Analysis of 60 GHz Band Indoor Wireless Channels with Channel Configurations

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Abstract - In this paper, 60 GHz indoor broadband wireless channels are measured with various configurations in a typical office environment. Measurements are taken at nine positions of the room and the base-station antenna is placed either at the center or at an edge of the measurement room, and the remote-station antenna is either sharp beam or broad beam type. The rms delay spread (RDS) and normalized received power (NRP) are estimated from the measurements. Bit error rate simulations are performed using impulse responses for two measurement positions with QPSK/DQPSK OFDM modulation. Using sharp beam antenna results in superior performances than using broad beam antenna in terms of both bit error rates (BER) and NRP penalty. Also, placing the base-station antenna at the center is superior to placing it at an edge in terms of BER and NRP.

Ⅰ. Introduction

60 GHz band has spurred a vogue of interest for indoor broadband communication applications in recent years. It provides many attractive features such as wide bandwidth availability and strong attenuation by wall and oxygen in the air. In high-speed indoor wireless communications, delay distortions due to multipath propagation give rise to performance degradation: this limits the maximum symbol rate [1]-[3].

The 60 GHz indoor communication channel has to be characterized to help design a more reliable and efficient communication system [1]-[4]. To this end we chose four transmitter and receiver channel configurations and analyzed their characteristics. The four configurations are determined by the location of the base-station antenna and by the beam pattern of the remote-station antenna. We compare the four configurations by bit error rate simulations when the signal is QPSK/DQPSK-OFDM modulated.

In chapter II, 60 GHz band indoor channels are measured for the proposed channel configurations in a typical office environment. From the measurement results, the RDS and NRP are evaluated and analyzed.

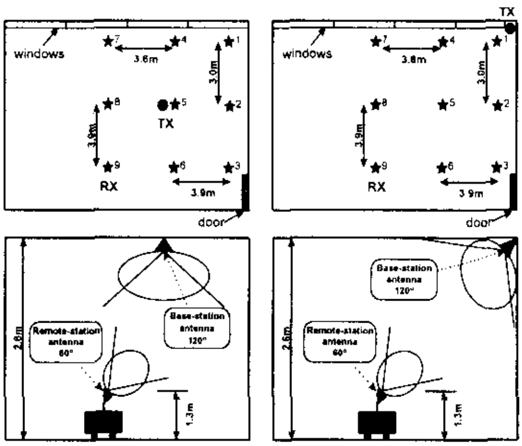
In chapter Ⅲ, BER simulations for QPSK/DQPSK OFDM modulation are done under the four channel configurations. Finally, this paper is concluded.

Ⅱ. Channel Measurements

Ⅱ-1. Description of Environments & Measurements

Measurements of 60 GHz millimeter-wave indoor radio channels were taken in a typical office environment using HP 8510C vector network analyzer [2][3]. The walls in the room were of brick/stone and plasterboard, and the floors were made of concrete. The room had several windows, partitions, desks and computers, typical of a modern office. The measurements were taken at nine positions under various channel configurations in which the base-station antenna was positioned either at the center or at a corner of the measuring region and the remote-station antenna was either of sharp beam type or of broad beam type.

Fig. 1 represents the measurement environments.



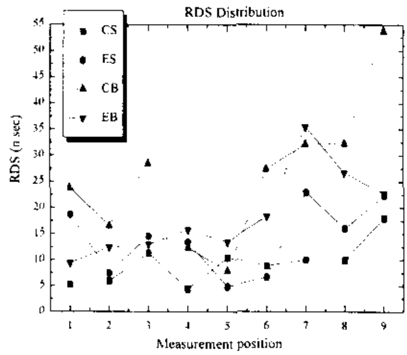
(a) (b)

Fig. 1 Overview of the measurement positions of the base-station antenna(TX) and remote-station antenna(RX) in the room. (a) Center located base-station (b) Edge located base-station

