The Effect of Human Body on Indoor Radio Wave Propagation at 57-64 GHz

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Introduction

Seven GHz bandwidth around 60 GHz frequencies has been released to develop high-rate short-range wireless data communication for a small area such as an office or a research lab. A regular propagation phenomenon in such environment is the shadowing of the Line-of-Sight (LOS) link caused by moving people. One research shows this phenomenon disconnects the LOS link for 2% of the time [1]; however, the blockage ratio could be higher depending on the number of people, geometry of the room, and transmitter-receiver (TX-RX) configuration. Moreover, it must be determined that how much attenuation is caused by a human body obscuring the LOS path. In this paper first the accurate ray-tracing analysis is used to answer this question. Next, a test set-up is developed to verify the accuracy of the simulation results by field tests.

Ray-tracing Analysis

In this work, a 3-D ray-tracing modeling, Geometrical Optics plus diffraction, is employed to evaluate the signal coverage at 60GHz frequency range for a regular office area. Fig. 1 and Fig. 2 show the simplified map of a seminar room used in this research to study the human body effects on wave propagation. The size of the room was 7.42m × 6.25m × 2.73 (l×w×h). The top and left walls in Fig. 1 (A and B in Fig. 2) were partially covered by whiteboards. Measurements showed that the reflection coefficient of these whiteboards is very high. Two layer windows had been installed on wall C and parts of the wall B and D in Fig. 2. There were also a big conference table and large-screen TV in this room. The floor was covered by carpet. The top left corner of the room, in proximity to whiteboards, was designated to the test area. The empirical data reported in [2] and [3] was used to calculate the reflection coefficients of the material in the room. Moreover, to evaluate the human body shadowing effect the measured permittivity data for biological tissues in [4] was used.

Two horn antennas with 24dB gain at 60GHz and roughly 10° beamwidth were used as the transmitter and receiver antennas (to model the antennas used in the field tests). Such directive antennas are used for two reasons: to provide the radiation gain required to combat high path loss at mm-wave range, and to attenuate the multipath components from Non-Line-Of-Sight (NLOS) directions. Fig. 3 shows the H-plane and E-plane radiation patterns of the horn antenna derived by HFSS software. The distance between TX and RX antennas, vertical distance in Fig. 1, was fixed at 3m. The heights of the receiver and transmitter antennas from the floor are 130 and 135cm, respectively. The

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horizontal distance between the transmitter antenna and the left wall (whiteboard) was 117cm.

A human body model, shown in Fig. 2, was placed 1m before the RX antenna to cover the 3dB beamwidth of both antennas. It was 1.7m tall. The RX antenna was moved along a horizontal line, in steps of 1mm, to cover a distance of ±60cm around the initial position. The total received power of all rays was calculated at each RX antenna position. This procedure was repeated at three frequencies, 57, 60 and 64GHz, with and without human body to find the shadowing loss.

Fig. 4 shows the attenuation in the received power caused by the human body at these frequencies along the horizontal line shown in Fig. 1. The maximum attenuation is occurs around x=0cm which is more than 40dB. The attenuation is larger for higher frequencies. The received power is almost symmetrical around the initial position (x=0). The maximum attenuation varies between 45 to 50 dB for different frequencies.

