Design of a Compact 2×2 Multi Band MIMO Antenna for Wireless Applications

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Abstract: ***This paper presentsacompactmulti band MIMO antenna for wireless applications. The proposed design is a 2×2 MIMO antenna which has both vertically radiating elements and horizontally radiating elements. This will enable us to have polarization diversity, which can be used as a simple technique for any MIMO antenna. One of the major challenge that MIMO antenna designers face is the mutual coupling effect.Here in the proposed design, by considering a stepped ground with slots and by placing the antenna elements orthogonal to each other, we are able to minimize the mutual coupling effects. The FR4 substrate has been used to designand fabricate the proposed MIMO antenna with a dimension of 70mm×70mm. The antenna resonating frequencycovers three bands 2.11GHz-2.23GHz, 3.24GHz-3.32GHz and 3.92GHz-4.42GHz with a VSWR value less than 2. We observed a minimum isolation of -10dB and a maximum isolation of -40dB for all the resonating frequency bands of the proposed MIMO antenna. The gain of the proposed MIMO antenna has been verified at the center frequencies of 2.18GHz, 3.28GHz and 4.17GHzis given as 1.84dB, 2.91dB and 3.49dB, respectively. The proposed antenna is useful for the wireless applications of WLAN, WiMAX and LTE bands.The proposed Antenna performance has been studied and verified in terms of radiation pattern, efficiency, envelope correlation coefficient (ECC), diversity gain and current filed distribution also.***

Index Terms : Triple band, MIMO antenna, polarization diversity, mutual coupling.

1. INTRODUCTION

Applications using wireless communication technology are growing rapidly, leading to new antenna models that can accommodate the dynamic requirements of these applications. High bandwidth and data rate are the prime requirements for the current wireless communication systems. For fourth generation mobile communication system antennas which can support multimedia services are to be used which should having high channel capacity, data transmission speed and system reliability. To satisfy the needs of the advanced systems, a new technology of Multi Input and MultiOutput(MIMO) antenna has been developed and used. The uniqueness of the MIMO system is that it can transmit and receive data from multiple channels at a single time without any need of additional spectrum bandwidth and radiation power.

Designing a MIMO antenna with a number of antenna elements is a challenge for antenna designers as the antenna is small in size and shares a same substrate. Further the inter element space between the adjacent antenna elements is lesswhichwill lead to high mutual coupling between the antenna elements. We need to overcome these coupling effects and design an antenna with more isolation and compactness.

A lot of research has been done to develop methods to reduce mutual coupling in the antenna array elements, which in turn increases the isolation level. To improve the compactness and maintain an optimal isolation an antenna of 270mm×210mm has been proposed in [1-3], which uses a dielectric slab as a substrate. A neutralization line has been used in [5-7] to decouple the coupling effect in a two element monopole antenna working in the frequency band of 2.5-2.7GHz. In [3],a dual band antenna has been proposed for mobile terminal application where in the ground have several branches and it helps in increasing the isolationlevelinthe antenna operating at 2.4GHz. The ground branches are also used to adjust the frequency of resonance.For the compact size of 90mm×60mm and an isolation of 11.5dB, the techniques of spatial diversity and pattern diversity are used in [8-11]. Independent fed antenna elements with pins which short the radiating element and ground planeare used to reduce the size of the MIMO antenna in [12]. A cross slotted MIMO antenna was presented in [13] which has a compact size of 70.11mm×70.11mm and an isolation of 24dB. The crossed slot is useful in isolation improvement. The exponentially tapered cavity backed slot antenna with polarization diversity having a size of 112.3mm×112.3mm resulted in an isolation of 25dB[14-15]. For increasing compactness of the antenna split ring resonators has also beenused,whichis also useful for increasing isolation level.But in such a scenario, the bandwidth of the antenna will be reduced. The conventional technique to reduce the mutual coupling effect is to have slots in the ground plane. The isolation resulting from the use of such slots in the corners is better than 15dB[16-20].

As discussed above, we can see that many MIMO antennas with four input ports are big in size with complex structure. The proposed work represents a triple frequency MIMO antenna, which has the capability of radiation pattern diversity besides, achieving a high isolation level between the diagonal antenna elements and adjacent antenna elements. The designed antenna resonates at the frequency bands of LTE, WLAN and WiMAX.

II.ANTENNA DESIGN

The antenna elements in the proposed 2×2 MIMO antenna are placed orthogonal to each other to transmit and receive the

