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NUMERICAL STUDY ON THE DISTURBANCE MEASUREMENTS RELATED TO THE PERFORMANCE OF DIGITAL WIRELESS COMMUNICATION SYSTEMS

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Abstract: We compared two different methods called RMS-AVG and APD, currently discussed in CISPR as the disturbance measurement method to evaluate the degradation of the digital wireless communication systems, by numerical simulations. Repetition pulse and Gaussian noise were added as the disturbance to the DQPSK coded signal at the transmission path. The disturbance effects on BER and on each reading by the two methods were obtained quantitatively. The comparison shows that both methods account for the disturbance effect on a digital wireless communication system.

Keywords: Digital wireless communication system, Disturbance measuring receiver, Amplitude probability distribution (APD), RMS- Average (RMS-AVG), BER (Bit Error Rate)

1. Introduction

High requirements of capacity, reliability and mobility for the digital wireless communication systems have led to the extremely rapid technological advances, expressly around/above 1 GHz over the last decade. Accordingly, new communication services such as PHS, GSM, and W-CDMA are now available. Moreover, many electric/electronic appliances now use high frequency signals, which is increasing the level of interference potential, particularly in the ISM band.

Thus, measurement of the disturbance above 1 GHz is important in maintaining communication quality. The current standard of the measuring receiver above 1 GHz established by CISPR specifies only a peak detector. However, the peak detector is highly doubtful if it is appropriate to evaluate the interfering potential with the digital communication systems, especially for the pulse disturbance with lower repetition frequencies. As with the bands from 9 kHz to 1000 MHz, quasi-peak (QP) detector is adopted. Although the QP measurement correlates well with the degradation of analog communication services, it does not for digital communication services used in the band above 1GHz.

There are two candidates for the new CISPR standard for the disturbance measurement method in the band higher than 1 GHz, one is the Amplitude Probability Distribution (APD) measurement method [1] and the other is the Root Mean Square- Average (RMS-AVG) measurement method [2]. Some studies have been conducted on their individual performance, but there has been no comparison of these methods. In this paper, we focus on the principle performance of these methods in numerical base-band simulations and clarify their respective advantages and disadvantages for the evaluation of disturbance effect on digital wireless communications.

2. Two candidates for a disturbance measurement method above 1GHz

2.1 APD measurement method

APD is defined as the "percentage of time that a disturbance intensity exceeds a threshold level" shown in Eq. (1) [1].

$$APD(R,T) = \text{prob}(\text{envelope } r(t) > R) = \sum_i t_i / T \qquad (1)$$

T is the total measurement time, and t_i is the time during which the intensity of disturbance $r(t)$ exceeds the level R. It is obvious that the APD can be obtained as an integral form of the probability distribution function from R to infinity. APD measured by using the video output signal of a spectrum analyzer or other measuring apparatuses. Measuring equipment used for APD has already been developed and experimental data of disturbance in several wireless communication services has been accumulated.

Such a statistical evaluation is reasonable and comprehensive for disturbance measurement, because disturbance is not a deterministic process in most cases. Some reports point out that the APD closely correlates with the degradation of digital wireless communication quality and it is possible to estimate BER (Bit Error Rate) from APD [3], [4]. However, it is necessary to decide one or several significant readings, which define the criterion, from the APD for the compliance test of the disturbance.

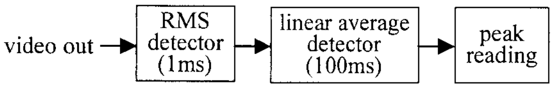

Fig. 1 RMS-AVG measurement system

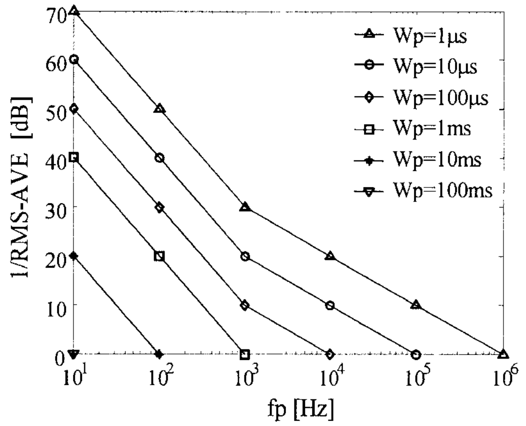

Fig. 2 Weighting curves obtained by RMS-AVG

2.2 RMS-AVG measurement method

In concurrence with the APD method, the RMS-AVG method shown in Fig. 1 has been proposed in CISPR as the disturbance measurement standard from 9 kHz up to 18 GHz. Here we introduce the outline based on [2].

