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A Compact 4-Port 2-Element MIMO Antenna for 5G Applications

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ABSTRACT: In this paper, a compact, low-profile four-port, two-element antenna for the 5G Internet of Things (IoT) and handheld applications is presented. A two-PIFA antenna system for diversity/MIMO applications is designed with a narrow inter-PIFA spacing of only 3 mm (less than 0.024 wavelength). The antenna structure contains two planar inverted-F antenna (PIFA) elements having the same shapes. Each antenna element has two feeding plates placed at the right angle to each other to make them cross-polarized for the exploitation of polarization diversity, whereas spatial diversity is employed by positioning two antennas diagonally on opposite sides of the antenna structure. For reducing mutual coupling, the etching of rectangular slots on each side of the ground plane beneath the top plate of each element has been done to stop the flow of current between two ports of the same antenna element. The proposed antenna system can cover the frequency range around 2.7 to 3.6 GHz for S11 < −10 dB, thus covering expected future 5G band (3300–3600 MHz). Maximum isolation achieved among ports is less than −25 dB, and envelope correlation coefficient is below 0.009 in bands of interest.

KEYWORDS: Antennas, planar antennas, PIFA, diversity, MIMO, mutual coupling, isolation.

I.INTRODUCTION

In just the past year, preliminary interest and discussions about a possible 5G standard have evolved into a full-fledged conversation that has captured the attention and imagination of researchers and engineers around the world. 5G, the next generation telecommunication standard is expected to have data rates of tens of megabits per second, i.e. up to 10 Gbps [1], [2]. Multiple-Input Multiple-Output (MIMO) means that two or more antennas are used simultaneously for transmission as well as for reception over a radio channel. MIMO technology uses multipath to achieve higher data rates simultaneously increasing reliability and range without using extra bandwidth, thus improving spectral efficiency to cope with the need of high data rates for different services [3]. The technique used to handle multipath fading in no clear Line- of-Sight (LOS) radio channels, called antenna diversity is employed by different schemes such as spatial, pattern and polarization diversities or a combination of these. To obtain diversity gain, one or more of these diversity methods can be implemented considering different factors which include the environment, interferences and available space [4], [5].

Massive Machine Type Communications. This supports a very large number of connected devices usually called Internet of Things (IoT), with varying quality of service requirements. The objective of this category is to provide very high density of connectivity where a single Base Station can support 10,000 or more devices providing an aggregate connectivity for more than a million devices per square kilometre at the network level. This category offers many applications like smart cities, smart power grids, smart-farms to mention a few.

The Internet of Things (IoT) is a generic term describing the practice of adding internet-connected sensors and actuators or controllers to objects, infrastructure or locations, and using the data to provide an improved service or capability. It is expected that the use of such devices, which can communicate with one another quickly and reliably, will automate a range of economic verticals including smart homes and smart cities. The deployment of IoT sensors is already well-advanced in some sectors, but 5G is expected to accelerate the uptake of IoT.

II. DESIGN METHODOLOGY

Four-port two-element MIMO antenna is shown in Fig. 1, with a ground plane having dimensions Wg × Lg (50 mm × 100 mm). FR-4 material is used as dielectric substrate having relative permittivity $\varepsilon r = 4.4$ and thickness t = 1.5 mm.

The two PIFAs are positioned on opposite diagonal ends of ground plane. Both elements of PIFA are identical where each PIFA consists of a top radiating plate having dimensions Wt × Lt where width and length of the top plate are Wt = 16 mm and Lt = 33 mm respectively. Each PIFA has a shorting plate and two feeding plates. Each shorting plate dimensions are Ws × (h + t), where width of each shorting plate is Ws = 1 mm, and these are positioned at respective upper ends of the ground plane beneath the top plates of each PIFA. Feeding plates 1 and 3 being positioned beneath top plate of each PIFA at respective upper ends of ground plane, have dimensions Wf1 ×h where Wf1 = Wf3 = 7 mm is the width of feeding plates 1 and 3 and h = 3.0 mm is the height of each PIFA.

