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ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R SM.1757-0
(05/2006)

Impact of devices using ultra-wideband technology on systems operating within radiocommunication services

SM Series

Spectrum management

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Note: *This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

Electronic Publication
Geneva, 2009

RECOMMENDATION ITU-R SM.1757-0*

Impact of devices using ultra-wideband technology on systems operating within radiocommunication services**

(2006)

Scope

This Recommendation is offering a summary of studies related to the impact of devices using UWB technology on radiocommunication services. These may be used as guidance for administrations when developing their national ultra-wideband (UWB) rules.

Keywords

Ultra-wideband, protection criteria, potential interference, minimum coupling loss

The ITU Radiocommunication Assembly,

considering

a) that intentional transmissions from devices using ultra-wideband (UWB) technology may extend over a very large frequency range;

b) that devices using UWB technology are being developed with transmissions that span numerous radiocommunication service allocations;

c) that devices using UWB technology may therefore impact, simultaneously, many systems operating within a number of radiocommunication services, including those which are used internationally;

d) that UWB technology may be integrated into many wireless applications such as short-range indoor and outdoor communications, radar imaging, medical imaging, asset tracking, surveillance, vehicular radar and intelligent transportation;

e) that it may be difficult to distinguish UWB transmissions from emissions or radiations in equipment that also contains other technologies, where different limits may apply;

f) that applications using UWB technology may benefit sectors such as public protection, construction, engineering, science, medical, consumer applications, information technology, multimedia entertainment and transportation;

g) that applications using UWB technology that are not presently recognized as operating under allocations to radiocommunication services would operate on a non-protected, non-interference basis;

h) that the impact of a specific UWB application on a radiocommunication service will vary according to the characteristics and protection requirements of that service and the characteristics of the specific type of UWB application;

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* Radiocommunication Study Group 1 made editorial amendments to this Recommendation in the years 2009, 2019 and 2023 in accordance with Resolution ITU-R 1.

** The Syrian Arab Republic reserves its position on this possible ITU-R Recommendation in regard to the protection of radiocommunication services (primary/secondary).

j) that there is a need to assess the impact from single and multiple transmitters using UWB technology on radiocommunication services;

k) that characteristics of devices using UWB technology, victim system characteristics, protection requirements of potential victim systems, analysis methodologies, and propagation models are required for studies with regard to the impact of devices using UWB technology on radiocommunication services;

l) that, according to the mutual deployment conditions of both radiocommunication systems and devices using UWB technology, different methodologies for the evaluation of the potential interference level are appropriate;

m) that appropriate methodologies may include deterministic single-entry and/or aggregate analyses, as well as statistical or forecast analysis for some of the parameters relevant to the study;

n) that there is a need to use common technical assumptions in interference analysis from devices using UWB technology into systems operating within radiocommunication services,

recognizing

a) No. **4.10** of the Radio Regulations (RR),

noting

a) that key technical and operational characteristics of devices using UWB technology for the purposes of undertaking technical studies are contained in Recommendation ITU-R SM.1755;

b) that a framework for the introduction of devices using UWB technology is contained in Recommendation ITU-R SM.1756;

c) that there is a need to apportion the maximum allowable interference for a given radiocommunication service between devices using UWB technology and other radiocommunication services where this apportionment is not determined;

d) that the characteristics and protection criteria of the various radiocommunication services are defined by the relevant ITU-R study groups and associated Recommendations;

e) that detailed interference studies relevant to the impact of devices using UWB technology on radiocommunication services are documented in Report ITU-R SM.2057, which also contains information on victim system characteristics, protection criteria and propagation models;

f) that the studies documented in Report ITU-R SM.2057 are based on UWB applications for radiocommunications below 10.6 GHz and vehicular radar around 24 GHz and 79 GHz;

g) that Report ITU-R SM.2028 contains a description of the Monte Carlo simulation methodology, and that ITU-R has a publicly available Spectrum Engineering and Monte Carlo Analysis Tool (SEAMCAT[1]),

recommends

1 that administrations may consider the results of studies as summarized in Annex 1 in order to assess the impact of devices using UWB technology on allocated radiocommunication services when developing their national UWB regulations;

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[1] SEAMCAT was developed by the group of Special Committee on Data Transmission (CEPT) Administrations, European Telecommunications Standards Institute (ETSI) members and international scientific bodies. SEAMCAT is publicly available on the ITU website at: http://www.itu.int/ITU-R/study-groups/rsg1/index.asp.

2 that, as described in Annex 2, deterministic methodologies should be used for analyses involving specific device(s) using UWB technology and statistical methodologies should be used for analyses involving interference probability for an aggregation or density of devices, except where safety services are involved;

3 that the impact of devices using UWB technology on safety services should be determined on a case-by-case basis in the form of an analysis demonstrating that the specified level of integrity, continuity and availability is still maintained under all operational conditions;

4 that the following Notes will be considered as part of this Recommendation:

NOTE 1 – Administrations authorizing or licensing devices using UWB technology should ensure, pursuant to the provisions of the RR, that these devices, will not cause interference to and will not claim protection from, or place constraints, on the radiocommunication services of other administrations as defined in the RR and operating in accordance with those Regulations.

NOTE 2 – Upon receipt of a notice of interference to the radiocommunication services referred to in Note 1 above from devices using UWB technology, administrations should take immediate action(s) to eliminate such interference.

Annex 1

Summary of studies related to the impact of devices using ultra-wideband technology on radiocommunication services

TABLE OF CONTENTS

Report ITU-R SM.2057 on impact of devices using UWB technology on systems operating within radiocommunication services contains detailed interference studies and measurement tests as well as studies on mitigation techniques considered within the ITU-R. These summaries are provided in this Annex as guidance for administrations when developing national UWB rules.

The assumptions and measurement conditions fundamentally affect the results of studies.

It is noted that administrations may wish to make their own analysis on mitigation factors and parameter sets that best fit to their country-specific situations when defining national regulations.

Some administrations have adopted or are in the process of adopting national regulations including technical and operational restrictions that may have been derived using different parameters and/or methodologies, taking into account, in particular, specific national deployment scenarios and technical characteristics, as well as other considerations. Examples of such regulations can be found in the Attachment to this Annex.

1.1 Summary of analytical studies

1.1.1 Summary tables of analytical studies relevant to the impact of devices using UWB technology on systems operating within radiocommunication services

The following Tables are provided as guidance for administrations when developing national UWB rules. It should be noted that in the time available not all frequency bands could be studied.

In the Tables presented below, the column “UWB e.i.r.p. density (dBm/MHz)” refers to the maximum average e.i.r.p. density limit for a single device using UWB technology. These e.i.r.p. density limits are derived for the given methodology, *I*/*N* protection criteria, activity factor, victim system characteristics, UWB characteristics, interference and deployment scenarios, and other assumptions. Details of relevant studies are given in the part of Report ITU-R SM.2057 listed in column 1.

In the studies in the Report ITU-R SM.2057, results and ranges were expressed in terms of minimum separation distance, *I*/*N* protection criteria, *C*/*I*, BER, etc.). These results are influenced by the methodology of interference analysis, propagation model, indoor/outdoor deployment, density of devices using UWB technology, UWB activity factor, distribution of UWB emitters, assumptions about wall/roof attenuation, antenna cable loss, difference between interferer(s) and victim receiver bandwidth, UWB pulse repetition frequency (PRF), dithered/non-dithered UWB signal, UWB e.i.r.p. density, and range of input parameters (receive antenna gain, azimuth and elevation angle, antenna height).

Users of these results should note that they were based on the methodologies, interference scenarios, assumptions, and parameters listed. In particular, it should be noted that most studies assumed that emissions from devices using UWB technology behave like additive white gaussian noise (AWGN), which is recognized to offer a worst-case approximation of UWB behaviour with respect to victim radiocommunication services. In most cases, no account was made for bandwidth differences between the device(s) using UWB technology and the victim receiver, pulse repetition frequency (PRF) of the UWB signal, and whether the UWB signal is dithered or non-dithered.

1.1.1.1 Impact of UWB on the mobile, radiodetermination, amateur and related services

1.1.1.1.1 Land mobile services except IMT-2000

Part of Report (Attachment)	Service/ applications	Frequency bands (MHz)	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz) or separation distance	Comments
A1.1.2	Land mobile services except IMT-2000 (GSM 900 downlink)	925-960 880-915	GSM handset Bandwidth (BW) = 200 kHz Noise floor = −120 dBm Sensitivity = −90 dBm Omnidirectional antenna (0 dBi)	SINR = 9 dB	Aggregate interference with victim surrounded by UWB interferer R_{min} = 1 m	−75	Mass deployment of UWB devices does not cause disruption to the GSM 900 systems under these conditions. Results are for 950 000 active device/km^2 (outdoor) or 1 500 000 active devices/km^2 (indoor) (Note 1)
A1.1.1.2	Land mobile services except IMT-2000 (IS-95 CDMA)	1 930-1 990 1 850-1 910 1 840-1 870 1 750-1 780	Frequency 1 900 MHz Receiver (Rx) BW = 1.23 MHz NF = 8 dB Rx antenna gain = 0 dBi Rx cable loss = 2 dB	I/N = −6 dB	Single interferer 1 m separation Free-space path loss Link budget analysis	−73	Test results satisfy frame-error-rate (FER) below 0.5% at desired signal level −100 dBm/1.23 MHz (Note 2)
A1.1.1.1	Land mobile services except IMT-2000 (IS-95 CDMA)	1 930-1 990 1 850-1 910	Rx BW = 1.23 MHz NF = 8 dB Handset cable loss = 0 dB Rx noise = −105 dBm	1.5% blocking probability	Aggregate. 1 in 10 devices have UWB at 1 m Propagation= $1/r^{3.5}$	−73	(Note 1, Note 2)
A1.1.5	Land mobile services except IMT-2000 (IS-95 CDMA)	869-894 824-849	Rx BW = 1.23 MHz Commercial terminals	I/N = −6	Single impulse interferer with centre frequency = 4.7 GHz, BW = 3.5 GHz and PRF = 9.6 MHz Free-space path-loss 1m separation	−80	Test results satisfy frame-error-rate (FER) below 0.5% at desired signal level −104 dBm/1.23 MHz (Note 2)

Part of Report (Attachment)	Service/ applications	Frequency bands (MHz)	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz) or separation distance	Comments
A1.1.5	Land mobile services except IMT-2000 (IS-95 CDMA)	869-894 824-849		0.4 dB degradation, $I/N = -10$ dB	Single interferer, 36 cm separation	−92.7	Based on CDMA2000 1x frequency scaling (Note 2)
	Land mobile services except IMT-2000 (IS-95 CDMA)	1 930-1 990 / 1 850-1 910		0.4 dB degradation, $I/N = -10$ dB	Single interferer, 36 cm separation	−85.8	Based on CDMA2000 1x frequency scaling (Note 2)
A1.1.4	Land mobile services except IMT-2000 (WiBro OFDM)	2 300-2 400	Rx BW = 9 MHz NF = 7 dB Receiver antenna gain = 0 dBi	1 dB degradation, $I/N = -6$ dB	Single interferer, 36 cm separation Indoor path loss Link budget analysis	−76.9	(Note 2)
A1.1.3	Land mobile services except IMT-2000 IS-95/IS-136 PCS 1800 DCS 1900	1 805-1 880 / 1 930-1 990	Rx BW (MHz): IS-95 = 1.25, IS-136 = 0.03, PCS/DCS = 0.2	Interference threshold (dBm): IS-95 = −110 IS-136 = −126 PCS/DCS = −117	Single interferer with indoor emission limits Free-space path loss for 2 m then $1/r^4$	Minimum separation distance 1.8 m to 2.4 m	(Note 2)

CDMA: code division multiple access

NOTE 1 – Results assume each device using UWB technology to be active simultaneously. In reality devices using UWB technology may not transmit continuously.

NOTE 2 – These studies assume that the device using UWB technology transmits continuously. In reality devices using UWB technology may not transmit continuously.

1.1.1.1.2 Maritime mobile service

In all maritime mobile services below, the integral methodology was used with a receiver antenna height = 15 m, antenna gain = 0 dBi, antenna cable loss = 0 dB, and active UWB device density = 50/km^2.

For each of the bands under consideration the worst-case value has been reported in the Table below. Where more than one receiver operates within a band, the values for the additional receivers are available in Attachment 1.2 of Report ITU-R SM.2057.

Part of Report (Attachment)	Service/ Applications	Frequency bands	Victim station characteristics	Service protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz)	Comments
A1.2	Maritime Loran C	90-110 kHz	Rx BW = 20 kHz	S/I = 10 dB + 6 dB for multi-system interference	Aggregate (50 active UWB/km^2) Free-space path loss	−48.9	(Note 1)
	Maritime DGNSS	285-325 kHz	Rx BW = 0.5 kHz	S/I = 10 dB + 6 dB for multi-system interference	Aggregate (50 active UWB/km^2) Free-space path loss	−44.9	(Note 1)
	Maritime NAVTEX	490-518 kHz	Rx BW = 0.27 kHz	S/I = 10 dB + 6 dB for multi-system interference	Aggregate (50 active UWB/km^2) Free-space path loss	−12.2	(Note 1)
	Maritime MF Radiotelegraphy	1.6-3.8 MHz	Rx BW = 3 kHz	S/I = 10 dB + 6 dB for multi-system interference	Aggregate (50 active UWB/km^2) Free-space path loss	−38.7	(Note 1)
	Maritime HF Radiotelegraphy	4-27.5 MHz	Rx BW = 3 kHz	S/I = 10 dB + 6 dB for multi-system interference	Aggregate (50 active UWB/km^2) Free-space path loss	−38.7	(Note 1)
	Maritime VHF DSC/Radiotelegraphy	156-163 MHz	Rx BW = 25 kHz	S/I = 10 dB + 6 dB for multi-system interference	Aggregate (50 active UWB/km^2) Free-space path loss	−62.1	(Note 1)
	Maritime UHF Radiotelegraphy	457-467 MHz	Rx BW = 12.5 kHz	S/I = 10 dB + 6 dB for multi-system interference	Aggregate (50 active UWB/km^2) Free-space path loss	−44.1	(Note 1)
	Maritime Primary Radar	2 900-3 100 MHz	Rx BW = 20 MHz	I/N = −10 dB + 6 dB for multi-system interference	Single interferer, 300 m separation Free-space path loss	−52.5	(Note2)
	Maritime Primary Radar/Search and Rescue Radar Transponder	9 200-9 500 MHz	Rx BW = 20 MHz	I/N = −10 dB + 6 dB for multi-system interference	Single interferer, 300 m separation Free-space path loss	−42.6	(Note2)

DGNSS: digital global aeronautical satellite system.

NOTE 1 – Results assume all devices using UWB technology to be active simultaneously.

NOTE 2 – The device using UWB technology transmits continuously i.e., 100% activity factor.

1.1.1.1.3 Aeronautical service

For each of the bands under consideration the worst-case value has been reported in the table below for the indicative model. Where more than one receiver operates within a band, the values for the additional receivers are available in Attachment 1.3 of Report ITU-R SM.2057.

Part of Report (Attachment)	Service/ Applications	Frequency bands	Victim station characteristics	Service protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz)	Comments
A1.3	Aeronautical NDB/Locator	190-535 kHz	Signal level > 35 dBm. Rx antenna gain = 0 dBi	*S*/*I* = 15 dB + aeronautical safety factor = 6 dB and 6 dB multiple interference source factor	Aggregate (50 active UWB/km^2) Outdoor/ indoor = 20/80% Uniform distribution Airborne methodology Free-space path loss	−44.5	Airborne receiver. (Note 1)
	Aeronautical marker beacon	74.8-75.2 MHz	Rx antenna gain = 0 dBi	*S*/*I* = 20 dB + aeronautical safety factor = 6 dB and 6 dB multiple interference source factor	Aggregate (50 active UWB/km^2) Outdoor/indoor = 20/80% Uniform distribution Airborne methodology Free-space path loss	−25.8	(Note 1)
	Aeronautical ILS localizer	108-117.975 MHz	Rx antenna gain = 0 dBi	*S*/*I* = 20 dB + aeronautical safety factor = 6 dB and 6 dB multiple interference source factor	Aggregate (50 active UWB/km^2) Outdoor/indoor = 20/80% Uniform distribution Airborne methodology Free-space path loss	−61.3	(Note 1)
	Aeronautical ILS localizer	108-117.975 MHz	I < −164.3 dBW/ MHz Rx antenna gain = 0 dBi	CW Interference threshold which takes into account the aeronautical safety factor of 6 dB as well as the multiple interference source factor of 10 dB and *S*/*I* = 46 dB	Aggregate (100 active UWB/km^2) Uniform distribution Free-space path loss	−97.3	From specific ILS study contained in § 1.3.2.1.1. (Note 1)

Part of Report (Attachment)	Service/ Applications	Frequency bands	Victim station characteristics	Service protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz)	Comments
A1.3	Aeronautical Air-ground and air-air communi-cations	117.975-137 MHz	Rx antenna gain = 0 dBi	*S*/*I* = 20 dB + aeronautical safety factor = 6 dB and 6 dB multiple interference source factor	Single interferer 30 m separation Free-space path loss	−63.9	(Note 1)
	Aeronautical Emergency frequencies	121.5, 123.1 and 243 MHz	Rx antenna gain = 0 dBi	*S*/*I* = 20 dB + aeronautical safety factor = 6 dB and 6 dB multiple interference source factor	Single interferer 30 m separation Free-space path loss	−63.9	(Note 1)
	Aeronautical ILS glide path	328.6-335.4 MHz	Rx antenna gain = 0 dBi	*S*/*I* = 20 dB + aeronautical safety factor = 6 dB and 6 dB multiple interference source factor	Aggregate (50 active UWB/km^2) Outdoor/indoor = 20/80% Uniform distribution Airborne methodology Free-space path loss	−46.5	(Note 1)
	Aeronautical Primary Radar	590-598 MHz	Rx antenna gain = 28 dBi	*I*/*N* = −6 dB + aeronautical safety factor = 6 dB and 6 dB multiple interference source factor	Single interferer, 400 m separation Free-space path loss	−75.1	(Note 2)
	Aeronautical DME/TACAN	960-1 215 MHz	Rx antenna gain = 0 dBi	*S*/*I* = 8 dB + aeronautical safety factor = 6 dB and 6 dB multiple interference source factor	Single interferer, 5 m separation Free-space path loss	−76.8	

Part of Report (Attachment)	Service/ Applications	Frequency bands	Victim station characteristics	Service protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz)	Comments
A1.3	Aeronautical DME/TACAN	960-1 215 MHz	I < −145 dBW/MHz Rx antenna gain = 0 dBi	CW Interference threshold which takes into account the aeronautical safety factor of 6 dB as well as the multiple interference source factor of 10 dB	Aggregate (100 active UWB/km^2) Uniform distribution Free-space path loss	−58.0	(Note 2)
	Aeronautical Primary Radar	1 215-1 400 MHz	Rx antenna gain = 38.9 dBi	I/N = −6 dB + aeronautical safety factor = 6 dB and 6 dB multiple interference source factor	Single interferer, 400 m separation Free-space path loss	−80.3	
	Aeronautical Primary surveillance radar	2 700-3 400 MHz	Rx antenna gain = 34.3 dBi	I/N = −10 dB + aeronautical safety factor = 6 dB and 6 dB multiple interference source factor	Single interferer, 170 m separation Free-space path loss	−79.9	
	Aeronautical Radio altimeter	4 200-4 400 MHz	Rx antenna gain = 0 dBi	S/I = 6 dB + aeronautical safety factor = 6 dB and 6 dB multiple interference source factor	Aggregate (50 active UWB/km^2) Outdoor/indoor = 20/80% Uniform distribution Airborne methodology Free-space path loss	−48.7	
	Aeronautical MLS	5 030-5 150 MHz	Rx antenna gain = 0 dBi	S/I = 25 dB + aeronautical safety factor = 6 dB and 6 dB multiple interference source factor	Aggregate (50 active UWB/km^2) Outdoor/indoor = 20/80% Uniform distribution Airborne methodology Free-space path loss	−44.7	

Part of Report (Attachment)	Service/ Applications	Frequency bands	Victim station characteristics	Service protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz)	Comments
A1.3	Aeronautical Precision approach radar	9 000-9 500 MHz	Rx antenna gain = 38 dBi	I/N = −6 dB + aeronautical safety factor = 6 dB and 6 dB multiple interference source factor	Single interferer, 20 m separation Free-space path loss	−87.2	

NDB: non-directional beacon.

ILS: instrument landing system.

DME: distance measuring equipment.

MLS: microwave landing system.

NOTE 1 – Results assume all devices using UWB technology to be active simultaneously.

NOTE 2 – The device using UWB technology transmits continuously i.e., 100% activity factor.

NOTE 3 – Caution must be exercised with respect to the application of the UWB e.i.r.p. density limits given for aeronautical services in the table above. These limits may not necessarily be sufficient to provide adequate protection to aeronautical radio services.

