ECC REPORT 149

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ANALYSIS ON COMPATIBILITY OF LOW POWER-ACTIVE MEDICAL IMPLANT (LP-AMI) APPLICATIONS WITHIN THE FREQUENCY RANGE 2360-3400 MHz, IN PARTICULAR FOR THE BAND 2483.5-2500 MHz, WITH INCUMBENT SERVICES

Cluj Napoca, September 2010

0 EXECUTIVE SUMMARY

This report has been developed in response to ETSI System Reference Document TR 102 655 in which ECC was requested to identify around 20 MHz of frequency band within 2360-3400 MHz for the advanced Low Power - Active Medical Implant (LP-AMI) telemetry applications. These applications will be used in professional environment by medical personnel to collect patient monitoring data in hospitals, elderly care houses and similar supervisory institutions. The requested amount of spectrum would allow having sufficiently large channels for fast transmission (e.g. 30 seconds) of large amounts of patient monitoring data collected within wider time frame operation (e.g. one week) than the presently available LP-AMI equipment operating in the 400 MHz band. This meanwhile keeping implanted unit's battery life within sought typical lasting of 10 years being a key medical requirement.

LP-AMI systems are intended for indoor use only since any transmissions by implantable devices (LP-AMI-D) will be triggered only under control of the master stationary peripheral interrogator unit – LP-AMI-P. In such manner LP-AMI-P becomes an obligatory controlling device enabling the professional operation of entire LP-AMI system within closed premises of medical care institutions.

It may be envisaged that some future medical implant applications may develop towards autonomous universal use (i.e. hearing aid implants, etc), however these future autonomous applications are not covered by the LP-AMI concept presented by TR 102 655 and studied in this report. Any such future developments of other types of active medical implants will be subject to additional compatibility studies and may cause setting different limits and conditions on their operation.

The study of co-existence of future LP-AMI applications with other services in frequency range 2360-3400 MHz has been carried in two stages. The first stage, reported in chapter 4 of this report, has established the overall co-existence trends if introducing LP-AMI applications in various sub-bands of the considered frequency range by applying worst-case MCL simulations. The results of this initial investigation are provided in Table 24, which led to recommend selecting the frequency band 2483.5-2500 MHz as the most promising candidate band for introduction of future advanced LP-AMI applications.

In order to confirm this preliminary identification, the more detailed statistical simulations were carried out for the various interference scenarios in the band 2483.5-2500 MHz, using real life assumptions of deployment patterns and applying Monte-Carlo based modelling with CEPT's spectrum engineering tool SEAMCAT.

These statistical simulations are described in greater detail in chapter 5 of this report; below is provided a summary of numerical results for all identified co-existence scenarios.

Co-existence scenario	**Probability of interference**	
	LP-AMI-P as interferer	**LP-AMI-P as victim**
LP-AMI vs MSS (in-band sharing)	**0.035-1.28%**	**Not applicable**
LP-AMI vs CGC (in-band sharing)	**0.05%**	**0.1%**
LP-AMI vs future RNSS (in-band sharing)	**0.02-0.36%**	**Not applicable**
LP-AMI vs IMT-2000 Downlink (adjacent band)	**0.0% (Note)**	**0.1%**
LP-AMI vs IMT-2000 Uplink (adjacent band)	**0.7% (Note)**	**1.2%**

Results of statistical simulations for LP-AMI co-existence scenarios in band 2483.5-2500 MHz

Note: this value is measured as capacity loss in reference cell of IMT-2000 network after introduction of LP-AMI-P interferer into power-balanced network structure. The quoted results show the simulated excess capacity loss in reference cell as compared with residual intra-system capacity loss values estimated by SEAMCAT for the entire modelled CDMA networks.

By looking at the summary of results it may be concluded that the statistical simulations of realistic deployment scenarios prove that LP-AMI applications have very good co-existence prospects with all existing and proposed future users of the band 2483.5-2500 MHz. To that effect it should be noted that the statistical simulations used, inter alia, assumptions that LP-AMI would be always used indoors due to necessary control by mains-powered LP-AMI-P device and that LP-AMI-P would employ the advance interference avoidance techniques, namely the LBT/AFS mechanism envisaged in ETSI TR 102 655. The studies in this report have confirmed the importance of employing these techniques as the means for improving co-existence prospects between LP-AMI applications and other users of this band, such as CGC and IMT-2000.

For information, the SEAMCAT and excel files used for the calculations for the study are available in a zip-file at the www.ecodocdb.dk next to this Report.

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LIST OF ABBREVIATIONS

The following table provides the list of abbreviations and their meaning in this report.

AFS	Adaptive Frequency Selection
AP	Access Point
APC	Adaptive Power Control
ATS	Aeronautical Telemetry Systems
BEM	Block Edge Mask
BS	Base Station
CDMA	Code division multiple access
CGC	Cellular Ground Component
ECA	European Common Allocation Table in ERC Report 25
EESS	Earth Exploration Satellite Service
e.i.r.p	Effective Isotropic Radiated Power
ENG/OB	Electronic News Gathering / Outside Broadcasting
FDD	Frequency Division Duplex
I/N	Interference-to-Noise ratio
IMT-2000	International Mobile Telecommunications system for year 2000
ISM	Industrial Scientific Medical applications
LBT	Listen Before Talk
LOS	Line-Of-Sight
LP-AMI	Low Power Active Medical Implant, the system consisting of LP-AMI-D and LP-AMI-P
LP-AMI-D	Low Power Active Medical Implant Device
LP-AMI-P	Low Power Medical Implant Peripheral Device
MCL	Minimum Coupling Loss, the interference evaluation method
MES	Mobile Earth Station, a user terminal within MSS
MS	Mobile Station, handheld user terminal used within mobile communication system
MSS	Mobile Satellite System
NLOS	Non-Line-of-Sight
RDSS	Radiodetermination service
RNSS	Radionavigation-satellite
Rx	Receiver
SAP/SAB	Services Ancillary to Programme making / Services Ancillary to Broadcasting
SRD	Short Range Devices, category that include LP-AMI
TDD	Time Division Duplex
Tx	Transmitter
UMTS	Universal Mobile Telecommunications System, a system of IMT-2000 family
WCDMA	Wideband Code Division Multiple Access, radio interface technology employed by UMTS networks
WLAN	Wireless Local Area Network

Analysis compatibility of Low Power-Active Medical Implant (LP-AMI) applications within the frequency range 2360-3400 MHz, in particular for the band 2483.5-2500 MHz, with incumbent services

1 INTRODUCTION AND BACKGROUND

ETSI has produced TR 102 655 [1] in which ECC was requested to identify around 20 MHz of frequency band within 2360-3400 MHz for the future advanced Low Power - Active Medical Implant (LP-AMI) applications and external telemetry medical products. This amount of spectrum would allow having sufficiently large channels for fast transmission of large amounts of patient monitoring data collected within wider time frame operation (e.g. one week) than the presently available LP-AMI equipment operating in the 400 MHz band. This meanwhile keeping implanted unit's battery life within sought typical lasting of 10 years being a key medical requirement.

For better understanding of the studies in this report, important distinction between different elements of LP-AMI as a system should be kept in mind as follows. LP-AMI is made of two communications components:

- LP-AMI's implantable device – LP-AMI-D, and
- The peripheral interrogator unit – LP-AMI-P.

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

It may be envisaged that some future medical implant applications may develop towards autonomous universal use (i.e. hearing aid implants, etc), however these future autonomous applications are not covered by the LP-AMI concept presented by TR 102 655 and studied in this report. Any such future developments of other types of active medical implants will be subject to additional compatibility studies and may cause setting different limits and conditions on their operation.

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

- LP-AMI-D may be transmitting only when cleared for that by controlling LP-AMI-P device, this will ensure that LP-AMI-Ds will only be transmitting in the indoor environments where LP-AMI-P are installed (hospital wards, elderly care houses, and similar institutions). This certainty of indoor usage will provide necessary mitigation of LP-AMI interference into other users of the subject bands that are used predominantly outdoors (MSS, RNSS);
- In addition to the above natural shielding, the LP-AMI-P will be required to employ additional interference mitigation mechanisms, such as Listen-Before-Transmit and Adaptive Frequency Selection (LBT/AFS). These mechanisms should be helpful for ensuring co-existence with other radiocommunications services and applications that may be used indoors (e.g. CGC, IMT-2000). Other than aiding co-existence with some other services, the LBT/AFS will be also helpful for ensuring intra-service co-existence of LP-AMI, e.g. in hospital scenarios where more than one LP-AMI system may be used in close proximity to each other.

Therefore, although this report addresses the overall co-existence of LP-AMI applications, it is the master LP-AMI-P device that acts as counterpart of other services in all presented studies. This important distinction should be kept in mind when considering various parameters to be used for representing LP-AMI as a system in the sharing studies.

Four possible options for placement of the new LP-AMI band were selected for this study based on initial discussions within relevant ECC working group:

- 2360-2400 MHz,
- 2400-2483.5 MHz,
- 2483.5-2500 MHz,
- 2700-3400 MHz.

In order to choose among these options the most technically feasible frequency band, it was decided to carry out this study in two phases as presented in this Report:

- First phase performed preliminary technical feasibility study of all candidate bands using worst-case static MCL approach in order to identify the most likely candidate band, i.e. the one that, without any particular mitigation on LP-AMI-P side, showed fewer critically impacted victim services, least severe constraints and smallest required separation distances,
- Second phase performed the more detailed statistical Monte-Carlo analysis of the candidate band identified in the first phase by analysing spatial and temporal dynamics of co-existence scenarios in order to evaluate more precisely the interference potential and establish any required conditions for avoiding practical interference.

This report presents the results of these studies and identifies the most technically feasible frequency band where future LP-AMI applications could be deployed with least potential of interference to other services and applications.

2 LP-AMI APPLICATIONS AND TECHNOLOGY

2.1 Current and future LP-AMI applications

First generations of Active Medical Implant Devices have been already for some time used in modern medical practices and are highly instrumental in saving or enhancing a significant number of lives of patients inflicted with various kinds of heart conditions, nervous disorders and diseases, which otherwise would have resulted in death or disability whereas implanted devices can significantly improve their quality of life.

The active medical implant system consists of:

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

Examples of these implanted devices are defibrillators, pacemakers, various types of nerve stimulators, sensors, implantable infusion pumps and cardiac resynchronization devices. Current systems are typically used in hospitals and/or doctor's office environments with increasing ambulatory remote monitoring in the patient's normal environment, i.e. while they are at their homes and wireless connected to the peripheral unit.

Due to the rapid development and increased use of existing active implantable medical devices it is desirable to increase the range of monitored days and system capacity significantly. Both higher data rates techniques and sufficient memory are available technologically and are already provided by other non-medical systems, for example Bluetooth and Wireless Local Area Networks. However, such systems use spectrum with high user density and, because of the protocols employed, require several orders of magnitude higher current consumption than is practical for strict battery limitations in medical implant systems. Therefore, a new spectrum for future LP-AMI applications was requested in order to be able to handle the increased demand as required as explained in the introductory and background section above. It is important to note that the spectrum should be worldwide to the maximum extent possible.

2.2 Proposed technical parameters

The following Table 1 shows the technical regulatory parameters that ETSI TR 102 655 [1] proposes for licence-exempt operation of future LP-AMI applications.

Candidate frequency bands, MHz	Band edge mask width (Note 2)	Maximum radiated power e.i.r.p. (Note 3)	Listen Before Talk (LBT)	Adaptive Power Control (APC)	Adaptive frequency selection (AFS)	Minimum number of channels
2360-2400	20 MHz	+10 dBm	Yes	Yes	Yes	20
2483.5-2500	16.5 MHz	+10 dBm	Yes	Yes	Yes	16
2700-3400	20 MHz	+10 dBm	Yes	Yes	Yes	20

Table 1: Proposed regulatory parameters for future LP-AMI applications (Note 1)

Note 1: It should be noted that Table 1 just repeats the original set of anticipated requirements outlined in TR 102 655. The original vision was that LBT should be realised as a simple power-gauge within channel bandwidth, so the receiver should detect any power in the channel, regardless of type of interfering system. However after this Report has been completed and the specific operating band had been chosen for LP-AMI, the ETSI should be requested to take the specific parameters of identified victim services into account when defining specifications for LBT/AFS (e.g. to ensure detection of CGC and IMT-2000 emissions) as well as the APC's dynamic range (e.g. 20 dB) during development of final harmonised standard for LP-AMI.

Note 2: The occupied bandwidth of the LP-AMI equipment is to be determined by the lowest and highest frequencies occupied by the power envelope where the output power falls to -20 dBc.

Note 3: This power is envisaged for mains powered LP-AMI-P devices to be used in indoor environments. The emitted power of implantable LP-AMI-D shall be limited by power supply restrictions and body penetration loss. The ETSI shall be requested to specify the anticipated radiated power limit for LP-AMI-D in final harmonised standard.

