Research on the Measurement Bandwidths and Emission Limits of Digital Communication Systems Based on Rms-Average Detector

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***Abstract*— Present international standards for maximum levels of unintentional radiated emission from electronic devices are developed to protect analog communication services. Due to the variety of digital communication frequency bands and channel bandwidths, in this paper, a set of measurement bandwidths and the key factors that effect future electric field strength levels were proposed, based on the rms-average detector CISPR recommended.**
Keywords: Digital communication systems, unintentional radiated emission, rms-average detector, measurement bandwidth, emission limits.

I. INTRODUCTION

The present commercial emission standards are developed to protect analog communication services. These standards still use a measurement detector, i.e., the quasi-peak detector, which captures the human perception of electromagnetic (EM) disturbances on analog radio receivers. However, this detector is not adequate to capture the effect of EM disturbances on digital radio receivers. A new weighting detector in [1] has been defined to better consider the impact of pulsed interferers on today’s dominant digital radio services. This new weighting detector with the name rms-average is a combination of the rms detector and the average detector with meter time constant. The specific configuration can be referred to [2] for standardized verification tests, employing the measurement bandwidths of [1] for analog systems.

In this paper, series of measurement bandwidths of the detector that focuses on digital systems have been proposed to compare the emf strength within a degree of BEP, employing a simplified model of radiation emission test. And some key factors of emission limits have been proposed, and the explicit values need complex statical computation.

II. MEASUREMENT BANDWIDTHS OF MODERN DIGITAL WIRELESS COMMUNICATION SYSTEMS

The quasi-peak detector is not adequate to capture the effect of EM disturbances on digital radio receivers. A new combined weighting detector in [1] has been defined to better consider the impact of pulsed interferers on today's dominant digital radio services. There is specific definition in [2] about its parameters when applied in standard test, employing the measurement bandwidth of analog system.

According to [3]，compared with average detector, the weighting characteristics of rms detector is much more approaching to the quasi-peak detector, so the rms detector is selected to be studied.

All radiated emission standards specify the measurement bandwidths to be used. The current measurement bandwidths in the CISPR standard EN55022 are shown in Table 1

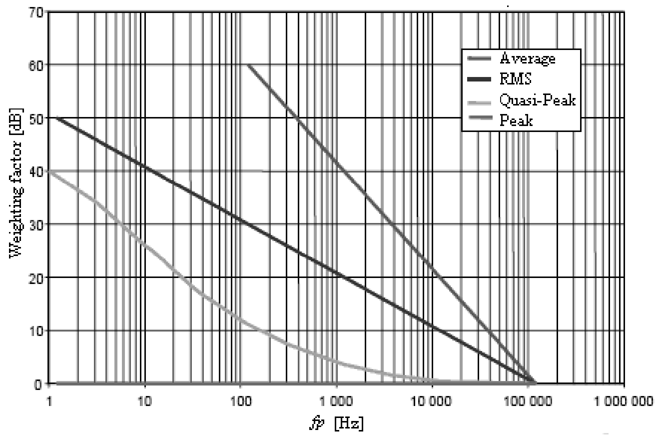

Fig. 1 Weighting curves for peak, quasi-peak, rms. and linear average detectors for CISPR bands C and D

TABLE 1

MEASUREMENT BANDWIDTHS ACCORDING TO EN55022

Frequency range	Measurement bandwidth
30MHz-1000MHz	120kHz
1GHz-18GHz	1MHz

Since the dynamic range in channel bandwidths in Table 2 is large, it is not convenient to use only one measurement bandwidth for each frequency range. If the difference between the measurement bandwidth and system bandwidth is too large, the correlation between the measured result and the corresponding interference impact on the system will be weak. If, for instance, the measurement bandwidth is considerably smaller than the system bandwidth and the bandwidth of the interference is larger than the measurement bandwidth, then the interference power perceived in the radio system will be much higher than is measured. This property is taken advantage of when spread spectrum techniques are used on computer clocks. In that case, the emission measurement limit can be passed but a victim radio communication system can perceive strong interference impact. Of course, there is always a disadvantage to use more than one measurement bandwidth since it will increase the total measurement time. On the other hand, the usefulness of the measurement increases if at least two sets of measurement band-widths are used.

