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# Impact of Transmitter and Receiver Distance of 3.5GHz Networks Channel Propagation in Line-of-Sight (LOS) and Non-Line-Of-Sight (NLOS) Environments

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**Abstract**

Malaysia is planned to implement 5G communication in an attempt to improve the country's digital infrastructure. Malaysia will implement 5G in two stages where the first stage is an enhancement of the current 4G technology, and the second phase is the transition to 5G by 2022 according to the Malaysian Communications and Multimedia Commission (MCMC). A 3.5 GHz higher frequency band creates higher path loss, so Malaysia National Task Force has conducted a study on the impact of the transmitter and receiver distance on the propagation loss. The research, however, only covered the theory study and the analysis based on parameter variation. This research is an approach to simulate the effect of the missing path propagation and obtained power due to transmitter and receiver distance in Line of Sight (LOS) and Non-Line of Sight (NLOS) environments. This research simulates the 3.5GHz frequency band in LOS and NLOS environments using the channel simulator developed by NYUSIM. The transmitter and receiver distances were varied from 50m to 200m. The outcome from the simulation show that the path loss rise when the transmitter and receiver distance rise while the power received weakens. The outcome of this research can be served as a guideline in Malaysia for field trials and techniques of interference mitigation.

**Keywords:** 5G, 3.5GHz, LOS, NLOS, path loss, power received.

## I. INTRODUCTION

Malaysia's government has established a task team to conduct 5G testing and research. A preliminary data gathering test was done by this task force. This 5G transition is expected to be completed by 2027, with 5G service available throughout Malaysia, from Perlis to Sabah.

5G is made up of a number of new technologies that can improve on current 4G technology. Massive multiple-input multiple-output (MIMO), millimeter-wave (mmWave) transmission, small cell networks, transmission beamforming, and small duplex are all important components in meeting 5G's projected criteria. There are a lot of studies linked to 5G that has been explored but the only limited source to discover 5G study in Malaysia.

For the time being, Malaysia has two priority spectrums: priority 1 and priority 2. Priority 1 is to concentrate on the C-band mid-band and mmWave high-band. Priority 2 focuses on 5G's low, mid, and high bands, which encompass both new and old IMT bands from 2G, 3G, and 4G networks. The testing that is currently being done in Malaysia is for the mid-band frequency range of 3.3GHz to 4.2GHz. According to the National Task Force Malaysia report (Malaysia

5G Task Force, June 2019), once 5G is globally launched, it will use mmWave technology.

In designing a good mobile communication system, path loss and received power produce by the system are important aspects to study. Higher path loss will lead to more signal losses. The impact if the path loss is high received power will become lower. Low received power represents a weak signal that will impact the internet speed. The current area was done by other researchers on path loss study involving other frequency but not what will Malaysia implement. This led to the proposed study to observe the path loss and received power impact when the transmitter and receiver distance increase in Malaysia at 3.5GHz frequency band in both environments.

In order to strive this goal, the NYUSIM channel simulator will be used to simulate a 3.5GHz signal in both LOS and NLOS environments. The goal is to analyse the impact of increasing transmitter and receiver distances on path loss propagation using the simulated results. Aside from that, it's to look at the changes in received power as the transmitter and receiver distances change.

This study focuses on expanding knowledge for the 5G network that will be implemented in Malaysia. The free-space path loss model will be covered, and the small-scale path loss parameters will be obtained using an open-source software called the NYUSIM channel simulator. This software simulation was listed in the ITU report as being utilised outside of the 3rd Generation Partnership Project (3GPP) body to simulate channel modelling. The rest of the paper is broken down into five sections. Section II covers the theoretical foundation and related works, whereas Section III explains the research technique. Section IV describes the measurement results, discussion, and analysis, and Section V draws a conclusion.

## II. LITERATURE REVIEW

### *5G Technology*

5G technology includes a few improvements which is mmWave transmission, small cell networks, MIMO technologies, transmission beamforming, and small duplex transmission (AG, 2020). On 5G, mmWave communication will be able to give faster speeds as well as more bandwidth. The small cell is the second 5G technical advancement. It's a low-power mini-based station that's been erected near the main high power - based station. The coverage area will be expanded, and the user will immediately switch to the nearest base station. The other 5G technology is to manage the network, the 4G-based station is supplied with dozens of antenna ports. More channels enable for more input and output to be sent at the same time.

Malaysia has 2 priorities for the 5G spectrum. The priority 1 spectrum consists of the 3.5 GHz (mid-band 3.3 GHz – 4.2 GHz) and mmWave spectrum (26GHz and 28GHz)

(High band in the range of 24.25GHz – 29.50GHz) (E. I. Adegoke, E. Kampert and M. D. Higgins, 2020). As for now, the only available spectrum globally is the 3.5GHz frequency band. Mid-band will provide wide availability in high channel bandwidth. 3.5GHz frequency band in Malaysia is currently in use by the government (3.3GHz –3.4GHz) and Fixed Satellite Services (3.4GHz – 4.2GHz) as portrayed in Fig. 1, however, the task force recommended to use 3.5GHz frequency band as in Fig. 2. This is because the 3.5GHz provides the same grid-like the current 4G spectrum grid on non-standalone architecture (NSA) (Malaysia 5G Task Force, June 2019).

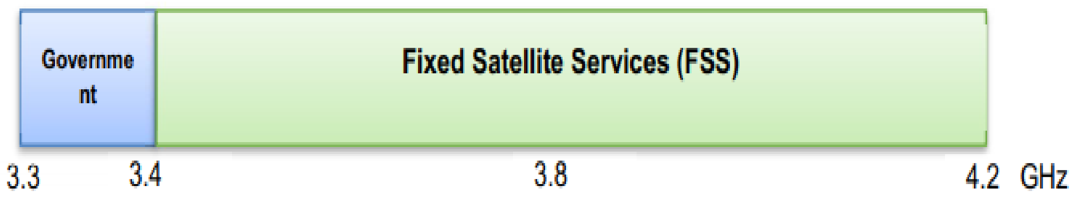



***Figure 1**. Current allocation in the 3.3GHz – 4.2GHz (E. I. Adegoke, E. Kampert and M. D. Higgins, 2020)*

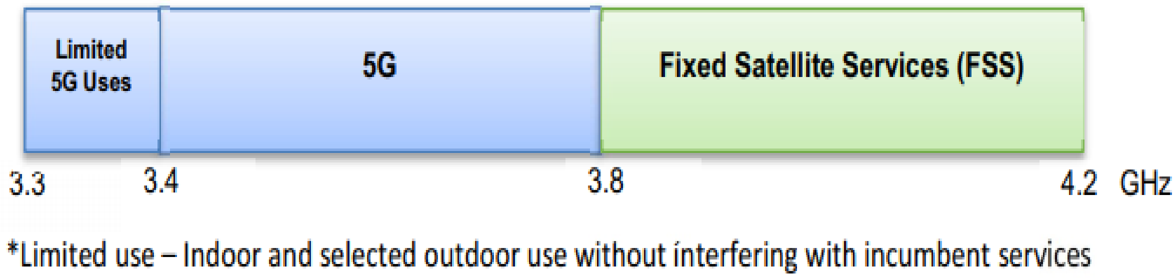



***Figure 2.** Recommendation from National task force 3.5 GHz (E. I. Adegoke, E. Kampert and M. D. Higgins, 2020)*

Priority 2 spectrum includes both new and existing IMT bands for 2G, 3G, and 4G networks and is based on the low, mid, and high bands for 5G. The use of the 700MHz frequency as a Priority 1 5G band is still up for debate in the industry. According to the 5G Task Force, the new enhanced Mobile Broadband (eMBB) requires just the 700MHz frequency band to deliver the best experience, as shown in Table 1.

