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Isolation Enchancement using Flag Shaped Stub in Compact MIMO Antenna

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***Abstract:** In this paper, a tri-band MIMO (multiple input, multiple output) antenna for WiMAX, WLAN and LTE applications are obtainable. The designed MIMO antenna is of size 36×22mm^2 with two indistinguishable monopole antenna components (MA) which are put on one side of the substrate. The ground plane with Flag-molded stub is put on the opposite side of the substrate to decrease shared coupling between the antenna components. Due to Flag- Shaped stub it introduces a new coupling path, which cancels the coupling between the MAs and enhance isolation. The operating bands of the proposed antenna are 2.4-2.74GHz, 5-5.4GHz, and 9-11GHz due to the slits and slots placed besides Flag-shaped stub. The isolation is better than 18dB and 20dB at lower band and upper band respectively.*
***Keywords:** MIMO antenna; Flag-shaped stub; multistandards;*

I. INTRODUCTION

A MIMO antenna is utilized as a reason of enhancing the channel capacity without the need of additional power or frequency band. Coupling should be less between the antennas in the transmitter. Area is a main constraint for the design of antenna, since MIMO antenna is compactly designed, the mutual coupling is high between the antennas. This can be reduced by implementing optimized isolation technique. Different techniques are used in the below mentioned reference papers such as meandered lines [5], tree-like structures [6], open stub [7] and protruded ground [8].

The issues of isolation, bandwidth and miniaturization of the multi wideband MIMO antennas are addressed in the reference papers [5-10]. References [9-10] operates at only one frequency band and unable to meet the characteristics of MIMO antenna. Reference paper [12] operates at two frequencies bands of 1920-2170MHz and 2400-2480MHz with the size of 95× $60mm^2$. In reference paper [1] designed antenna operates at dual wideband. It operates at lower band of 2.5-2.85GHz and upper band of 4.82-6.1GHz with a size of 36× $22mm^2$.

The MIMO antenna is consider to be effectively designed when the antenna size is small with high isolation. The proposed antenna serves the wireless applications such as LTE2500, WiMAX and WLAN (wireless local area network). The proposed antenna with a size of 36× $22mm^2$ has successfully covered three wideband of 2.4-2.74GHz, 5-5.4GHz and 9-11GHz that are able to operate in LTE2500 (2.5-2.7GHz), WLAN (5.15-5.35GHz), WiMAX (2.35GHz, 2.5GHz), Radar Detector(10.475-10.585 GHz), aeronautical navigation(9.3-10GHz), aeronautical military system (9.3-10.5GHz)

II. ANTENNA DESIGN

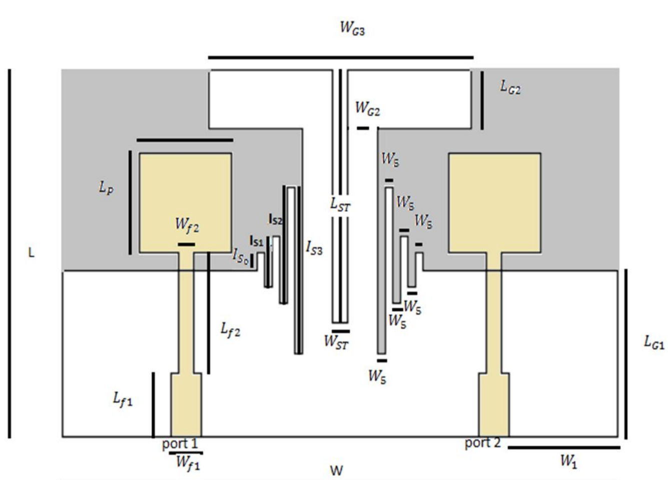

Fig. 1. Geometry of the proposed MIMO antenna, top layer (yellow color) and bottom layer (white color)

L	L_{G1}	L_{G2}	L_P	L_{F1}	L_{F2}	L_{ST}	I_{S1}	I_{S2}	I_{S3}
22	10	3.5	6	3.8	7.2	15.2	2	7	10
W	W_{G1}	W_{G2}	W_{G3}	W_{F1}	W_{F2}	W_{ST}	W_S	I_{S0}	
36	36	1.9	17	2	1	1	0.5	1	

