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Performance Evaluation of Propagation Model in Fifth Generation Millimeter Waves.

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Abstract — The Mmwaves spectrum spans the range from 30 GHz–300 GHz thus arrange from 24 GHz to 100 GHz is a proposed for 5G. The importance of millimeter waves in 5G is that they use high frequencies, this provides us with greater and wider coverage, higher multi-Gbps peak data speeds, ultra-low latency, more reliability. In this Paper we study and Perform Evaluate the Propagation model of 5G Mmwaves. The Propagation model is a term used to describe the signal transmitted from the sending station to receiving stations. The propagating signals at mmwaves suffers from high propagation path loss in large distance. In this paper, we simulate the urban microcellular modeling for 5G mmWave at carrier frequency 73 GHz, three different distances, the 100 m and 200 m and 500 m. This paper will focus on the problem of path loss (path loss exponent) and Shadowing (shadow fading standard deviation). The scenarios to be study for the wave Propagation it LOS (Directional and Omnidirectional), NLOS (Directional and Omnidirectional).The program used in the Simulation is NYUSIM. The NYUSIM program was developed by New York University, Tandon School of Engineering. NYUSIM is a matlab emulation software integration tool. This Paper presents the path loss in 5G Mm Waves for 100, 200, 500 m in 73 GHz.

Keywords: 5G, 73GHz, Propagation channel model, Path Loss, Path loss exponent, Millimeter waves, NYUSIM, Shadow fading standard deviation.

1 Introduction

THE In Wireless Telecommunications, 5G is the fifth-generation technology standard for broadband cellular networks. 5G wireless technology is meant to deliver higher multi-Gbps peak data speeds, ultra-low latency, more reliability, massive network capacity, increased availability. [1]. The main advantage of the new networks is that they will have greater bandwidth, giving higher download speeds, eventually up to 10 gigabits per second (Gbit/s).[2]. The increasing demand of applications in terms of throughput and latency explains the evolution of telecommunication standards. [3].

The Multiple antenna techniques such as beam forming and multiple input and multiple output (MIMO) played a major role in '5G' systems. Will be deployed in CM waves (3- 30GHz) and mmwaves (30-300 GHz) bands. [4]. The mmwaves It is also used Massive MIMO, Massive MIMO will greatly increase the network capacity by locating tens (or even more than a hundred) small antennae at the Base Station, which will form multiple signal beams directed at the devices connected to it .[5]. Also one of the most important topics in 5G he is Propagation model, the Propagation is a term used to describe the signal transmitted from the sending station to receiving stations. Related variables between the receiver and sender station are distance and frequency. [6].

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The Propagation parameters and channel models for understanding mmwaves propagation, such as line-of-sight (LOS) probabilities, Non line-of-sight (NLOS) probabilities large-scale path loss, and building penetration loss, as modeled by various standardization bodies, are compared over the 0.5-100 GHz range. [7]. Of the elements that affect propagation quality the Environment, The Environment maybe you can be Urban Micro cell area, Urban Macro cell area, Dense Urban,Rural Macro area, Office area, Shopping Mall area, Highway area, Open Air Festival area, Stadium area and other.[8]. The Propagation in 5G mmwaves Faces many technical problems that hinder its work and reduce its overall performances. The propagating signals at mmwaves suffers from propagation path loss in large distance so this Paper focus of these issue.

The most important of these The Objective of this paper is Perception of Propagation channel Models in 5G mmwaves. Analyze the Factors affecting the Propagation Model in 5G mmwaves. Perform evaluate outdoor urban small cell environments at three different distances, the 100 m and 200 m and 500 m for 73 GHz. problems is the Path loss.

For the urban microcellular is used in 5G system , The height of both the antenna at the BS and that at the UT is expected to be well below the tops of surrounding buildings. Both antennas are assumed to be outdoors in an area where roads the roads in the coverage area are classified as “the main street”, where there is LOS from all locations to the BS, with the possible exception of cases in which LOS is temporarily blocked by traffic (e.g., trucks and busses) on the road. Streets that intersect the main street are referred to as perpendicular streets, and those that run parallel to it are referred to as parallel roads. This scenario is defined for both LoS and NLOS cases. Cell shapes are defined by the surrounding buildings, and energy reaches NLOS roads as a result of propagation around

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corners, through buildings, and between them. The microcellular test environment contains outdoor and outdoor-to-indoor users, in the latter case the users are located indoors and Base Stations outdoors. The channel model for urban micro-cell scenario is called urban micro (UMi). [9].

The Simulation Tools, NYUSIM (New York University Simulation) is a MATLAB-based open-source channel simulator and the main interface of the program is a GUI. The NYUSIM program developed Tandon School of Engineering in New York University. NYUSIM is based on CI model, The CI model is easily implemented in existing 3GPP models. [10].

