Statistical Analysis and Re-generation of the Radiated Disturbances from Multiple Noise Sources

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***Abstract*—A re-generation method of radiated disturbances from multiple noise sources using statistical approach is suggested. The radiated disturbances from multiple noise sources consisting of an electric board and a Plasma Display Panel (PDP) TV are investigated. The frequency spectrum and the Amplitude Probability Distribution (APD) of radiated noises are measured. The radiated magnetic field from each noise source is measured below 30MHz, and then APD measurement is progressed at the frequencies where the noise sources radiate high disturbances in common. A sequence of noise pulses is observed from PDP TV, and the behavior of the APD of the electric board noise is similar to the Gaussian noise. The parameters of the disturbances are extracted using the Middleton's class *A* noise model and approximate empirical method. From the extracted parameters, random noise data is re-generated and radiated using a signal generator and antenna. APD Comparison of the measured multiple noises and re-generated noises is performed. The results show that the re-generation noises are well matched to measured noises. The re-generated noise can be applied to the performance evaluation of communication systems against non-Gaussian multiple noises circumstances.**

Keywords-multiple noise sources; radiated disturbance; amplitude probability distributio;, electric boar; plasma display panel.

I. INTRODUCTION

As the number of electric devices used in real situation is increased, problems of radiated interferences from multiple noise sources are more serious. In general, the multiple noises are assumed as Additive White Gaussian Noise (AWGN) [1] environments and most communication systems are designed to achieve optimal performance in AWGN environment. However, there are some applications where non-Gaussian noise or impulsive noise is dominant. Therefore, the performance evaluations of communications systems against the real multiple noise circumstance are necessary.

Since applying the performance evaluation in real situation has many difficulties, it is importance to re-generate the multiple noises in laboratory circumstance. The statistical analysis of multiple noises is required because the noise condition is not constant but various according to the time in real circumstance. Amplitude Probability Distribution (APD) measurement gives probabilistic information about the disturbances, which has higher sensitivity and repeatability than existing methods, such as peak or quasi-peak measurements [2]-[4].

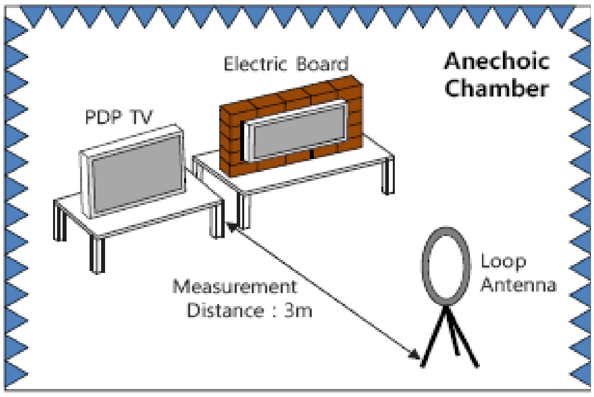

Figure 1. Measurement set-up

In this paper, a re-generation method of radiated disturbances from multiple noise sources using statistical approach is suggested. An electric board and a PDP TV are selected as noise sources for realizing an example of a real multiple noise circumstance. The spectra and APDs of radiated noises are measured according to the measurement methods from international standards of the special international committee on radio interference (CISPR) [5]. The statistical characteristics are analyzed using the Middleton's Class A noise model [6], which has been widely adopted due to the excellent agreement with measurement data. The parameters of the radiated noises are extracted using the approximate empirical method [7]-[8]. Using the extracted parameters, random noise data which has the statistically identical characteristics with the multiple noises is generated via a simulator. Then, the generated random noise is radiated in the air using a signal generator and an antenna.

Applying the suggested noise re-generation approach, radio noises which are statistically identical to the measured multiple noises can be radiated. Therefore, the performance evaluation of devices against the multiple noises in real circumstance can be performed easily in laboratory circumstance.

