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Ultra Wideband (UWB); RF conformance testing of radar level gauging applications in stillpipes TLPR

Reference

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ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
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Foreword

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

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**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 radar level gauges covered by the present document do not use the signal form of time domain UWB short pulses. Instead, they use the frequency domain based FMCW and/or SFCW waveforms. Thus the emission bandwidth generated by the FMCW and/or SFCW radars is strictly controlled by the equipment itself.

The specified requirements in the present document describe the worst case scenario (i.e. the possible highest emissions outgoing to the environment and incoming from interferer signal sources [10]) and is seen as a feasible test method to prove compliance of radar level gauging applications in stillpipes.

The background and related applications have been described in ETSI TR 102 750 [i.2] where the applications have been considered indoor like systems.

The purpose of revision of the present document is to update the previous version ETSI TS 102 692 (V1.1.1) [i.10] to cover the essential requirements of article 3.2 of the Directive 2014/53/EU [i.3].

1 Scope

The present document specifies the requirements for radar level gauging applications in stillpipes using UWB technology operating in the frequency range of 9 GHz to 10,6 GHz.

2 References

2.1 Normative 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.

Referenced documents which are not found to be publicly available in the expected location might be found at https://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.

The following referenced documents are necessary for the application of the present document.

[1] CISPR 16-1 (2003): "Specification for radio disturbance and immunity measuring apparatus and methods - Part 1: Radio disturbance and immunity measuring apparatus".

[2] ANSI C63.5 (2006): "American National Standard for Electromagnetic Compatibility - Radiated Emission Measurements in Electromagnetic Interference (EMI) Control - Calibration of Antennas (9 kHz to 40 GHz)".

[3] Void.

[4] ISO 4266-1 (2002): "Petroleum and liquid petroleum products -- Measurement of level and temperature in storage tanks by automatic methods -- Part 1: Measurement of level in atmospheric tanks".

[5] API MPMS 3.1A and 3.1B: "Manual of Petroleum Measurement Standards, Chapter 3: Tank Gauging", Section 1A: "Standard Practice for the Manual Gauging of Petroleum and Petroleum Products", published on 1 of August 2005; Tank Gauging Section 1B: "Standard Practice for Level Measurement of Liquid Hydrocarbons in Stationary Tanks by Automatic Tank Gauging", published on 1 of June 2001.

[6] Void.

[7] ETSI TR 100 028 (all parts) (V1.4.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Uncertainties in the measurement of mobile radio equipment characteristics".

[8] ETSI TR 102 273 (all parts) (V1.2.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Improvement on Radiated Methods of Measurement (using test site) and evaluation of the corresponding measurement uncertainties".

[9] Void.

[10] ETSI TS 103 361 (V1.1.1): "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".

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.

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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] Recommendation ITU-R SM.1754: "Measurement techniques of ultra-wideband transmissions".

[i.2] ETSI TR 102 750: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Radar level gauging applications in still pipes".

[i.3] Directive 2014/53/EU of the European Parliament and of the Council of 16 April 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC.

[i.4] Void.

[i.5] Void.

[i.6] Void.

[i.7] ETSI TS 103 052: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Radiated measurement methods and general arrangements for test sites up to 100 GHz".

[i.8] Commission Decision 2007/131/EC of 21 February 2007 on allowing the use of the radio spectrum for equipment using ultra-wideband technology in a harmonised manner in the Community.

[i.9] Recommendation ITU-R P.526-10 (02/07): "Propagation by diffraction".

[i.10] ETSI TS 102 692 (V.1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); RF conformance testing of radar level gauging applications in still pipes".

3 Definitions, symbols and abbreviations

3.1 Definitions

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

dedicated waveguide antenna: device/structure to excite a certain waveguide mode that propagates inside a waveguide only

duty cycle: ratio of the total on time of the transmitter to the total time

emissions: signals that leaked or are scattered into the air within the frequency range (that includes harmonics) which depend on equipment's frequency band of operation

equivalent isotropically radiated power (e.i.r.p.): total power transmitted, assuming an isotropic radiator

EUT: radar level gauge with a dedicated waveguide antenna on a dedicated stillpipe

external floating roof: roof made of metallic material such as aluminium

NOTE: It moves along with the filling liquid below the roof inside the tank.

Frequency Modulated Continuous Wave (FMCW) radar: radar where the transmitter power is fairly constant but possibly zero during periods giving a big duty cycle (such as 0,1 to 1)

NOTE: The frequency is modulated in some way giving a very wideband spectrum with a power versus time variation which is clearly not pulsed.

operating frequency (operating centre frequency): nominal frequency at which equipment is operated

pulsed radar: radar where the transmitter signal has a microwave power consisting of short RF pulses

radiated measurements: measurements that involve the absolute measurement of a radiated field

radiation: signals emitted intentionally inside a tank for level measurements

Stepped Frequency Continuous Wave (SFCW) radar: radar where the transmitter sequentially generates a number of frequencies with a step size

NOTE: At each moment of transmission, a monochromatic wave is emitted. It is distinguished from FMCW that has the instantaneous frequency band rather than a single frequency wave. The SFCW radar bandwidth is synthesized by signal processing to achieve required resolution bandwidth.

