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Mm-Wave Wideband MIMO Antenna for High Gain in 5G Generation

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ABSTRACT

This paper analyses the designing of millimeter (MM)-wave wideband with multiple input multiple output (MIMO) antenna to obtain high gain in 5G generation. The challenges of attaining better performance under varying frequency bands in MIMO antenna models are discussed and isolation methods developed for MIMO design are examined in this paper. The proposed design contains two circular patch array elements for two antennas each with a circle-shaped slot to boost bandwidth. The patch antenna's bandwidth is determined by using circle's radius. A part of the ground plane is integrated into the antenna to achieve an operating frequency range from 24-26 GHz, at 28 GHz. To reduce mutual coupling between elements decoupling surface is used between antennas. To improve gain and to optimize bandwidth, ground plane utilizes Defected Ground Structure (DGS), partially grounded technique is used. The techniques used is compared based on S-parameters and peak gain. MM-wave wideband MIMO meets the desired band requirements with high gain in 5G generation.

Keywords: multiple input multiple output (MIMO), millimeter-wave wideband, 5G generation, Defected Ground Structure (DGS).

1 Introduction

MIMO antenna is a wireless communication technology enabling simultaneous transmission of various data from sender to receiver by implementing multiple antennas at both transmitter and receiver side. Better MIMO antenna designing allows user to transmit multiple data streams using a single frequency channel. MIMO antenna designing consists of various features which includes array configuration, bandwidth support, polarization consideration, radiation patterns, diversity gains and antenna placements. The unwanted interference and noises is minimized with better antenna placements thereby, increasing the efficiency of the antenna.

The channel capacity is enhanced needless of extra radio frequency and transmitter power hence increasing the bit rate and capacity with reduced multipath issues [1]. To attain high diversity gain antenna port utilizes polarization, pattern and space diversities. Rectangular slots are cut under the top plate and small strips are cut in the middle for each antenna to reduce current flow among two ports of same antenna thereby, reducing the coupling effect between the antenna ports [2]. For solving single and multi-objective issues and to minimize the structure size Quad-MIMO dipole antenna is used [3]. The advent of the fifth-generation (5G)

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wireless communication technology brought about a significant revolution in the field of wireless networks. MIMO antennas are apt for modern wireless and communication devices which enables to achieve high data requirements by using several frequency bands and MIMO configuration as a result spectrum congestion is avoided [4].

To boost the data rate MIMO antenna generates various communication paths without extra frequency sources which makes it essential for wireless communication system [5]. By using this technology enhances the antenna performance to adapt 5G communication by increasing spectral efficiency needless of extra power and spectrum. MIMO antenna is designed for 5G wireless communication which covers complete frequency bands [6]. Therefore MIMO antennas are essential for 5G application [7]. Multi-Feed MIMO antennas is used for 5G metal-rimmed smart phone application because of its ability to achieve simpler structural configuration, improved isolation with multi connected antennas but struggles with high complexity and expenses [8]. Hence Planar Inverted-F Antenna pair (PIFA) is used to attain compact MIMO antenna system in the application of 5G smart phones with enhanced efficiency and wide band operations however they struggle with low gain and sensitivity [9]. Thus a four-element MIMO antenna with two circular shaped concentric rings and plus shaped stub which is wrapped in circular rings is used. This system functions based on Ka-band in four stages by using the Characteristic Mode Theory (CMA) thereby making is well suitable for millimeter-waves 5G wireless application [10].

The proposed system is improvised with two circular patch array elements which are etched with a circle-shaped slot for two antennas in order to boost the bandwidth. FR-4 substrate is used in the antenna's fabrication for minimal cost implementation and a decoupling surface is used between antennas, with orthogonally being maintained between ports to reduce mutual coupling. The designed antenna covers 5G MMW band with improved efficiency.

2 Recent Works

Zhao *et al* [2019] [11] have developed Self-Isolated MIMO for fifth generation system in mobile applications to attain compact size. The size reduction is obtained by using two vertical stubs in self-isolated antenna elements. The main intension of this system is to achieve good isolation and antenna efficiency without using decoupling and isolation techniques. Therefore, self-isolated MIMO antenna system ensures better communication capacity with high efficiency. However, MIMO antennas struggle with high hardware complexity hence Digital Signal Processor (DSP) is essential to process mathematical signals.