2 RELATED WORK.

This paper presents details and applications of a novel channel simulation software named NYUSIM, which can be used to generate realistic temporal and spatial channel responses to support realistic physical- and link-layer simulations and design for mmwaves in fifth-generation (5G) cellular communication. Case study is propagation channel measurements at millimeter-wave (mmWave) frequencies from 28 GHz in outdoor environments in urban microcell (UMi), a Omnidirectional and directional channel models have widely been studied and adopted by industry and researchers around the world to assist in wireless system design, yet directional channel models are also important to properly design and implement antenna arrays to exploit spatial diversity and/or beamforming gain in multiple-input multiple-output (MIMO) systems. Where f denotes the carrier frequency in GHz, d is the 3D T-R separation distance, n represents the path loss exponent (PLE), this paper has presented an open-source channel software simulator, NYUSIM, developed from extensive broadband propagation measurements at mmWave frequencies. NYUSIM recreates wideband PDP and channel statistics for a variety of carrier frequencies, RF bandwidths, antenna beamwidths, environment scenarios, and atmospheric conditions, for case studied is 28 GHz omnidirectional LOS is we measured PLE and Shadowing factor. [11].

They compared two candidates Wide propagation path loss models, alpha-beta gamma ABG model and CI reference distance model, for fifth generation (5G) wireless design Communication systems in urban small cell and college cells Scenarios. Comparisons were made using data obtained from 20 Diffusion campaign or ray tracing studies From 2 GHz to 73.5 GHz over distances ranging from 5 meters to1429 m.

This paper presents the alpha-beta-gamma (ABG) and close-in (CI) free space reference distance path loss models at mmWave frequencies, and provides a head-towhead comparison between the parameters and shadow fading, (SF) standard deviations in these two models in both UMi and UMa NLOS scenarios, using 20 sets of measurement or ray-tracing data. The Simulation Tool by Nokia, Aalborg University (AAU), Qualcomm, and Aalto University.

Finally, the parameters derived from 2 to73.5 GHz for UMi street canyon NLOS environments, indicate that the ABG model underestimates path loss to be less than free space when very close to the TX, and the CI model overestimates path loss close to the transmitter when compared to the ABG model, yet this is where errors are not as important in practical system design More importantly, the ABG model overestimates path loss (i.e., underestimates interference at greater distances) compared with the CI model. Thus, the ABG model could underestimate the true interference in system design, while the CI models more safe and conservative. [12].

3 PROPOSED METHODE.

As shown figure (3.1), Steps needed to generate the mmwaves channel model. The acronyms used in this figure are defined as follows. Urban Micro (UMi); Line-of-Sight (LOS); Non-Line-of-Sight (NLOS); Path Loss (PL); Transmitter (TX); Receiver (RX). Eight steps for create the Propagation System model scenario for 5G mmwaves. The first step, to creating a diffusion model is identification System scenario, Network Layout, The system scenario used in this research is Outdoor scenario. The Second step, the type of antenna is determined (MIMO) and the carrier frequency band (73 GHz). The third step, after that is determined Environment Scenario, the scenario used here is urban microcellular (UMi). The forth step, then the wave propagation cases are determined from the antenna, the propagation cases are LOS and NLOS. The Fifth step, then the Generated distance between the transmitter and receiver the distance between 100 m, 200 m, and 500 m for 73 GHz. The Sixth step, The Generate of the Cluster Power, Propagation time, and time delay. The Seventh step, Determine value of Azimuth and Elevation angle. The eighth step, Generate Channel Coefficients. Apply and calculate Path loss and Shadow Fading.

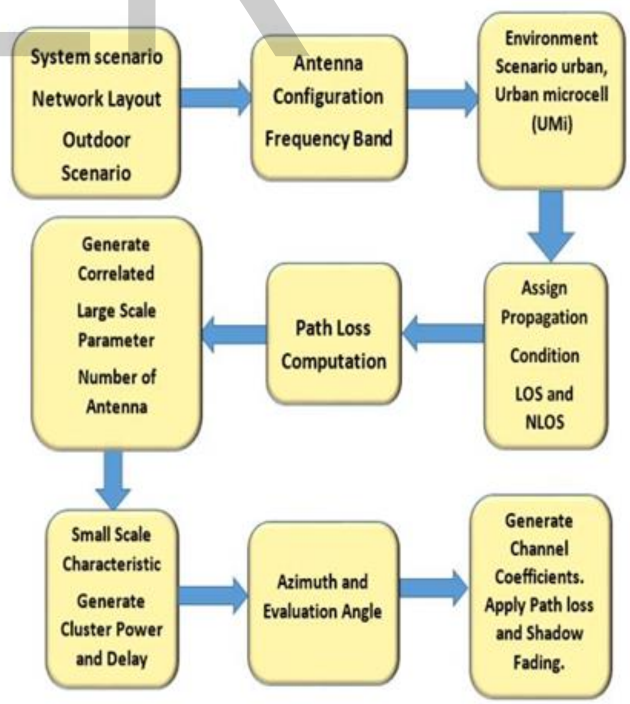

Figure 1.3. System Blook Diagram.