The RMS-AVG reading can be obtained using the video output signal of a spectrum analyzer or a scanning receiver. First, it takes the Root-Mean-Square (RMS) of video output every 1 ms. The next step is the linear averaging of an RMS data series every 100 ms (100 points) and finally, the taking of the peak reading as the result. Figure 2 shows the response of RMS-AVG detector for repetition pulse with frequency f_p and pulse width W_p. The reciprocal of RMS-AVG readings is used as the weightings of the RMS-AVG measuring receiver.

Several measurement results have been reported for digital wireless communication services, e.g. GSM, which show the possibility of detecting the degradation of communication quality. However, additional evidences to show the rationale of the period of RMS procedure (1ms) are necessary and quantitative considerations should be done to check the correlation between the readings and the communication performance.

3. Numerical simulation model for the communication performance and the disturbance measurements

Base-band numerical simulations were carried out to examine the fundamentals of APD and RMS-AVG methods. The simulation model is shown in Fig. 3. The continuous data mode of DQPSK on the PHS system is used for the simulations with the parameters shown in Table 1

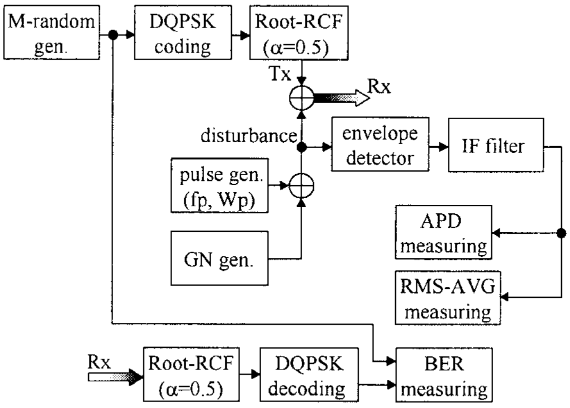

Fig. 3 Base-band simulation model of DQPSK for communication performance and disturbance measurements by APD and RMS-AVG methods

Table 1 Parameters of the digital wireless communication system used on the simulation based on the PHS system

Transmission method	π/4 shift DQPSK (M=4)
Symbol rate	f_s = 192 [ksps]
Sampling rate	$f_{sim} = 100 f_s$ = 19.2 [MHz]
Roll-off factor of the Root-RCF	$\alpha = 0.5$

The sum of the Gaussian noise and the repetition pulse with frequency f_p and pulse width W_p as the disturbance was added to the DQPSK coded signal. Gaussian noise expresses the internal noise of the measuring receiver. We used S/N=10 dB. Additionally, the fading effects on the transmission path were not considered in the absolute evaluation of disturbance effect.

APD and RMS-AVG readings were calculated after LPF to simulate the IF section of the measuring receiver. Its bandwidth shall be 1 MHz as required by [5]. In practice, a half of the bandwidth, 500 kHz (-3 dB) was used for the base-band simulations. The effect of the video filter in the receiver may be disregarded if its bandwidth is wider than the bandwidth of the RBW filter. Three times bandwidth for the video filter is recommended for the APD measurement.

4. Correlation between RMS-AVG/APD and BER

Figures 4 through 6 show the simulation results for BER, RMS-AVG and APD, respectively.

Correlations between RMS-AVG readings and BER, and the correlations between APD readings and

