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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).

Introduction

The present document describes the application of Tank Level Probing Radar for the use in a specific type of tank that is not covered by the existing standard EN 302 372 [i.10] describing Tank Level Probing Radar installed in a closed metallic tank. The present document describes an application of level probing radar used on a tank type called floating roof tank, where the tank roof is floating on the surface of the tank content. The level in the tank is probed via a pipe that is fixed at the bottom and top of the tank and extends through a hole in the floating roof. Figure 1 shows a typical floating roof tank with the radar gauge mounted on top of the pipe. The pipe is usually referred to as a "still pipe".

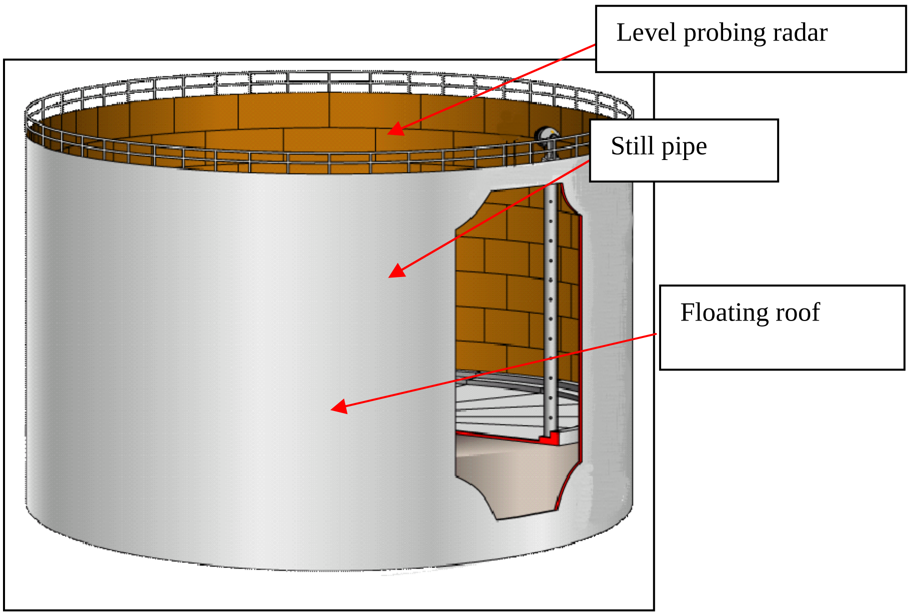

Figure 1: Floating roof tank with still pipe for level measuring.

This still pipe is perforated in order to enable the liquid to enter the pipe and to ensure that the level in the pipe is the same as on the outside. Floating roof tanks are used in petroleum refineries and storage plants together with closed metallic tanks.

The purpose of the present document is to describe the application and show that the radar energy propagating inside the pipe has a limited leakage to the outside of the tanks, and conformance to applicable standards can be achieved.

1 Scope

The present document provides guidance in resolving applications radar gauges installed on still pipe in external floating roof tanks.

The still pipe equipment consists of a TLPR and a dedicated still pipe to be operated in defined installation scenarios.

The purpose of the present document is to give a survey of the background for a possible future ETSI test specification for emissions from radar level gauging applications in still pipes that are not covered by EN 302 372 [i.10].

2 References

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2.1 Normative references

The following referenced documents are indispensable for the application of the present document. For dated references, only the edition cited applies. For non-specific references, the latest edition of the referenced document (including any amendments) applies.

Not applicable.

2.2 Informative references

The following referenced documents are not essential to the use of the present document but they assist the user with regard to a particular subject area**.** For non-specific references, the latest version of the referenced document (including any amendments) applies.

[i.1] Directive 1999/5/EC of the European Parliament and of the Council of 9 March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity.

[i.2] void.

[i.3] ECC Decision of 24 March 2006 amended 6 July 2007 at Constanta on the harmonized conditions for devices using Ultra-Wideband (UWB) technology in bands below 10.6 GHz (ECC/DEC/(06)04) amended 6 July 2007.

[i.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".

