

Indoor Path Loss Model for 4G Wireless Network at 2.6 GHz

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Abstract—In this paper, a short-range, narrowband indoor propagation at 2.6 GHz was measured and modeled. The measurement campaign was conducted to characterize the path loss (PL) of Radio frequency (RF) at the Razak School building corridor. The corridor has unique structure and segmented in different sections. The irregular structure of corridor, further with various interior material used gives the unique characterization to the received power. The research work made in this paper is predominately targets to characterizing radio link of 2.6 GHz frequency in typical indoor corridor.

Index Terms— Indoor environment, long term evolution (LTE), path loss model.

I. INTRODUCTION

THE RAPID expansion of multimedia services and explosive improvement in information technology (IT) leads the telecommunication technology grow accordingly. The evolution of the high speed, low cost services is takes anywhere at any time services in fourth generation of long term evolution (LTE) services. Therefore, achieving optimal performance is crucial issue in wireless cellular network. From the network planning, the wireless cellular network should be able to accommodate to the estimation quality of service (QoS). Moreover, the data received from transmitting to receiving side in wireless cellular network means by electromagnetic wave; which is highly influenced by separation distance, diffraction, reflection, refraction scattering, free space loss and etc., and may cause to signal degradation in wireless cellular network. Furthermore, the human density in the wireless area play important role in characterizing the wireless propagation. From previous study in [1] observed the reduction of received power as the density of human increase. Therefore, the path loss model is crucially important to characterize the radio wave propagation based on environmental effect.

The rest of the paper is organized as follows. Section 2 discusses the related work, Section 3 presents the

methodology while Section 4 and Section 5 include result, discussion and conclusion respectively.

II. RELATED WORKS

There are various path loss model from previous studies discuss about the indoor propagation of radio frequency in ultra-high frequency (UHF) band. The developing propagation model is largely based on the existing propagation model. These models are popular partly because of their scalability and reasonable complexity. Some of the most important models are briefly described below.

A. 2.1 ITU-R 123.87

The model describes about the indoor propagation in UHF spectrum band in various measurement environment such as; office, residential area, multi-floored building and etc. From the conducted measurement, it was observed that the characteristic of radio wave propagation in indoor environment influenced by the interior material and wall of building such as; metal, concrete, plasterboard and etc as shown on Table 1. Another major factor which contribute to temporal signal variation in indoor environment is the human movement, and reduce between 6 dB to 8 dB received power [2]. The basic path loss model can be expressed on as following:

$$L_{total} = 20 \log_{10} f + N \log_{10} d + L_f(n) - 28 \quad (1)$$

where N is the distance power loss coefficient, f is frequency in MHz, d is the separation distance and portable terminal (where $d > 1$ m), L_f is the floor penetration loss factor (dB) and n is the number of floor between base station and portable.

TABLE 1: RELATIVE PERMITTIVITY OF MATERIALS [2]

Material	Relative permittivity
Concrete	5.31
Brick	3.75

Plasterboard	2.94
Wood	1.99
Glass	6.27

B. WINNER + Final Channel Models

The model describes about the various set of environments ranging from indoor, outdoor-to-indoor (O2I), urban microcell (UMi), urban macrocell (Uma) and Suburban macrocell (SMa). The parameterization is based on measurement campaign. The model is 2D propagation model, with the small scale, angle-of-arrival (AOA) and angle-of-departure (AOD) [3]. Path loss model has been proposed as shown in following:

$$PL(dB) = 22.7 \log_{10} d + 27 + 20 \log_{10} f_c \quad (2)$$

where PL is the path loss in dB, d is the separation distance between transmitter and receiver and f_c is the center frequency.

III. METHODOLOGY

The measurement campaign was conducted to measure the path loss at the Razak' School building at Universiti Teknologi Malaysia (UTM) with irregular structure of corridor. The structure of corridor affects to unique characterization of signal propagation in indoor environment at 2.6 GHz frequency. The measurement campaign was conducted to measure the receive power during the normal office hour in the office corridor at Razak's School building at 70.0 m length, 4.0 m high and 4.0 m width dimension. The corridor is shown as in Fig. 2. Upon the irregular structure of corridor, it is divided into four (4) sections; A, B, C and mini lobby.

A. Equipment

Rohde and Schwarz SMP22 signal generator which operated 2-20 GHz frequency serves as transmitter. On the receiver site, the Rohde and Schwarz FSH6 spectrum analyzer which operated at 100 kHz to 6 GHz. The highly directional horn antenna at 10 dBi antenna gain is used. The transmitter and receiver heights are 2 m, 1.6 m respectively. The equipment setting as illustrated in Fig. 1:

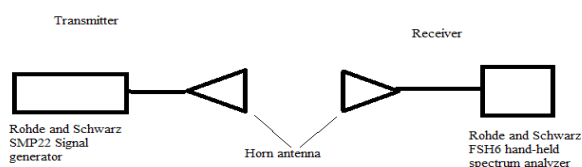


Fig. 1: Equipment setting for transmitter and receiver.

