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Original Article

Array Based Eight Element Stub Structure of π- Shaped MIMO Antenna for 5G Applications

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Abstract - *An array-based 2x2 MIMO (Multiple Input and Multiple Output) type of antenna is proposed with Π Shaped Stub Structure with improved band of operation. The proposed system exhibits eight port excitations, including ground with an area of 85×85mm2. The material of the substrate is FR4 with a thickness of 1.6mm. The design of Π shaped stubs is projected on elements of mutual earth of the proposed array-based Π designed structure at a center frequency of 6GHz. This type of frequency is suitable for 5G applications. The predictable antenna like array based "pi" shape intended stubs MIMO output has improved Bandwidth, deduction of mutual coupling in the range of a certain number of frequencies. This proposed antenna occupies the C band of operation. The projected-based Π Shaped Stub element has simulated the results like VSWR, S-Parameter, Radiation Pattern, Surface current distribution and Gain.*

Keywords - *MIMO Antenna Array, Π Shaped Stub, Microstrip Patch, 5G Application, 8 Element Array.*

1. Introduction

Different modes are used for Multiple Input Multiple Output (MIMO) antenna applications. One of the most important modes is TM_{10} mode—generally, the probe feed is located at one position. However, in two-port devices, two probe feeds are positioned at two differing locations. Some advantages are present in two-port devices. i.e., if any weak electric field is present at the first probe feed that leads to adjacent proximity of the second probe feed, thus, it produces very good port isolation [1]. MIMO antenna is also used for 5G mobile applications; a number of antenna pairs can form twice a number of antenna pair element MIMO antenna; for example, two antenna pairs can form a four-element MIMO antenna similarly 4 antenna pairs can form an 8-element MIMO antenna [2]. Array based MIMO antennas are 1 x 2 array,2x2 array,1x4 array etc can be used in array-based MIMO antennas.

At smaller bands of frequencies, antennas can operate as radiators and at higher bands, antennas can operate as bandpass filters [3]. The number of port cavities is divided into a number of unit cells that are addressed to design 5th generation (5G) MIMO subdivision-6GHz antennas. "JAIME MOLINS-BENLLIURE" proposes the four different cavity designs with: circular, square, hexagonal, and pentagonal and some representations are presented.[4]. Another method used for the 5G Application is Linear Patch Array (LPA), LPA means antenna units are connected in series connection [5]. The diplexer is one of the important factors in the MIMO antenna. Diplexer contains two elements in the MIMO antenna. To increase the band of frequencies, the Slot is etched in the middle of each substrate-integrated waveguide. Higher and lower frequency bands can be adjusted independently by varying the dimensions of every substrate-integrated waveguide. Thus lower band frequency is used for Wi-Max applications, and Higher band frequency is used in 5th Generation Communication [6]. For getting the different shapes, different types of slots are introduced. "Le chang" proposes the slotted quasi-quarter circle with the edge of the inner structure of the antenna elements, and on the other side, two edges are opened. To improve the isolation all number of elements should connected with the adjacent elements of the antenna structure. This type of antenna Covers 3.3 to 4.2GHz [7]

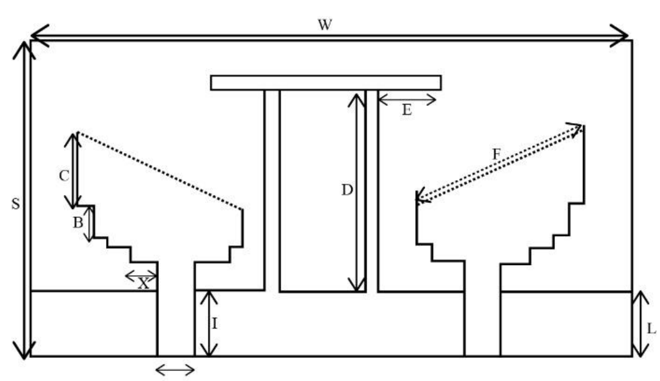
MIMO antenna design supports different applications like V2X, WLAN, Wi-Max,5G,6G, etc. Antenna polarizations will be in azimuthal and elevation angles. Vertical polarizations are in azimuthal angle and horizontal polarizations are in elevation angle. The parameters like VSWR, Gain, S parameters, and radiation patterns are to be simulated and fabricated and then compared [8]. Massive MIMO antenna will play a significant role in communication system networks. The main factor of the MIMO antenna is to reduce the mutual coupling and envelope correlation coefficient [9]. Array based MIMO antenna contains 1x2,2x2,2x4,4x4 array etc. This type of antenna arrays will produce the innervation of coupling between antennas and reduction of mutual coupling. This type of MIMO antenna array can improve the efficiency of antenna and isolation[10]. Coplanar waveguide is used for ultra-wideband (UWB) applications, and VNA (vector network analyser) is used for transmission and reflection coefficients. The two-port MIMO antenna is attained by positioning the two identical elements correspondingly, while the 4 port MIMO antenna is attained by positioning the 4 elements, etc[11].