1.1.1.1.4 IMT-2000

Part of Report (Attachment)	Service/ Applications	Frequency bands	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz) or separation distance	Comments
A1.4	IMT-2000	1 710-1 885 MHz		I/N = −6 dB	Single interferer, 36 cm separation	−86.4	Mobile station receiver (Note 2)
	IMT-2000	1 885-2 025 MHz		I/N = −6 dB	Single interferer, 36 cm separation	−85.9	Mobile station receiver (Note 2)
	IMT-2000	2 110-2 170 MHz		I/N = −6 dB	Single interferer, 36 cm separation	−85	Mobile station receiver (Note 2)

Part of Report (Attachment)	Service/ Applications	Frequency bands	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz) or separation distance	Comments
A1.4	IMT-2000	2 500-2 690 MHz		I/N = −6 dB	Single interferer, 36 cm separation	−83.1	Mobile station receiver (Note 2)
A1.4.7.1.1.1	IMT-2000 (CDMA-2000 (1X and 3X), TD-CDMA, W-CDMA, TD-SCDMA, DECT, UWC-136 TDMA).	1 710-1 885 MHz 1 885-2 025 MHz 2 110-2 170 MHz 2 500-2 690 MHz	Rx antenna gain = 0 dBi. Mobile station NF = 9 dB in thermal noise −101 dBm (DECT), −104 dBm (UWC-136 TDMA) to −105 dBm (rest of systems)	I/N = −6 dB	Single interferer 20 cm separation Link budget Free-space path loss	−80 to −87.5	Mobile station receiver (Note 2)
A1.4.7.1.1.2	IMT-2000 IMT-DS (W-CDMA)	2 110-2 170 MHz	Rx antenna gain = 16 dBi Feeder loss = 2 dB Head penetration loss = 0 to 3 dB NF = 5 dB	BLER target	Single interfere with data rates 100 to 250 Mbits/s, Methodology = link budget Worst-case indoor IMT-2000 at the edge of an urban cell	No impact at −115 Some degradation at −105 Service failure for CS144 and Voice 12.2 at −85	Mobile station receiver (Note 2)
A1.4.7.1.2	IMT-2000 HSDPA (W-CDMA)		Head penetration loss = 0 to 3 dB NF = 5 dB G factor = 5 dB	No criterion for capacity and 1% throughput degradation	Aggregate with data rates 100 to 250 Mbit/s, Methodology = link budget Worst-case indoor IMT-2000 at the edge of an urban cell	Minimum separation = 2 m at −65	Mobile station receiver

Part of Report (Attachment)	Service/ Applications	Frequency bands	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz) or separation distance	Comments
A1.4.7.2	IMT-2000 IMT-DS (W-CDMA)	2 110-2 170 MHz	Rx antenna gain = 18 dBi Head penetration loss = 0 to 3 dB NF = 4 dB	No criterion For single interferer	Single interferer with data rates 100 to 250 Mbit/s, UWB at h = 1.5 m Methodology = link budget Aggregate Randomly distributed UWB with h = 0 to 30 m 100% activity factor. Outdoor urban deployment UWB density 10 100 000 device/km^2	No capacity reduction and marginal (~ 2%) cell range reduction, −64.7	Base station receiver at 30 m height
			Rx antenna gain = 18 dBi Head penetration loss = 0 to 3 dB NF = 3 dB	For aggregate: $I_{UWB} < I_{UWBMax}$ = 1% (I_{UWBMax} is for 1% base station density)	Aggregate Randomly distributed UWB with h = 0 to 30 m 100% activity factor Outdoor urban deployment UWB density 10-100 000 device/km^2 No devices within 30 m	−52.4 to −87 for 10 UWB/km^2 to 100 000 indoor UWB devices/km^2, respectively	Base station receiver at 35 m height (Note 1)

Part of Report (Attachment)	Service/ Applications	Frequency bands	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz) or separation distance	Comments
A1.4.7.3.1	IMT-2000 IMT-DS (W-CDMA)	2 GHz	Head penetration loss = 0 to 3 dB NF = 9 dB	Per cent reduction in calls	Aggregate Randomly distributed UWB 1 000 UWB device/km^2 Monte Carlo methodology Propagation: $1/r^2$ for line-of-sight (LoS) and $d \leq \lambda$, and $1/r^{3.5}$ for non-LoS and $d > \lambda$ 10 dB wall loss	For −70 , call drop rate = 0.085% for 1 000 UWB/km^2 and call drop rate = 1% for 10 000 UWB/km^2 For −60, call drop rate = 0.6% for 1 000 UWB/km^2 and call drop rate = 5% for 10 000 UWB/km^2	Mobile station receiver at 1.5 m height Base station receiver at 6, 15 and 20 m height
A1.4.7.3.2	IMT-2000 IMT-2000 CDMA Direct Spread		Feeder loss = 2.5 dB NF = 6.6 dB	No criterion	Aggregate, Office hot-spot scenario Monte Carlo methodology UWB centre frequency at 4 GHz, and UWB bandwidth = 1.8 GHz Propagation: $1/r^2$	For −65 and a coupling loss = 20 dB, the minimum separation distance between UWB and mobile station = 0.1 m	Mobile station receiver

TD-CDMA: time division CDMA

W-CDMA: wideband CDMA.

NOTE 1 – Results assume all devices using UWB technology are active simultaneously.

NOTE 2 – The device using UWB technology transmits continuously i.e., 100% activity factor.

1.1.1.1.5 Wireless access systems including RLANs

Some of the studies used single interferer, the remaining studies used the "Integral methodology" and defined an additional factor called the aggregation factor to take into account the effect of multiple devices, the average activity factor and the victim immunity factor.

Part of Report (Attachment)	Service/ applications	Frequency bands	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz) or minimum separation distance	Comments
A1.5	WAS/RLAN IEEE 802.11a	5 150-5 350 MHz	≤5 dB implementation loss and ≤10 dB Rx noise figure	SINR degradation = 1 dB $I/N = -6$ dB	Single interferer. Propagation: $1/r^2$ for the first 5 m then $1/r^4$ UWB-free zone = 1 m	−41.3 Separation distance = 5.8 m	(Note 1)
	WAS/RLAN	5 470-5 725 MHz		1 dB degradation, $I/N = -6$ dB	Single interferer 36 cm separation	−66	
	WAS/RLAN IEEE 802.11b	2 400-2 483 MHz	Rx sensitivity = −84 to −93 dBm Implementation loss + Rx noise figure = 10 dB	SINR degradation = 1 dB, $I/N = -6$ dB	Single interferer Propagation: $1/r^2$ for the first 5 m then $1/r^4$ UWB-free zone = 1 m	For indoor 5.9 m at −51.3 For outdoor 2.2 m at −61.3 For indoor 2.3 m at −50.6 dBm/11 MHz For outdoor 0.7 m at −60.6 dBm/11 MHz	(Note 1)
	WAS/RLAN IEEE 802.11a	5 150-5 350 MHz	≤ 5 dB implementation loss and ≤ 10 dB Rx noise figure	SINR degradation of 1 dB	Aggregate: 0.2 UWB transmitters/m^2 Propagation: $1/r^2$ for the first 5 m then $1/r^4$ Integral methodology UWB-free zone = 1 m	−59.3 for an aggregation factor = 0.5 −48.3 for an aggregation factor = 0.04	
	WAS/RLAN IEEE 802.11b	2 400-2 483 MHz	Receiver sensitivity −84 to −93 dBm. Implementation loss + Rx noise figure = 10 dB	SINR degradation of 1 dB	Aggregate: 0.2 UWB uniformly distributed transmitters/m^2 Propagation: $1/r^2$ for the first 5 m then $1/r^4$ Integral methodology UWB-free zone = 1 m	−71.1 for an aggregation factor = 0.5 −60.1 for an aggregation factor = 0.04	

Part of Report (Attachment)	Service/ applications	Frequency bands	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz) or minimum separation distance	Comments
A1.5.5	WAS/RLAN IEEE 802.11a	5 150-5 350 MHz	≤ 5 dB implementation loss and ≤ 10 dB Rx noise figure Rx sensitivity for IEEE802.11a = −65 to −82 dBm Omnidirectional antenna gain = 0 dBi	10% FER (frame error rate)	Single interferer Indoor deployment Minimum coupling loss method Propagation-A: $1/r^2$ for the first 5 m then $1/r^4$ Propagation-B: Rec. ITU-R P.1238	−41.3 Propagation-A: At MUS +10 dB, d = 1.13 to 1.79 m At MUS, d = 3.58 to 5.67 m Propagation-B: At MUS +10 dB, d = 1.12 to 1.5 m At MUS, d = 2.34 to 3.16 m	Tests to measure C/I then the minimum separation distance is calculated at the minimum usable sensitivity (MUS) level (Note 1)

NOTE 1 – The device using UWB technology transmits continuously i.e., 100% activity factor.

1.1.1.1.6 Amateur and amateur-satellite service

Part of Report (Attachment)	Service/ applications	Frequency bands	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz)	Comments
A1.6	Amateur and amateur satellite service (Terrestrial and space-to-Earth satellite)	1 260-1 300 MHz	Antenna cable loss = 3 dB Rx noise temperature < 100 K NF = 1 dB Rx BW = 0.4 kHz for Morse and 2.7 kHz for SSB voice Rx antenna gain = 22 dBi on boresight	1 dB receiver degradation SNR = 2 dB for Morse and 6 dB for SSB voice	Single interferer, 100% activity factor Free-space path loss Minimum coupling loss method	−85.5	For on boresight, off boresight, Earth-Moon-Earth, and space-to-Earth satellite interference scenarios Polarizations of UWB interferer and victim are different (Note 1)
	Amateur and amateur satellite service (Terrestrial and space-to-Earth satellite)	2 300-2 450 MHz	Antenna cable loss = 3 dB Rx antenna gain = 25 dBi on boresight/0 dBi off boresight Rx noise temperature < 100 K NF = 1 dB Rx BW = 0.4 kHz for Morse and 2.7 kHz for SSB voice	1 dB receiver degradation SNR = 2 dB for Morse and 6 dB for SSB voice	Single interferer Free-space path loss 100% activity factor Minimum coupling loss method	−65	For on boresight, off boresight, Earth-Moon-Earth, and space-to-Earth satellite interference scenarios Polarizations of UWB interferer and victim are different (Note 1)
	Amateur and amateur satellite service (Terrestrial and space-to-Earth satellite)	3 400-3 500 MHz	Antenna cable loss = 3 dB Rx antenna gain = 27 dBi on boresight/0 dBi off boresight Rx noise temperature < 100 K NF = 1 dB Rx BW = 0.4 kHz for Morse and 2.7 kHz	1 dB receiver degradation SNR = 2 dB for Morse and 6 dB for SSB voice	Single interferer 100% activity factor Free-space propagation Minimum coupling loss method	−62 for on boresight and space-to-Earth −55 for off boresight −58 for Earth-Moon-Earth	Polarizations of UWB interferer and victim are different (Note 1)

Part of Report (Attachment)	Service/ applications	Frequency bands	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz)	Comments
A1.6	Amateur and amateur satellite service (Terrestrial and space-to-Earth satellite)	5 650-5 850 MHz	Antenna cable loss = 3 dB Rx antenna gain = 30 dBi on boresight/0 dBi off boresight. Rx noise temperature < 100 K NF = 1 dB Rx BW = 0.4 kHz for Morse and 2.7 kHz for SSB voice	1 dB receiver degradation SNR = 2 dB for Morse and 6 dB for SSB voice	Single interferer 100% activity factor Free-space propagation Minimum coupling loss method	−57 for on boresight and space-to-Earth −51 for off boresight −53 for Earth-Moon-Earth	Polarizations of UWB interferer and victim are different (Note 1)
	Amateur and amateur satellite service (Terrestrial and space-to-Earth satellite)	10-10.5 GHz	Antenna cable loss = 3 dB Rx antenna gain = 33 dBi on boresight/0 dBi off boresight Rx noise temperature < 100 K NF = 1 dB Rx BW = 0.4 kHz for Morse and 2.7 kHz for SSB voice	1 dB receiver degradation SNR = 2 dB for Morse and 6 dB for SSB voice	Single interferer 100% activity factor Minimum coupling loss method Free-space path loss	−59 for on boresight −46 for off boresight −48 for Earth-Moon-Earth −52 for space-to-Earth	Polarizations of UWB interferer and victim are different (Note 1)

NOTE 1 – The device using UWB technology transmits continuously i.e., 100% activity factor.

1.1.1.1.7 Meteorological radar

Part of Report (Attachment)	Service/ applications	Frequency bands	Victim station characteristics	Service protection requirement used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz)	Comments
A1.7	Meteorological radar	2 700-2 900 MHz	47.5 dBi antenna gain 30 m antenna height	$I/N = -10$ dB Rec. ITU-R M.1464	Aggregate (1 000 active device/km^2) Free-space propagation	−61.3	Study A: Representative of meteorological radars in the United States of America
			45.7, 43 and 39 dBi antenna gain 7 to 21 m antenna height (13 m average)		Aggregate, suburban 50 active devices/km^2 20% outdoor, 80% indoor Free-space propagation	−71	Study B: Difference with study A relates to the antenna height and antenna gain figures that are by a large amount controlling the level of interference
		5 600-5 650 MHz	45.7 and 43 dBi antenna gain 7 to 29 m antenna height (16 m average)	$I/N = -10$ dB Rec. ITU-R M.1638	Aggregate, suburban 50 active devices/km^2 20% outdoor, 80% indoor Free-space propagation	−65	Study B
		9 300-9 500 MHz	33 dBi antenna gain 5 to 15 m antenna height (10 m average)	$I/N = -10$ dB	Aggregate, suburban 50 active devices/km^2 20% outdoor, 80% indoor Free-space propagation	−60	Study B

1.1.1.2 Impact of UWB on the fixed service (FS)

Part of Report (Attachment)	Service/ applications	Frequency bands	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz)	Comments
A2.4.2	FS/P-P and P-MP	1 000-3 000 MHz	P-P ant. gain = 41 dBi CS antenna gain = 16 dBi TS antenna gain (outdoor TS) = 16 dBi TS antenna gain (indoor omnidirectional) = 0 dBi NF (outdoor) = 5 dB NF (indoor) = 5.5 dB	Rec. ITU-R F.1094 and WP 9A liaison statement ($I/N = -20$ dB)	See bands 3 000-6 000 MHz in next row	Same values than in bands 3 000-6 000 MHz in next row	For multiple FS sub-bands within 1-3 GHz, value extrapolated Wideband peak protection limit in 50 MHz bandwidth was evaluated 42 dB above e.i.r.p. limit (from actual tests)
A2.3.5.2	FS/P-MP	3 000-6 000 MHz	P-P antenna gain = 41 dBi CS antenna gain = 16 dBi TS antenna gain (outdoor TS) = 16 dBi TS antenna gain (indoor omni) = 0 dBi NF (outdoor) = 5 dB NF (indoor) = 5.5 dB	P-P, CS and outdoor TS: Rec. ITU-R F.1094 and WP 9A liaison statement ($I/N = -20$ dB) Indoor TS ITU-R WP 9A liaison statement ($I/N = -13$ dB)	Single-entry indoor FWA TS at 1 m separation without specific mitigation techniques (e.g. DAA) NOTE – This case overrides all possible aggregation scenarios.	−76.5	Wideband peak protection limit in 50 MHz bandwidth was evaluated 42 dB above e.i.r.p. limit (from actual tests)
A2.3.2.2	FS/P-P and P-MP				Single-entry to indoor FWA TS at 1 m separation with specific mitigation techniques (e.g. DAA) Single entry of a fixed UWB in LoS along boresight footprint to an outdoor P-P (Note). NOTE – This case may override all possible aggregation scenarios.	–57	Wideband peak protection limit in 50 MHz bandwidth was evaluated 42 dB above e.i.r.p. limit (from actual tests)

Part of Report (Attachment)	Service/ applications	Frequency bands	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz)	Comments
A2.4.1.2.2.2 A2.3.3.3.4 A2.4.1.2.1 A2.4.1.2.2.2 A2.4.1.3	FS/P-P and P-MP	3 000-6 000 MHz (*continued*)			Aggregate, urban Uniform distribution of UWB 10 000 device/km^2 *Case 1 study*: UWB deployment: 80% indoor and 20% outdoor, Free-space propagation plus mitigation factors for NLOS portion, indoor-to-outdoor attenuation, activity at 5% *Case 2 study*: UWB deployment: 100% indoor, 1% activity factor. IEEE802.16 NLOS propagation Monte Carlo analysis of mixed LOS/NLOS distribution derived from probability distributions of real urban area building height and indoor-to-outdoor attenuations activity at 1%	−60 From –40 to – 48 NOTE – Depending on different confidence assumptions for the large amount of possible variants affecting the studies and the possible inclusion of a 20% population of handheld devices.	Wideband peak protection limit in 50 MHz bandwidth was evaluated 42 dB above e.i.r.p. limit (from actual tests) For this scenario, no single outdoor and indoor entries are considered assuming the presence of specific mitigation techniques (e.g. DAA) or regulatory provisions (i.e. no unlicensed UWB fixed outdoor applications)

Part of Report (Attachment)	Service/ applications	Frequency bands	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz)	Comments
A2.4.1.2.2.2	FS/P-P	6 000-7 125 MHz	NF = 6 dB P-P antenna gain = 41 dBi	Rec. ITU-R F.1094 and WP 9A liaison statement ($I/N = -20$ dB)	Only aggregate, urban (10 000 UWB/km^2, 20% outdoor, 5% activity factor). See details in above bands 3 000-6 000 MHz NOTE – Case 2 not evaluated for bands above 4 GHz; however it is assumed that results are at least 6 dB more favourable.	–60 (Case 1) –41.3 (Case 2)	Wideband peak protection limit in 50 MHz bandwidth was evaluated 42 dB above e.i.r.p. limit (from actual tests) For this scenario, no single outdoor entries are considered assuming the presence of specific regulatory provisions (i.e., no unlicensed UWB fixed outdoor applications)
A2.4.1.2.2.2	FS/P-P	7 125-8 500 MHz		Rec. ITU-R F.1094 and WP 9A liaison statement ($I/N = -20$ dB)	Same as above bands 6 000-7 125 MHz	–57.5 (Case 1) –41. 3 (Case 2)	Wideband peak protection limit in 50 MHz bandwidth was evaluated 42 dB above e.i.r.p. limit (from actual tests) For this scenario, no single outdoor entries are considered assuming the presence of specific regulatory provisions (i.e. no unlicensed UWB fixed outdoor applications)

Part of Report (Attachment)	Service/ applications	Frequency bands	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz)	Comments
A2.4.1.2.2.2	FS/P-P and P-MP	10.15-10.65 GHz	NF (P-P and FWA TS) = 7 dB P-P and FWA TS antenna gain = 40 dBi	Rec. ITU-R F.1094 and WP 9A liaison statement (I/N = −20 dB)	Same as above bands 6 000-7 125 MHz	−55.5 (Case 1) −41.3 (Case 2)	Wideband peak protection limit in 50 MHz bandwidth was evaluated 42 dB above e.i.r.p. limit (from actual tests) For this scenario, no single outdoor entries are considered assuming the presence of specific regulatory provisions (i.e., no unlicensed UWB fixed outdoor applications)

Part of Report (Attachment)	Service/ applications	Frequency bands	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz)	Comments
A2.5	FS/P-P and P-MP	21-23.6 GHz 24.25-26.5 GHz 27.5-29.5 GHz	NF = 6 dB Minimum feeder loss = 0 dB P-P antenna gain = 41 dBi FWA sectorial antenna gain = 18 dBi	Rec. ITU-R F.1094 and WP 9A liaison statement ($I/N = -20$ dB assuming 0.5% apportionment for SRR)	Aggregate short range radar along a main road parallel to FS link: 4 active sensors (2 front 2 rear) per car; up to 4 lanes in each direction). Free space plus shielding effects. Two different studies on the same methodology but using different parameters, impact of mitigation factors and SRR activity factor of either 0 or 7 dB	Study 1 −50 to −60 (Note 1) Study 2 −41.3 (even with positive margin) (Note 2)	Wideband peak protection limit in 50 MHz bandwidth was evaluated 42 dB above e.i.r.p. limit (from actual tests)

NOTE 1 – Appropriate for countries where the deployment of P-P links, with low FS receiver antenna height and are frequently located along high traffic density roads combined with extensive use of these bands of FS links in mobile network infrastructure; an average SRR e.i.r.p. density limit of at least −50 dBm/MHz is necessary. However, where the joint concurrence probability of the more severe deployment situations (i.e., lower FS antenna heights closer to a road) are considered, an e.i.r.p. density limit of −60 dBm/MHz is necessary for long-term coexistence.

NOTE 2 – Appropriate for countries, where less stringent infrastructural requirements regarding the FS receiver height and distance to the road might exist, the SRR e.i.r.p. density limit of −41.3 dBm/MHz may be considered appropriate, when other mitigation factors (unpredictable but possibly present) are taken into account. However, this higher e.i.r.p. density increases the risk of interference from SRR to the FS in case where those mitigation factors may not be present.

1.1.1.3 Impact of UWB on the fixed-satellite service

Part of Report (Attachment)	Service/ applications	Frequency bands	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz)	Comments
A3	FSS – Satellite (uplink)	5 725-7 075 MHz 7 900-8 400 MHz	Satellite antenna gain = 35 dBi Noise temperature = 600 K	ITU-R S.1432 (I/N = −20 dB)	Aggregate methodology 10-20 simultaneously active devices/km^2 50% of UWB devices are indoors 1/r^2 path loss + 10 dB building loss	−41.3	UWB has negligible impact in the uplink direction in these bands and at this e.i.r.p. level
A3	FSS – Earth station, urban deployment (downlink)	3 400-4 200 MHz 4 500-4 800 MHz	Exclusion zone = 10 m, any antenna size or elevation (see Note 1) Rx noise temperature = 100 K	ITU-R S.1432 (I/N = −20 dB)	Satellite downlink methodology (aggregate) Uniform distribution of UWB devices, 100% indoor, 1.5 simultaneously active UWB devices/m^2 (office block “hotspot”) 1/r^2 path loss + 10 dB per obstruction (wall, ceiling)	−77	The computed maximum UWB e.i.r.p. device density for a given study depends on the methodology, parameters and assumptions. The studies selected for documentation here reflect the upper and lower bounds of those studies considered
					Satellite downlink methodology (aggregate) Uniform distribution of UWB devices, 100% indoor, 100 active UWB devices/km^2 Propagation model: 1/r^2 path loss + distribution of attenuation for obstructions	−61.9	

Part of Report (Attachment)	Service/ applications	Frequency bands	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz)	Comments
A3	FSS – Earth station, suburban deployment (downlink)	3 400-4 200 MHz 4 500-4 800 MHz	Exclusion zone = 50 m, any antenna size or elevation (see Note 1) Rx noise temperature = 100 K	ITU-R S.1432 ($I/N = -20$ dB)	Satellite downlink methodology (aggregate) Uniform distribution of UWB devices, 80% indoor, 50 active UWB devices/km^2 Propagation model: $1/r^2$ path loss + 10 to 15 dB building attenuation	−63	The computed maximum UWB e.i.r.p. device density for a given study depends on the methodology, parameters and assumptions. The studies selected for documentation here reflect the upper and lower bounds of those studies considered
					Satellite downlink methodology (aggregate) Uniform distribution of UWB devices, 80% indoor, 10 active UWB devices/km^2 Propagation model: $1/r^2$ path loss + distribution of attenuation for obstructions	−47.3	

Part of Report (Attachment)	Service/ applications	Frequency bands	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz)	Comments
A3	FSS – Earth station, rural deployment (downlink)	3 400-4 200 MHz 4 500-4 800 MHz	Exclusion zone = 100 m, any antenna size or elevation (see Note 1) Rx noise temperature = 100 K	ITU-R S.1432 ($I/N = -20$ dB)	Satellite downlink methodology (aggregate) Uniform distribution of UWB devices, 80% indoor, 5 active UWB devices/km^2 Propagation model: $1/r^2$ path loss + 10 to 15 dB building attenuation	−53	The computed maximum UWB e.i.r.p. device density for a given study depends on the methodology, parameters and assumptions. The studies selected for documentation here reflect the upper and lower bounds of those studies considered
					Satellite downlink methodology (aggregate) Uniform distribution of UWB devices, 80% indoor, 1 active UWB devices/km^2 Propagation model: $1/r^2$ path loss + distribution of attenuation for obstructions	−41.2	

Part of Report (Attachment)	Service/ applications	Frequency bands	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz)	Comments
A3	FSS – Earth station, feeder link for MSS (downlink)	3 550-3 700 MHz	Elevation = 10° Dish size = 11 m Noise temperature = 53 K	ITU-R S.1432 (I/N = −20 dB)	Single-entry methodology 10 m separation distance Propagation model: $1/r^2$ 1 MHz pulse repetition frequency	−63.6	
		6 700-7 075 MHz	Noise temperature = 100 K, any antenna size or elevation (see Note 1) 5 km/10 km study radii with 20 m/40 m exclusion zones respectively	ITU-R S.1432 (I/N = −20 dB)	Integral methodology 500/50 active UWB devices per km^2 respectively 80% indoor 10 dB through-wall attenuation	−65.2 to −55.2	The computed maximum UWB e.i.r.p. device densities (left) were calculated for two sets of assumptions, and reflect the upper and lower bounds considered

NOTE 1 – It was assumed in all studies that no UWB devices were present in the main beam of the earth station.

