Evaluation of Interference between Microwave Oven Noise and IEEE802.11b Using a GTEM Cell

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Abstract — In this paper, we proposed the evaluation method of the interference between the microwave oven noise and the signal of the IEEE802.11b by using the GTEM Cell. We used microwave oven noise, unintentional noise in time domain realized by combining signals from an AM (Amplitude Modulation) modulator and a FM (Frequency Modulation) modulator to evaluate the interference effects on IEEE802.11b. Finally we analyzed the effect of microwave oven noise to the throughput of IEEE802.11b by using APD (Amplitude Probability Distribution) of the interfering noise.

1. INTRODUCTION

Recently the enlargement and convergence of various radio communication services require the large usage of the spectrum in small area and then yield the large spectrum density. Especially radio communication services such as Bluetooth and IEEE 802.11b, Wireless LAN are being widely used in the industry fields. The frequency bands of the systems are assigned within ISM (Industrial, Scientific and Medical) bands such as 2.4 GHz. The communication performance of radio communication services is critically decreased because the equipment such as microwave oven generates the electromagnetic noise within 2.4 GHz bands. Therefore, it is important to study on the modeling for the interference noise generated by microwave oven to evaluate the interference effects on the communication performance, and these studies are being actively progressed in the various fields [1, 2]. Especially Middleton has suggested the test method that evaluate the communication performance with BER (Bit Error Rate) for the radio link by modeling the microwave oven noises as the impulse noise with the statistical methods using the APD (Amplitude Probability Distribution) [3]. The statistical modeling has been expressed as the statistical parameter of APD. There is no information for the noise wave in time domain, so it is difficult to evaluate the BER performance with the small amount of sampled data. In addition, this modeling method has a problem that the statistical parameter for the hopping frequency channel has to be obtained to evaluate the performance for the interference of the FHSS (Frequency Hopped Spread Spectrum) system because the noise signal of microwave oven has experienced the frequency changes in time domain. In Japan, according to the recent paper, the microwave oven noise has been measured in time domain and this has been embodied as the modeled noise in time domain by combining the amplitude modulation and the frequency modulation [4]. In this paper, the modeled noise of microwave oven in time domain is embodied for the purpose of using the unintentional noise, the interference signal in 2.4 GHz.

Also the evaluation environment is required to evaluate the communication performance, and it is generally achieved by embodying the radio communication system such as wireless LAN in the non-echo chamber [5]. This kind of method is embodied by putting both EUT (Equipment Under Test) and the antenna in the non-echo chamber extended by cable from communication AP (Access Point) outside of the non-echo chamber. But, this is difficult for the realization as well as the expensive cost. According to the recent research, it is introduced the measurement environment using PW cell (Parallel Wired cell) to possibly communicate with each other between EUT and AP [6]. Although this is basically the same theory as TEM cell, this is different in structure by eliminating the side of TEM cell. Additionally, the effect for the noise from many other sources can’t be totally excluded in yielding the measurement results because the side of PW cell is opened. The GTEM cell with the totally closed structure is used in this research in other to improve the problem in the case PW cell and increase the reliability for the performance evaluation of radio communication from many other noise sources.
This paper is intended to evaluate the interference effect of unintentional noise on the performance of the wireless communication service. For this, the modeled noise of the microwave oven is used as the unintentional noise in time domain. The reliability is ensured by using GTEM cell as the interference effect assessment environment, and the objective and general assessment analysis method is suggested for the interference effect.

2. THE SIMULATION AND REALIZATION OF MICROWAVE OVEN NOISE

Microwave oven is the equipment radiating RF energy in 2.45 GHz frequency band and largely used in each house and office. According to the difference of high voltage power used to drive the magnetron, the general RF energy generator, the microwave oven is divided into two kinds of types, transformer and switching. The frequency of AC power line uses 50 ∼ 60 Hz and 30 ∼ 50 kHz for two types each other [7]. The transformer type is used in this paper. The basic presumption for the model of microwave oven noise is as follows [4]:

1) The width of noise pulse in time domain is the same as width of the time gap of driving power \( V(t) \) exceeding the threshold power \( V_0 \).
2) The instantaneous amplitude of the pulse envelop curve is linearly changed for the driving power (AM).
3) Also the instantaneous frequency is linearly changed for the driving power (FM).

It is expressed as the Eq. (1).

\[
I(t) = I_0 U(V(t)) \exp \left[ 2\pi i \left( f_0 t + f_{\text{max}} \int_{-\infty}^{t} V(\zeta)d\zeta \right) \right] \tag{1}
\]

where \( f_0 \) is carrier frequency \( \cong 2.45 \) GHz, \( f_{\text{max}} \) is the maximum shift frequency of FM, \( V(t) \) is the normalized driving voltage and \( I_0 \) is the maximum amplitude and phase of the noise as the complex parameter. It is presumed that the phase has the uniform distribution in \( [0, 2\pi] \). \( U(V) \) is driven by the threshold voltage of the amplitude modulation, \( V_0 \) given in the Eq. (2).

\[
U(V) = \begin{cases} 
V & \text{for } V \geq V_0 \\
0 & \text{for } V < V_0 
\end{cases} \tag{2}
\]

Also, \( V(t) \) driven in magnetron can be represented as the Eq. (3), in case of the transformer type.

\[
V(t) = \cos (2\pi f_v t) \tag{3}
\]

where \( f_v \) is the frequency of the A.C. power.

The Fig. 1 shows modeling of the noise generated by combining both FM modulation signal and AM modulation signal in order to consider the operation of microwave oven as above mentioned. This can be simply realized using the signal generator. Generally, in case of microwave oven of the transformer type, the above mentioned parameter is presented as the Table 1 [4]. Fig. 2(a) shows the signal in the time domain when span equals 0 at 2.45 GHz and Fig. 2(b) shows the envelope amplitude in the frequency domain when spectrum analyzer is set with maximum hold mode.