***Table 1.** Recommendation for the re-allocation 3.5 GHz (E. I. Adegoke, E. Kampert and M. D. Higgins, 2020)*

| | Base Station Cofiguration | Device Confuration | Bandwidth | 5G Downlink Peak Cell Capacity |
|---|---|---|---|---|
| 700Mhz (FDD,n28) | 2T2R | 1T2R | 20MHz | ~230 Mbps |
| C-band (TDD,n78) | Massive MIMO 64T64R | 2T4R | 100MHz | ~5.8 Gbps |

***Langkawi 5G Testing***

The Malaysian government, in collaboration with TM Malaysia and the 5G National Task Force, held a 5G demonstration in Langkawi, as depicted in Fig. 3. This testing is carried out using Malaysia's current communication infrastructure. If no interference from a nearby FSS receiver is found, the Base Stations of the 5G need to be launched with the default configuration (Sector 1, 50MHz bandwidth, 30dBm transmit power), and the configuration will be ramped up following the pre-defined procedures below:

1. The transmission power will be increased from 30 dBm to 33 dBm, then to 35 dBm.
2. The bandwidth will be step up from 50MHz to 100MHz.

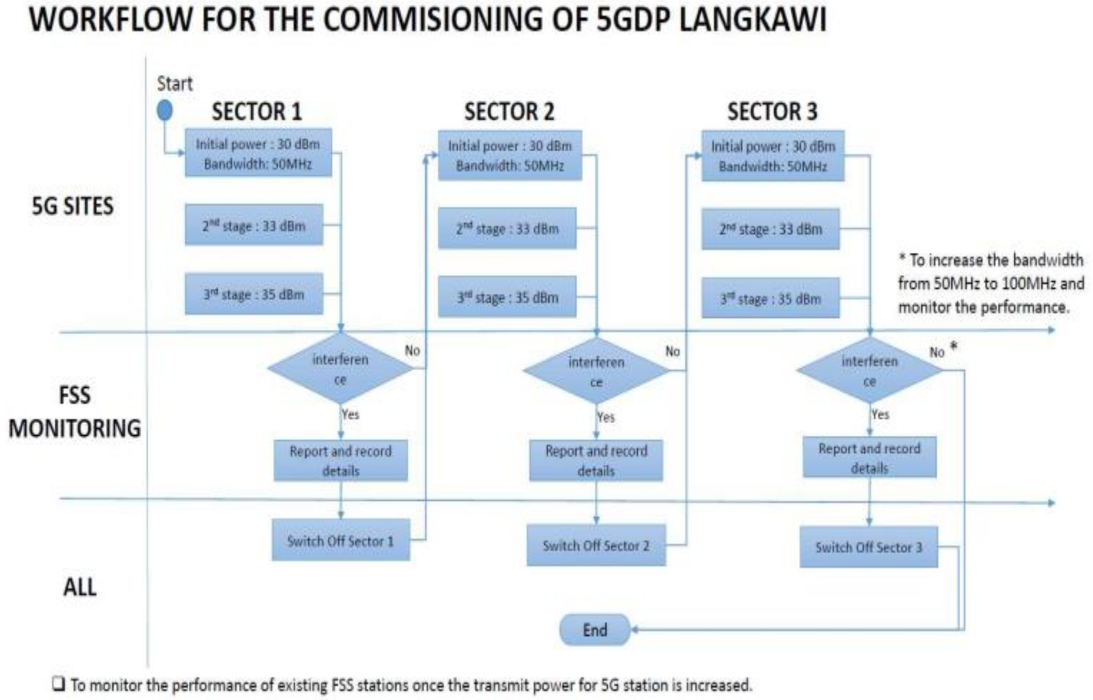



***Figure 3.*** Langkawi deployment testing *(Malaysia 5G Task Force, June 2019)*

***Langkawi 5G Testing***

Indoor Hotspot (InH), Urban Microcell (UMi), Urban Macrocell (UMa), and Rural Macrocell (RMa) are some of the deployment scenarios. The channel models for InH and UMi LoS and NLoS outdoor deployment situations are identical. Only Outdoor-to-Vehicle connections are evaluated in the UMa and RMa deployment scenarios, and these must be taken into account.

***Deployment scenarios***

Indoor Hotspot (InH), Urban Microcell (UMi), Urban Macrocell (UMa), and Rural Macrocell (RMa) are some of the deployment options. The channel models for InH and UMi LoS and NLoS outdoor deployment situations are identical. In the UMa and RMa deployment scenarios, only Outdoor-to-Vehicle connections are examined, and they must be taken into account.

***LOS and NLOS environments***

The first LOS model was based on a two-ray model with breakpoints (Rfwireless-world.com, 2020). The model was then tweaked to fit the data by merging novel model setups including path loss offset and breakpoint scaling factors, which are used to characterise local atmosphere scattering. NLOS is a channel radio frequency model that ranges from 0.8 GHz to 60 GHz. The model was able to cover the area in which the frequency range is considered. The difference between the LOS and the NLOS is depicted in Fig. 4 and 5.

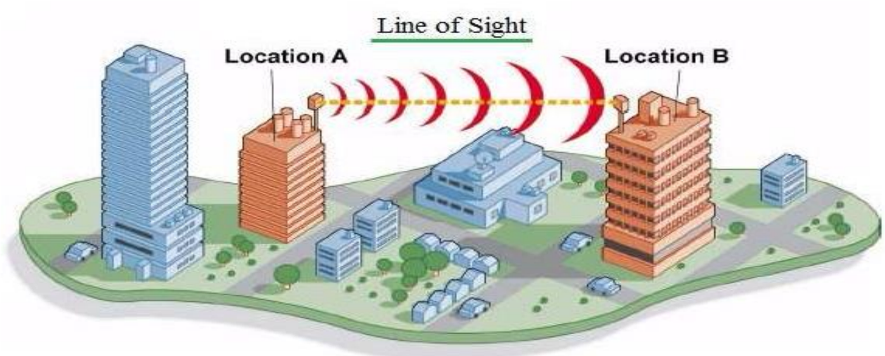



***Figure 4.*** *LOS illustration (Rfwireless-world.com, 2020)*

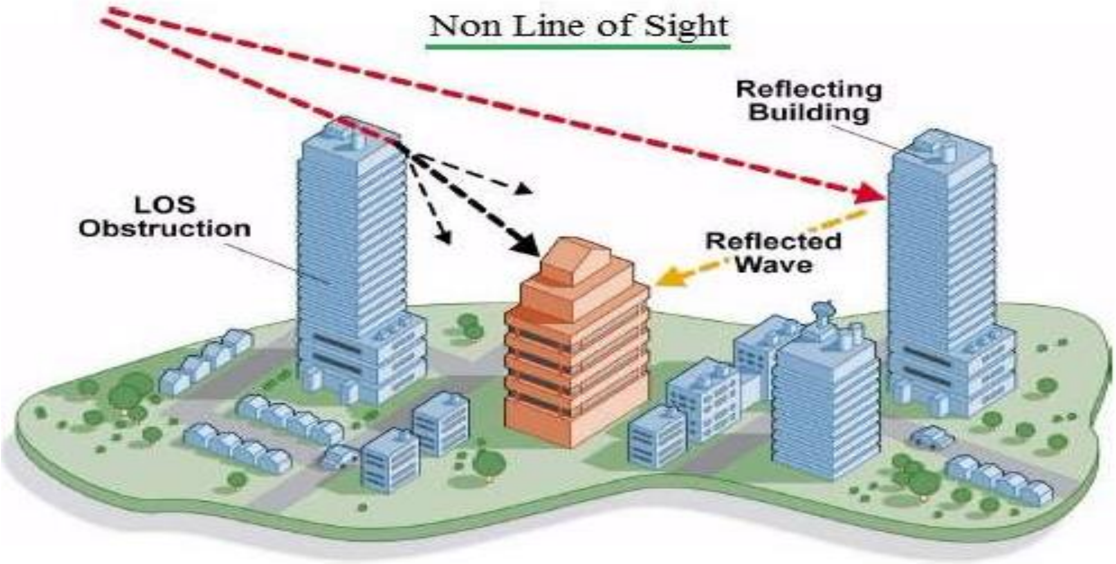



***Figure 5.*** *NLOS illustration (Rfwireless-world.com, 2020)*

***Path Loss Model***

Path loss models are useful for developing modulation and coding methods, calculating power budgets, and estimating cellular coverage and interference. The most extensively used path loss model for 5G is the free space path loss (FSPL) model.