[i.5] ECC(07)116-Annex 13: "Definitions for peak/mean power under ECC regulations for specific UWB applications".

[i.6] 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 harmonized manner in the Community.

[i.7] CISPR 16-1: "Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-1: Radio disturbance and immunity measuring apparatus - Measuring apparatus".

[i.8] 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".

[i.9] ITU-R Recommendation P.526-6 " Propagation by diffraction".

[i.10] ETSI EN 302 372-1: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Equipment for Detection and Movement; Tank Level Probing Radar (TLPR) operating in the frequency bands 5,8 GHz, 10 GHz, 25 GHz, 61 GHz and 77 GHz; Part 1: Technical characteristics and test methods".

3 Definitions, symbols and abbreviations

3.1 Definitions

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

dedicated antenna: antenna that is designed as an indispensable part of the equipment

dedicated still pipe: still pipe is always inserted inside the tank

NOTE: The pipe cannot be working alone or outside the tank like bypass pipe in process tank.

Device Under Test (DUT): TLPR under test without a test still pipe

duty cycle: ratio of the total on time of the transmitter to the total time in any one-hour period reflecting normal operational mode for pulsed modulation system

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

NOTE: For TLPRs there is no intended emission outside the tank.

Equipment Under Test (EUT): TLPR mounted on a test still pipe

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

NOTE: e.i.r.p. is conventionally the product of "power into the antenna" and "antenna gain". e.i.r.p. is used for both peak and average power.

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.

integral antenna: permanent fixed antenna, which may be built-in, designed as an indispensable part of the equipment

manufacturer: manufacturer of the equipment, or his authorized representative, or an equipment supplier to the European market

maximum mean e.i.r.p. spectral density: highest signal strength measured in any direction at any frequency within the defined range

NOTE: The mean e.i.r.p. spectral density is measured with a 1 MHz resolution bandwidth, an RMS detector and an averaging time of 1ms or less.

maximum peak e.i.r.p: highest signal strength measured in any direction at any frequency within the defined range

NOTE 1: The peak e.i.r.p. is measured within a 50 MHz bandwidth centred on the frequency at which the highest mean radiated power occurs.

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

power spectral density (psd): amount of the total power inside the measuring receiver bandwidth expressed in dBm/MHz

pulsed radar (or here simply "pulsed TLPR"): radar where the transmitter signal has a microwave power consisting of short RF pulses

Pulse Repetition Frequency (PRF): inverse of the Pulse Repetition Interval, averaged over a sufficiently long time to cover all PRF variations

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.

still pipe: still-well, stilling-well, guide pole: Vertical, perforated 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 still pipe at all levels in a tank. Still pipes are the preferred installation point of a Tank Level Probing Radar inserted inside a floating or open roof tanks.

3.2 Symbols

k Boltzmann constant

T Kelvin temperature

B Bandwidth

λ wavelength

Φ diameter of tanks

3.3 Abbreviations

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

E.I.R.P	Equivalent Isotropic Radiated Power
EFRT	External Floating Roof Tank
EM	ElectroMagnetic
FMCW	Frequency Modulated Continuous Wave

PRF	Pulse Repetition Frequency
RF	Radio Frequency
SFCW	Stepped Frequency Continuous Wave
TLPR	Tank Level Probing Radar

4 Products considered in the present document

4.1 Examples of still pipe installations

In all of the various scenarios at least one of the **products** or **functions** falls within the scope of article 3.2 of the R&TTE Directive 1999/5/EC [i.1], i.e. at least one of the **products** or **functions** is a Level Probing Radar.

The integration of a TLPR product in a still pipe needs careful consideration of the emissions. In principle there are two types of external floating roof structures, the single deck and the double deck floating roof structure. Floating roof seals, (primary and secondary) and floating roof drains are very important items of the floating roof tank to ensure safe and cost effective operation of the tank.

All external floating roof tanks are big (Φ = 30 - 80 m and ~20 m high) which implies a low density of gauges and always located in industrial areas with very restricted admittance. 100 floating roof tanks in a single area is considered as a big tank farm.