Metamaterial MIMO antennas are designed for the suppression of higher order modes. Metamaterial antenna designs are split ring resonator (SRR), Complimentary Split Ring Resonator (CSRR) etc. This type of antenna produces the dual band of operation and is used for the suppression of higher-order modes. Therefore, it produces a better ECC (Envelope correlation Coefficient) and Reflection Coefficient. CSRR is the reverse of the SRR. SRR contains an inner ring and an outer ring. Splitting in the inner ring is exactly opposite to the splitting in the outer ring[12]. Vertically polarized MIMO antenna can be designed for different bands of applications. Variation in the Radiation patterns or beams by designing the different shapes. Therefore, it achieves good isolation, better ECC and higher efficiency[13]. Different shapes can be used in MIMO patch antenna. Especially Spiral patch antenna produces very good performance rather than the normal shape of antennas. Two-element antenna arrays will produce 4 configurations of 2-port MIMO antenna, and four element antenna arrays will produce 16 configurations of 4-port MIMO antennae. These types of antennas are resonated from 27.3 GHz to 30.2 GHz [14]. Electromagnetic field Substrate Integrated Waveguide achieves dual band of operation. In this EMSIW measures the isolation between two side-to-side antenna elements. Dual bands of operations are very suitable for MIMO applications as well as improving the capacity of the channel [15]. Coplanar waveguide-based MIMO antenna is mostly useful for wireless communication networks. CPW antenna resonates from the S-band to the X-band of frequency ranges. Most of the antenna designs are fabricated on FR4 substrate. CPW antennas will perform good isolation and have a better envelope correlation coefficient [16]. Generally, Band stop filters are used for the miniaturization process in MIMO antennas. Reconfigurable MIMO antennas are also used for miniaturization. PIN diodes are used in the Reconfigurable MIMO antenna. If two PIN diodes will generate 4 states and 4 PIN diodes will generate 16 states. Depends on the number of diodes will check the performance of the MIMO antenna. Thus, it achieves high Gain, better radiation efficiency and high channel capacity [17].3x3 MIMO antenna array achieves maximum Bandwidth, maximum data rates, and maximum Gain. High-definition video transmission can be used for RF communication and resonates at 2.4GHz and 5.2GHz for antenna directions with horizontal and vertical polarization [18].

To enhance the isolation between the elements of the MIMO antenna with less cost, the elements of the antenna are orthogonal to each other and also have some detachment between elements plus different types of ground structures. MIMO-type of antennas can enhance from -20 to -40dB. Mean, while Gain, ECC, and radiation efficiency increase simultaneously. Generally, the Slot and stubs are used to improve the Bandwidth, impedance matching and efficiency [19]. Metamaterial based MIMO antennas are also used for some applications. One of the metamaterial antennae is a Split Ring Resonator (SRR), miniaturization will be done due to SRR technique. To reduce the size of the antenna, unit cells would be introduced in the SRR. Because of the SRR, we can decrease the size of the antenna elements. To improve the presentation of the antenna in terms of return loss, Gain, efficiency and ECC[20]. Ultra-wide band (UWB) MIMO antenna with Defective Ground structure is mainly used for better increment for isolation. Thus, the isolation results in nearly 20Db[21]. Xiaocheng wang proposed a stacked patch antenna array on the wafer level; this type of stacked patch antenna array achieves a constant maximum gain and better Bandwidth, and higher radiation pattern.[22].Multiple beams are produced by a beamformer, Analog and digital beamforming techniques are available in this beam former[23].

2. Two Port "π" Shaped Structure of Antenna Design

A Single pole antenna with π shaped stub structure has been designed and is represented as shown in Figure 1, and parameters are tabulated in Table 1. The material of the substrate is Fr4 with dimensions 50x35mm^2 with a thickness of 1.6mm at a frequency of 7.5GHz is to be simulated in HFSS software. The ground structure variations will impact transmission and reflection coefficient results, then it leads to bandwidth variations. If the quality factor increases, then the dielectric constant increases it will decrease the Bandwidth. Therefore, reduction bandwidth means it is useful for narrow band applications.