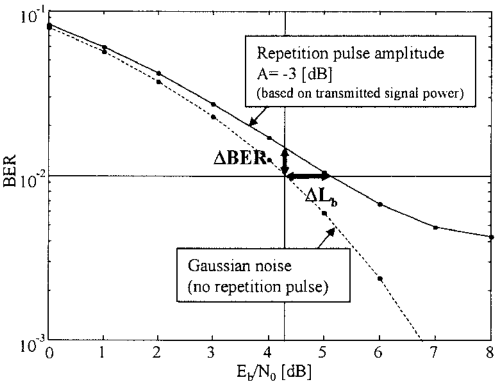

Fig. 4 Simulation results of BER with/without pulse disturbance

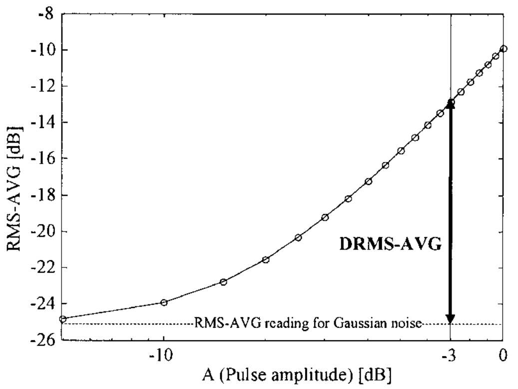

Fig.5 Quantification of the disturbance effect on RMS-AVG readings

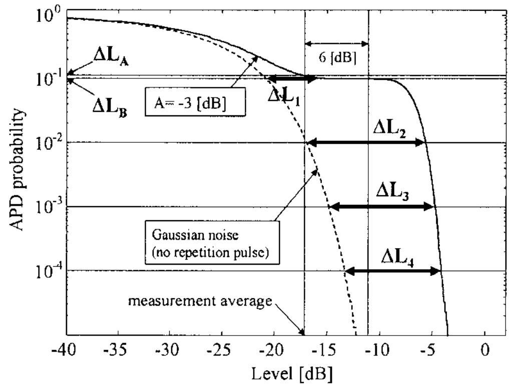

Fig. 6 Quantification of disturbance effect on APD

BER should be evaluated to consider that each method detects the BER degradations caused by disturbance. In Fig. 4, one appropriate BER (= 10^{-2}) allows us to decide ΔL_b and ΔBER, which represents the contribution of the pulse disturbance with the amplitude A (= -3 dB to the signal level) to the BER degradation. N_0 represents only the power of Gaussian noise; i.e. it does not include the repetition pulse power. Figure 5 shows equivalent ΔRMS-AVG, or the effect of the pulse disturbance on the RMS-AVG readings is defined in a similar way. In Fig. 6, ΔL_1 to ΔL_4 show the effect of disturbance on APD determined at each probability, 10^{-1}, 10^{-2}, 10^{-3} and 10^{-4}. Moreover, the L_A and L_B are given based on the average value of the disturbance and its double, respectively.

Figure 7 shows variations of each parameter as a function of the amplitude A of the repetitive pulse disturbance. Each panel shows (a) ΔL_b with BER=10^{-2}, which is the required detection ability at the PHS receiver [6], (b) ΔRMS-AVG, (c) ΔL_2 (d) ΔBER with constant BER=10^{-2}, (e) L_A. It is noted that ΔL_2 has the highest correlation with ΔL_b among ΔL_1 to ΔL_4 and L_A is a representative value that correlates well with ΔBER than L_B. Repetition pulse frequency is changed 100, 400, 1 k, 4 k, 10 k and 40 kHz with the same pulse width (= 2 μs) explained in panel (a). Typical pulse disturbance of microwave oven (switching type) shows repetition pulse frequency around 30 kHz, and the pulse width less than 1-2 μs for the measurement bandwidth of 300 kHz [3]. Therefore, parameter settings on the simulation are nearly practical for the pulse disturbance.