1.1.1.4 Impact of devices using UWB technology on the mobile-satellite services and the radionavigation satellite service

1.1.1.4.1 Mobile-satellite service (MSS)

1.1.1.4.1.1 Search and rescue systems

Part of Report (Attachment)	Service/ applications	Frequency bands	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p.density (dBm/MHz)	Comments
A4.1.1	MSS search and rescue systems (EPIRP Earth-to-space)	406-406.1 MHz	Satellite antenna gain = 3.9 dBi, minimum elevation = 5°	$I < -120.1$ dBm/MHz (Rec. ITU-R M.1478)	Aggregate UWB deployment: 20% outdoor, 80% indoor Free-space path loss 5 dB wall attenuation	−40 to −70 for 10 to 10 000 active UWB devices/km^2, respectively	
	MSS search and rescue systems (Cospas/Sarsat earth station)	1 544-1 545 MHz	Antenna gain = 21 dBi towards horizon	$I < -113.2$ dBm/MHz	Aggregate UWB deployment: 20% outdoor, 80% indoor Propagation: Rec. ITU-R P.1238-2 and 9 dB wall attenuation Interference method: Integral (R = 10 km)	−75 Separation distance = 10 m for 1 000 active UWB devices/km^2	
	MSS search and rescue systems (GSO earth station)	1 544-1 545 MHz	Antenna gain = 25 dBi towards horizon	$I < -133.2$ dBm/MHz	Aggregate; UWB deployment: 20% outdoor, 80% indoor Propagation: Rec. ITU-R P.1238-2 and 9 dB wall attenuation Interference method: Integral (R = 10 km)	−75 Separation distance = 0.1 km to 9.4 km for 100 to 1 000 active UWB devices/m^2, respectively	

1.1.1.4.1.2 Service links of GSO MSS systems

Part of Report (Attachment)	Service/ applications	Frequency bands	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz)	Comments
A4.1.2	Service links of GSO MSS (uplink)	1 626.5-1 660.5 MHz	BW = 34 MHz System noise temperature = 501 to 708 K Antenna peak gain 18.5 to 41 dBi	$I/N = -20$ dB	Aggregate, Global beam Propagation: Free-space 10 dB wall attenuation Indoor/outdoor: 80/20% Airborne aggregate interference model	−75.3 to −85.3 for 10 to 10 000 active UWB devices/ km^2, respectively	
4.1.2	Service links of GSO MSS (downlink)	1 525-1 559 MHz	BW = 60 to 200 kHz System noise temperature = 316 to 355 K Peak gain 18 dBi	$I/N = -20$ dB	Single interferer, 20 m separation Free-space path loss for MES terminals deployed in rural areas Rec. ITU-R P.1411 for MES terminals deployed in urban areas 10 dB wall attenuation	−98.4	
			Aero MES terminals BW = 60 to 200 kHz System noise temperature = 316 to 355 K Receive gain = 0 dBi	$I/N = -20$ dB	Airborne aggregate interference model	−75.3 to −98.0 for 10 to 10 000 active UWB devices/km^2, respectively	
4.1.2.10.3	GSO MSS (hand-held MES terminals downlink)	2 170-2 200 MHz	BW = 4.84 MHz Noise figure = 9 dB Antenna gain = 0 dBi	$I/N = -20$ dB	Single interferer Free-space path loss	−96.2 to −85.8 for 0.3 m to 1 m separation, respectively	
4.1.2.10.4	Non-GSO MSS (downlink)	2 170-2 200 MHz	BW = 1.4 kHz (min.) and 30 MHz (max.) Noise temperature = 158 K	$I/N = -20$ dB for average UWB emissions $I/N = -20 + 10 \log_{10}(B_{IF}/158 \text{ kHz})$ dB for peak UWB emissions	Single interferer Free-space path loss	−106.3 for average UWB emissions −98.3 for peak UWB emissions at 0.36 m separation distance	

1.1.1.4.2 Radionavigation satellite service (RNSS)

Part of Report (Attachment)	Service/ applications	Frequency bands (MHz)	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB application		UWB e.i.r.p. density		Comments
								Average (dBm/ MHz)	Spectral Line (dBm)	
A4.2	RNSS − GPS	1 164-1 300, 1 559-1 610	Noise power density = −111.5 dBm/ MHz Antenna gain = 0 dBi	I/N = −3 dB	Single interferer, 2 m separation, E-911 operational scenario Free-space path loss	Indoor communications Handheld (including outdoor) communications Vehicular radar		−75.3	−85.3	FCC R&O 02-48 notes an additional 0.2 dB decrease to align PSD values with other unlicensed devices in the United States of America. Also assumed a −3 dB UWB uncertainty factor and −10 dB difference between noise-like and CW interference (Note 1) (Note 2) The spectral lines are measured within 1 kHz bandwidth
						Ground-penetrating and wall-imaging radar, medical imaging		−65.3	−75.3	
						Through-wall imaging	BW < 960 MHz	−65.3	−75.3	
							BW > 960 MHz	−46.3	−56.3	
						Surveillance systems		−53.3	−63.3	
	RNSS – Galileo-safety of life applications	1 164-1 300, 1 559-1 610	Noise power density = −111.3 dBm/ MHz Antenna gain = 5 dBi	I/N = −20 dB	Single interferer, 30 m separation Free-space path loss			−79	−97	(Note 1) (Note 2) The spectral lines are measured within 1 kHz bandwidth
	RNSS – Galileo non-safety-of-life applications	1 164-1 300, 1 559-1 610	Noise power density = −111.3 dBm/ MHz Antenna gain = 0 dBi	I/N = −6 dB	Single interferer, 1 m separation Free-space path loss			−83.5	−101.5	(Note 1) (Note 2) The spectral lines are measured within a 1 kHz bandwidth

Part of Report (Attachment)	Service/ applications	Frequency bands (MHz)	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB application	UWB e.i.r.p. density		Comments
							Average (dBm/ MHz)	Spectral Line (dBm)	
A4.2	RNSS – GLONASS safety-of-life applications	1 164-1 300, 1 559-1 610	Noise power-density = −112.0 dBm/ MHz Antenna gain = 5 dBi	I/N = −20 dB	Single interferer, 30 m separation Free-space path loss		−79.0	−94.0	(Note 1) (Note 2) The spectral lines are measured within a 1 kHz bandwidth
					Aggregate interferers, 30 m separation Free-space path loss		−84.7	−99.7	
	RNSS – GLONASS non-safety-of-life applications	1 164-1 300, 1 559-1 610	Noise power-density = −112.0 dBm/ MHz Antenna gain = 3 dBi	I/N = −6 dB	Single interferer, 1 m separation Free-space path loss		−87.0	−102.0	(Note 1) (Note 2) The spectral lines are measured within a 1 kHz bandwidth

NOTE 1 – The device using UWB technology transmits continuously i.e., 100% activity factor.

NOTE 2 – The assumptions used with similar methodologies to determine the impact of emission of UWB devices on RNSS systems are not based on similar considerations, and have resulted in different values.

1.1.1.5 Impact of UWB on the broadcasting service

1.1.1.5.1 Terrestrial broadcasting

Part of Report (Attachment)	Service/ applications	Frequency bands	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz)	Comments
A5.1.1	Digital audio (T-DAB)	174-230 MHz (VHF)	Outdoor fixed reception /outdoor and indoor portable reception Rx BW = 1.536 MHz, sensitivity = −91 dBm Omnidirectional antenna gain = 0 dBi	(Note 3) (*I*/*N* = –20 dB is recommended by ITU-R SG 6)	Single interferer with a centre frequency at 1.38 GHz, bandwidth (−15 dB) = 3.8 GHz, PRF > 1 MHz MCL and free-space propagation 30 cm indoor/1 m outdoor separation	−97 (Note 3)	(Note 1)
		1 452-1 492 MHz (UHF)	Indoor portable reception/outdoor and indoor portable and mobile reception Rx BW = 1.536 MHz, sensitivity = −91 dBm Omnidirectional antenna gain = 2.15 dBi	(Note 3) (*I*/*N* = –20 dB is recommended by ITU-R SG 6).	Single interferer with a centre frequency at 1.38 GHz, bandwidth (−15 dB) = 3.8 GHz, PRF > 1 MHz MCL and free-space propagation 30 cm indoor/1 m outdoor separation	−85 (Note 3)	(Note 1)

Part of Report (Attachment)	Service/ applications	Frequency bands	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz)	Comments
A5.1.2	ISDB-T_{SB}	170-222 MHz	Mobile, portable/fixed Rx BW = 429, 500, 571 kHz (one segment) 1.29, 1.50, 1.71 MHz (three segments) Omnidirectional antenna gain = −0.85 dBi	I/N = −20 dB	Single interferer Free-space propagation 50 cm indoor/3 m outdoor separation	−114.7	(Note 1)
				I/N = −20 dB	Aggregate Free-space propagation 4 interferers 50 cm indoor/3 m outdoor separation	−120.7	(Note 1)
		470-770 MHz	Mobile, portable/fixed Rx BW= 429, 500, 571 kHz (one segment) 1.29, 1.50, 1.71 MHz (three segments) Omnidirectional antenna gain = −0.85 dBi	I/N = −20 dB	Single interferer Free-space propagation 50 cm indoor/3 m outdoor separation	−106.1	(Note 1)
				I/N = −20 dB	Aggregate Free-space propagation 4 interferers 50 cm indoor/3 m outdoor separation	−112.1	(Note 1)
A5.1.3	Digital TV (DVB-T)	174-230 MHz (VHF)	Outdoor fixed reception /outdoor and indoor portable reception Rx BW= 7/8 MHz, sensitivity = −80 to −90 dBm Omnidirectional antenna gain = 0 dBi	(Note 3) (I/N = −20 dB is recommended by ITU-R SG 6)	Single interferer with a centre frequency at 1.38 GHz, bandwidth (−15 dB) = 3.8 GHz, PRF > 1 MHz MCL and free-space propagation 50 cm indoor/3 m outdoor separation	−94 (Note 3)	(Note 1)
		470-862 MHz (UHF)	Outdoor fixed reception /outdoor and indoor portable reception Rx BW = 7/8 MHz, sensitivity = −80 to −90 dBm Omnidirectional antenna gain = 2.15 dBi	See Note 3 (I/N = −20 dB is recommended by SG 6)	Single interferer with a centre frequency at 1.38 GHz, bandwidth (−15 dB) = 3.8 GHz, PRF > 1 MHz MCL and free-space propagation 50 cm indoor/3 m outdoor separation	−89 (Note 3)	(Note 1)

Part of Report (Attachment)	Service/ applications	Frequency bands	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz)	Comments
A5.1.4	ATSC digital television	54-88 MHz (Low VHF)	Outdoor fixed reception /outdoor and indoor portable reception Rx BW = 6 MHz Omnidirectional antenna gain = 0 dBi	$I/N = -20$ dB	Single interferer Free-space propagation 50 cm indoor/3 m outdoor separation	−122	(Note 1)
					Aggregate Uniform distribution 5 km radius Outdoor $1/r^2$, $1/r^3$, $1/r^4$ 5 active devices/km^2 3 m minimum separation	−91	(Note 1)
		174-216 MHz	Outdoor fixed reception /outdoor and indoor portable reception Rx BW = 6 MHz Omnidirectional antenna gain = 0 dBi		Single interferer Free-space propagation 50 cm indoor/3 m outdoor separation	−113	(Note 1)
					Aggregate, uniform distribution 5 km radius Outdoor $1/r^2$, $1/r^3$, $1/r^4$ 5 active devices/km^2 3 m minimum separation	−84	(Note 1)
		470-806 MHz	Outdoor fixed reception /outdoor and indoor portable reception Rx BW = 6 MHz Omnidirectional antenna gain = 0 dBi		Single interferer Free-space propagation 50 cm indoor/3 m outdoor separation	−106	(Note 1)
					Aggregate Uniform distribution 5 km radius Outdoor $1/r^2$, $1/r^3$, $1/r^4$ 5 active devices/km^2 3 m minimum separation	−78	(Note 1)

Part of Report (Attachment)	Service/ applications	Frequency bands	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz)	Comments
A5.1.5	ISDB-T	170-222 MHz	Mobile, portable/fixed Rx BW = 429, 500, 571 kHz (one segment) 1.29, 1.50, 1.71 MHz (three segments) Omnidirectional antenna gain = −0.85 dBi	*I*/*N* = −20 dB	Single interferer Free-space propagation 50 cm indoor/3 m outdoor separation	−114.7	(Note 1)
					Aggregate Free-space propagation 4 interferers 50 cm indoor/3 m outdoor separation	−120.7	(Note 1)
		470-770 MHz	Mobile, portable/fixed Rx BW = 429, 500, 571 kHz (one segment) 1.29, 1.50, 1.71 MHz (three segments) Omnidirectional antenna gain = −0.85 dBi	*I*/*N* = −20 dB	Single interferer Free-space propagation 50 cm indoor/3 m outdoor separation	−106.1	(Note 1)
					Aggregate Free-space propagation 4 interferers 50 cm indoor/3 m outdoor separation	−112.1	(Note 1)
A5.1.6	Analogue TV	54-88 MHz (Low VHF)	Outdoor fixed reception/outdoor and indoor portable reception	*I*/*N* = −20 dB	Single interferer Free-space propagation 50 cm indoor/3 m outdoor separation	−115	(Note 1)
		174-216 MHz (High VHF)	Outdoor fixed reception/outdoor and indoor portable reception	*I*/*N* = −20 dB	Single interferer Free-space propagation 50 cm indoor/3 m outdoor separation	−106	(Note 1)
		470-806 MHz (UHF)	Outdoor fixed reception/outdoor and indoor portable reception	*I*/*N* = −20 dB	Single interferer Free-space propagation 50 cm indoor/3 m outdoor separation	−98	(Note 1)

NOTE 1 – The device using UWB technology transmits continuously i.e., 100% activity factor.

NOTE 2 – Results assume all devices using UWB technology to be active simultaneously.

NOTE 3 – These studies were done using a *I*/*N* = 0 dB (*C*/*I* = *C*/*N*). However, in case of interference from devices using UWB technology to broadcast services, the protection criteria provided by ITU-R Study Group 6, which is *I*/*N* = −20 dB found in Appendix 8 of Report ITU-R SM.2057, should be used.

1.1.1.5.2 Broadcasting-satellite service (BSS)

Part of Report (Attachment)	Service/ applications	Frequency bands	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz)	Comments
A5.2.1	BSS (S) SDARS	1 452-1 492 MHz and 2 320-2 345 MHz	Rx BW = 4.2 MHz, T = 158 K Rx noise = −110.4 dBm Rx antenna gain = 0 to 5 dB	I/N = −20 dB	Aggregate, Free-space path loss Deterministic methodology Indoor is based on two UWB devices	−90.3 for indoor UWB devices	The antenna gain is on an elevation of 25° to 90°
					Outdoor is based on four devices, all distances of 3 m	−93.3 for outdoor UWB devices	
A5.2.2	BSS (S) E-SDR	1 467-1 492 MHz	Rx BW = 5 MHz, G/T = −24.6 dB/K Rx antenna gain = 0 to 5 dB	I/N = −20 dB	Single UWB devices at 0.5 m separation	−104.2	
					Aggregate of two devices at 3 m separation (3 dB for multiple devices)	−93.4	
A5.2.3	BSS (S) SDMB	2 605-2 655 MHz	Rx BW = 25 MHz T = 150 K BER = 2×10^{-4} Noise figure = 3 dB Rx noise = −112.2 dBm/MHz	I/N = −20 dB	Single UWB device at 3 m separation	−81.9	
					Aggregate, Monte Carlo methodology 5% activity factor on 100/km^2 of interferer density	−88	
A5.2.4	BSS (S)	1452-1492 MHz	Rx BW = 25 MHz T = 100 K Rx antenna gain = 5 dBi for all angles	I/N = −20 dB	Single UWB device at 36 cm separation Free-space loss Deterministic methodology	−116.8	(Note 1)

Part of Report (Attachment)	Service/ applications	Frequency bands	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz)	Comments
A5.2.3	BSS (S)	2310-2360-MHz	Rx BW = 25 MHz T = 100 K Rx antenna gain = 5 dBi for all angles	I/N = −20 dB	Single UWB device at 36 cm separation Free-space loss Deterministic methodology	−112.5	(Note 1)
	BSS (S)	2 535-2 655 MHz	Rx BW = 25 MHz T = 100 K Rx antenna gain = 5 dBi for all angles	I/N = −20 dB	Single UWB device at 36 cm separation Free-space loss Deterministic methodology	−111.7	(Note 1)

NOTE 1 – Study based on very close proximity of UWB devices to the receiver and conservative assumptions.

1.1.1.6 Impact of UWB on the science services

1.1.1.6.1 Earth exploration-satellite service (EESS)

Part of Report (Attachment)	Service/ applications	Frequency band	Victim station characteristics	Protection criteria used in study	Reference analysis	UWB e.i.r.p. density (dBm/MHz) or minimum separation distance	Comments
A6.1.2.1.1	EESS (Earth-to-space)	2 025-2 110 MHz	Satellite antenna gain = 0 dBi	Rec. ITU-R SA.609-1	Aggregate interference UWB deployment: 20% outdoor and 80% indoor Free-space path loss 12 dB wall attenuation	−15 to −55 for 10 to 10 000 UWB devices/ km^2 respectively	(Note 1)
A6.1.2.1.2	EESS (space-to-Earth)	2 200-2 290 MHz	Typical earth station antenna gain = 31 dBi	Rec. ITU-R SA.609-1	Aggregate interference UWB deployment: 20% outdoor and 80% indoor Free-space path loss 12 dB wall attenuation Interference method: Integral (R_1 = 10 km)	For −52 (indoor), −62 (outdoor), the protection distance 3 km to 9.9 km for 10 to 1 000 UWB devices/km^2 respectively	(Note 1)

Part of Report (Attachment)	Service/ applications	Frequency band	Victim station characteristics	Protection criteria used in study	Reference analysis	UWB e.i.r.p. density (dBm/MHz) or minimum separation distance	Comments
A6.1.2.2	EESS (space-to-Earth)	8 025-8 400 MHz	Earth station antenna gain included in the protection criteria Maximum antenna gain = 55 dBi	Rec. ITU-R SA.1026-3	Aggregate interference Rural (1 000 active devices/km^2) 10 m separation Free-space path loss UWB deployment: 20% outdoor and 80% indoor Interference method: Integral (R_1 = 10-30 km)	−41	(Note 1)
		8 025-8 400 MHz	Antenna gain = 0 dBi in all directions	System noise temperature = 130 K I/N = −20 dB	Aggregate, interference, free-space path loss UWB deployment: 20% outdoor and 80% indoor; 10 dB indoor attenuation, Integral methodology Urban: 500 active devices/km^2 with 20 m exclusion zone and 5 km radius Suburban: 50 active devices/km^2 with 40 m exclusion zone and 10 km radius	Urban: −63.7 Suburban: −53.7	(Note 1)
Earth exploration-satellite service (active)							
A6.1.1.1	EESS (active): spaceborne altimeter	5 140-5 460 MHz 5 250-5 570 MHz	Nadir instrument Antenna gain = 32.2 dBi	−113 dBm/MHz	Aggregate interference UWB deployment: 20% outdoor and 80% indoor Free-space path loss 17 dB wall attenuation	−3 to −33- for 10 to 10 000 UWB devices/km^2 respectively	(Note 1)
A6.1.1.2	EESS (active): synthetic aperture radar	5 250-5 570 MHz	Satellite nadir angle of 32.5° Antenna gain = 42.7 dBi	−115.3 dBm/ MHz	Aggregate interference UWB deployment: 20% outdoor and 80% indoor Free-space path loss 17 dB wall attenuation	−11 to −41 for 10 to 10 000 UWB devices/km^2 respectively	(Note 1)

Earth exploration-satellite service (passive)							
A6.1.4	EESS (passive)	1 400-1 427 MHz	Characteristics of instruments used in impact analysis Satellite antenna gain = 9 to 35 dBi	Rec. ITU-R RS. 1029-2 1 to 5% apportionment of the interference criteria from a liaison statement from ITU-R WP 7C	Aggregate interference Free-space path loss 9 dB wall attenuation UWB deployment: 20% outdoor and 80%	−91 to −121 for 10 to 10 000 UWB devices/km^2 respectively	(Note 1)
		64.25-70.75 MHz 70.75-72.50 MHz	Characteristics of conical scan instruments used in impact analysis Satellite antenna gain = 38.8 dBi	Rec. ITU-R RS.1029-2 5% apportion-ment of the interference criteria. See above	Aggregate interferer Free-space path loss 17 dB wall attenuation UWB deployment: 20% outdoor and 80%	−64 to −94 for 10 to 10 000 UWB devices/km^2 respectively	(Note 1)
		10.6-10.7 GHz	Characteristics of conical scan instruments used in impact analysis Satellite antenna gain = 36 to 45 dBi	Rec. ITU-R RS.1029-2 5% apportion-ment of the interference criteria. See above	Aggregate interferer Free-space path loss 17 dB wall attenuation UWB deployment: 20% outdoor and 80%	−60 to −90 for 10 to 10 000 UWB devices/km^2 respectively	(Note 1)
A6.1.4	EESS (passive)	23.6-24 GHz	Characteristics of conical scan and nadir instruments used in impact analysis EESS antenna gain = 52 dBi	Rec. ITU-R RS.1029-2 1% to 5% apportionment of the interference criteria. See above	Aggregate interference, density of 123 (rural case), 330 (suburban case) and 453 (urban case) cars/km^2 Cars are equipped with up to 8 short range radars (SRRs) 100% of cars use SRR Free-space path loss	−70.6 for rural case −74.8 for suburban case −76.2 for urban case	100% deployment of SRR operating at −41.3 dBm/MHz results in interference exceeding the EESS threshold up to 34.9 dB with a 1% apportionment of the interference criteria

NOTE 1 – Results assume all devices using UWB technology to be active simultaneously with an activity factor of 5%.

1.1.1.6.2 Space Research Service (SRS)

Part of Report (Attachment)	Service/ applications	Frequency band	Victim station characteristics	Protection criteria used in study	Reference analysis	UWB e.i.r.p. density (dBm/MHz)	Comments
A6.2.1	SRS (Earth-to-space)	2 025-2 110 MHz	Satellite antenna gain = 0 dBi	Rec. ITU-R SA.609-1 1% apportionment of the interference criteria	Aggregate interference, 20% indoor 80% outdoor Free-space path loss 12 dB wall attenuation	−45 to −75 for 10 to 10 000 UWB devices/km^2 respectively	(Note 1)
A6.2.2	SRS (space-to-Earth)	2 200-2 290 MHz	Typical earth station	Rec. ITU-R SA. 609-1 1% apportionment of the interference criteria	Aggregate interference Free-space path loss Interference method: Integral (R_1 =10 to 30 km)	For −70, the separation distance is 6 km to 29.5 km for 10 to 1 000 UWB devices/km^2 respectively	
A6.2.2	SRS (space-to-Earth)	8 400-8 450 MHz	Typical earth station	Rec. ITU-R SA.1157 1% apportionment of the interference criteria	Aggregate interference Rural (100 active devices/km^2) 4 km separation Free-space path loss Interference method: Integral (R_1 = 10 to 30 km)	For −70, the separation distance is 10 m to 12 km for 10 to 10 000 UWB devices/km^2 respectively	(Note 1)

NOTE 1 – Results assume all devices using UWB technology to be active simultaneously with an activity factor of 5%.

