

Building Entry Loss Model for 24 to 31GHz band

Bolun Guo¹, Yong Wu¹, Jian Jiao¹, Boya Lv¹, Feng Zhou², Zhen Ma³, Jing-lu Sun²

¹Wireless Research Department, Huawei Technologies Co., LTD, Beijing, China

² China Academy of Information and Communication Technology, Beijing, China.

³Beijing Key Laboratory of Network System Architecture and Convergence Beijing University of Posts and Telecommunication, Beijing, China

Abstract - The millimeter wave is considered as one of the most important resources for the IMT system towards to the 5G. In this paper, building entry loss model of typical office building is studied. The characteristics are analyzed on the basis of 24 to 31 GHz measurement results.

Index Terms — Millimeter wave, Penetration loss, building entry loss.

1. Introduction

IMT system is widely deployed in below 6GHz band, but due to the rapid increase of the spectrum requirement, the new allocated spectrum in below 6GHz band is very limited. Millimeter wave band which can provide wider bandwidth is considered as the important complementary band of future 5G systems. However, higher frequency signal will face higher building entry loss which may reduce the outdoor to indoor coverage [1] and the related measurement data is limited because most of are below 6GHz [2]. In addition, building entry loss is also important to evaluate the compatibility between indoor IMT systems, e.g. indoor IMT station & indoor IMT terminal and other incumbent services in millimeter wave. This paper will evaluate the building entry loss model of office building in 24 to 31GHz frequency band.

The outline of the paper is as follows: Section 2 introduces building entry loss measurement scenario and other related parameters, Section 3 gives a description of the measurement results of the material penetration loss and building entry loss, Section 4 presents the proposed building entry loss model and finally conclusions are given in Section 5.

2. Measurement Scenario and Related Parameters

The measurements are taken in the environment shown in Fig. 1. One typical office buildings in China is measured, named as building A. Building A is with reinforced concrete shear wall and one-way transparent glass which is with a thin metal coating. The thickness of the bearing wall is 35cm ~ 38cm. In addition, the building's exterior wall is being equipped with thermal insulation material whose structure is the foam polyethylene sheet and metal reflective layer. The measurements are taken in frequency bands between 24 and 31 GHz in order to investigate the frequency dependence of the measurements.

The devices of measuring system are shown in Table I. Because the office building contains one-way transparent glass and concrete, material penetration loss is measured at first. In this case, the distance between transmitter and receiver is 2m. The transmitter and receiver's antenna bore sight is vertical to the material.



Fig. 1. Office building test scenario

TABLE I
Measurement System Parameters

| | |
|----------------------|--|
| Frequency (GHz) | 24GHz±250MHz, 28GHz±250MHz and 31GHz±250MHz |
| Transmitting antenna | Horn-directional vertical polarization antenna |
| Receiving antenna | Horn-directional vertical polarization antenna |
| Transmitter | Agilent E8267D signal generator |
| RF power amplifier | The output power in the test is 20dBm |
| Receiver | Agilent N9030A signal analyzer |

In addition to the material penetration loss measurement, the building entry loss is also measured. The receiving antenna is on an outdoor platform which is on 4th floor. Some transmitting points on the 4th floor indoor and on the 5th floor indoor are selected. The transmitter and receiver's antenna bore sight is vertical to the building wall to simplify the measurement. There are total 21 transmitter test points in the office building, 8 test points only has the outer wall loss and other 13 test point has both outer wall loss and inner wall loss.

3. Material Penetration Loss and Building Entry Loss Measurement Results

(1) Material Penetration Loss

The material penetration measurements results are shown in Fig. 2. One-way transparent and concrete materials used in

building A are tested to get the penetration loss. In order to compare the loss difference between below 6GHz and above 6GHz, 2.6GHz loss is also measured. Based on the measurement results, concrete material shows high frequency dependence characteristic. One-way transparent glass penetration loss is stable across different frequency. This makes the glass building entry loss higher than concrete wall in below 6GHz, but lower than concrete wall in 24-31GHz. It should be noted that the one-way glass loss value is larger than 20dB in both below and above 6GHz.

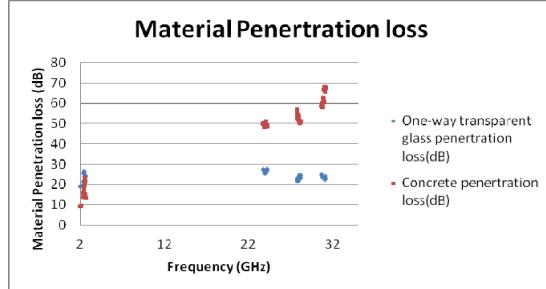


Fig. 2. Material penetration loss.

