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Design and Analysis of Compact MIMO Antenna with Enhanced Isolation Techniques for Wireless LAN applications

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Abstract - *A compact 2X2 and 4X4 Multiple-Input-Multiple-Output (MIMO) antennas are designed for Wireless Local Area Network (WLAN) applications with enhanced isolation. The frequency of operation is chosen to be 5GHz so that Multipath fading problem can be avoided by incorporating this into 802.11a standards that supports in Wi-Fi module. In this work three mutual reduction techniques are used. The orthogonal polarization method, parasitic element method and a novel neutralizing network method using hairpin filter is carried out. The isolation between the radiating patches is highly enhanced. The overall dimension of the proposed 2X2 and 4X4 WLAN MIMO antennas are 16 x 38 x 0.51 mm^3 and 39 x 39 x 0.51 mm^3, respectively. The measured bandwidth of 540MHz (4.71-5.25GHz) and 497MHz (4.69-5.19GHz) with better return loss of –43 dB and –42dB and isolation of -56dB and -38dB for 2X2 and 4X4 antennas are, respectively, achieved. The measured bandwidth, realized gain, diversity gain (DG), Envelope correlation coefficient (ECC) and radiation efficiency for 2X2 and 4X4 MIMO antenna is analyzed and achieved at 5GHz frequency. This approach increases the isolation between the antennas as compared to the other methods*

***Key Words*: MIMO (Multiple-Input-Multiple-Output), envelope correlation coefficient (ECC), DG (Diversity gain), WLAN, Multipath fading**

1. INTRODUCTION

The urge for high data rate and high reliability has led to the immense development in wireless technologies. With the advancement of Wireless Local Area Networks (WLAN), The Multiple-Input-Multiple-Output (MIMO) technology plays a crucial role by improving the data rate and wide coverage [1]. With the advancement of technology due to its various advantages, this introduces certain drawbacks. With MIMO technology the number of antennas increases, as the number increases the placement of antennas in a stipulated space with shared ground plane leads to increase of mutual coupling. To maintain isolation between the antennas is a challenge.

Spatial diversity and multiplexing allows multiple data packages to transmit independently and simultaneously by more than one antenna that are uncorrelated [1] [2]. As the spacing between two antennas is highly reduced, it causes mutual coupling and fluctuates the desired result. Therefore degrades the performance of MIMO antenna.

Improving the isolation between two antennas in MIMO configuration becomes crucial problem for WLAN applications [3]. The ports should be uncorrelated to achieve good performance. Here much attention has been focused on three special techniques to increase isolation. However, the simple and effective approach is to use the techniques, such as parasitic or slot element, defected ground structure, complementary split ring resonator and decoupling networks which can enhance isolation by means of physical implementation [4] [5].

In [6], two antenna elements are closely placed with about 0.115 λ_0 spacing between radiating patches. Here the isolation is achieved by using decoupling network, the shape used is meandering resonant branch for wideband and an inverted T- shaped slot etched on ground surface which provides lower band. The same technique is also used in [7], slotted meander line between the antenna arrays to achieve enhanced isolation. For 5GHz WLAN application, a six-port multiple-input-multiple-output (MIMO) antenna system with high port isolation for is proposed in [9]. Here orthogonal polarization technique is used. It consists of three vertically polarized and three horizontally polarized antenna elements alternately designed on a pyramidal metal structure. In [10] [12] [19], different shapes inspired by meta material concept are used acting as parasitic elements between antennas. Paper [14], uses T shaped slot with a capacitor to improve isolation. For 4 port MIMO antenna many papers use parasitic element mechanism as it gives more efficiency and less complications [16]. The isolation is also enhanced by simple folded slot-partial ground plane acting as defective ground surface as discussed in [17], this will also enhance bandwidth. In [18], Meta material inspired Polarization-Rotator wall is used, for millimeter-Wave MIMO antenna array. Various mutual coupling reduction/isolation improvement techniques are studied in [20].