In addition to the above generic regulatory requirements for LP-AMI applications, TR 102 655 also provides example of LP-AMI-P receiver parameters, as shown in Table 2.

Parameters	**Bandwidth**	
	100 kHz	**1 MHz**
KTB	-123.9 dBm	-113.9 dBm
NF	10 dB	10 dB
S/N ratio	12 dB	12 dB
Receiver sensitivity	-101.9 dBm	-91.9 dBm
Received signal @ 10m	-75.3 dBm	-75.3 dBm
Margin at a range of 10 m	26.6 dB	16.6 dB
Maximum range at a roll-off of 35 * log (d/10)	57.5 m	28.7 m

Table 2: Assumed LP-AMI-P receiver parameters

Notes:

- The received signal at 10m assumes 3cm implant depth.
- It should be noted that the maximum range for a conducted power of 10 dBm has been calculated based on the margin at 10m and a roll-off of 35 x log (d/10) beyond 10 m.

2.3 LP-AMI operation scenario

Regarding the modelling of impact of considered LP-AMI applications, it was considered that the most "typical worst case" scenario of LP-AMI interference would be from emissions of interrogation unit (LP-AMI-Peripheral device, LP-AMI-P) at full e.i.r.p. 10 dBm, but mitigated by building penetration loss of at least 10 dB (see [2] and [3]) due to assumed predominantly indoor operation, see Figure 1.

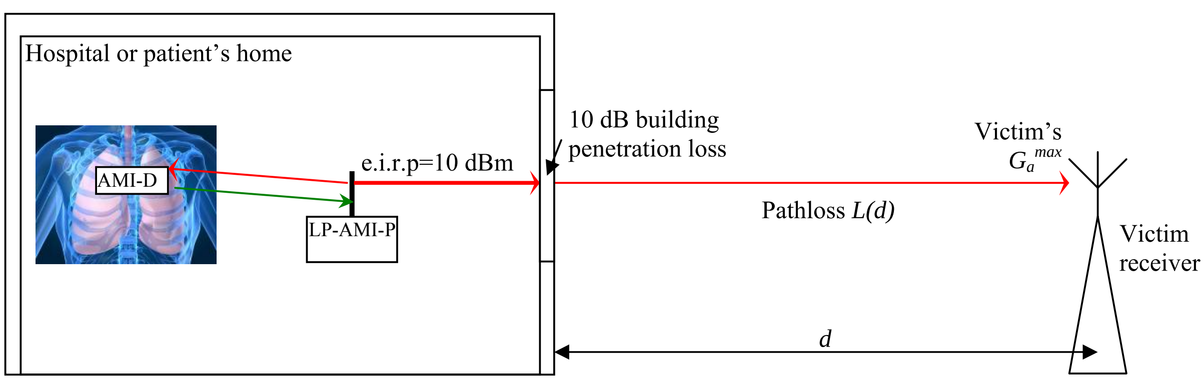

Figure 1: Considered critical impact scenario for LP-AMI operation

This assumption of worst case impact is based on the considered LP-AMI system usage scenarios where implanted in patients LP-AMI-Ds would be normally queried for information only during in-hospital visits or during remote care in patient homes.

The only envisaged occurrences of LP-AMI-D transmitting without being triggered by interrogator is for LP-AMI-D to issue an emergency request when it identifies the imminent critical health condition of monitored patient (e.g. cardiac arrest). Therefore the only possible cases of LP-AMI-Ds emitting outdoors would be when such critical situation happens during patient being outdoors. However in such cases the emissions from implanted LP-AMI-D would be anyway less critical due to anticipated lesser transmit power of battery-driven implantable unit (see Note 3 of Table 1) and also due to additional attenuation of some 20-30 dB or more due to body loss as reported in TR 102 655 [1], when implant is located 10 mm or deeper inside the patient's body.

3 INCUMBENT SERVICES IN CANDIDATE BANDS

The following Table 3 lists possible candidate bands for LP-AMI applications and identifies some typical incumbent services in the bands that need to be considered in co-existence studies.

The characteristics of incumbent systems including their relevant interference protection criteria are discussed in more detail in relevant sections further in the document.

Candidate band, MHz	Typical ECA services [4]	Typical applications	Comments
2360-2400	Aeronautical Telemetry	Aeronautical telemetry installations	Co-channel
	Mobile	SAP/SAB (ENG/OB) video links	Co-channel
		IMT-2000 (Future use)	Co-channel
	Amateur	Radio amateur stations	Co-channel
2400-2483.5	ISM/SRD	SRD: WLAN EN 300 328 [5] (IEEE-802.11)	Co-channel
	Notes 1, 2		
2483.5-2500	MSS	Globalstar mobile phones	Co-channel
	Mobile	CGC (Cellular Ground Component of MSS systems)	Co-channel
	Mobile	IMT-2000 above 2500 MHz	Adjacent band
	Notes 1, 2		
2483.5-2500	RDSS (Galileo)	Note 3	Co-channel
2700-3400	Radiolocation and ARN	Civil Aviation, Meteorological and military ground radars	Co-channel
	EESS (active)	Active Sensors	Sub-band 3.1-3.3 GHz

Table 3: List of considered LP-AMI candidate bands with identified incumbent users

Notes:

1. SAP/SAB (ENG/OB) tuning range extends up to 2500 MHz however in previously reported studies [6] it was shown that most of the SAP/SAB use is concentrated below 2400 MHz. Nevertheless, some CEPT countries reported using the entire tuning range for SAP/SAB operations, which therefore has to be considered by this report. In that sense it may be noted that LP-AMI interference range would be similar to that studied in 2360-2400 MHz band;
2. This band is also covered by a wider Fixed Service allocation however, besides of general trend of relocating fixed links to higher bands, it is shown that most of remaining FS use in the range 1350-2690 MHz is concentrated in other sub-bands than those considered here. This is proof by a general long standing CEPT policy of requiring relocation of all FS to bands above 3 GHz. For reference see ECC Report 003 [7] and the withdrawal of ECC Decision 008 of 1999 for fixed links in the frequency range 2.1 to 2.6 GHz.
3. WRC-12 Agenda Item 1.18 "to consider extending the existing primary and secondary radiodetermination-satellite service (space-to-Earth) allocations in the band 2 483.5-2 500 MHz in order to make a global primary allocation, and to determine the necessary regulatory provisions based upon the results of ITU R studies, in accordance with Resolution 613 (WRC 07)".

According to these findings, the first part of the study has considered co-existence prospects of proposed LP-AMI applications with the services listed for relevant bands, as shown in Table 3.

4 PART ONE: IDENTIFYING THE MOST FEASIBLE CANDIDATE BAND

4.1 Methodology and assumptions for initial compatibility studies

4.1.1 Calculations method

This first phase will consider the simplified coexistence studies by analysing single-entry static interference cases under worst case conditions. The standard MCL methodology will be applied to derive the maximum range of interference impact. In order to simplify the initial feasibility study, any temporal, spatial or dynamic characterisation of interference scenarios (duty cycles, density of interferers, use of LBT/APC/AFS, etc) will be left out in this phase, but will become part of more detailed statistical analysis in second phase.

For evaluating I/N interference objective, the following relationship will be used:

$$I/N = P_{Tx} + NFD + BWC + G_{Rx} - L - N_{Rx}$$

Where:

- P_{Tx}: e.i.r.p. of the interferer, dBm,
- *NFD*: net filter discrimination of interfering transmitter mask, dB:
  - o *NFD*=0 for co-channel interference scenarios
  - o $NFD=NFD(\Delta f)$ – for adjacent channel interference scenarios, where Δf is frequency shift between carriers,
- *BWC* : bandwidth correction factor:
  - o $BWC = -10*\log(BW_{interferer}/BW_{victim})$, if $BW_{interferer}>BW_{victim}$
  - o $BWC = 0$, if $BW_{interferer} \leq BW_{victim}$
- G_{Rx} : gain of the receiver (victim) antenna,
- *L* : propagation path loss,
- N_{Rx} : = thermal noise in victim receiver, $N=10*\log(k*T*BW[Hz])+NF_{Rx}+30$, dBm.

4.1.2 LP-AMI critical impact scenario

As described in §2.3 above, without any additional considerations.

4.1.3 Choice of propagation model

Two options of propagation environment were considered in this study:

- in majority of cases the interference scenarios will involve propagation along the terrestrial paths and interfering/victim LP-AMI-P device installed at reasonably low height within a building. In such cases Non-LOS mobile propagation model will be appropriate;
- in a few cases one of the LP-AMI-Ps counterparts may be used at very high elevations, such as equipment installed onboard aircraft (Aeronautical Telemetry transmitter) or helicopter (SAP/SAB reportage video camera). In such cases LOS conditions should be assumed which would lead to using Free Space Loss model.

For the first, most typical scenario of NLOS propagation, where interfering signal emanates from cluttered built-up environment and propagates towards victim along terrestrial path, it appears possible to consider several possible alternatives of propagation models that were used in various previous ECC compatibility studies in this frequency range:

- ITU-R Recommendation P.452 model [8],
- Okumura-Hata model (different variations of it),
- ERCEG model.

It was also considered whether ITU-R Recommendation P.1411 [9] (SRD model) could be used, however this option was excluded because this model is defined only for distances up to 1 km.

It was therefore decided in this stage to use ERCEG model, which was recently used in ECC studies [10] in similar interference scenarios and within the same frequency range in the neighbourhood of 3 GHz. Another advantage of this model is that it is conceptually simple and easy to implement in MCL calculations using conventional tools as Excel spreadsheets. In particular, option “Erceg-C” was used, which represents “Flat terrain with light tree cover” conditions, corresponding to “worst case” philosophy adopted throughout this part of the study.

Finally, it may be observed that the choice of the propagation model is anyway not very critical in this comparative phase, as long as all cases (i.e. situation in all considered bands) would be compared against each other using the same model.

4.2 Study for the band 2360-2400 MHz

4.2.1 Aeronautical Telemetry Systems

Aeronautical Telemetry Systems (ATS) are employing transmitters mounted on an aircraft-under-test, which transmits telemetry data to ground-based receiving station. Such systems are therefore used only in a few countries in Europe where industries deal with testing of aircrafts. Their usage time is limited to the duration of aircraft testing. During operation, the high gain parabolic antenna of receiving station tracks the position of aircraft in the sky, therefore any interference arriving over terrestrial path may assume to be falling in the side-lobes of the receiver antenna.

From the available data on digital ATS used in ECC studies [11, 12], one can deduce the necessary operational parameters for ATS.

4.2.2 SAP/SAB

Description of typical SAP/SAB (also known as ENG/OB) applications is given in aforementioned ECC Report 002 [6]. It is shown there that typical SAP/SAB applications in this frequency range are the video reportage links, with signal being transmitted to transportable studio from handheld or vehicle mounted camera. Sometimes such links might be also used in airborne configuration, e.g. with the reportage camera being mounted onboard a helicopter. However in this case the receiver is still ground-based studio.

The parameters of SAP/SAB links as victim receivers to be used in this study were taken from the recent ECC study in ECC Report 100 [10], which considered interference into similar SAP/SAB links in neighbouring 3.4 GHz band.

4.2.3 IMT-2000 MS

Although currently there is a limited number of IMT-2000 systems deployed in this band, this band has been allocated by ITU for this purpose and especially some Asian as well as European countries are planning on deploying IMT-2000 in this band (part of 2300-2400 MHz). Considering the need for global accessibility of chosen band for LP-AMI applications, it was decided to include consideration of interference to IMT-2000 MS in this band.

In absence of specific data on the type of IMT-2000 systems to be considered for this band, it was decided to use the data for WCDMA/UMTS systems, as reported in e.g. ECC Report 045 [13] and ECC Report 064 [2].

4.2.4 Radio Amateur stations

The Radio Amateur stations in this band are used for receiving signals over terrestrial paths and from Radio Amateur satellite transmitters. Although amateur stations are often built through experimentation of private users and their precise characteristics are difficult to establish, some data was however collected when preparing the ECC Report 064 [2] and it was used in performing calculations in this study.

The results of calculated MCL interference distances for the identified incumbent services are presented in the Tables 4 and 5 below.

LP-AMI-P -> Incumbent services	**Victim system:**			
Band 2360-2400 MHz	**ATS Ground Rx**	**SAP/SAB Rx**	**IMT-2000 MS**	**Amateur**
Receiver bandwidth, kHz	5000	8000	3840	3
Receiver noise figure, dB	4	5	9	1
Receiver antenna height, m	30	10	10	10
Receiver antenna gain, dBi	0 (Note 1)	10	0	0 (Note 1)
Operating frequency, MHz	2360	2360	2360	2360
N, receiver thermal noise, dBm	**-102.84**	**-99.8**	**-99.0**	**-138.1**
Interferer's e.i.r.p radiated outdoor, dBm	0	0	0	0
Interferer's BW, kHz	1000	1000	1000	1000
BW correction factor, dB	**0**	**0**	**0**	**-25.23**
Interferer's NFD (adjacent band interf), dB	0	0	0	0
Interferer's antenna height, m	3	3	3	3
I/N objective, dB	-10	-6	-6	-10
Minimum path loss, dB	**112.84**	**115.8**	**105.0**	**122.8**
Interference distance Erceg-C model, km	**0.680**	**0.468**	**0.299**	**0.627**

Table 4: Results of calculated interference distances in 2360-2400 MHz band: LP-AMI-P as interferer
Note1: The gain in side lobes of high gain directional (parabolic) antennas.

