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Technical Report

Electromagnetic compatibility and Radio spectrum Matters (ERM); Short-Range Devices (SRD); Radar Level Gauges operating in the frequency band 24,05 GHz to 25,50 GHz; System Reference Document

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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 covers Pulse and FMCW tank level probing radar applications in the gigahertz range, based on SRD technologies, with potential benefits for a wide range of applications such as process control, custody transfer measurement, safety (e.g. to prevent spilling) and industrial applications.

The purpose of producing the present document is to lay a foundation for industry to quickly bring innovative and useful products to the market while avoiding any harmful interference with other services and equipment.

The emphasis in the present document is on commercial use of Tank Level Probing Radars (TLPRs).

TLPRs, in the scope of the present document, operate only when installed in closed (not open) metallic tanks or reinforced concrete tanks, or similar enclosure structures made of comparable attenuating material. This operational constraint ensures that the emissions outside of the tanks or enclosure structures do not exceed very low, defined limits (even less than spurious emissions), for the purpose of determining the fill level of the contents of such tanks. Commercial TLPR applications using pulse RF or FMCW technology within the scope of the present document typically operate or are foreseen in the following frequency bands:

- 4,5 GHz to 7 GHz;
- 8,5 GHz to 11,5 GHz;
- 24,05 GHz to 27 GHz;
- 57 GHz to 64 GHz; and
- 75 GHz to 85 GHz.

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) for amending the ERC Recommendation 70-03, annex 6 [1].

1 Scope

The present document provides information on the intended applications, the technical parameters and the radio spectrum requirements for TLPR based on e.g. pulse RF or FMCW, operating specifically in the frequency bands:

- 4,5 GHz to 7 GHz;
- 8,5 GHz to 11,5 GHz;
- 24,05 GHz to 27 GHz;
- 57 GHz to 64 GHz; and
- 75 GHz to 85 GHz.

The present document describes pulse RF and FMCW systems that are used in tank level measurement applications.

The scope is limited to radars operated as short range devices (because of their commercial usage and design), in which the TLPR is installed in closed (not open) metallic tanks or reinforced concrete tanks, or similar enclosure structures made of comparable attenuating material, holding a substance, liquid or powder, whose level is a variable. It does not include any radar systems in applications where they would be operated outside closed (not open) metallic tank or reinforced concrete tank, or similar enclosure structure made of comparable attenuating material.

The radar applications in the present document are not intended for communications purposes. Their intended usage excludes any intended radiation into free space which sets it apart from any type of communications equipment.

Additional information is given in the following annexes:

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

2 References

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

[1] CEPT/ERC Recommendation 70-03: "Relating to the use of Short Range Devices (SRD)".

[2] ITU Radio Regulations.

[3] ITU-R Recommendation SM.1538-1: "Technical and operating parameters and spectrum requirements for short-range radiocommunication devices".

[4] ETSI EN 300 440-1 (V1.3.1): "Electromagnetic compatibility and Radio spectrum Matter (ERM); Short Range Devices;(SRD); Radio equipment to be used in the 1 GHz to 40 GHz frequency range; Part 1: Technical characteristics and test methods".

3 Definitions and abbreviations

3.1 Definitions

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

FMCW radar: radar system using a frequency modulated continuous wave RF carrier

pulse radar: radar system transmitting and receiving short RF pulses

range resolution: ability to resolve two targets at different ranges

tank level probing radar: system using a short pulse of RF energy to generate a wide band emission or a FMCW emission in order to provide highly accurate short range measurement distance typical of material level measurement in tank enclosures

3.2 Abbreviations

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

CEPT	European Conference of Post and Telecommunications
dB	Decibel
e.i.r.p.	Equivalent Isotropically Radiated Power
ECC	Electronic Communications Committee
EMC	Electromagnetic Compatibility
ERC	European Radiocommunications Committee
FMCW	Frequency Modulated Continuous Wave
ISM	Industrial, Scientific and Medical
ITU	International Telecommunications Union
PRF	Pulse Repetition Frequency
RF	Radio Frequency
SRD	Short Range Device
SRDoc	System Reference Document
TLPR	Tank Level Probing Radar

4 Executive summary

The present document provides a basis for a general, non-individual, licence-exempt arrangement for tank level probing radar (TLPR) systems. TLPR will play a pivotal role in the economic direction of major mass material storage infrastructure projects. TLPRs provide high accuracy and outstanding reliability, high resistance to dirt and tank atmosphere, regardless of the substance in the tank, its temperature or pressure, allowing precise control of manufacturing processes and storage facilities.

The objective of designers and operators of TLPRs is to direct signals from the tank top towards the surface of a substance contained in a closed (not open) metallic tank or reinforced concrete tank, or similar enclosure structure made of comparable attenuating material, such that only extremely low unwanted emissions occur outside the tank (limits described in annex B).

The applications where TLPRs operate, e.g. tanks containing internal structures, etc. demand a relatively high bandwidth and/or power to provide sufficient distance resolution between the surface echo and other disturbing echoes. In either case the shielding provided by the tank, the absorption of RF energy by the substance in the tank, and the orientation of the antenna to point in a downward direction will act to contain the RF energy radiated from the TLPR to levels that are well below the limits prescribed in existing EMC standards.

