CEPT ECC
Electronic Communications Committee

ECC Report 207

Adjacent band co-existence of SRDs in the band 863-870 MHz in light of the LTE usage below 862 MHz

Approved 31 January 2014

0 EXECUTIVE SUMMARY

This ECC report was developed as part of co-existence studies identified within the CEPT Roadmap for review of spectrum requirements for various SRD and RFID applications in the UHF spectrum. Due to the complexity of the issue the work on co-existence of SRDs in the band 863-870 MHz is separated into two reports. This report considers adjacent band co-existence situation for SRDs in subject band in the light of the changed noise environment (LTE impact). Another report will complement this first report with assessments of the applicable technical regulatory SRD requirements with the view on facilitating SRD innovation and more efficient use of the band.

This report contains results of SEAMCAT simulations, analytical calculations and practical tests.

Two fundamentally different mechanisms were identified as sources of possible interference from LTE UE into SRDs: blocking effect and interference from unwanted emissions falling into the band of SRDs. They differ in that blocking can be mitigated by improving the victim's receiver characteristics, while mitigating unwanted in-band interference requires a reduction of the OoB emissions of the interferer.

Measurements indicated that a potential for interference exists when LTE UE is used in the proximity of up to several metres from an SRD receiver. Where the interference occurs, it manifests itself either as a reduction in SRD operational range, or as a degradation/ loss of function.

Two main situations were investigated. In Scenario 1 ("same room") a single LTE UE is allocated in block C (852-862 MHz) and is transmitting at the same time when the SRD is receiving and is located within 10 m range of the SRD receiver, in an indoor environment, to simulate the case of a person using their LTE UE in premises where an SRD receiver is present. In general, it is expected that the LTE UEs and SRDs are likely to operate at the same premises (see section 4). In the second case i.e. Scenario 2 ("macro") the LTE network deployment is considered: one SRD receiver and LTE UE(s) are randomly located in a 3-cell network, with no specific assumptions on the relative position between SRD and LTE UE.

In the Scenario 2 "macro" the probability of interference was found to be mostly below 1% (only for Cat. 3 SRD receivers up to 5 %) and therefore this case is not considered critical and not addressed in the following discussion.

The results for the Scenario 1 "same room" are summarised in Table 20: and are between 2 % and 42 %. The range of results in Table 20: is caused by different SRD frequencies (863/869 MHz), different assumptions on the wanted signal at the SRD receiver and different LTE UE masks.

It has to be noted that the simulation results are comparable for all analysed SRD types (Results for alarm applications according to EN 54-25 [12] are similar to Cat.1 receivers from EN 300 220-1 [8] and EN 301357-1[13]; results for Cat.2 receivers from EN 300 220-1 and EN 301357-1 are similar).

Table 1: Summary same room scenario

LTE UE mask	Cat.3 SRD Receiver	Cat.2 SRD receiver	Cat.1 SRD receiver (Note 1)
according ETSI TS 136 101 [11] with 1.4/3/5/10 MHz bandwidth (Note 2)	The probability of interference was found to be in the range 10% and 42%.	The probability of interference was found to be in the range 5% to 31%.	The probability of interference was found to be in the range 2% to 29%.
according to a measured mask from a real LTE UE implementation with 10 MHz bandwidth (see Figure 2:)	The probability of interference was found to be in the range 16% and 41%.	The probability of interference was found to be in the range 5% to 17%.	The probability of interference was found to be in the range 2% to 7%.
Comments	The main issue is blocking.	The prevailing component can be blocking or in-band interference, depending on the considered LTE UE emission mask	The dominant effect is in-band interference from OoB emissions, depending on the considered LTE UE emission mask

Note 1: The SRD Receiver Category 1 is a high performance receiver comparable to an Rx for PMR (Professional Mobile Radio) and implemented by social alarm power supplied base station. The Rx Cat.1 power consumption, size and cost (all elements very critical for SRDs) make it impractical for regular SRD applications, especially considering that the utmost of them are battery operated.
Note 2: It has to be noted that in this report the LTE UE Tx mask was used in accordance to ETSI TS 136 101 [11] which shows 1.5 dB lower power values as the harmonised standard EN 301 908-13. However, the impact on the result is only marginal.

The following interim conclusions can be drawn from Table 20:

- The interference risk varies dependent on the configuration between low (e.g. real measured LTE mask, upper frequency boundary, Cat. 1 receiver, optimistic SRD signal distribution), and large values (e.g. 10 MHz LTE mask, lower frequency boundary, Cat. 3 receiver, pessimistic SRD signal distribution)
- Cat 3 SRD receivers cannot coexist with nearby LTE UE due to SRD receiver blocking effects, and receiver performance degradation due to receiver selectivity (blocking) cannot be improved by reducing the interfering OoB emissions. Thus the removal of SRD receiver Cat. 3 in the band 863-870 MHz from the market place would reduce the risk of interference caused by blocking, but this alone is not sufficient.
- Cat.1 SRD receivers may coexist with a measured mask from a real LTE UE implementation (15-20 dB lower OoB emissions), but may not with the LTE UE masks from the ETSI standard. However, manufacturing associations note that the use of a Cat. 1 receiver is not viable for SRD applications except for very specific high performance alarm base stations (e.g. EN 300 220 [8]).

Considering the above first observations, the following evaluation is limited to the typical SRD receiver Category 2 as the main anticipated counterpart for LTE in 800 MHz co-existence scenario.

Table 21: shows the results for SRD receiver category 2 used at typical frequencies.

Table 2: Results for SRD Cat. 2 receivers

	LTE Max masks 10 MHz	LTE Max mask 1.4 MHz	measured mask from a real LTE UE implementation
Wireless audio and metering at 863 MHz	▪ 22 % - 31 %	▪ 10 % - 14 %	▪ 12 % - 17 %
Non-specific SRD 868 MHz (results for alarms at 869 are in the same order)	▪ 17 % - 24 %	▪ 4 % - 5 %	▪ 5 % - 6 %

Note: the lower value is from dRSS approach 2, the higher value is from dRSS approach 1 (see Table 4:)

The most critical situation is for SRDs operating close to the 863 MHz border. **Error! Reference source not found.** shows that for wireless audio and SRDs using Cat 2 receivers the risk of interference is well above 5 %.

The risk can further be reduced with higher frequency offsets from the lower border frequency; e.g. Non-specific SRDs with Cat. 2 receivers working at 868 MHz may coexist with LTE for both assumed SRDs signal levels (dRSS approach 1 and 2) as long as the LTE OoB emissions are 15-20 dB below its ETSI specification (as confirmed by real measurements) or the LTE UE is only using 1.4 MHz of the available 10 MHz bandwidth.

Note: It should be noted that it was not possible to get a common understanding on the signal levels for SRDs between SRD and LTE community. The SRD community suggested the dRSS approach 1 as representative, while the LTE community suggested dRSS approach 2. The dRSS approach 2 is the result when considering the Extended hata SRD indoor path loss model in SEAMCAT with distances up to the operational distances assumed for SRDs. The SRD community criticised that the relatively high signal levels may be caused by the implemented indoor-indoor model currently implemented in SEAMCAT and that this model (which is mainly considering free space loss plus a certain number of wall losses and standard deviations) should be updated.

An interference probability of below 5 % can be reached generally at the expense of a reduction in SRD operating distance (derived from dRSS approach 2 simulations):

- Cat.3 receiver at 863.1 MHz (LTE 10MHz mask) reduction from 40m to 17m (-58%);
- Cat.2 receiver at 863.1 MHz (LTE 10MHz mask) reduction from 40m to 21m (-48%);
- Cat.2 receiver at 869 MHz (LTE 10MHz mask) reduction from 40m to 24m (-40%);
- Cat.2 receiver at 863.1 MHz (a measured mask from a real LTE UE implementation) reduction from 40m to 28m (-30%);
- Cat.2 receiver at 863.1 MHz (LTE 1.4MHz mask) reduction from 40m to 30m (-25%);
- Cat.2 receiver at 865 MHz (LTE 1.4MHz and real mask) reduction from 40m to 38m (-5%); .

The LTE UE devices compliant with mask from ETSI TS 136 101 [11] with 1.4 MHz bandwidth may not produce harmful interference. However, LTE is a complex technology (see section 3) and it is expected that the resource block allocation and thus the used bandwidth will be dynamically changing over short periods of time. The consequence is that all masks/bandwidths are expected to be used at any location but with different occurrence probabilities in time (e.g. higher probability of small resource block allocations vs. lower probability of high resource block allocations). In a real network typically 3-5 UEs are scheduled in each transmission time interval sharing the 10 MHz channel bandwidth. Therefore, the result for the bandwidths of 1.4 MHz and 3 MHz represents the likely impact of LTE UE on SRDs. The precise interference effect of this dynamic LTE behaviour will also depend on the characteristics of the SRDs: e.g. audio links may experience constantly recurring interference effects while SRDs using digital modulations may be better able to resist (e.g. FEC, acknowledgement).

In this study, only the probability of interference when the LTE UE is using block C or part of block C was considered. Therefore it was not taken into account that the UE can be using other bands or other blocks in the 800 MHz band. The likelihood of using block C is therefore not factored in the above results .This likelihood depends on several factors that can vary over time: for example, the network planning and loading, the number of mobile operators in the country, and on the overall availability of spectrum for mobile communications.

In addition it should be noted that the numerical results of studies provided in this report are based on assumption that the LTE UE is permanently transmitting (100 % activity factor). Therefore, the probability of receiving interference will statistically be reduced by a factor approximating the actual activity of the LTE UE transmissions. Here it should be considered that data uploading is not necessarily connected to an end user action at the same location (e.g. watching videos from a home NAS via an LTE link).

This report considers a power control strategy resulting in a LTE UE power distribution close to “Set 2” specified in ETSI TR 136 942 [15] . A more aggressive power control strategy is introduced in ETSI TR 136 942 (“Set 1”), which may lead to higher interference probabilities. However, it is not expected that operators would use this strategy in interference limited networks to avoid interference to other operators and their own system (see Annex 4).

In addition only an urban scenario with a LTE cell size of 350m has been considered in detail in this report. The main expected difference in rural environments would be that the LTE network would be more likely noise-limited than interference limited, with the possible consequence of a more aggressive power control strategy taken by the network providers and thus a potential higher interference probability to SRDs (see Annex 4). Until there is wide spread deployment of LTE there is uncertainty to this point.

Summary of main findings:

1. There is little risk of harmful interference if the LTE UE and the SRDs are not used on the same premises (separation distance >10m).
2. There is a risk of interference when an LTE UE is used in block C on the same premises (distances ≤ 10 m) as an SRD but this risk of interference varies due to several factors such as SRD operating distance and SRD receiver category and LTE UE emission mask: the risk can be high if an LTE UE is used towards its full capability, with high resource block allocations, in block C, which cannot be overcome by the SRD user in many cases.
3. Cat 3 SRD receivers (e.g. from EN 300 220) cannot coexist with LTE UE due to SRD receiver blocking effect. The future removal of SRD Cat. 3 receivers in the band 863-870 MHz from the market place can reduce statistically blocking effects on total population of SRD receivers in the long term perspective.
4. The SRD Cat.1 receiver may coexist with a measured mask from a real LTE UE implementation (15-20 dB lower OoB emissions), but may not with the LTE UE masks from the ETSI standard. However, manufacturing associations note that the use of a Cat. 1 receiver is not viable for SRD applications due to size, cost and power consumption, except for very specific high performance alarm base stations (e.g. EN 300 220).
5. SRD receivers with min Cat. 2 blocking performance may coexist with LTE under the following assumptions:
    - If the LTE UE is transmitting with OoB emissions complying with the 1.4 MHz mask (5 LTE UEs share the 10 MHz channel) from the standard; but all LTE UEs are expected to change their bandwidth and thus applicable OoB masks dynamically with different occurrence probabilities in time (e.g. high probability of small resource block allocations vs low probability of high resource block allocations).
    - If the real LTE UE OoB emissions for 3, 5 and 10 MHz bandwidth (1-3 LTE UEs share the 10 MHz channel) are below the mask specification in standards (e.g. by 15-20 dB for the 10 MHz mask). Available measurements’ results from a real LTE UE implementation confirmed that this may be realistic assumption as measured OoB emissions were well below the specification (in static transmission states of EUT).
    - At the expense of a reduction in SRD operating distance (e.g. down to 50% for the 10 MHz LTE UE mask from the standard) with the possible consequence that a certain percentage of SRD devices will no longer function as intended.
    - The performance degradation of Cat. 2 receivers is due to blocking and LTE UE unwanted emissions.

6. SRDs experience the high LTE UE OoB emissions, that are caused by high (25-50) resource block allocations in the LTE UE but the activity factor of the LTE UE has not been considered in this report. However, it should be expected that the most critical LTE UE mask (one user is using all resource blocks available in the cell) will happen in real life only for short time periods (noting that the LTE base-station reallocates resources between LTE UEs with a time interval of 1 ms).
7. The most likely impacted SRD type may be an audio receiver (including baby alarms) in the band 863-865 MHz, as they are working close in frequency to the LTE band. In addition, audio receivers may already be affected by very short LTE UE bursts with high resource block allocations, but this has not been analysed in detail in this report. However, some measurements were provided (see Annex 3).
8. SRDs using digital modulations may be better able to resist interference from LTE UE (e.g. thanks to using FEC, acknowledgement with re-transmission), but the OoB emission of the LTE UE as per the current standard may generally lead to desensitisation and false signal level triggering in those receivers. It should be noted that any reduction of SRD throughput and/or increase of retransmissions cause a decrease of battery lifetime.

Considering all above it appears that the most severely impacted SRDs are those of Cat.3 receivers, mainly due to blocking effect. Using Cat.2 receivers will help coexistence with adjacent band LTE use and this will improve one of the interference problems (i.e. blocking).

With regard to the other interference problem (i.e. OoB emissions), measurements provided in this report have shown that LTE UE OoB emissions are significantly below the mask specification in current standards. This provides an opportunity for a possible solution for coexistence together with the SRD industry moving towards the performance seen in Cat. 2 receivers.

In addition, it may be anticipated that the interference situation will be further improved in deployed LTE networks, as the most critical high resource block allocations have a lower probability of occurrence than the less critical low resource block allocations.

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
ACLR	Adjacent Channel Leakage Ratios
ACS	Adjacent Channel Selectivity
AFA	Adaptive Frequency Agility
BTS	Base Transmitting Station (feeder station serving a cell in mobile radio system)
BW	Bandwidth
Cat	Category of SRD receivers
CDF	Cumulative distribution function
CDMA	Code Division Multiple Access
CEPT	European Conference of Postal and Telecommunications Administrations
CSMA	Carrier Sensing Multiple Access
DC	Duty Cycle
dRSS	desired Received Signal Strength (term used in SEAMCAT)
DSSS	Direct sequence spread spectrum
ECC	Electronic Communications Committee
e.i.r.p.	equivalent isotropically radiated power
ETSI	European Telecommunications Standards Institute
FDMA	Frequency Division Multiple Access
FHSS	Frequency Hopping Spread Spectrum
IL	Interfering Link
iRSS	interference Received Signal Strength (term used in SEAMCAT)
LBT	Listen Before Talk (Transmit)
LDC	Low Duty Cycle
LTE	Long Term Evolution, a telephone and mobile broadband communication standard
NAS	Network Attached Storage
MCL	Minimum Coupling Loss
MS	Mobile Station (user terminal)
OFDM	Orthogonal Frequency Division Multiplexing
OoB	Out of Band emissions
RF	Radio Frequency
RFID	Radio Frequency Identification System
Rx	Receiver
SEA	Spectrum Emission Mask
SRD	Short Range Device
TPC	Transmit Power Control
TRP	Total Radiated Power
Tx	Transmitter
UHF	Ultra High Frequency band (300-3000 MHz)
UE	User Equipment
VL	Victim Link

1 INTRODUCTION

This ECC report was developed as part of co-existence studies identified within the CEPT Roadmap for review of spectrum requirements for various SRD and RFID applications in the UHF spectrum:

- Intra-SRD compatibility situation should be assessed, possibly taking into account the results from the 863-870 MHz review. Consider enhanced sharing possibilities of applications in 863-865 MHz and 865-868 MHz;
- Take into account the change of the noise environment due to the introduction of LTE Mobile Systems uplink below 862 MHz.

Due to the complexity of the issue the work on co-existence of SRDs in the band 863-870 MHz is separated into two reports. This report considers adjacent band co-existence situation for SRDs in subject band in the light of the changed noise environment (LTE impact). Another report will complement this first report with assessments on the applicable technical regulatory SRD requirements with the view on facilitating SRD innovation and more efficient use of the band.

2 SRD APPLICATIONS IN THE BAND 863-870 MHZ

The use of the band 863-870 MHz by SRD is already well established in Europe and fully harmonised in the EU/EEA territory by the mandatory EC Decision 2006/771/EC [1] and its subsequent revisions.

There are several surveys made by CEPT that can shed light on the actual situation in this band. One of these it is the recent ECC Report 182 “Survey about the use of the frequency band 863-870 MHz” (September 2012) [2]. From the analysis there it emerges that the most numerous SRD applications, with more than 40 million units sold annually (whole conservative figure) in this band includes:

- All kinds of Metering;
- Home automation (incl. all kinds of remote controls);
- Alarms (incl. intrusion sensing);
- Automotive;
- Industrial (incl. sensors);
- Audio.

The above mentioned whole conservative figure was also recently assumed by the European Commission Communication COM (2012) 478 (2012-09-03) to the EU Parliament and the Council on “Promoting the shared use of radio spectrum” [3].

This study shall therefore choose among these applications to be used as representative examples of typical SRD applications in this band. It should be noted that any such shortened list of representative families will inevitably exclude some others, such as RFID which is also used in this band, of course. However it was assumed that those other families of devices would not be more susceptible to interference than the examples studied here.

The survey results also showed that majority of devices rely on simple mitigation techniques such as DC, whereas more elaborate mechanisms such as LBT/AFA, FHSS, DSSS *(by descending order)* are less widely used.

Another important survey has been carried out by the ECC PT FM22 as multi-stage monitoring campaign carried out in total of 12 European countries, with the latest report available in Doc. FM(11)071 (April 2011). The following of its findings may be of relevance to this study:

- typical SRD channel bandwidths in use are 25 kHz in channel-prescribed sub-bands and an average of 150 kHz in parts of the bands that do not have prescribed channelization;
- the most occupied sub-bands are 863-865 MHz and 868-870 MHz with the largest concentration of SRD use observed in residential parts of the cities;
- the sub-band 865-868 MHz is used by RFIDs, which are accordingly concentrated in industrial areas, logistic and shopping centres, including airports. Therefore the occupancy of this sub-band as seen across the cities is rather limited for instance.

These findings well correspond to observations in ECC Report182 [2]: the first one relating to majority of devices being simple DC-based devices, the two latter findings correspond to observation that the list of most sold applications is dominated by home-based devices such as metering, home automation, alarms and audio devices.

Based on practical observations from above referenced surveys and providing for certain spread of different parameters and operational sub-bands, this report will carry out studies for three representative types of SRDs as shown below with indicating respective the CEPT Recommendation’s rules of ERC/REC 70-03 [5] annexes/band options (in line with the EC Decision 2006/771/EC [1] and its subsequent revisions):

- Metering – corresponding to Annex 1 Band g (25 mW, DC=0.1%, BW=200 kHz);
- Alarms – corresponding to Annex 7 Band c (25 mW, DC=10%, BW=25 kHz);
- Wireless audio – corresponding to Annex 13 Band a (10 mW, DC=100%, BW=200 kHz).

