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Technical Report

Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra Wide Band Sensor technology (UWB); System Reference Document; Part 2: Object Discrimination and Characterization (ODC) applications for power tool devices operating in the frequency band of 2,2 GHz to 8,5 GHz

Reference

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Contents

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM).

The present document is part 2 of a multi-part deliverable covering Short Range Devices (SRD) System Reference Documents; Technical characteristics for SRD equipment using Ultra Wide Band technology (UWB) for sensor applications as identified below:

Part 1: "Building material analysis and classification applications operating in the frequency band from 2,2 GHz to 8 GHz";

Part 2: "Object Discrimination and Characterization (ODC) applications for power tool devices operating in the frequency band of 2,2 GHz to 8,5 GHz";

Part 3: "Location tracking applications type 1 operating in the frequency band from 6 GHz to 9 GHz for indoor and outdoor usage";

Part 4: "Object identification for surveillance applications operating in the frequency band from 2,2 GHz to 8 GHz";

Part 5: "Location tracking applications type 2 operating in the frequency band from 6 GHz to 9 GHz for indoor and outdoor usage";

Part 6: "Object Detection for mobile, construction, agriculture and off-road applications operating in the frequency band from 6 GHz to 8,5 GHz".

Introduction

Ultra wide band sensors enable a new generation of devices, allowing the identification and classification of objects, in addition to detecting their presence and position. The operation is contactless and works over a short distance of less then 40 cm, even if the object is hidden by an obstacle.

Applications for such devices are widespread. The following list gives an overview:

- Position detection and identification of human extremities for enhanced operational safety with potentially dangerous tools.
- Pre-impact protection and pre-impact detection or direct contact avoidance for hidden objects to be detected for building work applications.

Frequencies in the lower GHz range are prerequisite for such a kind of object classification equipment, allowing the electromagnetic wave to penetrate objects like cloth or human tissue. The wave penetrating an object inside returns much more information (such as inhomogenities, object composition, dielectricity, etc.) about the object than just the surface reflection. A certain bandwidth is required to receive a characteristic response from the target and to ensure sufficient resolution needed for target separation.

The present document is based on the TR 102 495-2 [6] but specifies a subset of applications for power tools.

The present report is intended to include necessary information to be forwarded to the Electronic Communications Committee (ECC) under the MoU between ETSI and the ECC.

1 Scope

The present document provides information on the intended applications, the technical parameters and the radio spectrum requirements for UWB object classification sensor equipment operating in the frequency band from 2,2 GHz to 8,5 GHz.

The applications which operate in close proximities can be divided in two different categories:

Category 1: Proximity Sensing of Human tissue

- Sensing and position detection of human tissue (extremities) for user-protection applications, e.g. for tooling equipment (table top saw);

Category 2: Pre-impact protection (direct contact avoidance for building work)

- Measure the thickness of materials and penetrate materials for "Break through" protection and avoid direct contact for building, construction type work (e.g. drilling machine); pre-impact detection.

The present document includes necessary information including:

- Detailed market information (annex A).
- Technical information (annex B).
- Expected compatibility issues (annex C).

The present document does not cover communication, through-wall, building material analysis and classification and ground probing radar devices.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication and/or edition or version number) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long term validity.

[1] CEPT/ECC Report 64: "The protection requirements of radiocommunication systems below 10.6 GHz from generic UWB applications" Helsinki, February 2005.

[2] CEPT/ERC Report 25: "The European Table of Frequency Allocations and Utilizations Covering the Frequency Range 9 kHz to 275 GHz" Lisboa January 2002 - Dublin 2003 - ey 2004 - Copenhagen 2004.

[3] Void.

[4] ETSI TR 102 495-1: "Electromagnetic compatibility and Radio spectrum Matters (ERM);Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra Wide Band Sensor technology (UWB); System Reference Document Part 1: Building material analysis and classification applications operating in the frequency band from 2,2 GHz to 8 GHz".

[5] CEN TR 15350: "Mechanical vibration- Guideline for the assessment of exposure to hand-transmitted vibration based on information provided by manufacturers of machinery".

[6] ETSI TR 102 495-2 (V1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra Wide Band Sensor technology (UWB); System Reference Document Part 2: Object Discrimination and Characterization applications operating in the frequency band from 2,2 GHz to 8 GHz".

[7] ETSI EN 302 435: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra WideBand technology (UWB); Building Material Analysis and Classification equipment applications operating in the frequency band from 2,2 GHz to 8 GHz; Part 2: Harmonized EN covering essential requirements of article 3.2 of the R&TTE Directive".

[8] ECC/DEC/(06)04: ECC Decision of 24 March 2006 on the harmonized conditions for devices using Ultra-Wideband (UWB) technology in bands below 10,6 GHz.

[9] ECC/DEC/(07)01: ECC Decision of 30 March 2007 on Building Material Analysis (BMA) devices using UWB technology.

[10] M 0407: Standardization mandate forwarded to CEN/CENELEC/ETSI for harmonized standards covering ultra-wideband equipment.

[11] ECC(07)(050)R2: Minutes of the 16th meeting of ECC, Krakow, 26-30 March 2007.

[12] Springer Engineering tables, ISBN 3-540-64159-9; Springer publishing 2/2004.

[13] "M-Sequence Ultra-Wideband-Radar: State of Development and Applications", Sachs, J.; Peyerl, P.; Zetik, R.; Crabbe, S., Radar 2003, Adelaide (Australia), pp. 6, September 2003.

[14] "Radar Imaging of Small Objects Closely Below the Earth Surface", PhD from Norwegian University of Science and Technology, NTNU, Trondheim, 2000 Egil S. Eide:.

[15] "Visible Human Project".

NOTE: See http://www.nlm.nih.gov/research/visible/visible_human.html.

[16] U.S. Consumer Product Safety Commission;

NOTE: See http://www.cpsc.gov/.