Given the similarity in bandwidth to unintentionally radiated digital device emissions and the desire to limit electromagnetic radiation in general, the present document proposes that a general EMC standard should be used to specify the radiation from tank level probing radar systems as measured outside of the enclosure, in which the radar is installed coupled with technical specifications for power output, spurious emissions, duty cycle and antenna gain. This essentially would provide a regulatory structure that ensures these systems do not become sources of radiation that will cause any interference to existing primary or secondary services in the requested band.

TLPRs do not communicate any information via the radar signal to any other equipment; therefore no protocol communications standard is required for these systems.

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

4.1 Status of the present document

The draft version, V 0.0.1, was approved by ERM-TG31A and was presented to ERM-RM for discussion and approval at its #28 meeting in Montegrotto. The draft version V1.1.1_1.1.1 is the outcome of the discussion within ERM-RM#28. Version 1.1.1_1.1.2 incorporates minor editorials and has been forwarded to CEPT as a first phase SRDoc for immediate consideration. ERM-RM informed CEPT that the information on the 24,05 GHz to 27 GHz is stable, and that ERM-RM aims at providing CEPT, very rapidly, a more complete version of the document (expected to cover also the additional frequency bands to be considered for TLPRs). Version 1.1.1_1.2.1 includes the additional frequency bands and other information required by CEPT. It was approved by ERM-TG31A.Version 1.1.1_1.2.2 was circulated for approval by correspondence within ERM-RM until 19 October 2004.

The present document V1.1.1_1.2.3 has been approved by ERM-RM and is submitted to ERM#24 for approval for publication. It will be sent to the CEPT for consideration.

4.2 Market information

For detailed market information, see annex A.

4.3 Technical system description

For detailed technical information on tank level probing radars, see annex B.

5 Current regulations

The current regulations in annex 6 ("Equipment for Detecting Movement and Equipment for Alert") of CEPT/ERC Recommendation 70-03 [1] contain provisions for operation in the band from 24,05 GHz to 24,25 GHz at a power level of 100 mW. However, this bandwidth is insufficient to permit the operation of TLPRs capable of providing the range resolution and accuracy necessary to provide industrial users of TLPRs with the capability they have requested.

Article No. 4.4 of the Radio Regulations [2] has been relied upon by national administrations (and CEPT as well) in many contexts to authorize applications not conforming to the Table of Frequency Allocations in the Radio Regulations (e.g. Short Range Devices which are operated in ISM frequency bands). TLPR equipment, as described in this document, might also be operated under Article Radio Regulations No. 4.4.

Further, it should be noted that ITU-R Recommendation SM.1538-1 [3] recommends that national spectrum authorities consider permitting the following bands for TLPRs:

- 4,5 GHz to 7 GHz;
- 8,5 GHz to 11,5 GHz;
- 24,05 GHz to 27 GHz;
- 57 GHz to 64 GHz (within annex 1, "Additional applications" in ITU-R Recommendation SM 1538-1 [3]);
- 76 GHz to 78 GHz.

NOTE: The frequencies 0,5 GHz to 3 GHz are recommended for TLPR in Recommendation ITU-Recommendation SM. 1538-1 [3] but are not stated here because industry representatives in ETSI have shown no interest for them.

Industry feels that the bandwidths for the higher frequencies are not sufficient for all purposes and proposes extensions as shown in clause 6, table s 6.1 and table 6.2.

6 Proposed regulations

It is proposed that TLPR be permitted to operate with the specifications in tables 6.1 (for FMCW systems) and table 6.2 (for pulse systems). Further, it should be stipulated that usage must be in closed (not open) metallic tanks or reinforced concrete tanks, or similar enclosure structures made of comparable attenuating material.

Table 6.1: Proposed radio interface requirements for FMCW systems

Frequency band (see note 1)	Max. radiated bandwidth (see note 2)	Max. antenna input power conducted	Max. radiated power inside tank, e.i.r.p.	Max. duty cycle (see note 3)	Max. unwanted emissions outside tank worst-case
4,5 GHz to 7 GHz	-10 dBc at band edge	+10 dBm	+24 dBm	100 %	- 41,3 dBm/MHz
8,5 GHz to 11,5 GHz		+10 dBm	+30 dBm		
24,05 GHz to 27 GHz		+10 dBm	+43 dBm		
57 GHz to 64 GHz		+10 dBm	+43 dBm		
75 GHz to 85 GHz		+10 dBm	+43 dBm		
NOTE 1: Bandwidth according to ITU-R Recommendation SM.1538-1 [3] except for 75 GHz to 85 GHz frequency band. NOTE 2: Occupied bandwidth: -10 dBc at band edge within the declared frequency band. NOTE 3: Duty cycle according to ITU-R Recommendation SM.1538-1 [3].					

