

**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**



Reference

DTR/ERM-RM-044-1

Keywords

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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 1 of a multi-part deliverable covering Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra Wide Band technology (UWB), 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 applications";
- Part 3: "Location tracking applications operating in the frequency band from 6 GHz to 9 GHz";
- Part 4: "Object identification for surveillance applications".

Introduction

Ultra wideband technology enables a new generation of devices for building material analysis and classification of buried objects and material.

The non-destructive scanning of building structures offers large economical advantage compared to conventional destructive methods.

These handheld devices are lightweight and are manually operated at low power. They exhibit a low activity factor during operation. The typical total operational duration is limited to a few minutes as the area of interest is usually confined to a few m² and the measurement results are instantaneously available.

Due to the low activity factor, the limited activation time per task, the nature of the applications, random use over time and location of the usage, no aggregation occurs.

The devices are designed to work only in direct contact to the building structure being scanned and are designed to couple the electromagnetic signal directly into the building structure. The devices will not operate without physical contact to the building structure to be investigated.

Parasitic, undesired radiation into free space is significantly reduced due to the device design and the additional attenuation of the measured building structure. Equipment features (e.g. deactivation switch, dynamic power control, listen-before-talk) may reduce such radiation even further.

Frequencies in the lower GHz range are necessary to penetrate lossy building materials, such as concrete, because they exhibit a large attenuation which increases with frequency and to minimize clutter. A large bandwidth is required to ensure sufficient measurement resolution, needed for object identification, separation and classification.

1 Scope

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

It describes handheld systems that are manually operated to scan a building structure for hidden objects and to analyze building material properties. In addition, the equipment design only supports activation when in direct contact to the structure or material being investigated.

It includes necessary information to support the co-operation between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Post and Telecommunications Administrations (CEPT), including:

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

The present document does not cover through-wall and ground probing radar devices.

2 References

For the purposes of this Technical Report (TR) the following references apply:

- [1] CEPT/ECC Report 64: "The protection requirements of radiocommunications systems below 10,6 GHz from generic UWB applications" Helsinki, February 2005
<http://www.ero.dk/doc98/Official/pdf/ECCREP064.pdf>.
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- [23] Document TG3#11-55-A4R0: "Draft ECC Decision of xx 2006 on the harmonized conditions for the use of UWB devices below 10,6 GHz".
- [24] TG3#11-56R0: Draft final CEPT report.

3 Definitions, symbols 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 (echoes) e.g. from inhomogenities, interfaces, gravel stones, cavities in building material structures

spatial resolution: ability to discriminate between two adjacent targets

undesired emissions: any emissions into free space resulting from the wanted emission. It can be caused by:

- leaked emissions from the antenna; and/or
- scattered/reflected emissions from the building material; and/or

- transmitted emissions through the building material.

undesired maximum average power density: power density caused by the undesired emissions. It is proposed to measure it as depicted in figure B.2.1 with the device applied to the worst case material.

3.2 Symbols

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

c	velocity of light in a vacuum
δR	range resolution
δt	time interval between the arrivals of two signals from targets separated in range by δR
E_R	relative dielectric constant of earth materials
T_P	pulse rise time

3.3 Abbreviations

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

A/D	Analogue to Digital Converter
BW	Bandwidth
DIY	do-it-yourself
dB	Decibel
dBm	Decibel reference to 1mW
CEPT	Conference Europeenne des Administrations de Postes et des Telecommunications
DUT	Device under test
ECC	European Communication Committee
EIRP	Effective Isotropic Radiated Power
ERC	European Radiocommunications Committee
ERP	Effective Radiated Power
GPR	Ground Probing Radar
ISM	Industrial, Scientific and Medical
LBT	Listen-Before-Talk
PRF	Pulse Repetition Frequency
PSD	Power Spectral Density
SRD	Short Range Device
TEM	Transverse Electromagnetic Wave
TWPR	Through-Wall Probing Radar
UWB	Ultra Wide Band
VHF	Very High Frequency
WPR	Wall Probing Radar

4 Executive summary

The present document describes a new generation of devices using Ultra Wide Band Sensor technology for building material analysis and classification applications.

These devices are handheld and operated manually.

Due to the low activity factor, the limited operation time per task, the nature of the applications, random use over time and location, it is assumed that no aggregation occurs.

In addition, the equipment design only supports operation taking place in direct contact to the structure or material being investigated. In addition, Listen-Before-Talk (LBT) may be implemented to detect certain other victim devices operating within the same frequency range.

The construction and operating conditions of such devices assure very low parasitic, undesired emissions and the number of devices is quite limited. UWB sensor devices operate with very low activity factors.

There is evidence that these devices significantly improve maintenance tasks, quality assessments and provide saving potentials. Public safety is enhanced, e.g. for consumer usage by detection of gas pipes or electrical installations or for inspections of large buildings and structures.

The main application for the equipment described are social benefit by providing a means to detect salt, water content of bridges and thereby assessing the corrosion state, particularly for consumer and public safety is addressed (*unlike professional GPR/WPR does*), e.g. by detection of gas pipes or electrical installations.

A high bandwidth is required to obtain sufficient spatial resolution.