[17] "Final report of the safety Working Group on road safety"; Directorate-General for the Information Society of the European Commission.

[18] "Supplement 5 to OET Bulletin 65"; Federal Communications Commission;

NOTE: See http://www.fcc.gov.

[19] Holzberufsgenossenschaft Deutschland; Employers liability insurance association Germany, Munich;

NOTE: See www.holz-bg.de.

[20] FCC 03-03: "Revision of Part 15 of the Commission's Rules Regarding UWB Transmission Systems" April 5, 2005.

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

activity factor: reflects the effective transmission time ratio

clutter: undesired radar reflections (echos) e.g. from inhomogenities, interfaces

spatial resolution: the ability to discriminate between two adjacent targets

pre-impact detection: "break through" protection and direct contact avoidance for building work

Total Radiated Power (TRP): integration of the emissions in the whole area around the ODC-scenario

NOTE: The integration is over a sphere (same procedure as for Total Radiated Power (TRP) [7]). This value is comparable to an equivalent isotropic radiator.

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

CEPT	Conférence Européenne des Administrations des Postes et des Télécommunications
CW	Continuous-Wave
dB	deciBel
dBm	deciBel relative to 1 mW
DC	Direct Current
e.i.r.p.	equivalent isotropically radiated power
ECC	Electronic Communications Committee
ERC	European Radiocommunications Committee
ITU-R	International Telecommunications Union-Radio sector
LBT	Listen Before Talk
LDC	Low Duty Cycle
ODC	Object Discrimination & Characterization
PN	Pseudo Noise
ps	picosecond
RF	Radio Frequency
SINAD	Signal Including Noise And Distortion
SRD	Short Range Device
TRP	Total Radiated Power
UWB	Ultra WideBand

4 Executive summary

The present document describes a new generation of devices using Ultra Wide Band technology for object classification applications operating in close proximity to objects at distances less then 40 cm.

Such devices will lead to significant user-protection improvements in critical areas e.g. manual operation and material handling close to potentially dangerous tools, In consequence, a significant socio-economic benefit results from the introduction of these devices.

Reliable object discrimination and characterization can be achieved by using UWB technology. A reasonable bandwidth provides the required accuracy in combination with a sufficient level of radiated power to receive characteristic responses from objects and their precise position.

Market and technical information including the required spectrum, and a discussion of compatibility issues are presented in the annexes A and B.

4.1 Status of the present document

The draft of the present document was created in ERM TG31C and its version 1.2.1_2.0.3 was approved by WG ERM RM#36. It was subsequently submitted to WGFM for their consideration. After some further work, it was offered to TC-ERM#32 where it was approved for publication.

4.2 Market information

For detailed market information, see annex A.

4.3 Technical system description

For detailed technical information, see annex B.

5 Current regulations

The present ECC generic decision for UWB communications [8] is not applicable since lower frequencies are needed to penetrate the objects, i.e. human tissue or wet materials.

This sensor application features significantly different and more effective mitigation factors compared with UWB communication devices.

The FCC has released an UWB regulation in 4/2002 and the last revision was published in 04/2005 [3].

6 Proposed parameters for regulation

Based on the needs of the intended applications described in the scope of these present document, the following limits are proposed for the ongoing considerations in ECC WGFM and ECC WGSE.

The Total Radiated Power spectral density (definition see [7]) has to be 5 dB below the maximum mean e.i.r.p. spectral density limits in table 6.1.

Table 6.1: Proposed parameters for regulation

Frequency range	Maximum mean e.i.r.p. spectral density	Maximum peak e.i.r.p. (measured in 50 MHz)
Below 1,73 GHz See note 1	-85 dBm/MHz	-45 dBm
1,73 GHz to 2,2 GHz	-65 dBm/MHz	-25 dBm
2,2 GHz to 2,5 GHz	-50 dBm/MHz	-10 dBm
2,5 GHz to 2,69 GHz See note 1	-65 dBm/MHz	-25 dBm
2,69 GHz to 2,7 GHz See note 2	-55 dBm/MHz	-15 dBm
2,7 GHz to 3,4 GHz See note 1	-82 dBm/MHz	-42 dBm
3,4 GHz to 4,8 GHz	-50 dBm/MHz	-10 dBm
4,8 GHz to 5 GHz See note 2	-55 dBm/MHz	-15 dBm
5 GHz to 8 GHz	-50 dBm/MHz	-10 dBm
8 GHz to 8,5 GHz	-50 dBm/MHz	-10 dBm
8,5 GHz to 10,6 GHz	-65 dBm/MHz	-25 dBm
Above 10,6 GHz	-85 dBm/MHz	-45 dBm
NOTE 1: Devices using a Listen Before Talk (LBT) mechanism, and comparable emission levels as described in the draft harmonized standard EN 302 435 [7] which meets the technical requirements defined within annex 2 of the ECC/DEC/(07)01 [9], are permitted to operate in frequency range 1,215 GHz to 1,3 GHz with a maximum mean e.i.r.p. limit of -70 dBm/MHz e.i.r.p. and a maximum peak limit of -30 dBm/50MHz e.i.r.p. and from 2,5 GHz to 2,69 GHz and 2,7 GHz to 3,4 GHz with a maximum mean e.i.r.p. limit of -50 dBm/MHz e.i.r.p. and a maximum peak limit of -10 dBm/50MHz e.i.r.p. NOTE 2: To protect the RAS bands 2,69 GHz to 2,7 GHz and 4,8 GHz to 5 GHz, the Total Radiated Power spectral density has to be below -65 dBm/MHz.		

The minimum Pulse Repetition Frequency equals or exceeds 5 MHz.

The proposed regulation should be a general (non-individual) licensing arrangement for both categories.

It is also proposed that the regulation may contain appropriate mitigation requirements.