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4 SYSTEM MODEL CONSIDRATION.

In this section we will study Properties affecting propagation model, together with the mathematical equations used to calculate each characteristic.

4.1 Path Loss model

Path loss is the reduction in power density of a radio waves as it propagates over the channel, which is defined as: -

PL [dB] = 10 (Log) 10 Pt/Pr (3.1)

Pr (d,λ)= Pt Gt Gr ((λ/(4πd3d)) ^2 (3.2) [13].

Where GT and GR are the antenna gains at the TX and RX, PT and PR are the transmitted and received power, d3D is the spatial distance between the TX and RX, λ is the wave length.

The CI model, has its frequency dependence expressed primarily by the frequency dependent FSPL) in the initial meter of propagation. The CI model is simply implemented in existing 3GPP models.

PL^CI (f, d) [dB] = FSPL (f, 1 m) [dB] + 10$n$log10 (d) +X^ σ (3.3).

Where n denotes the single model parameter, d is the 3D T-R separation distance, and FSPL (f, 1 m) denotes the free space path loss in dB at a T-R separation distance of 1 m at the carrier frequency, 10n describing path loss in dB in terms of decades of distances beginning at 1 m, FSPL by where c is the speed of light.

FSPL (f, 1 m) [dB] = 20log10 (4πf/c) (3.4). [14].

4.2 LOS and NLOS Probability Model.

In the literature on mmwaves, it is common to describe the path loss for LOS and NLOS conditions separately. Therefore, a model is needed to predict whether a user equipment (UE) is within a clear LOS of a base station (BS) or is blocked to be in an NLOS region The LOS probability is frequency-independent and is modeled as a function of distance between transmitter and receiver, which can be blocked, affected by environment layout.

LOS probability models in the UMi, as it was mentioned in the section 2.7 of chapter 2, the UMi scenario is defined for high user density areas with an inter-site distance (ISDs) of up to 300 m and BS height below rooftops. Different organizations have developed the UMi LOS and NLOS probability models. The equation is:-

Pr,LOS(d)=(min(d1/(d,1))(1-exp((-d)/d2)+(exp((-d)/d2)))^2 (3.6).

The NLOS probability models in the UMi is:-

PL=max ((PL)(UMi - LOS (d_3D), (PL)(UMi - NLOS (d3D)) (3.7). [15].

4.3 Path loss exponent (PLE).

In wireless communication studies, path loss is represented by the path loss exponent, whose value is normally in the range of 2 to 4dB, where 2 is for propagation in free space, the PLE equal 4 of more for relatively lossy environments, such as trees, Obstacles, buildings and so forth, cause the actual attenuation of the received power to follow a log-normal distribution and for the case of full specula reflection, the path loss exponent can reach values in the range of 4 to 7 dB.

PL (d) =PL (do) +10*n*Log d/do +Xσ (3.8)

L=10 n $(\text{Log})_{10}$ (d) +c (3.9)

Where X_σ follows a zero-mean Gaussian distribution with standard deviation 2 < σ < 12, the path-loss exponent (PLE) γ ranges from 2 to 7. L is the path loss in decibels, d is the distance between the transmitter and the receiver, n is the path loss exponent, usually measured in meters, and C is a constant which accounts for system losses. [16].

4.4 Shadow Fading Standard Deviation.

Shadowing is the effect that the received signal power fluctuates due to objects obstructing the propagation path between transmitter and receiver. Previous studies measured mean powers at 10 m intervals and studied shadowing over 1000 m intervals. The maximum shadow standard deviation experienced was about 12 dB, but 50% of all experiments showed shadowing equal to 4 dB. [14].

Xσ^CI=(PL)^CI(f,d)[dB]-FSPL(f,1m)+10nLog$_{10}$(d)A-nD (3.10). [14].

Xσ^CI Follows a zero-mean Gaussian distribution with standard deviation 2 < σ < 12, where N is the number of path loss data points. Thus minimizing the SF standard deviation σ ^Ci is equivalent to minimizing the term ∑ (AnD)^(2) is minimized, its derivative with respect to n should be zero, denotes is 10Log$_{10}$ (d).

σ √((∑Xσ^CI)/N)=√(∑(AnD)^(2)/N)) (3.11). [17].

5 SIMULATION ENVIRONMEN &DESCRIPTION.

Carrying out will study of Propagation model measurement of 5G mmwaves is based on Carrier Frequency (73GHz). Environment Outdoor Urban microcellular (UMi) area. Antenna Direction (LOS, NLOS for directional, Omnidirectional). Region (Outdoor). In the simulations will be made using a NYUSIM program. Simulation will be UMi Scenario, The Scenario is urban microcellular area (UMi), in case Carrier Frequency (73 GHz), In the case of LOS and NLOS For each carrier frequency.

