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# Path Loss Models for 5G Communications System in Corridors Environment

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### ABSTRACT

This paper presents the propagation path loss channel models, developed from real-field measurement in Universiti Teknologi Malaysia (UTM) Kuala Lumpur, Malaysia. The purpose of the study is to characterize the channel at 28 GHz for 5G communications system in line-of-sight (LOS) corridors environment. Measurement campaigns were conducted to measure the wireless signal of received signal strength at three different construction of straight corridors, narrow, wide and open corridors. The large-scale path loss models are developed using the closed-in reference distance (CI) and floating – intercept (FI) modelling approaches. Besides contributing path loss (PL) models at 28 GHz for different corridors dimension, the result found in this work discovered the breakpoint distance (*dbp*) of radio propagation is seen varies differently at those corridors. PLE in CI model, open corridor significantly exaggerates of 1.92 compared to the narrow and wide corridor of 1.60 and 1.83 PLEs respectively. The lower than free-space (PLE is 2) in the corridors, attributes to the waveguide phenomenon within the corridors.

## 1. Introduction

The rapidly increasing demands for higher mobile data rates and ubiquitous data access have led to a spectrum crunch over the traditional wireless communication frequency bands, i.e., below 6 GHz [1]. As the current technology is expected unable to cope with the demand, the new standardization toward fifth generation (5G) communication is aggressively studied [2-6]. However, many aspects of 5G propagation channel have not yet been thoroughly evaluated [7-11].

The key to achieving future generation mobile communication of 5G, the technology has to move to the higher frequency band of millimetre-wave [12,13], where the availability of very large bandwidth in frequency bands. ITU has revealed the attractive focus of 5G deployment range between 24.25-86 GHz in WRC'15 for IMT-2020 [14-18]. As the existing channel model are evaluated

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for as high as 6 GHz [19], the application of the new spectrum bands draws special attention to channel characterization [20-26] .

In a closed environment for LOS scenario, the multipath reflection from surrounding environment, such as ceiling, wall, and floor rise the effect of channel waveguiding [27]. Measurement at 915 MHz and 2.4 GHz in the corridor environment shows the construction of the wide corridor increase the path loss exponent ( $PLE$ ), compared to narrow construction corridor [28,29]. In [30], the measurement campaigns conducted to study the path loss ( $PL$ ) at L-shaped and straight corridor particularly MIMO application.  $PL$  study was conducted at 5 GHz. The short-range channel characterization was conducted at 15 GHz for a different construction of indoor corridor. The closed and semi-closed corridor have been evaluated for  $PLE$  and shadow fading, where the authors agree  $PLE$  is unreliable to the carrier frequency in LOS case [31].

In channel characterization, the existence of obstacle may degrade the received signal strength (RSS) due to deflecting effect that bounces the [32-36]. In [37], the propagation work on the NLOS link due to deflection obstacle was measured in the T-shape corridor at 60 GHz. In the non-straight corridor environment, the multipath fading comes through reflection, diffraction, and transmission. The study performed in [38] presented the narrowband  $PL$  models base on measurement campaigns and ray-tracing approach at 900 MHz and 2.44 GHz.

The similar approach of ray-tracing is applied to characterize corridor in non-line-of-sight (NLOS) scenario [39]. Many of empirical models are developed for corridor environment, especially below 6 GHz. To the author's best knowledge, there is none work literature studied the  $PL$  propagation model for the different structure of corridor, particularly at 28 GHz. In this paper, the measurement base channel propagation was conducted to evaluate and model  $PL$  and shadow fading, for 5G communication system at 28 GHz. Three types of corridors were measured, open structure outdoor corridor, narrow structure indoor corridor, and wide structure tunnel corridor.

The author in [40] has discussed about the propagation for third-order closed-in  $PL$  model for indoor corridor measurement campaign. The path loss for similar enclosed corridor has been measured at 28 GHz and 38 GHz with different antenna polarization, vertical-to-vertical and vertical-to-horizontal [29]. The indoor radio wave frequency has been studied for various campaign as discussed in [42-45].