The mitigation factors to be considered for both categories are:

- Presence and position detection of different materials (i.e. triggered by a separate detection technology such as a light beam), This ensures a very short operating range, usage only in close proximity to the object.
- Integral antenna only.
- Listen-Before-Transmit functionality (LBT) as well as duty cycle restrictions (see clause A.3) may be employed which are in line with the operational requirements of the application requirements.

NOTE: Listen-Before-Talk as described in draft EN 302 435-1 [7] with the limits in compliance with ECC/DEC(07)01 [9].

- Mobile operation is excluded. The sensor is an integral and indispensable part of the tool in use. The tool itself can only be used when being stationary during use. The activation of the sensor occurs only when the tool is activated.
- Focused emissions, shielding and the TRP concept.

7 Main conclusions

The ODC sensor applications described in the present document presents a unique way for contactless identification of objects in the close proximity to potentially dangerous parts of tools. Such information include:

- accurate position, distance and size;
- material characteristics like complex permittivity.

Such devices will lead to significant improvements of the safety to operators during the operation of dangerous tools, to enhance user- safety. In consequence, a socio-economic benefit results from the introduction of these devices.

8 Expected ECC and ETSI actions

The new mandate M407 EN [10] was received by ETSI, calling for release of candidate Harmonized European Standards for UWB sensor applications.

WGFM and WGSE continue the work from ECC_TG3 and under revised terms of reference. This work includes UWB imaging devices such as UWB sensors (16th meeting of ECC, Krakow, 26-30 March 2007) [11].

ETSI requests ECC to consider the present document which includes the necessary information under the MoU between ETSI and the ECC for a new regulation for ODC sensor applications.

ETSI requests ECC to perform the relevant compatibility studies to determine whether the emissions and mitigation factors described in the present document are appropriate to protect radio services.

It is expected that ECC will create a new ECC decision early 2008 for ODC sensor applications operating in the frequency band from 2,2 GHz to 8,5 GHz.

A new draft Harmonized European Standard for the ODC sensor equipment covered by the present document is under development in ETSI ERM TG31C.

Annex A: Detailed market information

A.1 Range of applications

Ultra wideband sensors enable a novel class of applications, allowing the identification and classification of objects, additionally to detecting their presence and position. Such sensors also allow the monitoring of the status of an object or a person. A number of examples for applications are summarized below.

Category 1: Proximity Sensing of Human tissue, "Protection Sensing"

- detection of small objects like a finger or other extremities in the presence of obstacles (e.g. wood), positioned close to a hazard like a saw blade;
- applications typically for benchtop market, (increasing the occupational safety);
- usage in close proximity to hazard area (0 cm to 20 cm);
- tools are transportable but during usage stationary located or fixed at one position inside the building lot.