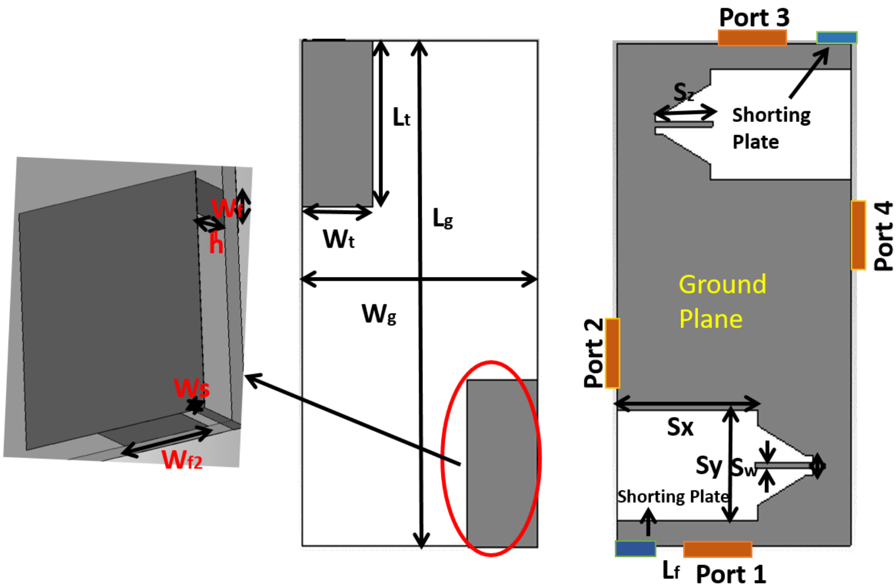

Figure 1. Structure of the 4-port, 2- element antenna

The feeding plates 2 and 4 are positioned under top plate of each PIFA at the side of ground plane having dimensions Wf2 ×h where Wf2 =Wf4 =5mm being width of feeding plates 2 and 4. Separation between shorting and feeding plate 1 is Lf = 1 mm, and separation of feeding plates 2 and 4 from their respective upper ends of ground plane is Df = 27 mm. Since the two ports under the same radiating element of each PIFA are placed very close to each other, there is a need of using an isolation technique for decreasing mutual coupling between two ports. For this purpose, a slot is cut in the ground plane and rectangular chamfered strips is added at the corners of the slot and rectangular strip is added with (Sz =12.5 and Sw =1 mm) beneath top-plate of each PIFA. These etched slots and chamfered strips decrease the current flow between two feeds of the same PIFA through ground plane, which reduces the mutual coupling between them and make them work independently. Bottom side of ground plane depicted through Fig. 2, shows that two-slots are etched where the dimension of each slot is Sx × Sy (42 mm × 22 mm), and the separation of each slot from higher ends of ground plane is Dy = 5 mm.

Table 1: Dimensions of proposed antennas (mm)

Parameter	Wg	Lg	Sz	Wt	Lt	Ws	h	Wf1
Value	50	100	12.5	16	33	1	3	7
Parameter	Wf3	Wf2	Wf4	Lf	Df	Sx	Sy	Dy
Value	7	5	5	1	27	42	22	5

III. RESULTS AND DISCUSSION

A 4-port MIMO antenna is simulated using CST MICROWAVE STUDIO. Figure 2. Depicts the simulated results of reflection coefficients S11, S22, S33, S44, and the mutual coupling S21, S31, S41 with respect to port1 are shown in Figure 3. The operating bandwidth of the proposed antenna is obtained from all the 4 ports for reflection coefficient less than -10 dB is from 2.4 to 3.8 GHz. From Figure 3 observed that the maximum isolation is achieved between 2 ports of PIFA is blow -24 dB whereas the minimum isolation achieved between the ports of same PIFA element is around -15 dB in region of interest. Figure 4 shows that the VSWR is less than 2 overall operating bandwidth.