The overall observation acknowledges that CI and FI model are the best for millimetre-wave channel propagation model range between 28 GHz to 100 GHz. The CI and FI model are widely used in measurement campaign for Line-of-sight (LOS) and Non-line-of-sight (NLOS) [21,40,46-51].

The remainder of the paper is organized as follows. Measurement description and scenario are described in Section 2 and the  $PL$  models are presented in Section 3. In Section 4, the numerical result and discussion are drawn, before the conclusion of the paper in Section 5.

## **2. Channel Measurement**

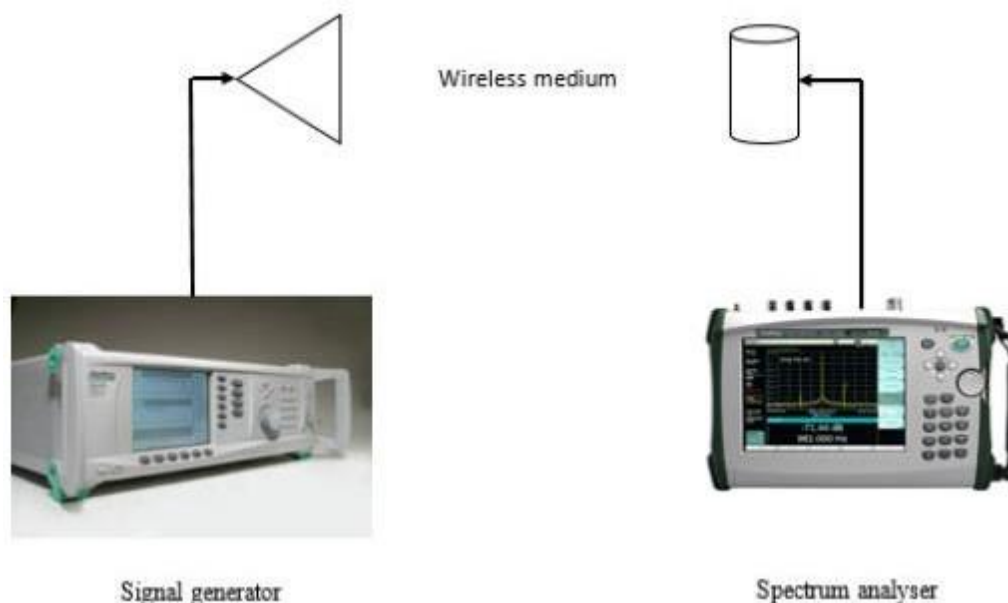
### **2.1 Open Corridor**

The open corridor located outdoor, without wall enfold. The open corridor is constructed from metal zinc ceiling and covered by porcelain tile floor. Apart of that, the corridor is implanted with the permanent metal pole at every 1.5 m, as depicted in Figure. The dimension of the open corridor is 3.5 m height, 2.5 m width, and 100 m length.

### **2.2 Wide Corridor**

The wide corridor is a tunnel-like corridor, constructed of 30 m reinforced concrete walls and ceiling, while the corridor floor is covered by cement tile. The dimension of the wide corridor is 2.5

m height, 3.6 m width, and 60 m length. Furthermore, the corridor is built with openings structure particularly at 13 m (0.3 m width), 14 m (1 m width) and 15 m (1 m width) of the corridor.