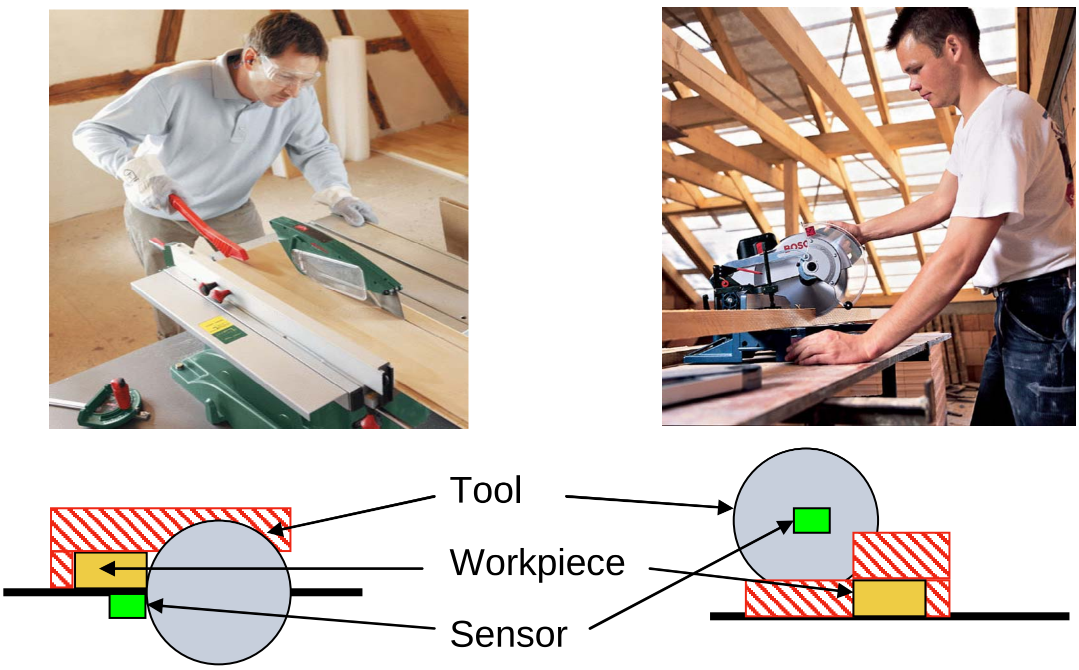

Figure A.1.1: Saw Scenario

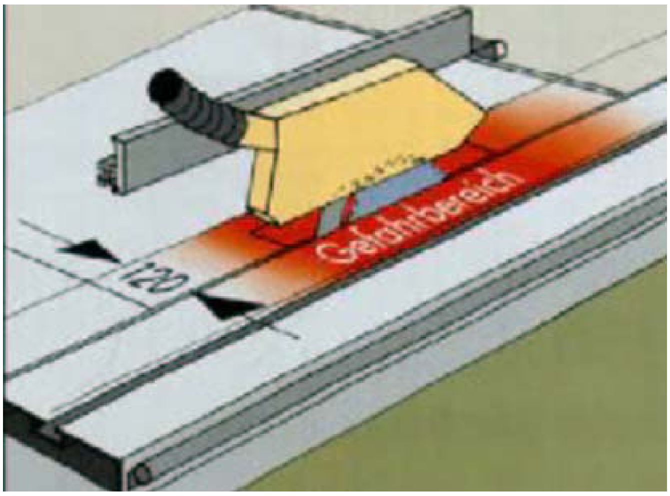

Figure A.1.2: Table top saw blade

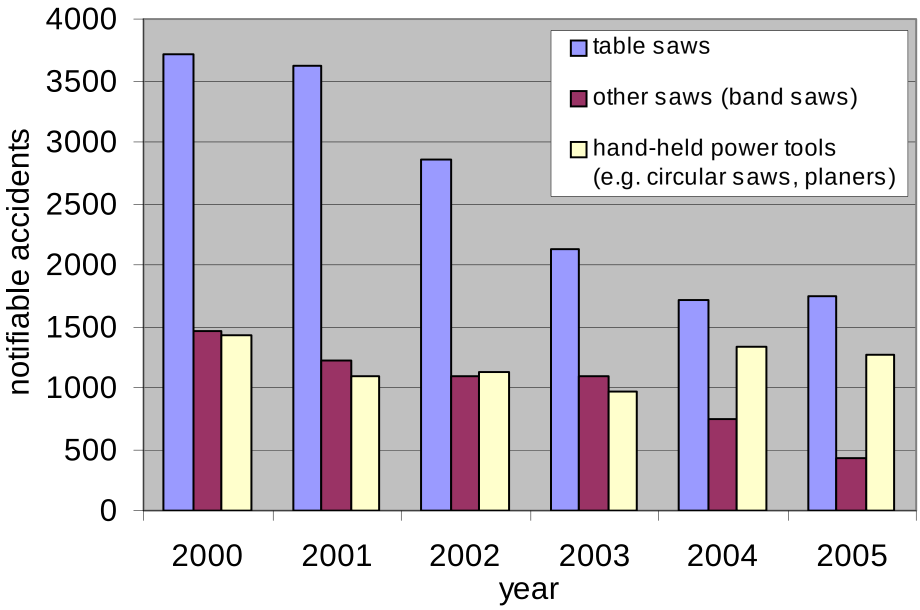

Figure A.1.3: Injuries from accidents in Germany [19]

U.S. hospitals treated an estimated 37 000 injuries resulting from table saw use in 2003 alone. More than three-quarters of injuries resulted from contact with the blade, including 4 100 amputations, according to the Consumer Product Safety Commission. The agency estimated the cost of table saw injuries in 2001 at nearly $2 billion [16].

Category 2: Pre-impact protection and direct contact avoidance for building work

The application will be used for high end drilling and percussion drilling machines. It is planned to mount it directly to the tool. The UWB sensor application monitors the drilling process and controls the drilling machine also depending on the inhomogenities in the material. The user will be warned acoustical or optical if a collision with unexpected objects inside the material (e.g. gas-water pipes or electric cables) may happen.

The UWB application will be active synchronously to the operation of the drilling machine which will be supported by this application.

The usage in close proximity to the area under work (0 cm to 40 cm).

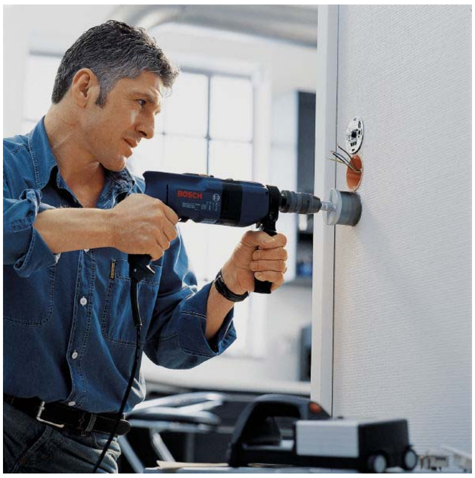

Figure A.1.4: Pre-impact situation

A.2 Market size and value

There is a certain demand for such devices in the European and global markets. The largest markets are driven by consumer applications such as proximity sensing as safety devices and object identification for security surveillance.

Category 1: Proximity Sensing of Human tissue (benchtop tools)

Table A.2.1: Total market size per year in million euro

Benchtop tools market (in mio EUR) (see note)			
Year	2007	2009	2014
Europe	590	665	746
World	1 460	1 608	1 807
NOTE Market Analysis Bosch GmbH 2005.			

The price range is between 300 € and 700 €/device depending of feature class. An average of 500 € is taken into account.

Table A.2.2: Total market size per year in million devices

Benchtop tools value (in mio devices)			
Year	2007	2009	2014
Europe	1 200	1 330	1 490
World	2 900	3 210	3 610

It is assumed that approximately 30 % of the professional high end product range (30 % of the whole market) will be equipped with this application.

This leads to approximately 130 000 devices/year (10 %) in whole Europe (year 2009).

Table A.2.3: trades in the building sector

In 2007	Germany (see note)	Europe (extrapolated)
a. Construction trades	7 300	44 000
b. Building industry	8 500	52 000
total	15 800	96 000
NOTE: http://www-ec.destatis.de.		

It is assumed that 15 % of the devices will be used by DIY (20 000). The remaining 110 000 will lead to approximately 1,2 devices per enterprise (year 2009).

These protection facilities based on UWB technology integrated into the tools will increase the shop cost of approximately 30 %. This leads to a n average price of sale of about 700 €/device.

The Lifetime of these kind of tools is between 50 hours and 200 hours depending on assignment.

Category 2: Pre-impact protection and direct contact avoidance for building work

- Drilling machine market volume in Europe (2007).
- Hammer drill 2 kg to 4 kg (see note): 1 018 000.
- Hammer drill > 4 kg (see note): 328 000.
- Percussion drill: 1 200 000.
- Total 2 546 000.
- Thereof 30 % premium range tools which are considered here: 760 000.
- Compared to Category 1 tools this leads to 250 000 devices equipped with UWB sensors.
- The typical life time of the drilling machines is between 50 hours and 200 hours.
- Loudness level (noise level): acoustic pressure between 90 dB and 99 dB; acoustic power between 100 dB and 112 dB.

