ETSI TR 103 581 V1.1.1 (2019-11)

Use of measurement detectors in radio measurement methods

Reference

DTR/ERM-RM-270

Keywords

measurement, radio, testing, validation

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 Report (TR) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM).

Modal verbs terminology

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

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Introduction

At the ETSI TC ERM meeting #62 in June 2017 the issue of measurement detectors was discussed and it was indicated by ERM WGRM chairman that the Quasi Peak (QP) detector may be no longer appropriate in radio standards and should possibly be avoided in future. Concerns were raised that before ETSI will take any decision in this regard ETSI should carefully consider the issue of measurement detectors. Measurement results not only with QP also with RMS and Average detector vary with signal shape and measurement receiver setting, which is not the intention of typical radio measurements. Harmonised standards covering the essential requirements of article 3.2 of the Radio Equipment Directive (RED) [i.23] should contain reproducible measurements. But common measurement procedures and settings for the different detectors are currently not available in ETSI.

1 Scope

The present document provides to ETSI technical group's information on the use of measurement detectors (e.g. quasi peak, RMS, average, peak) in radio measurement methods.

The focus in the present document is on measurement detectors used in spectrum analysers and EMI receivers. Various other technologies to measure RF signals do exist, like specific true RMS sensors and selective voltmeters. They are not further studied in the present document but could be of specific use in some cases.

EMI measurement methods and audio measurements/detectors (e.g. SINAD) are not in the scope of the present document.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

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

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

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

[i.1] CENELEC EN 55016-1-1:2010 + A1:2010 + A2:2014: "Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-1: Radio disturbance and immunity measuring apparatus - Measuring apparatus".

[i.2] CENELEC EN 55016-1-1: 2004: "Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-1: Radio disturbance and immunity measuring apparatus - Measuring apparatus".

[i.3] Application note by Dipl. -Ing. Dieter Schwarzbeck: "The EMI-Receiver according to CISPR 16-1-1".

NOTE: Available at http://www.schwarzbeck.de/appnotes/EMIRcvrCISPR16.pdf.

[i.4] Commission implementing Decision (EU) 2017/1483 of 8 August 2017 amending Decision 2006/771/EC on harmonisation of the radio spectrum for use by short-range devices and repealing Decision 2006/804/EC.

[i.5] ERC Recommendation 70-03: "Relating to the use of Short Range Devices (SRD)", 13 October 2017.

[i.6] ETSI EN 300 330 (V2.1.1): "Short Range Devices (SRD); Radio equipment in the frequency range 9 kHz to 25 MHz and inductive loop systems in the frequency range 9 kHz to 30 MHz; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU".

[i.7] ETSI EN 300 220-2 (V3.1.1): "Short Range Devices (SRD) operating in the frequency range 25 MHz to 1 000 MHz; Part 2: Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU for non specific radio equipment".

[i.8] ETSI EN 300 328 (V2.1.1): "Wideband transmission systems; Data transmission equipment operating in the 2,4 GHz ISM band and using wide band modulation techniques; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU".

[i.9] ECC/DEC(04)03: "ECC Decision of 19 March 2004 on the frequency band 77 - 81 GHz to be designated for the use of Automotive Short Range Radars".

[i.10] ECC/DEC(06)04: "ECC Decision of 24 March 2006 amended 9 December 2011 on the harmonised conditions for devices using UWB technology in bands below 10.6 GHz".

[i.11] ECC/DEC(06)08: "ECC Decision of 1 December 2006 on the conditions for use of the radio spectrum by Ground- and Wall- Probing Radar (GPR/WPR) imaging systems".

[i.12] ECC/DEC(11)02: "ECC Decision of 11 March 2011 on industrial Level Probing Radars (LPR) operating in frequency bands 6-8.5 GHz, 24.05-26.5 GHz, 57-64 GHz and 75-85 GHz".

[i.13] ERC Recommendation 74-01: "Unwanted emissions in the spurious domain", Cardiff 2011.

[i.14] ITU Radio Regulations, Edition of 2016.

[i.15] ANSI 63.10-2013: "American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices".

[i.16] FCC Part 15: "Electronic Code of Federal Regulations, Title 47: Telecommunication, Part 15: Radio frequency devices", May 15, 2018.