In addition, it was also considered useful to include simulations for Non-specific SRDs that may be implemented in accordance with Annex 1 of ERC/REC 70-03.

Relevant SRD parameters and their values are listed in Table 3:.

Table 3: Typical SRD parameters and values used in simulations

Parameter	Non-specific	Metering	Alarms	Audio
Typical centre frequency (MHz)	868.1	863.05	869.6625	864.9
Bandwidth (kHz)	200	200	25	200
DC (%]	0.1	0.1	10	100
Receiver noise dBm	-112	-112	-120	-114
NF dB	9 dB	9 dB	10 dB	7 dB
Sensitivity (dBm)	-104	-104	-112	-97
Transmitter Output Power (dBm)	14	14	14	10
Antenna gain Rx, dBi	-5	-5	-5	-5
Assumed typical indoor operating range (m)	40	40	40	20 (Note 1)
C/(I) objective (dB)	8	8	8	17 analog (8 digital)
Selectivity, ACS, blocking	EN 300220-1 [4], see ANNEX 1:	EN 300220-1 [4], see ANNEX 1:	EN 54-25 [8], see ANNEX 1:	EN 301357-1 [9], see ANNEX 1:

Note 1: Tour guide systems may have max distances of 100m

The wanted SRD link was configured with two different sets of parameters for the dRSS distribution (see Table 4:).

Table 4: Assumptions for the victim link

Parameter	Non-specific	Metering	Alarms	Audio
dRSS approach 1: user defined dRSS with a mean dRSS 20dB (Gaussian distributed) above sensitivity	-84dBm, std dev 10 dB	-84dBm, std dev 10 dB	-92dBm, std dev 10 dB	-84dBm, std dev 10 dB
dRSS approach 2: real distance simulation, distance up to typical operating distance from Table 1	Mean -77 dBm, std dev 17 dB	Mean -77 dBm, std dev 17 dB	Mean -77 dBm, std dev 17 dB	Mean -62 dBm, std dev 13 dB

Both approaches may be relevant in real life: Approach 1 gives lower maximal dRSS values (up to -50 dBm) and thus may be seen to represent cases with SRD working at higher operational range, whereas approach 2 gives higher maximum dRSS values (up to -20/-30 dBm) and therefore represents operational scenario where SRD path distance may be seen as lower.

The following figure visualise the two approaches and gives some further information.

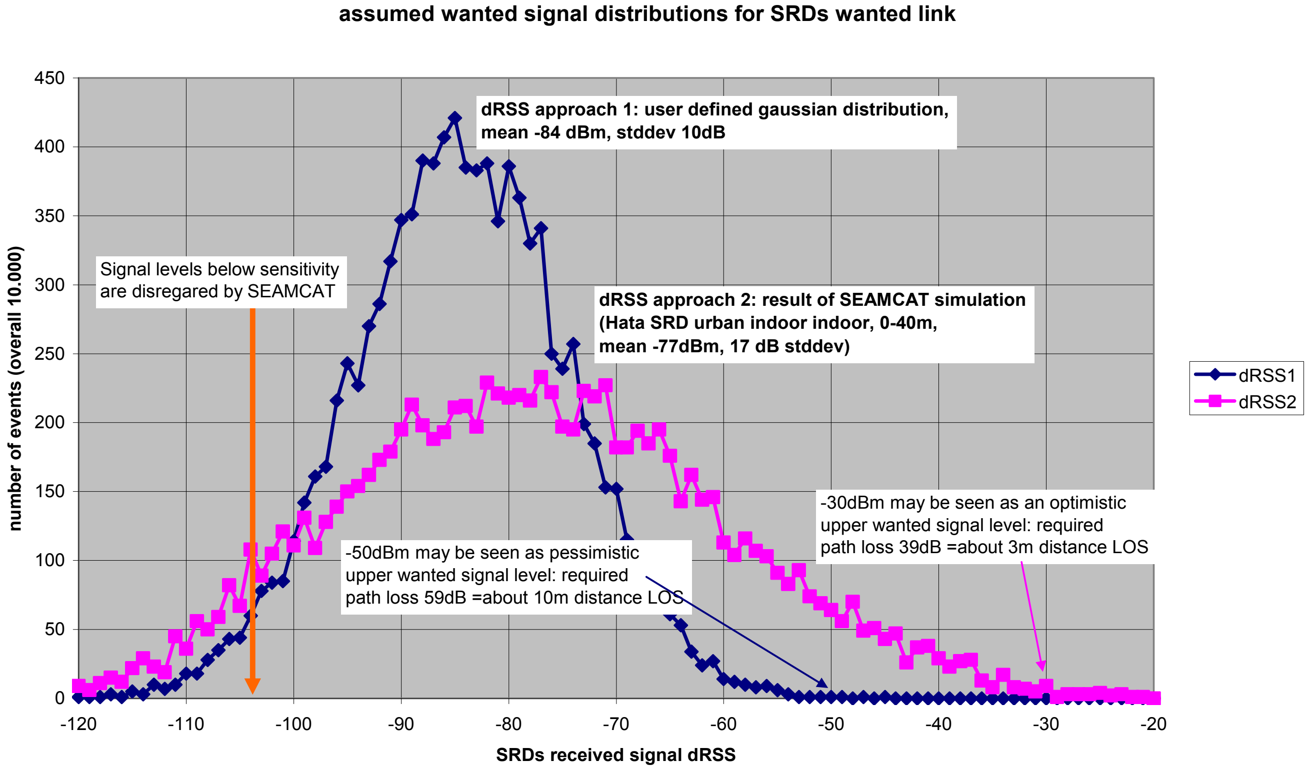

Figure 1: Assumed wanted signal distributions for SRDs (for 200 kHz receivers)

Selectivity parameters are to be in accordance with ETSI Harmonised Standard EN 300 220-1 [8] (see ANNEX 1:).

It should be noted that any analysis with SRD Rx Cat.1 is just an exercise limited to Social Alarm peripheral (base) unit only. The Rx Cat. 1 is a high performance receiver comparable to an Rx for PMR (Professional Mobile Radio). The Rx Cat.1 power consumption, size and cost (all elements very critical for SRDs) make it impractical for regular SRD applications, especially considering that the utmost of them are battery operated. However even not being the Rx Cat.1 a typical SRDs design options, a simulation exercise study was considered of interest to better understand a comparison between Rx Cat. 2 (the utmost used for SRDs) and Cat. 3.

3 LTE PARAMETERS

LTE is a very advanced and complex technology. Spectrum flexibility is a key feature of LTE radio access. It consists of several components, including deployment in different sized spectrum and deployment in divers frequency ranges, both in paired (FDD) and unpaired (TDD) frequency bands. There are a number of frequency bands identified for mobile use. Most of these bands were already defined for operation with UMTS/GSM, and LTE is the next technology to be deployed in those bands in addition to new bands specified for LTE.

Some of the bands used for mobile systems and whose may be potential bands for LTE in CEPT countries are as follows:

- 790-862 MHz;
- 880-915 MHz / 925-960 MHz;
- 1710-1785 MHz / 1805-1880 MHz;
- 1900-1980 MHz / 2010-2025 MHz / 2110-2170 MHz;
- 2500-2690 MHz;
- 3400-3600 MHz / 3600-3800 MHz.

In this study, the compatibility between LTE UE and SRD in 800 MHz band has been analysed. The 800 MHz band is divided into three blocks of 10 MHz: Block A, B and C; see Table 5:. Block C is the closest frequency range to SRD. Therefore, only block C is considered in this study.

Table 5: 800 MHz block allocation

	Frequency Range/ Uplink
Block A	832-842 MHz
Block B	842-852 MHz
Block C	852-862 MHz

Table 6: summarizes the LTE UE Tx and BS Rx characteristics.

Table 6: LTE Uplink parameters and values used in simulations

	LTE UE Tx	LTE BS Rx
Bandwidth (MHz)	10	
APC/output power range (dBm)	-40…23 = 63 dB	n/a
Antenna Height (m)	1.5	30
Antenna Gain (dBi)	0	17
Number of active users	1 to 5	
Max no of Resource Blocks (RB)	50	
Cell size (km)	0.35	

The UE Tx power is specified at antenna connector and thus equivalent to a Total Radiated Power (TRP) limit. In addition ECC Decision (09)03 [6] clearly indicates that 23 dBm is e.i.r.p. for fixed terminal and TRP for mobile and nomadic terminal stations. For isotropic antennas TRP is equivalent to e.i.r.p.. For mobile and nomadic terminals there is in theory a possibility of using directive high gain. However, such external antennas are not supplied by mobile operators, and such antennas are not supplied or endorsed by the mobile operators concerned. It is also no difference expected in the used probabilistic simulations, as with random orientation of a possible directive antenna the TRP limit is relevant. Directive antennas are therefore not considered in the coexistence studies.

This report considers a power control strategy resulting in a LTE UE power distribution close to “Set 2” specified in ETSI TR 136 942 [15]. A more aggressive power control strategy is introduced in ETSI TR 136

942 ("Set 1"), which may lead to higher interference probabilities. However, it is not expected that operators would use this strategy in interference limited networks to avoid interference to other operators and their own system (see Annex 4).

In addition only an urban scenario with a LTE cell size of 350 m has been considered in detail in this report. The main expected difference in rural environments would be that the LTE network would be more likely noise-limited than interference limited, with the possible consequence of a more aggressive power control strategy taken by the network providers and thus a potential higher interference probability to SRDs (see Annex 4). Until there is wide spread deployment of LTE there is uncertainty to this point.

For the compatibility studies, the UE spectrum masks from core specification ETSI TS 136 101 (V11.4.0 2013-04) [11] was used (see Table 7:).

Table 7: General E-UTRA spectrum emission mask

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

In addition some measured masks from real LTE UE implementations were considered in this report (see Figure 2:).

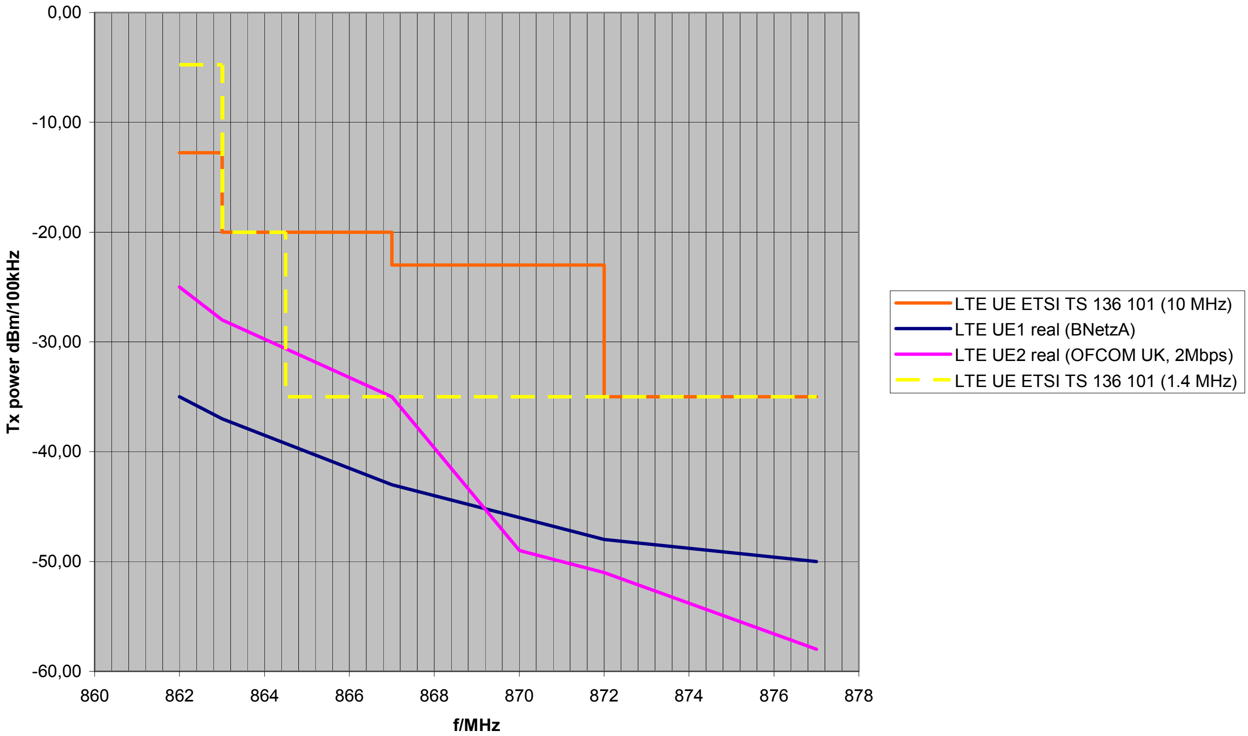

Figure 2: Considered LTE UE masks

The Tx power of the LTE UE was modelled as Gaussian distribution with a mean power of 20 dBm and 1dB stddev (see Figure 3:) in order to reflect losses due to the antenna gain (0 to -3 dBi) and hand/body losses (0-4 dB).

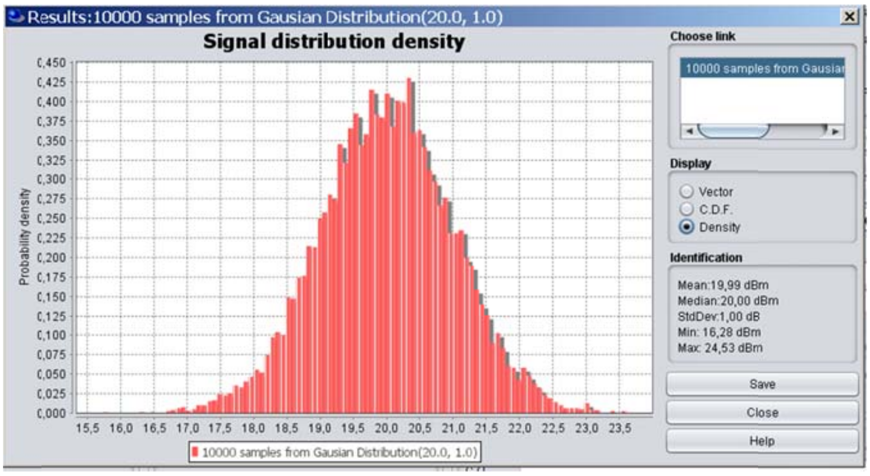

Figure 3: LTE UE TX power distribution to consider antenna and body losses

3.1 NUMBER OF ACTIVE UE PER CELL

The LTE uplink is based on OFDM transmission which allows for orthogonal separation of uplink transmissions. Orthogonal separation is beneficial as it avoids interference between uplink transmissions from *different* UEs within the cell (intra-cell interference). As shown in Figure 4:, OFDM as a user-multiplexing scheme implies that in each transmission time interval, *different* subsets of the overall set of Resource Blocks (RBs) are used for data transmission from *different* UEs. In other words, only one single UE with the total allocated bandwidth, 50 RBs, can be scheduled in one cell at a given instance in time, i.e. signal frame transmission time interval. More active UEs may be then supported in given cell by alternating their transmissions in time.

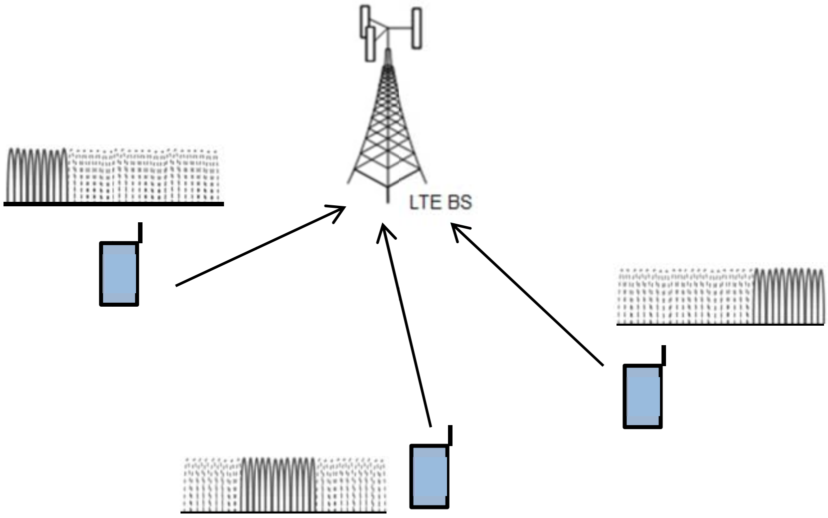

Figure 4: OFDM as a user-multiplexing scheme in LTE uplink (in singular time)

In each time instant, the *scheduler* controls to which UEs the different number of resource blocks should be assigned. To support scheduling, a UE will provide the network among others with Control signalling and Sounding Reference Signals (SRS),

Control signalling (carried by the PUCCH, Physical Uplink Control Channel) is deliberately mapped to resource blocks at the outer edge of the system bandwidth, in order to reduce out-of-band emissions caused by data transmissions on the inner RBs, as well as maximizing flexibility for data transmission scheduling in the central part of the band, See Figure 5:.

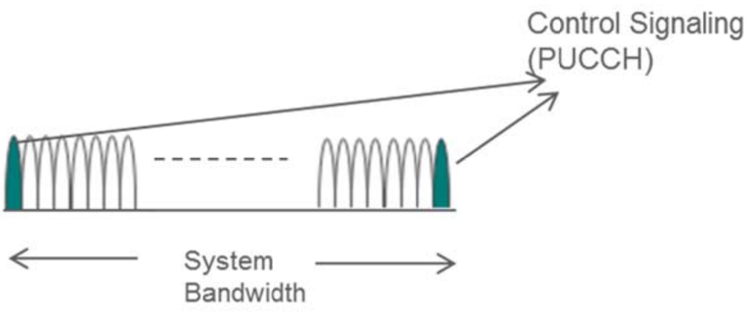

Figure 5: Control signalling

The LTE uplink is primarily based on maintaining orthogonality between different uplink data transmission and the shared control signalling (PUCCH) or sounding reference signal (SRS). The orthogonality between data transmission of different UE's is guaranteed due to OFDM transmission scheme. However, Control signalling from multiple UEs is multiplexed via orthogonal coding by using cyclic time shift orthogonality and/or time-domain block spreading.

The uplink reference signal and control signalling in LTE are based on Zadoff-Chu(ZC) sequences In a given uplink symbol, different cyclic time shifts of a Zadoff–Chu (ZC) sequence are modulated with a UE-specific QAM symbol carrying the necessary control signalling information, with the supported number of cyclic time shifts determining the number of UEs which can be multiplexed per FDMA symbol. As the PUCCH RB spans 12 subcarriers, the LTE PUCCH supports up to 12 cyclic shifts per PUCCH RB.

The same as control signalling, the SRS also limits the number of simultaneous UEs due to limited number of cyclic time shifts, 8 cyclic shifts.

It should be mentioned that in a network, system optimization requires some degree of coordination between cells and eNodeBs, in order to avoid inter-cell interference. Considering the whole network, some eNodeBs avoid scheduling transmissions in certain resource blocks which are used by neighbouring eNodeBs for cell-edge users.

Therefore considering these limitations and need for coordination, typically in each transmission time interval 3 to 5 UEs are scheduled in each cell.