This thesis work, presents 2x2 and 4x4 MIMO antenna using three different mutual coupling reduction techniques. Here, the center frequency of operation is 5GHz which is suitable for WLAN applications. It is a Patch antenna with slots on each side to improve the return loss, Rogers 6035 with dielectric of 3.5 and thickness of 0.51mm is being used. Analysis is being done using three different techniques.

The remainder of the paper is organized as follows: In section 2, we explain the antenna design and geometry. Then, in section 3 provides the results and discussions and section 3 concludes the paper.

2. ANTENNA DESIGN AND GEOMETRY

The compact 2X2 and 4X4 MIMO antennas are designed for Wireless local area network (WLAN) applications and simulated using AWR software. The geometry of the proposed initial design is shown in fig 1. As per the Conventional design at 5GHz, the size of the antenna should be 15.91mm x 20mm x 0.51mm but for compactness of antenna, the size is being reduced to 15.85mm x 9mm x 0.51mm with defective ground surface. Reducing the antenna size to almost less than 50% without degrading its performance is one of the key factors in implementing any new MIMO antennas. Etching slots from both radiating elements and the ground planes is considered to reduce the actual size of the antenna. Its scattering parameters are shown in figure 2. The plot shows a return loss of -38.12dB with a bandwidth of 689MHz around the center frequency 5GHz.

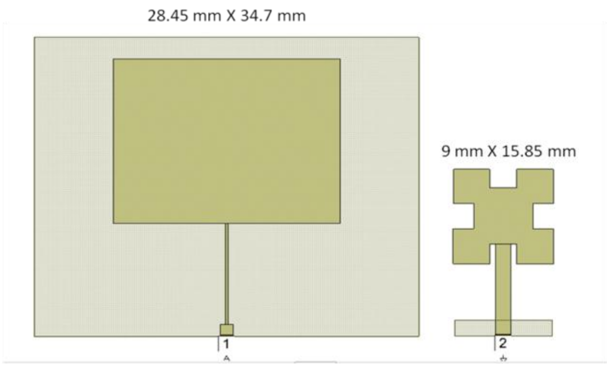


Fig 1: Comparison between conventional and compact design

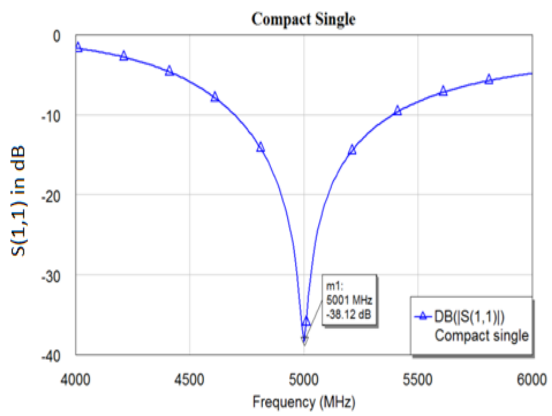


Fig 2: Simulated return loss (S11) for compact design

Here in this work three methods of mutual coupling reduction techniques are implemented and analyzed.

2.1 Orthogonal Polarization Position Based MIMO Antenna

Placing the radiating patches in orthogonal way is one way to reduce mutual coupling. For 2x2 (2 port) MIMO antenna as shown in figure 3, a pair of antennas at a distance of D= 0.166λo and separate defective ground surface, placed orthogonal to each other, the S-parameter measurement is being observed as shown in figure 4. Return loss of -31.62dB and Isolation of -34.4dB is achieved. As the two patches are separated less than D=0.5λo it becomes highly difficult to reduce mutual coupling.

