Practical Papers, Articles and Application Notes

Flavio Canavero, Technical Editor

The first paper of this issue is entitled "Experience with the RMS-Average detector" by Jens Medler from Rohde & Schwarz (Munich, Germany). In this paper, the author discusses a new weighting detector introduced by a recent amendment to the CISPR 16-1-1 publication. This new weighting detector (identified as RMS-Average detector) is a combination of the RMS and Average function of EMI receivers, and was specified to better consider the impact of pulsed interferences on today's dominant digital radio services.

The second paper is entitled "A RF-Insensitive Electro-Explosive Device with 500V Standoff Capability," by Thomas A. Baginski and Keith A. Thomas from Auburn University. In this paper, the authors present a monolithic electro-explosive device which is capable of standing off a high potential for extended periods of time. This standoff capability ensures the device remains unaffected by exposure to harsh electromagnetic environments.

In conclusion, I encourage (as always) all readers to actively participate to this column, either by submitting manuscripts they deem appropriate, or by nominating other authors having something exciting to share with the EMC community. I will follow all suggestions, and with the help of independent reviewers I sincerely hope to be able to provide a great variety of enjoyable and instructive papers. Please communicate with me, preferably by email at canavero@ieee.org.

Experience with the RMS-Average Detector

Jens Medler
Rohde & Schwarz GmbH & Co. KG, Test and Measurement Division, Standardization and Application Support for EMC Test Equipment, Muehldorfstrasse 15, D-81671 Muenchen, Germany
E-mail: jens.medler@rohde-schwarz.com

Abstract—Purpose of weighting along with the defined weighting function for the new RMS-Average detector is introduced. Extensive comparison measurements were performed by using the required Quasi-Peak and Average detectors and the new RMS-Average detector for both conducted and radiated emission measurements to confirm the weighting function and for the definition of emission limits for the new RMS-Average detector.

I. Introduction

A new weighting detector in publication CISPR 16-1-1 has been defined to better consider the impact of pulsed interferers on today's dominant digital radio services [1]. This new weighting detector with the name RMS-Average is a combination of the RMS detector and the Average detector with meter time constant.

II. Purpose of Weighting

Generally, weighted measurements of impulsive disturbance are made for minimizing the cost of disturbance suppression, while keeping an agreed level of radio protection.

A short time after installation of AM radio in 1922, numerous complaints were raised from radio listeners and subsequent disturbance suppression was unavoidable. But measurement methods were not available at that time and as a consequence first standards were instruction guides for disturbance suppression only. Later on the disturbance voltage measurement method was developed.

With the foundation of CISPR (Comité International Spécial des Perturbations Radioélectriques) in 1933 systematic investigations were started with the aim to define unified weighting methods. It was recognized that the effect on radio communication services depends on the type of interference (broadband or narrowband) and on the type of service itself. In particular, the dependency on the pulse repetition frequency (PRF) led to the definition of the well known Quasi-peak detector.

For the analog receiver, the psychophysical annoyance of the interference effect is a subjective quantity (acoustic or visual) but cannot be measured in figures usually and we can say the Quasi-peak detector is a simulation of the radio receiver plus the listener.

For the digital receiver, the interference effect may be defined by the critical Bit Error Ratio (BER) or Bit Error Probability (BEP), for which perfect error correction can still occur or by another objective and reproducible parameter. This means further investigations were necessary for the definition of an adequate weighting function for measuring electromagnetic disturbances in the age of digital radio services.

III. Weighting Characteristic

A possibility for evaluating a weighting characteristic is to perform measurements and simulations for showing the impact of interference signals on various modulation schemes. For this purpose the interference source level to obtain a constant BER for all PRFs of interest is recorded. Based on these results, a weighting function can be created. Once the weighting function is defined, a detector with these properties can be developed.

Weighting characteristic = peak voltage level as a function of PRF for a constant effect on a specific radio communication system.

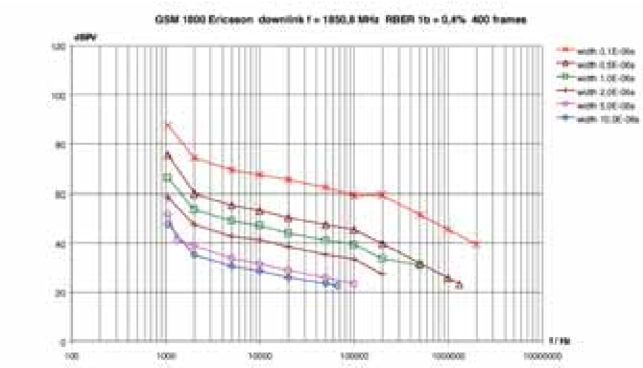

Fig. 1. Effect of impulsive disturbance on GSM radio communication system as investigated in [2].