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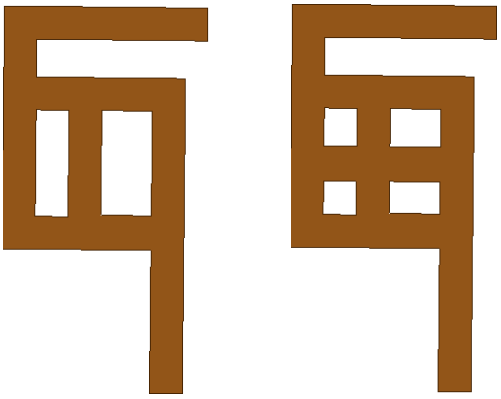
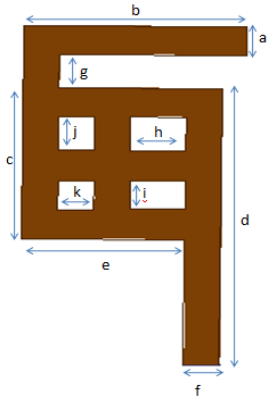
signals in both horizontal and vertical directions. All the antenna elements are excited with a 50 ohm port at the input. Each antenna element has a slotted square patch and a T shaped ground plane with two vertical slots. The proposed MIMO antenna has polarization diversity and is designed and fabricated by using FR4 substrate of dimensions 70mm×70mm using Ansys HFSS software. The dielectric constant of the FR4 substrate used is 4.3,which has a thickness of 1.524mm. Figure 1 depicts the schematic view of the proposed radiating patch and the ground plane of a single antenna element. The finalized antenna design parameters are presented in the Table 1 below. The simulated and fabricated models of the proposed 2×2 MIMO antenna are shown in figure 2.

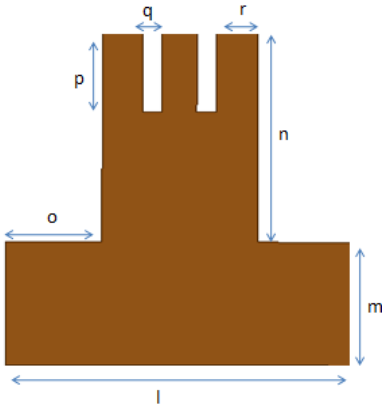
(a) Antenna 1 (b) Antenna 2



(c) Antenna 3 (d)Antenna 4



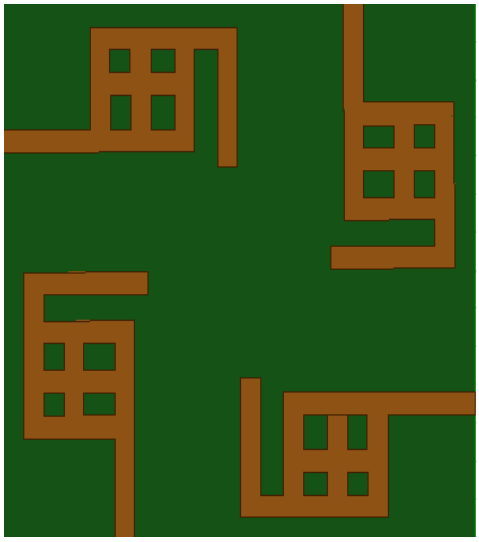
Radiating element



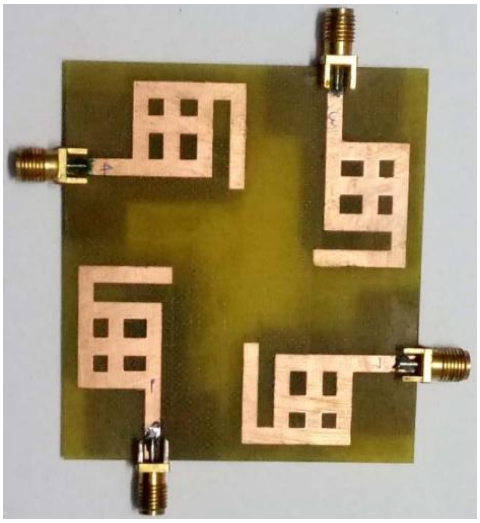
Ground plane

Figure.1. Radiating element and ground plane of single antenna element

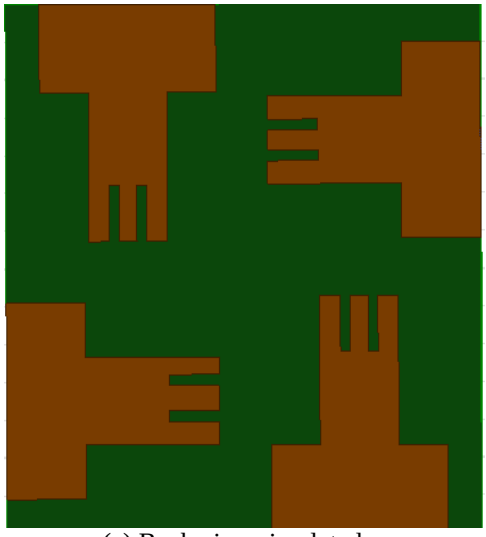
The proposed antenna resonates at three frequencies of which the lowest frequency resonatesdue to the perimeter generated by the total length of sides a to f while the middle frequency resonates due to the four rectangular slots inside the patch with dimensions represented by h, i, j and k.The higher frequency resonates due to the slot with width g. The T shaped ground plane with two vertical slots in the bottom is useful for getting low return loss value for all the three operating frequencies.



