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A virtual analysis on Millimeter Wave Communication for 5G Technology

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Abstract:

5G network is a combination of 4G and WWWW using CDMA multiplexing. This implementation supports cloud based management and hence provides a wide range of spectrum The range of frequencies assigned ranges from 700MHz to 6 GHz. The basic requirements and challenges in 5G networks are discussed in this paper. The major concepts of 5G network is integrated into an architecture which includes MIMO systems, D2D communications, IoT, IoV, Big Data, Software Defined Radio and Millimeter Wave communication. Considering the effective usage of bandwidth and signal strength, Millimeter Wave (mmW) communication plays a important role. In this communication extremely small cells are considered, which decreases the attenuation with the use more directive antennas to compensate for the higher attenuations. Simulation is carried out with the help of 5G mmW Simulator known as NYSIM to model channels from 2 to 73 GHz that is suitable in 3GPP and the graphical user interface (GUI) of the 5G mmW Simulator. Simulation for different active elements for the transmitting and receiving antennas is be carried out to understand and analyze the signal strength to compensate for higher attenuation.

Keywords : *5G systems, MIMO, mmW communication, NYSIM*

1 INTRODUCTION

FIFTH generation development and study started from the year 2014-15. This 5G network is the combination of 4G and World Wide Wireless Web (WWWW) which uses CDMA multiplexing involving both horizontal and vertical handoff. The 5G schemes involves a new technology known as Filtered-Orthogonal Frequency Division Multiplexing (Filtered-OFDM) which facilitates the coexistence of different output waveforms with different OFDM parameters. The 5G schemes is based on a very flat architecture combining the base station (BS) and the base station controller (BSC) known as the Cloud-Radio Access Packet Core (C-RAN). There is no circuit core in 5G as the one involved in 3G wireless systems. The virtual Enhanced Packet Core (vEPC) is a software upgrade that is based on 4G Long Term Evolution (LTE) packet core. 5G implementation supports cloud based management and creation and a wide range of spectrum. The range of frequencies assigned to wireless communications range from 700 MHz to 6 GHz. 5G systems not only operate in this range but also extend through centimeter and millimeter bands up to 100 GHz and below 6 GHz, the 5G schemes merge with the 4G technology. The prescribed range offers greater bandwidth but with smaller coverage leading to path loss [4].

2 FRAMEWORK AND CONSIDERATION IN 5G

2.1 Basic requirements of 5G Networks

Energy efficiency: Larger is the BTS, larger is the energy requirement. Energy consumption occurs at two stages, ie., one is the energy consumed by the BTS during transmission and reception of signals and the other at the mobile station. Energy consumption depends on the size of the BTS. Lesser is the size of BTS, lower is the power. This situation gives rise to increased handoffs. Hence there is a trade-off between the size of the BTS and the power consumed at the mobile station.

Spectrum Efficiency: Spectrum Efficiency is defined by the optimum usage of the spectrum. It is the

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usage of the required bandwidth so as to reduce the wastage of the radio spectrum. The main consideration is the scarcity of the spectrum as 5G involves enormous data transmission [5], [6].

Backhauling: There is a trade-off between the powers saved by the small and low power base stations to control the backhaul traffic as the power consumption is comparable with the small cells. It is taken care that the backhauling is included in the overall budget of the mobile radio networks so as to optimize the system [2].

Storage Capacity: Data storage in advanced technology gives rise to capacity problem which puts an extra pressure. This problem is rectified using cloud computing which focuses on maximizing the effectiveness of the resources that are shared on the network.

2.2 Challenges in 5G Networks

In spite of the considerations and advantages of 5G, the scheme faces certain challenges in day-to-day applications [3].

Heterogeneous devices: In today's scenario there are around 7 billion devices connected to the wireless network. Most of them are mobile devices and the others are user defined devices which are basically connected to the internet. Hence the number of users increases day by day. They should be developed with the capability of handling high traffic M2M devices by introducing high characteristics network.

Massive traffic: The traffic is increasing annually at the rate of 40% in order to contribute to the worldwide subscriptions of around 2 billion mobile networks. The density of the mobile users keep on increasing day by day based on the capacity demand to be tackled in a very specific time. This is one of major challenge in mere future.

