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AMENDMENT 2
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INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

Amendment 2

Specification for radio disturbance and immunity measuring apparatus and methods –

Part 3: CISPR technical reports

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FOREWORD

This amendment has been prepared by CISPR subcommittee A: Radio interference measurements and statistical methods.

The text of this amendment is based on the following documents:

DTR	Report on voting
CISPR/A/659/DTR	CISPR/A/681/RVC
CISPR/A/662/DTR	CISPR/A/678/RVC

Full information on the voting for the approval of this amendment can be found in the report on voting indicated in the above table.

The committee has decided that the contents of this amendment and the base publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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3 Definitions

Add, on page 9, after 3.11, the following new definitions:

3.12
weighting (e.g. of impulsive disturbance)
the pulse-repetition-frequency (PRF) dependent conversion (mostly reduction) of a peak-detected impulse voltage level to an indication which corresponds to the interference effect on radio reception

NOTE 1 For the analog receiver, the interference effect is the psychophysical annoyance, i.e. a subjective quantity (audible or visual, usually not a certain number of misunderstandings of a spoken text).

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.

3.13
weighting characteristic
the peak voltage level as a function of PRF for a constant effect on a specific radio-communication system, i.e., the disturbance is weighted by the radio communication system itself

3.14
weighting function
weighting curve
the relationship between input peak voltage level and PRF for constant level indication of a measuring receiver with a weighting detector, i.e. the curve of response of a measuring receiver to repeated pulses

3.15
weighting factor
the value in dB of the weighting function relative to a reference PRF or relative to the peak value

3.16
weighting detector
detector which provides an agreed weighting function

3.17
weighted disturbance measurement
measurement of disturbance using a weighting detector

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4 Technical Reports

Add, after the existing subclause 4.7 published in Amendment 1, the following new subclauses 4.8 and 4.9:

4.8 Background material on the definition of the r.m.s.-average weighting detector for measuring receivers

4.8.1 Introduction – purpose of weighted measurement of disturbance

Generally, a weighted measurement of impulsive disturbance serves the purpose of minimizing the cost of disturbance suppression, while keeping an agreed level of radio protection. The weighting of a disturbance for its effect on modern digital radiocommunication services is important for the definition of emission limits that will protect these services. Amendment 1 of CISPR 16-1-1 defines a detector that is a combination of an r.m.s. and an average detector. The selection of the type of detector and of the transition between these detector functions is based on measurements and theoretical investigations.

4.8.2 General principle of weighting – the CISPR quasi-peak detector

The effect on radiocommunication services depends on the type of interference (e.g. broadband or narrowband, pulse rate etc.) and on the type of service itself. The effect of the pulse rate was recognized a short time after the CISPR was founded in 1933. As a result, the quasi-peak weighting receiver for the frequency range of 150 kHz to 1 605 kHz was defined as shown for band B in Figure 4.8.1. However in CISPR 1 [1] it was already accepted that “Subsequent experience has shown that the r.m.s. voltmeter might give a more accurate assessment” but the quasi-peak type of voltmeter has been retained for certain reasons – mainly for continuity.

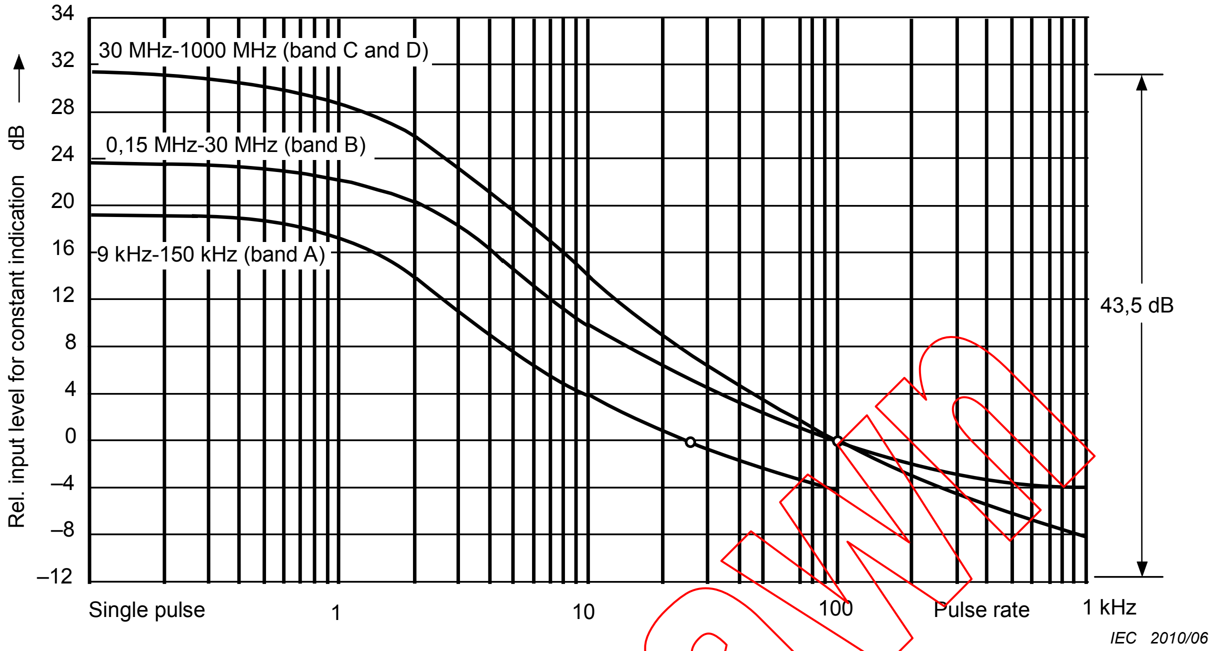

Figure 4.8.1 – Weighting curves of quasi-peak measuring receivers for the different frequency ranges as defined in CISPR 16-1-1. The weighting factor is shown relative to a reference pulse rate (25 Hz or 100 Hz)

4.8.3 Other detectors defined in CISPR 16-1-1

- **Peak detector**

The peak detector follows the signal at the output of the IF envelope detector and holds the maximum value during the measurement time (also called dwell time) until its discharge is forced. This indication is independent of the pulse repetition frequency (PRF).