(2) Building entry Loss

Compared with material penetration loss, building entry loss is more close to the real scenario. The signal's entry loss is dependent not only the material itself, but also depend on the structure of the building, the location of the transmitter or the receiver in the building. Fig. 3 provides the outer wall building entry loss measurement results. In addition to 24 to 31GHz case, 3.5GHz, 5GHz and 15GHz results are also provided to compare the difference performance. Based on the measurement results, high frequency dependence characteristic is observed.

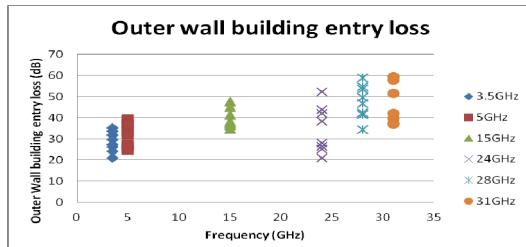


Fig. 3. Outer wall building entry loss.

If both the inner wall and outer wall loss are considered, the results will be more complex because of the complex building structure and location variability. Fig.4 provides the CDF curve of the 24 to 31GHz building entry loss. 3.5GHz results are also provided to compare the performance.

4. Indoor Building Entry Loss Model

The measurement results show that material penetration and building entry loss maybe modeled as a frequency dependent formula as in Equation (1). The parameters for one-way transparent and concrete materials and office building entry loss in this model are shown in Table II. σ is

the standard deviation of the measured path loss and estimated loss based on this model.

$$\text{PenetrationLoss} = a + b \times f(\text{GHz}) + N(0, \sigma) \quad (1)$$

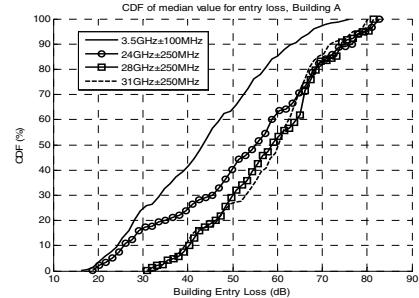


Fig. 4. Outer + inner wall building entry loss.

TABLE II
Penetration Loss Parameters

| Parameter | a | b | σ |
|---|-------|-------|----------|
| One-way transparent glass | 25.56 | -0.04 | 1.7 |
| Concrete | 8.14 | 1.71 | 3.5 |
| Office building entry loss (outer wall) | 27.85 | 0.60 | 8.1 |

ITU-R Report M.2135 [3] provides the outdoor to indoor path loss model as the following,

$$\text{PathLoss} = PL_d + PL_{tw} + PL_{in} \quad (2)$$

Where PL_d , PL_{tw} , PL_{in} are the path loss between Tx antenna and Rx antenna, building penetration loss, and path loss in indoor, respectively. Path loss in indoor is defined as $0.5*din$ which also includes the inner wall penetration. Based on the measurement, the inner wall building penetration depends on the material and location very much and $0.5*din$ may be lower than the actual loss if the signal faces higher loss material, e.g. concrete [4]. Further study about this inner wall penetration is necessary.

5. Conclusion

In this paper, 24 to 31GHz one-way transparent glass and concrete penetration loss is analyzed at first. Then the office building entry loss is analyzed. The measurement results show that building entry loss maybe modeled as a frequency dependent formula. Inner wall building entry loss is also an important and the CDF loss curves which constrain both outdoor and indoor loss are provided.

References

- [1] Eliane Semaan, Fredrik Harrysson, Anders Furuskar, Henrik Asplund, "Outdoor-to-Indoor Coverage in High Frequency Bands," IEEE Globecom 2014 workshop, 2014.
- [2] Rep. ITU-R P.2346" Compilation of measurement data relating to building entry loss," ITU-R Report, P Series, ITU.
- [3] Rep. ITU-R M.2135-1" Guidelines for evaluation of radio interface technologies for IMT-Advanced," ITU-R Report, M Series, ITU.
- [4] Minoru Inomata, Wataru Yamada, Motoharu Sasaki, Takeshi Onizawa, "Outdoor-to-Indoor Path Loss Model for 8 to 37 GHz Band," ISAP2015, 2015.