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In this section some of the terms that appear in the simulation results will be explained here, As follows:-

(A). The Line of Sight (LOS), propagation is a characteristic of electromagnetic radiation or acoustic wave propagation which means wave travel in a direct path from the source to the receiver.

(B). The Non-Line of Sight (NLOS) refers to the path of propagation of a radio frequency (RF) that is obscured (partially or completely) by obstacles, thus making it difficult for the radio signal to pass through. Common obstacles between radio transmitters and radio receivers are tall buildings, trees, physical landscape. While some obstacles absorb and others reflect the radio signal; they all limit the transmission ability of signals.

(C). The n denotes the path loss exponent (PLE) in wireless communication studies, path loss is represented by the path loss exponent, whose value is normally in the range of the PLE (2-7 dB). [16].

(D). The σ is the shadow fading standard deviation, Shadowing is the effect that the received signal power fluctuates due to objects obstructing the propagation path between transmitter and receiver, whose value is normally in the range shadow standard deviation experienced (2-12 dB). [17].

6- SIMMULATION PARAMETER.

Table I. Simulation parameter

Channel Parameter	Specification UMi
Scenario	UMi, LOS / NLOS
Carrier Frequency	73 GHz
Bandwidth	800 MHz
Height of BS	15 m
Temperature	25 °C
TX-RX Separation	100 m, 200 m, 500 m
Number of RX locations	300
TX Power	25 dBm
Tx & Rx Array Type, Ntx	ULA, 4
Tx & Rx Antenna Spacing	0.5 λ
(AZ) and (EL) HPBWs	10°, 10°
Modulation	OFDM

7- RESULTS & DISCUSSION

In this section carrying out present the results obtained from running simulation for UMi scenario. This Scenario to Study is Carrier Frequency (73 GHz) for LOS and NLOS for Directional and Omnidirectional Scenario. The results are the frequency study at three different distances, 100 m, 200 m, and 500 m. Omnidirectional and directional path loss values for the 73 GHz UMi, (a) LOS and (b) NLOS scenarios. The n denotes the path loss exponent (PLE), σ is the shadow fading standard deviation, "omni" represents omnidirectional, "dir" denotes directional, and "dir-best" means the direction with the strongest received power.

The UMi LOS scenario, as Shown in figure (7.1), **for distance 100 m** that directional PLE ndir at =3.4 with a shadowing factor (SF) σdir =11.7 dB is higher than the omnidirectional PLE nomni of =2 and σomni= 4.3 dB, as in the literature for the LOS. However, the directional best PLE, or strongest possible link created in directional path, is very close to omnidirectional PLE. The directional best PLE ndir-best at =2.2 and directional best shadowing factor (SF) σdir-best at =4.4 dB. The path loss increases faster for the NLOS scenario than LOS, with regards to increase in distance due to obstruction on the signal path, Because of obstructions such as glass buildings, concrete, trees, etc. Note that the Path Loss for Omnidirectional LOS between Tx and Rx Distance at 10 m is about between < 60 at 90 dB, while in directional is about between < 90 at >120 dB, while to find directional best equal 90 dB. At 100 m in the omnidirectional equal 90 dB, while in directional about between < 90 at 150 dB, while to find directional best about between < 120 at 150 dB.

While for a distance of 200 m you will notice {As shown in figure (7.2)}, that directional PLE ndir at =3.4 with a shadowing factor (SF) σdir =12.1 dB is higher than the omnidirectional PLE nomni of =2.2 and σomni= 4.1 dB, the directional best PLE ndir-best at =2.4 and directional best shadowing factor (SF) σdir-best at =4.6 dB. Note that the Path Loss for Omnidirectional LOS between Tx and Rx Distance at 10 m is equal 90 dB, while in directional is about between < 90 at 150 dB, while to find directional best equal 90 dB. At 100 m in the omnidirectional about between < 90 at > 120 dB while in directional about between 120 at > 180 dB, while to find directional best is equal 120 dB. At 200 m in the omnidirectional about between < 90 - 120 dB, while in directional about between 120 at 180 dB, while to find directional best is equal 120 dB.

While for a distance of 500 m you will notice {As shown in figure (7.3)}, that directional PLE ndir at =3.4 with a shadowing factor (SF) σdir = 12.5 dB is higher than the omnidirectional PLE nomni of =2.5 and σomni= 4.4 dB, the directional best PLE ndir-best at =2.6 and directional best shadowing factor (SF) σdir-best at =4.7 dB. Note that the Path Loss for Omnidirectional LOS between Tx and Rx Distance at 10 m is equal 90 dB, while in directional is about between < 120 at > 150 dB, while to find directional best equal 90 dB. At 100 m in the omnidirectional equal 120dB, while in directional about between 120 at 180 dB, while to find directional best is equal 120 dB. At 500 m in the omnidirectional is equal 120 dB, while in directional about between < 120 at 180 dB, while to find directional best is equal 120 dB.