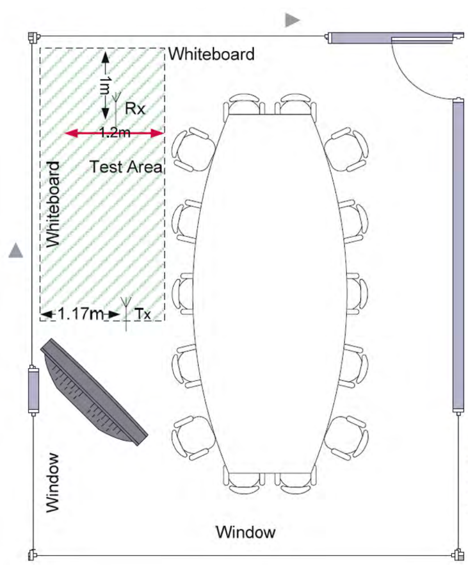

Fig. 1 Seminar room

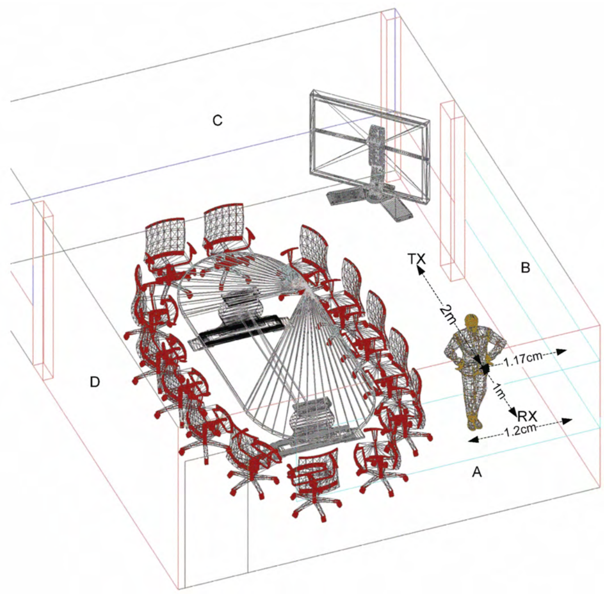

Fig. 2 The 3D view of the simulation environment.

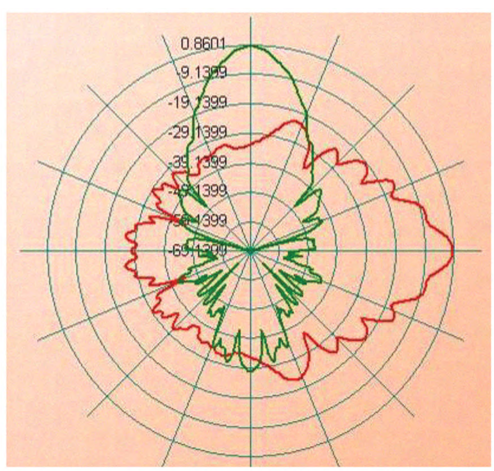

Fig. 3 Radiation pattern of the horn Antenna

Experimental Results

A test set-up was developed to measure the attenuation of the human body at 50-75 GHz frequency range. Fig. 5 shows parts of this set-up, which consisted of two rectangular horn antennas with 24dB gain at 60GHz as discussed earlier. Agilent E8267D PSG with E8257DS15 mm-wave source module was used as the source. On the receiver side, Agilent E4448A spectrum analyzer along with 11974V preselected mixer was used to measure the spectrum of the received signal. Wave absorbers with 40dB attenuation were used to weaken the reflections from source module and mixer. The coordinates of the RX and TX antennas are the same as those shown in Fig. 1 and 2.

To measure the shadowing loss of the human body, the RX antenna was moved in steps of 5cm. At each point the received power spectrum was measured at three frequencies, i.e. 57, 60 and 64GHz. Fig. 6 shows the LOS (no shadowing) measured spectrum at one of these RX locations. Fig. 7 compares the measured shadowing loss with ray-racing results for the same room. There is a good agreement between the simulation and measurement results from x=-10 to x=60cm. The maximum measured loss is around 40dB which occurs when the human body blocks the LOS path completely.

In conclusion, it was shown that the shadowing loss of the human body at 57-64GHz can exceed 40dB. Ray-tracing analysis provides good approximation of the wave propagation at this frequency range. These results are of crucial importance for link budget design of 60 GHz indoor wireless networks.

Acknowledgement

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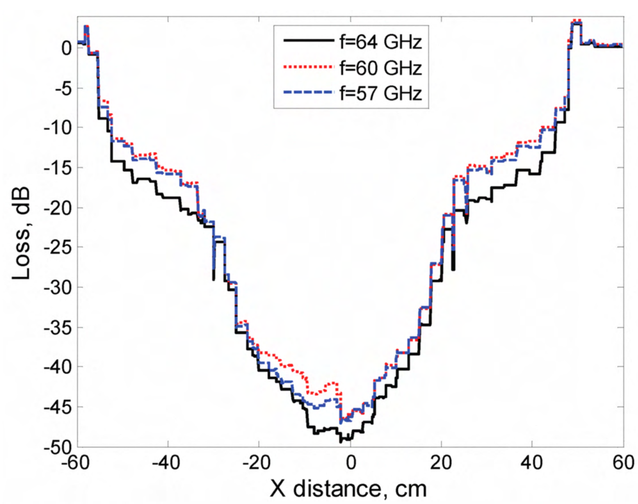

Fig. 4 Ray-tracing results. These curves show the difference between the calculated received power with and without human body.