stillpipe: still-well, stilling-well, guide pole: Vertical, perforated metallic pipe built into a tank to reduce measurement errors arising from liquid turbulence, surface flow or agitation of the liquid

NOTE: Any equipment made of a perforated steel pipe with diameters varying from a few centimetres up to several decimetres. The perforations enable the liquid to freely flow into and out of the stillpipe at all levels in a tank. Stillpipes are the preferred installation point of a Tank Level Probing Radar inserted inside a floating or open roof tanks.

stillpipe TLPR: tank level probing radar coupled onto a stillpipe as one part installed through an external floating roof in a tank

user manual: end user documentation to be included with the device

3.2 Symbols

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

a	edge length of corner reflector (compare figure M.1)
$a^{dB}_{coupler(1-2)}$	coupling loss of the directional coupler between ports 1 and 2 in dB
$a^{dB}_{coupler(1-3)}$	coupling loss of the directional coupler between ports 1 and 3 in dB
$a^{dB}_{cable\_A}$	cable loss of coaxial RF-cable A in dB
$a^{dB}_{cable\_B}$	cable loss of coaxial RF-cable B in dB
$a^{dB}_{attn\_A}$	attenuation of the coaxial attenuator A in dB
$a^{dB}_{attn\_B}$	attenuation of the coaxial attenuator B in dB
c	velocity of light in a vacuum
cl1	cable loss 1
cl2	cable loss 2
dB	deciBel
dBi	gain in deciBel relative to an isotropic antenna
dBm	deciBel reference to 1 mW
D	duty cycle
E	electrical field strength
E_R	relative dielectric constant of earth materials
E_{rms}	average electrical field strength measured as root mean square
f_c	frequency at which the emission is the peak power at maximum
G	efficient antenna gain of radiating structure
G_{LNA}	gain of the measurement LNA

G_A	gain of the measurement antenna
$G(f)$	antenna gain over frequency
f_H	highest frequency of the frequency band of operation
f_L	lowest frequency of the frequency band of operation
k	boltzmann constant
P	power
$P_{e.i.r.p.}$	power spectral density
P_m	measured spectral power
$P_{wall,\ e.i.r.p.}$	unwanted power spectral density
$P_{r\_interferer}$ $\left(P^{\mathrm{dBm}}_{r\_interferer}\right)$	received interferer power at the location of the TLPR in Watt (in dBm)
$P_{t\_interferer}$ $\left(P^{dBm}_{t\_interferer}\right)$	transmitted interferer power (generated by the signal generator) in Watt (in dBm)
P_{r_real} $\left(P^{dBm}_{r\_real}\right)$	received echo power in the real measurement scenario in Watt (in dBm)
P_t $\left(P^{dBm}_t\right)$	maximum value of peak power of the TLPR in Watt (in dBm) in the real measurement scenario
$P_{r\_equivalent}$ $\left(P^{dBm}_{r\_\mathrm{equivalent}}\right)$	received echo power in the equivalent measurement scenario in Watt (in dBm)
P_s	output power of the signal generator measured by power meter
R	distance
rms	root mean square
r	reflection coefficient of the considered surface in the real measurement scenario
R_{max}	maximum measurement distance which the individual sensor is still able to reliably measure under the influence of an interferer
R	distance between stillpipe TLPR and test antenna
t	time
Δd	measurement value variation over time during a distance measurement
λ	wavelength in general or wavelength of the TLPR transmit signal at centre frequency
ε_r	relative permittivity of the surface material in the real measurement scenario

3.3 Abbreviations

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

AC/DC	Alternating Current/Direct Current
API	American Petroleum Institute
BFWA	Broadband Fixed Wireless Access
BW	BandWidth
CE	European Conformity
DC	Duty Cycle
e.i.r.p.	equivalent isotropically radiated power
EM	ElectroMagnetic
EUT	Equipment Under Test
FMCW	Frequency Modulated Continuous Wave
IT	Information Technology
LNA	Low Noise Amplifier
NLOS	Non Line-Of -Sight
OATS	Open Area Test Site
OE	Other Emissions
PC	Personal Computer
RF	Radio Frequency
RMS	Remote Management System
RX	Receiver
SFCW	Stepped Frequency Continuous Wave
SMA	Sub Miniature type A (connector)

TLPR Tank Level Probing Radar
TX Transmitter
UWB Ultra WideBand
VSWR Voltage Standing Wave Ratio

4 General testing requirements

4.1 Environmental conditions

Tests defined in the present document shall be carried out at representative points within the boundary limits of the declared operational environmental profile.

Where technical performance varies subject to environmental conditions, tests shall be carried out under a sufficient variety of environmental conditions (within the boundary limits of the declared operational environmental profile) to give confidence of compliance for the affected technical requirements. The test conditions are defined in clause 5.

4.2 Presentation of equipment for testing purposes

The manufacturer shall submit one or more samples of the equipment as appropriate for testing.

Additionally, technical documentation and operating manuals, sufficient to allow testing to be performed, shall be supplied.