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The UMi NLOS scenario,), for distance 100 m {As Shown in figure (7.4)}, for the directional path in NLOS case, the PLE increases to ndir at =4.5 when comparing with LOS, and with a shadowing factor σdir of = 12.1 dB, the directional is higher than the omnidirectional PLE nomni of =3.3 and σomni=6.7 dB. The directional best PLE ndir-best at =3.5 and directional best shadowing factor (SF) σdir-best at =7 dB. Note that the Path Loss for Omnidirectional LOS between Tx and Rx Distance at 10 m is equal 90 dB, while in directional is about between 90 at 150 dB, while to find directional best equal 90 dB. At 100 m in the omnidirectional equal 120 dB, while in directional about between < 120 at 180 dB, while to find directional best is equal 120 dB.

While for a distance of 200 m you will notice {As shown in figure (7.5)}, for the directional path in NLOS case, the PLE increases to ndir at =4.7 when comparing with LOS, and with a shadowing factor σdir of = 12.6 dB, the directional is higher than the omnidirectional PLE nomni of =3.7 and σomni =6.9 dB. The directional best PLE ndir-best at =3.9 and directional best shadowing factor (SF) σdir-best at =7.2 dB. Note that the Path Loss for Omnidirectional LOS between Tx and Rx Distance at 10 m is equal 90 dB, while in directional is about between 120 at >180 dB, while to find directional best equal 120 dB. At 100 m in the omnidirectional equal 120 dB, while in directional about between < 150 at 180 dB, while to find directional best is about between 120 at 150 dB. At 200 m in the omnidirectional about between <120dB at 150 dB, while in directional about between 150 at 180 dB, while to find directional best is about between < 120 at 150 dB.

While for a distance of 500 m you will notice {As shown in figure (7.6)}, for the directional path in NLOS case, the PLE increases to ndir at =4.6 when comparing with LOS, and with a shadowing factor σdir of = 13.7 dB, the directional is higher than the omnidirectional PLE nomni of =3.9 and σomni =7.1 dB. The directional best PLE ndir-best at =4.1 and directional best shadowing factor (SF) σdir-best at =7.6 dB. Note that the Path Loss for Omnidirectional LOS between Tx and Rx Distance at 10 m is about between <90 at >120 dB, while in directional is equal 120 dB, while to find directional best about between < 90 at >120dB. At 100 m in the omnidirectional is about between <120 at 150 dB, while in directional about between 150 at 180 dB, while to find directional best is about between <120 at 150 dB. At 500 m in the omnidirectional is equal 150 dB, while in the directional is equal 180dB, while to find directional best is about between < 150 at 180 dB.

Table II. Path Loss Directional & Omni & D-best (UMi, LOS, 73 GHz)

Distance	100 m	200 m	500 m
Dir - Path loss exponent.	3.4	3.4	3.4
Dir - Shadow Fading S.deviation.	11.7 dB	12.1 dB	12.5 dB
Omni - Path loss exponent.	2	2.2	2.5
Omni- Shadow Fading S.deviation.	4.3 dB	4.1 dB	4.4 dB
Dir-best - Path loss exponent.	2.2	2.4	2.6
Dir-best - Shadow Fading S.deviation.	4.4 dB	4.6 dB	4.7 dB

Table III. Path Loss Directional & Omni & D-best (UMi, NLOS, 73 GHz)

Distance	100 m	200 m	500 m
Dir - Path loss exponent.	4.5	4.7	4.6
Dir - Shadow Fading S.deviation.	12.1 dB	12.6 dB	13.7 dB
Omni - Path loss exponent.	3.3	3.7	3.9
Omni- Shadow Fading S.deviation.	6.7 dB	6.9 dB	7.1 dB
Dir-best - Path loss exponent.	3.5	3.9	4.1
Dir-best - Shadow Fading S.deviation.	7 dB	7.2 dB	7.6 dB

