CEPT Report 009

Report from CEPT to the European Commission
in response to the Mandate to:

Harmonise radio spectrum use for Ultra-Wideband Systems in the European Union

Final Report on 28 October 2005 by the:

CEPT ECC
Electronic Communications Committee

Electronic Communications Committee (ECC)
within the European Conference of Postal and Telecommunications Administrations (CEPT)

1 INTRODUCTION

This is the final report by the European Conference of Postal and Telecommunications Administrations (CEPT) to the European Commission (EC) in response to the Second Mandate from the European Commission on UWB issued to CEPT on June 6th, 2005. The first Mandate given by the Commission to CEPT on April 7th 2004 on this issue led to a final CEPT Report being delivered to the Commission on March 23rd 2005 (doc. RSCOM05-23). The ECC had recognised that a number of elements in the report have not been fully resolved within CEPT and that further work was needed to finalise the harmonised technical conditions of use of the radio spectrum for UWB in the EU.

Pursuant to art. 4 of the Radio Spectrum Decision, the second mandate requested CEPT to finalise all relevant work to identify harmonised conditions of use of radio spectrum in the European Union for all significant types of UWB applications (i.e. communications, imaging, location-tracking, etc.), with priority for applications considered to be closest to user take-up.

This final report has been developed within ECC Task Group 3 (TG3) with contributions from administrations and observers (industry and international organisations) and was approved by the ECC meeting in October 2005 in accordance with the timescales of the Mandate. It defines the conditions of use of the radio spectrum by generic UWB devices which provide some level of confidence for the protection of other radio services from harmful interference. A draft ECC decision has been developed on the basis of those conditions and is provided in **attachment 1** to this report. Further work is necessary within CEPT relating to specific UWB categories and also to explore some additional solutions which could help in the development of UWB.

2 UWB COMMUNICATION APPLICATIONS

2.1 Introduction

As requested by the Second Mandate, all efforts have been made to identify suitable solutions for the development of UWB communication applications, including an impact analysis, the refinement of compatibility studies, measurement campaigns, the assessment of potential mitigation techniques.

2.2 Technical studies

Complementary technical compatibility studies based on refined interference scenarios and propagation models have been carried out with fixed satellite service and fixed service.

2.2.1 Complementary compatibility studies on Fixed Satellite Service

Extensive studies have been carried out to further analyse the impact of UWB on fixed satellite service in the band 3.4-4.2 GHz, 4.5-4.8 GHz and 7.25-7.75 GHz. These studies are summarized in **annex 1**.

The results highly depend on the assumptions on the propagation model, on the environment considered (rural/suburban/rural) and on activity factor. In order to determine a PSD level which would provide some level of confidence for the protection of FSS while facilitating the development of UWB, an activity factor of 1% was finally assumed.

However, considering that all studies have assumed 100% indoor device, the importance of avoiding any outdoor UWB on fixed location or connected to outdoor fixed antenna should be noted.

2.2.2 Complementary compatibility studies on Fixed Service

Extensive studies have also been carried out on the impact of UWB on fixed services in the bands 3.4-5 GHz and 6-8.5 GHz. These studies are summarised in **annex 2**.

Band 3.4 to 5 GHz

The new studies attempt to include a more realistic propagation model compared to the analysis performed in ECC Report 64. The model includes the impact of both LoS and NLoS propagation using building heights based upon statistics from Milan, Italy, as a representative European city.

The results of the new studies suggest that the aggregation of UWB devices could meet the FS protection criteria for outdoor FS systems with a PSD level of -45.3 dBm/MHz to -37.8 dBm/MHz with a 1% activity factor and 95% confidence levels, and PSD levels of -48.3 dBm/MHz to -40.8 dBm/MHz with a 1% activity factor and 99% confidence levels. Increasing the activity factor lowers the required PSD levels by about 4-5 dB for a 5% activity factor and about 10 dB for a 17% activity factor.

However, it should be noted that, in any case, a PSD level of less than −70 dBm/MHz should be regulated for protecting indoor BFWA applications, unless suitable mitigation techniques are enforced.

Band 6 to 8.5 GHz

One study carried out with same scenario and approach used in the 3.4-5 GHz band and with a UWB reference level of –35 dBm/MHz has shown that, provided that the average activity factor is kept lower that 5% and no UWB outdoor applications are allowed besides hand-held devices, this level might be sufficient for protecting, with 95% confidence, FS from aggregate interference of a large population of indoor UWB devices with some margin for multiple scenario aggregation; also in this case 99% confidence might be reached with ~3 dB lower UWB reference level.

The importance of avoiding any outdoor UWB on fixed location or connected to outdoor fixed antenna is emphasised; Report 64 demonstrated beyond any possible doubt that a single outdoor entry in LOS condition would already largely exceed the FS protection criteria.

2.2.3 Mitigation techniques

During the elaboration of the ECC decision, several mitigation techniques were proposed in order to increase maximum e.i.r.p. in the band 3.1-4.95 GHz to a level sufficient for enabling UWB operation.

