by 10 dB the increase in average throughput loss due to spurious emission is less than 5%. This is by ignoring the effect of blocking. In order to account for an envelope within the spurious emission domain for such narrowband SRD systems towards wideband systems, a limit can be defined for below 915 MHz as an additional baseline over 5 MHz BW with: --29 dBm over 5 MHz e.r.p. This assumes 2.15 dBi antenna gain. The general spurious emission requirement with -36 dBm/100 kHz still applies.

A3.2.6.3 Additional baseline and DC restriction in order to protect cellular UL in 880-915 MHz

The maximum spurious emission level and/or DC from Short Range Devices (SRDs) in order to have the possible average throughput loss less than 5% in the cellular UL is investigated in this section. Using the simulation as outlined in the sections above with the following settings:

- 1/4 of maximum density and maximum duty cycle and for TN with 70% indoor;
- Considering just 1st RFID channel (1.1 MHz offset to cellular uplink band-edge to band-edge) and each SRD system (NBN, UNB and CSS) considered separate in the results;
- With APC enabled beside for UNB as APC is not defined. With APC enabled for NAP and TN means the unwanted emission gets reduced relative with transmit output power in logarithmic scale.

Figure 20 gives for NBN and CSS SRD technologies the DC reduction and/or unwanted emission reduction required in order that the increase in average bitrate loss in the cellular system stays less than 5%:

- The DC reduction factor is given by (max-DC/reduced DC) where the max. DC is 10% for NAP and 2.5% for NN;
- The unwanted emission reduction below 915 MHz in dB is relative to the unwanted emission mask as defined for each technology. For NBN it is with respect to the -36 dBm/100 kHz general spurious emission requirement.

It is found in general that the main contributors of the blocking and unwanted emission effect from CSS, UNB and NBN SRD are:

- For NBN, the NAP and NN (500 mW) are the main contributor to the unwanted emission and blocking and therefore the TN (25 mW) contribution can be ignored. In the results below for NBN the DC reduction and unwanted emission limit is only applied to the NAP and NN. The interference contribution to the cellular receiver from NBN NAP/NN is mainly from the unwanted emission but also the blocking causes increase in the average bitrate loss more than 5%. This can be seen in the Figure 20 that, for unwanted emission reduction higher than about 9 dB, the DC reduction needed stays constant. The additional baseline in e.r.p. below 915 MHz NBN can be calculated from Figure 20 with: -36 dBm/100 kHz (at the antenna connector) - reduction in dB + antenna gain dBi - 2.15 dB e.i.r.p.-to-e.r.p. conversion. The antenna gain for the NAP/NN is 2.15 dBi. For NBN part of the unwanted emission into the cellular band is in the OOB domain, considering this the DC reduction factor needed is 2.5 for NAP/NN for 0 dB unwanted emission reduction;

- For CSS, the NAP (500 mW) is the main contributor to the unwanted emission and blocking interference and therefore the TN (25 mW) contribution can be ignored. This is due to the NAP antenna height and additional wall loss for TN even if the DC*density ratio for the TN is higher than for the NAP. The interference contribution to the cellular receiver from CSS NAP is about the same level for the blocking and unwanted emission. The additional baseline in e.r.p. for below 915 MHz CSS can be calculated from the Figure 20 with: -39 dBm/100kHz e.r.p. - reduction in dB dB. For the NAP, the antenna gain is 5.5 dBi;
- For UNB, the TN (25 mW) is the main contributor for the interference as the NAP (500 mW) density is very low. Interference due to blocking from TN can be ignored. The 25 mW TN is not considered in this section with respect to unwanted emission or DC reduction.

In order to protect the cellular (880 to 915 MHz) from interference and possible increase in average bitrate loss more than 5% from 500 mW (e.r.p.) NAP/NNs, the following additional unwanted emission baseline in combination with a reduction in the max. allowed DC can be used either:

1) No additional baseline or reduction in unwanted emission (OOB/spurious emission) and a DC limited to 3.1% for NAP (minimum NBN, CSS) and to 1% for NN, and no DC reduction needed for NAP UNB. This accounts for DC reduction factor of 3.2 from 10% to 3.1% for NAP and DC reduction factor of 2.5 from 2.5% to 1% for NN.