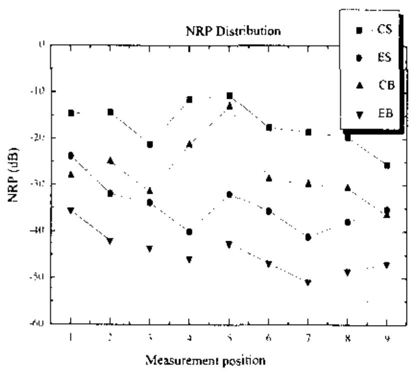
In Fig. 1(a), the base-station antenna is located at the center of the room at the height of 2.6 m from the floor and the remote-station antenna, 1.3 m high, is located at one of nine measurement positions. All of them have circular polarization. The base-station antenna is omni-directional antenna with 120° beam width. The remote-station antenna has two types : omni-directional antenna with 60° beam width and directional antenna with 15° beam width. In Fig. 1(b), all the measurement conditions are the same as in Fig. 1(a) except that the base-staion antenna is now located at the edge of the room. The four configurations of Fig. 1 are denoted as CS, CB, ES and EB in which C and E represent the Center and Edge position of the base-station antenna, respectively, and S and B represent the Sharp and Broad beamed remote-station antenna, respectively. All measurements were performed with a center frequency of 59.7 GHz and a bandwidth of 1 GHz for four channel configurations at the nine positions.

II-2. Measurement Results

The complex valued transfer functions of the channels were measured by frequency sweeping method, and then an inverse Fourier transform was applied to the measurements to give time domain impulse responses [1][2]. The root-mean-square(rms) delay spread (RDS) values and the normalized received power (NRP) values are estimated from the impulse responses. The RDS value is a good measure of the dispersion of the radio channel and is an important parameter for determining the maximum symbol rate [4]. The NRP(normalized received power) is also important parameter to estimate the power loss ratio and the link budget between the transmitter and the receiver [3]. In Fig. 2, the RDS and the NRP of the four channel configurations are calculated at each position.



(a) RDS distribution



(b) NRP distribution

Fig. 2. RDS and NRP distribution of measurement positions for each channel configuration(CS, ES, CB, EB)

In Fig. 2(a), the RDS values are plotted against the measurement positions for each channel configuration. The RDS values are less than 55 nsec. The RDS values of ES and CS channel are in general smaller than those of EB and CB channel.

The CS configuration has the lowest RDS values overall. The beam pattern of the remote-station antenna has a large impact on the RDS.

The distributions of NRP are obtained from the received power for each channel configuration in Fig. 2(b). The NRP of CS and CB channel are larger than those of ES and EB channel. And the NRP of CB is even larger than that of ES.

Ⅲ. Simulation of the BER Performance

Ⅲ-1. OFDM Transmission Model and Simulation Parameters

To analyze the performance of four channel configurations(CS, CB, ES, EB) on 60 GHz band indoor high-speed transmission channels, we refer to the OFDM transmission model given in Fig. 3 [5]-[7].

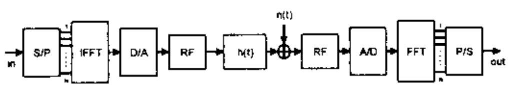


Fig. 3. OFDM transmission model

In the simulation, following simulation parameters were used.

- Sampling frequency : 200 MHz
- IFFT/FFT points : 256 (Block length:1280 nsec)
- Subcarrier spacing : 781.25 kHz
- Cyclic prefix samples : 32 (Guard interval:160 nsec)
- Raw data rate : 355 Mbps
- Subcarrier modulation : QPSK, DQPSK
- Channel : AWGN, four channel configurations (CS, CB, ES, EB)
- Remote-station position : 2 and 9

Ⅲ-2. Results on BER Performance Analysis

In Figs. from 4 to 7, the bit error rate (BER) for uncoded data are plotted at various E_b/N_o. Figs. 4 and 5 are for the receiver position 2 and Figs. 6 and 7 are for the position 9. In Figs. 4 and 6, data are QPSK modulated while in Figs. 5 and 7, data are DQPSK modulated. In all cases, the received signal is detected without any equalization.

The CS and ES configurations with sharp beam remote-station antenna consistently achieve lower bit error rates than the CB and EB configurations with broad beam antenna. This shows that using sharp beam antenna achieves superior performances than using broad beam antenna. When the remote-station antenna is at position 2 in Fig. 4 and 5, ES and EB configurations attain BER performances at each E_b/N_o very close to those achieved by CS and CB, respectively.