1.1.1.6.3 Radio astronomy service (RAS)

Part of Report (Attachment)	Service/ Applications	Frequency bands	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz)	Comments
A6.3	RAS Continuum observations (broadband)	608-614 MHz (Note 3)	Single-dish Antenna gain = 0 dBi	Rec. ITU-R RA.769	Aggregate, (5 active UWB/km^2, 20% outdoor) (Note 1)	−113.2	(Note 2)

Part of Report (Attachment)	Service/ Applications	Frequency bands	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz)	Comments
	RAS Continuum observations (broadband)	1 330.0-1 400.0 MHz	Single-dish Antenna gain = 0 dBi	Rec. ITU-R RA.769	Aggregate, (5 active UWB/km^2, 20% outdoor) (Note 1)	−111.4	(Note 2)
	RAS Continuum observations (broadband)	1 400.0-1 427.0 MHz	Single-dish Antenna gain = 0 dBi	Rec. ITU-R RA.769	Aggregate, (5 active UWB/km^2, 20% outdoor) (Note 1)	−111.4	(Note 2)
	RAS Spectral line observations (narrow-band)	1 610.6-1 613.8 MHz	Single-dish Antenna gain = 0 dBi	Rec. ITU-R RA.769	Aggregate, (5 active UWB/km^2, 20% outdoor) (Note 1)	−90.6	(Note 2)
A6.3	RAS Continuum observations (broadband)	1 660.0-1 670.0 MHz	Single-dish Antenna gain = 0 dBi	Rec. ITU-R. RA.769	Aggregate, (5 active UWB/km^2, 20% outdoor) (Note 1)	−103.8	(Note 2)
	RAS Spectral line observations (narrow-band)	1 718.8-1 722.2 MHz	Single-dish Antenna gain = 0 dBi	Rec. ITU-R RA.769	Aggregate (5 active UWB/km^2, 20% outdoor) (Note 1)	−90.2	(Note 2)
	RAS Continuum observations (broadband)	2 655.0-2 690.0 MHz	Single-dish Antenna gain = 0 dBi	Rec. ITU-R RA.769	Aggregate, (5 active UWB/km^2, 20% outdoor) (Note 1)	−100.0	(Note 2)
	RAS Continuum observations (broadband)	2 690.0-2 700.0 MHz	Single-dish Antenna gain = 0 dBi	Rec. ITU-R RA.769	Aggregate, (5 active UWB/km^2, 20% outdoor) (Note 1)	−100.0	(Note 2).
	RAS Spectral line observations (narrow-band)	3 260.0-3 267.0 MHz	Single-dish Antenna gain = 0 dBi	Rec. ITU-R RA.769	Aggregate, (5 active UWB/km^2, 20% outdoor) (Note 1)	−82.9	(Note 2)

Part of Report (Attachment)	Service/ Applications	Frequency bands	Victim station characteristics	Protection criteria used in study	Interference scenario	UWB e.i.r.p. density (dBm/MHz)	Comments
	RAS Spectral line observations (narrow-band)	3 332.0-3 339.0 MHz	Single-dish Antenna gain = 0 dBi	Rec. ITU-R RA.769	Aggregate, (5 active UWB/km^2, 20% outdoor)	−82.9	(Note 2)
	RAS Spectral line observations (narrow-band)	3 345.8-3 352.5 MHz	Single-dish Antenna gain = 0 dBi	Rec. ITU-R RA.769	Aggregate, (5 active UWB/km^2, 20% outdoor) (Note 4)	−82.9	(Note 2)
	RAS Continuum observations (broadband)	4 800.0-4 990.0 MHz	Single-dish Antenna gain = 0 dBi	Rec. ITU-R RA.769	Aggregate, (5 active UWB/km^2, 20% outdoor) (Note 1)	−93.4	(Note 2)
A6.3	RAS Continuum observations (broadband)	4 990.0-5 000.0 MHz	Single-dish Antenna gain = 0 dBi	Rec. ITU-R RA.769	Aggregate, (5 active UWB/km^2, 20% outdoor) (Note 1)	−93.4	(Note 2)
	RAS Spectral line observations (narrow-band)	6 650.0-6 675.2 MHz	Single-dish Antenna gain = 0 dBi	Rec. ITU-R RA.769	Aggregate, (5 active UWB/km^2, 20% outdoor) (Note 1)	−77.9	(Note 2)
	RAS Continuum observations (broadband)	23.6-24 GHz	Single-dish Antenna gain = 0 dBi	Rec. ITU-R RA.769	Aggregate, (100 active SRR/km^2) (Note 1)	−109.2	(Note 2)
	RAS Continuum observations (broadband)	~79 GHz	Single-dish Antenna gain = 0 dBi	Rec. ITU-R RA.769	Aggregate, (100 active SRR/km^2) (Note 1)	−97.4	(Note 2)

NOTE 1 – Analyses used the summation methodology (R_1 = 30 m R_o = 500 km), path loss calculated with Recommendation ITU-R P.452 with a percentage of time of 10%, and 2% fraction of data loss due to interference.

NOTE 2 – Results assume all devices using UWB technology to be active simultaneously.

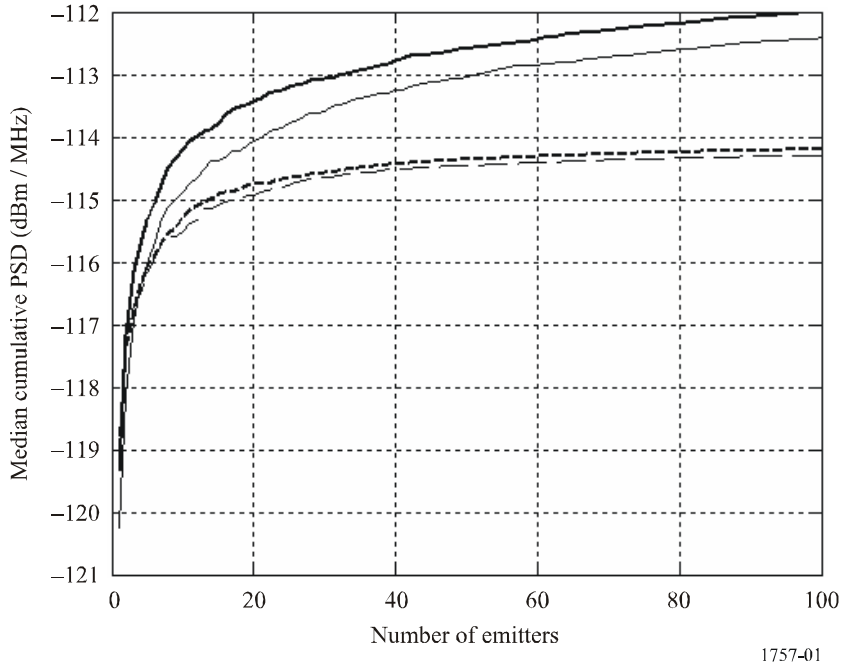
NOTE – The study conducted by one administration shows that the maximum UWB e.i.r.p. density depends on site specific factors and needs to be calculated on a case by case basis (see an example in § 6.3.2.1.5.2 of Attachment 6 of Report ITU-R SM.2057).

1.1.2 Impact of the number of UWB emitters

The results of a study in Report ITU-R SM.2057 show that the average cumulative power spectral-density (PSD) over some number of distributions increases with the number of emitters up to a certain value beyond which the PSD does not increase appreciably or increases slowly with the number of distance-sorted emitters. Most of the cumulative PSD at the antenna of the victim receiver is contributed by the few UWB transmitters located closest to the victim receiver. An example is given in Fig. 1 for a fixed e.i.r.p. density, which shows the median cumulative PSD versus number of distance-sorted emitters (sorted by distance from a generic victim receiver placed at the centre of the area with an omnidirectional antenna).

FIGURE 1

Median cumulative PSD against number of distance-sorted emitters in a 1 000 × 1 000 m zone for two-ray (solid lines) and modified two-ray (dashed lines) propagation models for 80 (thin lines) and 200 (thick lines) random distributions for UWB e.i.r.p. density = −41.3 dBm/MHz



1.2 Summary tables of laboratory and field test measurements related to the impact of devices using UWB on systems operating within radiocommunication services

Measurement studies were carried out in the laboratory and field tests to determine the impact of certain specific UWB signal interference on the systems of some radiocommunication services. The measurements have been performed in specific conditions and with specific UWB prototypes that are not necessarily covering all situations or taking into account protection criteria agreed within the ITU-R.

1.2.1 Laboratory and field test measurements related to the impact of devices using UWB technology on systems operating within land mobile service except IMT-2000

1.2.1.1 Impact of a single device using UWB technology

Affected service	Reference	Purpose of test	Test configuration	UWB device characteristics	Results
GSM downlink (1 800 MHz)	Attachment 7 to the Report, § A7.1.1 and A7.1.1.6	Test measurements to determine the C/I_{UWB} required for the protection of a GSM handset from a single device using UWB technology in a controlled laboratory environment	The victim handset is a commercially available GSM mobile phone Base station signal generated by an Agilent 8960 Series 10 wireless communications test set running the E1968A GSM/GPRS Mobile Test Application (version A.03.32) Tests measured residual BER for four received signal levels (−102, −96, −90, and −84 dBm) and two coding schemes (CS-1, CS-2). The −102 dBm corresponds to the reference sensitivity level of the handset (as specified in 3GPP TS 05.05/45.005)	The UWB impulse source is compliant with United States of America rules 30 different impulse-based UWB signal types are used (combinations of PRF, PPM, and mono/bi-phase) Laboratory tests are also repeated with a multi-band OFDM UWB transmitter (compliant with United States of America rules) in three 528 MHz bands centred on 3.432 , 3.960 and 4.488 GHz	C/I_{UWB} = 11 dB The MB-OFDM UWB signal did not affect the BER of the GSM downlink for a GSM received signal level = −102 dBm and for both coding schemes CS-1 and CS-2

Affected service	Reference	Purpose of test	Test configuration	UWB device characteristics	Results
GPRS downlink (1 800 MHz)	Attachment 7 to Report, § A7.1.1.5	Test measurements to determine the C/I_{UWB} ratio required for the protection of a GPRS handset from a single device using UWB technology in a controlled laboratory environment	The victim handset is a commercially available GPRS mobile phone Base station signal generated by an Agilent 8960 Series 10 wireless communications test set running the E1968A GSM/GPRS Mobile Test Application (version A.03.32) Experiments measured block error rate (BLER) for four received signal levels (−100, −95, −90, and −85 dBm) and two coding schemes (CS-1, CS-2). The −100 dBm corresponds to the reference sensitivity level in 3GPP TS 51.010-1 V5.9.0 Section 14.16.1.2 for a class 1 DCS 1 800 handset	The UWB impulse source is compliant with United States of America rules 30 different impulse-based UWB signal types are used (combinations of PRF, PPM, and mono/bi-phase) Laboratory tests are also repeated with a multi-band OFDM UWB transmitter (compliant with United States of America rules) in three 528 MHz bands centred on 3.432, 3.960 and 4.488 GHz	C/I_{UWB} = 10 dB for both coding schemes CS-1 and CS-2 The MB-OFDM UWB signal did not affect the BLER of the GPRS downlink for a received signal level = −100 dBm and for both coding schemes CS-1 and CS-2

Affected service	Reference	Purpose of test	Test configuration	UWB device characteristics	Results
GSM/GPRS 1 800 MHz downlink	Attachment 7 to Report	Field tests to determine an appropriate UWB e.i.r.p. density limit (dBm/MHz) for the GSM/GPRS 1 800 MHz band that will ensure that, under test conditions, the presence of a single device using UWB technology in the vicinity of a handset will not trigger the power control mechanism of the BTS serving the handset in an indoor environment	Commercial GSM and GPRS network and handsets were used for tests with the help of a major mobile cellular operator Base station transmission power and RxQual of the GSM handset were used as the monitoring parameters. For GPRS BLER and LLC throughput was used	The UWB impulse source is compliant wit United States of America rules 19 different impulse-based UWB signal types are used (combinations of PRF, PPM, and mono/bi-phase) The device using UWB technology is located at 30 cm away from a victim handset	Threshold e.i.r.p. values are higher than −53 dBm/MHz (currently permitted United States of America mask for indoor devices using UWB technology). Assuming a free-space path loss of 27 dB over 30 cm and a bandwidth scaling factor of 7 dB, the C/I_{UWB} observed in this experiment ranges from −3 dB to 4 dB, which is much lower than the 11 dB required for the protection of GSM and GPRS systems

1.2.1.2 Impact of multiple devices using UWB technology

Affected Service	Reference	Purpose of test	Test configuration	UWB device characteristics	Results
GSM/GPRS downlink (1 800 MHz)	Section 4 to Report, § A4.4.3.1	Laboratory tests to measure the residual BER (RBER) of the GSM downlink and the block error rate (BLER) of the GPRS downlink in the presence of 1, 2, 4 and 8 active UWB transmitters. Test measurements to determine the C/I_{UWB} ratio required for protection of a GSM handset from multiple devices using UWB technology	The victim handset is a commercially available GSM mobile phone Base station signal generated by a wireless communications test set running the E1968A GSM/GPRS Mobile Test Application (version A.03.32) Tests measured residual BER for a received signal level at handset −90 dBm. Coding scheme CS-2 was used with GPRS	The emission limits of the 8 UWB sources are compliant with United States of America rules 30 different impulse-based UWB signal types are used (combinations of PRF, PPM, and mono/bi-phase)	For the GSM case, the results provide experimental evidence that linear power addition applies well to the aggregation of UWB signals Similar results are reached for GPRS considering the logarithmic average of the I_{UWB} values For the given number of UWB sources, the log average C/I_{UWB} increases linearly with the number of active UWB transmitters

Affected Service	Reference	Purpose of test	Test configuration	UWB device characteristics	Results	
GSM/GPRS 1 800 MHz downlink	Attachment 7 to Report, § A7.1.1.6 and A7.1.3	Field tests to determine an appropriate UWB e.i.r.p. density limit (dBm/MHz) for the GSM/GPRS 1 800 MHz band that will ensure that, under test conditions, the presence of a single device using UWB technology in the vicinity of a handset will not trigger the power control mechanism of the BTS serving the handset in an indoor environment	Commercial GSM and GPRS network and handsets were used with the help of a major mobile cellular operator Devices using UWB technology are located at 30 cm and 50 cm away from a victim handset at cell boundary and also near base station scenarios Base station transmission power and RxQual of the GSM handset was used as the monitoring parameters For GPRS BLER and LLC downlink throughput was used	Multiple devices using UWB technology compliant with United States of America rules are used: 1, 2, and 4 Experiments are carried out both indoors and outdoors at e.i.r.p. density of −63 dBm/MHz and for 3 types of UWB signals	Indoor GSM: No degradation was observed for near BS and cell edge at 50 cm separation For cell edge at 30 cm separation, the impact of the number of devices using UWB technology is not clear, partly because of environmental factors	Indoor GPRS: No measurable impact on the performance of the victim receiver regardless of the UWB signal type or number of transmitters for all test scenarios
					Outdoor GSM: No measurable degradation in the victim receiver's performance regardless of the UWB signal type or number of transmitters for all test scenarios	Outdoor GPRS: No measurable impact on the performance of the victim receiver for all test scenarios

1.2.2 Test measurements related to the impact of devices using UWB technology on systems operating within IMT-2000

Affected Service	Reference	Purpose of Test	Test Configuration	UWB Device Characteristics	Results
IMT-DS downlink	Attachment 7 to Report, § A7.2	Laboratory measurements to determine the required level of protection of an IMT-DS user equipment (UE) from a single device using UWB technology. This is done by measuring $\hat{I}_{or}/I_{UWB}$ to determine relative to the UWB signal, how much stronger the IMT-DS signal had to be at the user equipment receiver in order that the UE be still capable of meeting its minimum performance requirements	The victim handset used in the experiment was an ordinary, commercially available IMT-DS mobile phone. The base station signal was generated by a test set running the E1963A IMT-DS Mobile Test Application (version A.05.16) Tests are for two different channel types (12.2k RMC, 64k RMC) and at 4 different received signal levels (−106, −101, −96, and −91 dBm). The −106 dBm corresponds to the reference $\hat{I}_{or}$ specified in Table 6.2.2 of 3GPP TS 34.121	The UWB impulse source is compliant wit United States of America rules 44 different impulse-based UWB signal types are used	$\hat{I}_{or}/I_{UWB} = -8$ dB for the 12.2 k RMC channel and $\hat{I}_{or}/I_{UWB} = -4$ dB for the 64 k RMC channel at PRFs greater than 0.3 MHz, regardless of the $\hat{I}_{or}$ level ($\hat{I}_{or}$ is the UE's received signal level and I_{UWB} is the amount of UWB power within the 3 dB bandwidth (3.84 MHz) of the UE's receiver) The UWB signal was too weak to have any measurable impact on the IMT-DS downlink

Affected Service	Reference	Purpose of Test	Test Configuration	UWB Device Characteristics	Results
IMT-DS downlink	Attachment 7 to Report, § A7.2	Laboratory measurements to determine if the UWB spectral energy (below 3.1 GHz) of the multi-band OFDM Alliance (MBOA) transmitter would cause harmful interference to a IMT-DS user equipment	The victim handset used in the experiment was an ordinary, commercially available IMT-DS mobile phone. The base station signal was generated by an Agilent 8960 Series 10 test set running the E1963A IMT-DS Mobile Test Application (version A.05.16) Tests are for 2 different channel types (12.2k RMC, 64k RMC) and 4 different received signal levels (−106, −101, −96 and −91 dBm).The −106 dBm corresponds to the reference $\hat{I}_{or}$ specified in Table 6.2.2 of 3GPP TS 34.121	The UWB source is a multi-band OFDM UWB transmitter's (compliant with US rules) in three 528 MHz bands centred on 3.432 GHz, 3.960 GHz and 4.488 GHz	MB-OFDM results are perfectly consistent with the results for the impulse-based UWB signal types suggesting that both MB-OFDM UWB and high-PRF impulse-based UWB signals affect the user equipment receiver in similar ways

Affected Service	Reference	Purpose of Test	Test Configuration	UWB Device Characteristics	Results
IMT-DS downlink	Attachment 7 to Report, § A7.2	Field tests to determine an appropriate e.i.r.p. density limit for the IMT-DS downlink band (2 100 MHz) that will ensure that, under test conditions, the presence of a device using UWB technology in the vicinity of a UE will not impact the downlink DPCH power control serving the UE	Commercial IMT-DS network and handsets were used with the help of a major mobile cellular operator	The UWB source is compliant wit United States of America rules 12 different impulse-based UWB signal types are used The UWB transmitter was placed at 30 cm away from the victim handset	$\hat{I}_{or}/I_{UWB}$ ranges from −17 dB to −9 dB for the 12.2 k voice call (CPICH RSCP = −90 dBm) ($\hat{I}_{or}$ is the UE's received signal level and I_{UWB} is the amount of UWB power within the 3 dB bandwidth (3.84 MHz) of the UE's receiver) For a 384 kbit/s data connection (CPICH RSCP = −75 dBm), the threshold e.i.r.p. values obtained ranged from −57 dBm/MHz to −55 dBm/MHz
IMT-DS downlink	Section 4 to Report, § A4.4.3.2	Laboratory measurements to determine the required level of protection of an IMT-DS UE from multiple devices using UWB technology Test measurements to determine the C/I_{UWB} ratio required for protection of a GSM handset from multiple devices using UWB technology	The handset (UE) was a commercial off-the-shelf unit The base station signal was generated by an Agilent 8960 Series 10 test set running the E1963A IMT-DS Mobile Test Application (version A.05.16) Tests measured loopback BER for a received signal level at handset −96 dBm	The UWB sources are compliant with United States of America rules 32 different impulse-based UWB signal types are used	For up to 8 UWB transmitters, results show a linear increase in $\hat{I}_{or}/I_{UWB}$ for every doubling of the number of active transmitters

1.2.3 Test measurements related to the impact of devices using UWB technology on systems operating within Wireless access systems including RLANs

Affected Service	Reference	Purpose of test	Test configuration	UWB device characteristics	Results
RLAN IEEE 802.11a	Attachment 7 to Report, § A7.3.1	Experimental measurements of interference to determine impact of certain devices using UWB technology to RLAN throughput with respect the distances	For RLAN AP and STA, Proxim AP−600 v 2.1.1 and Client are used. The measurement frequency is 5.180 GHz and emission power of RLAN transmitter is 40 mW The distance between the RLAN transmitter and receiver was 5 m. RLAN equipment tested did not use TPC and DFS	A DS-CDMA transmitter and a MB-OFDM transmitter were used. The emission level of Impulse, DS-CDMA and OFDM devices using UWB technology at 5.18 GHz are −51.3 dBm/MHz, −75.2 dBm/MHz and −95 dBm/MHz, respectively	The interference effects can be disregarded when the victim RLAN terminal is located at the distance 0.2 m from the device using UWB technology, assuming average WiFi operating conditions
RLAN IEEE 802.11a	Attachment 7 to Report, § A7.3.2	Laboratory measurements to determine how the throughput of an IEEE 802.11a communication link is affected by the presence of a short-pulse UWB interferer in one typical indoor scenario	A wireless line-of-sight link (4.92 m) between a Proxim Harmony 802.11a access point and an IBM T30 Thinkpad equipped with a Proxim 802.11a Cardbus RLAN card. The access point operated with an e.i.r.p. of 100 mW in a 20 MHz channel centred on 5 180 MHz. The distance between the RLAN transmitter and receiver was 5 m. RLAN equipment tested did not use TPC and DFS	Two UWB impulse devices conforming to the US rules were used: a UWB TX Module boosted by one of two LNAs to give 32.5 dB or 40 dB gain at 5 GHz. The devices using UWB technology were placed 0.3 m and 0.5 m away from the victim laptop. The UWB transmitter's antenna pointed directly at the RLAN card and matched its polarization Different UWB PRFs, and pulse shapes are used with dithered/ non-dithered signals	At a separation distance of 0.5 m, the UWB interference was too weak to impact on the RLAN throughput. At a separation distance of 0.3 m, the throughput of the 802.11a link fell from around 22 to 19 Mbit/s for a UWB e.i.r.p. −41.3 dBm/MHz. Time-dithered UWB signals were not necessarily more benign than non-dithered signals. The shape of the UWB pulse did not appear to have an impact on the amount of interference observed

1.2.4 Test measurements related to the impact of devices using UWB technology on systems operating within the fixed service

