The Effects of Microwave Oven over the IEEE 802.11 FHSS Wireless LAN Card

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Abstract— *In this paper, we have investigated the effects of microwave ovens over the IEEE 802.11 FHSS Wireless LAN Card. The measured MAC Frame Error Rate (FER) is affected by the microwave ovens. The signal spectrum radiated from the microwave oven can be used to verify the measured FER data. The performance of the specific bands assigned to some geographic locations in the IEEE 802.11 standard have been discussed in the paper. From these measurement results we can obtain that the performance of some channels within the IEEE 802.11 FHSS Wireless LAN Card can be seriously deteriorated. Therefore, the location of microwave oven and the specific channels for the wireless LAN Card should be pre-determined according to the experience guideline.*

Key words: *802.11Wireless LAN, FHSS and Microwave oven*

I. INTRODUCTION

Recently, the technology of wireless communication has progressed rapidly. However, the wireless data communication products such as wireless LAN and wireless ATM have been investigated in the laboratory. In June 1997, the IEEE 802.11 draft 6 [1] has been announced by the IEEE computer society. Many manufacturers manufacture the wireless LAN card and some products have been brought in markets now. Because the operation frequencies of the wireless LAN card are within the ISM band, there exist some extraneous sources within the same frequency band to interfere each other. Since the most significant interference in this band is caused by the microwave oven, some authors have investigated the effects of it. In paper [2], the authors have experimentally measured the interference radiated from the microwave oven and discussed the statistical characteristics of interference from the time domain. The performance improvement with Bose-Chaudhuri-Hocquenghem (BCH) code has been shown in [3]. The statistical model of microwave oven in the time domain has been showed in [4] and [5] has been investigated about the interferences from two kinds of microwave oven over the Wireless LAN Card. However, few papers actually measure the interference using the Wireless LAN Card in terms of MAC frame error rate (FER). Therefore, we use the IEEE 802.11 FHSS LAN Card and measure the MAC FER in some channels to obtain the interference distribution from the microwave oven. In order to demonstrate the measurement results, we have measured the signal spectrum radiated by microwave oven and compared to the differences of FER. Furthermore, we discuss the different specific bands which are assigned to some geographic locations in the standard.

This paper is organized as follows. Brief introduction of IEEE 802.11 Wireless LAN is given in section II. In section III, we describe the measurement environment and different measurement conditions. In section IV, we obtain some measurement results and discussion. Finally, the conclusions of this paper are given in section V.

II. IEEE 802.11 WIRELESS LAN

IEEE 802.11 draft 6 [1] has been announced in June 1997. The media access control (MAC) layer and physical (PHY) layer of wireless LAN has been defined in this standard. In order to be used in different environments successfully, the standard defines two architectures in the MAC layer protocol which are Ad Hoc network and infrastructure network. The benefit of Ad Hoc network (figure 1) is that the set up time for this network is very short. However stations in the network can only communicate to each other. Therefore, if the user want to connect to the internet, he must use the infrastructure network instead of Ad Hoc network, as figure 2. In this network, the stations can exchange data to the other users within the internet through a Access Point. Furthermore, there are three medium types defined in the PHY layer:

1. Direct Sequence Spread Spectrum (DSSS)
2. Frequency Hopping Spread Spectrum (FHSS)
3. Diffused Infrared

DSSS and FHSS system are being used in 2.4 GHz which is the unlicensed band for ISM (industrial, scientific, medical). Therefore, interference from other signal sources may affect the performance of Wireless LAN Card. In order to avoid the interference, we have measured the effects from microwave oven by using the IEEE 802.11 FHSS Wireless LAN Card.

III. Measurement Environment

The measurement environment and equipment are shown as figure 3. We have used one pair notebooks connected by IEEE 802.11 FHSS WLAN Cards to measure the effects from the operating microwave oven. The effects are measured by directly transmitting the MAC frames at the transmitter and recording the frame error rate at the receiver. In order to study the relationship of the distance and directions between notebooks and microwave oven, we have designed several experimental cases as follows:

a. In order to find the effect of the receiver we design four experimental cases. The location of transmitter, receiver, and microwave oven are given as figure 4(a)-(d). We measure the effects from the four directions (front, back, right, and left) of microwave oven to the receiver at distance from 1m to 5m when the distance between transmitter and microwave oven is 15m.
b. The location of transmitter, receiver, cement wall, and microwave oven is as figure 5. This is the general case we locate the microwave oven in the kitchen or office. In this case, we also measure the effects at different distance.
c. In order to find the effect at the transmitter, we design the measurement case and the location is as figure 6. We measure the effects to the transmitter at difference distance from the microwave oven.

