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Path Loss and Channel Modeling at 3.5GHz for 5G Cellular System

Path Loss and Channel Modeling at 3.5GHz for 5G Cellular System

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Abstract. Wireless channel characterization is the basis of the architecture of the wireless communication system. The detailed propagation models are indeed the requirement for fifth generation communication network design. This paper presents the characteristics of channel propagation for a fifth-generation system in Line-of - Sight (LOS) and Non-Line- of- Sight (NLOS) scenarios with co-polarization (V-V) and cross polarization (V-H) in a second floor/Communication Engineering Department/Electronics college building at 3.5GHz frequency. The comparison between two path loss models shows that the Close-In (CI) of free space reference distance path loss model is more suitable than Floating-Intercept (FI) path loss model. The results of both models show that the path loss exponent value (n) is ranged between 1.7 and 2.9 for the LOS scenario, while it was between 2.1and 3.1 for NLOS scenario for both co-polarization and cross polarization.

Keywords: 5G, Path loss, Wireless InSite, 3.5GHz, Indoor Environment.

1. Introduction

Wireless networking technology has progressed quickly to meet the demands of new techniques in a number of applications. However, the demand for high-speed data and connectivity is growing[1]. Compared to the fourth generation (4G), named Long-Term Evolution (LTE) and Long-Term Evolution Advanced (LTE-A), fifth generation (5G) introduces sever new devices scenarios that have diversified features such as ultra-high traffic volume density, ultra-high link density, and ultrahigh mobility[2]. Wireless channel characterization is the basis of the architecture of the wireless communication system. The detailed propagation models are indeed the requirement for 5G communication network design [3]. At present, 5G is the first cellular system designed to accommodate any 400MHz to 90GHz spectrum[4]. Mid-band is Sub-6 GHz bands in Fifth-Generation-New-Radio (5G-NR) included band numbers: number 77 (3.3-4.2 GHz) and number79 (4.4-5.0 GHz). However, just within the 3.4-3.7 GHz range could be the final spectrum bandwidth occupied exclusively for 5G systems[5]. The 3.5GHz frequency band has been suggested as a candidate frequency for the implementation of the 5G microwave band. As a result, channel characterizations at this carrier frequency are crucial in order to prepare for the launch of fifth generation[6].Thus, the aim of the research is to investigate path loss modelling by employing the shooting and bounding ray-tracing (SBRT) simulation in the long corridor indoor environment at 3.5GHz (in this case ;Line- of- Sight (LOS) and Non-Line-of-Sight(NLOS) conditions with co and cross polarization). The rest of the Paper is organized as follows: Section 2 presents the theory about path loss of channel characteristics. Related works are explored in section 3. Simulation setup has been discussed in section 4. Results have been analyzed in section 5, and finally, the conclusions of this paper have been synopsized in section 6.

IOP Conf. Series: Materials Science and Engineering 1152 (2021) 012006 doi:10.1088/1757-899X/1152/1/012006

2. Path loss of Channel Characteristic (PL)
The path loss is decrease in an electromagnetic wave power density (attenuation) during cross-section propagation[7] .In the law of the path, several variables play a major role, the long distances between the transmitting and receiving antennas since the route can pass through multiple barriers, resulting in successive losses, as well as multipath, which cause reflections and collisions between the paths[8] .The Path Loss calculation is given as equation (1) [9].

$$L_{\text{path}}\,[\text{dB}] = P_T\,(\text{dBm}) - P_R\,(\text{dBm}) + G_T\,(\text{dBi}) + G_R\,(\text{dBi}) - L_S\,(\text{dB}) \quad (1)$$

Here G_T and G_R refer to transmit and receive antenna gains, respectively.P_T and P_R is referring to transmitted and received power, respectively. L_S refer to the other losses in the process. For the fifth generation system, path loss models are critical for network coverage and performance analysis[10] .For the single-frequency, both of the Close-In free space of reference distance and Floating-Intercept path loss models are generic all-frequency models that explain large-scale propagation path loss in a given scenario at all applicable frequencies[11]. Concerning computation complexity, the Close-In path loss model outperformed the Floating-Intercept model, The minimum mean-square error(MMSE) approach only needed to estimate one parameter for the CI path loss model[12], which was path loss exponent (n) utilizing a real physical anchor point that expresses the free space transmitted power from the TX antenna to the close-in distance d_0[13]. Whereas, MMSE was used to estimate two parameters (α and β) in the FI path loss model[12], and does not take into account a physical anchor for the transmitted power[13]. Finally, the complexity of the FI model is two times greater than the complexity of the CI model [12].