- **Average detector**

The average detector determines the linear average of the signal at the output of the IF envelope detector. It should be kept in mind that for low PRFs, CISPR 16-1-1 specifies the average detector measurement result as the maximum scale deflection of a meter with a time constant specified for the quasi-peak detector. This is necessary to avoid reduced level indication for a pulse modulated disturbance by using long measurement times. The weighting function varies with 20 dB per decade of the PRF (see Figure 4.8.2).

- **RMS detector**

The r.m.s. detector determines the r.m.s. value of the signal at the output of the IF envelope detector. Despite being mentioned in [1] and being described in CISPR 16-1-1, at the time of writing of this report it has not been put to practical use in CISPR product standards. The weighting function varies with 10 dB per decade of the PRF (see Figure 4.8.2). Up to now, no meter time constant applies for the r.m.s. detector for intermittent, unsteady and drifting narrowband disturbances.

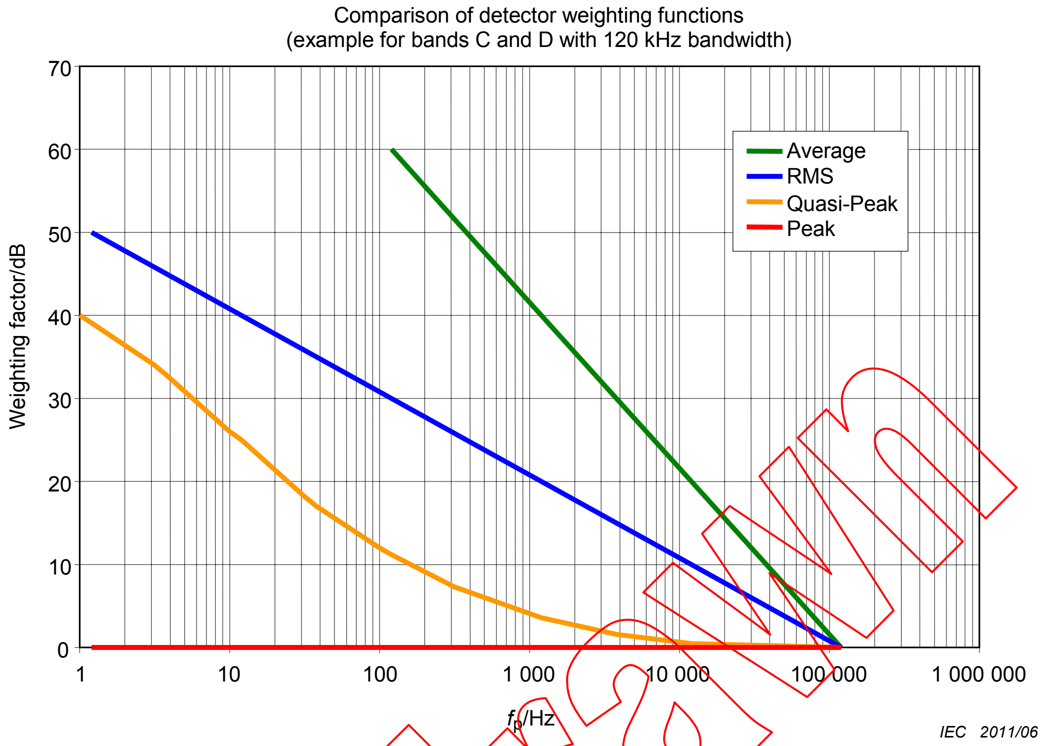

Figure 4.8.2 – Weighting curves for peak, quasi-peak, r.m.s. and linear average detectors for CISPR bands C and D

4.8.4 Procedures for measuring pulse weighting characteristics of digital radiocommunications services

All modern radio services use digital modulation schemes. This is not only true for mobile radio but also for audio and TV. Procedures for data compression and processing of analog signals (voice and picture) are used together with data redundancy for error correction. Usually, up to a certain critical bit-error ratio (BER) the system can correct errors so that perfect reception occurs.

Whereas analog radio systems require signal-to-noise ratios of as much as 50 dB for satisfactory operation, in general, digital radio communication systems allow error-free operation down to signal-to-noise ratios of approximately 10 dB. However the transition region from error-free operation to malfunction is small. Therefore planning guidelines for digital radio are based on almost 100 % coverage. When a digital radio receiver operates at low input levels, the susceptibility to radio disturbance is important. In mobile radio reception, the susceptibility to radio disturbance is combined with the problem of multi-path propagation.

4.8.4.1 Principles of measurement

The significance of the weighting curve for band B in Figure 4.8.1 is as follows: to a listener the degradation of reception quality, caused by a 100-Hz pulse, is equivalent to the degradation from a 10-Hz pulse, if the pulse level is increased by an amount of 10 dB. In analogy to the above, an interference source with certain characteristics will produce a certain BER, e.g. 10^{-3} in a digital radiocommunication system, when the interfering signal is received in addition to the radio signal. The BER will depend e.g. on the pulse repetition frequency (PRF) and the level of the interfering signal. In order to keep the BER constant, the level of the interfering signal will have to be readjusted while the PRF is varied. This level variation vs. PRF determines the weighting characteristics. Measurement systems with BER indication are needed to determine the required level of the interfering signal for a constant BER as e.g. shown in Figure 4.8.3.

