Design and Analysis of MIMO Antenna for ISM band Application

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***Abstract*— The design and analysis of MIMO antenna with U shaped ground structure is proposed for ISM band application. The antenna comprises of semicircular patch with t slot etched and U shaped ground structure to reduce the mutual coupling between closely spaced antenna elements. The overall dimensions of the antenna are 40x38.5x1.6 mm^3. This antenna is designed and its performance is analyzed from the ADS simulation software. The proposed MIMO antenna resonates at the frequency 2.4GHz with return loss<-27dB and isolation<-25dB. At this frequency band simulated gain is about 0.58dBi, directivity is about 7.1dBi. For the proposed MIMO antenna the Envelope Correlation Coefficient is below 0.5. Hence it has high isolation with closely spaced antennas to be suitable for MIMO communication.**

Keywords*— *Compact MIMO antenna; Slot; Defected Ground Structure; ECC; Isolation;

I. INTRODUCTION

Nowadays Multiple antenna configurations can be used to overcome the effects of multi-path and fading when trying to achieve high data throughput in limited-bandwidth channels. MIMO exploits spatial diversity by having several transmit and receive antennas. It can greatly increase the capacity of channels by independently sending streams of date across multiple antennas. Isolation is the important consideration in MIMO antenna. Hence U shape ground structure contributes to electromagnetic shielding. Under this circumstance, the induced current magnitude is nearly zero around the middle of the AIPD, leaving room for the RFIC and other components, ultimately reducing the risk of potential electromagnetic interference [1].

Many authors have proposed several solution to improve mutual coupling such as defected ground plane, cutting resonant slot in ground plane, electromagnet band gap (EBG), placing parasitic element between antenna element and neutralization lines [2][3]. These solution tend to improve mutual coupling for example in paper defected ground plane has been used to achieve isolation up to 20dB with minimum distance between antenna element is lesser. Some authors have also used tree like structure over the modified ground plane in order to achieve good isolation between antenna elements as discussed in [4]By using DGS and parasitic element a 2x 1 compact 4-shaped multiple-input-multiple-output (MIMO) antenna is designed. A defected ground plane structure (DGS) is etched in the ground plane to reduce mutual coupling effect between two antennas. Parasitic elements in F shape is added at comer to improve the isolation. This proposed antenna covers two frequency band in lower and higher frequency band which is 2440MHz-2560MHz and 5120MHz- 5260MHz. By DGS the lower band isolation<-14.S4dB at and higher band isolation <-20.9. The gains of these antennas are 1.4dBi and 2.5dBi at 2.5GHz and 5.2 GHz. Parasitic elements are mainly used to improve the gain of MIMO antenna [5].

For MIMO antennas, a wide band printed dipole using V-shaped ground branches is designed. To improve the impedance matching dipole with an integrated balun and V shaped ground branches are introduced. All three WiMAX bands (2.30, 2.50, and 3.30 GHz) and the 2.40 GHz WLAN band are covered. This antenna is most suitable for wireless routers and adapters [6]. A Dual ISM band MIMO Antenna was typically employed for WiFi and WiMax Application. The antenna has two sickle shaped radiator patch with microstrip feed line. In ground plane the rectangular shape slot and trident shape structure is employed to provide isolation between closely spaced antennas. For this configuration the antenna achieved better operating bandwidth at 2.4 and 5.2 GHz with satisfactory return loss and isolation [7].

II. MIMO ANTENNA DESIGN

A. *MIMO Antenna Structure*

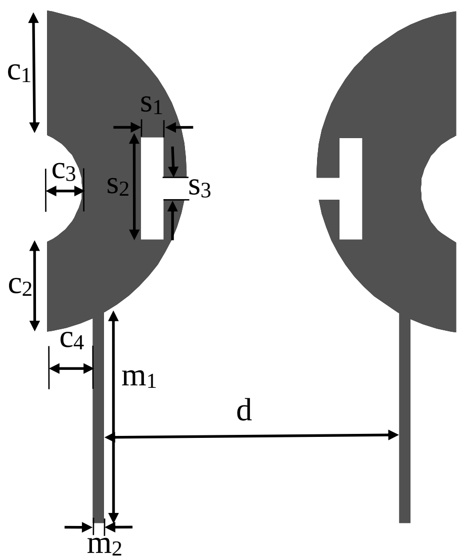


Fig. 1 MIMO Antenna Structure

The MIMO Antenna structure comprises of two antenna elements as semi circular etched with t shaped slot. The feed is given at the microstrip line. The dimensions of the antenna is shown in Table I. The parameters of the antenna elements are c_1, c_2, c_3, c_4, s_1, s_2, s_3, m_1, m_2, d.