3. Related Works
Over the past 25 years, there have been numerous studies of indoor wireless transmission and channel models for frequency below 6GHz. For example, authors in [14]employed half-wave dipole antenna for indoor analysis 433MHz. The findings demonstrated the comparison between the simulation and measurement results at a different location inside a laboratory building /Durban university. The measured and simulated results were slightly close to one another. Using a similar setting, another study demonstrated that the path loss increases with carrier frequency and load walls at a different frequency from 800MHz-6GHz[15]. Furthermore, an indoor path loss prediction for NLOS analysis was conducted by A. Bhuvaneshwari, R. Hemalatha et al. The study was carried out at wide corridor. The transmitter was stationary and the receiver moves at discrete distances along the corridor at 2.4GHz frequency band. The findings demonstrated that the loss increased as separation distances increased due to the propagation mechanisms of the signals in the propagation path[16]. The authors also indicated as a comparative analysis of the two bands, indoor measurement results obtained with channel sounder fitted using omnidirectional and horn antennas at 2.9 and 29 GHz frequency bands. The measurements were taken for two different floors within a Qualcomm building in Bridgewater, New Jersey, in the United States. The results showed that the path loss exponent (n) values at 29GHz is higher than the 2.9 GHz frequency bands due to the a number of partition walls between the links and the electrical properties of materials [17].

4. Simulation Setup
The case study used in this paper focuses on the second-floor corridor areas in the Electronics Engineering College/Department of Communication engineering building. The building was planned and simulated with software Wireless InSite (WI), the construction design layout is shown in Figure (1). In (WI), the materials are predefined where the walls are made up of brick with permittivity $\epsilon_r = 4.4$, and conductivity $\sigma = 0.001$ S/m, the ceiling and floor are made of concrete with $\epsilon_r = 15$, and $\sigma = 0.015$ S/m. The characteristics of the transmitter and receiver antennas used are described in table 1. Omnidirectional antennas with gain (2dBi) were vertically polarized for co-polarization, whereas the Tx antenna was vertically polarized and the Rx antenna was horizontally polarized for the cross-polarization cases at 3.5GHz frequency band. The Tx antenna was located at a stationary location along the corridor of the second floor of the building for the evaluation procedure, while evaluation started with the Rx

moving along the corridor. The distance of the route ranges from (0.02-10) m. The total number of points obtained that have been analyzed in this work is 469 points with a separation distance of 0.02 m. Both LOS and NLOS scenarios were included in this research. For the whole inquiry, the serious effects of various construction materials were taken into consideration.

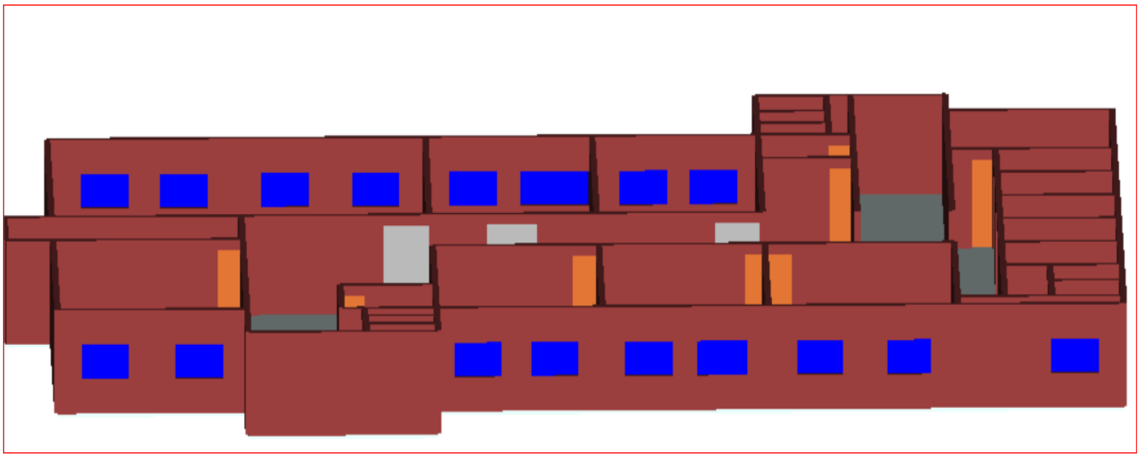

Figure 1. 3D view of the Second Floor Using floor Plan Editor.

Table 1. Antenna Specifications.

Item	Value
Frequency (GHz)	3.5
Transmit Antenna Power (dBm)	2.00
Tx-Antenna Gain (dBi)	2.15
Rx-Antenna Gain (dBi)	2.15
Tx-Antenna Height (m)	1.34
Rx-Antenna Height (m)	1.34

5. Results

The previously clarified case study was simulated using wireless InSite software. In this paper, the basic path loss models investigated are Close-In path loss model (CI) and Floating-Intercept (FI) path loss model.