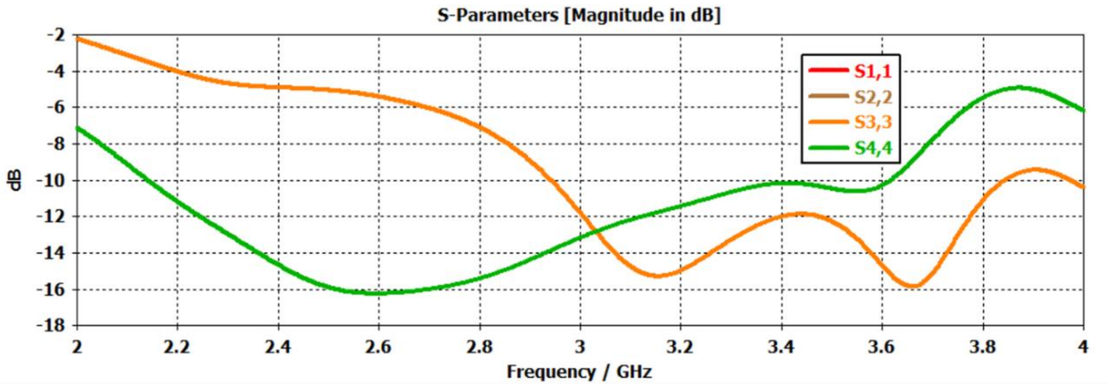

Figure 2. Simulated Reflection Coefficients (dB) of 4-port MIMO Antenna

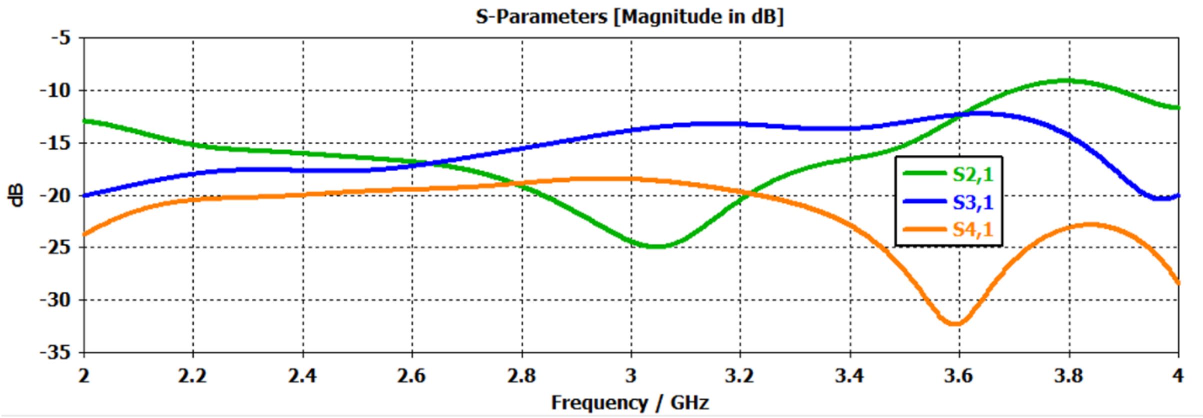

Figure3. Simulated Mutual Coupling of 4-port MIMO Antenna

The simulated 2D and 3D radiation patterns of four port MIMO antenna are presented in Figure 5 and Figure 6. Which clearly indicates that the pairs of port1 & port3 and the pairs of port 2 &port 4.have complimentary radiation patterns to prove the diversity performance with respect to envelope correlation coefficient and diversity gain.

