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TECHNICAL SPECIFICATION

**Short Range Devices (SRD) and Ultra Wide Band (UWB);
Measurement techniques and specification for
RX conformance tests with target simulator**

Reference

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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

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Executive summary

Automotive radars follow regulation for certification testing and the respective definition of limits for compliance. The present document describes new types of test equipment such as radar target generators, anechoic chambers and methods of measurements.

Introduction

Radars are increasingly taking a more important role in the evolving fusion of a variety of sensors to enhance Advanced Driver-Assistance Systems (ADAS) in the direction of Autonomous Driving (AD). Many of these functions go beyond driving convenience are related to safety, either reducing road accidents with all participants or ensuring pedestrian safety. Automotive radar regulations need to improve test coverage and the definition of compliance limits. The former requires a new type of test equipment, the radar echo generator or also called radar target simulator, which enables a radar to be functionally tested in a controlled laboratory environment as it would be operating on the road. The later requires new methods to achieve far-field measurement accuracy in much smaller distances.

With the out phasing of 24 GHz automotive radar implementations in some regions, the present document focusses on the high frequencies, namely 76 GHz to 81 GHz, without limiting measurement procedures and methods to these frequencies. Radars, operating in these frequency bands, require relatively large measurement distances, using the traditional far-field setups, resulting on costly and for some measurements impractical chamber dimensions to achieve reasonable test accuracies. Compact antenna test range concepts for over-the-air testing will go a long way in supporting regulators and the industry to establish the compliance limits required for the modern larger MIMO automotive radar sensors.

At higher frequencies, such as E-Band frequencies where automotive vehicle radar operates today, larger bandwidths, and MIMO Tx/Rx arrays implementations enable improved resolutions to create more sophisticated ADAS/AD functions. Higher integration and number of devices in combination with higher frequencies and larger bandwidths might also require to allow compliance limits to adopt the use of intermediate-frequency test strategies. MIMO technology demands the use of monostatic antennas to enhance the accuracy of angular measurement resolution and resolution.

1 Scope

The present document contains information on radar target simulators and their application for radar tests identified in ETSI EN 303 883-1 [i.1] and ETSI EN 303 883-2 [i.2].

The present document describes measurement setups and approaches for anechoic chambers both far-field and near field-to-far field transforming.

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/.

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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] ETSI EN 303 883-1 (V1.2.1) (02-2021): "Short Range Devices (SRD) and Ultra Wide Band (UWB); Part 1: Measurement techniques for transmitter requirements".

[i.2] ETSI EN 303 883-2 (V1.2.1) (02-2021): "Short Range Devices (SRD) and Ultra Wide Band (UWB); Part 2: Measurement techniques for receiver requirements".

[i.3] Federal Communications Commission § 15.253 (20.09.2022).

NOTE: Available at https://www.gpo.gov/fdsys/pkg/CFR-2013-title47-vol1/pdf/CFR-2013-title47-vol1-sec15-253.pdf.

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

radar echo generator (REG), radar target simulator (RTS): Are both descriptions for the same type of equipment that can generate synthetic radar echo returns for testing of an actively transmitting radar sensor. This test instruments are specifically designed to test actively transmitting radar sensors according to ETSI EN harmonised standards.

3.2 Symbols

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

A_{RTS}	Attenuation within the RTS/REG [in dB]
c_0	Speed of light [in m/s]
D_{Air}	the physical distance between RTS/REG frontend and EUT [in m]
f_c	Centre frequency of the Local Oscillator of the RTS/REG [in Hz]
f_D	Doppler frequency shift
G_{TX_Ant}	Antenna gain of the RTS/REG transmit antenna [in dB]
G_{RX_Ant}	Antenna gain of the RTS/REG receive antenna [in dB]
t_{proc}	RTS/REG processing time [in s]
t_{tof}	Time of flight [in s]
R	distance of the artificial object generated by the RTS/REG [in m]
R_{sim}	Simulated distance of a target [in m]
v_1	Speed of electromagnetic wave in medium 1 [in m/s]

3.3 Abbreviations

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

5G	Fifth-Generation
AD	Autonomous Driving
ADAS	Advanced Driver Assistance Systems
ADC	Analog Digital Converter
AWG	Arbitrary Waveform Generator
CATR	Compact Antenna Test Range
CW	Continuous Wave
DAC	Digital Analogue Converter
DRFM	Digital Radio Frequency Memory
EUT	Equipment Under Test
FCC	Federal Communications Commission
FF	Far Field
FFT	Fast Fourier Transformation
FMCW	Frequency Modulated Continuous Wave
FODL	Fiber Optical Delay Line
FOV	Field Of View
FSPL	Free Space Path Loss
GUI	Graphical User Interface
I/Q	Inphase/Quadrature phase
IF	Intermediate Frequency
LO	Local Oscillator
LRR	Long Range Radar
MIMO	Multiple Input Multiple Output
mmW	millimetre Wave
MRR	Mid Range Radar
OSI	Open Simulation Interface
RBR	Receiver Baseline Resilience