Table 6.2: Proposed radio interface requirements for pulse systems

Frequency band (see note 1)	Max. radiated bandwidth (see note 2)	Max. antenna input power (peak) conducted	Max. peak power inside tank, e.i.r.p.	Max. average power inside tank, e.i.r.p.	Max. duty cycle (see note 3)	Max. unwanted emissions outside tank worst-case
4,5 GHz to 7 GHz	-10 dBc at Band edge	+10 dBm	+24 dBm	+4 dBm	0,1 % - 1 %	- 41,3 dBm/MHz
8,5 GHz to 11,5 GHz		+10 dBm	+30 dBm	+10 dBm		
24,05 GHz to 27 GHz		+10 dBm	+43 dBm	+23 dBm		
57 GHz to 64 GHz		+10 dBm	+43 dBm	+23 dBm		
75 GHz to 85 GHz		+10 dBm	+43 dBm	+23 dBm		
NOTE 1: Bandwidth according to ITU-R Recommendation SM.1538-1 [3] except for 75 GHz to 85 GHz frequency band. NOTE 2: Occupied bandwidth: -10 dBc at band edge within the declared frequency band. NOTE 3: Duty cycle according to ITU-R Recommendation SM.1538-1 [3].						

The parameters specified in tables 6.1 and 6.2 provide a maximum cap on power and bandwidth and are measured in free space using appropriate measurement techniques. As a further precaution against any potential interference, the equipment must be installed in a typical tank as specified in the owner's manual to comply with the essential requirements.

7 Main conclusions

TLPRs are used in many industries to measure the amount of various substances, primarily stored in closed (not open) metallic tanks or reinforced concrete tanks, or similar enclosure structures made of comparable attenuating material. The industries in which are used are mostly concerned with process control. TLPRs are used in facilities such as refineries, chemical plants, pharmaceutical plants, pulp and paper mills, food and beverage plants, power plants, etc.

All of these industries have storage and process tanks throughout their facilities where intermediate or final products are stored or processed and which require level measurement gauges.

TLPR provides substance level information to all sectors of the manufacturing and distribution communities having a need for storage of liquids and other products used in any economic sector.

8 Expected ETSI and ECC actions

It is proposed that the ECC considers the present document, which 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) for amending annex 6 of the CEPT Recommendation 70-03 [1].

ETSI believes that procedures for administrating and ensuring adherence to regulations should be kept to a minimum, both for the regulator as well as for the users of TLPR.

ETSI:

- to approve the SRDoc and forward it to CEPT/WGFM;
- to elaborate a new product standard for TLPR, in order to address the specific issue of installation of TLPR in tanks since existing standards are not fully adequate for TLPR.

ECC:

- to study the application of TLPRs in the frequency bands of the present document;
- to amend annex 6 of the CEPT/ERC Recommedation 70-03 [1] in order to introduce the bands for TLPR applications.

Annex A:
Detailed market information

A.1 Range of applications

Measuring of substance levels by microwave (TLPR) started commercially 1976 on tanker ships and 1984 on large storage tanks in ports, refineries, and storage plants. In the beginning it was quite an expensive method compared to older methods (e.g. floats). However, radar technology experienced a fast growth despite the high price because it proved to be the most reliable solution to the severe environmental conditions in cargo tanks. TLPR technology is now mature and cost effective primarily due to the development of low cost microwave semiconductors. The market has rapidly expanded, and today the majority of new tanks are equipped with TLPRs.

Currently TLPRs find main applications, for example, in the following industries:

- refineries;
- chemical;
- petrochemical;
- pharmaceutical;
- power engineering;
- custody transfer;
- food and beverage;
- cement, powder, wood chips and other solid material applications;
- aviation fuel depots;
- water and sewage treatment, etc.

Figure A.1: Examples of TLPR applications

Some of the main advantages of the TLPR are:

- high measuring accuracy;
- high repeatability;
- robust measuring performance in a variety of tanks and process conditions;
- high reliability;
- minimum maintenance requirements and wear as result of no moving parts;

- level measurement independent of medium permits a wide range of applications;
- easy installation;
- non-contacting measuring principle;
- high long-term stability resulting from self-calibration since the device has a highly stable internal reference;
- improvement in environmental protection and human safety due to reduced spillage;
- efficient alarm handling.

A.2 Market size and value

Figure A.2. shows the total level instrument sales during the period 1970 to 2005. It also shows sales of TLPRs in this market. It can clearly be seen that TLPRs are rapidly replacing other technologies in this market. The total worldwide market for TLPR products in 2002 was US$350 million projected to grow to more than US$700 million (Source ARC, ICI, F&S, VDC – all well known market research organizations). In 2004, 50 % of the TLPR market is in Europe.

