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**System Reference document (SRdoc);
Transmission characteristics;
Technical characteristics for level probing radar
within the frequency range 75 GHz to 85 GHz**

Reference

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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 has been developed to support the co-operation between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Post and Telecommunications Administrations (CEPT).

Modal verbs terminology

In the present document "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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Introduction

The present document includes necessary information to support the co-operation under the MoU between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Post and Telecommunications Administrations (CEPT).

LPRs as covered by ETSI EN 302 729 [i.4] are required to operate having a strict (stable) downward orientation of the antenna under any operating condition in combination with other antenna restrictions as e.g. beam width and gain.

As the half sphere concept which can be found in CEPT ECC Report 139 [i.2] has been verified by compatibility studies of LPRs with other radio services the present document aims to rely on this concept while showing that LPRs having other than the combinations of the antenna requirements and antenna position which can be found in ETSI EN 302 729 [i.4] will maintain a maximum e.i.r.p. on the half sphere of -41,3 dBm. For this reason the present document gives a set of pre-selected use cases each having different character well suited for its intended application.

The present document at hand requests for better fitting antenna requirements which are optimally adapted to the situations found in the field. Current LPRs contrary to expectations do not have sufficient capabilities tracking the level of the measured product in some applications. Particularly from applications where the level of solids has to be measured the LPR industry receives frequent customer complaints where instruments fail to measure an accurate level of the product. Additionally customers now demand for embedding a volumetric measurement into their e.g. materials management.

The need for adapting the restrictions on antenna orientation and antenna requirements for LPR radiodetermination devices was identified in order to cover measurement tasks which cannot be conducted adequately or cannot be conducted at all at the moment due to the limited antenna orientation capabilities and/or beam width.

Today's regulation with the requirement that the antennas need to point strictly downwards blocks either applications where tilting the antenna is required to get a sufficient receive signal or applications with electronical or mechanical beam steering. The antenna beam width limitation blocks applications with the usage of comparable systems using low gain antennae.

The present document requests mainly:

- More usable and application specific positions of the LPR antenna other than strictly pointing downwards.
- More usable and application specific requirements of LPR antennas in terms of e.g. beamwidth or side lobe suppression while maintaining the downward orientation towards the ground.

The appropriated compensation for each of the above mentioned requirements in order to stay with the half sphere concept can be found in detail in Table 2. The present document covers therefore the request for more relaxed antenna requirements, especially in terms of orientation and beam width for LPRs as radiodetermination applications using UWB technology within in the 75 GHz to 85 GHz range. The intention is to create a basis for the LPR industry to maintain and expand market access without loss of its customer satisfaction in this technology while still avoiding any harmful interference with other radio services.

Communications applications or hybrid applications as a combination of sensor and communications applications are not treated within the scope of the present document.

The half sphere concept as used by the current regulation has been established by ERM TG TLPR which now has merged into ERM TG UWB.

The present document was developed by ERM TG UWB. The information in it has not yet undergone coordination by ERM. It contains preliminary information.

1 Scope

The present document describes LPR radiodetermination applications within the frequency range 75 GHz to 85 GHz which may require a change of the present frequency utilization within CEPT. The described UWB radiodetermination applications for future systems are split into the following classes and use cases:

- Object detection and classification/characterization.
- Motion, speed and presence detection.
- Distance measurement.
- Contour detection of solid material heaps.

The present document includes in particular:

- Market information.
- Technical information including expected sharing and compatibility issues.

NOTE: The information on sharing and compatibility issues is required when new spectrum or new spectrum usage is requested.

- Regulatory issues.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

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

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] European Commission Decision 2013/752/EU of 11 December 2013 (amending Decision 2006/771/EC on harmonisation of the radio spectrum for use by short-range devices and repealing Decision 2005/928/EC).

[i.2] CEPT ECC Report 139: "Impact of Level Probing Radars Using Ultra-Wideband Technology on Radiocommunications Services", Rottach-Egern, February 2010.