Figure 1 shows the weighting characteristics found for a mobile operating in the 1800 MHz (GSM 1800) frequency band. The characteristics typically rise with about 10 dB per decade between 200 kHz and 2 kHz PRF and with about 20 dB per decade below 2 kHz PRF.

A lot more weighting characteristics were determined in [2] for GSM 900 and GSM 1800 as well as DECT, CDMA, DRM, DAB, DVB-T, and FM modulation schemes. Looking at these results we can see that above a certain corner frequency, the weighting characteristic decreases with approximately 10 dB per decade of PRF. Below this corner frequency, the weighting characteristic decreases with a higher rate.

IV. Weighting Function

A decrease of 10 dB per decade corresponds to the weighting function of an RMS detector. A higher rate of decrease (20 dB/decade) can be achieved using the linear average detector function. This behaviour can be approximated by a combination of two detectors, the RMS and the linear Average detector. The Average detector applies the meter time constant as described in CISPR 16-1-1 for intermittent, unsteady and drifting narrowband disturbances.

Weighting function = relationship between input peak voltage level and PRF for constant level indication of a measuring receiver with a weighting detector.

For CISPR Band A (9 kHz to 150 kHz) and CISPR Band B (150 kHz to 30 MHz) a corner frequency f_c of 10 Hz, whereas for CISPR Bands C/D (30 MHz to 1 GHz) a corner frequency f_c of 100 Hz and for CISPR Band E (1 GHz to 18 GHz) a corner

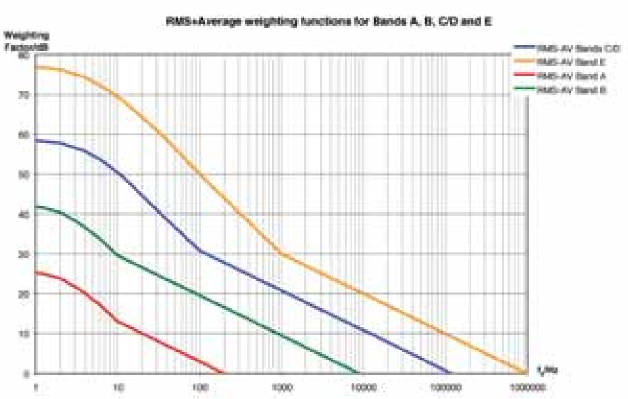

Fig. 2. RMS-Average weighting functions for Band A, B, C/D and E.

frequency f_c of 1000 Hz was selected [2].

It is not possible to satisfy the protection requirements of all services with the same perfection, therefore the selection of the various corner frequencies between the proposed Average and RMS weighting functions in each band can be regarded as a compromise.

V. Construction

The RMS-Average detector consists of an RMS detector with a computing time equal to the reciprocal of the corner frequency fc followed by a linear Average detector with meter time constant and Peak reading.

For example, in Band C/D the RMS computing time is 10 ms and will give rms values of the disturbance signal within 10 ms. The 10 ms packets are then weighted using a linear average function. The peak reading function after a meter time constant of 100 ms is effective then for low repetition pulses (f_p below 10 Hz) which causes the weighting curve to approximate the asymptote of 58,7 dB as shown in Figure 2. This means, for pulse-modulated signals with a PRF lower than 10 Hz the measurement result is not the average!

VI. Measurement Data

Two Round-Robin Tests (RRT) were performed for getting experience in using the RMS-Average detector during conducted and radiated emission measurements on consumer electronic equipment in accordance with CISPR 13 Ed. 4.1 and on information technology equipment in accordance with CISPR 22 Ed. 5.

For comparison purpose the measurements were performed by using the required Quasi-peak and Average detectors and the new RMS-Average detector for both conducted and radiated emission measurements.

Each test was performed by using three different measurement times (10 ms, 100 ms and 1 s). Significant differences in result were not be ascertained by using different measurement times.

A. Measurement Data from Consumer Electronic Equipment

The following consumer electronic equipment was selected for the test:

- EUT1 – Analogue TV Receiver,
- EUT2 – Analogue TV Receiver,
- EUT3 – Analogue TV Receiver,
- EUT4 – Digital TV Receiver (DVB-T),
- EUT5 – Set-Top-Box (DVB-T),
- EUT6 – Analogue FM Receiver,
- EUT7 – Analogue AV Media Center.