RBS	Receiver Baseline Sensitivity
RCS	Radar Cross Section
REG	Radar Echo Generator
RF	Radio Frequency
RTS	Radar Target Simulator
RX	Receive
SG	Signal Generator
SRR	Short Range Radar
TX	Transmit
US	United States

4 Overview

4.1 Info

The present document provides practical information and guidance on RTS/REG for compliance tests of Short Range devices such as automotive radars. The applicability of the procedures described in the present document is not limited to EUT covered.

5 Radar Target Simulator (Radar Echo Generators)

5.1 Types

5.1.1 General

There is a variety of Radar Target Simulator/Radar Echo Generator (RTS/REG) solutions available, that range from simple reflectors to complex digital test equipment. This clause describes several types of equipment.

5.1.2 Analog

Analog target simulators apply physical delay lines to delay the incoming electromagnetic wave from the radar and simulates an object in a certain range R_{sim} from the radar, formula (1). The simulated range is the sum of the speed of the electromagnetic wave in air/vacuum (speed of light c_0) multiplied by the time of flight t_{tof} divided by two and the speed in a certain medium (with speed v_1) multiplied by the time within the medium t_{proc} respectively. This includes the time for passing physical distance to the RTS/REG forth and back as well as the internal signal processing time.

$$R_{sim} = \frac{c_0 t_{tof}}{2} + v_1 t_{proc} \quad (1)$$

- R_{sim} Simulated distance of a target [in m]
- c_0 Speed of light [in m/s]
- t_{tof} Time of flight [in s]
- v_1 Speed of electromagnetic wave in medium 1 [in m/s]
- t_{proc} RTS/REG processing time [in s]

To delay the signal Fiber Optical Delay Lines (FODLs) are often used. FODLs are relatively flexible, phase coherent and can create small systems that convert the RF signal of the radar to optical and delay of a certain length. Often an Intermediate Frequency (IF) is used as low frequency signal handling is easier and creates less loss. After delay, the signal is then reconverted to RF and retransmitted to the radar. Some systems are also able to introduce Doppler frequency shift.

FODLs offer constant delay versus frequency, are immune to vibration, are largely resistant to electromagnetic interference, and fiber delays do not radiate energy. Repeatability of simulation, low system cost and time-savings are key advantages. FODLs cannot generate time-variant range-Doppler targets (a target which has a change in range and Doppler over time due to its own dynamics), nor do they offer continuous range settings or arbitrary signal attenuation and gain.

RCS can be simulated by attenuating the radar signal. After considering free space loss and antenna gain (EUT and RTS/REG) the attenuated signal indicates a target with a certain RCS.

Figure 1 shows a simplified sketch of the optical delay line system including Doppler frequency shift f_D.

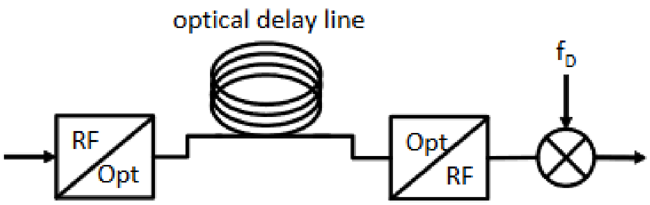

Figure 1: Optical delay line including Doppler frequency shift f_D

5.1.3 Digital

Digital target simulators rely on digital signal processing. The target generator receives an electromagnetic wave from the radar and modifies it digitally to picture the desired scenario. Adding delay on the signal simulates a distance to an object, frequency shift simulates a Doppler shift indicating the velocity of an object, and signal attenuation indicate a certain RCS. In addition, it is possible to add multiple delays, frequency shifts, and attenuation simulating multiple targets.

Often Digital Radio Frequency Memory (DRFM) is used to manipulate the radar signal digitally - down-converting, filtering and digitizing the received RF signal before storing and modifying it. Signals are then reconverted to analogue and mixed to RF frequency using the same Local Oscillator (LO) used for down-conversion. This is important to reduce phase noise. The minimum delay introduced by a DRFM is mainly limited by its ADC and DAC. In addition, signal processing adds a delay to the radar echo signal. Typical minimum range delays range from below 100 ns to below 1 µs. A further consideration is how the analogue RF signal is represented in the digital domain (amplitude, phase, I/Q) and the number of bits, because this is what mainly determines the DRFM's signal fidelity. Figure 2 shows a sketch of a digital representation of an RTS/REG where f_c denotes the carrier frequency of the down converting local oscillator.