Affected Service	Reference	Purpose of test	Test configuration	UWB device characteristics	Results
Fixed service	Attachment 7 to Report, § A7.4	to determine and specify the relevant UWB automotive short-range radar (SRR) maximum peak and/or mean interference level which lead to impact consistent with the protection objective regarding the FS link budget in the 24 GHz band	Tests were performed at R&D labs of a major FS systems manufacturer in Europe and were attended, besides the representative of four different SRR manufacturers also by representatives of some Administrations as independent witnesses. The FS system selected had a wideband receiver bandwidth ~41 MHz	Four types of UWB SRR used in tests are described in ETSI System Reference Document TR 101 892	Good correlation of UWB SRR r.m.s. power density with white noise assumption provided that the peak to r.m.s. ratio is limited to 42 dB maximum For high peak to r.m.s. emissions, the BER is initially caused by peak interference only For low peak to r.m.s. ratio devices, errors are initially caused by r.m.s. contribution only No significant difference have been found between degradation measured at BER = 10^{-6} and BER = 10^{-8} Limitation of the peak to r.m.s. value is necessary for ensuring protection to FS link

1.2.5 Test measurements related to the impact of devices using UWB technology on systems operating within the fixed satellite-service

Affected Service	Reference	Purpose of test	Test configuration	UWB device characteristics	Results
FSS 6/4 GHz links	Attachment 7 to Report, § A7.5	Tests to evaluate the impact of devices using UWB technology on FSS digital carriers by finding the point at which the performance of the modem was degraded beyond its normal threshold BER performance, or where the modem lost synchronization Test s are conduct for PRFs from 200 kHz to 100 MHz, on a set of digital FSS modems from 64 kbit/s to 45 Mbit/s with receiver bandwidths of 56 kHz to 25 MHz respectively and operating using various modulation schemes	An FSS/UWB test setup was assembled to simulate a conventional 6/4 GHz FSS satellite link. The link consisted of a Tx digital satellite modem, a 6 GHz upconverter, a 6/4 GHz Test Translator, a 4 GHz downconverter and a Rx digital modem. The link *C*/*N* was adjusted by combining a noise source with the 6 GHz upconverter signal Emissions from a 4 GHz device using UWB technology were injected into a 4 GHz FSS digital receiver and measurements were taken of the peak and r.m.s. levels when the digital modem suffered degraded performance or loss of synchronization	UWB components were assembled to simulate a device using UWB technology operating in the 4 GHz band The UWB signal was approximately 500 MHz and a wide range of PRF was used in the tests	The required *C*/*I* to avoid loss of synchronization for digital modems of 512 kbit/s or greater was from 4 to 11 dB The UWB r.m.s. interference levels were measured with a one MHz video bandwidth and found to correlate with CW or noise like interference levels. The UWB peak power levels were measured with a 3 MHz bandwidth and did not cause any noticeable additional degradation on the modem performance
FSS 6/4 GHz ground station receiver	Attachment 7 to Report, § A7.5	Laboratory validation tests to characterize the effects of the LNA/LBA on interfering signals prior to their reaching of the receiver models versus the selected UWB	The 6/4 GHz receiver degradation was caused by UWB Interference effects were evaluated based on observed degradation in signal quality	UWB signal e.i.r.p. density level was −41.3 dBm/MHz. Other UWB parameters (PRF, power level, and presence of dithering) were varied	The 8-PSK receiver failed when the aggregate UWB power reached −102.4 dBm. This is equivalent to approximately 8 000 emitters uniformly distributed within a 5 km radius or about 0.8 devices per acre for an antenna elevation angle of 5°

Affected Service	Reference	Purpose of test	Test configuration	UWB device characteristics	Results
FSS 6/4 GHz Receiver downlink	Attachment 7 to Report, § A7.5.1.4	A series of laboratory and field measurements to determine the minimum *C*/*I* ratio needed to prevent a UWB interferer from causing bit errors in a 6/4 GHz FSS receiver Lab test and two field tests were carried out near a local satellite operator's 6/4 GHz satellite dish with a very low elevation angle	In the lab, all signals were conducted, and the uplink-to-downlink frequency translation was effected using a mixer and a local oscillator In the first field test, we set up a temporary 3.7 m satellite dish to receive a signal relayed by MEASAT-2 In the second field test, a UWB transmitter approximately 6 m away from the edge of an 11 m C-band satellite dish directed at PamAmSat's PAS-2 satellite. The elevation angle of the dish was about 16°. The downlink was a QPSK-modulated multiplexed digital video signal with a carrier frequency of 3.7435 GHz, a symbol rate (i.e. 3 dB bandwidth) of 21.799 MHz, a code rate of 3/4, and Reed-Solomon outer coding	Both short-pulse and multi-band OFDM UWB signals were considered The short-pulse UWB transmitter used 7 combinations of PRF, PPM and pulse polarity at e.i.r.p. density of about −41.3 dBm/MHz The MB-OFDM signal is based on the Multi-Band OFDM PHY specification. The MB-OFDM transmitter produces an output of around −41.3 dBm/MHz between 3.2 GHz and 4.8 GHz. Taking into account the gain of the UWB antenna, the MB-OFDM transmitter would actually exceed the United States of America limit by about 2 dB	*C*/*I* depends largely on the satellite modem configuration (data rate, code rate, etc.) and can range from about 2 dB to 20 dB. Furthermore, there appears to be very little difference between the severity of the interference caused by short-pulse UWB and MB-OFDM UWB signals as long as they introduce the same amount of power into the victim FSS receiver's pass-band A US-compliant short-pulse or MB-OFDM device using UWB technology operating in the vicinity of a satellite dish is unlikely to have any measurable impact on the satellite downlink

1.2.6 Test measurements related to the impact of devices using UWB technology on systems operating within the broadcasting satellite service

Affected Service	Reference	Purpose of test	Test configuration	UWB device characteristics	Results
Satellite digital multimedia broadcast (SDMB)	Attachment 7 to Report, § A7.6	The purpose of the experiment was to measure the impact of certain devices using UWB technology to a typical SDMB receiver Performance degradation is measured according to the distance between satellite digital multimedia broadcasting (SDMB) receiver and devices using UWB technology	A typical satellite digital multimedia broadcasting (SDMB) receiver is used. The centre frequency is 2 642.5 MHz and the channel bandwidth is 25 MHz The received level of SDMB was −95 dBm	The e.i.r.p. density of the devices using UWB technology at the centre frequency of the SDMB were − 61.3 dBm/MHz for the impulse UWB transmitter and −72.31 dBm/MHz for the MB-OFDM transmitter	The allowable distance between a device using UWB technology and a typical SDMB receiver should be greater than 2 m when the e.i.r.p. density of device using UWB technology at the centre frequency of SDMB is −61.3 dBm/MHz and 0.8 m when the e.i.r.p. density is −72.31 dBm/MHz

1.2.7 Impact of multiple UWB transmitters on the ambient radio noise environment

Affected Service	Reference	Purpose of test	Test configuration	UWB device characteristics	Results
Ambient radio noise environment (all services)	Section 4 to Report, § A4.4.3.3	To study how aggregated UWB emissions from multiple devices (0, 1, 2, 4 and 8) affect the ambient radio noise environment in eight selected frequency bands	The measurement system used to measure the power spectral-density (on a per MHz basis) of the ambient urban environment in frequency bands (1 565.0, 1 735.0, 1 830.0, 1 973.0, 2 163.0, 2 305.0, 4 205.0, and 5 105.0 MHz)	The short-pulse devices using UWB technology transmit simultaneously at e.i.r.p. density compliant with United States of America rules	The aggregate effect of multiple UWB emitters was shown to be roughly linear Discrete spectral lines UWB emissions can have noticeable impact on the ambient radio noise environment

1.3 Summary of mitigation techniques

Various mitigation techniques can be used in order to reduce the impact of devices using UWB technology on radiocommunication systems:

- *Spectral control techniques of UWB emissions*:
  - smoothing the power spectral-density of UWB signals by an appropriate choice of the timing jitter;
  - using a pseudo-noise code sequence to decrease the spikiness of the UWB signals and to lower the power spectral-density (PSD) in certain frequency bands;
  - using various pulse shapes to control the fractional bandwidth and the PSD of UWB signals.
- *Cross polarization*: cross polarization can be effective in mitigating interference from some devices using UWB technology when polarizations of the interferer(s) and the victim receiver are known.
- *Notch filtering*: notch filters can suppress certain spectral contents of the mono-cycle UWB pulse or other UWB pulses. However, notch filtering may be impractical to implement since in-band notches may impair the performance of devices using UWB technology.
- *UWB modulation and channelization schemes*: several modulation and channelization schemes have been studied and implemented for UWB transmissions. The type of the modulation technique impacts the power spectral-density of the radiated UWB signal and consequently its impact on systems of radiocommunication services. Certain modulation techniques can offer better coexistence among devices using UWB technology and radiocommunication systems. Some other modulation techniques exhibit advantages when used for UWB transmission in certain environments.
- *Frequency hopping*: it is possible to reduce the emission to certain frequency bands by hopping the frequency of the UWB signal in a proper manner. Moreover, emission to the frequency band of a victim system can be effectively suppressed by disabling the hopping to the corresponding frequency band.
- *Chirp signalling*: it is possible to reduce the emission to the frequency band of a victim system by continuously changing the frequency of the UWB pulse.
- *Frequency agile modulation*: frequency agile UWB modulation allows for an emission level definition according to actual requirements at each portion of the UWB RF spectrum. It could also support programmable emission levels based on regional code transferred to the physical layer from the upper layers.
- *Carrier-leak-free burst oscillator*: using a burst oscillator that does not generate carrier leak at pulse-off allows locating the spectrum of the oscillator at an arbitrary position within the permitted band for the device using UWB technology. Consequently, a device using UWB technology and a carrier-leak-free burst oscillator may effectively mitigate interference by locating the interfering spectrum sufficiently far from the victim band.
- *Spatial radiation control techniques*: these techniques limit the radiation of the UWB signal in certain directions and reduce the total transmit power:
  - *Antenna directivity*: in certain UWB applications (e.g. GPR and vehicular radar), the directivity of UWB antennas could help minimize the interference.
  - *Multiple antenna directivity*: a number of approaches using multi-element antennas at one or both sides of the radio link can be used: switched beam (angular) diversity on the receive side; switched beam diversity on the transmit side; and spatial diversity on the receive side, on the transmit side, or on both sides, using several combining schemes.

  - *Array antenna*: an array antenna technique makes it possible to spatially and adaptively restrict the radiation to a victim system according to the locations of the interferer and the victim system. This also enables to reduce the total emission power. Various adaptation algorithms can be used.

– *Combined mitigation techniques*: combining multiple mitigation techniques makes it possible to reduce interference in a flexible and effective manner.

– *Detect and avoid (DAA) technology*: this technique has recently been proposed to mitigate UWB interference. The general principle is that UWB devices should detect the presence of signals from other radio systems and reduce its transmitted power down to a level where it does not cause interference to these systems. The reliable implementation of such DAA mechanisms based on requirements that need to be defined is not trivial and their effectiveness has not yet been demonstrated. Therefore, further research and investigation of DAA as a mitigation technique is required.

Attachment 1
to Annex 1

1 Summary of regulations of the United States of America

1.1 Introduction

The general technical requirements of the United States applicable to devices using UWB technology are:

– Devices using UWB technology may not be employed for the operation of toys, or on board an aircraft, a ship or a satellite.

– Emissions from digital circuitry used to enable the operation of the UWB transmitter must comply with the radiated emission limits of Table 1 (9 kHz-960 MHz) found below, and of a field strength of 500 μV/m at a measurement distance of 3 m (above 960 MHz).

– For devices using UWB technology where the frequency f_M, is above 960 MHz, there is a limit of 0 dBm e.i.r.p. on the peak level of the emissions contained within a 50 MHz bandwidth centred on f_M.

– Radiated emission levels at and below 960 MHz are based on measurements employing a CISPR quasi-peak detector. Radiated emission levels above 960 MHz are based on RMS average measurements using a spectrum analyser with a resolution bandwidth of 1 MHz and an averaging time of 1 ms or less. If pulse gating is employed where the transmitter is quiescent for intervals that are long compared to the nominal pulse repetition interval, measurements must be made with the pulse train gated on.

– The frequency at which the highest radiated emission (f_M) occurs must be contained within the UWB bandwidth.

– When a peak measurement is required, it is acceptable to use a resolution bandwidth (RBW) other than 50 MHz. This RBW must not be lower than 1 MHz or greater than 50 MHz, and the measurement must be centred on f_M. If a RBW other than 50 MHz is employed, the peak e.i.r.p. limit must be 20 log (RBW/50) dBm, where RBW is the RBW in MHz. This may be converted to a peak field strength level at 3 m.

1.2 National coordination requirements

Imaging systems require coordination through national spectrum managers before the equipment may be used. The operator must comply with any constraints on equipment usage resulting from this coordination. The coordination report must identify those geographical areas within which the operation of an imaging system requires additional coordination or within which the operation of an imaging system is prohibited.

1.3 Specific technical requirements for devices using ultra-wideband technology

A GPR system that is to be designed to operate while being hand-held and a wall imaging system must contain a manually operated switch that causes the transmitter to cease operation within 10 s of being released by the operator. In lieu of a switch located on the imaging system, it is permissible to operate an imaging system by remote control provided the imaging system ceases transmission within 10 s of the remote switch being released by the operator.

Regulations adopted by the United States of America require that emissions from a UWB vehicular radar in the 23.6-24.0 GHz band at angles of 38° or greater above the horizontal plane be attenuated 25 dB below the level in the horizontal plane. For equipment authorized, manufactured or imported on or after 1 January 2005, the required attenuation applies to emissions at angles of 30° or greater. On 1 January 2010, the required attenuation increases to 30 dB, and on 1 January 2014, it increases to 35 dB. This level of attenuation can be achieved through the antenna directivity, through a reduction in output power or any other means.

TABLE 1

Emission limits applicable to UWB ground-penetrating radar and wall-imaging radar (based on CISPR quasi-peak-detection) from 9 kHz to 960 MHz

Frequency (MHz)	Field strength (μV/m)	Measurement distance (m)
0.009-0.490	2 400/F(kHz)	300
0.490-1.705	24 000/F(kHz)	30
1.705-30.0	30	30
30.0-88.0	100	3
88.0-216.0	150	3
216.0-960.0	200	3

The emission limits shown in Table 1 are based on measurements employing a CISPR[2] quasi-peak detector except for the frequency bands 9-90 kHz, and 110-490 kHz. Radiated emission limits in these two bands are based on measurements employing an average detector.

Note that in the United States of America, the UWB emission limits at or below 960 MHz are expressed in μV/m, while the e.i.r.p. UWB emission limits above 960 MHz are expressed in dBm/MHz. The emission limits above 960 MHz are also based on an average detector.

2 CISPR 16:

- from 30 to 1 000 MHz: quasi-peak detector with measurement bandwidth = 120 kHz
- above 1 000 MHz: average detector with measurement bandwidth = 1 MHz

UWB technical summary Table for the United States of America

(In this Table, unless otherwise stated, the unit of frequency is MHz and the unit of e.i.r.p. is dBm/MHz.)

	GPR and wall imaging systems*	**Through-wall imaging systems (1)**	**Through-wall imaging systems (2)**	**Surveillance systems**	**Medical imaging systems**	**Vehicular radar systems**	**Indoor communication systems**	**Outdoor, hand-held communication systems**
Operating bands	The UWB bandwidth of an imaging system must be below 10.6 GHz	Through-wall imaging systems with the UWB bandwidth below 960 MHz	For equipment operating with centre frequency, f_c, and f_m between 1 990 and 10 600 MHz.	The UWB bandwidth of a surveillance imaging system must be contained between 1 990 and 10 600 MHz	The UWB bandwidth of a medical imaging system must be contained between 3 100 and 10 600 MHz	The UWB bandwidth must be contained between 22 GHz and 29 GHz. The centre frequency and the frequency at which the highest level emission occurs must be greater than 24.075 GHz	The UWB bandwidth of a indoor UWB system must be contained between 3 100 and 10 600 MHz	The UWB bandwidth of an outdoor, hand-held device must be contained between 3 100 and 10 600 MHz
Limitations of service	Operation is limited to purposes associated with law enforcement, fire fighting, emergency rescue, scientific research, commercial mining, or construction	Operation is limited to through-wall imaging systems operated by law enforcement, emergency rescue or firefighting organizations that are under the authority of a local or state government	This equipment may be operated only for law enforcement applications, providing emergency services, and necessary training operations	Operation is limited to fixed surveillance systems operated by law enforcement, fire or emergency rescue organizations or by manufacturer licensees, petroleum licensees or power licensees	Operation is limited to medical imaging systems used at the direction of, or under the supervision of, a licensed health care practitioner. The operation of medical imaging systems requires coordination	Operation is limited to UWB field disturbance sensors mounted in terrestrial transportation vehicles. These devices must operate only when the vehicle engine is running	Operation is limited to UWB transmitters employed solely for indoor operation	UWB devices are relatively small and primarily hand-held while being operated, and do not employ a fixed infrastructure
Radiated emission limits of resolution bandwidth of 1 MHz	*Frequency* *e.i.r.p.* 960-1 610 –65.3 1 610-1 990 –53.3 1 990-3 100 –51.3 3 100-10 600 –41.3 Above 10 600 –51.3	*Frequency* *e.i.r.p.* 960-1 610 –65.3 1 610-1 990 –53.3 Above 1 990 –51.3	*Frequency* *e.i.r.p.* 960-1 610 –46.3 1 610-1 990 –41.3 Above 1 990 –51.3	*Frequency* *e.i.r.p.* 960-1 610 –53.3 1 610-1 990 51.3 1 990-10 600 –41.3 Above 10 60. –51.3	*Frequency* *e.i.r.p.* 960-1 610 –65.3 1 610-1 990 –53.3 1 990-3 100 –51.3 3 100-10 600 –41.3 Above 10 600 –51.3	*Frequency* *e.i.r.p.* 960-1 610 –75.3 1 610-22 000 –61.3 22 000-29 000 –41.3 29 000-31 000 –51.3 Above 31 000 –61.3	*Frequency* *e.i.r.p.* 960-1 610 –75.3 1 610-1 990 –53.3 1 990-3 100 –51.3 3 100-10 600 –41.3 Above 10 600 –51.3	*Frequency* *e.i.r.p.* 960-1610 –75.3 1 610-1 990 –63.3 1 990-3 100 –61.3 3 100-10 600 –41.3 Above 10 600 –61.3
Limits for resolution bandwidth of no less than 1 kHz	*Frequency* *e.i.r.p.* 1 164-1 240 –75.3 1 559-1 610 –75.3	*Frequency* *e.i.r.p.* 1 164-1 240 –75.3 1 559-1 610 –75.3	*Frequency* *e.i.r.p.* 1 164-1 240 –56.3 1 559-1 610 –56.3	*Frequency* *e.i.r.p.* 1 164-1 240 –63.3 1 559-1 610 –63.3	*Frequency* *e.i.r.p.* 1 164-1 240 –75.3 1 559-1 610 –75.3	*Frequency* *e.i.r.p.* 1 164-1 240 –85.3 1 559-1 610 –85.3	*Frequency* *e.i.r.p.* 1 164-1 240 –85.3 1 559-1 610 –85.3	*Frequency* *e.i.r.p.* 1 164-1 240 –85.3 1 559-1 610 –85.3

* See Table 1 for emission limits applicable to UWB GPR and wall-imaging systems in the frequency range 9 kHz to 960 MHz.

2 Summary of proposed CEPT regulations

CEPT has developed UWB regulations for different applications that are applicable within these administrations, which include PSD masks and other regulatory provisions for generic UWB devices and vehicular radar systems.

Other regulations are also being developed for specific classes of UWB device (e.g. ground and wall penetrating radar) which do not meet the technical requirements for generic UWB devices.

2.1 Technical requirements for generic UWB devices[3]

CEPT has defined the harmonized conditions for the use of generic UWB devices below 10.6 GHz, subject to final adoption process. These devices shall comply with the regulatory framework for placing on the market, free movement and putting into service of radio equipment in these countries, which may be demonstrated by compliance with harmonized standards or equivalent technical specifications. These devices are exempt from individual licensing and operate on a non-interference, non-protected basis.

The technical requirements for the permitted devices are defined in § 2.1.1.

These provisions are not applicable to:

– flying models[4],

– outdoor installations and infrastructure, including those with externally mounted antennas,

– devices installed in road and rail vehicles, aircraft and other aviation.

(i.e. UWB devices in these types of product are not exempt from individual licensing).

The following restrictions on use apply to permitted devices

– operation not allowed at a fixed outdoor location.

It is still under consideration whether operation will be allowed aboard an aircraft or a ship. An adequate regulatory mechanism for possibly banning such use would furthermore need to be identified.

UWB devices may be permitted to operate in the band 4.2-4.8 GHz without DAA until 30 June 2010 with a mean e.i.r.p. density limit of –41.3 dBm/MHz and a maximum peak e.i.r.p. density of 0 dBm/50 MHz. The situation would be reviewed in 3 years in the light of WRC-07 results.

In the frequency band 3.1 to 4.95 GHz CEPT administrations support investigation of DAA mechanisms with a view of allowing UWB devices in this band with a maximum average e.i.r.p. density of –41.3 dBm/MHz and a maximum peak e.i.r.p. density of 0 dBm/50 MHz while ensuring the protection of radio services in the band. It has however to be noted that 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 investigation of DAA is needed. Only if the effectiveness of DAA mechanism is validated, UWB devices incorporating it will be permitted to operate.

CEPT administrations will monitor the efficiency of video coding for UWB devices placed on the market to verify that no significant amount of devices will appear on the market which use less efficient coding and to review the proposed regulation otherwise.

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[3] The draft Decision containing these regulations has not yet been considered by the CEPT Electronic Communications Committee (ECC). The document will then be open for a period for public comments, before final adoption by ECC expected in March 2006.

[4] It is still under consideration whether these provisions will apply to toys.

2.1.1 Technical requirements for UWB devices below 10.6 GHz

2.1.1.1 Maximum e.i.r.p. limits

Frequency range (GHz)	Maximum average e.i.r.p. density (dBm/MHz)	Maximum peak e.i.r.p. density (dBm/50 MHz)
Below 1.6	–90	–50
1.6 to 2.7	–85	–45
2.7 to 3.1	–70	–30
3.1 to 4.95 (Notes 1-4)	–70	–30
4.95 to 6	–70	–30
6 to 9	–41.3	0
9 to 10.6	–65	–25
Above 10.6	–85	–45

NOTE 1 – In the frequency band 3.1 to 4.95 GHz, CEPT administrations support investigation of DAA mechanisms in order to ensure compatibility of UWB devices with radio services in the band with a view of allowing UWB devices in this band with a maximum average e.i.r.p. density of –41.3 dBm/MHz and a maximum peak e.i.r.p. density of 0 dBm/50 MHz. ECC will review the decision in the light of the results of these investigations.

NOTE 2 – In the frequency band 3.1 to 4.95 GHz, UWB devices may be permitted with a maximum average e.i.r.p. density (provisionally in the range of –41.3 to –45 dBm/MHz), a maximum peak e.i.r.p. density of 0 dBm/50 MHz and a maximum duty cycle of 5% over one second and 0.5% over one hour.

NOTE 3 – In the frequency band 4.2 to 4.8 GHz, UWB devices may be permitted until 30 June 2010 with a maximum average e.i.r.p. density of –41.3 dBm/MHz and a maximum peak e.i.r.p. density of 0 dBm/50 MHz.

NOTE 4 – In the frequency band 3.1 to 4.95 GHz, CEPT administrations support investigation of possible other mitigation techniques, in order to ensure compatibility of UWB devices with radio services.