With regard to SEAMCAT simulation, the Macro cell deployment will be simulated with a radius of 350m where 3 to 5 UEs are scheduled per sector in each snapshot (9 to 15 per 350 m radius) with uniform distribution in the cell area.

Assumptions for the simulations:

- 1 UE per sector for 10 MHz bandwidth;
- 2 UE per sector for 5 MHz bandwidth;
- 3 UE per sector for 3 MHz bandwidth;
- 5 UEs per sector for 1.4 MHz bandwidth;
- 1 UE per sector for the measured mask from a real LTE UE implementation (BNetzA, 10 MHz bandwidth).

3.2 LTE UE TRANSMISSION CHARACTERISTICS

The co-existence problem in adjacent band can occur due to:

- Unwanted emissions from transmitter filtering which are defined as out-of-band (OoB) emissions that affect victim receiver as in-channel unwanted signal, or
- Blocking interference when strong interfering transmitter in adjacent band may not be sufficiently cancelled by victim receiver's selectivity and destabilises reception.

It should be mentioned that interference caused by unwanted emissions in general could be reduced by minimising unwanted (OoB) emissions at the interfering transmitter, whereas the impact of blocking interference could be reduced by improving the selectivity of victim receiver (e.g. Cat. 2 vs. Cat. 3 SRD receivers). In both cases the impact may be also reduced by increasing frequency separation between victim and interferer channels. But it should be mentioned that receiver performance degradation due to receiver selectivity (blocking) cannot be improved by reducing the interfering OoB emissions.

In this section the LTE UE transmission characteristics in OoB domain are investigated.

LTE as a very advanced and complex technology has very flexible transmission schemes in order to optimize the network performance by optimum usage of resources namely spectrum and power supply.

Restrictions on LTE UE OoB emissions are typically defined in two different ways by 3GPP:

- Spectrum emission mask (SEM);
- Adjacent channel leakage ratios (ACLR).

Both SEM and ACLR are ways to measure the performance of a transmitter. SEM provides the mechanism for suppression of unwanted power outside the carrier bandwidth, while the ACLR measures the exact amount of power that can be 'leaked' into adjacent channels. In LTE specifications, SEM has a narrower measurement bandwidth than ACLR which is the average of power over a wider bandwidth. In LTE requirements, ACLR gives stricter performance requirement than SEM, thus satisfying ACLR values would also satisfy SEM requirements which also means if a UE exactly meets the SEM requirement; the UE can not be approved since it doesn't satisfy ACLR levels.

ETSI TS 136 101 [11] provides the specification for SEM and ACLRs that any UE should be able to satisfy. Table 7: and Table 8: summarize the specification values for UE SEM and UE ACLR requirements, respectively.

Table 8: General requirements for E-UTRA$_{ACLR}$

E-UTRA Channel Bandwidth : 10 MHz					
E-UTRA$_{ACLR1}$	30 dB	UTRA$_{ACLR1}$	33 dB	UTRA$_{ACLR2}$	36 dB
E-UTRA channel Measurement bandwidth	9.0 MHz	UTRA 5MHz channel Measurement bandwidth	3,84 MHz	UTRA 5MHz channel Measurement bandwidth	3.84 MHz
Adjacent channel centre frequency offset [MHz]	+10 / -10	Adjacent channel centre frequency offset [MHz]	$+5+BW_{UTRA}/2$ / $-5-BW_{UTRA}/2$	Adjacent channel centre frequency offset [MHz]	$+5+3*BW_{UTRA}/2$ / $-5-3*BW_{UTRA}/2$

The specified requirements should be fulfilled in all cases including maximum UE transmit power of 23dBm, maximum uplink resource-block allocation and in the full temperature range of -10°C to +55°C for extreme weather conditions. Thus, using these values as estimates for the actual UE out-of-band emissions for all transmit powers and for all possible resource allocations can be expected to over-estimate the actual UE OoB emission and lead to pessimistic conclusions on the impact of LTE UE interference. In other words, specification provides the upper limits of ACLR, i.e. the worst case ACLR values. In reality, actual emission level is lower and heavily depends on:

- LTE UE transmit power: LTE has power control and in operational scenarios emissions are dynamically changing and may be significantly reduced below full power level;
- LTE UE allocated channel bandwidth;
- LTE UE resource block assignment: size and position of assigned resource block in frequency-domain;
- Extra margins considered by design engineers such as to allow for aging, component batch, test margins, extreme conditions, should result in lower emission;

Figure 6:, from measurements done by Ofcom, UK, shows the effect of changing LTE link's data throughput on UE allocated channel bandwidth and its OoB emission levels. The OoB emission decreases significantly by decreasing the allocated bandwidth For example at 867 MHz a UE with lowest allocation bandwidth has 25 dB less OoB emission comparing with a UE with full bandwidth allocation, which indicates that the physical channel configuration has a large impact on RF performance.

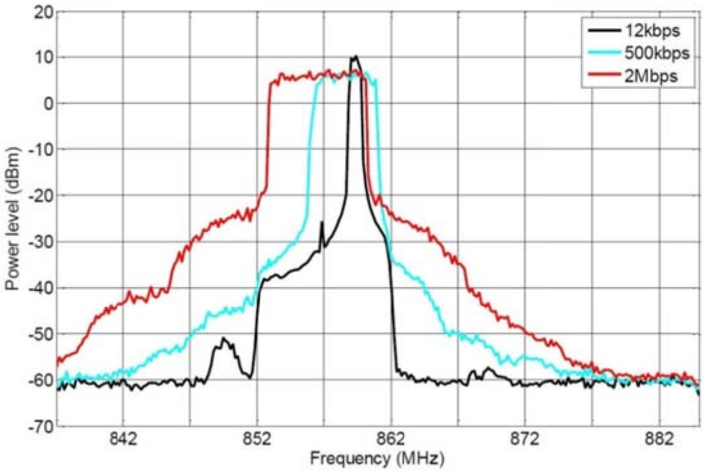

Figure 6: A snapshot of the in-band and out-of-band power level (resolution bandwidth 180 kHz), measured from a production LTE user (Ofcom/UK)

From the above it can be concluded that the scenario when only one UE is scheduled with full UL frequency allocation and maximum power in close proximity to the victim can be specified as a 'worst case' scenario.

4 COEXISTENCE SCENARIO

In general, it is expected that the LTE UEs and SRDs are likely to operate at the same premises. This conclusion can be derived from the large and growing numbers of ubiquitous SRD devices as evidenced by many surveys and industry/ETSI documents and from the forecasts for continued growth of using mobile personal data-hungry devices, as shown in Figure 7:. It should also be mentioned that the growth of mobile devices will occur in both existing and new frequency bands.

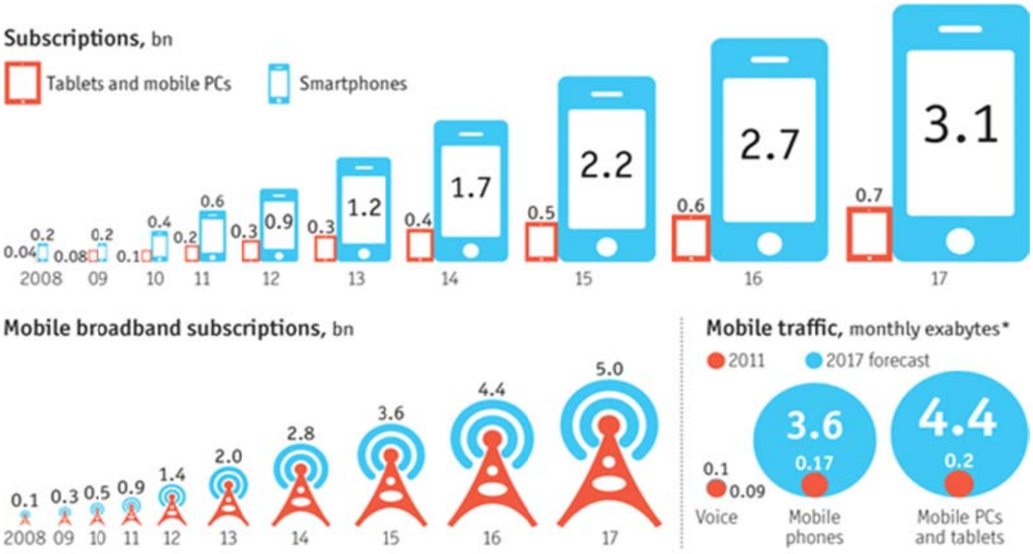

Figure 7: Forecasts for use of mobile data devices (Source: Ericsson/The Economist)

This means that it will increase the statistical proximity between mobile terminal devices and SRDs. At the same time mobile terminals are multi-standard equipment supporting several technologies such as LTE, UMTS/HSPA and GSM which could switch to the appropriate technology depending on the need. In addition, mobile terminals are multi-band equipment which could support multiple frequency bands allocated to mobile broadband, such as 2100 MHz (2x60 MHz), 1800 MHz (2x75 MHz); 2600 MHz (2x70 MHz + 50 MHz), 900 MHz (2x35 MHz), 3500 MHz (200 MHz), 3700MHz (200 MHz), and potentially other bands. Where available these alternative frequencies reduce the likelihood of close proximity between mobile terminals using block C and SRD receivers in 863-870 MHz.

However, in this study only the probability of interference when the LTE UE is using block C or part of block C was considered. It was not taken into account that the UE can be using other bands or other blocks in the 800 MHz band. The likelihood of using block C is therefore not factored in this report. This likelihood depends on several factors: for example, the network planning and loading, the number of mobile operators in the country, and on the overall availability of spectrum for mobile communications.

In addition it should be noted that the numerical results of studies provided in this report are based on assumption that the LTE UE is permanently transmitting (100 % activity factor). Therefore, the probability of receiving interference will be reduced by a factor approximating the actual activity of the LTE UE transmissions.

With the above observations, this study considered two co-existence scenarios.

The first looks at the situation when LTE UE and SRD are co-located in close proximity, i.e. Scenario 1 what is also known as “same room scenario”. Current discussions in 3GPP of the new LTE Release 12 (freeze date expected in 2014), indicates that industry assumes about 70% of traffic will be generated at home or in offices, and those are the exact spaces where most of SRD use is likely to be found (such as above mentioned applications of home automation, metering, wireless audio etc). This scenario is illustrated in Figure 8:.

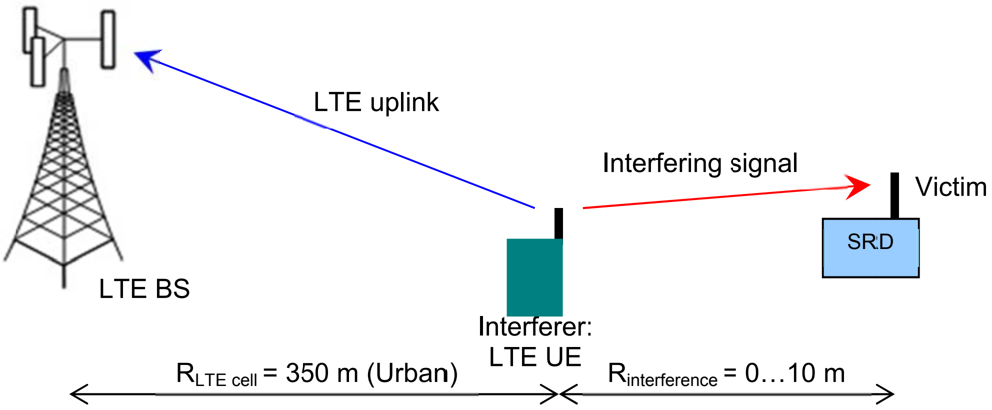

Figure 8: Scenario 1: co-located LTE UE and SRD ("same room")

The Scenario 2 looks more broadly looks more broadly at levels of interference that may be experienced by any given SRD from LTE devices deployed anywhere in an LTE cell. Since it may be assumed with certainty that any SRD in a typical urban scenario will "see" the "endless" LTE cellular structure, in this case it is logical to place a particular victim SRD at the centre of simulation and surround it by LTE UEs randomly deployed within 350 m radius cells around it. This scenario is illustrated in Figure 9:.

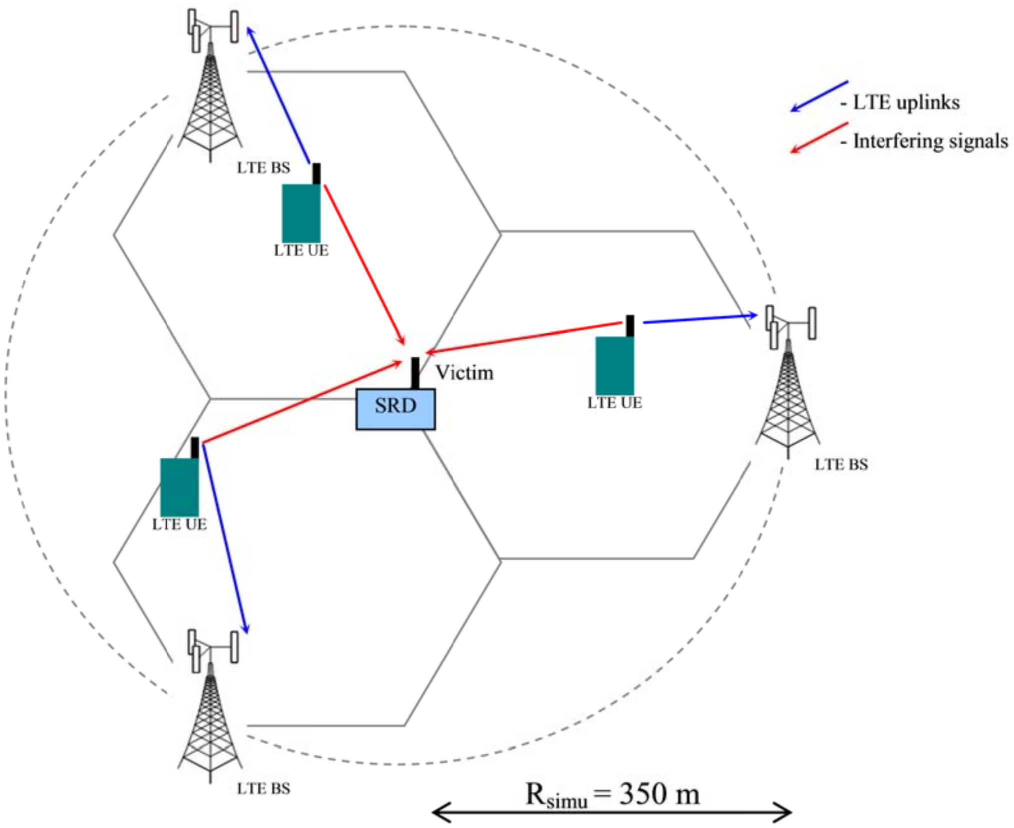

Figure 9: Scenario 2: Victim SRD within endless cellular structure

In this scenario the simulations assumes for example 15 active LTE UEs with 1.4 MHz bandwidth, located randomly within the neighbourhood of SRD victim. This corresponds to the assumption that each of the surrounding LTE cells has at any given time 5 active UEs.

5 ADJACENT BAND CO-EXISTENCE AROUND 863 MHZ BAND EDGE

This section provides compatibility studies on the adjacent band impact of LTE used below 862 MHz on SRDs used above 863 MHz.

5.1 ANALYTICAL STUDY

The details of an analytical analysis are provided in ANNEX 2:.

As the results for non-specific, metering and alarms SRDs are in the same order only one result is provided in the below tables. The results for audio SRDs are about a factor of 1.5 higher.

Table 9: Summary protection distances for unwanted emissions masks (see Figure 2:)

f/MHz	863				869			
Propagation conditions	LOS (pessimistic assumption)		Exp3.5 (optimistic assumption)		LOS (pessimistic assumption)		Exp3.5 (optimistic assumption)	
Margin above sensitivity	low margin	high margin	low margin	high margin	low margin	high margin	low margin	high margin
TS 136 101 (10MHz)	250 m	80 m	24 m	12 m	180 m	60 m	20 m	10 m
TS 136 101 (1.4MHz)	250 m	80 m	24 m	12 m	40 m	15 m	9 m	4 m
measured mask BNetzA	35 m	11 m	8 m	4 m	13 m	4 m	4 m	2 m
measured mask OFCOM	100 m	30 m	14 m	7 m	9 m	3 m	3 m	2 m

Table 10: Summary protection distances for blocking and different SRD receiver categories

Frequency offset	1 MHz				7 MHz			
Propagation conditions	LOS (pessimistic assumption)		Exp3.5 (optimistic assumption)		LOS (pessimistic assumption)		Exp3.5 (optimistic assumption)	
Margin above sensitivity	low margin	high margin	low margin	high margin	low margin	high margin	low margin	high margin
Cat 1 (EN 301357-1)	9 m	3 m	3 m	2 m	5 m	2 m	2 m	1 m
Cat 2 (EN 301357-1)	290 m	90 m	25 m	13 m	50 m	16 m	10 m	5 m
Cat 1 (EN 300220-1)	5 m	2 m	3 m	1 m	1 m	1 m	< 1 m	< 1 m

Frequency offset	1 MHz				7 MHz			
Propagation conditions	LOS (pessimistic assumption)		Exp3.5 (optimistic assumption)		LOS (pessimistic assumption)		Exp3.5 (optimistic assumption)	
Margin above sensitivity	low margin	high margin	low margin	high margin	low margin	high margin	low margin	high margin
Cat 2 (EN 300220-1)	3400 m	1100 m	100 m	50 m	77 m	24 m	12 m	6 m
Cat 3 (EN 300220-1)	5400 m	1700 m	140 m	70 m	1200 m	380 m	60 m	30 m

Those results have been further compressed under NLOS conditions and high margin into Table 11:.

Table 11: Impact ranges under NLOS conditions and high margin (optimistic)

	SRD cat 1 receiver	Audio cat1 receiver	Audio Cat 2 receiver	SRD cat 2 receiver	SRD cat 3 receiver
TS 136 101 LTE mask (10 MHz)	Unwanted: **10-12** m	Unwanted: **15-18** m	Unwanted: **15-18** m	Unwanted: **10**-12 m	Unwanted: 10-12 m
	Blocking ≤ 1 m	Blocking 1-2 m	Blocking 5-13 m	Blocking 6-**50** m	Blocking **30-140** m
TS 136 101 LTE mask (1.4 MHz)	Unwanted: **4-12** m	Unwanted: **6-18** m	Unwanted: **6-18** m	Unwanted: 4-12 m	Unwanted: 4-12 m
	Blocking ≤ 1 m	Blocking 1-2 m	Blocking 5-13 m	Blocking **6-50** m	Blocking **30-140** m
LTE measured mask	Unwanted: **2-4** m	Unwanted: **3-6 m**	Unwanted: 3-6 m	Unwanted: 2-4 m	Unwanted: 2-4 m
	Blocking ≤ 1 m	Blocking 1-2 m	Blocking **5-13** m	Blocking **6-50** m	Blocking **30-140** m

Note 1: the distance range comes from the border frequencies 863 MHz (higher distance) and 869 MHz (lower distance)

It should be noted that any analysis with SRD Rx Cat.1 is just an exercise limited to Social Alarm peripheral (base) unit only. The Rx Cat. 1 is a high performance receiver comparable to an Rx for PMR (Professional Mobile Radio). The Rx Cat.1 power consumption, size and cost (all elements very critical for SRDs) make it impractical for regular SRD applications, especially considering that the utmost of them are battery operated. However even not being the Rx Cat.1 a typical SRDs design options, a simulation exercise study was considered of interest to better understand a comparison between Rx Cat. 2 (the utmost used for SRDs) and Cat. 3.