NOTE: Weight of the device (drilling machine).

A.3 Traffic evaluation

Category 1: Proximity sensing of human tissue and material analysis

- The daily usage is assumed to be 0,4 hours which leads to 500 days lifetime or 2,5 years (5 days/week). This is also the replacement time of such a tool.
- 0,4 h/usage time during 12 hours leads to an activity factor of 3 %. (professional use).
- 0,04 h for DIY which leads to an activity factor of 0,3 %.

Category 2: Pre-impact detection application

- Activity: operation time of 0,4 h/day.

Table A.3.1: typical daily usage of this tools [5]

Type of machine	Craft enterprise (h/day)	Light industry (h/day)
Drilling < 4 kg	0,25	0,5
Drilling ≥ 4 kg	0,25	0,5
Percussion drill	0,15	-
Total average	0,25	0.5

Table A.3.2: Drilling velocity (cm/s)

Type/drill bit diameter (mm)	8	14	18	20	25	30	35	40	55	100
Drilling < 4 kg	70	38	24	-	-	-	-	-	-	-
Drilling ≥ 4 kg	-	-	-	29	24	15	12	7	-	-
Percussion drill	-	-	30	29	24	23	21	13	6	4

- An average using time of 20 min/12 h is assumed.
- The activity factor is comparable to the TR 102 495-1 Building Material analysis with 0,28 % [4].
- The possibility of introducing the LDC on top of the LBT is under investigation.

Annex B:
Technical information

B.1 Detailed technical description

The short range classification applications described in the present document can be realized using different approaches. For example a direct pulse-based base band method can be used. Other approaches may be a PN coded digital modulation with a certain mid frequency.

A simple block diagram of a generic UWB sensor system

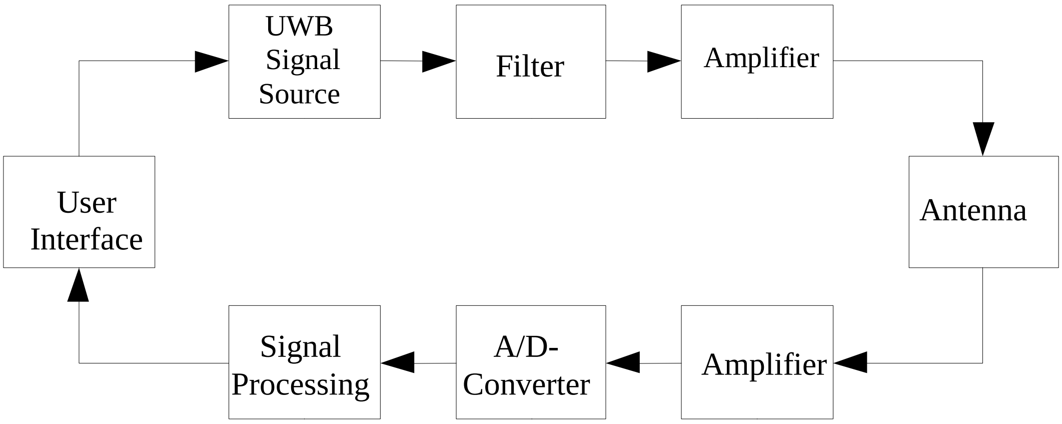

Figure B.1.1: Block diagram of an UWB Sensors system

The system is designed to radiate a broadband signal and capture a return signal caused by a remote object. A single measurement does not allow the objects to be characterized. Typically the device is operated at repeated intervals and a sequence of return signals is recorded to build up a pattern of waveforms and to allow movement information to be decoded. The following digital signal processing steps create a result, which may be further processed by an external device or presented to an operator.

The block diagram in figure B.1.1 shows the user interface triggering the UWB signal source. Therefore, the signal source will just be switched on, when the user actively starts a measurement. The signal source is followed by a filter ensuring compliance with the spectrum mask. After sufficient amplification, the antenna will transmit the signal into free space. A target object will reflect fractions of the signal. These reflected signals are received by the antenna. After amplification of the received analogue signal it is converted into a digital data stream. This data stream is then processed and the result is either transmitted to an external device or displayed on the user interface.

B.1.1 UWB Sensor Types

There are several alternative approaches for realizing UWB-sensor devices, see [13] and [14]. Different applications require waveforms that can provide the most suitable measurement data of the targets of interest. When designing a UWB-sensor, the choice of waveform must take into account the waveform's possible advantages and disadvantages for the specific application, and evaluate the cost and complexity of implementing the waveform.

The key to a powerful UWB-sensor is the use of an appropriate stimulation signal because the whole device structure and the sensor efficiency depend upon it. With regards to this point, the most important aspects may be summarized in what follows:

- The stimulus must be generated in a stable manner by simple means up to several GHz bandwidth.
- Using repetitive stimuli, cost effective under-sampling methods for signal gathering can be employed. It is allowed to work with a certain degree of under sampling without data loss since the time variation of targets is comparatively smaller with respect to its settling time.
- The Signal/Noise Ratio can be improved by averaging over several samples.

Pulsed UWB Sensor Systems

The most obvious and straightforward UWB sensor waveform is the impulse or short pulse. The time duration of these impulses is usually 0,1 ns to 1 ns. The typical pulse repetition frequency is greater than 5 MHz. If the pulses are transmitted without carrier, they are often termed carrier less impulses or base band video pulses. In many cases, it is advantageous to remove the DC content of the pulses by differentiation or high pass filtering. The resulting pulses are often called monocycle pulses. A popular short duration waveform is the Ricker wavelet that can be described mathematically as the negative of a second derivative of a Gaussian pulse. All short impulses can be generated using different high-voltage impulse sources that are based on the principle of rapid discharge of stored energy in a short transmission line. Transistors (or semiconductors in general) operated in the avalanche mode provide the rapid discharge of energy giving rise and fall times in the order of 100 ps.

