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Performance Analysis of Hybrid beam M-MIMO for High Frequency Range

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ABSTRACT: With the advanced development in the field of wireless communication (4G to 5G and 6 G), there is a noticeable increase in the number of devices that are going to rise exponentially. Any two users communicating with each other using different communication bands is the major requirement associated with mm-wave communication, or, in other ways, for 5G and 6G (Next Generation), the requirement for filling this generation gap between different mobile generations is major challenge in the market. It is vitally important, whatever frequency band is used, that frequency band provides spectrum efficiency and also used efficiently to serve the maximum number of users, besides this all intra-band communication is also the challenge in the case of the next generation after 4G. The role of spectrum sensing and spectrum changing plays a major area of research for new-generation technology. Hybrid precoding for Massive- MIMO is a very popular algorithm used for 5G. This is a very useful technique to improve the rate of data transfer. with the data rate, the received signal quality is also another important parameter for determining the performance of any network error vector magnitude is a very popular figure of merit, this vector is used for determining the quality of the signal received this vector gives the difference between the expected and the actual received signal value. This parameter is used in this paper for judging the performance of different higher frequencies. The Massive-MIMO techniques is well known to perform strongly in the 5G frequency band. This paper works towards the performance of 6G(mm waves) in terms of Error Vector Magnitude(EVM) and Bit Error Rate (BER). The hardware structure used in this analysis is the Hybrid precoding for Massive MIMO that uses many antennas for beam forming. This structure is very complex and costly, so improvement in the range is also playing a significant role in this communication band. In this research, the hybrid precoding model versatility for 6G is tested, the considerable frequency bands for testing are 50GHz, 70GHz, 100GHz, and 120GHz.

Key Words: Hybrid Beam Forming, Massive-Multiple Input Multiple Output, Orthogonal Matching Pursuit, Joint Spatial Division Multiplexing, Non-Orthogonal Multiple Access.

Contents

1. Introduction

Hybrid Beam-forming is a good technique for data rate improvement in sensor network technology or any IOT-based application. In wireless multimedia sensor networks or 5G technology, the data rate plays an important role because of the multimedia data transmission. If the transformation is from 4G to 5G or from 5G to 6G, there is a dramatically changing in data rate. The Hybrid beam-forming not only improves the data rate but also lowers the complexity of the MIMO system. Now, first point is to think about the difference between MIMO and Massive MIMO and how Massive MIMO fulfills all major requirements associated with new-generation technology. MIMO is defined as the technique having multiple transmitting and receiving antennae that help improving the capacity of any radio link multiple times, so MIMO is high bandwidth communication. On the other hand, the Massive-MIMO is defined as a physical -layer, in which the base station is equipped with a large number of active antenna elements that spatially multiplex many users. M-MIMO has the gains of all Multi-user MIMO system. Now

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discuss the beam forming, this is a process of directing the radiation pattern in a particular direction. In this, the desired directions have constructive interference and the undesired directions have destructive interference. Based on architecture, the beam-forming techniques are divided into three types Analog, Digital, and Hybrid. The analog beam-forming use the minimum number of hardware and the software overhead, and it is more energy efficient. The digital beam forming used a separate RF Chain for each antenna and supported the spatial multiplexing. A precoder is used to control the amplitude and phase of broadcast signals from each antenna element. There are many precoding methods available in the market such as Maximum Ratio Transmission(MRT),Zero-Forcing(ZF),and Regularized Zero Forcing(RZF). In this hybrid precoding approach, the digital precoding weights are computed for each group and the value of these weights depends on the Channel sate information. The Hybrid beamforming is done at the transmitting end of the system. The figure of merit considered here is Error Vector Magnitude (EVM) and Bit Error Rate (BER). EVM told the difference between the expected complex voltage value of a demodulated symbol and the value of the actual received symbol. This Figure of merit is very useful in determining the quality of digitally modulated telecommunication signals. This parameter plays an important role in broadband communication and helps to characterize the signal when a large amount of data has been transmitted at a relatively high speed. BER is defined as the ratio of a number of bits in error divided by total number of transmitted bits. BER gives a go or no-go level of any system . There are several benefits associated with Massive-MIMO, but some challenges also come with the deployment of this technique. This technique requires a lot of research before implementation in the current wireless scenario. Before going inside the physical architecture of 5G, it is also required to focus on the frequency bands and the mode of operation defined for 5G. The first band from 6GHz to 7 GHz is used by the LTE, LTE-Advanced (LTE-A), and WLAN technologies. This band suffers from a few technical issues such as RF characteristics. The RF resources of this band are already validated by 3G and 4G and the disadvantage of this band is it is not secured because of large number of frequencies are already in use. The second band is around 30GHz to 100 GHz this band is not in use till now and offers high-speed data and large capacity. One disadvantage of this band is large over-the-air (OTA) signal attenuation also presents many technical issues so it is not used by the mobile operator. There are two operating modes of 5G, First the Non-Standalone(NSA) mode using a combination of New Radio (NR)technology for 5G and LTE/LTE(A), Second the Stand Alone (SA) mode using a unique 5G NR Technology. The organization of the rest of the paper is as follows: After giving the detailed methodology behind this work in the introduction part, the section 2 present most of the mechanisms involved and the latest work in the field of Hybrid precoding and M-MIMO. In section 3, the physical layer used in the analysis is discussed. In section 4, the simulation results at different frequencies are given. Section 5 finally concludes the analysis done inside the paper.