Altogether 71 test frequencies were identified on the tested consumer electronic equipment:

27 frequencies from disturbance voltage measurements at mains terminals, hereof

- 16 frequencies with broadband disturbance characteristic
- 11 frequencies with narrowband disturbance characteristic

29 frequencies from radiated emission measurements, hereof

- 13 frequencies with broadband disturbance characteristic
- 16 frequencies with narrowband disturbance characteristic

15 test frequencies from disturbance voltage measurements at antenna terminals. All identified frequencies had narrowband disturbance characteristic.

Legend:

- CRMS = RMS-Average detector,
- CAV = Average detector with meter time constant,
- QP = Quasi-Peak detector.

In the below tables measurements with RMS-Average detector (CRMS) are normalized to average detector (CAV) and quasi-peak detector (QP) values.

The 16 test frequencies with broadband disturbance characteristic from disturbance voltage measurements at mains terminals result in the following differences:

	CRMS-CAV in dB	QP-CRMS in dB
Maximum value:	13,1	14,1
Minimum value:	1,8	5,0
Mean value:	4,4	8,6

The 13 test frequencies with broadband disturbance characteristic from radiated emission measurements result in the following differences:

	CRMS-CAV in dB	QP-CRMS in dB
Maximum value:	1,2	3,8
Minimum value:	0,0	0,6
Mean value:	0,4	2,1

In case of broadband disturbances Average results are always the lowest values and Quasi-peak results are always the highest values. As expected, the RMS-Average results are closer to the Average values than to Quasi-peak results. The difference is determined by the pulse repetition frequency (PRF).

The 11 test frequencies with narrowband disturbance characteristic from disturbance voltage measurements at mains terminals result in the following differences:

	CRMS-CAV in dB	QP-CRMS in dB
Maximum value:	1,3	3,8
Minimum value:	0,0	–0,2
Mean value:	0,4	2,0

The 16 test frequencies with narrowband disturbance characteristic from radiated emission measurements result in the following differences:

	CRMS-CAV in dB	QP-CRMS in dB
Maximum value:	1,0	6,7
Minimum value:	0,0	0,8
Mean value:	0,4	3,0

In case of narrowband disturbances, Average and RMS-Average results are more or less identical. Quasi-peak results are slightly higher, especially for modulated narrowband disturbances

The 15 test frequencies with narrowband disturbance characteristic from disturbance voltage measurements at antenna terminals result in the following differences:

	CRMS-CAV in dB	QP-CRMS in dB
Maximum value:	0,4	3,5
Minimum value:	–0,2	0,0
Mean value:	0,1	1,8

No broadband disturbances were measured during the voltage test at antenna terminals. The results for narrowband disturbances for Average, RMS-Average as well as Quasi-peak detector are more or less identical due to the nature of the measured local oscillator frequencies. The Quasi-peak results were slightly high-

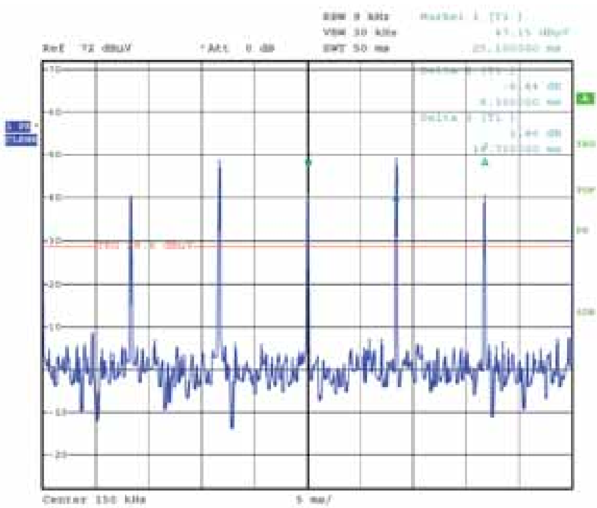

Fig. 3. Result of PRF measurement for EUT7.

er for EUT2 because of a small signal to noise ratio.

For EUT7 the PRF was measured at a test frequency of 150 kHz for verifying the weighting factor of the RMS-average detector. The PRF was about 120 Hz as shown in Figure 3.

The defined detector response in CISPR 16-1-1 resulting in a difference of about 31 dB between average and quasi-peak detector for a PRF of 120 Hz. The defined detector response for the RMS-average detector in accordance with Amendment 2:2006 to TR CISPR 16-3:2003 (2nd Ed.) [2] resulting in a difference of about 18 dB between average and RMS-average results for a PRF of 120 Hz.