Sokunbi *et al* [2023] [12] have introduced Wideband MIMO for millimetre wave applications to enhance the wireless communication operation. To improve the inter-element isolation and bandwidth various slots of different shapes are used to measure the concentration of surface waves on radiating patch. The variation in output voltage from both the antennas is used to evaluate mutual coupling and various parameters is applied to attain lowest edge-to-edge

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spacing. Therefore, MIMO antenna assures increased bandwidth, isolation with reduced correlation coefficient and inter-element spacing.

Hussain *et al* [2019] [13] have developed Ultra-Wide-Band (UWB) Multi-Function MIMO antenna system for Cognitive Radio (CR). The MIMO antenna system is integrated with 4-element half annular slot based Ultra-Wide-Band (UWB) and 4 element slot-line based on Frequency Reconfigurable (FR) where each and every FR is packed with specific Split Ring Resonator (SRR) which is used to attain multi-band process. Therefore, UWB based antenna assures higher bandwidth whereby enabling faster communication but still not suitable for all kind of application.

Cui *et al* [2019] [14] have introduced Dual-Band MIMO antenna for 5G smartphone applications for enhanced communication. The dual-band MIMO antenna is designed using 4 sets of Dual-Antenna Array (DAA) where each DAA consists of T-shaped Decoupling Stub (TSDS) with two double branch monopoles for reducing the mutual coupling through the decoupling structure. By using decoupling structures enhances the independence of array units thereby, attaining higher wideband. Therefore Dual-band MIMO guarantees better reflection coefficients with good isolations hence making it applicable for fifth generation applications. Despite this, optimization design need to be applied for the better performance of the system.

Yuan *et al* [2020] [15] have implemented UWB MIMO with high element isolation for 5G smartphone application. The UWB MIMO antenna system generates four resonance by using the T-shaped and C-shaped slots to improve the system bandwidth. To enhance the isolation of MIMO antenna system, H-shaped slots are used thereby the system achieves higher bandwidth with better elemental isolation crossing effective frequency band. Therefore, UWB MIMO antenna system ensures higher radiation efficiencies which makes it reliable for 5G applications. Nevertheless, millimeter wave need to be used for low interference and improved security.

3 Proposed Work Explanation

This model proposes the design of mm-wave wideband MIMO for improved UWB frequency in MIMO and 5G wireless communication. To maximize the connectivity among the wireless devices, MIMO antennas containing high diversity and high gain is considered. To attain minimum interference and cross talk problems the designed antenna achieves increased beam width coverage with low side lobe levels where polarization diversity is measured to improve the data transmission and signal capacity of antenna. Thereby enabling efficient wireless communication making it suitable for 5G applications.

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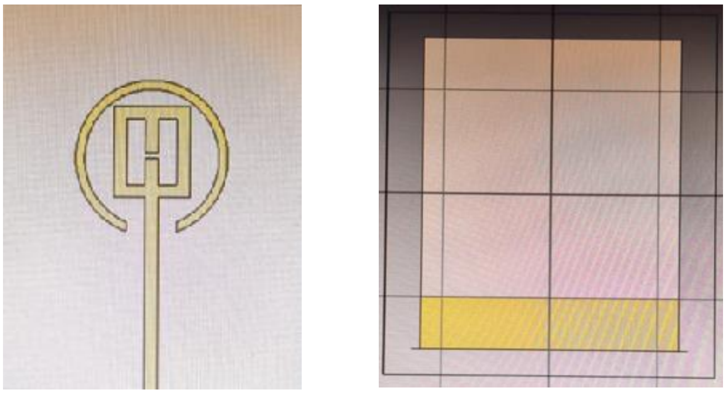

Figure 1: *The proposed antenna Top view and Back view.*

Two antennas consisting of two circular patch array elements is considered in which each antenna is attached with a circle-shaped slot to enhance bandwidth. In array antenna, a decoupling surface is used between two antennas, to reduce mutual coupling by maintaining orthogonally between the ports. The patch antenna's bandwidth is determined by measuring circle's radius where the antenna is partially grounded. Therefore, the designed antenna is suitable for the 5G MMW band.

3.1 Partially Grounded Structure

This method is deployed to enhance bandwidth and gain, open-source ground cuts are deployed by altering the ground and rectangular slots at separate location and orientation without changing the dimension. FR-4 substrate is placed in top layer for micro-strip feeding lines where a portion of ground is incised into bottom layer. FR-4 substrate used appear as dielectric material between ground plane and patch of the micro-strip antenna and patch used acts as resonator. Therefore, using this technique improved bandwidth indicating that partially grounded structure leads to improved bandwidth and gain.

