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A Flag-like MIMO Antenna Design for Wireless and IoT Applications

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Abstract*: An UWB antenna having two notch bands is proposed in this paper. This structure helps to improve the isolation characteristics and is used for Wi-max and WLAN applications. For enhancement of isolation here we used two split ring resonators on left and right of the feedline with the edge to edge spacing of 0.5. Further, some parameters like Envelope Correlation Coefficient (ECC), diversity with respect to gain, efficiency with respect to efficiency, peak gain and radiation patterns are discussed. Two pairs of split ring resonators act as a decoupling-elements which leads to the formation of two notch bands between 5GHz to 8GHz(C-Band), 10.4GHz to 10.7GHz (X-Band). A stable gain of 4.2dB and efficiency of 89% is maintained throughout the UWB region. The proposed design is stimulated using ANSYS electronic desktop 19 and prototype is fabricated using FR4 substrate on PCB prototype machine. The results obtained from the simulation tool and from the experimental setup are analyzed which shows that proposed MIMO diversity antenna is suitable for dual notched UWB applications.

Index Terms*: Ultra-wide band antenna (UWB), MIMO antenna.

I. INTRODUCTION

MIMO antenna technology is emerging in the field of wireless communications nowadays.

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The major issues that are occurred in the communication link usually, the non-line-of-sight problems and multi path signal fading and this causes the communication terrible with low signal reception. MIMO antennas can be a good solution to mitigate these impairments which helps to improve the system capacity.

Smart devices now a days are utilized very much in the modern Internet of Things connected devices for which compact printed antennas are required. However, considering the issue of space within the portable devices, accommodating multiple antennas within the module is challenging.Taking into the account of working frequencies and constrained accessibility of space, ports of antenna are subjected to the high mutual coupling between each other. So, there is huge requirement for small and productively efficient MIMO antenna with more separation and less mutual coupling [2-5]. The major point focused in MIMO framework is that it can transfer 7.4 GHz of data (within the range of 3-10GHz) with very less power. The rise of the Internet of Things (IoT) in the most recent couple of years has prompted an expanding interest for wireless communication modules which are undetectably coordinated within basic objects and that help high amount of data transmitted at once to meet the prerequisites of different kinds of future rising wireless applications [6]. Applications of IoT includes sensor-based information gathering, wireless communication, control system etc. The applications mentioned are used for only short distance communication with radio recurrence, cost management, accessibility of heaps of transmission capacity, advancement and the most prominent test. These include main highlights that shows this design is ideal for IoT applications [7-8]. Previously, numerous antennas having bandwidth from 3.1GHz to 10.6GHz are reported in the references [9-12]. A hexagon-like MIMO antenna is given the reference [9] which is used as a grounded stub and it works from 3GHz-11 GHz where inter-port isolation is more than 20 dB. A MIMO antenna configuration consisting of A-shaped dielectric resonator antenna is proposed in the reference [10] gives a genuinely steady radiation design, offers an impedance bandwidth from 3.24GHz to 6.0 GHz and with the better isolation more than 20dB. A MIMO antenna comprising of 4 ports and monopole of L-shape coordinated using SRR is presented in reference [11]. The 2 port MIMO antenna having cylindrical dielectric resonator is given in the reference [12], the isolation between the two ports is about 25dB.

All the papers given above proposed an improved version of UWB MIMO antenna modules, but with only limited analysis and also there exists some drawbacks. But, over the assigned range of frequencies that comes under UWB range, these antennas aim for the reduction of EMI with different standards in wireless communication. In order to resolve this problem, some monopole UWB MIMO structures with band notched characteristics have been demonstrated.

A MIMO antenna with 2 ports having notch at 2 bands with radiator attached to it using metal strip which was placed below the patch is proposed in the reference [13]. A UWB Multiple Input Multiple Output architecture using open stub that is designed to have one notch band is presented in [14]. Moreover, for the profitable usage of MIMO technology in the design of antennas, the mutual coupling, envelope correlation coefficient (ECC) and losses in the channels should to be less with large amount of isolation among the radiating elements.