Table: Dimensions Of Proposed Mimo Antenna

The dimensions of the projected MIMO antenna is depicted in Fig. 1. The antenna is realized on a $36 \times 22mm^2$ FR4 substrate. This substrate is 1.6mm thick has relative dielectric constant of 4.4 and has loss tangent 0.019. The MIMO antenna consists of two identical monopole antenna elements represented as MA_1 and MA_2. A Flag-shaped stub is placed at the center on the ground. Flag-Shaped stub is hosted on the ground to reduce the mutual coupling between elements and enhance the isolation between ports 1 and 2. The two antenna elements, MA_1 and MA_2 are placed in parallel on side of the substrate with dimensions of $L_p \times L_p$ are fed by micro strip line with dimensions of $W_f \times L_f$ through port 1 and 2. The ground plane placed on back side of the substrate with dimensions $W \times L_{G1}$ and as a rectangular slits with dimensions of $W_{ST} \times L_{ST}$.

III. RESULTS AND ANALYSIS

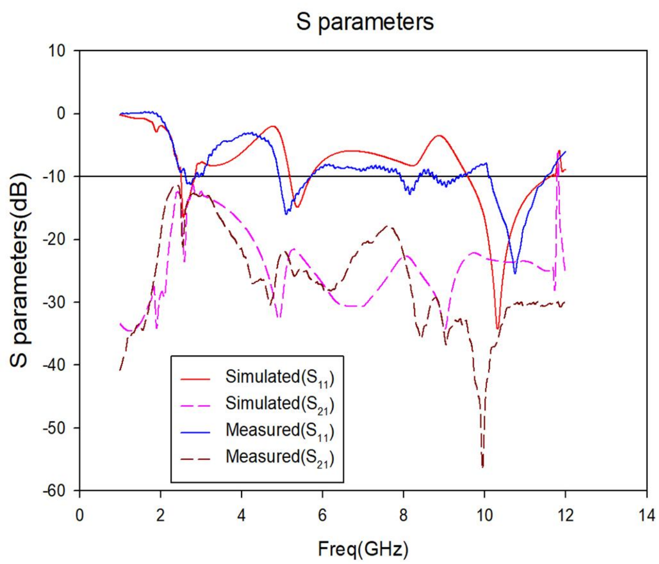

Fig. 2. Simulated and Measured Results S_{11} and S_{21} of MIMO antenna.

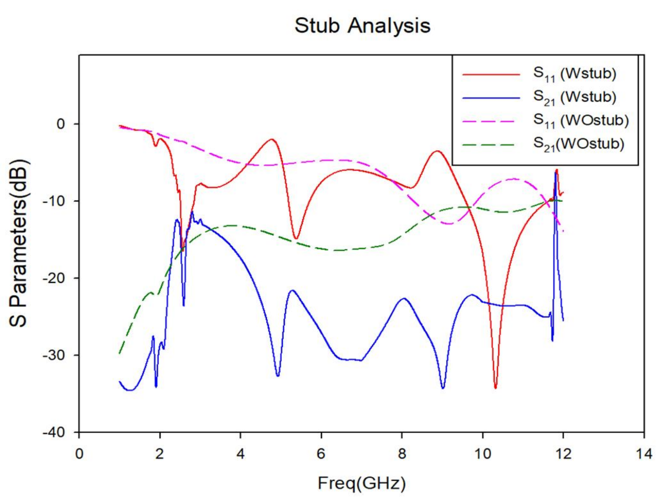

Fig. 3. Comparison between S_{11} and S_{21} with and without T-shaped stub.

When Flag-Shaped Stub is excluded from the designed MIMO antenna the Return loss is -2dB at 2.58GHz, -5dB at 5.2GHz and -8dB at 10.55GHz. Again when Flag-Shaped Stub is introduced better Return loss is obtained at all three frequencies and isolation increases rapidly due to the coupling path introduced by the Flag-Shaped Stub and cancel out the coupling between Monopole antennas.