The FSPL is a tool for predicting the strength of an RF signal at a given distance. This is a theoretical value, as there are many barriers, reflections, and losses been taken to account when evaluating the signal in the real time condition. This method is the best approximation for estimating the loss of signal when propagating through free space. The FSPL formula is expressed as in (1) (G. R. MacCartney, S. Sun, and T. S. Rappaport, 2017):

$$PL^{CI}(f,d)[dB] = FSPL(f,1\,m)[dB] + 10n\log_{10}\left(\frac{d}{d_0}\right) + AT[dB] + X_\sigma^{CI}$$

where $d \geq d_0$ m (1)

path loss exponent that be subject to the environment are represent as n, the distance between the transmitter and the receiver is denoted by the letter d. The antenna gain is AT, and the shadowing factor is X. Table 2 displays the ITU path loss exponent standard in various situations:

***Table 2.*** *Path loss exponent for different environments (n) (3GPP, Service requirements for next generation new services and markets, 2020)*

| Environment | Path Loss Exponent (n) |
|---|---|
| Free space | 2 |
| Urban area cellular radio | 2.7 to 3.5 |
| Suburban cellular radio | 3 to 5 |
| Inside a building – line – of - sight | 1.6 to 1.8 |
| Obstructed in building | 4 to 6 |
| Obstructed in factory | 2 to 3 |

The National 5G Task Force used path loss modeling as shown in Figure 6. The goal of these investigations is to compile the theoretical distance computation between the 5G base station and the Fixed Satellite Service (FSS) receivers so they can coexist alongside to each other in the C-band spectrum. Fig. 6 shows the experiment model uses the free-space model for LOS and the 3GPP Uma model for NLOS with the separation distance requirement between the 5G Base Station (assumed height =30m) and FSS receiver (assume height= 5m) (Malaysia 5G Task Force, June 2019).

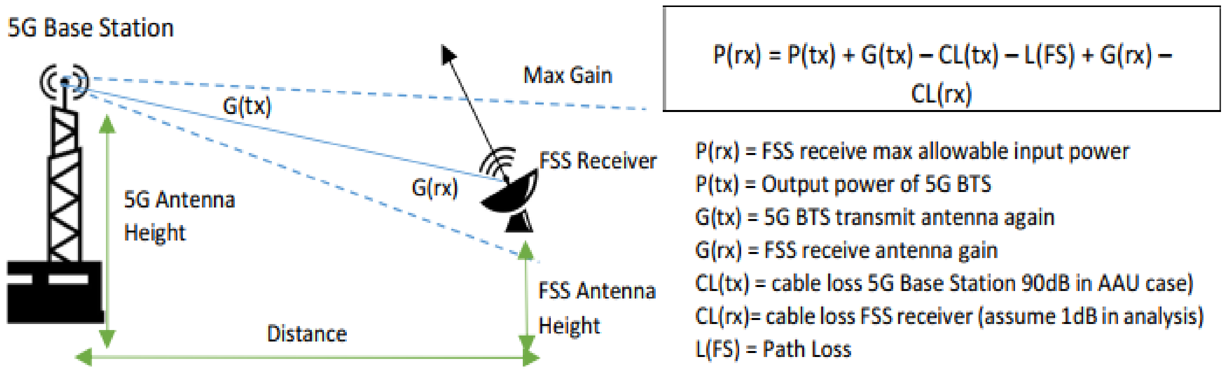



***Figure 6.*** *Path loss model by 5G national task force (E. I. Adegoke, E. Kampert and M. D. Higgins, 2020)*

Based on ITU 3GPP TR 38.901 version 15.0.0 Release 15, Fig. 7 depicts the flow for channel coefficient creation (3GPP, Service requirements for next generation new services and markets, 2020). It all starts with the parameters generation. The researcher must create a scenario, assign LOS/NLOS, calculate path loss, and develop correlated large-scale parameters throughout this phase. Then proceed to the second block, which contains the small-scale parameters, which includes the delays generation, cluster power, arrival and departure angles, random coupling ray preformation, and XPRs generation. The coefficient generation block is the final step, which includes drawing random beginning phases, generating channel coefficients, and applying path loss and shadowing.

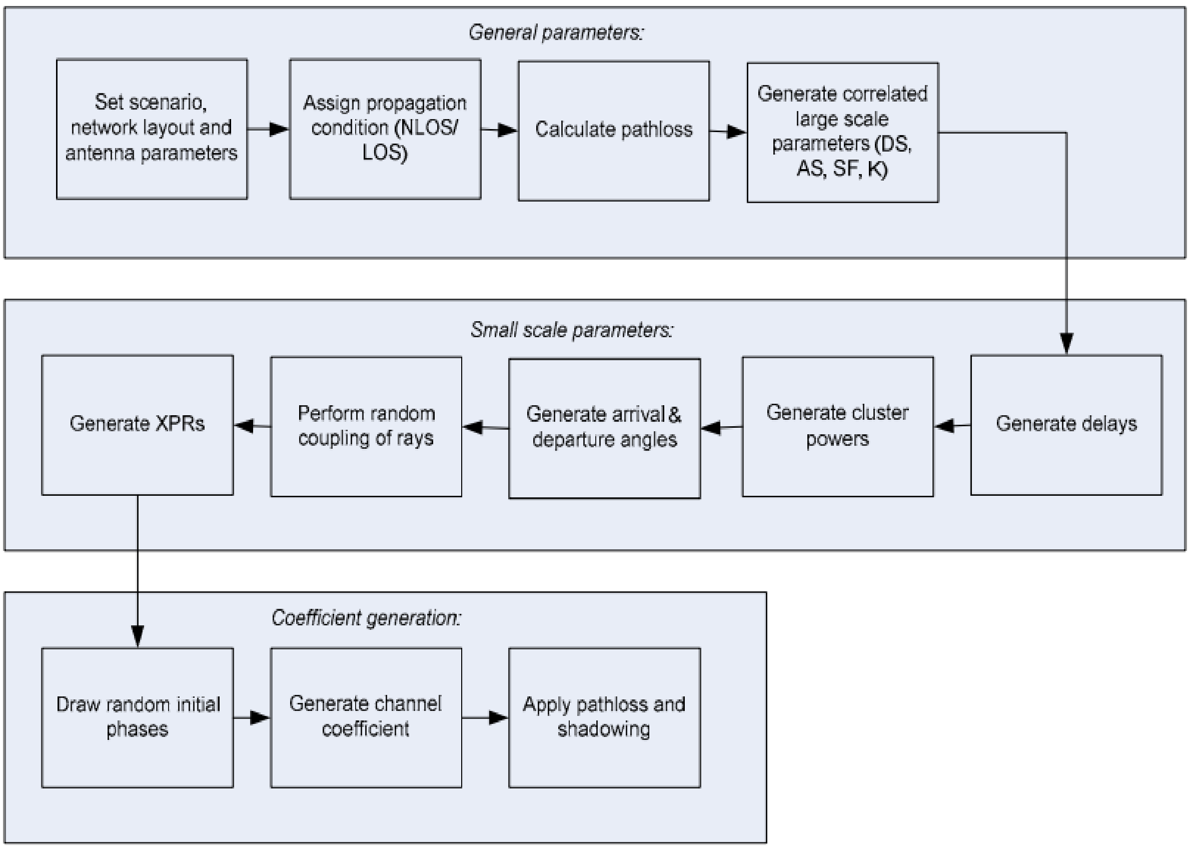



*Figure 7. Channel coefficient generation ITU flow (3GPP, Service requirements for next generation new services and markets, 2020)*

## III.RELATED WORKS

To fulfil the needs of 5G criteria, several researchers have been researched around the world. The first publication, E. I. Adegoke, Erik Kampert, and Matthew D. Higgins from WMG, The University of Warwick have done research in Empirical Indoor Path Loss Models at 3.5GHz for 5G Communications Network Planning, these researchers, looked at large-scale fading at 3.5 GHz for 5G communications (Y. A. Alqudah, 2012). The second article, Path Loss Simulator for the 3GPP 5G Channel Models, by Víctor Vilchez Díaz and Diogenes Marcano Aviles, looked into a web-based simulator for large-scale path loss models for 5G network frequencies, according to the 3GPP TR 38.901 report (E. I. Adegoke, E. Kampert and M. D. Higgins, 2020).