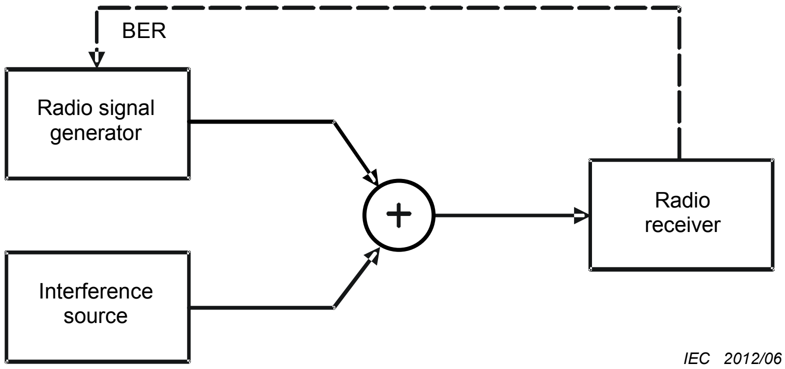

Figure 4.8.3 – Test setup for the measurement of the pulse weighting characteristics of a digital radiocommunication system

The test setup shown in Figure 4.8.3 consists of a radio signal generator that transmits the wanted radio signal to the receiver. For the determination of the BER, the radio receiver either has to know the original bit sequence for comparison with the detected bit sequence or the latter must be looped back to the radio signal generator for comparison with the original. Both systems are available and have been used for tests. Mobile radio testers, e.g., apply the loop-back principle.

4.8.4.2 Generation of the interference signal

A signal generator with pulse-modulation capability can be used to generate the interference signal. For correct measurements, the pulse modulator requires a high ON/OFF ratio of more than 60 dB. Using the appropriate pulse width, the interference spectrum can be broadband or narrowband, where the definition of broadband and narrowband is relative to the communication channel bandwidth. Figure 4.8.4 gives an example of an interference spectrum used for the determination of weighting characteristics.

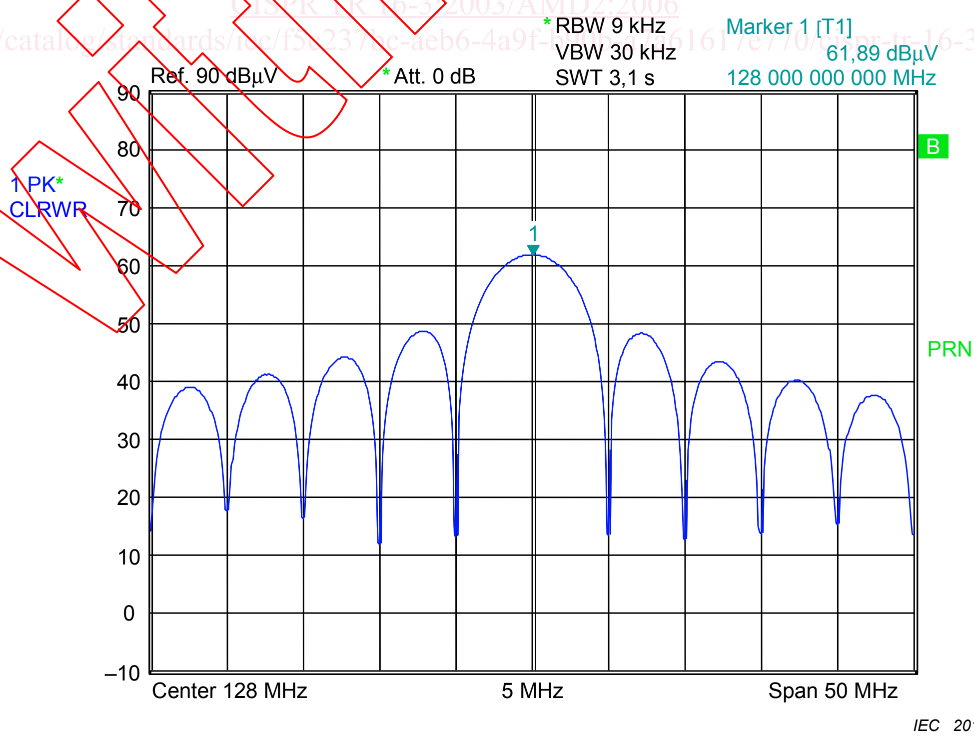

Figure 4.8.4 – Example of an interference spectrum: pulse modulated carrier with a pulse duration of 0,2 µs and a PRF < 10 kHz

With increasing pulse duration, the main lobe of the spectrum becomes narrower. This is also used to study the effect of narrowband pulses on radiocommunication systems. The advantage of using a band-limited pulse spectrum instead of a broadband pulse generator is to avoid overloading the receiver under test. Otherwise non-linearity effects could cause deterioration of the weighting characteristics. In addition to pulse-modulated carriers, unmodulated carriers can be used to determine the sensitivity of different systems to narrowband (CW signal) EMI.

Extensive measurements have also been presented in [2] with on/off-keying of a QPSK-modulated signal, thus keeping the spectrum width wider than the system bandwidth even with longer pulse durations. Since actual receivers do not provide BER indication, the method described in the ITU Recommendation 1368 was used as the failure criteria: DVB-T reception was regarded as distorted when more than one visible erroneous block was shown on the screen within an observation period of 20 s. Alternatively, any picture-freeze, also for short periods, was regarded as a failure. For DRM, the reception was considered as distorted when the system showed more than one dropout in a 20 s observation time.

Further measurements have been made with spread-spectrum modulated carriers in order to study the effect of spread-spectrum clock interference on wideband radiocommunication services (see [3] and [4]).

