WIDEBAND MILLIMETER WAVE CHANNEL SOUNDER AND INDOOR PROPAGATION EXPERIMENT AT 60 GHz

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1. Introduction

The millimeter-wave band around 60 GHz is considered suitable for future indoor high-speed wireless communications systems such as millimeter-wave wireless local area networks (WLAN) whose data transmission rate is expected to be higher than several tens of Mbps. Since high-speed digital transmission characteristics may be severely influenced by indoor propagation environments and system configuration [1],[2], it is of primary importance to know the effects of millimeter-wave indoor propagation characteristics on high-speed digital transmission characteristics such as bit-error rates. We have developed a wideband millimeter-wave channel sounder which enables us to measure multipath propagation characteristic at 60 GHz and bit-error characteristics for BPSK transmission rates up to 500 Mbps almost simultaneously. By using this sounder, Communications Research Laboratory have just started a measurement campaign on indoor millimeter wave propagation in collaboration with Association of Radio Industries and Businesses under which twenty private companies voluntarily formed an experimental group to promote the development of millimeter-wave wireless local area network (WLAN) system.

Preliminary measurement results which demonstrate the superior performance of this measurement system are described in the later half of this paper. Further experimental results on the indoor multipath propagation and digital transmission measurements will be presented at the Symposium.

2. Wideband Millimeter-Wave Channel Sounder

The block diagram of the channel sounder we have developed is shown in Fig. 1. The main part of the channel sounder is a Cox-type multipath measurement system which is based on the swept time-delay correlation method [3]. In this measurement system, a maximal-length pseudo-random binary sequence generated by an 8-stage shift register (PN-GEN) at a chip rate of 512 MHz was used to bi-phase (BPSK) modulate a 2.5-GHz IF signal. By mixing this modulated IF signal with a 57-GHz local signal, it is then upconverted to the transmit signal at 59.5 GHz. The nominal transmit power is 10 dBm. At the receiver, the received signal, after amplification, is mixed with a local signal phase-locked to the local signal of the transmitter and is downconverted to the first IF signal in the 2.5-GHz band. Received polarization can be switched between two orthogonal polarizations by an orthomode transducer and a switching circuit. The received first IF signal is mixed with an m-sequence identical with that generated for the transmitter but clocked at a slightly (2549/2550) slower rate (511.8 MHz), and is downconverted into the second IF signal. This second IF signal is digitally quadrature demodulated and then translated into in-phase and quadrature-phase components of complex impulse responses by digital integration with a digital signal processor.

Since the difference in the clock rate of the m-sequences for the transmitter and receiver is 0.2 MHz which corresponds to a time scaling factor of 2550, complete impulse responses are measured every 1.27 ms. Since the length of the 8-stage sift-register generated m-sequence is 255, the maximum measurable delay is 499 ns and the time-sidelobe level of the measured impulse response is 48 dB below the correlation peak. The time resolution of the impulse response estimate is about 2 ns.

In addition to the multipath impulse response measurements, this measurement system has a capability of measuring the received power and the bit-error rate (BER) of the channel which can be compared with the measured multipath characteristics. The received power was measured by monitoring the control voltage of AGC amplifier at the first IF stage. For the BER measurements, the BPSK transmission rate of 64, 128, 256, or 512 Mbps can be selected. The minimum detectable BER is 1×10^{-9} since the BER is measured over 10^9 transmitted bits. Carrier phase and bit synchronizations at the receiver are automatically achieved by the use of the information of the peak of the PN-code correlation. With the transmitter and receiver connected back to back, the degradation of required received signal level for a given BER from ideal BPSK transmission was less than 2 dB for the transmission rate other than 512 Mbps.

In a measurement sequence, the measurements of impulse response and BER can be switched alternately. This makes it possible for us to measure the impulse responses and BER almost simultaneously.

3. Indoor Propagation and Digital Transmission Measurements

The measurement was made in an open-plan room with a floor area of 30 m x 20 m whose interior structure was typical of modern office rooms. The height of ceiling was 2.6 m. The multipath propagation and digital transmission characteristics were measured by using our channel sounder described in the previous section within this room for various configurations of transmitter and receiver, various types of antennas, and various configurations of furniture.

