Journal of Engineering Science and Technology Review 17 (4) (2024) 72-82

Research Article

JOURNAL OF
Engineering Science and Technology Review

www.jestr.org

Performance Analysis of 6G Channel Model for frequencies at 85GHz, 90GHz and 95GHz under the Influence of Real-Time Parameters

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Received 7 March 2024; Accepted 19 April 2024

Abstract

Communication has been a crucial aspect of information and worldwide connectivity for a long time. The enhancement in communication technology is demanding, making promulgating information so fast and enlarging. The Research in the 6G Channel model is gaining momentum to meet the skyrocketing demand of the present cellular network. In the present scenario, the mm-wave signal can accomplish wide bandwidth requirements and high data rates (up to GBps) for upholding 6G standards. However, channel modelling in mm-wave communication remained challenging because of the stringent Line-of-sight (LOS) requirement and a low Signal to Noise Ratio (SNR). This paper aims to design and survey a channel model of 6G Communication system. Using NYUSIM software, channel modelling simulations have been carried out on Bhubaneswar city as a case study. NYUSIM enables researchers to precisely model and simulate wireless channels, which is necessary for the design and optimization of wireless systems and technologies. It also offers a standardized structure and flexibility for a wide range of research applications. In this paper, we investigate 85GHz, 90GHz, and 95GHz channels in Bhubaneswar to assess performance for Omni-directional and Directional power delay profiles in terms of pathloss, pathloss exponent, and received power. In this study, both the urban microcell (UMi) and the urban macrocell (UMa) scenario are considered at a distance of 10m to 100m in both LOS and NLOS environments. Simulation results are tabulated under different cases for comparison.

Keywords: channel modeling, LOS, NLOS, Path Loss, NYUSIM, 6G.

1. Introduction

Communication technology is advancing exponentially with the increase in the human population. Communication has been a driving force behind worldwide connectedness and information distribution. It has changed the way we connect, share knowledge, and address global concerns, affecting practically every area of modern life. However, despite its numerous advantages, it presents serious concerns about privacy, security, disinformation, and digital divisions that must be addressed as we continue to rely on it for global connectivity and information transmission. The world has been under a crunch of huge wireless network traffic stipulations for the last few years [1]. The increasing demand for wireless traffic is envisioned to skyrocket in the forthcoming because of the extensive development of data-hungry technologies like the Internet of Things (IoT), Artificial Intelligence (AI), cryptography, network slicing, homographic encryption, location-based services distributed advanced systems, E-commerce and Mobile Payments, Augmented and Virtual Reality and robust beamforming. The confluence of these technologies, as well as the continual development of new wireless standards and infrastructure, are driving the spike in wireless traffic. This trend is projected to continue as wireless connectivity is further incorporated into daily living, commercial processes, and developing technology. To meet the unparalleled demand of the users, the current network needs to be upgraded to support ten times more devices that are a hundred times more authentic [2]. Major milestone achieved for different generations of communication is tabulated in Table 1.

Currently, there exist two possible ways to advance in the rate of wireless data transfer: an increment in the utilization of spectrum or an increment in the bandwidth of the spectrum [3] and using advanced modulation and coding techniques. The increment of bandwidth of spectrum is much simpler than the increment of spectrum utilization; an increment of the available bandwidth several times over can increase data transfer speed by a similar extent. But the existing frequency bands are already extremely crowded, forcing Researchers to search for new spectrum resources that fulfill user demands (high data rate and faster data transmission). Millimeter Wave bands are expected to be the key to modern 6G wireless systems because of the huge availability of bandwidth, which can help accommodate ultra-high data rate communication [4].

The 6G network system is just the extension of the 5G network but in a higher frequency spectrum, which deliberately combines new technologies driven by fascinating underlying services. Both 5G and 6G networks use greater frequency bands than previous generations of wireless technology, with 6G going even further into the terahertz spectrum to achieve significantly faster data throughput, lower latency, and new applications. 6G is planned to supplement and expand on the foundation laid down by 5G rather than directly replace it, and the two are expected to coexist in the future wireless environment. The

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ISSN: 1791-2377
doi:10.25103/jestr.174.10

medium between sending and receiving antennas is called a channel, which forms the base for data communication. Therefore, channel modeling is crucial in designing a wireless communication system because the channel depends on capacity. Many factors are considered when analyzing channel modeling, such as bandwidth, weather conditions, number of transmitters and receivers, and base station height. Modeling is needed by the channel for designing a communication system block that diminishes errors and maximizes data transfer [4].

Our Research is being carried out with the help of an open-source channel model simulator software named NYUSIM, a mmWave wireless communication channel modeling software that is developed by New York University academics (NYU) [5]. It can predict channel capacity, signal strength, and other performance parameters. This Research explores and approaches innovative solutions to eliminate limited attenuation, designing antennae, and propagation of 6G models.

Table 1. Advancement in Wireless Communications [1]

	1G	2G/2.5G	3G	4G	5G	6G
Deployment	1970/1984	1992/1999	2002	2010	2019	Yet to deploy
BandWidth	30KHz	200KHz	5MHz	1.25-20MHz	0.25-2GHz	Upto 3 THz
Data capacity	2Kbps	10Kbps	384Kbps	200Mbps to 1Gbps	1Gbps and above	10Gbps and above
Frequency	150MHz/900 MHz	1.8GHz(900MH z)	1.6-2GHz	2-8GHz	30-300GHz	30-300GHz
Multiplexing	FDMA	TDMA CDMA	W-CDMA	OFDM based MIMO Turbo coding	OFDM based mMIMO	OFDM based new waveform cmW & mmW
Service	Mobile Telephony	2G:Digital Voice,short messaging 2.5G: Higher capacity packetized data	Integrated high quality audio, video, and data	Dyanamic information access, wear-able	Introduction of AI capabilities devices	Optical and acoustic communication, beteer satellite communication
Technology	Analog cellular technology	Digital cellular technology	CDMA, UNIS EDGE technology	LTE, Wi-Fi	Unified IP and seamless combination of broadband, LAN/WAN/PAN/W LAN	Artificial Intelligence, Blockchain,cryptography, homographic encryption

In this paper, our primary focus is enhancing communication-related parameters for establishing an obstruction-less secure communication setup. 6G is expected to operate at much higher frequencies than 5G, bringing new interference, attenuation, and propagation challenges. The objective of 6G modeling is to develop user-friendly models, analyze their behavior in complex and dynamic environments, and further optimize their performance as per requirement. Channel modeling is a fundamental tool for designing, analyzing, and optimizing wireless communication systems. It assists engineers and researchers in understanding how signals behave in the wireless medium and gives significant insights for the development of dependable and efficient wireless networks. Overall, the objective is to provide a detailed understanding of wireless channel behavior and to analyze the impact of various factors on wireless channel path loss and interference. Therefore, this research focuses on the frequency characteristics of 85GHz,90GHz, and 95GHz, as frequency is a top priority in channel modeling. This paper analyzes various analytical mmWave properties such as OPDP, DPDP, SSPDP, and omnidirectional & and directional losses for different mmWave bands for a 6G urban microcell/macrocell scenario in LOS and NLOS environment. Our Research involves thoroughly analyzing the consequences of using different mmWave bands, which can be potentially allocated to companies and Research bodies soon. The need of exploration in the field of 6G is needful as the resulting consequences can be framed as regulations to design a statistical channel for various used samples in 6G networks. 6G will help map the financially impacted population in the technologically evolving world, paving the way for exploring more opportunities that facilitate an easier way of living tomorrow.