Diverse Requirements: Systems connected to internet in order to meet the requirements of the companies. In future the internet may also be replaced by the processing done with the help of sensors and actuators. The requirements may be based on the applications to provide high quality of service.

Cost: Compatible handsets are required to use this 5G technology into the smart phones. Continuous network updating is required in order to accommodate large amount of data which in turn increases the cost of installation.

3 INTEGRATED ARCHITECTURE OF 5G COMMUNICATION

The major concepts of 5G are integrated into the architecture as shown in Figure 1 and are explained as follows:

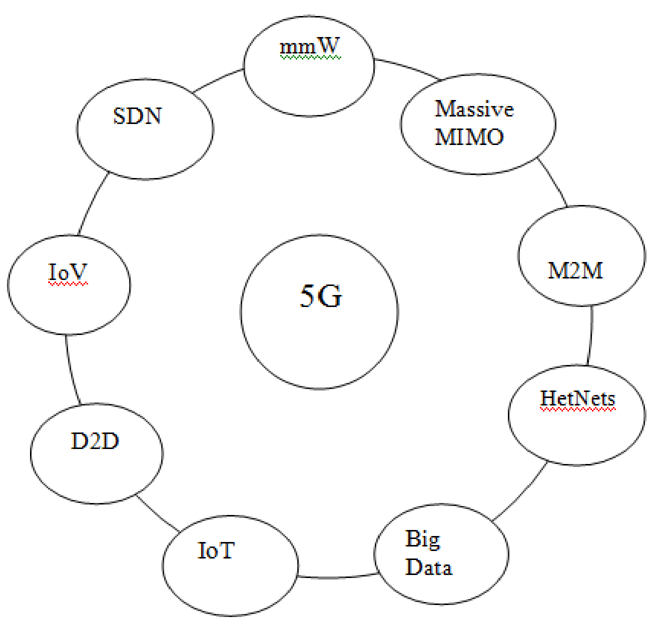

Fig. 1. Integrated Architecture of 5G Communication

3.1 Massive MIMO Systems

The Shannon's capacity theorem fixes an upper bound to the capacity of a link in bit per second so as to obtain higher data rates. The channel capacity is approximated by

$$C= \min(M,N)*b*\log2(1+SNR)$$

Where M is the number of antennas at the transmitter and N is the number of antennas at the receiver of the MIMO system, B is the channel bandwidth and SNR is the signal to noise ratio of the link. Hence Massive Multiple Input Multiple Output system is an extension of the Multiple Input Multiple Output system with considerably increased capacity due to increase in the number of antennas. By increasing the active antennas in the array, the antenna beam can be controlled in both vertical and horizontal directions thereby improving the SNR. This helps in increasing the capacity of the link which would reduce power transmission thereby saving energy [1], [4].

The capacity can be increased by 10-fold or even more with the help of this system and this is achieved by using spatial multiplexing where the antennas are dedicated to a particular direction. This also adds an advantage of energy saving by 100-fold as the terminals receive a high data rate. Since each terminal is provided with full bandwidth and minimum latency, this system reduce the overheads that is caused by controlling information present in the physical and MAC layer. They use sizeable low-cost amplifiers and hence cost effective. Apart from this system is robust to jamming and interference since the entire system will not fail if one or more antennas fail. The limitation of the system is that they are complex with fast and distributed signal processing. The major challenge faced is the reduction in internal power consumption so as to achieve higher energy efficiency since the amount of data that is exchanged is very vast and also needs to be processed under real time conditions.

3.2 Non-Orthogonal Waveforms

Recent wireless communication standards inherent Orthogonal Frequency Division Multiplexing (OFDM) due to its robustness, high spectrum efficiency and ease of implementation. The major limitation in OFDM is that it has conflict with 5G technologies in satisfying IoT requirements like high peak to average power ratio (PAPR), signaling overhead in time and energy due to cyclic prefix and high out of band emission. Hence to overcome these limitations new non-orthogonal waveforms are introduce in 5G systems that are more efficient than filtered OFDM and windowed OFDM.

The requirement of synchronization in OFDM is also a limitation in IoT scenario as they need to work coarsely synchronized. For a tactile Internet scenario, the significant problem is high latency. This increases by the usage of long symbols and long time frame in OFDM system. Hence the use of OFDM is limited for the tactile Internet scenario.