LP	**WP**	**LF**	**WF**	**LG1**	**LG2**	**WG1**	**WG2**	**W**
8.95	**6.4**	**14**	**1.2**	**10.5**	**1**	**7**	**2**	**0.8**
L	**L1**	**W1**	**L2**	**W2**	**W3**	**W4**	**W5**	**-**
0.5	**2**	**1.6**	**3**	**0.5**	**0.4**	**0.5**	**0.8**	**-**

Table 1: Design parameters of proposed Ultra-wide Band antenna

II. ANTENNA DESIGN

The designed antenna is shown in the Figure 1. By using FR-4 material we have designed this antenna which has 0.8 mm thickness, loss tangent counts to 0.02 and dielectric constant of 4.3 as shown in Figure 1. The dimensions this antenna is measured to be 32mm × 24 mm × 0.8mm on overall. As we have the local wireless network frequencies in UWB range, we are adding the slots on the patch to add the notched characteristics wherever necessary and get the desired band required for IoT applications. This helps us to prevent the design from Electro Magnetic Interference (EMI) and consumes only little amount of power with higher data rates. The novelty of the plan is its simple structure and compactness. The upsides of this structure are smaller in size and being utilized for different applications at various frequency bands**.**

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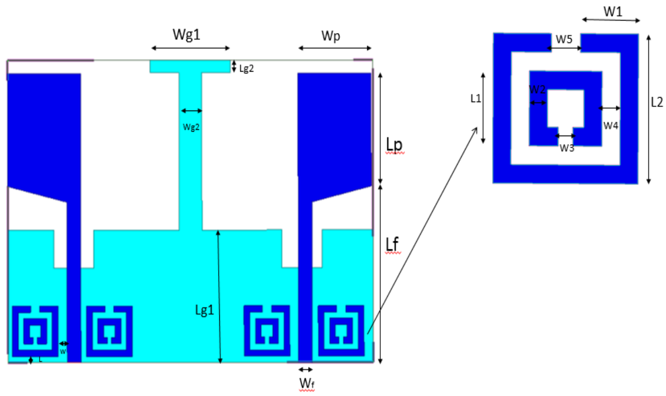
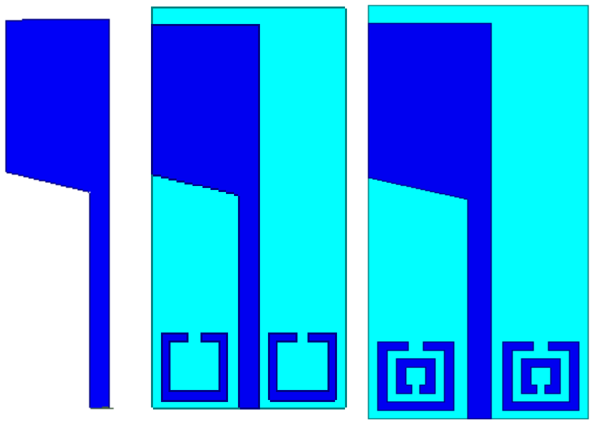


Figure.1 Geometry of the proposed antenna (top side, bottom side)

A. Design procedure

The High-Frequency Structure Simulation tool of ANSYS is used to model and simulate the proposed antenna design. The development of antenna involves mainly two steps. The plan of the antenna is introduced in the first step. In the second step deals with the design of split ring resonator (SRR). The antenna's iteration 0, 1 and 2 is shown in Figure 2



(a) (b) (c)

Figure.2 Antenna iterations.

[a] Zero iteration; [b]First iteration; [c]Second iteration

The antenna which is designed iteration wise is shown in figure 2. In iteration 2[a] a monopole antenna with flag shaped radiator, in iteration 2[b] single split ring resonators are accommodated (one on each side) on both the sides of feedline, in iteration 2[c] a single SRR is replaced with double SRR to improve bandwidth of the design. In addition to this a ground is attached to this model as shown in fig 4[a] but to improve the isolation characteristics we have manipulated the structure with T-shaped stub in the ground.