Continuous-Wave (CW) UWB Sensor Systems

A sensor system that transmits continuously is termed a Continuous-Wave (CW) sensor. There are mainly two types of CW UWB sensors:

- Sine wave UWB sensors.
- Pseudo Noise UWB sensors.

Sine wave UWB sensors

A sine wave which stimulates the test objects is swept or stepped over the frequency band of interest. Usually a heterodyne receiver, based on fundamental or harmonic mixing, captures the scattered return signal. It provides the characteristic complex transfer function of the sensor arrangement at every frequency point. This principle is certainly the most sensitive method due to the excellent noise rejection and suppression of intermodulation products by the narrow band IF filters. The low crest factor of the sine waves promotes the handling of signals rich in energy resulting in large SINAD-values. Furthermore, highly sophisticated synthesizer sources provide for stable operational conditions so that effective methods can be applied to remove systematic errors. Stepped frequency radars are typical devices applying this approach.

Pseudo Noise UWB-sensors

Pulse compression sensors traditionally apply phase-coded long duration pulses to increase the pulse energy while maintaining the resolution. Various code sequences have been developed and applied, and the Barker code is maybe the most well-known. The development of spread-spectrum techniques for communications and navigation has led to new sensor systems based on these techniques. Maximum length Pseudo Noise (PN) sequences with high bit-rates generate a wideband noise-like signal that is suitable for range measurement. In a PN sensor system, the received echoes are correlated with an internally delayed replica of the transmitted signal, and the resulting output has a peak response when the internal delay equals the target delay. By pushing a digital shift register with a stable single tone RF-oscillator, PN sequences can be generated up to tenths of GHz of bandwidth. These signals have a high energy even at small amplitudes. Small voltage signals are suitable to be handled by integrated circuits and they may be switched extremely fast. Thus low crest factor signals promote a high bandwidth and an excellent jitter performance.

B.2 Technical justification for spectrum

Present sensing technologies are inaccurate, have insufficient resolution and cannot meet the requirements for the needed applications. Therefore, UWB sensor technology can be applied for all applications described under clause A.1.

The frequencies in the lower GHz range (i.e. below 3 GHz) are essential to provide the needed penetration into materials usually having low pass characteristics, otherwise no usable return signals are received and no object classification can be performed. In order to have a sufficient resolution the total bandwidth of about 6 GHz is needed.

Especially human tissue shows a large increase in electrical conductivity over frequency, leading to a high attenuation [15], and [18]. See table B.2.1.

Table B.2.1: Relative velocity permittivity ε_r and conductivity σ of head and body tissue

Target Frequency	Head		Body	
(MHz)	ε_r	σ (S/m)	ε_r	σ (S/m)
150	52,3	0,76	61,9	0,80
300	45,3	0,87	58,2	0,92
450	43,5	0,87	56,7	0,94
835	41,5	0,90	55,2	0,97
900	41,5	0,97	55,0	1,05
915	41,5	0,98	55,0	1,06
1 450	40,5	1,20	54,0	1,30
1 610	40,3	1,29	53,8	1,40
1 800 to 2 000	40,0	1,40	53,3	1,52
2 450	39,2	1,80	52,7	1,95
3 000	38,5	2,40	52,0	2,73
5 800	35,3	5,27	48,2	6,00

Many organic substances exhibit a large and frequency dependent attenuation, which leads to the requirement of a low frequency band edge for such UWB applications.

B.2.1 Power

There are several factors having a negative influence on the received signal:

- the large and material dependent attenuation;
- a large amount of noise due to the large bandwidth;
- clutter caused by surrounding objects.

The power spectral density given in clause 6, is needed in order to receive a signal that contains the necessary information for the signal processing to achieve reliable object identification.