[i.17] FCC Knowledge Database (KDB).

NOTE: Available at https://apps.fcc.gov/oetcf/kdb/index.cfm.

[i.18] SEAMCAT, Spectrum Engineering Advanced Monte Carlo Analysis Tool.

NOTE: Available at www.seamcat.org.

[i.19] CENELEC EN 55016-2-3: 2010 + A1:2010 + AC:2013 + A2:2014: "Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-3: Methods of measurement of disturbances and immunity - Radiated disturbance measurements".

[i.20] RAUSCHER, C.: "Fundamentals of Spectrum Analysis", 7th edition, 2011, ISBN 978-3-939837-01-5.

[i.21] LIEBL, DETLEV: "Measuring with modern spectrum analysers", 02/2013.

NOTE: Available at https://cdn.rohde-schwarz.com/pws/dl_downloads/dl_application/application_notes/1ma201_1/1MA201_9e_spectrum_analyzers_meas.pdf.

[i.22] CENELEC EN 55013: "Sound and television broadcast receivers and associated equipment - Radio disturbance characteristics - Limits and methods of measurement".

[i.23] 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.24] ETSI EN 302 264 (V2.1.1): "Short Range Devices; Transport and Traffic Telematics (TTT); Short Range Radar equipment operating in the 77 GHz to 81 GHz band; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU".

[i.25] ETSI EN 302 065-1 (V2.1.1): "Short Range Devices (SRD) using Ultra Wide Band technology (UWB); Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU; Part 1: Requirements for Generic UWB applications".

[i.26] ETSI EN 302 066 (V2.1.1): "Short Range Devices (SRD); Ground- and Wall- Probing Radar applications (GPR/WPR) imaging systems; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.27] ECC Report 64 (February 2005): "The protection requirements of radiocommunications systems below 10.6 GHz from generic UWB applications".

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

CISPR-detector: measurement detector as defined in CENELEC EN 55016-1-1 [i.1] and as used in an EMI receiver

EMI receiver: measurement instrument as defined in CENELEC EN 55016-1-1 [i.1]

measurement instrument: EMI receiver or spectrum analyser, both with or without FFT-based functions

Occupied Bandwidth (OBW) (according to [i.14] Article 1.153): "The width of a frequency band such that, below the lower and above the upper frequency limits, the mean powers emitted are each equal to a specified percentage 0.5% of the total mean power of a given emission."

Spectrum Analyser (SA): measurement instrument to assess the spectrum's shape and energy content of the signal at its input

3.2 Symbols

Void.

3.3 Abbreviations

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

ADC	Analog-to-Digital Converter
AM	Amplitude Modulation
AV	Average
BW	Bandwidth
CEPT	European Conference of Postal and Telecommunications Administrations
CISPR	Comité International Spécial des Perturbations Radioélectriques (International Special Committee on Radio Interference)
CR	Trace mode clear write
CW	Continuous Wave
DC	Duty Cycle
DUT	Device Under Test
e.i.r.p.	equivalent isotropic radiated power
EC	European Commission
ECC	Electronic Communications Committee of CEPT
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EU	European Union
EUT	Equipment Under Test
FCC	Federal Communications Commission
FFT	Fast Fourier Transform
IF	Intermediate Frequency
ISM	Industrial, Scientific and Medical
KDB	Knowledge Database
LO	Local Oscillator
LPR	Level Probing Radar
MH	Maxhold
OBW	Occupied Bandwidth
OFDM	Orthogonal Frequency-Division Multiplexing

PEP	Peak Envelope Power
PK	Peak
PRF	Pulse Repetition Frequency
QAM	Quadrature Amplitude Modulation
QP	Quasi Peak
RBW	Resolution BandWidth
RC	Resistor-Capacitor
REC	Recommendation
RF	Radio Frequency
RMS	Root Mean Square
RMS-AV	RMS-Average
RTA	RealTime spectrum Analyser (FFT based)
SA	Spectrum Analyser
SINAD	Signal-to-Interference ratio including Noise And Distortion
SRD	Short Range Devices
SRdoc	System Reference document
SRR	Short Range Radar
SWT	Sweeptime
SZ	Spectrum analyser Zero span
TGSRR	Tasks Group Short Range Radar
Ton	Time period when the signal is switched on
Toff	Time period when the signal is switched off
UWB	Ultra-WideBand
VBW	Video Bandwidth
WGFM	Working Group Frequency Management
WGRM	Working Group Radio Matters
WGSE	Working Group Spectrum Engineering

4 Regulatory requirements

4.0 General

Clause 4 provides an overview on the current practice on the consideration of the measurement detectors in ETSI and CEPT, before an in-depth analysis of measurement detectors and measurement instruments is offered in clauses 5, 6 and 7.

