A 2.4 GHz 802.11b Throughput Estimation in a Noisy Environment Using an Experimental Noise Parameter

Min-Ho Hur · Sung-Jin Lim · Sewoong Kwon · Young-Joong Yoon

Abstract

In this paper, a numerical permissible disturbance model is proposed to preserve a throughput performance of a 2.4 GHz wireless LAN service. The model is composed of two parameters, a peak value and a time rate of noise signal. The model parameters are experimentally determined from an APD parameter measurement. The APD parameter is measured by using the APD measurement method which is recommended from CISPR/A/447/CD.

Key words : APD, MWO, Wireless LAN, Time Rate, Radiation Limits.

Ⅰ. Introduction

Recently, wireless digital communication services are dramatically increased at a frequency band above 1 GHz and it is reported that a radiated noise from noise sources causes performance reduction in a wireless digital communication system above 1 GHz[1]. But the permissible disturbance limits for emission standards or standardized measurement methods are not provided in that case. So disturbance measurement methods and permissible disturbance limits are under discussion in international special committee on radio interference (CISPR) for frequencies above 1 GHz. In a recent research, it is known that the statistical parameter of noise amplitude is related with a performance of wireless communication systems[2]~[4]. Furthermore, a new parameter APD, the time rate of an unwanted signal, is proposed[4]. In this paper, a numerical permissible disturbance model using a peak value and a time rate of noise signal is proposed. The method which is proposed from CISPR/A/447/CD is used to measure noise and get a statistical parameter, APD. The correlation between a statistical parameter and throughput of a wireless LAN is examined, and a numerical permissible disturbance model is provided about interference effects of the peak value and time rate of spurious noises.

Ⅱ. Amplitude Probability Distribution(APD)

A quality of a wireless communication service is usually expressed as a value of a BER or a throughput. Also, it has been reported that degradation of BER or throughput can be estimated from an Amplitude Probability Distribution, APD[4]. If an APD can be measured with a high accuracy, an APD can be an optimal index for the assessment of interference on wireless communication service. As shown in Fig. 1, the duration of the i-th disturbance pulse $W_i(k)$ is defined as the duration when the noise envelope is beyond the sliced level $E_k(k=1, 2, ..., m)$. The APD, is defined by

$$APD\,(E_k) = \frac{\sum_{i}^{n(E_k)} W_i(E_k)}{T_o} \qquad (1)$$

where $n(E_k)$ represents the number of pulse that exceeds the level of E_k, and T_o means a total measurement time[4]~[6].

Ⅲ. The Measurement System

In free space environment, it is not easy to identify a wireless LAN and a noise signal from measured signals. So a wired measurement system is constructed

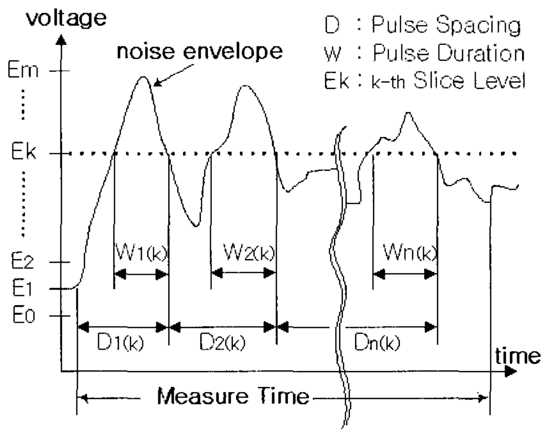


Fig. 1. The change of noise signal according to time.

Manuscript received December 16, 2004 ; revised April 28, 2005. (ID No. 20041216-038J)
Department of Electric & Electronic Engineering, Yonsei University, Seoul, Korea.

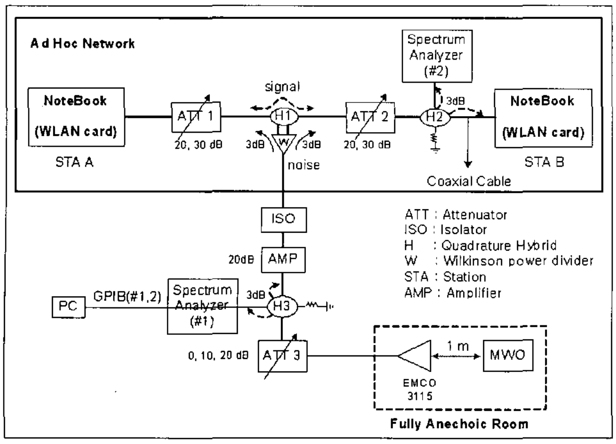


Fig. 2. A wired measurement system.

with an emphasis on separating a wireless LAN and a noise signal[6]~[8].