2. Related Works

The use of 5G communication is currently gaining attention as a solution to the problem presented by the substantial amounts of traffic demand for wireless streaming video services and Internet-of-Things (IoT) devices. Ali et al., gives the idea about the different beam forming techniques for M-MIMO system, these techniques are the backbone of 5G system. In this review paper the various beam forming concepts are discussed and how these techniques are help to improve the throughput is analyzed. This paper told the importance of adaptive beam forming for reducing the power consumption and eliminating the interference. This paper states that the optimal beam forming will provide the highest performance to full fill the requirement of the next generation wireless communication system1). In 2020, Robin Chataut and Robert Akl, gives the overview of M-MIM0 for 5G and beyond network, this paper discuss the challenges which are being faced while using these techniques. These challenges are related to channel estimation, precoding, signal detection, and energy efficiency. The M-MIMO offers great benefits for 5G and 6G networks 2). After analyzing the IEEE 802.15.3C standard this has been observed that for high data rate indoor communications 60GHz is an important frequency band. This band suffer from signal attenuation and high penetration loss. In this the impact of Rake receiver is also considered3). Borges et. al.,gives the idea about the opportunities and challenges associated with 5G & 6G. Although large spatial multiplexing and diversity gains are the benefit of 5G but hardware complexity and computational complexity are still challenges with this4). Singh and Joshi gives a survey for the mm-wave range(30-300

