# A Study on the Installation Effect of the EM Wave Absorber to Wireless LAN Communication Environment

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**Abstract**

The application of EM-Wave absorbers to create a better environment for use of wireless LANs (WLANs) was investigated. Indoor EM wave propagation and data throughput were measured for an experimental room, in order to investigate the effectiveness of applying EM wave absorbers. Comparisons were made between a reflective environment and one using a three layered absorber made from common building materials. Use of the three layered absorber reduced the delay profile by half, and increased average throughput by 40%. So, desired results of the better wireless LAN communication environment were confirmed by the installation of EM wave absorber by this work. Simulation by ray tracing method was performed and the relationship of throughput to delay spread for the experimental room was also discussed in this paper.

## §1. Introduction

In recent years, wireless LAN systems have been used increasingly widely in office buildings and homes. In parallel with increased usage, more attention is being paid to the propagation of wireless LAN signals, on one hand from the viewpoint of security risk and on the other from the viewpoint of unwanted signal attenuation due to multipathing and/or fading.

Possibilities for dealing with these issues include constructing EM shields around the area of WLAN usage or applying EM wave absorbers to the certain portion of the room to prevent multi path. Among above absorbers, three layered type EM absorber[1] using only general building materials is recently developed and submitted as building material type absorber for wireless LAN communication environment, which main advantages are cost and handling, with 12dB absorption performance for up to 30 degree TE and TM polarization wave.

Keywords : EM wave absorber; Building material; Wireless LAN; Throughput; Delay spread; Propagation

A few works[2],[3] has previously been directed improving the electromagnetic environment for wireless communication by placing absorbers, and some EM wave absorbers[4],[5] already have been proposed. Very few works, however, investigate the effect of setting EM wave absorbers actually in the room as building member.

For this situation, the measurement of throughput for wireless LAN commercial equipment (IEEE802.11b) and the indoor propagation by dipole antenna and vector network analyzer were conducted, in order to investigate the effect of the installation of developed three layered absorber to the moderated wireless LAN experimental communication environment room in this paper.

## §2. Room Environment and Materials

The size of the room used for this experiment was 4.53m(short side)×6.22m(long side)×2.70m(height). The floor of the room was not replaceable (300mm thickness concrete with steel deck), but the walls and ceiling were replaceable. The ceiling was modular and the walls could be slid in and out of position. Fig. 1 shows the outline of the experimental room used for the investigation. The room was on the second floor of the building, with the steel deck for third floor 1.5m over the ceiling. The short side of the wall was backed onto plasterboards.

Aluminum plate was used for the ceiling and the wall. The sound absorbing ordinary rock wool with 15mm thickness (denoted as “rock wool” in this paper) and EM wave absorbing rock wool with 11.9mm thickness (denoted as “ceiling absorber” in this paper) were used for the ceiling except portions of lighting. The three layered type EM wave absorber consisted by only common interior building materials (denoted as “three layered absorber” in this paper) was used for the one long side wall. The developed three layered absorber was consisted by two layers of common building materials with air gap between. Fig. 2 shows the structure of the three layered absorber. The other walls comprised two aluminum plates, separated by a 20mm air gap.

A total of four environments were examined by applying above materials to the wall and the ceiling; aluminum for the walls and the ceiling and concrete for the floor (Envi.A), the three layered absorber for one long side wall, aluminum for the other walls and the ceiling (Envi.B), three layered absorber for the one long side wall, aluminum for the other walls and the rock wool for the ceiling (Envi.C), and three layered absorber for one long side wall, aluminum for the other walls and the ceiling absorber for the ceiling (Envi.D). Table 1 shows four room environments with used