To detect weak targets a minimum power level is necessary. Building materials typically provide a high attenuation for UWB signals of 1 dB/cm or more. This ensures a low parasitic, undesired transmission of the UWB signals into free space. The close proximity of the device to the building material and the special design of the device ensure low parasitic reflection or radiation into free space.

4.1 Status of the System Reference Document

The present document has included several inputs from ECC TG3. These were received after submitting a preliminary version of the TR 102 495-1.

4.1.1 Limits proposed in clause 6

It should be noted that the limits proposed in clause 6 have so far not been unanimously agreed within ETSI.

4.1.2 Statement from Secretariat d'Etat a l'Industrie

The Secretariat d'Etat a l'Industrie expressed concerns with the proposed PSD limits as provided in clause 6.

4.1.3 Statement of ETSI TC SES

"TC SES welcomes SRDocs providing full description of technical characteristics of UWB equipments, in order to provide proper input to compatibility issues. However, it is TC SES's understanding that compatibility issues between UWB and other systems are the sole responsibility of ECC TG3. As a matter of fact, such compatibility studies are currently debated within the ECC TG3 group, with technical analysis due to be completed during September 2005. Approval by ECC TG3 of a final report on this matter can reasonably be expected at the end of 2005.

Pending the outcome of ECC TG3 compatibility studies, TC SES can not approve any UWB SRDocs requesting frequencies within satellite bands where the proposed regulation of emission limits contained in those SRDocs exceed the provisional limits proposed by ECC TG3 in ECC Report 64 (Feb 2005) [1].

After approval of ECC TG3 final report on compatibility studies between UWB and other equipments, TC SES will be ready to reconsider UWB SRDocs in the light of ECC TG3's recommendations. Before that, aforementioned documents can not be endorsed by TC SES".

4.1.4 Comments from France Telecom

France Telecom suggests that ETSI UWB task groups fully take the work carried out by ECC-TG3 into consideration. At this stage, France Telecom expresses its reservations concerning certain emission powers levels, proposed frequency ranges and potential of interference of systems operating in other bands.

4.1.5 Comments of Deutsche Telekom

In particular the limits proposed in the frequency range between 2,2 GHz and 3,1 GHz exceed considerably the limits for generic UWB applications proposed by ECC TG3. With a necessary separation distance of 20 m to 30 m these limits bear a potential to cause harmful interference e.g. into UMTS/IMT-2000 application in the 2,6 GHz extension band.

4.1.6 Comments of Vodafone and Siemens MC

Vodafone and Siemens MC expressed support of the comment of Deutsche Telekom.

4.1.7 Comments from Bosch, Hilti, Ubisense, JSC

Although the limits for the UWB building material analysis sensors exceed those anticipated for generic UWB applications in the range from 2,2 GHz to 3,1 GHz, it must be noted that the sensors have a considerably different transmit characteristic compared with UWB for communications and therefore, use more effective mitigation factors to protect other radio services, such as much lower activity, absence of aggregation, manual operation, listen-before-talk, deactivation mechanism (material/wall contact needed), highly directive antenna. In consequence, the proposed limits in the present document are considered feasible and sufficient to avoid harmful interference.

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

There are no current regulations permitting the operation of UWB Sensor devices covered by the present document in Europe.

The FCC has released an UWB regulation which included UWB imaging devices in 4/2002 and revised it in 03/2003 [6].

6 Proposed regulations

Based on the needs of the intended applications described in the scope of the present document, the following limits are proposed as input values for the ongoing discussions and considerations in ECC-TG3.

Table 6.1: Proposed regulations

Frequency (GHz)	Undesired maximum average power density (ERP) (dBm/MHz)	PRF (MHz) (for pulsed UWB sensor devices (see note))
2,2 GHz to 8 GHz	-50	>5
NOTE: For more Details see clause B.1.1.		

The proposed regulation is for a general licensing arrangement for material analysis and classification applications. In addition, it is also proposed that the regulation may contain appropriate mitigation requirements, e.g.:

- integrated antenna only;
- equipment design requirements to minimize undesired emissions;
- handheld devices only;
- manual operations only;
- transmitter power control;
- listen-before-talk.

7 Main conclusions

The applications described in the present document present a method for non-destructive inspection of building structures. This is a major improvement to currently available measurement techniques and presents a large benefit and market need.

The construction and operating conditions of such devices assure very low parasitic, undesired emissions and the number of devices is quite limited. UWB sensor devices operate with very low activity factors.

There is evidence that these devices significantly improve maintenance tasks, quality assessments and provide saving potentials.

Public safety is enhanced, e.g. for consumer usage by detection of gas pipes or electrical installations or for inspections of large buildings and structures.

The main application for the equipment described are social benefit by providing a means to detect salt, water content of bridges and thereby assessing the corrosion state, particularly consumer and public safety is addressed unlike professional GPR/WPR does, e.g. by detection of gas pipes or electrical installations.

Therefore, a socio-economic benefit results from the introduction of these devices.

8 Expected ECC and ETSI actions

Mandate M/329 was received by ETSI, calling for release of Harmonized Standards for UWB.

ECC-TG3 continues to work under revised ToR. This work includes UWB imaging devices such as UWB sensors.

ETSI requests the ECC to consider the present document, which includes necessary information under the MoU between ETSI and the ECC for the creation of a regulatory framework.