In the following section SEAMCAT simulations are conducted to get further details about the practical relevance of those results.

5.2 SEAMCAT SIMULATIONS

5.2.1 Scenario 1 “same room”, Urban

In this section simulations for the “same room” scenario with urban LTE cell sizes are provided. The tables provide some of simulation settings in addition to main parameters of LTE and SRD listed in sections 2 and 3.

Figure 10: below shows illustration of the simulated scenario as reproduced in SEAMCAT.

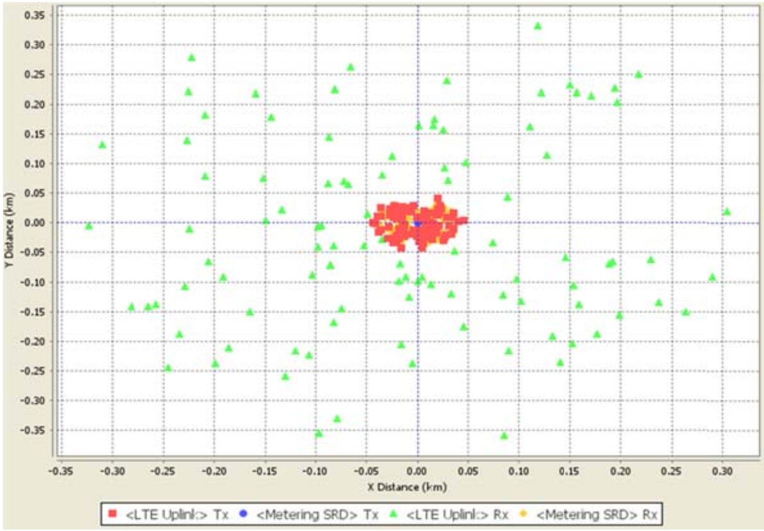

Figure 10: Scenario 1 “same room” reproduced in SEAMCAT simulations

The generic mode of SEAMCAT is used in this report which doesn’t model the LTE network rather it applies to a single cell model since the network influences a number of parameters of the UE.

Table 12: Settings of SEAMCAT simulations for the scenario 1 “same room” , urban

Simulation input / output parameters	Settings/Results
ILK: LTE UE	
Frequency, MHz	10 MHz bandwidth: 857.0 5 MHz bandwidth: 2 frequencies in Block C, randomly selected 3 MHz bandwidth: 3 frequencies in Block C, randomly selected 1.4 MHz bandwidth: 6 frequencies in Block C, randomly selected
ILT power, dBm	Gaussian distribution: mean 20dBm and 1dB stddev
ILT transmitter mask	▪ TS 136 101 for 1.4 to 10 MHz (see Table 7:) ▪ BNetzA static 10 MHz (see Figure 2:)
ILT power control	APC range 63 dB
ILR sensitivity and TPC threshold	▪ 10 MHz: -98.5 dBm ▪ 5 MHz: -101.5 dBm ▪ 3 MHz: -103 dBm ▪ 1.4MHz: -106.8 dBm
ILT antenna gain and height	0 dBi, 1.5 m
ILR antenna gain and height	17 dBi, 30 m
ILT → ILR path	Uniform polar distance 0…350 m (Note 2) Extended Hata model (Urban, ind-outd/above roof)

Simulation input / output parameters	Settings/Results			
ILT active devices	1			
Victim Link - SRD Family Type:	Non-specific	Metering	Alarms	Audio
C/I criterion dB	8	8	8	17
VLR selectivity	EN 300220-1	EN 300220-1	EN 54-25	EN 301357-1
VLR bandwidth	200 kHz	200 kHz	25 kHz	200 kHz
VLR sensitivity, dBm	-104	-104	-112	-97
VLR dRSS	Approach 1: user defined dRSS, Gaussian distribution, Approach 2: distance simulation Details see Table 4			
VLR noise floor, dBm	-112	-112	-120	-114
VLR height	1.5 m			
VLR antenna gain dBi	-5	-5	-5	-5
ILT → VLR positioning mode	“None”, random distance 0…10 m Hata-SRD model (Urban, ind-ind, below roof)			

Note 1: Results for metering and non-specific SRDs are expected to be identical, therefore only 3 applications were considered in the simulations: metering, alarms, and audio SRDs
Note 2: The used generic SEAMCAT mode doesn’t offer to use a MCL value, and the Minimum Coupling Loss value of 70 dB applied in 3 GPP specifications is not used. However, due the height decoupling between UE and BS of 28.5 m a decoupling of about 60dB is used in the simulations.

The results of scenario 1 simulations with dRSS approach 1 are given in section 5.2.1.1 and for approach 2 in section 5.2.1.2.

5.2.1.1 Scenario 1 results with dRSS approach 1

Table 13: Probability of exceeding a C/I objective for the same room scenario, metering, dRSS approach 1 (values: unwanted, blocking, unwanted and blocking)

Metering (EN 300220-1)									
SRD frequency	863.1 MHz			865 MHz			869 MHz		
SRD receiver	Cat.1	Cat.2	Cat. 3	Cat.1	Cat.2	Cat. 3	Cat.1	Cat. 2	Cat. 3
TS 136 101 10 MHz	29.2% 0.09% 29.2%	29.7% 17.2% 31.0%	29.6% 39.67% 41.8%	29.1% 0.07% 29.1%	29.4% 9.43% 29.8%	29.1% 30.9% 35.7%	24.4% 0.07% 24.4%	23.7% 4.94% 23.7%	23.8 % 22.3 % 28.1 %
TS 136 101 5 MHz		16.1% 15.73% 19.95%							
TS 136 101 3 MHz		15.4% 12.59% 18.15%							
TS 136 101 1.4 MHz	▪ 7.55 % 0.04	▪ 7.94 % 12.4	▪ 8.84 % 39.1	▪ 6.08 % 0.01	▪ 6.06 % 7.6	▪ 8.28 % 31.0	▪ 4.12 % 0.01	▪ 3.93 % 2.53	8.3% 23.1 %

Metering (EN 300220-1)									
SRD frequency	863.1 MHz			865 MHz			869 MHz		
SRD receiver	Cat.1	Cat.2	Cat. 3	Cat.1	Cat.2	Cat. 3	Cat.1	Cat. 2	Cat. 3
	% 7.55 %	% 13.9 %	% 40.0 %	% 6.08 %	% 9.53 %	% 31.0 %	% 4.12 %	% 4.72 %	23.7 %
measured mask from a real LTE UE implementation (BNetzA)	6.56% 0.08% 6.57%	6.98% 16.5% 17.1%	7.46% 40.7% 40.8%	4.95% 0.08% 4.95%	4.79% 9.43% 10.6%	4.24% 30.1% 30.2%	2.30% 0.10% 2.30%	2.64% 5.30% 6.00%	2.44 % 22.5 % 22.5 %

Note 1: during the development of this report is was observed that the path loss values for Extended Hata and Extended Hata-SRD at short distances (<1m) can be unrealistic low (even negative), and thus a minimum MCL factor should be implemented; to verify the error the simulations were repeated with a specific plugin being able to select an MCL value of 30dB and those result were comparable. Thus all simulations in this report are performed with the Extended Hata model implemented in SEAMCAT version 4.0.1.

It should be noted that any analysis with SRD Rx Cat.1 is just an exercise limited to Social Alarm peripheral (base) unit only. The Rx Cat. 1 is a high performance receiver comparable to an Rx for PMR (Professional Mobile Radio). The Rx Cat.1 power consumption, size and cost (all elements very critical for SRDs) make it impractical for regular SRD applications, especially considering that the utmost of them are battery operated. However even not being the Rx Cat.1 a typical SRDs design options, a simulation exercise study was considered of interest to better understand a comparison between Rx Cat. 2 (the utmost used for SRDs) and Cat. 3.

Table 14: Probability of exceeding a C/I objective for same room scenario, alarms and audio, dRSS approach 1, (values: unwanted, blocking, unwanted and blocking)

	Alarms (EN54-25)			Audio (EN 301357-1)					
SRD frequency	863.0125 MHz	865 MHz	869 MHz	863.1 MHz		865 MHz		869 MHz	
SRD receiver	EN54-25	EN54-25	EN54-25	Cat.1	Cat.2	Cat.1	Cat.2	Cat.1	Cat.2
TS 136 101 10 MHz	27.0% 4.02% 27.1%	27.1% 3.47% 27.2%	22.3% 2.34% 22.3%	32.6% 1.47% 32.6%	32.8% 15.23% 33.5%	33.0% 0.73% 33.0%	33.1% 11.08% 33.4%	27.8% 0.39% 27.8%	27.6% 7.88% 27.8%
TS 136 101 5 MHz	16.1% 5.91% 16.5%				18.7% 15.1% 21.3%				
TS 136 101 3 MHz	14.2% 4.28% 14.5%				18.2% 11.9% 19.8%				
TS 136 101 1.4 MHz	7.55% 4.28% 8.51%	5.24% 1.69% 5.68%	3.6% 1.2% 3.89%	9.81% 0.61% 9.81%	9.39% 10.2% 13.0%	7.05% 0.38% 7.12%	6.91% 6.66% 9.46%	4.93% 0.18% 4.94%	4.73% 3.68% 6.08%
measured mask from a real LTE UE	5.79% 4.02%	4.44% 3.43%	2.05% 2.36%	8.44% 1.57%	8.84% 15.7%	5.92% 0.70%	5.94% 10.4%	3.16% 0.32%	3.30% 8.12%

	Alarms (EN54-25)			Audio (EN 301357-1)					
SRD frequency	863.0125 MHz	865 MHz	869 MHz	863.1 MHz		865 MHz		869 MHz	
SRD receiver	EN54-25	EN54-25	EN54-25	Cat.1	Cat.2	Cat.1	Cat.2	Cat.1	Cat.2
implementation (BNetzA)	7.29%	5.82%	3.53%	8.57%	17.0%	6.00%	11.8%	3.27%	8.67%

Some further simulations were run to find out the required mean margin above the SRD receiver sensitivity to achieve a risk of interference of about 5% at 863 MHz (see Table 15:).

Table 15: Required mean margin above sensitivity to achieve about 5 % risk of interference

	Dominant effect	Max mask 10 MHz	Max mask 1.4 MHz	measured mask from a real LTE UE implementation
SRDs Cat. 3	blocking	45 dB	45 dB	45 dB
SRDs Cat. 2	mixed	40 dB	30 dB	30 dB
SRDs Cat. 1	unwanted	40 dB	20 dB	20 dB
Alarms	mixed	40 dB	20 dB	20 dB
Audio Cat. 2	mixed	40 dB	30 dB	30 dB
Audio Cat. 1	unwanted	20 dB	20 dB	20 dB

Table 15: shows that LTE may coexist with SRDs at the expense of a higher required margin above sensitivity which in practice means a reduction in SRD operating distance,

5.2.1.2 Scenario 1 results with dRSS approach 2

Table 16: Probability of exceeding a C/I objective for the scenario 1 "same room", metering, dRSS approach 2 (values: unwanted, blocking, unwanted and blocking)

	Metering (EN 300220-1)								
SRD frequency	863.1 MHz			865 MHz			869 MHz		
SRD receiver	Cat.1	Cat.2	Cat. 3	Cat.1	Cat.2	Cat. 3	Cat.1	Cat. 2	Cat. 3
TS 136 101 10 MHz	20.9% 0.06% 20.9%	21.0% 12.2% 22.0%	20.9% 28.9% 30.4%	20.9% 0.06% 20.9%	21.3% 7.24% 21.5%	21.3% 22.7% 26.2%	17.2% 0.06% 17.2%	17.2% 3.92% 17.2%	17.0% 15.9% 20.1%
TS 136 101 1.4 MHz	5.96% 0.03% 5.96%	6.22% 9.45% 10.4%	5.92% 21.3% 21.4%	4.46% 0.03% 4.46%	4.38% 5.26% 6.53%	4.44% 15.9% 16.1%	2.90% 0.02% 2.90%	2.86% 1.97% 3.48%	2.90% 10.0% 10.2%
measured mask from a real LTE UE implementation (BNetzA 10 MHz)	5.21% 0.07% 5.22%	4.76% 11.7% 12.1%	5.19% 28.8% 28.9%	3.81% 0.07% 3.82%	3.72% 6.86% 7.53%	3.71% 21.9% 22.0%	2.03% 0.05% 2.04%	2.23% 4.02% 4.60%	1.98% 16.1% 16.2%

Note 1: during the development of this report is was observed that the path loss values for Extended Hata and Extended Hata-SRD at short distances (<1m) can be unrealistic low (even negative), and thus a minimum MCL factor should be implemented; to verify the error the simulations were repeated with a specific plugin being able to select an MCL value of 30dB and those result

were comparable. Thus all simulations in this report are performed with the Extended Hata model implemented in SEAMCAT version 4.0.1.

It should be noted that any analysis with SRD Rx Cat.1 is just an exercise limited to Social Alarm peripheral (base) unit only. The Rx Cat. 1 is a high performance receiver comparable to an Rx for PMR (Professional Mobile Radio). The Rx Cat.1 power consumption, size and cost (all elements very critical for SRDs) make it impractical for regular SRD applications, especially considering that the utmost of them are battery operated. However even not being the Rx Cat.1 a typical SRDs design options, a simulation exercise study was considered of interest to better understand a comparison between Rx Cat. 2 (the utmost used for SRDs) and Cat. 3.

Table 17: Probability of exceeding a C/I objective for scenario 1 "same room", alarms and audio, dRSS approach 2 (values: unwanted, blocking, unwanted and blocking)

	Alarms (EN54-25)			Audio (EN 301357-1)					
SRD frequency	863.0125 MHz	865 MHz	869 MHz	863.1 MHz		865 MHz		869 MHz	
SRD receiver	EN54-25	EN54-25	EN54-25	Cat.1	Cat.2	Cat.1	Cat.2	Cat.1	Cat.2
TS 136 101 10 MHz	12.9% 1.87% 13.0%	13.0% 1.46% 13.0%	9.98% 0.86% 10.1%	14.0% 0.39% 14.0%	14.0% 5.34% 14.4%	14.4% 0.10% 14.4%	13.9% 3.37% 14.1%	11.2% 0.12% 11.2%	11.0% 1.97% 11.2%
TS 136 101 5 MHz	7.14% 2.56% 7.38%								
TS 136 101 3 MHz	6.43% 1.87% 6.62%								
TS 136 101 1.4 MHz	3.32% 1.96% 3.73%	2.43% 0.80% 2.60%	1.46% 0.46% 1.56%	3.03% 0.10% 3.04%	3.44% 3.77% 5.16%	2.37% 0.09% 2.37%	2.42% 2.34% 3.47%	1.40% 0.02% 1.40%	1.21% 1.02% 1.71%
measured mask from a real LTE UE implementation (BNetzA 10 MHz) 10 MHz	2.81% 1.94% 3.41%	1.95% 1.46% 2.51%	0.98% 1.15% 1.61%	2.35% 0.31% 2.43%	2.55% 5.48% 6.05%	1.97% 0.19% 1.98%	1.59% 2.87%' 3.26%	0.75% 0.05% 0.76%	0.72% 1.89% 2.12%

Some further simulations were run to find out the equivalent reduction of SRD operational distance to achieve sufficient protection margin against OoB emissions with the max LTE UE mask (10 MHz bandwidth) so that a risk of interference at 863 MHz is about 5% :

- Metering: from 40m to 20m;
- Alarms: from 40m to 30m;
- Audio: from 20m to 10m.

5.2.2 Scenario 2 "macro"

The settings for the macro scenario are only different to the scenario 1 "same room" (see Table 12:) for the following parameters:

- ILT to VLR path: "None", random distance 0…300 m (scenario 1: 0-10 m);
- The wanted SRD link was only configured with dRSS approach 1 (user defined dRSS);
- ILT number of active interferers within 3 sectors:
- 3 for the 10 MHz LTE mask;
- 15 for the 1.4 MHz LTE mask;
- 3 for the measured mask from a real LTE UE implementation (BNetzA, 10 MHz BW).

The distance was set to 300m due to the limitation of the Extended Hata-SRD model until this distance, and because the Extended Hata model is not specified for Tx and Rx at low height and would thus lead to incorrect (about 20dB too high) path loss values (see Figure 11:).

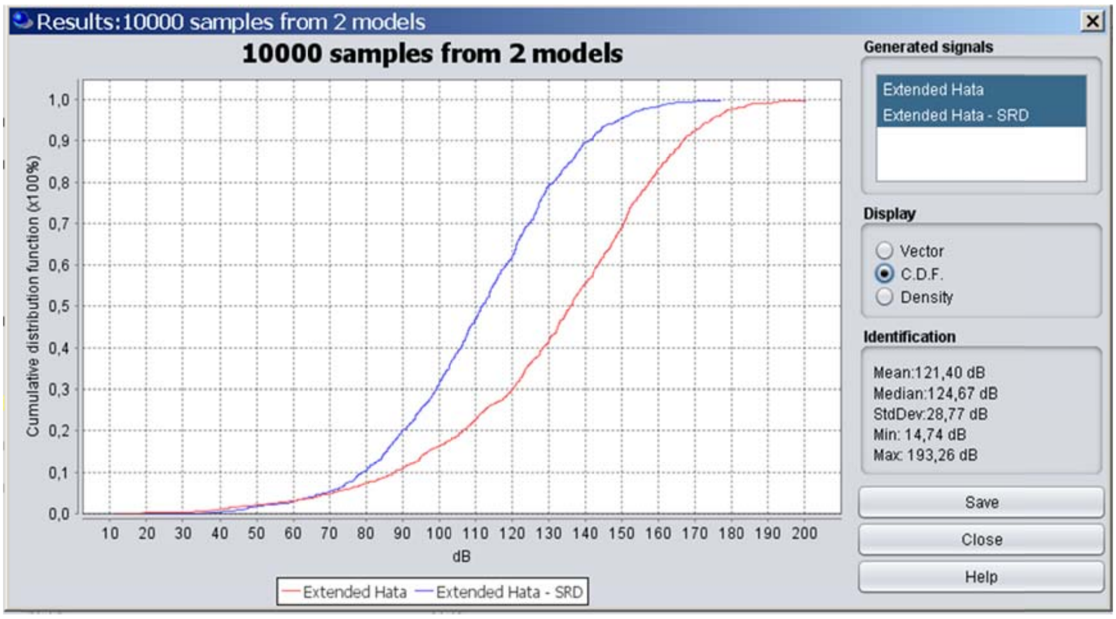

Figure 11: Comparison of path loss of Extended Hata and Extended Hata-SRD (Tx and Rx at 1.5m height, 0-300m)

Figure 12: below shows illustration of simulated scenario 2 "macro" as reproduced in SEAMCAT.