Two mitigation techniques have been considered:
- Low Duty Cycle (LDC) limitation
- Detect and Avoid (DAA) mechanisms

LDC limitation has been considered as one possible mitigation technique for UWB devices operating in the band 3.1 to 4.95 GHz. Two parameters have to be defined;
- Duty cycle limitation: The current double-limitation proposal (5% over one second, 0.5% over one hour) needs to be reviewed in order to take into account BFWA and other services' characteristics. Maximum burst duration and a minimum 'off' period would also be needed. Average power is measured with 100% duty cycle, however.
- Emission level for LDC UWB devices operating below 4.95 GHz: Two levels have been proposed (-41.3 / -45 dBm/MHz) and are not yet decided.

Particular attention was paid to Detect and Avoid (DAA) mechanisms, which detect the presence of signals from other radio systems (such as fixed broadband wireless access and mobile services) and reduce the transmitted power of the UWB device down to a level where it does not cause interference to indoor reception of these systems. The proposal for DAA is:

- To protect indoor services operating between 3.1 and 4.95 GHz.
- To consider the technical and regulatory feasibility of a phased approach by removing DAA requirement in the band 4.2-4.8 GHz until 2010 considering potential identification of spectrum for systems beyond IMT-2000 under WRC-07 agenda item 1.4.
- To define maximum emission levels to protect outdoor services between 3.1 and 4.95 GHz considering indoor deployment limitation for UWB devices: (-41.3 dBm/MHz).
- To define emission levels for “avoid operation” mode to protect indoor services, considering achievable solutions (e.g for MB-OFDM, -65 / -70 dBm/MHz) as stated by the industry and protection limits objectives (-70 / -85 dBm/MHz).
- Generic parameters of the indoor services to be protected have to be defined in order to enable industry to propose DAA solutions. These parameters include but are not limited to the following parameters
  - Minimum output power
  - Sensitivity
  - Activity ratio in idle mode
  - Typical session duration for defining time between consecutive detection operations

The reliable implementation of such DAA mechanisms, based on requirements that are to be defined, is not trivial and their feasibility has not yet been validated. Therefore, further research and investigation of DAA is encouraged. Once the effectiveness of DAA mechanism is validated, UWB devices incorporating it will be permitted.

2.2.4 Measurement campaigns

Several measurement campaigns have been carried out to measure the impact of UWB on fixed service (including WiMax) and mobile service (UMTS). These studies are summarized in **annex 3**. They have broadly confirmed the protection requirement assumed in ECC Report 64.

2.2.5 Report on impact analysis

Based on the deployment scenarios and protection distances assumed in the studies in ECC Report 64, the majority of the radiocommunication services considered require up to 20-30 dB more stringent generic UWB PSD limits than the FCC e.i.r.p. density limits. If the victim radiocommunication service is operated in an outdoor environment, as is the case for e.g. FS, FSS, RAS, EESS etc, then the increase of noise due to the aggregate UWB interference generally determines the generic UWB PSD limit. If the victim radiocommunication service is operated in the indoor environment, e.g. DVB-T, IMT-2000, RLAN etc., then the closest UWB interferer becomes the dominant interference factor due to small spatial separation (small path loss).

It was recognized that regulatory solutions based on the maximum generic UWB PSD limits calculated in ECC Report 64, while protecting existing services with a high degree of confidence, would not facilitate UWB operation in Europe.

Further analysis has been performed within the frame of a second mandate issued by the European Commission to CEPT in June 2005, including in particular:

- complementary technical studies focused on three selected coexistence scenarios (Fixed Satellite Services, outdoor Fixed Services and indoor FWA scenarios);
- an impact analysis, structured per frequency range, initially considering an e.i.r.p. density limit of -55 dBm/MHz in the 3.1 – 10.6 GHz frequency range, taking into account possible mitigation factors in particular restriction to indoor UWB applications.

The impact of different PSD limits has been studied on both radiocommunication services and UWB devices. This analysis distinguished primarily the following frequency ranges: below 3.1 GHz, 3.1 - 5 GHz, 5 - 6 GHz, 6 - 10.6 GHz and above 10.6 GHz.

For the bands below 3.1 GHz and above 10.6 GHz, the generic limits of ECC Report 64 are the basis for limitation of emissions of UWB applications.

Technical studies confirmed the susceptibility of radars (aeronautical, maritime, meteorological and military) to both single entry and aggregate interference from UWB devices and for which an EIRP density level in the order of -65/-70dBm/MHz may provide adequate protection to radars, although theoretical studies suggest the need for tighter figures.

It was agreed that in the 6-9 GHz band, standing the assumed mitigations (e.g. UWB operation at fixed outdoor location not permitted and careful monitoring of high activity video applications), an e.i.r.p. density level of –41.3 dBm/MHz would provide some level of confidence for the protection of incumbent services that are operating outdoor.

A report[1] on UWB requirements and communications link budget analyses has also been developed under this work item; analysing the effects of various power levels on the viability of UWB from both a technical and an economic perspective. Though no definitive conclusions could be reached, this document provides detailed explanations how UWB devices performance is impacted by application conditions, by UWB devices operation modes and by UWB devices implementation.

2.3 Possible elements of a monitoring and review mechanism

Procedures of review of ECC Decisions on UWB devices, expected 3 years after the introduction of any ECC decision, need to be supported by:

- the collection of market data on the numbers and types of UWB devices being placed on national markets;
- measurements on the characteristics of these devices;
- monitoring the impact of UWB devices on incumbent users, including the rise in noise due to the aggregate effect;
- collecting evidence of any interference caused to incumbent services by UWB devices.