2.1.1.2 Other requirements

Pulse repetition frequency

The PRF for UWB devices shall not be less than 1 MHz. This restriction does not apply to burst repetition frequency.

NOTE 1 – It may not be necessary to have this restriction as well as the peak e.i.r.p. limit.

Transmission activity

A communications system shall transmit only when it is sending information to an associated receiver or attempting to acquire or maintain association. The device shall cease transmission within ten seconds unless it receives an acknowledgement from an associated receiver that its transmission is being received. An acknowledgement of transmission must continue to be received by the UWB device at least every 10 s, or it must cease transmitting. A device operating as a communication system is characterized by transmission between at least two devices.

Non-communication systems such as imaging systems shall contain a manually operated switch that causes the transmitter to cease operation within 10 s of being released by the operator. In lieu of a switch located on the imaging system, it is permissible to operate an imaging system by remote control provided the imaging system ceases transmission within 10 s of the remote switch being released by the operator.

2.2 Specific technical requirements for automotive short range radars (SRRs) in the 24 GHz band in CEPT

a) In these technical requirements, SRR are defined as radiocommunication equipment that falls in the general category of vehicular radar systems and provides collision mitigation and traffic safety applications.

b) In order to allow early introduction of SRR applications in CEPT the 24 GHz frequency range is designated for SRR systems on a temporary basis as follows:

- 24.15 GHz ± 2.5 GHz for the ultra-wideband component, with a maximum mean power density of –41.3 dBm/MHz e.i.r.p. and peak power density of 0 dBm/50 MHz e.i.r.p;
- 24.05-24.25 GHz for the narrow-band emission mode/component, which may only consist of an unmodulated carrier, with a maximum peak power of 20 dBm e.i.r.p and a duty cycle limited to 10% for peak emissions higher than -10 dBm e.i.r.p.

c) The temporary frequency designation for SRR equipment in the 24 GHz range is on a non-interference and non-protected basis.

d) Emissions within the 23.6-24 GHz band that appear 30° or greater above the horizontal plane shall be attenuated by at least 25 dB up to 2010 and 30 dB up to 1 July 2013 for SRR systems operating in the 24 GHz range as defined in b).

e) 24 GHz SRR systems transmitting in the band 23.6-24 GHz with an e.i.r.p. higher than –74 dBm/MHz or in any neighbouring band to which No. 5.149 of the RR applies with an e.i.r.p. higher than –57 dBm/MHz, shall be fitted with an automatic deactivation mechanism to ensure protection of radio astronomy sites as well as manual deactivation to ensure that emissions are restricted only to those administrations that have implemented the temporary solution. In order to allow an early implementation of 24 GHz SRR Systems the automatic deactivation shall be made mandatory from 1 July 2007. Before that date, manual deactivation is required.

f) Where an automatic deactivation mechanism is implemented, 24 GHz SRR systems must be de-activated within the specified separation distance from specified radio astronomy sites.

g) The 24 GHz frequency range may only be used for new SRR systems until the reference date, that is set to 1 July 2013. After this reference date, the 79 GHz range for new SRR systems, or alternative permitted technical solutions, must be used for road vehicle collision mitigation and traffic safety applications, while existing 24 GHz equipment may still operate in the 24 GHz band to the end of lifetime of the vehicles.

h) The percentage of vehicles equipped with 24 GHz SRR devices must not exceed 7.0% in each Administration.

2.3 Specific technical requirements for automotive short range radars in the 79 GHz band **in CEPT**

– In these technical requirements, short range radar (SRR) equipment is defined as applications providing road vehicle based radar functions for collision mitigation and traffic safety applications.

– The 79 GHz frequency range (77-81 GHz) is designated for SRR equipment on a non-interference and non-protected basis with a maximum mean power density of –3 dBm/MHz e.i.r.p. associated with an peak limit of 55 dBm e.i.r.p.

The maximum mean power density outside a vehicle resulting from the operation of one SRR equipment shall not exceed –9 dBm/MHz e.i.r.p.

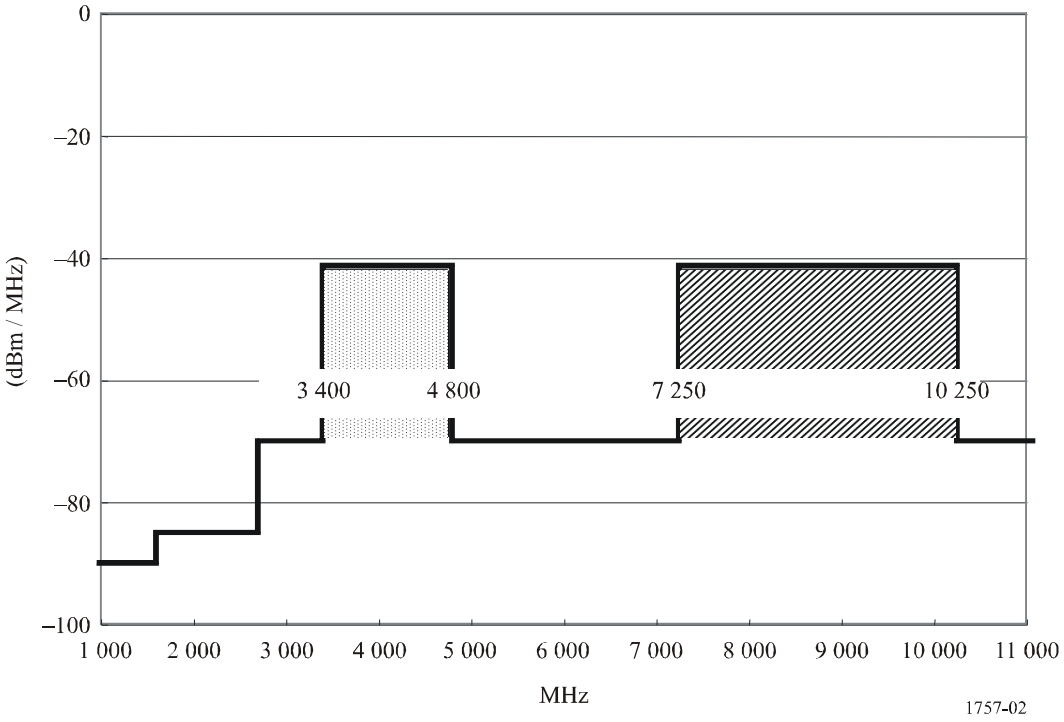
3 Specific technical requirements for Japan

In Japan, discussion for the development of indoor UWB regulation has been initiated by using a preliminary UWB transmission mask illustrated in Fig. 2. With this preliminary mask, impact analysis regarding other incumbent radiocommunication systems will be continued, and Japan will make any necessary adjustments to the UWB transmission mask as needed. The final report of the study is planned to be published by the end of March 2006.

3.1 Basic concept of the preliminary UWB transmission mask

FIGURE 2

Preliminary UWB transmission mask for impact analysis (only indoor use) of Japan



– This preliminary mask is used under the condition that all UWB devices are limited to only indoor use.

– Lower band (3 400-4 800 MHz, dotted area): Taking account of the current situation that there are existing radiocommunication systems in this frequency band, and that this frequency band is expected to be used for future mobile communications as well as appropriate band for development of UWB devices, UWB devices could emit at equal to or less than the limit of –41.3 dBm/MHz of FCC rule under the condition that UWB devices are equipped with interference avoidance techniques such as DAA that can protect systems beyond IMT-2000, ENG and other radiocommunication services effectively, when the techniques become available. The transmission level for UWB devices without interference avoidance techniques such as DAA will be equal to or less than the lower transmission level of –70 dBm/MHz proposed by CEPT (full details are contained in § 2.1.1.1 of this Attachment) based upon protection level for radiocommunication systems.

– Middle band (4 800-7 250 MHz): Taking account of the technical difficulty of frequency sharing with passive services, UWB devices could emit at equal to or less than the lower transmission level of –70 dBm/MHz proposed by CEPT based upon previous protection

level for radiocommunication systems (current details are contained in § 2.1.1.1 of this Attachment).

– Higher band (7 250-10 250 MHz, see hatched area by oblique line in Fig. 2): Taking account of the requirement, development and dissemination of UWB devices as well as to initiate further discussion, UWB devices could emit at equal to or less than FCC rule level of –41.3 dBm/MHz.

– Lower out of band (below 3 400 MHz): UWB devices could emit at equal to or less than the transmission mask proposed by CEPT.

– Higher out of band (above 10 250 MHz): UWB devices could emit at equal to or less than the lower transmission level of –70 dBm/MHz proposed by CEPT based upon previous protection level for radiocommunication systems (current details are contained in § 2.1.1.1 of this Attachment).

Annex 2

Methodologies to assess the impact of devices using UWB technology on systems operating within radiocommunication services

TABLE OF CONTENTS

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2.1 Introduction

This Annex is organized into three sections: impact of a single device using UWB technology, impact of an aggregation of devices using UWB technology, and bandwidth correction factor (BWCF), which is relevant to both single and aggregate methodologies. BWCF defined in § 2.4 may need to be taken into account for some UWB technologies.

2.2 Impact of a single device using UWB technology

A number of methodologies are proposed as listed below.

2.2.1 Link budget methodology

The maximum permitted equivalent isotropic radiated power (e.i.r.p.) level of an interfering UWB signal may be determined by using the following simple equation:

$$EIRP_{MAX} = I_{MAX} - G_R(\theta) + L_P + L_R \quad (1)$$

where:

$EIRP_{MAX}$: the maximum average permitted e.i.r.p. density of the interfering device, (dBm/B_{REF}), where the reference bandwidth B_{REF} is usually taken to be one MHz

I_{MAX}: the maximum permissible interference power level at the receiver input, normalized (dBm/B_{REF})

$G_R(\theta)$: the victim receiver's antenna gain in the direction of the UWB device (dBi)

L_P: the propagation loss between transmitting and receiving antennas (dB)

L_R: the insertion loss (loss between the receiver antenna and receiver input) (dB). A zero dB may be assumed if no value is available.

The use of the link budget methodology to calculate the maximum permitted UWB interference level from multiple devices using UWB technology is given in § 2.3.6.

2.2.1.1 Applicability of the link budget methodology to the radionavigation satellite service (RNSS)

For noise-like UWB interferers, the maximum allowable emission level from the UWB device is based on an average e.i.r.p. limit. The e.i.r.p. is the power supplied to the antenna of the UWB device multiplied by the relative antenna gain of the UWB device in the direction of the RNSS receiver. The maximum allowable EIRP for a single emitter is computed using the following equation (2):

$$EIRP_{MAX} = I_{MAX} - G_R(\theta) + L_P + L_R - L_{safety} - L_{allotment} \quad (2)$$

where:

I_{MAX}: the interference threshold of the UWB signal at the input of the RNSS receiver normalized (dBm/B_{REF})

L_P: the propagation loss between transmitting and receiving antennas (dB). For free-space propagation loss: $L_P = 20 \log(f) + 20 \log(d) - 27.55$. Where f (MHz) is the frequency, and $d(m)$ is the minimum distance separation between the RNSS receiver and the interfering device. Additional losses may have to be considered for propagation through walls, roofs, or other obstructions based on the deployment scenario (e.g. indoor)

L_{safety}: the aviation safety margin in dB. In the case of safety-of-life applications, the safety margin is 5.6 dB (Recommendation ITU-R M.1477)

$L_{allotment}$: the factor for interference allotment (dB).

The use of the link budget methodology to calculate the maximum permitted interference level from multiple devices using UWB technology into RNSS receivers is given in § 2.3.6.1.

The methodologies used to determine impact of emissions of devices using UWB technology on RNSS systems reflects the needs of three types of RNSS systems operating or planned to be operated by different organizations. In one case, the administration of one of the system types has adopted rules and regulations which apply to the protection of all services (including all RNSS systems) from the impact of emissions from UWB devices for their national territory.

In summary different methodologies have been used to determine the impact of emissions of devices using UWB technology on RNSS systems.

2.2.2 Minimum coupling loss method

The first step of the procedure used to estimate the minimum protection distance – i.e. the separation distance necessary to reduce the co-frequency interference to a tolerable level – is to calculate the minimum coupling loss (MCL), which is given by equation (3):

$$MCL = P_{UWB-RAD} + 10 \log BW_{victim} - P_{RX} + C/I \quad (3)$$

where:

MCL: the minimum coupling loss required to avoid harmful interference (dB)

$P_{UWB\text{-}RAD}$: the maximum average radiated e.i.r.p. density in dBm/MHz over the victim bandwidth

P_{RX}: the victim receiver sensitivity (dBm)

C/*I*: the carrier to interference ratio (dB)

BW_{victim}: the IF bandwidth of the victim receiver (MHz).

Additional terms can be inserted in the above MCL formula to correct for artefacts, e.g. changes in UWB e.i.r.p. density over the victim bandwidth, and receiver antenna gain G_R.

The second step is then to convert the MCL into a protection distance by using an appropriate propagation path-loss model, which may include additional propagation factors such as obstacle loss, etc.

2.2.3 Blocking probability for CDMA PCS

The blocking probability caused to CDMA PCS by a device using UWB technology at distance *d* m away can be given by equation (4):

$$P_{b|d} = P_r\{s > s_{max}\} = 1 - s_{max}^2 \quad (4)$$

where:

$$s_{max} = \left(1 + \frac{I_{uwb1}/N}{d^2}\right)^{-1/\gamma} \quad (5)$$

γ: the path-loss exponent, generally between 3 and 4

$I_{uwb\,1}$: the interference received by PCS handset from a UWB 1 m away (dBm/B_{REF}) where B_{REF} is the reference bandwidth

N: the PCS handset receiver noise (dBm).

2.3 Impact of an aggregation of devices using UWB technology

In applying aggregate methodologies, a few guiding principles may be applied as follows, to ensure that the analysis is representative of realistic scenarios:

– Estimates of activity factors for various types of devices using UWB technology, including relevant statistical variation in device deployment and operational parameters, can be found in Recommendation ITU-R SM.1755.

– Antenna directivity should be considered in an interference analysis, taking into account the number of antennas of devices using UWB technology that are pointing directly at the victim receiver.

– Outdoor communication devices may represent a small percentage of the total number of devices using UWB technology. Where outdoor handheld communication devices using UWB technology are used, they are likely to be operated approximately 2 m above ground.
– Some receivers may not be susceptible to peak emissions from devices using UWB technology but rather, these receivers will be sensitive to the aggregate of average emissions levels produced by the devices using UWB technology.
– The assumption of a uniform device density of devices using UWB technology may not be appropriate for aggregate analyses involving large areas. In such cases, a statistical method or a device deployment model may be needed that includes variations in device density over the area being analysed.

2.3.1 Integral methodology

The integral methodology assumes a uniform distribution of emitters using UWB technology in a circular area around a victim receiver (Rx) as shown in Fig. 3. A differential circular area is defined at a distance r (m) from the victim receiver, $dA(m^2) = 2\pi r\, dr$. The total transmitted power in dA is:

$$dP_{tot}\,(W) = \rho P G_t\, dA \tag{6}$$

where:

P(W): average power delivered to the transmit antenna

G_t: gain of the transmit antenna

ρ: represents the average density of UWB emitters(number of UWB devices/m^2).

The differential power flux density at a distance r from the victim receiver is then:

$$dPFD(W/m^2) = dP_{tot}/(4\pi r^2) = \rho.P.G_t.dA/(4\pi r^2) \tag{7}$$

For a reference bandwidth B_{REF}, integrating the dPFD over a range R_1 to R_o m yields the total spectral power flux density ($SPFD$) at the victim receiver:

$$SPFD(W/m^2.MHz) = PFD/B_{REF} = (\rho.P.G_t/2\, B_{REF}) \ln(R_o/R_1) \tag{8}$$

The product $P.G_t$ is the average equivalent isotropically radiated power (e.i.r.p.) and $P.G_t/B_{REF}$ is the e.i.r.p. density per the reference bandwidth.

The average density ρ of the emitters should be scaled down by an activity factor, η, representing the percentage of active emitters using UWB technology.

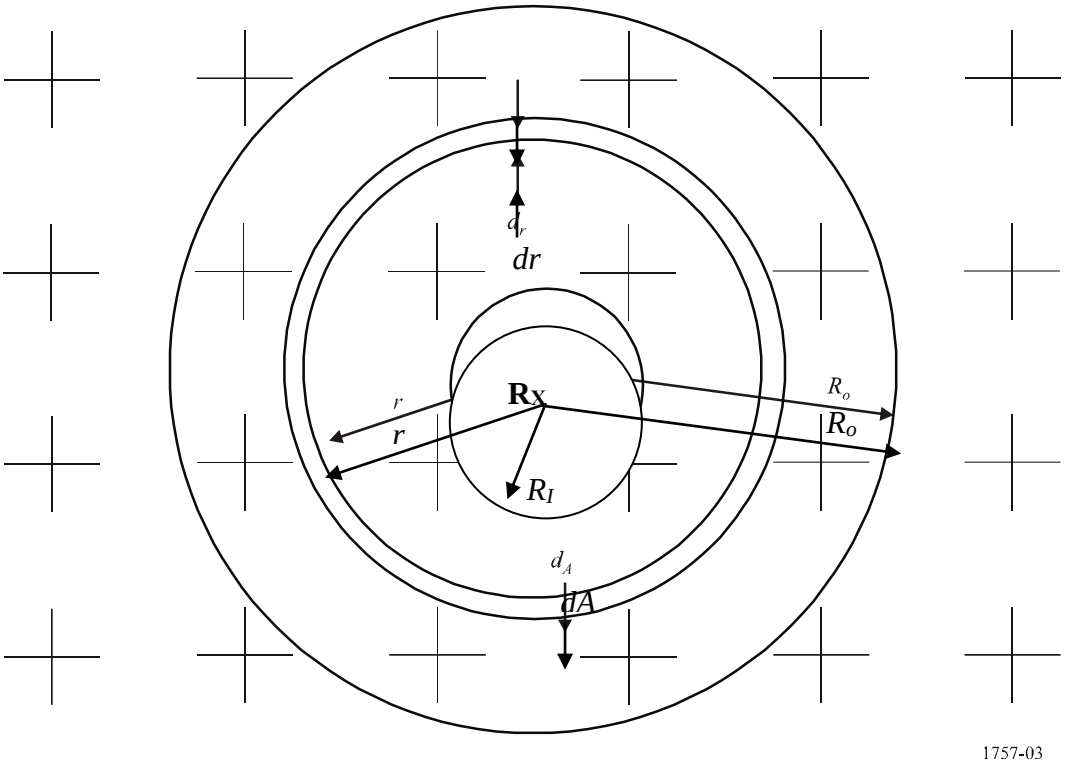
For an isotropic receiving antenna with an effective area $A_e = \lambda^2/4\pi$, the differential interference power reaching this antenna is equal to:

$$dI = (e.i.r.p.).G_R\, .A_e\, dA/(4\pi r^2) \tag{9}$$

where G_R is the directional antenna gain of the victim receiver.

FIGURE 3

The integral methodology



Integrating over a range bounded by an inner ring (R_I) and an outer ring (R_o), the average aggregate interference power density I (W) per reference bandwidth can be written as:

$$I = 2\pi.\alpha\eta\rho \ln(R_o/R_I) \quad (10)$$

where:

$\alpha = (e.i.r.p.).G_R .(\lambda/4\pi)^2$: constant term valid in the case of omnidirectional emissions and free-space propagation;

e.i.r.p.: average e.i.r.p. of the UWB transmitting device (W) per reference bandwidth)

λ: wavelength (m)

ρ: average density of emitters (emitters/m^2)

η: activity factor of emitters

R_o: outer radius of the observed zone

R_I: inner radius of the observed zone.

The impact of propagation through walls, roofs, or other obstructions may have to be considered based on the deployment scenario.

2.3.2 Monte Carlo methodology

The Monte Carlo methodology is capable of providing any desired level of mathematical accuracy and statistical validity and confidence to calculations of the probability of interference for any kind of radiocommunication system, including impact of devices using UWB technology on radiocommunication systems. Accuracy and statistical validity and confidence is limited by

– how closely the mathematical model(s) describe the interference scenarios in consideration, and

– the number of trials done to calculate whether or not interference is present.

The Monte Carlo methodology uses randomly generated values for uncertain variables, based on probability distributions applicable to these variables. The methodology combines a large number of cases of independent variables and generates statistical results. A particular advantage of using a Monte Carlo simulation is its ability to develop a statistical distribution of the predicted aggregate interference level (i.e. a cumulative distribution function) that takes into account the uncertainties of significant elements of the aggregate interference model, such as UWB deployment densities, activity factors, etc. This methodology is therefore particularly useful when an estimate is desired of the probability that a certain aggregate interference power level is exceeded.

The ITU-R has developed the Monte Carlo simulation methodology as a statistical tool for compatibility studies between radiocommunication services. An overview of this methodology is provided in Report ITU-R SM.2028. In addition, Recommendation ITU-R M.1634 describes the use of the Monte Carlo methodology for compatibility with the mobile service.

For terrestrial radio services and satellite downlinks, the Monte Carlo simulation methodology assumes a victim receiver operating amongst a population of uniformly random distributed interferers. For the case of satellite uplinks, the simulation assumes that the devices using UWB technology are distributed over the Earth's surface seen by the satellite uplink according to a uniform probability distribution.

The desired signal level at the victim receiver can be calculated from the transmit power, antenna gains, and path loss. The effect of each interferer on the victim receiver is determined using the transmit power, antenna gains, path loss, transmitter unwanted emission characteristic, receiver blocking and frequency separation.

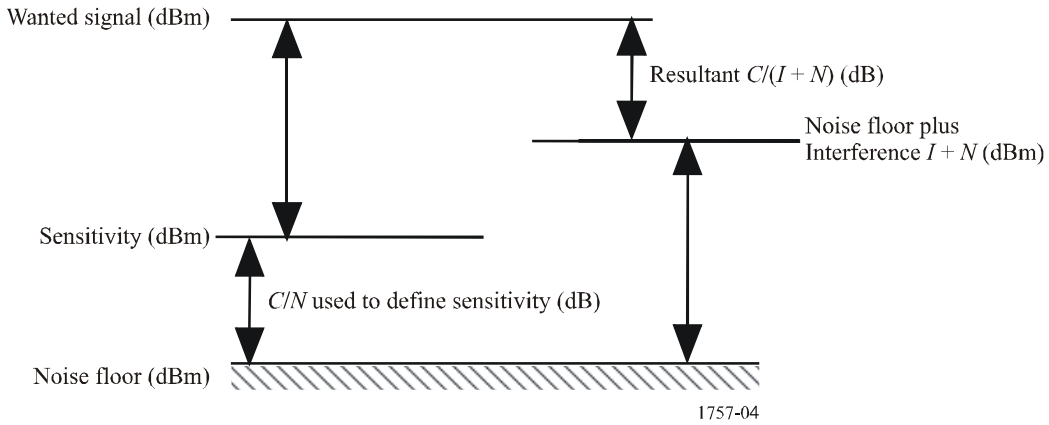
For some services, interference is considered to take place when the resultant C/I is less than the protection ratio as illustrated in Fig. 4.