3.2 Decoupling Structure

Decoupling structure is implemented between antennas for the reduction of mutual coupling among the ports. Tuning dimensions and positions of elements are essential steps involved for designing efficient decoupling structure or MIMO antenna system. By utilizing decoupling structure in MIMO system enhances the isolation between the antennas with improved wideband efficiency. Decoupling consists of various techniques but our system is designed using Defected Ground Structure (DGS) because it acts as a band-stop filter that creates high isolation between closely kept ports.

3.3 Defected Ground Structure

DGS is deployed to reduce unwanted deviation in radiation by controlling the radiation properties of the antenna. DGS enables easy fabrication with its compact size and relatively simple parameter extraction. DGS are a single or multiple compact geometric shots implanted

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onto the ground plane whereby resulting in mutual coupling reduction with enhanced isolation between the antennas. DGS incorporated into ground using planar transmission line includes micro-strip. The shape of the slots used affects the performance of DGS unit. DGS is deployed to achieve reduction in harmonics, cross polarization reduction, mutual coupling reduction circular polarization. DGS minimises the higher-order harmonics which in turn eliminates the harmonic resonance. Cross polarization (XP) is reduced by etching DGS to the micro-strip substrate thereby, reducing only the XP without affecting the input impedance. For circular polarization of patch antennas DGS is used under the feed line structures which are edge coupled to the micro-strip patch antennas in a single substrate whereby, enhancing the wireless communication system. The advantages of using DGS are circuit size becomes compact, DGS easy to design and fabricate and higher precisions are achieved with the introduction of DGS into the MIMO antenna system.

3.4 S-Parameters

Array of nn antenna elements in a network with n number of ports is considered. Where n-port of incident waves are represented using $a1$, $a2$,…, an $a1$,$a2$,…,an and outgoing waves are represented using $b1$,$b2$,…,bn $b1$,$b2$,…,bn. Therefore, relationship between them is expressed using equation (1)

$$\begin{cases} b_1 = S_{11}a_1 + S_{12}a_2 + \cdots + S_{1n}a_n \\ b_2 = S_{21}a_1 + S_{22}a_2 + \cdots + S_{2n}a_n \\ b_n = S_{n1}a_1 + S_{n2}a_2 + \cdots + S_{nn}a_n \end{cases} \tag{1}$$

Equation (1) is also expressed by $b = Sa,$ (2)

Where,

$$a = [a_1, a_2, \dots, a_n]^T \tag{3}$$

$$b = [b_1, b_2, \dots, b_n]^T \tag{4}$$

$$S = \begin{bmatrix} S_{11} & S_{12}.. & S_{1n} \\ S_{21} & S_{22}.. & S_{2n} \\ S_{n1} & S_{n1}.. & S_{nn} \end{bmatrix} \tag{5}$$

In which S_{ii} is the Reflection Coefficient. The impedance matching situation is used to evaluate operation bandwidth of MIMO system. To attain required operation bandwidth S_{ii} needs to be adjusted and S_{ij} is used to represent voltage transmission from port *j* to port *i* which is used to measure mutual coupling between two ports where S_{ij} represents transmission co efficient. Equation for S-Parameters containing two-port network is expressed by,

$$S = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \tag{6}$$

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Where S_{11} represents input reflection coefficient/input return loss and S_{22} represents output reflection coefficient/output return loss, S_{12} denotes reverse transmission coefficient /isolation and finally S_{21} denotes forward transmission coefficient or gain.