3.3 Non-Orthogonal Multiple Access

Different multiple access techniques like Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA) and Orthogonal Frequency Division Multiplexing (OFDM) techniques share channels between them by either frequency, time or codes. All these techniques come under Orthogonal Multiple Access (OMA) techniques and they do not satisfy the 5G requirements from the perspective of energy efficiency. Hence a new channel sharing technique known as Non-orthogonal Multiple Access (NOMA) was proposed so as to improve the spectral connectivity, connectivity, low cost and low latency. This new technique can be categorized into two, namely, Code domain multiplexing and power domain multiplexing.

Code domain multiplexing allots different codes but the power domain multiplexing allocates based on channel power conditions and then they are multiplexed over frequency or time resources. Most common NOMA schemes considered for 5G communications are SCMA (sparse code multiple access), RSMA (Receiver sense multiple access), PDMA (pattern division multiple access), MUSA (multi-user shared access), BDMA (beam division multiple access), IDMA (interleaved division multiple access), MUST (multi-user superposition transmission), SoDeMA (software defined multiple access) and BDM (bit division multiplexing).

3.4 Device-to-Device (D2D) Communications

Device-to-Device (D2D) communications is the most commonly studied protocol. It has two different approaches. First is the communication between the terminals and the base station with the help of other terminals and the second is the direct communications between the terminals without the involvement of the base station. D2D functions are similar to the Bluetooth or Wi-Fi technologies, but at times it outperforms them with the advantages of working on both licensed and un-licensed spectrums, higher transmission range and transmission power and higher data rates assuring the Quality of Service. It has many advantages like increased spectral efficiency, increased system capacity, increased throughput and reduced latency and power consumption but also faces some challenges like mobility, security, interference management and resource allocation.

3.5 Heterogeneous Networks (HETNETS)

A very big network has different classes of base stations namely, macro, pico and femto with the help of smaller cells. Hence the network is densified by using less power so as to improve the network coverage and also its capacity by deploying low power small BS to connect these small cells. The cell coverage is extended to both indoor and outdoor coverage. With reduced cell size, spectral efficiency is increased, energy is also conserved with greater connectivity and attenuation problem is also solved. The usage of small cells increases the SNR value, which increases the capacity of the link and increases the energy saving.

The basic concept behind using small cell is the separation between control plane and data plane. If the control plane provides mobility and connectivity based on macro-cell, the data plane provides data transport based on pico and femto cells. The macro-cells are hexagonal in shape and this is very helpful in handoff condition where the mechanism consumes lots of power. Macro-cells are further divided into smaller cells known as femto-cells. With the help of these femto-cells, the gap that remains uncovered is very easily covered and this increases the coverage area at the edge of every cell.

3.6 Internet of Things (IoT)

Internet of Things (IoT) is refers to a network or interconnections of physical objects, or “things,” embedded with electronics, software, sensors and network connectivity for automatic information exchange. Internet of Things is a revolutionary communication that aims in connecting the digital devices with the internet through an invisible and innovative framework. This technology combines the sensor network, communication network, intelligent computing and internet technology so as to achieve intelligent processing. Hence IoT is the network of connecting physical objects to the Internet without internal connections. Connecting with the trend updates, IoT is expected to have significant impact on home applications and business applications, thereby improving the quality of life and also the business opportunities for global economical growth.

3.7 Internet of Vehicles (IoV)

Internet of Vehicle (IoV) is an evaluation application where vehicles communicate with each other leading to a smarter transportation with nearly null collisions. The major limitation is that, not only the manufacture will be able to access the controller area network but also the adjacent car would be able to access the data flow of the sensors. Another issue that is addressed is the security and google also has developed a new protocol related to vehicles named Open Auto Alliance (OAA) which is added to speed up the implementation process of IoV. Self-drive vehicles have been developed which leads to the Intelligent Transportation system(ITS) to govern the following challenging issues:

- Delay constraints
- Prioritization of data packets
- Congestion control
- Privacy and liability
- Reliability
- Secure localization
- Risk analysis and management

The Vehicular Ad-hoc networks (VANETs) form a new protocol which integrated mobile networks to provide a safe and smart transportation system.

