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EXPERIMENTAL RESULTS ON 100-Mbps DIGITAL TRANSMISSION OVER A MILLIMETER-WAVE INDOOR WIRELESS CHANNEL AT 60 GHz

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1 Introduction

As computer terminals and workstations proliferate in offices and factories, demand for indoor high-speed wireless networks is increasing. The millimeter-wave band is considered promising for this application because of the available broad frequency spectrum, the compactness of radio equipment, and the portability of terminals. Few attempts has been made for practical experiment of indoor wireless network systems using the millimeter-wave band carrying data rates above 10 Mbps. A suitability of the use of millimeter waves for high-speed wireless network systems must be confirmed by practical experiments. Accordingly, we made experiments on 100-Mbps digital transmission over a millimeter-wave indoor wireless channel at 60 GHz in a typical indoor environment. By using these experimental results, we examined the feasibility of high-speed wireless transmission over a millimeter-wave channel, and we propose an example of suitable configuration for the high-speed digital transmission system using the millimeter wave.

2 Measured Room and Experimental Setup

Digital transmission experiments were made at 60 GHz for the evaluation of indoor transmission channels. The plan of the measured room and the arrangement of furniture are shown in Fig. 1. The floor area was 13.51 m × 7.81 m, and the height of the ceiling was 2.57 m above the floor. The heights of the high and low steel partitions were 1.73 m and 1.33 m, respectively. The transmitter was located just under the ceiling at a corner (T1 in Fig. 1) of the room. The height of the transmitter antenna was 2.33 m. A wide-beam scalar-feed horn antenna (3-dB width : $\sim 60°$) was used for the transmitter to illuminate all over the room. This antenna was pointed toward the position D in Fig. 1. The receiver was located at each position denoted by A to R in Fig. 1. In order to measure bit-error rates, the transmitted millimeter-wave carrier at 59.25 GHz was ASK modulated by on-off keying with a pseudo-random sequence at a rate of 100 Mbps. The transmission power was 8 dBm. At the receiver, bit-error rate was measured after envelope detection by comparing the detected sequence with the replica of the transmitted sequence. Since each bit-error rate was measured for 20 seconds, the measurable minimum bit-error rate was 5×10^{-10}. At each receiver position, the receiving pyramidal-horn

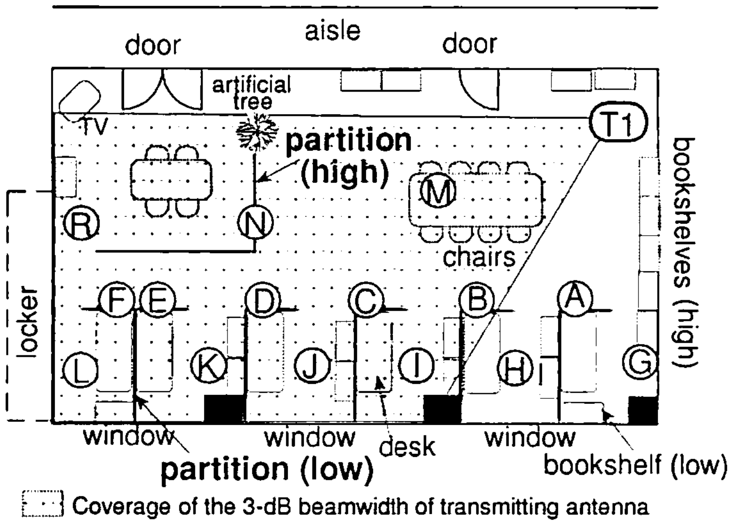

Figure 1: The room where the measurements were conducted.

antenna whose 3-dB width was about 11° was pointed toward the transmitter antenna. All of the transmission experiments were made on line-of-sight (LOS) links by setting the receiver above the height of nearby partitions except at the position L where the height dependence of the transmission characteristics was measured to examine the effects of the shadowing due to a partition on an obstructed line-of-site (OBS) link.

For receiver position L, receiver heights below nearby partition were also chosen behind the partition for measuring in the OBS link. The effect of the furniture for transmission channels was examined by comparing the measurement results with and without furniture.

3 Measurement Results

3.1 Measurement results of bit-error rate at each receiver position

The bit-error rate was measured at each receiver position employing vertical polarization. Since the bit-error rate was found to vary depending on the receiver height, we use, in the following discussions, the bit-error rate measured at the receiver height where the minimum BER was achieved within a height range from 0 to 15 cm above the height of partition for each receiver position. Measurement results of bit-error rate at each receiver position are shown in Fig. 2. In Fig. 2, figures in ovals indicate the exponents of a base 10 of the bit-error rates measured in the room with furniture, and figures without ovals indicate the differences in the bit-error rates measured in the room with and without furniture. For the difference, the positive sign indicates the case that the bit-error rate increased due to furniture. The bit-error rates less than 10^{-6} were measured at almost all the receiver positions regardless of the existence of furniture. This demonstrates that the use of a transmitter antenna with a 3-dB beam width of 60° is sufficient to cover this room as far as the LOS path is not obstructed. Multipath suppression by antenna directivity [1][2] also contributes to the low bit-error rate achieved by the narrow beam receiver antenna.