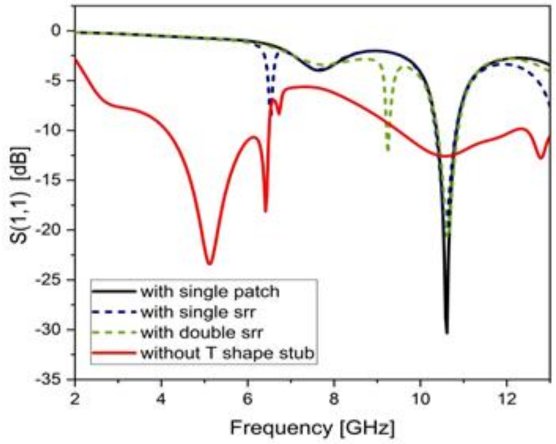


Figure.3 S parameters of Antenna for different iterations

For the analysis of the proposed UWB MIMO antenna, two iterations namely iteration A and iteration B are produced. In iteration A (fig 4(a)) and B(fig 4(B)) the analysis is based on structure of ground plane that is with and without t shaped stub. Bandwidth is more in iteration B due to the placement stub on the ground plane.

Also, two self-complementary SRR's are placed on each side of the antenna and are placed in the middle of ground plane is shown in the Figure 4. The ground-plane is etched underneath the substrate where the T-shaped ground stub coming vertically in between the 2 ports (radiating elements) which makes the two ports to be well isolated as shown in figure 5

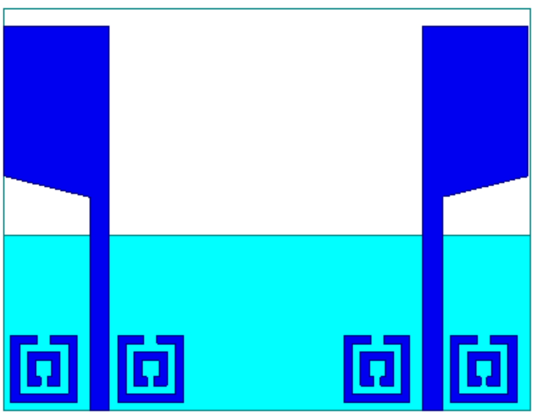


Figure 4(a) antenna with out t stub in ground

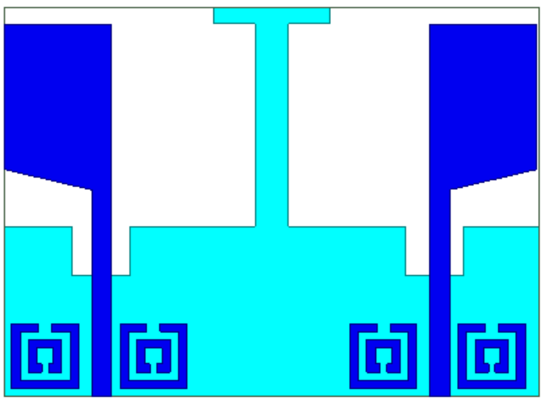


Figure 4(b) antenna t-shape stub in ground.

B. Effect of T-Shaped ground stub

The T-shaped ground stub helps in the enhancement of matching and isolation [14]. It is placed in the middle of the two elements as appeared in Figure 4. The variations in simulated S-parameters for the proposed design without adding the T-stub in the ground plane and adding it are presented in Figure 4 B.