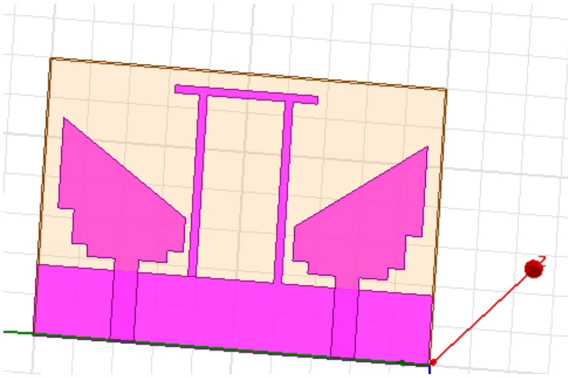


Fig. 1 Representation of the existing method Pi shape

Table 1. Dimensions of the antenna design structure

Size	Value
A	3.54mm
B	4.31mm
C	11.46mm
D	23mm
E	5mm
F	22.3mm
W	50mm
S	30mm
L	9mm
w	3mm
l	10.3mm

Similarly, if the quality factor decreases, then the dielectric constant decreases then it will increase the Bandwidth. Therefore, improvement in bandwidth leads to wider band applications. The drawback of this existing method is that it does not resonate at the center frequency.

3. Eight Port Array Based "π" Shaped Stub Structure of Antenna Design

To solve the problem of the existing method, we can design the array-based π shape stub structure with an excitation of eight ports. The proposed method designed an array-based π structure with eight-port excitations; all single pole pi shape antennae are arranged in a 2x2 array structure as shown in figure 2. The main factor of the MIMO elements is used to maintain the durable coupling between the MIMO elements. The proposed method resonates at a center frequency only, i.e. 6GHz and therefore, it is used for 5G applications.

In this proposed method, an array-based "pi" shape stub structure establishes an eight-port antenna with four single pole antennas arranged adjacent to each other in a ring manner. If the coupling between the MIMO elements is weaker, then there will be poor isolation due to improper impedance matching. Similarly, if there is a strong coupling between the MIMO elements, then there will be good isolation due to perfect impedance matching. The effect of the coupling of the excited antenna has a particular effect on the adjacent elements of the ports. The proposed array-based pi shape stub structure is fabricated on FR4 substrate material with a thickness of 1.6mm, eight ports are excited by giving feed lines to the ports, and the impedance is 50ohm. The stub structure was formed by insertion of the cutting in the patch step by step.

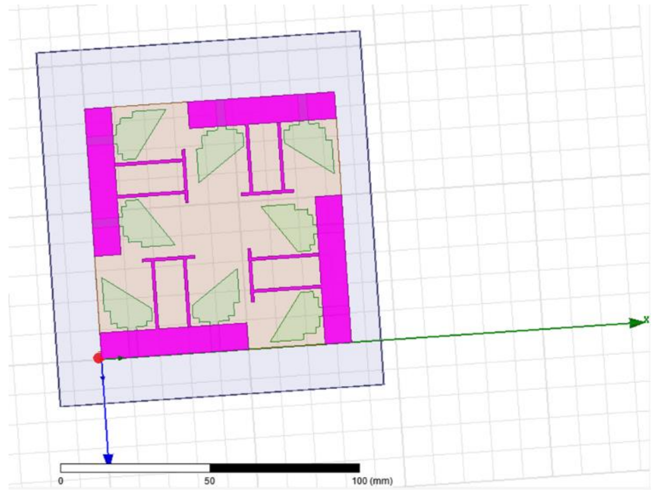


Fig. 2 Proposed system with array-based π-shaped stub structure of MIMO antenna

4. Structure of the Decoupling Method

The process of the decoupling is defined through the distribution of the surface current, as shown in Figures 3&4, if one element is stimulated and all remaining other elements are avoided in the MIMO antenna. The distribution of the surface current implies a better port-to-port coupling effect. The eight-port array-based pi structure of the decoupling mechanism represents the direction of flow of current in the stimulated antenna is constant and adjacent ports in ring manner elements have opposite directions.