TABLE I
DIMENSION PARAMETERS OF THE ANTENNA ELEMENT

c_1	5.6mm	s_2	4.7mm
c_2	4.4mm	s_3	1.1mm
c_3	1.5mm	m_1	9.3mm
c_4	2.1mm	m_2	0.5mm
s_1	1.1mm	d	12.9mm

B. *MIMO Antenna Ground Structure*

The ground structure is shown in figure 2 in which the U shaped slot is etched and it acts as a shielding for electromagnetic interference around the antenna gap. The ground structure consists of two sets of complementary facing strips and each U shaped slots acts as a shielding of interference. Hence it will improve the isolation of the MIMO antenna to be suitable for wireless communication. It will reduce the mutual coupling between closely spaced antenna elements.

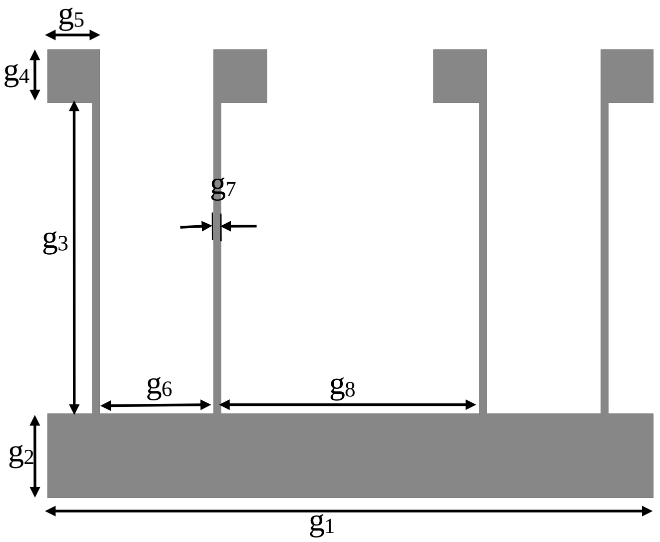


Fig. 2 MIMO Antenna Ground Structure

The dimensions of the ground structure and its U shaped slots are listed in the table II. The following are the parameters g_1, g_2, g_3, g_4, g_5, g_6, g_7 and g_8.

TABLE III
DIMENSION PARAMETERS OF THE GROUND STRUCTURE

g_1	36mm	g_5	3.1mm
g_2	5mm	g_6	6.8mm
g_3	18.5mm	g_7	0.3mm
g_4	3.1mm	g_8	15.3mm

C. *MIMO Antenna Geometry*

The overall configuration of the proposed MIMO antenna is shown in the following figure 3.

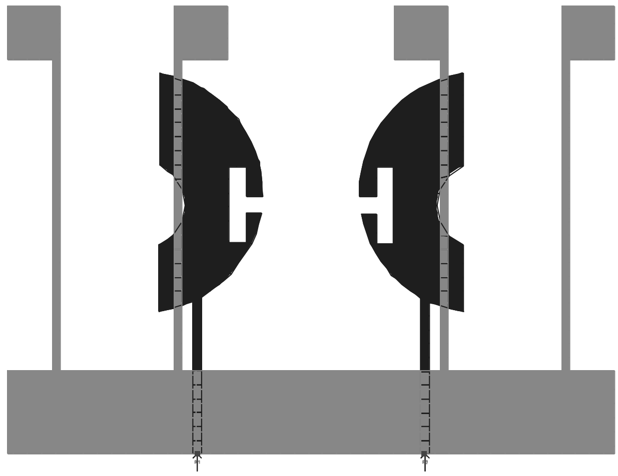


Fig. 3 MIMO Antenna Geometry

III. SIMULATED RESULTS

The following figure 4 shows the antenna structure with ports. Figure 5 showing simulated results of scattering parameters for ISM band MIMO Antenna. Here S_{11}, S_{22}, S_{12} and S_{21} are obtained from Advanced Design System simulation software version 11.01.