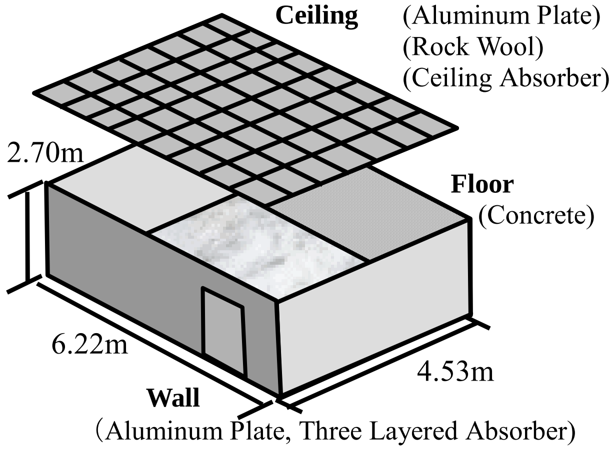


**Fig.1** Outline of the room for investigation

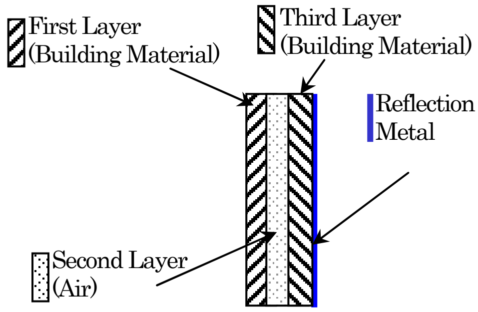


**Fig.2** Structure for the three layered absorber

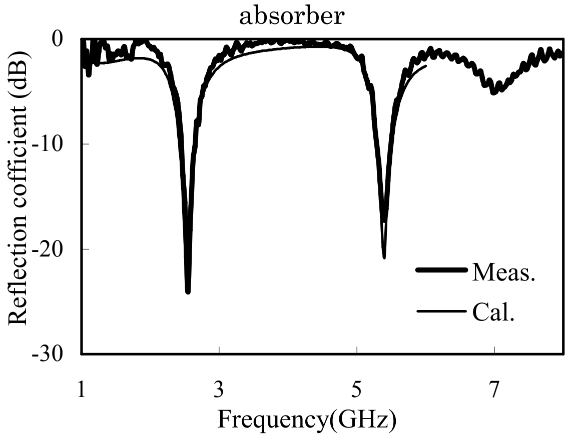


**Fig.3** Frequency Characteristic of the Absorber

**Table 1**. Configuration of the room environments

| Room Environment | Ceiling | Wall | | Floor |
|---|---|---|---|---|
| | | One long side | Other | |
| Envi. A | aluminum | aluminum | aluminum | concrete |
| Envi. B | aluminum | three layered absorber | aluminum | concrete |
| Envi. C | rock wool | three layered absorber | aluminum | concrete |
| Envi. D | ceiling absorber | three layered absorber | | |

materials.

Fiber reinforced cement board was used as the building materials for the three layered absorber in this investigation. Fig. 2 shows the measured reflection coefficient (TE wave, 8.5 degree for incident angle, denoted as "Meas.") for the above three layered absorber by free space measurement system[6] compared with data (denoted as "Cal.") calculated from the measured thickness of each layer and the estimated complex permittivity[7] from water content. Measured reflection coefficient by conducting in 8.5 degree as oblique incident angle of TE wave has been already confirmed as data by normal incident measurement in the past work[6]. The average reflection coefficients for the three layered absorber in the range from 2.4GHz to 2.5GHz are 10.4dB for the vertical incident (measurement data) and 6.3dB and 5.1dB for 30 degrees oblique incident of TE and TM wave (calculated data), respectively.

## §3. Experiment

Two experiments were conducted to investigate the effect of installation of three layered absorber for four room environments: data throughput measurement and indoor propagation measurement.

The transiting point (a WLAN access point equipment for the throughput measurement, and a dipole antenna for the propagation measurement) was set at the center of the room -0.14m below the ceiling. Receiving points (a laptop PC with wireless LAN card for the throughput measurement and a dipole antenna for the propagation measurement were placed at 30 points --- 5 points along the short wall (every 1m at 0.31m from the long wall) and 6 points along long wall (another every 1m at 0.26m from short wall). The height of the receiving points was 0.75m, which is referring from the height of the common office desks.

### 3.1 Throughput measurement

The access point equipment (denoted as "AP" in this paper) and the laptop PC with wireless LAN card (denoted as "STA" in this paper) were used for the throughput measurement. Both components were designed to the IEEE802.11b standard.