2. 6G Channel Models

2.1 6G millimeter Wave(mmWave) Technology

A mmWave, in frequency spectrum between 30-300 GHz and corresponding wavelengths ranging between 1-10 mm, is referred as Extremely High Frequency (EHF) as per the International Telecommunication Union (ITU). mmWaves has a wholesome influence on 6G of its design architecture and modern wireless communication systems. mmWave spectrum provides at least 10 times larger channel bandwidth than the traditionally used spectrum [7] The mmWave spectrum, as well as possible investigation of the THz spectrum, is a critical component of 6G design. It enables 6G networks to deliver unparalleled data rates, ultra-low latency, huge interconnectedness, and a variety of innovative applications, making mmWave a critical component in the development of 6G wireless systems. Millimeter-wave (mm-wave) bands are important for 6G wireless systems for various reasons, notwithstanding the specific challenges they present: Spectrum availability, massive connectivity, spatial multiplexing, high-resolution sensing, spectrum reuse, wireless sensing and localization, low latency, and so on. Further, Millimeter wave (mmWave) technologies are highly prioritized and satisfactory for their MIMO models. Various channels and access points can be utilized simultaneously for high-speed data transfer. However, when it comes to channel modelling, mm-wave communication brings distinct issues. Propagation Characteristics, Multipath and Beamforming, Blockage and Shadowing, Fading and Variability, Non-Isotropic Antennas, Channel Measurement and Feedback, Environmental Factors, and so on are some of the important problems. It is engaged in doubling the capacity of radio channels by implementing multiple transmitters and receiving antennas to attain multipath propagation simultaneously mmWave technologies provide the advantages of large bandwidth, spatial diversity, and the ability to perform effective beamforming, making them ideal for MIMO models. The cheap cost deployment and synthesizing advanced technology make the mmWave spectrum explorable to the telecom industry, academia, and Research institutions. High atmospheric depreciation and consumption by gases in the atmosphere generally decrease the range and strength of the signal waves. Humidity and rain have some sort of adverse impact on its total output. Because of the higher robustness of the wave, the inflated-frequency wavelengths can be obstructed by barriers like buildings, trees, and shadowing. Therefore, NLOS and LOS are considered more vulnerable to these frequencies. mmWave technologies can be utilized in various applications, such as radar interception systems for military purposes (aerial surveillance) and civilian use, a thermal imaging system for threat detection and medical security purposes, and high-speed point-to-point communication [8]. To eliminate this technology's limitations, we can use massive MIMO, beamforming, and small cells. Other detailing of frequencies is shown in Fig.1

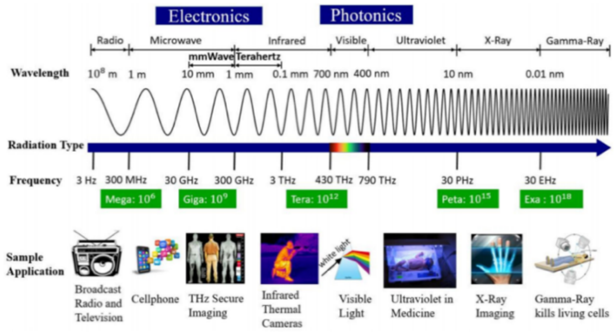


Fig. 1. Illustration of various frequency bands [8]

2.2 Literature survey

Recent Research and studies in the area of mmWave communication has persuaded Researchers to an improvised Research in modeling outdoor and indoor 6G channels and systems [9]. When considering both NLOS and LOS,the scenario to signalize the channel is typically addressed in urban macro and urban microenvironments. 6G is now in its early Research stage, and extensive Research will be carried out for more exploration on its niche areas. A large number of studies on potential solutions for 6G networks have lately been released. Some notable research projects have already begun. Y.Zhu et al.'s research in [11] provides a blueprint for the potential of Intelligent Reflecting Surfaces (IRSs) in improving 6G communication performance in a non-line-of-sight environment with minimum interference. H. Tataria et al [18] give a thorough view on the architectural design of 6G networks and propose solutions for future core networks in their study. In 2018, the Finnish University of Oulu published a white paper on 6G wireless communication network, exploring network architecture and Research challenges [10]. In 2019, the University of Texas Researched a vision for a 6G wireless system. Similarly, Scientists from the University of Bristol in the UK have explored the quantum communication protocol for 6G Communication. In parallel, Indian academia, too, is doing research in 6G networks. After the launch of 5G in October 2022, India started Researching 6G, keeping in view the 5G architecture. Academic institutes and the Department of Telecommunication (DoT) collaborated to set up a high-level forum to drive India's Research and development efforts in 6G technology. Presently several IITs and organizations are vigorously involved in 6G Research. Indian Institute of Science (IISc) is currently involved in designing new antennas for the 6G communication system. IIT Madras has successfully established a 6G testbed for developing and Researching 6G communication technologies focusing on the terahertz frequency range. IIT Delhi has entrenched a 6G lab to promote Research in 6G technologies, including mmWave technology and low-power communication. Various telecom organizations such as Reliance Jio and Bharti Airtel are investing in 6G Research and development, focusing on cost effect 6G network architectures. To persuade India's digital transformation, the government, academia, and industry partners need to focus on diverse Research in 6G technology, which can drive India's position as a leader in this field.

Many channel simulators have also been built to simulate channel models prior to their practical deployment in networks in order to gain out-of-the-loop information of the impacts on its many parameters. Some notable channel simulators have been published. Smith detailed a computer program for Rayleigh distributed channel modeling of indoor and outdoor channels in [19]. Rappaport et al. created the SIRCIM (Simulation of Indoor Radio Channel Impulse Response Model), which runs at frequencies ranging from 10 MHz to 60 GHz [20]. Fung et al. developed BERSIM, a simulation software for estimating link standards for mobile radio communication networks without the need for radio frequency hardware in real-time [21].

For development in 6G architecture, needful basic solutions involve using higher frequency bands and smaller cell sizes. However, this invites higher power consumption and operational cost. Path loss and signal attenuation can be suffered because of high-frequency bands [12]. To address current limitations and enable new services, some fundamental changes in designing are required for higher data rates; advanced modulation schemes like Quadrature amplitude modulation (QAM) and massive MIMO antenna technologies should be focused. For lower latency, which is crucial for real-time applications, network architecture such as distributed computing and edge computing is to be focused [11]. For greater reliability and security in 6G, its architecture needs to implement features such as enhanced encryption, network slicing, Blockchain, artificial intelligence, and machine learning.

3. Theory

3.1 Channel

The channel forms an important aspect of the communication system. In general, it is a medium through which information is transmitted from sender to receiver. The channel can be physical (optical fiber, wireless radio waves) or virtual(internet). For efficient channel modeling, understanding of properties of the channel is essential. The information obtained during the analysis of the properties of the channel can be applied to the framework plan of the wireless communication system [1].

3.2 LOS and NLOS Environment

Generally, two environments are considered for radio wave propagation i.e., LOS (Line of Sight) and NLOS (Non-Line of Sight). LOS refers to a situation in which there is no obstruction between transmitter and receiver, resulting in smooth propagation of radio signals. This will result in strong signal absorption, reduced signal attenuation, and good signal quality. While in NLOS, there will be an obstruction between the transmitter and the receiver, the radio signal is diffracted or absorbed by the obstacles leading to signal depreciation, multipath interference, and decreased quality of communication. The environment type is crucial in designing a modern wireless communication system. Improvement in design parameters is needed to improve communication for the NLOS environment [15].