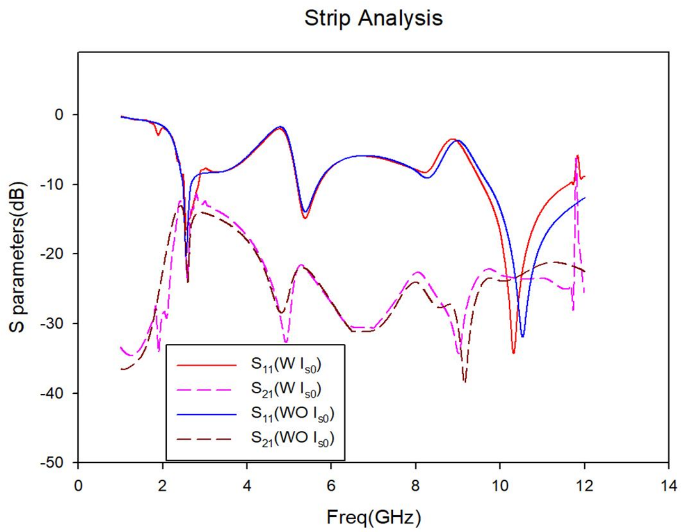

Fig. 4. Simulated Results S_{11} and S_{21} with and without stripI_{s0}.

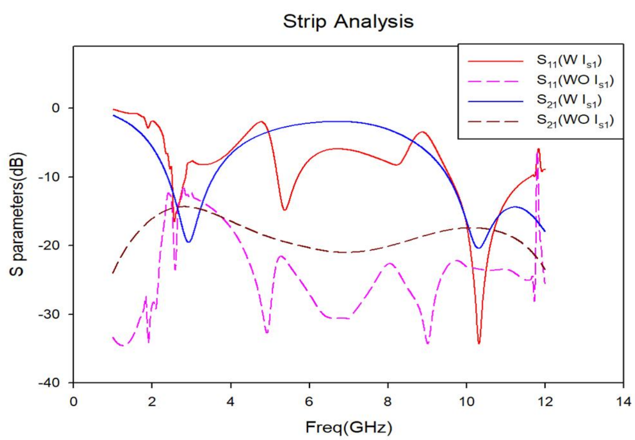

Fig. 5. Simulated Results S_{11} and S_{21} with and without stripI_{s1}.

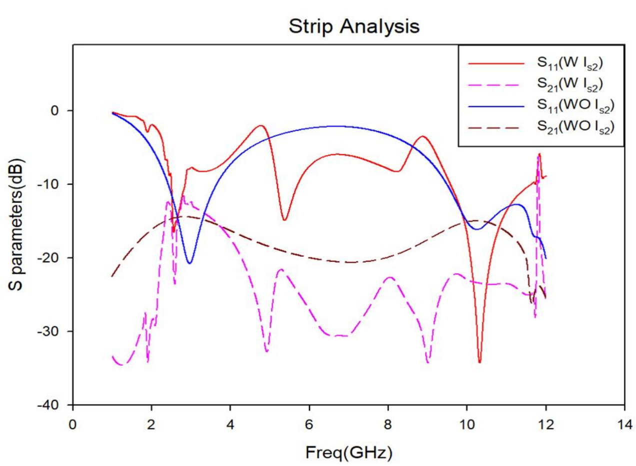

Fig. 6. Simulated Results S_{11} and S_{21} with and without stripI_{s2}.

Above Fig .4, Fig .5 and Fig .6 represent the analysis of S parameters of MIMO antenna with and without strips I_{s0}, I_{s1} and I_{s2}.

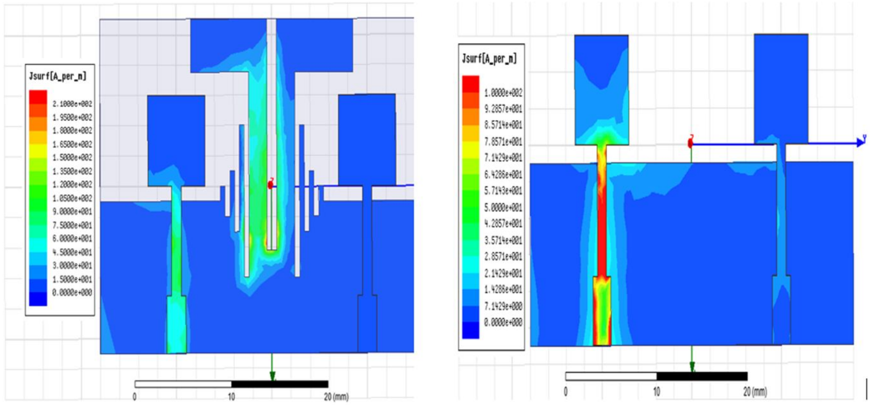

Fig. 7. Simulated Current Distribution Results with and without T shaped Stub at 2.58GHz.