ETSI asks CEPT-ECC to perform the relevant compatibility studies to determine whether the emissions described in the present document are appropriate to protect other radio services and to provide the practical measures to ensure the protection of other radio services in the anticipated bands and emission levels.

A draft harmonized European standard for the equipment covered by the present document is under development in ETSI ERM TG31C.

Annex A: Detailed market information

A.1 Range of applications

UWB material analysis and classification devices have a wide variety of applications in **non-destructive** testing that could not be addressed adequately before. This addresses a large group of users with diverse applications, taking advantage of this technology.

A measurement depth of approximately 15 cm is sufficient to estimate the status of the building material, water and salt content as well as pipes and cables detection.

- **Detecting and determining the position and depth of:**

- electric cables and wires (low-voltage and three-phase cables);
- metal of all types such as copper, aluminium, iron or steel;
- metal tubes such as gas or water pipes;
- plastic tubes used for floor heating;
- steel armour in concrete;
- wood (studs);
- cavities;
- tendon cables behind meshes of rebar;
- rebars, pipes, conduits etc. deep in concrete.

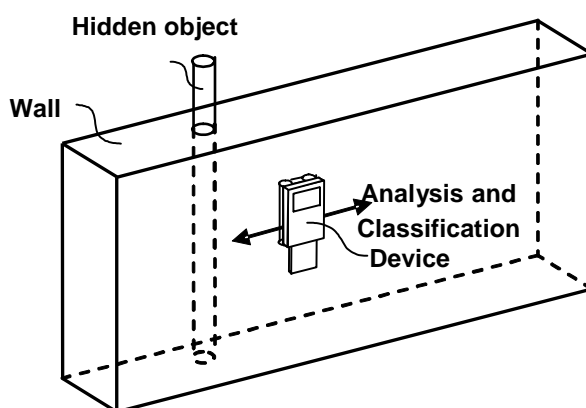


Figure A.1.1: Principle scenario for detecting and determining the position and depth of buried objects in a wall



Figure A.1.2: Scenario for detecting hidden electrical cables and pipes



Figure A.1.3: Scenario for drilling into a plastic water pipe without the use of such a UWB sensor device



Figure A.1.4: Photo from a realistic detecting scenario in a tunnel

- **Determining the water and salt content of:**
 - concrete and light construction structures;
 - historic buildings;
 - concrete structures like bridges.
- **Inspection and quality assessment of:**
 - floors, decks, slabs and balconies;
 - tunnels;
 - relative concrete condition for renovation planning.
- Determining the thickness of building structures
- Non-destructive analysis without the drawback of additional weakening of building structures
- High economic savings potential for authorities
 - UWB sensors improve the quality of assessments of bridges, tunnels etc., and thereby reduce overall long term maintenance costs for authorities.

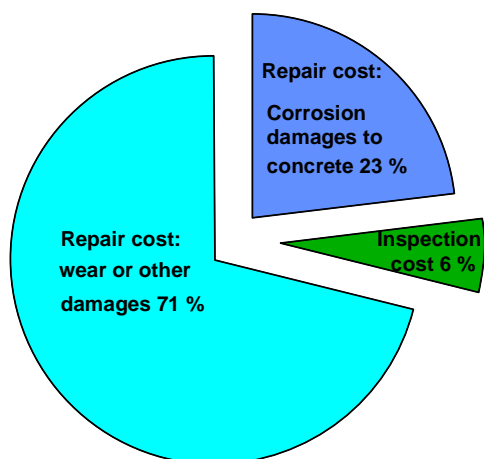


Figure A.1.5: Example: bridge maintenance repair cost per year (1 400 Mio € for 250 000 bridges, main roads (EU))
 left: Diagram shows the cost structure [4]
 right: Photo of realistic measurement scenario (marking of detect objects)

- UWB sensors enhance public safety due to unique inspection capabilities on structures

EXAMPLE: Pedestrian bridge collapse / broken tendon-cables due to corrosion.



Figure A.1.6: Photo from a bridge collapse (cause: broken tendon cables) [5]



Figure A.1.7: Photo from broken tendon cables

A.2 Market size and value

There is a large demand for such devices in the European and global markets. Users of such devices include skilled workers, experts, art historians, architects, planners, environmentalists, civil engineers as well as ordinary DIYs.

The estimated sales volume in Europe could be between 20 000 and 40 000 units per year with an estimated annual growth of 50 % over the first 4-6 years.

Initial market placement is expected to be in 2006.