[i.3] ETSI EN 302 372 (V2.1.1) (10-2016): "Short Range Devices (SRD); Tank level Probing Radar (TLPR) equipment operating in the frequency ranges 4,5 GHz to 7 GHz, 8,5 GHz to 10,6 GHz, 24,05 GHz to 27 GHz, 57 GHz to 64 GHz, 75 GHz to 85 GHz; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.4] ETSI EN 302 729 (V2.1.1) (10-2016): "Short Range Devices (SRD); Level Probing Radar (LPR) equipment operating in the frequency ranges 6 GHz to 8,5 GHz, 24,05 GHz to 26,5 GHz, 57 GHz to 64 GHz, 75 GHz to 85 GHz; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.5] ETSI TS 103 361 (V1.1.1) (03-2016):" Short Range Devices (SRD) using Ultra Wide Band technology (UWB); Receiver technical requirements, parameters and measurement procedures to fulfil the requirements of the Directive 2014/53/EU".

[i.6] ITU-R "Radio Regulations Articles" Edition of 2016.

[i.7] ETSI EN 305 550 (V2.1.0): "Short Range Devices (SRD); Radio equipment to be used in the 40 GHz to 246 GHz frequency range; Harmonized Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.8] ETSI EN 303 883 (V1.1.1) (09-2016): "Short Range Devices (SRD) using Ultra Wide Band (UWB); Measurement Techniques".

[i.9] ERC Recommendation 70-03: "Relating to the use of Short Range Devices (SRD)"; 13 Oct 2017 edition.

[i.10] Sweden's Minerals Strategy: For sustainable use of Sweden's mineral resources that creates growth throughout the country.

[i.11] European Commission: "The raw materials initiative - meeting our critical needs for growth and jobs in Europe", COM(2008) 699, 2008. .

[i.12] ECC Decision (11)02: "Industrial Level Probing Radars (LPR) operating in frequency bands 6 - 8.5 GHz, 24.05 - 26.5 GHz, 57 - 64 GHz and 75 - 85 GHz".

[i.13] Recommendation ITU-R M.2057: 'Systems characteristics of automotive radars operating in the frequency band 76-81 GHz for intelligent transport systems applications'.

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms given in ETSI EN 303 883 [i.8], ETSI TS 103 361 [i.5] and the following apply:

Activity Factor (AF): activity factor of a radiodetermination device is usually defined as the ratio of active measurement periods t_{meas} (bursts, sweeps, scans) within the overall repetitive measurement cycle T_{meas_cycle}

Adaptive Power Control (APC): adaptive power control is an automatic mechanism to regulate the transmitter power. It is controlled by the received power within the total receiver bandwidth

blocking distance: minimum distance from the target to the antenna of a LPR sensor which is at least necessary in order to guarantee a reliable measurement

NOTE: If the distance to the target falls below the blocking distance, the measurement may fail because the sensor is less sensitive or "blind" at close ranges.

Duty Cycle (DC): product of the pulse repetition frequency (PRF) and the pulse duration t_{pulse}

equivalent isotropically radiated power (e.i.r.p.): product of "power fed into the antenna" and "antenna gain". The e.i.r.p is used for both peak and average power

Frequency Modulated Continuous Wave (FMCW): based on a periodically linear frequency sweep of the transmit signal. For distance measurement sensors often a sawtooth or a triangular modulation scheme is used

NOTE 1: By mixing the current transmit signal with the reflected signal the round trip time of the individual echoes and thus the distance of the different targets can be determined.

NOTE 2: Although the instantaneous bandwidth of a FMCW Radar is close to zero the recorded power versus time variation results in a wideband spectrum which is clearly not pulsed.

Stepped Frequency Continuous Wave (SFCW): transmitted frequencies are changed by incremental increase

NOTE: Although the instantaneous bandwidth of an SFCW Radar is close to zero the recorded power versus time variation results in a wideband spectrum which is clearly not pulsed.