GHz), this paper compared the spectral effeciency of different precoding techniques using different BS antenna array size5). Kumar et al. Gives the detection techniques for 5G. This technique combines the QR Decomposition M-algorithm- Maximum Likelihood and Beam forming approach. The performance of this algorithm is compared with existing technique such as zero forcing , minimum mean square error, Gauss seidel detector, Jacobi scheme, and Approximation Message passing etc. The performance parameter used for comparison are BER and complexity6). Ravilla Dilli analyzed the FR-frequency band by doing Hybrid beam forming. The variables such as number of users, number of antennas, and the type of modulation are changed and performance at 28GHz, 39GHz, and 66GHz have been investigated 7). Qsama et al., wrote the review paper on various precoding methods for mm-wave. These beam-forming are analyzed based on their hardware structure. The paper highlighted that hybrid precoding improve the spectral efficiency but still there are many challenges in implementing these techniques for THz communication system8). Pattnaik et al., gives an application based analysis of IOT, in which a real-time location monitoring of employees are done inside the underground mines.. This monitoring is the vision for 6G IOT system and Blue tooth Low Energy (BLE) is used in this experiment. This article gives the various challenges with different area of applications for IOT and 6G in real world 9).In another paper it also addressed that 6GHz band is insufficient for supporting emerging bandwidth and high data rate requirement so research take a move towards mm-wave communication but the use of nobal optimization algorithms does not overcome the performance degradation due to high signal loss at this frequency. The solution of this is intelligent reflecting surfaces(IRS). This paper surveys the designing and applications of IRS technology for achieving the good SE(Spectral efficiency) and Energy Efficiency (EE) for 5G and 6G10).Hamid et al., also proposed a hybrid beamforming approach.This paper reported the effectiveness of three approaches(based on architecture) in terms of SNR vs BER performance. Hybrid beamforming is evaluated for different number of antennas. Paper highlighted that the configuration of antenna array significantly affect the function of the system 11). Kumar et al., proposed the hybrid detection technique for 5G and B5G. In this work the various hybrid algorithm such as QR- Maximum Likelihood detection, QR- minimum mean square error, QR- Zero forcing equalizer are implemented for different MIMO structures. The use of MIMO improve the spectral efficiency but make the detection typical12). Javid and Shiekh et al., proposed the Energy and Spectrum efficient hybrid technique for 5G and next generation. This technique utilized the interference aware beam selection that support the large number of users with small number of RF chains. The results shows that this technique achieve higher sum rate and perform better in terms of spectrum efficiency 13). Raj et. al., write the comprehensive review on the designing of MIMO antennas. The designing approach of various MIMO antennas are discussed for 5G. The performance parameters that are considerd envelope correlation coefficient, total active reflection coefficient, and mean effective gain etc.14). Dash and Thampy presented a channel estimation approach for 5G network. The proposed RNN-LSTM is trained by using weight parameters optimally using hybrid particle swarm optimization. The performance evaluation parameters are Bit Error Rate(BER) and Mean Square Error(MSE). The complexity is also compared with standard estimator like LS and MMSE 15). Silpa and Mohan presented the various communication protocols for 5G and 6G. Channel modeling is an important issue for 5G and 6G technology. This paper gives the overview of various 6G specifications16). Armghan et al., presented a 4 port MIMO antenna for aeronautical and 5G applications. Three types of parametric analysis that are done in this paper is variation in length, width of sickle-shaped patches and varying sizes of DGS. The results shows that all diversity parameters are with in the allowable range. This antenna is well suited for 5G applications 17). Dangi et al., presented the key technologies and directions for 6G network. The various technologies associated with 6G are visible light connectivity, block chain, and symbiotic broadcasting.These technologies shows that the 6G requires the socially integrated network structure and provides lower latency and faster data transmission than 5G network18). Ahmad et al., explained the dependability of 6G networks. Dependability is a combined approach related to reliability, availability, safety, and security. This paper highlighted that edge computing, FL, and movable softwarized network functions are the directions that have been encounters for 6G network 19). Suverna et al. Analyzed the performance of a 4 -Port MIMO Antenna operate at a frequency range of 22.5-29.1GHz, for reducing the mutual coupling between antenna elements the elements are arranged orthogonally and four stubs are added between them. The parameters used for comparision are S-parameters voltage standing wave ratio(VSWR), isolation level, and peak gain