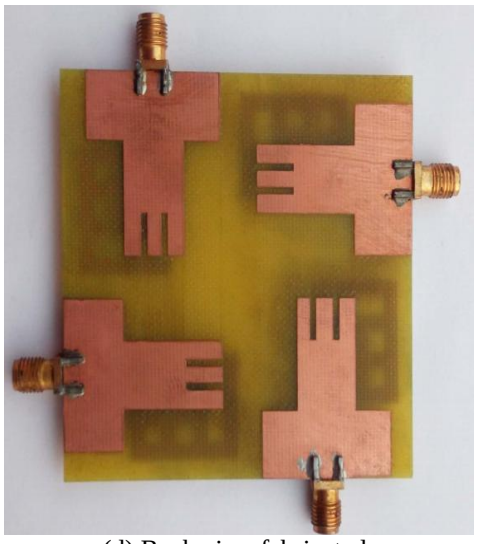
(a) Front view simulated



(b) Front view fabricated



(c) Back view simulated



(d) Back view fabricated

Figure.2. Simulated and fabricated 2×2 MIMO Antenna

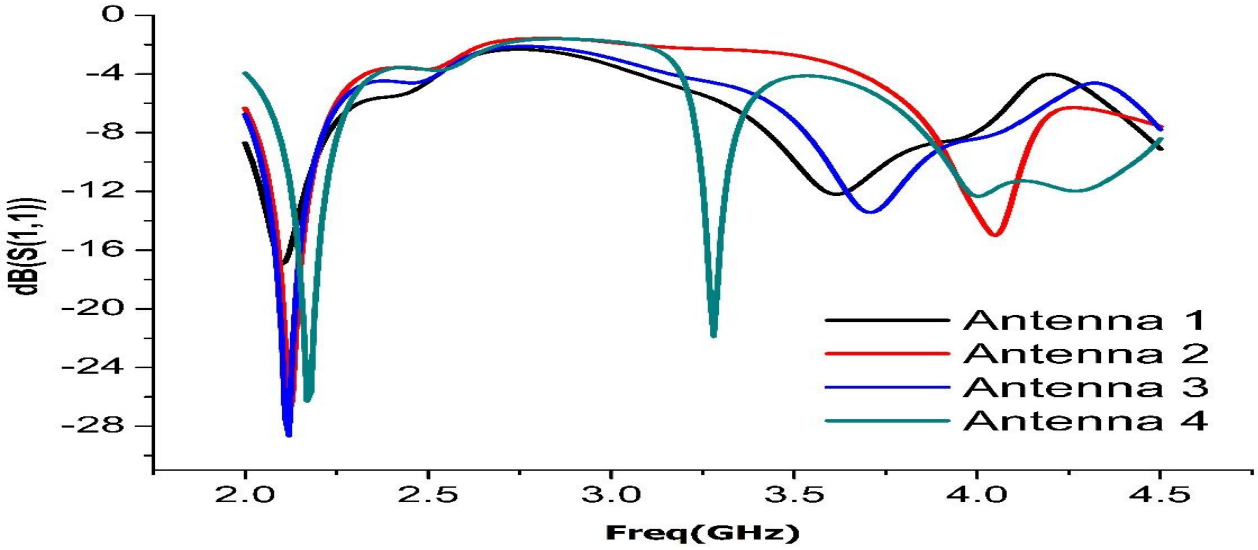
Table 1.Parameters of the proposed antenna

Parameter	Value (mm)	Parameter	Value (mm)
a	2.96	J	3.44
b	18.35	K	2.96
c	15.52	L	26
d	28.4	M	11.66
e	13.44	N	19.74
f	2.96	O	7.2
g	3.41	P	7.43
h	4.56	Q	1.48
i	2.88	R	3

