Measurements of Shadowing Loss at 3 and 7 GHz for Small-Cell Planning in University Building

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***Abstract*—This paper proposes the measurement results for the shadowing loss in the university building. Especially, the class room was investigated at 3 and 7 GHz. The measurements of shadowing loss for the classroom building with a corridor was performed at the height of the 2-storey (6.3 m). The 50% of shadowing losses are 11.1 and 22.7 dB at 3 and 7 GHz, respectively. The transmission losses at the corridor also measured with the 2.8 and 10.7 dB at 3 and 7 GHz, respectively. This fact can be utilized for the small-cell planning in the university.**

I. Introduction

The definition of building shadowing loss was established by the International Telecommunication Union (ITU-R) [1], which is written as the difference between the median of the location variability of the signal level outside the illuminated face of the building and the signal level outside the opposite face of the building at the same height above ground, with multipath fading spatially averaged for both signals.

The schematic view of the shadowing loss is shown in Figure 1 from [1], which includes the direct path drawn in the red dotted line and the detour path drawn in red solid line. Therefore, it can be said that the building shadowing loss includes the building entry loss [2-5], exit loss [6-7], and the losses within building [8]. Meanwhile, the propagation loss in outdoor environments are discussed in [9-10]

The building entry loss are studied in [2-5] and the propagation model has been established. The building exit loss are considered to be the same as the building entry loss [4], and their terms are used interchangeably [1]. The losses within the building are, however, not reported much even the definition is built in [1]. This shadowing loss is useful for the small cell planning of sharing the same frequency band in the small area.

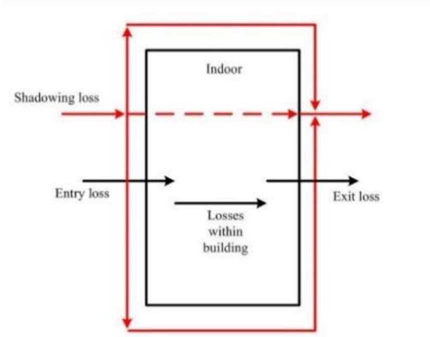


Fig. 1. Schematic view of shadowing loss from Recommendation ITU-R P.2040-1

II. Measurement of Building Shadowing Loss

A. Measurement campaign

Figure 2 shows the 10-storey building with two classrooms and one corridor. Figure 2 (a), (b) shows the illuminated side and the opposite side of the building, respectively. The wall is composed of the glass and the concrete material. One notes that the size of the window and concrete wall is different between the illuminated and opposite side. Figure (c) shows a photograph of the side view of the building. The emergency stairway is connected to the building, and the trees with 3-storey are placed. As shown in Figure 2(d), the classroom is an open space with a series of desks and chairs. Figure 2(e) is a corridor between the classrooms. The door of the classroom is made of the metal, and a series of lockers is placed at one-side.

(a) (b) (c)

(d) (e)

Fig. 2. Building with two classroom and one corridor in Chosun University (Gwangju, Korea): (a) illuminated side, (b) opposite side (c) side view of building, (d) classroom, (e) corridor

The transmitter (Tx) and receiver (Rx) systems can be seen in the photos in Figure 3. The transmitter system consists of a signal generator, power amplifier, 6-meter plastic supporter, and an omnidirectional biconical antenna. The receiver system consists of a spectrum analyser, two kinds of low noise amplifiers, 6-meter plastic supporter, and a biconical antenna. When the measurements are performed in the corridor, the local averaging stage was utilized instead of the 6-meter plastic supporter. A laptop was used to acquire the recorded data from the spectrum analyser and control the motion controller of the local averaging stage. Measurements were conducted with a sinusoidal signal at frequencies of 3 and 7 GHz.

(a) (b) (c)

Fig. 3. The measurement setups for building shadowing loss: (a) transmitter (Tx), (b) receiver (Rx) in the opposite, (c) receiver (Rx) with local averaging stage in the corridor

The positions of the transmitter and receiver are marked in Fig. 4. The hollow square is the position of transmitter, which is aligned with the centre of the window block. The hollow circle in Fig. 4 is the reference point. For each transmission point, the reference positions are aligned by moving the Rx system. The interval of the reference position is 1 m. The red filled circles shown in Fig. 4 are the receiving positions, and its interval is also 1 m. All points of Tx and Rx is the height of 2-storey of 6.3 m.

