Performance Analysis of Radio Propagation in 5G Networks for Line of Sight (LOS) and Non-Line of Sight (NLOS) Environments

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Abstract

5G connectivity will be used in Malaysia as part of a plan to upgrade the nation's digital infrastructure. As stated by the Malaysian Communications and Multimedia Commission @ K-KOMM, the country is planning to adopt 5G in multiple stages, with the primary stage takes on the improvement of the country's present 4G connectivity, while the secondary stage is transitioning to 5G by 2022. (MCMC). The 3.5 GHz band is the main focus of 5G mobile networks due to the increasing capacity demands. It is a difficult undertaking, though, because a 3.5 GHz higher frequency range produces a larger path attenuation/path loss. Consequently, it is crucial to measure the signal strength path attenuation for figuring out the frequency band's viable coverage. This study measured the received power and path attenuation/path loss propagation by taking two main parameters; the transmitter distance (Tx) and receiver distance (Rx) in both situations (Line-of-Sight (LOS) & Non-Line-of-Sight (NLOS)) to assess the results. Both of the receiver (Rx) and transmitter (Tx) distances increased by 5 meters for every measurement taken starting from 10 up till 55 meters in both situations to measure the 5G networks radio propagation. According to the measurement results, the route loss rises as transmitter and receiver distances widen while received power declines. As conclusion, increased route loss affects the received power of radio propagation in 5G networks, thus, it can be determined that the ranges for distance between 5 and 55 metres is appropriate to be develop for both of the situations, in LOS and NLOS. The findings of this study can be used in Malaysia as a standard for field tests and interference mitigation methods.(Abstract)

Keywords: - Line of Sight, Non-Line of Sight, Path Loss Propagation, 5G (key words).

1. Introduction

The newer 5G wireless network promises faster speeds, more broadband capacity, and lower latency. It's critical for society to use 5G's faster upload and download speeds in areas like education, where students might learn about human anatomy digitally via augmented reality or virtual reality, allowing them to visualize certain portions of the anatomy without having to dissect an actual body. For a seamless learning experience, this system would need to send data at a rate of terabytes per second.

It is crucial to build a rigorous plan and thorough calculation towards the 5G mid-band network in order to adopt such technology for societal use. Necessary factors such as the antenna's size, the distance from one antenna to another antenna, the user equipment (UE), the antenna's height, the wave propagation capacity in LOS and NLOS, and the spectrum allotment are all needed to take into account in this planning. Theoretically, the foundation of 5G using this higher 3.5GHz, mid-band frequency wireless communication is that because the wavelength is tiny, blocking or shadowing can occur, which can significantly lower the radio link's output. Wave propagation must therefore be taken into account in order to successfully introduce 5G technology to society. This research's main contribution is its analysis of radio propagation in a 5G mid-band wireless network.

The following parts of the paper is organized into five sections differently. Section II explains all works related to this research and Section III presents methodology used in the research. Results and discussion, are described in Section IV and lastly, a conclusion is drawn in Section V.

2. Related Works

Due to the widespread use of 4G, the propagation of waves from earlier technologies has been thoroughly examined. As the technology has been implemented all across the world, a great deal of research has been done on the analysis of radio propagation for 4G. However, due to the technology's application being restricted to a few regions, Malaysia is still in the early stages of adopting the most recent technology, 5G. The analysis on the viability of 5G existing together with the current services in the IMT-2020 candidate bands in Malaysia has been presented by the authors in [1]. The researchers claimed that when 5G is deployed utilising the proposed mmWave bands that ranges from 24 GHz to 86 GHz utilized by the International Telecommunication Union (ITU), the principal services affected specifically will be the 28 GHz band fixed services.

The 5G Demonstration Project has been deployed in Malaysia in a number of locations, including in a megamall in Kuala Lumpur called Berjaya Times Square Mall, where the main vendor was one of Malaysia's telecommunication provider, U-Mobile Malaysia and another one in the state of Kedah Darul Aman, specifically in the district of Langkawi which was launched by Malaysia's primary telecommunication provide, Telekom Malaysia Berhad(TM) [2]. A task force was established by the Malaysian Communications and Multimedia Commission (MCMC) in November 2018 called National 5G Task Force to examine 5G deployment utilising the 3GPP UMA model for the NLOS and the free-space model for the LOS [3]. The introduction of 5G will be postponed for a year due to the voided spectrum allotment, according to author [4] in Nikkei Asia. According to the author of [5], Malaysia lacks the devices and apps necessary to achieve 5G in the first quarter of 2021. According to the paper in [6], the Malaysian government has conducted two studies related to the deployment of 5G, firstly on the non-ionizing radiation, and the study on spectrum in order to produce a comprehensive picture of what providers should obtain from the spectrum frequency.

Another study that was conducted inside Malaysia used an outdoor environment for its setting. This study was done by measuring the outside wide band system mmWave propagation in a

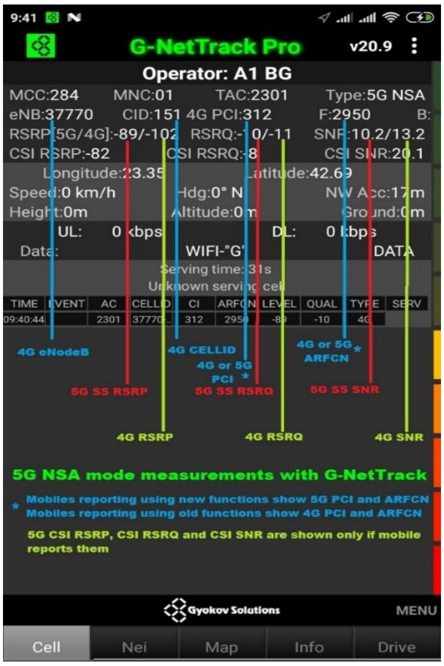
5G wireless network at a frequency of 28 GHz, although it has a constraint in that it was only done outside. In addition, the cost of implementing 5G is high due to the large number of base stations required to support the quicker data rate and enormous bandwidth that 5G will offer. To reduce costs and implement 5G in an effective way and ensure that the entire country has access to 5G technology of the same calibre, careful planning and calculation are necessary. As a result, this research will examine the radio propagation performance analysis in 5G networks through test field measurement employing test tool equipment.

3. Methodology

This section explains the detail on the field test measurement using G-NetTrack Lite at Berjaya Times Square, Kuala Lumpur.