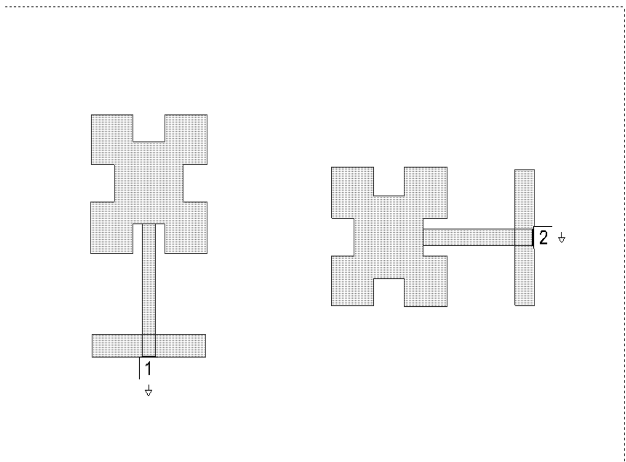


Fig 3: 2x2 MIMO antenna with orthogonal placement

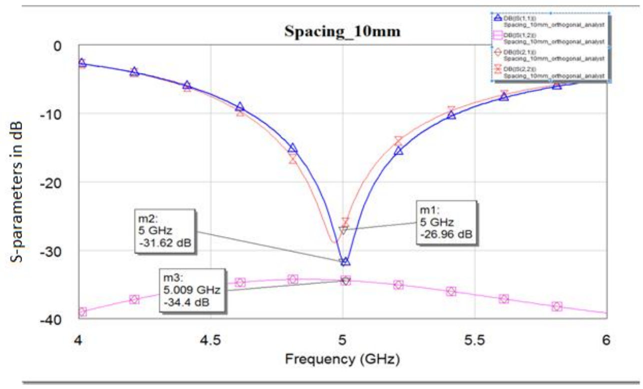


Fig 4: Simulated S-Parameters for orthogonal pair of antennas

The same design is implemented for 4 Port MIMO antenna as shown in figure 5, and S parameter results such as return loss and isolation are observed in fig 6.

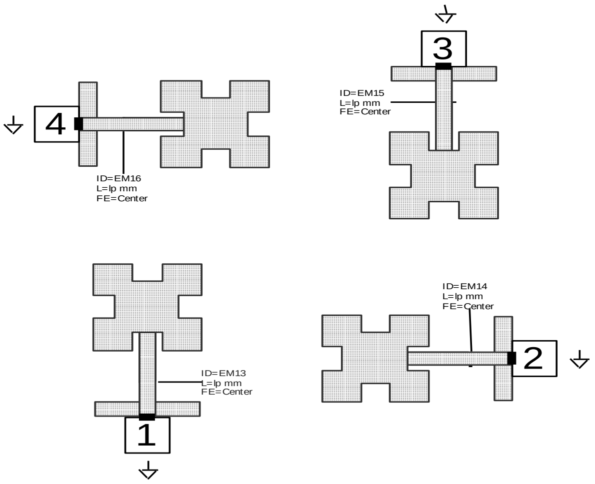


Fig 5: Orthogonal placement of 4X4 MIMO Antenna

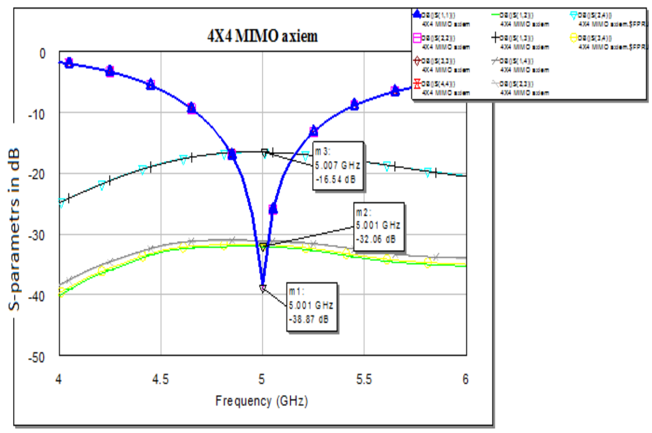


Fig 6: Simulated S-Parameters for 4X4 MIMO antenna

2.2Parasitic Element Placement Based MIMO antenna

Parasitic element is an element with certain shape and size placed between the radiating patches to reduce the mutual coupling. By placing a staircase structure in the bottom the mutual coupling is reduced in both 2x2 and 4x4 MIMO antenna. Isolation of -40.68dB and -36.84dB is observed for 2x2 and 4x4 MIMO antenna respectively.