The potential long term aggregate effect of UWB devices on outdoor victim receivers, in particular on FS and FSS stations, remains a matter of concern, taking e.g. into account deployment of earth stations in urban areas and the use of small dishes in the band 7 GHz.

It should be noted that maximum mean e.i.r.p. limit for UWB has been based on compatibility analysis using an activity factor which assumes that video will be transmitted only using high efficiency coding, such as MPEG2 and MPEG4. If a significant number of devices appear on the market which transmits with higher activity factors, then this regulation will have to be reviewed in order to consider the introduction of duty cycle restriction.

WRC-07 may envisage identification of part of this spectrum for systems beyond IMT-2000 for real deployment after 2015. Taking into account the predicted lifetime of consumer devices, this may allow

[1] Available on www.ero.dk as Annex 5 to the report of the 10th meeting of ECC TG3 (ref. TG3#10_42-A5_R0)

operation of new UWB devices in the 4.2 – 4.8 GHz frequency band until at least 2010 without DAA mechanisms. If this band is identified for systems beyond IMT-2000 under WRC-07 agenda item 1.4, then, from a specified date, new products would have either to operate in other bands or to implement DAA, once validated. The situation will be reviewed in 3 years in the light of WRC-07 results.

2.4 Consideration of economic studies

Some administrations have undertaken national studies on the economic impact of the introduction of UWB which they used in the elaboration of their proposals for regulation of UWB devices below 10.6 GHz.

Only limited elements were submitted for consideration by ECC TG3 concerning the economic studies. A study from United Kingdom highlighted the safety and related economic impact of UWB interference on radars and aeronautical systems.

2.5 Regulatory deliverable

A general regulation for UWB devices shall incorporate clear ***scope & definitions***; ***operational restrictions*** and ***technical requirements***.

Key features of the proposals developed under the ***scope & definitions*** are presented below:

- No restrictive definition for “UWB”
- Generic framework for “UWB devices”, with some restrictions
- No distinction between indoor and hand-held UWB devices
- “Underlay” regulatory specificity of UWB
- Restrictions on specific categories of devices:

Prior considerations on the scope and definitions for the proposed European UWB regulation are essential for clarifying what type of technology, device or application would be permitted.

This analysis should furthermore be particularly relevant when developing the purpose (i.e. Article 1) and definitions (i.e. Article 2) of the relevant EC Decision.

General principles for scope & definitions and operational restrictions applicable to the proposed generic regulatory framework for UWB devices are presented below. This takes into account global regulatory environment; in particular elements contained in the FCC rules.

❑ No restrictive definition for “UWB”

Unlike the FCC rules which include a definition of an *Ultra-wideband (UWB) transmitter*[2], it seems preferable that regulators do not try and define Ultra-Wideband (UWB) technology as this could create unnecessary regulatory barriers and conformity issues.

Associated definitions for *UWB bandwidth*, *Centre frequency*, *Fractional bandwidth* contained in the FCC rules[3] may consequently not be needed in the CEPT deliverable.

<u>It was therefore concluded that no restrictive definition for “UWB” is required</u>. The intention is rather to define a general regulation under which certain radio devices - to which the “R&TTE Directive” applies - will be permitted.

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[2] See FCC 47 CFR § 15.503 - *(d) Ultra-wideband (UWB) transmitter. An intentional radiator that, at any point in time, has a fractional bandwidth equal to or greater than 0.20 or has a UWB bandwidth equal to or greater than 500 MHz, regardless of the fractional bandwidth.*

[3] See FCC 47 CFR § 15.503

- Generic framework for “UWB devices”, with some restrictions

It was concluded that the regulatory framework should be “generic”, with some restrictions. In other words, the reference general CEPT regulation for UWB devices should not be *specific* to certain type of product or applications in the first place. It should rather be *generic*, though *exclusive* of certain categories of devices that present a significant interference potential to radiocommunication services.

The focus should furthermore be on “devices” rather than “technology” or “application” as the regulatory framework to be developed shall precisely apply to “devices” that are intended to be placed on the market under the R&TTE directive.

Devices operating under a *general regulation for UWB devices* will typically be license-free, shall not cause harmful interference and not claim protection. They could commonly be referred to as “UWB devices” in the sense that they do not operate under a specific frequency band but as *underlay* devices, within some defined ***operational restrictions*** and ***technical requirements***.

- No distinction between indoor and hand-held UWB devices

Among specificities of the proposed regulatory approach, no distinction is made between indoor and hand-held UWB systems unlike in the FCC rules. However, outdoor installations and infrastructure have been explicitly excluded.

- “Underlay” regulatory specificity of UWB

Based on the “underlay” regulatory specificity of UWB, no frequency band was “assigned to UWB” nor “made available to UWB” (unlike e.g. in *Article 1* of Commission Decision 2005/513/EC on 5 GHz WAS/RLANs) or “designated to UWB” (unlike e.g. in *Decide 1* of ECC/DEC/(04)08 on 5 GHz WAS/RLANs).

It was furthermore decided not to distinguish between intentional and unwanted emissions. Such concepts are necessary for operation within allocated/assigned frequency bands, not for an underlay regulatory layer.

The purpose of this *general regulation for UWB devices* is simply to define the “**harmonised conditions for the use in Europe of UWB devices below 10.6 GHz**”.