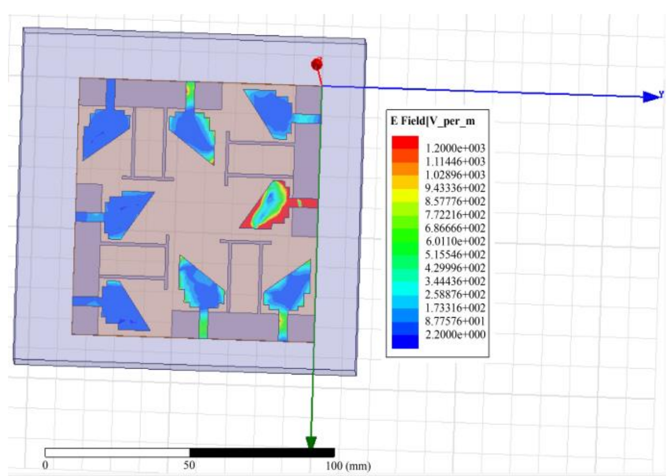


Fig. 3 Electric field distribution in Array-based Pi Shape Stub structure design

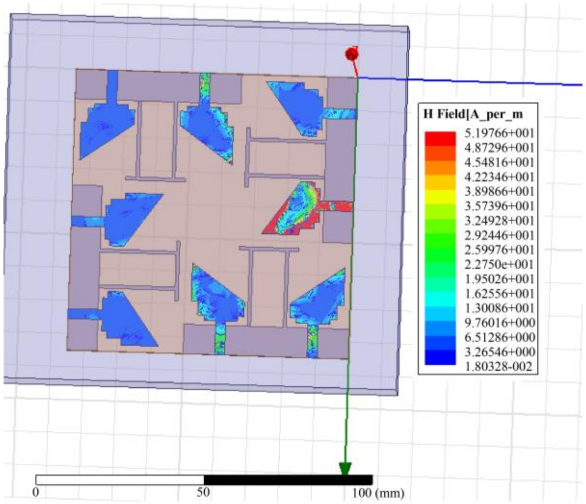


Fig. 4 Magnetic field distribution in Array-based Pi shape stub structure design

The opposite current is achieved by the defective ground structure of the decoupling mechanism, which leads to a reduction in the coupling effect. It extends to the current in defected ground structure is more and more then reduces the mutual coupling between elements.

Finally decoupling structure leads to reduces the coupling between antenna elements. Existing methods like T, F and Pi-shaped stubs are Single pole antenna elements, and the proposed method is array array-based pi-shaped stub structure due to MIMO elements.

The following table 2 represents the comparison of existing methods with the proposed method for various parameters.

Table 2. Comparison between existing methods and the proposed method

S.No	Type of Antenna	Dimensions (mm)	No. of elements	Bandwidth	Gain	Return Loss	VSWR
1	T shape stub type of antenna	50x35x1.6	2	1.5-2.8	>3.5dB	-17.4dB	1.6-2.2
2	F shape stub type of antenna	50x35x1.6	2	1.8-2.4	>3.2dB	-16.8dB	1.5-2
3	π shape stub type of antenna	50x35x1.6	2	2-2.5	>3.8dB	-21.5dB	1.2-1.8
4	Proposed method Π shape stub type of array antenna	85x85x1.6	8	3.4-3.8	>4.1dB	-25.4dB	0.9

The proposed method achieves better characteristics like return loss, Gain, Bandwidth and VSWR. Return loss achieves -25.4dB rather than existing methods(-17.4dB,-16.8dB and -21.5dB), and Gain achieves greater than 4.1dB rather than existing methods(>3.5dB,>3.2dB and >3.8dB) and VSWR achieves the results in the range of 0.9 to 1 rather than existing methods(1.6-2.2,1.5-2,1.2-1.8) and similarly Bandwidth achieves better results i.e 3.4-3.8 rather than existing methods(1.5-2.8,1.8-2.4,2-2.5).

5. Results and Discussion

5.1. S parameter

The S parameter indicates the return loss. Maximum return loss indicates that the lesser amount of power returns back from the load; similarly, minimum return loss indicates that the maximum amount of power returns back from the load.

This proposed method achieves -25.4 dB at a resonant frequency of 6GHz, as shown in Figure 5.

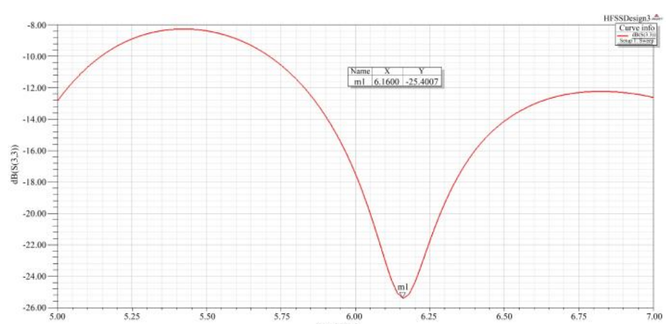


Fig. 5 S parameter of Array-based π shape stub method at a frequency of 6 GHz

5.2. VSWR

Voltage Standing wave ratio is the ratio of higher voltage to smaller voltage. If the VSWR is 1, then the return loss will be infinity. If the return loss is higher, then VSWR is low; similarly, if the return loss is lower, then VSWR is high. The proposed method achieves 0.9 at a resonant frequency of 6GHz, as shown in Figure 6.