Fig. 2 shows a wired measurement system. This measurement system is composed of two parts. One part is communication part which is composed of two notebooks that have a wireless LAN card modified to link with wire and is setting to an Ad-Hoc mode. Other part is an observation part which is spectrum analyzer, an amplifier, attenuators, and connecting components. The noise is injected from a noise source that is collected with EMCO3115 antenna in a fully anechoic chamber room. The other measurement system parts are placed at an outer room. So, in this measurement system, there are no interfering factors except a noise from a noise source.

The spectrum analyzer #1 is used to measure amplitude of noise and the spectrum analyzer #2 is used to measure noise or wireless LAN signal. A distance between the wireless LAN and a noise source can be changed with the attenuator(ATT3). A distance between STA A and STA B can be changed with attenuators (ATT1, ATT2). The measurement is doing simultaneously, so the relation between a noise amplitude and a throughput of wireless LAN can be examined simultaneously. So a relation analysis of measured parameters is possible with that measurement system.

Ⅳ. Measurement and Modeling

4-1 Interference Measurement of MWO Noise

A microwave oven(MWO) can be characterized as a high power pulse source in a residence circumstances, and it can be a noise source of a wireless digital communication service at 2.4 GHz. So the relation between the throughput reduction of a wireless LAN

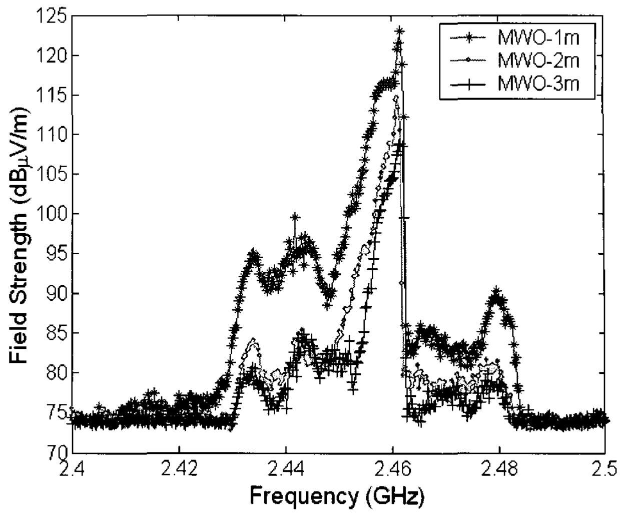


Fig. 3. Radiation amplitudes of MWO noise at different distances.

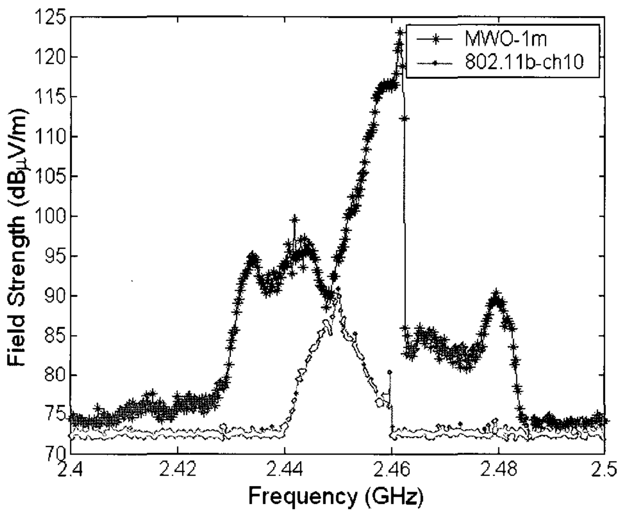


Fig. 4. Radiated amplitudes of MWO noise and wireless LAN signal.