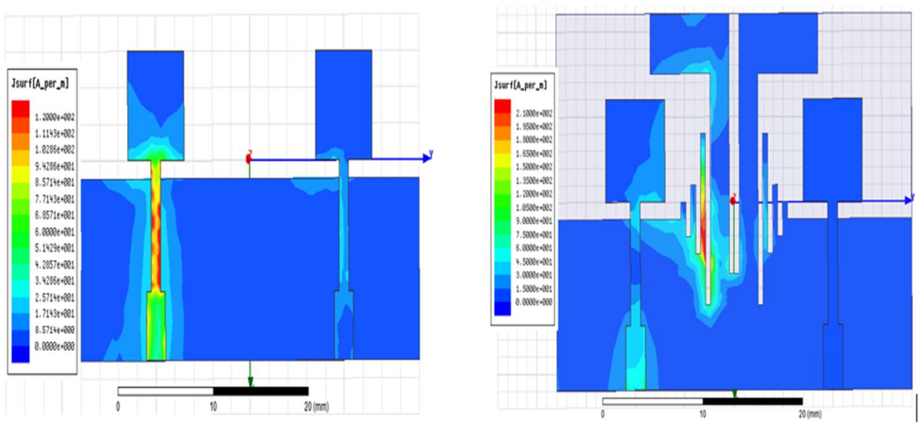

Fig. 8. Simulated Current Distribution Results without and with T shaped Stub at 5.2GHz.

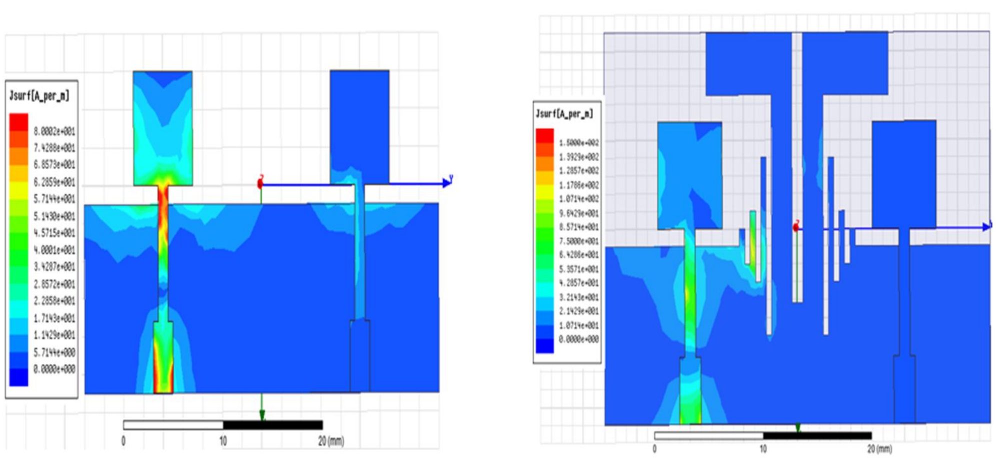

Fig. 9. Simulated Current Distribution Results without and with T shaped Stub at 10.55GHz.

Without T shaped stub in the proposed MIMO antenna there will be a high coupling between two Monopole antennas, this can be observed in Fig .7 for 2.58GHz and similarly for other two other frequencies in Fig .8 and Fig .9. As we have implemented Defective Ground Structure (DGS) technique by introducing T shaped stub and strips produces another coupling path and this creates another coupling current which cancel out the signal between the two Monopole antennas. We can observe that the coupling between two Monopole antennas in Fig .7, Fig .8 and Fig .9 for 2.58GHz, 5.2GHz and 10.55GHz respectively.