Table 4.8.1 – Overview of types of interference used in the experimental study of weighting characteristics

Interference signals	**Pulse-modulated**	**On/Off-keyed QPSK-modulated**	**Spread-spectrum modulated**
Pulse width in relation to signal bandwidth	T < 1/B to 100/B	T < 1/B to 100/B	Continuous
T = pulse width, B = radio signal bandwidth			

4.8.4.3 Other principles of measurement

The receiver under test should receive a signal that is just sufficient to give quasi error-free reception (e.g. a BER ≈ 10^{-7} or a factor of 10^{-3} lower than the critical BER). Thus the receiver operates like a receiver at the rim of a coverage area, where a disturbance above the emission limit can easily cause interference.

For radio telephone systems, where the downlink (to the mobile) and uplink (to the base station) frequencies are in different bands, the use of a pulse modulated carrier helps to concentrate the interference on the mobile receiver and thus avoids interference with the loop-back connection.

4.8.5 Theoretical studies

The work of developing measurement procedures considering a digital radio receiver as a disturbance victim, is a very complex problem since there are many different modulation and coding schemes to consider as digital communication services are undergoing rapid development. The results of theoretical studies for radio systems using error correction have been presented in [5] and [6]. These studies are based on the same fundamental assumptions that are explained above:

- the BER is the performance parameter of interest for the digital communication system;
- the repetitive pulsed disturbance is the waveform of particular interest;
- the disturbance pulses have a pulse duration that is short compared to the digital symbols transmitted.

Results for some selected convolutional codes (for more details, see [5]):

A convolutional code is generated by passing the information sequence through a linear finite-state shift register. In general, the shift register consists of *K* stages and *n* algebraic function generators. The input data to the channel encoder is shifted into and along the shift register *k* bits at a time. The number of output bits for each *k*-input sequence is *n* bits. The rate *R* of the code is defined as *n/k*. The parameter *K* is called the constraint length of the convolutional code. In Figures 4.8.5 a) and b) as well as 4.8.6 a) and b) the r.m.s. and peak values corresponding to a constant BER of 10^{-3} are shown for different convolutional codes and *binary phase shift keying* (BPSK) modulation. These results have been simulated with ACOLADE©[1)] (Advanced Communication Link Analysis and Design Environment). In the graphs, the pulse repetition frequency of the disturbance is presented as related (normalized) to the gross-bit rate (or symbol rate) R_s of the communication system. The simulation is done in the band-pass domain. This means that the results can be transformed to an arbitrary carrier frequency. The disturbance pulse width is 10 % of the bit duration time. For the lowest rate *R* = ¼, the r.m.s. value is approximately constant down to the critical point where it increases rapidly. Thus, for a well-protected system, the r.m.s. value corresponding to a constant BER is constant with respect to the pulse repetition frequency of the repetitive pulsed disturbance.

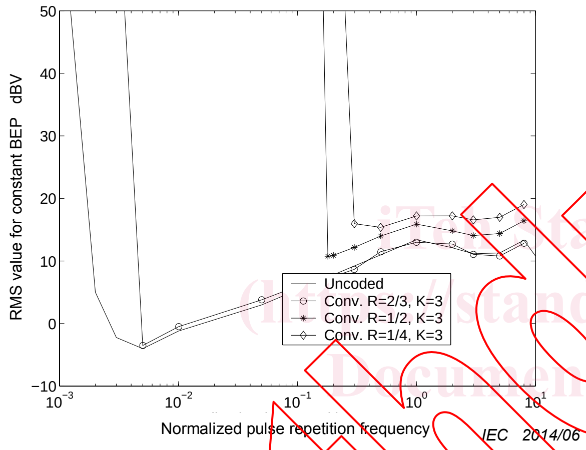

Figure 4.8.5 a) – The r.m.s. level for constant BEP for three *K*=3, convolutional codes of different rate

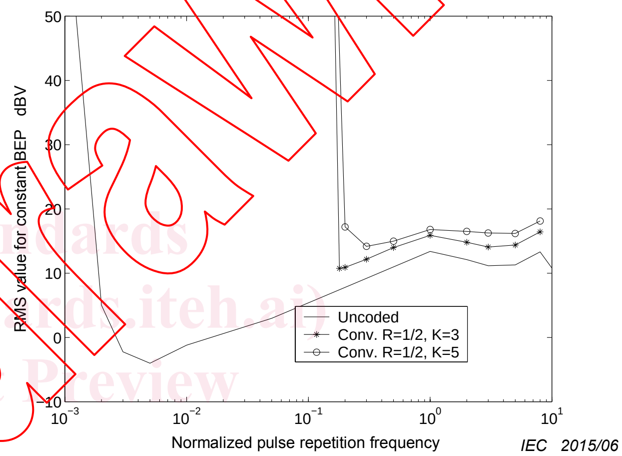

Figure 4.8.6 a) –The r.m.s. level for constant BEP for two rate ½, convolutional codes

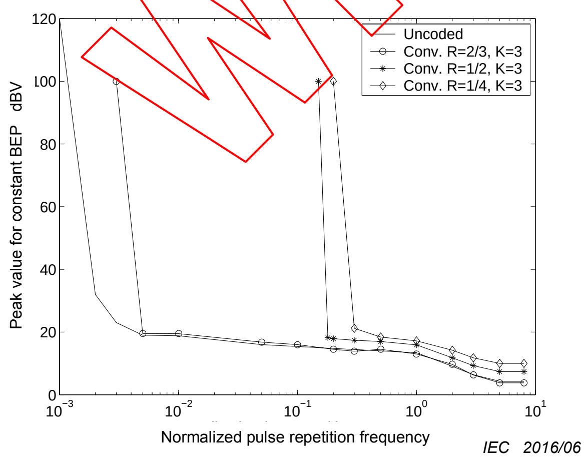

Figure 4.8.5 b) – The peak level for constant BEP for three *K*=3, convolutional codes of different rate