The AP was connected to a server PC with celeron 1GHz CPU and 756MB memory by ethernet cable (100baseT), and communicated through wireless LAN to STA (Pentium III 700MHz CPU and 256MB memory). Throughput measurement was conducted by file transfer from STA to the server PC through TCP/IP connection. The file for the transfer was MS-Office cabinet file with 67871282 Bytes. File transfers were conducted twice for each measuring point and the amount of data transferred over 30 sec was recorded. The average of these two figures was used as the data throughput rate. Where the two figures disagreed by more than 10%, another measurement was taken.

Fig.4 shows the distribution of throughput measurements for four room environments. Comparing of the measured results for Envi. A to those of Envi. B, the throughputs for Envi. B are larger than those of Envi. A at all measuring points, and Envi. B shows a 40% greater average data throughput rate than Envi A. The average throughputs among 30 measured points are 2.51MBps, 3.51MBps, 3.58MBps and 3.30MBps for

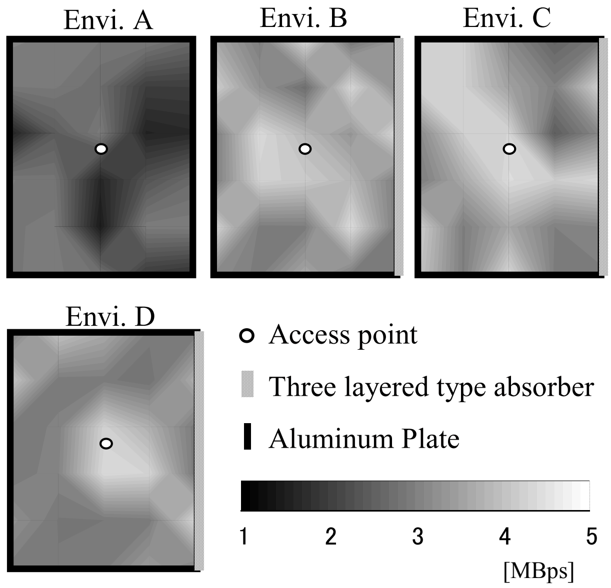


**Fig. 4** Throughput distribution for each environment

Envi. A, Envi. B, Envi. C and Envi. D, respectively.

As mentioned above, Envi. A is very reflective environment and Envi. B is replaced one long side wall only. Further comparisons of the result for Envi.B to those for Envi.C and Envi.D show only marginal differences. So, the results of throughput measurement are confirmed the effectiveness of the installation of the three layered absorber to the one long side wall for the wireless LAN communication environment.

### 3.2 Indoor propagation measurement

Half wavelength dipole antenna (KBA-613) and vector network analyzer (VNA, HP8753A) were used for the propagation measurement under four room environments (Envi. A, Envi. B, Envi. C and Envi. D). Frequency range for the measurement was 2.25GHz to 2.65GHz (2.45GHz as center and 400MHz as width), and the antenna factor of the dipole antenna at 2.45GHz was 36.0dB. Data points of $S_{21}$ and averaging times were 801 and 64, respectively. The $S_{21}$ of the VNA with the two antennas separated 1m apart in an anechoic chamber was used as a reference. Inverse Fast Fourier transfer of the measured $S_{21}$ was conducted to the delay profile for an each measurement point.

Transmitting antenna was set -0.14m from the surface of the ceiling at the center of the room, and the antenna line was vertical to the floor. Receiving antennas were set 0.75m from the floor at regular interval of 1m for long side and short side of the room (6 points for long side and 5 points for short side, thus total 30 measurement points). The directions of the antennas lines were set vertical to the floor for the transmitting antenna and parallel to the long side wall for the receiving antenna, referring to the common wireless LAN equipments (typically access point and wireless LAN adapters), and the same setup used for the throughput experiment.

Delay spread, S, were calculated[8] from the measured delay profile by equation (1), as shown below,

$$S = \sqrt{\frac{\sum_{i=1}^{N}(\tau_i - T_D - \tau_M)^2 \times P(\tau_i)}{\sum_{i=1}^{N} P(\tau_i)}} \qquad (1)$$

$$T_D = \frac{\sum_{i=1}^{N}\tau_i \times P(\tau_i)}{\sum_{i=1}^{N} P(\tau_i)} - \tau_M \qquad (2)$$

where $P(\tau_i)$ is the receiving power at the time $\tau_i$, $\tau_i$ is the time when $P(\tau_i)$ is over the cutoff level at the first time, $\tau_N$ is the time when $P(\tau)$ is below the cutoff time at the last time, and $\tau_M$ is the time when the signal achieved at the first time. The cutoff level is set –60dB from the measured delay profile.