channel and a statistic characteristic of a MWO noise is evaluated. In a frequency domain, an amplitude of MWO noise was measured at each distance, as shown in Fig. 3. The highest strength was produced at 2.46 GHz band. The figure shows a different peak value as a distance is changed. Fig. 4 shows a comparison between radiated amplitude of MWO noise and that of a wireless LAN signal. A radiated amplitude of wireless LAN signal is smaller than that of a MWO noise. According to this result, a noise radiation of the MWO can be affect to wireless LAN channels and the interference effect is different on each wireless LAN channel. Fig. 5 shows a throughput comparison of wireless LAN 7th channel when MWO is turned on and turned off. Because measuring time is fixed, the number

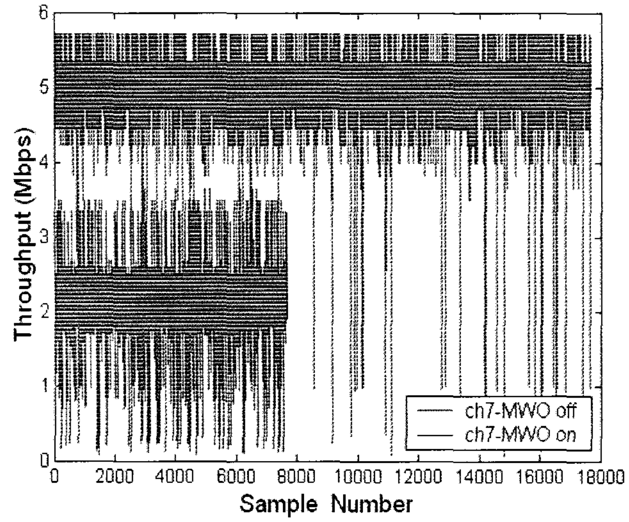


Fig. 5. Throughput when noise exist or not.

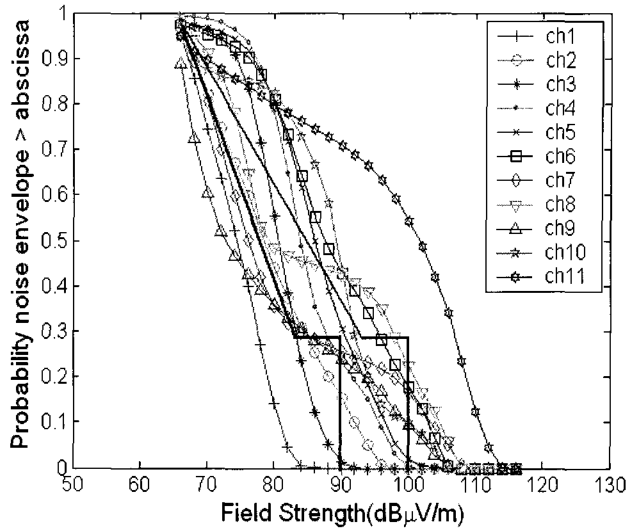


Fig. 6. APD characteristics of a MWO.

Table 1. Reduced throughputs of wireless LAN channels (Unit: Mbps).

ch. 1	ch. 2	ch. 3	ch. 4	ch. 5	ch. 6
3~4	2~3	2.2~2.6	2.2~2.7	2.2~2.6	2.2~2.6
ch. 7	ch. 8	ch. 9	ch. 10	ch. 11	-
2.2~2.6	2.2~2.6	2.4~2.8	2.2~2.6	2.2~2.7	-

of samples is different on each case in Fig. 5. In the case of MWO turned off, a throughput of a wireless LAN is 5~5.2 Mbps, but in the case of MWO turned on, a measured throughput considerably reduced to 2~3 Mbps and the measured sample number is reduced below 8,000 samples during 5 minutes. In Table 1, it shows reduced throughputs of all wireless LAN channels when MWO is turned on.

4-2 Numerical Spurious Restriction Model

In this paper, a new permissible disturbance model based on an APD parameter is proposed. In this model, a throughput of wireless LAN is related with a peak value and a time rate of an noise emitted from noise source.