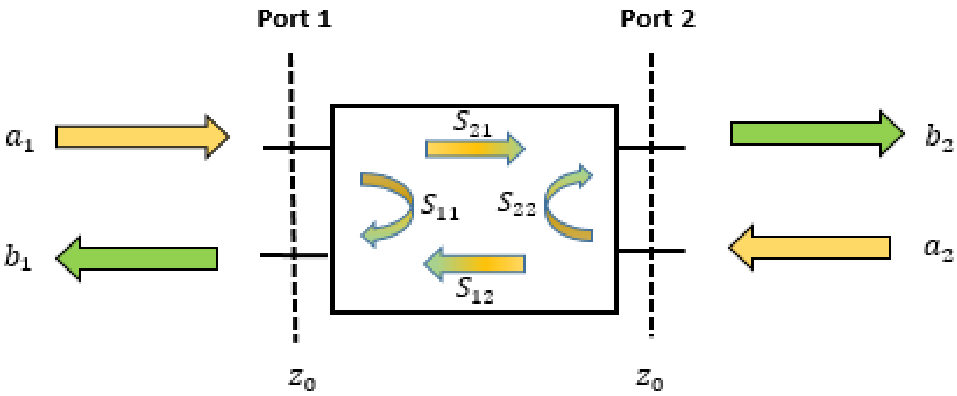

Figure 2: *S-parameter representation in a 2-port network*

Figure 2 represents 2-port network representation of the S-parameter where S_{11} and S_{22} represents the reflection coefficient, S_{12} and S_{21} represent the transmission coefficient.
Considering the power from port 1 as P_1 and the power from port 2 asP_2, then isolation of ports are measured using Equation (7).

$$S_{12}(dB) = 20lg|S_{21}| = 10lg\frac{p_2}{p_1}, \tag{7}$$

From the above equation it is evident that degree of mutual coupling is inversely related to transmission coefficient. Therefore, larger transmission coefficient results in smaller degree of mutual coupling of antenna.

4 Result and Discussion

This paper proposes implementation of mm-wave wideband MIMO antenna to achieve high gain in 5G communications by using two circular patch arrays with partially grounded structure and decoupling structure to reduce mutual coupling between the antennas and MM-wave patch antennas are deployed because of its low profile, light weight, small size and simple design. These antennas are suitable for wireless communication system due to its high gain and enhanced efficiency.

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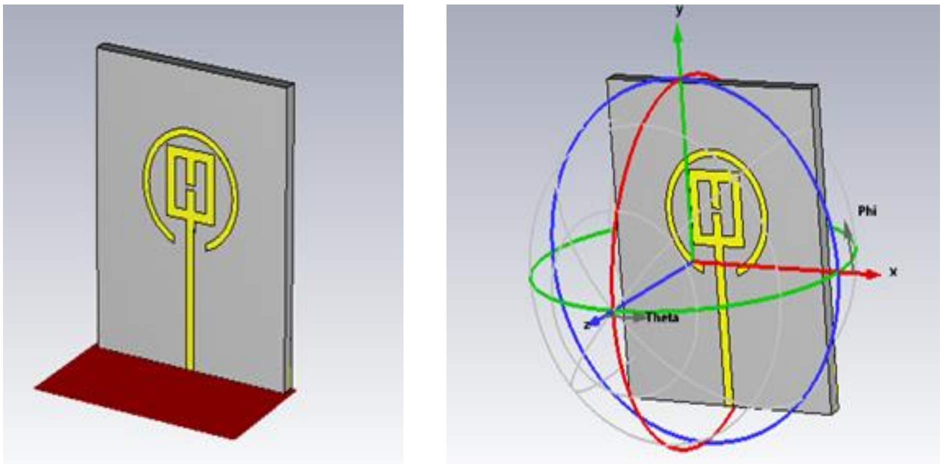

Figure 3: *The proposed mm wave patch antenna*

Figure 3 represents the proposed millimetre wave patch antenna for high gain in 5G application that is smaller in geometrical dimension and compact in size. These antennas enable wireless communication by transmitting and receiving wave signals through antenna arrays at both transmitter and receiver side.

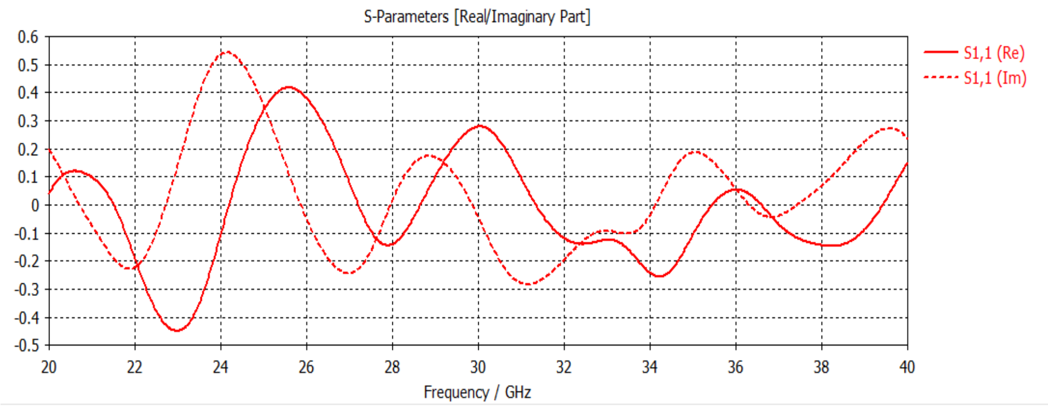

Figure 4: *S-Parameter based on real/imaginary part*

Figure 4 represents S-Parameters based on real/imaginary part which consists of both magnitude and phase. In order to obtain power gain only the magnitude part is considered.