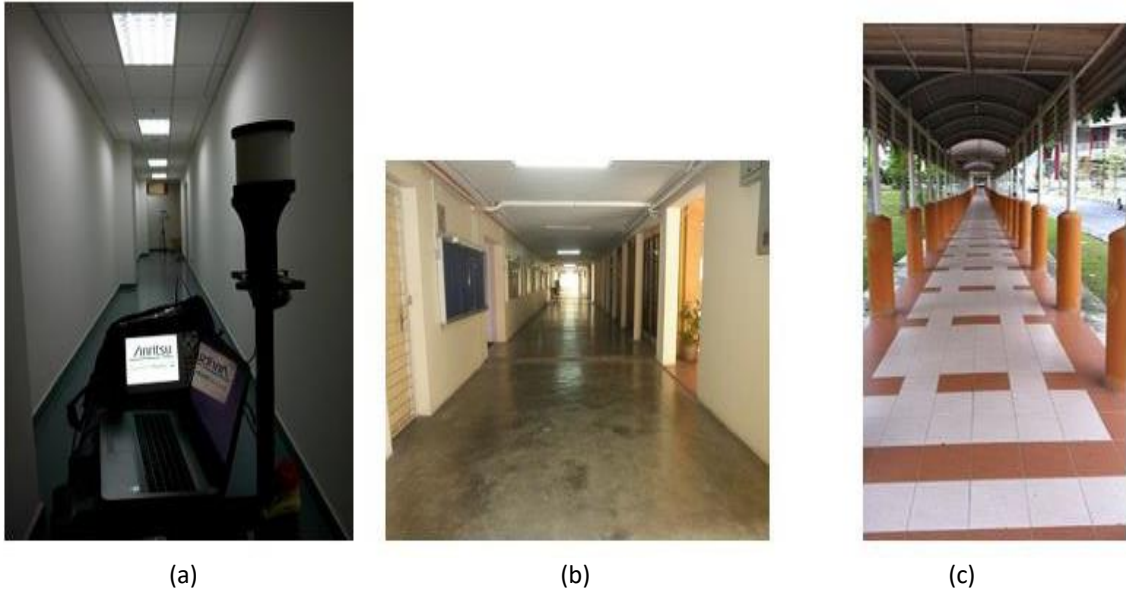


**Fig. 1.** Measurement setup for 28 GHz

### 2.3 Narrow Corridor

For narrow corridor, the corridor is located at 4th floor of Malaysia-Japan International Institute of Technology in UTM-Kuala Lumpur campus. The wall is enclosed by reinforced concrete wall, of 23 cm thickness, the ceiling is made of asbestos, and the floor is covered by porcelain tile. The dimension of the narrow corridor is 3.5 m height, 1.5 widths, and 40 lengths. The corridor structure as depicted in Figure 2 (a) to (c) [18].

For this measurement campaigns, TX was kept stationary at one end of the corridor, while RX is a move for each 1 m adjacent away toward the end of another corridor side, to capture RSS at every 1 m distance. The repeated measurements are performed to obtain a precise value of RSS. The average of RSS was then used to compute the PL and shadow fading and hence the PLEs are further extracted. To verify the measured results, the measurements campaign was conducted repeated, where the TX and RX are aligned to each other boresight. Moreover, the measurements campaign was conducted during the off-hour, to avoid human induce and movement interference.



**Fig. 2.** The construction of (a) narrow corridor, (b) wide corridor and (c) open corridor

### 3. Path Loss Models

The CI path loss model is presented as statistical path loss model of a single frequency, which is derived from the measurement dataset and as is shown as follow:

$$PL^{CI} [dB] = PL_{d_0} + 10n \log_{10} \left( \frac{d}{d_0} \right) + \chi_{\sigma}^{CI} \quad (1)$$

where  $PL_{d_0}$  is the free-space reference distance at  $d_0=1$  m,  $d$  is the distance of 3-D TX-RX separation,  $n$  is the path loss exponent parameter that derived from least-square error approach which fits the measurement data, and  $\chi_{\sigma}^{CI}$  is a zero-mean Gaussian random variable with standard deviation  $\sigma$  in decibels.