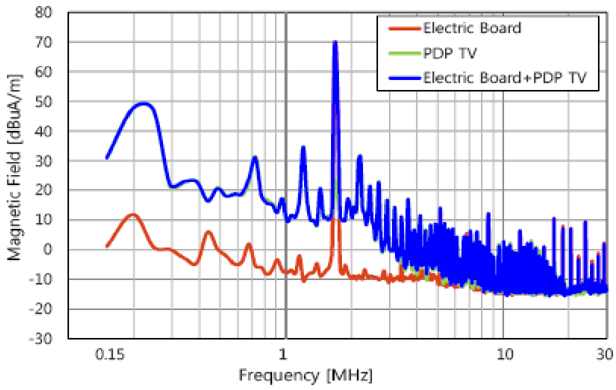

Figure 2. Disturbance spectra from noise sources

II. MEASUREMENT

A. Measurement set-up

The special international committee on radio interference (CISPR) regulates the measurement methods of radiated disturbance. CISPR11[9] and CISPR16-1-4 [10] provide the measurement method of the magnetic field below 30MHz using an Open Area Test Site (OATS) method, and CISPR15 [11] provides another measurement method below 30MHz using a loop antenna system .

We performed the measurements of the radiated noises from multiple sources in an anechoic chamber according to the measurement method of OATS. As shown in Fig. 1, the antenna is a loop with 0.6m diameter, and the separation distance between the antenna and multiple sources is 3m. The electric board and PDP TV composing the multiple noise sources are placed side by side. The radiated noises are measured in terms of magnetic field strength in dB (uA/m).

B. Radiatedmagnetic field from 150k to 30MHz

Measurements of radiated magnetic fields of a multiple noises are performed in the peak mode with 9 kHz resolution bandwidth (RBW). The radiated disturbance is entirely measured from 150 kHz to 30 MHz, when each of the electric board and PDP TV is operated and then both of them are activated simultaneously. As presented in fig. 2, high radiated disturbance from electric board is shown at the fundamental frequency of 1.71MHz and the harmonic frequencies. Several high disturbances shown between 5MHz and 8MHz is supposed to come from inside circuits composing the electric board. The PDP TV shows more dense disturbances at the fundamental frequency of 240kHz and the harmonic frequencies. The disturbances from multiple noise sources show the combined shape of the two noises.

To investigate the fluctuation of noises according to the time, the radiated noise is measured with zero frequency range. Fig. 3 shows an example of each noise fluctuation from the electric board and PDP TV measured at 5.15MHz.

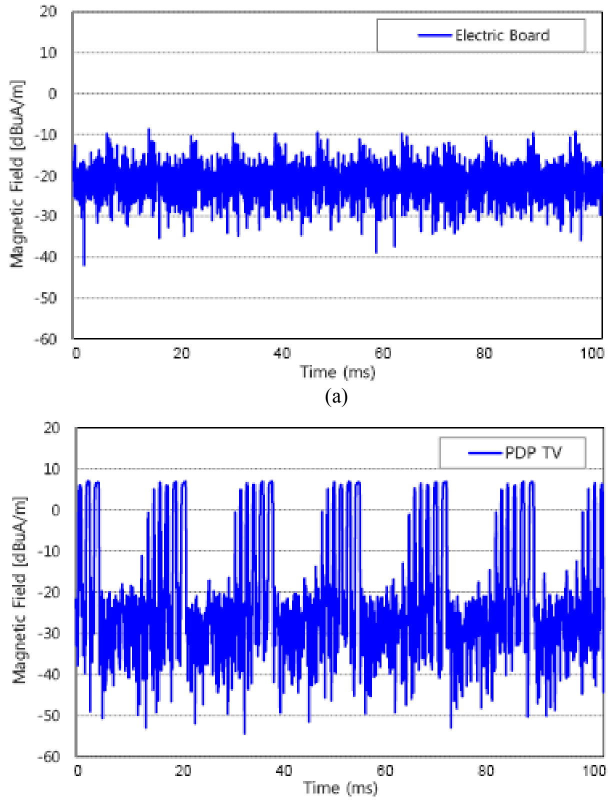

Figure 3. Noise fluctuations at 5.15MHz (a) Electric Board (b) PDP TV

The disturbances from electric board show relatively slight variation according to the time, whereas the noise from PDP TV shows high fluctuation periodically.