Next, the research on the Power Analysis and Modeling Based on Field Measurements Using 3.5 GHz WiMAX Network by Yazan A Alqudah from Princess Sumaya University for The fast deployment of WiMAX technology around the world has enabled researchers to conduct study based on actual field observations. This report studied an important aspect of network deployment which is power analysis (Aviles, V. V. Díaz and D. Marcano, 2018). Furthermore, Shu Suna, Theodore S. Rappaport, Sundeep Rangan, Timothy A. Thomas, Amitava Ghosh, Istva n Z. Kovacs, Ignacio Rodriguez, Ozge Koymen, Andrzej Partyka, and Jan Jarvel Ainen from NYU WIRELESS and Tandon School of Engineering, New York University published Propagation Path Loss Models for 5G Urban Micro and Macro-Cellular Scenarios. This paper examines two candidate large-scale propagation route loss models, the alpha-beta-gamma (ABG) model and the close-in (CI) free space reference distance model, for the design of fifth-generation (5G) wireless communication systems in urban micro- and macro-cellular contexts. (Y. A. Alqudah, 2012).

Other than that, research from Shu Sun, George R. MacCartney Jr., and Theodore S. Rappaport from NYU WIRELESS and NYU Tandon School of Engineering, New York University studied on a Novel Millimeter-Wave Channel Simulator and Applications for 5G Wireless Communications. The researcher discusses the features and applications of NYUSIM, a new channel simulation software that able to be used in order to simulate spatial channel responses and realistic temporal for physical and link-layer simulations and design for fifth-generation (5G) cellular communications. (Sun, Shu & Rappaport, T.S. & Rangan, Sundeep & Thomas, Timothy & Ghosh, Amitava & Kovacs, Istvan & Rodriguez Larrad, Ignacio & Koymen, Ozge & Partyka, Andrzej & Järveläinen, 2018).

To enhance the understanding in testing the 5G network, several research papers have been taken into consideration to improve the researcher's knowledge. A report from Konshiro Kitao and friends from NTT DOCOMO has developed a simulation tool and done a simulation of the 5G network in Tokyo perspective. The 5G studies are done on the system that are used multi-antenna technologies. The tool then will calculate the propagation characteristic on the ray-tracing and the SINR/throughout. The advantage of the simulation is the test has been done with an actual location where it is already equipped with 5G. The drawback is this paper does not manipulate the transmitter and receiver distance (K. Kitao, A. Benjebbour, T. Imai, Y. Kishiyama, M. Inomata, and Y. Okumura, 2018).

Following that, a research from China's SRRC looked into interference protection requirements derived from semi-physical simulation tests for the 40 GHz band, as well as the feasibility of spectrum combability and sharing between 5G and FSS systems. This is to see if their country meets the application requirements for future wireless mobile communications in the 40 GHz band. The VUE programme is used for this simulation (S. Sun, G. R. MacCartney and T. S. Rappaport, 2017). Last but not least, there's the national 5G Task Force report, provides a quantitative analysis of the technological feasibility of 5G and FSS coexistence by conducting a theoretical study, lab test, and field test in specific places, as well as a mitigation plan. (Malaysia 5G Task Force, June 2019).

Furthermore, the paper Investigation of Future 5G-IoT Millimeter-Wave Network Performance at 38 GHz for Urban Microcell Outdoor Environment by Faizan Qamar, MHD Nour Hindia, Kaharudin Dimyati, Kamarul Ariffin Noordin, Mohammed Bahjat Majed, Tharek Abd Rahman, and Iraj Sadegh Amiri looked at the outputs of FI path loss, particularly for V-V antenna polarization gave outcomes of device simulation that were unacceptable for the NLOS scenario (Qamar, F.; Hindia, M.N.; Dimyati, K.; Noordin, K.A.; Majed, M.B.; Abd Rahman, T.; Amiri, I.S, 2019).

As a conclusion from all the mentioned papers, it shows that what has the previous researcher done, what has been achieved and what has not been done yet. Thus, it is essential to analyze the impact of the transmitter and receiver distance on the path loss propagation as well as to the received power changes.

## IV. METHODOLOGY

***Project hypothesis***

The purpose of this research is to provide a free-space path loss model for the 3.5GHz band that works in both LOS and NLOS scenarios. The simulation will be run on the NYUSIM channel simulator software. This project's main purpose is to figure out how the gap between the transmitter and receiver impacts path loss and received power.

This experiment is predicted to have an acceptable distance ranges needed between transmitter and receiver at the end of this simulation as the path loss grows, affecting the received power gradually weakening.

***Experiment set up***

To prove the hypothesis, simulation parameters were set up as in Table 3:

***Table 3.*** *Simulation Parameters*

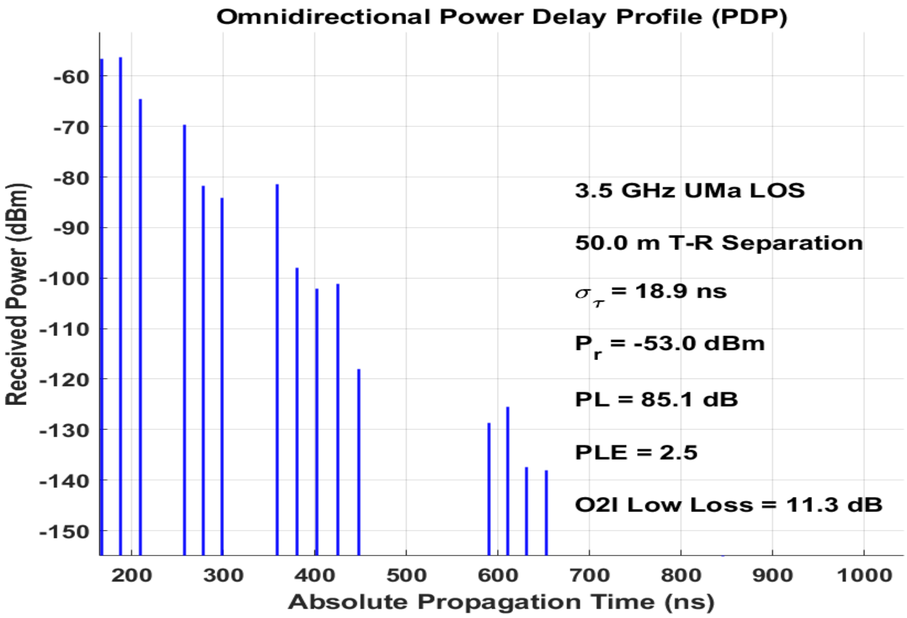
| Channel Parameter | | Antenna Parameter | |
|---|---|---|---|
| Distance range option | 10-500m | Tx array type | ULA |
| Frequency | 3.5 Ghz | Rx array type | ULA |
| RF bandwidth | 100 MHz | Device configuration | 2Tx 4Rx |
| Scenario | UMa | TX Antenna Azimuth HPBW | 10 |
| Environment | LOS and NLOS | TX Antenna Elevation HPBW | 10 |
| Transmit power | 35dBm | RX Antenna Azimuth HPBW | 10 |
| Biometric pressure | 1013.25 mbar | RX Antenna Elevation HPBW | 40 |
| Humidity | 60% | Spacial consistency | Neglected |
| Temperature | 33 Celcius | Human blockage | Neglected |
| T-R distance | 50m, 100m, 200m | | |

Angle of departure, angle of arrival, power dissipation, omnidirectional power delay profile, directional power delay with the strongest power, and small-scale power delay profile will all be simulated outcomes.

## V. RESULTS AND DISCUSSION

The simulated results are presented as in Fig. 8 - 13. The results are presented by each simulation setup. The total experiment setup is 8. The distance to be tested is in the range of 50m, 100m, and 200m, as 5G is expected to require a large number of small cell deployments, necessitating a short distance. The simulated results in form of path loss and received power are tabulated into several graphs.