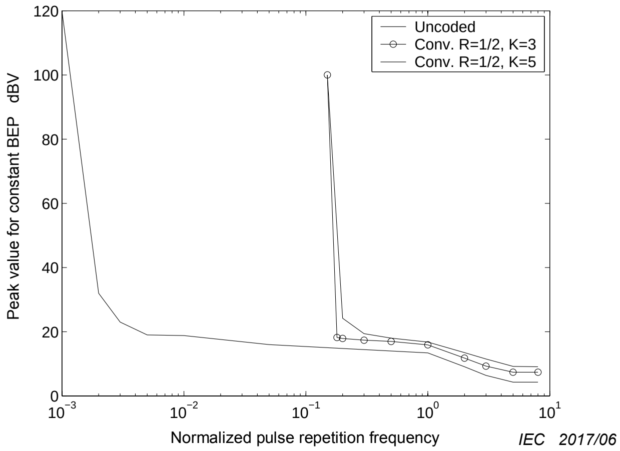

Figure 4.8.6 b) –The peak level for constant BEP for two rate ½, convolutional code

1) ACOLADE© is an example of a suitable product available commercially. This information is given for the convenience of users of this Technical Report and does not constitute an endorsement by IEC of this product.

The results in Figure 4.8.5 show the following: above the symbol rate R_s, the weighting characteristic follows the r.m.s. value of the impulsive signal that causes the interference. Below R_s, the weighting characteristic depends on the amount of coding: for the uncoded signal, the peak value increases with less than 10 dB per decade as the PRF decreases. With better coding, the part of the weighting characteristic with flat response becomes shorter. Therefore, it is important to characterize real radiocommunication systems in order to obtain meaningful results.

4.8.6 Experimental results

The methods described in 4.8.4 have been used for the measurement results in this part. The test signals are described where necessary.

4.8.6.1 Weighting in band A

For band A, i.e. below 150 kHz, no measurement results of digital radiocommunication systems are available.

NOTE Weighting of radio disturbance generally requires a consideration of intermittent, unsteady and drifting narrowband disturbances. Therefore the concept of defining a corner frequency, below which the average detector becomes effective has been applied to band A as well, using the corner frequency proposed for band B, since the original CISPR specification of the r.m.s. detector does not apply a meter time constant.

4.8.6.2 Weighting in band B

Weighting of interference to the Digital Radio Mondial (DRM) Broadcast System

At the World Radio Conference (WRC) in June 2003, the new Digital Radio Mondial was officially started. During the four week duration of the conference, a great number of special DRM transmissions became available from many radio stations. The measurements reported below, were taken on 8 July, 2003, when a great number of transmissions were still available.

DRM uses OFDM (Orthogonal Frequency Division Multiplex) with 200 carriers. The occupied bandwidth of each transmission is 10 kHz. In addition to the digitized audio signal, a certain amount of data (radio station information etc.) is transmitted. A conventional AM receiver can be used to downconvert the signal to an IF of 12 kHz, which is then decoded using a digital signal processor and a special DRM software radio.

During the time of measurement, the radio stations in table 4.8.2 were received at the station near Munich, with amateur dipole antennas mounted on the roof with a higher receive input voltage (50 to 60 dBµV) than required for the experiment.

Table 4.8.2 – DRM radio stations received for the measurement of the weighting characteristics

Frequency kHz	**Beam**	**Target**	**Av. DRM power** kW	**Program**	**Transmit site**
5975	060	W Europe	40	T-Systems Media Broadcast	Jülich
6095	ND	Europe	35	RTL/music and short announcements	Junglinster, Luxembourg
6140	ND	W & C Europe	40	DW English	Jülich
7320	105	W & C Europe	33	BBCWS	Rampisham
13605	037	C Europe	6	IBB/R. Sawa	Morocco
15440	040	W & C Europe	80	DW English	Sines
"W & C" means West and Central (Europe)					

The various transmissions were available for 1h or 2 h. The measurement results (weighting characteristics) were essentially the same for all frequencies, even if the amount of data transmitted in addition to the audio signal was not the same. Time dependent fading of the input signal had to be compensated for manually using a step attenuator that was inserted in the antenna connection, see Figure 4.8.7.

Principally the same type of interference signal was generated as in Figure 4.8.4. However, for a signal with an occupied bandwidth of 10 kHz, it is possible to use a longer pulse duration (10 µs or more).

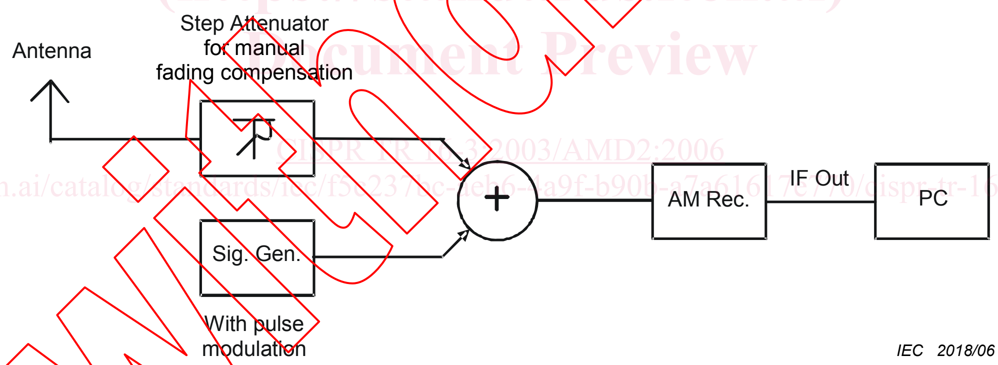

Figure 4.8.7 – Test setup for the measurement of weighting curves for Digital Radio Mondial (DRM). The received signal was downconverted to an IF of 12 kHz for decoding by special hard and software in a personal computer (PC)

Since no indication of BER was available, the "Audio" status indication on the PC (DRM software radio display) was used as a criterion. As soon as the interference becomes too high, the "Audio" status indication will turn from green to red.