- Restrictions on specific categories of devices

As proposed in this regulatory approach for UWB, the type of radio devices that would be permitted to be placed on the market and to operate is basically “generic”, with some explicit restrictions.

Complementary restrictions are proposed in order to mitigate critical interference scenarios & effects that have been identified in the process of CEPT work on UWB.

In this respect, the ECC Decision is not applicable to:

a. flying models
b. outdoor installations and infrastructure, including those with externally mounted antennas,
c. devices installed in road and rail vehicles, aircraft and other aviation;

Consequently, the licence-exempt provision is not applicable and the operation of UWB devices is not allowed at a fixed outdoor location. The possibility of not allowing operation aboard aircraft or ship is also under consideration due to the risk of interference to related safety services. Such restriction may be enforced using other regulatory mechanisms (ie, civil aviation and maritime regulatory framework) to be identified.

3 SPECIFIC UWB APPLICATIONS

The second EC mandate requested to consider also specific UWB application categories. So far, ETSI has only finalized one SRDoc for a specific UWB application, for GPR/WPR imaging systems, for which ETSI standard EN 302 066 has now been published.

No CEPT deliverables have yet been completed on any of these specific UWB, but progress has been made in particular on GPR/WPR and on building material analysis. Work will continue within ECC in order to define suitable regulatory solutions for these specific UWB applications.

3.1 UWB sensors applications

3.1.1 Location Tracking

The requirements of location tracking systems intended to operate from 6 – 9 GHz are covered under the draft *general regulation for UWB devices below 10.6 GHz.*

3.1.2 Location Application for Emergency Services (LAES)

The dominant application for the equipment described in ETSI draft SRDoc is an indoor location application to be used by emergency services (police, fire workers, civil protection authorities, etc.). Further activities will be needed within CEPT.

3.1.3 Building Material Analysis

The work on building material analysis systems progressed and the industry has adapted its requirement in order to provide better protection to some other services. Possible regulatory approaches have been investigated but no final conclusion has been reached so far.

An analysis of the impact of these requirements on radio services needs to be completed.

3.2 GPR / WPR Imaging systems

The large frequency range of operation of these systems covers frequency bands listed by RR Article 5.340 which states that “All emissions are prohibited” and the potential impact of GPR/WPR imaging systems on purely passive satellite services remains a concern since only a power limit for undesired radiated emissions would be an effective mitigation factor with respect to the effect of a single imaging system on passive microwave radiometers.

The possibility of coordination of these systems with some terrestrial stations is under investigation and the GPR/WPR industry will provide description of what would be an adequate licensing scheme from their perspective as part of a harmonized regulatory framework for the operation of GPR/WPR imaging systems in Europe.

A draft ECC Decision has been developed but its adoption is still pending further work on the issues identified above.

4 WORK PROGRAM FOR FUTURE ACTIVITIES ON UWB

Concerning general UWB devices below 10.6 GHz, future activities should focus on the definition of the requirements for adequate mitigation techniques and assessment of their effectiveness.

Concerning specific UWB applications, CEPT has considered the requirements of following UWB Sensors applications:

- Building Material Analysis and Classification applications
- Object Discrimination and Characterization Applications
- Location Tracking applications
- Location Application for Emergency

As for GPR/WPR imaging systems, ETSI EN 302 066 is now published.

At this stage, only ‘Building material analysis applications’ and ‘GPR/WPR imaging systems’ have been identified as sufficiently mature items for analysis of compatibility and development of possible regulatory solutions.

Some regulatory aspects in relation to ‘Location Application for Emergency’ needs to be reviewed as the dominant application for the equipment described in ETSI documentation is precisely an indoor location application to be used by emergency services (police, fire workers, civil protection authorities, etc.) and may therefore not fall within the scope of R&TTE directive.

Annex 1

Complementary compatibility studies on Fixed Satellite Service (FSS)

In the following, a summary of complementary compatibility studies performed on FSS is provided.

Victim Radiocommunication **Fixed Satellite Service – downlink**

- Application

The fixed-satellite service has operated in the 4/6 GHz bands since commercial satellite services were initiated using the geostationary orbit during the 1960s. As a result, there are a large number of earth stations installed around the world which are used on a continuous basis for transmitting telephony, internet and broadcast feed. More particularly, these bands are heavily used in Europe for international telephony with other regions of the world or to enable Internet connectivity to regions that are far from the terrestrial Internet backbone (e.g. Africa, Middle-East, overseas territories of CEPT countries).

- Frequency band

3 400-4 200 MHz and 4 500-4 800 MHz, 7250-7750 MHz

- Receiver station : Category B

Typical FSS parameters at 4 and 7 GHz band

Downlink bands	3 400-4 200 MHz and 4 500-4 800 MHz, 7250-7750 MHz[4]					
Antenna reference pattern	Recommendation ITU-R S.465					
Earth station off-axis gain towards the local horizon (dBi)[1, 2]	Elev. Angle	5° [3]	10°	20°	30°	≥48°
	Off-axis gain	14.5	7.0	–0.5	–4.9	–10.0
Bandwidths (range)	40 kHz-72 MHz					
Polarization	Linear or circular					
Noise temperature of ES receiver system	100 K					
Deployment	All regions, in all locations (rural, semi-urban, urban)[5]					

1 The values were derived by assuming a local horizon at 0° of elevation.

2 The off-axis antenna gain is independent of the ES antenna diameter for the range of antennas considered. It is recommended that the elevation angles and gain values provided be used to calculate the interference into the FSS ES.