C. APD measurement at the common frequencies

APD measurement method gives probabilistic information about the disturbance. The ordinate axis of the APD curve displays the probability that the disturbance envelope exceeds the abscissa level. When there is no impulsive input, the APD curve is gradually declined from the left top to the right side of bottom. When impulses are received, the APD shows drastic extension to the right side in the middle of the curve and the peak value of impulse appears on the abscissa of APD.

To investigate the effect of radiated disturbance from multiple noise sources, APD measurement is made at frequencies where both of the electric board and the PDP TV generate high disturbances. From the disturbance spectra of fig. 2, frequencies of 3.43, 5.15, 6.13 and 7.11MHz are selected. At each frequency, APD measurements are performed for 120 second using R&S ESU EMI receiver. Fig. 4 shows the APD measurement results of radiated noises from each of the electric board and PDP TV and both noise sources.

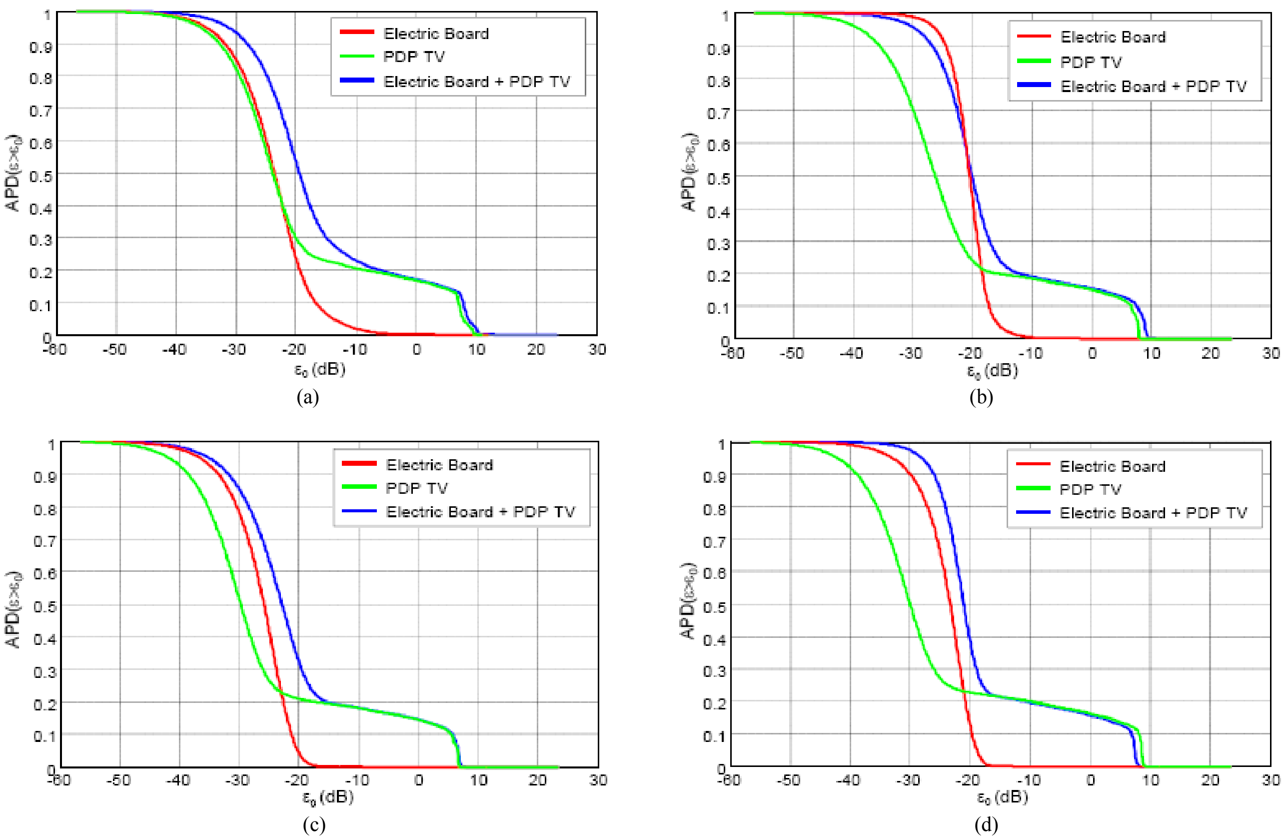

Figure 4. APD measurements of multiple noises (a) At 3.43MHz (b) At 5.15MHz (c) At 6.13MHz (d) At 7.11MHz