Fig.5 shows the distribution of the delay spead for each environment. These results indicate that replaceing one long side wall with the three layered absorber reduced the delay spread for all measurment points when compared to the very reflecting environment, where the walls and ceiling were all alminum. The average of the reduction in the delay spread among 30 measured points from the Envi. A to the Envi. B is 50%. Changing the

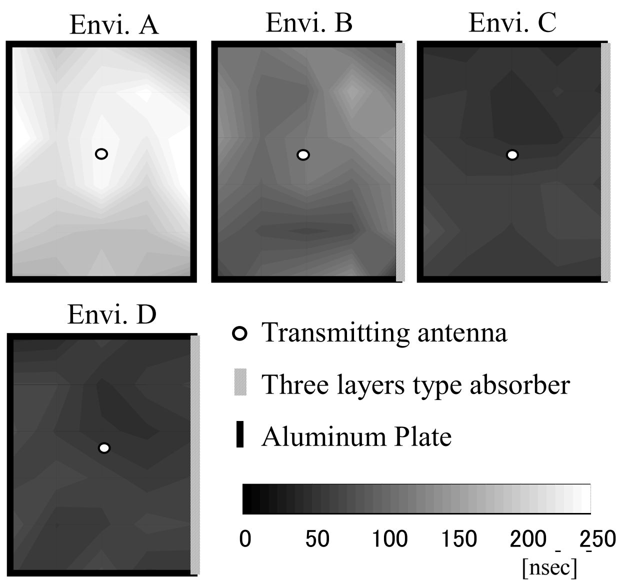


**Fig.5** Delay spread characteristic for each environment

ceiling from alminium plate (Envi.A) to rock wool (Envi. C) or ceiling absorber (Envi.D) makes the average delay spread just 25% of that observed in Envi. A.

## §4. Simulation

Delay profile and delay spread also were calculated by ray tracing method simulation using the improved geometrical optics algorithm[9][10]. As basic investigations of the simulation, the measured delay profiles at certain points are compared to those by ray tracing method under the condition that the direction of the line of transmitting and receiving antenna were set same direction (vertical to the floor). Fig.6 shows the comparison at receiving point 8 (Rx8). Data from simulation are similar to those from the measurement.

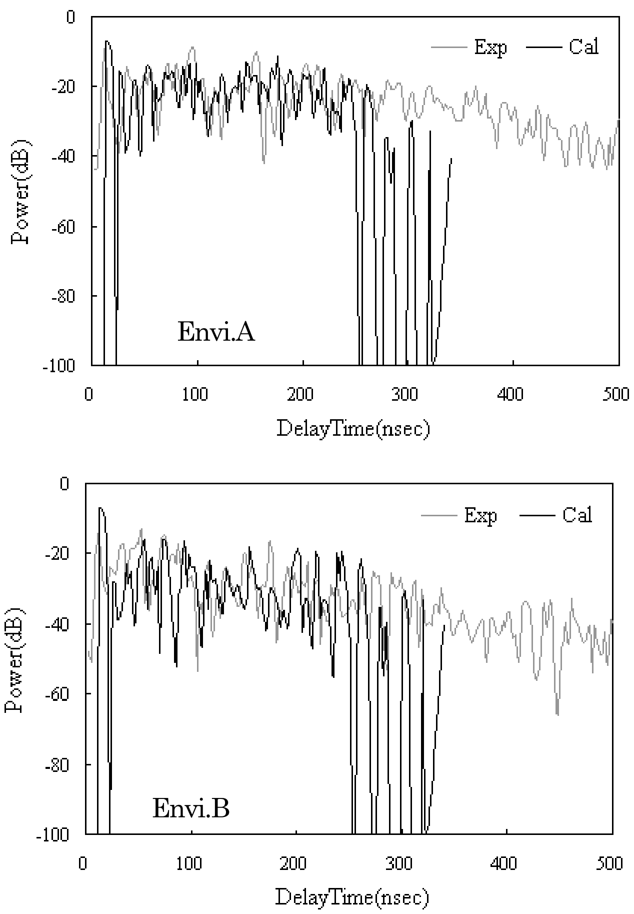


**Fig.6** Comparison of the delay profile by the calculation for those by Experiment for Envi.A(upper figure) and Envi.B (lower figure) at Rx8