20).For high speed wireless communication Tera hertz(THz)band is good solution, but the signal in this band suffer from different loss such as free spreading loss, molecular absorption loss etc. An architecture and channel parameters are proposed by Ning, et al., for THz UM-MIMO21).on the other side for sensor network the power consumption is a necessary requirement in a paer by khalaf et al., hybrid beamforming based architecture is proposed for resource management. The difficulties associated with these techniques as well as the advantages are also analyzed and the conclusion is made how this will helpin reducing cost and power in mm-wave technology22). Tiwari and Gahlot highlighted the advantages of MIMO antennas along with the challenges of compact MIMO and ideal isolation. In mm-wave communication short wavelength,connection loss,path loss, and bandwidth are the major area of concern. MIMO, Massive-MIMO, MV-MIMO are the requirement of 5G system because they improve data rates, spectral efficiency, and capacity but face the challenges of higher power consumption 23). Cell-free massive MIMO is a physical layer technology for future wireless network or mm-wave technologies.In this paper conventional CF is compared with CF M-MIMO systems which offers array gain to minimize the inherent inter cell interference(ICI) of networks. The integration of CF M-MIMO with PIS,PS,LIS,UAV and AI will provide efficient mm-wave communication 24).In a survey by Roy and Salehi et al.,the the AI enabled beam forming techniques are integrated for out of band and multi-modal data coming from devices operating at different frequency band. The data fusion discussed here is an open challenge for 6G world. This survey described relevant deep learning architecture for multi-modal beaming forming 25). In a paper by D.S Brilhante et al. The complexity is being discussed for 5G and 6G network when beamforming and beam management has been done. This complexity is due to the mobility of users, high number of antennas, and a large number of frequencies. The AIML based algorithms gives the best solution of this problems, this paper examined the different challenges and solution based on supervised/unsupervised, semi supervised, and reinforcement learning 26). M. Majidzadeh and J. Kaleva etal. investigated the radio frequency architecture for hybrid beam forming, The optimization techniques for single and multiuser system is proposed, Geometric ULA and NYUSIM Model are used to compare the rate performance. A sub-array -based zero-forcing algorithms is proposed in this paper27). Hybrid beamforming is very useful in improving the wireless fidelity. The in-depth analysis of Hybrid beamforming is done based on link, frequency band, scattering, carrier network etc. A solution is provided by W. Shahjehan et al. for the development of optimized advanced wireless communication system 28). For the advancement of wireless communication NOMA,m-MIMO, and mm-wave technology play a crucial role. These technology provide the integration of both Spectral efficiency(SE) and Energy efficiency(EE) along with the reliable and faster approach NOMA,M-MIMO,and mm-wave combination with a complex hybrid architecture is helpful in achieving the high spectral efficiency and low energy consumption 29).Self Interference is still a problem with full duplex communication system, Full duplex communication system is still a challenge in case of sensor network because when wireless link transmit and receive data using same frequency band then self interference take place. Two architecture for transmit and receive beamforming based FD systems are TR-FD2 and TR-HBFD 30).For improving the security and rebustness studies of mechanism based on attack samples are necessary 31). P.M. Tshakwanda et al., proposed a transformative approach in his article for novel speed optimized LSTM(SP-LSTM)model, In this approach a combination of SP-LSTM networks and RL is proposed 32). M.Shafi et al. Gave the research requirements of 6G 33).M.Shu and W.Sun et al. Proposed the digital twin technology, that full fill the requirements of new generation digital and intelligent network 34). P. Soto et al.,gives the in-depth architectural design for NI spectrum. The main aim is to design a streamline the deployment of nodes, their coordination, trackling their issues and effective data management, so mainly this paper handles the open issues and challenges in deployment and managing of nodes35). S. Islam et al. Proposed the architecture of 5G/6G network for smart city applications 36). Jumaah and Qasim told that hybrid beam forming reduced the computational complexity up to 98%, so it is a useful model for 5G network. The beam forming not only preserve the energy in active mode but also it helps in preserving energy in sleep mode. In this paper the precoding is splited and weights are combined using orthogonal matching pursuit algorithm 37).The commercial roll out of 5G networks and their associated services is currently in its early stages of development. However, the challenges and technological advancements have spurred the exploration of 6G networks. According to predictions, 6G networks will rule the upcoming ten years (2030–2055) and in a period of extensive connection dubbed ”everything connected. Several countries have already initiated research and development efforts into 6G networks, such as Finland's flagship 6 Genesis program launched in 2018. Additionally, the ITU has established the "Network 2030" group to investigate technologies for networks beyond 2030.

3. Material and Methods

The lower GHz bands are deeply populated, so the exploration of the 30GHz-3THz band is very essential requirement. Before going inside the architecture, first discuss the features and challenges of 5G and 6G. The frequency range used by 5G is 30GHz to 100 GHz recently after this Frequency range has been under research for 6G that is (100GHz to 3THz) the data rate for 6G is up to Tbps and the Latency is less than 1ms. Millions of devices are connected within a Km range and this spectrum is 10 times more efficient than 5G.

In M-MIMO the antenna elements are controllable. The hybrid beamforming is used at the transmitting side. The full channel sounding method is used for channel state information. The MIMO is used to improve capacity and coverage while hybrid beamforming is used to improve the gain and minimize the interference. The model used here for the evaluation of the performance has a Transmitter, channel, receiver, and hybrid weight. The data stream generated at the transmitter side is preceded. The pre-coding method used is the combination of digital baseband data and analog RF components. The main purpose of using hybrid Beam-forming is to lower the power and utilize the RF chain efficiently.

Massive MIMO is a multi-user system with n_t transmitting arrays, $(n_t)^{RF}$ number of RF chains on the transmitting side and n_r receiving antenna arrays, $(n_r)^{RF}$ number of RF chains for reducing interference and maximizing gains, the sectorization is done on the transmitting side.

The signal transmitted at the base station side is given by,

$$X = T_{RF} \sum_{n=1}^{\infty} T_{BBk} S_k \tag{3.1}$$

Where the transmitted symbol vector is given by,

$$S'_K = [S_1, S_2, S_3, \ldots\ldots\ldots\ldots\ldots.., S_n]^T \tag{3.2}$$

T_{BBk} is the analog beam forming matrix and T_{RF} is known as the digital beamforming matrix.