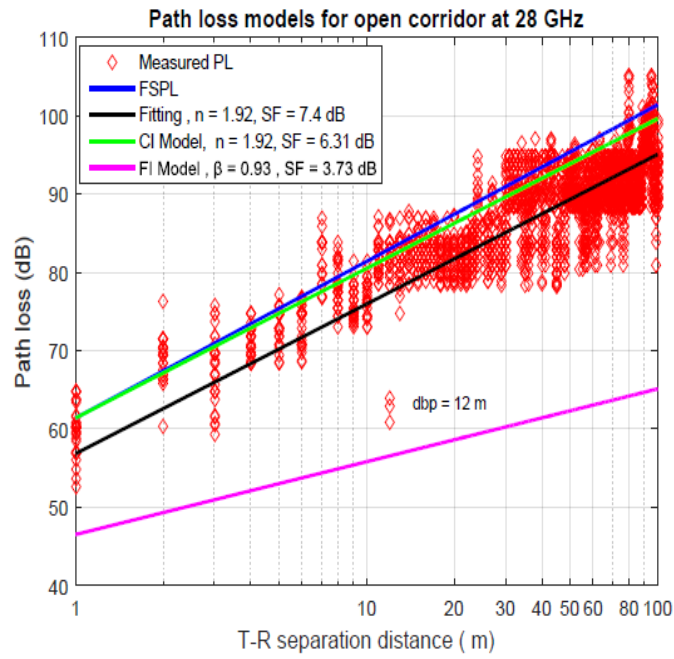
Another path loss model is called the floating-intercept (FI) path loss model which used in the WINNER II and 3GPP standards [14,15]. It is based on the floating-intercept ( $\alpha$ ) and line slope ( $\beta$ ) to provide the best minimum error fit of collected path losses as follows:

$$PL^{FI} [dB] = \alpha + 10 \cdot \beta \log_{10}(d) + \chi_{\sigma}^{FI} \quad (2)$$

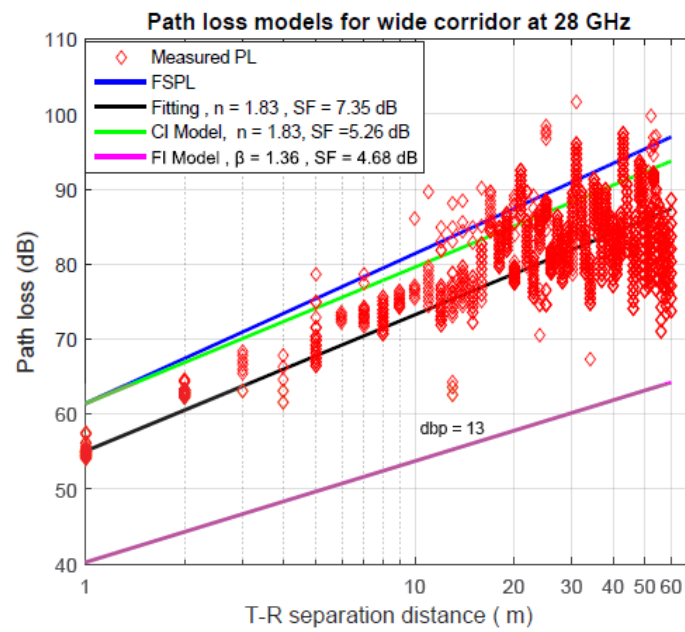
where  $\chi_{\sigma}^{FI}$  is a zero mean Gaussian (in dB) shadow fading random variable, which describes large-scale signal fluctuations about the mean path loss over distance.

### 4 Result and Discussion

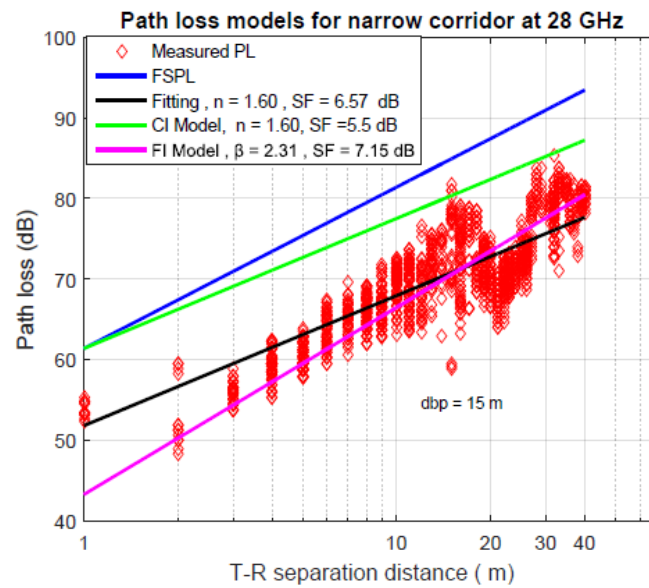
The following Figure 3 to Figure 5 provide the measured and models parameterization of PL and shadow fading obtained for three differently dimensional corridors at 28 GHz.