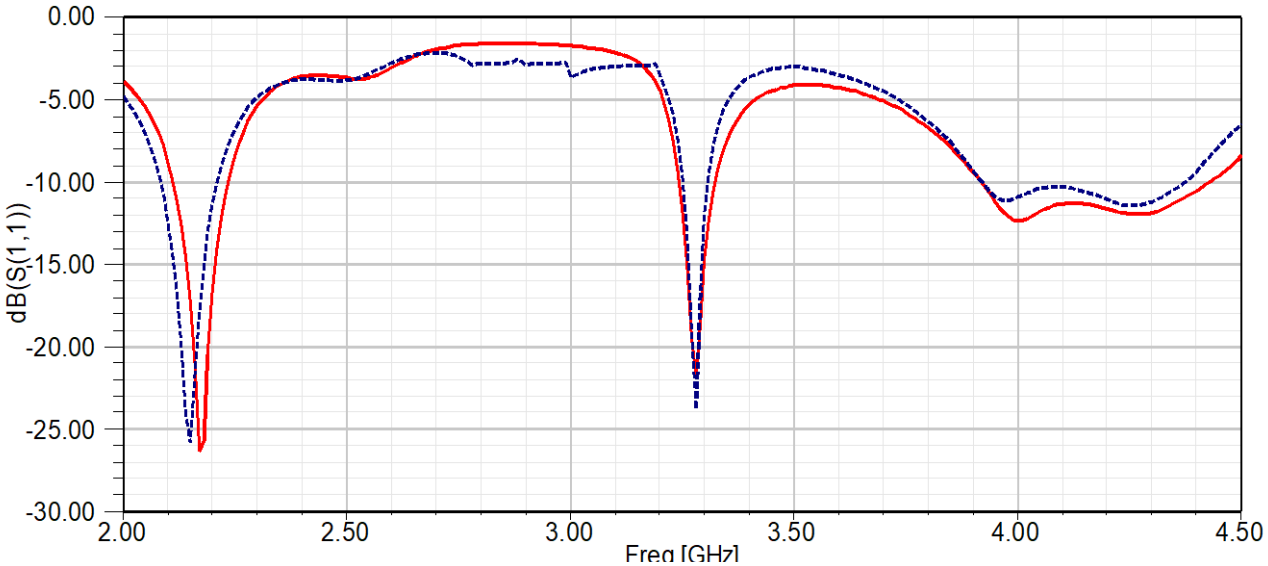
III. RESULTS AND ANALYSIS

The parameters of the proposed 2×2 MIMO antenna are optimized for achieving a minimum return loss and mutual coupling. The simulated and measured return loss plot is as shown in the Fig. 3. It is observed that a triple band resonance is achieved with the proposed antenna with bandwidths ranging from 2.11GHz to 2.23GHz, 3.24GHz to 3.32GHz and 3.92GHz to 4.42GHz. The isolation between the adjacent elements and diagonal elements in the second and third resonating bands is more than 35dB. But the isolation is less in the first resonating band, which is around 12dB. This may be due to the effect of the antenna compactness improvement techniques implemented in the antenna design.

The effect of the vertical and horizontal coupling strips inside the square ring is presented in figure 3(a). Here,we can observe that without any coupling strips the antenna, has dual frequency of operation but the impedance matching is very low. But with the introduction of any one of the coupling strips, the impedance matching has improved and when we introduce both the coupling strips, it resulted in the generation of the third resonating frequency in between the existing dual operating frequencies.



(a) Return loss for different Antenna stages



(b) Simulated(——) and measured(-----)

Figure .3. Return Loss of proposed antenna

Voltage Standing Wave Ration is another major impedance matching parameter which shows the level of impedance matching. Fig. 4 below shows the VSWR plot of the proposed antenna.

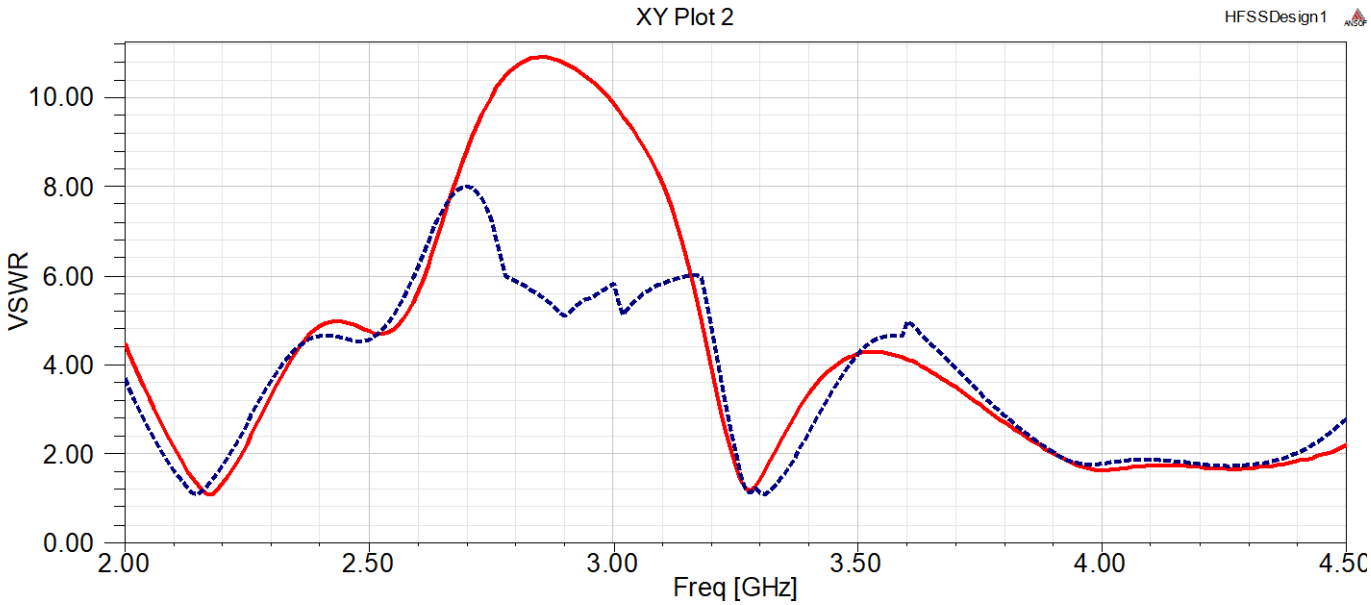


Figure.4. Simulated(——) and measured(-----)VSWR of proposed antenna

We observed the VSWR values of 1.10, 1.21 and 1.52 at 2.18GHz, 3.6GHz and 3.98GHz, respectively. Fig. 5, Fig. 6 and Fig. 7 below shows the isolation plots of the proposed antenna. Isolation between the antenna elements depends on the gain of the antenna, better gain leads to low isolation and vice versa. The gain values of the proposed antenna element at 2.18GHz, 3.28GHz and 4.17GHz are 1.84dB, 2.91dB and 3.49dB, respectively as shown below in Fig.8