3 5° is considered as the minimum operational elevation angle.

4 These typical FSS parameters were assumed to also apply to the 7250-7750 MHz band and 7900-8400 MHz [Note : it has to be confirmed for the European case]

5 FSS antennas in this band may be deployed in a variety of environments smaller antennas (1.8m-3,8m) are commonly deployed on the roofs of buildings in urban or semi-urban locations , whereas larger antennas (4.5m and above) are typically mounted on the ground and deployed in semi-urban or rural locations.

Typical MSS Feeder link earth stations parameters

Parameter	**Symbol**	**Inmarsat-3 Feeder link earth station**	**Inmarsat-4 Feeder link earth station**	**Units**
Downlink Frequency Band		3550-3700	3550-3700	MHz
Antenna Reference Pattern		RR. App 7	RR. App 7	
System noise temp	T_S	71	52.5	K
IF bandwidth	B_{IF}	40	40	MHz

- Protection requirement

Recommendation ITU-R S.1432 contains the allowable degradations to the FSS below 15 GHz. The Recommendation states that for all sources of long-term interference that is neither from FSS systems, nor from systems having co-primary status, the allowable interference noise contribution is 1%.

Interference scenario & methodology

- UWB characteristics
  - PSD limit — FCC mask , average power UWB emission, peak power UWB emission
- Aggregate interference
  - Methodology — Cumulative distribution of I/N ratios
  - Propagation model — Various
- **Reference deployment scenario** — Relevant for categories B & C, aggregate analysis.

Deployment scenario 1	(1a) Rural	(1b) Suburban	(1c) Dense Urban
UWB density (/km²)	100	1000	10000
Activity factor	1%, 5 %, 17%	1%, 5 %, 17%	1%, 5 %, 17%
Density of active UWB transmitters (/km²)	1, 5, 17	10, 50, 170	100, 500, 1700
% Outdoor	0%	0%	0%

Results of theoretical compatibility studies

- Aggregate interference

Monte Carlo simulation models were used in all cases, and a number of scenarios modelled. The major differences between the simulations was the choice of different propagation models used. All results assumed 100% indoor devices.

Resulting I/N at FSS receiver for: Rural deployment, radius =10 km, Den.100unit/km^2, Excl.100m

Resulting I/N (dB)	***(iii)*** ***802.16 (C)***	***(vi)*** ***Free-Space Loss plus combination of additional losses***	***(v)*** ***Free-Space Loss plus fixed indoor attenuation***	***(iv)*** ***MultiSlope (free-space breakpoint=100m)***
99% (I/N) ***1% AF***	-32.08	-20.7	-19.6	-15.28
99% (I/N) ***5% AF***	-21.28	-16.4	-15.9	-7.16
99% (I/N) ***17% AF***	-10.4	-13.4	-10.7	-4.76

Resulting I/N at FSS receiver for: Suburban deployment., R.3 km, Den.1000unit/km^2, Excl.50m,

Resulting I/N (dB)	***(i)* Random Building Model 3m/20m antenna height**	***(vi)* Free-Space Loss plus combination of additional losses**	***(v)* Free-Space Loss plus fixed indoor attenuation**	***(iii)* 802.16 (B)**	***(iv)* MultiSlope (free-space breakpoint=100m)**
99% (I/N) 1% AF	-20 / -20	-12.1	-9.1	-5.84	-3.12
99% (I/N) 5% AF	-12 / -17	-9.6	-3.3	-0.92	1.2
99% (I/N) 17% AF	-	-6.4	1.4	1.8	3.96

Resulting I/N at FSS receiver for for: Urban deployment, R.3km, Den.10000unit/km^2, Excl.30m

Resulting I/N (dB)	***(i)* Random Building Model 25m antenna height, 30m excl.**	***(ii)* M.1225 i/o**	***(iii)* 802.16 (A)**	***(iv)* Multi-Slope (free-space breakpoint=50m)**	***(vi)* Free-Space Loss plus combination of additional losses**	***(v)* Free-Space Loss plus fixed indoor attenuation**
99% (I/N) 1% AF	–18	–17	–6.4	–4.2	0.4	5.1
99% (I/N) 5% AF	–14	–12	–2.36	–0.2	3.1	11.5
99% (I/N) 17% AF	-	–9	1.2	3.36	6.0	16.4

The following propagation models were used:

(i) “Random Building Model”: The random building model is based upon a statistical model for buildings based upon building height statistics from the city of Milan, Italy chosen as a representative European city. This model explicitly determines whether paths are LoS or NLoS for each device location, includes devices randomly located in the buildings at various heights, uses a free space propagation for LoS, uses an 802.16 model for NLoS, and includes an indoor-to-outdoor attenuation factor in the range 12 – 40 dB. This model was also used in the coexistence analysis of Fixed Services and UWB devices in a suburban and urban environment.

(ii) ITU-R Rec.M.1225 (indoor to outdoor): This model comes from ITU-R SG8, and has been intended for cell planning purposes in mobile systems. This model does not include an additional indoor-to-outdoor factor, which is assumed to be part of the model.