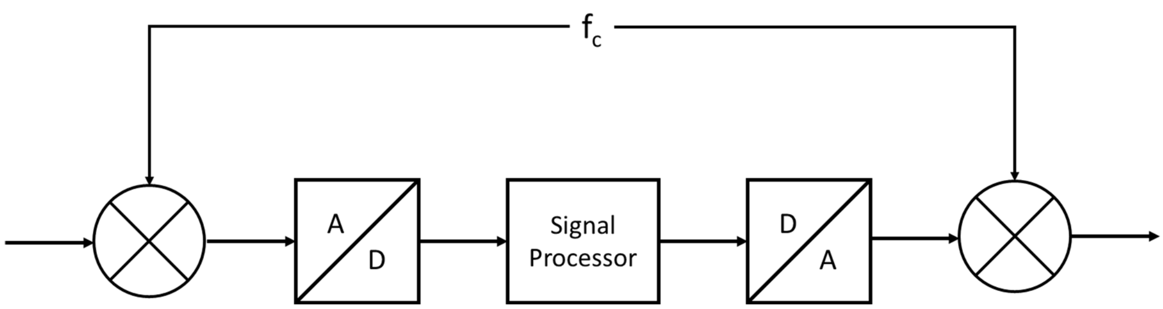

Figure 2: Digital representation of an RTS/REG

5.1.4 Hybrid

Hybrid target generators combine analogue and digital target simulator architectures and reduce the disadvantages of each individual approach. Usually, the analogue technique is used to simulate short distances which is more complex when using a digital target simulator since the required signal processing time limits the distance minimum that can be simulated.

On the other hand, the benefit of the high flexibility of digital target simulators can be used to simulate more complex schemes with multiple targets. Generating a scenario using analogue and digital simulation techniques requires precise synchronization and calibration between both modes.

5.1.5 Frontends

For different test needs, different form factors of target simulators exist. Integrated RF architecture combines the RF frontend as well as signal processing hardware/delay lines in one chassis.

A remote frontend has a separated RF frontend including mixers. Usually the connection to a base unit with delay line and controller is done using IF cables. Remote frontends offer more flexible use cases and easier integration into systems while an integrated RF target simulator eliminates possible problems with an accurate calibration of the flexible IF cables. All types of radar target simulators can be built as integrated RF or remote frontend type.

5.1.6 Differences

The analogue target simulator offers the possibility to simulate short distances while a longer signal processing delay in the digital units results in a greater minimum range to an object. On the other hand, the digital target simulator often offers more flexibility to simulate complex scenarios with multiple targets. Analog target simulators exist with one fixed distance, multiple fixed distances or variable distance using a switch matrix to toggle between different fiber-optic lengths. Faster switching of the distances can simulate a dynamic scenario of a target but phase jumps and attenuation. Depending on the update rate of the radar, the required phase coherence and RCS switching between different lengths back and forth could also simulate multiple targets.

The hybrid target simulator combines both approaches utilizing the fiber-optic cable of the analogue RTS/REG to simulating short distances and the flexibility of the digital RTS/REG for more distant and complex scenarios.

5.2 Parameters

5.2.1 General

There are many technical parameters of a RTS/REG that have to be defined before testing a radar sensor. This clause explains how to understand and interpret these parameters.

5.2.2 RCS

The relative size of an object detected by a radar sensor is defined as Radar Cross Section (RCS). Not only the RCS absolute value is important, but also the dynamic range of the RCS that can be simulated. As there can be targets in close range and far range with high and low RCS for example, the dynamic range is important. The dynamic range defines power values which can be simulated by the instrument.

In the following the effect on the RCS of different RTS/REG settings and measurement setup specific parameters are described.

The RCS calculation within a RTS/REG is done by the following formula (2).

$$RCS = -A_{RTS} + G_{TX_{Ant}} + G_{RX_{Ant}} + 20log\left(\frac{c_0}{f_c}\right) - 10log(4\pi) + 40log\left(\frac{D_{Air}+R}{D_{Air}}\right) \quad (2)$$

- RCS Resulting Radar Cross Section
- A_{RTS} Attenuation within the RTS/REG [in dB]
- G_{TX_Ant} Antenna gain of the RTS/REG transmit antenna [in dB]
- G_{RX_Ant} Antenna gain of the RTS/REG receive antenna [in dB]
- c_0 Speed of light [in m/s]
- f_c Centre frequency the RTS/REG is set to [in Hz]
- D_{Air} The physical distance between RTS/REG frontend and EUT [in m]
- R Distance of the artificial object generated by the RTS/REG [in m]; e.g. 150 m