4.1 Overview

A common European process from the idea of a new radio system to the harmonised standard with measurement procedures (ETSI, CEPT, EC) is shortly summarized in Table 1. Table 1 also includes some indication on the importance of a measurement detector in the different steps.

Table 1: The importance of a measurement detector

ETSI SRdoc	A new radio systems is described in a System Reference Document (SRdoc) by ETSI to trigger the rule-making in CEPT.	The measurement detector is usually not considered in the SRdoc
CEPT Compatibility studies	CEPT considers the SRdoc in Working Group Frequency Management (WGFM) and will typically first request the Working Group Spectrum Engineering (WGSE) to conduct compatibility studies. WGSE analyses then if the new radio systems can coexist with existing systems and will publish their results in an ECC Report; these studies are considering more and more the probability of interference by using Monte Carlo simulations (e.g. with the open source software SEAMCAT [i.18]), by observing the time-, frequency- and spatial domain.	The compatibility studies do seldom contain information on the measurement detectors
CEPT rule making	WGFM creates a new regulation based on the WGSE studies.	The regulatory limits do seldom contain information on the measurement detectors
ETSI harmonised standard	ETSI may then create a harmonised standard including measurement procedures for the regulatory requirements, that leads to reproducible and stable measurement results.	The measurement detector is an essential part for each requirement

4.2 Examples of regulations without requirements on detectors

Many frequency regulations only mention the frequency band and the radiated power limit in this band and there is no information about the measurement detector (and also mostly no details on the measurement bandwidth).

A few popular examples for SRDs from EC Decision 2017/1483/EU [i.4] and ERC Recommendation 70-03 [i.5] are provided in Table 2.

Table 2: Examples of frequency assignments without information on measurement detectors from [i.4] and [i.5]

Frequency range	Category of short-range devices	Transmit power/field strength/power density limit
13 553 kHz - 13 567 kHz	Inductive devices	42 dBμA/m at 10 metres
868 MHz - 868,6 MHz	Non-specific short-range devices	25 mW e.r.p.
2 400 MHz - 2 483,5 MHz	Wideband data transmission devices	100 mW e.i.r.p. and 100 mW/100 kHz e.i.r.p. density applies when frequency hopping modulation is used, 10 mW/MHz e.i.r.p. density applies when other types of modulation are used

No requirements on the measurement detector are requested in these cases. What does that mean for the measurement standard? It is completely up to the ETSI technical bodies to develop appropriate requirements for the measurement detectors, since there is not common guidance available. The harmonised standards for the equipment in the above frequency bands are containing for example the following requirements regarding measurement detectors:

- ETSI EN 300 330 [i.6] for 13,56 MHz: Quasi Peak
- ETSI EN 300 220-2 [i.7] for 868 MHz:
    - *"Unless stated otherwise, an RMS detector shall be used.*
    - *The RBW of the spectrum analyser shall be wide enough to cover the complete power envelope of the signal of the EUT.*
    - *In the case of non-constant envelope modulation, a peak detector shall be used."*

- ETSI EN 300 328 [i.8] for 2,4 GHz:
  - *"The RF output power is defined as the mean equivalent isotropically radiated power (e.i.r.p.) of the equipment during a transmission burst.*
  - *Use a fast power sensor suitable for 2,4 GHz and capable of minimum 1 MS/s.*
  - *Sample speed 1 MS/s or faster.*
  - *The samples shall represent the RMS power of the signal.*
  - *Between the start and stop times of each individual burst calculate the RMS power over the burst…."*

4.3 Examples of regulations with requirements on detectors

4.3.1 Definitions from Radio Regulations

The mean power is defined in Article 1.158 of the ITU Radio Regulations [i.14] as "*The average power supplied to the antenna transmission line by a transmitter during an interval of time sufficiently long compared with the lowest frequency encountered in the modulation taken under normal operating conditions.*"