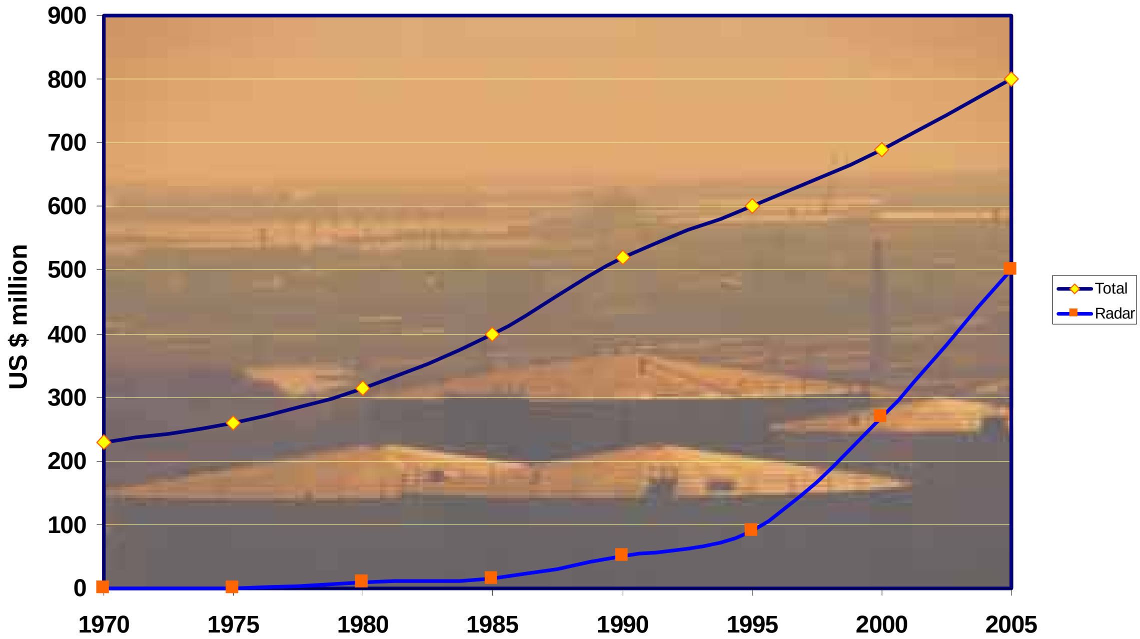

Figure A.2: Total Level Sales (all technologies) and Radar Level Sales (Source: ARC, ICI, F&S, VDC)

Today, TLPR devices are commonly available in the following frequencies:

- 4,5 GHz to 7 GHz;
- 8,5 GHz to 11,5 GHz;
- 24,05 GHz to 27 GHz.

Future developments are expected in the following bands:

- 57 GHz to 64 GHz;
- 75 GHz to 85 GHz.

A.3 Deployment

TLPR equipment within the scope of the present document is essentially a professional system strictly for commercial usage that is installed and maintained by professionally trained individuals. Their use is associated with new, industrial construction and in retrofitting existing industrial facilities.

The assumption is that no more than an average of ten TLPR units per square kilometres per frequency band will exist in industrial plant areas.

Annex B: Technical information

B.1 Detailed technical description

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

A TLPR comprises of three main architectural blocks:

1) The in-tank antenna that functionally emits microwaves into the tank and transmits them downwards to the surface, and receives reflected signals from the surface and leads these back to the electronics. The tank flange seals the tank from the outside environment (see figure B.1.1) and prevents microwaves from leaking out of the tank. Additionally, there are strict requirements on the seal from a safety point of view to prevent leakage into the environment.

2) The electronics generate and receive microwaves on a desired frequency using either FMCW or pulse modulation principle. After receiving the microwaves the analog signal is processed using advanced signal processing to generate a process parameter or other desirable output. The output is then provided to the user by use of a display or one of several different types of standard communication means. There are strict requirements on the electronics from a safety aspect to eliminate any risk of initiating an explosion should there be a volatile gas in the environment.

3) The housing contains and protects the electronics from the environment. It may have explosion proof properties, must be water tight and enable the user to easily install and maintain the TLPR.

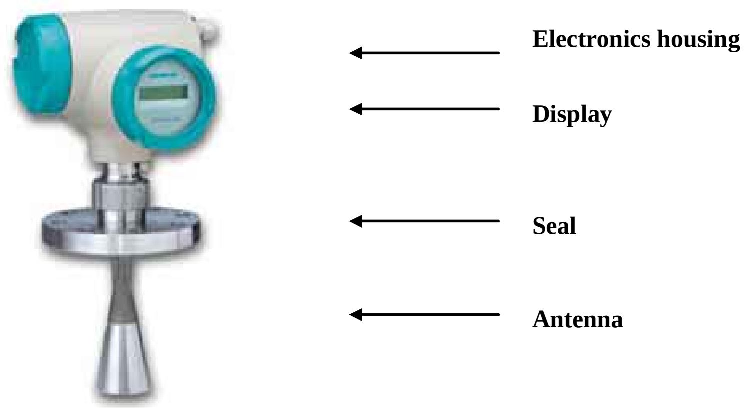

Figure B.1.1: An example of a TLPR

Today, TLPRs use either a time of flight or FMCW principle to measure level. For time of flight the TLPR transmits a short pulse (of about 1 nanosecond) into the tank and measures the time it takes for this pulse to travel through the tank and bounce off the surface back to the TLPR. For FMCW the TLPR changes the transmitted frequency at a known change rate, and then compare transmitted frequency to received frequency. The frequency difference is proportional to the distance to the surface.

When operating in a tank, the TLPR will receive several different reflections. The surface which is the main objective to identify and follow is one echo, other echoes may come from various structures in the tank such as agitators, baffles, inlets, other instruments, heating coils, the tank bottom (in case of a low dielectric liquid), etc. It should be noted that the surface reflection may not be the strongest echo in the tank.

In order to distinguish between the different echoes, and to be able to identify and track the surface, a number of different optimization parameters exist for a user. They include frequency, antenna type and diameter, installation point on the tank, configuration of signal processing parameters, etc. A key performance driver is bandwidth both in terms of accuracy and ability to resolve (distinguish between) two echoes that are close together. Therefore, TLPRs exist on several different frequency bands where they need a larger bandwidth than most other microwave devices would use.