![Figure 1: Model of the microwave oven noise.](image-url)
Table 1: Noise parameter of the microwave oven.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC mains frequency: $f_v$</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Threshold voltage: $V_0$</td>
<td>0.3</td>
</tr>
<tr>
<td>Carrier frequency: $f_0$</td>
<td>2.42 GHz</td>
</tr>
<tr>
<td>Frequency deviation: $f_{\text{max}}$</td>
<td>43 MHz</td>
</tr>
<tr>
<td>Amplitude: $I_0$</td>
<td>28.7 mV</td>
</tr>
</tbody>
</table>

3. INTERFERENCE EFFECT ANALYSIS

The Fig. 3 is the test outline diagram for the mutual effect analysis between the microwave oven noise and IEEE 802.11b. The signal generator is used as the input signal of GTEM cell generating the modeled microwave oven noise and is connected by the wireless putting the wireless notebook and AP inside GTEM cell to minimize the outside interference. Also, the AP in GTEM cell is connected to the outside notebook using LAN cable. We transmits data using 802.11b wireless link, measures the throughput transmitted from EUT inside GTEM cell and seeks the APD curve from this. The APD curve means the probability distribution that will be bigger than the specific thresholds.

The Fig. 4 shows both the frequency bands of IEEE 802.11b and the occupied frequency distribution of microwave oven noise [8]. Channel 1, 2 and 3 of wireless LAN are not shared by oven noise bandwidth from 2.434 GHz to 2.466 GHz, but channel 8 and 9 are totally co-shared by oven noise spectrum. The rest of channels are partially overlapped.

The Fig. 5 is the results that measure the envelope amplitude of microwave oven noise in time domain on each center frequencies of IEEE802.11b channels partially or totally shared by microwave oven noise. It shows that the time occupied rate and amplitude size of microwave oven noise is different according to the center frequency of the channel. Table 2 shows the occupied bandwidth in the frequency domain, time-occupied rate in time domain and maximum value of the interference.

![Figure 2: Measured values of microwave oven noise modeled. (a) Time domain (at 2.45 GHz), (b) Frequency domain.](image)

![Figure 3: The setup for interference measurement of microwave oven noise and IEEE802.11b.](image)

![Figure 4: The frequency bands of the microwave oven noise and IEEE802.11b.](image)
Table 2: Parameter of microwave oven noise interference to wireless LAN channels.

<table>
<thead>
<tr>
<th>Channel</th>
<th>Occupied bandwidth(%)</th>
<th>Time occupied (ms)</th>
<th>Max (dBµV )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ch 6</td>
<td>64</td>
<td>7.11</td>
<td>72.72</td>
</tr>
<tr>
<td>Ch 7</td>
<td>86</td>
<td>7.06</td>
<td>74.24</td>
</tr>
<tr>
<td>Ch 8</td>
<td>100</td>
<td>2.9</td>
<td>75.71</td>
</tr>
<tr>
<td>Ch 9</td>
<td>100</td>
<td>2.9</td>
<td>77.13</td>
</tr>
<tr>
<td>Ch 10</td>
<td>86</td>
<td>3.38</td>
<td>78.11</td>
</tr>
<tr>
<td>Ch 11</td>
<td>64</td>
<td>8.37</td>
<td>79.13</td>
</tr>
</tbody>
</table>

Figure 6: APD of the measured interference between microwave oven noise and IEEE802.b.

noise of microwave oven based on each IEEE 802.11b channels.

The Fig. 6 shows the result presenting the interference effect on each channels of 802.11b as the probability distribution when microwave oven noise is inputted into the GTEM cell.

According to the analysis of the result, the probability for channel 1, 2 and 3 that throughput will be over 5.5 Mbps recommended in IEEE standards is 90%. That means the bandwidth doesn’t have the shared bandwidth at all, so it presents there is no mutual interference between two systems. Also, the wider frequency bandwidth of LAN channel means the larger shared bandwidth and the lower throughput generally, except for channel 8 and 9. The reason is that the above cases for channel 8 and 9 are resulted from the relatively short occupied time, about 2.9 ms when compared with the other IEEE802.11b channels.

In this paper, the result shows that the microwave oven noise is generated according to the change of the amplitude and the frequency with time. Therefore when analyzing the mutual interference effect with wireless LAN, the performance of communication is assessed by the amplitude and time occupied rate in time domain as well as the mutually shared bandwidth in frequency domain.
4. CONCLUSION

This paper modeled the noise by combining both the amplitude modulation and the frequency modulation as the theory of microwave oven noise to analyze the mutual effect between microwave oven noise and IEEE802.11b. Also, GTEM cell was used to realize the environment for the evaluation of interference between two systems. The analysis for the effect of microwave oven noise on each channels of IEEE 802.11b has been done by monitoring the transmission throughput on Wireless LAN channels using the amplitude probability distribution.

As a result of the measurement, all of channel 1, 2 and 3 doesn’t have the sharing bandwidth with microwave oven noise in frequency domain at all, and the probability that throughput will be represented over 5.5 Mbps is over 90% in this case. But for the other channel, the more the bandwidth of the microwave oven noise and LAN channels is overlapped, the higher the probability is, and the lower throughput is. Although the sharing bandwidth of channel 8 and 9 is wider than channel 7, 10 and 11, throughput of channel 8 and 9 is higher than over 1 Mbps when compared with channel 7, 10 and 11. The reason is due to the relatively short occupied rate in the time domain of microwave oven noise. It means that interference effect for the throughput is more critical in time domain from the viewpoint of occupied time rate than in the frequency domain from the viewpoint of the shared bandwidth.

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REFERENCES