Or

2) Considering an additional baseline of -25 dBm e.r.p. into the victim's 5 MHz receiver, a DC limited to 3.6% for NAP CSS and 8% for NAP NBN and to 2% for NBN NN would be necessary, and no DC reduction needed for NAP UNB. This accounts for an envelope in the spurious emission domain for such narrowband SRD systems towards wideband systems. Further unwanted emission reduction (>7 dB, for CSS NAP) with lower additional baseline does not help a lot because the blocking starts to get dominant.

The general spurious emission requirement with -36 dBm/100 kHz will still apply for items 1) and 2).

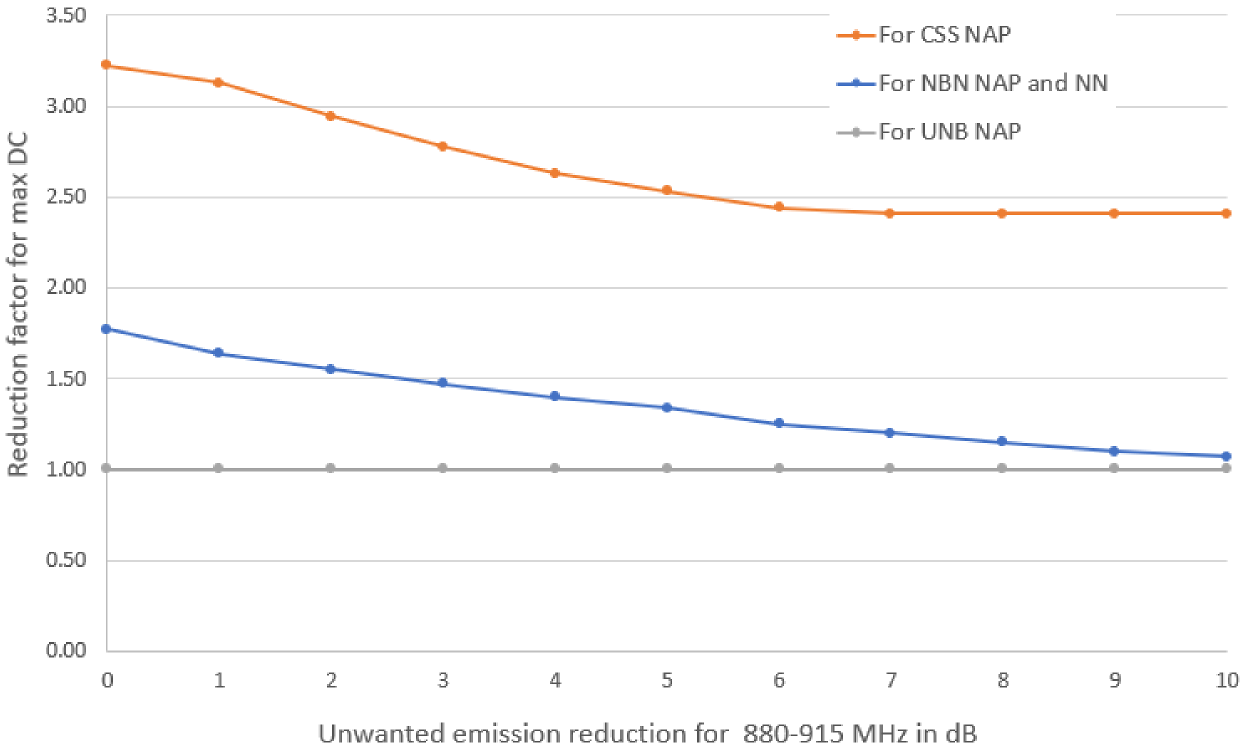

Figure 20: Reduction factor for max. DC corresponding to various levels of unwanted emission, for an average bitrate loss below 5% on the victim MFCN