4.3.2 UWB regulations

- The first UWB regulation published was **ECC/DEC(04)03** [i.9] for car radars in the band 77-81 GHz. Decides 2 of ECC/DEC(04)03 says "*that the 79 GHz frequency range (77-81 GHz) is designated for Short Range Radar (SRR) equipment on a non-interference and non-protected basis with a maximum mean power density of -3 dBm/MHz e.i.r.p. associated with an peak limit of 55 dBm e.i.r.p.;*". The limitation here is not such clear as in ECC/DEC(06)04 (see below), but the harmonised standard ETSI EN 302 264 [i.24] being developed by ETSI ERM TGSRR has adopted later the same procedures as the ETSI EN 302 065-1 [i.25] is doing according to ECC/DEC(06)04 [i.10].
- **ECC/DEC(06)04** [i.10] contains in decides 2 clear information on the measurement detector to be used: *"that, for the purpose of the Decision, the following definitions apply: a) Maximum mean e.i.r.p. spectral density: the highest signal strength measured in any direction at any frequency within the defined range. The mean e.i.r.p. spectral density is measured with a 1 MHz resolution bandwidth, an RMS detector and an averaging time of 1 ms or less. b) Maximum peak e.i.r.p.: the highest signal strength measured in any direction at any frequency within the defined range. The peak e.i.r.p. is defined within a 50 MHz bandwidth".*
- The following requirements are provided in **ECC/DEC(06)08** [i.11]: *"Maximum mean and peak power densities of any undesired emission emanating from GPR/WPR imaging systems are defined below. For pragmatic reasons and for taking the mitigation factors into account, the mean power density shall be determined by formula (1) or (2) below and the peak values shall be measured according to ETSI EN 302 066".*
- **ECC/DEC(11)02** [i.12] contains in Annex 1 the following information on the measurement detector to be used: "*(1) Mean e.i.r.p. spectral density within LPR antenna mainbeam is the average power per unit bandwidth radiated in the direction of the maximum level;(2) Peak e.i.r.p. within mainbeam is the power contained within a 50 MHz bandwidth at the frequency at which the highest mean radiated power occurs. If measured in a bandwidth of x MHz, this level is to be scaled down by a factor of 20log(50/x) dB".*

The requirement for such a detailed prescription of the limits including the measurements detectors in the UWB regulation comes from the large possible occupied bandwidth of these systems (e.g. pulsed systems with a pulse width of 1 ps, MB-OFDM with a bandwidth of 500 MHz each OFDM symbol) resulting in a large peak/average ratio. In addition the large frequency ranges of the UWB systems are overlapping with many primary and secondary radio services which explains the need for a careful description of the limits.

Considering p) of ECC/DEC(06)04 [i.10] provides further background information: "*that ECC Report 64 has considered interference potential resulting from mean power and only limited consideration has been given to peak power interference, time gating and frequency hopping. ECC may review this Decision in the light of these possible implications*".

4.3.3 ERC Recommendation 74-01

ERC Recommendation 74-01 [i.13] contains in recommendation 6 some guidance on how to measure the spurious emissions:

"… Unless the Peak Envelope Power (PEP) is explicitly quoted, the spurious domain emission limits specified in this Recommendation from the transmitter into the antenna port are in terms of mean power. The mean power (P) of any spurious domain transmission from a burst transmitter is the mean power averaged over the burst duration."

4.3.4 FCC Part 15

In FCC part 15 "radio frequency devices" [i.16] describes in clause 15.35 the "Measurement detector functions and bandwidths". FCC part 15 applies to "intentional, unintentional, or incidental radiators which may be operated without an individual license", and thus it also applies to SRDs. The typical detector in FCC part 15 below 1 GHz is the quasi peak (15.35.a) and above 1 GHz average and peak (15.35.b). FCC applies different limits for different detectors.

For the fundamental emission special measurement methods are defined in ANSI 63.10 [i.15] and FCC documents (see FCC knowledge database -KDB [i.17], e.g. guidance for compliance measurements according section 15.247).

4.4 Summary and consequences for the present document

More or less clear prescriptions on measurement detectors are available in frequency regulation where a high potential peak/average ratio (UWB) and where a frequency overlap with primary and secondary radio users (co-channel) is expected (UWB, spurious emissions).