Field Test Measurement Setup

Fig. 1 displays the application implemented during measurement called G-Net Track Lite Software obtained from the Phone Application Store, Google's Play Store. It is installed in smartphone Realme 7 5G RMX2111 that supports 5G technology. Fig. 2 displays another application, Smart Measure that has the abilities to calculate the distances between transmitter (Tx) and receiver (Rx) and it can be downloaded from the Phone Application Store, Google Play Store. Fig. 3 displays the 5G repeater's height calculated using the Smart



Measure application

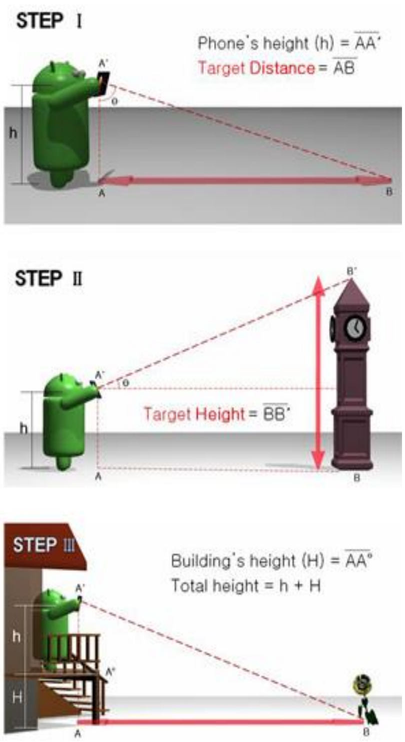


Fig. 1: G-NetTrack Lite Software(left), Fig. 2: Smart Measure Software (right)

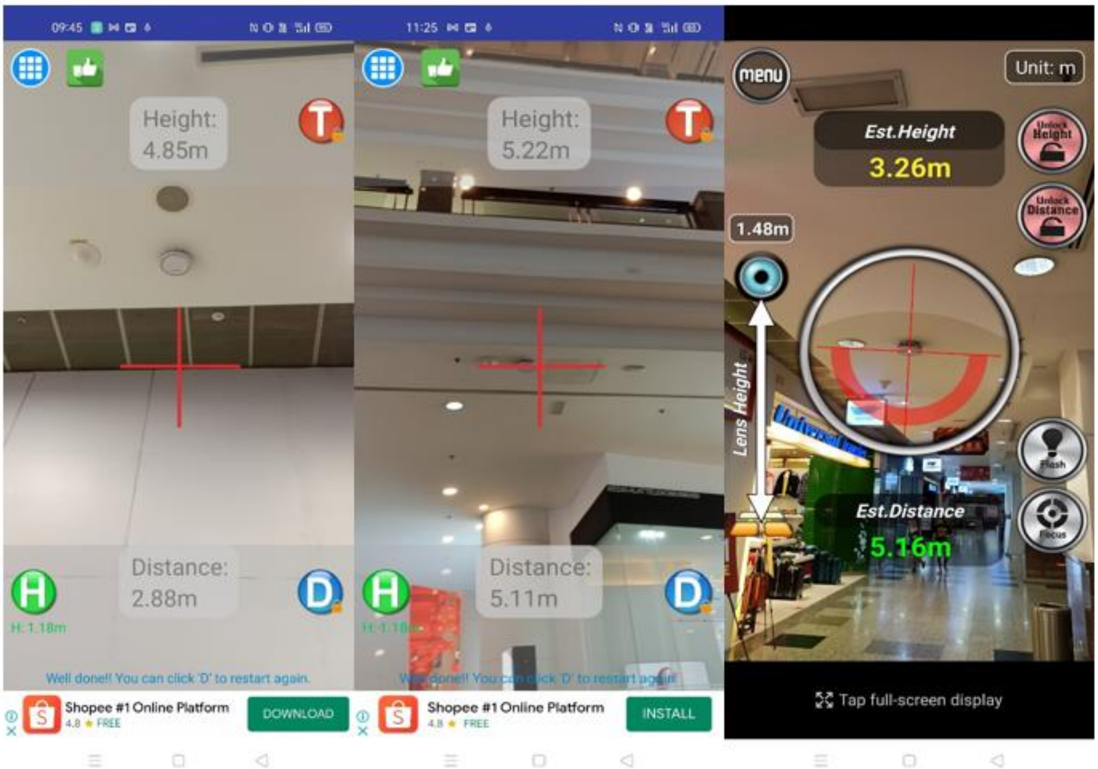


Fig. 3: Height of transmitter and receiver

Fig. 4 shows the 5G NR Standard Acceptable Range for Reference Signal Received Power RSRP [8]. The yellow colour indicates the acceptable good signal strength

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performance for 5G networks. Fig. 5(a) and (b) show the flow chart for the field test measurement conducted in LOS and NLOS environments. RSRP is the signal strength or signal level and is the most important measurement in LTE and 5G networks. The main focus of this project is to study the effect of both of the parameters, the transmitter distance (Tx) and receiver distance (Rx), towards the path loss and received power. Due to the route loss increasing and has an impact on the received power's gradually declining strength, this experiment is expected to produce an appropriate calculated range of distances between receiver and transmitter at the end of these tests.

NR RSRP			
	0>	X	>=-75
	-75>	X	>=-85
	-85>	X	>=-95
	-95>	X	>=-105
	-105>	X	>=-120
	-120>	X	>=-140

Fig. 4: 5G NR RSRP Standard Acceptable Range

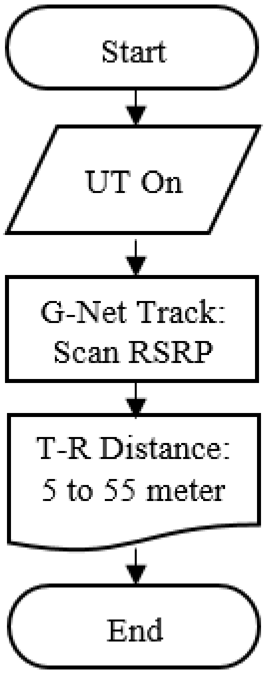

Fig. 5(a): Collecting RSRP for LOS environment

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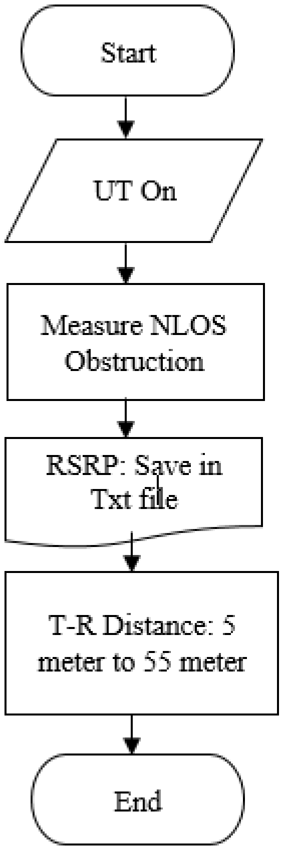


Fig. 5(b): Collecting RSRP for NLOS environment

Signal strength measurement for LOS environment at Berjaya Times Square, Kuala Lumpur.