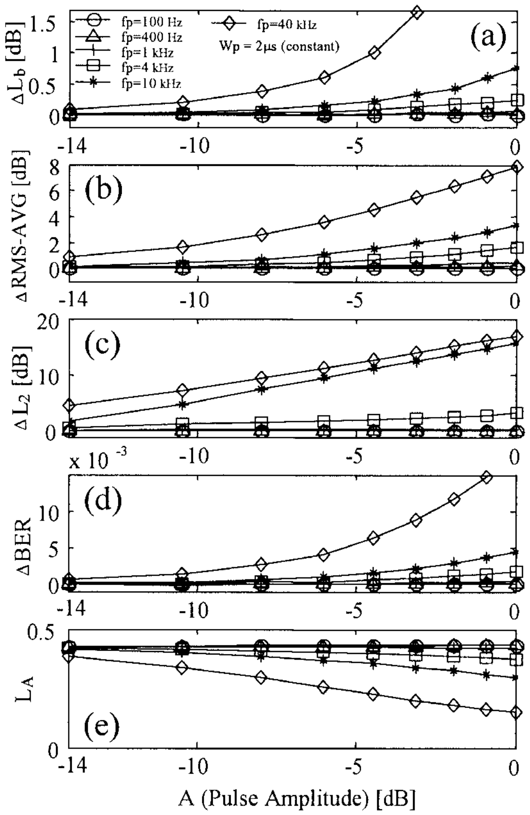

Fig. 7 Simulation results for BER=10^{-2}, pulse width=2μs. (a) ΔL_b as a disturbance effect on BER, (b) ΔRMS-AVG readings of disturbance, (c) ΔL_3 readings from APD at the probability=10^{-2}, (d) ΔBER as a disturbance effect on BER measured on lengthwise direction, (e) L_A as a disturbance effect from APD, for each repetition pulse that has amplitude A and frequency f_p

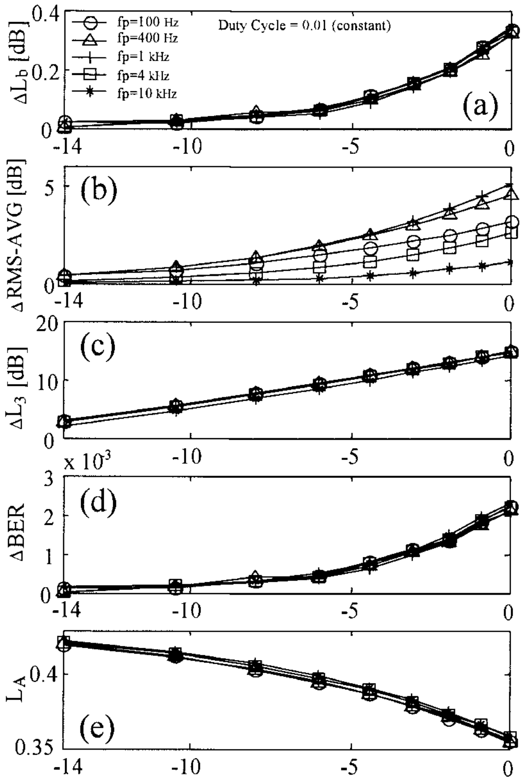

Fig. 8 Simulation results for BER=10^{-3}, duty cycle=1%

ΔL_b and ΔBER show the significant increase exponentially with the increase of disturbance. ΔRMS-AVG variations correlate well with ΔL_b. Also, L_A shows a high negative correlation with ΔBER. ΔL_2 shows increase corresponding with ΔL_b, but it does not have correlations as much as ΔRMS-AVG. ΔRMS-AVG and L_A are promising factor of disturbance measurement at this example.

Figure 8 shows the simulation results same as Figure 7, but for the constant duty cycle (1%). Repetition pulse frequency is changed 100, 400, 1k, 4k and 10k Hz as indicated in panel (a). In this case, total noise power is exactly the same because of a constant duty cycle, so that the BER variations are almost the same for a different repetition frequency as shown in panels (a) and (d). It is certain that any APD readings in panels (c) and (e) can account for BER performance. However, the frequency response of ΔRMS-AVG in panel (b) is different from others. The measuring sensibility expressed by the gradient of the curve is gradually increased f_p=100, 400 Hz, and reaching maximum at f_p=1 kHz caused by 1 ms RMS procedure. All the rest, f_p=4, 10 kHz, show a decrease in sensitivity. This specialized characteristic must be investigated to confirm whether it is in agreement with practical situation.

In addition, simulations with other values of BER constant and duty cycles were examined. Although the nonlinearity of ΔL_b is more appealing for the high BER constant, similar trends were obtained.

5. Conclusions and future work

The simulation results demonstrate that both the RMS-AVG and APD measurement methods can capture the essential features of the disturbance effect on BER. In particular, the index L_A obtained from APD correlates well with disturbance effect on BER in both cases, for the constant pulse width and for the constant duty cycle. RMS-AVG method has particular characteristics with repetition frequencies of disturbance because of 1 ms RMS procedure.

The experiments for the real digital wireless communication services are indispensable for further considerations, where the following points should be considered well.

(1) Characteristics of IF filter on the receiver.
(2) Sensibility of each method for disturbance.
(3) Throughput besides BER as the indicator of degradation of communication quality.

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