3.3 Urban Microcell and Urban Macrocell Scenario(UMi&UMa)

Regarding telecommunication, different types of cellular network infrastructure are considered for providing wireless coverage in urban areas. They are called urban microcells (UMi) and urban macrocells (UMa). An urban microcell, a small cellular base station, typically provides coverage in densely populated areas. Microcells have restricted coverage areas ranging from a few 100 meters to a few km and are designed to manage a small number of users simultaneously. Earlier macrocellular network prototypes cannot give adequate coverage, which is overcome by microcells. Urban macrocells come into the picture when there is less demand for capacity and coverage in comparison to densely populated areas [1]. It provides coverage to a wider area, typically covering huge square kilometers. Both are essential constituents of modern cellular networks as they permit mobile network operators to provide definitive coverage in urban areas with high insistence on mobile data services.

3.4 Path Loss

Path loss in communication is the decrement or attenuation of the signal power or strength that travels through the propagating medium (air, water, physical hindrance) from the Tx to Rx. These losses happen due to various aspects, such as absorption losses (penetration losses), refraction, reflection, and diffraction losses. Path loss is a censorious factor considered while designing a wireless communication system. Path loss is distinctively modeled using the Friis transmission equation [5]

$$PL(d_0) = 20\log_{10}(\frac{4\pi d_0}{\lambda}) \quad (1)$$

where d_0 represents transmitter to receiver distance, and λ represents the wavelength.

The following equation helps to evaluate the amount of path loss:

$$PL^{CI}(f,d)[\text{dB}]=\text{FSPL(f,1,m)[dB]}+10\text{n}\log_{10}\left(\frac{d}{d_0}\right)+ AT[dB] + \chi_{\sigma}^{CI}, where\ d \geq d_0 \quad (2)$$

where d denotes the 3D T-R separation distance, f represents the carrier frequencyin GHz, n indicates the path loss exponent (PLE), d0 denotes the free space reference distance in meters, AT is the attenuation term caused by the atmosphere, and χ_{σ}^{CI} is a zero -mean gaussian random variable and FSPL(f,1m) represents the path loss occurred in free space in dB.

For a distance of 1m between transmitter and receiver, the path loss that occurred in free space is calculated as [5]:

$$FSPL(f,1,m)[dB] = 20\log_{10}(\frac{4\pi f * 10^9}{c})\text{=32.4[dB]+20}\log_{10}(f) \quad (3)$$

where c is the speed of light in free space. The term AT can be evaluated as [5]:

$$\text{AT[dB]=}\alpha\text{[dB/m] * d[m]} \quad (4)$$

where α represents the attenuation factor in dB/m for the frequency ranging from 1GHz-100GHz.

3.5 Received Signal Power

It is the total amount of power comprised of the radio frequency signal received by the transmitter with the help of the radio receiver. It is measured in terms of dBm(decibels-milliwatt). The received signal power is impacted by several parameters, such as interference, antenna gain, distance, and hindrances. It is an important factor considered in wireless communication technology as it resolute the quality of the signal received and SNR (signal and noise). Using the Friis transmission equation, the power received can be evaluated as [9]:

$$P_r[dBm] = P_t[dBm] + G_t[dB] + G_r[dB] - PL(d)[dB] \quad (5)$$

where *Gr, Gt, Pt,* and *Pr* denote receiving antenna gain, transmitting antenna gain, transmitted power, and received signal power.PL(d) and λ represent average path loss at distance d and wavelength, respectively.

3.6 Delay Spread

Multipath propagation gives rise to a phenomenon called delay spread in the wireless communication system. Multiple sets of signals are received at the receiver end at different time moments for the same signal pulse from the transmitter. The RMS delay spread characterizes the time-discursiveness of the channel. Delay spread has an effective influence on ISI (Inter Symbol Interference). The lower the delay spread value, the lower the ISI will be, and vice-versa. Regarding the delay spread, up-limit bandwidth is measured by coherence bandwidth that can be transmitted through a channel free of Inter-symbol interference (ISI).

$$B_c \approx \frac{1}{\tau_{rms}} \quad (6)$$

τ_{rms}represents delay spread. The wireless channel becomes more frequency selective with a larger delay spread value.so the more precise definition of coherence bandwidth is associated to the frequency correlation function:

For a correlation greater than 0.9,

$$B_c \approx \frac{1}{50\tau_{rms}}$$

For a correlation greater than 0.5,

$$B_c \approx \frac{1}{5\tau_{rms}}$$

The symbol length should be specified according to delay spread to design a symbol structure in the wireless communication system. The delay spread is an important parameter in designing the wireless system, as significant time dispersion could be introduced along the propagation environment.

4. Methodology

4.1 Initiation of the Research

Firstly, we thoroughly studied the basic 6G parameter based on existing 5G architecture. Our analysis sources comprise books, channel modeling-based Research papers, and Research publications. We have also gone through various communication-related mathematical equations. We focused on various advancing communication-related technologies, which helped us to move from 5G to 6G architecture. We also learned about different challenges that must be tackled while considering establishing 6G architecture.

4.2 NYUSIM

The word NYUSIM can be fragmented into two parts, first 'NYU' stands for New York University, and 'SIM' stands for Simulator. NYUSIM, a novel mmWave channel simulator, was developed by Rappaport and his teams at New York University, USA, based on substantial global transmission channel measurements. The Research is carried out by Researchers, students, lecturers, academia, and industry associated with 5G and 6G networks, millimeter waves (mmWave), artificial intelligence, and various applications related to modern wireless technology. NYUSIM helps in mobility scenarios and configuration, allowing users to examine the response of wireless systems under various conditions. NYUSIM carries out Monte Carlo simulations, bringing about a few samples of CIRs at various frequencies [17]. This channel simulator has thirty input parameters, broadly categorized into two: twelve are for antenna properties/parameters, and eighteen are for channel parameters. This Simulator enables us to handle different bandwidths ranging from 0 to 800 MHz, different carrier frequencies ranging from 500MHz to 100GHz, antenna beam width angles varying from 7° to 45° for elevation and 7° to 360° for azimuth [5]. Various scenarios can also be operated, like urban macrocells, urban microcells, and rural macrocells. Various MIMO antennae can be configured as per the requirement. Various weather conditions can be provided as an input parameter that will tend the simulation result very close to the accuracy.

Several other channel parameters have been utilized by earlier Researchers. After the diversified study of various channel simulator software, we found that NYUSIM is superior to mmWave communication in terms of performance. The NYUSIM simulator is downloaded from [6]. Before implementing the simulation, we must have the primary statistics along with the supporting data of the specified region, whose results are to be examined. As shown in fig.3, the Research block diagram provides the hierarchical steps to be followed while carrying out the channel modeling process. In the preliminary stage, the corresponding values of required bandwidth, suitable scenario, environment, consideration of barrier parameters, and various supporting data (rainfall, humidity, temperature) are entered into specific columns of the region. This is followed by setting up of the number of transmitters and receivers. After providing the required parameters when the simulation is carried out, it gives out a collective output of various graphs analyzed later in the paper.