The measurement was made on three different floors namely Lower Ground floor, Ground floor, and Level 1 floor.

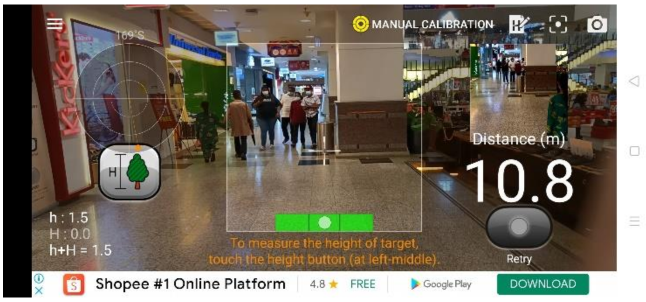


Fig. 6: RSRP measurement for LOS environment at a Tx-Rx separation gap of 10 meters at LG floor

The measurement for the LOS environment at 10 metres on the Lower Ground (LG) floor, where the repeater or router was placed 5 metres above the ground, is shown in Fig. 6.

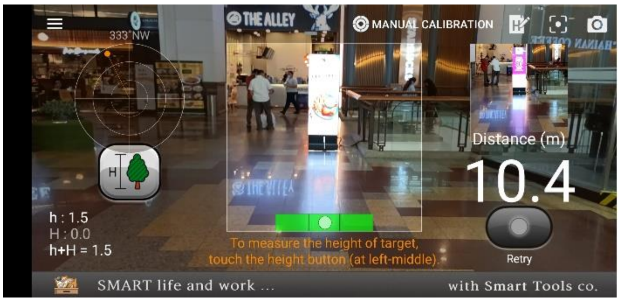


Fig. 7: RSRP measurement for LOS environment at a Tx-Rx separation gap of 10 meters at GF floor

Fig. 7 shows the measurement for LOS at 10 meters in the Ground Floor (GF) floor. The repeater is situated above the LED board at 5 meters. All of the test measurements from 10 to 55 meters used the base of the LED board as the target base to produce an efficient separation distance.

Fig. 8: RSRP measurement for LOS environment at a Tx-Rx separation gap of 10 meters at L1 floor

The measurement for the LOS environment at 10 metres at the L1 floor is shown in Fig. 8.

Signal strength measurement for NLOS environment at Berjaya Times Square, Kuala Lumpur.

The measurement was made on the same three different floors namely Lower Ground floor, Ground floor, and Level 1 floor.

Fig. 9: RSRP measurement for NLOS environment at a Tx-Rx separation gap of 10 meters at LG floor

Fig. 9 shows the NLOS environment measurement at 10 meters made at the Lower Ground (LG) floor. In NLOS environment, the measurement is made outside of the mall where the repeater is situated between UT and the glass door. The width of the glass door is measured at approximately > 2cm.

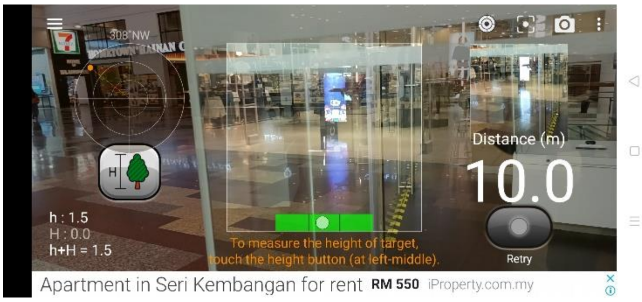


Fig. 10: RSRP measurement for NLOS environment at a Tx-Rx separation gap of 10 meters at GF floor

Fig. 10 shows the NLOS environment measurement at 10 meters made at the Ground Floor (GF) floor. The width of the glass door is measured at approximately > 4 cm. The targeted base is pointed at the base of the LED board.

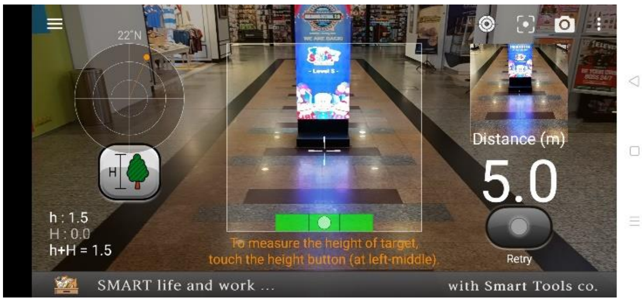


Fig. 11: RSRP measurement for NLOS environment at a Tx-Rx separation gap of 10 meters at L1 floor

Fig. 11 shows the NLOS environment measurement at 10 meters where the distance between the repeater and LED board is at 5 meters with the additional 5 meters between the LED board to the UT. The width of the LED board is measured at 19 cm.