B.2.2 Frequency mask

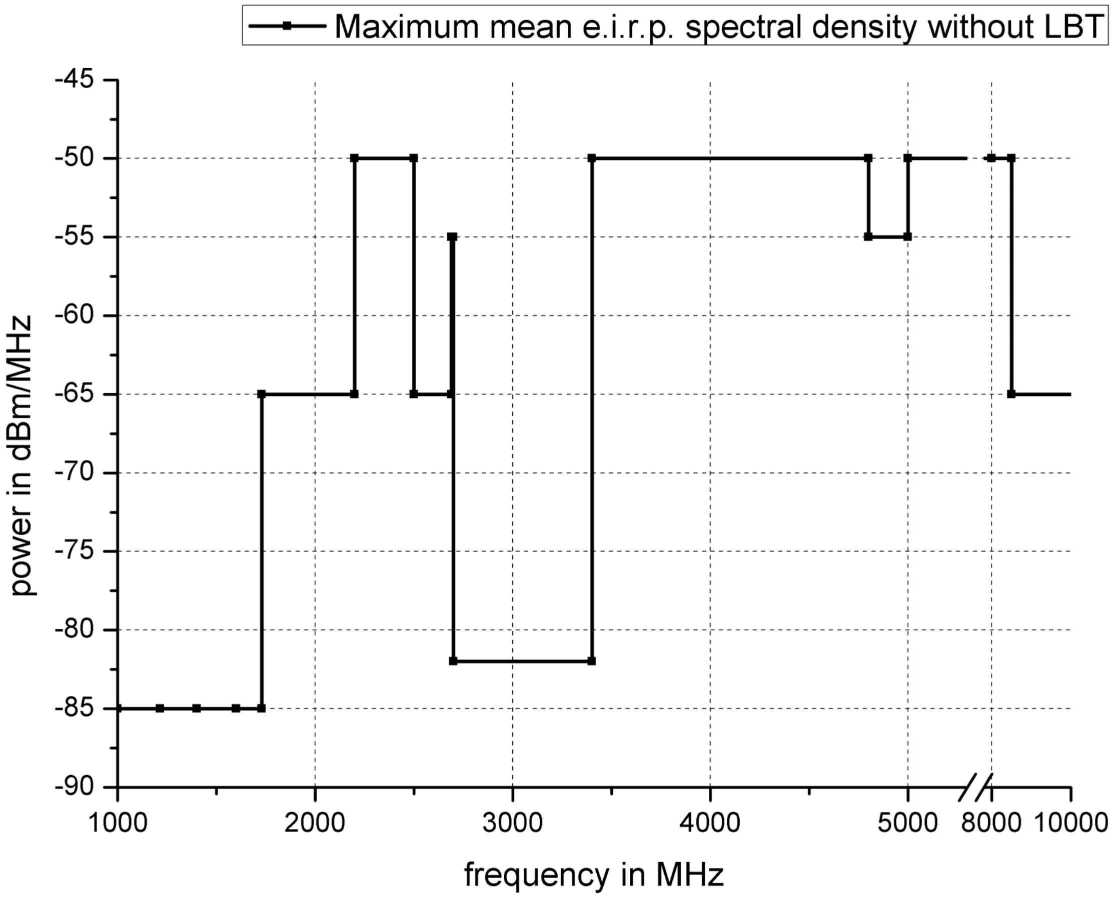

Figure B.2.1: spectral mask without LBT function

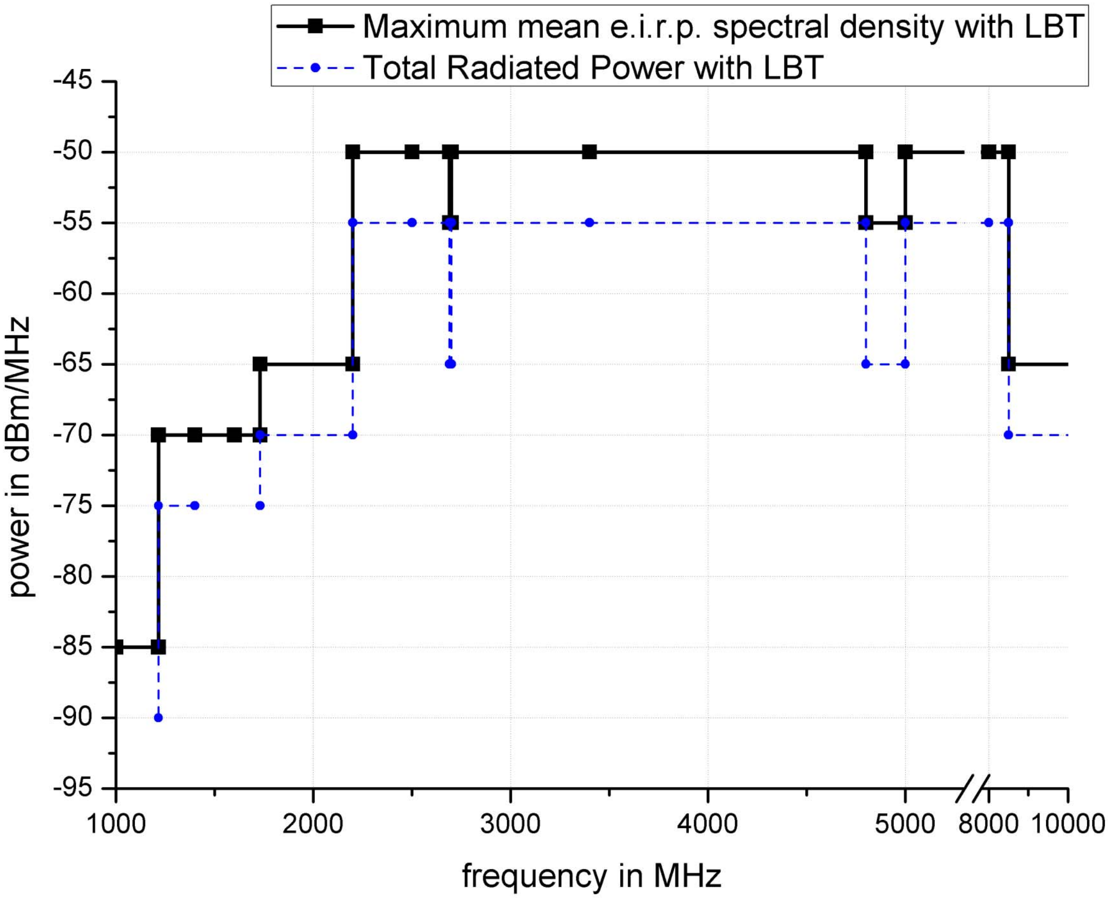

Figure B.2.2: spectral mask with LBT function

B.2.3 Bandwidth requirement

Frequencies in the lower GHz range are prerequisite for object classification applications, allowing the electromagnetic wave to penetrate objects. The wave penetrating an object must contain the needed information for the proper functioning of the application, especially for the proximity sensing of human extremities for safety critical devices in dangerous tools or detection of weapons and explosives.

A large bandwidth is required to ensure sufficient resolution needed for object separation. This is extremely important to discriminate between the actual object of interest and other sources of reflection that falsify the result if not detected properly.

For object characterization, measuring the complex permittivity (dielectric constant and conductivity) over a broad frequency range is necessary to achieve unambiguous and reliable results.

B.2.4 Measurement principle for the limit values

Measurement will be done over the whole sphere part of the scenario in an angle step of 15 degree and with a frequency step of 1 MHz between 1 GHz and 10,6 GHz.

The reference spatial midpoint of the measurement "sphere" is the location of the UWB sensor in combination with the device.