The left-hand side of Fig. 4 represents the case when there is no interference. In this case the resultant C/I ratio is equal to the sum of the protection ratio and the margin. The right-hand side of Fig. 4 represents the case when interference is introduced. The interference adds to the noise-floor and the resultant C/I is the difference between the increased noise-floor and the desired signal level.

Different criteria for calculation of interference probability can be accommodated depending on the particular interference criteria of the affected radio service. A cumulative probability functions can be calculated for C/I, I, $C/(N + I)$, or $N/(N + I)$ random variables.

FIGURE 4

Illustration of signal levels used in the Monte Carlo methodology



2.3.3 Summation methodology

The summation methodology assumes that all emitters using UWB technology to be located on equally spaced concentric rings with the victim receiver in the centre of the distribution as shown in Fig. 5. The emitters using UWB technology are bounded by an inner ring (R_I) and an outer ring (R_o). The inner ring defines the boundary of an UWB-free zone. The emitters using UWB technology are evenly spaced from each other on each ring. Since all the emitters on each ring have the same distance to the receiver, the path loss is the same for all the emitters on that ring. The total received power is the summation of power levels contributed by each ring.

Table 2 shows a list of all parameters used and their units of measurement.

FIGURE 5

The summation methodology

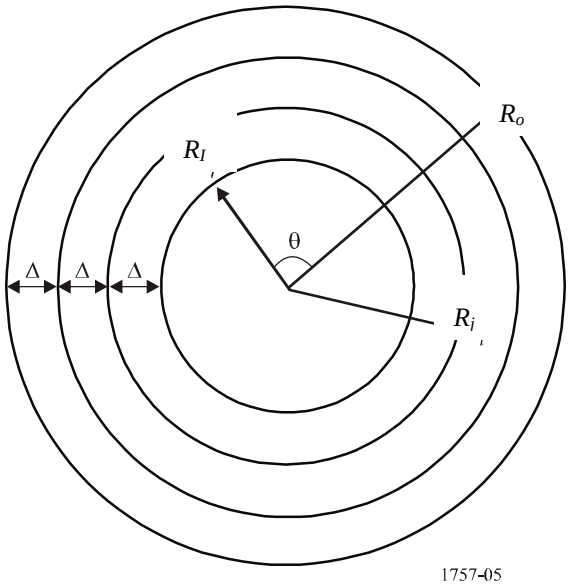


TABLE 2

R_I	Inner ring radius (km)

R_o	Outer ring radius (km)
R_j	The *j*-th ring radius in the distribution (km)
θ	Sector angle defined by the antenna horizontal beam width (rad)
K	Density of emitters using UWB technology (# km^2)
T	Total number of emitters in the full annulus
N	Number of emitters in the sector outlined by angle θ
N_j	Number of emitters in the sector in the *j*-th ring
Δ	Separation distance between rings (km)
M	Number of rings used
EIRP	Effective isotropic radiated power density (W/B_{REF})
G_j	Receiver's antenna gain in the direction of the *j*-th interfering source
L_j	Path loss between a transmitter in the *j*-th ring and the receiver
B_{RX}	IF bandwidth of the interfered with receiver
B_{REF}	Reference bandwidth
η	UWB activity factor of UWB emitters

The user defines the density K of emitters using UWB technology, and the total number of emitters in the annulus is calculated by: $T = K\pi\ (R_o^2 - R_I^2)$. The ring separation distance Δ is given by: $\Delta = 1/\sqrt{K}$.

The total number of rings (M), rounded to the nearest integer, is given by: $M = \{(R_o - R_I)/\Delta\} + 1$.

The radius R_j is used to calculate the path loss between the *j*-th ring and the antenna of the victim receiver. R_j is the inner ring plus the *j*-th ring separation distance Δ:

$$R_j = R_I + (j - 1)\Delta \qquad j = 1 \text{ to } M \tag{11}$$

The emitter distribution is based on having the ratio of number of emitters on each ring-to-ring radius to be constant. This leads to:

$$N_j = 2N\ \{R_I + (j - 1)\Delta\}/\{2M\ R_I + \Delta(M - 1)M\} \tag{12}$$

where $N = T\theta/2\pi$. is the number of emitters in a sector outlined by angle θ.

The power density received at the centre comes from combining the above equations to be:

$$P_R\ (single) = EIRP.(G_j/L) \tag{13}$$

L: the propagation loss between the transmitting and receiving antennas, in dB. Additional losses may have to be considered such as the insertion loss (loss between the receiver antenna and receiver input).

Assuming that all UWB emitters having identical characteristics and the same transmit power level, then the aggregate power density (Watts/B_{REF}) received at the victim receiver is:

$$P_R\,(aggregate\ ) = EIRP\ \sum_{j=1}^{M} \frac{N_j.G_j}{L_j} \tag{14}$$

The density N_j of the emitters should be scaled by an activity factor, η, representing the percentage of active UWB emitters.

2.3.4 Methodologies to assess interference into satellite networks

Methodologies to assess the aggregate interference into satellite networks from transmitting devices using UWB technology might include:

– The Monte Carlo simulation methodology.

– The summation methodology.

– Simplified methodologies of satellite Earth-to-space or space-to-Earth links.

Development of closed form analytical expressions for the aggregate interference into a satellite link may lead to complex expressions, especially where widely-used shaped-beam satellite antennas are used.

Available simplifications of the summation methodology described in § 2.3.3 may lend themselves to simpler calculations and may provide accurate estimates.

2.3.4.1 Methodologies that estimate interference into satellite uplinks

2.3.4.1.1 Satellite uplink summation methodology

The summation methodology can be extended to cover the case of satellite uplinks using a three-dimensional analogue to the ring summation, as illustrated in Fig. 6. In this case, the interference summation is performed over a circular area on the Earth's surface. The centre of this area is the boresight of the satellite antenna beam, i.e. the point on the Earth's surface, which is intersected by the main axis of the antenna beam (designated as point BS in Fig. 6). In general, the antenna beam boresight (BS) is offset by a fixed angle β_0 (measured at the centre of the Earth) from the sub-satellite (SS) point corresponding to the off-nadir angle α_0 of the satellite antenna main beam axis.

The outer edge of this circular area is defined by the Earth central angle τ_{max} that is chosen to equal the largest central angle within the projection of the specified contour of the sensor beam on the Earth's surface.

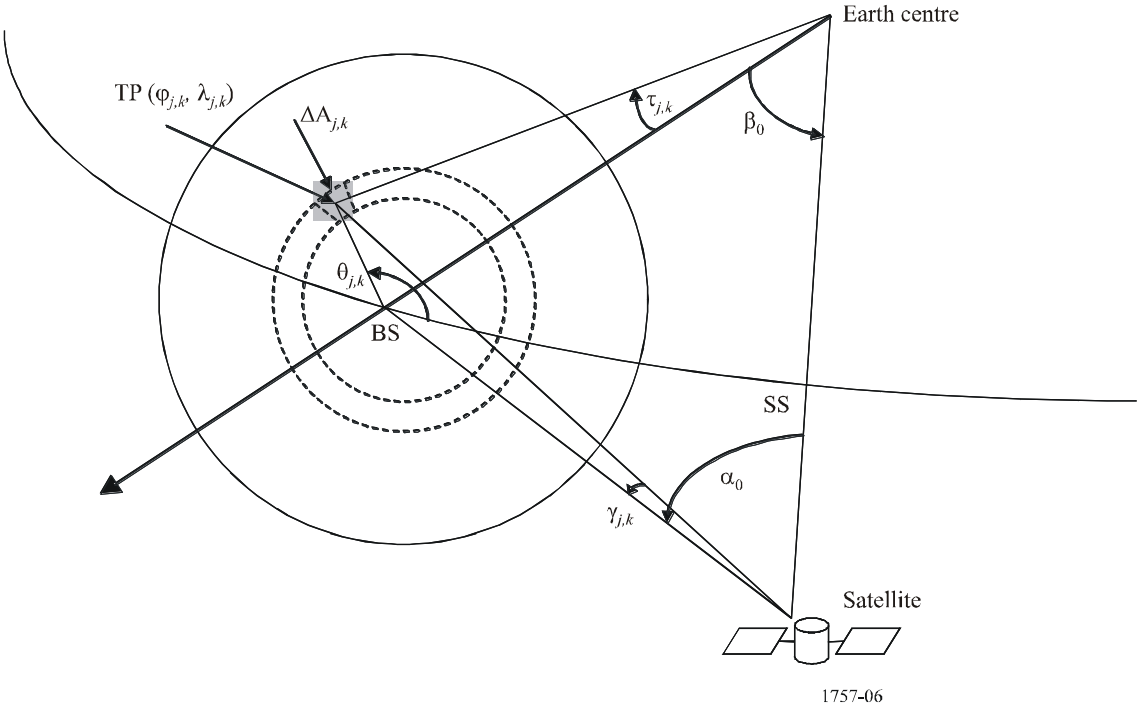
The circular summation area is divided into small circular areas surrounding the boresight and *N* concentric rings centred on the boresight, one of which is illustrated in Fig. 6. Standard geometric formulas are used to calculate the size of the small circular area in terms of a zone of the spherical surface with one base, and the area of a concentric ring in terms of a zone with two bases of the spherical surface.

For the summation, each ring is divided into *M* sectors, each spanning an azimuth angle of 360°/*M*. Thus, there are $N(M + 1)$ elemental areas in the summation (*N* and *M* here are different from those in Table 2). Each sector defines an elemental area ΔA_{jk} surrounding a test point (TP) that characterizes the interference contribution to the interference summation. At each step of the summation, the location of the test point is defined in terms of an Earth central angle τ_j to the centre of the elemental area and by the azimuth θ_k between 0° and 360°, with the great circle arc from BS to SS along the Earth's surface defining the 0° direction. The TP (τ_j, θ_k) coordinates can be transformed into other coordinate systems for calculating the off-axis angle $\gamma_{j,k}$ at the satellite to

evaluate the antenna gain and for calculating the distance $d_{j,k}$ between the satellite and test point needed to calculate the path loss.

FIGURE 6

Basic geometry of uplink ring summation



The total received interference power I_{total} is calculated from equation (15):

$$I_{total} = I_0 + \sum_{j=1}^{N}\sum_{k=1}^{M} EIRP_{uwb} - L\left(d_{j,k}\right) + G_{sat}\left(\gamma_{j,k}\right) + 10\log_{10}\left(\eta\,\rho_{uwb}\Delta A_{j,k}\right) \quad (15)$$

where:

I_0: interference contribution (dBW/B_{REF}) from the central zone from equation (16)

$EIRP_{uwb}$: average UWB e.i.r.p. in the direction of the satellite receiver within the reference bandwidth (dBW/B_{REF})

$L\left(d_{j,k}\right)$: propagation loss (dB) for distance $d_{j,k}$ from transmitter to elemental area $\Delta A_{j,k}$

$G_{sat}\left(\gamma_{j,k}\right)$: antenna gain (dBi) at off-axis angle $\gamma_{j,k}$ towards elemental area $\Delta A_{j,k}$

ρ_{uwb}: UWB density (devices/km^2)

η: activity factor of emitters

$\Delta A_{j,k}$: elemental area (km^2) for summation step (τ_j, θ_k)

$$I_0 = EIRP_{uwb} - L\left(d_0\right) + G_{sat}\left(0\right) + 10\log_{10}\left(\eta\,\rho_{uwb}\cdot\Delta A_0\right) \quad (16)$$

where:

d_0: distance from satellite to beam boresight on Earth's surface (km)

$G_{sat}(0)$: sensor main beam gain (dBi)

ΔA_0: area of central zone (km^2) = $2 \cdot \pi \cdot E_{radius}^2 (1 - \cos(\tau_0))$ where τ_0 is a small Earth central angle and E_{radius} = 6 378 km

Each ring area is defined by the Earth central angle τ_j pointing to its centre, and by an azimuth angle measured from the BS-SS great circle arc, whose values are given by:

$$\tau_j = (j - 0.5) \cdot (\Delta\tau) + \tau_0 \qquad \text{and} \qquad \Delta\tau = \frac{\tau_{max} - \tau_0}{N} \tag{17a}$$

$$\theta_k = (k - 0.5) \cdot (\Delta\theta) \qquad \text{and} \qquad \Delta\theta = \frac{360^\circ}{M} \tag{17b}$$

The size of each elemental area $\Delta A_{j,k}$ (km$^{2)}$ is calculated as follows:

$$\Delta A_{j,k} = \frac{2 \cdot \pi \cdot E_{radius}^2 \cdot [\cos(\tau_{k-1}) - \cos(\tau_k)]}{M} \tag{18}$$

This methodology has very general application, for GSO and non-GSO satellite networks, and can be used to make estimates as accurate as desired by increasing the number of elemental areas $\{\Delta A_{j,k}\}$. However, the calculation of I_{total} is quite complex in the general case.

This methodology assumes free-space propagation conditions between emitter(s) using UWB technology and the victim receiver. The impact of propagation through walls, roofs, other obstructions, and cables may have to be considered based on the deployment scenario.

2.3.4.1.2 Simplified summation methodology for GSO satellite uplinks

Three different approximations of the above methodology described below can be used in different applications. The three approximations are similar in that the satellite antenna gain of the GSO satellite is approximated as being constant out to a specified distance from the boresight of the antenna beam, and equal to zero beyond that distance. These approximations differ in the specification of the antenna gain within the contour, and the size of that contour around the antenna boresight.

The receiving antenna of a GSO satellite can receive interference from a very large number of transmitting devices using UWB technology. Because of this, the aggregate interference at the satellite receiver from the devices using UWB technology can be Gaussian in nature, independent of the detailed characteristics of the UWB waveform or its duty cycle. The UWB parameter of concern is the total interference power at the satellite receiver input from the devices using UWB technology located on the Earth's surface, weighted by the satellite's receiving antenna gain characteristics.

For free-space propagation, the interference power I_j from the j-th transmitting device using UWB technology received in B_{MHz} bandwidth is:

$$I_j = P_j + G_j - 92.5 - 20 \log(d_j) - 20 \log(f) - L_A + G_{SAT}(j) + 10 \log(B_{MHz}) - L_R \tag{19}$$

where:

P_j: average power density delivered to the transmit antenna (dBW/MHz) of the UWB device, averaged over a reference bandwidth = 1 MHz

G_j: gain in dBi of the j-th UWB transmit antenna towards the satellite

d_j: distance in km from the j-th transmitting device using UWB technology to the satellite

f: carrier frequency (GHz)

L_A: clear-air atmospheric attenuation (dB)

$G_{SAT}(j)$: gain in dBi of the satellite's receiving antenna toward the j-th transmitting device using UWB technology

B_{MHZ}: IF bandwidth of the satellite receiver (MHz)

L_R: insertion loss (loss between the receiver antenna and receiver input) (dB). A zero dB may be assumed if no value is available.

Equation (19) is valid for free-space propagation conditions.

The aggregate power at the satellite receiver is the power addition of the N individual interfering terms $\{I_j\}$. The result of that power addition (dB) terms, is:

$$I_{AGG} = 10 \log \left\{ \sum_j 10^{(Ij/10)} \right\} \tag{20}$$

Note that the number N over which this power sum is theoretically done is expected to be a very large number.

Different types of simplification can be made to equation (19), depending on its application, to make estimation of the aggregate interference at the satellite receiver more tractable.

– One approximation of equation (19) in order to estimate whether interference from devices using UWB technology is potentially harmful in uplink path of the satellite network involves the following:
  – The distances $\{d_j\}$ are each replaced by the distance to the satellite from the location on the ground of the boresight of the satellite beam, as described in Annex II of RR Appendix 8. That distance is specified as d_0.
  – The gain G_j of the j-th UWB transmitter is set at unity or 0 dBi for all j. The rational for this is that the direction of the antennas of the devices using UWB technology are at random angles with respect to the direction of the satellite. Averaged over all directions, the gain of an antenna is by definition unity or 0 dBi.
  – The power density P_j delivered to the antenna of each of the j-th UWB transmitters is set at the maximum permissible average value for that device.
  – The satellite gain $G_{SAT}(j)$ is replaced by a value which is 3 dB below the satellite peak gain.
  – As a complementary approximation to No. 4 above, the addition is carried out over an area of the Earth's surface covered by the satellite antenna's beam down to 20 dB below its peak value.

Other combinations of simplifications 4 and 5 can be made as appropriate.

With these simplifications, equation (20) can be re-written as:

$$I_{AGG} = 10 \log(N) + P - 92.5 - 20 \log (d_0) - 20 \log(f) - L_A + G_{SAT}(-3 \text{ dB}) - L_R - L_{AF} \tag{21}$$

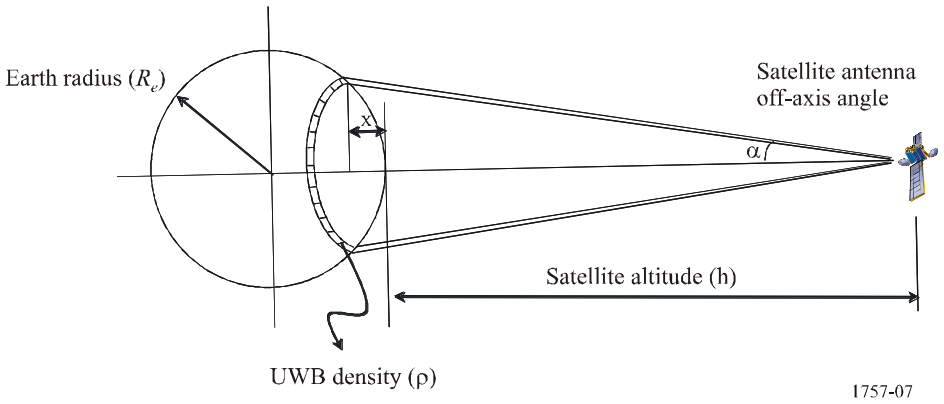
where L_{AF} (dB) is the activity factor of the multiple devices using UWB technology.

The only UWB parameter not specified in the right side of equation (21) is N. If I_{AGG} is known the maximum number of devices using UWB technology, N, within the −3 dB contour of the satellite antenna beam can be calculated.

– A second approximation of equation (19) is to calculate the aggregate interference at an FSS satellite receiver by assuming the sub-satellite point for a nadir-pointing beam with a constant antenna gain. The interference is then calculated by integrating UWB transmissions over the satellite coverage area. Figure 7 illustrates the geometry.

FIGURE 7

Aggregate UWB – FSS satellite interference geometry



In this approximation G_{SAT} is set at the maximum antenna gain instead of the −3 dB gain, and set equal to zero outside of a specific value of G_{SAT}, possibly the −3 dB contour of the antenna gain.

– A third approximation of equation (19) assumes a relationship between the coverage area and the antenna gain without taking into account the elevation angle seen from the devices using UWB technology. This approximation can be implemented by assuming that the gain within the satellite antenna beam is constant over the coverage area (s m^2). The satellite antenna gain G_{sat} is approximated by:

$G_{sat} \approx 10 \log (4\pi\ r^2/s)$, where r (m) is the distance between the satellite and its coverage area. This approximation is essentially the same as the above two, in which the gain is a constant value out to a specified contour, and set equal to zero outside of this contour.

Interference from devices using UWB technology into FSS uplink is calculated as:

$$\begin{aligned} I_{AGG} = \quad & P_d + 10 \log s + G_{sat} - 20 \log(4\pi r/\lambda) - L_R - L_{AF} \\ \approx \quad & P_d + 10 \log s + 10 \log (4\pi r^2/s) - 20 \log(4\pi r/\lambda) - L_R - L_{AF} \\ & = P_d + 10 \log(\lambda^2/4\pi\square\square) + 10 \log(B_{MHz}) - L_R - L_{AF} \end{aligned} \tag{22}$$

where P_d is the e.i.r.p. density/ m^2 averaged over satellite beam coverage.

Equation (22) is for a line-of-sight between UWB emitters and the satellite receiver. In addition, it assumes all devices using UWB technology to operate simultaneously.

The difference between this approximation and that in first approximation above is that in this case the result is expressed in terms of the power transmitted from the devices using UWB technology and the number of such active devices/m^2, rather than the device power and the number of devices

within the antenna beam. Both descriptions have their own application in the overall study of the impact of devices using UWB technology on uplink breams of GSO satellite networks.

2.3.4.2 Satellite downlink methodology

A receiving earth station can be impacted by the aggregate effect of a population of devices using UWB technology located around it.

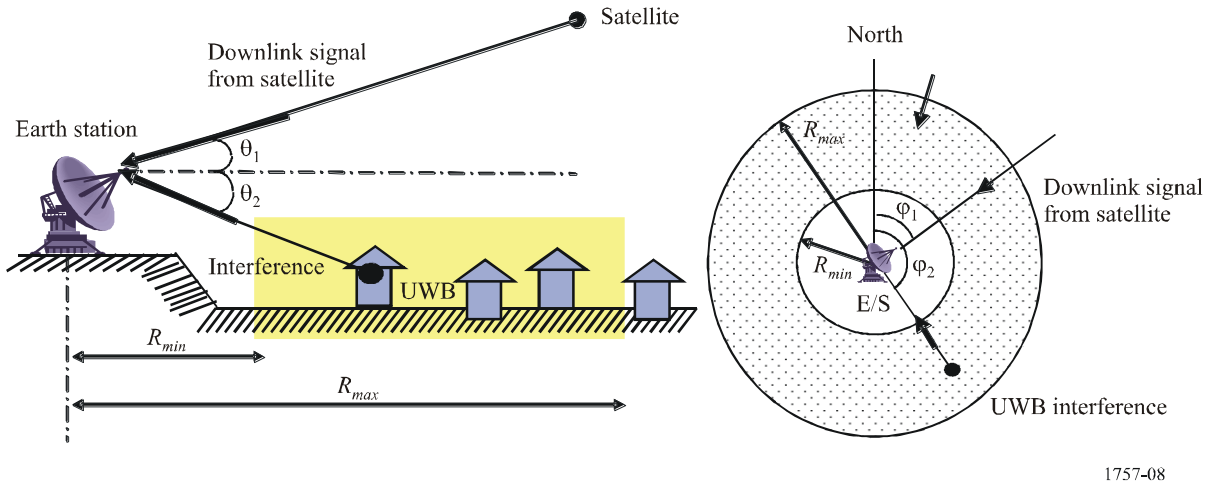
To determine the extent of such an effect, the following model can be used to simulate a distribution of identical devices using UWB technology uniformly or randomly distributed around the earth station receiver subject to the following constraints:

$$R_{min} < r \leq R_{max}, \qquad 0 < \varphi \leq 2\pi\ , \qquad 0 < z \leq Z_{max} \tag{23}$$

The inner radius is reflective of the extremely low probability that any device using UWB technology may be present closer than R_{min} to a fixed antenna system. The outer radius of R_{max} is assumed to be the maximum distance such that any emitter using UWB technology placed beyond this point from the fixed antenna would not make a significant contribution to the aggregate interference level. The distribution in z should account for locations in buildings of devices using UWB technology. This distribution represents an earth station deployed at the centre of a dense urban deployment configuration. Figure 8 shows how a distribution of emitters using UWB technology could be placed uniformly or randomly within a radius of R_{max} and an earth station antenna height of h_0.