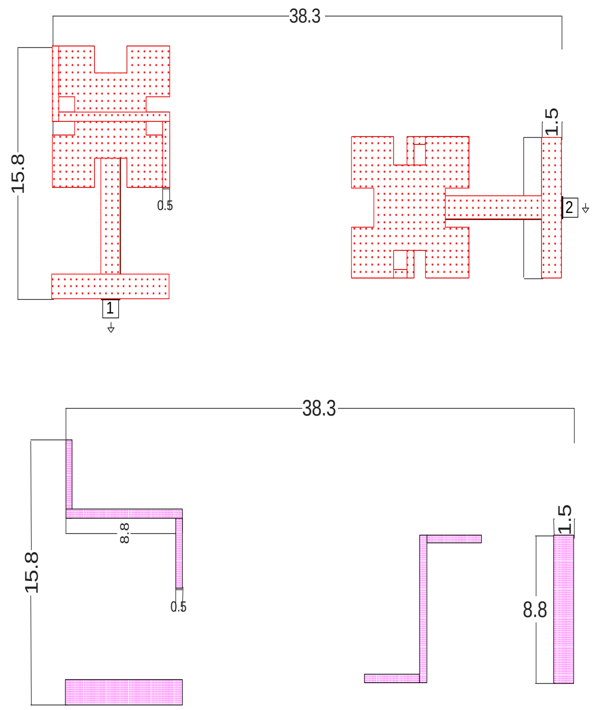


Fig 7: 2X2 MIMO antenna by parasitic element placement (a) top layer (b) bottom layer

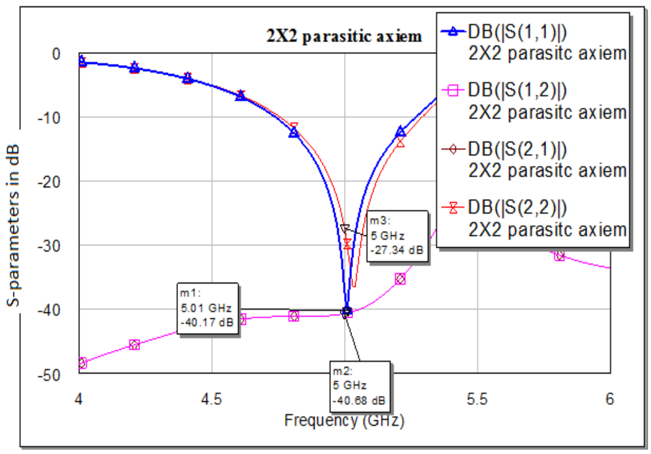


Fig 8: Simulated S parameter result for parasitic element

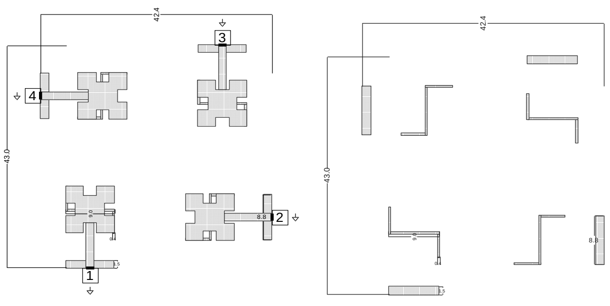


Fig 9: 4X4 MIMO antenna by parasitic element placement (a) top layer (b) bottom layer

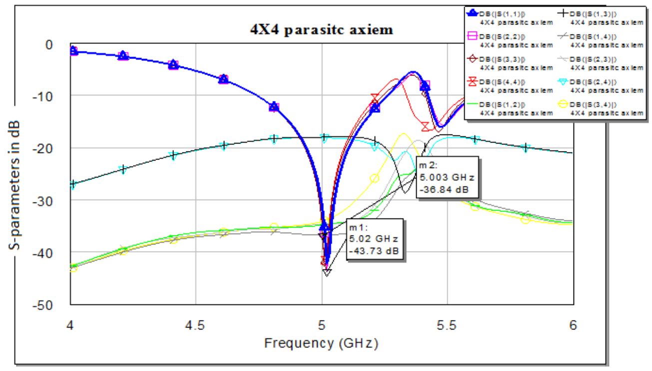


Fig 10: Simulated S-parameter results for 4x4 Antenna

2.3Band Stop Filter Effect in MIMO Antenna

Placing a Hairpin structured band pass filter between the two radiating patches will act as isolation technique in MIMO concept. The design is shown in figure 11 and simulated results are being observed from the graph below shown in figure 12. This filter well suits for 2X2 MIMO antenna rather than 4X4 MIMO antenna, 4X4 antenna has been kept for future work.

