Method of evaluating electromagnetic-interference characteristics of MIMO wireless LANs

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***Abstract*—We evaluated the electromagnetic-interference characteristics of MIMO (Multiple Input Multiple Output) WLAN (Wireless Local Aria Network) by using an opened PW (Parallel Wired) cell that was placed in a radio anechoic chamber. We used two types of the interference wave such as the narrowband AM (Amplitude Modulation) wave specified by the IEC 61000-4-3 standards and the broadband communication signal of a WLAN specified by the IEEE802.11b standards. When impressing the AM wave as the narrowband interference, it was clear that the throughput characteristic of MIMO WLAN for all channels from Ch.1 to ch.4 was the same order and only about 5dB better than that for the conventional WLAN. On the other hand, when the communication wave of WLAN IEEE802.11b was impressed to Ch.1 and Ch.2 included in the occupied bandwidth of MIMO WLAN as the broadband interference, it was revealed that the throughput characteristic of MIMO WLAN deteriorated remarkably and the power ratio D (Desired wave) /U (Undesired wave) given the same throughput increased about 60dB.**

Key words: MIMO WLAN, Opened PW cell, IEEE802.11, Radio anechoic chamber.

I. INTRODUCTION

Wireless LANs (WLANs) using the 2.4-GHz band are becoming increasingly popular because they do not require licenses to employ them and we can attain them at a reasonable price [1]. However, this frequency band is called the Industrial, Scientific, and Medical (ISM) band and is used by other ISM equipment, e.g., microwave ovens. Therefore, electromagnetic interference among these types of equipment is a very serious problem [2][3]. For example, if we use a microwave oven near a WLAN, communication ceases due to electromagnetic interference. Therefore, we need to establish a quantitative method of evaluating the immunity characteristics of WLANs against the electromagnetic-interference.

Our laboratory has been studied a quantitative method for evaluating electromagnetic-interference characteristics when the interference wave is impressed to one side of WLAN communicating each other in a Parallel Wired (PW) cell that is placed in a radio anechoic chamber [4][5]. In addition, our laboratory has been studied more quantitative method for evaluating electromagnetic-interference characteristics when a signal from Ultra Wide Band (UWB) is impressed to WLAN IEEE802.11a using 5GHz band as the electromagnetic-interference in GHz transverse electromagnetic mode (G-TEM) cell [6][7].

IEEE802.11n is being settled now as new WLAN standard. This is based on a conventional IEEE802.11a and IEEE802.11g standard of WLAN and use the same frequency band and modulation method as conventional WLAN. IEEE802.11n uses multiple antennas to be able to transmit and receive multiple stream paths. Because MIMO multiple stream communications requires environment of multiple communication paths, it may show a different electromagnetic interference characteristics from the conventional WLAN IEEE802.11g. However, such case for MIMO WLAN has not been studied yet.

In this study, it is purpose to clarify experimentally the difference of electromagnetic-interference characteristics between WLAN IEEE802.11n and the conventional WLAN IEEE802.11g. We used two types of interference as Undesired (U) waves. The first was an AM (Amplitude Modulation) wave specified by the IEC 61000-4-3 standards, which is the radiated electromagnetic-field immunity test with the modulation frequency of 1 kHz and the modulation depth of 80%. The second U-wave was the communication signal of a WLAN specified by the IEEE802.11b standards, which use the same frequency band of 2.4 GHz as the IEEE802.11g standards but its modulation method is the Direct Sequence Spread Spectrum (DSSS). In addition, we used the PW cell to impress an electric field to only one side of a multiple stream communicating WLAN IEEE802.11n.