Simulation using NYUSIM Milimeter-Wave Simulator for LOS and NLOS Environment

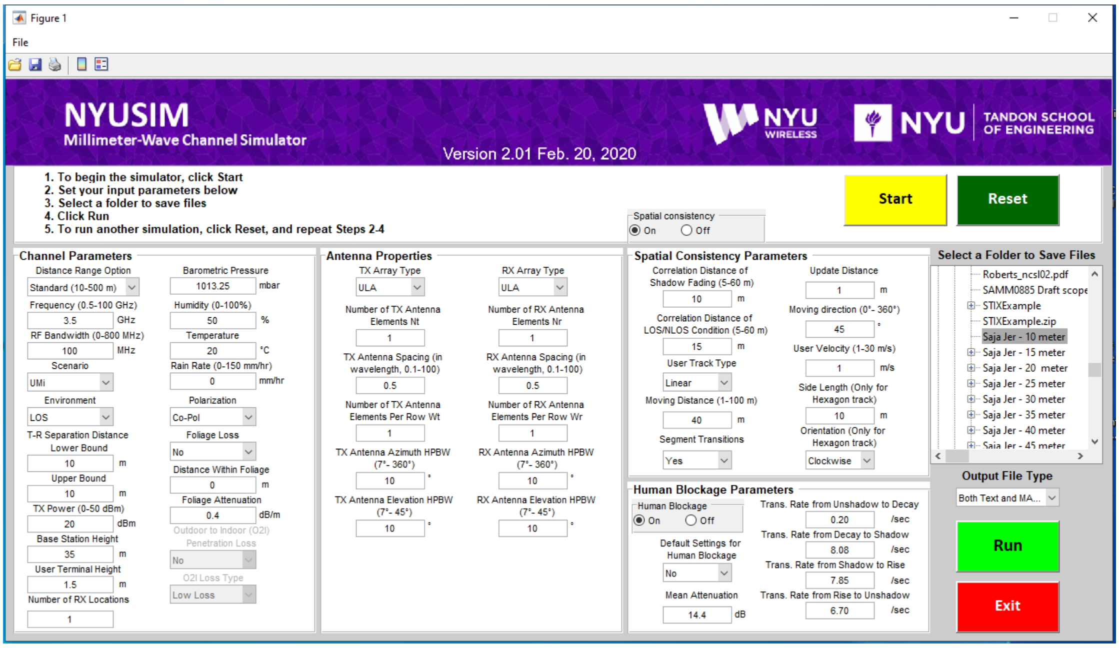


Fig. 12: NYUSIM Simulation GUI for LOS environment at a Tx-Rx separation gap of 10 meters

Figure 12 displays the simulation made on the graphical user interface (GUI) that sets the environment for line of sight (LOS) at Tx-Rx that separates the gap between for 10 meters.

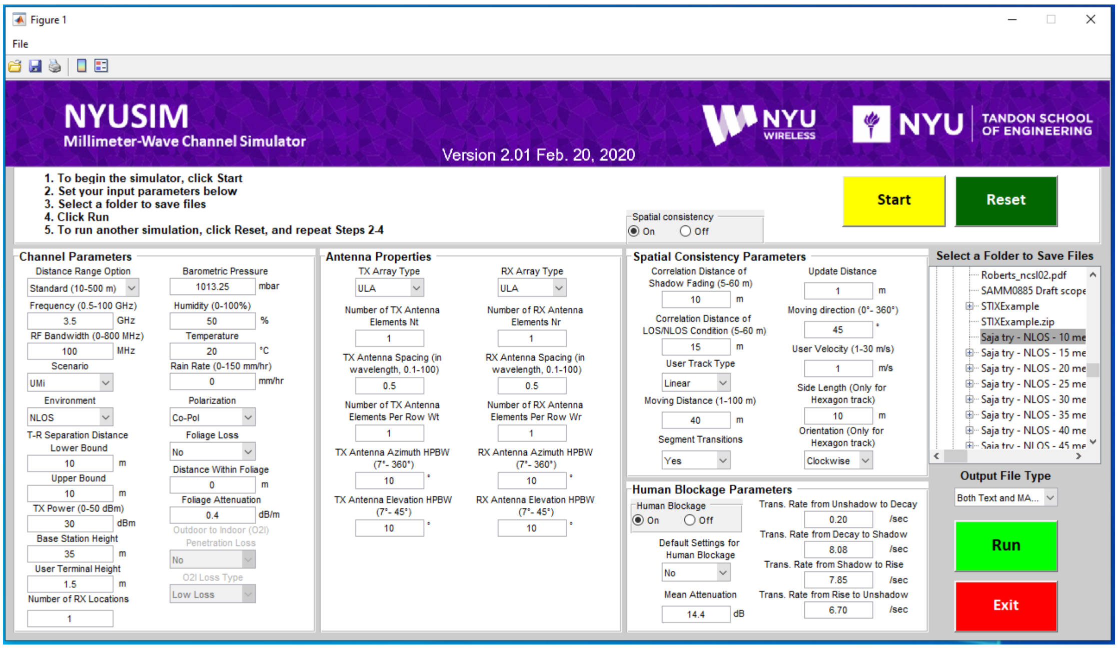
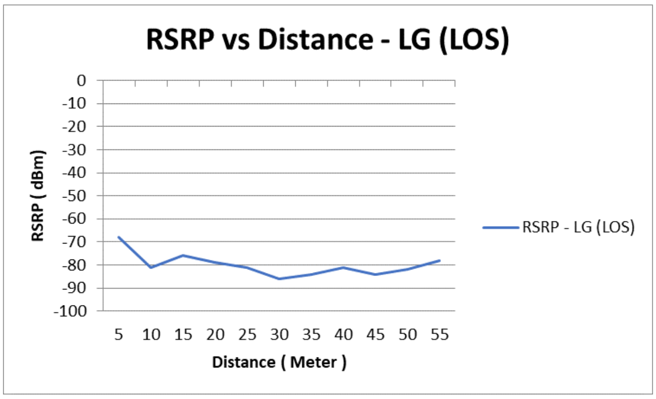


Fig. 13: NYUSIM Simulation GUI for NLOS environment at a Tx-Rx separation gap of 10 meters

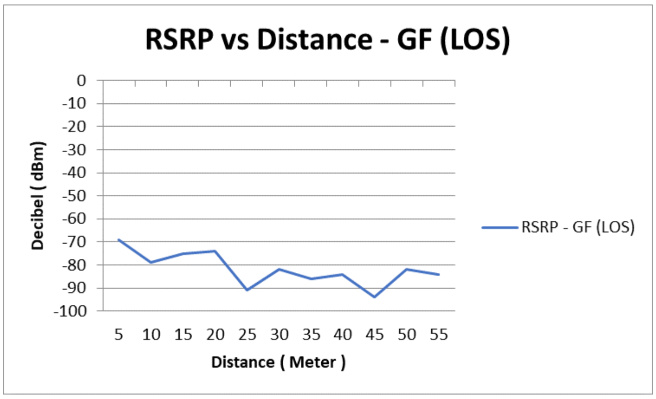
Figure 13 displays the simulation made on the graphical user interface (GUI) that sets the environment for non-line of sight (NLOS) at Tx-Rx that separates the gap between for 10 meters.

4. Results and Discussion

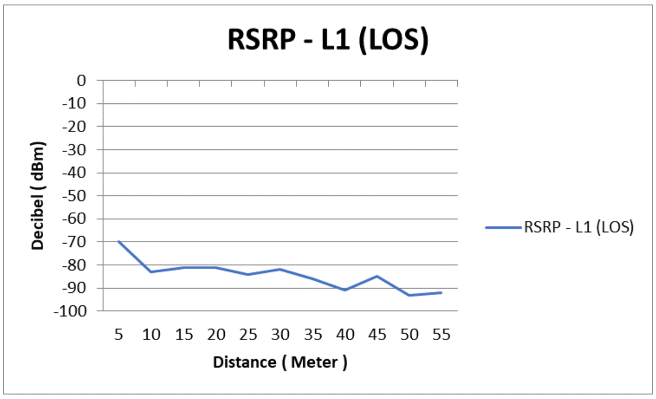
Collecting RSRP for LOS environment at Berjaya Times Square, Kuala Lumpur.