B.2 Technical justification for multiple frequency bands

The objective of TLPR systems is to accurately and reliably measure substance levels contained within a closed (not open) metallic tank or reinforced concrete tank, or similar enclosure structure made of comparable attenuating material. The TLPR performs its function by transmitting an electromagnetic signal (either as a pulse or as a continuous frequency modulated wave) towards the surface of the substance in the tank. A fraction of this signal is then reflected by the surface in the direction of the TLPR which receives it and processes it in order to provide a distance measurement. Subtracting this distance from the total tank height will give the level of substance in the tank. In all applications, the objective of the TLPR designer and user is to contain the radiated energy inside the tank.

TLPR manufacturers must be able to provide users with many different options or variants of the TLPR because the tanks, tank environment, and properties of the substance stored in the tank vary a lot, and can be combined into an infinite number of potential applications. Each application will provide a unique microwave challenge to the TLPR that must be solved by selecting the right type of TLPR with the right options, and configuring it appropriately.

Tanks exist in many different sizes, shapes and forms ranging in size from small process tanks (that may be 1 m in height and diameter) to large storage tanks (e.g. in ports) that may be 70 m in diameter and 50 m high. This is illustrated in figure B.2.1.

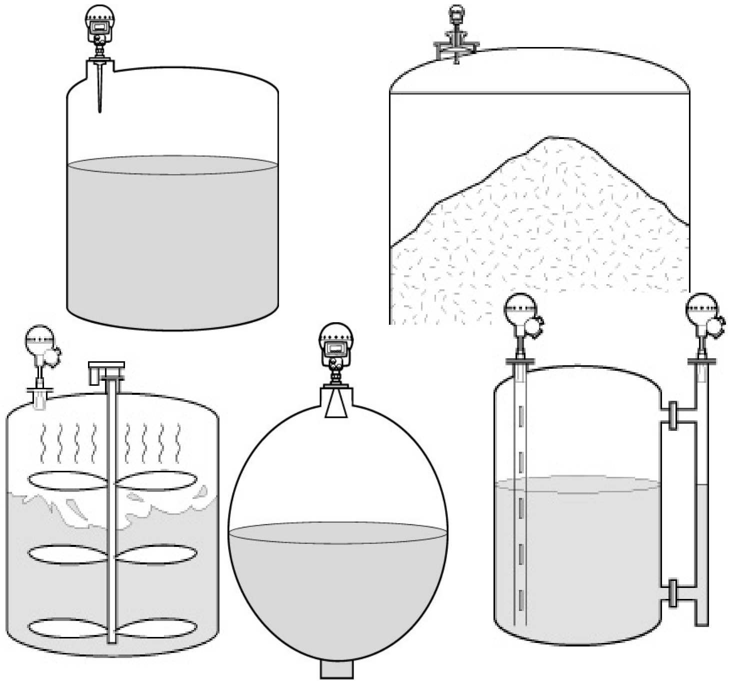

Figure B.2.1: Different types of TLPR applications

The inside of the tanks also show a large variety. The bottom may be flat, spherical, conical, concave or convex. Tanks normally have other installations besides the TLPR. These installations include inlet pipes, other instruments (e.g. pressure sensors, temperature sensors, level switches, etc.), agitators, beams, ladders (in large tanks), etc. Furthermore, looking at the TLPR installation, different tanks provide very different installation conditions. The TLPR is typically installed in an opening (nozzle or flange), or on a pipe (that may have many different diameters and properties) that sits inside or outside the tank. These openings, where the TLPRs are installed, come in many different sizes and are in some cases close to the centre of the tank and in other cases close to the side.

The tank environment varies significantly from one application to another. In process industry there may be foam, mist, vortices, splashing, agitation, waves in the surface, high temperature and pressure, etc. In storage tanks, the surface is normally calm. In all types of tanks you may experience condensation and/or contamination on antennas. The effect of contamination on the antenna is illustrated in figure B.2.2.

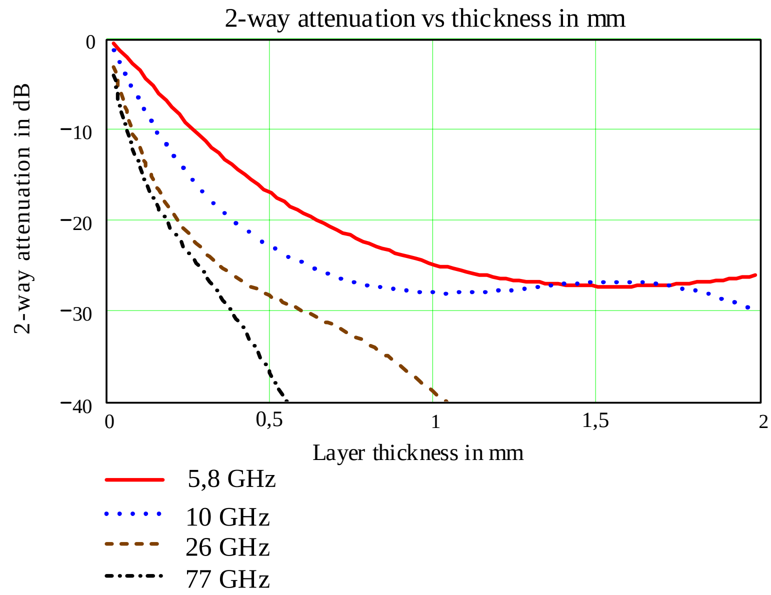

Figure B.2.2: Two-way attenuation of the signal due to antenna contamination (reference Microwave Aquametry)