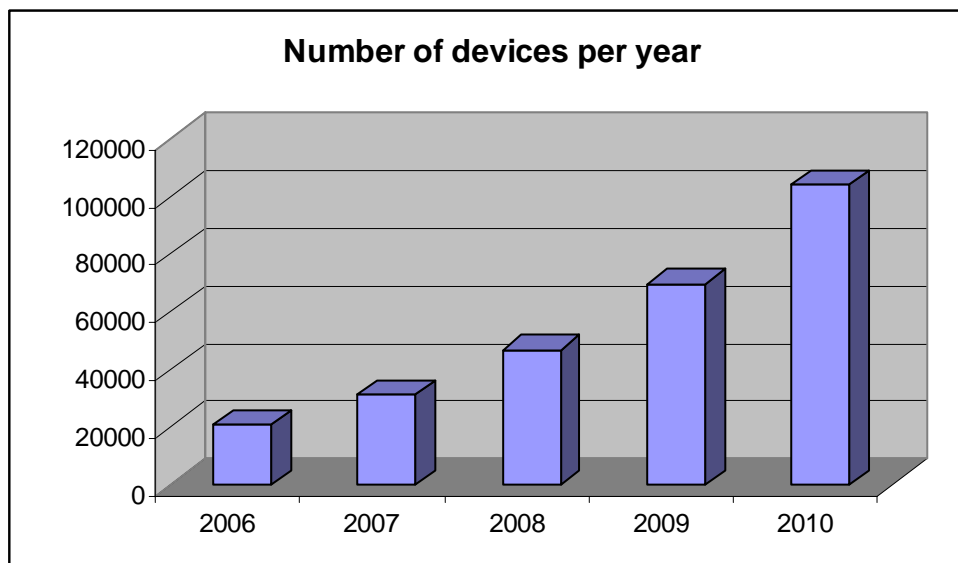


Figure A.2.1: Expected number of devices per year (2006-2010)

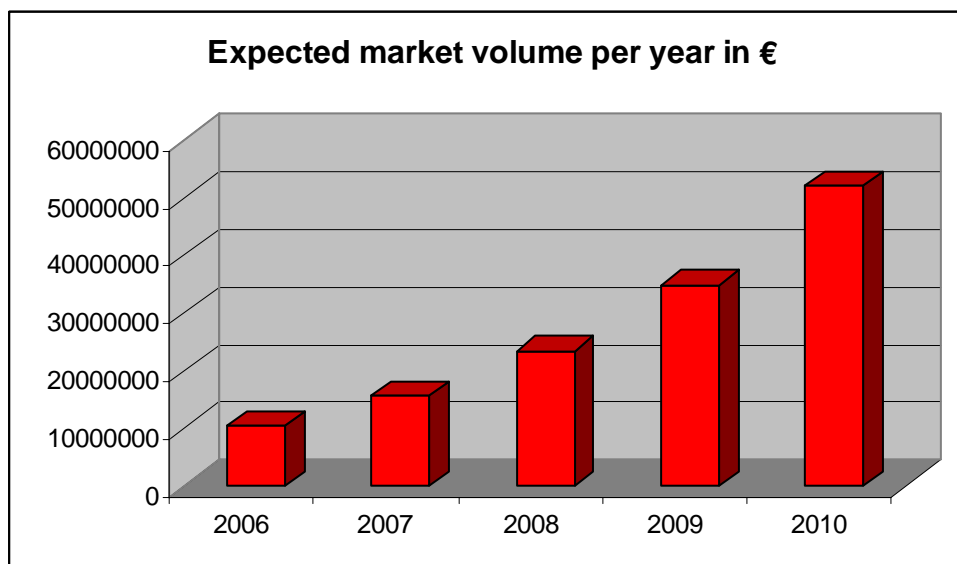


Figure A.2.2: Expected market volume per year in Euros

A.3 Traffic evaluation

These types of devices are typically used for renovation and inspection purposes with predominantly indoor application. The usage pattern is only short-term due to its handheld operation and instant display of the measurement results.

The average duration of operation for the actual measurement is low. The transmitter is activated only by manual activity. The operational area is usually confined to a few m².

In addition, the probability of simultaneous operation of more than one device in close proximity is extremely small.

Table A.3.1: Parameters for typical operational activity / usage pattern

Summarized operation time per 12h	20 min (10 measurement tasks with 2 min operation time/task)
Summarized transmitter on time per 12h	2 min (transmitter on time 12 sec./ task; 10 tasks x 12sec.)
Activity factor	0,28 %

Annex B: Technical information

B.1 Detailed technical description

A simplified block diagram of an UWB building material analysis and classification system is shown in figure B.1.1.

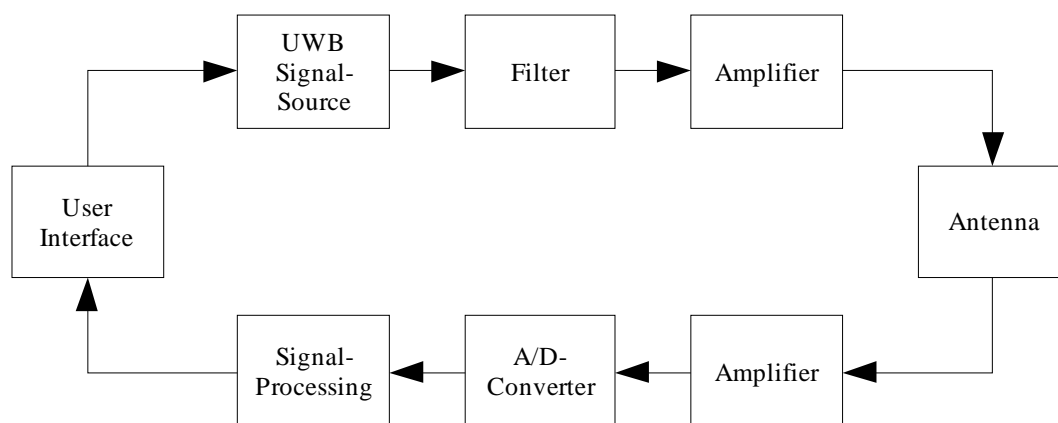


Figure B.1.1: Block diagram of a UWB building material analysis and classification system

The system is designed to radiate a broadband signal into the building and capture the corresponding return signal caused by the material surface, inhomogeneities, and buried objects. A single measurement does not allow the buried objects to be characterized. Typically the device is moved over the building material surface, and a sequence of return signals is recorded to build up a pattern of waveforms and to allow the spatial information to be decoded. The following digital signal processing steps create an easy understandable result, which will be displayed on the user interface. The position at which each waveform is recorded may be triggered automatically by position sensors or manually by the 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 couple the signal into the building material. The surface of the material as well as inhomogeneities and buried objects in the material 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 displayed on the user interface.