At all the measured frequencies, the APD graphs of electric board show gradual decrease. On the other hand, the APDs of PDP TV are gradually decreased and extended in the middle of curve. The APD shapes of multiple noises are similar to those of the PDP TV; however, the levels in the left side are higher than those of PDP TV due to the effects of noise from electric board. Uniquely, the APD of multiple noises at 5.15MHz is less than that of electric board in some range. It is considered that the noises from electric board and PDP TV are cancelled out by the each other.

III. EXTRACTION OF NOISE PARAMETERS

The characteristics of multiple noises can be investigated by applying Middleton's Class A noise model. The model is appropriate to describe a highly impulsive interference and show good agreement with measurement data. It is defined by two parameters of A and Γ. A is the impulsive index which is the product of the mean number of disturbance events per second and the mean length of a disturbance. Γ is the Gaussian factor, as the ratio of mean power of the Gaussian component and that of impulsive non-Gaussian component.

Approximate empirical method is applied to estimate noise parameters. A is approximately extracted at the point where the sharp rise in disturbance versus probability occurs. Γ is extracted at the point where the straight-line starts to bend in probability versus disturbance. The smaller is A, the properties of the disturbance are dominated by the characteristic of typical, individual impulses and the disturbance shows the non-Gaussian properties. However, as A is close to zero, the noise exhibits a Gaussian property. The smaller is Γ, the intensity of non-Gaussian component is stronger related to the Gaussian component of the disturbance.

TABLE I. PARAMETERS OF THE MULTIPLE NOISES

Frequency [MHz]	Electric Board		PDP TV		Electric Board + PDP TV	
	A	Γ	A	Γ	A	Γ
3.43	0	0.007	0.22	0.0048	0.23	0.0125
5.15	0	0.01	0.195	0.0028	0.2	0.011
6.13	0	0.038	0.19	0.0014	0.19	0.006
7.11	0	0.0063	0.215	0.0013	0.21	0.007

Table I shows the noise parameters extracted from the APD measurement, when each of the electric board and PDP TV is operated and then both of them are activated simultaneously. At all frequencies, the values of A parameter of electric board are nearly 0. This means the disturbances from the electric board are non-impulsive Gaussian noises. When investigating the A parameters extracted from the PDP