3.8 Software-Defined Network (SDN)

Software Defined Network is one of the promising techniques for 5G. The SDN controller adjusts the bandwidth dynamically for each radio access network and henceforth adjusted to the baseband unit (BBU). The controller has two main parts namely Unified Control Entity (UCE) and Unified Gateway (UGW). Each part plays an important role but on the whole the SDN controller provides the flexibility management of the system. The 5G heterogeneous radio access improves efficiency by decreasing traffic and also controls the quality of the user experience by varying the jitter, latency and throughput.

3.9 Millimeter Wave (mmW) Communications

Most of the existing communications operate in the frequency band below 6 GHz due to the propagation conditions in these bands. The increase in data rates in 5G, stretches its higher frequencies in the millimeter wave band as a result increasing the channel bandwidth. The frequencies are expected to reach 10+ GHz under millimeter wave deployment. This increases the propagation loss, i.e. signal becomes weak due to loss as frequency increases, which decreases the range of millimeter wave communication. This is the major challenge of this communication and in addition it is sensitive to the obstacles like furniture, buildings, people with extremely high absorptions and also very strongly affected by weather conditions like electrical storms, thunder, rain and atmospheric gases and undergoes high signal attenuation due to free space propagation. To overcome these problems extremely small cells are considered, which decreases the attenuation with the use more directive antennas to compensate for the higher attenuations or by the use indoor base stations to overcome the material absorption problem [5], [6].

4 MILLIMETER WAVE (MMW) COMMUNICATIONS

In communication industry, mobile communication is one of the fastest developing segments. Day by day the numbers mobile users keep on increasing. This results in dense mobile traffic, less efficiency, latency, greater usage of bandwidth, reduced signal strength and less reliable system. Hence there is a need for an effective bandwidth usage with good signal strength. The key solution to this is the Millimeter Wave communication which provides a reliable and efficient system in 5G technology. It ranges from 30GHz to 300GHz and its wavelength ranges from 10mm to 1mm. the antenna size is smaller due to its shorter wavelength. It has an ultrahigh bandwidth and has high frequency gain and also suitable for frequency reuse. Millimeter Wave communication has been used in radar and military applications and now it is slowly emerging into commercial applications. The major disadvantage of this communication is that it is a short distance communication.

5 SIMULATION RESULTS

One of the promising technologies implemented under 5G communications is the Millimeter Wave communications. The simulation is done with the help of 5G mmW Simulator known as NYSIM released by New York University. This NYSIM is an open source model simulator for 5G channels to model channels from 2 to 73 GHz that is suitable in 3GPP helping in academic and industrial simulations and the graphical user interface (GUI) of the 5G mmW Simulator is shown in Figure 2 and the results in term of Angle of Arrival (AOA), Angle of Departure (AOD) obtained for a Single transmitting and single receiving antenna elements (1X1) are shown in Figure 3 to 8.