(iii) 802.16: This model comes from IEEE 802.16 standards group, for the prediction of propagation for WiMAX-type systems. The model is based upon a set of measurements taken in a suburban environment in the US when a mobile device is located near the ground and a basestation is located on a mast several meters high.,

(iv) Multi-slope: This model assumes propagation losses proportional to range as follows: r^2 (0 – 50m) / r^3 (50m – 2000m) / r^4 (>2000m). An additional factor of 10dB is added for building losses, and [XXX] dB for shadowing.

(v) Free-space plus fixed attenuation : This model represents the case of free-space loss plus a fixed 10dB of indoor losses

(vi) Free-space plus additional: This model assumes free-space propagation loss, plus additional losses consisting of a combination of attenuations due to windows, walls, trees and other clutter in a given path.

Since there does not exist a set of measurements evaluating the propagation for the expected scenarios involving UWB devices operating in the same geographic area as a FSS downlink terminal, the above models can only be considered as general guidelines of the range of likely interference to be experienced by an FSS receiver. It is recognized that some propagation models, like the M.1225 models, have traditionally been used for cell planning purposes and may over-estimate path loss for these interference scenarios; others such as free-space loss or multi-slope variants are commonly used for interference studies within ECC but may under-estimate path loss. These results are intended to provide regulators information regarding the impact of different assumptions on the path loss models and the sensitivity of the results to the models and selected confidence levels – the results should be compared with the FSS protection criteria of -20dB I/N. It is further estimated that power control may lower the above I/N values by approximately 3 dB, in the case of an implementation of TPC with a random distribution of attenuation between 0 to 8 dB. However this implementation has to be confirmed.

The UWB Industry, having contributed many simulation results studying FSS and UWB coexistence, believes that care should be taken when considering the above results. First, the results above are based upon a 99% confidence level in the theoretical monte-carlo simulations. When considering a slightly lower confidence level of 90%, the I/N reduces by 7-10 dB for the suburban studies and 5 – 7 dB for the urban studies based upon the 'Random Building Model' suggesting that the 99% confidence level is capturing the worst case scenarios. Second, although the 802.16 model is one of the few based upon actual measurement results, it is only relevant for the situation of a basestation transmitting on a mast high in the air and a mobile terminal on the ground. In the interference scenario studied here, both the FSS antenna and UWB device could be located on the ground, or a FSS could be located on the top of a building with UWB devices in near-by buildings. Neither of these cases are covered by existing measurements and would likely result in much higher propagation losses compared to the 802.16 and other free-space and multi-slope models. All the other models are strictly theoretical and have not been validated with measurements. The Random Building Model was agreed to for the fixed services scenario for UWB and fixed services coexistence, which has similar interference scenarios as FSS and UWB. This model was developed over the course of several meetings with the fixed services industry to include the impact of both LoS and NLoS paths, as well as incorporating random UWB device distribution within buildings with multiple floors. Therefore, the UWB industry supports the use of the random building model as being most appropriate for both the suburban and urban environments, and we believe the combination of very high confidence levels and low I/N < -20 dB should ensure no harmful interference for FSS systems. In addition, a periodic review and monitoring process could help ensure that the activity factors and potential interference is tightly tracked and changes to the regulations could be made as appropriate is the assumptions used in the models turn out to be too conservative.

The FSS industry supported the use of models (iv) and (v) as suitable propagation models for assessing interference criteria, as they are commonly used in other ECC and ITU-R studies for assessment of compatibility. The FSS participants did not consider appropriate the use of M.1225, IEEE 802.16 and other similar models ((i) – (iii) above), as these models are not designed for predicting propagation in interference scenarios. The FSS industry therefore believes that the results gained using propagation models (i) – (iii) under-estimate the likelihood of interference being caused to the FSS.

Considering results for FSS in the 7.2-7.8 GHz band

A simple extrapolation of the above results to the upper frequency bands requires consideration of the following:

1. Changing the centre frequency from 3.8 GHz to 7.2 GHz yields an additional 5.5 dB reduction in I/N.
2. Typical attenuation through material can be expected to be higher in the higher frequency bands. This could result in an I/N reduction on the order of at least 3-5 dB. More careful studies would be needed to determine an appropriate model.
3. General propagation characteristics may be different between the lower frequency and upper frequency bands, especially for NLoS propagation.
4. Antenna patterns may be different due to the different dish sizes at the upper frequency bands. Due to the difference of FSS characteristics in the upper frequency, FSS receivers in the upper frequency band might be more sensible than in the lower frequency.

5. Due to specificity of FSS usage in the upper band, the deployment might be different (especially for urban case).

Due to those considerations, the same FSS level protection can be expected in the upper frequency bands than the one presented for lower frequency.