3.2 Symbols

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

f_L	lowest frequency of the operating bandwidth
f_H	highest frequency of the operating bandwidth
t_{meas}	active measurement time segment
T_{meas_cycle}	overall repetitive measurement cycle time (including possible idle time segments)
t_{pulse}	pulse duration in a pulsed system or the duration of an individual frequency step in an SFCW modulation scheme

3.3 Abbreviations

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

AF	Activity Factor
APC	Adaptive Power Control
DAA	Detect And Avoid
DC	Duty Cycle
DUT	Device Under Test
e.i.r.p	equivalent isotropically radiated power
EESS	Earth Exploration Service Satellite
FMCW	Frequency Modulated Continuous Wave
FSL	Free Space Loss
IC	Integrated Circuit
ITU-R	International Telecommunication Union - Radio sector
LBT	Listen Before Talk
LPR	Level probing Radar
PRF	Pulse Repetition Frequency
RAS	Radio Astronomy Station
Rx	Receiver
SFCW	Stepped Frequency Continuous Wave
SRD	Short Range Devices
TC	Technical Commitee
TGU-WB	Task Group Ultra-Wide Band
TLPR	Tank Level Probing Radar
Tx	Transmitter
UWB	Ultra-WideBand

4 Comments on the System Reference Document

4.1 Statements by ETSI Members

No statements or comments have been issued by ETSI members.

5 Presentation of the UWB-LPR systems and technology

5.1 Use cases of LPR sensor systems

Microwaves travel at the speed of light and this speed is essentially constant under a variety of different environmental conditions. This makes the use of microwaves a very robust measuring principle which is preferred when high accuracy is required and environmental conditions, such as temperature, pressure, etc. may vary.

Some of the main advantages of microwave technology for all kinds of sensors are therefore:

- high measurement accuracy;
- high repeatability;
- robust measuring performance in a variety of environmental- and process conditions;
- high reliability;
- minimum or even no maintenance requirements and wear as a result of no moving parts;
- easy installation;
- non-contact measuring principle provides a high independency of ambient conditions or process properties,
- superior long-term stability resulting from self-calibration mechanisms since devices have always stable internal references which are independent of temperature or humidity;
- efficient handling of many devices due to the support of different interfaces;
- the antenna or the radome is usually very robust against contamination with dust, dirt or other adverse environmental influences.

All these factors combined provide a technology that over time has proven to bring improvements in environmental protection, human safety, accident prevention and avoidance as well as a more efficient and sustainable use of natural resources and higher quality of end-products in different manufacturing industries.

There are already commercially available sensors on the market which partly cover some. Level Probing Radars (LPR) [i.4] working for example in the frequency band 75 to 85 GHz.

- Tank Level Probing Radars (TLPR) [i.3].

More information about some already existing systems can be found in annex A.

As indicated in the scope of the present document the UWB-LPR radiodetermination applications for potential future systems are classified into the following use cases:

- Object detection and classification/characterization.
- Motion, speed and presence detection.
- Distance measurement.
- Contour detection of solid material heaps.

With industry 4.0 a tremendous increase of automation requirements is expected. More and more individualized products will be fabricated in high automated production lines which contain lots of compact and flexible production units. These production units will contain sensors for both the production processes and for reconfiguration and change. Due to flexible and frequent changes in the process, residuals of prior products and cleaning substances should be detected for example with very high accuracy and resolution in order to maintain product quality and production efficiency.

Electric mobility and energy revolution are given as e.g. one of the drivers of the fast growing mining and minerals business induced by the battery industry which is moving towards highly sophisticated technologies and seeks for e.g. vanadium and lithium which are mining minerals. At the same time mining companies - amongst others - are going to increase efficiency by a combination of modern technologies towards so called digital mines.

Other technologies as LASER, optical sensing, ultra-sonic or photogrammetry are prone to dust and to foggy conditions. Therefore LPRs are one of the core technologies for such industries as e.g. waste management, pulp and paper and agriculture.