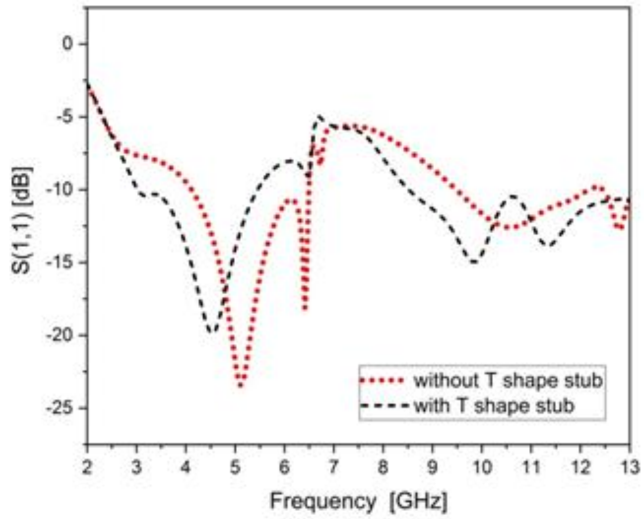


Figure 5. S paramters of UWB MIMO antenna with and without T-shape.

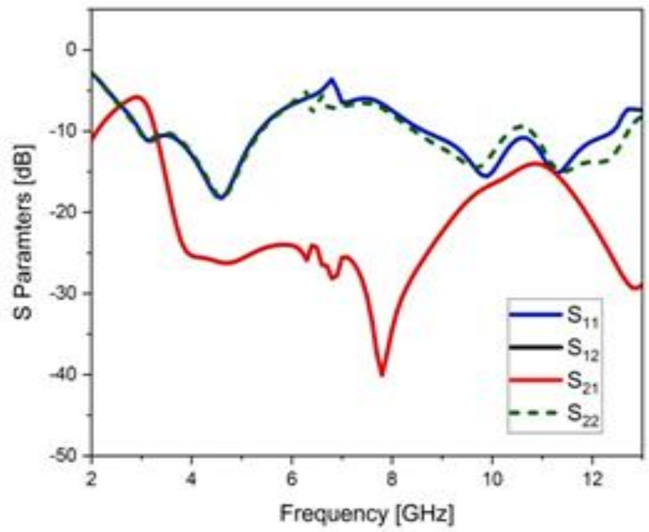


Figure 6. S parametrers of the proposed antenna.

III. RESULTS AND DISCUSSION

To validate this design, the preliminary version of the antenna structure is manufactured using PCB prototype machine and measured using combination analyzer. The measured and simulated outcomes vary slightly in the view of manufacture errors, and natural impacts. The simulated (reflection coefficient vs frequency) and practical results ought to have good correlation. The peak gain observed in measured results, swings between -2dB to 6dB across 3GHz–12GHz which can be understood from Figure 7 and more than 90% of the incident power is radiated throughout the UWB except for the notched bands which is interpreted in Figure 8.

Figure 9 shows the fabricated pictures prototyped antenna.

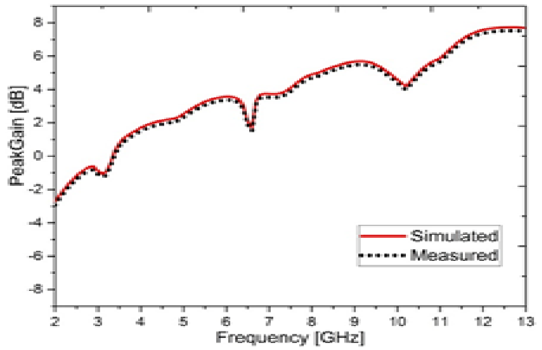


Figure 7. Peak gain vs Frequency Simulated and measured.

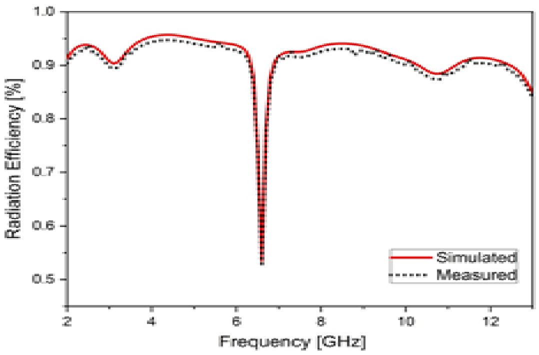


Figure 8. Radiation efficiency Simulated and measured.