Incumbent services -> LP-AMI-P	**Interfering system:**			
Band 2360-2400 MHz	**ATS Aircraft Tx**	**SAP/SAB Heli**	**IMT-2000 BS**	**Amateur**
Interferer's Ptx, dBm	41.8	30	43	40
Interferer's BW, kHz	5000	8000	3840	3
BW correction factor, dB	**-6.99**	**-9.03**	**-5.84**	**0.00**
Interferer's NFD (adjacent band interf), dB	0	0	0	0
Interferer's antenna gain, dBi	0	4	17	25
Interferer's antenna height, m	**10000**	**700**	30	10
Receiver bandwidth, kHz	1000	1000	1000	1000
Receiver noise figure, dB	9	9	9	9
Receiver antenna height, m	3	3	3	3
Building attenuation loss, dB	-10	-10	-10	-10
Operating frequency, MHz	2360	2360	2360	2360
N, receiver thermal noise, dBm	**-104.8**	**-104.8**	**-104.8**	**-104.8**
I/N objective, dB	0	0	0	0
Minimum path loss, dB	**129.64**	**119.80**	**148.99**	**159.83**
Interference distance Erceg-C model, km	**30.70 (Note 1)**	**9.89 (Note 1)**	**5.132**	**2.91**

Table 5: Results of calculated interference distances in 2360-2400 MHz band: LP-AMI-P as victim
Notes 1: Results obtained with Free Space Loss model due to assumption of airborne transmitters.

The results reported in Table 4 show reasonably moderate interference distances in the direction from LP-AMI-P. However Table 5 shows significant increase of interference range into LP-AMI, especially for the cases of interference from airborne transmitters of ATS and SAP/SAB. Therefore it is obvious that any considered use of LP-AMI applications in this band would require careful analysis of interference avoidance mechanisms within LP-AMI-P, such as LBT/AFS, which is foreseen by TR 102 655 specifications and would have to be transferred as essential requirement to the future harmonised standard.

4.3 Study for the band 2400-2483.5 MHz

4.3.1 Short Range Devices (SRD)

For the purposes of this study it was decided to use the WLAN systems utilising IEEE 802.11 b/g standard as the most critical representative system for co-existence analysis with LP-AMI applications. This is because WLANs in 2.4 GHz today have extremely widely proliferated in all built up areas (both industrial and residential) in all of European countries. In particular, it has been observed that WLAN are widely used in hospitals by installing a lot of Access Points for wireless data connectivity, enabling medical personnel to use their PDAs or Smartphones to get wireless non-critical communications to access the hospital databases, to localise medical equipment, to download-upload patients journal's data or even to establish VoIP communications etc.

For these studies the typical WLAN was modelled as DSSS system with 15 MHz channel bandwidth with 20 dBm e.i.r.p, for regulatory references and previous studies, see ERC Rec. 70-03 [14], ETSI EN 300 328 [5] and ERC Report 109 [15].

Note also that because of the scenario where both LP-AMI-P and WLAN Access Point (AP) were located inside the same building, the direct LOS coupling should be assumed, suggesting use of the Free Space Model for path loss calculation.

4.3.2 Industrial Scientific Medical (ISM) devices

Some of the examples of ISM applications that could be considered as potential interferers to LP-AMI-P for the considered scenarios of hospital environment would be e.g. cauterising tools used as surgery aids in hospitals or microwave ovens that might be found both in hospitals and patient homes. However, it appears that the leakage of RF power from microwave ovens is very small (e.g. 0.2 mW/cm^2 quoted in some sources [16]) compared with other applications such as WLAN AP. Regarding the cauterising tools, this study could not get hold of any reliable data that would allow deterministic characterising of RF emissions from these devices. Therefore for the above described reasons, both of these ISM devices were left out of this study.

The results of calculated MCL interference distances for the identified critical WLAN applications in the band 2400-2483.5 MHz are presented in the Tables 6 and 7 below.

LP-AMI-P -> Incumbent services	**Victim system:**
Band 2400-2483.5 MHz	**WLAN 802.11 AP**
Receiver bandwidth, kHz	15000
Receiver noise figure, dB	10
Receiver antenna height, m	10
Receiver antenna gain, dBi	2
Operating frequency, MHz	2450
N, receiver thermal noise, dBm	**-92.07**
Interferer's e.i.r.p, dBm	10
Interferer's BW, kHz	1000
BW correction factor, dB	**0**
Interferer's NFD (adjacent band interf), dB	0
Interferer's antenna height, m	3
I/N objective, dB	0
Minimum path loss, dB	**104.07**
Interference distance FSL model, km	**1.56**

Table 6: Results of calculated interference distances in 2400-2483.5 MHz band: LP-AMI-P as interferer

Incumbent services -> LP-AMI-P	**Interferer:**
Band 2400-2483.5 MHz	**WLAN 802.11 AP**
Interferer's Ptx, dBm	20
Interferer's BW, kHz	15000
BW correction factor, dB	**-11.76**
Interferer's NFD (adjacent band interf), dB	0
Interferer's antenna gain, dBi	0
Interferer's antenna height, m	10
Receiver bandwidth, kHz	1000
Receiver noise figure, dB	9
Receiver antenna height, m	3
Building attenuation loss, dB	**0**
Operating frequency, MHz	2450
N, receiver thermal noise, dBm	**-104.8**
I/N objective, dB	0
Minimum path loss, dB	**113.07**
Interference distance FSL model, km	**4.39**

Table 7: Results of calculated interference distances in 2400-2483.5 MHz band: LP-AMI-P as victim

Looking at the results in Tables 6 and 7 one could notice the relative severity of situation in this band, where the necessary interference protection distance could not be realised within the considered typical scenario of LP-AMI-P and WLAN operation inside the same building. Even though interference from LP-AMI-P into WLAN probably might be mitigated thanks to short durations of LP-AMI-P transmissions offset by the in-built durability of repetitive WLAN transmissions. However, the WLAN’s impact on victim LP-AMI-P, which is characterised by inherent safety of human life implications - and time-critical short bursts transmissions, might be more difficult to overcome due to constant nature of WLAN transmissions in heavily loaded WLAN network environment.

4.4 Study for the band 2483.5-2500 MHz

4.4.1 MSS (Globalstar) Mobile Earth Stations

The band 2483.5-2500 MHz is used for MSS communications in the direction Space-to-Earth, paired with 1610-1626.5 MHz for transmissions Earth-to-Space. Today this MSS allocation is being utilised by Globalstar system, which is based on CDMA IS-95 technology and serves around 300 000 reported subscribers worldwide.

One important operational circumstance that needs to be considered when studying co-existence between LP-and MSS is the fact that MSS’s Mobile Earth Stations (MES) are not supposed to be operated indoors, given that buildings usually constitute impenetrable obstacle for weak MSS signals. Therefore, given that LP-AMI systems are expected to be operated indoors, as explained in the Introduction – Background section 3; the assumption of having building penetration loss as a part of interference link budget still holds also in this scenario.

One may also right away discard any danger of interference from MSS into LP-AMI systems, if it were operated in this band, as the weak satellite downlink signals, further weakened by building entry loss, should be hardly discernible by LP-AMI-P receivers. Therefore this study only addresses the potential of interference from LP-AMI-P into Globalstar MES receivers.

The relevant parameters for Globalstar MES to be used in the analysis were taken from the most recent WGSE (SE40) documents [17-18].

4.4.2 MSS Cellular Ground Component (CGC)

The CGC is an emerging future possible idea of supplementary evolution of the MSS networks whereas terrestrial base stations would be installed in order to improve the coverage of MSS signals, e.g. within conditions of dense urban environments where very low sky observation angles severely hamper reliable reception of MSS satellite signals (so called “city canyon” scenario). Detailed description of intended operation of CGC as a part of Globalstar system may be found e.g. in aforementioned draft SE40 report [17].

This also noting that for systems to be considered in the studies related to the introduction of CGC associated with non GSO MSS systems in the bands 1.6 and 2.5 GHz, it was decided to limit the studies to the GLOBALSTAR case in the band 2483.5-2500 MHz and IRIDIUM and GLOBALSTAR in the band 1610-1626.5 MHz, for which parameters were received by CEPT.

Important feature of CGC to be considered in this study is that CGC would be operated in a portion of the same frequency bands as their satellite-based mother-systems. In other words, the CGC for Globalstar system deployed in frequency band 2483.5-2500 MHz would also operate in the same band but just on a sub-set of available radio channels. Therefore when analysing CGC as part of co-existence analysis with LP-AMI applications, we still need to consider the same MSS MES device as victim receiver, but now we need to consider CGC BS emissions as potential interferer to LP-AMI-P receiver. The required parameters of CGC BS emissions are taken from the same SE40 draft ECC Report on the subject. When considering interference from CGC BS to AMI-P, it may be safely assumed that the LP-AMI-P’s LBT/AFS function will be able to detect the powerful emissions from terrestrial CGC BS and will choose an adjacent channel for LP-AMI operation. This means that MCL calculations may assume interference in adjacent channel.

4.4.3 Adjacent band interference into IMT-2000 within 2500-2690 MHz

During initial consideration of candidate bands for LP-AMI, the concerns were expressed of possible adjacent band interference of LP-AMI applications in the band 2483.5-2500 MHz vis-à-vis IMT-2000 systems operated within the band 2500-2690 MHz.

The similar consideration was recently made in other studies with regard to interference between terrestrial CGC installations and IMT-2000 [17] and the current knowledge indicates that although the lower 2500 MHz band is commonly intended for IMT-2000 uplink, the possibility of deploying TDD systems right at the edge of the 2500 MHz border remains a valid national option and therefore could not be disregarded.

Therefore, this initial study assumed that the worst case for adjacent band interference to consider would be IMT-2000’s TDD operations near the 2500 MHz partition. This would result in the unwanted LP-AMI-P emissions inflicting nearby IMT-2000 MS receiver and LP-AMI-P being potentially affected by unwanted emissions from powerful IMT-2000 BS. In order to evaluate emissions level for the latter case, the study assumed that the IMT-2000 BSs should be designed and deployed with a view on respecting Block Edge Mask (BEM) limits, such as the ones established for 2500 MHz band by CEPT [20]. These specify the baseline maximum e.i.r.p limit of 4 dBm/MHz immediately outside of allocated blocks[1].

Note that also for the case of interference into IMT-2000 MS, it might be assumed that the mobile terminal might be in direct proximity to the patient, therefore LOS conditions should not be excluded and therefore Free Space Loss model might be appropriate.

The results of calculated MCL interference distances for the identified incumbent services in the band 2483.5-2500 MHz are presented in the Tables 8 and 9 below.

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[1] This study used this figure as a worst case assumption, in reality Administrations are urged to consider applying stricter limits beyond the band edges (normally BEM applies on the edge of a block assigned to operator, i.e. in-band limits), which may be the BEM’s baseline OOB emission limit of -45 dBm/MHz or even less, depending on sharing situation in subject adjacent band

LP-AMI-P -> Incumbent services	Victim system:		
Band 2483.5-2500 MHz	**Globalstar MSS MES**	**CGC MES Rx**	**IMT-2000 2.6 GHz MS Rx**
Receiver bandwidth, kHz	1230	1230	3840
Receiver noise figure, dB	0	5	9
Receiver antenna height, m	10	10	3
Receiver antenna gain, dBi	0	0	0
Operating frequency, MHz	2490	2490	2502.5
N, receiver thermal noise, dBm	**-112.9**	**-107.9**	**-99.0**
Interferer's e.i.r.p, dBm	10	10	10
Building attenuation loss, dB	10	10	10
Interferer's BW, kHz	1000	1000	1000
BW correction factor, dB	**0**	**0**	**0**
Interferer's NFD (adjacent band interf), dB (Note 2)	0	0	**-30**
Interferer's antenna height, m	3	3	3
I/N objective, dB	-10	-10	-6
Minimum path loss, dB	**122.93**	**117.9**	**75.0**
Interference distance Erceg-C model, km	**0.614**	**0.499**	**0.05 (Note 1)**

Table 8: Results of calculated interference distances in 2483.5-2500 MHz band: LP-AMI-P as interferer

Notes: 1. Results obtained with Free Space Loss model due to assumption of possible LOS coupling;
2. The ETSI TR 102 655 [1] did not specify the Net Filter Discrimination for LP-AMI-P, therefore the value of -30 dB was taken by this study as a conservative assumption, taking into account the LP-AMI-P's filtering capabilities made known from R&D efforts by LP-AMI industry. This value should be fed back to the ETSI to be included as minimum requirement in future harmonised standard for LP-AMI.