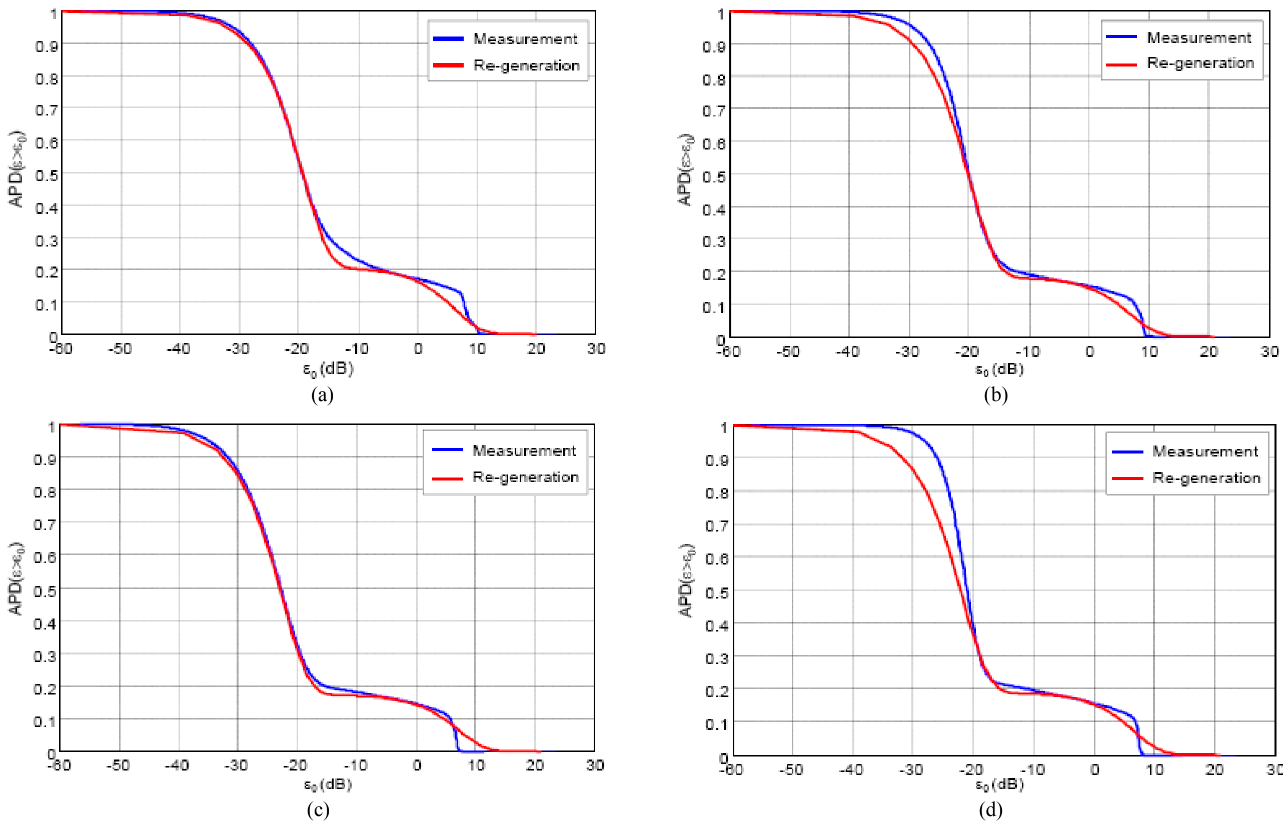

Figure 5. APD Comparison of measured multiple noises and re-generated noises (a) At 3.43MHz (b) At 5.15MHz (c) At 6.13MHz (d) At 7.11MHz

TV and multiple noise sources, they show similar values at each frequency. It means the impulsive components of multiple noise sources mostly come from the PDP TV, whereas, Γ parameters of the PDP TV and multiple sources have different values at each frequency. The Γ values of multiple noise sources are higher than those of PDP TV. It is because the non-impulsive noises from electric board are applied to the multiple noises.

IV. NOISE RE-GENERATION

Using the extracted noise parameters, multiple noises are re-generated. The statistical functions are determined by the parameter values of A and Γ, and the random noise data following the determined statistical functions are generated using a simulator tool. For each measured frequency, one million points of random data are generated. The data is downloaded *to a signal generator and radiated through an antenna. The* re-generated noise is measured by another antenna. Fig. 5 shows the comparisons of APD graphs of measured multiple noises and re-generated noises at each frequency. Even though there is slight difference between two APD graphs at the left side at 7.11MHz, the APD shapes of re-generated noises are generally well matched to that of measured noises.

V. CONCLUSIONS

The re-generation method of radiated disturbances from multiple noise sources using statistical approach was suggested. The statistical characteristics of radiated disturbance from multiple noise sources are analyzed through the APD measurement. The radiated noises from electric board and PDP TV are measured from 150 kHz to 30 MHz, and then frequencies where both noise sources radiate disturbances in common are selected. At each frequency, the APD is measured and then the characteristic parameters of the noises are extracted using the Middleton's class A noise model and approximate empirical method. Random noise data is re-generated from the extracted parameters and radiated using a signal generator and antenna. APD Comparison of the measure multiple noises and re-generated noises shows that re-generated noises reproduce the measured multiple noises with the similar statistical characteristics. The re-generated noise can be applied to the performance evaluation of electric devices against the multiple noises.

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