Figure 2: Example of an external floating roof tank with still pipe and TLPR

The external floating roof is made of metallic material such as aluminium. The still pipes (stilling wells) are always inserted through the external floating roofs into the tanks. The positions of small openings on the pipe are always below the tank upper edges, i.e. always shielded by tank shell on horizontal plane. The pictures show some examples of the practical installations of radar gauges on EFRT.

The pipe perforations include various opening shapes like holes and slots. Typical perforations can be referred to corresponding ISO standard [i.4] or API Standard [i.8].

Figure 3: The perforated still pipes ready for installation in EFRT (left); operational perforated still pipe with floating roof (right)

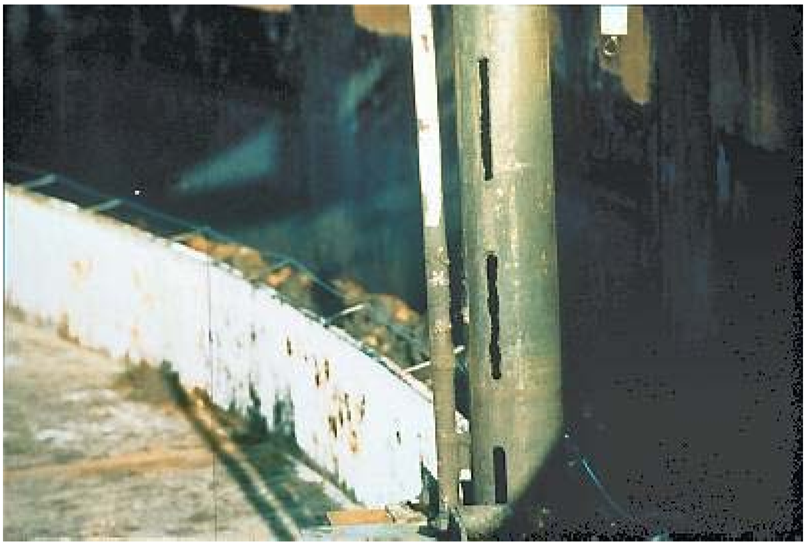

Figure 3a: Example of slotted still pipe.

4.1.1 Installation scenario

The commonly encountered installation scenario for a level radar gauge used on the external floating roof tank is a single perforated still pipe with the radar gauge on its top. The still pipe is fixed close to the tank shell. The tank shell can be regarded as the shielding to possible horizontal leakage of the guided energy inside the pipe. The still pipe acts as a waveguide with excited circular electrical field which is less sensitive to the irregular pipe wall conditions so that the power coupling to transversely radial directions is reduced to a low level.

The main purpose with the floating roof design is to avoid a vapour filled space which makes an explosion much less likely and reduces the liquid loss through evaporation. The still-pipe enables a very stable mounting of the radar gauge for accurate measurements with mm-accuracy and at the time of the design of the tank (perhaps several decades ago) the still pipe was dedicated for mechanical level gauging and for product sampling.

Figure 4: Typical EFRT with perforated still pipe under construction

5 Concept of adherence to existing regulation for still pipe radars

5.1 Applicable regulations

The Commission Decision 2007/131/EC [i.6] on UWB devices allows a maximum mean e.i.r.p spectral density of -65 dBm/MHz for indoor use in the frequency range from 8,5 GHz to 10,6 GHz. In addition, the EC Decision explicitly stipulates the possibility of having equipment conforming to other limits than those stated provided there are appropriate mitigation techniques in place.

The present document outlines how TLPR in still pipes and their installation requirements could be considered under the present regulation.

5.2 Indoor-like shielding

Radar level gauges together with a dedicated still pipe in an industrial tank farm environment can be considered indoor like. Conditions comparable to indoor are met and the Commission Decision 2007/131/EC [i.6] can be fulfilled. Since very big tanks are located outdoors, some extra precautions (e.g. power reduction, still pipe, tank-wall shielding of radar waves) have to be applied to reduce the emission to a level comparable to indoor installations.