***LOS environment at 50m, 100m and, 200m transmitter and receiver distances***

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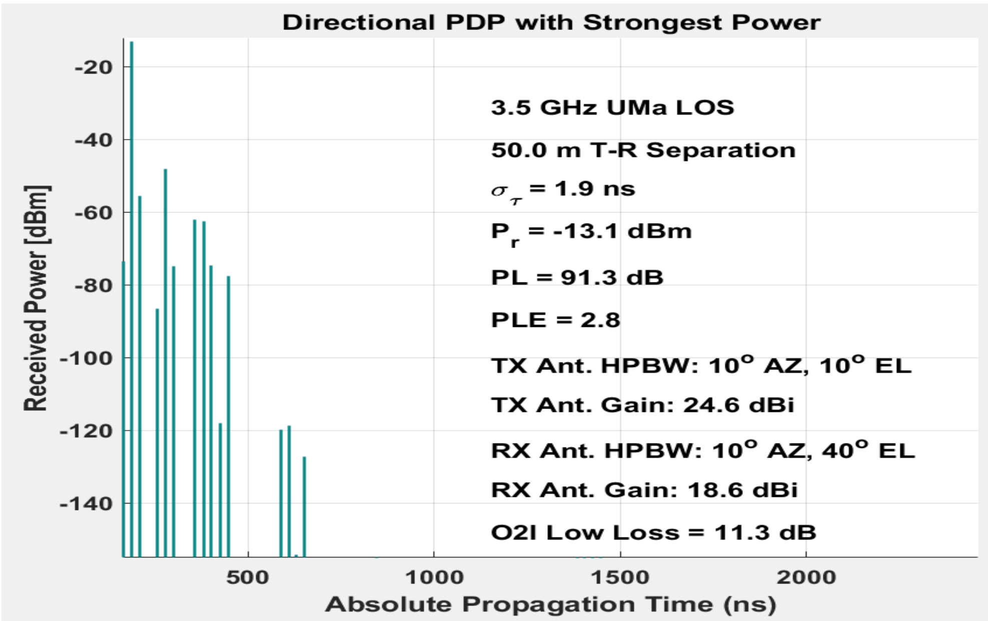


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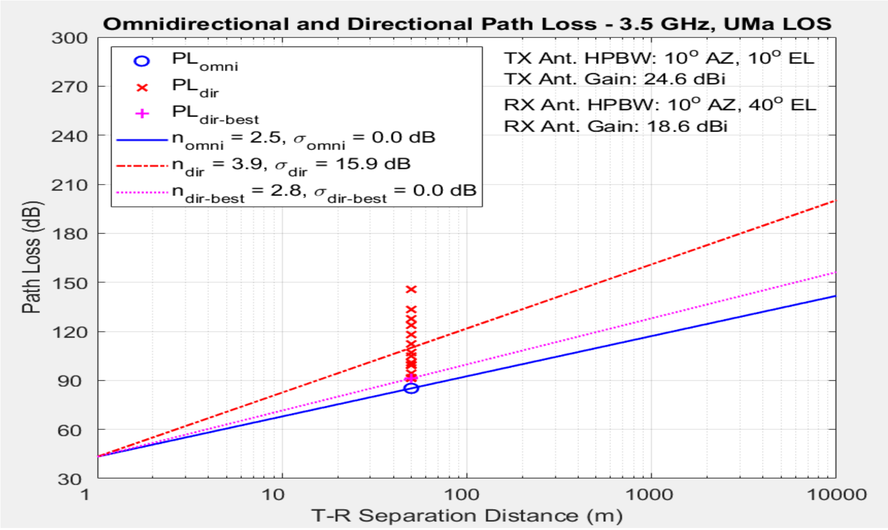


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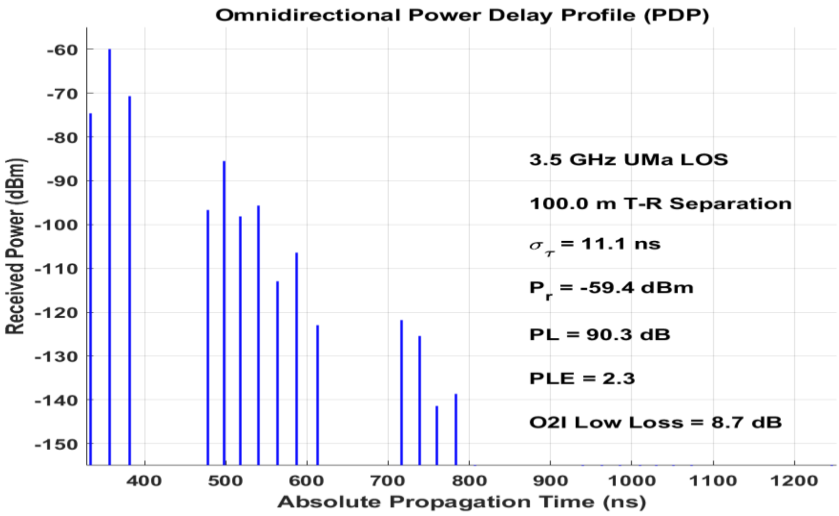
***Figure 8.*** *Simulation result for LOS environment at 50m transmitter and receiver distance (a) received power in omnidirectional (b) received power in omnidirectional (c) path loss*

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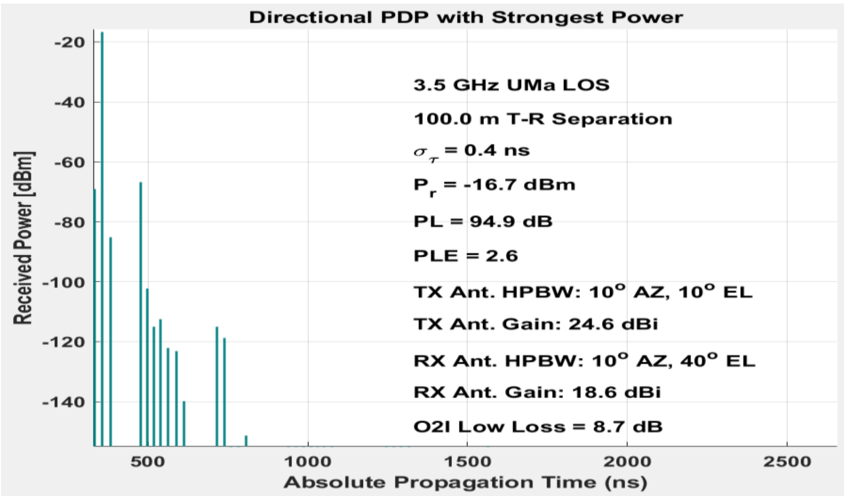


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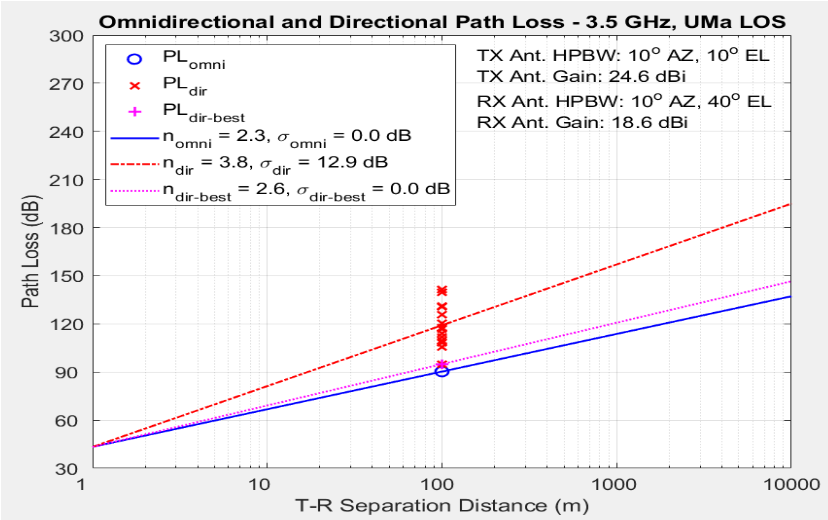