Incumbent services -> LP-AMI-P	Interfering system:	
Band 2483.5-2500 MHz	**CGC BS Tx**	**IMT 2.6 GHz BS Tx**
Interferer's Ptx, dBm	-2 (Note 1)	4 (Note 2)
Interferer's BW, kHz	1500	1000
BW correction factor, dB	**-1.76**	**0.00**
Interferer's NFD (adjacent band interf), dB	0	0
Interferer's antenna gain, dBi	19	0
Interferer's antenna height, m	30	30
Receiver bandwidth, kHz	1000	1000
Receiver noise figure, dB	9	9
Receiver antenna height, m	3	3
Building attenuation loss, dB	-10	-10
Operating frequency, MHz	2490	2490
N, receiver thermal noise, dBm	**-104.8**	**-104.8**
I/N objective, dB	0	0
Minimum path loss, dB	**110.07**	**98.83**
Interference distance Erceg-C model, km	**0.563**	**0.300**

Table 9: Results of calculated interference distances in 2483.5-2500 MHz band: LP-AMI-P as victim

Note 1: the power in adjacent channel (in-band power of 43 dBm reduced by 45 dB to account for filter, see p. 14 in [24]).
Note 2: see explanations in the text (prior to the Table 8) and associated footnote 1therein.

Looking at the results in Tables 8 and 9, one may regard the obtained interference ranges in the order of hundreds of meters as quite moderate, however the fact is that here LP-AMI-P has to counteract with personal communications devices, therefore one may not fully exclude their operation in the direct proximity to the patient with active LP-AMI system either in hospital or home observation environment. Therefore choosing this band would require more detailed statistical study of dynamics of these scenarios and possible use of various mechanisms for interference mitigation. This is one of the reasons why in ETSI TR 102 655 [1] it is anticipated to use LBT/AFS techniques that may take care of LP-AMI co-existence in both interference directions (i.e. as victim and interferer). This, all together with other dynamic factors such as the LP-AMI systems' extremely low duty cycle and the very low density of MSS (Globalstar) and CGC (devices/km²), indicates a good promise for an efficient spectrum sharing.

On the other hand, it should be also noted that for the case of co-existence with IMT-2000 the absolute worst scenario was intentionally chosen here, presuming TDD operation at the edge of the 2500 MHz band. This however might be rather exceptional case since the ECC recommended prime option for IMT-2000 deployment in the 2.6 GHz band [20] presumes FDD uplink placed at the lower edge of the 2500 MHz, which would greatly improve on co-existence situation (LP-AMI-P on IMT MS). This latter configuration might however increase impact in the other direction (IMT MS to LP-AMI-P), which will be considered closely in simulations reported in section 5.

4.4.4 SAP/SAB

As mentioned previously in the report (see Note 1 of Table 3), in few CEPT countries they may be some other services occasionally using this frequency band, such as SAP/SAB applications. The interference impact range between LP-AMI-P and these applications would be the same as shown in Tables 4 and 5 of section 4.2.4. However, the probability of interaction with SAP/SAB is generally very low in itself, considering that SAP/SAB use in this frequency range is represented typically by TV reportage cameras, which tend to be used very occasionally and in highly localised manner, such as during staged TV reportages from large events like Tour de France, large national celebrations, etc. Since it is the LP-AMI who would be the victim of such co-existence occurrences, any such occasional interference instances would have to be taken care of by the LBT/AFS mechanism of LP-AMI-P.

Note also that use of this range by airborne SAP/SAB would probably mean that no other services considered in this section (such as CGC, MSS) would be in active use in a given country as they would prove more sensitive recipient of SAP/SAB interference. Therefore co-existence situation with occasional and easily detectable SAP/SAB usage would actually represent most favourable climate for LP-AMI deployment.

4.5 Study for the band 2700-3400 MHz

4.5.1 Radiolocation and Aeronautical Radionavigation

These allocations are used for deployment of various civil and military radars, including those serving as ground-based radars for Aeronautical Radionavigation and meteorology. These are the high power pulsed radars with typical operational range in the order of 150 to 300 km.

One can in particular note that, due to meteorological radars specificities (in the 2700-2900 MHz band), any possible requirement for LBT would imply a 10 minutes waiting period before being able to transmit any signal and is therefore assumed not to be compatible with LP-AMI's operational constraints (due to potential urgency of transmission to the patient implant).

Typical radar parameters necessary for this study were taken with reference to values used in several preceding CEPT studies [21-22].

4.5.2 EESS Active Sensors

These applications are mentioned in ECA Utilisations column; however this study could not obtain any parameters describing use of such applications in the frequency sub-band 3.1-3.3 GHz. Therefore these applications were left out from further study.

The results of calculated MCL interference distances for the identified incumbent radiolocation service in the band 2700-3400 MHz are presented in the Tables 10 and 11 below.

LP-AMI-P -> Incumbent services	**Victim system:**	**Victim system:**
Band 2700-3400 MHz	**Civ/mil radars**	**Meteo radars**
Receiver bandwidth, kHz (Note: IF filter)	1600	600
Receiver noise figure, dB	2	3
Receiver antenna height, m	30	13
Receiver antenna gain, dBi	35	43
Operating frequency, MHz	3100	2800
N, receiver thermal noise, dBm	**-109.79**	**-113.05**
Interferer's e.i.r.p. radiated outdoor, dBm	0	0
Interferer's BW, kHz	1000	1000
BW correction factor, dB	**0**	**-2.2**
Interferer's NFD (adjacent band interf), dB	0	0
Interferer's antenna height, m	3	3
I/N objective, dB	-6	-10
Minimum path loss, dB	**150.79**	**163.83**
Interference distance (Free space), km	Far above radio horizon	Far above radio horizon
Interference distance Erceg-C model, km	**4.778**	**4.388**

Table 10: Results of calculated interference distances in 2700-3400 MHz band: LP-AMI-P as interferer

Incumbent services -> LP-AMI-P	**Interferer:**	**Interferer:**
Band 2700-3400 MHz	**Civ/mil radars**	**Meteo radars**
Interferer's Ptx, dBm	65	84
Interferer's BW, kHz	10000	600
BW correction factor, dB	**-10.00**	**-2.2**
Interferer's NFD (adjacent band interf), dB	0	0
Interferer's antenna gain, dBi	35	43
Interferer's antenna height, m	30	13
Receiver bandwidth, kHz	1000	1000
Receiver noise figure, dB	9	9
Receiver antenna height, m	3	3
Building attenuation loss, dB	-10	-10
Operating frequency, MHz	3100	2800
N, receiver thermal noise, dBm	**-104.8**	**-104.8**
I/N objective, dB	0	0
Minimum path loss, dB	**184.83**	**218**
Interference distance free space, km	Far above radio horizon	Far above radio horizon
Interference distance Erceg-C model, km	**32.073**	**61.017**

Table 11: Results of calculated interference distances in 2700-3400 MHz band: LP-AMI-P as victim

Calculation results reported in Tables 10 and 11 show significant interference distance ranges, especially in the direction of interference into LP-AMI-P, even considering Erceg-C model, whereas, considering free space propagation, interference distances would always be above radio horizon.

To this respect, it may be assumes that more detailed considerations of co-existence in this frequency band would not allow finding satisfactory sharing conditions.

4.6 Interim conclusions

As a summary of analysis of co-existence for the proposed LP-AMI applications in several considered frequency bands, the Table 12 below lists the most critical of identified interference situations in each of the studied bands.

Note that the choice of the most critical case in each band is made not only with regard to the maximum interference range of various incumbent services, but also taking into account the likeliness of such case appearing.

For example, in the band 2360-2400 MHz the largest interference range was estimated for interference to and from the Aeronautical Telemetry service. However, noting that these services are used only at few installations in Europe, instead the co-existence with IMT-2000 terminals was considered most critical due to their anticipated omnipresent deployment.

Candidate band, MHz	Interference counterpart/direction	Interference range	Comments
2360-2400	IMT-2000 BS → LP-AMI-P	5 km	Interference range much larger than the typical cell range of IMT-2000, therefore LP-AMI-P is likely to be affected by emissions from multiple BS within the interference range
2400-2483.5	LP-AMI-P ↔ WLAN (IEEE 802.11 b/g)	1.5-4.5 km	Risk of co-location. Heavy usage of the band puts a question on likely efficiency of /LBT/AFS solution
2483.5-2500	LP-AMI-P → Globalstar MES	600 m	Risk of indoor operation of Globalstar MES in case of its use within CGC sub-band, if implemented. However mitigation techniques like LBT/AFS could address this issue (detailed statistical simulations may be used to verify this assumption)
2700-3400	LP-AMI-P ↔ radars	5-38 km most cases above the radio horizon	Risk of severe co-channel interference from extremely high power radar transmitters as well as high risk of interference from LP-AMI-P to radars. In addition, LBT/AFS use is discouraged by long listening times imposed in this band in similar previous study [21] or by meteorological radars.

Table 12: Identified critical interference scenarios in candidate LP-AMI bands

Therefore, as a result of first part of this study, it appears that the band 2483.5-2500 MHz should be considered as the most feasible candidate band for the deployment of future advanced LP-AMI applications.

To that effect it should be noted that ETSI TR 102 655 [1] anticipates the use of LBT/AFS techniques that should help improving LP-AMI-P co-existence in both interference directions (i.e. as victim and interferer) against some of the services that might be used alongside with the LP-AMI in indoor scenarios. Also other factors, such as wall shielding of interference to MSS and RSS, also the extremely low duty cycle of LP-AMI applications and the very low device density of MSS (Globalstar) and CGC networks, all together seem to offer good prospects for an efficient and safe spectrum sharing in the identified preferred frequency band.

It was therefore decided that the second part of this study should perform more elaborate statistical evaluation of co-existence of proposed LP-AMI applications with other services in the frequency band 2483.5-2500.

5 PART TWO: STATISTICAL STUDY FOR THE BAND 2483.5-2500 MHz

Note that all simulations described in this section were carried out with the latest version of CEPT spectrum engineering tool SEAMCAT (version 3.1.46 build 341 from 20 October 2009) [23]. All relevant SEAMCAT scenario files are attached in separate ZIP folder along with this report.

5.1 Other services to be considered

Previously Table 3 has already listed incumbent services and their applications in the band 2483.5-2500 MHz that need to be considered for co-existence with LP-AMI applications.

In this regard it should be noted that LP-AMI applications would be deployed under the regulatory provisions of existing ITU Radio Regulations and ECA [4] primary allocation to Mobile service.

The characteristics of incumbent systems including their relevant interference protection criteria are discussed in more detail in relevant sections further in the document.

However, besides the incumbent services in the band, this more detailed stage of the study noted that the frequency band 2483.5-2500 MHz is currently also under discussion with regard to agenda item 1.18 of WRC-12 („*to consider extending the existing primary and secondary radiodetermination-satellite service (space-to-Earth) allocations in the band 2483.5-2500 MHz in order to make a global primary allocation, and to determine the necessary regulatory provisions based upon the results of ITU-R studies, in accordance with Resolution 613 (WRC-07)*”).

This study therefore will also look on the issue of co-existence between LP-AMI applications and future proposed use of the band by radiodetermination satellite service receivers.

5.2 Co-existence with MSS (Globalstar) Mobile Earth Stations

5.2.1 Scenario review

The band 2483.5-2500 MHz is used for MSS communications in the direction Space-to-Earth, as was previously discussed in §4.4.1.

The most important point to be reiterated is that MSS’s Mobile Earth Stations (MES) are not supposed to be operated indoors. Therefore, given that LP-AMI-P are expected to be operated indoors, the assumption of having building penetration loss as a part of interference link budget is very relevant in this scenario.

One may also right away discard any danger of interference from MSS into LP-AMI-P based on the following quick check:
- Globalstar downlink signal should comply with max PFD limit (for single satellite) of -126 dBW/m^2/MHz on the ground,
- Effective antenna area at 2500 MHz is -29.4 dB(m^2), LP-AMI-P receiver bandwidth 1 MHz, additional 10 dB loss to be added to account for building penetration,
- Resulting MSS downlink signal power in LP-AMI-P receiver is -165.4 dBW= -135.4 dBm,
- Even considering power summation from multiple Globalstar satellites, the resulting interfering power compares favourably with the noise floor of LP-AMI-P receiver of -104.8 dBm.

It thus may be concluded that MSS downlink should not pose any danger to LP-AMI operations. Therefore it was decided to limit statistical study only to the case of interference from LP-AMI-P into Globalstar MES receivers, as illustrated in Figure 2.