(a)



(b)

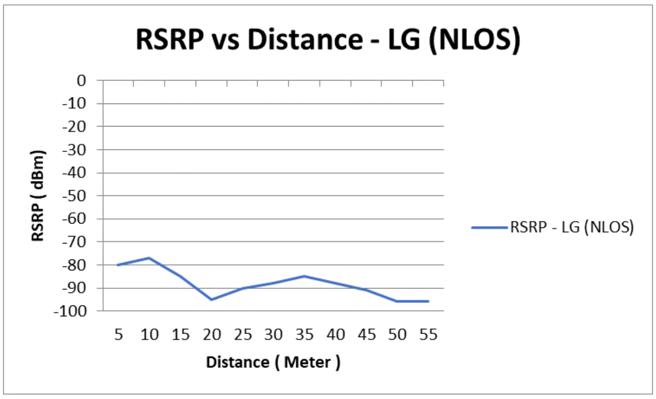


(c)

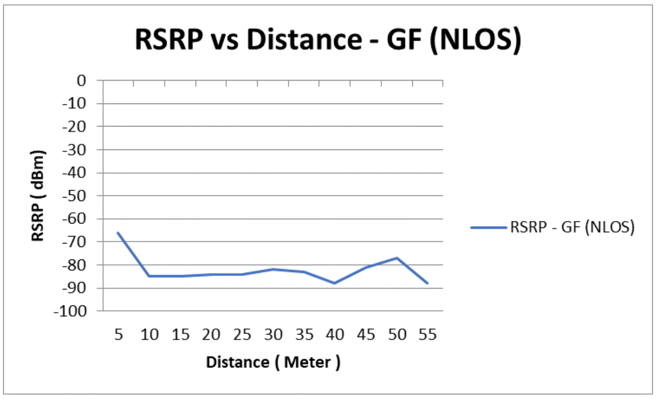
Fig. 14: RSRP at three floors (a) LG (b) GF (c) L1 for LOS environment

The RSRP at three floors for a LOS environment are shown in Fig. 14. Three of the floors provided strong signal strengths between -65 dBm and -70 dBm at the beginning distance of 5 metres. Considering the first level, the lower ground floor, the signal strength is worse at a distance of 30 metres and best at a distance of 5 metres. The worst signal strength on the second floor, which is the ground floor, is created at a distance of 45 metres, and the best signal strength is produced at a distance of 5 metres. The weakest signal strength on the third floor, level 1, is at a distance of 50 metres, and the maximum signal strength is at a distance of 5 metres. The signal strengths for each floor range from -75 dBm to -80 dBm for the LG floor, -80 dBm to -85 dBm for the GF floor, and ranges of -90 to -95 dBm for the Level One (L1) floor, which produced the lowest signal strength at a distance of 55 metres. According to the acceptable range standardized by 5G NR for RSRP as shown in Fig. 4, results showed can conclude that the distance range between 5 and 55 metres is appropriate to be planned for the LOS environment. Regarding the route loss that spreads through the greatest distance, the L1 floor at a distance of 55 metres has the weakest signal strength. In addition to greater distance, the height of the building has an impact on the route loss during signal transmission.

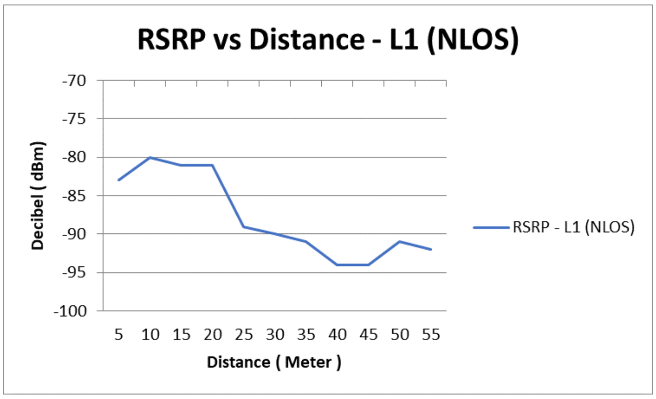
Collecting RSRP for NLOS environment at Berjaya Times Square, Kuala Lumpur.



(a)



(b)



(c)

Fig. 15: RSRP at three floors (a) LG (b) GF (c) L1 for NLOS environment

The signal intensity for three floors in an NLOS setting is shown in Fig. 15. The signal strength at the LG floor is between -75 dBm and -80 dBm. The signal strength at the GF floor ranged from -65 dBm to -70 dBm. The L1 floor's signal strength was the worst for distance at 5 meters, measuring between -80 and -85 dBm. The LG floor has the worst signal strength at 50 meters away and the best signal strength at 5 meters away. The GF floor's signal strength is worst at 40 meters and 55 meters, while it is strongest at 5 meters. For the L1 floor, the distance at which the signal is weakest is 45 meters, while the distance at which it is strongest is 5 meters. The signal strength readings on the three separate floors vary, and the LG floor has the lowest signal strength at 55 meters out of the three floors. According to the standardize acceptable range made by 5G NR for RSRP shown in Fig. 4, results shown comparing to the acceptable range strengthen the views that the distance range between 5 and 55 meters is appropriate to be planned for the NLOS environment. The LG floor has the poorest signal strength at a distance of 55 meters, which is three stories up. This is because the user terminal's ability to receive signals from the transmitter has been lost due to the user terminal's distance from the transmitter and the barrier caused by the glass door.

Simulating Millimetre-Wave for LOS Environment for a range of distance from 10 meters to 55 meters.

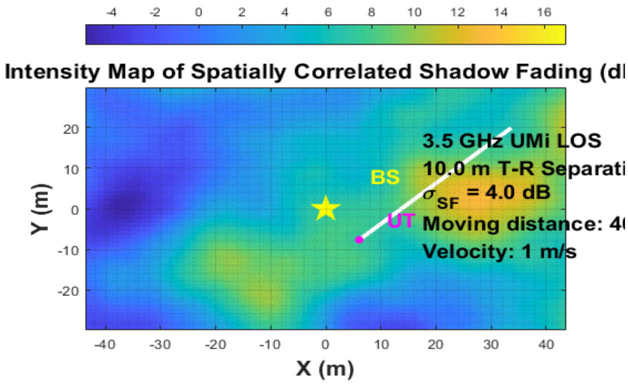


Fig. 16: Spatially Correlated Shadow Fading concentrated map for line-of-sight (LOS) situation for 10-meters

The spatially correlated shadow fading concentrated map at 10-metres in a line-of-sight (LOS) situation is shown in Figure 16. This map was created by filtering the independent shadow fading map using an exponential function. The separation distance between T-R for the shadow fading is 10.0 metres, and it is located in the UMi LOS environment. The signal strength intensifies as it gets closer to the transmitter, which is the primary reason the orientation of the user-track/phone enters the area coloured in yellow. Higher concentration directs to the yellow-coloured side while lower concentration directs to the blue-coloured side.