No requirements on measurement detectors in frequency regulations are usually requested in pure SRD and ISM frequency bands, where the frequency assignment is based on non-interference and non-protection, and where usually no primary or secondary radio users are expected at the same frequency as the radio user (co-channel).

Guidance on the use of measurement detectors would be beneficial, especially for cases without any requirements from the frequency regulation.

Time has come to evaluate how the existing detectors behave in combination with radio signals used by current radio systems. In particular, to prevent the development of artificial test scenarios to demonstrate compliance with the essential requirements stated in article 3.2 of the Radio Equipment Directive [i.23].

Clause 5 will explain the measurement detectors as parts of measurement instruments, clause 6 will summarize the relevant measurement detectors and clause 7 will practically show the impact of different measurement detectors when measuring different signals.

5 Detectors as parts of measurement instruments

5.0 Introduction

This clause gives a rough description of spectrum analysers and measurement receivers (measurement instruments). Detectors are parts of these instruments. The choice of measurement parameters, including the detector, influences other parameters. Thus, certain knowledge as pointed out in this clause is required when choosing how to measure with those instruments.

The main focus is on the instrument's overall architecture, the way how results are presented to the user and the different settings the user has to choose.

A more in-depth description of measurement instruments can be found in [i.20].

5.1 General

Measurement detectors are integral parts of measurement instruments. Their purpose is to assess the signal's envelope (see Figure 1) with a weighting function. This weighting influences the measured value shown by the instrument. The type of detector defines what weighting function is applied. Every detector has its own behaviour.

These detectors can be implemented by analog or digital circuits.

A description of the available weighting detectors is provided in clause 6.

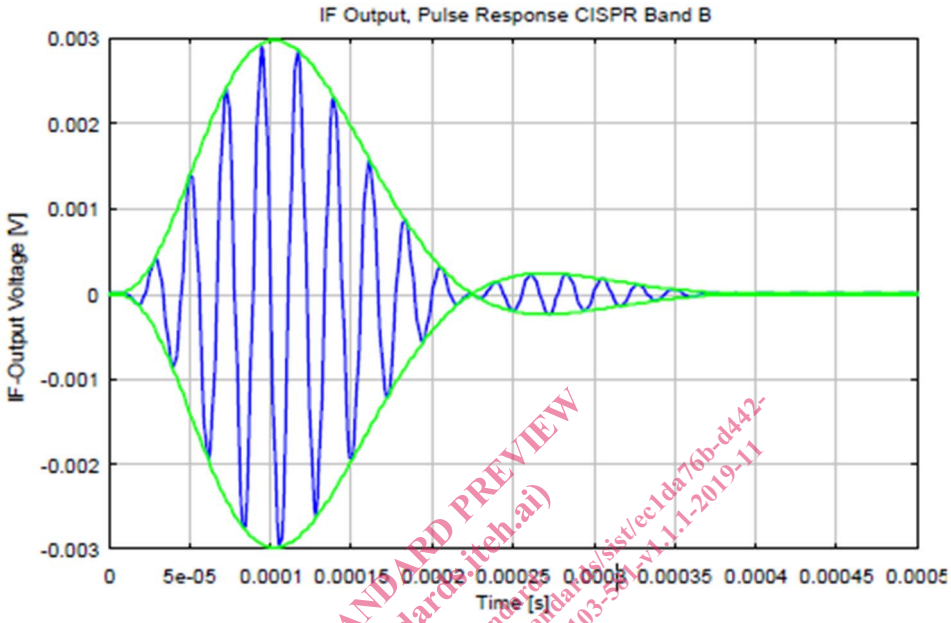

Figure 1: Signal plotted as voltage vs. time (blue) and its envelope (green)

5.2 Basic function of measurement instruments

5.2.0 Generic

The measurement instruments in the present document are either spectrum analysers or EMI-receivers. Both instrument types can either be conventional (sweeping a frequency range by continuously tuning the local oscillator) or FFT-based.

For spectrum analysers - suited as an all-purpose measurement instrument - no normative definitions exist. For EMI-receivers, certain minimum requirements regarding hardware parameters and measurement functions are found in CENELEC EN 55016-1-1 [i.1].