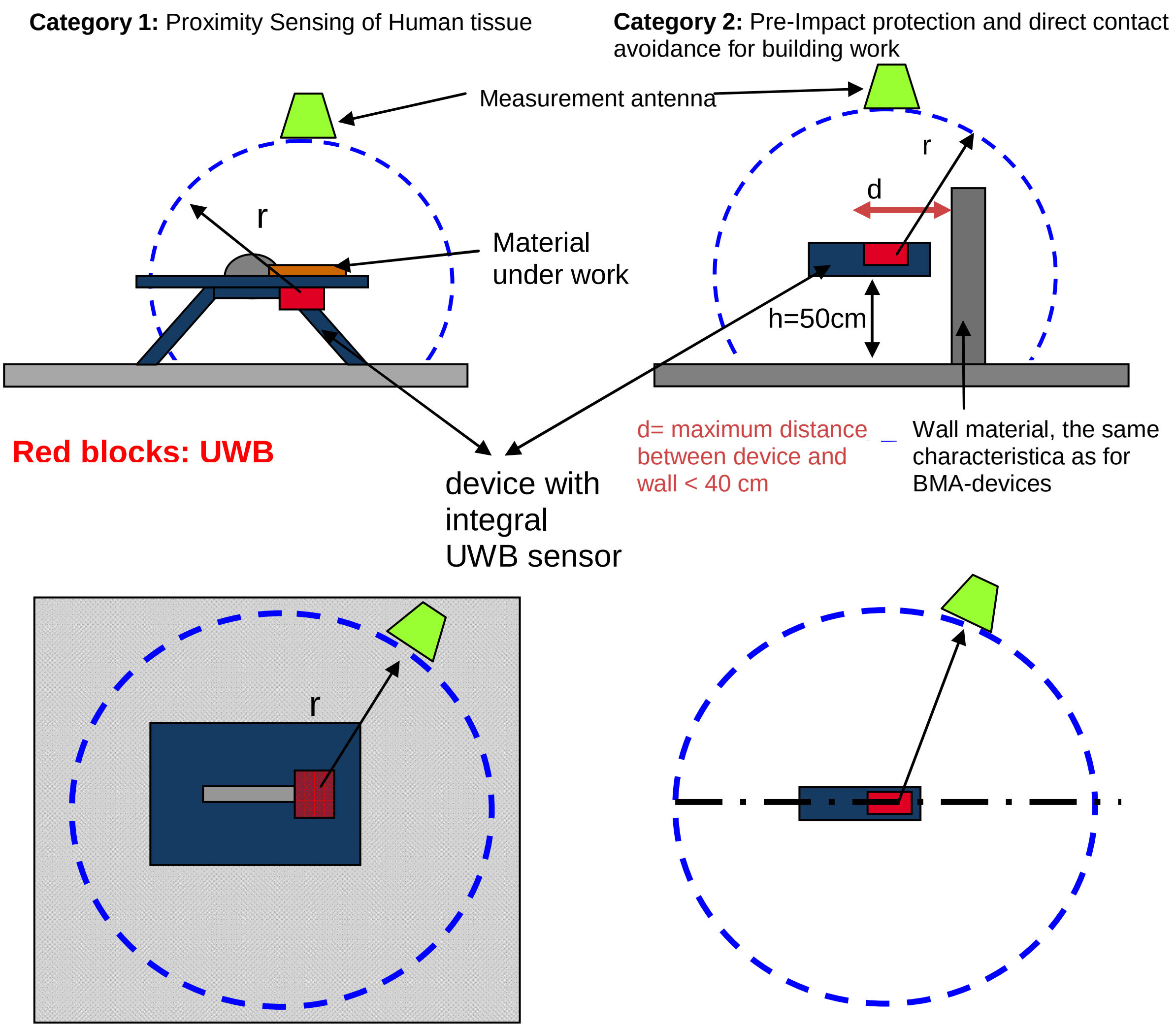

Figure B.2.4: Measurement of the max mean and the total radiated power over the sphere of the application scenario

Annex C: Expected compatibility issues

C.1 Coexistence issues

Possible coexistence problems need to be investigated in ECC. The ECC Report 64 [1], although focussing on UWB for communications equipment, should also be considered as an source of information for the purpose of new compatibility studies for UWB sensors. In addition, the results of the compatibility studies for the BMA devices can be considered.

It has to be taken into account that the usage of the devices for Proximity Sensing of Human tissue and Pre-impact protection takes place in a acoustically noisy environment (building site),during usage of the device no or only restricted acoustic communication is possible, because the loudness level (acoustic noise) is between 90 dB and 99 dB and the acoustic power between 100 dB and 112 dB (1 m distance). The allowed acoustic power emission in residential estates is 55 dB (during the day). For industrial zones 70dB (see reference [12]. The remaining 40 dB leads to a separation distance of about 50 m (free space) in which any acoustical communication is disturbed (doubling the distance leads to 6 dB reduced noise level).

C.2 Current ITU-R allocations

There is no current ITU-R allocation corresponding to these devices. The present document assumes operation according to a provision of the Radio Regulations (RR4.4) that does not require any new allocation (i.e. on a non-protected basis and causing no harmful interference).

Due to the broad range of frequencies covered, an excerpt of the European Common Allocation Table [2] is not reproduced here. Please see [2] for further details.

C.3 Sharing issues

Sharing will be required with all services within the proposed frequency ranges.

The following technical aspects (mitigation factors) need to be taken into account as these will decrease the probability of interference with the existing radio services in a suitable manner:

- mitigation factors are e.g. (see clause 6 for more detailed information about the mitigation factors);
- usage in close proximity to object only (< 20 cm for category 1 and < 40 cm for category 2);
- manual operation synchronized with the switch on time of the tool;
- no aggregation for this type of devices;
- integrated antenna element excites emissions with directivity combined with shielding provisions-as described in clause 6.

History

Document history		
V1.1.1	May 2006	Publication
V1.2.1	September 2007	Publication