IV. Measurement Result and Discussion

In this section, we display and analyze the measurement results about the three cases introduced in section III. In IEEE 802.11 standard, channels in FHSS are separated by 1.0MHz from 2.4GHz to 2.5GHz. Thus, we measure the FER from channel 1 to 99 spaced by 10 channels.

a. From figure 7(a)-(d), we can find that the effect is more serious in the front side of microwave oven. The effects from left and right sides are almost the same. Although the effect at the back side is critical, it's smaller than the front side. Moreover, effects are centralized around 40th channel for all directions and the interference decreased as the distance increased.
   In figure 7(a), the FER is under 55% in all channels for all distances. When the distance is 1m, the interference distributes from ch1 to ch40, ch70, and ch90 and the FER decreases as the distance increases. In figure 7(b), the interference centralize at ch40 and especially when the distance is large than 1m. In figure 7(c)(d), the interference distribution is almost the same and centralizes at ch40.
   In order to demonstrate the result, we measure the signal spectrum radiated by microwave oven from the front, back, and right ends in figure 10(a)-(c), respectively. In these figures, the central frequency is 2.450GHz and the spanning band is 200MHz. Comparing to figure 7 and figure 10, we can demonstrate the measurement results of FER are correct and the most significant interference is around ch40.
b. In figure 8, we find that the interference would be reduced when there is a cement wall between the receiver and the microwave oven. We also find that the interference is also distributed around ch40 but the FER is under 15%.
c. From figure 9 we obtain that the most significant interference is still around ch40. But the interference compare to case a is lower in other channels.

Table I lists the operating frequency range of each geographic location defined in the standard. From this table we find that most channels of North America and Europe band would be interfered. However the most significant interference from microwave oven can be avoided in other bands.

V. Conclusion

From these experimental measurement results, we find that the effects from microwave oven to the transceiver are serious in some channels. Therefore, we must care about the location of microwave oven when using the wireless LAN in office or residence. However the FHSS system transmits data through a set of hopping sequences, the interference would be avoided if we shorten the packet length when transmitting. Further, we will measure the packet error rate by transmitting UDP packets to demonstrate the results after transmitting through a set of hopping sequences.

Acknowledgement: The authors would like to thank Mr. Lee and Mr. Teng in National DataComm Corporation, Taiwan.

Table I. The operating frequency range in each geographic location

Lower limit (GHz)	Upper limit (GHz)	Regulatory range (GHz)	Regulatory Channels	Geography
2.402	2.480	2.400~2.4835	Ch2~Ch80	North America
2.402	2.480	2.400~2.4835		Europe*
2.473	2.495	2.471~2.497	Ch73~Ch95	Japan
2.447	2.473	2.445~2.475	Ch47~Ch73	Spain
2.448	2.482	2.4465~2.4835	Ch48~Ch82	France
*Excluding Spain and France				

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[5] Ad Kamerman and Nedim Erkocevic, "Microwave oven interference on wireless LANs operating in the 2.4 GHz ISM band", PIMRC '97, vol.3, pp.1221 – 1227.