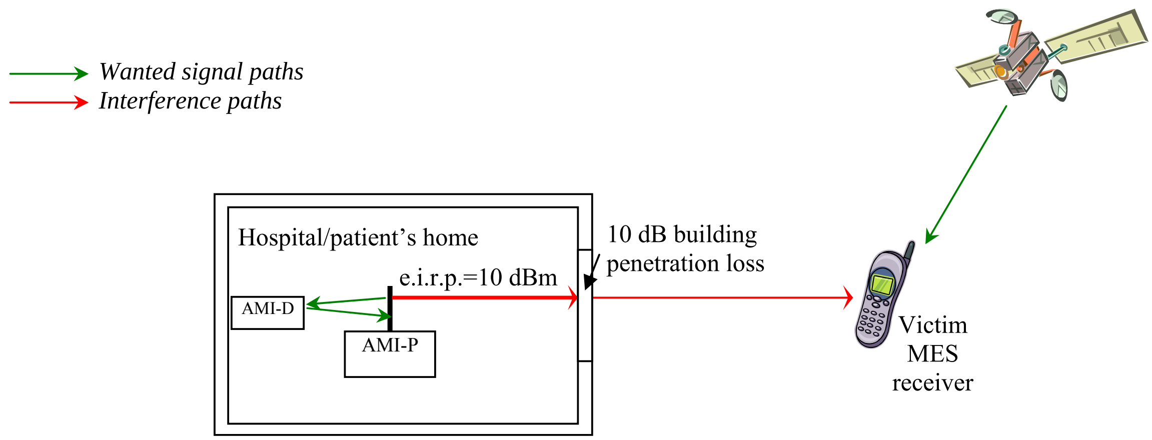

Figure 2: Interference scenario LP-AMI vs MSS (Globalstar)

The relevant parameters for Globalstar MES to be used in statistical study were taken from the most recent WGSE (SE40) documents [24-25].

5.2.2 Simulation results

As described in §5.2.1, only one direction of interference, from LP-AMI-P to MSS MES, was considered. Specific SEAMCAT parameter settings that were used for this case study are shown in Table 13.

Parameter	Unit	Value used
Victim system definition		
Operating channel centre frequency	MHz	2499.15
Antenna gain (non-directional)	dBi	2
Rx noise floor	dBm	-112.9
Reception bandwidth	kHz	1230
Interference criterion: I/N	dB	-12
Interfering system definition		
Operating channel centre frequency	MHz	2499.15
Transmitter power (e.i.r.p.) (*Note 1*)	dBm	10
Antenna gain	dBi	0
Channel bandwidth	MHz	1
Transmitter mask, outside 1 MHz transmission channel	dBc	-20, at $\Delta f = \pm 0.5$ MHz -45, at $\Delta f = \pm 2.5$ MHz
Average density of transmitters	1/km^2	10
Activity factor (duty cycle)	%	10

Table 13: SEAMCAT parameter settings for interference scenario LP-AMI-P to MSS MES

Note 1: Full e.i.r.p. value entered since the Extended-Hata model used in simulations contains "indoor-outdoor" setting which automatically adds 10 dB building attenuation loss into link budget calculations.

Since the SEAMCAT could not simulate fluctuations of desired CDMA signal from satellite station, it was decided to use interference criterion of I/N=-12 dB, as established in similar CEPT study [25]. Therefore the dRSS signal was set to constant at some 3 dB above sensitivity level, but it was anyway irrelevant for calculation of interference since only I and N relation was analysed by the tool.

Note that the centre frequency of LP-AMI-P was deliberately set to be constant (which is reasonable to assume as in this case the LBT/AFS mechanism in LP-AMI-P may not be relied on for detecting of weak MSS signals) and assigned exactly the same value as that of Globalstar MES centre frequency in order to consider worst-case option. In reality it may be expected that the channelling raster of two systems may be different providing for partial overlap and thus additional mitigation of part of interference.

The choice of placement of interferer vs victim could not be established with great precision as both MSS phones and LP-AMI-P devices are niche applications and would be used comparatively sparsely on a European scale (compared with ubiquitous SRD devices as car alarms, WLANs etc). As a practical approach to modelling worst case of interference, it was proposed to use SEAMCAT interferer vs. victim placement mode “Closest interferer”, with the assumption of a concentrated area of LP-AMI-P devices, e.g. on a hospital campus, giving an arbitrary estimate of LP-AMI-P density of 10 units/km^2.

With the above assumptions and settings, several runs of the SEAMCAT simulation produced probability of interference as shown below:

Propagation model between interfering transmitter and victim receiver	Environment	Interfering Transmitter location	Victim receiver location	iRSS mean dBm/1.23MHz	Probability of interference
Extended Hata	Urban	indoor	outdoor	-190	0.035 %
Extended Hata	Suburban	indoor	outdoor	-178	0.1%
Extended Hata	Rural	indoor	outdoor	-158	1.28%

Table 14: SEAMCAT probability of interference

Note that the use of Free Space Loss model in simulations was considered but turned down as irrelevant due to the fact that LP-AMI would be always used indoors while MSS would be always used outdoors, which does not comply with direct line-of-sight conditions normally presumed for application of FSL.

The attached SEAMCAT scenario file “*AMI-P_to_MSS_Rx.sws*” may be used in order to reproduce this simulation.

5.3 Co-existence scenario with MSS Cellular Ground Component (CGC)

5.3.1 Scenario review

The CGC was introduced in §4.4.2. Detailed description of intended operation of CGC as a part of Globalstar system may be found e.g. in aforementioned draft SE40 report [24].

Important feature to be remembered is that CGC would be operated in a portion of the same frequency bands as their satellite-based mother-systems, but just on a sub-set of available radio channels (assignment of channels between satellite and ground components will be done centrally from the MSS network control centre, in this case from the Globalstar control centre in California, USA). This de-facto partitioning of the band opens up opportunities for flexible “overlay” operation of other devices, such as LP-AMI applications,who might utilise different portions of the band depending on actual usage conditions in them. This assumption is made possible by use of LBT/AFS mechanism in LP-AMI-P, which will sense the presence of strong signals within terrestrial CGC systems and will choose the channels where CGC is not operated, e.g. the channels used by mother-MSS system.

In any case, the CGC will correspond with the same MES as used with the original MSS mother-system, in this case Globalstar, but the interference scenarios will differ due to use of high power terrestrial stations that may cause interference to LP-AMI-P receiver. It should be also noted that when used with CGC, the MES will have better link budget and could be therefore operated indoors. The interference scenarios for LP-AMI co-existence with CGC are illustrated in Figure 3.

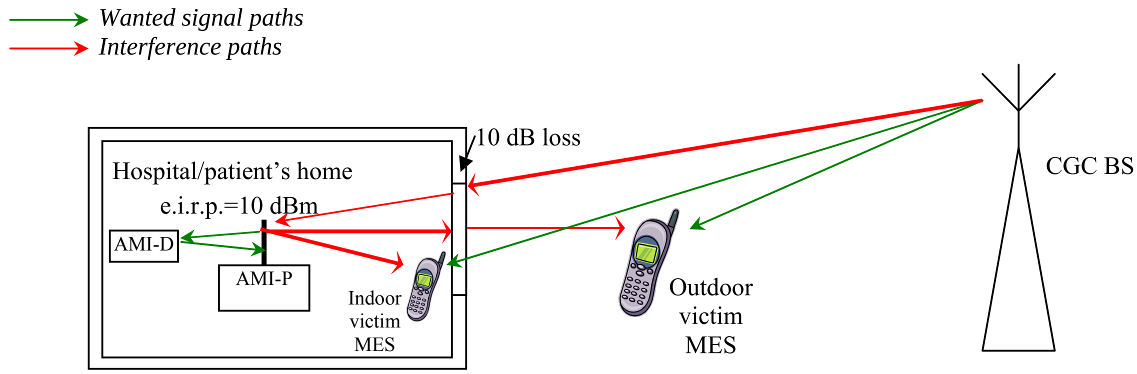

Figure 3: Interference scenarios LP-AMI vs MSS CGC

The relevant technical parameters of CGC used within Globalstar system were taken from the previously referenced SE40 document [16] that contains report on (ongoing) CEPT studies for introduction of CGC in Europe.

5.3.2 Simulation results: LP-AMI-P to MSS MES in CGC mode

This scenario is similar to the scenario considered in §5.2 (LP-AMI-P → MSS MES) with one notable difference, i.e. that when MSS MES is corresponding with terrestrial CGC BS link budget will be much more favourable, allowing it to work inside the buildings. This means that the scenario has to account for the case where victim MSS MES is placed inside the same building with LP-AMI-P. This circumstance was modelled by setting two levels of LP-AMI-P transmitter power: one at 0 dBm (when LP-AMI-P and MES are separated by wall) and one at +10 dBm (the case when LP-AMI-P and MES are inside the same building). The probabilities of those two power level were set to 50-50%, i.e. to assume equal probability of MES operated indoors or outdoors. Note that this is in itself a very worst case assumption, since it gives 50% probability of MES and LP-AMI-P operating inside the same building.

With this only change to transmitter power level settings, the list of SEAMCAT parameter settings that were used for this case study are shown in Table 15.

Parameter	Unit	Value used
Victim system definition		
Operating channel centre frequency	MHz	2499.15
Antenna gain (non-directional)	dBi	2
Rx noise floor	dBm	-107.9
Reception bandwidth	kHz	1230
Interference criterion: I/N	dB	-12
Interfering system definition		
Operating channel centre frequency	MHz	2499.15
Transmitter power (e.i.r.p.) (*Note 1*)	dBm	0/10
Antenna gain	dBi	0
Transmitter mask, outside 1 MHz transmission channel	dBc	-20, at Δf= ±0.5 MHz -45, at Δf= ±2.5 MHz
Average density of transmitters	1/km^2	10
Activity factor (duty cycle)	%	10

Table 15: SEAMCAT settings for interference scenario LP-AMI-P to MSS MES in CGC mode

Note 1: Interfering transmitter power was set in SEAMCAT scenario to switch randomly between two values to represent presence/absence of building attenuation loss. Due to this randomisation of indoor-outdoor position, the "indoor-outdoor" setting in Extended-Hata model used in simulations was disabled and switched to "outdoor-outdoor".

All other values and assumptions were used the same as for the LP-AMI-P → MSS MES study reported previously.

The SEAMCAT simulations that were carried out for the above scenario produced probability of interference of 0.03-0.05%, i.e. of the same marginal value as in the case with MSS MES. Use the attached SEAMCAT scenario file "AMI-P_to_CGC_Rx.sws" in order to reproduce this simulation.

5.3.3 Simulation results: CGC Base Station to LP-AMI-P reception

This scenario provides a new angle as in this case it is LP-AMI-P device that will be a victim. Appropriately updated list of SEAMCAT parameters for this scenario is given below in Table 16.

Parameter	Unit	Value used
Victim system definition		
Operating channel centre frequency (*Note 1*)	MHz	2484.5-2499.5
Antenna gain (non-directional)	dBi	0
Rx noise floor	dBm	-104.8
Reception bandwidth	kHz	1000
Operational level of received signal @ 10 m from implant	dBm	-75.3
Interference criterion: C/I	dB	12
Interfering system definition		
Operating channel centre frequency	MHz	2499.15
Transmitter power (to antenna)	dBm	43 (*Note 2*)
Antenna gain	dBi	19
Transmitter mask, outside 1.23 MHz transmission channel	dBc	>750 kHz -45 dBc/30 kHz >1.98 MHz -60 dBc/30 kHz (*Note 3*)
Average density of transmitters	1/km^2	0.02
Activity factor (duty cycle)	%	100

Table 16: SEAMCAT parameter settings for interference scenario CGC BS to LP-AMI-P

Notes:
1. Randomly distributed within entire band to model operation of LBT/AFS mechanism in LP-AMI-P;
2. The impact of building attenuation loss to be modelled by activating "indoor-outdoor" setting in the Extended-Hata propagation model used in simulations;
3. See p. 14 in [24].

The average density of CGC BS was calculated assuming cell radius of 4 km (macro-cell), resulting in a cell area of 50 km^2, which leads to BS density of 0.02.
Note that in this case of interference from strong signal of CGC BS, it may be assumed that LBT/AFS mechanism of LP-AMI-P will start sensing the interfering signal and avoiding it. This was modelled by setting random switching of LP-AMI-P frequencies over the entire available band.

The SEAMCAT simulations that were carried out for the above scenario produced probability of interference of around 0.1%. The attached SEAMCAT scenario file "CGC-BS_to_AMI-P.sws" may be used in order to reproduce this simulation.

5.4 Co-existence with IMT-2000 in adjacent 2500-2690 MHz band

5.4.1 Scenario review

For initial introduction of this scenario, please refer to §4.4.3.

Although lower part of IMT-2000 band would be normally used for uplink in FDD configuration, it was noted that TDD mode of IMT-2000 operation may not be excluded. Therefore the worst case for adjacent band interference between LP-AMI-P and IMT-2000 would have to consider TDD mode with downlink operations near the 2500 MHz partition. This would result in unwanted LP-AMI-P emissions inflicting nearby IMT-2000 MS receiver and LP-AMI-P being potentially affected by unwanted emissions from powerful IMT-2000 BS. This scenario configuration is similar to the case with CGC (except that in this case it would be adjacent band interference) and is depicted in Figure 4.

