Path Loss Measurements and Modeling for Indoor Office Scenario at 28 and 38 GHz

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Abstract - **In this paper, we present the experimental path loss models for a typical indoor office propagation scenario. Channel measurements have been performed using a wideband channel sounder in the 28 and 38 GHz frequency bands. We derive path loss exponents and shadow fading factors based on the two popular path loss models, i.e., Close-in (CI) free space reference distance model and Floating-intercept (FI) model. Our measurement results show that the CI model is more appropriate for indoor path loss modeling than the FI model.**

Index Terms — **Millimeter-wave, channel measurement, path loss models, indoor office.**

1. Introduction

According to recent ITU-R Working Party 5D studies on "Framework and overall objectives of the future development of IMT for 2020 and beyond" [1], it is expected that the frequency bands above 6 GHz can be utilized for the fifth generation (5G) wireless communications. The ITU-R Working Party 3K also established a new Correspondence Group CG-3K-6 which is to study the impact of higher frequencies (from 6 to 100 GHz) to propagation models and related characteristics. The CG-3K-6 primarily targets the modification of Recommendations ITU-R P.1411 and P.1238 in the higher frequencies, with the aim of progressing as much as possible the above studies until the end of 2017 [2]. These recommendations, however, still need to be updated based on more extensive measurement data for covering millimeter-wave bands. Furthermore, it is necessary to develop more general path loss models not only geometry-based specific models for popular usages. For this reason, this paper investigates the general path loss models and performances through the analysis of field measurement data which is obtained in an indoor office environment at 28 and 38 GHz.

2. Summary of Path Loss Measurements

To obtain path loss characteristics, we conducted a measurement campaign in a typical office environment at 28 and 38 GHz using the ETRI channel sounder [3] and a pair of omnidirectional antennas equipped at the transmitter (TX) and receiver (RX). Table I describes the configurations for the office measurement.

Fig. 1 shows the office map on which the locations of TX and RX are marked. The office has a dimension of 72 m (L) x 23 m (W) x 2.6 m (H), in which cubicle areas, meeting rooms, corridors, pillars, etc. are laid out. The outside walls of the building are composed of concrete and large tempered glass, whereas the inside walls and ceilings are made of reinforced concrete, steel and plaster board. As shown in the Fig. 1, path loss measurements collected at two TX (red points) and 48 RX locations (blue, green and orange points distributed evenly in the office) with the TX-RX separation distances ranging from 6 m to 54 m, consequently a total of 67 TX-RX location combinations (35 in LOS and 32 in NLOS conditions). It is noted that the TX and RX antennas are installed at the height of 2.5 m and 1.2 m, respectively.

TABLE I
Path Loss Measurement Configurations

Configurations	Parameters
Center frequency	28 / 38 GHz
Channel Bandwidth	500 MHz
PN code length of probing signal	4095 chips
Maximum power of TX (w/o antenna)	+29 dBm at 28 GHz +21 dBm at 38 GHz
Gain of omnidirectional antenna	5 dBi at 28 GHz 6 dBi at 38 GHz
Automatic gain control range of RX	60 dB

3. Measurement Results and Analysis

From measured data, the path loss (PL) and shadow fading (SF) parameters are derived based on the two popular path loss models [4], i.e., Close-in (CI) free space reference distance model and Floating-intercept (FI) model.

The CI PL model is given by:

$$\mathrm{PL}(f,d)[\mathrm{dB}] = \mathrm{FSPL}(f,1\mathrm{m}) + 10\log_{10}\left(\frac{d}{1\mathrm{m}}\right) + X_{\sigma} \quad (1)$$

, where n denotes the PL exponent (PLE) and d is distance in meters. X_{σ} is the SF term in dB. FSPL(f,1m) is the free space path loss in 1m reference distance.

The FI PL model is given as:

$$\mathrm{PL}[\mathrm{dB}] = 10\alpha\log_{10}(d) + \beta + X_{\sigma} \quad (2)$$

, where α represents a dependency coefficient with respect to distance, and β is the path loss offset determined typically by fitting with measurement data.

Fig. 2 and 3 show measured path loss results of the 28 and 38 GHz corresponding to TX-RX distance and fitting curves along with the CI (1) and the FI (2) prediction models for LOS and NLOS condition, respectively.