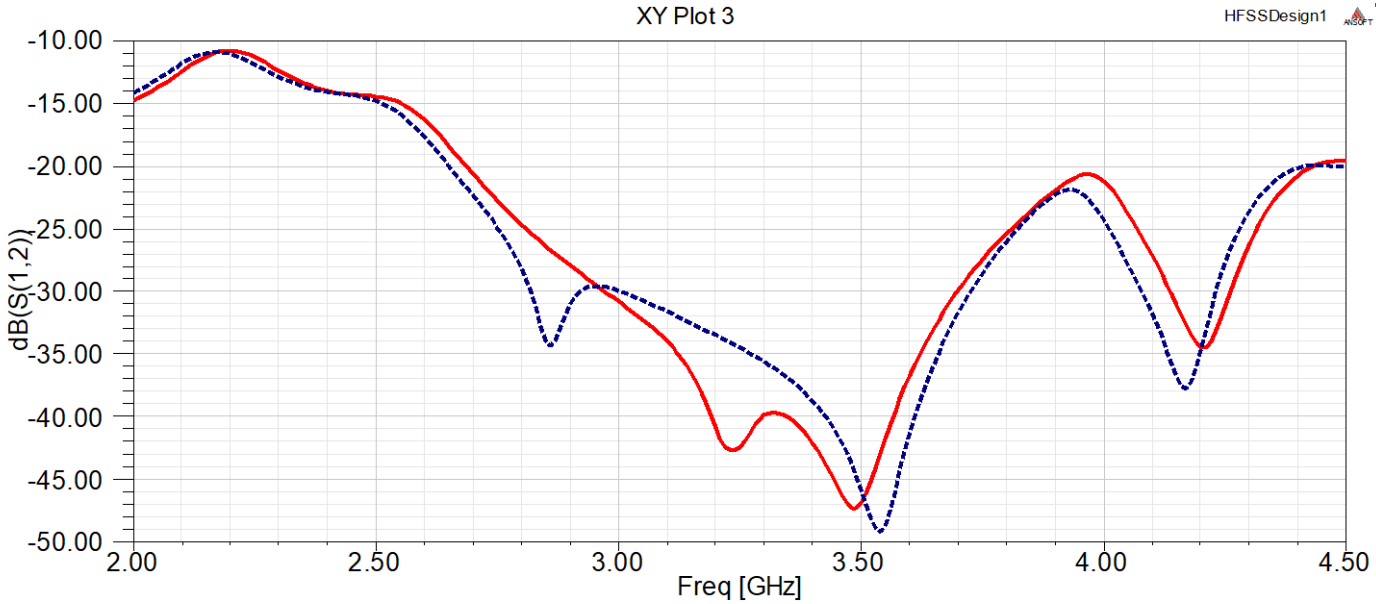


Figure.5.Simulated(——) and measured(-----) S_{12} Plot

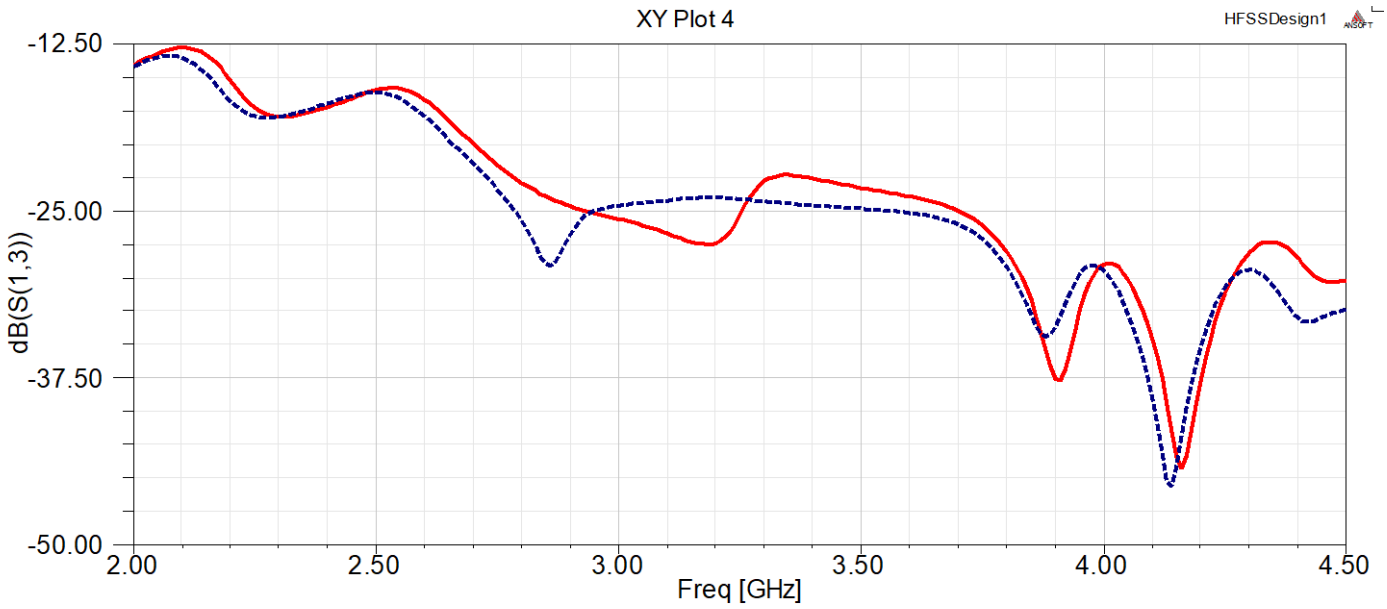


Figure.6. Simulated(——) and measured(-----)S_{13} Plot