As an example, a 0,1 mm thick wet layer on antenna will cause an attenuation of the signal of 12 dB at 26 GHz. At 6 GHz the same attenuation is achieved by a layer that is three to four times thicker. If an attenuation of 25 dB can be accepted, a TLPR operating at 6 GHz to 10 GHz will function when subjected to a several mm thicker layer while a high frequency TLPR will stand only ~0,4 mm.

There are several ways to manage contamination on the antenna. An example of contaminated antennas is illustrated in figure B.2.3. In an environment where condensation occurs, antennas are designed to avoid thick build up of the condensing substance. In a contaminating environment, the antennas may be cleaned at regular intervals. In both these examples, it is desirable to use lower frequencies to minimize the affect of condensation or to minimize the need for cleaning (maintenance).

Figure B.2.3: Examples of antenna contamination

The effect of surface conditions (turbulence) as a function of frequency is shown in figure B.2.4.

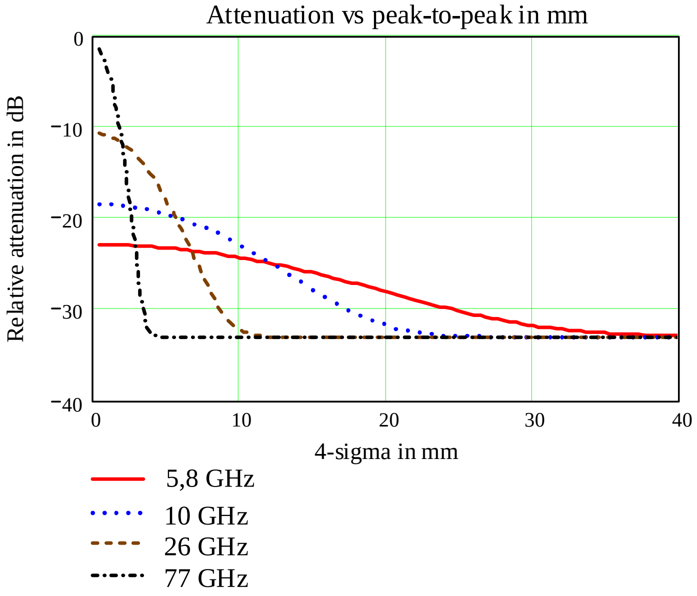

Figure B.2.4: Attenuation of the signal due to turbulence (sigma: standard measure of the surface deviation; 4-sigma: peak to peak)

In the extremely turbulent environment (i.e. 4-sigma ~ 35 mm to 40 mm), the frequency is not an important factor but the received signal is proportional to antenna size. The higher frequency gives more reflection at a smooth surface but is much more sensitive to turbulence.

The higher frequency has a narrower antenna beam which is advantageous for measurement in tanks with many obstructions. See figure B.2.5.

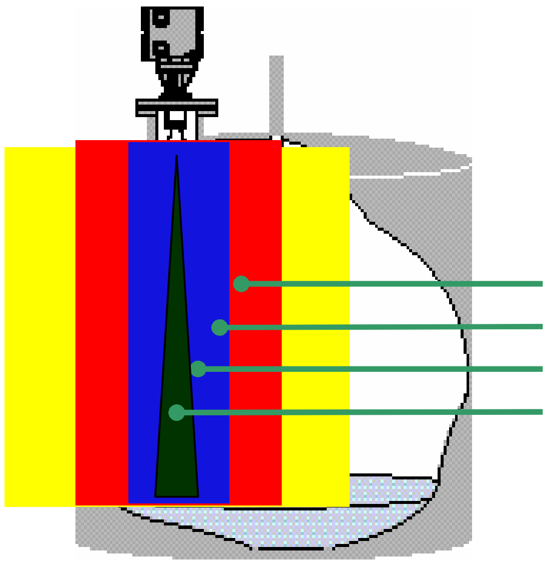

Figure B.2.5 Antenna beam versus frequency

The substance stored in the different tanks will have different dielectric constants that provide a stronger or weaker echo to the TLPR.

Over time manufacturers have done significant research to understand all the above conditions that the TLPR will experience and how these will impact the TLPR performance. A number of key parameters of the TLPR can be varied to provide robust measurements for most existing conditions. The most important parameters include transmitted frequency, antenna type, antenna size, antenna design, signal processing configuration, and bandwidth.