As explained earlier, the signal level is attenuated so that the reception quality is just enough. The weighting characteristic (see Figure 4.8.8) shows a 10 dB/decade increase of the interference signal for PRFs between 1 kHz and 5 Hz. The nonlinearities are mainly due to uncompensated fading of the input signal. A detailed weighting curve is shown for a pulse width of 10 µs. For higher pulse widths, the weighting curve was measured only at three (resp. four) points to verify the 10 dB/decade behaviour. Below a PRF of 5 Hz, the weighting curve rises suddenly. And below about 2 Hz, the signal cannot be disturbed by the pulse width of 500 µs. However lightning strokes are reported to generate longer dropouts, which indicates that longer clicks might cause such dropouts as well.

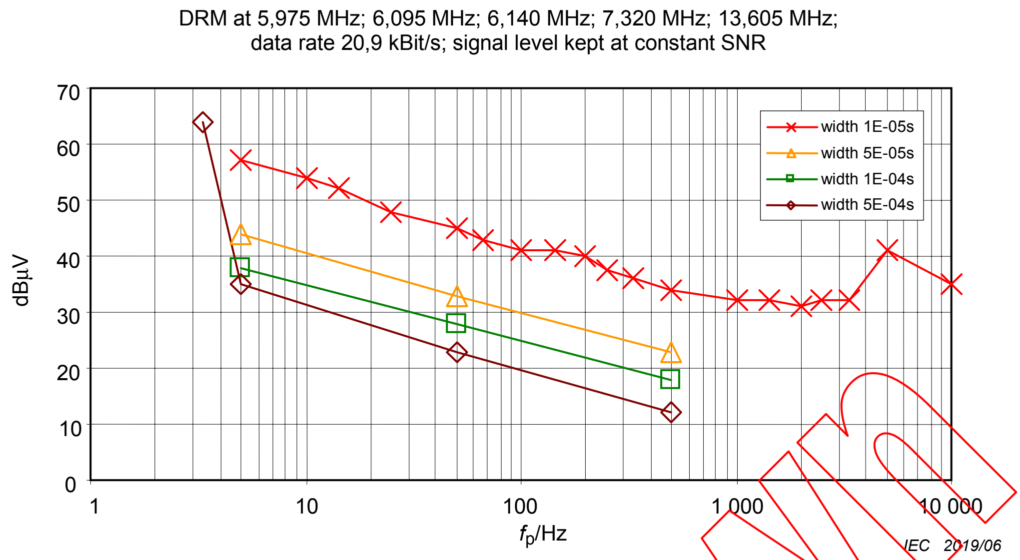

Figure 4.8.8 – Weighting characteristics for DRM signals for various pulse widths of the pulse-modulated carrier. Since the DRM signals are actual radio signals, the exact modulation scheme is not known

The report [2] describes the following DRM signals and two receiver types for the measurements:

- Mode B, Modulation 16/64QAM, Interleave 2 sec, protection level 1 / 0
- Mode B, Modulation 16/64QAM, Interleave 2 sec, protection level 0 / 0

The interference signal for Figures 4.8.9 and 4.9.10 is a pulse-modulated carrier with additional QPSK modulation in order to generate a wide bandwidth of the interference spectrum as explained in 4.8.4.2.

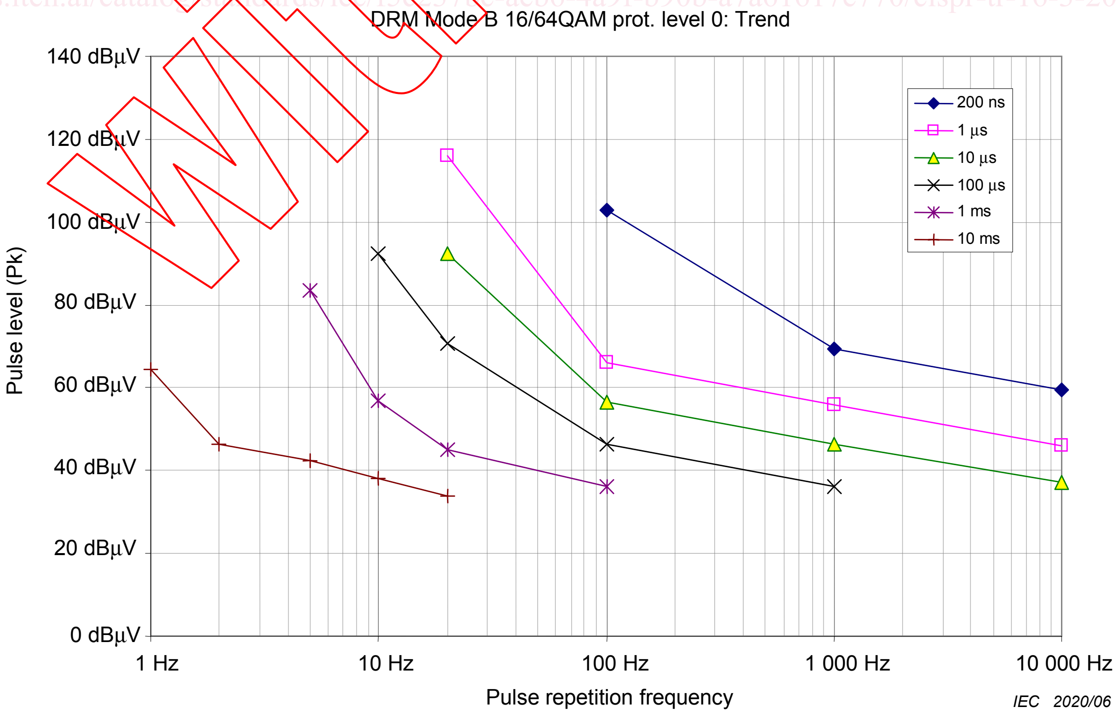

Figure 4.8.9 – Weighting characteristics for DRM protection level 0: average of results for two receivers