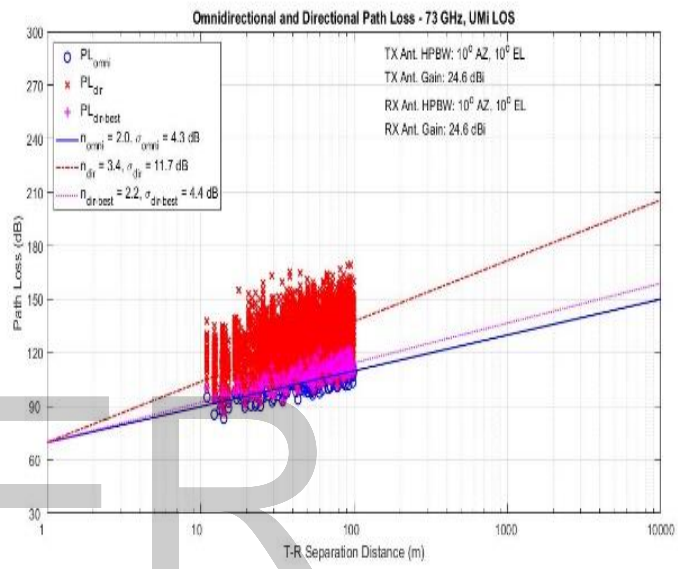

Figure (7.1).Path Loss 73 GHz-100 m, UMi, LOS

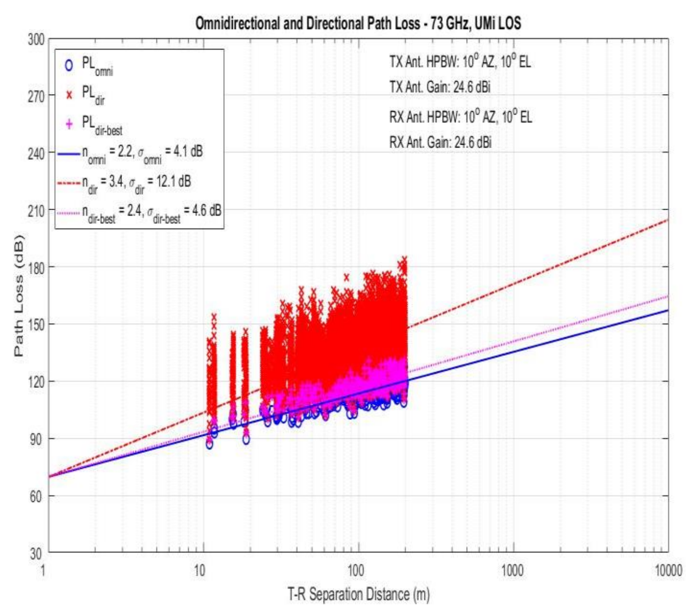

Figure (7.2).Path Loss 73 GHz-200 m, UMi, LOS

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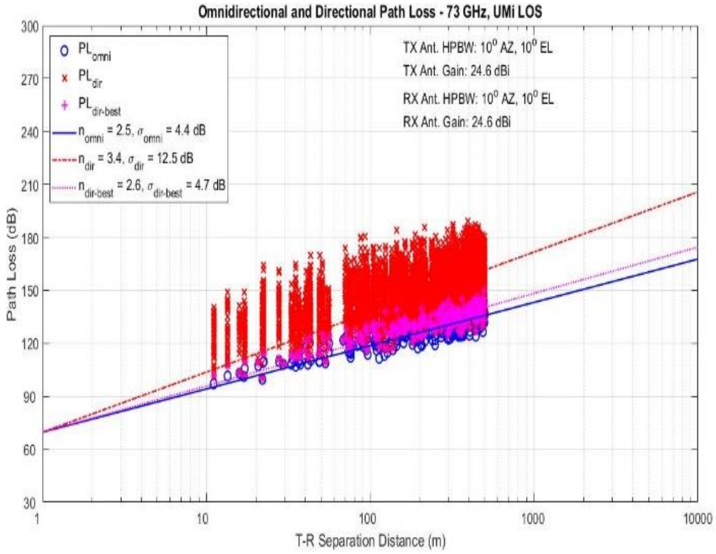