Additionally, a listen-before-talk (LBT) mechanism is being considered. In this case the UWB transmission will not be activated if a signal of another radio device is received. The effect of LBT in reducing the interference potential is limited taking into account:

- the maximum usable receiver sensitivity of devices operating ultra- wideband;
- the fact that the other radio services and applications operate with narrower bandwidth than UWB, low or medium power or use a high dynamic range for the transmitter power.

B.1.1 UWB Signal Source

There are several alternative approaches for realizing UWB-sensor devices, [21] and [22]. Different applications require waveforms that can provide the most suitable measurement data of the targets of interest. When designing an 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 >5 MHz. If the pulses are transmitted without carrier, they are often termed carrierless impulses or baseband 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 synthesiser 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 technologies for Building Material and Classification are inaccurate, may need destructive testing, and are time consuming. Therefore UWB imaging technology is applied for the applications as noted under clause A.1.

The requirements are such that only frequencies in the lower frequency range (i.e. below 3 GHz) provide the needed penetration into lossy materials (usually having low pass characteristics) otherwise no return signals are received and no building material analysis and classification of the material can be done. More details are given in the literature (see bibliography). Beside the operation at lower frequency ranges, a high bandwidth is essential to provide the needed resolution.

Alternative technologies for these applications which might operate at single frequencies and/or use narrow frequency bands are not able to meet the requirements.

B.2.1 Power

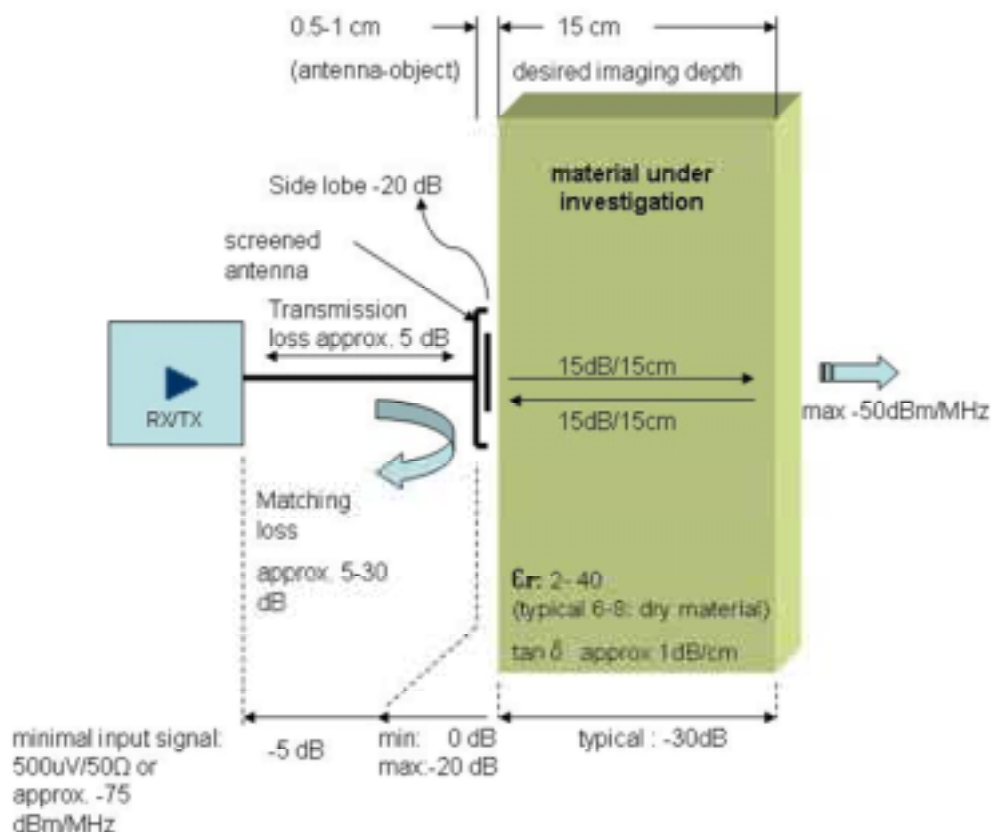
There are several factors which are influencing the received signal:

- Large and material dependent attenuation;
- A large fraction of noise due to the bandwidth;
- Clutter caused by material inhomogenities (e.g. small stones in concrete).

The power spectral density in clause 6, "Proposed Regulations", is needed in order to receive a signal that contains the necessary information for the signal processing and to find the buried objects or to classify the material properties. In order to detect the echoes from weak targets such as plastic pipes in a wall, a high dynamic range is necessary. UWB sensors are handheld devices, they are not static sensors. Typically they are scanned over the surface of the building material structure, and thus, the integration time is limited to a few milliseconds. As a consequence, the necessary dynamic range can only be achieved by the indicated power levels.