5.1. Close-In Free Space Path loss Model (CI)

The CI model is described in equation (2) [18].

$$PL_{CI}(f, d)\,[dB] = PL\,(f, d_0) + 10n\log_{10}(d/d_0) + X\sigma_{CI} \quad (2)$$
$$\text{For } d \geq d_0, \text{ where } d_0 = 1.010 \text{ m}$$

$PL(f,d_0)$ refers to the free space path loss in dB at reference distance (d_0 = 1.010m), n is the path loss exponent, d is the T-R separation distance between the transmitter and receiver antennas and $X\sigma$ refers to a zero-mean Gaussian-distributed random variable with standard deviation σ dB.

Figures 2 and 3 include illustrations of the Close-In (CI) line plots at 3.5 GHz frequency band for the situation LOS and NLOS co-polarization and cross polarization with curve fitting. For co-polarization (Vertical-Vertical) antenna, the path loss exponent (PLE) values in the LOS and NLOS cases study were 1.7, 2.1, respectively. And for cross polarization (V-H) antenna in the LOS and NLOS cases, the path loss exponent (PLE) values were 2.9, 3.1, respectively. As seen for co-polarization(V-V) antenna LOS case PLE value is 1.7 which is less than the theoretical free space path loss exponent (n=2), whereas for cross polarization (V-H) antenna the PLE value is 2.1 larger than theoretical free space path loss also larger than co-polarization due to that cross polarization(V-H) refers to propagation in one state of polarization and reception in the state of orthogonal polarization unlike co-polarization transmitting and receiving in one state of polarization so there is no additional loss to the path loss. For NLOS environment, the PLE values for both polarizations are larger than LOS path exponent values due to the lack of a clear route in the NLOS case study. The CI path loss model parameters for LOS and NLOS cases are presented in table 2.

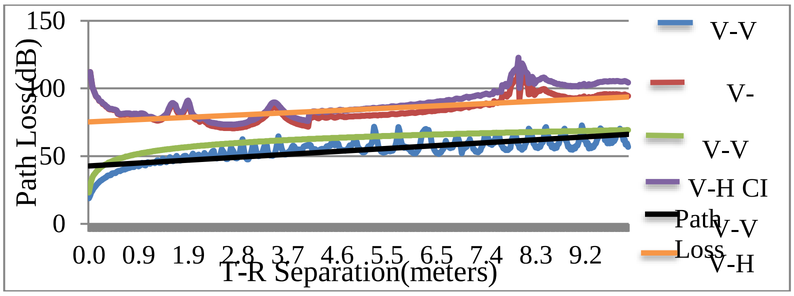

Figure 2. Close-In Path Loss Model, Simulation Path Loss with Curve Fitting for the LOS with Co-Polarization and Cross Polarization along the Corridor.

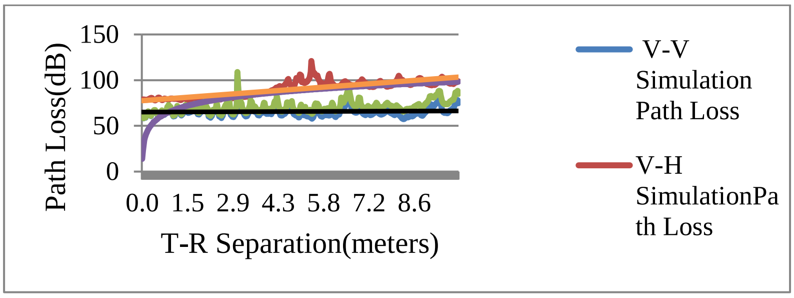

Figure 3. Close-In Path Loss Model, Simulation Path Loss with Curve Fitting for the NLOS with Co-Polarization and Cross Polarization along the Corridor.

Table 2. Close-In Path Loss Model Parameters for LOS and NLOS Cases.

	Co-Polarization (*LOS*)	Cross-Polarization (*NLOS*)	**Co-** Polarization (*NLOS*)	**Cross-** Polarization (*NLOS*)
PLE(n)	1.70	2.90	2.10	3.10
***σ* (dB)**	0.97	3.20	3.29	6.02

5.2. Floating Intercept Path Loss Model (FI)

In the standard WINNER II and 3GPP, the floating-intercept (FI) path loss model is used. FI path loss model depend on the floating-intercept (α) value and line slope (β) as shown in equation (3) [13].

$$PL_{FI}\,(d)\,[dB] = \alpha + 10\beta\,\log_{10}(d) + X\sigma_{FI} \tag{3}$$

Here $X\sigma_{FI}$ is a zero mean Gaussian shadow fading random variable with standard deviation σ. The minimum mean-square error (MMSE) is used as a best-fit as in the Close-In model and needs to be solved for α and β to obtain the standard deviation. The results of the FI path loss model for the 3.5GHz frequency band in the line-of-sight (LOS) and non-line-of-Sight (NLOS) environments are shown in