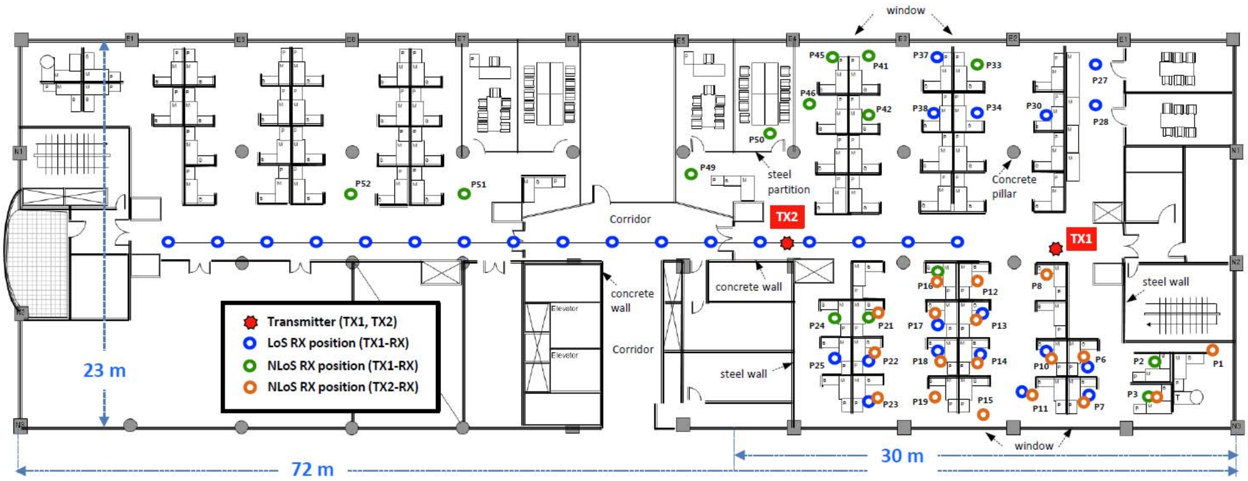

Fig. 1. The office layout and measurement spots at 28 and 38 GHz

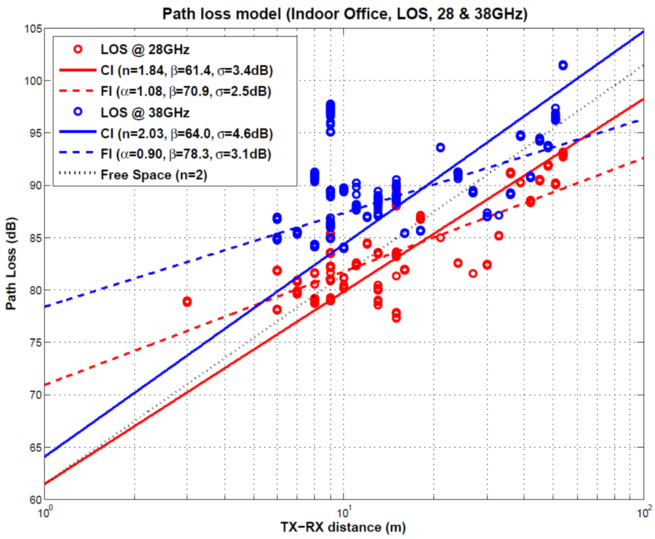

Fig. 2. Path loss results in LOS case and fitting curves based on the CI and FI models at 28 and 38 GHz

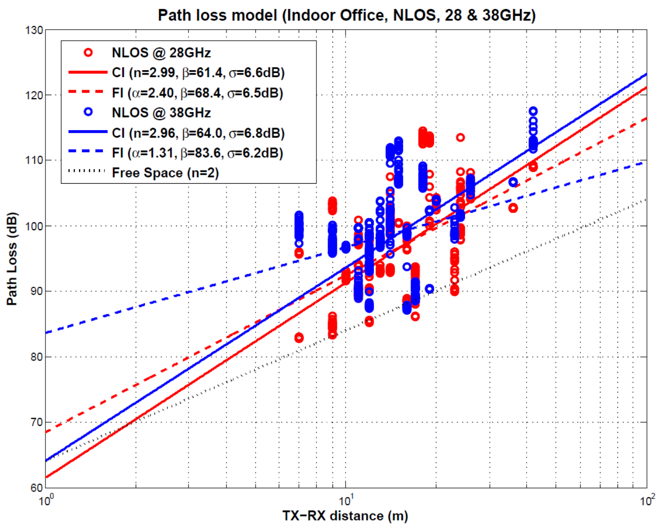

Fig. 3. Path loss results in NLOS case and fitting curves based on the CI and FI models at 28 and 38 GHz

Based on our measurement results, we have the following observation.

- In LOS condition, the PLEs of two CI curves (28 and 38 GHz) are close to the theoretical free space PLE (n=2). The propagation loss of 38 GHz is more severe than 28 GHz in both models.
- In NLOS condition, the PLEs and SFs of two CI curves are similar each other, and the path loss has frequency dependency like LOS case. However, it can be observed that the two FI curves (28 and 38 GHz) intersect with each other at the point of 25 m. Comparing to the CI model, the path loss can be underestimated at closer distance and overestimated at far distance on the FI prediction model.

4. Conclusion

In this paper, we compared two popular path loss models, i.e., CI and FI models, using measurement data in the 28 and 38 GHz for indoor office scenario. Our experimental results show that the CI model is more suitable than FI prediction for indoor office scenario since the CI curves of 28 and 38 GHz are stable at all distances even if standard deviations of two models are similar. These measurement results will be useful for future development of millimeter-wave channel model.

Acknowledgment

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