4.3 Supporting Data, Research Location&Various Input Parameters

In our Research, we have taken the case study as the city of Bhubaneswar, Odisha, located at 20.2961°N latitude and 85.8245°E longitude. Bhubaneswar has a tropical Savanna climate, with hot and humid summers and mild winters.
This Research is in the requirement for various weather conditions such as average temperature(C°), average rain rate(mm/hr), humidity (in %), and barometric pressure (supporting data) conditions over the Bhubaneswar region. The average data of a year is considered with reference to these used parameters [14].

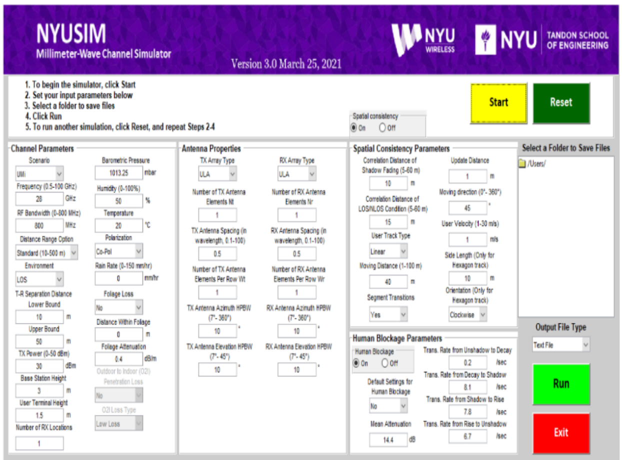


Fig. 2. Nyusim Interface[5]

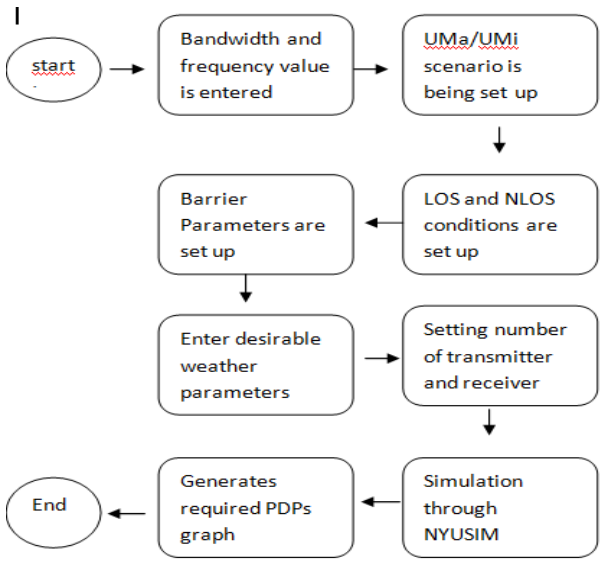


Fig. 3. Block diagram

The primitive input specification and their surmises during the simulation process are tabulated in Table 2. Here, three frequency bands(85GHz,90GHz,95GHz) are considered for the channel modeling of the 6G Network.

Table 2. Input parameters

Channel Parameters		Antenna Properties	
RF bandwidth	800 MHz	TX Array Type	ULA
Scenario	UMi/UMa	RX Array Type	ULA
Environment	LOS/NLOS	Number of TX Antenna Elements	3
Lower Bound of T-R Separation Distance	10 m	Number of RX Antenna Elements	3
Upper Bound of T-R Separation Distance	100 m	TX Antenna Spacing	0.5 wavelength

TX Power	30dBm	RX Antenna Spacing	0.5 wavelength
Barometric Pressure	1007 mbar	Number of TX Antenna Elements Per Row*Wt*	1
Humidity	76%	Number of RXAntenna Elements Per Row*W*	1
Temperature	28^0C	TX Antenna Azimuth HPBW	10^0
Rain Rate	0.2 mm/hr	TX Antenna Elevation HPBW	10^0
Polarization	Co-Pol	RX Antenna Azimuth HPBW	10^0
Foliage Loss	No	RX Antenna Elevation HPBW	10^0

5. Simulation and Result Analysis

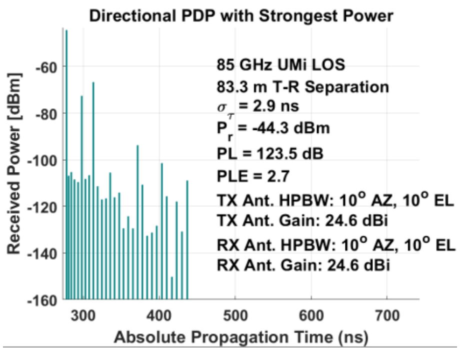
This section executes extensive simulation to get the optimum result using primitive input parameters and supporting data entered in their respective channel and antenna parameters. In NYUSIM software, there are four major: Spatial consistency parameters, Human blockage parameters, Antenna properties, and Channel parameters. The first two parameters are optional. In our Research, we opted for the last two parameters and neglected the first ones by keeping the button-off mode.

In the section consisting of channel parameters, we have considered UMi and Uma (scenarios, both LOS and NLOS environments, along with frequency bands of 85,90, and 95 GHz.

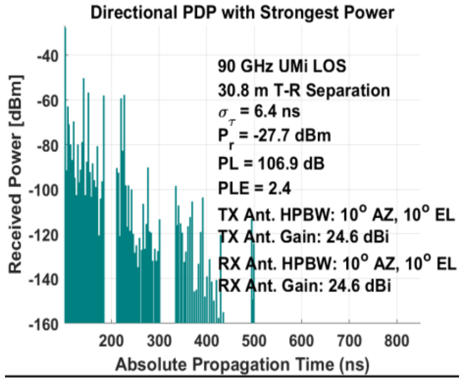
After the simulation on various frequency bands along with the environment and scenario, six output figures in each simulation are obtained: AOA (Angle of arrival) power spectrum, AOD (Angle of departure) power spectrum, omnidirectional PDP, directional PDP, small-scale PDP, and directional and omnidirectional path loss. The PDP signifies received signal power as a function of time delay. In general, it gives an idea about what process a signal undergoes while it is retrieved at the receiver end with interchanging signal strength as it propagates through a multipath channel with the raised value of propagation delay. Various desired information is obtained, which can be considered a parameter while designing and optimizing wireless communication systems.

Our main purpose of this research is to analyze the power delay profile regarding path loss exponent, path loss, delay spread, and power received. All the results are discussed further. Post-simulation, we have categorized our simulation, depending upon the scenario and environment for different frequencies, into four different cases as follows:

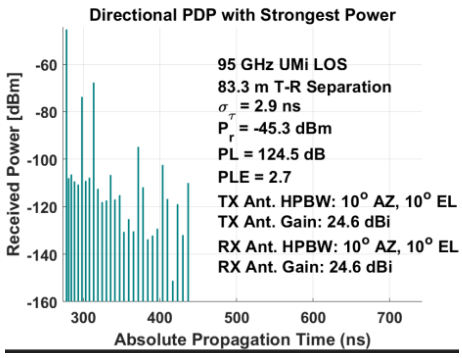
Case 1: UMi LOS



(i) 85 GHz

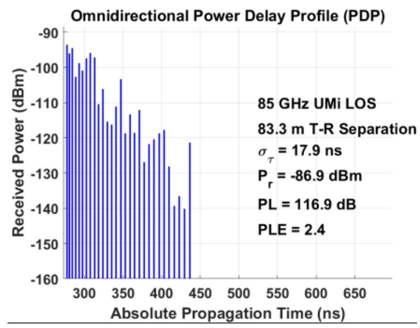


(ii) 90 GHz

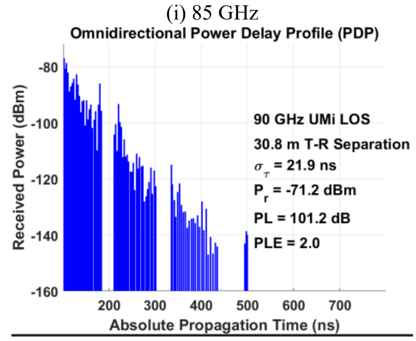


(iii) 95 GHz

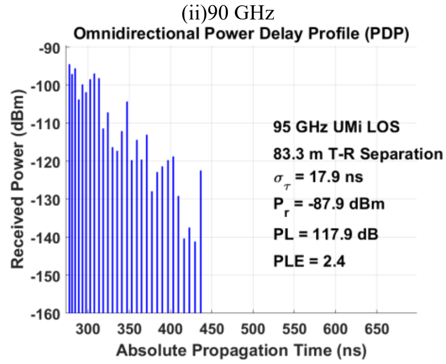
Fig. 4. Directional PDP for UMi LOS



(i) 85 GHz



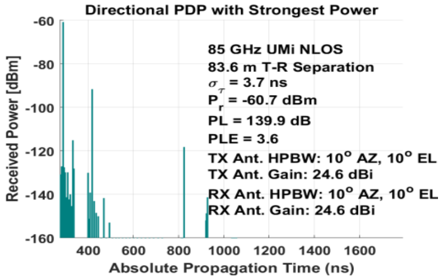
(ii)90 GHz



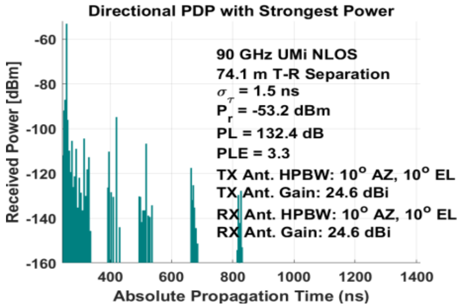
(iii)95 GHz

Fig. 5. Omnidirectional PDP for UMi LOS

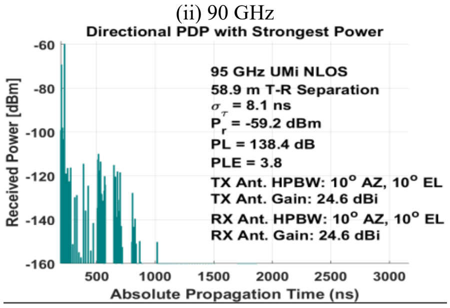
Case 2: UMi NLOS



(i)85 GHz

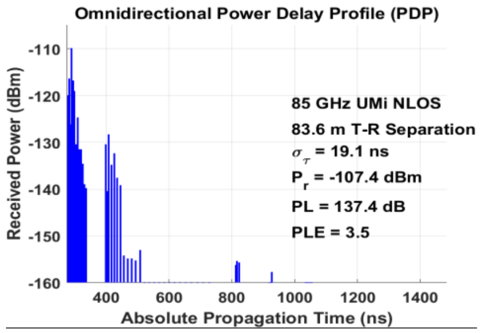


(ii) 90 GHz

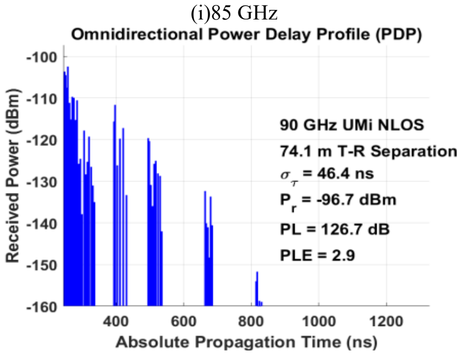


(iii) 95 GHz

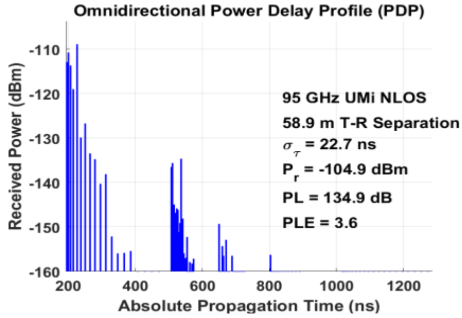
Fig. 6. Directional PDP for UMi NLOS



(i)85 GHz



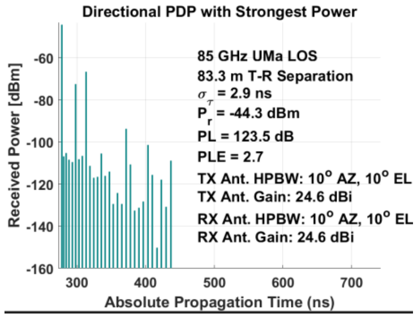
(ii)90 GHz



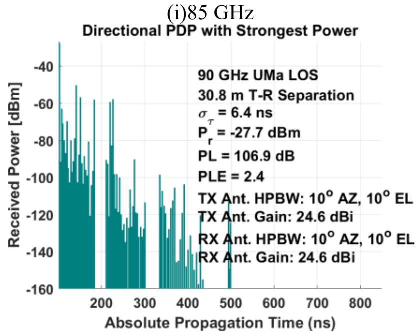
(iii)95 GHz

Fig. 7. Omnidirectional PDP for UMi NLOS

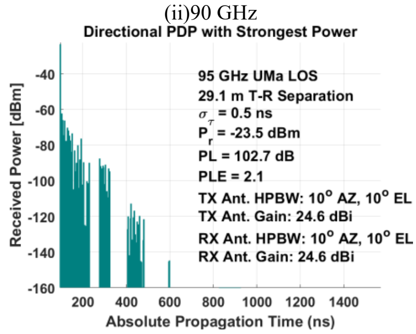
Case 3: UMa LOS



(i)85 GHz

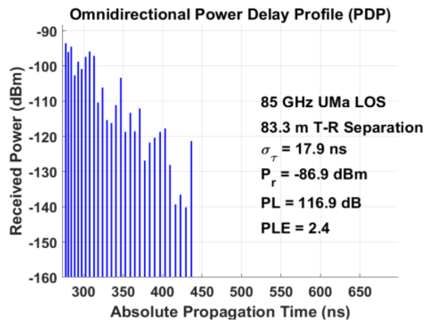


(ii)90 GHz

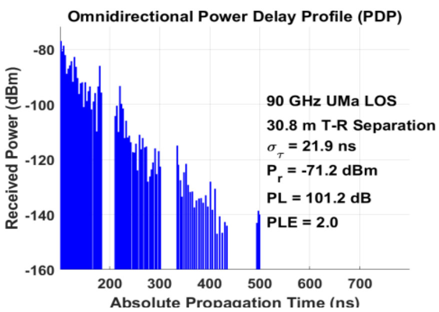


(iii)95 GHz

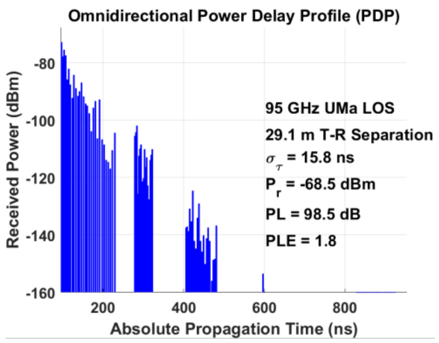
Fig. 8. Directional PDP for UMa LOS



(i)85 GHz



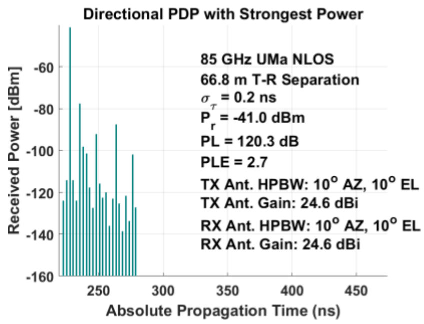
(ii)90 GHz



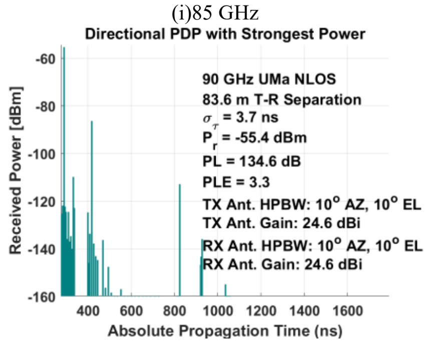
(iii)95 GHz

Fig. 9. Omnidirectional PDP for UMa LOS

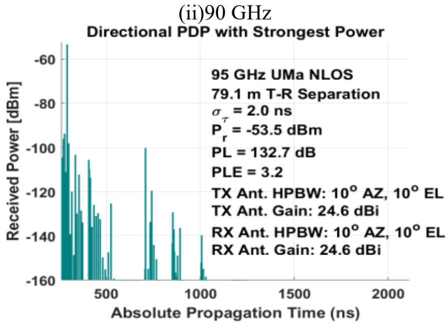
Case 4: UMa NLOS



(i)85 GHz

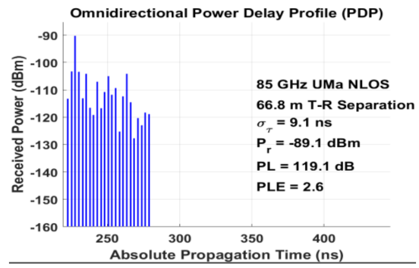


(ii)90 GHz

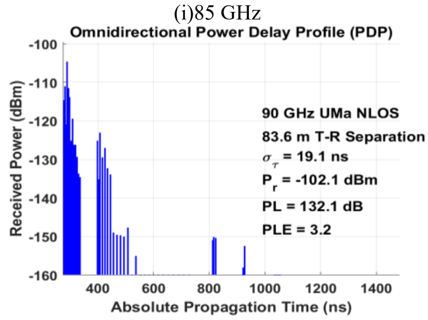


(iii)95 GHz

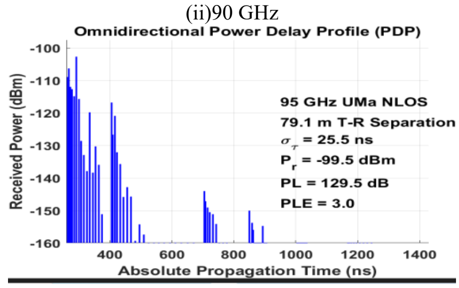
Fig. 10. Omnidirectional PDP for UMa NLOS



(i)85 GHz



(ii)90 GHz



(iii)95 GHz

Fig. 11. Omnidirectional PDP for UMa NLOS

5.1 Path Loss Value

Directional path loss will always be greater than the omnidirectional condition because of its directional pattern. The directional antenna filters out various multipath components, which results in receiving less energy, which further implies higher directional path loss [18]. Considering the first case (Case 1), the highest path loss for both omnidirectional and directional PDP is for 95 GHz, i.e., 117.9 dB and 124.5 dB, respectively, while the lowest path loss for both omnidirectional and directional PDP is for 90 GHz, i.e., 101.2 dB and 106.9 dB respectively. According to the second case (Case 2), 85 GHz has the highest path loss for both omnidirectional (137.4 dB) and directional (139.9 dB) PDP, respectively, while 90 GHz has a lower path loss for both omnidirectional (126.7 dB) and directional (132.4 dB) PDP. For the third case (Case 3) environment and scenario, 95 GHz has the lowest path loss for both omnidirectional (98.5 dB) and directional (102.7 dB) PDP, respectively, while85 GHz has the highest path loss for both omnidirectional (116.9 dB) and directional (123.5 dB) PDP. Similarly, for the fourth case (Case 4),90 GHz has the highest path loss for both omnidirectional (132.1 dB) and directional (134.6 dB), respectively, while 85 GHz has the lowest path loss for both omnidirectional (119.1 dB) and directional (120.3 dB) PDP. Experimentally, we found that, in all frequency bands(85GHz,90GHz,95GHz), directional PDP has higher path loss than omnidirectional PDP.

5.2 Path Loss Exponent