5.2 Object detection

5.2.1 Contour detection

Imaging Radar systems are used for 3D visualizing of arbitrary surfaces and objects (contour detection). The principle can be utilized for example for precise volumetric measurements of different bulk solids stored in stockpiles such as sand, gravel, stones, wood chips, coal, corn, fertiliser, etc. These materials shape a characteristic angle of repose when stored on a stockpile.

With a one dimensional distance sensor measuring towards only a small area on the surface and assuming the surface to be flat, often the volume expansion of the whole stockpile cannot be determined with sufficient accuracy. This problem can be overcome by installing several distance measurement systems uniformly and densely distributed over the measuring surface. However, this solution is unfavourable in terms of costs and installation effort.

Therefore a single imaging Radar system installed in a suitable position can be used which generates an exact image of the surface contour. This facilitates the calculation of the residual volume on the stockpile.

Imaging Radar systems therefore often use beamforming techniques with phased array antennas providing control of the beam direction (beam steering) and pattern shape including the side lobes without the need for rotating the entire unit mechanically. Comparable technologies to beam steering are known and these ones are using rather low gain antennas but demand a higher processing power. Detailed technical characteristics are given in one of the sub-classes in clause 7.

The application environment can be indicated as outdoor industrial areas where aggregation effects are highly unlikely due to a low density of measuring sites, the increased FSL in the higher frequency bands as 75 GHz to 85 GHz and larger distances between individual sensors.

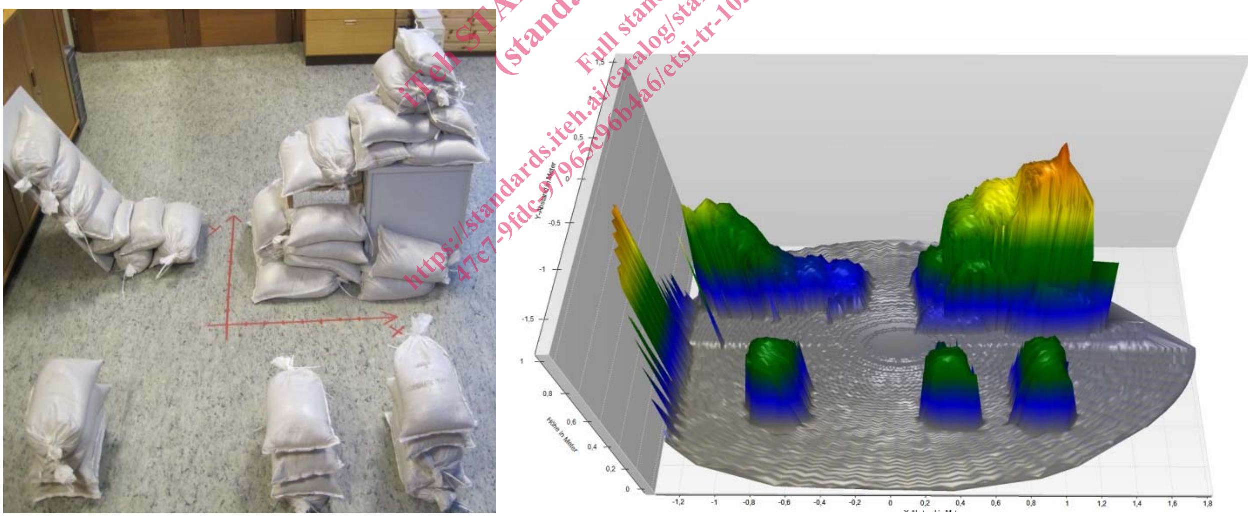

Figure 1: Measurement scenario with sandbags (left) and corresponding radar image (right)

5.3 Motion, speed and presence detection

5.3.1 Contactless flow measurement

The flow rate measurement in flumes, rivers and other running water bodies plays a prominent role for example in wastewater treatment, municipal water supply and especially in flooding prevention. With an accurate measurement of the flow rate in rivers in combination with the water level an exact flood forecasting is possible. This helps to take early measures against severe harm to infrastructure and people due to an impending flood.