ANNEX 4: STUDIES FOR INFORMATION

Table 62: 2 RFID Channels used for high-power SRDs (NBN Systems)

	Max. DC			80% Max. DC			60% Max. DC			40% Max. DC			20% Max. DC		
NBN Mask \ Propagation model	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Blocking only (for information)	5.8	5.6	4.9	4.8	4.3	3.9	3.54	3.3	2.8	3.78	3.1	2	2.4	1.2	1.14
-36 dBm/100 kHz (with spurious aggregation, for information)	24.3	18.4	16.2	18.6	14.9	12.7	14.4	11	10.1	9.3	8	6.7	5.5	3.6	3.4
-36 dBm/100 kHz (without spurious aggregation)	18	14.7	13.2	15.8	12.2	10.8	12	9.2	8.8	8.1	6.4	5.6	4.1	3.1	3
-54 dBm/100 kHz (with spurious aggregation, for information)	9.8	6.4	5.3	9	5.2	4.3	6.6	3.7	3.4	4.1	3.5	2.3	2.4	1.5	1.7
-54 dBm/100 kHz (without spurious aggregation)	9.5	6	5.1	7.4	4.9	4.4	5.9	3.6	3.2	3.8	2.9	2.2	2.1	1.4	1.1
Propagation models: (1) Extended Hata with variations (2) Extended Hata without variations (3) ITU-R P.1411 [25] (TN-NN) and extended Hata (NN-NAP) without variation															

Table 63: 2 RFID Channels used for high-power SRDs (LPWAN UBN Systems)

DC NAP	Max=10%		80% Max. DC		60% Max. DC		40% Max. DC		20% Max. DC		10% Max. DC	
DC TN	Max=1%		80% Max. DC		60% Max. DC		40% Max. DC		20% Max. DC		10% Max. DC	
UNB Mask \ Propagation model	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Blocking only (for information)	5.9	0.95	5.4	0.9	4.5	0.85	2.7	0.66	1.8	0.34	0.94	0.2
-36 dBm/100 kHz (with spurious aggregation, for information)	43.3	28.5	38.1	23.5	28.2	17.9	20.1	11.8	10.3	7	6.1	3.5
-36 dBm/100 kHz (without spurious aggregation)	36.5	19.2	29.1	15.4	23	12.1	16.8	8.4	8.3	4.2	4.4	3.2
Propagation models: (1) Extended Hata with variations (2) Extended Hata without variations												

Table 64: 2 RFID Channels used for high-power SRDs (LPWAN CSS Systems)

DC: NAP	Max=10%		80% Max. DC		60% Max. DC		40% Max. DC		20% Max. DC		10% Max. DC	
DC TN	Max=1%		80% Max. DC		60% Max. DC		40% Max. DC		20% Max. DC		10% Max. DC	
CSS Mask \ Propagation model	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Blocking only (for information)	8.9	4.2	7.6	3.5	5.6	2.8	3.9	1.8	2.1	0.9	1.1	0.5
-36 dBm/100 kHz (with spurious aggregation, for information)	23.3	12.4	18.3	10.4	15.1	8.4	10.6	5.1	4.9	2.8	2.6	1.4
-36 dBm/100 kHz (without spurious aggregation)	13.9	6.8	10.9	5.6	8.8	4.2	5.6	2.6	2.95	1.5	1.5	0.8
Propagation models: (1) Extended Hata with variations (2) Extended Hata without variations												

ANNEX 5: LIST OF REFERENCES

[1] ETSI TR 103 526: “Technical characteristics for Low Power Wide Area Networks Chirp Spread Spectrum (LPWAN-CSS) operating in the UHF spectrum below 1 GHz”, July 2017.

[2] ETSI TR 103 435: “Technical characteristics for Ultra Narrow Band (UNB) SRDs operating in the UHF spectrum below 1 GHz”, February 2017.