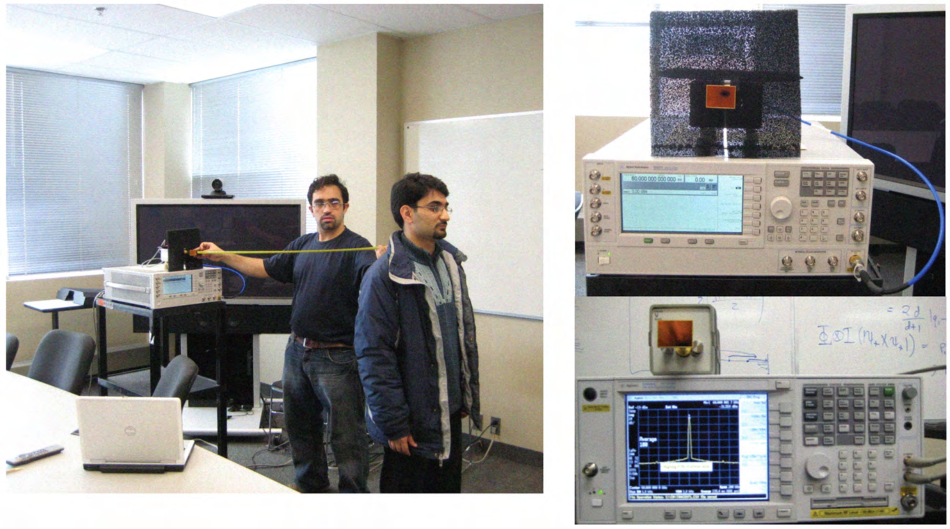

Fig. 5 Left: Test set-up. Top-Right: Source and transmitter antenna. Bottom-Right: Receiver antenna and spectrum analyzer.

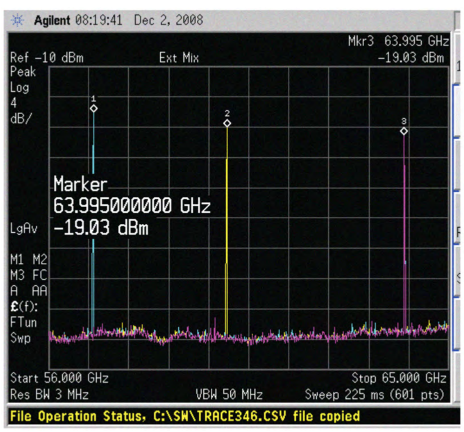

Fig. 6 Spectrum of the received power

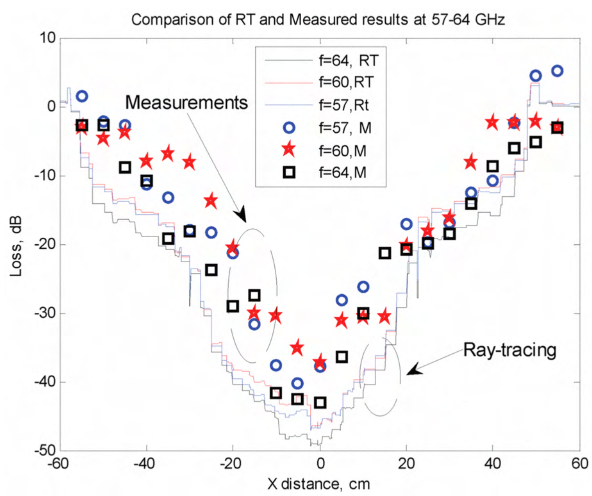

Fig. 7 Comparison of the experimental and simulation results.

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