The Channel matrix is denoted by H_K and it is given by, $\begin{bmatrix} H_{11} & H_{12} & H_{1nt} \\ H_{21} & H_{21} & H_{2nt} \\ H_{n1r} & H_{n2r} & H_{nnt} \end{bmatrix}$

The overall power constraint is $\left\| T_{RF} T_{BB} \right\|^2 F = \rho$,

Where, ρ is the power of communication.

This is a hybrid encoding system, the received signal at the receiving end user is given by,

$$Y = H_K T_{RF} \sum_{n=1}^{\infty} T_{BBK} S_K + n \tag{3.3}$$

The Channel model for 5G, massive MIMO is given by,

$$H_k = \sqrt{N1N2/L} \sum_{l=1}^{\mathrm{L}} \alpha_{MS} \alpha_{BS} \alpha \tag{3.4}$$

where, α_{MS} is the response of the Mobile station array, α_{BS} is the response of base station arrays, N_1 and N_2 are the numbers of the base station and mobile station respectively and α is a complex gain of a particular path between BS and MS.

The received signal from the u_{th} MS is given by,

$$R_u = H_K \sum_{n=1}^{\infty} T_{RF} f_n^{BB} S_n + n_u \tag{3.5}$$

In the Hybrid precoding Algorithm, the input is the F base station and W Mobile station, the RF size of the base station is $2^{B_{RF}^{BS}}$ and the mobile station is $2^{B_{RF}^{MS}}$.

OFDM (Orthogonal Frequency Division Multiple Access), are very useful sub-carrier technique, this technique is very useful for any communication system. The advantage of using sub-carrier is not only useful in spacing but this is a technique of utilizing the spectrum efficiently more sub-carriers mean more connections or devices. So the low number of sub-carriers is useful in terms of less loaded network links but if a large number of sub-carriers are used then the spectrum is utilized efficiently.

4. Results and Discussion

In this section, the numerical simulation is used to show the outcomes of the hybrid beam forming algorithm for M-MIMO with hybrid precoding at different frequencies using MATLAB Software, the frequencies taken into consideration are 50GHz,100GHz,70GHz, and 120GHz. The channel sampling rate considered here is 100 MSPS and the number of rays used for Frf and Fbb partitioning is 500 for 50GHz and 70GHz and for 120GHz, it is 1000. The modulation technique used is 16QAM for all frequencies but for 120 GHz it is 256 QAM the rest simulation parameters are given below in Table1,

Table 1: Simulation Parameters

Simulation Parameters	Values
BS Tx Antennas	16,256
US Antennas	8
Bits/ Subcarriers	8
OFDM Data symbols	10,100
No. of rays for frr fbb partitioning	500,1000
Users	5
Data Streams per users	[4 3 2 4 3]
Channel Type	Scattering /MIMO
Noise Figure	5-10 dB
Channel Sampling rate	100 MSPS
Communication Range	(500m to 5km)

The 3D response pattern or the hybrid weight beam pattern is shown below in Fig.1 and Fig.2 respectively.