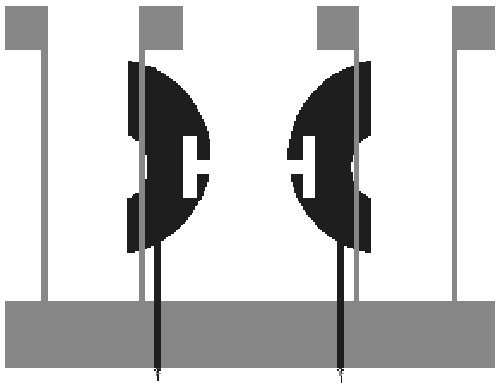


Fig. 4 MIMO Antenna Structure with ports

The S_{11} is the Return loss of antenna element 1 and S_{22} is the Return loss of antenna element 2. S_{12} and S_{21} are the mutual coupling or Isolation between antenna element 1 and 2. Figure 5 and 6 shows the return loss which is <27dB and isolation is <25dB for antenna 1. Figure 7 shows both the S_{11} and S_{21} for antenna 1. The figure 8 and 9 shows the return loss and isolation which is <-27dB and <25dB for antenna 2. Similarly figure 10 shows both the return loss and isolation for antenna element 2 which is same as the antenna 1. The simulation results of radiation pattern, gain and directivity, absolute fields and polarization are also presented.