**Fig. 3.** Path loss models for open corridor



**Fig. 4.** Path loss models for wide corridor



**Fig. 5.** Path loss models for narrow corridor

As given in Table 1, the  $PL_{do}$  for CI and FI model varies differently as CI considers 1 m reference distance, while FI model estimates the non-physical PL. PLE in CI model, open corridor significantly exaggerates of 1.92 compared to the narrow and wide corridor of 1.60 and 1.83 PLEs respectively. The lower than free-space (PLE is 2) in the corridors, attributes to the waveguide phenomenon within the corridors. However, the open corridor indicates high attenuation compared to the wide and narrow corridor, as the PLE of the open corridor is near to free-space.

For shadow fading, the fading in corridors varies typically for surround environments, range from 4.68 dB to 7.15 dB. Among of three corridors, PL in open corridor PL varies closely to free-space path loss (FSPL), followed by a wide corridor and narrow corridor respectively. This is due to multipath reflection in the narrow corridor, which is a constructive rise, the RSS within the corridor.

On the other hand, the multipath reflection is lowest at the open corridor and moderate at the wide corridor, thus the range of average PL is insignificant compared to a narrow corridor.

For the case of breakpoint distance ( $dbp$ ), despite short T-R separation distance within 100 m, the result reveal diverges  $dbp$  can be observed for short range communication at 28 GHz. For narrow corridor, the result shows 17 m  $dbp$ , while 12 m for open corridor and 15 m for wide corridor respectively. This indicates the tapered environment able to contain strongest RSS within to enhance the coverage wider and longer, compared to open environment. The high attenuation fluctuation is observed after the  $dbp$ , due to high destruction multipath reflection of corridor surrounding. This behavior promotes the relaying approach at certain a distance within the corridor or tunnel to enhance the RSS for better end user experience.

**Table 1**

Path loss models parameters for open, wide and narrow corridors at 28 GHz

|               |             |         |               |
|---------------|-------------|---------|---------------|
| <i>Open</i>   |             |         |               |
| CI            | <i>PLdo</i> | PLE     | Shadow fading |
|               | 61.39       | 1.92    | 6.31          |
| FI            | $\alpha$    | $\beta$ | Shadow fading |
|               | 46.51       | 0.93    | 3.73          |
| <i>Wide</i>   |             |         |               |
| CI            | <i>PLdo</i> | PLE     | Shadow fading |
|               | 61.39       | 1.83    | 5.26          |
| FI            | $\alpha$    | $\beta$ | Shadow fading |
|               | 40.22       | 1.36    | 4.68          |
| <i>Narrow</i> |             |         |               |
| CI            | <i>PLdo</i> | PLE     | Shadow fading |
|               | 61.36       | 1.6     | 5.5           |
| FI            | $\alpha$    | $\beta$ | Shadow fading |
|               | 43.29       | 2.37    | 7.15          |

## 5. Conclusion

This paper presents the measurement of PL and shadow fading models at three-dimensional different corridors at 28 GHz. The parameter of PL, PLE and shadow fading are studied, additionally with the characterization of breakpoint distance. The average PL values show the multipath reflection in narrow corridor escalates the RSS values, thus extend the coverage for longer distance. Furthermore, the result of *dbp* distance promotes the similar extension of radio signal in narrow corridor. As the multipath reflection is less attributed in the open corridor and wide corridor, the PLEs are observed higher than in narrow corridor. Moreover, the *dbps* are seen shorter than in narrowband, indicate the higher attenuation of RF losses characterization.

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