Fig. 2 and Fig. 3 show typical examples of the measurement results. In these cases, measurements were made to investigate the effects of antenna directivity and furniture for a room environment furnished

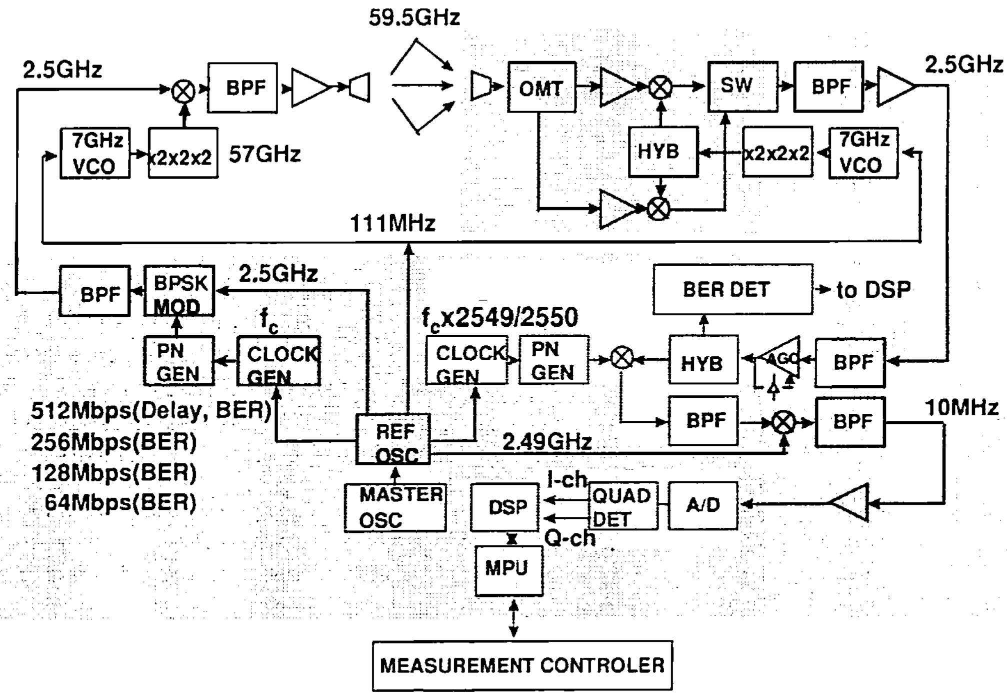

Figure 1: Wideband millimeter-wave channel sounder

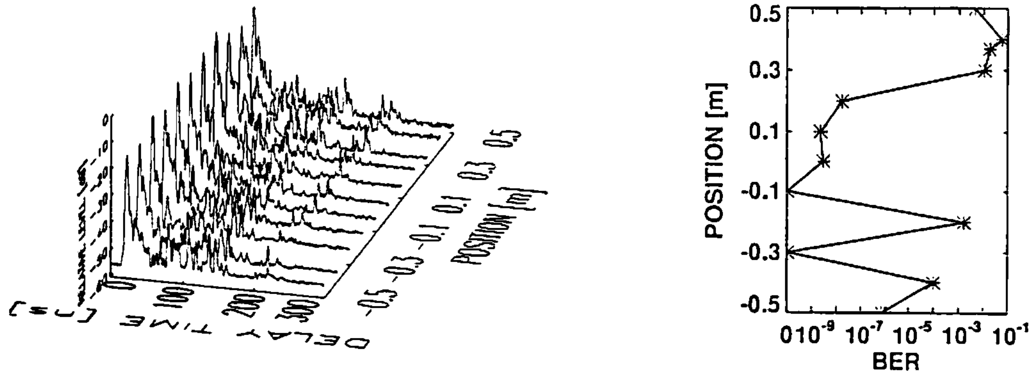

Figure 2: Impulse responses and BER measured by a wide-beam (60°) receiving antenna for LOS condition (−0.5 m < POSITION < 0.35 m) and for OBS condition behind partition (POSITION > 0.35 cm)