The measurement results at 150 kHz from EUT7 are showing a difference of 27 dB between average and quasi-peak reading and a difference of 13 dB between average and RMS-average. It can be concluded that the achieved measurement results are conforming to the expected weighting factor of the detector.

B. Measurement Data from Information Technology Equipment

The following information technology equipment was selected for the test:

- EUT1 – Desktop Computer,
- EUT2 – Copy machine,
- EUT3 – Artificial EUT including pulse generator,
- EUT4 – Desktop PC with LCD monitor and printer,
- EUT5 – Game console,
- EUT6 – Workstation,
- EUT7 – Telecommunication Network Multiplexer.

Altogether 84 test frequencies were identified on the tested information technology equipment:

49 frequencies from conducted emission measurements, hereof

- 32 frequencies with broadband disturbance characteristic
- 17 frequencies with narrowband disturbance characteristic

35 frequencies from radiated emission measurements, hereof

- 22 frequencies with broadband disturbance characteristic
- 13 frequencies with narrowband disturbance characteristic

The 32 test frequencies with broadband disturbance characteristic from disturbance voltage measurements at mains terminals result in the following differences:

	CRMS-CAV in dB	QP-CRMS in dB
Maximum value:	24,3	15,1
Minimum value:	0,2	2,2
Mean value:	3,8	7,2

The 22 test frequencies with broadband disturbance characteristic from radiated emission measurements result in the following differences:

	CRMS-CAV in dB	QP-CRMS in dB
Maximum value:	3.2	10,5
Minimum value:	0,0	1,1
Mean value:	1,4	5,3

In case of broadband disturbances results with the Average detector are always the lowest values and Quasi-peak results are always the highest values. As expected, the RMS-Average results are closer to the average values than to quasi-peak results. The difference is determined by the pulse repetition frequency (PRF).

The 17 test frequencies with narrowband disturbance characteristic from disturbance voltage measurements at mains terminals result in the following differences:

	CRMS-CAV in dB	QP-CRMS in dB
Maximum value:	0,3	2,5
Minimum value:	–0,2	–0,4
Mean value:	0,1	0,6

The 13 test frequencies with narrowband disturbance characteristic from radiated emission measurements result in the following differences:

	CRMS-CAV in dB	QP-CRMS in dB
Maximum value:	1,2	3,8
Minimum value:	0,0	0,6
Mean value:	0,4	2,1

In case of narrowband disturbances Average and RMS-Average results are more or less identical. Quasi-peak results are slightly higher, especially for modulated narrowband disturbances.

VII. Proposed Limit Values

The weighting of a disturbance for its effect on modern digital radio communication services is important for the definition of emission limits that will protect these services. Based on the achieved results it is proposed to introduce the following emission limits for the RMS-Average detector.

Measurement of disturbance voltage at the mains terminals and disturbance power measurement:

- proposed limit value of +4 dB to the AV limit,
- proposed limit value of −6 dB from the QP limit.

The two emission limits can be replaced by a single limit for the RMS-Average detector. The above proposal suggests a correction of the limit value by +4 dB to the AV, and a corresponding correction of −6 dB to the QP limit value. This proposal is based on the broadband disturbances results from the disturbance voltage measurements at mains terminals.

This would mean that narrowband signals are underweighted but it has been shown that such kinds of disturbances are not critical for the protection of digital radio services.

Measurement of disturbance voltage at the antenna terminals and radiated disturbances measurement:

- proposed limit value is the same as for QP.

Where only quasi-peak limits are specified, it is proposed to keep the limit value unchanged. This proposal is based on the narrowband disturbance results from both the disturbance voltage at the antenna terminals and the radiated disturbance measurements.

The existing QP emission limits can be replaced by a single limit for the RMS-Average detector to evaluate both narrowband

and broadband disturbances. This means that the existing QP limit is not only used for the weighting of broadband disturbances, it has to consider the AV characteristic for the weighting of narrowband disturbances as well. As a consequence the existing QP limit cannot be reduced as done for conducted disturbance and disturbance power measurements, which means that narrowband disturbances are weighted in the same manner as before.

VIII. Standardization Update

With the introduction of the RMS-average detector in basic standard CISPR 16-1-1 a long development process has been completed. The weighting function of the RMS detector was already under discussion when CISPR 1 (2nd Ed.) was published in 1972. The introductory note states: "Subsequent experience has shown that the rms voltmeter might give a more accurate assessment" but the quasi-peak type of voltmeter has been retained for certain reasons—mainly for continuity.