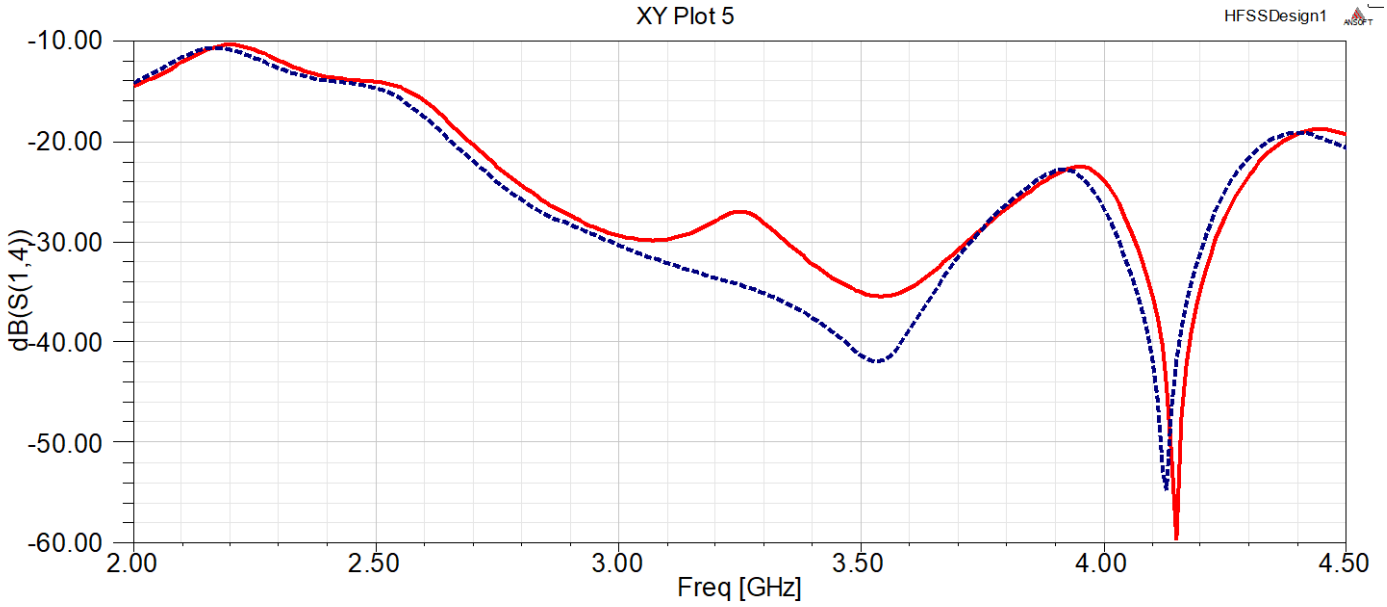
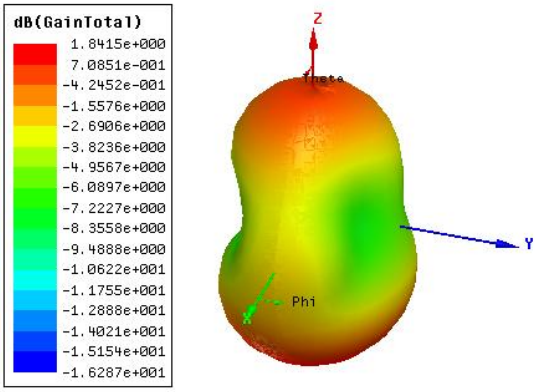
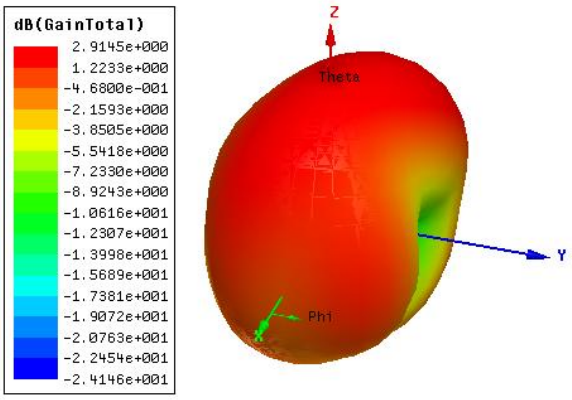
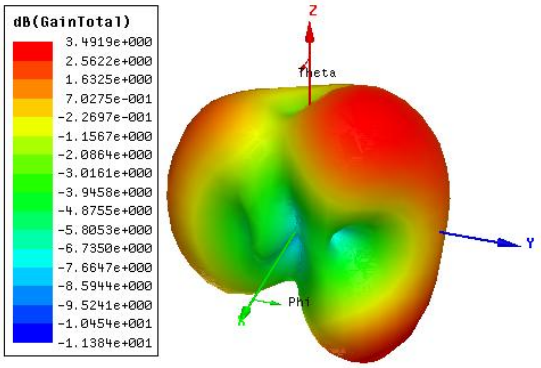