5.3 Mitigation of EM interferences to victim radio devices

The mitigation can be classified into four categories:

5.3.1 Low density of still pipe units

All external floating roof tanks are big (Φ = 30 - 80 m and ~20 m high), which implies a low density of TLPRs installed in still pipes, and are always located in industrial hazardous areas with very restricted admittance. Only a very low percentage of such installed areas exist in a country. 100 floating roof tanks in a single area are considered as a big tank farm.

5.3.2 Shielding effects

5.3.2.1 Primary shielding

A TLPR mounted on a closed pipe is a completely shielded system with a very high screening attenuation. In order to enable the liquid to flow freely within the pipe it is necessary to have the pipe perforated.

The excited EM field has the unique property that confines the energy propagating inside the cylindrical pipe along axis. In this way, the emission from the perforations of the pipe with EFRT should be limited and could occur upside the floating roof.

The primary shielding provided by the still pipe is used in the present consideration to differentiate from radars operating at the open-air. The main purpose in the radar design for still pipe applications is to measure the liquid reflections inside the pipe.

5.3.2.2 Secondary shielding

An external floating roof is made of metallic material such as aluminium. The roof acts as a second shielding to prevent the radiated energy from going through it to open air. Furthermore, the tank wall plays a role in screening the leaked signal from the perforations, since those holes are always surrounded by the tank wall. The tank shell by knife-edge diffraction makes the emission in horizontal direction quite small. The knife-edge diffraction is described in ITU-R Recommendation P.526 [i.9] and with typical measurement there is app. 30 dB attenuation for horizontal directions. The perforations are always started at 0,5 m to 1 m below the top of the tank shell which is a natural upper limit for the liquid movements. No openings above the floating roof could exist in practice. The reduction factor of the tankwall shielding is about 30 dB.

The installation sites of dedicated still pipes are always within an industrial tank farm and/or terminal area, as shown in figure 2. The density of the installed units are very low and results in a low probability of having interference with other radio devices.

Some specific installation scenarios like double inserted pipes (shifted holes) could provide additional shielding. In this case an additional reduction factor of 30 dB is foreseen.

5.3.3 Frequency domain and time domain mitigation techniques

5.3.3.1 Frequency domain

For SFCW/FMCW modulation, the instantaneous bandwidth of the radar signal is close to zero. The mitigation naturally offered by SFCW/FMCW radar is the zero instantaneous bandwidth. The swept band over longer time is not able to generate simultaneous interferences to the victim receivers. For instance, the stepped Frequency Radar sweeps ca. 1 000 steps, within a period of approx. 100 ms. At each step the radar transmits a different frequency with dwell time of 100 μs within 1 MHz. For a 10 MHz victim receiver bandwidth, the equivalent duty cycle is 10×100 μs / 100 ms = 1 %. This is equivalent to provide the same effect as a 20 dB lower radiated power.

This concept cannot be used by pulsed radars having a large instantaneous bandwidth. For these radars, the time domain duty cycle should be considered as appropriate.

5.3.3.2 Time domain

Although the instantaneous bandwidth being large, the time domain duty cycle means the ratio of the total on time of the transmitter to the total time in any one-hour period reflecting normal operational mode for pulsed modulation system. This can be used in case of pulsed radars.

5.3.4 Reduction of transmit power

Power reduction is needed when the mitigation categories above are insufficient for meeting the limits stipulated in Commission Decision 2007/131/EC [i.6]. That method was already used on the first still pipe radar gauge approved for RF emission by FTZ in Germany 1988 where 20 dB reduction was applied to reach the emission level applicable at that time.

5.4 Thermal Radiation

At high elevation angles (i.e. typical elevation angles for alignment towards a satellite receiver front end or an aeronautical onboard aircraft receiver) the edge diffraction will not contribute.

According to the Planck's law, the thermal radiation from a "black" surface is calculated by $4\pi kTB/\lambda^2$ and equals at 10 GHz to about -73 dBm/MHz* m^2. An outdoor tank with diameter of 40 meters has got an thermal radiation of approximately -42 dBm /MHz.