Analogue radio services have been replaced by digital radio services successively in the last decade. This means the established weighting methods need to be reconsidered to serve an adequate protection level for today's dominant digital radio services. To do so CISPR has started extensive investigation to get experience particular about the impact of pulsed interferers on digital radio services. The results were published as background material to weighting detector measurements in Amendment 2:2006 to TR CISPR 16-3:2003 (2nd Ed.) [2]. Based on these results a new weighting function was developed—the RMS-average detector. Finally this newly proposed detector was published in Amendment 2:2007 to CISPR 16-1-1:2006 (2nd Ed.) [1] based on unanimous vote.

Amendment 2:2007 to CISPR 16-1-1:2006 (2nd Ed.) [1]

- Existing RMS detector is replaced by new RMS-average detector.
- Frequency range 9 kHz to 18 GHz.
- Specific definition for overload factor and response to pulses has been added.

Amendment 2:2006 to TR CISPR 16-3:2003 (2nd Ed.) [2]

- Rationale for introduction of RMS-average detector.
- A lot of weighting characteristics are shown: DRM, DVB-T, DAB, TETRA, FM, GSM 900 and GSM 1800, DECT, IS-95, J-STD 008, CDMA2000.
- Proposal for weighting function and corner frequencies.
- Examples of measurement results for some broadband disturbance sources, measured with the average, RMS-Average and quasi-peak detectors at frequencies in Bands B and C.

CISPR/I/261/CDV—New Amd. 3 to CISPR 13 4th Ed.

- CDV (Committee Draft for Vote) in voting period.
- Introduction of the RMS-average detector as an alternative to quasi-peak and average detector for disturbance power conducted and radiated emission measurements.
- Used detector must be stated in the test report.
- For re-testing the equipment the detector stated in the test report shall be used.
- Limit definition.

Conclusions

The RMS-Average detector corresponds to the weighting characteristic of digital radio communication systems. The weighting function for the RMS-Average detector was confirmed by the achieved results. It can be concluded that the RMS-Average detector ensures an adequate protection level.

The RMS-Average detector can be used for the entire CISPR frequency range; hence there is no need to change the detector for measurements above 1 GHz.

The definition of one limit to replace AV and Quasi-peak makes sense. Based on the broadband disturbances results from the voltage test at mains terminals a correction of +4 dB to the AV limit value and −6 dB to the QP limit seems to be appropriate. For frequency bands using only quasi-peak limits it is proposed to keep the limit value unchanged which means that narrowband disturbances are weighted in the same manner as before.

Faster measurements are possible when the RMS-Average detector is used instead of the quasi-peak detector for final measurements.

Acknowledgment

The measurements of the first RRT were performed in the laboratories of Philips in Eindhoven, Netherlands, Sony in Pencoed, UK, Loewe in Kronach, Germany, and Bose in Framingham (MA), USA between May 8 and August 25, 2006.

The measurements of the second RRT were performed in the laboratories of Alcatel-Lucent in Vimercate, Italy; Apple Computer in Cupertino (CA), US; Fujitsu-Siemens Computers in Augsburg, Germany; JQA Organization at Tsuru site, Japan; Kansai Electronic Industry Development Center at Keihanna site, Japan; SHARP in Hamburg, Germany; and Sony in Stuttgart, Germany between May 2 and July 27, 2007.

The author would like to thank all participants for their efforts in doing the measurements and for sharing their data.

References

[1] Amendment A2:2007 to CISPR 16-1-1:2006: *Weighting of interference according to its effect on digital communication services*

[2] Amendment A2:2006 to CISPR 16-3:2003: *Background material on the definition of the r.m.s.-average weighting detector for measuring receivers.*

Jens Medler received his Dipl.-Ing. degree in Information Technology Engineering in 1992 from the Technical University of Chemnitz. He worked as system engineer in a small firm of consulting engineers before he joined Rohde & Schwarz in 1996. Based in Munich, Germany, the company specializes in test and radio equipment.

Originally, he was engaged in the development of EMC test systems and application software for testing consumer electronic equipment. In 2006, he became responsible for the standardization and application support of EMI test receivers and accessories for both hardware and software.

Jens Medler has been an active member of various CISPR Subcommittees since 1999. This includes CISPR/A on measurement instrumentation and CISPR/I on information technology equipment, multimedia equipment and receivers. Since April 2007, he is acting as Secretary of CISPR/A/WG2; the CISPR Working Group on EMC measurement methods, statistical techniques and uncertainty.