The first TLPRs were developed around 10 GHz since this had been established as the optimum frequency for use in large storage tanks combining robustness to condensation and contamination with a reasonable antenna beam. A narrow antenna beam is desirable in the storage tanks with large measuring distances (up to 50 m) to avoid interference from structures, walls etc, that exist inside the tank. Later developments (during the 1990s) produced TLPRs first at 6 GHz and later 26 GHz. This development was primarily driven by applications in the process industry where the tanks are typically shorter, but the conditions (structures, foaming, contamination, etc.) inside the tanks more extreme than in the large storage tanks - thus requiring a slightly different optimization of the TLPR. For future developments, it is predicted that higher frequencies between 57 GHz to 64 GHz or 75 GHz to 85 GHz will be employed. There are several advantages of higher frequencies including a narrow antenna beam, the possibility to increase the bandwidth, which will contribute to accuracy and ability to resolve echoes in the tank, and the potential to reuse low cost components from other applications (e.g. automotive).

A short summary of advantages and disadvantages are shown in table B.2.1.

Table B.2.1: Advantages and disadvantages of different frequency bands

Frequency bands	Advantages	Disadvantages
4,5 GHz to 7 GHz	Foam, condensation, contamination, turbulence, waves on the surface.	Large lobe angle.
8,5 GHz to 11,5 GHz	Condensation, contamination, turbulence, waves on the surface	
24,05 GHz to 27 GHz	Relatively calm surfaces, small lobe angle.	Foam, condensation, contamination, turbulence, higher power requirements.
57 GHz to 64 GHz and 75 GHz to 85 GHz	Ability to increase bandwidth, calm surfaces, small openings, easier to seal, lower cost, smallest lobe angle.	Foam, condensation, contamination, turbulence, higher power requirements.

Inevitably there may be some low level leakage of the signal into the air outside the tank due to discontinuities at nozzle openings and, in some cases, necessary vent arrangements for the tank. Measurements show that the leakage emissions outside the tank are at least 5 dB to 10 dB below the maximum permitted levels specified in the relevant EMC standards. The TLPR community has sought to ensure that systems do not cause any interference to existing services. Over the last three decades there have been no reports or complaints about interference between TLPRs and other radio services.

B.3 Bandwidth requirement

There is a strong market demand to extend the use of TLPRs to more level measuring applications (see figure A.2). These applications involve new, more stringent requirements. One potential issue is that the demands for accuracy and resolution require a large bandwidth.

TLPRs operate by radiating short radar pulses or radiating a FMCW modulated signal into the tank. When a radar signal reaches the substance with a different dielectric constant, a small portion of the signal is reflected to the receiver and the remaining signal is scattered and basically absorbed by the substance in the tank. An ideal case would be just one echo reflected to the receiver, i.e. having only the signal reflected from the substance surface. In this case there would not be a need for a large bandwidth. However, the receiver takes up many other undesired disturbance echoes besides the desired surface echo. This decreases the measurement performance. The disturbing echoes originate from reflection of the signal from other obstacles in the tank. The tank's shape, size and content varies considerably. This is illustrated in figure B.3.1. Inside the tank there are often many obstacles (e.g. agitators) and other installations that are the cause of disturbing echoes. Furthermore, TLPRs are often installed in existing tanks where nozzles and openings are placed near the tank wall. When installed on such tanks, the signal emitted from the TLPRs is being reflected from the tank wall, once again causing the disturbing echoes.

Figure B.3.1: Different interference structures inside a tank

In order to distinguish the surface echo from disturbing echoes caused by the tank structure a bandwidth as high as possible is required. The radar resolution in terms of a distance is closely related to the bandwidth which is illustrated in figure B.3.2.

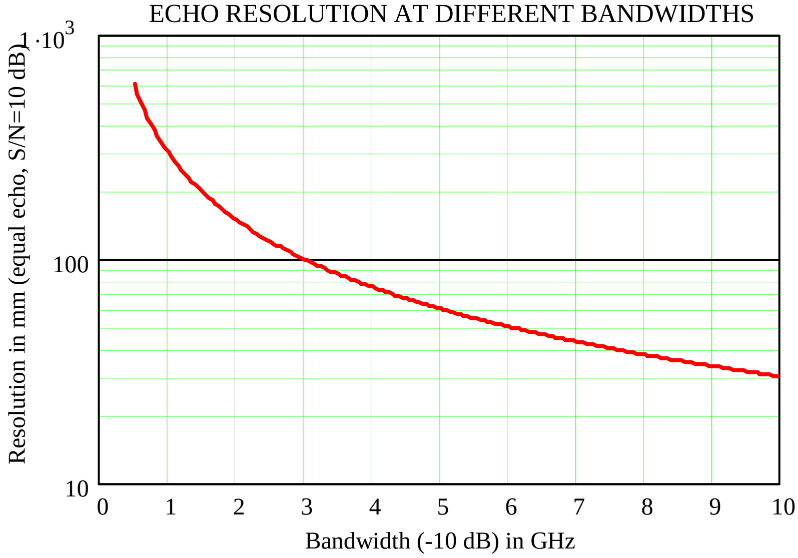

Figure B.3.2: Echo resolution vs. Bandwidth

The ability to accurately resolve the measured distance is determined by width of radiated pulse or in the case of FMCW sweep rate. To achieve required measurement performance closely adjacent echoes must be resolved (e.g. one to a few hundred mm or less apart closely adjacent echoes must be resolved). The technical difficulty is to obtain accurate measurement of the signal propagation time from the moment it is emitted via an antenna to the moment an echo is received after reflection.