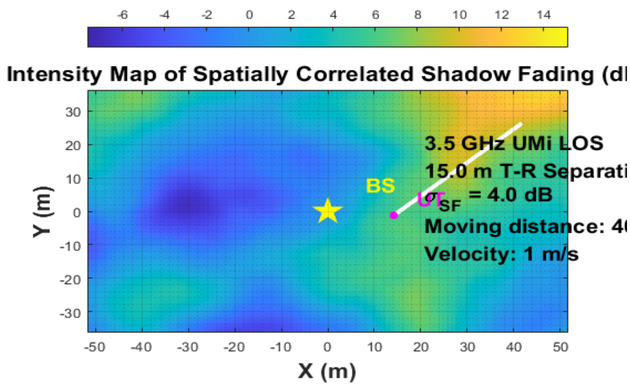


Fig. 17: Spatially Correlated Shadow Fading concentrated map for line-of-sight (LOS) situation for 15-meters

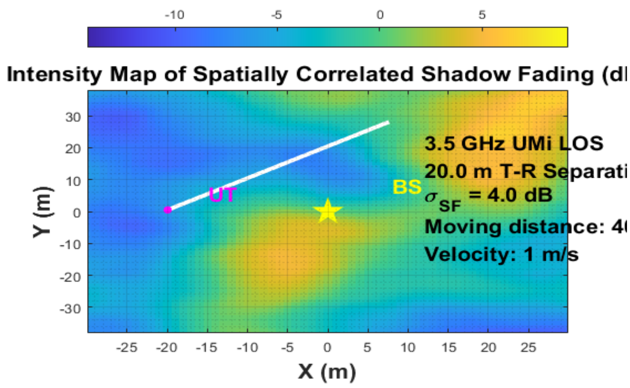


Fig. 18: Spatially Correlated Shadow Fading concentrated map for line-of-sight (LOS) situation for 20-meters

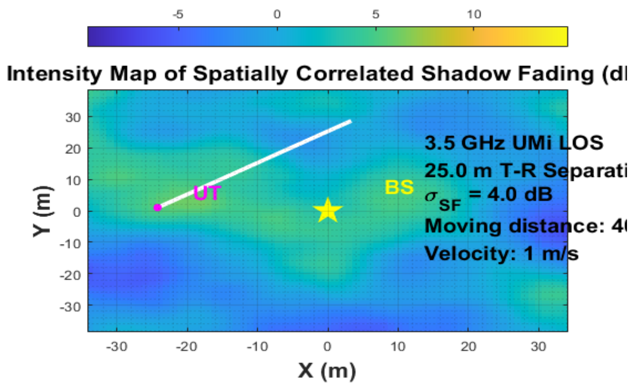


Fig. 19: Spatially Correlated Shadow Fading concentrated map for line-of-sight (LOS) situation for 25-meters

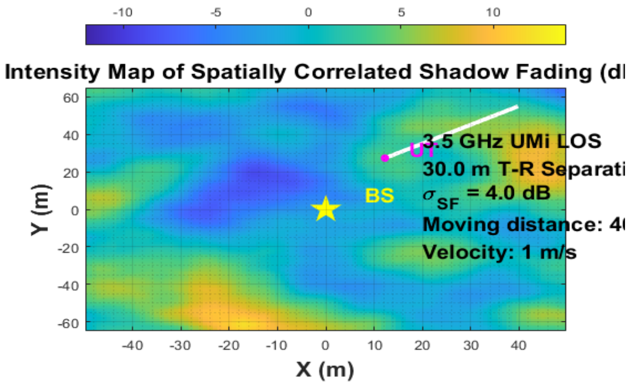


Fig. 20: Spatially Correlated Shadow Fading concentrated map for line-of-sight (LOS) situation for 30-meters

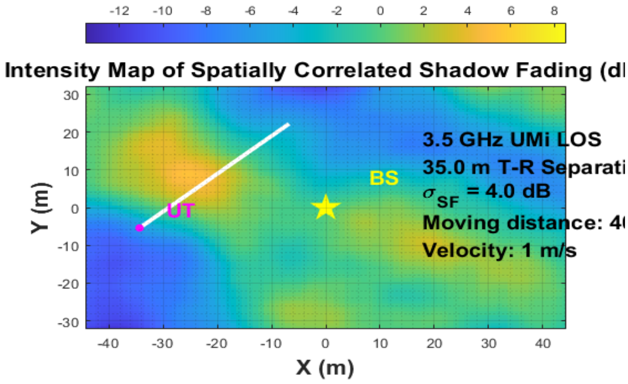


Fig. 21: Spatially Correlated Shadow Fading concentrated map for line-of-sight (LOS) situation for 35-meters

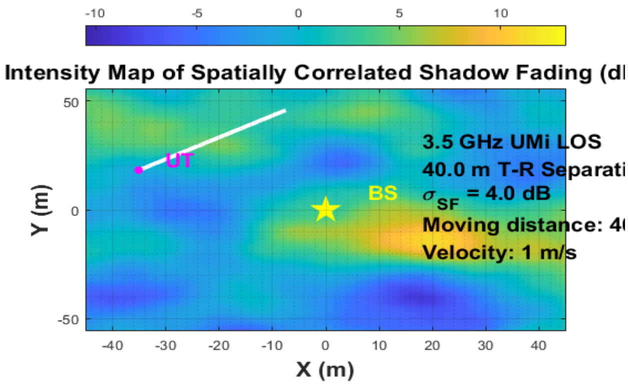


Fig. 22: Spatially Correlated Shadow Fading concentrated map for line-of-sight (LOS) situation for 40-meters