[3] ETSI EN 303 204: “Electromagnetic compatibility and Radio spectrum Matters (ERM); Network Based Short Range Devices (SRD); Radio equipment to be used in the 870 MHz to 876 MHz frequency range with power levels ranging up to 500 mW”

[4] ETSI TS 145 005: “GSM/EDGE; Radio transmission and reception”

[5] ETSI TR 102 886: "Electromagnetic compatibility and Radio spectrum Matters (ERM);Technical characteristics of Smart Metering (SM)Short Range Devices (SRD) in the UHF Band; System Reference Document, SRDs, Spectrum Requirements for Smart Metering European access profile Protocol (PR-SMEP)"

[6] Report ITU-R M.2292: "Characteristics of terrestrial IMT-Advanced systems for frequency sharing/interference analyses"

[7] ECC Report 200: "Co-existence studies for proposed SRD and RFID applications in the frequency band 870-876 MHz and 915-921 MHz", approved September 2013

[8] ERC Recommendation 74-01: "Unwanted emissions in the spurious domain", approved 1998 and latest amended May 2019

[9] ECC Recommendation (19)02: "Unwanted Emissions – Guidance and methodologies when using typical equipment performance in sharing/compatibility studies", approved May 2019

[10] ECC Report 249: "Unwanted emissions of common radio systems: measurements and use in sharing/compatibility studies ", approved April 2016

[11] ETSI EN 300 220: "Short Range Devices (SRD) operating in the frequency range 25 MHz to 1 000 MHz; Part 3-1: Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU; Low duty cycle high reliability equipment, social alarms equipment operating on designated frequencies (869,200 MHz to 869,250 MHz) "

[12] ERC Recommendation 70-03: "Relating to the use of Short Range Devices (SRD)" approved 1997, latest amended June 2021

[13] ECC Report 246: "Wideband and Higher DC Short Range Devices in 870-875.8 MHz and 915.2-920.8 MHz (companion to ECC Report 200)", approved January 2017

[14] ECC Report 261: "Short Range Devices in the frequency range 862-870 MHz", approved January 2017

[15] ETSI TS 136 101 "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception (3GPP TS 36.101 version 15.3.0 Release 15)"

[16] ETSI TR 103 055: “Electromagnetic compatibility and Radio spectrum Matters (ERM); System Reference document (SRdoc): Spectrum Requirements for Short Range Device, Metropolitan Mesh Machine Networks (M3N) and Smart Metering (SM) applications”

[17] ECC Decision (06)13: "Designation of the bands 880-915 MHz, 925-960 MHz, 1710-1785 MHz and 1805-1880 MHz for terrestrial UMTS, LTE, WiMAX and IoT cellular systems", approved December 2006 and latest amended March 2019

[18] 3GPP TS 36.104: "Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception"

[19] ECC Report 310: “Evaluation of receiver parameters and the future role of receiver characteristics in spectrum management, including in sharing and compatibility studies”, approved January 2020

[20] ECC Report 318: "Compatibility between RMR and MFCN in the 900 MHz range, the 1900-1920 MHz band and the 2290-2300 MHz band", approved July 2020

[21] ECC Report 252: “SEAMCAT Handbook Edition 2”, approved April 2016

[22] Recommendation ITU-R F.1336-4: "Reference radiation patterns of omnidirectional, sectoral and other antennas for the fixed and mobile services for use in sharing studies in the frequency range from 400 MHz to about 70 GHz"

[23] Neubauer and Bonek: "Impact of the Variation in the Background Noise Floor on UMTS System Capacity", Vehicular Technology Conference, 1988, IEEE 38th, February 2001

[24] ECC Report 313: "Technical study for co-existence between RMR in the 900 MHz range and other applications in adjacent bands", approved May 2020

[25] Recommendation ITU-R P.1411: “Propagation data and prediction methods for the planning of short-range outdoor radio communication systems and radio local area networks in the frequency range 300 MHz to 100 GHz”

[26] Recommendation ITU-R P.525: “Calculation of free-space attenuation”

[27] 3GPP TR 36.942. “Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Frequency (RF) system scenarios”