II. METHOD OF EVALUATING ELECTROMAGNETIC INTERFERENCE CHARACTERISTICS FOR WIRELESS LAN

Figure 1 show outline of the measurement system used to examine electromagnetic interference characteristics. A WLAN Station (ST) is set at the center of the PW cell located in the radio anechoic chamber, and the WLAN Access Point (AP) is set at a point 3 m from the ST. We used MIMO WLAN specified in the IEEE802.11g/n standards as the

Desired (D) wave, and we also used the conventional WLAN specified in IEEE802.11g standards as the Desired (D) wave, in order to know an effect of MIMO. We measured the throughput characteristics of the WLAN while keeping the modulation method of QPSK and encoding rate of 3/4 for corresponding to transmission rate of 18 Mbps for the conventional WLAN. Moreover, it is targeted for evaluating that each of WLAN use one time speed mode that depends on channel spacing of 20MHz. On the other hand, we do not use communication wave of IEEE802.11a using 5GHz in the MIMO WLAN IEEE802.11n. The center frequency of the desired wave was set on 2.412 GHz (Ch. 1), and an interference wave was impressed to the MIMO WLAN IEEE802.11g/n using 2 stream of 2 × 3MIMO and the conventional WLAN IEEE802.11g. .

We used two types of interference as the Undesired (U) waves for evaluating the dependence of the bandwidth of interference waves for the immunity characteristics of the MIMO WLAN. The first was an Amplitude Modulation (AM) wave specified by the IEC 61000-4-3 standards, which is the radiated electromagnetic-field immunity test where the modulation frequency is 1 kHz and the modulation depth is 80%. As this AM wave appeared to have a narrowband spectrum in the gigahertz band, we called it as a narrowband interference wave [6]. The second U-wave was the communication signal of a WLAN specified by the IEEE802.11b standards. The WLAN IEEE802.11b standards use a frequency band of 2.4 GHz, which is the same band as in the IEEE802.11g standards but its modulation method is the Direct Sequence Spread Spectrum (DSSS), which is different from the WLAN IEEE802.11g standards using OFDM (Orthogonal Frequency Division Multiplexing). As the WLAN IEEE802.11b standards have occupied a bandwidth of about 22 MHz, they have appeared to have a wideband spectrum in the gigahertz band. Therefore, we called the communication signal for the WLAN IEEE802.11b standards as a wideband interference wave.

The relation between throughput and D (desired)/U (Undesired) was measured while impressing the interference wave to the PW cell at each channel from Ch.1 to Ch.4 as shown in Fig.2. Each channel had a spacing of 5 MHz. Where, An electric powers of D and U correspond to the total electric power, which is obtained by integrating the peak value displayed as an average power of spectrum analyser over the receiving bandwidth corresponding to D and U. The power level of MIMO WLAN and the conventional WLAN are -43dBm and -68dBm respectively. So, because we cannot adjust these power level on this system, the power levels of D for MIMO WLAN and the conventional WLAN are difference at D/U = 0dB.