Figure (7.3).Path Loss 73 GHz-500 m, UMi, LOS

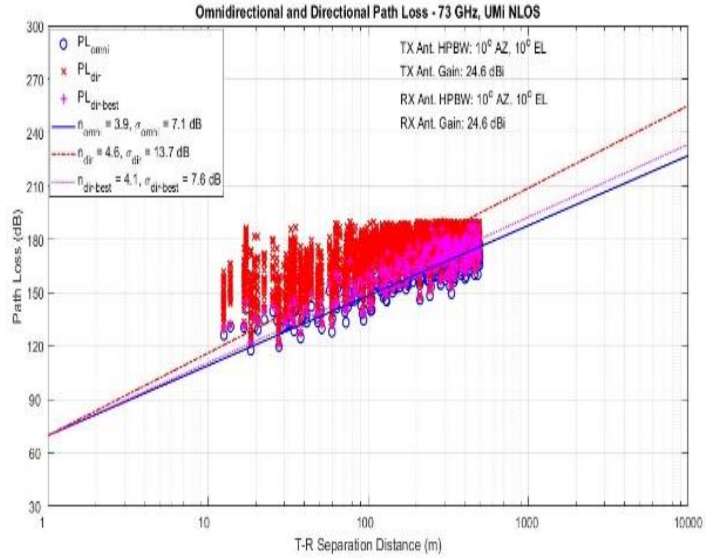

Figure (7.6).Path Loss 73 GHz-500 m, UMi, NLOS

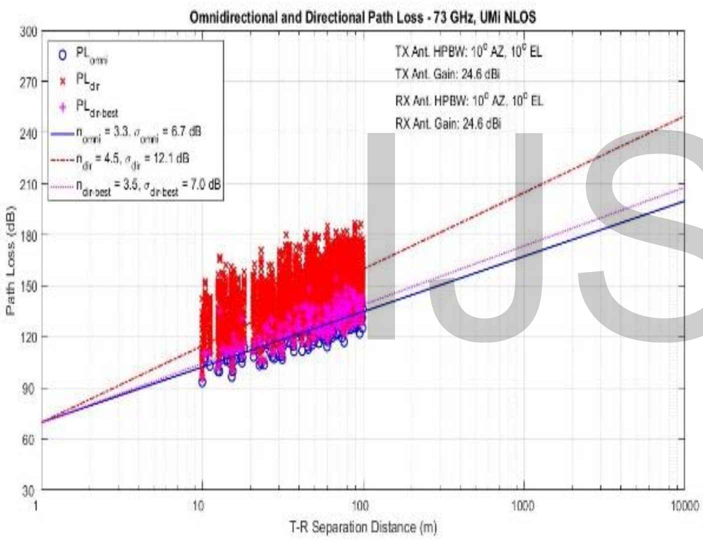

Figure (7.4).Path Loss 73 GHz-100 m, UMi, NLOS

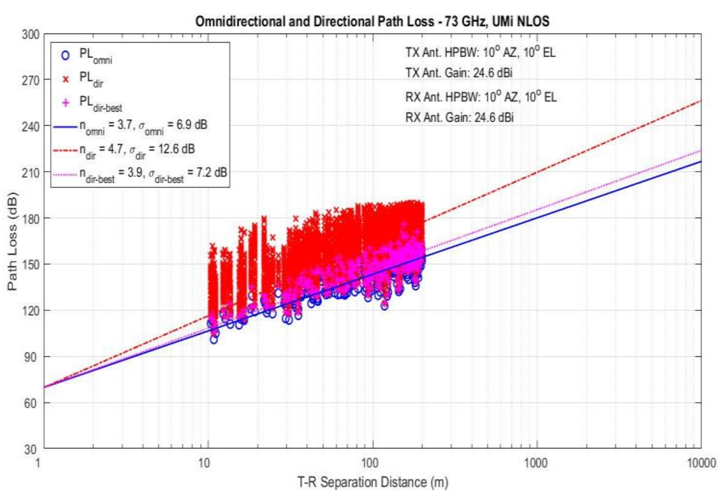

Figure (7.5).Path Loss 73 GHz-200 m, UMi, NLOS

8 CONCLUSION

This paper highlighted of channel Propagation model for 5G mmwaves communications at the carrier frequency of 73 GHz. The importance of millimeter waves in 5G is that they use high frequencies, this provides us with greater and wider coverage, higher multi-Gbps peak data speeds, ultra-low latency, more reliability, Millimeter waves communication is a key enabling of the Internet of Things technology in the 5G networks. This paper dealt with the Propagation model in 5G mmwaves. This paper discussed the propagation model, the characteristics of the propagation channel. The problems with the propagation channel are, these are as follows, Path loss (Path loss exponent), and shadowing (Shadow fading standard deviation). To evaluated and performed the outdoor urban microcell environments in term of dense cellular network architecture with a maximum radius cell of 100 m, 200 m, 500 m for 73 GHz. By use NYUSIM tool, I studied to outdoor urban micro cellular scenario, for LOS and NLOS cases, the antenna in Directional and Omnidirectional. In summary, Observed that the path loss increased linearly with increasing distance. The path loss is higher for directional propagation in both cases (LOS and NLOS), and even higher under NLOS conditions, this is because Obstacles between wireless transmitters and receivers, The path loss increases faster for the NLOS scenario than LOS, with regards to increase in distance due to obstruction on the signal path, Because of obstructions such as glass buildings, concrete, trees, etc. For shadowing factor (SF) Note the directional higher twice from omnidirectional, Shadowing factor (SF) σdir (directional) in dB for LOS and NLOS small difference between them. PLE and SF is a best directional roughly equal to the value PLE and SF omnidirectional.

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REFERENCES

[1]. Qualcomm, “Everything you need to know about 5G”, what is 5G, [online], June 2020, 23/1/2021, https://www.qualcomm.com/5g/what-is-5g .

[2]. Woon Hau Chin, Russell J. Haines, zhong fan, ”Emerging Technologies and Research Challenges for 5G Wireless Networks”, Article in IEEE Wireless Communications, Toshiba Research Europe Limited, Bristol, United Kingdom, April 2014.