The path loss exponent measures how fast the signal strength reduces with distance. Considering the first case (Case 1), the highest path loss exponent for both omnidirectional and directional PDP is for 95 GHz i.e., 2.4 and 2.7, respectively, while the lowest path loss for both omnidirectional and directional PDP is for 90 GHz, i.e., 2.0 and 2.4 respectively. According to the second case (Case 2), 85 GHz has the highest path loss exponent for both Omni-directional (3.5) and directional (3.6) PDP, respectively while 90 GHz has lower path loss for both omnidirectional (2.9) and directional (3.3) PDP. For the third case (Case 3) environment and scenario,95 GHz has the lowest path loss exponent for both Omni-directional (1.8) and directional (2.1) PDP, respectively, while85 GHz has the highest path loss exponent for both Omni-directional (2.4) and directional (2.7) PDP. Similarly, for the fourth case (Case 4),90 GHz has the highest path loss for both Omni-directional (3.2) and directional (3.3), respectively, while 85 GHz has the lowest path loss exponent for both Omni-directional (2.6) and directional (2.7) PDP.

In a directional antenna, the signal is more or less focused in a particular direction, resulting in higher signal strength. However, the strength of signals coming from different directions was reduced. However, in the case of omnidirectional antennas, the signal is radiated equally from all directions, resulting in a finer unwavering distribution of signal strength all over the antenna that concludes in a lower path loss exponent. Post-simulation, we verified the result obtained to be correct according to the theory formulated.

5.3 Received power

It is the total power received by the receiving antenna after the propagation of the signal through different mediums (air, water, and other mediums). It is considered an important component to examine the standard of the signal received. A lower value of negative power implies a high signal power value in a communication system [18]. The power received nearer to zero signifies a stronger signal. Considering the first case (Case 1), the highest received power for directional and omnidirectional PDP is for 90 GHz, i.e., -27.7 dBm and -71.2 dBm, respectively, while the lowest received power for both directional and omnidirectional PDP is for 95 GHz i.e., -45.3 dBm and -87.9 dBm respectively. According to the second case (Case 2),90 GHz has the highest received power for both directional (-53.2 dBm) and omnidirectional (-96.7 dBm) PDP, respectively, while 85 GHz has a lower received power for both directional (-60.7 dBm) and omnidirectional (-107.4 dBm) PDP. For the third case (Case 3) environment and scenario,85 GHz has the lowest received power for both directional (-44.3 dBm) and omnidirectional (-86.9 dBm) PDP, respectively, while95 GHz has the highest received power for both directional (-23.5 dBm) and omnidirectional (-68.5 dBm) PDP. Similarly, for the fourth case (Case 4),85 GHz has the highest received power for both directional (-41.0 dBm) and omnidirectional (-89.1 dBm), respectively, while 90 GHz has the lowest received power for both directional (-55.4 dBm) and omnidirectional (-102.1 dBm) PDP.