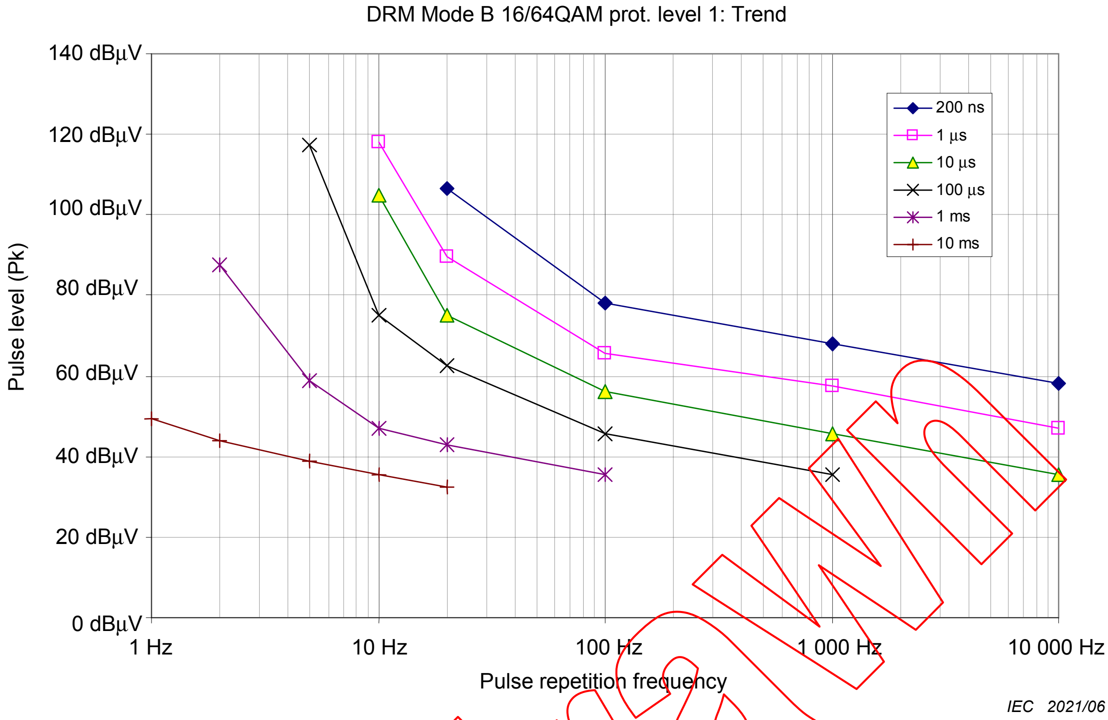

Figure 4.8.10 – Weighting characteristics for DRM protection level 1: average of results for two receivers

The weighting characteristics in Figures 4.8.9 and 10 show a 10 dB/decade slope down to approx. 100 Hz. Since there is no other digital radio system in band B, the corner frequency of the proposed RMS/AV detector between r.m.s. and linear average detection for this frequency band can only be based on the results of DRM (see 4.8.7). A corner frequency of 10 Hz is therefore proposed for band B as a compromise between the two results.

4.8.6.3 Weighting in bands C/D

4.8.6.3.1 Weighting of impulsive interference to Digital Video Broadcast Terrestrial (DVB-T)

- **Test setup**

One test setup for DVB-T consists of a DVB-T signal generator and a DVB-T measuring receiver. The components are connected via coaxial cables. The interference signal (a pulse-modulated carrier, see Figure 4.8.4 for an example of the spectrum) is fed into the signalling connection via a combiner.

The parameters used are the following.

DVB-T uses COFDM (Coded Orthogonal Frequency Division Multiplex) with 6817 (8k) or 1705 (2k) carriers. The OFDM carriers may be modulated either with QPSK (Quadrature Phase Shift Keying) or with 64 QAM (Quadrature Amplitude Modulation), resp. 16 QAM. QAM is preferred to QPSK as QAM allows higher data transfer rates. The transmission code rate *CR* is defined by *CR* = number of information bits/(number of information bits + error protection bits). Values of *CR* = 2/3 and 3/4 are used in actual systems. Each COFDM symbol is followed by a guard interval *GI* which is *GI* = 1/8 in actual systems. The DVB-T modulation and coding system allows many combinations, of which only a few are relevant. Therefore the parameters used in systems operating in some European countries have been selected. These allow transmission rates between 14,745 Mbit/s and 24,88 Mbit/s (see Table 4.8.4) depending on modulation and code rate. Different coders and decoders are used in the system. The bit-error ratio (BER) reading can be taken before the Viterbi decoder as well as before and after the Reed Solomon decoder of the measuring receiver. A comparison is given in Table 4.8.3. The transmission level is set so that the BER after the Reed Solomon decoder without interference is just below 10^{-8}. This results in different signal levels depending on the system parameters. The interference levels have then been adjusted to a critical value of BER = $2,0*10^{-4}$ before the Reed Solomon decoder.

For the BER measurement, the modulator generates a Pseudo Random Binary Sequence (PRBS) as data stream. The evaluation of the data stream is done in the receiver in two different procedures. The BER before Viterbi and before Reed-Solomon is evaluated by correlation. Flags in the bit stream are used to determine the BER after Reed-Solomon. If the decoder does not recognize a flag as correct, the following bit combination is determined to be false.