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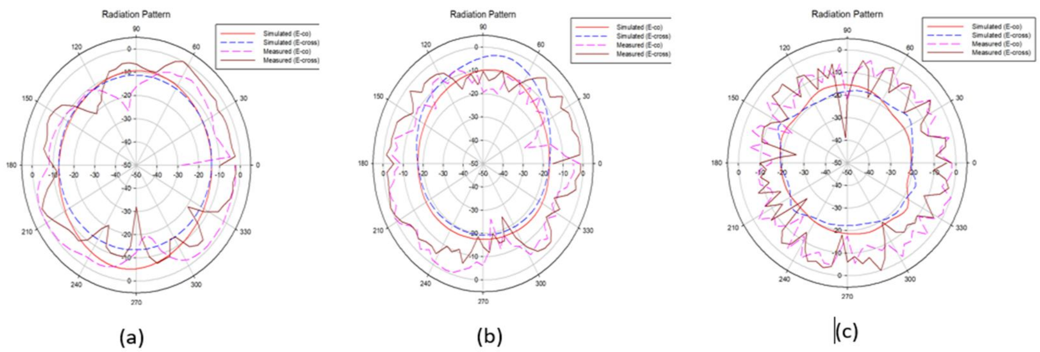

Fig. 10. Radiation Pattern of E-co and E-cross at 2.58GHz, 5.2GHz and 10.55GHz.

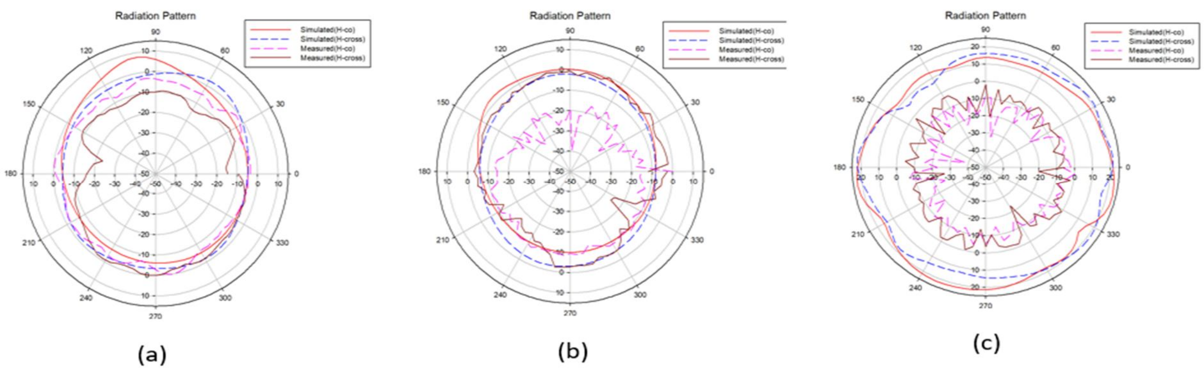

Fig. 11. Radiation Pattern of H-co and H-cross at 2.58GHz, 5.2GHz and 10.55GHz.

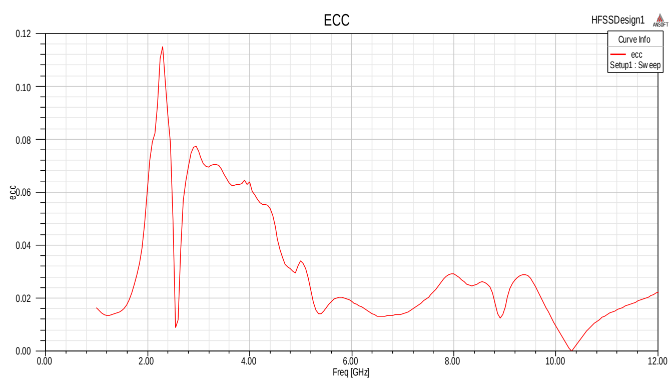

Fig. 12. Envelope correlation coefficient (ECC) of MIMO antenna.

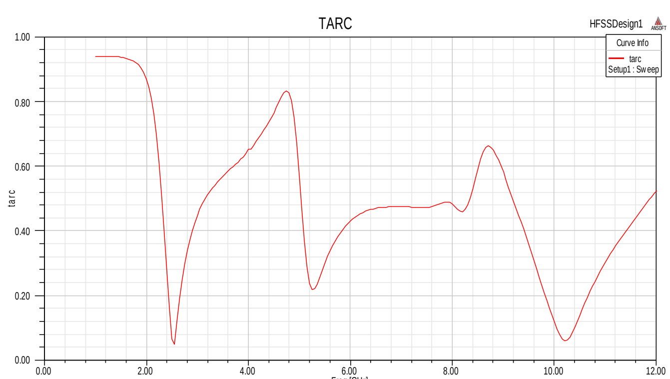

Fig. 13. Total Active Reflection Coefficient (TARC) of MIMO antenna.