The performance of the equipment submitted for testing shall be representative of the performance of the corresponding production model. In order to avoid any ambiguity in that assessment, the present document contains instructions for the presentation of equipment for testing purposes (see clause 4), conditions of testing (see clauses 5 and 6), interpretation of results (see clause 7), the measurement methods and limits for transmitters (see clause 8), receiver conformance requirements (see clause 9) and conformance test suite for receiver parameters (see clause 10).

The manufacturer shall offer equipment complete with any auxiliary equipment needed for testing.

4.3 Choice of model for testing

4.3.0 General

One or more samples of the EUT, as described in annex C, shall be tested for both transmitter and receiver parameters, respectively in accordance with clauses 8 and 10.

4.3.1 Declarations by the manufacturer

The manufacturer shall submit the necessary information regarding the equipment with respect to all technical requirements set by the present document.

4.3.2 Marking and equipment identification

The equipment shall be marked in a visible place. This marking shall be legible and durable.

The marking shall include as a minimum:

- The name of the manufacturer or his trademark.
- The type designation. This is the manufacturer's numeric or alphanumeric code or name that is specific to particular equipment.

4.4 Mechanical and electrical design

4.4.1 General

The equipment submitted by the manufacturer shall be designed, constructed and manufactured in accordance with good engineering practice and with the aim of minimizing harmful interference to other equipment and services and maximizing the handling capability of interferer signals from other equipment to the receiver.

4.5 Interpretation of the measurement results

4.5.0 General

The interpretation of the results recorded on the appropriate test report for the measurements described in the present document shall be as follows:

- the measured value relating to the corresponding limit together with the appropriate mitigation factors as described in clause 8.4 shall be used to decide whether an equipment meets the requirements of the present document;
- the measurement uncertainty value for the measurement of each parameter shall be included in the test report.

The measurement uncertainty is explained in clause 7. Additionally, the interpretation of the measured results depending on the measurement uncertainty is described in clauses 4.5.1 and 4.5.2.

For radiated UWB emissions measurements below 9 GHz and above 10,6 GHz it may not be possible to reduce measurement uncertainty to the levels specified in clause 7, table 2 (due to the very low signal level limits and the consequent requirement for high levels of amplification across wide bandwidths). In these cases alone it is acceptable to employ the alternative interpretation procedure specified in clause 4.5.2.

4.5.1 Measurement uncertainty is equal to or less than maximum acceptable uncertainty

The interpretation of the results when comparing measurement values with specification limits shall be as follows:

a) When the measured value does not exceed the limit value the equipment under test meets the requirements of the present document.

b) When the measured value exceeds the limit value the equipment under test does not meet the requirements of the present document.

c) The measurement uncertainty calculated by the test technician carrying out the measurement shall be recorded in the test report.

d) The measurement uncertainty calculated by the test technician may be a maximum value for a range of values of measurement, or may be the measurement uncertainty for the specific measurement undertaken. The method used shall be recorded in the test report.

4.5.2 Measurement uncertainty is greater than maximum acceptable uncertainty

The interpretation of the results when comparing measurement values with specification limits should be as follows:

a) When the measured value plus the difference between the measurement uncertainty calculated by the test technician and the maximum acceptable measurement uncertainty does not exceed the limit value, the equipment under test meets the requirements of the present document.

b) When the measured value plus the difference between the measurement uncertainty calculated by the test technician and the maximum acceptable measurement uncertainty exceeds the limit value the equipment under test does not meet the requirements of the present document.

c) The measurement uncertainty calculated by the test technician carrying out the measurement shall be recorded in the test report.

d) The measurement uncertainty calculated by the test technician may be a maximum value for a range of values of measurement, or may be the measurement uncertainty for the specific measurement undertaken. The method used shall be recorded in the test report.

5 Test conditions, power sources and ambient temperatures

5.1 Normal conditions

All testing shall be made under normal test conditions.

The test conditions and procedures shall be as specified in clause 5.2.

5.2 External test power source

5.2.0 General

During tests, the power source of the equipment shall be an external test power source, capable of producing normal voltages. The internal impedance of the external test power source shall be low enough for its effect on the test results to be negligible.

The test voltage shall be measured at the point of connection of the power cable to the equipment.

During tests, the external test power source voltages shall be within a tolerance of ±1 % relative to the voltage at the beginning of each test. The level of this tolerance can be critical for certain measurements. Using a smaller tolerance provides a reduced uncertainty level for these measurements.

The power source used during the test shall be stated in the test report.

5.2.1 Internal test power source

For radiated measurements on portable equipment with integral antenna, fully charged internal batteries should be used. The batteries used should be as supplied or recommended by the manufacturer. If internal batteries are used, at the end of each test the voltage shall be within a tolerance of less than ±5 % relative to the voltage at the beginning of each test.

5.3 Normal test conditions

5.3.1 Normal temperature and humidity

The normal temperature and humidity conditions for tests shall be any convenient combination of temperature and humidity within the following ranges:

- temperature + 15 °C to + 35 °C;
- relative humidity 20 % to 75 %.

When it is impractical to carry out tests under these conditions, a note to this effect, stating the ambient temperature and relative humidity during the tests, shall be added to the test report.