B. Measurement environment

The measurement campaign was conducted at Razak's School building which segmented into Section A, B, C and enclosed by mini lobby. The Fig. 2 shows the layout of the corridor floor plan.

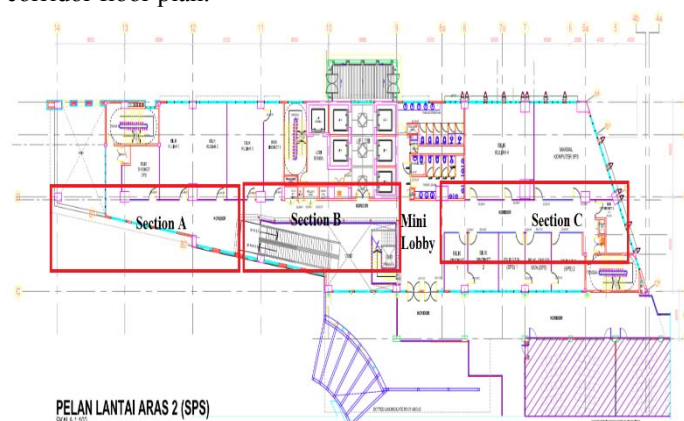


Fig. 2: The floor plan of Razak's School UTM corridor.

1) Section A

The size of the corridor is 18 m length, 1.5 m width and 4 m height respectively as shown in Fig 3. The corridor is floored by porcelain tiles. The wall on the left side is made of plasterboard while right side wall made of tinted glass.

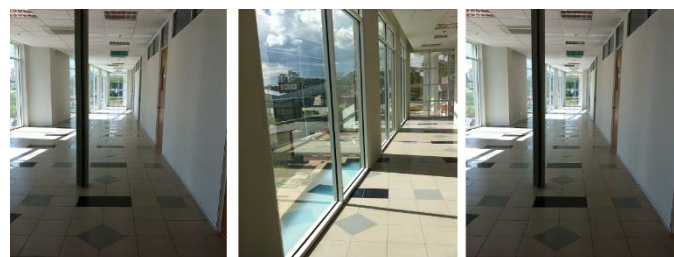


Fig. 3: Section A corridor: 18 m tie floor, tinted glass wall and concrete wall at left side wall, and plasterboard wall and wooden door at right side of the wall. The corridor size is 18 m x 1.5 m x 4 m length, width and height respectively.

2) Section B corridor:

The corridor at section B is 20 length, 1.3 m width and 4 m height respectively as shown in Fig. 4. The floor is covered by porcelain tiles. On the right side, it has the clear glass barrier. The glass barrier separates the corridor and escalator. On the left side, the wall is made of plasterboard.



Fig 4: The corridor at Section B., plasterboard wall, the clear glass barrier, tinted glass door and wooden door.

3) Mini lobby:

The corridor also enclosed with a mini lobby between of Section B and C corridor as shown in Fig. 5. The mini lobby is also floored by the porcelain tiles and the wall is made of tinted glass 4 m length and 5m height of the glass door.



Fig. 5: Mini lobby section in the between of Section B and C corridor.

4) Section C:

The Section C corridor is 31 m length, 2 m width and 4 m height as shown in Fig. 6. It is floored with porcelain tiles. The wall is made of plasterboard on the left side and tinted glass wall and door on the right side.



Figure 6: The Section C corridor, with plywood door and glass wall.

C. Measurement procedures

The measurement was conducted to measure path loss in indoor corridor at Razak's School building of UTM-Kuala Lumpur. The line-of-sight (LOS) case for during office hour with existence of people walking was studied. The standard size of person is 1.7 m tall and 0.45 m wide shoulders. Moreover, the densities of passers-by are approximately 0.042 persons/m² during the normal period of office hour [2].

D. Theoretical background

Path loss (PL) can be expressed as [4] :

$$R = T_r + T_g + R_g - SL - PL \quad (3)$$

where R is the average received power (dBm), T_r is the transmitted power (dBm), T_g is the transmitter gain (dBi), R_g

is the receiver gain (dBi), SL is the system loss and PL is the measured path loss (dB).

The model received power was converted into path loss (PL) using Matlab as:

$$PL (dB) = 10 \log_{10} \frac{T_p}{R_p(d)} \quad (4)$$

where PL is the path loss in dB, T_p is the transmitted power (dBm), R_p is the received power in dBm at distance d in meter. The distance power loss coefficients include an implicit allowance for transmission through walls and through obstacles, and for other loss mechanisms likely to be encountered within a single floor of a building and the model propagation loss.

The Two-Ray model can be very useful in predicting the received signal. It can further serve in the development of multipath propagation model. According to [4] the path loss model for the Two-Ray model (with antenna gain) is calculated as :

$$PL(dB) = 40 \log d - (10 \log G_t + 10 \log G_r + 20 \log h_t + 20 \log h_r) \quad (5)$$

where PL is the path loss in dB, the G_t and G_r are the transmitter and receiver antenna gain in dBi respectively, h_t and h_r are the height of transmitter and receiver antennas in meter respectively.