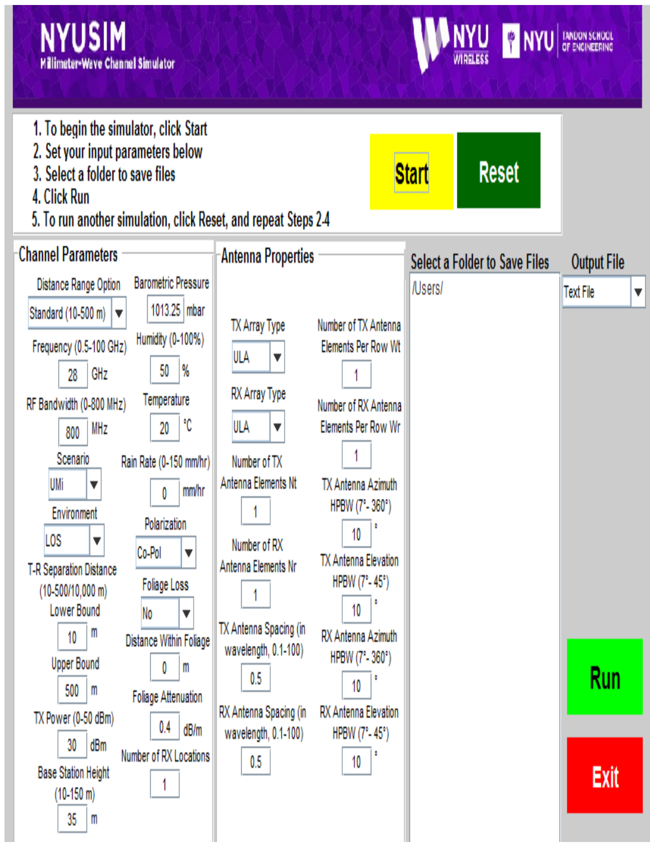

Fig. 2.Graphical User Interface of 5G mmW Simulator

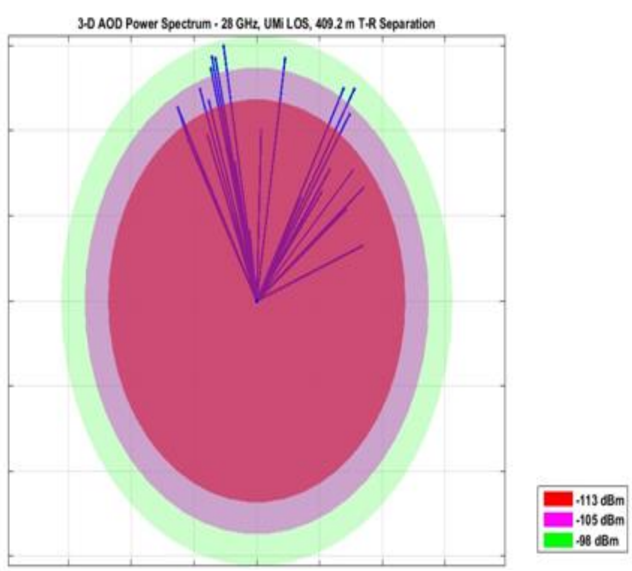

Fig. 3. 3D AOD Power Spectrum for 1X1 antenna element

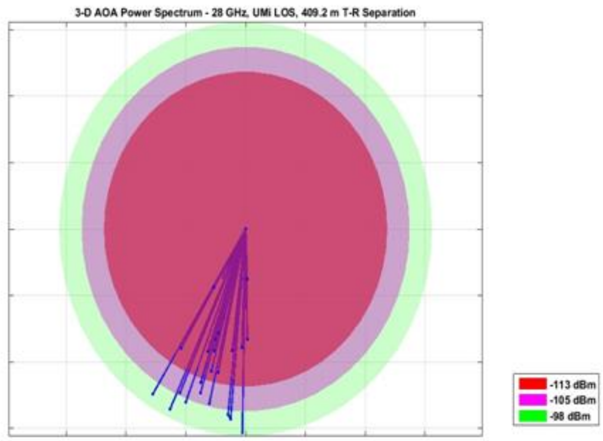

Fig. 4. 3D AOA Power Spectrum for 1X1 antenna element

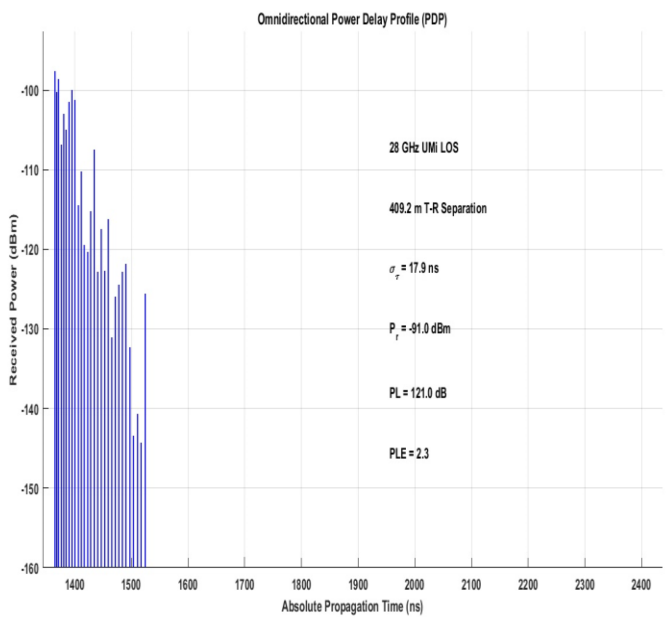

Fig. 5. Omnidirectional Power Delay Profile (PDP) for 1X1 antenna element

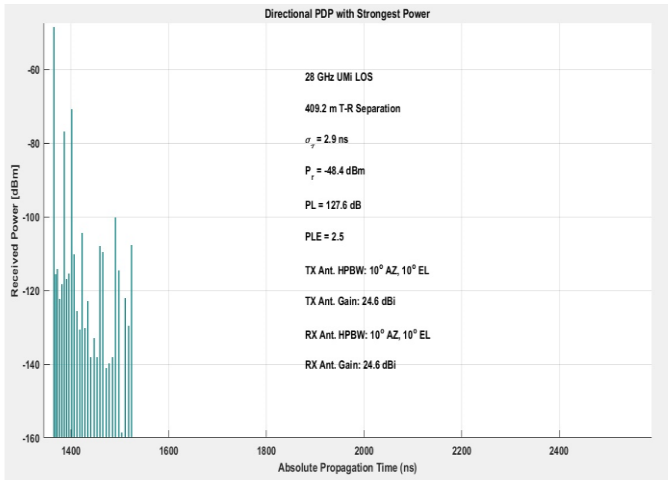

Fig. 6. Directional Power Delay Profile (PDP) with Strongest Profile for 1X1 antenna element

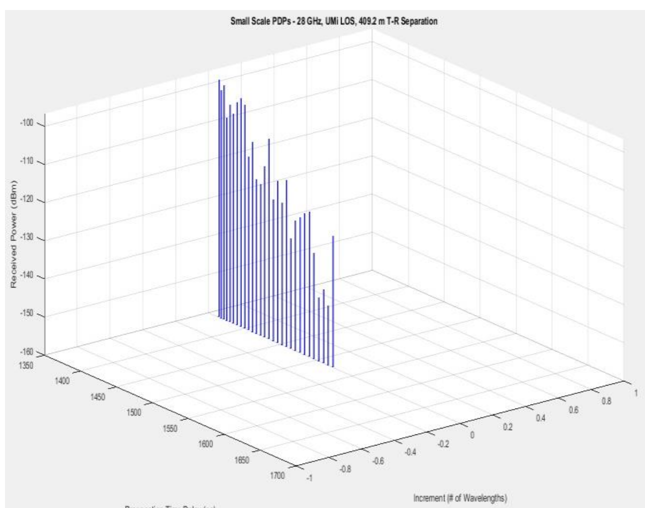

Fig. 7. Small Scale PDPs for 1X1 antenna element

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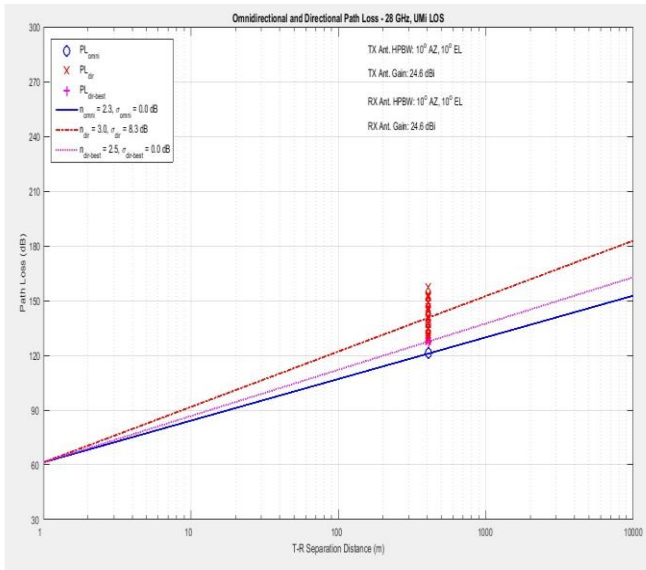

Fig. 8. Omnidirectional and Directional Path Loss for 1X1 antenna element

6 CONCLUSON

The graphical user interface (GUI) of the 5G mmW Simulator is used and the results in term of Angle of Arrival (AOA), Angle of Departure (AOD) obtained for a Single transmitting and single receiving antenna elements (1X1) was simulated. Similarly the simulation is carried out with the parameters AOA, AOD, Omni-directional Power Delay Profile, Directional PDP with strongest power, Small scale PDPs and Path Loss and are plotted in the mmW Simulator for a 1x2, 2x1, 2x2, 2x3 active elements for the transmitting and receiving antennas can be carried out to understand and analyze the signal strength to compensate for higher attenuation.

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