[3]. Michel Matalatala, Margot Deruyck, Emmeric Tanghe, Luc Martens, and Wout Joseph, “Performance Evaluation of 5G Millimeter-Waves Cellular Access Networks Using a Capacity-Based Network Deployment Tool”, Hindawi Mobile Information Systems Volume 2017, January 2017.

[4]. Frederick W Vook, Amitava Ghosh, Timothy A. Thomas, “MIMO and Beamforming Solutions for 5G Technology” , IEEE MTT-S International Microwave Symposium (IMS2014), Nokia Solutions and Networks, Arlington Heights, II 60004, USA, July 2014. .

[5]. Ali Zaidi, Xiaoping Chen “Massive MIMO”, Journal of Network and Computer Applications, [online], May 2018, 26/1/2021, https://www.sciencedirect.com/topics/engineering/massive-mimo

[6]. Zahera Naseem, Iram Nausheen, Zahwa Mirza, Dept. of Electronics & Communication Engineering, Anjuman College of Engineering & Technology, Maharashtra, India, “PROPAGATION MODELS FOR WIRELESS COMMUNICATION SYSTEM”, International Research Journal of Engineering and Technology (IRJET), Page (1), Jan-2018.

[7]. Theodore S. Rappaport, Yunchou Xing, George R. MacCartney, Jr, Andreas F. Molisch, Evangelos Mellios, Jianhua Zhang, “Overview of Millimeter Waves Communications for Fifth-Generation (5G) Wireless Networks—With a Focus on Propagation Models”, IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, VOL. 65, NO. 12, Page (2, 3), DECEMBER 2017.

[8]. AFIF OSSEIRAN, JOSE F. MONSERRAT, PATRICK MARSCH, “5G Mobile and Wireless Communications Technology”, University Printing House, Cambridge CB2 8BS, United Kingdom, The 5G wireless propagation channel models Chapter, Page (357-359). 2016.

[9]. This ITU-R, M Series Mobile, radio determination, amateur and related satellites services, “Guidelines for evaluation of radio interface technologies for IMT-Advanced”, Electronic Publication Geneva, 2010.

[10]. Shihao Ju, Shu Sun, and Theodore. S. Rappaport, “NYUSIM User Manual”, Version 2.01a, New York University and NYU WIRELESS, February 20, 2020.

[11]. S. Sun, G. R. MacCartney Jr., and T. S. Rappaport, “A novel millimeter-wave channel simulator and applications for 5G wireless communications,” 2017 IEEE International Conference on Communications (ICC), Paris, May 2017.

[12]. Shu Sun, Theodore S. Rappaport; Sundeep Rangan; Timothy A. Thomas; Amitava Ghosh; Istvan Z. Kovacs; Ignacio Rodriguez, Ozge Koymen, Andrzej Partyka, Jan Jarvelainen, ”Propagation Path Loss Models for 5G Urban Micro and Macro-Cellular Scenarios” ,Published in: IEEE 83rd Vehicular Technology Conference (VTC Spring), July 2016.

[13]. Shu Sun, Theodore S. Rappaport, Mansoor Shafi, Pan Tang, Jianhua Zhang, Peter J. Smith, “Propagation Models and Performance Evaluation for 5G Millimeter-Wave Bands” ,IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, VOL. 67, NO. 9, SEPTEMBER 2018.

[14]. Shu Sun, Theodore S. Rappaport; Sundeep Rangan; Timothy A. Thomas; Amitava Ghosh; Istvan Z. Kovacs; Ignacio Rodriguez, OzgKoymen, Andrzej Partyka, Jan Jarvelainen, ”Propagation Path Loss Models for 5G Urban Micro and Macro-Cellular Scenarios” ,Published in: IEEE 83rd Vehicular Technology Conference (VTC Spring), July 2016.

[15]. Theodore S. Rappaport, Yunchou Xing, George R. MacCartney, Jr, Andreas F. Molisch, Evangelos Mellios, Jianhua Zhang, “Overview of Millimeter Wave Communications for Fifth-Generation (5G) Wireless Networks—With a Focus on Propagation Models”, IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, VOL. 65, NO. 12, Page (4, 5, 6), DECEMBER 2017.

[16]. Yongchang Hu, Geert Leus, “Self-Estimation of Path-Loss Exponent in Wireless Networks and Applications”, this article has been accepted for publication in a future issue of this journal, IEEE Transactions on Vehicular Technology, 2014.

[17]. Jean Paul Linnartz, “Wireless communication”, he U.C. Berkeley Continuing Education in Engineering, University Extension program, [online], In the second edition released in 2000, 7/28/2021.
http://www.wirelesscommunication.nl/reference/chaptr03/shadow/shadow.htm