This experiment is carried out on the same measuring time, 5 minutes. The goal of a measurement is to show a relation between a throughput and a noise signal characteristic like a peak value and a time rate. Attenuation levels of ATT1, 2 and ATT3 is configured to have a profit path loss. Fig. 6 and Fig. 7 show measured APD and throughputs when attenuators is configured that ATT3 is 10 dB, ATT1 and ATT2 is 20 dB. This ATT3 attenuator level determined to have 0 dB measurement system gain and to have a path loss which is equal to 3 m measurement distance between MWO and receiving antenna in wireless circumstance. The APD results are calculated from a measured field strength that is measured by the spectrum analyzer #1. The spectrum analyzer is configured to 0 Hz span, so it can measure a time domain signal at a center frequency. APDs and throughputs are measured from the wired measurement system simultaneously[7],[8].

As shown in Fig. 6, the line of ch. 1~ch. 11 means that the measured value is collected when the center frequency of the spectrum analyzer is configured to a frequency of each channel of a 802.11b wireless LAN service[7],[8]. In these results, radiation characteristic corresponding to each wireless LAN channel is different from the other one.

Fig. 7 shows throughput characteristics of a wireless LAN when MWO is turned on. It shows that a throughput is interfered by a MWO noise except channel 1 and channel 2. Center frequencies of channel 1 and channel 2 are far from the maximum radiation frequency of a MWO[8]. So it is supposed that an interference effect is reduced as it is away from maximum radiation frequency of a MWO, and throughput is inversely proposed when a peak value and time rate of unwanted radiation is increased. From these observations, the statistical parameter APD of a noise signal is useful to examine a wireless LAN throughput evaluation, because the parameter can present a peak value and time rate characteristics.

In the numerical spurious restriction model, it supposes that throughput is interfered by two values, peak and time rate from the observation of these measured results.

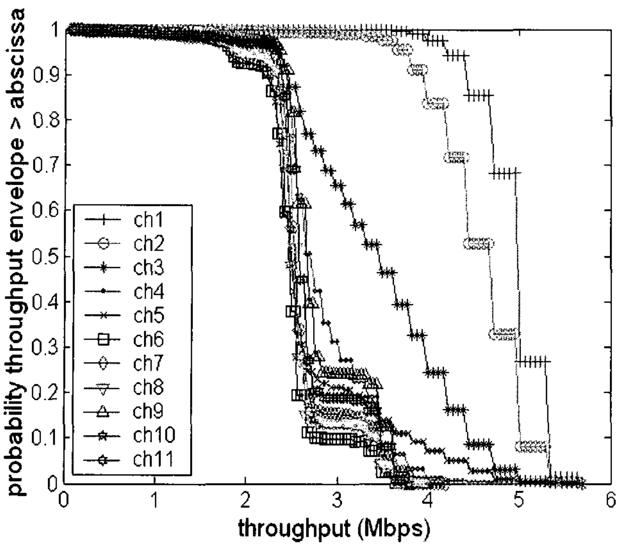


Fig. 7. Wireless LAN throughput characteristics on each channel when MWO is turned on.

In the Table 2, the throughput is categorized as three case, 5.2 Mbps, 4.7～4 Mbps, 3～2.5 Mbps and peak values of MWO noise are summarized. The dominant characteristics to interfere a throughput are a peak value. From these observations, the criterion of a peak value has two criteria values, 90 dBμV/m and 100 dBμV/m. The criterion of a time rate is selected at 30 % from a result in Fig. 6. It is a single slope line from a thermal noise level to the strength level which is 5 dB smaller than the peak value as shown in Fig. 6. When a peak value is larger than this peak value criteria, throughput is affected by a noise signal, and when a time rate of a noise signal is larger than the criteria line(that means the noise signal has a large and dense field strength in a time domain), it effects to a throughput.

Table 2. Permissible limits at each channel.

Channel	MWO (dBμV/m)	Throughput (Mbps)	Permissible Limits (dBμV/m)
1	84	5.2	Below 90
2	95	4.7	90～100
3	94	4	
4	102	3	Above 100
5	103	2.6	
6	106	2.4	
7	109	2.5	
8	109	2.5	
9	106	2.5	
10	107	2.5	
11	115	2.5	

V. Conclusion

In this paper, it is considered that a throughput of 802.11b wireless LAN service has related with APD parameter, which is composed of the peak value and time rate of radiated noise. Through the experimental approach, the function of statistic interference characteristic of MWO noise, APD characteristic and throughput is evaluated in a 802.11b wireless LAN service. The relation is modeled by a numerical model with a peak value and time rate characteristics of APD. By doing this, an APD is a suitable measurement method to evaluate the effect on the wireless communication service in a noise environment. Additionally, the numerical permissible disturbance model and its experimental parameter are proposed. From these results, APD is useful parameter that evaluates performance reduction characteristics of wireless communication service in a noise environment.