Figure B.2.1 demonstrates the relationship between necessary power and material analysis capability.

Signal budget UWB sensor building material analysis



NOTE: Attenuation value of the material will be changed to worst-case. However, the maximum PSD limit of -50 dBm/MHz remains unchanged.

Figure B.2.1: Signal budget for a building material analysis and classification UWB sensor device

B.2.2 Frequency Mask

In view of the density, user pattern, minimum protection distance and activity factors, the UWB Sensors group's proposal considered both, a carefully-designed mask and the relevant mitigation techniques to protect existing users of the radio spectrum whilst enabling practical deployment of market-ready UWB systems.

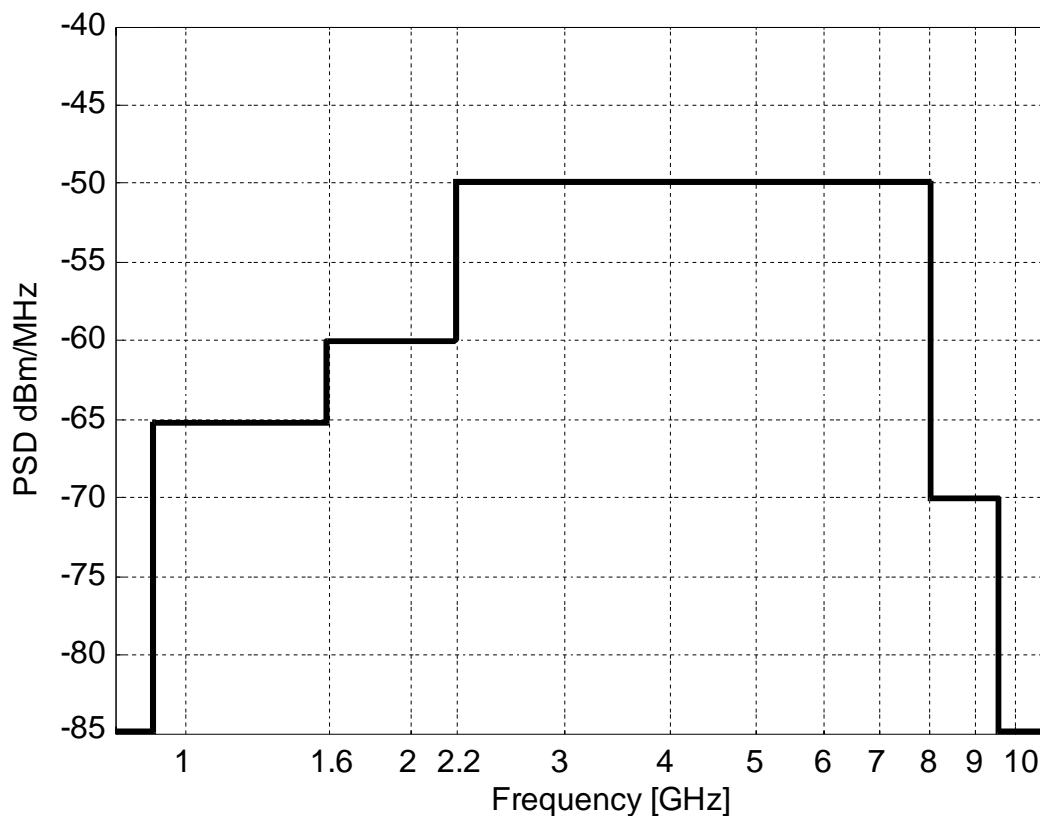


Figure B.2.2: spectral mask for UWB Building Material Analysis and Classification devices

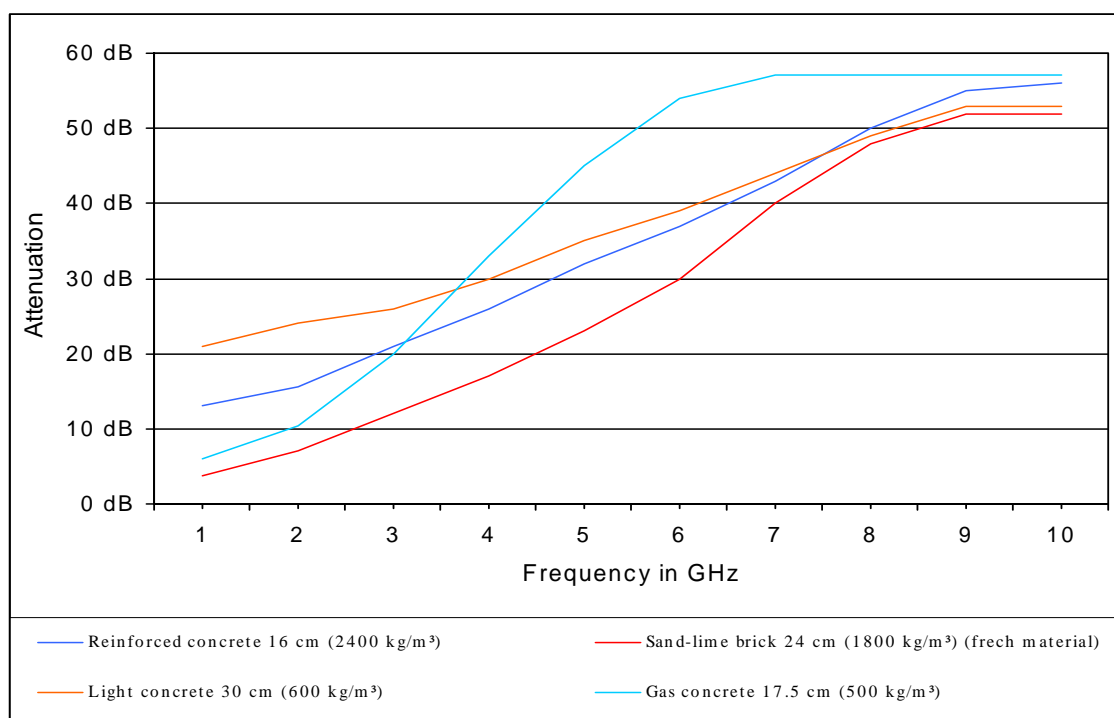
Table B.2.1: Unwanted emission for Building material Analysis and Classification device