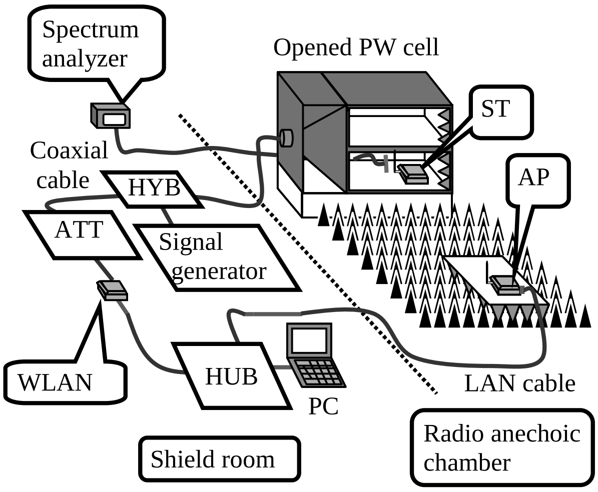

Fig.1. System for measuring electromagnetic interference

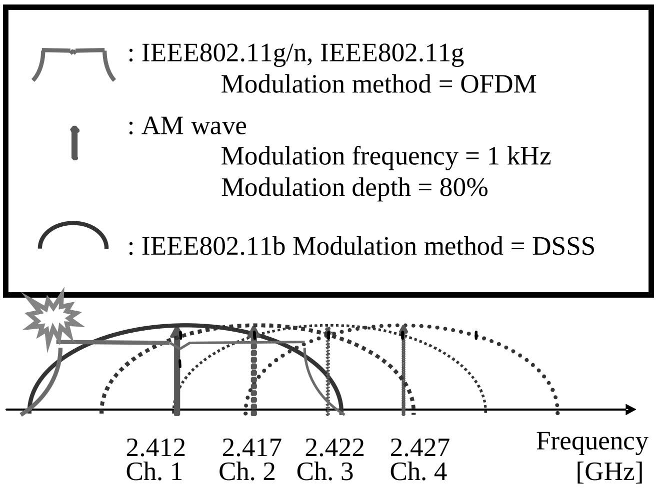

Fig.2. Channel arrangement for desired and undesired waves

We measured the throughput characteristics by using software called "Nte-Mi". The data size was fixed at 1024 bytes. Since measurement value of the throughput fluctuates, we measured it after stabilization. The interference wave emitted from WLAN IEEE802.11b was impressed to the equipment under test through the PW cell, and in this case, WLAN was transmitting a data compulsorily. In addition, the throughput corresponding to each D/U that is shown as vertical axis of throughput characteristic, is displayed by percentage, which is normalized by the maximum throughput obtained when the interference wave is not impressed.

III. Comparison of MIMO WLAN and Conventional WLAN Characteristics Against Narrowband Interference Wave

Figure 3 shows the throughput characteristic measured when the AM wave was impressed to MIMO WLAN as the narrowband interference wave. When the interference wave was impressed to Ch.1 and Ch.2 included in the occupied bandwidth of MIMO WLAN, an almost equal throughput characteristic was obtained. Moreover, it has been understood that the throughput characteristic improves about 5dB on Ch.3 that is boundary of the occupied bandwidth of MIMO WLAN. In addition, the throughput characteristic on Ch.4 existing outside of the occupied bandwidth is improved greater than that on Ch.3.

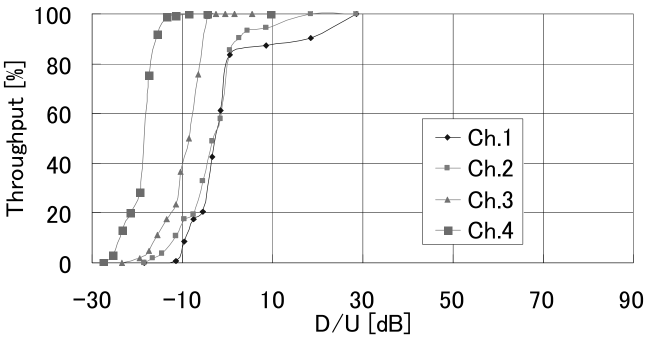

Fig.3. Throughput characteristics of MIMO WLAN when impressing AM wave

Figure 4 shows the throughput characteristics when the AM wave is impressed to the conventional WLAN as the narrowband interference wave. Because the levels of D for MIMO WLAN and the conventional WLAN are -42.5dBm and -68dBm respectively, which cannot be adjusted in this measurement system, the levels of D in D/U=0dB are different in MIMO WLAN and the conventional WLAN. When comparing with Fig.3, the throughput characteristic of MIMO WLAN for all channels from Ch.1 to ch.4 is the same order and only about 5dB better than that for the conventional WLAN.

