

The characteristics of millimeter-wave propagation for NLOS in indoor

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Abstract— The propagation characteristic of 60 GHz with NLOS case was measured in an empty office room, which was 13 x 8.6 x 3 m. The NLOS was made by a partition which was in front of a transmitter. The transmitter was located in a corner and the receiving points were 70 and they had 1 m spacing between them. Four antennas, an omni directional antenna, a 45° beamwidth, a 30° beamwidth, and a 12° beamwidth horn antennas were used at receiver. Also, the simulated results using ray-tracing method was compared to measured results. Finally a propagation model for 60 GHz with NLOS was proposed to use in indoor.

Keywords— 60 GHz, NLOS, ray-tracing

I. INTRODUCTION

Millimeter-wave band is unsuitable for using outdoor and long distance because it has high attenuation by oxygen of atmosphere and rain[1], but it has been suggested for using indoor and short radio path[2],[3]. The spectrum resource of millimeter-wave is plentiful and it can be used with wide bandwidth, so millimeter-wave is suitable for multimedia high speed transmission[4]. Recently, a product using 60 GHz, in case of line-of-sight(LOS), can transmit moving pictures with HD class is showed in the market.

People are moving in the indoor at any time. The radio path of 60 GHz is obstructed by furniture or any other ornament. It needs to study of non line-of-sight(NLOS) case for stable and seamless wireless service.

The propagation characteristic of 60 GHz with NLOS case was measured in an empty office room. The NLOS was made by a partition which was in front of a transmitter. Also, the simulated results using ray-tracing method was compared to measured results. Finally a propagation model for 60 GHz with NLOS was proposed to use in indoor.

II. MEASUREMENTS AND SIMULATIONS OF 60 GHz PROPAGATION CHARACTERISTICS

The measurements of 60 GHz propagation characteristics were done in an empty room, which was 13 x 8.6 x 3 m. The transmitter was located in a corner and composed of a mmW

band signal generator, an amplifier, and an omni directional antenna. The receiver was composed of a LNA, a spectrum analyzer, and a computer to record the measured data. The receiving points were 70 and they had 1 m spacing between them. Four antennas, an omni directional antenna, a 45° beamwidth, a 30° beamwidth, and a 12° beamwidth horn antennas were used at receiver. A partition was in front of the transmitter, then almost radio paths were NLOS. The height of transmitter and receiver was 1.5m, and the distance of between them was minimum 2 m to maximum 11.7 m.

The ray-tracing with image method was used for simulation which considered all conditions like glass windows, iron doors, and 4 pillars located at 4 corners. It was included reflections as well as diffractions.

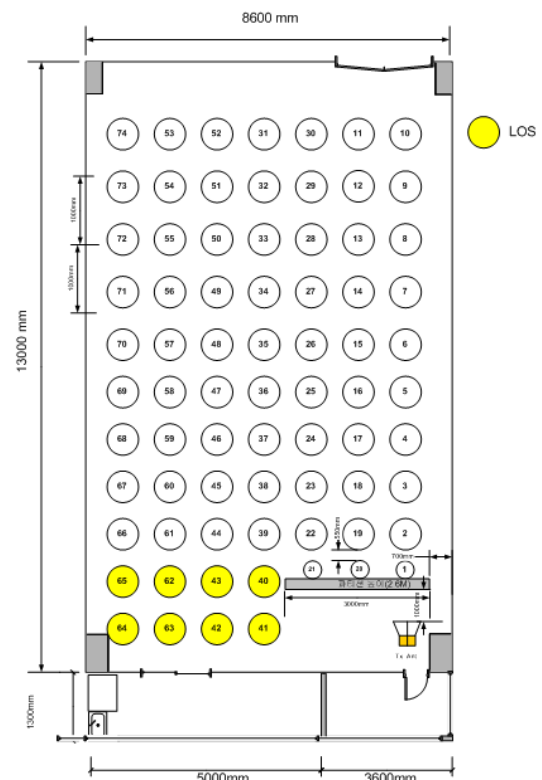


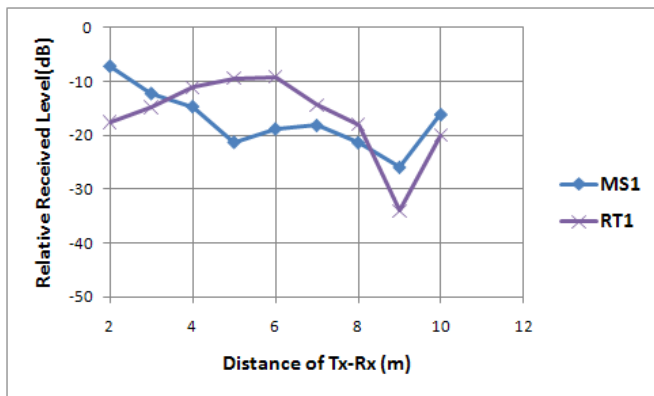
Figure 1. An empty office room and position of a transmitter and receivers