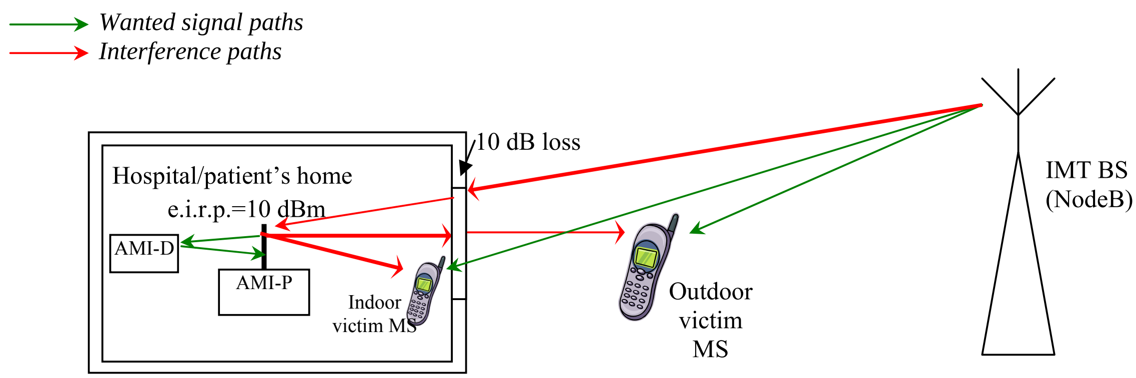

Figure 4: Interference scenarios LP-AMI vs IMT-2000 Downlink

As was mentioned in §4.4.3, this study used IMT-2000 BS emission limits derived from their relevant BEM limits [19]. These specify the baseline maximum e.i.r.p. limit of 4 dBm/MHz immediately outside of allocated blocks.

However, it was felt that the detailed statistical simulations should be also used for verifying co-existence for cases, when IMT-2000 would be operated in uplink mode near the band edge. In this case the interference scenario changes, as depicted in Figure 5 below.

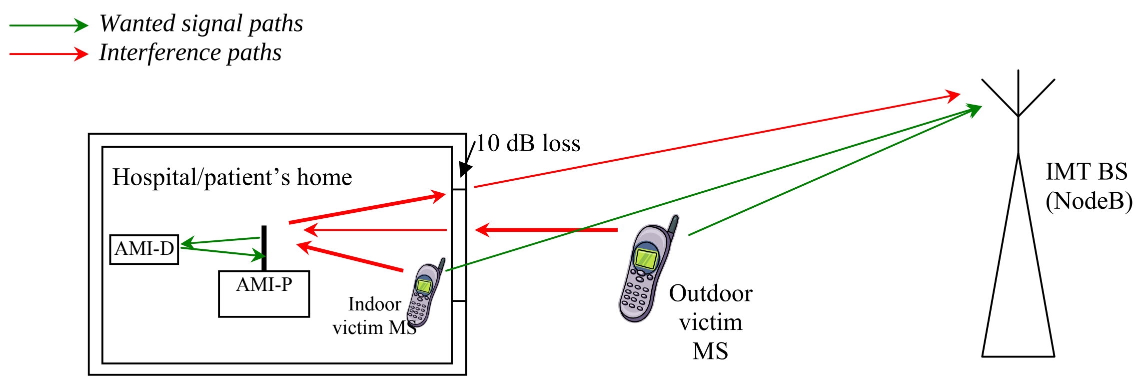

Figure 5: Interference scenarios LP-AMI vs IMT-2000 Uplink

Another circumstance to be considered here is that IMT-2000 deployed in the band 2500-2690 MHz would be a system employing some of the advanced modulation and multiple access methods, such as CDMA or OFDMA. These technologies are designed, inter alia, to provide better resistance to interference, in particular that the interference would manifest itself not by straightforward disruption of victim communications, but through a gradual reduction of victim link (system) capacity. Therefore some more sophisticated simulation methods should be used to consider impact of interference in such systems. The statistical simulations carried out in this study have relied on CDMA module in SEAMCAT-3. At the time of performing this study the OFDMA module for SEAMCAT was still in the stage of development, however it was felt that the consideration of LP-AMI co-existence with CDMA alone would provide sufficient degree of certainty also for OFDMA system. This may be illustrated by comparing the MS receiver reference sensitivity of two systems. For the considered CDMA system the reference MS sensitivity is -105 dBm, whereas for OFDMA system it is -91 dBm. This shows that MS in CDMA system has lower threshold for interference than in the OFDMA system, which supports the notion of using CDMA as a reference victim system in this band.

It should be noted particularly that in this case the counterpart of LP-AMI-P is the full scale terrestrial CDMA-based network. Therefore SEAMCAT CDMA module will be used for simulating IMT-2000 system as a fragment of endless CDMA network with LP-AMI-P placed near the centre of central reference cell of CDMA network.

It was considered that the suitable parameters of IMT-2000 systems to be used in statistical simulations may be taken from ITU-R Report M.2039 [26]. Therefore the IMT-2000 system was modelled with parameters specified in M.2039 for Macro-cell deployment of IMT-2000 CDMA TDD system.

5.4.2 Simulation results: LP-AMI-P to IMT-2000 Downlink (MS Rx)

In the case of victim CDMA system, it is being simulated by SEAMCAT as a pattern of 57 cells, representing 3-sector deployment. Cells were populated with appropriately selected number of users (46 users per cell, the number found using special in-built SEAMCAT algorithm for establishing optimal CDMA network load) and with interfering system dropped in appropriate place inside the network, see an example in Figure 6.

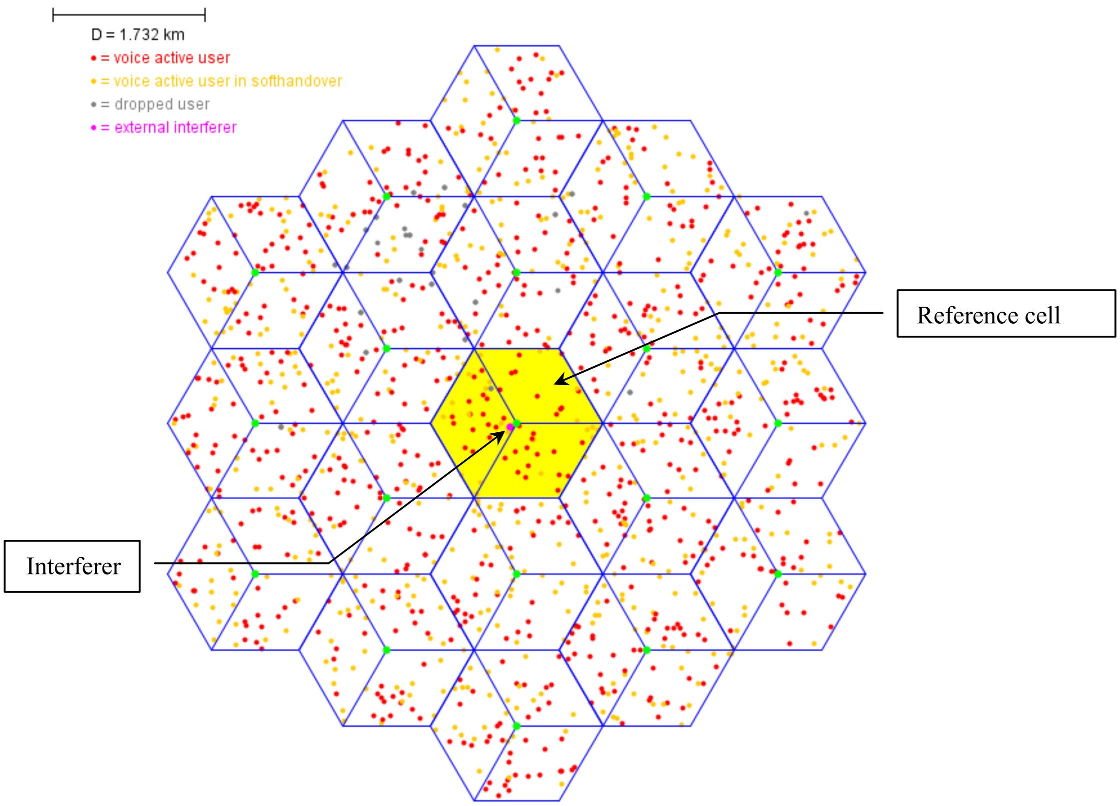

Figure 6: Single snapshot of simulated interference scenario LP-AMI-P to IMT-2000 downlink

Important feature of simulating CDMA system is that the power control mechanism is modelled within the network, meaning that the powers of base stations are adjusted to serve the randomly generated set of users in the best possible manner, including attempt to balance any increase in external noise (interference). Therefore interference to victim CDMA network is gauged not in terms of probability of exceeding some fixed parameter (such as C/I or I/N), but in terms of loss of capacity caused by external interferer, i.e. in instances when system is not more capable to pump up power to offset the impact of interference.

The choice of settings of SEAMCAT parameters for this scenario are shown in Table 17.

Parameter	**Unit**	**Value used**
Victim system definition: CDMA Downlink mode (*Note 1*)		
Operating channel centre frequency	MHz	2502.5
System Link Level Data		WCDMA @ 1900 MHz
MS receiver noise figure	dB	9
BS maximum broadcast power	dBm	43
BS antenna gain (3-sector)	dBi	17
Cell radius (Macro-cell scenario)	km	1
Interfering system definition		
Operating channel centre frequency	MHz	2499.15
Transmitter power (e.i.r.p.)	dBm	10
Antenna gain	dBi	0
Transmitter mask, outside 1 MHz transmission channel	dBc	-20, at Δf= ±0.5 MHz -45, at Δf= ±2.5 MHz

Table 17: SEAMCAT settings for interference scenario LP-AMI-P to IMT-2000 MS

Note 1: other CDMA system settings were retained their default values.

Note that the CDMA system Link level data for WCDMA in 1900 MHz band was chosen in the absence of suitable reference data for 2500 MHz band. However it was felt that the bands were sufficiently close to provide for reasonable approximation of operation of CDMA system with existing data.

The SEAMCAT simulation that was carried out for the above scenario (1000 snapshots, limited by simulation time of 11 hours) produced an estimate of extra capacity loss in reference cell of 0.02%, see Figure 7. This very low loss (which looks more like a residual effect of network's own re-adjustment where some calls may be disconnected from time to time in power re-balancing process, e.g. the same simulation show the extent of own intra-network capacity loss between snapshots of around 7%) is not surprising given the adjacent band interaction with the low-power device.

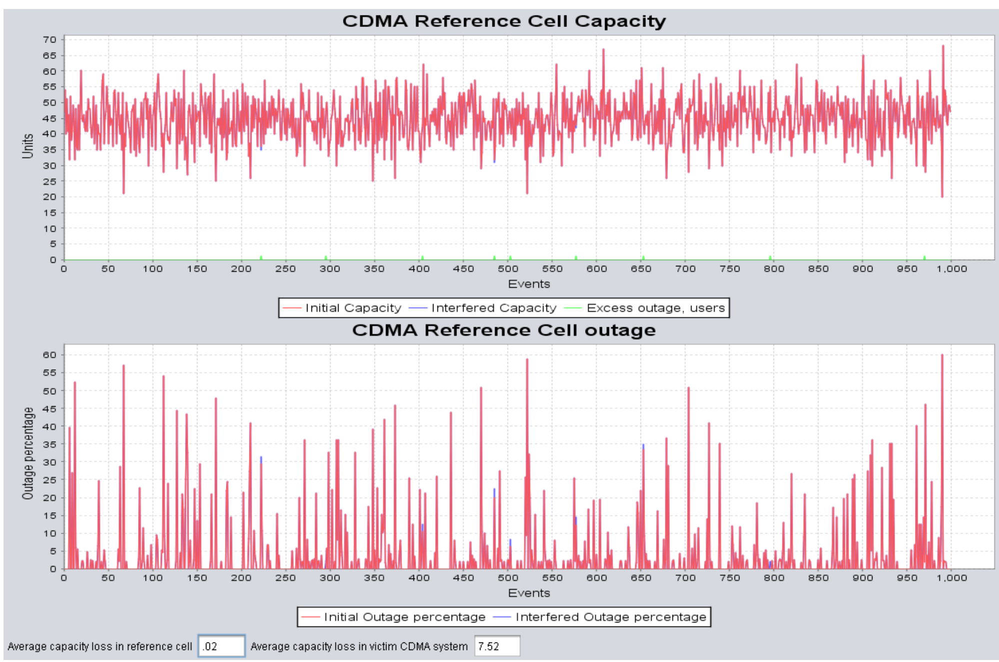

Figure 7: Results of simulated interference scenario LP-AMI-P to IMT-2000 downlink

The attached SEAMCAT scenario file "AMI-P_to_IMT-2000-DL.sws" may be used in order to reproduce this simulation.