Figures 4 and 5 for co-polarization (V-V) and cross polarization (V-H) respectively. In the co-polarization (V-V) LOS case compared to free-space path loss (FSPL), α values are different. It was 42.71dB compared to the theoretical free space path loss (FSPL) value was 43.39dB, while in cross polarization (V-H) LOS, α value was 75.28dB compared to the 43.39dB theoretical free space path loss (FSPL) at d_0= 1.010 m. In the case Vertical-Vertical (V-V) antenna polarization NLOS, α value was 65.09dB compared to the 43.39dB theoretical free space path loss (FSPL). In cross polarization antenna (V-H) NLOS case, α value was 77.50dB compared to the 43.39dB theoretical free space path loss (FSPL). Slope value (β) of the minimum-square mean fit line for the co-polarization antenna LOS case was 2.35 larger than free space (β=2) while close to the free space in the case co-polarization NLOS case. For the cross polarization (V-H) the β slope is 1.84 for the LOS and 2.57 for the NLOS. β only functions as a basic slope that provides the best fit for a data line plot and in any way has no physical basis or frequency dependence. This does not necessarily mean that the NLOS signals have more distance attenuation than the free-space signals. For the Floating-Intercept path loss model table 3, displays the parameters.

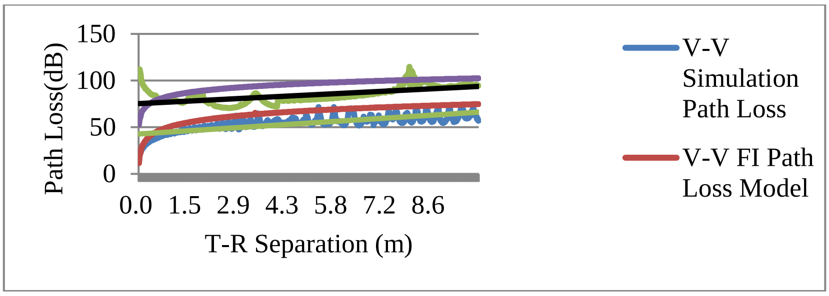

Figure 4. Floating-Intercept Path Loss Model, Simulation Path Loss with Curve Fitting for the LOS with Co-Polarization and Cross Polarization along the Corridor.

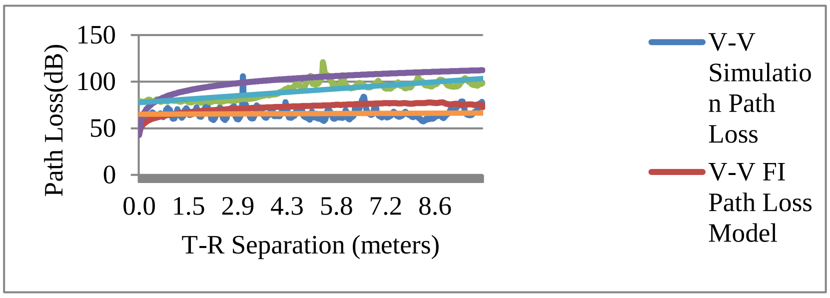

Figure 5. Floating-Intercept Path Loss Model, Simulation Path Loss with Curve Fitting for the NLOS with Co-Polarization and Cross Polarization along the Corridor.

Table 3. Floating-Intercept Path Loss Model Parameters for LOS and NLOS Cases.

	Co-Polarization (*LOS*)	Cross-Polarization (*LOS*)	Co-Polarization (*NLOS*)	Cross-Polarization (*NLOS*)
PLE(n)	1.70	2.90	2.10	3.10
$\boldsymbol{\beta}$	2.35	1.84	1.28	2.57
$\boldsymbol{\sigma}$ **(dB)**	8.76	8.72	5.10	9.01

6. Conclusions

This paper describes the path loss models for the indoor environment at 3.5GHz frequency band. The effects of path loss when transmitting 5G signals over the 3.5GHz frequency band were determined using simulation results. The comparison between two path loss models shows that by using the Close-In model-to-model path loss settings, the results were nearly similar to the simulated path loss, suggesting that the CI model is more reliable than the FI model. As a result, the findings indicate that the Floating-Intercept (FI) model is not physically adequate for the LOS and NLOS environment channels. Many techniques and investigations may be used for future research to enhance the emergence of the mid-band as a main frequency band for 5G connectivity and problems with uplink Coverage assistance.

Acknowledgments
Finally: The authors would like to thank the staff of communication engineering department specially Dr.Dia Ali and Mr. Mohammed Sameer for their help.

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