Envi.A was consisted by aluminum walls (all sides), aluminum ceiling, and concrete floor. Envi.B was consisted by aluminum walls (three sides), three layered absorber (one long side), aluminum ceiling, and concrete floor. Fig.2 already show the structure of the three layered absorber by common building materials (fiber reinforced cement board). Absorption performances for the absorber are also already shown at Fig.3 for frequency characteristic (normal incident), and are newly shown at Fig.7 for angle characteristic (2.45GHz).

Further basic investigations for the simulation

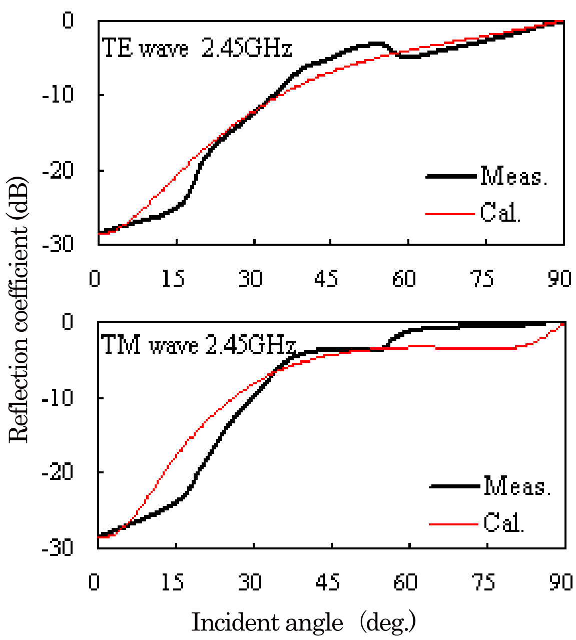


**Fig.7** Absorption performance (frequency characteristic) for three lavered absorber

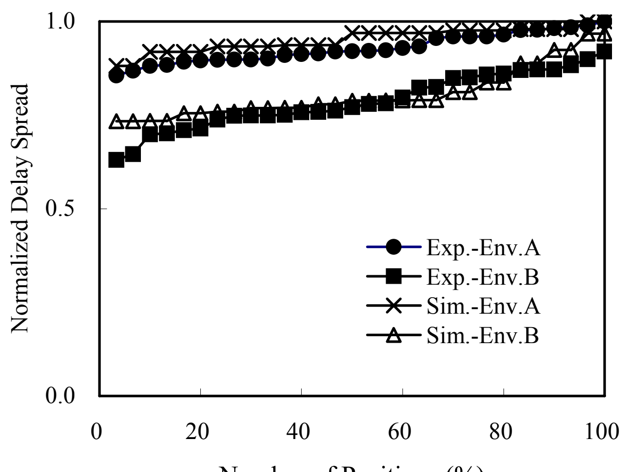


**Fig.8** Number of the positions for the delay spread

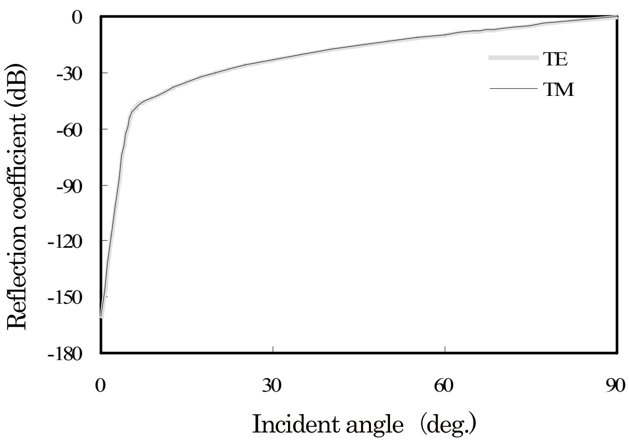


Fig.9 Absorption performance (frequency

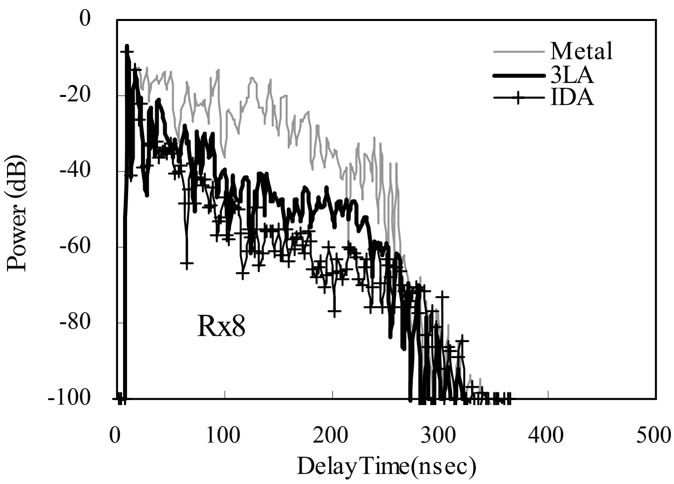


Fig.10 Delay profile for each case (Rx8)

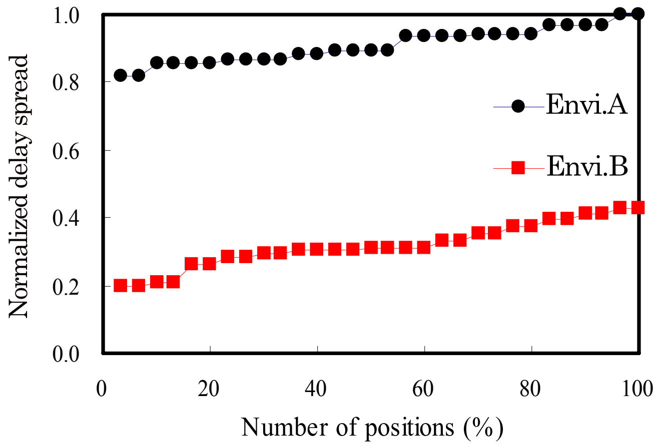


Fig.11 Comparison of number of positions by simulation

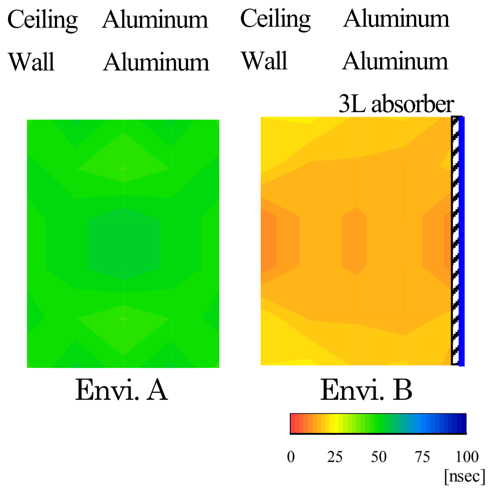


Fig.12 Comparison of delay spread desitributionby simulation

were conducted at 30 measured points described in Experiment (§3), and the delay profiles and the delay spread also were calculated by the simulated delay profiles at the 2.45GHz, which was the center frequency for the measurement. The number of surfaces for the room and times for reflection of rays were 6 and 18, respectively. The number of ray for these simulations was 8473.

Fig. 8 shows the comparison of the numbers of positions by the experiment to those by the simulation for Envi. A and Envi. B among 30 measurement points, in setting the same direction of transmitting and receiving antenna line, which was vertical to the floor. Delay spreads for data marked Exp. and Sim. in Fig. 8 are normalized by maximum value of the delay spread among the experiment and the simulation, respectively.

Delay spreads by the simulation of ray tracing method were calculated up to 200 ns, because of the limitation of the calculation time. Fig. 8 indicates that the numbers of the positions to the normalized delay spread by the simulation are very similar to those by the experiment for both Envi. A and Envi. B, so the effectiveness of the simulation is confirmed.

Further simulations were conducted in order to confirm the installation effect of the absorber. Fig.10 shows a comparison of replacing one aluminum plate side wall with the three layered absorber using only interior builing material (3LA) and an ideal absorber with one layer (IDA), which absorption performance (angle characteristic) is shown in Fig.9, at receiving point 8 (Rx8).