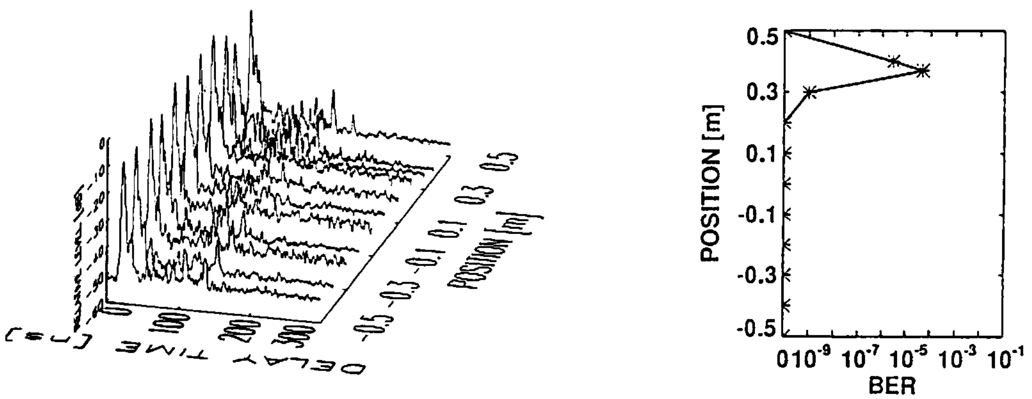

Figure 3: Impulse responses and BER measured by a narrow-beam (25°) receiving antenna for LOS condition (−0.5 m < POSITION < 0.35 m) and for OBS condition behind partition (POSITION > 0.35 cm)

with low partitions and steel desks. In order to simulate a base station antenna installed at the ceiling, the transmitting antenna with an omnidirectional pattern was installed 40 cm below the ceiling at the center of the room. In this case, the impulse responses and the corresponding bit-error rates (BER) were measured by a receiving antennas simulating a portable remote terminal at every 10 cm on a straight course on an aisle between low partitions. The distance of the receiving antenna form the transmitter was about 7 m. The receiving antenna was installed 1.1 m above the floor and was pointed toward the transmitting base station antenna. On most of the measurement course (POSITION < 0.35 m in Fig. 2 and Fig. 3n), the transmitting antenna was on line-of-sight (LOS), except for the case that POSITION is larger than 0.35 m where the line-of-sight path was obstructed (OBS) by a 43-mm thick low partition whose surfaces were cloth-covered 2.5-mm thick plywood with hollow space in between framed by metallic edge. The height of the partition was 1.5 m. Fig. 2 and Fig. 3 show the impulse responses measured at a chip rate of 512 Mbps and BER measured at 128 Mbps at every 10 cm on the course for wide-beam and narrow-beam receiving antennas, respectively. The beam widths of the wide-beam and narrow-beam antennas were 60° and 25°, respectively, and the polarization was circular both for transmission and reception.

From these measurement results, it is confirmed that a very high delay-time resolution of about 2 ns and a very low time-sidelobe level of less than -42 dB relative to the correlation peak are achieved in the impulse response measurements by our channel sounder.

By comparing the impulse responses shown in Fig. 2 and Fig. 3, it is found for the case of the narrow-beam receiving antenna that the received level increased by about 7 dB, which corresponds to the difference in receiving antenna gain, while the levels of multipath delayed wave were suppressed as compared with the case of the wide-beam receiving antenna. For the case that the transmitter was on line-of-sight from the receiver (POSITION < 0.3 m in Fig. 2 and Fig. 3), almost error free (BER $< 10^{-9}$) transmission was achieved by the narrow-beam receiving antenna, while BER fluctuated significantly for the case of the wide-beam receiving antenna. This fluctuation of BER for the wide-beam receiving antenna can be explained by the flat fading due to the reflection from the ceiling. It is noteworthy that BER less than 10^{-9} was also achieved by the narrow-beam receiving antenna even when the line-of-sight was obstructed (OBS) by a partition except when it was obstructed by the metallic edge (POSITION $\sim$ 0.35 m). This is due to the fact that the examined partitions were fairly transparent with only several decibels around 60 GHz.

4. Conclusions

Preliminary experimental results demonstrated the superior performance of the channel sounder with the delay-time resolution as high as about 2 ns and its usefulness for the simultaneous analysis of millimeter-wave indoor multipath propagation and BER characteristics. The experimental campaign on indoor millimeter-wave propagation for millimeter-wave WLAN is still in progress. Further results of this campaign will be presented at the Symposium.

Acknowledgment

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