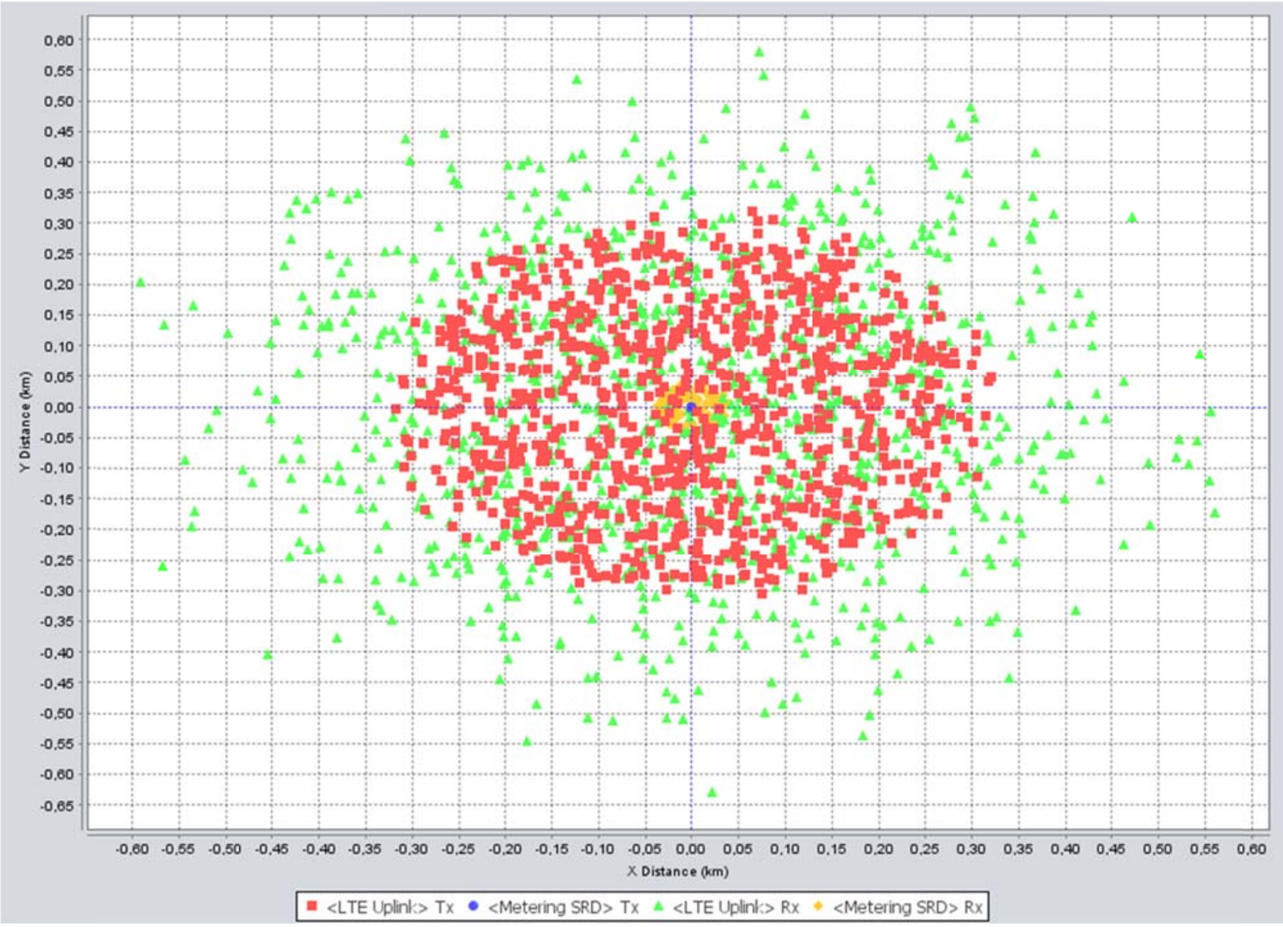

Figure 12: Scenario 2 "Macro" as reproduced in SEAMCAT simulations

Due to the similarity of the results for the different SRD applications observed in the previous section, here only simulations for metering applications are provided. In addition only the worst and best case transmitter masks were analysed due to the generally low risk of interference even for the worst case mask.

Table 18: Probability of exceeding a C/I objective for scenario 2, metering (values: unwanted, blocking, unwanted and blocking)

	Metering (EN 300220-1)								
SRD frequency	863.1 MHz			865 MHz			869 MHz		
SRD receiver	Cat.1	Cat.2	Cat. 3	Cat.1	Cat.2	Cat. 3	Cat.1	Cat. 2	Cat. 3
TS 136 101 10 MHz	0.33% 0.00% 0.33%	0.39% 0.08% 0.41%	0.36% 0.79% 0.93% Note 1	0.38% 0.00% 0.38%	0.35% 0.00% 0.36%	0.29% 0.35% 0.45%	0.20% 0.00% 0.20%	0.24% 0.00% 0.24%	0.27% 0.25% 0.35%
TS 136 101 1.4 MHz	0.21% 0.00% 0.21%	0.30% 0.53% 0.63%	0.17% 4.41% 4.46%			0.22% 2.12% 2.16%			0.24% 1.07% 1.12%
measured mask from a real LTE UE	0.01% 0.00%	0.06% 0.15%	0,02% 0.72%						

	Metering (EN 300220-1)								
SRD frequency	863.1 MHz			865 MHz			869 MHz		
SRD receiver	Cat.1	Cat.2	Cat. 3	Cat.1	Cat.2	Cat. 3	Cat.1	Cat. 2	Cat. 3
implementation (BNetzA 10 MHz)	0.01%	0.15%	0.72%						

Note 1: the impact of different assumptions was analysed further for this setting:
ILT-VLR path Extended Hata - SRD indoor/outdoor: 1.8;
ILT-VLR path Extended Hata indoor/indoor: 0.5;
ILT-VLR path Extended Hata indoor/outdoor: 0.8;
ILT-VLR path Extended Hata-SRD outdoor/outdoor: 1.2.

It should be noted that any analysis with SRD Rx Cat.1 is just an exercise limited to Social Alarm peripheral (base) unit only. The Rx Cat. 1 is a high performance receiver comparable to an Rx for PMR (Professional Mobile Radio). The Rx Cat.1 power consumption, size and cost (all elements very critical for SRDs) make it impractical for regular SRD applications, especially considering that the utmost of them are battery operated. However even not being the Rx Cat.1 a typical SRDs design options, a simulation exercise study was considered of interest to better understand a comparison between Rx Cat. 2 (the utmost used for SRDs) and Cat. 3.

The results of SEAMCAT simulations for the macro scenario indicate very low risk of interference.

5.2.3 Results of practical testing

Prior to completion of this report, CEPT had been informed of several testing campaigns that addressed LTE vs. SRD co-existence around 863 MHz. The summary overview of these tests and their findings is provided in ANNEX 3: of this report.

As an overall conclusion from that analysis, it may be noted that practical tests demonstrated that real LTE UE devices may create interference to SRD operation when operating in the scenario 1”same room“, such as at separation distances of less than 10 m. The impact distance would be at the upper limit of some 7-9 m if assuming that LTE UE operated with full bandwidth and using OoB emission limits, such as outlined in ETSI TS 136 101. The impact distance would be reduced to 1-2 m if assuming that realistic OoB emissions might be reduced to the level corresponding to around 15 dB below the ETSI TS 136 101 limits.

5.2.4 Summary of coexistence studies

The following results refer to the case where the LTE UE is using block C or part of block C. Therefore it is not taken into account that the UE can be using other bands or other blocks in the 800 MHz. The probability of using block C is therefore not factored in the results below. This probability depends on several factors that vary over time: for example, the network planning and loading, the number of mobile operators in the country, LTE implementation in other bands than 800 MHz and on the overall availability of spectrum for mobile communications

One should note that, in case of three operators licensed one block each, when using the 800 MHz band, the terminal of operator having block C will use always this one (if other LTE bands are not available).

The results are comparable for all analysed SRD types:

- Results for alarm applications according to EN 54-25 are similar to Cat.1 receivers from EN 300 220-1 and EN 301357-1
- Results for Cat.2 receivers from EN 300 220-1 and EN 301357-1 are similar

Therefore, Table 19:summarises the findings from section 5 without differentiation of SRD types (the lower value is from dRSS approach 2, the higher value is from dRSS approach 1).

Table 19: Summary of results for different conditions and scenarios

SRD receiver category	LTE UE Masks from ETSI TS 136 101		measured mask from a real LTE UE implementation	
	863 MHz	869 MHz	863 MHz	869 MHz
Cat 1	▪ AN (10MHz UE): 12 m SC1(10MHz UE): 21-29 % SC1(1.4MHz UE): 6-8 % SC2 (1.4MHz UE): 0.4 % SC2 (10MHz UE): 0.3 %	▪ AN (10MHz UE): 10 m SC1(10MHz UE): 17-24 % SC1(1.4MHz UE): 3-4% SC2 (1.4MHz UE): 0.2 % SC2 (10MHz UE): 0.2 %	▪ AN (10MHz UE): 4 m SC1(10MHz UE): 5-7% SC2 (10MHz UE): 0.1%	▪ AN (10MHz UE): 2 m SC1(10MHz UE): 2-3% SC2 (10MHz UE): <0.1 %
Cat 2	▪ AN (10MHz UE): 50 m SC1(10MHz UE): 22-31 % SC1(1.4MHz UE): 10-14 % SC2 (1.4MHz UE): 0.6 % SC2 (10MHz UE): 0.4 %	▪ AN (10 MHz UE): 10 m SC1(10MHz UE):17-24 % SC1(1.4MHz UE): 4-5 % SC2 (1.4MHz UE): <0.6 % SC2 (10MHz UE): 0.2 %	▪ AN (10MHz UE): 50 m SC1(10MHz UE): 12-17 % SC2 (10MHz UE): 0.2 %	▪ AN (10MHz UE): 6 m SC1(10MHz UE): 5-6 % SC2 (10MHz UE): <0.2 %
Cat 3	▪ AN (10MHz UE): 140 m SC1 (10MHz UE): 30-42 % SC1(1.4MHz UE): 21-40 % SC2 (1.4MHz UE): 4.5 % SC2 (10MHz UE): 0.9 %	▪ AN (10 MHz UE): 30 m SC1(10MHz UE): 20-28 % SC1(1.4MHz UE): 10-24 % SC2 (1.4MHz UE): 1 % SC2 (10MHz UE): 0.4 %	▪ AN (10MHz UE): 140 m SC1(10MHz UE): 29-41 % SC2 (10MHz UE): 0.7 %	▪ AN (10MHz UE): 30 m SC1(10MHz UE): 16-23 % SC2 (10MHz UE): <0.7 %

Notes:
1. AN: analytical calculations, distances derived for urban environments (propagation exponent 3.5)
2. SC1: scenario 1, same room SEAMCAT simulations, risk of interference, lower value dRSS approach 1, higher value dRSS approach 2 (see table 2)
3. SC2: scenario 2, macro SEAMCAT simulations, risk of interference

The above simulation results were complemented with the results of many practical tests, which have shown that emissions from LTE UE may disrupt SRD operation if LTE UE interferer was placed between 1 m (typical case) and 9 m (worst case) from SRD victim.

6 USE OF MITIGATION TECHNIQUES TO ENHANCE ADJACENT BAND CO-EXISTENCE

This section provides additional consideration on use of special mitigation techniques to improve co-existence of LTE uplink below 862 MHz with the operation of SRDs in the band 863-870 MHz.

6.1 RECEIVER SELECTIVITY

This issue was deeply analysed in section 5. SRD Rx. Cat. 2 may be recommended as state-of-the-art good practice SRD design in order to improve the coexistence with LTE in the same room scenario.

6.2 LOW DUTY CYCLE/ ACTIVITY FACTOR

Some natural mitigation of interference would be occurring due to the pattern of use of both LTE UE and SRD emissions. However the precise effect of this mitigation is difficult to estimate quantitatively, due to highly varying (diurnal/spatial/user type) patterns of temporal activity of LTE UE users and different SRD applications.

6.3 FHSS

The effect of this technique may be modest to non-existent as the studies reported in this report shown minor dependence of interference impact as a function of frequency separation, within the confines of subject SRD band. The combination of this band with other SRD bands maybe possible and further improves the effectiveness of FHSS. Adaptive FHSS systems may improve the impact further (see LBT+AFA).

6.4 DSSS

It may be expected that DSSS techniques might improve resilience of victim SRDs, thanks to general abilities of DSSS modulation to overcome in-channel noise effects. However, this resilience improvement would be again limited due to the fact that DSSS is most efficient against narrow-band interfering signals whereas broadband OoB emissions from LTE UE would appear in victim receiver as white Gaussian noise therefore polluting the entire reception spectrum and affecting the ability to re-integrate useful signal from noise.

6.5 LBT (+AFA)

It may be expected that the presence of the OoB emissions of the LTE UE in SRD channels would be detected by power sensing function of LBT mechanism. The effect could be for wideband emissions in theory that the whole band could be blocked. But there may be an improvement possible for frequency dependent OoB emissions of the LTE UE in real life. To avoid unwanted emission effects those channels could be avoided or disregarded. The combination of this band with other SRD bands maybe possible and further improves the effectiveness of LBT+AFA.

7 CONCLUSIONS

Two fundamentally different mechanisms were identified as sources of possible interference from LTE UE into SRDs: blocking effect and interference from unwanted emissions falling into the band of SRDs. They differ in that blocking can be mitigated by improving the victim's receiver characteristics, while mitigating unwanted in-band interference requires a reduction of the OoB emissions of the interferer.

Measurements indicated that a potential for interference exists when LTE UE is used in the proximity of up to several metres from an SRD receiver. Where the interference occurs, it manifests itself either as a reduction in SRD operational range, or a degradation / loss of function.

Two main situations were investigated. In Scenario 1 ("same room") a single LTE UE is allocated in block C (852-862 MHz) and is transmitting at the same time when the SRD is receiving and is located within 10 m range of the SRD receiver, in an indoor environment, to simulate the case of a person using their LTE UE in premises where an SRD receiver is present. In general, it is expected that the LTE UEs and SRDs are likely to operate at the same premises (see section 4). In the second case i.e. Scenario 2 ("macro") the LTE network deployment is considered: one SRD receiver and LTE UE(s) are randomly located in a 3-cell network, with no specific assumptions on the relative position between SRD and LTE UE.

In the Scenario 2 "macro" the probability of interference was found to be mostly below 1% (only for Cat. 3 SRD receivers up to 5 %) and therefore this case is not considered critical and not addressed in the following discussion.

The results for the Scenario 1 "same room" are summarised in Table 20: and are between 2 % and 42 %. The range of results in Table 20: is caused by different SRD frequencies (863/869 MHz), different assumptions on the wanted signal at the SRD receiver and different LTE UE masks.

It has to be noted that the simulation results are comparable for all analysed SRD types (Results for alarm applications according to EN 54-25 [12] are similar to Cat.1 receivers from EN 300 220-1 [8] and EN 301357-1[13]; results for Cat.2 receivers from EN 300 220-1 and EN 301357-1 are similar).

Table 20: Summary same room scenario

LTE UE mask	Cat.3 SRD Receiver	Cat.2 SRD receiver	Cat.1 SRD receiver (Note 1)
according ETSI TS 136 101 [11] with 1.4/3/5/10 MHz bandwidth (Note 2)	The probability of interference was found to be in the range 10% and 42%.	The probability of interference was found to be in the range 5% to 31%.	The probability of interference was found to be in the range 2% to 29%.
according to a measured mask from a real LTE UE implementation with 10 MHz bandwidth (see Figure 2:)	The probability of interference was found to be in the range 16% and 41%.	The probability of interference was found to be in the range 5% to 17%.	The probability of interference was found to be in the range 2% to 7%.
Comments	The main issue is blocking.	The prevailing component can be blocking or in-band interference, depending on the considered LTE UE emission mask	The dominant effect is in-band interference from OoB emissions, depending on the considered LTE UE emission mask

Note 1: The SRD Receiver Category 1 is a high performance receiver comparable to an Rx for PMR (Professional Mobile Radio) and implemented by social alarm power supplied base station. The Rx Cat.1 power consumption, size and cost (all elements very critical for SRDs) make it impractical for regular SRD applications, especially considering that the utmost of them are battery operated.

Note 2: It has to be noted that in this report the LTE UE Tx mask was used in accordance to ETSI TS 136 101 [11] which shows 1.5 dB lower power values as the harmonised standard EN 301 908-13 [17]. However, the impact on the result is only marginal.

The following interim conclusions can be drawn from Table 20:

- The interference risk varies dependent on the configuration between low (e.g. real measured LTE mask, upper frequency boundary, Cat. 1 receiver, optimistic SRD signal distribution), and large values (e.g. 10 MHz LTE mask, lower frequency boundary, Cat. 3 receiver, pessimistic SRD signal distribution)
- Cat 3 SRD receivers cannot coexist with nearby LTE UE due to SRD receiver blocking effects, and receiver performance degradation due to receiver selectivity (blocking) cannot be improved by reducing the interfering OoB emissions. Thus the removal of SRD receiver Cat. 3 in the band 863-870 MHz from the market place would reduce the risk of interference caused by blocking, but this alone is not sufficient.
- Cat.1 SRD receivers may coexist with a measured mask from a real LTE UE implementation (15-20 dB lower OoB emissions), but may not with the LTE UE masks from the ETSI standard. However, manufacturing associations note that the use of a Cat. 1 receiver is not viable for SRD applications except for very specific high performance alarm base stations (e.g. EN 300 220 [8]).

Considering the above first observations, the following evaluation is limited to the typical SRD receiver Category 2 as the main anticipated counterpart for LTE in 800 MHz co-existence scenario.

Table 21: shows the results for SRD receiver category 2 used at typical frequencies.

Table 21: Results for SRD Cat. 2 receivers

	LTE Max masks 10 MHz	LTE Max mask 1.4 MHz	Measured mask from a real LTE UE implementation
Wireless audio and metering at 863 MHz	▪ 22 % - 31 %	▪ 10 % - 14 %	▪ 12 % - 17 %
Non-specific SRD 868 MHz (results for alarms at 869 are in the same order)	▪ 17 % - 24 %	▪ 4 % - 5 %	▪ 5 % - 6 %

Note: the lower value is from dRSS approach 2, the higher value is from dRSS approach 1 (see Table 4:)

The most critical situation is for SRDs operating close to the 863 MHz border. **Error! Reference source not found.** shows that for wireless audio and SRDs using Cat 2 receivers the risk of interference is well above 5 %.

The risk can further be reduced with higher frequency offsets from the lower border frequency; e.g. Non-specific SRDs with Cat. 2 receivers working at 868 MHz may coexist with LTE for both assumed SRDs signal levels (dRSS approach 1 and 2) as long as the LTE OoB emissions are 15-20 dB below its ETSI specification (as confirmed by real measurements) or the LTE UE is only using 1.4 MHz of the available 10 MHz bandwidth.

Note: It should be noted that it was not possible to get a common understanding on the signal levels for SRDs between SRD and LTE community. The SRD community suggested the dRSS approach 1 as representative, while the LTE community suggested dRSS approach 2. The dRSS approach 2 is the result when considering the Extended hata SRD indoor path loss model in SEAMCAT with distances up to the operational distances assumed for SRDs. The SRD community criticised that the relatively high signal levels may be caused by the implemented indoor-indoor model currently implemented in SEAMCAT and that this model (which is mainly considering free space loss plus a certain number of wall losses and standard deviations) should be updated.