Frequency range (MHz)	Power limit values for unwanted emission (e.r.p.) (dBm/MHz)
< 870	-85 (-95 dBm/100 kHz)
> 870 - 1 600	-65,3
1 600 - 2 200	-61,3
8 000 - 9 600	-70
> 9 600	-85

B.2.3 Frequency dependency of attenuation and clutter

The objective of UWB building material analysis and classification systems is to radiate an electromagnetic signal into the building material and to receive a very small fraction of that signal in order to detect hidden objects or to classify the building material.

B.2.3.1 Frequency dependency of attenuation



In order to fulfil this task, the signal must penetrate the material. To ensure a sufficient penetration depth, low frequencies are needed. The required spatial resolution is gained by using a large bandwidth.

In all cases the objective of the radar designer is to couple the signal into the building material.

Signals that leak into the air are regarded as undesired radiation, with reflections from adjacent objects confusing the required response.

B.2.3.2 Frequency dependency of clutter

Many construction materials are made of inhomogeneous components. In concrete, the additives are gravel stones of 16-32 mm diameter. These stones act each as individual scattering objects causing correlated noise called clutter. Clutter in radar sensor system refers to the radar signals returned from materials inhomogeneities. In the case of concrete it would be mainly the energy scattered by the larger aggregates. The same is true for bricks, where the holes generate unwanted radar reflections. A standard wall radar system is not noise limited but rather *clutter limited*. Although the distribution of the gravel stones in the concrete is random, this noise is correlated with the signal and it is hard to separate the clutter signal from the object reflection.

It is well known, that a good way to suppress clutter is to select a wavelength bigger than the typical diameter of the unwanted scatter. In this case, the radar cross section of the unwanted scatter can be calculated by the so called Raleigh approximation. In this zone, the radar cross section decreases rapidly with increasing wavelength, so that the clutter becomes more or less invisible.

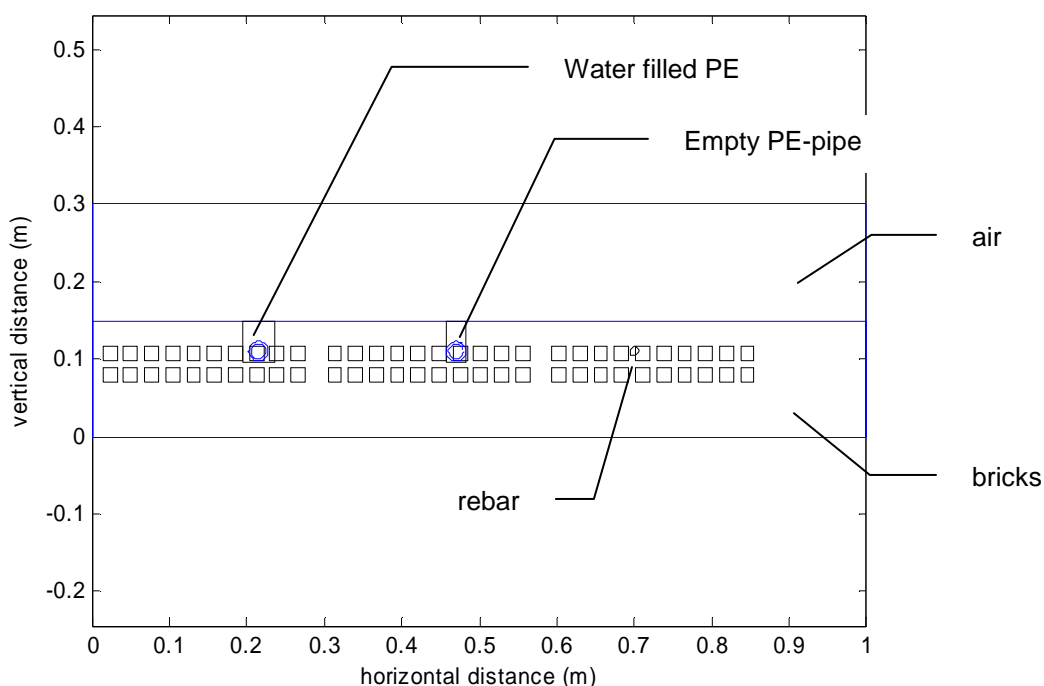
The following FDTD simulation shows the effect of the choice of the centre frequency on clutter and the detection probability of plastic pipes and rebars in bricks.