The indoor radio PL is characterized by both an average PL and its associated shadow fading statistics. The distance power loss coefficients include an implicit allowance for transmission through walls and through obstacles, and for other loss mechanisms likely to be encountered within a single floor of a building and the model propagation loss.

IV. RESULT AND DISCUSSION

The variation of path loss with TX –RX separation distance is shown in Fig. 7.

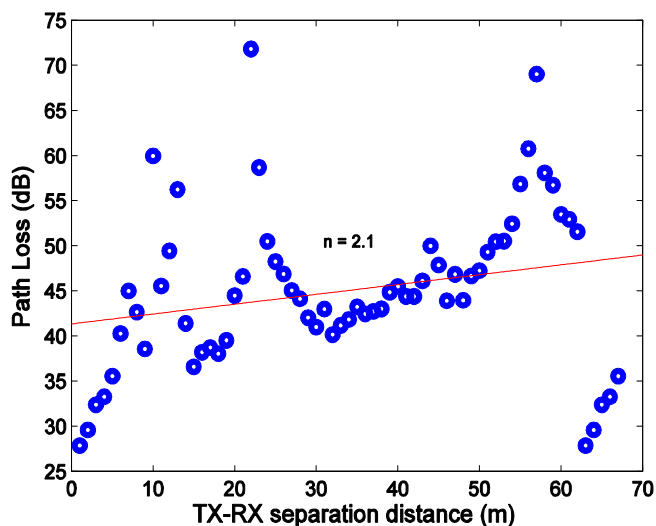


Fig. 7: Result of indoor path loss exponent

From figure, it is observed that the path loss is varies as corresponding to the environment, which include the size of corridor, the wall and interior furniture's. At the section A, from 1 m to 10 m distance, the size of corridor was gradually immense since the corridor is surrounded with the similar wall and interior material at both side of wall. The wall at the section is made of plasterboard and tinted glass wall on the other side. The path loss gradually varies by the factor of separation distance between transmitter and receiver since there is no significant different to the furniture, materials and environment surrounding. However, within the same Section A, high variance of the path loss is observed at from distance 11 m to 17 m. The area and structure of the corridor is suddenly expanding (Fig. 2), which give the sudden change of the attenuation values. Moreover, the corridor is occupied with the wooden door which contribute to the high attenuation to the received signal.

At Section B, the attenuation is gradually escalating from distance 18 m to 21 m. However, the most significant attenuation is observed at distance 22 m and 23 m. It is noticed that the corridor area is content with the solid-wooden door at the main entrance from escalator to the main corridor compound which effect to the highest attenuation of the path loss. On the other hand, the distance at 24 m to the 37 m, the graph shows the decreasing of the attenuation result. Despite of the material of the clear glass barrier, tinted glass wall, and other material surround, the narrow structure of the corridor also gives a variation to the path loss in indoor environment. The narrow size of the corridor give high reflection which helps to contain the signal within a building and reduce the attenuation.

At mini lobby, the variation of the attenuation is almost identical. The structure of the lobby which is wide with less obstruction allows for high received signal. However, it is quite effected when the receiver is placed near to the furniture as at position 44 m which gives approximately 1.61 dB attenuation.

At Section C, the variation of the attenuation has irregular pattern, with the highest attenuation observed at distance 57 m. The receiver antenna at the 57 m position was located near to the series of plywood doors between the distances of 52 m to 58 m which effects the variation of the path loss. The path loss exponent is estimated by using the log-distance model which is expressed as [4]:

$$PL(d) = PL(d_0) + 10n \log\left(\frac{d}{d_0}\right) + W_\sigma \quad (6)$$

where $PL(d)$ is the measured path loss at distance d , $PL(d_0)$ is the path loss at the reference distance d_0 of 1 m, n is the path loss exponent and W_σ is the normal random variable with standard deviation σ in dB. Based on (6), the linear regression fitting is used to calculate the path loss exponent and standard deviation as shown in Table 2.

TABLE 2: PATH LOSS COMPARISON

Path loss model	PLE, n	Standard deviation (σ_{dB})
Razak's School	2.1	41.33
ITU-R 1238-7 [2]	2	-

From the Table 2, it can be show that path loss exponent for this work almost the same for ITU-R 1238-7.

V. CONCLUSION

The path loss was measured for indoor propagation at 2.6 GHz deployed for LTE network. The corridor has irregular structure which effects unique characterization in indoor propagation. The analysis is focus on path loss exponent and standard deviation in the indoor corridor during office hour scenario. The path loss exponent (PLE), n is 2.1 is compared to ITU-R 1238-7 [2]. From the comparison to ITU-R 1238-7, the path loss model Razak's School building is compatible as ITU-R 1238-7 at 2.6 GHz, especially for LTE services. The proposed statistic characteristic are very useful for network node spacing, power control, frequency spectrum utilizing, etc., in indoor 2.6-GHz-band LTE cellular communications.

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