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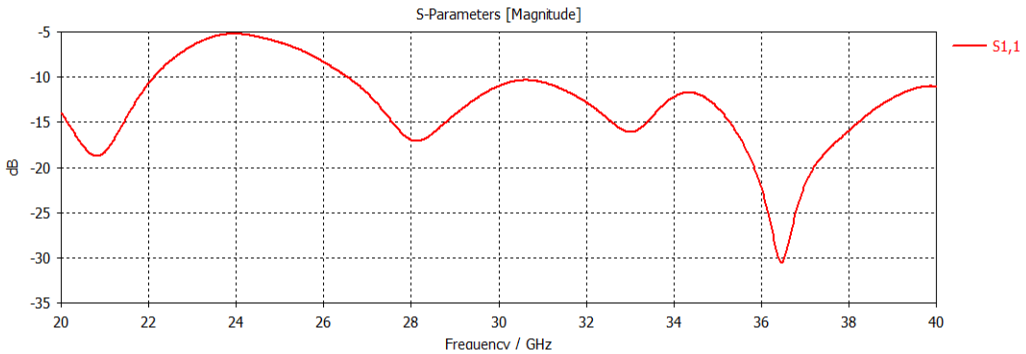

Figure 5: *S-Parameter based on magnitude*

Figure 5 represents the real part that is plotted against the frequency range from 20 to 40 GHz.

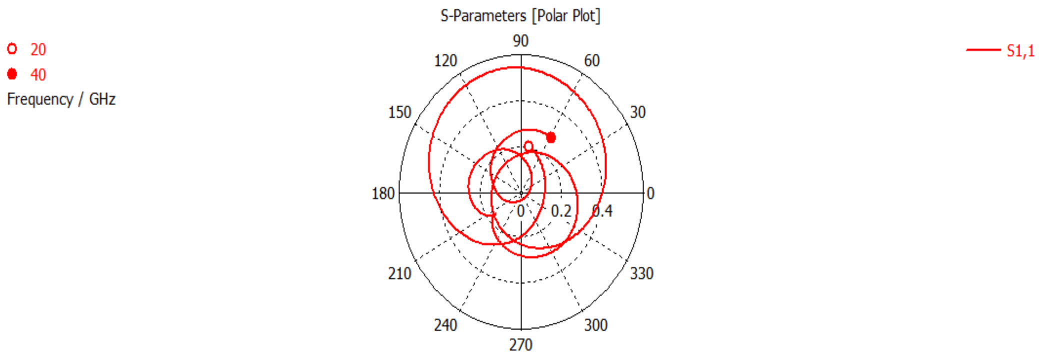

Figure 6: *Gain plot*

Figure 6 represents chart that characterize S-Parameters in graphical method making it easy for human interpretation thereby allowing impedance matching.

5 Conclusion

Thus proposed design of mm-wave wideband MIMO antenna for high gain in 5G generation is successfully implemented by using the CSI MW Studio Suite and antenna array performances is analyzed from experimental results, which show that the isolation levels are more than 15 dB in both the 2.4–4.2 GHz and 4.2–5.37 GHz bands, with reflection coefficients less than −10 dB. Moreover, antenna works by resonating at 2.4 to 4.2 GHz with a bandwidth of 4.80 to 6.80 GHz. Finally, the experimental data on reflection coefficient, mutual coupling, and radiation patterns is obtained, making the proposed antenna suitable for 5G mm-wave communications with desired isolation value.

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Reference

1. Kabiri Yasin; Alejandro L. Borja; James R. Kelly; Pei Xiao, Year: 2019, "A technique for MIMO antenna design with flexible element number and pattern diversity," IEEE Access Vol: 7, pp. 86157–86167.