An interference probability of below 5 % can be reached generally at the expense of a reduction in SRD operating distance (derived from dRSS approach 2 simulations):

- Cat.3 receiver at 863.1 MHz (LTE 10MHz mask) reduction from 40m to 17m (-58%);
- Cat.2 receiver at 863.1 MHz (LTE 10MHz mask) reduction from 40m to 21m (-48%);
- Cat.2 receiver at 869 MHz (LTE 10MHz mask) reduction from 40m to 24m (-40%);
- Cat.2 receiver at 863.1 MHz (a measured mask from a real LTE UE implementation) reduction from 40m to 28m (-30%);
- Cat.2 receiver at 863.1 MHz (LTE 1.4MHz mask) reduction from 40m to 30m (-25%);
- Cat.2 receiver at 865 MHz (LTE 1.4MHz and real mask) reduction from 40m to 38m (-5%); .

The LTE UE devices compliant with mask from ETSI TS 136 101 with 1.4 MHz bandwidth may not produce harmful interference. However, LTE is a complex technology (see section 3) and it is expected that the resource block allocation and thus the used bandwidth will be dynamically changing over short periods of time. The consequence is that all masks/bandwidths are expected to be used at any location but with different occurrence probabilities in time (e.g. higher probability of small resource block allocations vs. lower probability of high resource block allocations). In a real network typically 3-5 UEs are scheduled in each transmission time interval sharing the 10 MHz channel bandwidth. Therefore, the result for the bandwidths of 1.4 MHz and 3 MHz represents the likely impact of LTE UE on SRDs. The precise interference effect of this dynamic LTE behaviour will also depend on the characteristics of the SRDs: e.g. audio links may experience constantly recurring interference effects while SRDs using digital modulations may be better able to resist (e.g. FEC, acknowledgement).

In this study, only the probability of interference when the LTE UE is using block C or part of block C was considered. Therefore it was not taken into account that the UE can be using other bands or other blocks in the 800 MHz band. The likelihood of using block C is therefore not factored in the above results .This likelihood depends on several factors that can vary over time: for example, the network planning and loading, the number of mobile operators in the country, and on the overall availability of spectrum for mobile communications.

In addition it should be noted that the numerical results of studies provided in this report are based on assumption that the LTE UE is permanently transmitting (100 % activity factor). Therefore, the probability of receiving interference will statistically be reduced by a factor approximating the actual activity of the LTE UE transmissions. Here it should be considered that data uploading is not necessarily connected to an end user action at the same location (e.g. watching videos from a home NAS via an LTE link).

This report considers a power control strategy resulting in a LTE UE power distribution close to “Set 2” specified in ETSI TR 136 942. A more aggressive power control strategy is introduced in ETSI TR 136 942 (“Set 1”), which may lead to higher interference probabilities. However, it is not expected that operators would use this strategy in interference limited networks to avoid interference to other operators and their own system (see Annex 4).

In addition only an urban scenario with a LTE cell size of 350m has been considered in detail in this report. The main expected difference in rural environments would be that the LTE network would be more likely noise-limited than interference limited, with the possible consequence of a more aggressive power control strategy taken by the network providers and thus a potential higher interference probability to SRDs (see Annex 4). Until there is wide spread deployment of LTE there is uncertainty to this point.

Summary of main findings:

1. There is little risk of harmful interference if the LTE UE and the SRDs are not used on the same premises (separation distance >10m).
2. There is a risk of interference when an LTE UE is used in block C on the same premises (distances ≤ 10 m) as an SRD but this risk of interference varies due to several factors such as SRD operating distance and SRD receiver category and LTE UE emission mask: the risk can be high if an LTE UE is used towards its full capability, with high resource block allocations, in block C, which cannot be overcome by the SRD user in many cases.
3. Cat 3 SRD receivers (e.g. from EN 300 220) cannot coexist with LTE UE due to SRD receiver blocking effect. The future removal of SRD Cat. 3 receivers in the band 863-870 MHz from the

market place can reduce statistically blocking effects on total population of SRD receivers in the long term perspective.

4. The SRD Cat.1 receiver may coexist with a measured mask from a real LTE UE implementation (15-20 dB lower OoB emissions), but may not with the LTE UE masks from the ETSI standard. However, manufacturing associations note that the use of a Cat. 1 receiver is not viable for SRD applications due to size, cost and power consumption, except for very specific high performance alarm base stations (e.g. EN 300 220).
5. SRD receivers with min Cat. 2 blocking performance may coexist with LTE under the following assumptions:
   - If the LTE UE is transmitting with OoB emissions complying with the 1.4 MHz mask (5 LTE UEs share the 10 MHz channel) from the standard; but all LTE UEs are expected to change their bandwidth and thus applicable OoB masks dynamically with different occurrence probabilities in time (e.g. high probability of small resource block allocations vs low probability of high resource block allocations).
   - If the real LTE UE OoB emissions for 3, 5 and 10 MHz bandwidth (1-3 LTE UEs share the 10 MHz channel) are below the mask specification in standards (e.g. by 15-20 dB for the 10 MHz mask). Available measurements' results from a real LTE UE implementation confirmed that this may be realistic assumption as measured OoB emissions were well below the specification (in static transmission states of EUT).
   - At the expense of a reduction in SRD operating distance (e.g. down to 50% for the 10 MHz LTE UE mask from the standard) with the possible consequence that a certain percentage of SRD devices will no longer function as intended.
   - The performance degradation of Cat. 2 receivers is due to blocking and LTE UE unwanted emissions.
6. SRDs experience the high LTE UE OoB emissions, that are caused by high (25-50) resource block allocations in the LTE UE but the activity factor of the LTE UE has not been considered in this report. However, it should be expected that the most critical LTE UE mask (one user is using all resource blocks available in the cell) will happen in real life only for short time periods (noting that the LTE base-station reallocates resources between LTE UEs with a time interval of 1 ms).
7. The most likely impacted SRD type may be an audio receiver (including baby alarms) in the band 863-865 MHz, as they are working close in frequency to the LTE band. In addition, audio receivers may already be affected by very short LTE UE bursts with high resource block allocations, but this has not been analysed in detail in this report. However, some measurements were provided (see Annex 3).
8. SRDs using digital modulations may be better able to resist interference from LTE UE (e.g. thanks to using FEC, acknowledgement with re-transmission), but the OoB emission of the LTE UE as per the current standard may generally lead to desensitisation and false signal level triggering in those receivers. It should be noted that any reduction of SRD throughput and/or increase of retransmissions cause a decrease of battery lifetime.

Considering all above it appears that the most severely impacted SRDs are those of Cat.3 receivers, mainly due to blocking effect. Using Cat.2 receivers will help coexistence with adjacent band LTE use and this will improve one of the interference problems (i.e. blocking).

With regard to the other interference problem (i.e. OoB emissions), measurements provided in this report have shown that LTE UE OoB emissions are significantly below the mask specification in current standards. This provides an opportunity for a possible solution for coexistence together with the SRD industry moving towards the performance seen in Cat. 2 receivers.

In addition, it may be anticipated that the interference situation will be further improved in deployed LTE networks, as the most critical high resource block allocations have a lower probability of occurrence than the less critical low resource block allocations.

ANNEX 1: SELECTIVITY OF SRD APPLICATIONS

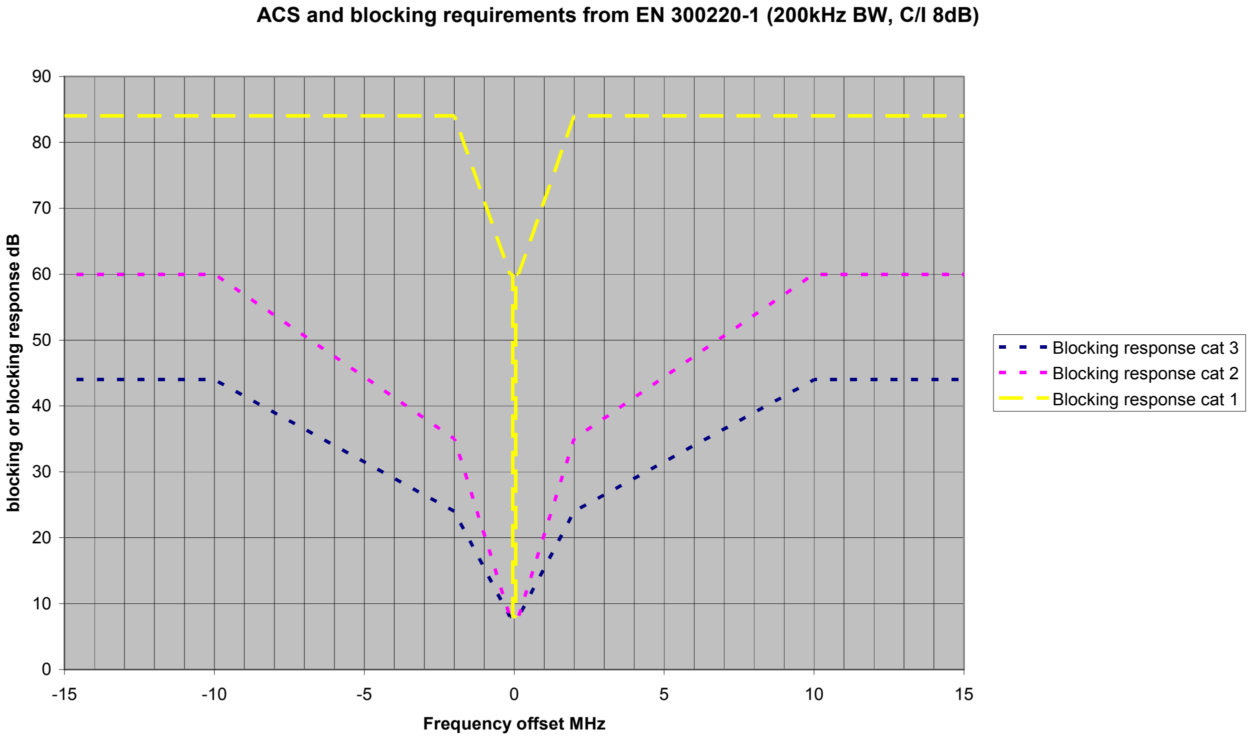

Figure 13: ACS and blocking requirements for SRDs

It should be noted that EN 300 220 SRD Cat 2 devices are available with better than EN54-25 blocking performance.

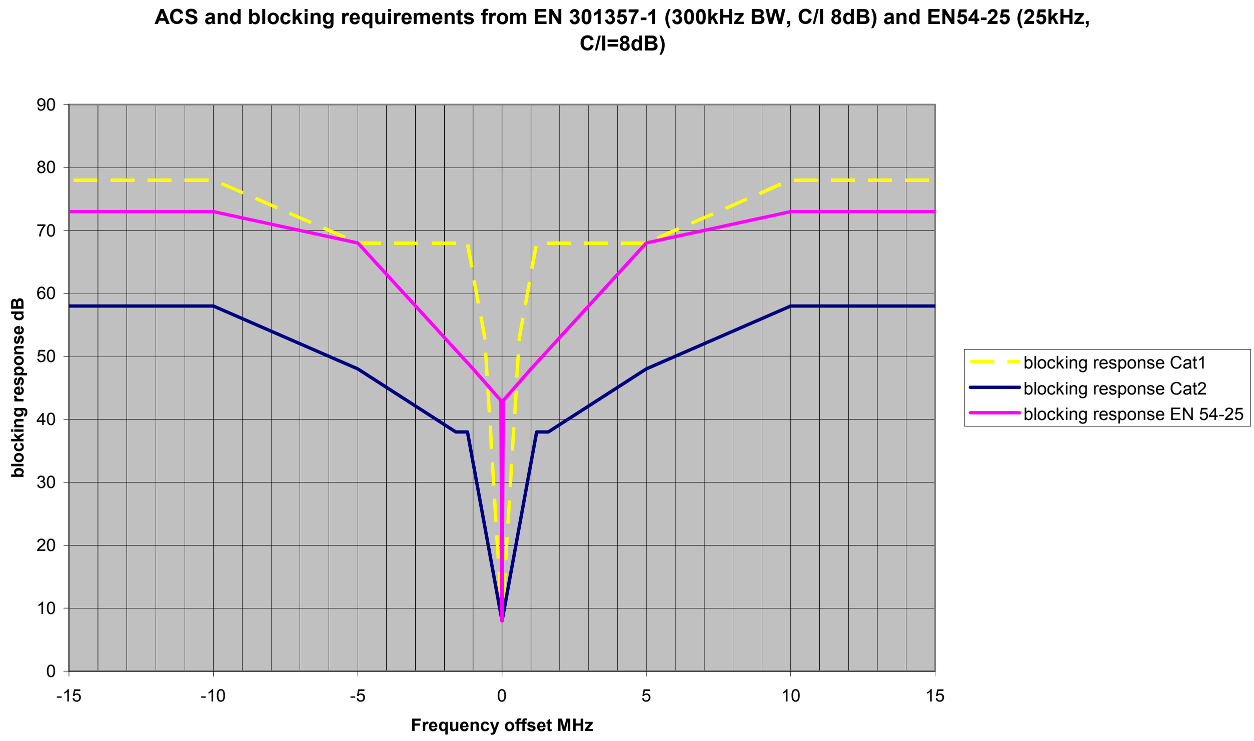

Figure 14: Blocking characteristics for wireless audio and alarms

Note: the ACS and blocking values has to be chosen carefully; it is not correct to assume that the adjacent power reduced by the ACS or blocking values from the standard can be assumed as the equivalent interfering power; ACS is usually the difference between adjacent power and wanted signal. Thus, the equivalent interfering power of the adjacent signal is the ACS/blocking value plus C/I. In addition the blocking response should be used for the blocking response. See Table below for details.

ANNEX 2: ANALYTICAL STUDY

The following tables are showing the required separation distances between the 4 different SRD applications and LTE terminals:

- Table 22: Unwanted emissions, Free space loss, SRDs wanted signal with low margin above sensitivity
- Table 23:**Error! Reference source not found.** Unwanted emissions, LOS,, Free space loss, SRDs wanted signal with high margin above sensitivity
- Table 24: Unwanted emissions, urban propagation conditions (exp. 3.5), SRDs wanted signal with low margin above sensitivity
- Table 25: Unwanted emissions, urban propagation conditions (exp. 3.5), SRDs wanted signal with high margin above sensitivity
- Table 26:**Error! Reference source not found.** and Table 27:**Error! Reference source not found.** Blocking effects

The used unwanted emissions masks are shown in Figure 2:.

Table 22: Unwanted impact, low margin, LOS

	Non-specific	Metering	Alarms	Audio
f/GHz	0.868	0.868	0.868	0.868
noise figure	9	9	10	7
BW/MHz	0.2	0.2	0.025	0.2
ktBF	-111.99	-111.99	-120.02	-113.99
sensitivity dBm	-103.99	-103.99	-112.02	-96.99
magin dB	10	10	10	10
C/I dB	8	8	8	17
Ge dBi	-5	-5	-5	-5
Imax dBm/BW	-101.9897	-101.9897	-110.0206	-103.9897
Propagation exp	2	2	2	2

LTE UE ETSI TS 136 101 (10 MHz)		23 dBm							
dF MHz	f/MHz	BW/kHz	dP	Tx power dBm/BW (for 23 dBm)	Tx power dBm/100 kHz	Distance m	Distance m	Distance m	Distance m
0	862	30	41	-18	-12.77	627.94	627.94	559.65	790.53
1	863	30	41	-18	-12.77	627.94	627.94	559.65	790.53
1.001	863.001	1000	33	-10	-20.00	273.20	273.20	243.49	343.94
5	867	1000	33	-10	-20.00	273.20	273.20	243.49	343.94
5.001	867.001	1000	36	-13	-23.00	193.41	193.41	172.38	243.49
8	870	1000	36	-13	-23.00	193.41	193.41	172.38	243.49
10	872	1000	36	-13	-23.00	193.41	193.41	172.38	243.49
10.001	872.001	1000	48	-25	-35.00	48.58	48.58	43.30	61.16
15	877	1000	48	-25	-35.00	48.58	48.58	43.30	61.16

LTE UE ETSI TS 136 101 (1.4 MHz)		23 dBm							
dF MHz	f/MHz	BW/kHz	dP	Tx power dBm/BW (for 23 dBm)	Tx power dBm/100 kHz	Distance m	Distance m	Distance m	Distance m
0	862	30	33	-10	-4.77	1577.32	1577.32	1405.79	1985.73
1	863	30	33	-10	-4.77	1577.32	1577.32	1405.79	1985.73
1.001	863.001	1000	33	-10	-20.00	273.20	273.20	243.49	343.94
2.5	864.5	1000	33	-10	-20.00	273.20	273.20	243.49	343.94
2.5001	864.5001	1000	48	-25	-35.00	48.58	48.58	43.30	61.16
5	867	1000	48	-25	-35.00	48.58	48.58	43.30	61.16

5.001	867.001	1000	48	-25	-35.00	48.58	48.58	43.30	61.16
8	870	1000	48	-25	-35.00	48.58	48.58	43.30	61.16
10	872	1000	48	-25	-35.00	48.58	48.58	43.30	61.16
10.001	872.001	1000	48	-25	-35.00	48.58	48.58	43.30	61.16
15	877	1000	48	-25	-35.00	48.58	48.58	43.30	61.16

LTE UE1 real (BnetzA)		23 dBm							
dF MHz	f/MHz	BW/kHz	dP	Tx power dBm/BW (for 23 dBm)	Tx power dBm/100 kHz	Distance m	Distance m	Distance m	Distance m
0	862		58.00		-35.00	48.58	48.58	43.30	61.16
1	863		60.00		-37.00	38.59	38.59	34.39	48.58
1.001	863.001		60.00		-37.00	38.59	38.59	34.39	48.58
5	867		66.00		-43.00	19.34	19.34	17.24	24.35
5.001	867.001		66.00		-43.00	19.34	19.34	17.24	24.35
8	870		69.00		-46.00	13.69	13.69	12.20	17.24
10	872		71.00		-48.00	10.88	10.88	9.69	13.69
10.001	872.001		71.00		-48.00	10.88	10.88	9.69	13.69
15	877		73.00		-50.00	8.64	8.64	7.70	10.88

LTE UE2 real (OFCOM UK)		23 dBm							
dF MHz	f/MHz	BW/kHz	dP	Tx power dBm/BW (for 23 dBm)	Tx power dBm/100 kHz	Distance m	Distance m	Distance m	Distance m
0	862		48.00		-25.00	153.63	153.63	136.92	193.41
1	863		51.00		-28.00	108.76	108.76	96.93	136.92
1.001	863.001		51.00		-28.00	108.76	108.76	96.93	136.92
5	867		58.00		-35.00	48.58	48.58	43.30	61.16
5.001	867.001		58.00		-35.00	48.58	48.58	43.30	61.16
8	870		72.00		-49.00	9.69	9.69	8.64	12.20
10	872		74.00		-51.00	7.70	7.70	6.86	9.69
10.001	872.001		74.00		-51.00	7.70	7.70	6.86	9.69