FIGURE 8

Geometry for aggregate interference analysis



The offset angle α is the combined angle derived from elevation and azimuth angle from the earth station antenna in the direction of the emitter using UWB technology, and is calculated by equation (24) (see Fig. 8 for definition of θ_1, θ_2, φ_1 and φ_2).

$$\alpha = \cos^{-1}\{\cos(\theta_2 - \theta_1)\cos(\varphi_2 - \varphi_1)\} \tag{24}$$

If α_j represents the angle that the *j*-th emitter makes with the fixed antenna's boresight, then the off-axis gain of an FSS antenna in this scenario is computed by the constraint:

$$G(\alpha_j) = 32 - 25\log(\alpha_j) \quad \text{dBi} \qquad \text{when } 1° \leq \alpha_j \leq 48°$$

$$G(\alpha_j) = -10 \text{ dBi} \qquad \text{when } 48° < \alpha_j$$

The formula for the earth station antenna gain shown above represents a bounding value for commonly used antennas in the FSS. The actual gain pattern of the antenna under consideration should be used when it is available.

The received UWB power at the Earth station receiver is computed using the equation:

$$I_j \text{ (dBW/MHz)} = P_j + G_R(\alpha_j) - L_p(d_j) - L_R \quad (25)$$

where:

P_j: e.i.r.p. density (dBW/MHz) of the transmitting device

d_j: distance (km) from the j-th transmitting device to the earth station

Lp: appropriate path loss attenuation (dB) including man-made blockage

$G_R(\alpha_j)$: gain in dBi of the Earth station receiving antenna toward the j-th transmitting UWB device

L_R: insertion loss (loss between the receiver antenna and receiver input) (dB). A zero dB may be assumed if no value is available.

The aggregate power at the earth station receiver is the power addition of the N individual interfering terms $\{I_j\}$ as given in equation (20).

An appropriate path loss model should be used to compute the received power taking into account whether the device using UWB technology is outdoor or inside a building.

2.3.5 Airborne aggregate interference model

The airborne aggregate interference model can be directly used for both satellite receivers and receivers on board aircraft including aeronautical mobile earth stations (MESS) terminals.

The average aggregate interference A in (W per unit bandwidth) can be written as:

$$A = \alpha\rho\pi R_e \ln\left(\left(2(R_e + h)H + h^2\right)/h^2\right)/(R_e + h) \quad (26)$$

with:

$\alpha = e.i.r.p.(\lambda/4\pi)2.G_R$: constant term valid in the case of omnidirectional emissions and free-space propagation

$e.i.r.p$: average e.i.r.p. of the transmitting device (W per unit bandwidth)

G_R: victim receiver antenna gain

λ: wavelength (m)

ρ : average density of emitters (emitters/m^2)

R_e: Earth's radius

h: satellite height (m)

R: radius of the observed zone

$H = R_e(1 - \cos(R/R_e))$.

This methodology assumes all devices using UWB technology to be active simultaneously. Additional factors may have to be considered based on the deployment scenario:

– additional losses due to propagation through walls, roofs, or other obstructions (e.g. indoor);

– the insertion loss (loss between the receiver antenna and receiver input) (dB). A unity value (zero dB) may be assumed if no value is available.

2.3.6 Application of the link budget methodology for multiple emitters using UWB technology

The link budget methodology can be used to calculate the impact of multiple emitters using UWB technology on a victim receiver. An additional factor that accounts for multiple emitters using UWB technology can be added to equation (1) of § 2.2.1. Example applications of this methodology to radionavigation and aeronautical safety services are given below.

2.3.6.1 Applicability of the link budget methodology to assess interference from multiple emitters using UWB technology into RNSS

For multiple emitters using UWB technology, an additional factor to account will be added. Equation (2) becomes:

$$EIRP_{MAX} = I_{MAX} - GR(\theta) + L_P + L_R + L_{AF} - L_{safety} - L_{allotment} - L_{multiple} \quad (27)$$

where:

$L_{multiple}$: a factor to account for multiple UWB devices (dB).

$L_{allotment}$: factor to be considered if there is a potential for other than UWB interference sources at the same time, an allowance should be made for the aggregate interference (dB).

A further description of the methodology can be found in § 2.2.1.

2.3.6.2 Applicability of the link budget methodology to assess interference from multiple emitters using UWB technology into aeronautical safety services

The level of harmful interference into aeronautical safety systems needs to be determined on a case-by-case basis in form of a safety analysis. This analysis would assess the use being made of the safety system and demonstrate that the specific integrity level is still maintained under all operational conditions.

This section outlines the applicability of the link budget methodology, which may be used for the initial evaluation of the potential for interference to aeronautical safety services from emissions of devices using UWB technology. Safety services in general are based on the reception of emissions with higher levels of integrity and availability than is generally required for other radiocommunication services. Ultra-wideband devices may affect, simultaneously, stations of several aeronautical safety services including the aeronautical radio navigation services (ARNS), aeronautical mobile service (route) (AMS(R)) and aeronautical mobile satellite service (route) (AMSS(R)).

$$EIRP_{MAX} = I_{UWB\text{-}max} + L_R + L_{AF} - L_{safety} - L_{allomentt} - L_{multiple} \quad (28)$$

where:

$EIRP_{MAX}$: tolerable interference emission limit of a single device (dBm/MHz)

I_{UWB_max}: maximum level of UWB interference signal power at the victim receiver antenna port that still allows the receiver to meet its performance requirements. To be derived by measurements when the desired signal is at the appropriate minimum required level, and the result may be specific to the UWB waveform tested (dBm/MHz)

L_{safety}: aeronautical safety service margin (dB) (see also Recommendations ITU-R M.1477 and ITU-R M.1535);

$L_{multiple}$: factor to be considered if there is a potential for more than one UWB source of interference at the same time, an allowance should be made for the aggregate interference (dB). The propagation loss and antenna gain are included in this factor. For the determination of $L_{multiple}$ the formula given for the airborne aggregate model may be used after rearrangement.

$$L_{multiple} = 10 \log \left(\frac{\lambda^2 \cdot G_R \cdot \rho \cdot R_e}{16 \pi (R_e + h)} \cdot \ln \left(\frac{2(R_e + h) \cdot H + h^2}{h^2} \right) \right)$$

Different parameters of devices using UWB technology may have an impact on the transmitted waveform. It is important to note that different interference signal characteristics could affect the operation of aeronautical safety services in different ways. Annex 10 to the Convention on International Civil Aviation does not specify all receiver interference protection criteria necessary to fully evaluate the potential for interference to aeronautical safety services from emissions of devices using UWB technology.

A key element for the interference analysis is the knowledge of the maximum value of UWB interference signal power I_{UWB_max} that still allows the receiver to meet its performance requirements. These values need to be derived by measurements, and the results may be specific to the UWB waveform tested. Therefore, standardized test procedures need to be developed. Recommendation ITU-R SM.1140 may provide guidance in the development of such test procedures. Caution should be exercised with the application of frequency assignment planning criteria for harmful interference from non-aeronautical sources. These criteria adopted internationally within the aeronautical services are based on the operational usage and the interference environment. In addition, there is comprehensive and significant additional protection provided through the organizational instruments, such as international aeronautical standards, practical testing, safety cases and equipment certification, with ICAO as a focal point (see also Recommendation ITU-R SM.1535). The additional protection measures are largely non-existent for non-aeronautical sources, some of which are only partially regulated by the ITU. Consequently, there is not necessarily an inherent relationship between aeronautical protection criteria and those criteria which may be appropriate to safety services for application to non-aeronautical sources of harmful interference. Each potential non-aeronautical source of harmful interference requires individual consideration in this respect.

2.4 Method to determine the bandwidth correction factor (BWCF)

The methodologies to determine the impact of one device using UWB technology or an aggregation of devices using UWB technology on radiocommunication systems are premised on determining the maximum permitted e.i.r.p levels of these devices and the minimum separation distance between them and radiocommunication systems. Given that devices using UWB technology are characterized by an extremely large bandwidth compared to traditional radio service applications, it is important to determine the permitted e.i.r.p density of devices using UWB technology in a reference bandwidth (B_{REF}).

A victim receiver generally has an IF or selectivity bandwidth (B_{RX}) that is different from the reference measurement bandwidth used to determine the e.i.r.p. of an UWB transmitter. Hence, a second step in determining e.i.r.p. levels is to posit a bandwidth correction factor (BWCF). A BWCF relates the average (rms) power level measured within the reference bandwidth (typically

1 MHz) and provides a correction for the UWB signal's average power level ($BWCF_A$) or peak power level ($BWCF_P$) observed within a victim receiver's selectivity filter bandwidth.

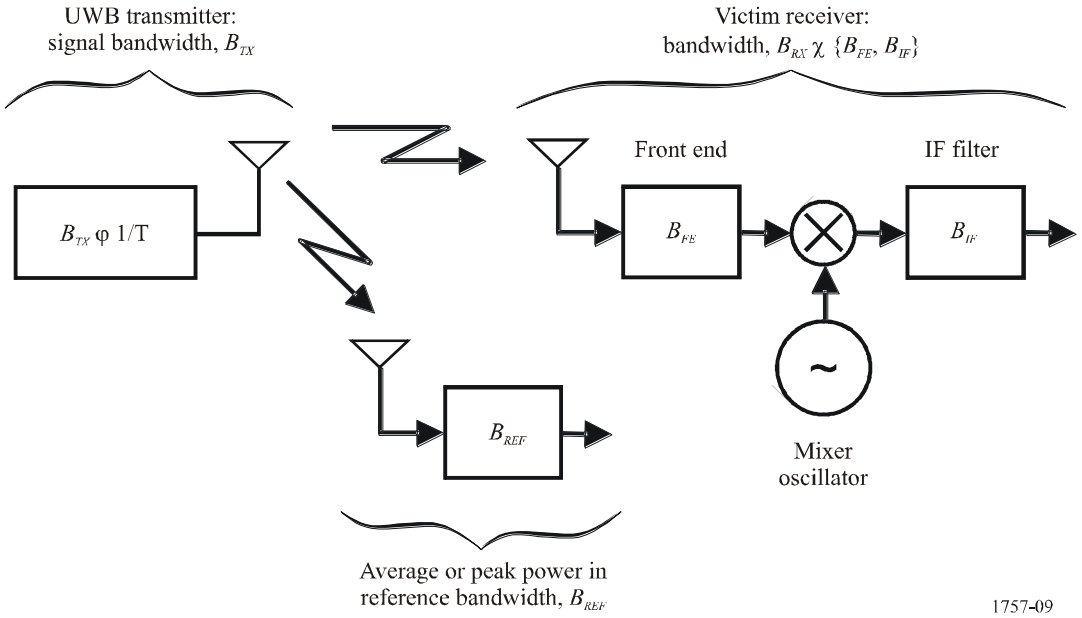
2.4.1 Determination of emission and interference power levels

An initial step in determining the maximum permitted effective isotropic radiated power (e.i.r.p.) level and the separation distance required to ensure protection is to establish a method to determine an UWB transmitter's e.i.r.p. and the resulting interference level within a victim receiver's selectivity bandwidth. Figure 9 shows the generic situation of an UWB transmitter emitting pulsed signals of width T, spreading its emitted energy over a bandwidth $B_{TX} \approx 1/T$, and a victim receiver with front end (FE) filter bandwidth B_{FE} and Intermediate Frequency filter with bandwidth B_{IF}, where for UWB signals both B_{FE} and B_{IF} are inherently much smaller than $B_{TX} \approx 1/T$. The Figure also indicates the determination of the transmitter's emitted average or peak power as observed in the reference bandwidth B_{REF}, with B_{REF} also much smaller than B_{TX} (i.e. $B_{REF} << B_{TX}$).

There are two reasons for determining the average and peak power levels of UWB signals observed at a victim receiver: (i) to assess the potential of the FE to overload (nonlinear behaviour) and (ii) to assess the potential interference level at the victim receiver's selectivity filter, which is usually the IF filter. Thus, depending on the receiver's performance criteria, the average and peak power levels of the interfering UWB signal will be determined at the output of either the FE filter (B_{FE}) or, more likely, the IF (selectivity) filter (B_{IF}). The receiver's (selectivity) bandwidth (B_{RX}) will be represented by either B_{FE} or B_{IF}, depending on the selection criteria. It should be the smallest bandwidth of B_{FE} and B_{IF} as could be seen from Fig. 9.

FIGURE 9

Generic setup for determination of emission and interference power levels



It is assumed that the average and peak powers of UWB signals are determined (calculated, simulated or measured) within a reference filter bandwidth B_{REF} that is much smaller than $1/T$.

Narrowband victim receivers operate with selectivity bandwidths much smaller than the emitted UWB signal's bandwidth – i.e. $B_{TX} \approx 1/T$. For example, one particular administration has determined that 50 MHz is about the widest bandwidth that would be employed by any victim radio receiver of an authorized radiocommunication service. Thus, this administration proposed to

determine the peak power with a reference bandwidth of at most 50 MHz, while for practical reasons (e.g. selectivity of available measurement equipment) a measurement bandwidth of at least 1 MHz was found appropriate. Therefore, this administration adopted for average power determination B_{REF} = 1 MHz and for peak power determination 1 MHz ≤ B_{REF} ≤ 50 MHz.

2.4.2 Definition of non-dithered and dithered UWB signals

Although a BWCF must be applicable to all types of (modulated) UWB signals, one administration defined it specifically for non-dithered and dithered signals, where:

– non-dithered UWB signals are defined as a series of identical pulses emitted at fixed time intervals between pulses (constant PRF);

– dithered UWB signals consist of identical, time-hopped pulses, emitted one pulse per time slot whose duration is 1/PRF, with randomly varying time intervals between pulses that are uniformly distributed over at least one half of the time slot duration period.

2.4.3 Observation time window

An observation time window must be defined in two situations:

– when average UWB signal power levels are determined by computational simulations or

– when average power measurements on UWB signals are performed. A value for the observation time window of one millisecond (1 ms), implying implies that meaningful results for pulsed UWB signals can only be obtained if their PRF is larger than about 10 kHz. Correspondingly, the lowest assumed PRF for pulsed UWB signals is 10 kHz.

The required observation time window to determine the peak power of an UWB signal has not been discussed in the available technical literature. However, it has been verified by simulation that a value of one tenth of 0.1 ms appears adequate to obtain stable results.

2.4.4 Average and peak power determination

Consider a victim receiver's interference relevant bandwidth B_{RX}, where from previous definitions (see Fig. 9) B_{RX} can be either B_{IF} or B_{FE}. Denote further an average power measured within the receiver bandwidth B_{RX} as $P_A(B_{RX})$ and an average power measured within the reference bandwidth B_{REF} as $P_A(B_{REF})$. In all cases, it is assumed that the energy spectral-density of an individual UWB pulse has a constant value (E_P) across the victim receiver's bandwidth, B_{RX}. The BWCF for average power, $BWCF_A$, is then defined relative to the average (rms) reference power, $P_A(B_{REF})$, (dB) (here and elsewhere "log" is the logarithm for base 10) as:

$$BWCF_A = 10 \log\{P_A(B_{RX})/P_A(B_{REF})\} \quad (29)$$

Similarly, denote a peak power measured within the receiver bandwidth B_{RX} as $P_P(B_{RX})$ and a peak power measured within the reference bandwidth B_{REF} as $P_P(B_{REF})$. The BWCF for peak power, $BWCF_P$, is then defined relative to the average (rms) reference power, $P_A(B_{REF})$ (dB) as:

$$BWCF_P = 10 \log\{P_P(B_{RX})/P_A(B_{REF})\} \quad (30)$$

For pulsed UWB signals with a constant (non-dithered signals) or average (dithered signals) PRF, in units of Hz, the average and peak powers observed (measured) within a bandwidth B_M, where B_M is either B_{REF} or B_{RX}, can be obtained as follows:

Non-dithered signals:

$$P_A(B_M) = 1.064\, E_P\, B_M\, PRF \qquad \text{for} \qquad 10 \text{ kHz} \leq PRF < 1.064\, B_M$$

$P_A(B_M) = E_P\,(PRF)^2$ for $1.064\,B_M \le PRF$

$P_P(B_M) = 5.254\,E_P\,(B_M)^2$ for $PRF < 2.292\,B_M$

$P_P(B_M) = E_P\,(PRF)^2$ for $2.292\,B_M \le PRF$.

Dithered signals:

$P_A(B_M) = 1.064\,E_P\,B_M\,PRF$ for $10\text{ kHz} \le PRF$

$P_P(B_M) = 5.320\,E_P\,(B_M)^2$ for $PRF < 0.5\,B_M$

$P_P(B_M) = 10.64\,E_P\,B_M\,PRF$ for $0.5\,B_M \le PRF$

With the above definitions and results, substituting B_M as appropriate by B_{RX} or B_{REF}, gives expressions for $BWCF_A$ and $BWCF_P$ in terms of B_{RX}, B_{REF} and the PRF, as follows.

2.4.5 $BWCF_{A/P}$ for non-dithered UWB signals

For non-dithered UWB emissions, the *BWCF* for average power, $BWCF_A$, in units of dB, is given by the following expressions, where $PRF \ge 10$ kHz:

$BWCF_A = 0$ for $B_{RX} \le PRF$ and $B_{REF} < PRF$

$BWCF_A = 10 \log (PRF/B_{REF})$ for $B_{RX} \le PRF$ and $B_{REF} \ge PRF$

$BWCF_A = 10 \log (B_{RX}/PRF)$ for $PRF \le B_{RX}$ and $B_{REF} < PRF$

$BWCF_A = 10 \log (B_{RX}/B_{REF})$ for $PRF \le B_{RX}$ and $B_{REF} \ge PRF$

For non-dithered UWB emissions, the *BWCF* for peak power, $BWCF_P$, in units of dB, is given by the following expressions:

$BWCF_P = 0$ for $B_{RX} \le 0.45\,PRF$ and $B_{REF} < PRF$

$BWCF_P = 10 \log (PRF/B_{REF})$ for $B_{RX} \le 0.45\,PRF$ and $B_{REF} \ge PRF$

$BWCF_P = 20 \log\{B_{RX}/(0.45\,PRF)\}$ for $0.45\,PRF \le B_{RX}$ and $B_{REF} < PRF$

$BWCF_P = 10 \log\{(B_{RX})^2/(0.2\,PRF\,B_{REF})\}$, for $0.45\,PRF \le B_{RX}$ and $B_{REF} \ge PRF$

2.4.6 $BWCF_{A/P}$ for dithered UWB signals

For dithered UWB emissions, the *BWCF* for average power, $BWCF_A$, in units of dB, is given by the following expression, where $PRF \ge 10$ kHz:

$BWCF_A = 10 \log (B_{RX}/B_{REF})$ for any value of B_{RX} and B_{REF}

For dithered UWB emissions, the *BWCF* for peak power, $BWCF_P$, in units of dB, is given by the following expression:

$BWCF_P = 10 \log\{(B_{RX})^2/(0.2\,PRF\,B_{REF})\}$ for $0.2\,PRF < B_{RX}$ and any B_{REF}

For $B_{RX} \le 0.2\,PRF$, the UWB signal time waveform at the filter output with bandwidth B_{RX} will be noise-like and consequently, average (rms) power is more appropriate than peak power to assess receiver performance degradation. Therefore, to determine $BWCF_P$ for $B_{RX} \le 0.2\,PRF$, the equation $BWCF_A = 10 \log(B_{RX}/B_{REF})$ should be used for any value of B_{RX} and B_{REF}.

B_{RX} (= B_{IF}) = 50 MHz: For B_{IF} = 50 MHz, the $BWCF_P$ equation for dithered signals is not directly applicable to determine the peak power. For noise-like signals in particular, the peak power is roughly 10 dB greater than the average power. Hence, the equation's applicability in terms of *PRF* range has to be modified. Thus, for dithered signals with B_{RX} = 50 MHz, the *BWCF* for peak power, $BWCF_P$, is given as follows:

$$BWCF_P = 10 \log\{(B_{RX})^2/(0.2\ PRF\ B_{REF})\} \quad \text{for} \quad 2.0\ PRF < B_{RX} \text{ and any } B_{REF}$$

$$BWCF_P = 10 + 10 \log(B_{RX}/B_{REF}) \quad \text{for} \quad 2.0\ PRF \geq B_{RX} \text{ and any } B_{REF}$$

2.4.7 Classification of modulated UWB signals as non-dithered or dithered signals

Dithered and non-dithered UWB signals are based on very specific UWB pulses (see § 2.4.2). For any different type of (modulated) UWB signal, it is important to determine to what degree this signal's average and peak power properties match the respective properties of dithered or non-dithered signals. For any type of UWB signal the average and peak power characteristics are a function of the signal's specific modulation parameters; for pulsed UWB signals the PRF is the predominant parameter. However, the characterization as a dithered or non-dithered signal is not straightforward for modulation schemes where the PRF is not the primary modulation parameter.

The classification shown in Table 3 can provide a useful guideline of what can be expected of a signal's properties in terms of its dithered or non-dithered nature.

TABLE 3

Classification of modulated UWB signals of equal power and the approximate range of the *PRF* (for average power determination: *PRF* ≥ 10 kHz) where the average or peak power level coincides with the corresponding power level

Modulation	Average power		Peak power	
	Non-dithered	**Dithered**	**Non-dithered**	**Dithered**
Non-dithered	any *PRF*	$PRF < B_M$	Any *PRF*	$PRF < 0.5\ B_M$
Dithered	$PRF < B_M$	Any *PRF*	$PRF < 0.5\ B_M$	any *PRF*
2-PAM[1] (Binary antipodal)	$PRF < B_M$	Any *PRF*	$PRF < 10\ B_M$	$PRF < 0.5\ B_M$ and $10\ B_M < PRF$
2-PPM[2]	any *PRF*	$PRF < B_M$	$PRF < B_M$	$PRF < 0.5\ B_M$ and $10\ B_M < PRF$
2-PAM/2-PPM[3]	$PRF < B_M$	Any *PRF*	$PRF < B_M$	$PRF < 0.5\ B_M$ and $10\ B_M < PRF$
White gaussian noise	$PRF < B_M$	Any *PRF*	$PRF \approx 10\ B_M$[4]	$0.5\ B_M < PRF$[4]
DS-UWB[5]	$PRF < B_M$	Any *PRF*	$PRF < 10\ B_M$	$PRF < 0.5\ B_M$ and $10\ B_M < PRF$
OFDM	OFDM UWB signals cannot be characterized with a *PRF* parameter, therefore they cannot simply be characterized as "dithered" or "non dithered" signals			

(1) 2-PAM: Binary pulse amplitude modulation; i.i.d. polarity modulated stream of pulses.

(2) 2-PPM: Binary pulse position modulation; pulse delay equals 50% of the symbol duration (1/PRF).

(3) Combination of 2-PAM and 2-PPM (i.e. 2 bits/symbol).

(4) The peak power of a white gaussian noise signal with average power PA exceeds the peak power of a pass-band filtered (BM) dithered signal of the same average power PA with a probability of 0.001% when the signal's PRF satisfies BM < 2.0 PRF.

(5) DS-UWB signals have been considered as pulsed signals for a data rate of 110 Mbit/s.

In Table 3, the bandwidth B_M stands for the reference measurement bandwidth B_{REF} or the victim receiver's selectivity bandwidth B_{RX}, i.e. B_M corresponds to either B_{REF} or B_{RX}.