The majority of the directional antenna's signal propagation is directed towards the receiving antenna. The signal transmitted by the omnidirectional antenna is dispersed uniformly along all directions, indicating that only a small percentage of the signal transmitted is received by the receiving antenna. Our simulation results matched the formulated theory.

5.4 Delay spread

It is the measurement of the attenuation of the signal caused due to multipath propagation. Delay spread can have a notable influence on the signal received. Higher delay spread makes retrieving the data difficult at the receiver end. Its importance lies in how adversely it impacts ISI (Inter symbol interference). We can expect an ISI-free channel if the symbol duration is long enough as compared to the delay spread. For case 1, the results of delay spread obtained for various frequency bands, i.e., 85,90 and 95 GHz, are 2.9 ns,6.4 ns, and 2.9 ns, respectively, in directional PDP and 17.9 ns,21.9 ns, and 17.9 ns respectively in omnidirectional PDP. For case 2 at the same frequency bands, the delay spread obtained are 3.7 ns,1.5 ns, and 8.1 ns, respectively, for directional PDP and 19.1 ns,46.4 ns, and 22.9 ns, for omnidirectional. Subsequently, for case 3, at the same frequency bands, the results for delay spread obtained are 2.9 ns, 6.4 ns, and 0.5 ns, respectively, for directional PDP and 17.9 ns,21.9 ns, and 15.8 ns, respectively, for omnidirectional PDP. For the last case, the results obtained for delay spread for various frequency bands are 0.2 ns,3.7 ns, and 2.1 ns, respectively, for directional and 9.1 ns,19.1 ns, and 25.5 ns, respectively, for omnidirectional PDP.

In wireless communication channels, delay spread can be reduced using directional antennas, and it is because the antenna can concentrate more in a specific direction leading to a reduction in the number of multipath reflections and improvising the SNR in that specific direction which leads to lower delay spread. An omnidirectional antenna radiates energy in all directions, resulting in higher signal reflection and affinity towards delay spread. For different environments and scenarios, both directional and omnidirectional PDP delay spread, received power, path loss, and path loss exponent have been provided in Table 3. The table below provides an overview of all desired and essential data to analyze channel dependence on various frequencies.

Table 3. Illustration of Outputs

Freq. Parameter(GHz)	UMi																	
	LOS									NLOS								
	Pr(dBm)		PLE		PL(dB)		T-R(m)	DELAY SPREAD(ns)		Pr(dBm)		PLE		PL(dB)		T-R(m)	DELAY SPREAD(ns)	
	dir	omni	dir	omni	dir	omni	Omni/dir	dir	omni	dir	omni	dir	omni	dir	omni	Omni/dir	dir	omni
85	-44.3	-86.9	2.7	2.4	123.5	116.9	83.3	2.9	17.9	-60.7	-107.4	3.6	3.5	139.9	137.4	83.6	3.7	19.1
90	-27.7	-71.2	2.4	2.0	106.9	101.2	30.8	6.4	21.9	-53.2	-96.7	3.3	2.9	132.4	126.7	74.1	1.5	46.4
95	-45.3	-87.9	2.7	2.4	124.5	117.9	83.3	2.9	17.9	-59.2	-104.9	3.8	3.6	138.4	134.9	58.9	8.1	22.9
Freq. Parameter(GHz)	UMa																	
	LOS									NLOS								
	Pr(dBm)		PLE		PL(dB)		T-R(m)	DELAY SPREAD(ns)		Pr(dBm)		PLE		PL(dB)		T-R(m)	DELAY SPREAD(ns)	
	dir	omni	dir	omni	dir	omni	Omni/dir	dir	omni	dir	omni	dir	omni	dir	omni	Omni/dir	dir	omni
85	-44.3	-86.9	2.7	2.4	123.5	116.9	83.3	2.9	17.9	-41.0	-89.1	2.7	2.6	120.3	119.1	27.4	0.2	9.1
90	-27.7	-71.2	2.4	2.0	106.9	101.2	30.8	6.4	21.9	-55.4	-102.1	3.3	3.2	134.6	132.1	21.3	3.7	19.1
95	-23.5	-68.5	2.1	1.8	102.7	98.5	29.1	0.5	15.8	-53.5	-99.5	3.2	3.0	132.7	129.5	79.1	2.1	25.5

6. Conclusion

6G communication is now in its *initial* research stage and requires a thorough analysis for its establishment. In this paper, the design of the modeling for 6G communication network was carried out using NYUSIM software. Our research has categorized our simulation into four categories/cases based on different scenarios(UMi, UMa) and environments (LOS, NLOS) tested with frequencies of 85,90, and 95 GHz, considering a bandwidth of 800 MHz. Here we have considered the Temple City, Bhubaneswar area as a case study(considering weather conditions as supporting data required in the simulation) to determine which environment and scenario conditions among the four cases could be better for establishing 6G networks. After the simulation, the channel parameter power delay profile (both directional and omnidirectional) is analyzed for various bands of frequencies. On comparison between both omnidirectional and directional PDP, it can be observed for all the cases that overall values of directional PDP surmount the values of omnidirectional PDP. Our observation shows that different frequency gives the ideal result for different cases. In the current scenario, we cannot simultaneously attain power and bandwidth efficiency. Our Research focused on power efficiency, i.e., received power. Other parameters we have considered include path loss, path loss exponent, and delay spread. The analysis of channel modeling through this Research could be useful in designing and modeling an analytical channel model for futuristic 6^{th-} generation mmWave communication. In the future more comprehensive study is required for further investigation into other parameters such as bit error rate, antenna configuration based on rain rate, temperature, humidity, and Tx-Rx separation on the power received.

7. Challenges and Future Research

Researchers and developers have started Researching the niche areas directing to go beyond 5G. This holds an urgency to meet human needs regarding high data rates and pacify future challenges [7]. 6G network paves the way to reach all around the globe, despite topography and all other climatic conditions. But a lot of challenging issues are encountered in the way to establish 6G network architecture. The most basic challenge for the establishment of 6G architecture is the infrastructural setup, which results because of lesser trained personnel which make maintenance difficult, harsh terrain and climatic barriers acts as an obstruction and makes outreaching difficult for setting up and maintenance of different equipment and inadequate business due to scarce population [12]. An impressive enhancement in cellular networks is needed to grapple with societal mechanization, IoT, network compaction, authenticity, and public protection. Moreover, Blockchain has characteristics of third-party elimination, segregated architectonics, obscurital transparency, and lesser processing latency, making Blockchain a coherent assured technology. Device compatibility also poses a challenge in switching from 5G to 6G. Mobile phones with 5G should carry the capacity to grapple with the modern 6G features. Enhancing the network operability to put it at par with 6G features may also increase the device cost [16]. mmWave frequencies are more prone to atmospheric conditions leading to attenuative and dispersive effects in the signal. Highly focused Research on efficient spectrum management and interference problems is required. This holds importance in attaining improvised service quality and efficient resource utilization [12]. There is also a need to inspect how interference issues can be minimized using interference reduction methods. Beamforming in massive MIMO systems also holds importance in communication with higher data rates. The combination of MIMO and mmWave is an effective method for achieving high data rates, increased capacity, and reliable communication in next-generation wireless systems such as 5G and beyond. An efficient MIMO system in mmWave frequency band poses a challenge due to its transmission characteristics. More Research methodologies such as NOMA must be explored extensively for channel prediction, efficient management in power allocation, and minimization of interference in modern wireless communication systems [13]. In the future, there is a need to integrate AI with 6G technology for smart decision-making. The amalgamation of 6G with edge computing technology enables quick data synthesis and inspection. The growth of 6G technology will need cooperation among various fields and crucial expenditure in indagation and development.