Annex 2

Complementary Compatibility Studies on Fixed Service (FS)

In the following, conclusions of new studies on aggregate interference evaluation for protection of outdoor FS stations are provided.
- Report 64 used mitigation in terms of Kfactors (chosen without particular connection to any real scenario)
- New study made on a real typical urban environment using real building height distribution and some real FS location using statistical NLOS propagation models for both the outdoor and the indoor to outdoor propagation models.
- Results given in term of cumulative probability of interference level exceeded have shown that Kfactors (particularly the Klos and the Kindoor) in Report 64 might be considered overly conservative.
- Two different studies (Intel TG11_18R1 and Siemens TG11_05R2) made in frequency range ~3.6 GHz within the same scenario with similar assumptions for the UWB deployment (indoor only) but with different integration methodology (still considered equivalent in principle) have given similar results.
- One study also explored the possible additional 20% of hand-held outdoor UWB devices and evaluate the impact on the indoor only population using the same activity factors as indoor devices which may be overly conservative given the expected lower activity of outdoor handheld devices (assuming no outdoor infrastructures)
- Slightly different additional factors have been proposed in the two studies for consolidating a possible UWB PSD for safely protect FS links, resulted in similarly different proposed PSD limits.
- A third study TG11_22R1 produced study within the same scenario but at 7.7 GHz, adopting similar methodology of document 18 with modifications only in the indoor to outdoor attenuation (expected to be more severe in higher bands)

the following tables present the results in term of I/N based upon a transmit PSD level of -41.3 dBm/MHz for the frequency bands below 5 GHz and -35 dBm/MHz for the frequency bands above 7.7 GHz.

Frequency bands 3.4 – 5 GHz

I/N values obtained with UWB reference level at –41.3 dBm/MHz

Average AF	1 %		5 %		17 %	
Simulation method	Intel	Siemens	Intel	Siemens	Intel	Siemens
I/N (dB) Aggregation at 95% confidence	–21	–19	–15	–12	–11	–6.3
Contribution of additional 20% UWB outdoor handheld devices (AF 1% Siemens) (AF 0.01% Intel)	0.5 at most	3	none	1	none	none
Contribution for multiple aggregation scenario (e.g. one specific “hot spot” building contribution with similar average AF derived from App.1 to Annex 1 of Report 64)	0 (note 1)	3	0	3	0	3
Expected overall I/N (dB) with no further mitigation (UWB PSD –41.3 dBm/MHz)	–20.5	–13	–15	–8	–11	–3.3
Potential average improvement from power control option (8 dB range) (UWB PSD –41.3 dBm/MHz)	3	3	3.5	3.5	3	3

I/N (dB) objective	–20	–20	–20	–20	–20	–20
Missing (margin) from the objective with power control (dB)	(3.5)	4	1.5	8.5	6	13.7
Missing (margin) from the objective with no power control (dB)	(0.5)	7	5	12	9	16.7
UWB PSD level (dBm/MHz) for 95% confidence of matching (Note) with power control (dB)	**–37.8**	**–45.3**	**–42.8**	**–49.8**	**–47.3**	**–54.7**
UWB PSD level (dBm/MHz) for 99% confidence of matching (Note 2)	**–40.8**	**–48.3**	**–46.3**	**–53.3**	**–50.3**	**–57.7**
Note 1: The impact of replacing a residential building with an office building should not yield a difference in interference levels due to similar or less activity factors for UWB devices in the office environment. Note 2: studies have shown that for reaching 99% confidence level, additional 3 dB lower PSD may be needed.						

Frequency bands 7/8 GHz

I/N values obtained with a UWB reference level at –35 dBm/MHz.

TABLE 1. I/N ratios with 95% confidence levels for various activity factors, 100% indoor devices

# item	Shadowing (9 dB)	Power control 0..-8 dB	Activity factor	I/N value (dB) urban/suburban
1	No	No	1%	-32 / -30
2	No	No	5%	-26 / -25
3	No	No	17%	-22 / -21
4	No	No	100%	na / na
5	Yes	No	1%	-29 / -30
6	Yes	No	5%	-23 / -24
7	Yes	No	17%	-18 / -20
8	Yes	No	100%	na / na
9	Yes	Yes	1%	na / na
10	Yes	Yes	5%	na / na
11	Yes	Yes	17%	na / na
12	Yes	Yes	100%	na/ na

Also in this case the difference for reaching 99% confidence is ~3dB.
No specific study has been done for hand-held outdoor device contribution however we could assume that findings in lower band can conservatively adopted also in this band. Therefore the same considerations for further contributions from outdoor hand-held and multiple scenario aggregation are valid also in this band; this will result in a maximum 6 dB enhancement of the above values.

- **3.4 - 5 GHz conclusions**

The new studies attempt to include a more realistic propagation model compared to the analysis performed in Report 64. The model includes the impact of both LoS and NLoS propagation using statistical building heights based upon statistics from the city of Milan, Italy, as a representative European city.

The results of the new studies suggest that the aggregation of UWB devices could meet the FS protection criteria for outdoor FS systems with a PSD level of -45.3 dBm/MHz to -37.8 dBm/MHz with a 1% activity factor and 95% confidence levels, and PSD levels of -48.3 dBm/MHz to -40.8 dBm/MHz with a 1% activity factor and 99% confidence levels. Increasing the activity factor lowers the required PSD levels by about 4-5 dB for a 5% activity factor and about 10 dB for a 17% activity factor.
However, it should be noted that, in any case, a PSD level of less than –70 dBm/MHz should be regulated for protecting indoor BFWA applications, unless suitable mitigation techniques are enforced.