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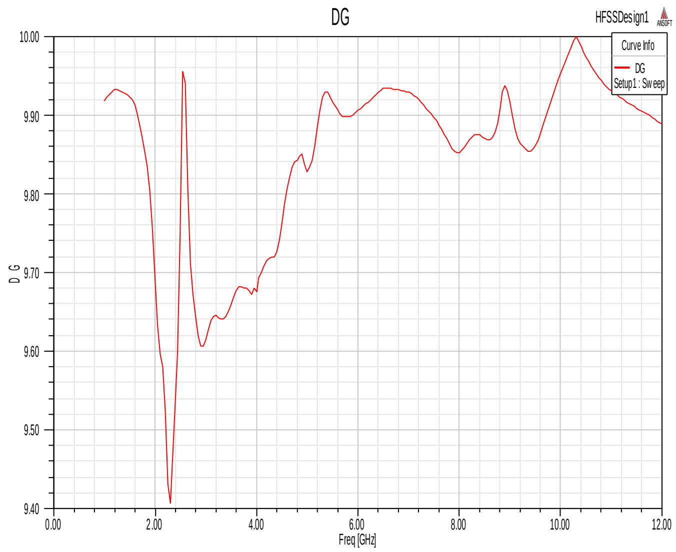

Fig. 14. Diversity gain (DG) of designed MIMO antenna.

The Envelope correlation coefficient (ECC) and Diversity Gain (DG) are two significant parameters to calculate the effectiveness of the MIMO antenna system. ECC concludes how individualistic the two antennas radiation patterns are. On the off chance, that one antenna is very horizontally polarized and the other antenna is very vertically polarized then the correlation between the two antennas would be zero. When ECC=0, it expresses that the antennas are completely decoupled, while ECC=1, it expresses that the antennas are essentially short circuited.

$$|\rho_{e12}|^2 = \left| \frac{|S_{11}^* S_{12} + S_{21}^* S_{22}|^2}{|(1-|S_{11}|^2-|S_{21}|^2)(1-|S_{22}|^2-|S_{12}|^2)\eta_{rad1}\eta_{rad2}|^{\frac{1}{2}}} \right|^2 \qquad (1)$$

Where 1 and 2 refers to the antenna elements 1 and 2 and radiation efficiencies of the antenna elements are η_{rad1}, η_{rad2}. MIMO antenna must satisfy the condition of low correlation [$\rho_{e12} < 0.5$]. In the Fig. 12, we can notice that the simulated result for ECC of the MIMO antenna is less than 0.12.

Diversity gain is characterized as the increase in the Signal to Noise (SNR) due to addition of one or more communication channel, or how much transmission power can be reduced when diversity scheme is introduced, without any loss. Diversity gain (DG) is expressed in terms of decibels (dB). The diversity gain (DG) for the proposed MIMO antenna is obtained using equation (2).

$$DG = 10\sqrt{1 - |\rho_{e12}|^2} \qquad (2)$$

TARC is characterized as the proportion of the square root of total reflected power divided by the square root of total incident power, TARC can be expressed as

$$\Gamma = \sqrt{\frac{|S_{11} + S_{12}^* e^{J\theta}|^2 + |S_{21} + S_{22}^* e^{J\theta}|^2}{2}} \qquad (3)$$

The Total Active Reflection Coefficient (TARC) for the proposed MIMO antenna is simulated using the equation (3).

IV. CONCLUSION

The proposed antenna is of dimension $36 \times 22mm^2$ with two Monopole antennas placed above the surface of the substrate and T-shaped stub and strips are located on other side of the substrate. This stubs and strips introduces an additional coupling path and this path creates a coupling current, reduces the coupling effect between the two identical monopole antennas, and increases the isolation between the antennas. The designed MIMO antenna operates at three band of frequencies 2.4-2.74GHz, 5-5.4GHz and 9-11GHz respectively. The Proposed MIMO antenna is intended for various applications such as LTE2500, WiMAX and WLAN. The Designed antenna of size of $36{\times}22mm^2$ has effectively secured three wideband of 2.4-2.74GHz, 5-5.4GHz and 9-11GHz that has applications in LTE2500 (2.5-2.7GHz), WLAN (5.15-5.35GHz), WiMAX (2.35GHz, 2.5GHz), Radar Detector(10.475-10.585 GHz) , aeronautical navigation(9.3-10GHz), aeronautical military system(9.3-10.5GHz).

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