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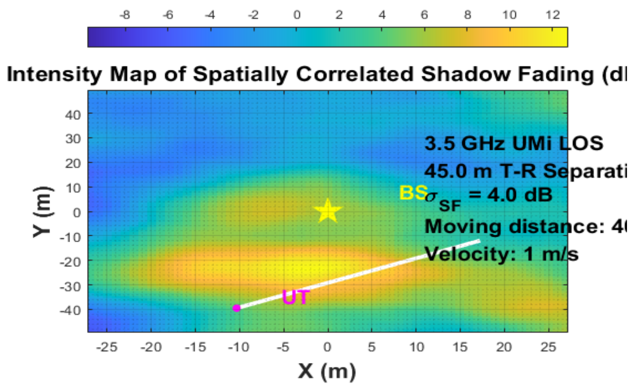

Fig. 23: Spatially Correlated Shadow Fading concentrated map for line-of-sight (LOS) situation for 45-meters

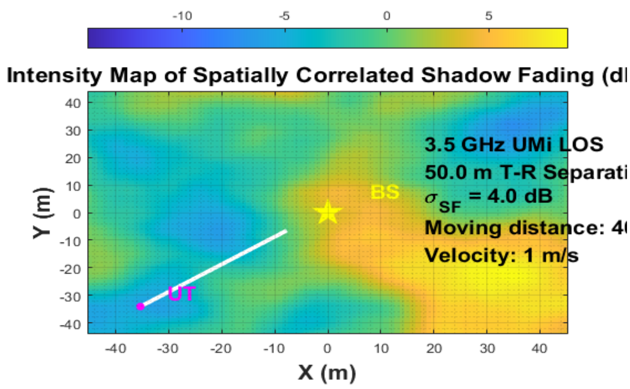

Fig. 24: Spatially Correlated Shadow Fading concentrated map for line-of-sight (LOS) situation for 50-meters

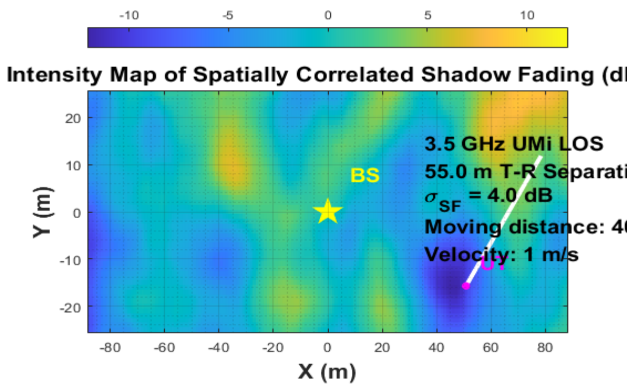

Fig. 25: Spatially Correlated Shadow Fading concentrated map for line-of-sight (LOS) situation for 55-meters

Simulating Millimeter-Wave for NLOS Environment for a range of distance from 10 meters to 55 meters.

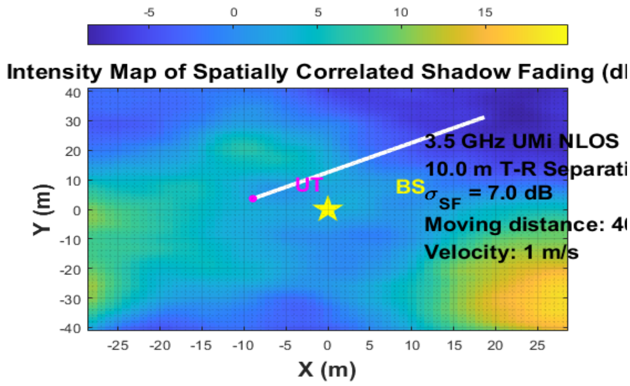

Fig. 26: Spatially Correlated Shadow Fading concentrated map for non-line-of-sight (NLOS) situation for 10-meters

The spatially associated shadow-faded intensity map for the NLOS environment at 10 metres is shown in Figure 26. In the UMi Non-Line-of-Sight (NLOS) situation, with a distance separated of 10.0 metres between the transmitter (Tx) and receiver (Rx), the shadow fading has a [dB] N (0, 7) value. Due to the interference from the NLOS environment, the signal's strength is on the blue side.

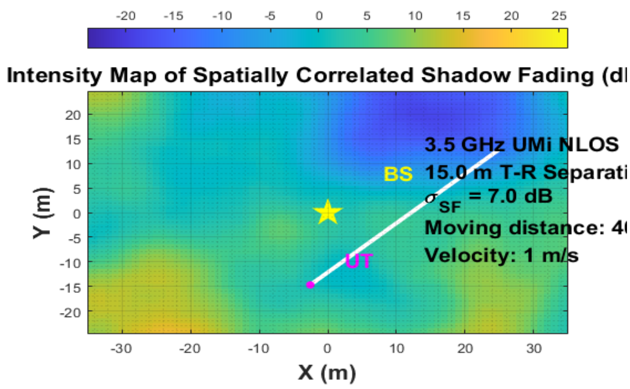

Fig. 27: Spatially Correlated Shadow Fading concentrated map for non-line-of-sight (NLOS) situation for 15-meters

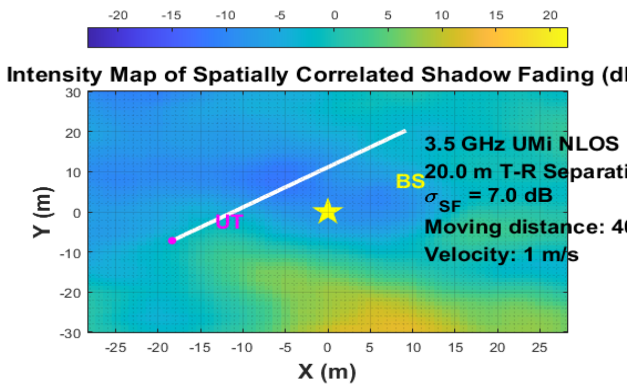

Fig. 28: Spatially Correlated Shadow Fading concentrated map for non-line-of-sight (NLOS) situation for 20-meters

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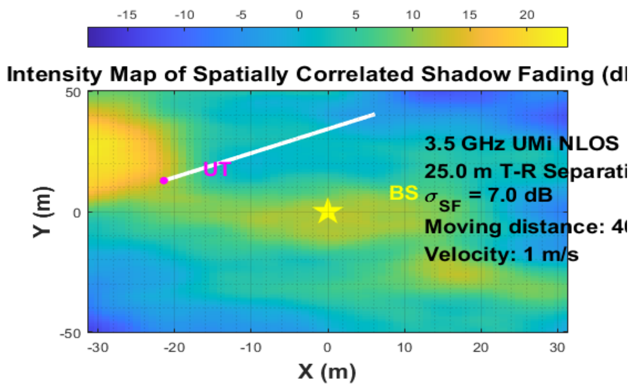

Fig. 29: Spatially Correlated Shadow Fading concentrated map for non-line-of-sight (NLOS) situation for 25-meters