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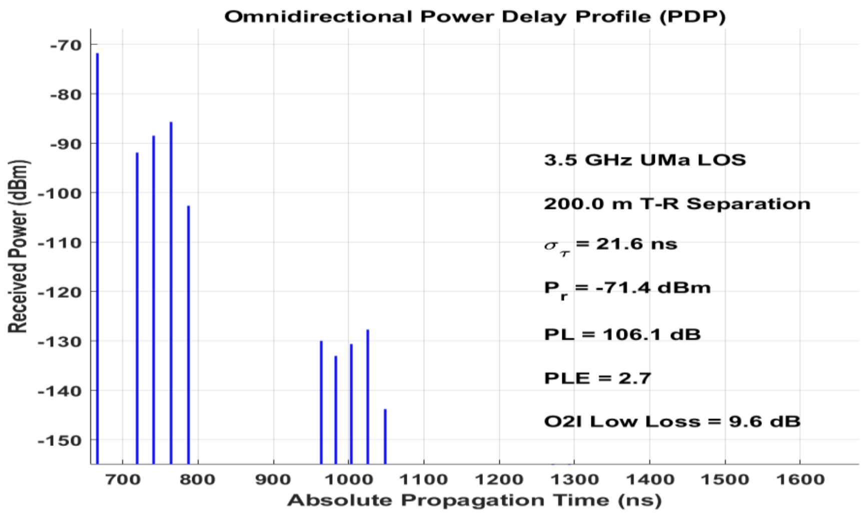
***Figure 9.*** *Simulation result for LOS environment at 100m transmitter and receiver distance (a) path loss (b) received power in directional (c) received power in omnidirectional*

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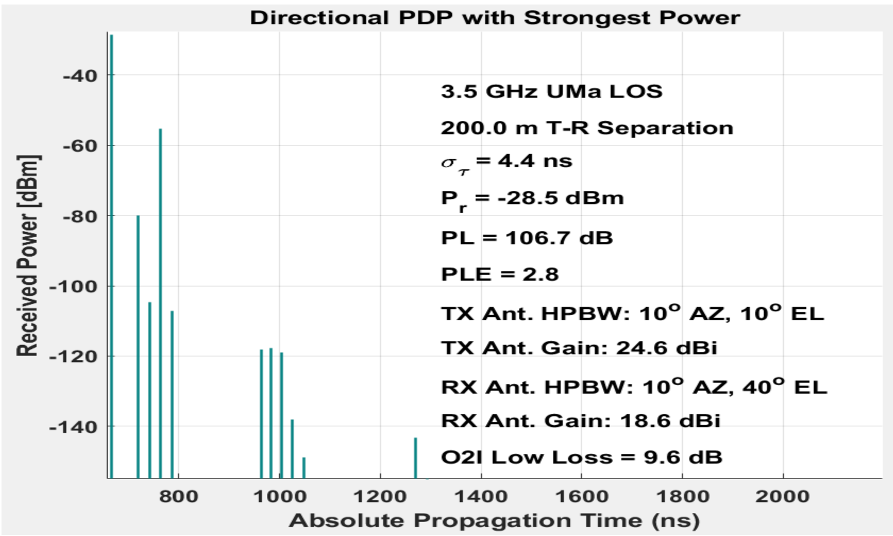


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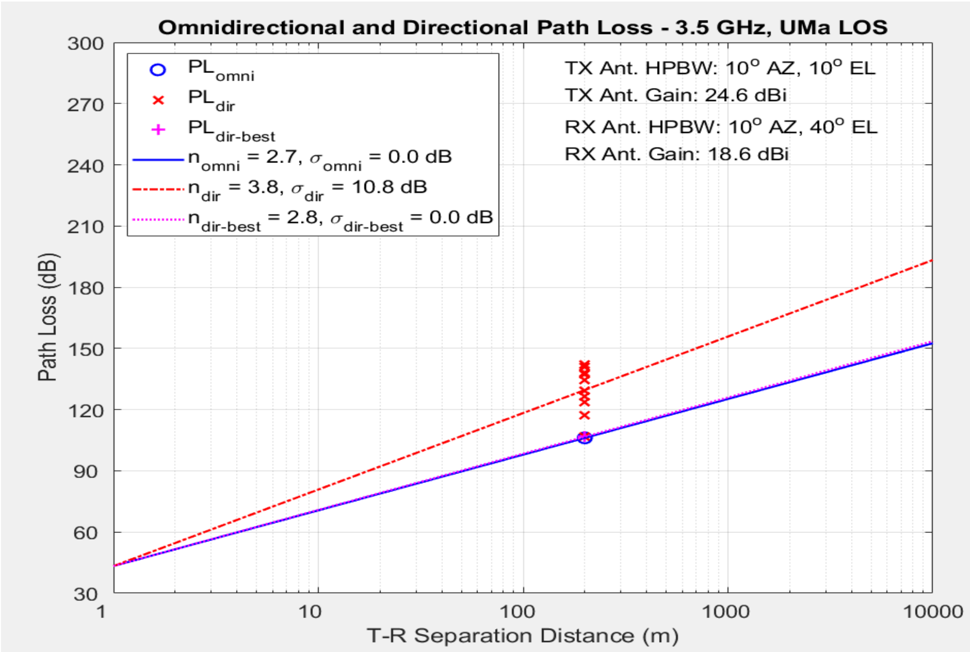


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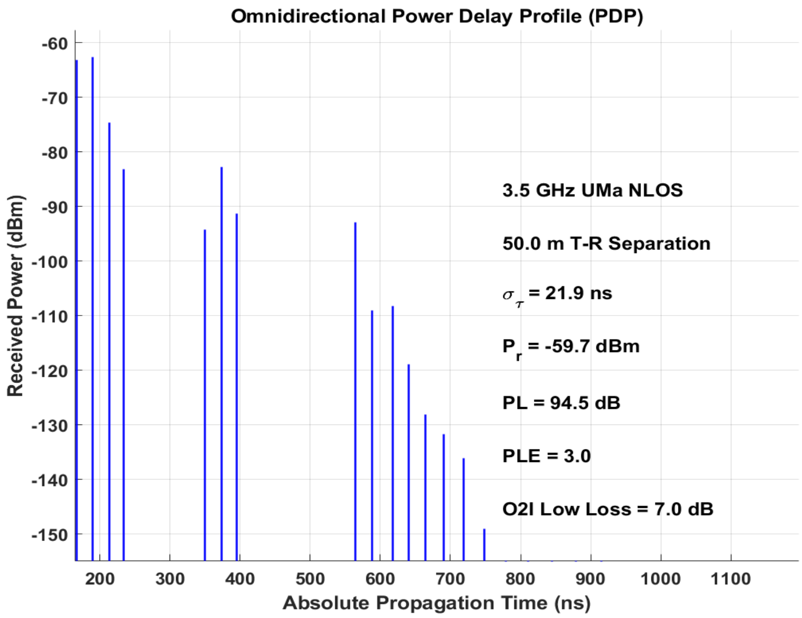
***Figure 10.*** *Simulation result for LOS environment at 200m transmitter and receiver distance (a) received power in omnidirectional (b) received power in omnidirectional (c) path loss*

Fig. 8, 9, and 10 show the simulated result for the LOS environment at 50m, 100m, and 200m distances between transmitter and receiver. The lowest path loss attained is 85.1dBm for omnidirectional and 91.3dBm for directional and the highest path loss is 106.1dBm for omnidirectional and 106.7dBm for directional at 200m transmitter and receiver distance. Then, the lowest received power is -71.4dBm in an omnidirectional while -28.5dBm in directional at 200m transmitter and receiver distance.