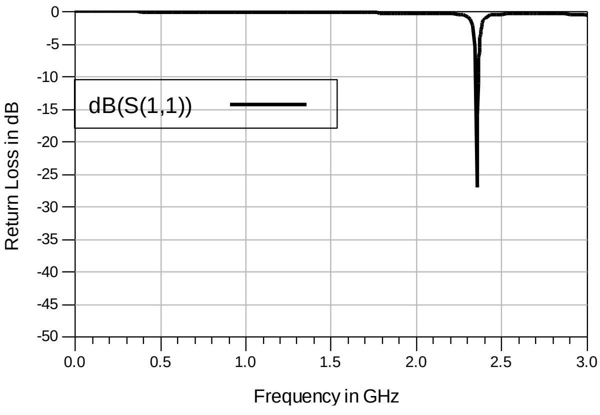


Fig. 5 Return Loss for Antenna 1

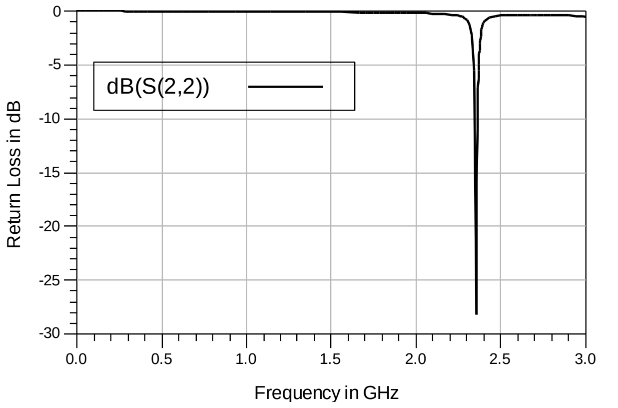


Fig. 8 Return Loss of Antenna 2

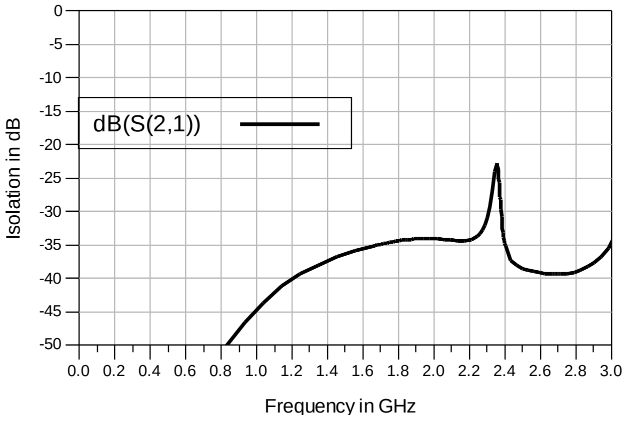


Fig. 6 Isolation for Antenna 1

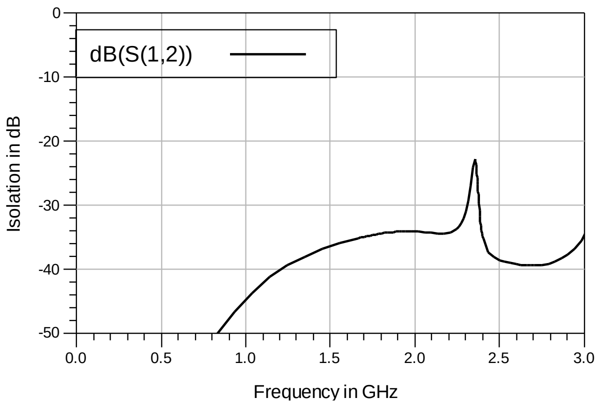


Fig. 9 Isolation for Antenna 2

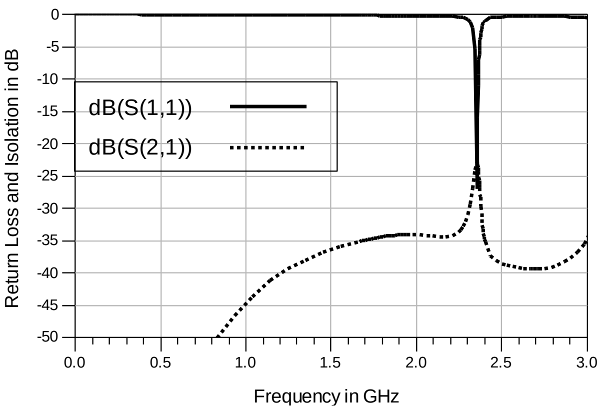


Fig. 7 Return Loss and Isolation for Antenna 1

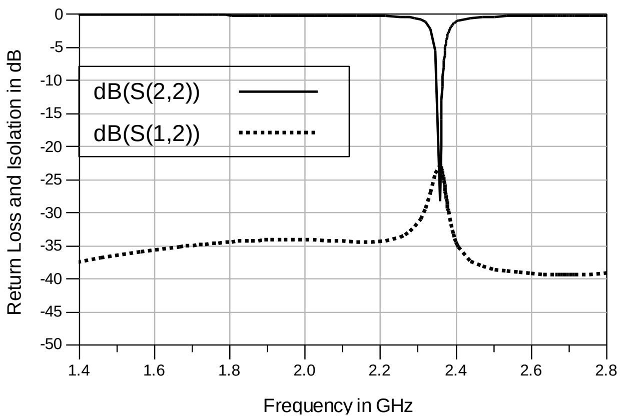


Fig. 10 Return Loss and Isolation for Antenna 2

The 3D structure of the proposed antenna is shown in figure 11. The main design criteria for MIMO wireless communication is Envelope Correlation Coefficient (ECC).

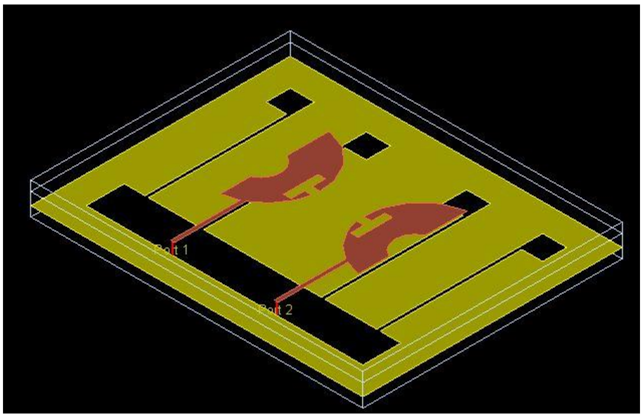


Fig. 11 3D View of the proposed MIMO antenna

The ECC is calculated from the formula,

$$\rho=|S^*_{11} S_{21}- S^*_{12} S_{22}|^2/(1-|S_{11}|^2-|S_{21}|^2)(1-|S_{22}|^2-|S_{12}|^2)....(1)$$

where **ρ** represents the Envelope Correlation Coefficient. The proposed MIMO antenna has ECC as 0.3 which is less than 0.5. Since having low ECC it has high isolation to be suitable for high datarate MIMO communication.