2. Chattha Hassan Tariq; Muhammad Kamran Ishfaq; Bilal A. Khawaja; Abubakar Sharif; Nathirulla Sheriff, Year: 2021, "Compact multiport MIMO antenna system for 5G IoT and cellular handheld applications," IEEE Antennas and Wireless Propagation Letters, Vol: 20, no: 11, pp. 2136–2140.

3. Hasbestan Vahid Hosseini; Yousef Farhang; Kambiz Majidzadeh; Changiz Ghobadi, Year: 2023, "Multi-objective hybrid optimization algorithm for design a printed MIMO antenna with n78–5G NR frequency band applications," IEEE Access, Vol: 11, pp. 68231–68242.

4. Hussain Rifaqat; Muhammad U. Khan; Mohammad S. Sharawi, Year: 2019, "Design and analysis of a miniaturized meandered slot-line-based quad-band frequency agile MIMO antenna," IEEE Transactions on Antennas and Propagation, Vol: 68, no: 3, pp. 2410–2415.

5. Ji Zhongwei; Yuke Guo; Yuqi He; Luyu Zhao; Guan-Long Huang; Chuangzhu Zhou; Qinjuan Zhang; Wei Lin, Year: 2021, "Low mutual coupling design for 5G MIMO antennas using multi-feed technology and its application on metal-rimmed mobile phones," IEEE Access, Vol: 9, pp. 151023–151036.

6. Hei Yong Qiang; Jia Geng He; Wen Tao Li, Year: 2021, "Wideband decoupled 8-element MIMO antenna for 5G mobile terminal applications," IEEE Antennas and Wireless Propagation Letters, Vol: 20, no: 8, pp. 1448–1452.

7. Wang Hanyang; Pengfei Wu, Year: 2023, "Wideband MIMO antennas for 5G mobile terminals," IEEE Open Journal of Antennas and Propagation, Vol: 4, pp. 74–80.

8. Vigneswaran Dhasarathan; Thien khanh Tran; Jayshri S. Kulkarni; Brian Garner ;Yang Li,Year : 2023, "Mutual Coupling Reduction in Dual-Band MIMO Antenna Using Parasitic Dollar-Shaped Structure for Modern Wireless Communication," IEEE Access, Vol: 11, pp. 5617–5628.

9. Yuan Xiao-Ting; Zhe Chen; Tianqi Gu; Tao Yuan, "A wideband PIFA-pair-based MIMO antenna for 5G smartphones," IEEE Antennas and Wireless Propagation Letters, Vol: 20, no: 3, pp. 371–375.

10. Shariff BG Parveez; Akshay Anil Naik; Tanweer Ali; Pallavi R. Mane; Rajiv Mohan David; Sameena Pathan; Jaume Anguera, Year: 2023, "High-Isolation Wide-Band Four-Element MIMO Antenna Covering Ka-Band for 5G Wireless Applications," IEEE Access, Vol:11, pp.123030 – 123046.

International Journal of Advanced Trends in Engineering and Management (IJATEM)
Vol. 03(06), June 2024, pp. 21-30

11. Zhao Anping; Zhouyou Ren, Year: 2019, "Size reduction of self-isolated MIMO antenna system for 5G mobile phone applications," IEEE Antennas and Wireless Propagation Letters, Vol: 18, no: 1, pp. 152–156.

12. Sokunbi Oludayo; Hussein Attia; Abubakar Hamza; Atif Shamim; Yiyang Yu; Ahmed A. Kishk, Year:2023, "New self-isolated wideband MIMO antenna system for 5G mm-wave applications using slot characteristics," IEEE Open Journal of Antennas and Propagation, Vol: 4, pp. 81–90.

13. Hussain Rifaqat; Mohammad S. Sharawi, Year: 2019, "An integrated slot-based frequency-agile and UWB multifunction MIMO antenna system," IEEE Antennas and Wireless Propagation Letters, Vol: 18, no: 10, pp. 2150–2154.

14. Cui Lun; Jingli Guo; Ying Liu, Year: 2019, "An 8-element dual-band MIMO antenna with decoupling stub for 5G smartphone applications," IEEE Antennas and Wireless Propagation Letters, Vol: 18, no: 10, pp. 2095–2099.

15. Yuan Xiao-Ting; Wei He; Kai-Dong Hong; Chong-Zhi Han; Zhe Chen; Tao Yuan, Year: 2020, "Ultra-wideband MIMO antenna system with high element-isolation for 5G smartphone application," IEEE Access, Vol: 8, pp. 56281–56289.