***NLOS environment at 50m, 100m, and 200m transmitter and receiver distances***

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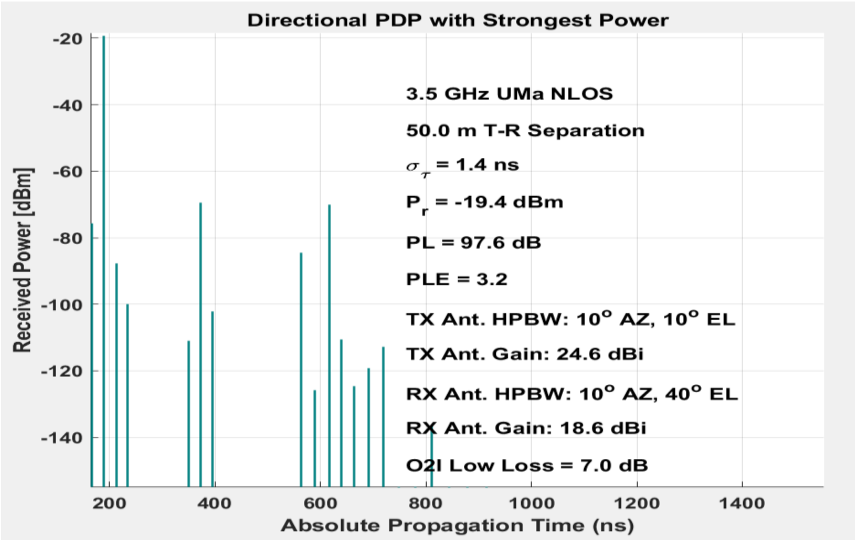


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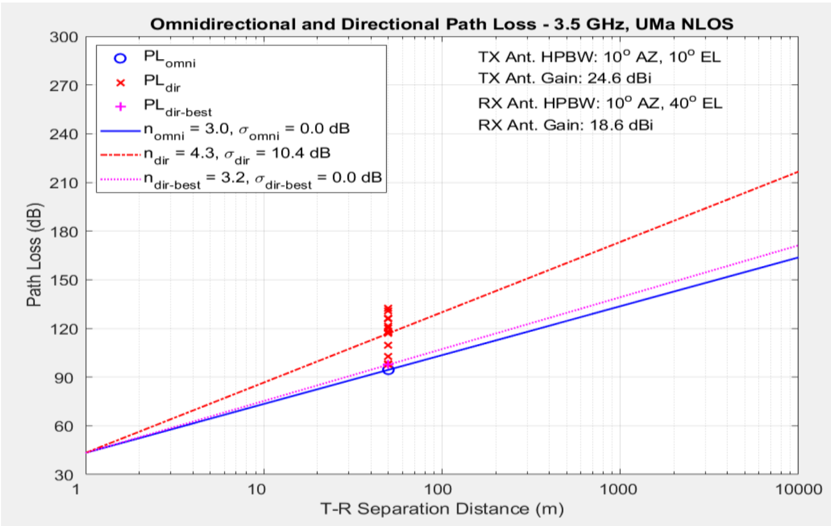


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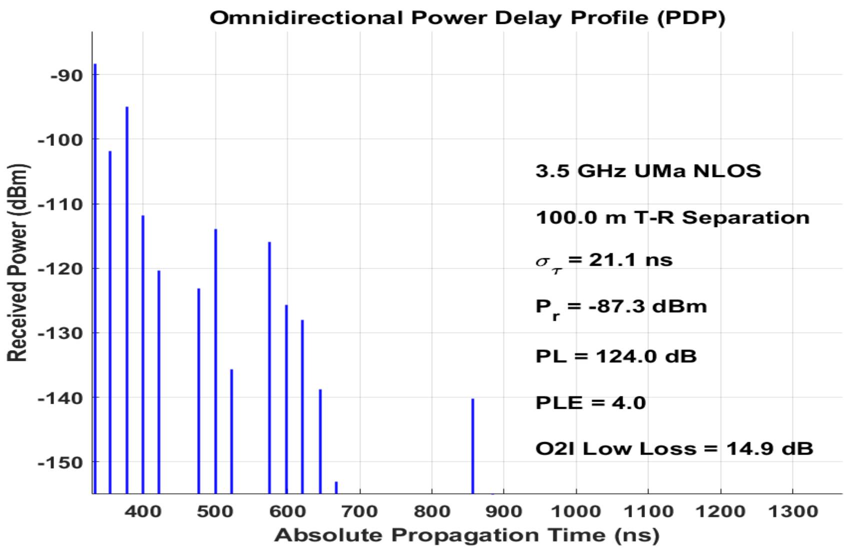
***Figure 11.*** *Simulation result for NLOS environment at 50m transmitter and receiver distance (a) received power in omnidirectional (b) received power in omnidirectional (c) path loss*

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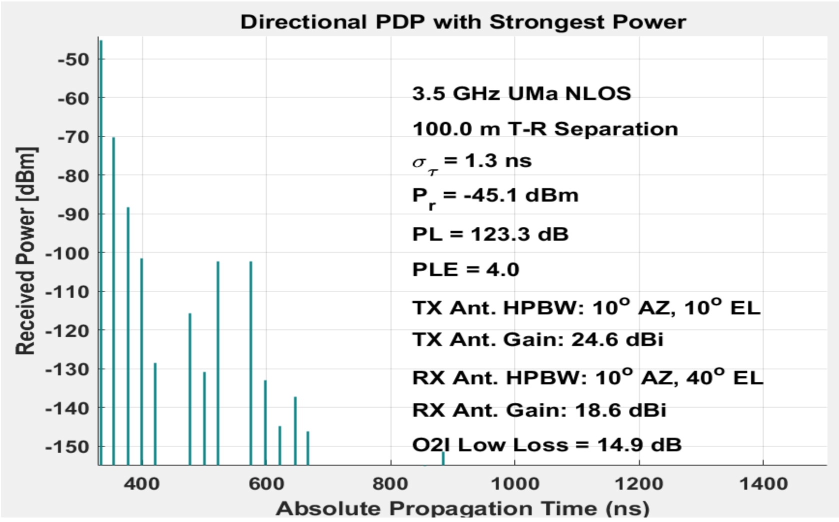


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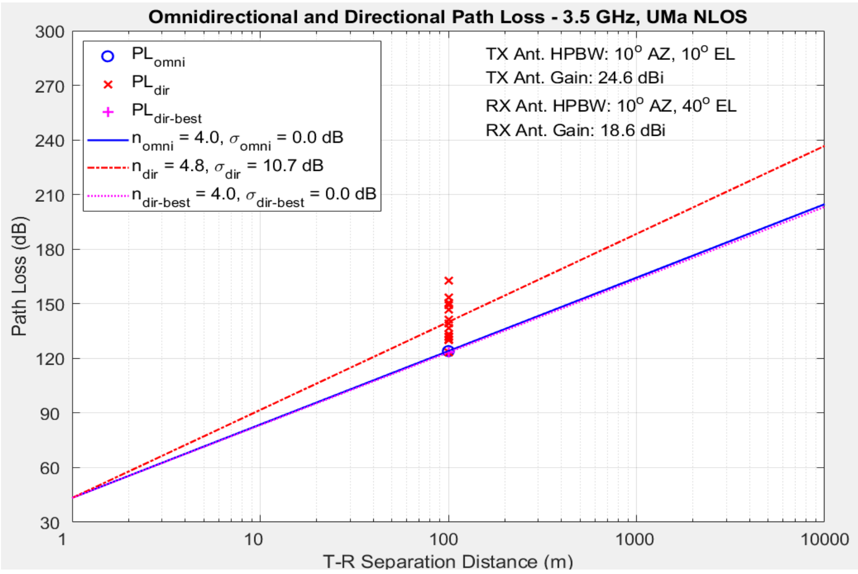


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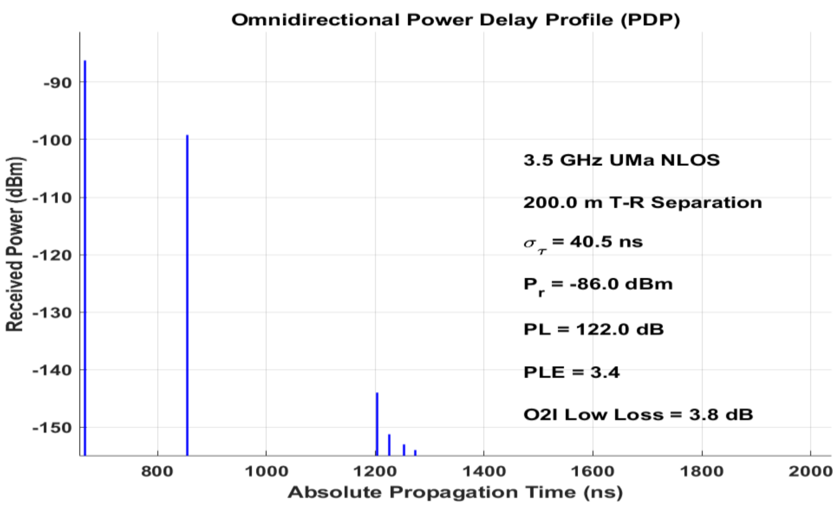
***Figure 12.*** *Simulation result for NLOS environment at 100m transmitter and receiver distance (a) received power in omnidirectional (b) received power in omnidirectional (c) path loss*