TABLE 2

CHANNEL BANDWIDTHS OF SOME STANDARDIZED WIRELESS SERVICES

Standard	Frequency range（MHz）	Channel bandwidth
TETRA	China：806 -821 , 851 -866 Europe：410-430,870-876/915-921,450-470,385-390/395-399.9	25kHz、50kHz，100kHz，150kHz
DVB-T	175-230,470-802	6MHz,7MHz,8 MHz
GSM 900	890-915,1805-1880	200kHz
GSM 1800	1710-1785,935-960	200kHz
WCDMA/FDD	1920-1980,2110-2170; 1850-1910,1930-1990	5MHz
WCDMA/TDD	1900-1920,2010-2025;1850-1910,1930-1990;1910-1930	5MHz
TD-SCDMA	2010-2025,2110-2170	5MHz
Bluetooth	2402-2480	1MHz
IEEE 802.11b,g	2400-2483.5	20MHz
IEEE 802.16	10000-66000	28MHz

TABLE 3

MEASUREMENT BANDWIDTHS ACCORDING TO CISPR 16-1-1

Frequency range	Measurement bandwidth
30MHz-1000MHz	100kHz-500kHz
1GHz-18GHz	300kHz-2MHz

TABLE 4

PROPOSED MEASUREMENT BANDWIDTHS

Frequency range	Measurement bandwidth（NB）	Measurement bandwidth（BB）
30MHz-230MHz	200kHz	1MHz
230MHz-1GHz	200kHz	2MHz
1GHz-1.9GHz	1MHz	5MHz
1.9GHz-18GHz	1MHz	20MHz

III. SETUP FOR DETERMINE THE PROPOSED MEASUREMENT BANDWIDTHS

All radiated emission standards are based on a certain collocation scenario where a certain amount of interference has been considered acceptable for the analog service considered. In this section, a collocation scenario (see Fig. 2) for electronic devices in the vicinity of digital communication system is chosen as a basis for the upcoming derivation of acceptable measurement bandwidths.

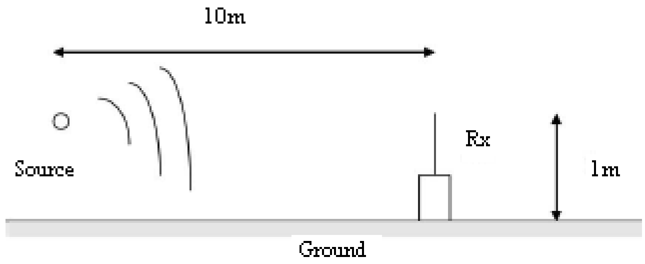

Fig.2 Collocation scenario with radiated emission from collocated equipment

A collocation distance of 10 m is chosen as the reference distance for the emission limits. It is assumed that the radio communication system has a bit-error probability (BEP) of approximately 10^{-5} in the undisturbed case. The radiated disturbance is allowed to increase the BEP to approximately 10^{-3}. The modulation scheme binary phase-shift keying (BPSK) is selected as a reference for calculations.

IV. HOW TO DEAL WITH ERROR-CORRECTING CODES EFFECT

[3] has shown that the performance in terms of BEP of digital radio communication systems, which are well protected with error-correcting codes, is related to the rms value of a repetitive pulsed signal. In Fig. 3, the rms value to obtain a constant BEP is shown. Furthermore, [5][6] have shown that this relation is very simple as the rms value corresponding to a certain BEP, is approximately constant with respect to the pulse-repetition frequency $1/T_P$ of the disturbance signal for such frequencies exceeding the symbol rate RS of the digital radio system (see Fig. 3). The rms level for pulse repetition frequencies above RS is within a few decibels, which is the same as for additive white Gaussian noise (AWGN) and pure sine-wave interference. Thus, it is possible to determine the maximum-allowed electric field strength, caused by repetitive impulsive signals, such that the BEP does not exceed a certain requirement. Several digital systems practical measurements in [3] also contribute to this point.

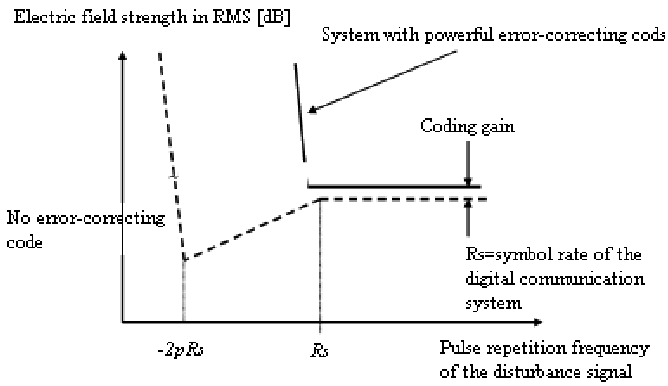

Fig.3 Principal relation between the rms value, for constant BER, and the pulse repetition frequency of the disturbance signal.