Current systems have a 1 GHz to 2 GHz wide sweep or 0,5 nanosecond to 1 nanosecond pulses. Pulse width of typically 1 nanosecond pulse (depending on the pulse shape) corresponds to at least 1 GHz bandwidth. This bandwidth gives in practice around 300 mm resolution which is insufficient for the user today. For future systems there is demand for a substantial improvement in many applications. The higher the bandwidth the shorter the pulses. With shorter pulses the echo resolution becomes better, and it is therefore easier to distinguish between two echoes that are close to each other.

Consequently, a wider bandwidth such as 8 GHz to 10 GHz in future systems is required. A large bandwidth, such as 10 GHz, will give a considerable improvement in resolution, i.e. up to 20 mm resolution. One typical need for wide bandwidth is to distinguish echoes that are close together in the tank, for instance the echo from the oil surface and that from the tank bottom. A target at a shallow depth can be distinguished if the time interval δt for the signal to travel between the system and the substance level is greater than the pulse width. Thus, as the distance between the system and the material whose level is to be measured is reduced, the pulse duration must also be reduced which means larger bandwidth of the system is required.

Accuracy is very important and some applications require an accuracy below 1 mm. Today typical requirements for accuracy are 2 mm over 20 m or 0,01 % which also can be expressed in time as 13 picosecond. An application example where very high measurement accuracy is needed is custody transfer services where an accuracy of better than 1 mm is required. The accuracy is more or less closely related to the bandwidth which is easier to obtain at higher frequencies.

The high measurement accuracy is partly a consequence of a high measurement resolution. Large bandwidth TLPRs have a high resolution capability which enables moderating the influence of the disturbing echoes and makes it possible for a system to measure substance level more accurately. If two echoes are mixed up the accuracy will be destroyed. To avoid mixing echoes, high resolution is required and a wide bandwidth is the only robust method to improve separation. For example, in a pulsed TLPR system mixing of echoes can be seen as irregularities in the pulse shape which are a fraction of the pulse length. Such irregularities decrease the ability of finding the top of the pulse and in that way reduces measurement performance accuracy.

In order to meet a high accuracy and high resolution demand of the market, an extremely wide frequency bandwidth should be available, which is only possible at higher frequencies.

B.4 Radiation limits outside the tank

The proposed radiation limits outside the tank are shown in tables 6.1 and 6.2.

B.5 Information on current version of relevant ETSI standard

In order to cover the radiation limits a new standard for TLPRs is necessary because:

1) the existing generic standard, EN 300 440 [4], is not fully adequate for TLPRs;

2) there are no product standards available for TLPRs.

The new standard shall address the specific concept that TLPRs are installed in closed (not open) metallic tanks or reinforced concrete tanks, or similar enclosure structures made of comparable attenuating material to define the unwanted radiation limits outside the tank.

Annex C:
Expected compatibility issues

C.1 Coexistence issues

Compatibility issues are not expected because TLPRs are installed in closed (not open) metallic tanks or reinforced concrete tanks, or similar enclosure structures made of comparable attenuating material, and the primary or secondary users in the same band co-exist without problems. The numbers of TLPR units will not proliferate to the point where aggregation could affect any of the primary services in the band and, based on the proposal, any detectable emissions outside the tank enclosure must meet the proposed limit in clause 6, tables 6.1 and 6.2.

Over the last three decades there have been no reports or complaints about interference between TLPRs and other radio services.

Furthermore, installation of the antenna inside the tanks pointing downwards mitigates any external emissions from interfering with TLPR systems.

Tests have been performed on installed units as described above and no emission above the limits from TLPR was detectable outside the tank.

C.2 Current ITU allocations

The current ITU allocations for the proposed TLPR frequencies are shown in table C.2.1.

Table C.2.1: ITU allocations for proposed TLPR frequencies

frequency Band	ITU allocations
4,5 GHz to 7 GHz	Fixed Service, Mobile Service, Aeronautical Radio Navigation, Fixed - Satellite Service, Space Research, Maritime Navigation, Earth Exploration - Satellite, Amateur Service, Radio location Service, Maritime Radio Navigation
8,5 GHz to 11,5 GHz	Radiolocation Service, Earth Exploration - Satellite, Radio Astronomy/Space Research, Aeronautical Radio Navigation, Maritime Radio Navigation, Fixed Service, Mobile Services, Radio Astronomy, Fixed Satellite
24,05 GHz to 27 GHz	Fixed Service, Mobile Service, Standard frequency and time signal satellite service, Earth Exploration Satellite Service, Inter Satellite Service, Amateur Service, Radio Location Service
57 GHz to 64 GHz	Inter Satellite, Radio Location, Fixed Service, Mobile Service, Earth Exploration, Space Research
75 GHz to 85 GHz	Radio Astronomy, Radio Location, Amateur Service, Space Research, Broadcasting, Fixed Services, Mobile Services, Fixed Satellite

TLPRs are proposed to be regulated in CEPT/ERC Recommendation 70-03 [1] and consequently no change of the radio services allocation table is needed.

C.3 Sharing issues

Due to the proposed low emission levels in clause 6, tables 6.1 and 6.2 and the special installation requirements, sharing issues are not expected.

History

Document history		
V1.1.1	November 2004	Publication