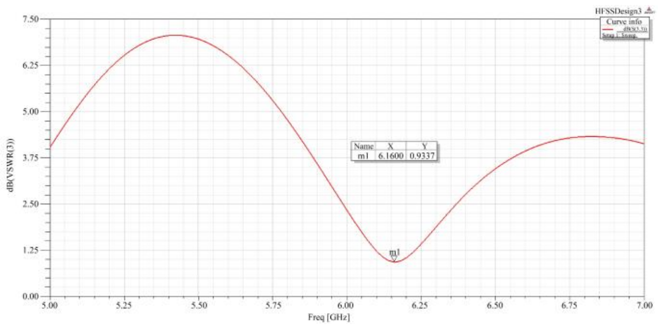
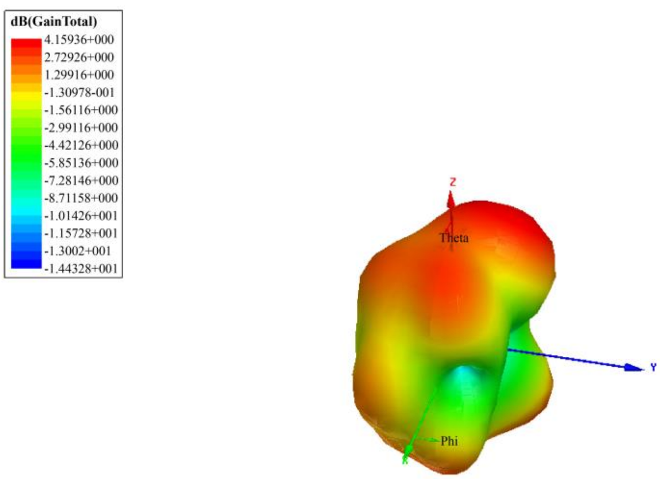


Fig. 6 VSWR parameter of Array-based π shape stub method at a frequency of 6 GHz

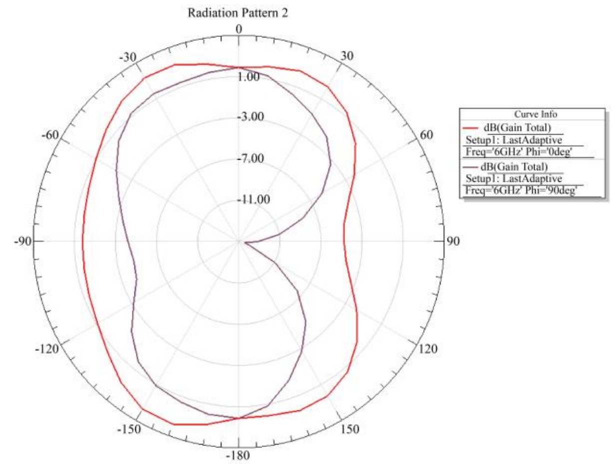
5.3. GAIN

Gain indicates max amount of power is propagated in a particular direction. The remaining sidelobes contain less amount of power. It is represented in dB. The following figure shows a gain for the proposed method.



5.4. Radiation Pattern

It represents maximum power at peak directions and less power at remaining directions. The following figure represents the radiation pattern. RED colour indicates the radiation pattern at 6GHz at phi is 0 degrees, and the violet colour indicates the radiation pattern at 6GHz at phi is 90 degrees.



6. Conclusion

In this proposed method, eight eight-port MIMO antenna arrays with **π** shape stub structures are designed. This method achieves the proper impedance matching and resonates at a particular frequency, i.e. 6GHz and therefore, it is used for 5G applications. MIMO antenna array mainly focuses on the reduction of mutual coupling. This method exhibits maximum Gain and maximum Bandwidth. The array-based pi-shape stub structure produces the better return loss, i.e., 25.4dB, and VSWR is 0.9. Therefore, all the characteristics are simulated by using HFSS software, the parameters like S parameter, VSWR, Gain and radiation pattern

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