Fig.10 again confirms the installation effect of the absorber (3LA and IDA) to the wireless LAN environment.

## §5. Discussion

### 5.1 Comparison of the Propagation Results by Simulation to those by Experiment

After basic investigations, further simulations for the installation effect of the actual absorber were conducted for the whole investigation room described at Fig.1. Fig.11 shows the number of positions for Envi.A and Envi.B, and Fig.12 shows distribution of the delay spread for 30 points in the room.

The difference of the above two environments is the installed three layered absorber by only common building material to the one long side wall. Two figures introduce the clear effect of the installation of the absorber.

In addition, the comparison of the above results by simulation to those by experiments show similar tendency by the installation of the absorber (Installation of the absorber to the only one long wall makes large improvement of the delay spread at every point, and the installation effect lay whole area of the room).

So, the installation effect of the absorber is confirmed by both of experiment and simulation.

### 5.2 Correlation between throughput and delay spread

In the discussion on the quality of the wireless communication, the correlation of the throughput to the BER (bit error rate) and/or the delay spread is one of the important factors. Most of the above, however, are just analytical investigation or the experimental ones but not focusing on the installation effect of the EM wave absorber.

Fig. 13 shows the correlation of the throughput and the delay spread from the propagation measurement for each environment. This figure indicates that the area for Envi.B is clearly different from that for Envi.A and Envi.C, and the distinguish of the area for Envi.C and that for Envi.D is difficult. So, the area for Envi.B

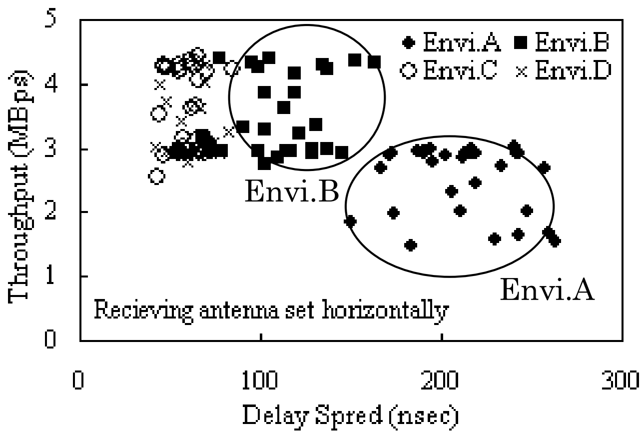


**Fig.13** Throughput characteristic to delay spread for each environment

introduces the threshold delay spread of the better communication environment, which is about 130 nsec from the figure.

## §6. Conclusion

Throughput measurement by commercial wireless LAN equipment (IEEE802.11b) and indoor propagation by dipole antenna were conducted at 30 points in the experimental room (4.53m×6.22m×2.70m), in order to investigate the effeteness of the installation of the EM wave absorber for the better wireless LAN communication environment.

Comparison of well reflected environment (the ceiling and the wall were metal, and the floor was concrete), replacing of one long side wall to the three layered absorber, which was consisted by only general building materials, with the average absorption performance was 10.4 dB (2.4GHz to 2.5GHz), makes the throughput larger than that of well reflected environment for all measured points and the average of the throughput is 40% larger than that. Further replacing of the ceiling to the sound absorbing rock wool and/or the ceiling absorber makes few improvement of the throughput.

Another comparison of well reflected environment, replacing of one long side wall to the three layered absorber makes the delay spread half to that of well reflected environment, and further replacing of the ceiling to the sound absorbing rock wool and the ceiling absorber makes that quarter.

Above two experimental results indicate the installation of the three layered absorber only to the one side wall makes large improvement for the wireless LAN communication environment.

Simulation by ray tracing method also performed to this room and the results for number of positions to the normalized delay spread calculated by the simulation are similar to those from the experiment.

The correlation between throughput and delay spread calculated from the measured delay profile indicates that the installation of the three layered absorber introduces the threshold of the better communication environment, which is about 130 nsec.

A useful and necessary extension of this work for other materials and conditions should be performed as next works.

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**short comment** The developed absorber is very unique and should be useful. So, I try to proceed to distribute this absorber every possible market related wireless communication field.