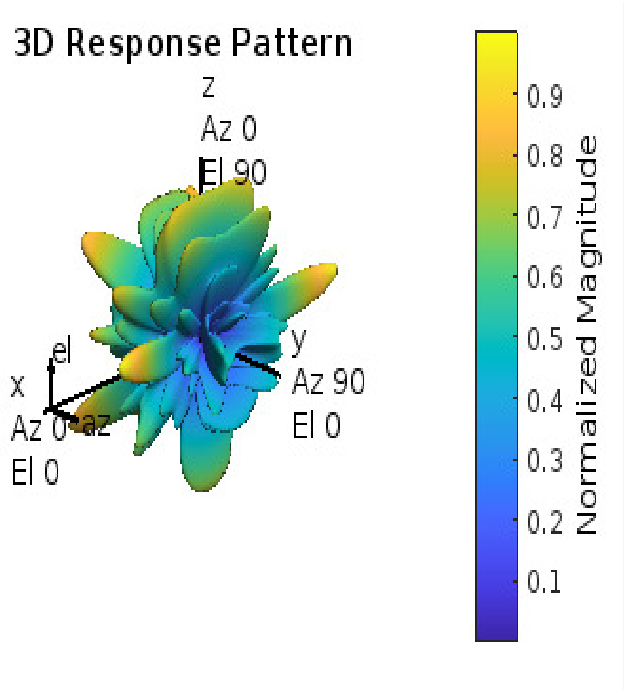

Figure 1: Beam Pattern at 50GHz

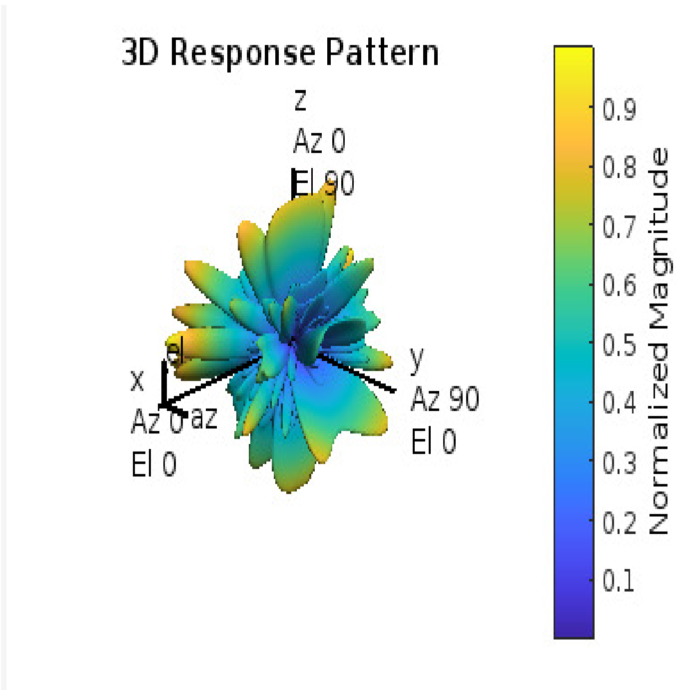

Figure 2: Beam Pattern at 120GHz

The value of EVM for all users at 50GHz from 700m to 5 Km range is given in Fig.3. This Figure specifies that the value of EVM is significantly high after the 4 Km range at 50 GHz.

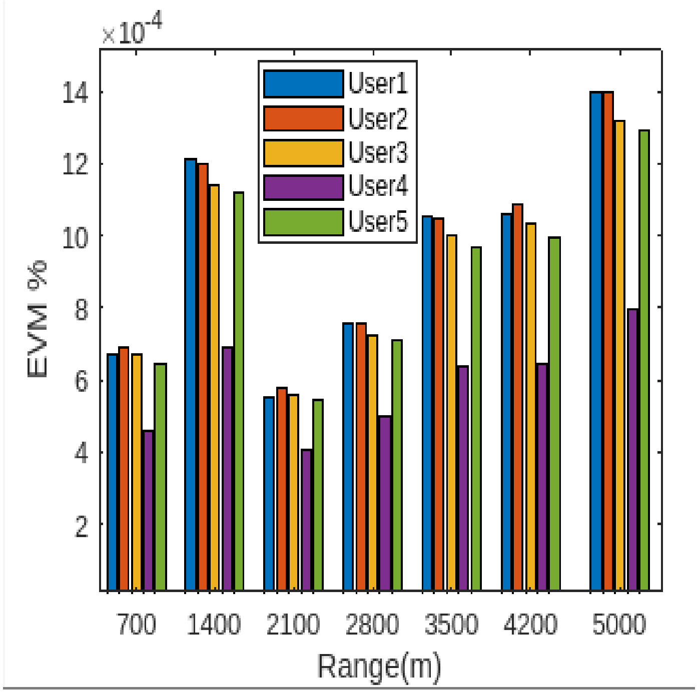

Figure 3: EVM Values at 50GHz

At 120 GHz the EVM value of users are compared at 700m and 2km range. The results show that the performance of 120GHz is good at 2km range. The EVM pattern for users at 120 GHz is shown below in Fig. 4. Ravilla Dilli told that the RMS EVM value at 28 GHz depends on the data streams associated with each user[7]. In this paper, its value for user1 is 0.37929% and for user 3 is 2.1165% the user1 has three independent data streams whereas the user 3 has only 1 independent data stream. The conclusion behind this is RMS EVM value is decreasing with higher number of data streams. In this paper, the performance of the 70GHz system is evaluated in scattering channels at 1km and 2km range and the value of EVMs are compared the user1 and user4 have the same number of data streams but the value of RMSEVM for user 1 at 1km range is 0.00042906 and user 4 is 68.04086. at 2km range, its value for user1 is 121.5117 and for user4 it is 561.9582. so the overall conclusion is that at 70 GHz the RMS EVM value is independent of a number of data streams per user.The 70 GHz system is evaluated for the 256 QAM modulation method and scattering channel. The response of the system at the frequency 70GHz for the range 1km in terms of BER and EVM is given below in Table 2.,