The radar was simulated using a monostatic configuration with an ideal infinitesimal dipole antenna emitting a Ricker wavelet of a given centre frequency. The centre frequency was chosen to be 2,2 GHz in the first simulation and 3,5 GHz in the second one.

Object 1: empty PE-pipe (diameter 25 mm) in a grout groove of 40 mm width.

Object 2: empty PE-pipe (diameter 25 mm) in a grout groove of 25 mm width.

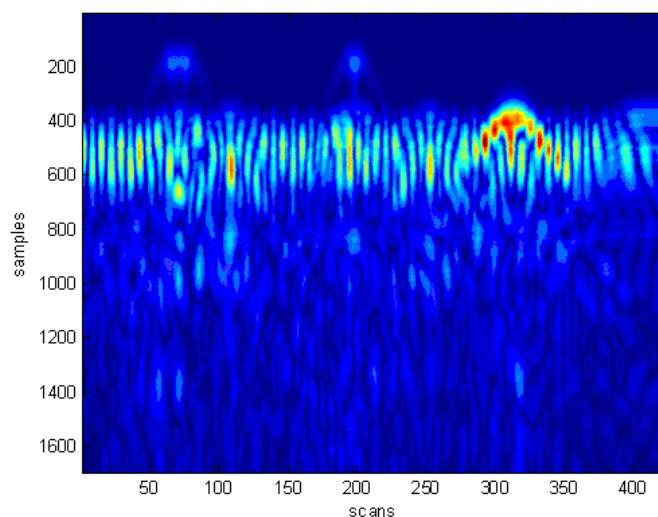
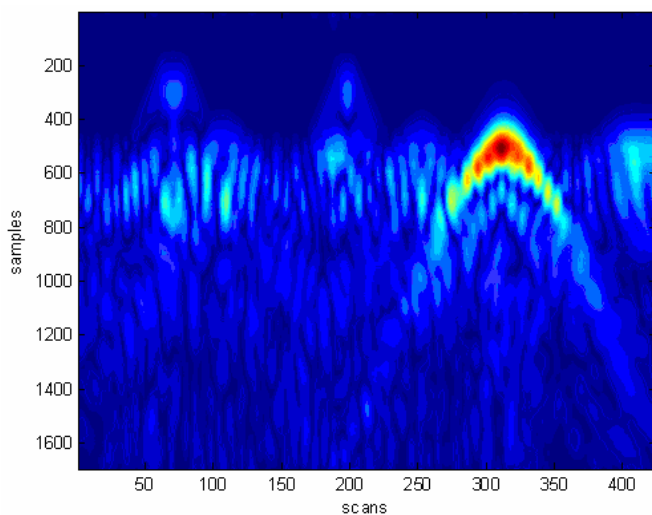
Object 3: rebar iron.



The following two figures show the results of the simulations in form of two B-scans at two different frequencies. The only signal processing steps used were a background removal and a Hilbert transformation. One scan corresponds to 2 mm distance.

2,2 GHz

3,5 GHz



From the above B-scans, it is evident, that at the higher centre frequency of 3,5 GHz the holes in the bricks become already significant scatterers - so called clutter. For an algorithm, it will be hard to detect the PE pipes at higher frequencies (3,5 GHz). It is better not to detect the holes in the bricks.

Therefore it is essential for UWB sensors systems for material analysis and classification to emit frequencies in the frequency range of 2,2 GHz to 3,1 GHz in order to suppress unwanted reflections.

For more information about building material attenuation, see clause 2.

B.3 Bandwidth requirement

The purpose of a UWB building material analysis and classification system is to detect objects in building structures and classify the material. The required spatial resolution to separate two adjacent objects is $\delta R = 10$ mm. For this requirement the associated bandwidth BW for a general radar system is:

$$BW = \frac{c}{4 \cdot \delta R \cdot \sqrt{\epsilon_r}}$$

The maximum value for the bandwidth follows from the lowest dielectric constant of $\epsilon_r = 1,5$ for gas type concrete. This leads to a necessary bandwidth of 6 GHz.

Annex C: Expected compatibility issues

C.1 Coexistence issues

Possible coexistence problems need to be investigated in ECC-TG3. ECC Report 64 [1], although focussing on UWB for communications equipment, should also be considered as a source of information for the purpose of new compatibility studies for UWB sensors.

C.2 Current ITU 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 [3] is not reproduced here. Please see [3] for further details.

C.3 Sharing issues

Several issues have to be taken into account, which will decrease the probability of interference with the existing radio services.

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:

- low usage activity factor;
- confined usage area;
- no aggregation effect;
- equipment designed to minimize undesired emissions (e.g. antenna design to couple maximum energy to the wall and minimize reflections and leakage);
- physical contact with the material under investigation is required to enable and activate transmission;
- handheld devices only;
- manual operations only (e.g. non- locking switch);
- transmitter power control (if appropriate);
- listen- before- talk (if appropriate).

History

Document history		
V1.1.1	January 2006	Publication