Table 23: Unwanted impact, high margin, LOS

						Non-specific	Metering	Alarms	Audio
					f/GHz	0.868	0.868	0.868	0.868
					noise figure	9	9	10	7
					BW/MHz	0.2	0.2	0.025	0.2
					kTBF	-111.99	-111.99	-120.02	-113.99
					sensitivity dBm	-103.99	-103.99	-112.02	-96.99
					magin dB	20	20	20	20
					C/I dB	8	8	8	17
					Ge dBi	-5	-5	-5	-5
					Imax dBm/BW	-91.9897	-91.9897	-100.0206	-93.9897
					propagation exp	2	2	2	2
LTE UE ETSI TS 136 101 (10 MHz)		23 dBm							
dF MHz	f/MHz	BW/kHz	dP	Tx power dBm/BW (for 23 dBm)	Tx power dBm/100 kHz	Distance m	Distance m	Distance m	Distance m
0	862	30	41	-18	-12.77	198.57	198.57	176.98	249.99
1	863	30	41	-18	-12.77	198.57	198.57	176.98	249.99
1.001	863.001	1000	33	-10	-20.00	86.39	86.39	77.00	108.76
5	867	1000	33	-10	-20.00	86.39	86.39	77.00	108.76
5.001	867.001	1000	36	-13	-23.00	61.16	61.16	54.51	77.00
8	870	1000	36	-13	-23.00	61.16	61.16	54.51	77.00
10	872	1000	36	-13	-23.00	61.16	61.16	54.51	77.00
10.001	872.001	1000	48	-25	-35.00	15.36	15.36	13.69	19.34
15	877	1000	48	-25	-35.00	15.36	15.36	13.69	19.34

LTE UE ETSI TS 136 101 (1.4 MHz)		23 dBm							
dF MHz	f/MHz	BW/kHz	dP	Tx power dBm/BW (for 23 dBm)	Tx power dBm/100 kHz	Distance m	Distance m	Distance m	Distance m
0	862	30	33	-10	-4.77	498.79	498.79	444.55	627.94
1	863	30	33	-10	-4.77	498.79	498.79	444.55	627.94
1.001	863.001	1000	33	-10	-20.00	86.39	86.39	77.00	108.76
2.5	864.5	1000	33	-10	-20.00	86.39	86.39	77.00	108.76
2.5001	864.5001	1000	48	-25	-35.00	15.36	15.36	13.69	19.34
5	867	1000	48	-25	-35.00	15.36	15.36	13.69	19.34

5.001	867.001	1000	48	-25	-35.00	15.36	15.36	13.69	19.34
8	870	1000	48	-25	-35.00	15.36	15.36	13.69	19.34
10	872	1000	48	-25	-35.00	15.36	15.36	13.69	19.34
10.001	872.001	1000	48	-25	-35.00	15.36	15.36	13.69	19.34
15	877	1000	48	-25	-35.00	15.36	15.36	13.69	19.34

LTE UE1 real (BNetzA))		23 dBm							
dF MHz	f/MHz	BW/kHz	dP	Tx power dBm/BW (for 23 dBm)	Tx power dBm/100 kHz	Distance m	Distance m	Distance m	Distance m
0	862		58.00		-35.00	15.36	15.36	13.69	19.34
1	863		60.00		-37.00	12.20	12.20	10.88	15.36
1.001	863.001		60.00		-37.00	12.20	12.20	10.88	15.36
5	867		66.00		-43.00	6.12	6.12	5.45	7.70
5.001	867.001		66.00		-43.00	6.12	6.12	5.45	7.70
8	870		69.00		-46.00	4.33	4.33	3.86	5.45
10	872		71.00		-48.00	3.44	3.44	3.07	4.33
10.001	872.001		71.00		-48.00	3.44	3.44	3.07	4.33
15	877		73.00		-50.00	2.73	2.73	2.43	3.44

LTE UE2 real (OFCOM UK)		23 dBm							
dF MHz	f/MHz	BW/kHz	dP	Tx power dBm/BW (for 23 dBm)	Tx power dBm/100 kHz	Distance m	Distance m	Distance m	Distance m
0	862		48.00		-25.00	48.58	48.58	43.30	61.16
1	863		51.00		-28.00	34.39	34.39	30.65	43.30
1.001	863.001		51.00		-28.00	34.39	34.39	30.65	43.30
5	867		58.00		-35.00	15.36	15.36	13.69	19.34
5.001	867.001		58.00		-35.00	15.36	15.36	13.69	19.34
8	870		72.00		-49.00	3.07	3.07	2.73	3.86
10	872		74.00		-51.00	2.43	2.43	2.17	3.07
10.001	872.001		74.00		-51.00	2.43	2.43	2.17	3.07

Table 24: Unwanted impact, low margin, Exponent 3.5

	Non-specific	Metering	Alarms	Audio
f/GHz	0.868	0.868	0.868	0.868
noise figure	9	9	10	7
BW/MHz	0.2	0.2	0.025	0.2
kTBF	-111.99	-111.99	-120.02	-113.99
sensitivity dBm	-103.99	-103.99	-112.02	-96.99
magin dB	10	10	10	10
C/I dB	8	8	8	17
Ge dBi	-5	-5	-5	-5
Imax dBm/BW	-101.9897	-101.9897	-110.0206	-103.9897
Propagation exp	3.5	3.5	3.5	3.5

LTE UE ETSI TS 136 101 (10 MHz)		23 dBm							
dF MHz	f/MHz	BW/kHz	dP	Tx power dBm/BW (for 23 dBm)	Tx power dBm/100 kHz	Distance m	Distance m	Distance m	Distance m
0	862	30	41	-18	-12.77	39.70	39.70	37.17	45.28
1	863	30	41	-18	-12.77	39.70	39.70	37.17	45.28
1.001	863.001	1000	33	-10	-20.00	24.68	24.68	23.10	28.15
5	867	1000	33	-10	-20.00	24.68	24.68	23.10	28.15
5.001	867.001	1000	36	-13	-23.00	20.26	20.26	18.97	23.10
8	870	1000	36	-13	-23.00	20.26	20.26	18.97	23.10
10	872	1000	36	-13	-23.00	20.26	20.26	18.97	23.10
10.001	872.001	1000	48	-25	-35.00	9.20	9.20	8.61	10.49
15	877	1000	48	-25	-35.00	9.20	9.20	8.61	10.49

LTE UE ETSI TS 136 101 (1.4 MHz)		23 dBm							
dF MHz	f/MHz	BW/kHz	dP	Tx power dBm/BW (for 23 dBm)	Tx power dBm/100 kHz	Distance m	Distance m	Distance m	Distance m
0	862	30	33	-10	-4.77	67.20	67.20	62.92	76.65
1	863	30	33	-10	-4.77	67.20	67.20	62.92	76.65
1.001	863.001	1000	33	-10	-20.00	24.68	24.68	23.10	28.15
2.5	864.5	1000	33	-10	-20.00	24.68	24.68	23.10	28.15
2.5001	864.5001	1000	48	-25	-35.00	9.20	9.20	8.61	10.49

5	867	1000	48	-25	-35.00	9.20	9.20	8.61	10.49
5.001	867.001	1000	48	-25	-35.00	9.20	9.20	8.61	10.49
8	870	1000	48	-25	-35.00	9.20	9.20	8.61	10.49
10	872	1000	48	-25	-35.00	9.20	9.20	8.61	10.49
10.001	872.001	1000	48	-25	-35.00	9.20	9.20	8.61	10.49
15	877	1000	48	-25	-35.00	9.20	9.20	8.61	10.49

LTE UE1 real (BNetzA))		23 dBm							
dF MHz	f/MHz	BW/kHz	dP	Tx power dBm/BW (for 23 dBm)	Tx power dBm/100 kHz	Distance m	Distance m	Distance m	Distance m
0	862		58.00		-35.00	9.20	9.20	8.61	10.49
1	863		60.00		-37.00	8.06	8.06	7.55	9.20
1.001	863.001		60.00		-37.00	8.06	8.06	7.55	9.20
5	867		66.00		-43.00	5.43	5.43	5.09	6.20
5.001	867.001		66.00		-43.00	5.43	5.43	5.09	6.20
8	870		69.00		-46.00	4.46	4.46	4.18	5.09
10	872		71.00		-48.00	3.91	3.91	3.66	4.46
10.001	872.001		71.00		-48.00	3.91	3.91	3.66	4.46
15	877		73.00		-50.00	3.43	3.43	3.21	3.91

LTE UE2 real (OFCOM UK)		23 dBm							
dF MHz	f/MHz	BW/kHz	dP	Tx power dBm/BW (for 23 dBm)	Tx power dBm/100 kHz	Distance m	Distance m	Distance m	Distance m
0	862		48.00		-25.00	17.76	17.76	16.63	20.26
1	863		51.00		-28.00	14.58	14.58	13.65	16.63
1.001	863.001		51.00		-28.00	14.58	14.58	13.65	16.63
5	867		58.00		-35.00	9.20	9.20	8.61	10.49
5.001	867.001		58.00		-35.00	9.20	9.20	8.61	10.49
8	870		72.00		-49.00	3.66	3.66	3.43	4.18
10	872		74.00		-51.00	3.21	3.21	3.01	3.66
10.001	872.001		74.00		-51.00	3.21	3.21	3.01	3.66

Table 25: Unwanted impact, high margin, Exponent 3.5

	Non-specific	Metering	Alarms	Audio
f/GHz	0.868	0.868	0.868	0.868
noise figure	9	9	10	7
BW/MHz	0.2	0.2	0.025	0.2
kTBF	-111.99	-111.99	-120.02	-113.99
sensitivity dBm	-103.99	-103.99	-112.02	-96.99
magin dB	20	20	20	20
C/I dB	8	8	8	17
Ge dBi	-5	-5	-5	-5
Imax dBm/BW	-91.9897	-91.99	-100.0206	-93.9897
Propagation exp	3.5	3.5	3.5	3.5

LTE UE ETSI TS 136 101 (10 MHz)		23 dBm							
dF MHz	f/MHz	BW/kHz	dP	Tx power dBm/BW (for 23 dBm)	Tx power dBm/100 kHz	Distance m	Distance m	Distance m	Distance m
0	862	30	41	-18	-12.77	20.56	20.56	19.25	23.46
1	863	30	41	-18	-12.77	20.56	20.56	19.25	23.46
1.001	863.001	1000	33	-10	-20.00	12.78	12.78	11.97	14.58
5	867	1000	33	-10	-20.00	12.78	12.78	11.97	14.58
5.001	867.001	1000	36	-13	-23.00	10.49	10.49	9.82	11.97
8	870	1000	36	-13	-23.00	10.49	10.49	9.82	11.97
10	872	1000	36	-13	-23.00	10.49	10.49	9.82	11.97
10.001	872.001	1000	48	-25	-35.00	4.76	4.76	4.46	5.43
15	877	1000	48	-25	-35.00	4.76	4.76	4.46	5.43

LTE UE ETSI TS 136 101 (1.4 MHz)		23 dBm							
dF MHz	f/MHz	BW/kHz	dP	Tx power dBm/BW (for 23 dBm)	Tx power dBm/100 kHz	Distance m	Distance m	Distance m	Distance m
0	862	30	33	-10	-4.77	34.81	34.81	32.59	39.70
1	863	30	33	-10	-4.77	34.81	34.81	32.59	39.70
1.001	863.001	1000	33	-10	-20.00	12.78	12.78	11.97	14.58
2.5	864.5	1000	33	-10	-20.00	12.78	12.78	11.97	14.58
2.5001	864.5001	1000	48	-25	-35.00	4.76	4.76	4.46	5.43
5	867	1000	48	-25	-35.00	4.76	4.76	4.46	5.43

5.001	867.001	1000	48	-25	-35.00	4.76	4.76	4.46	5.43
8	870	1000	48	-25	-35.00	4.76	4.76	4.46	5.43
10	872	1000	48	-25	-35.00	4.76	4.76	4.46	5.43
10.001	872.001	1000	48	-25	-35.00	4.76	4.76	4.46	5.43
15	877	1000	48	-25	-35.00	4.76	4.76	4.46	5.43

LTE UE1 real (BNetzA))		23 dBm							
dF MHz	f/MHz	BW/kHz	dP	Tx power dBm/BW (for 23 dBm)	Tx power dBm/ 100 kHz	Distance m	Distance m	Distance m	Distance m
0	862		58.00		-35.00	4.76	4.76	4.46	5.43
1	863		60.00		-37.00	4.18	4.18	3.91	4.76
1.001	863.001		60.00		-37.00	4.18	4.18	3.91	4.76
5	867		66.00		-43.00	2.81	2.81	2.64	3.21
5.001	867.001		66.00		-43.00	2.81	2.81	2.64	3.21
8	870		69.00		-46.00	2.31	2.31	2.16	2.64
10	872		71.00		-48.00	2.03	2.03	1.90	2.31
10.001	872.001		71.00		-48.00	2.03	2.03	1.90	2.31
15	877		73.00		-50.00	1.78	1.78	1.66	2.03

LTE UE2 real (OFCOM UK)		23 dBm							
dF MHz	f/MHz	BW/kHz	dP	Tx power dBm/BW (for 23 dBm)	Tx power dBm/ 100 kHz	Distance m	Distance m	Distance m	Distance m
0	862		48.00		-25.00	9.20	9.20	8.61	10.49
1	863		51.00		-28.00	7.55	7.55	7.07	8.61
1.001	863.001		51.00		-28.00	7.55	7.55	7.07	8.61
5	867		58.00		-35.00	4.76	4.76	4.46	5.43
5.001	867.001		58.00		-35.00	4.76	4.76	4.46	5.43
8	870		72.00		-49.00	1.90	1.90	1.78	2.16
10	872		74.00		-51.00	1.66	1.66	1.56	1.90
10.001	872.001		74.00		-51.00	1.66	1.66	1.56	1.90

Table 26: Blocking calculations (metering)

	Low margin		High margin	
Tx power LTE UE	23	23	23	23
Propagation exp	3.5	2	3.5	2
Ge dBi	-5	-5	-5	-5
Imax co-channel dBm	-102.00	-102.00	-92.00	-92.00

EN 300 220-1 cat 1 (v2.4.1 2012-05)								
Non-spec SRD	f/MHz	Blocking response	BW/MHz	Imax dBm	Distance m	Distance m	Distance m	Distance m
0.05	862.95	60.00	0.10	-42.00	5.43	19.34	2.81	6.12
0.15	862.85	60.00	0.10	-42.00	5.43	19.34	2.81	6.12
1.00	862.00	71.00	0.10	-31.00	2.64	5.45	1.36	1.72
2.00	861.00	84.00	0.10	-18.00	1.12	1.22	0.58	0.39
7.00	856.00	84.00	0.10	-18.00	1.12	1.22	0.58	0.39
10.00	853.00	84.00	0.10	-18.00	1.12	1.22	0.58	0.39

EN 300 220-1 cat 2 (v2.4.1 2012-05)								
Non-spec SRD	f/MHz	Blocking response	BW/MHz	Imax dBm	Distance m	Distance m	Distance m	Distance m
0.05	862.95	0.00	0.10	-102.00	281.46	19341.06	145.78	6116.18
0.15	862.85	0.00	0.10	-102.00	281.46	19341.06	145.78	6116.18
0.50	862.50	7.50	0.10	-94.50	171.84	8156.06	89.01	2579.17
1.00	862.00	15.00	0.10	-87.00	104.92	3439.38	54.34	1087.63
2.00	861.00	35.00	0.10	-67.00	28.15	343.94	14.58	108.76
7.00	856.00	48.00	0.10	-54.00	11.97	77.00	6.20	24.35
10.00	853.00	60.00	0.10	-42.00	5.43	19.34	2.81	6.12

EN 300 220-1 cat 3 (v2.4.1 2012-05)								
Non-spec SRD	f/MHz	Blocking response	BW/MHz	Imax dBm	Distance m	Distance m	Distance m	Distance m
0.05	862.95	0.00	0.10	-102.00	281.46	19341.06	145.78	6116.18
0.15	862.85	0.00	0.10	-102.00	281.46	19341.06	145.78	6116.18
0.50	862.50	6.00	0.10	-96.00	189.67	9693.49	98.24	3065.35
1.00	862.00	11.00	0.10	-91.00	136.50	5451.05	70.70	1723.77
2.00	861.00	24.00	0.10	-78.00	58.04	1220.34	30.06	385.90
7.00	856.00	24.00	0.10	-78.00	58.04	1220.34	30.06	385.90
10.00	853.00	38.00	0.10	-64.00	23.10	243.49	11.97	77.00

Note: The blocking characteristics were extrapolated for cat 1 and Cat 2 receivers between 0.15 and 2 MHz

Table 27: Blocking calculations (audio)

					Low margin		High margin	
				Tx power LTE UE	23	23	23	23
				Propagation exp	3.5	2	3.5	2
				Ge dBi	-5	-5	-5	-5
				Imax co-channel dBm	-104.00	-104.00	-94.00	-94.00
EN 301 357 cat 2								
Audio	**f/MHz**	**Blocking response**	**BW/MHz**	**Imax dBm**	**Distance m**	**Distance m**	**Distance m**	**Distance m**
0.60	862.40	23.00	0.30	-81.00	68.60	1635.23	35.53	517.11
1.20	861.80	38.00	0.30	-66.00	25.57	290.79	13.24	91.96
1.600	861.40	38.00	0.30	-66.00	25.57	290.79	13.24	91.96
5.000	858.00	48.00	0.30	-56.00	13.24	91.96	6.86	29.08
7.000	856.00	53.00	0.30	-51.00	9.53	51.71	4.94	16.35
10.000	853.00	58.00	0.30	-46.00	6.86	29.08	3.55	9.20
EN 301 357-1 cat 1								
Audio	**f/MHz**	**Blocking response**	**BW/MHz**	**Imax dBm**	**Distance m**	**Distance m**	**Distance m**	**Distance m**
0.60	862.40	53.00	0.30	-51.00	9.53	51.71	4.94	16.35
1.20	861.80	68.00	0.30	-36.00	3.55	9.20	1.84	2.91
1.600	861.40	68.00	0.30	-36.00	3.55	9.20	1.84	2.91
5.000	858.00	68.00	0.30	-36.00	3.55	9.20	1.84	2.91
7.000	856.00	73.00	0.30	-31.00	2.56	5.17	1.32	1.64
10.000	853.00	78.00	0.30	-26.00	1.84	2.91	0.95	0.92

Note: The ACS and blocking values has to be chosen carefully; it is not correct to assume that the adjacent power reduced by the ACS or blocking values from the standard can be assumed as the equivalent interfering power. ACS is usually the difference between adjacent power and wanted signal. Thus, the equivalent interfering power of the adjacent signal is the ACS/blocking value plus C/I.

ANNEX 3: OVERVIEW OF PRACTICAL TESTS

Prior to completion of this report, various practical tests of LTE vs. SRD co-existence around 863 MHz were performed. These various documents and their underlying tests had looked at the issue of whether OoB emissions or blocking effects from LTE UE uplink in the upper part of the 790-862 MHz band may be creating any significant interference potential to SRDs deployed in the band 863-870 MHz.

This annex provides a summary overview of those different tests and compares their set-ups and results in order to try to spell out any common observations that may feed into the overall conclusions of this report.

List of considered test reports

Table 28: below lists reported and discussed LTE-SRD tests carried out prior to writing this report (i.e. by June 2013). All documents had been reviewed and further analysed here.

To provide an instant summary overview of circumstances and results, the table also lists some key elements/results of the tests:

- An indication of applied/measured LTE UE's OoB mask, by taking a reference point at dF=6 MHz (which corresponds to the point where outermost LTE channel emissions start overlapping the SRD 863-870 MHz band);
- The assumed loading of LTE UE in terms of data traffic transmitted on the UL at the time of testing;
- Indication whether victim link operation were found affected, and if yes, at what distance.

Note that as regards the OoB mask used, most of the sources did not provide tabulated mask values, in which case an approximate check point was derived from the provided graphs/spectrum analyser plots.