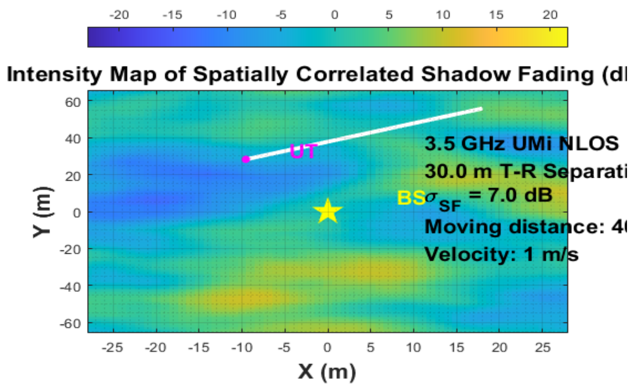

Fig. 30: Spatially Correlated Shadow Fading concentrated map for non-line-of-sight (NLOS) situation for 30-meters

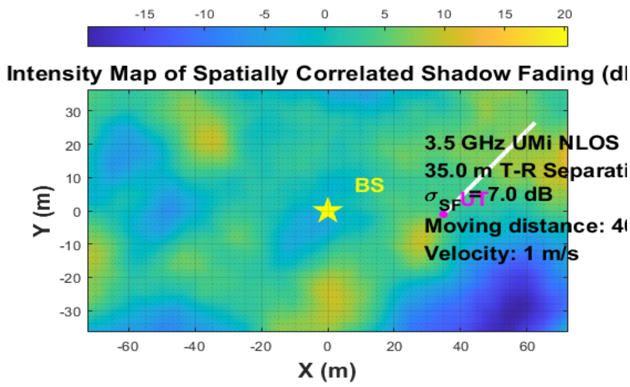

Fig. 31: Spatially Correlated Shadow Fading concentrated map for non-line-of-sight (NLOS) situation for 35-meters

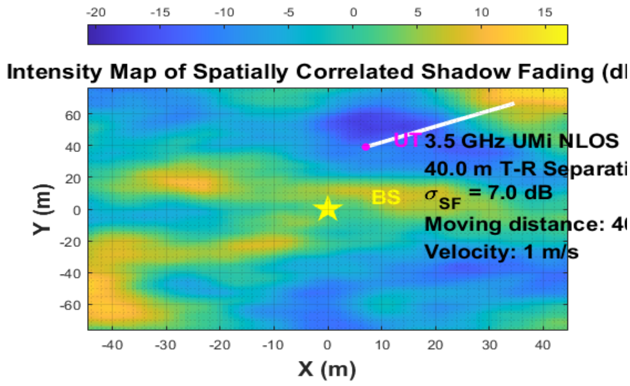

Fig. 32: Spatially Correlated Shadow Fading concentrated map for non-line-of-sight (NLOS) situation for 40-meters

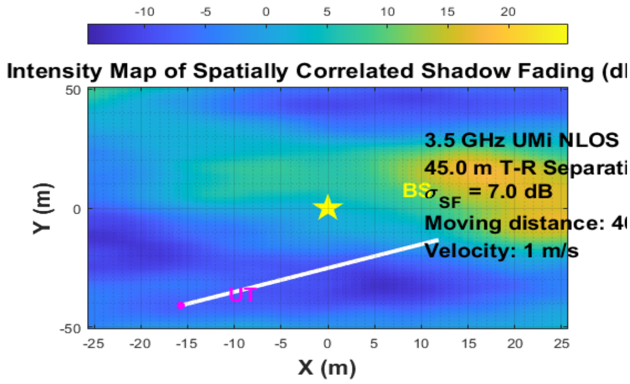

Fig. 33: Spatially Correlated Shadow Fading concentrated map for non-line-of-sight (NLOS) situation for 45-meters

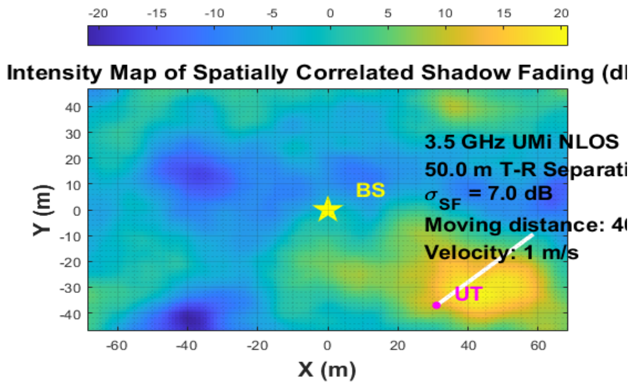

Fig. 34: Spatially Correlated Shadow Fading concentrated map for non-line-of-sight (NLOS) situation for 50-meters

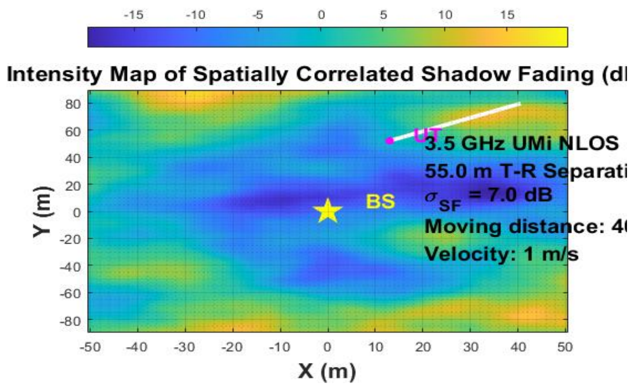

Fig. 35: Spatially Correlated Shadow Fading concentrated map for non-line-of-sight (NLOS) situation for 55-meters

5. Conclusion

In this study, network performance is measured and examined in relation to how the propagation of 3.5 Giga-Hertz (GHz) channel-frequency provides effects towards the growth in the separation between the distance of transmitter to the receiver. As a result, path loss increases as the distance between the transmitter and receiver grows. However, increasing distance equals to the reduce in power received. As the frequency 3.5 GHz located inside the upper band for both line-of-sight (LOS) and non-line-of-sight (NLOS) settings, conclusions may be made that the planning distance range of 5 m to 55 m is suitable. Generally speaking, the range for a higher wireless signal frequency is shorter. Higher frequency signals cannot easily pass-through walls, floors, and other barriers. The findings of this study will aid future academics who look at Malaysia's adoption of 5G technology. A study on situating the transmitter and the receiver can be expanded upon for further projects. At the 3.5 GHz frequency band, it's also important to consider the antenna's design and how height affects received power.

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