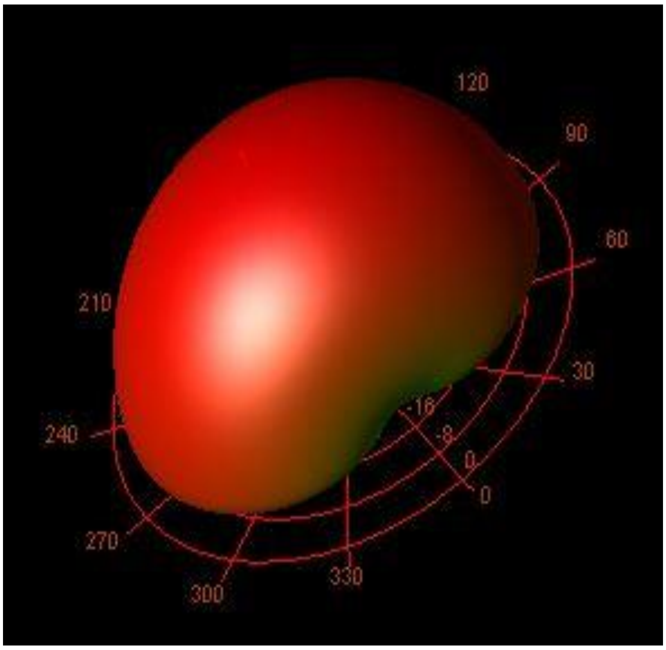
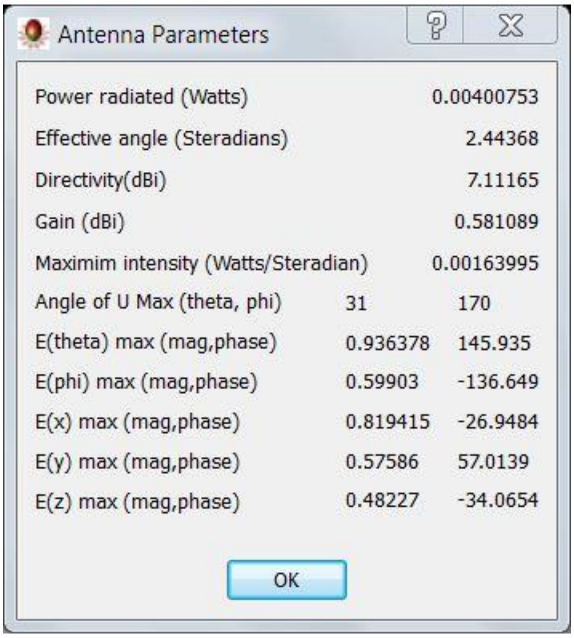


Fig. 12 Radiation Pattern of the Proposed MIMO antenna

The MIMO antenna radiation pattern shows the omni direction pattern which is shown in figure 12. The antenna parameters are shown in the following figure 13.

The simulated gain and directivity of the proposed MIMO antenna at 2.4GHz are 0.5dBi and 7.1dBi. The absolute fields of E theta, E phi and H theta, H phi at 2.4GHz is shown in figure 14, 15.



Antenna Parameters

Power radiated (Watts)		0.00400753
Effective angle (Steradians)		2.44368
Directivity(dBi)		7.11165
Gain (dBi)		0.581089
Maximim intensity (Watts/Steradian)		0.00163995
Angle of U Max (theta, phi)	31	170
E(theta) max (mag,phase)	0.936378	145.935
E(phi) max (mag,phase)	0.59903	-136.649
E(x) max (mag,phase)	0.819415	-26.9484
E(y) max (mag,phase)	0.57586	57.0139
E(z) max (mag,phase)	0.48227	-34.0654

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Fig. 13 Antenna Parameters

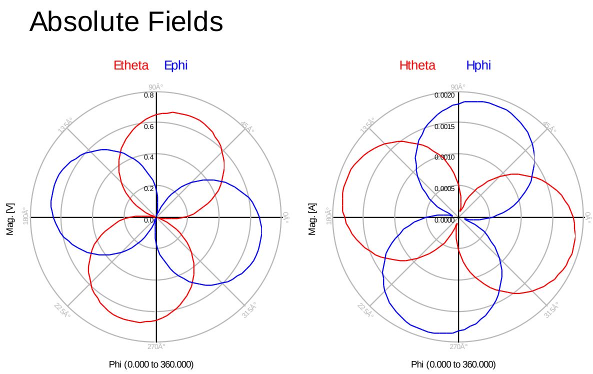

Fig. 14 Absolute Fields

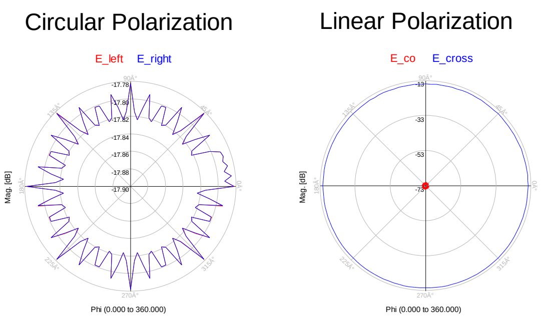

Fig. 15 Polarization of the Proposed MIMO Antenna

IV. CONCLUSION

A Semi circular shaped MIMO antenna element with t shaped slot and with U shaped ground is presented. U shaped ground structure is implemented to reduce the mutual coupling between closely spaced antennas and hence isolation is improved. The isolation obtained at 2.4GHz ISM band is <25dB with compact MIMO antenna structure. It has low ECC which results in further proof of better isolation to be suitable for MIMO communication. The Return loss is less than 27dB. The observed gain of an antenna is 0.5dBi and directivity is 7.1dBi at 2.4GHz. Hence this antenna is suitable for ISM band application.

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