Figure.7. Simulated(——) and measured(-----)S_{14} Plot





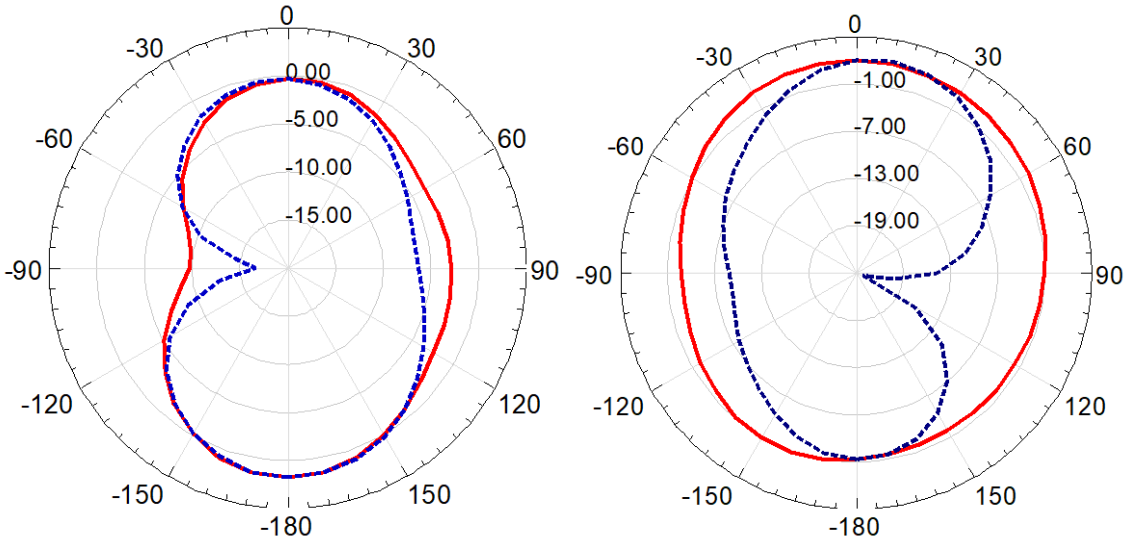
(a) 2.18GHz (b) 3.28GHz



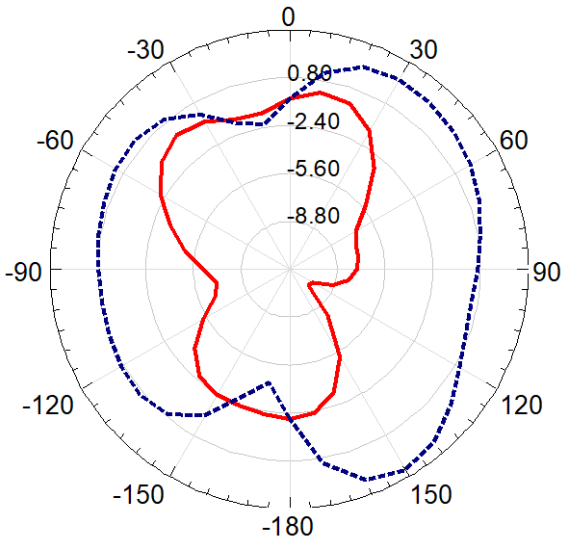
(c) 4.17GHz

Figure.8. Antenna Gain

The simulated Elevation Plane and Azimuthal Plane patterns of the 2×2 MIMO antenna are shown in the Fig. 9.



(a) 2.18GHz (b) 3.28GHz



(c) 4.17GHz

Figure.9. E plane(——) and H Plane(-----)radiation patterns

In addition to radiation patterns, the envelope correlation coefficient (ECC) is another key parameterto describe the diversity performance of anyMIMO antenna. The lesser values of ECC represent low correlation among the MIMO antenna elements, which is calculated using equation (1). The ECC has crucial significance as its measurement is based on the Reflection coefficients of all the antenna elements which shown in the figure 10below.From the results shown, it is obvious that the proposed antenna with the slotted stepped ground has worked effectively.

$$\left|\rho_e(i,j,N)\right| = \frac{\left|\sum_{n=1}^{N} S_{i,n}^{*} S_{n,j}\right|}{\sqrt{\left|\prod_{k(=i,j)}\left[1-\sum_{n=1}^{N} S_{i,n}^{*} S_{n,k}\right]\right|}} \quad (1)$$

Table 2.ECC of proposed2 × 2 MIMO antenna

Frequency(GHz)	ECC(Simulated)	ECC(Measured)
2.18	0.016	0.036
3.28	6.25×10^{-3}	0.018
4.17	4.68×10^{-3}	0.0124

The diversity gain is also one of the important diversity parameters, which is obtained in terms of maximum theoretical diversity gain (10 dB) and correlation coefficient, using equation (2). The higher value of diversity gain is better the isolation and vice versa. The measured values of diversity gains atthree resonant (2.18GHz, 3.28 GHzand 4.17GHz)frequencies are9.99dB. Thesimulateddiversitygains atthese resonantfrequenciesare10dB. The diversity gain verses frequency graph is shown in the figure 10.