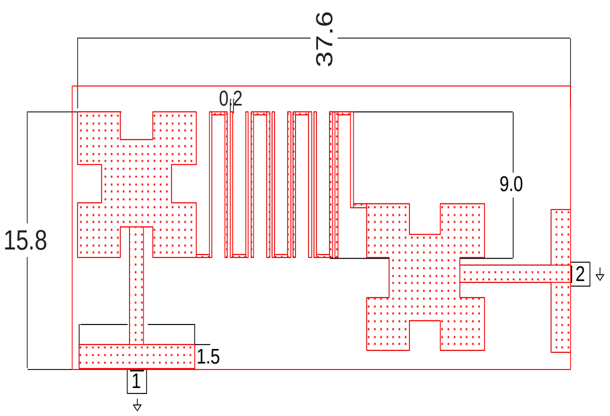


Fig 11: 2X2 MIMO antenna using band stop filter

Using this hairpin structured band stop filter very high isolation is improved to -56.69dB with a return loss of -26dB, gain around 2.82dB and VSWR 1.103. So among all the methods mentioned above this method can be stated as best choice for 2X2 MIMO antenna. The filter here grounds the EM field at 5GHz and does not allow interference with one another.

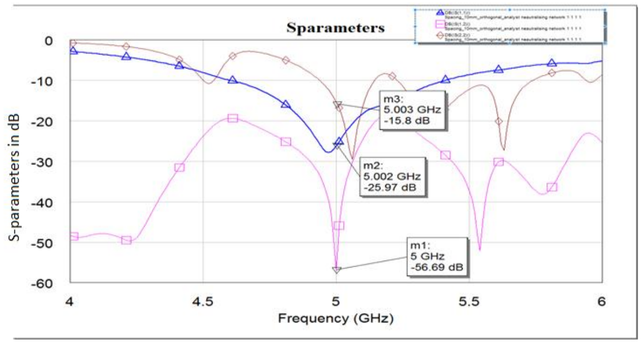
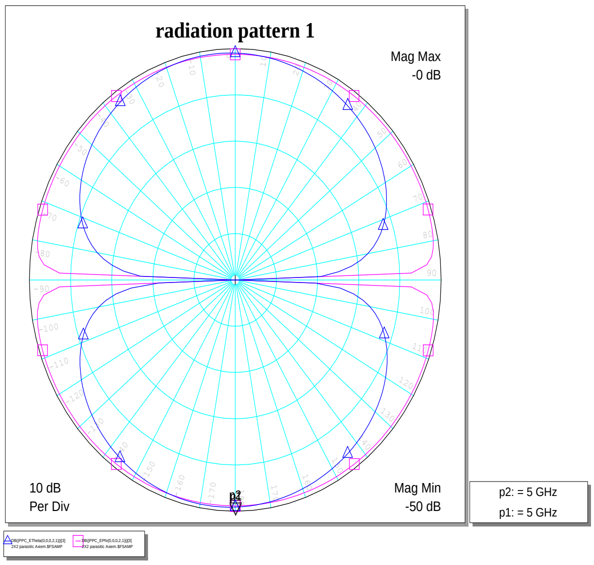


Fig 12: Simulated S-parameter results for band stop filter antenna

3. Results and Conclusion

3.1 Radiation pattern

The below figures show radiation pattern in isotropic medium, this pattern is obtained by orthogonal polarization placement antennas. The top figure shows 2X2 MIMO antenna pattern and below figure shows 4X4 MIMO antenna pattern