It is expected that this method will be an important part to protect the communication quality of wireless communication service by providing interference restriction levels of unwanted radiation from noise sources in the future.

This research was supported by the EMERC (ElectroMagnetic Environment Research Center) in Chungnam National University, one of IT Research Centers.

References

[1] S. Unawong, S. Miyamoto, and N. Morinaga, "Effects of microwave oven interference on the performance of ISM-band DSSS system", *IEEE International Symposium*, vol. 1, pp. 24-28, Aug. 1998.

[2] M. Uchino. T. Shinozuka, and R. Sato, "Development of APD measuring equipment and its faculty", *in Proc. on IEEE Int. Symp. on EMC*, Denver, Aug. 1998.

[3] CISPR/A/346/NP, *Porposal of Requirement Intem Relating to Amplitude Probability Distributioin(APD) Neasuring Function of Spectrum Analyzer*, Dec. 2001.

[4] CISPR/A/447/CD, *Spectrum Analyzer and Scanning Receivers for the Frequency Range 1 GHz to 18 GHz: Amplitude Probability Distributioin(APD)*, May 2003.

[5] Anritsu corp., "About CISPR movements", *3GPP TSG-T1 WG1 EMC #5*, Japan, Sep. 1999.

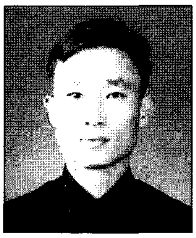
[6] Y. Yamanaka, T. Shinozuka, "Measurement and estimation of BER degradation of PHS due to elec-

tromagnetic disturbance form microwave ovens", *IEICE Trans.* vol. J79-B-Ⅱ, 11, pp. 827-834, Nov. 1996.

[7] S. J. Lim, M. H. Hur, S. Kwon, and Y. J. Yoon, "An empirical 802.11b WLAN performance prediction model in a noise environment by APD", *EMC'04*, Sendai, vol. 1, pp. 73-76, Jun. 2004.

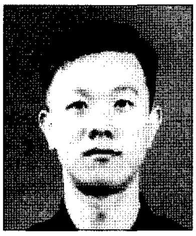
[8] Min-Ho Hur, "A study on the estimation of performance of wireless communication service with APD", *M.S. Thesis*, Yonsei university, 2004.

Min-Ho Hur



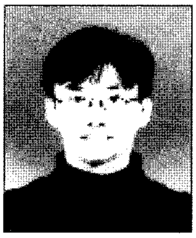
received his B.S. from dept. of electrical & electronic eng., republic of Korea naval academy, Korea in 1995. He is currently a M.S. student of dept. of electrical & electronic eng., Yonsei University, Korea. He is now researching on propagation of radio-waves, EMI/EMC.

Sung-Jin Lim



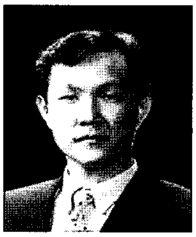
received his B.S. from dept. of International relationship, republic of Korea military academy, Korea in 1997. He is currently a M.S. student of dept. of electrical & electronic eng., Yonsei University, Korea. He is now researching on propagation of radio-waves, EMI/EMC.

Sewoong Kwon



is a doctoral student in dept. of electrical & electronic eng., Yonsei University, Korea. He received B.S. and M.S. degree from dept. of electrical & electronic eng., Yonsei University, Korea in 1999 and 2001, respectively. He is now researching on propagation of radio-waves, antennas, and microstrip materials.

Young-Joong Yoon



received B.S. and M.S. degree from Yonsei University, Korea in 1981 and 1986, respectively. He received Ph.D. degree from the University of Georgia Inst. of Tech. in 1991. Since 1993 he has been a professor of dept. of electrical & electronic eng., Yonsei University, Korea. His research interests include propagation of radio-waves, antennas, microstrip materials, and EMI/EMC.