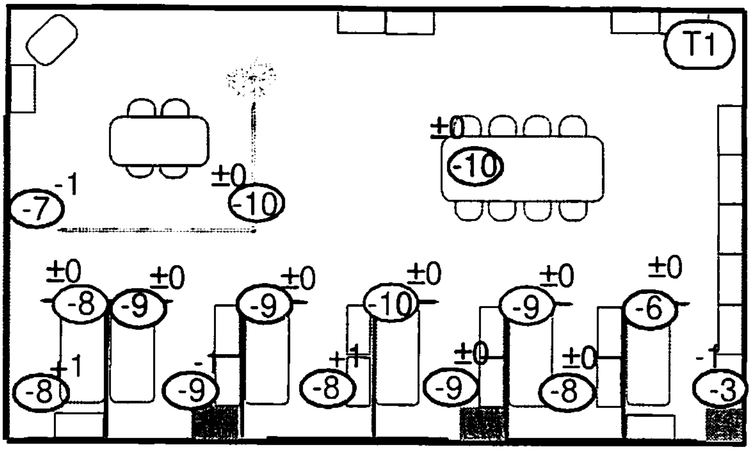

Figure 2: Bit-error rate measured at each receiver position with furniture and its difference from the bit-error rate measured without furniture. Bit-error rate 10^{-N} is denoted as $-N$. Bit-error rates less than 10^{-9} are indicated as -10.

3.2 Height dependence of bit-error rate

The height dependence of the bit-error rate and received power at the receiver position L is shown in Fig. 3. Dotted and broken curves in Fig. 3 show the measurement results for the room with and without furniture, respectively. It is found in Fig. 3 that the bit-error rate and the received power showed significant height dependence and inversely correlated with each other. This height dependence is explained by the interference between the direct wave and the multipath from the ceiling because a part of main beam of the transmitting antenna was reflected by the ceiling in the present experimental configuration. In order to confirm this, the height dependence of received power was estimated by a simple two-ray model consisting of a direct wave and a multipath from the ceiling. The result of this estimation is shown as the solid curve in Fig. 3. The agreement in the period of the interference pattern between the estimated and measured variations of the received power is fairly good. Thus, the cause of the height dependence of the bit-error rate is the interference between the direct wave and the multipath from the ceiling. From the argument above, it is suggested that the bit-error rate can be improved by changing the receiver height a few centimeters or by keeping the main beam of the transmitter from being reflected by the ceiling.

It should be also noted that the direct wave was obstructed (OBS) by the steel partition when the receiver height was less than 128 cm at the receiver position L. In Fig. 3, the receiving power for the OBS link in the measurement with partition were about 10 dB less than those for the LOS link in the measurement without partition, and the bit-error rate for the OBS link was about 2 order of magnitude higher than those for LOS link. Thus, it seems that the establishment of the LOS link is indispensable to error-free high-speed transmission.

4 Conclusions

The feasibility of high-speed wireless transmission over a millimeter-wave channel in furnished rooms was demonstrated when an LOS-link was established by directive transmitter and receiver antenna. The quality of transmission channel was improved by changing the

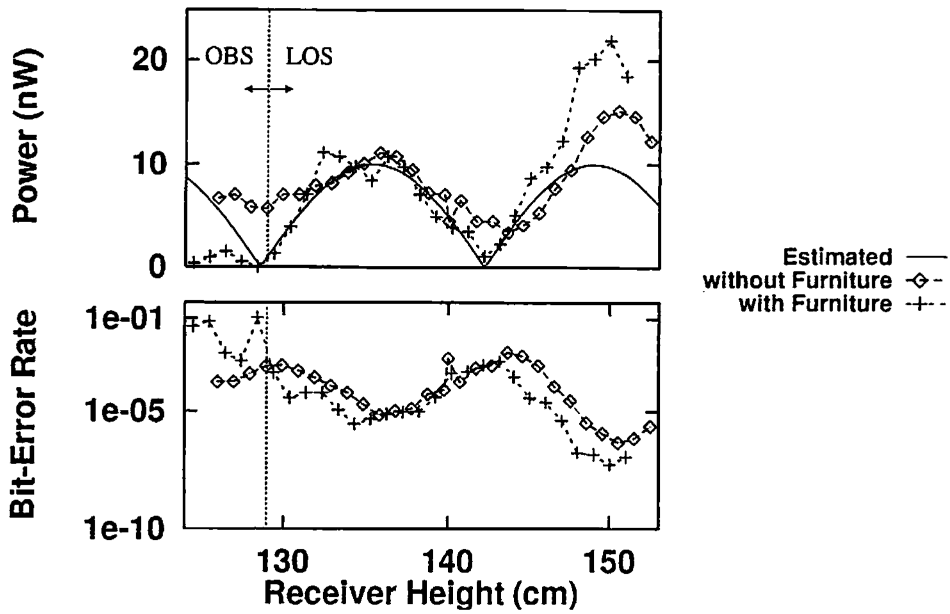

Figure 3: Height dependence of received power and bit-error rate at receiver position L.

receiver height a few centimeters as far as the LOS path was not obstructed. It is also suggested that the antenna configuration keeping the main beam of the transmitter from being reflected by the ceiling enables us to reduce the effect of the interference, and improves the quality of millimeter-wave indoor high-speed transmission channel.

Acknowledgment

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References

[1] T. Manabe, Y. Miura, and T. Ihara, "Effects of antenna directivity on indoor multipath propagation characteristics," 6th IEEE International Symposium on Personal, Indoor and Mobil Radio Communications (PIMRC 95), Toronto, Canada, Sept. 27-29 (1995).

[2] P. F. Driessen, "High speed indoor wireless systems with directional antennas," 44th IEEE Vehicular Technology Conference, Stockholm, June. 8-10 (1994).

[3] T. Manabe, K. Sato, H. Masuzawa, K. Taira, T. Ihara, Y. Kasashima, and K. Yamaki, "Polarization dependence of multipath propagation and high-speed transmission characteristics of indoor millimeter-wave channel at 60 GHz," IEEE Trans. Vehicular Tech. vol. 44, pp. 268-274 (1995).