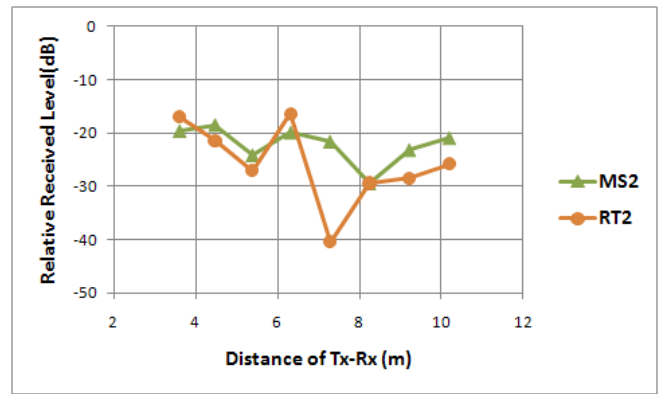
Figure 2. A partition to make NLOS

III. MEASUREMENT AND SIMULATION RESULTS ANALYSIS

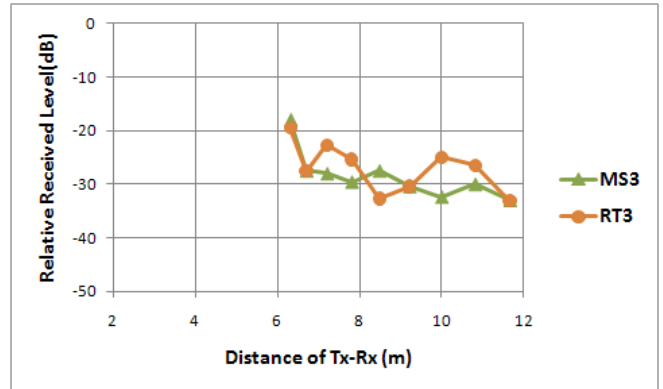
Figure 3 shows comparison of measurement and simulation results which are relative received level according to the distance of between Tx and Rx. MS1, MS2, MS3, and MS4 represents measurement results, and RT1, RT2, RT3, and RT4 represents simulation results. There are very fluctuating received level because of multipath fading from many reflection and diffraction waves. Figure 3 (a), (b), and (c) comes with both of omni directional transmitter and receiver antennas and (d) comes with omni directional transmitter antenna for Tx and 30° beam width horn antenna for Rx. There are some difference at 2 m, 5 m, and 6 m points between MS1 and RT1, at 7.2 m point between MS2 and RT4, and at 4.5 m point between MS4 and RT4. They are good agreement at the remained other points between measurement results and simulation results.



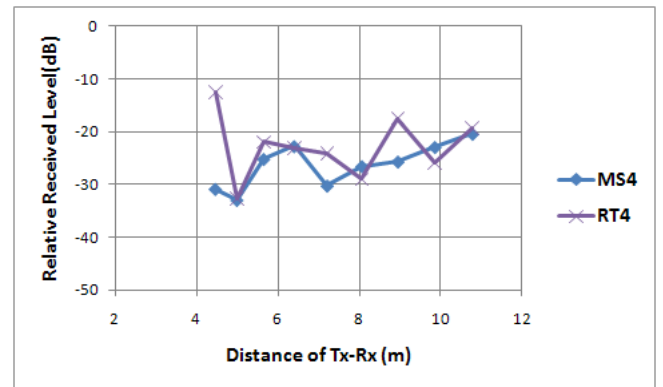
(a)



(b)



(c)



(d)

Figure 3. Comparison of measurement and simulation results

The simple propagation model represented by attenuation index is equation (1). Y means path loss, X means distance between Tx and Rx. The attenuation index of free space propagation is 20.

$$Y = -A \cdot \log_{10}(X) + B \quad (1)$$

Table 1 shows the attenuation index according to antenna beam width. From this measurement and simulation results, we acquired that the attenuation index decrease in proportion as beam width decrease.

<Table 1> Attenuation index according to antenna beam width

Beam width	Omni	45°	30°	12°
Measurement	15.9	5.8	1.9	1.3
Simulation	12.9	4.3	3.0	2.6

IV. CONCLUSIONS

Generally the attenuation index of propagation model is higher than that of free space. It is 20 ~ 30 in case of LOS mobile communication, and 30 ~ 40 in NLOS case[5],[6]. But it is 18 ~ 22 in mmW band because they have LOS and indoor cases. That means it will have smaller loss than free space loss in some cases.

In this study, the attenuation indices from measured and simulated results are very small compared to 20, that of free space. The attenuation index decrease in proportion as beam width decrease. The reasons are the multipaths from reflections and diffractions are longer than direct path and the room has maximum 13 m which is not enough to show the effect of distance.

ACKNOWLEDGMENT

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