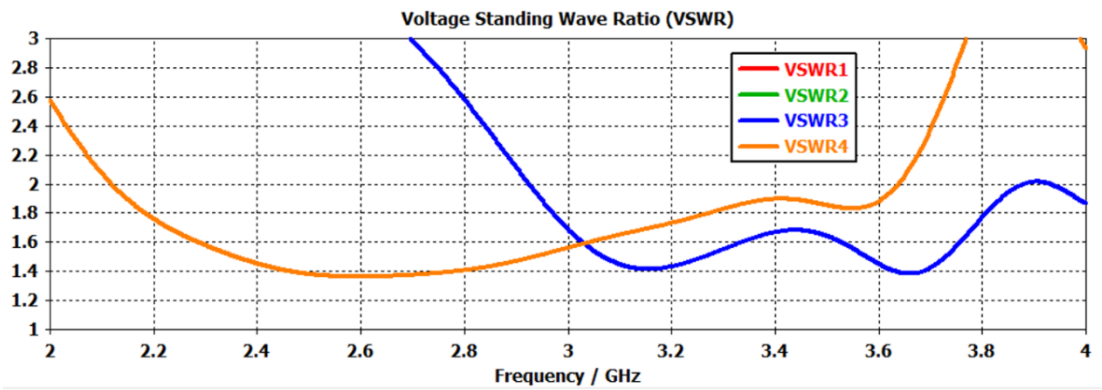

Figure4. VSWR of the Proposed 4-port MIMO Antenna

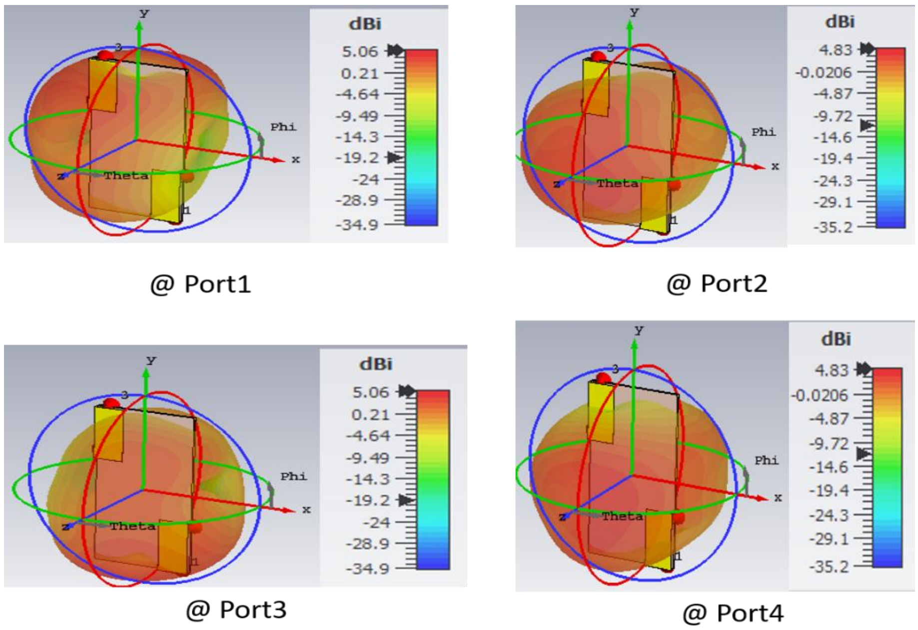

Figure 5. 3D pattern of the 4-port MIMO Antenna

The two conditions of obtaining the diversity gain are met by this four-port two-element antenna asthe correlation coefficient remains below 0.009 as obvious from the Figure 7 and diversity gain is less than 9.95 dB from the Figure 8 Which shows a graph of correlation coefficients and diversity gain as a function of frequency between ports 1,2, 3 and 4. Peak gains obtained by all the four ports in 3.1 GHz to 3.8 GHz frequency range are shown in Figure 9, which depicts that minimum peak gain obtained between 3.1 GHz and 3.8 GHz is above 4.4 dB.