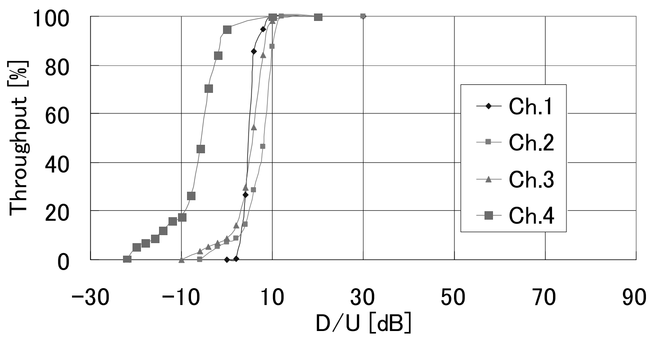

Fig.4. Throughput characteristics of conventional WLAN when impressing AM wave

IV. Comparison of MIMO WLAN and Conventional WLAN Characteristics Against Wideband Interference Wave

Figure 5 shows the throughput characteristics when the communication wave by IEEE802.11b is impressed to MIMO WLAN as an interference wave. When the interference wave is impressed to Ch.1 and 2 included in the occupied bandwidth of MIMO WLAN, it was necessary to assure above D/U of 60dB in order to maintain normal the communication, and D/U in Ch.1 became extremely worse 60dB than that when impressing the AM wave as shown in Fig.3. On the other hand, when the interference wave was impressed to Ch.3 corresponding to be outside of the occupied bandwidth for MIMO WLAN, it was understood that the throughput characteristic was improved about 40dB comparing with that to Ch.2.

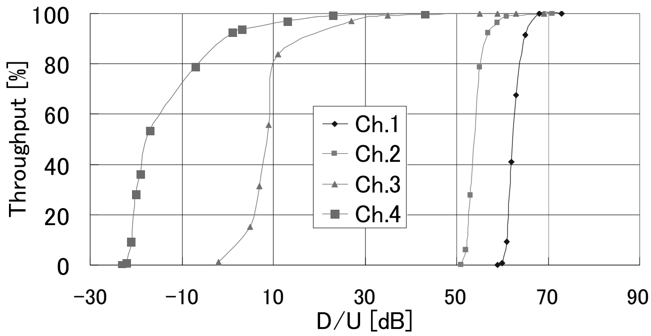

Fig.5. Throughput characteristics of MIMO WLAN when impressing IEEE802.11b wave

Figure 6 shows the throughput characteristic when the communication wave by IEEE802.11b is impressed to the conventional WLAN as the interference wave. The throughput characteristics of the conventional WLAN when impressing to the IEEE802.11b did not become worse than that of MIMO WLAN as shown in Fig.5, and was the same order as that when impressing the AM wave as shown in Fig.4. By comparing Fig.4 with Fig.5, and also Fig.4 with Fig.3, it was revealed that the throughput characteristic of MIMO WLAN deteriorates remarkably and C/I given the same throughput increases about 60dB when the broadband interference wave such as the communication wave of WLAN IEEE802.11b is impressed to Ch.1 and Ch.2 included in the occupied bandwidth of MIMO WLAN.

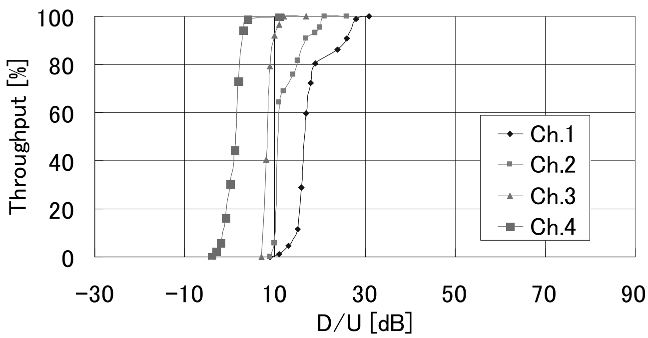

Fig.6. Throughput characteristics of conventional WLAN when impressing IEEE802.11b wave

V. Conclusion

We evaluated the electromagnetic-interference characteristics of MIMO WLAN by using an opened PW cell that was placed in a radio anechoic chamber. We used two types of the interference wave such as the narrowband AM (Amplitude Modulation) wave specified by the IEC 61000-4-3 standards and the broadband communication signal of a WLAN specified by the IEEE802.11b standards. When impressing the AM wave as the narrowband interference, it was clear that the throughput characteristic of MIMO WLAN for all channels from Ch.1 to ch.4 was the same order and only about 5dB better than that for the conventional WLAN. On the other hand, when the communication wave of WLAN IEEE802.11b was impressed to Ch.1 and Ch.2 included in the occupied bandwidth of MIMO WLAN as the broadband interference, it was revealed that the throughput characteristic of MIMO WLAN deteriorated remarkably and the power ratio D (Desired wave) /U (Undesired wave) given the same throughput increased about 60dB.

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