Table 2: EVM AND BER VALUES

	USER 1	USER 2	USER 3	USER 4	USER 5
Group No.	1	1	1	2	2
RMS EVM Percentage	0.00041398	0.0040748	0.0004245	81.1431	85.9775
BER	0	0	0	0.13417	0.35001
Group No.	1	2	1	1	2
RMS EVM Percentage	0.00096779	176137865.1578	264329299.605	23459825.697	90.9654
BER	0	0.49535	0.50144	0.50317	0.23352
Group No.	1	1	2	3	3
RMSEVM Percentage	0.00029317	0.0002986	6.4743	24.3092	5.6025
BER	0	0	0	0.00260	0
Group No.	1	2	3	2	4
RMS EVM Percentage	0.00020309	0.00018984	766517785.635	31119.3812	0.00024509
BER	0	0	0.49840	0.49511	0

From the above table it is clear the value of EVM factor and BER for a particular user is not only dependent on the data stream but a proper grouping of users by any system also plays a significant role, the number of groups made by systems also play a game-changing role in this technique. From the first 2 rows of this table, it is concluded that if we change the group of any user then the performance of the system degrades in terms of EVM and BER.

So finally, it concluded from the results that if we want to improve the performance of the 5G system in terms of EVM and BER, it is very important to think about the modulation technique, the number of independent data streams, and the grouping of users inside the cells and the number of groups or cells. The range constraints improve in this frequency band practical difficulty is in making groups of users.

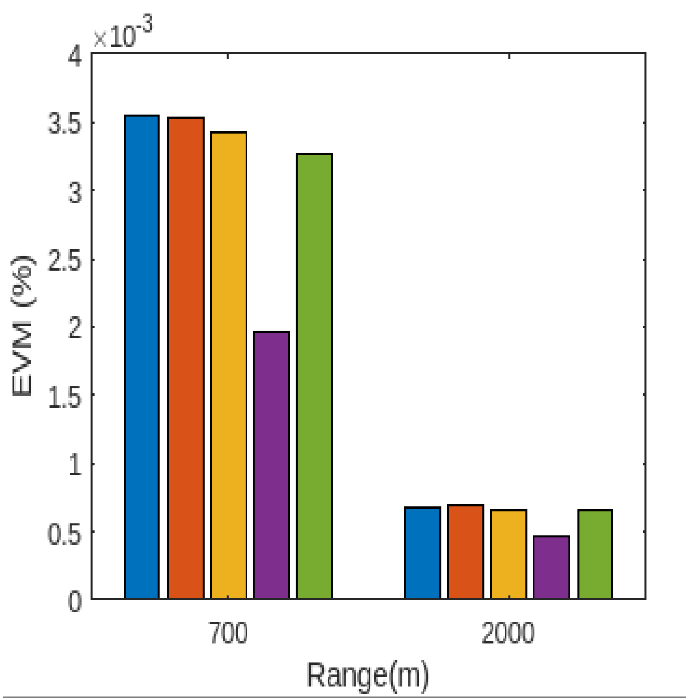

Figure 4: EVM Values at 120GHz

5. Conclusion

The need for a spectrum that accommodates all users that use different frequency bands is a very important requirement for a 6G network to survive in the market. Now a days the advancement of IOT technology increases the data traffic, and the requirement of handoff between two frequencies is very much necessary for 6G. The data rate also plays an important role, so the requirement of Massive-MIMO wireless access technology is a good solution. This technology integrates a large number of antennas, which enhances spectral efficiency and meets the demands of future telecommunications. This paper provides an extensive overview of different frequency bands and the quality of signal received at different frequencies using the M-MIMO physical layer. Various deployment challenges were also discussed for higher frequency bands. Furthermore, this paper outlines the received signal quality in terms of EVM. We hope that this paper will be helpful to understand the key challenges with the high-frequency spectrum. Further research is the path loss study of data after the integration of different IoT devices operating in different frequency bands.

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