Thus the average of the emitted power from the tank surface will be well below the thermal noise as seen from the sky.

5.5 Pulse Repetition Frequency (PRF)

Pulsed radars used in still pipes typically use PRF values higher than 100 kHz or in the range of some MHz. The effect of their resulting spectral lines in the comb spectrum may have some effect on some victim radio services and applications, e.g. radiolocation. However, the actual effect may depend on many parameters such as pulse length, pulse train organization and pulse repetition of both, the radar in the still pipe as well as the parameters of the possible victim.

The above may promise of being an interesting mitigation factor. This area could possibly be further investigated in the future to find out about possible coexistence.

6 Measurement examples

As most tanks have extremely large dimensions and since they are located in hazardous areas, it is impractical to conduct in-situ tests with expensive and high sensitivity equipment that is not explosion proof. A representative test setup will be developed and used by test laboratories to verify that the EUT complies with the regulations.

Figure 5 shows an example of a possible test setup.

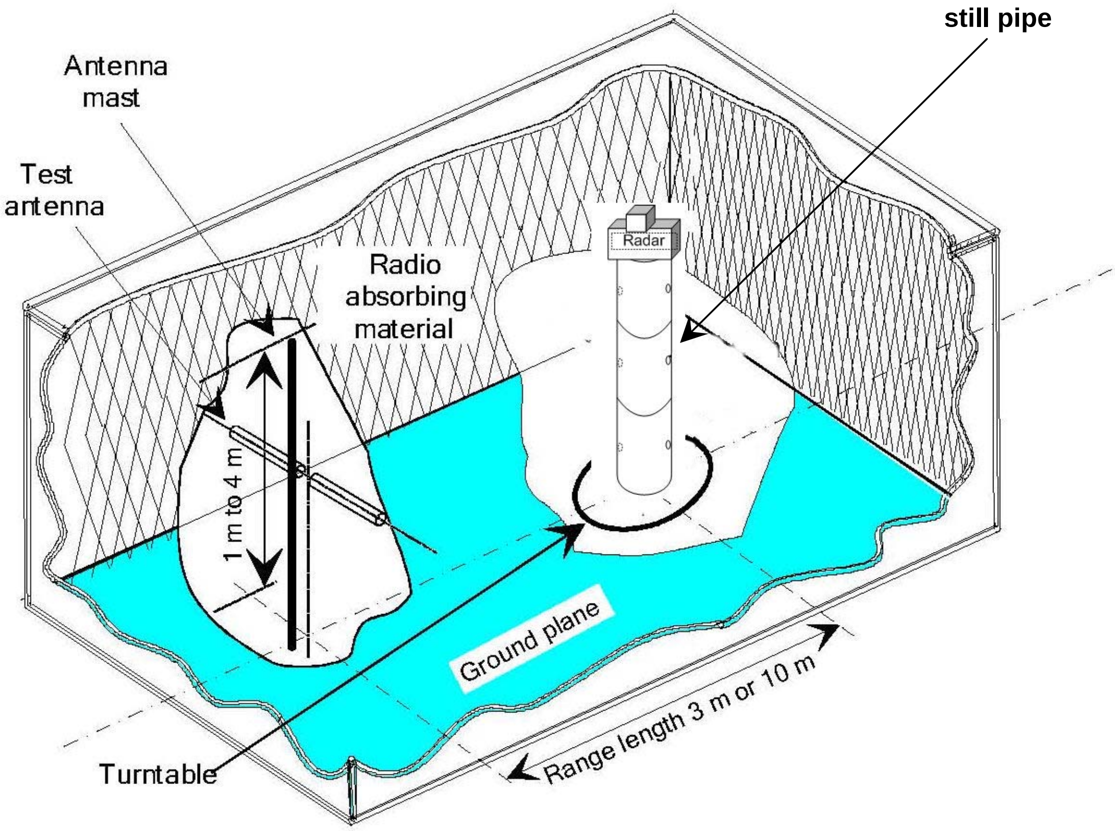

Figure 5: Example of a possible test setup

History

Document history		
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