$$D_{DG} = 10 * \sqrt{1-\left|\rho\right|^2} \quad (2)$$

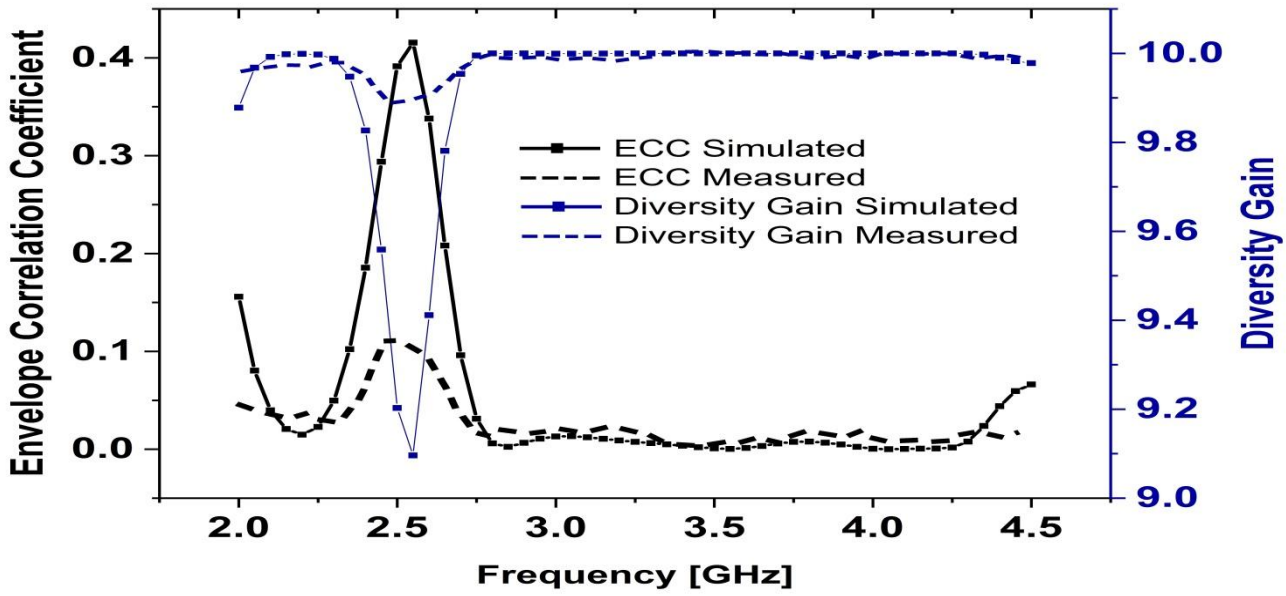
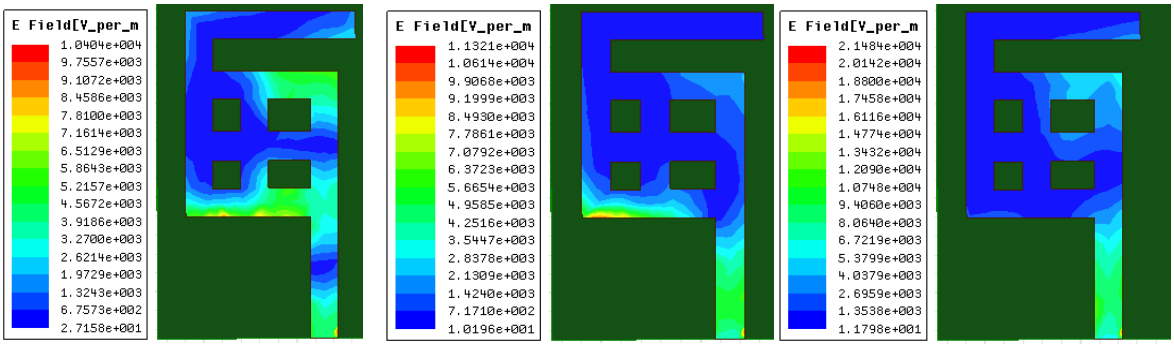


Figure.10. Envelope correlation coefficient and Diversity gain

In [16] a dual band antenna is designed using a G-shaped patch antenna with a Defective ground plane, where in the two operating frequencies of the antennas are 2.58GHz and 5.3GHz. By the proposed antenna has triple frequency of operation and the overall antenna size is same for both the antennas. The current distributions of the antenna at the three operating frequencies of 2.18GHz, 3.28GHz and 4.17GHz are shown below in the figure 11.



(a) 2.18GHz (b) 3.28GHz (c) 4.17GHz

Figure.11. Current Distributions

IV. CONCLUSION

A Triple band compact four element MIMO antenna is proposed for wireless communication applications. The proposed antenna has orthogonally aligned antenna elements. Isolation between the antenna elements has been improved by using an orthogonally placed slotted ground plane. The resonating frequency band covers the frequency range of 2.11GHz to 2.23GHz, 3.24GHz to 3.32GHz and 3.92GHz to 4.42GHz. The mutual coupling has been reduced to a considerable range by implementing the partial ground orthogonally to each other. The efficiency of the proposed MIMO antenna at the three resonating frequencies of 2.18GHz, 3.28GHz and 4.17GHz are given as 60%, 63% and 73%,respectively.

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