Table 28: List of CEPT PT SE24 input documents that discussed results of practical LTE vs SRD co-existence tests

SE24 Doc. No.	Source	Addressed SRD use family	LTE UE signal source	LTE UE OoB	Blocking effects considered?	Configuration of Victim	LTE UE traffic load	impact distance
M65_15R0	OFCOM UK	PMSE/Wireless Audio	Signal generator	-30 dBc	Yes	30dB margin, operating distance <69m	Maximum	< 5 m
M66_26R0	OFCOM UK	SRD not considered, LTE OoB measurements only	Real devices	-42 dBc (2) (3)	/		varying	Impact not tested
M68_01R0	APWPT	PMSE/Wireless Audio	Real devices	-25 dBc	Yes	Not clear	Varying	No impact
M68_20R0	BNetzA, Germany	PMSE/Wireless Audio	Lab set up incl. model signals of real devices	-50 dBc (5)	Yes	SINAD 30dB (0 dB margin)	Varying	<3-20m
M70_09R0	Hager, Somfy, Legrand, Delta Dore, Velux	Home Automation devices in the band 868-870MHz	Real devices (USB, mobile)	-18dBc @868.3MHz	Yes	Sensitivity level+3dB	Varying from 100kb/s to 17Mb/s	Measurement performed at 1m and 2m
M71_04R0	CRA, Lithuania	Non-specific SRDs of two types	Signal generator	-36 dBc (4) -50 dBc (5)	No	0dB margin 20dB margin	N/A	< 8-9 m < 1.5m

Notes:
1 – measured for dynamic LTE UE signal with transients
2 – for 2 Mb/s reference signal (15-40% of RBs in use) chosen max speed for live network testing (cf. Fig. 9 of test report)
3 – noted 20-40 dB upward OoB level variations for cases of RB use changing up to 50-100%
4 – corresponds to TS 136 101 LTE UE's OoB mask limits
5 – corresponds to one case of practically measured LTE UE's OoB emissions as reported in M68_20R0

Observations

Based on the provided analysis of the various input documents, it is possible to offer the following observations:

- Practical tests demonstrated a significant dependence of OoB emissions both on LTE UE load in terms of RBs, but even more so on the transient processes that are always present in real-life LTE link due to constant dynamic re-adjustment of various link parameters;
- Of the reported tests, the one provided in M68_20R0 appears to be most comprehensive in terms of analysing various LTE link loads and situations of both static and real dynamic signal with transient processes;
- All tests that considered actual impact on victim SRDs have discovered the harmful interference from LTE UE to SRD reaching disruptive levels when the max distance from interfering LTE UE to victim SRD receiver is in the order of 1.5-9 m, the precise threshold distance depending on the SRD type and whether assuming normative (TS 136 101) OoB limits or some of the practically measured LTE UE OoB levels under different loads;
- The latest document M71_04 additionally measured the MCL for closely co-located (0 m) devices in subject band, which was shown to be around 10-15 dB.

As an overall conclusion it may be said that practical tests clearly demonstrated that real LTE UE devices may create interference to SRD operation when operating in the same room scenario. The necessary protection distance would be at some 7-9 m if assuming the current normative OoB emission limits, such as outlined in ETSI TS 136 101. The protection distance would be reduced to 1-2 m if assuming some realistic OoB emissions being around 15 dB below the ETSI TS 136 101 limits.

ANNEX 4: ADAPTIVE POWER CONTROL STRATEGIES

The results of any coexistence or compatibility analysis, which involve LTE systems, are highly dependent upon the assumptions made regarding the systems being simulated. In such analysis, some simulation assumptions are closely related to each other, such as operating frequency, cell radius, power control parameters, propagation model, user density and terrain environment (urban/suburban/rural). Therefore, assumptions should be made in a proper way in order to be realistic and consistent.

Cell radius results from the link budget which highly depends on environment (urban/suburban/rural), propagation loss and operating frequency assumed. So, the proper cell radius should be selected to be consistent with these assumptions. Power control parameters also depend on operating frequency, propagation model, cell type (macro/micro/pico) and cell radius. The open loop power control algorithm, which is used for LTE coexistence studies (see [15]), sets the UE Tx power based on the path loss between the user equipment (UE) and its serving base station (BS) and some other parameters including that which corresponds to the percentage of active users transmitting with the maximum UE power. In particular, care should be taken when selecting this parameter, in order that the percentage of the users with UE maximum Tx power is close to that in a real network. If there are too many users transmitting with the maximum power, the uplink of the LTE system will operate in a very high IoT (Interference over Thermal, also called Noise Rise) condition, which is the result of excessive interference at the BS receiver of a specific radio cell due to high Tx power of active UEs in other radio cells. This condition will cause the uplink cell edge throughput to deteriorate or even the cell coverage to shrink. The stability of the overall system will be affected due to unstable UL control channel performance under high IoT condition. Also high Tx power will reduce the active time and standby time of the user equipment. The power consumption is a serious problem for smart phones and it can impact the user experience significantly. Therefore, an appropriate setting for power control parameters would allow a reasonable portion of total UEs (in the order of 2%~5% for macro cells, less than 1% for pico cells or mixed macro/pico cells) to transmit with the maximum power, depending on operating frequency and cell radius. The power control parameters will be determined by some pre-simulations.

To illustrate the above discussion in a concrete example, the performance of a macro LTE network with different power control parameters is presented below eNB IoT CDF (Figure 15) and UL C/I CDF (Figure 16). The network is assumed to operate in an interference limited suburban environment in the 700MHz frequency range. The Inter-Site-Distance (ISD) is assumed to be 3km and a modified Hata model given in the ITU-R Report SM.2028 [16] is used for calculating path loss. We assume 6 UEs per cell/sector in the following simulation.

With a proper selection of power control settings (PC setting 2 in Table 29, which corresponds to PC Set 2 in 3GPP TR 36.942 [15]), the network will operate at a moderate IoT condition and achieve a good tradeoff between the overall system stability and the average throughput. With an aggressive power control setting (PC setting 1 in Table 28, which corresponds to PC Set 1 in 3GPP TR 36.942 [15]), the portion of UEs transmitting with the maximum power will increase and the average throughput can increase, too. However, IoT of the network will be higher, which will deteriorate the cell edge throughput (and the C/I distribution in the cell) and make the system less stable. With a too conservative power control setting (PC setting 3 in Table 29, introduced here just for comparison purposes and doesn’t correspond to any PC set in 3GPP TR 36.942 [15]), the UE transmission power will be lower resulting in a quite low IoT. The price to be paid is a much lower average and cell edge throughput in the network. Therefore, it is not necessary and appropriate for an operator to select an over-conservative power control configuration, rather a balanced one. E.g. in the example network, PC setting 2 is the most appropriate one, which achieves the best tradeoff among UE Tx power, IoT and the network throughput performance. PC setting 3 is too conservative since the throughput is low. PC setting 1 is too aggressive since the IoT operating point of the network is the highest which may cause unstable control channel quality. With this power control setting, the portion of UEs with the maximum transmit power is the highest and also the portion of UEs with bad C/I performance is the highest. In addition, such a power control setting results in a considerable capacity loss of a UMTS network operating in the adjacent channel (see Table 7.3a in 3GPP TR 36.942 [15]), whereas PC setting 2 results in an acceptable capacity loss of a UMTS network operating in the adjacent channel (see Table 7.3b in 3GPP TR 36.942 [15]).

Table 29: Simulation results of different PC settings

	PC setting 1	PC setting 2	PC setting 3
PLxile in dB	115	122	130
γ	1	1	1
▪ Portion of UE with maximum Tx power	24.8%	2.6%	0.003%
Average IoT in dB	14.00	8.81	0.89
▪ Average throughput (b/s/Hz)	0.522	0.417	0.252
▪ 5% CDF throughput (b/s/Hz)	0.167	0.177	0.141

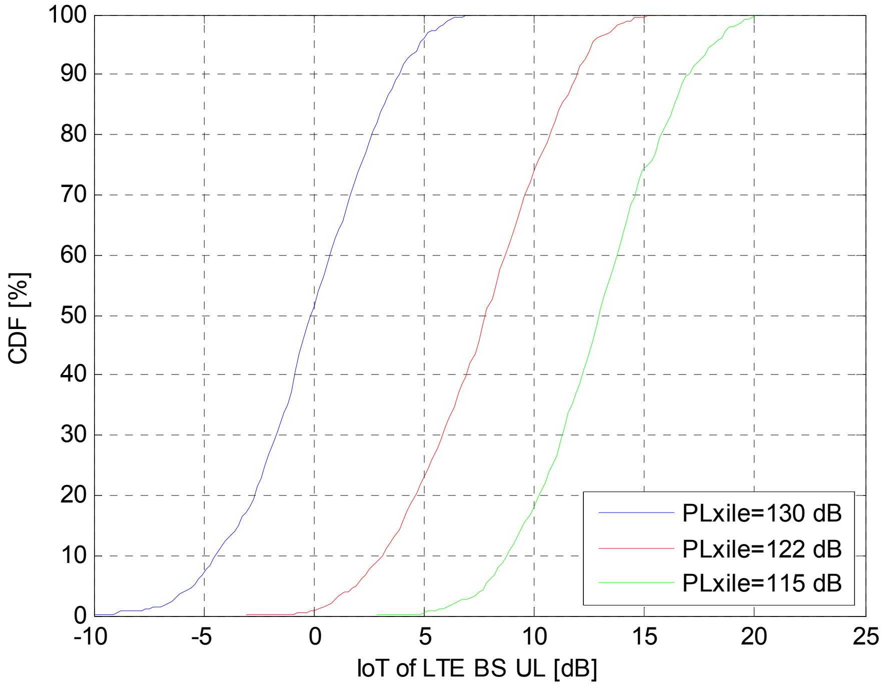

Figure 15: LTE eNB IoT CDF with different power control parameters

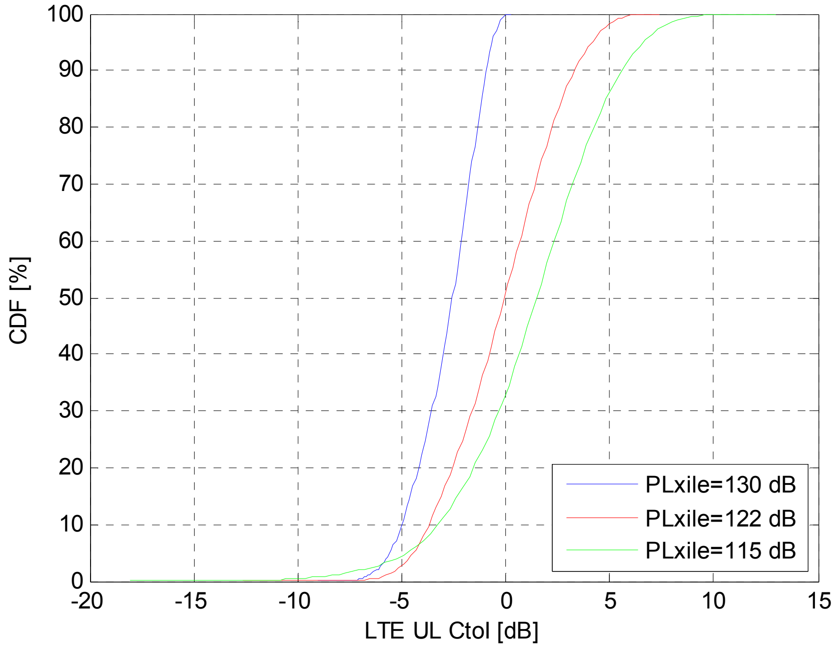

Figure 16: LTE UL C/I CDF with different power control parameters

The below two figures are showing in addition that the SEAMCAT configuration used in this report ("SEAMCAT APC") delivers a LTE UE power distribution between Set 1 and Set 2 from 3 GPP TR 36.942 but much closer to Set 2.

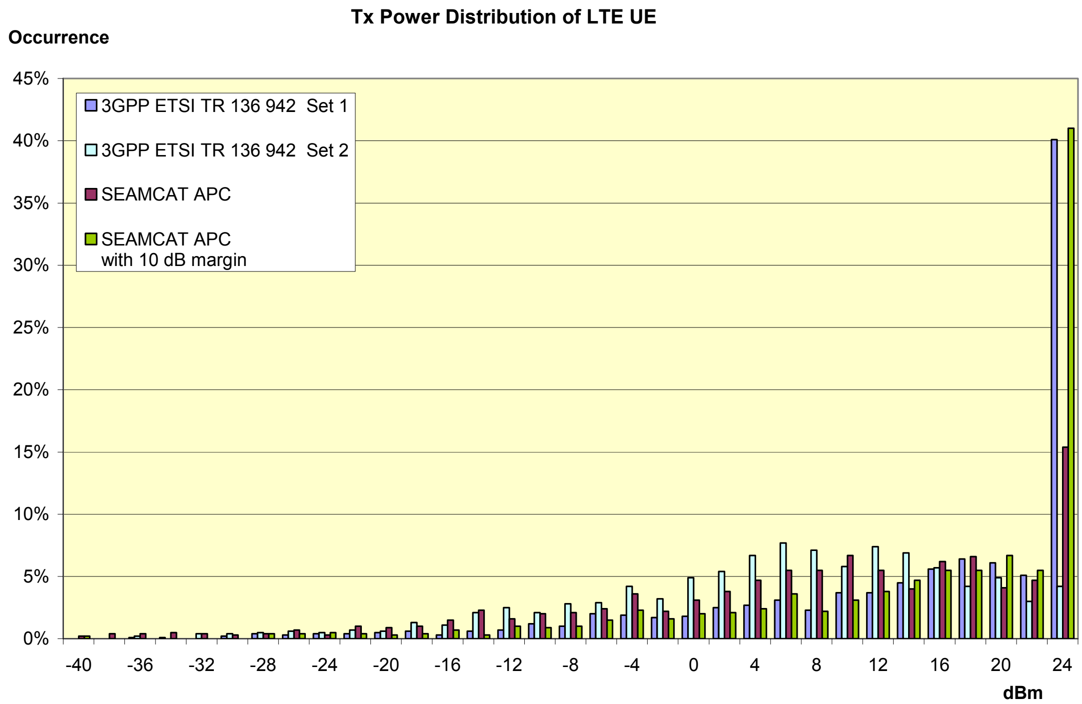

Figure 17: Tx-Power Distribution of LTE UE

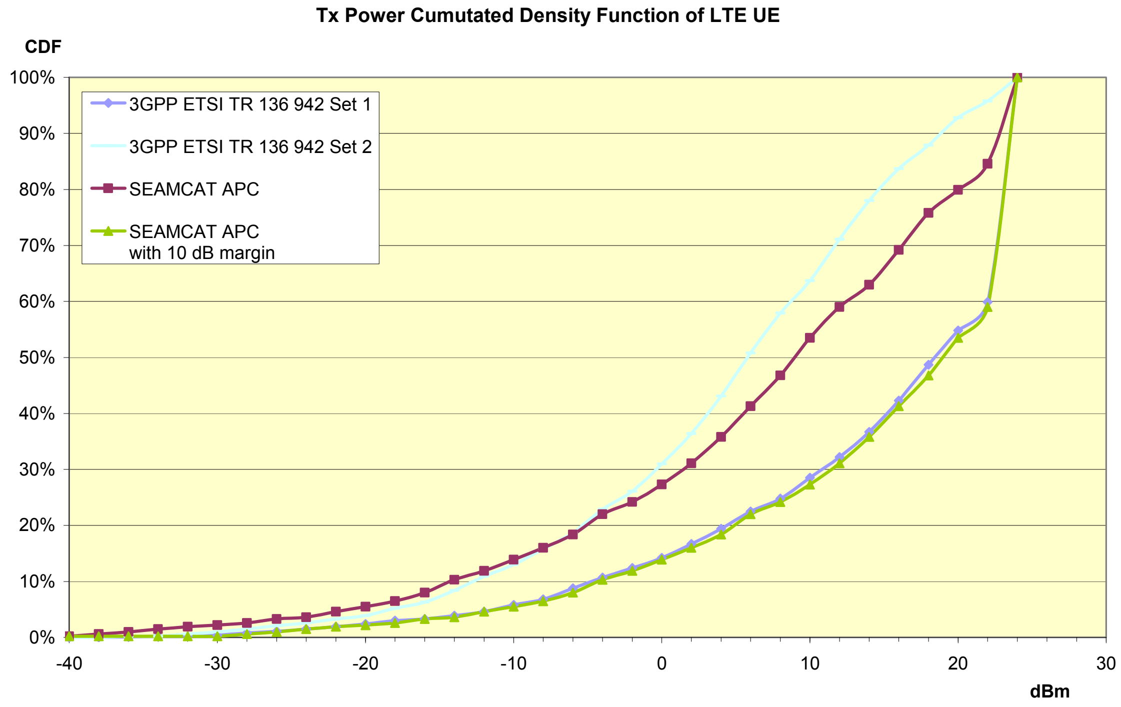

Figure 18: Tx-Power Cumulated Density Function of LTE UE

ANNEX 5: LIST OF REFERENCES

[1] EC Decision 2006/771/EC: COMMISSION DECISION of 9 November 2006 on harmonisation of the radio spectrum for use by short-range devices

[2] ECC Report 182: Survey about the use of the frequency band 863-870 MHz

[3] European Commission Communication COM (2012) 478 (2012-09-03) to the EU Parliament and the Council on “Promoting the shared use of radio spectrum”

[4] ECC Report 37. Compatibility of planned SRD applications with currently existing radiocommunications applications in the frequency band 863 – 870 MHz.

[5] ECC Recommendation 70-03 Relating to the use of Short Range Devices (SRD)

[6] ECC Decision(09)03: ECC Decision of 30 October 2009 on harmonised conditions for mobile/fixed communications networks (MFCN) operating in the band 790 - 862 MHz

[7] Spectrum Engineering Advanced Monte-Carlo Analysis Tool (SEAMCAT) software - free download and user manual available at: www.seamcat.org

[8] ETSI EN 300 220 (all parts) V2.4.1 (2012-05). Radio equipment to be used in the 25 MHz to 1 000 MHz frequency range with power levels ranging up to 500 mW

[9] ETSI TR 102 649-2 V1.3.1. System Reference Document for Radio Frequency Identification (RFID) and SRD equipment; Part 2: Additional spectrum requirements for UHF RFID, non-specific SRDs and specific SRDs

[10] LTE User Equipment Coexistence with 862 - 870MHz, OFCOM UK (M70_04R0_SE24), Publication date: 11th September 2012

[11] ETSI TS 136 101, (2013-04); LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception, (3GPP TS 36.101 version 11.4.0 Release 11)

[12] EN 54-25:2009-02; Fire detection and fire alarm systems – Part 25: Components using radio links

[13] ETSI EN 301 357-1 V1.4.1 (2008-11); Cordless audio devices in the range 25 MHz to 2 000 MHz; Part 1: Technical characteristics and test methods

[14] ERC Recommendation 74-01: UNWANTED EMISSIONS IN THE SPURIOUS DOMAIN

[15] ETSI TR 136 942(3GPP TR36.942v10.2.0) “Evolved Universal Terrestrial Radio Access Network (E-UTRA); Radio Frequency (RF) system scenarios”, 2010-12.

[16] Report ITU-R SM.2028, “Monte Carlo simulation methodology for the use in sharing and compatibility studies between different radio services or systems”.

[17] EN 301 908-13 Repeaters and User Equipment (UE) for IMT-2000 Third-Generation cellular networks