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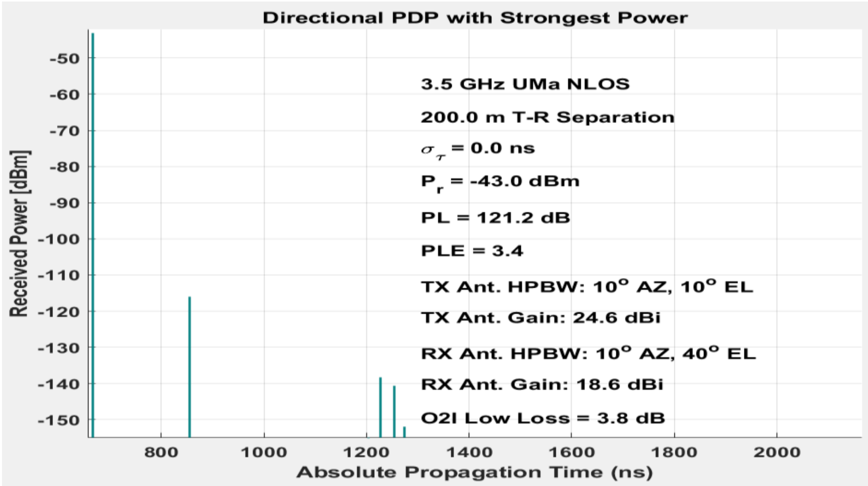


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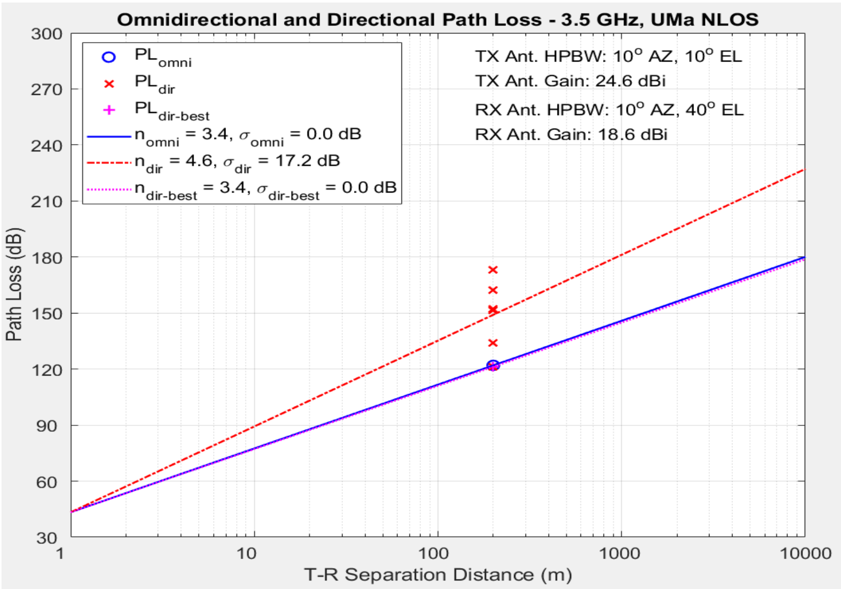


**(c)**

***Figure 13.*** *Simulation result for NLOS environment at 200m transmitter and receiver distance (a) received power in omnidirectional (b) received power in omnidirectional (c) path loss.*

Fig. 11, 12, and 13 show the simulated result for the NLOS environment at 50m, 100m, and 200m distances between transmitter and receiver. The lowest path loss attained is 94.5dBm for omnidirectional and 97.6dBm for directional and the highest path loss is 122.0dBm for omnidirectional and 121.2dBm for directional at 200m transmitter and receiver distance. Then, the lowest received power is -86.0dBm in an omnidirectional while -45.1dBm in directional at 200m transmitter and receiver distance.

From all figures, it can be stated that the path loss is increasing along with distance increases. The path loss at a higher distance induces more path loss as compared to the lower distance for both environments. The lowest path loss for omnidirectional is when measurement at 50m transmitter and receiver distance which is 85.1dBm and the highest path loss is at 100m transmitter and receiver distance which is 124.0dBm. For the directional antenna, the lowest path loss is 91.3dBm at 50m transmitter and receiver distance while the highest path loss is recorded at 123.3dBm for 100m transmitter and receiver distance. The lowest path loss was recorded under LOS conditions while the highest path loss was recorded in the NLOS environment. Because there is more reflection, diffraction, scattering, and doppler effect in the

NLOS environment, path loss increases as the distance grows.

The route loss increases as the distance grows in all of the figures. Path loss at a higher distance creates more path loss than path loss at a lower distance in both cases. The lowest path loss for omnidirectional measurement is 85.1dBm at 50 metres between transmitter and receiver, while the largest path loss is 124.0dBm at 100 metres between transmitter and receiver.. The directional antenna has a route loss of 91.3dBm for 50m transmitter and receiver distance and a path loss of 123.3dBm for 100m transmitter and receiver distance. The LOS scenario resulted in the lowest path loss, while the NLOS scenario resulted in the highest path loss. The reason is that when the distance expands the path loss will increase due to more reflection, diffraction, scattering, and doppler effect during the NLOS environment.

The received power from both surroundings is then assessed for directional and omnidirectional applications. The highest received power for omnidirectional is -53.0dBm when measured at 50m transmitter and receiver distance. The lowest received power is -87.3dBm at a distance of 200m between the transmitter and receiver. The highest received power for the directional antenna is -13.1dBm at 50m gap between transmitter and receiver, while the lowest is -43.0dBm at 200m space between transmitter and receiver. Omnidirectional received power is lower than directional received power. The pointing factor of an electromagnetic wave is critical for achieving optimal service quality, especially in the NLOS environment. The reason for this is that as the path loss and other losses increase during propagation, the received power decreases. Throughout the transmission, the loss absorbed the transmit power, reducing the received power.

Referring to the specification in Table 4, the range of the power received for the excellent signal is less than -80dBm while the good signal is range -90dBm to -100dBm (Frontiercomputercorp.com, 2021). Based on this specification, this show for LOS and NLOS environments at a transmitter and receiver distance of 50m to 200m provides an excellent and good signal. Within the route loss measured, it is reasonable to conclude that the requisite distance ranges between transmitter and receiver are acceptable.

***Table 4 .*** *Reference Signal Received Power (Frontiercomputercorp.com, 2021)*

| | RSRP (dBm) Reference Signal Received Power | RSRQ (dB) Received Signal Reference Quality | SINR (dB) Signal Interference & Noise Ratio |
|---|---|---|---|
| Excellent | >- 80 | >-10 | -20 |
| Good | -80 to -90 | -10 to -15 | 13 to 20 |
| Marginal | -90 to -100 | -15 to -20 | 0 to 13 |
| Weak | <-100 | <-20 | <0 |

## VI. CONCLUSION

In this paper, the network performance is obtained from the simulation of the 3.5GHz by using the NYUSIM channel simulator. The simulation is to analyze the impact of the 3.5GHz channel propagation towards the increment of the space between the transmitter and the receiver. In conclusion, as the gap between the transmitter and receiver rises the path loss rise too. While the power received power will decreases when the distances increase. It can be concluded that the distance range between 50m to 200m is still acceptable to be planned as the 3.5GHz is in the higher frequency band. Higher wireless signal frequency usually has a shorter range. Walls, floors, and other obstructions can’t easily move through higher frequency signals. The outcome of this study would benefit future researchers to study 5G technology development in Malaysia. For future works, a study on planning the positioning of the transmitter and the receiver can be further extended. The antenna design and effects of height on received power must also be observed at the 3.5GHz frequency band.

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