References

[1] H. Walidainy, R. Adriman, Y. Away, and N. Nasaruddin, "Channel Modeling for 6G Communications: A Survey," in *2021 Int. Conf. Comp. Sys., Inform. Technol., Electr. Engineer. (COSITE)*, Banda Aceh, Indonesia: IEEE, Oct. 2021, pp. 1–6. doi: 10.1109/COSITE52651.2021.9649545.

[2] H. Tataria, M. Shafi, A. F. Molisch, M. Dohler, H. Sjoland, and F. Tufvesson, "6G Wireless Systems: Vision, Requirements, Challenges, Insights, and Opportunities," *Proc. IEEE*, vol. 109, no. 7, pp. 1166–1199, Jul. 2021, doi: 10.1109/JPROC.2021.3061701.

[3] W. Jiang, B. Han, M. A. Habibi, and H. D. Schotten, "The Road Towards 6G: A Comprehensive Survey," *IEEE Open J. Commun. Soc.*, vol. 2, pp. 334–366, 2021, doi: 10.1109/OJCOMS.2021.3057679.

[4] K. B. Letaief, W. Chen, Y. Shi, J. Zhang, and Y.-J. A. Zhang, "The Roadmap to 6G: AI Empowered Wireless Networks," *IEEE Commun. Mag.*, vol. 57, no. 8, pp. 84–90, Aug. 2019, doi: 10.1109/MCOM.2019.1900271.

[5] "NYUSIM User Manual." New York University and NYU WIRELESS, Apr. 2017. [Online]. Available: https://wireless.engineering.nyu.edu/wp-content/uploads/2017/03/User-Manual-for-NYUSIM_v1.5.pdf

[6] *NYUSIM Simulator*. MatLab. NYU Wireless. [Online]. Available: https://wireless.engineering.nyu.edu/nyusim/

[7] P. Mitra *et al.*, "Towards 6G Communications: Architecture, Challenges, and Future Directions," in *2021 12th Int. Conf. Comp. Commun. Network. Technol. (ICCCNT)*, Kharagpur, India: IEEE, Jul. 2021, pp. 1–7. doi: 10.1109/ICCCNT51525.2021.9580084.

[8] T. S. Rappaport *et al.*, "Wireless Communications and Applications Above 100 GHz: Opportunities and Challenges for 6G and Beyond," *IEEE Access*, vol. 7, pp. 78729–78757, Jul. 2019, doi: 10.1109/ACCESS.2019.2921522.

[9] R. Hasan, M. M. Mowla, M. A. Rashid, M. K. Hosain, and I. Ahmad, “A Statistical Analysis of Channel Modeling for 5G mmWave Communications,” in *2019 Int. Conf. Electr., Comp. Communic. Engin. (ECCE)*, Cox’sBazar, Bangladesh: IEEE, Feb. 2019, pp. 1–6. doi: 10.1109/ECACE.2019.8679507.

[10] W. Saad, M. Bennis, and M. Chen, “A Vision of 6G Wireless Systems: Applications, Trends, Technologies, and Open Research Problems,” *IEEE Network*, vol. 34, no. 3, pp. 134–142, May 2020, doi: 10.1109/MNET.001.1900287.

[11] V. Fung, T. S. Rappaport, and B. Thoma, “Bit error simulation for pi /4 DQPSK mobile radio communications using two-ray and measurement-based impulse response models,” *IEEE J. Select. Areas Commun.*, vol. 11, no. 3, pp. 393–405, Apr. 1993, doi: 10.1109/49.219546.

[12] S. Elmeadawy and R. M. Shubair, “6G Wireless Communications: Future Technologies and Research Challenges,” in *2019 Int. Conf. Electr. Comput. Technol. Applic. (ICECTA)*, Ras Al Khaimah, United Arab Emirates: IEEE, Nov. 2019, pp. 1–5. doi: 10.1109/ICECTA48151.2019.8959607.

[13] G. Liu *et al.*, “Vision, requirements and network architecture of 6G mobile network beyond 2030,” *China Commun.*, vol. 17, no. 9, pp. 92–104, Sep. 2020, doi: 10.23919/JCC.2020.09.008.

[14] “Government of Odisha,” Government of Odisha. [Online]. Available: https://odisha.gov.in

[15] D. Capano, “Wireless line-of-sight, non-line-of-sight, beyond-line-of-sight propagation,” Control Engineering. [Online]. Available: https://www.controleng.com/articles/wireless-line-of-sight-non-line-of-sight-beyond-line-of-sight-propagation/

[16] L. Yan, C. Han, and J. Yuan, “Hybrid Precoding for 6G Terahertz Communications: Performance Evaluation and Open Problems,” in *2020 2nd 6G Wirel. Summit (6G SUMMIT)*, Levi, Finland: IEEE, Mar. 2020, pp. 1–5. doi: 10.1109/6GSUMMIT49458.2020.9083795.

[17] S. M. Shamim, Md. S. Hossain, G. M. K. Ta-seen, M. B. A. Miah, and M. S. Uddin, “Performance Analysis of Omni-Directional and Directional Power Delay Profile for Millimeter Wave 5G Cellular Networks in LOS Environment,” in *2018 Int. Conf. Adv. Electr. Electron. Engineer. (ICAEEE)*, Gazipur, Bangladesh: IEEE, Nov. 2018, pp. 1–4. doi: 10.1109/ICAEEE.2018.8642967.

[18] S. Y. Seidel, K. Takamizawa, and T. S. Rappaport, “Application of second-order statistics for an indoor radio channel model,” in *IEEE 39th Vehicular Techn. Conf.*, San Francisco, CA, USA: IEEE, 1989, pp. 888–892. doi: 10.1109/VETEC.1989.40179.

[19] T. S. Rappaport, S. Y. Seidel and K. Takamizawa, "Statistical channel impulse response models for factory and open plan building radio communicate system design," *IEEE Trans. on Commun.*, vol. 39, no. 5, pp. 794-807, May 1991, doi: 10.1109/26.87142.

[20] T. S. Rappaport, "Indoor radio communications for factories of the future," *IEEE Commun. Mag.*, vol. 27, no. 5, pp. 15-24, May 1989, doi: 10.1109/35.29535.

Abbreviations

LOS : Line of Sight
NLOS : Non Line of Sight
UMi : Urban Micro Cell
UMa : Urban Macro Cell
MIMO : Multiple Input Multiple Output
NOMA: Non Orthogonal Multiple Access
SNR: Signal to Noise Ratio
IOT : Internet of Things
PDP : Power Delay Profile
Tx : Transmitter
Rx : Receiver
DPDP : Directional Power Delay Profile
OPDP : Omnidirectional Power Delay Profile
SSPDP : Small-Scale Power Delay Profile