5.4.3 Simulation results: IMT-2000 Downlink (BS Tx) to LP-AMI-P receiver

In this case the CDMA system acts as interferer so SEAMCAT, after power tuning the CDMA network constellation, will record the powers of relevant CDMA transmitters (BS in this case dealing with downlink) and will use them for calculating power of interfering signal in the LP-AMI-P receiver.

The list of most important SEAMCAT parameter settings for this scenario is shown in Table 18.

Parameter	Unit	Value used
Victim system definition		
Operating channel centre frequency (*Note 1*)	MHz	2484.5-2499.5
Antenna gain (non-directional)	dBi	0
Rx noise floor	dBm	-104.8
Reception bandwidth	kHz	1000
Operational level of received signal @ 10 m from implant	dBm	-75.3
Interference criterion: C/I	dB	12
Interfering system definition: CDMA Downlink mode (*Note 2*)		
Operating channel centre frequency	MHz	2502.5
System Link Level Data		WCDMA @ 1900 MHz
BS maximum broadcast power	dBm	43
BS antenna gain (3-sector)	dBi	17
MS receiver noise figure	dB	9
Cell radius (Macro cell scenario)	km	1
Unwanted emissions mask	dBc	-40 (>2.5 MHz)

Table 18: SEAMCAT settings for interference scenario IMT-2000 WCDMA BS to LP-AMI-P

Notes:

1. Randomly distributed within entire band to model operation of LBT/AFS mechanism in LP-AMI-P;
2. Other relevant CDMA system settings were retained their default values.

The SEAMCAT simulation that was carried out for the above scenario produced probability of interference of 0%, i.e. no discernible interference impact at all (simulated interfering signal average iRSS=-153.81 dBm, vs. reference desired signal power of -75.3 dBm).

Attention of this study was drawn to the fact that the downlink of OFDMA IMT-2000 systems (such as IEEE 802.16 WiMAX) might prove more critical interferer to LP-AMI than the WCDMA BS. Therefore an addition simulation was carried out to study this case, employing the SEAMCAT release 3.2.0 that has implemented OFDMA modelling. The parameter settings used in SEAMCAT simulations are shown in Table 19.

Parameter	Unit	Value used
Victim system definition		
Operating channel centre frequency (*Note 1*)	MHz	2484.5-2499.5
Antenna gain (non-directional)	dBi	0
Rx noise floor	dBm	-104.8
Reception bandwidth	kHz	1000
Operational level of received signal @ 10 m from implant	dBm	-75.3
Interference criterion: C/I	dB	12
Interfering system definition: TDD OFDMA Downlink mode (*Note 2*)		
Operating channel centre frequency	MHz	2505
Channel bandwidth	MHz	10
BS maximum broadcast power	dBm	46
BS antenna gain (3-sector)	dBi	17
Cell radius (Macro cell scenario)	km	1
Unwanted emissions mask	dBc	As per Table 6 of [28]

Table 19: SEAMCAT settings for interference scenario IMT-2000 TDD OFDMA BS to LP-AMI-P

Notes:

1. Randomly distributed within entire band to model operation of LBT/AFS mechanism in LP-AMI-P;
2. Other relevant OFDMA system settings were retained their default values.

The SEAMCAT simulation that was carried out for the above scenario produced probability of interference of 0-0.1%, i.e. very marginal interference impact (simulated interfering signal average iRSS=-129.13 dBm, vs. reference desired signal power of -75.3 dBm).

The attached SEAMCAT scenario files “IMT-2000-DL_to_AMI-P.sws” and “WiMAX-DL_to_AMI-P.sws” may be used in order to reproduce these simulations.

5.4.4 Simulation results: LP-AMI-P to IMT-2000 Uplink (BS Rx)

In this case (see Figure 5) the victim is Base Station of a full scale CDMA system, which again should be simulated by SEAMCAT as a pattern of 19 hexagonal cells, populated with appropriately selected number of users and with interfering LP-AMI-P dropped randomly within the central (reference) cell of the network, see Figure 6 and further clarifications in §5.4.3. However in this case the CDMA network is operated in uplink mode and the relevant parameters as shown in Table 20.

Parameter	**Unit**	**Value used**
Victim system definition: CDMA Uplink mode (*Note 1*)		
Operating channel centre frequency	MHz	2502.5
System Link Level Data		WCDMA @ 1900 MHz
Base station blocking attenuation	dB	46
Base station receiver noise figure	dB	5
MS transmit power	dBm	20
Number of users per cell		34 (Note 2)
Cell radius (Macro cell scenario)	km	1
Interfering system definition		
Operating channel centre frequency	MHz	2499.15
Transmitter power (e.i.r.p.)	dBm	10
Antenna gain	dBi	0
Transmitter mask, outside 1 MHz transmission channel	dBc	-20, at Δf= ±0.5 MHz -45, at Δf= ±2.5 MHz

Table 20: SEAMCAT settings for interference scenario LP-AMI-P to IMT-2000 BS Rx

Notes
1. Other CDMA system settings were retained their default values;
2. Obtained with the help of SEAMCAT CDMA capacity finder

The SEAMCAT simulation that was carried out for the above scenario produced an estimate of capacity loss in reference cell of 0.7%, see Figure 8. As with the case of downlink, this should be compared with inherent residual effects of own intra-network capacity losses across the network, which in this simulation was estimated at 0.6%. In other words, one could see that presence of interferer in a given reference cell caused only marginal rise in loss of CDMA users.

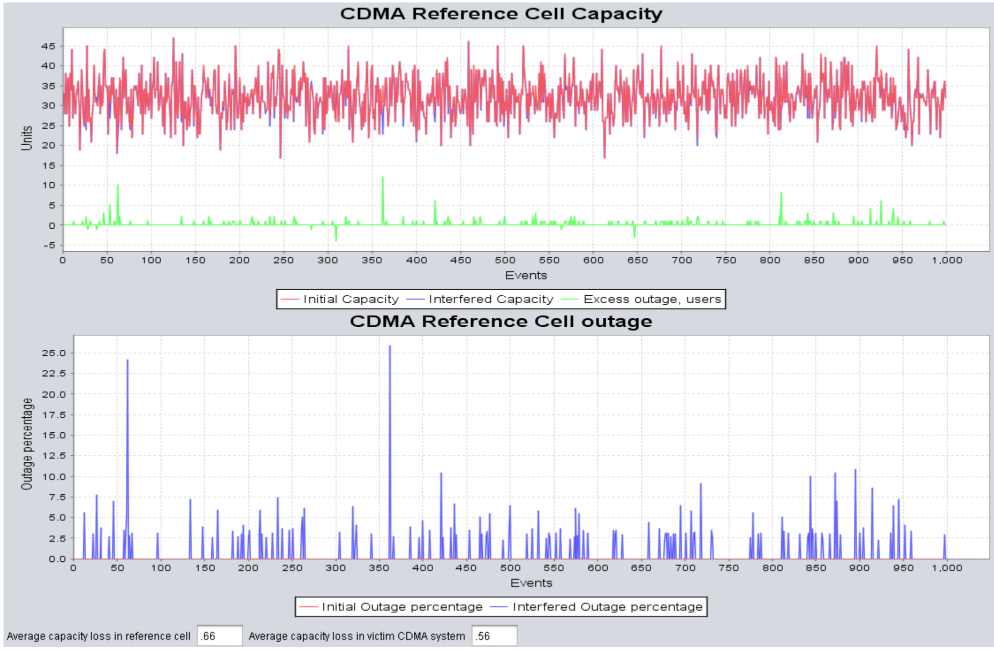

Figure 8: Results of simulated interference scenario LP-AMI-P to IMT-2000 downlink

The attached SEAMCAT scenario file “AMI-P_to_IMT-2000-UL.sws” may be used in order to reproduce this simulation.

5.4.5 Simulation results: IMT-2000 Uplink (MS Tx) to LP-AMI-P receiver

In this case the interferer is the individual mobile station of IMT-2000 system, and quite different sharing scenario should be considered as in this case it could be not excluded, that the IMT-2000 MS as handheld terminal could be brought by users in close proximity (the same room) to LP-AMI-P operation.

Although it should be commented that normally LP-AMI-P operation in places like hospitals should be protected from physical presence of operational MS terminals due to usual practice of prohibiting all radio transmitting devices in hospital intensive care and diagnostic areas. Even if one could assume inadvertent bringing of MS terminals into hospital, the violation would be still becoming apparent if the MS were really to receive a call, then it would be natural to assume that the forgetful person would leave the hospital examination room if wishing to answer the call.

However, since LP-AMI-P could be also operated in patients’ homes, the case of the same room operation could not be excluded, if only for home-operated cases.

Therefore it will be reasonable to simulate the situation with MS operating in close proximity from LP-AMI-P. However, it is also apparent that in this case the LBT/AFS mechanism of LP-AMI-P will be at its most meaningful operation since it will be well positioned to detect the blocking effect of out-of-band emissions from MS transmitter and move the operation of entire LP-AMI system to lower frequencies.

In this case it will not be necessary to simulate the entire CDMA network cluster; instead simulations will assume out-of band interference from a WCDMA MS transmitting at full power. The relevant RF emission parameters for WCDMA MS operating in frequency band 2500-2690 MHz (Band VII according 3GPP specifications) were taken from ETSI TS 125 101 [27].

The list of most important SEAMCAT parameter settings for this scenario is shown in Table 19.

Parameter	Unit	Value used
Victim system definition		
Operating channel centre frequency (*Note 1*)	MHz	2484.5-2489.5
Antenna gain (non-directional)	dBi	0
Rx noise floor	dBm	-104.8
Reception bandwidth	kHz	1000
Operational level of received signal @ 10 m from implant (user defined dRSS setting in SEAMCAT)	dBm	-75.3
Blocking response	dB	45
Interference criterion: C/I	dB	12
Interfering system definition: CDMA MS Tx		
Operating channel centre frequency	MHz	2502.5
MS maximum emitted power (*Note 2*)	dBm	24
MS antenna gain (non-directional)	dBi	0
MS antenna height	m	1.5
Out-of-band unwanted emissions mask	dBc	Table 6.10 [27]
Interference area radius	m	100
Propagation model on interference path		Hata-SRD

Table 21: SEAMCAT settings for interference scenario IMT-2000 MS to LP-AMI-P

Notes:
1. Randomly distributed within lower part of the band assuming that LBT/AFS mechanism in LP-AMI-P will detect IMT-2000 emissions with high degree probability and will restrain LP-AMI system's operation to lower part of the band;
2. Maximum power for class 3 allowed in Band VII [27].

The SEAMCAT simulation that was carried out for the above scenario produced probability of interference of 0.7-0.8% in unwanted mode and around 1% in blocking mode (1.2% combined impact). This probability of interference is sufficiently low to be comfortably below the usual 5% threshold considered reasonable for the case of interference with non-stationary mobile services.
Note that in this scenario of IMT-2000 MS interference into LP-AMI operation, the case could be envisaged that the mobile phone would be brought into the very same room where LP-AMI where operated (e.g. hospital ward, doctor's ambulatory, patient home). However this occurrence was not considered in the above simulations because:

- It may be safely assumed that the operation of mobile phones would be normally prohibited in hospital wards that use sensitive electronic equipment;
- Then even if the mobile phone was brought into such environment and left switched on due to simple oversight (or negligence) on the part of the user, it might be causing interference only if actually responding to a call, which would be naturally reacted to by the medical personnel to the effect of removing/switching-off the phone from the diagnostics ward or patient's room;
- And finally, if all above anticipated measures of human control failed (such as in case of mobile phone being left switched on and sending to the network regular activity update bursts, which naturally would be very seldom since the location would not be changing while the mobile was kept in the same room with the LP-AMI-P) the LBT/AFS mechanism of LP-AMI-P should be able to detect intruding emissions of mobile phone and either change the LP-AMI operating channel or interrupt communication with LP-AMI-D until disappearance of interfering signal. The later should result by a "warning indication" in the LP-AMI-P unit.

The attached SEAMCAT scenario file "IMT-2000-MS_to_AMI-P-Rx.sws" may be used in order to reproduce this simulation.

5.5 Co-existence with proposed future Radionavigation-satellite service applications (Galileo)

5.5.1 Scenario review

The upgrading of Radiodetermination service (RDSS) in this frequency band to primary status on a global basis has been proposed for consideration at the next WRC-12 at a behest of the European Galileo system. The new global primary allocation is intended to facilitate new navigation signals for the next generation of Galileo satellites in subject frequency band. The band 2483.5-2500 MHz, because of its proximity to the mobile service allocations above 2.5GHz, may offer attractive synergies of Radionavigation-satellite (RNSS) with terrestrial mobile systems due to improved antenna efficiencies and use of shared hardware not possible with other RNSS bands. Although the request is for upgrading the RDSS allocation, in fact the Galileo intends using it for RNSS purposes, which is possible since RNSS is a sub-set of RDSS as per definition in Radio Regulations.