- **6 - 8.5 GHz conclusions**

One study, carried out with same scenario and approach used in the 3.4-5 GHz band and with a UWB reference level of –35 dBm/MHz, has shown that, provided that the average activity factor is kept lower that 5% and no UWB outdoor applications are allowed besides hand-held devices, this level might be sufficient for protecting, with 95% confidence, FS from aggregate interference of a large population of indoor UWB devices with some margin for multiple scenario aggregation; also in this case 99% confidence might be reached with ~3 dB lower UWB reference level.
The importance of avoiding any outdoor UWB on fixed location or connected to outdoor fixed antenna is emphasized; Report 64 demonstrated beyond any possible doubt that a single outdoor entry in LOS condition would already largely exceed the FS protection criteria.

Annex 3

Report on Measurement Campaigns

The following presents the outcome of measurement campaigns performed within ECC TG3.

- **<u>Measurement campaigns results of UWB interference on UMTS services:</u>**

Document TG3#10_12R1 provides a summary of the three measurement campaigns conducted within TG3 ad hoc measurement group between UWB devices and Mobile services receivers:

- Measurement campaign conducted by France Telecom: GSM1800 and UMTS-FDD
- Measurement campaign conducted by Nokia: On UMTS-FDD
- Measurement campaign conducted by Swisscom: On UMTS-FDD

The measurement campaigns scenario and results are summarised here below:

- The first measurement campaign, based on same assumptions as in ECC Report 64 allowed verifying the theoretical studies.
- The second measurement campaign was conducted by Nokia on UMTS radio system with conditions similar to the cell edge. In these conditions, the out-of-band emission limit (-75.4 dBm/MHz) produces insignificant amount of interference, if the separation distance is more than one meter. When the distance decreases to 36cm, we observe an increase of DCPH signal level by 1.5dB in order to maintain a BLER of 1%. The slope given for degradation impact versus the distance follows the theoretical law, but a gap between the experimental results and the theoretical results is observed, due to non isotropic antennas.
- The third measurement campaign from Swisscom put in evidence the existence of background noise linked to the UMTS network environment (CPICH channel signal), which is location dependant (UE location distance versus the BTS).

These measurement campaign results were considered along with theoretical studies on UWB and UMTS coexistence as reference assumptions in order to define the protection limit for mobile services below 3.1 GHz.

- **<u>Measurement campaigns results of UWB interference on Fixed Services:</u>**

Document TG3#11_42R1 provides a summary of the two measurement campaigns conducted within TG3 ad hoc measurement group between UWB devices and Fixed services, and includes also two complementary studies:

The two measurement campaigns conducted within the TG3 ad hoc group:

- Measurement campaign conducted by RegTP: On 3.5GHz Marconi Digital Multipoint System
- Measurement campaign conducted by ANFR and OFCOM-Bakom on in-situ WiMax system: On 3.5GHz WiMax system provided by Swisscom Innovation

The two complementary studies are:

- Measurement campaign results conducted by Siemens between UWB devices and SRR in the 23GHz bands.
- Coexistence simulation study completed by Texas Instruments evaluating the impact of UWB signal on 64-QAM fixed service receiver in the 3.5GHz band. This study allows to evaluate the coexistence improvements between UWB devices and in-band incumbent services when mitigation techniques are applied (notching with AIC).

The second measurement campaign conducted on in-situ 3.5GHz WiMax system is giving the following results:

Concerning equipment under test (WiMax client), we note several particularities:

- Antenna gain of the WiMax client is very important, and we must take into account that for an indoor system (for example) the antenna is always omnidirectionnal.
- 64QAM is a modulation which is in the standard definition of the WiMax and this operation mode was not supported by the equipment under test. This modulation is more sensitive.

Concerning measurement conditions:

We observe that in the absence of any UWB interference some problems are occurred to reach the more sensitive state of the WiMax equipment under test (QAM16/LFEC)

- Without UWB, at the location 1, we reached this WiMax operation mode.
- At the location 2, we never have reached this operation mode.

Summary results of the measurement campaign:

- PRF impact: we note that PRF variation in a range of 12 to 30 MHz involved a variation of 5dB of the UWB PSD threshold.
- quality of service degradation due to UWB interferer:
  - Concerning influence of the distance, we obtained following results by averaging UWB PSD values for each PRF to get a reliable link (QAM16/HFEC):[location 1: Schosshalde]

Distance between UWB/ WiMax antennas	-1 dB attenuation gain (Direction 3)	-7 dB attenuation gain (Direction 2)	-22 dB attenuation gain (Direction 1)
0,41 m	-77 dBm/MHz	-71 dBm/MHz	-56 dBm/MHz
0,75 m	-68,7 dBm/MHz	-62,7 dBm/MHz	-47,7 dBm/MHz
1,51 m	-62,7 dBm/MHz	-56,7 dBm/MHz	-41,7 dBm/MHz

UWB transmitted PSD measured at the output of UWB system which involved a change of state of the WiMax link

Comparison of measurements results with theoretical studies:

- Report 64 proposed, for FWA define below, a limit at -68 dBm/MHz:
  - Frequency band : 3,4 – 3,8 GHz
  - Separation distance : 1m
  - Receive antenna gain : 16 dBi

  Measurement results confirm this level for a WiMax state as 16QAM/HFEC.

- Along with theoretical results, it’s proposed to consider these measurement results observed for 41cm and 75cm for the definition of the protection limit for Wimax indoor systems.