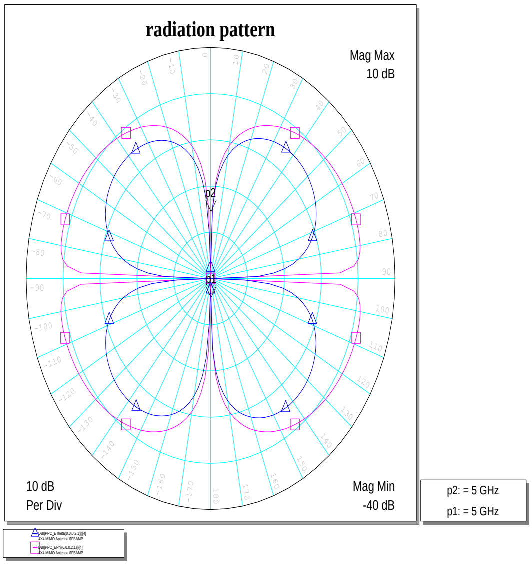


Fig 13: Radiation pattern of orthogonal polarization

The next figure shows radiation pattern when parasitic elements are placed in ground surface. The first figure shows 2X2 parasitic MIMO antenna whereas second figure shows 4X4 MIMO antenna.

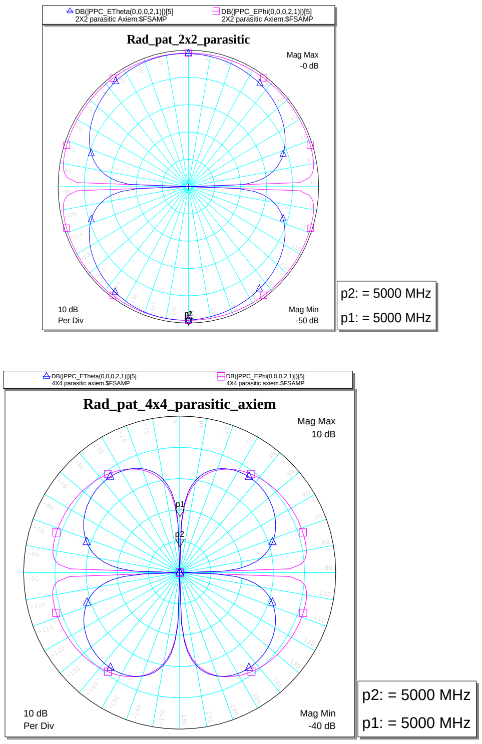


Fig 14: radiation pattern for 2X2 and 4X4 MIMO antenna with parasitic element placement

Further, the radiation pattern of 2X2 MIMO antenna with hairpin structure is shown below.

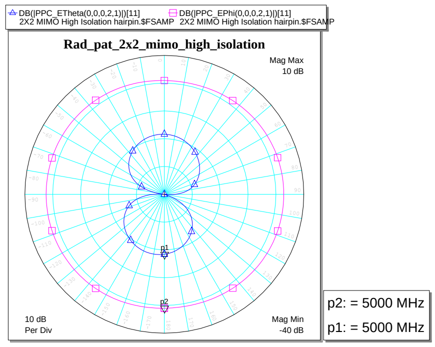


Fig 15: Radiation pattern for Hairpin structure antenna

3.2 Envelope Correlation Coefficient

Envelope correlation coefficient tells how independent two antennas are. If one antenna was horizontally polarized n other was completely vertical polarized then both antennas would have zero Units ECC. From the designed antennas ECC value obtained at 5GHz for all three designs is 0.0001 as shown in below figure.

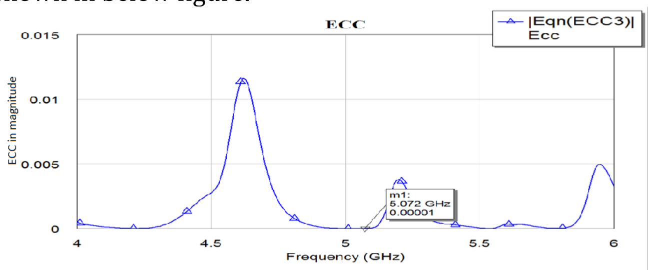


Fig 16: ECC for all the three designs

3.3 Diversity Gain

Diversity gain is an increase in SNR due to some diversity scheme, that is, how much transmission power can be reduced when diversity scheme is introduced without performance loss. Ideally the value should be 10, practically it will be around 9.5. Here in this project 9.9 diversity gain is obtained.