Although upgrading of allocation is conditional on the new service being able to prove its compatibility with other primary services already existing in the band (and LP-AMI applications would be operating within an existing primary allocation to Mobile service), it was considered prudent to consider practical co-existence between LP-AMI and RNSS given their planned co-habitation of the same band within the same geographic region.

Considering the interference scenario, it will be similar to the scenario in the case of co-existence with MSS. In this case the RNSS would be also operated in downlink mode and interference from satellite signal into LP-AMI-P receiver may be disregarded. That is why only the interference direction from LP-AMI-P into RNSS receiver should be considered, see Figure 9.

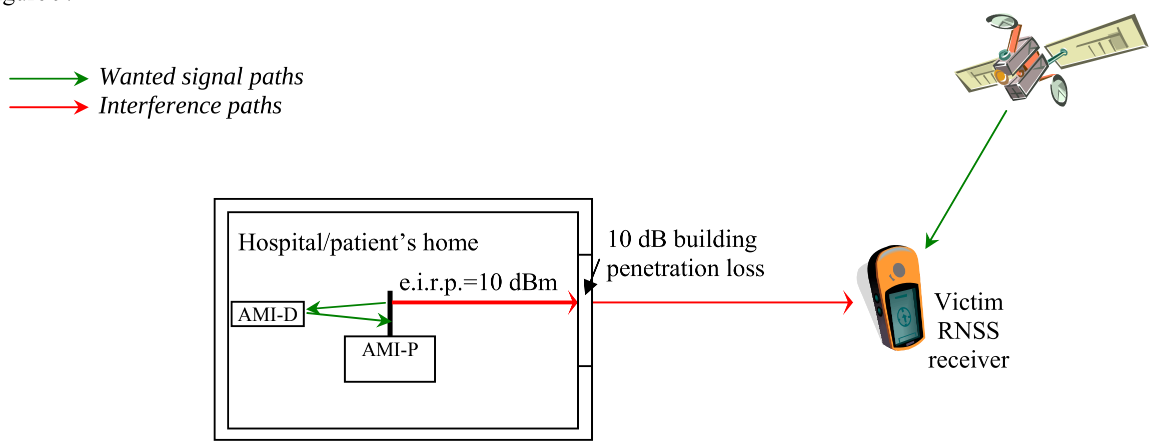

Figure 9: Interference scenario LP-AMI vs. RNSS (Galileo evolution)

Another similarity with MSS case is that also in the case of RNSS the victim receivers are supposed to be operated outdoors, therefore building penetration loss will always be present as one of interference mitigation factors.

The relevant technical parameters for RNSS receivers to be used in the study were collected from previously referenced draft SE40 report [24].

5.5.2 Simulation results

As described in §5.5.1 above, only one direction of interference, from LP-AMI-P to RNSS receiver, was considered in this case. This case is also very much reminiscent of simulations of LP-AMI-P → MSS MES case, as it also dealt with the satellite downlink as victim.

In this case it is difficult to establish precise receiver parameters for RNSS receivers, as it is unclear at this stage what kind of signal would be used. Therefore the draft SE40 report [24] suggests using the threshold of -146 dBW/MHz as interference criterion for evaluating compatibility with future RNSS in this frequency band. Therefore the SEAMCAT scenario has set equivalent RNSS receiver bandwidth of 1 MHz and -116 dBm as receiver noise floor, which was then used as interference threshold by applying I/N=0 dB criterion.

Specific SEAMCAT parameter settings that were used for this case study are shown in Table 22.

Parameter	**Unit**	**Value used**
Victim system definition		
Operating channel centre frequency	MHz	2499.15
Antenna gain (non-directional)	dBi	0
Rx noise floor	dBm	-116
Reception bandwidth	kHz	1000
Interference criterion: I/N	dB	0
Interfering system definition		
Operating channel centre frequency	MHz	2499.15
Transmitter power (e.i.r.p.) (*Note 1*)	dBm	10
Antenna gain	dBi	0
Transmitter mask, outside 1 MHz transmission channel	dBc	-20, at Δf= ±0.5 MHz -45, at Δf= ±2.5 MHz
Average density of transmitters	$1/km^2$	10
Activity factor (duty cycle)	%	10

Table 22: SEAMCAT parameter settings for interference scenario LP-AMI-P to RNSS Receiver

Note 1: Full e.i.r.p. value entered since the Extended-Hata model used in simulations contains "indoor-outdoor" setting which automatically adds 10 dB building attenuation loss into link budget calculations.

The placement of interferer vs. victim and other settings remained as was described in §5.2.2.
With the above assumptions and settings, the SEAMCAT simulations produced probability of interference as shown below:

Propagation model between interfering transmitter and victim receiver	Environment	Interfering Transmitter location	Victim receiver location	Probability of interference
Extended hata	Urban	indoor	outdoor	0.02%
Extended hata	Suburban	indoor	outdoor	0.025%
Extended hata	Rural	indoor	outdoor	0.36%

Table 23: SEAMCAT probability of interference

Note that similarly as in the case with MSS, the use of Free Space Loss model in simulations was considered but turned down as irrelevant due to the fact that LP-AMI would be always used indoors while RNSS would be most of the time used outdoors, which does not comply with direct line-of-sight conditions normally presumed for application of FSL.

The attached SEAMCAT scenario file "AMI-P_to_RNSS_Rx.sws" can be used in order to reproduce this simulation.

6 OVERALL CONCLUSIONS OF THE REPORT

The study of co-existence of future LP-AMI applications with other services in frequency range 2360-3400 MHz has been carried in two stages. The first stage, reported in chapter 4 of this report, has established the overall co-existence trends if introducing LP-AMI applications in various sub-bands of the considered frequency range by applying worst-case MCL simulations. The results of this initial investigation are re-iterated below in Table 24.

Candidate band, MHz	Interference counterpart/direction	Interference range	Comments
2360-2400	IMT-2000 BS → LP-AMI-P	5 km	Interference range much larger than the typical cell range of IMT-2000, therefore LP-AMI-P is likely to be affected by emissions from multiple BS within the interference range
2400-2483.5	LP-AMI-P ↔ WLAN (IEEE 802.11 b/g)	1.5-4.5 km	Risk of co-location. Heavy usage of the band puts a question on likely efficiency of AFS/LBT solution
2483.5-2500	LP-AMI-P → Globalstar MES	600 m	Risk of indoor operation of Globalstar MES in case of its use within CGC sub-band, if implemented. However mitigation techniques like LBT/AFS could address this issue (detailed statistical simulations were used in the second part of the report to verify this assumption)
2700-3400	LP-AMI-P ↔ radars	5-38 km most cases above the radio horizon	Risk of severe co-channel interference from extremely high power radar transmitters as well as high risk of interference from LP-AMI-P to radars. In addition. LBT/AFS use discouraged by long listening times imposed in this band in similar previous stud [14] or by meteorological radars.

Table 24: Identified critical interference scenarios in various candidate LP-AMI bands

Having considered the above results of first part of the study, the band 2483.5-2500 MHz was selected as the most promising candidate band for introduction of future advanced LP-AMI applications.

In order to confirm this preliminary identification, the more detailed statistical simulations were carried out for the various interference scenarios in the band 2483.5-2500 MHz, using real life assumptions of deployment patterns and applying Monte-Carlo based modelling with CEPT's spectrum engineering tool SEAMCAT.

These statistical simulations are described in greater detail in chapter 5 of this report; below Table 25 provides a summary of numerical results for all identified co-existence scenarios.

Co-existence scenario	Probability of interference	
	LP-AMI-P as interferer	LP-AMI-P as victim
LP-AMI vs MSS (in-band sharing)	**0.035-1.28%**	**Not applicable**
LP-AMI vs CGC (in-band sharing)	**0.05%**	**0.1%**
LP-AMI vs future RNSS (in-band sharing)	**0.02-0.36%**	**Not applicable**
LP-AMI vs IMT-2000 Downlink (adjacent band)	**0.0% (Note)**	**0.1%**
LP-AMI vs IMT-2000 Uplink (adjacent band)	**0.7% (Note)**	**1.2%**

Table 25: Results of statistical simulations for LP-AMI co-existence scenarios in band 2483.5-2500 MHz

Note: measured as capacity loss in reference cell of IMT-2000 network after introduction of LP-AMI-P interferer into power-balanced network structure. The quoted results show the simulated excess capacity loss in reference cell as compared with residual intra-system capacity loss values estimated by SEAMCAT for the entire modelled CDMA networks.

By looking at the summary of results provided in Table 22 it may be concluded that the statistical simulations of realistic deployment scenarios prove that LP-AMI applications have very good co-existence prospects with all existing and proposed future users of the band 2483.5-2500 MHz.

To that effect it should be noted that the statistical simulations used, inter alia, assumption of LP-AMI-P employing the advanced interference avoidance techniques, namely the LBT/AFS mechanism envisaged in ETSI TR 102 655 [1]. The studies in this report have confirmed the importance of employing these techniques as the means for improving co-existence prospects between LP-AMI applications and other users of this band.

ANNEX 1: LIST OF REFERENCES

[1] TR 102 655 ERM System reference document: Low Power Active Medical Implants (LP-AMI) operating in a 20 MHz band within 2 360 MHz to 3 400 MHz. Version 1.1.1 (2008-11)

[2] ECC Report 064: The Protection Requirements of Radiocommunications Systems below 10.6 GHz from generic UWB Applications

[3] ECC Report 123: The Impact of ODC Applications using UWB Technology on Radio Services

[4] ERC Report 025: European Common Allocation Table (ECA)

[5] ETSI EN 300 328. Data transmission equipment operating in the 2.4 GHz ISM band and using wide band modulation techniques

[6] ECC Report 002: SAP/SAB (incl. ENG/OB) Spectrum Use and Future Requirements

[7] ECC Report 003: Fixed Service in Europe: Current Use and Future Trends Post-2002

[8] Recommendation ITU-R P.452 : Prediction procedure for the evaluation of interference between stations on the surface of the Earth at frequencies above about 0.1 GHz

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

[10] ECC Report 100: Compatibility Studies in the Band 3400- 3800 MHz Between Broadband Wireless Access (BWA) Systems and Other Services

[11] ECC Report 006: Technical impact on existing primary services in the band 2700-2900 MHz due to the proposed introduction of new systems

[12] ECC Report 110: Compatibility studies between Broad-Band Disaster Relief (BBDR) and other systems

[13] ECC Report 045: Sharing and adjacent band compatibility between UMTS/IMT-2000 in the band 2500-2690 MHz and other services

[14] ERC Recommendation 70-03: Relating to the use of Short Range Devices (SRD).

[15] ERC Report 109: Compatibility of Bluetooth with other existing and proposed radiocommunication systems in the 2.45 GHz frequency band.

[16] Consumer information provided by the Canadian Centre for Occupational Health and Safety at: http://www.ccohs.ca/oshanswers/phys_agents/microwave_ovens.html

[17] Document SE40(09)TEMP05 – Draft ECC Report on Non-GSO MSS CGC

[18] Document SE40(09)027, Table 1, p. 3, also Doc. SE40(09)036

[19] CEPT Report 19 to the European Commission in response to EC Mandate to develop least restrictive technical conditions for frequency bands addressed in the context of WAPECS

[20] ECC/DEC/(05)05: on harmonised utilisation of spectrum for IMT-2000/UMTS systems operating within the band 2500-2690 MHz.

[21] ECC Report 120: Technical requirements for UWB DAA (Detect and Avoid) devices to ensure the protection of radiolocation services in the bands 3.1-3.4 GHz and 8.5-9 GHz and BWA terminals in the band 3.4 -4.2 GHz

[22] ECC Report 006: Technical impact on existing primary services in the band 2700-2900 MHz due to the proposed introduction of new systems

[23] SEAMCAT software tool is freely available at http://www.seamcat.org

[24] Draft ECC Report on "Introduction of Mobile Satellite Complementary Ground Components in the bands 1610-1626.5 MHz and 2483.5-2500 MHz", published as Annex 5 to the Minutes of SE40 meeting (Brest, 24-25 September 2009)

[25] ECC Report 150 on "Compatibility Studies Between RDSS and other services in the band 2483.5-2500 MHz"

[26] ITU-R Report SM.2039-1: Characteristics of terrestrial IMT-2000 systems for frequency sharing/interference analyses (2009)

[27] ETSI EN 302 544-1: Broadband Data Transmission Systems operating in the 2 500 MHz to 2 690 MHz frequency band; Part 1: TDD Base Stations; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive (2010-01)

[28] ETSI TS 125 101: Universal Mobile Telecommunications System (UMTS); User Equipment (UE) radio transmission and reception (FDD) (3GPP TS 25.101 version 8.8.0 Release 8) (2009-10)