The relationship in Table 4.8.3 was found experimentally between the bit error ratios before and after the Viterbi and Reed Solomon decoders for two pulse rates.

Table 4.8.3 – Comparison of BER values for the same interference level

Pulse rate Hz	**10 k**	**500 k**
BER before Viterbi decoder	$1,5*10^{-2}$	$4,4*10^{-3}$
BER before Reed Solomon	$2,0*10^{-4}$	$2,0*10^{-4}$
BER after Reed Solomon	$1,0*10^{-6}$	$1,0*10^{-8}$

So, the results with BER measured before Reed Solomon (with $2,0*10^{-4}$) and after Reed Solomon (with $1,0*10^{-6}$) are roughly comparable.

Table 4.8.4 – Transmission parameters of DVB-T systems used in various countries

Country	**Modulation**	**Code rate**	**Guard interval**	**Transfer rate**
France/UK	64QAM 2k	3/4	1/8	24,88 Mbit/s
Spain	64QAM 8k	3/4	1/8	24,88 Mbit/s
Germany	16QAM 8k	2/3	1/8	14,745 Mbit/s

The measurement results are presented in Figures 4.8.11, 4.8.12 and 4.8.13. In all tests, the interference signal leading to these results are pulse-modulated carriers.

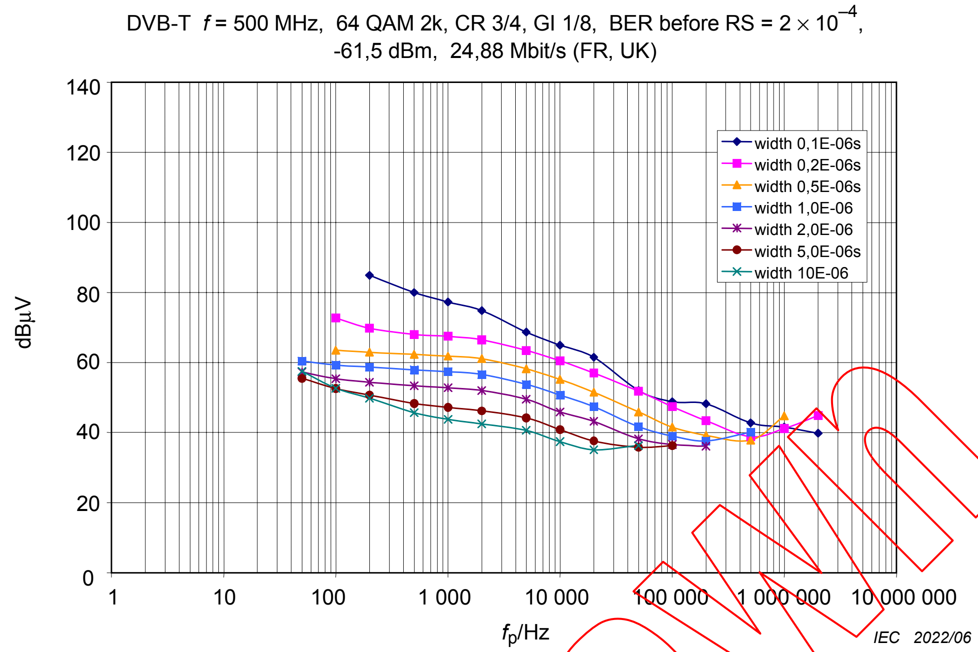

Figure 4.8.11 – Weighting characteristics for DVB-T with 64QAM 2k, *CR* 3/4 (as used in France and United Kingdom)

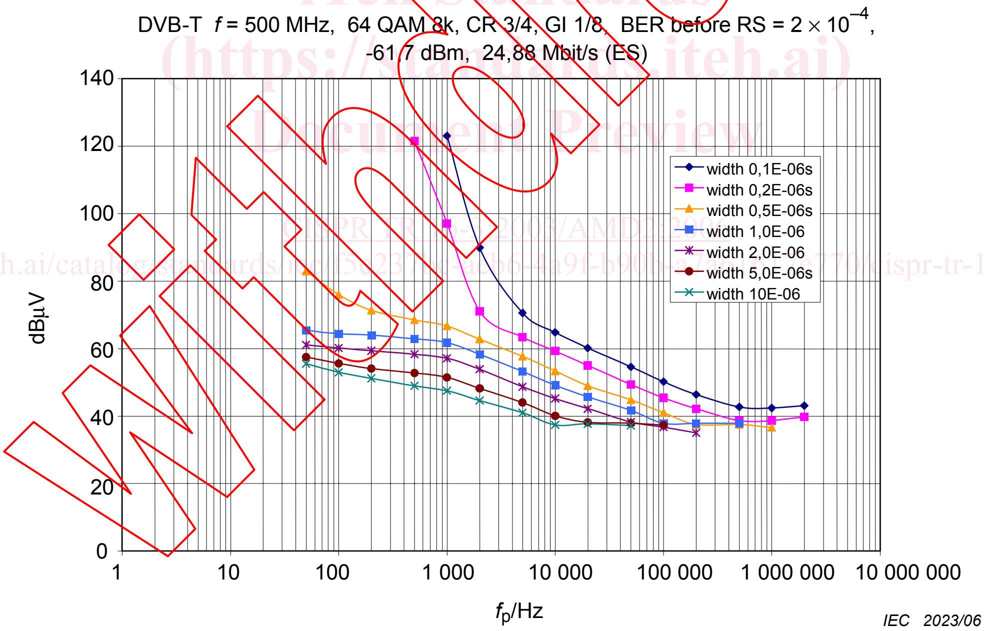

Figure 4.8.12 – Weighting characteristics for DVB-T with 64QAM 8k, *CR* 3/4 (as used in Spain)