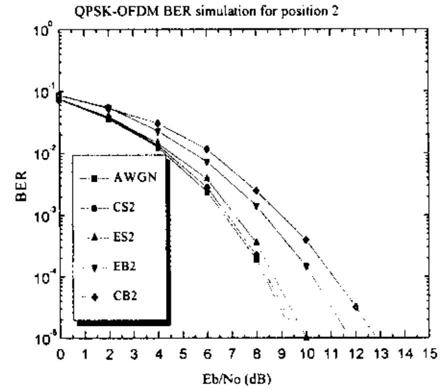


Fig 4. QPSK-OFDM BER simulation for position 2

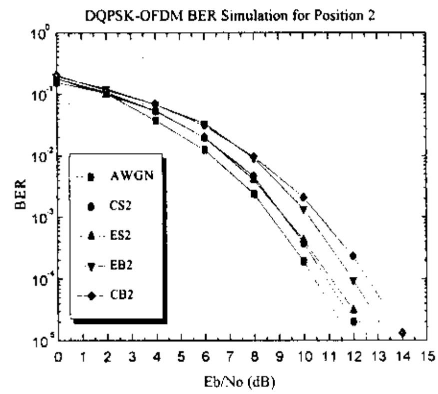


Fig. 5. DQPSK-OFDM BER simulation for position 2

At position 9 in Fig. 6 and 7, CS and EB still have little differences in performance, but CB and EB now show performance gaps of 3 dB and 1.5 dB at BER of 10^{-3}, respectively.

In these figures, the bit error rates are plotted for each E_b/N_o. However, recalling the NRP plot of Fig. 2(b), the actual received E_b/N_o will be different for each configuration for a given transmitter power and receiver sensitivity.

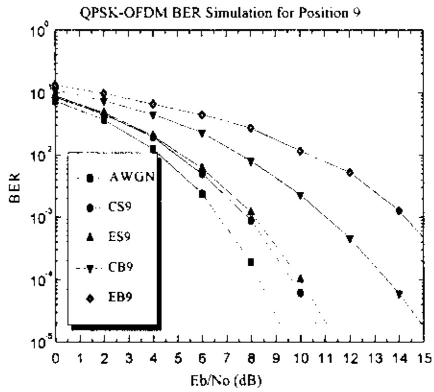


Fig. 6. QPSK-OFDM BER simulation for position 9

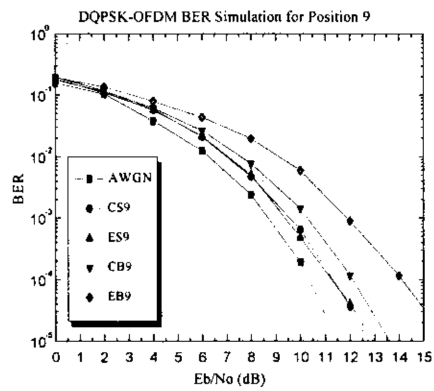


Fig. 7. DQPSK-OFDM BER simulation for position 9

CB and EB of broad beam pattern antenna suffer about 10 dB penalty in E_b/N_o over CS and ES of sharp beam antenna at both positions, respectively. ES and EB with edge positioned base-station antenna are also penalized by about 10~15 dB over CS and CB. When we take these NRP values into considerations in the BER comparison, the performance gaps will be even further magnified.

We therefore conclude that CS attains the best performance and thus should be chosen. However, in practice the broad beam antenna is preferred over the sharp beam antenna from the user point of view. Among the configurations with broad beam antenna, CB with DQPSK modulation achieves the best performance.

Ⅳ. Conclusions

In this paper, 60 GHz band indoor wireless channels are measured with four different configurations in a typical office environment. RDS and NRP value of each configuration are estimated from the measurements. At two selected positions of the room, the bit error rate performances of each configuration are compared with QPSK/DQPSK OFDM modulation. Overall, the sharp beam remote station achieves superior performances than the broad beam remote-station in terms of both bit error rate and NRP penalty. CS and CB configurations with the center positioned base station antenna always achieve superior performances compared with ES and EB configurations with the edge positioned base-station antenna in terms of BER and NRP penalty. Finally, QPSK modulation even without equalization attains lower BER values than DQPSK modulation for all cases except for CB and EB at position 9 of Fig. 7.

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