With this knowledge, it is possible to amend present radiated emission standards for digital communication systems. The choice of pulsed interference as reference source is motivated by the fact that pulsed interference in most cases causes the worst performance degradation on digital radio systems. Whether an emission limit should be based on the coded or uncoded case is open, the margins due to coded case could refer to the specific modulation scheme.

The measured rms value V_{rms} can be related to the electric field strength $E_{\mathrm{R}}(r)$ of the interference by knowing the antenna and receiver properties of the measurement system. If the interference source is electrically small, then the far-field antenna theory can be used. The received interference power, SI, at the radio receiver input can, then, be estimated as

$$S_{\mathrm{I}} = \frac{\lambda^2}{4\pi Z_0} pqG_{\mathrm{R}} E_{\mathrm{R}}^2(r) \quad (1)$$

Where λ is wavelength (in meters); G_{R} is antenna gain of the radio receiving antenna in the direction of the interfering source; p is polarization matching factor $0<p\leq 1$; q is matching factor between radio antenna impedance and load impedance, $0<q\leq 1$; $E_{\mathrm{R}}(r)$ is electrical field strength (volts/meter) of the radiated interference at the receiving radio antenna; Z_0 is wave impedance for free space (= 377 Ω); r is separation distance between the undesired interference source and the radio receiver.

$E_{\mathrm{R}}(r)$ is the measured electric field strength during emission measurement. Knowing the receiver impedance Z_{r}, it is possible to compute a relation $V_{\mathrm{rms}}(S_{\mathrm{I}})$, since $V_{\mathrm{rms}} = \sqrt{Z_{\mathrm{r}} \times S_{\mathrm{I}}}$. The connection to the corresponding BEP is established through standard equations. As an example, we show how this connection is outlined for binary communication systems. It has been shown that for AWGN, the bit-error rate (BER) $P_{\mathrm{b}}(\gamma)$ is a function of

$$\begin{aligned} P_{\mathrm{b}}(\gamma) &= P_{\mathrm{b}}\left(\frac{E_b}{N_I + N_0}\right) \\ &= P_{\mathrm{b}}\left(\frac{E_b}{\frac{1}{R_b}\cdot S_I + N_0}\right) \\ &\approx P_{\mathrm{b}}\left(\frac{E_b}{\frac{1}{R_b}\cdot\frac{\lambda^2}{4\pi Z_0} pqG_{\mathrm{R}} E_{\mathrm{R}}^2(r) + N_0}\right) \\ &\cong P_{\mathrm{b}}\left(\frac{E_b}{\frac{1}{B_R}\cdot\frac{\lambda^2}{4\pi Z_0} pqG_{\mathrm{R}} E_{\mathrm{R}}^2(r) + N_0}\right) \end{aligned} \quad (2)$$

$$P_{\mathrm{b}}\left(\frac{E_b}{N_I + N_0}\right) = P_{\mathrm{b}}\left(\frac{1}{\frac{1}{\mathrm{SIR}} + \frac{1}{\mathrm{SNR}}}\right) = P_{\mathrm{b}}\left(\frac{\mathrm{SIR}\times\mathrm{SNR}}{\mathrm{SIR}+\mathrm{SNR}}\right) \quad (3)$$

Where signal-to-interference ratio (SIR) = E_b/N_I and the signal to noise ratio (SNR) = E_b/N_0 . Thus, via (2), we can connect V_{rms} to P_b . The function $P_b(\gamma)$ is the BEP for interference with AWGN without any error-correcting codes. As an example, (4) shows $P_b(\gamma)$ for the modulation scheme BPSK

$$P_b(\gamma) = \frac{1}{2}\mathrm{erfc}(\sqrt{\gamma}) \quad (4)$$

Where erfc is the standard complementary error function. Thus, γ is replaced with the expression inside the brackets in (2) if we want to consider the mix of thermal and radiated interference. The selected system parameters are shown in Table 5.