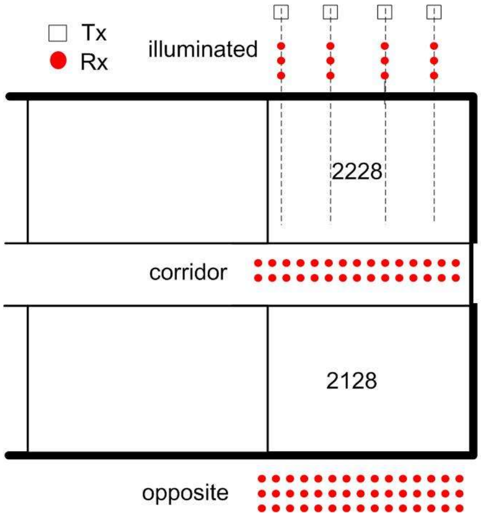


Fig. 4. The Tx and Rx measurement points for building shadowing loss

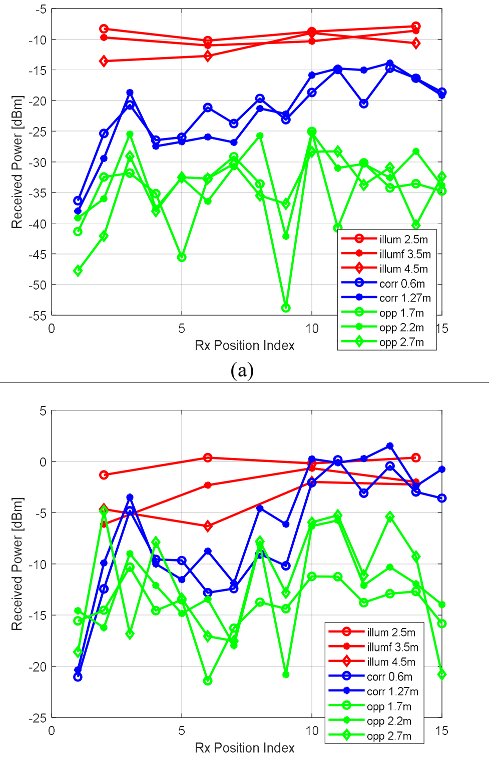
B. *Measurement results of building shadowing loss*

The received power at 3 and 7 GHz are shown in Fig. 5. The Rx position index starts from the left of the Rx group in Fig. 4. The value in the legend with the text "illum" in Figure 5 means the distance from the Tx antenna to the reference position. The value in the legend with the text "corr" in Figure 5 means the distance from the concrete wall of the corridor to the Rx position. The value in the legend with the text "opp" in Figure 5 means the distance from the window of the opposite side to the Rx position through the building.

As shown in Fig. 5, the receive power at the illuminated position is the highest, the power at the corridor is medium, and the receiver power at the opposite side is the lowest. As the Rx is positioned far away, the received power is decreased. This phenomenon is the general rule and can be examined in both frequency of 3 and 7 GHz.

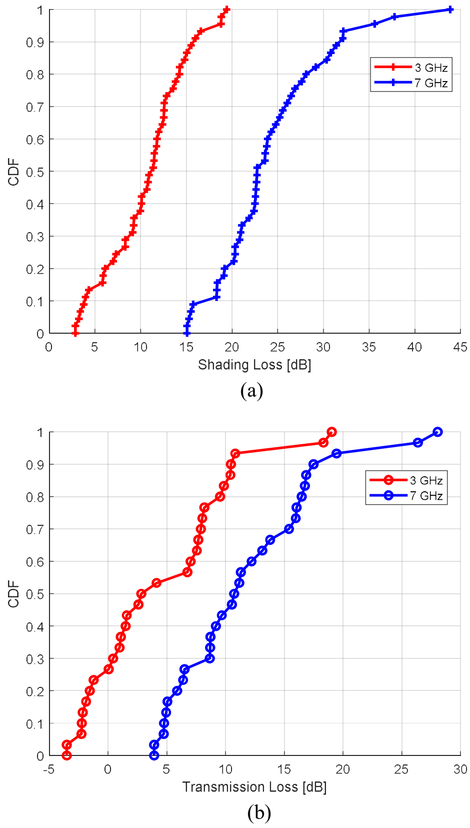
However, one notes that the power differences between the illuminated side, Rx in the corridor and Rx on the opposite side are distinct for 7 GHz compared with 3 GHz. Another point that should be noted is that the receive power at the right side of the Rx group is higher than the left side of the Rx group. As shown in Fig. 5(a), even at 3 GHz, the received power at the corridor is similar to that at the reference position.

The cumulative distribution function (CDF) of building shadowing loss is drawn in Fig. 6. The median values of the receive power at the illuminated positions are calculated and used for evaluating the shadowing loss at the opposite side and the transmission loss at the corridor Fig. 5 (a) revealed 50% losses of 11.1 dB and 22.7 dB at the opposite side at 3 and 7 GHz, respectively. Fig. 5 (b) revealed 50% losses of 2.8 dB and 10.7 dB at the corridor at 3 and 7 GHz, respectively. The loss is smaller than 0 for the corridor in Fig. 6(b) is consider due to the diffraction and leakage around the building.



(b)

Fig. 5. Received power for measurement results: (a) at 3 GHz, and (b) at 7 GHz



(b)

Fig. 6. CDF for measurement results: (a) Shadow loss at the opposite side, (b) Transmission loss at the corridor

III. CONCLUSION

In this study, the shadowing loss for the classroom building with a corridor was performed at the height of the 2-storey (6.3 m). The 50% of shadowing losses are 11.1 and 22.7 dB at 3 and 7 GHz, respectively. The transmission losses at the corridor also measured with the 2.8 and 10.7 dB at 3 and 7 GHz, respectively. From this measurement campaign, we note that the shadowing loss passing through the building is much different from the transmission loss measured at the corridor which is the lateral center of the building. We can also note that as the Rx approaches the edge of the building, the received power increased up to the that for the reference position. This information as well as the shadowing loss could give guidance for sharing studies of small cell planning.

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