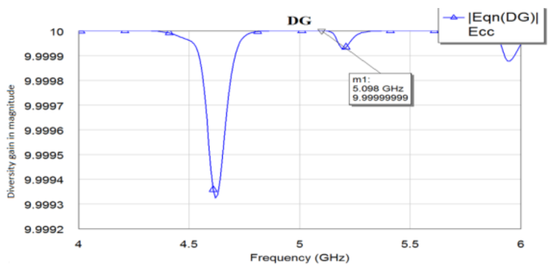


Fig 17: Diversity gain at 5GHz

3.4 VSWR

The VSWR value is observed to be 1.103 for all the above designs.

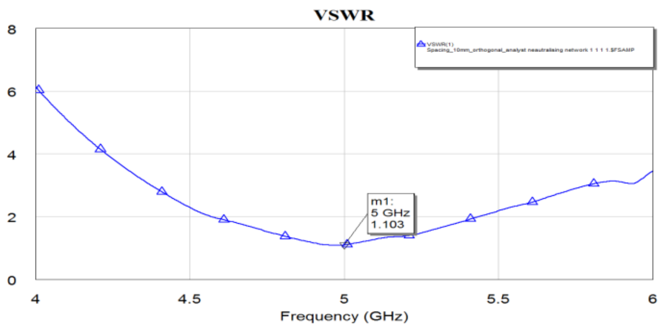


Fig 18: VSWR plot

3.5 Gain

As all the antennas are isotropic radiators, the observed gain is 2.82dBi.

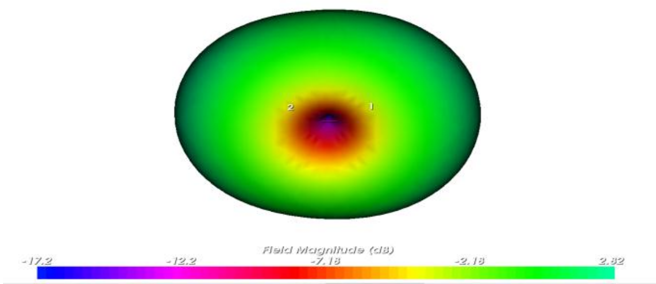


Fig 19: Gain plot

4. Analysis Table

The below table consist of return loss and isolation for all the designs carried during the thesis work.

Type of antenna	Method used	Area	Return loss	Isolation
Single	Conventional	(15.65X20.5)mm	-26.94dB	-
	Compact	(9X15.85)mm	-38.12dB	-
2X2 MIMO Antenna	Compact with 30mm Spacing	(48X15.75)mm	-27.02dB	-14.41dB
	Compact with 10mm spacing	(40X15.85)mm	-35.12dB	-9.853dB
	Parasitic element	(40X15.85)mm	-40.17dB	-40.68dB
	Neutalising Network	(40X15.85)mm	-26dB	-56.69dB
4X4 MIMO Antenna	Compact with 10mm spacing	(38X38)mm	-38.87dB	-32.08dB
	Parastic element	(38X38)mm	-43.73dB	-36.84dB

Table 1: Analysis table

5. COCLUSION

This paper implements three different mutual coupling reduction techniques for both 2X2 and 4X4 MIMO configurations. Orthogonal placement of radiating elements causes zero cross correlation. Placing parasitic element in the ground plane gives effective and efficient solution to MIMO antennas. In this isolation of -40dB and return loss of -40dB is achieved. The third technique, in which, band stop filter shows potential solution to decrease mutual coupling. A very high isolation of -56dB is achieved for 2X2 MIMO antenna with a return loss of -26dB and 4X4 MIMO antenna is kept for future work. The MIMO antenna has compact size, higher efficiency, good diversity gain (DG) and lower envelop correlation coefficient (ECC). The proposed antenna has been successfully simulated and analyzed, the results shows that it could be a good choice for the WLAN applications.

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