TABLE 5

SELECTED SYSTEM PARAMETERS FOR THE CALCULATED EMISSION LIMITS

Parameter	Value
Noise Fig. NF(dB)	15
SNR(dB)	≈10
SIR(dB)	≈10
BEP	10^{-3}
Selected modulation	BPSK

In a final emission standard, the statistics of complaints and sources of interference should be taken into account [4]. For such an analysis, the four events, given as follows :

A. "The desired transmitter is transmitting";
B. "The wanted signal is satisfactorily received in the absence of unwanted energy";
C. "Another equipment is producing unwanted energy";
D. "The wanted signal is satisfactorily received in the presence of the unwanted energy."

In this paper, we show what the effects of the selected measurement bandwidth to the emission test results could be for the case when the probability is equal to 1 for these four events.

V. DIFFERENT EFFECTS AT THE SAME FREQUENCY EMPLOYING DIFFERENT BANDWIDTHS

The product in (1) can be simplified as a constant at a specific frequency, therefore when employing different measurement bandwidths B_{R1}, B_{R2}, the field strength ratio can be

$$\frac{E_{R1}(r)}{E_{R2}(r)} \propto \sqrt{\frac{B_{R1}}{B_{R2}}}$$

In table 4, the calculated ratios of supposed bandwidths and reference bandwidths have been listed. According to Fig.4, the ratio is a little more than 1dB at 30MHz and 230MHz with narrow bandwidth interference and the rest are very close to the standard ones. While in the case of wideband interference, the ratios are larger, which could be more than 6dB. [3] has listed several research results on the variational measurement bandwidths effects, and the difference value of weighting factor between the cases that employing different measurement bandwidths, 120kHz and 1MHz, is about 10dB for C, D frequency bands. If the present standard limits are adopted, the test results are inclined to fail. For digital communication systems, the weighting factors of rms detector is smaller then quasi-peak detector's in band C and D.

Obviously, the conclusion above is based on the uncoded case for large pulse repetition frequencies; see Fig. 3, which corresponds to the coded case without taking any advantage of the "coding gain." [3] has listed several practical measurement results of different digital systems, and the analysis is based on statical measurement results. When the digital systems are transmitted data, the BEP requirements are much stricter, and the transmission distance, data speed, channel bandwidth, encoded mode are varied due to the standards selected. Therefore, the old international standards are not adequate to evaluate and protect the digital systems, neither do the one-value limit standard.

The present emission limits are based on the reference measurement bandwidths, and it has been made clear that in case of dispute data measured with the reference bandwidth shall take precedence. Consequently, it should be a factor when pre-compliance test.

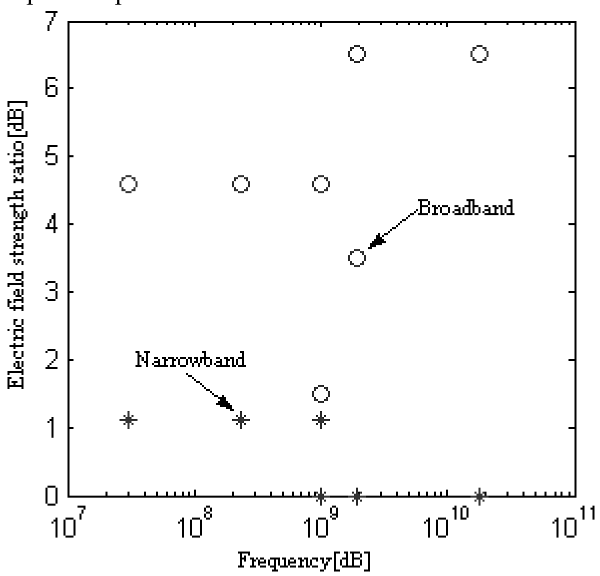

Fig. 4 Electoral field strength variations at the same frequency due to different bandwidths

VI. CONCLUSION

The present international standards for maximum levels of unintentional radiated emission from electronic devices are developed to protect analog communication services. A new weighting detector in [1] has been defined to better consider the impact of pulsed interferers on today's dominant digital radio services. This new weighting detector with the name rms-average is a combination of the rms detector and the average detector with meter time constant, employing the reference bandwidths and emission limits of analog systems.

In this paper, series of measurement bandwidths of the detector that focuses on digital systems have been proposed to compare the emf. strength, employing a simplified model of radiation emission test. Finally, some key factors of emission limits have been proposed, and the explicit values need complex statical computation.

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