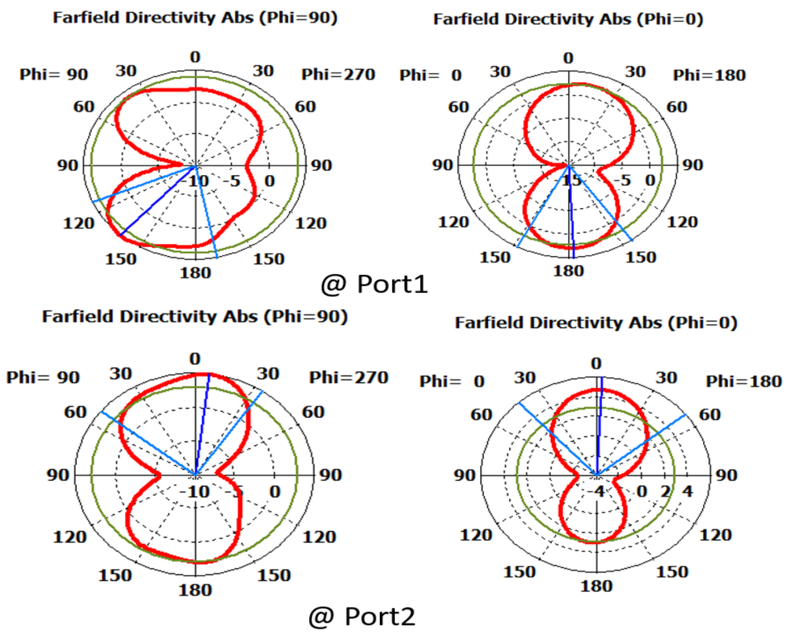

Figure 6. 2D Radiation Pattern of 4-port MIMO Antenna

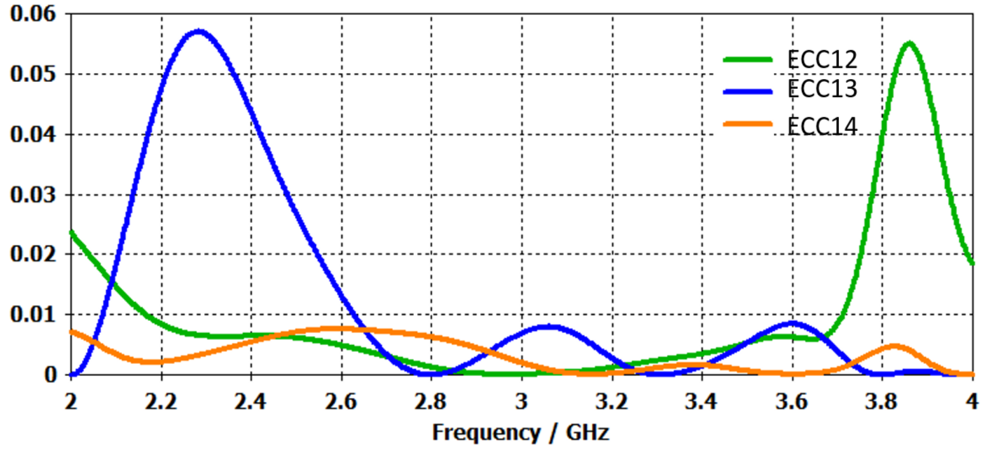

Figure 7. Envelope Correlation Coefficient of the 4-port MIMO Antenna

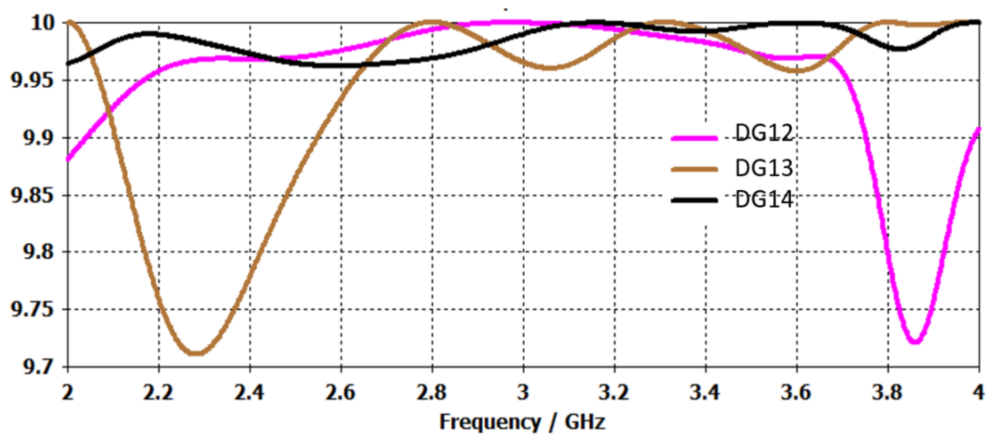

Figure 8. Diversity Gain of the 4-Port MIMO Antenna

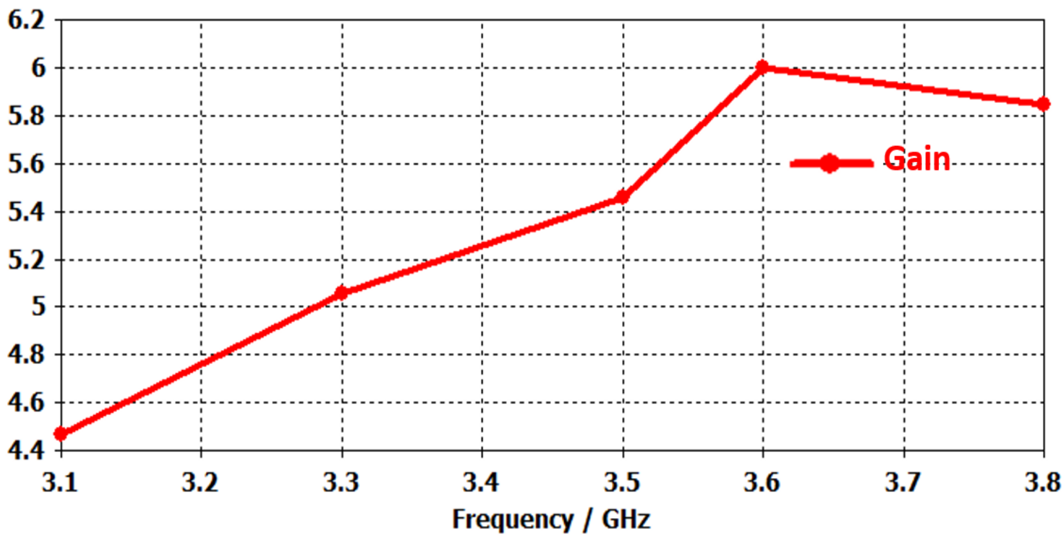

Figure 9. Gain of the 4-port MIMO Antenna

IV. CONCLUSION

A low-profile and compact 4-port, 2-element antenna using PIFA as antenna element is presented for 5G IoT and cellular portable applications as diversity and MIMO antenna. The mechanism has been explained. The S-parameters, radiation patterns, and gains have been simulated. The envelope correlation coefficient and diversity gain of the proposed antennas satisfies the criteria ECC <0.009 and DG < 9.95 dB. All the simulated results show that our proposed antenna system of high isolation is very suitable for diversity or MIMO applications.

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