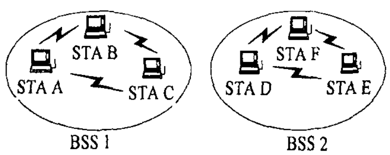

Figure 1. Ad Hoc Network

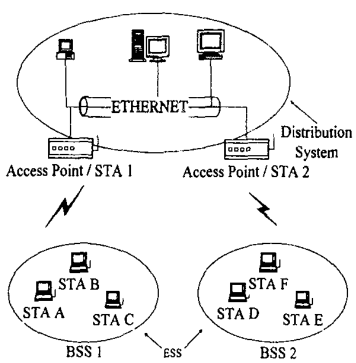

Figure 2. Infrastructure Network

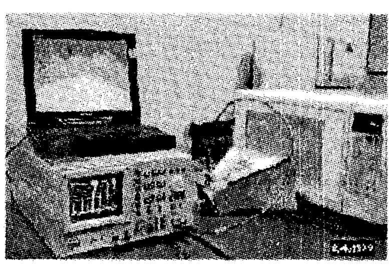

Figure 3. Experimental environment and equipment

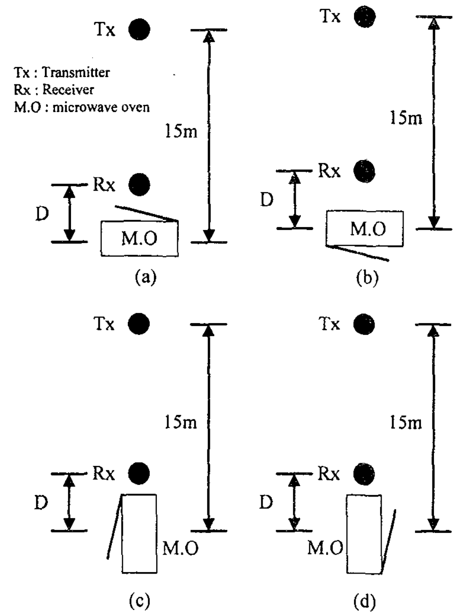

Figure 4. Measurement environment in case a

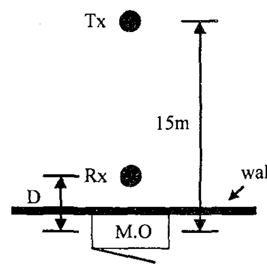

Figure 5. Measurement environment in case b

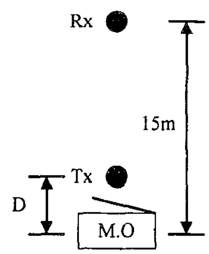

Figure 6. Measurement environment in case c

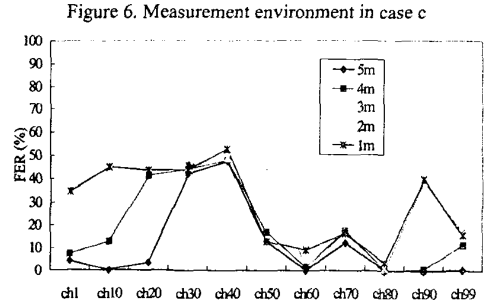

Figure 7(a). The measurement results from the front side

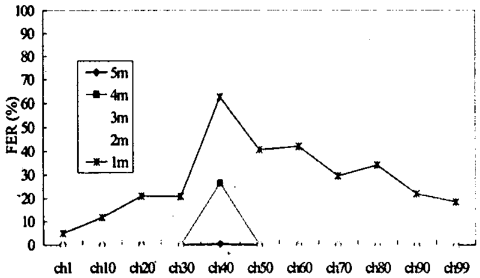

Figure 7(b). The measurement results from the back side

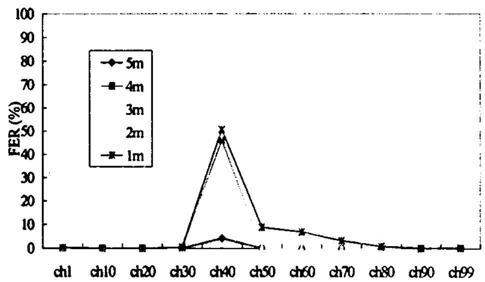

Figure 7(c). The measurement results from the left side

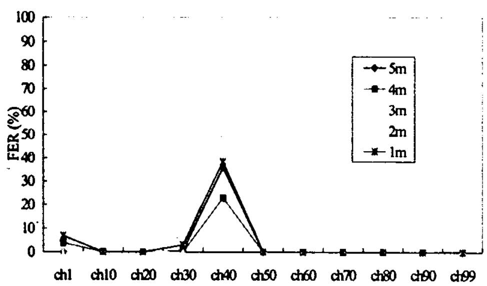

Figure 7(d). The measurement results from the right side

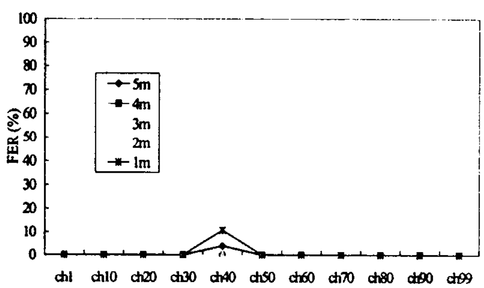

Figure 8. The measurement results obstructed by the cement wall

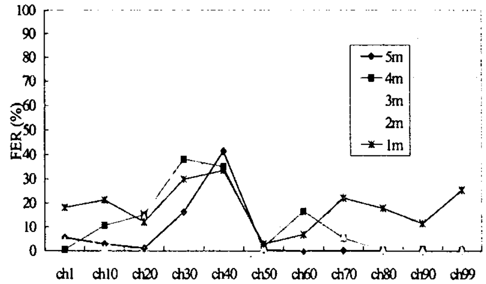

Figure 9. The measurement results in case c

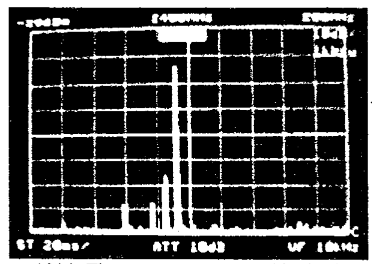

Figure 10(a). The spectrum measured in the front end

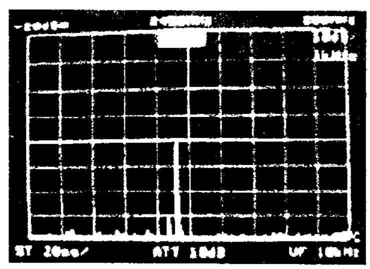

Figure 10(b). The spectrum measured in the back end

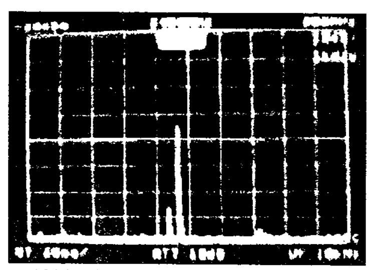

Figure 10(c). The spectrum measured in the right end