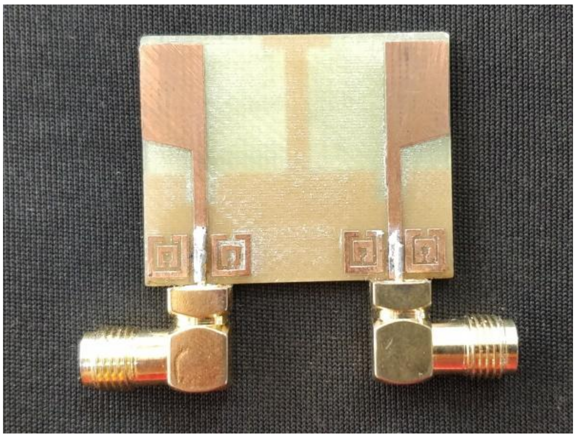


Figure 9(a) Top side of fabricated antenna.

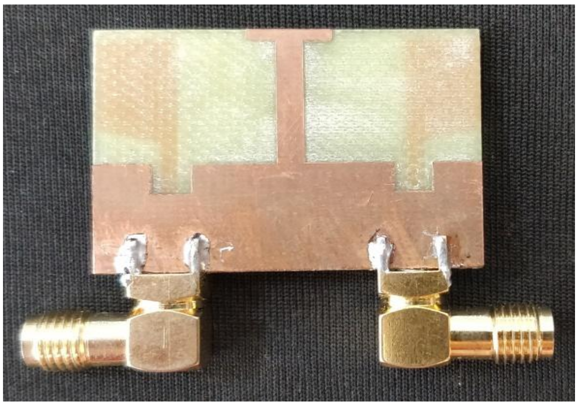


Figure 9(b). Bottom side of fabricated antenna.

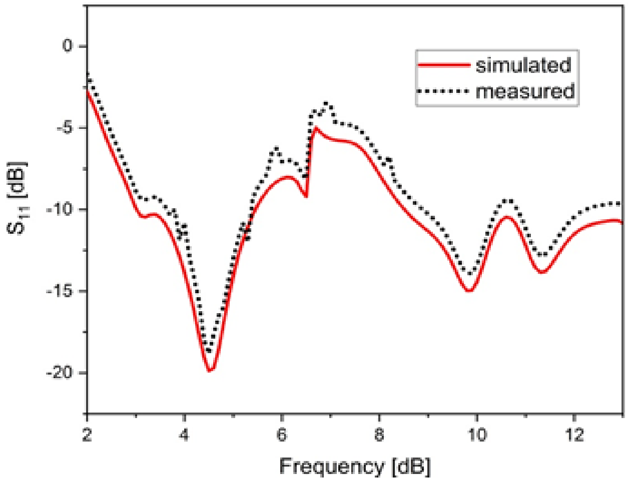
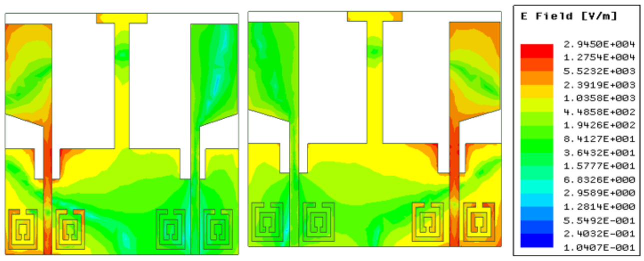


Figure 10. Simulated and measured S_{11}-parameter vs frequency characteristics of proposed antenna.

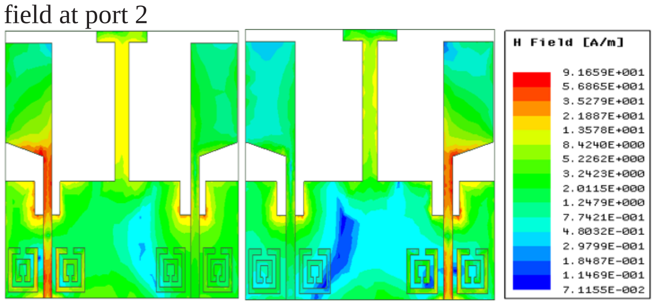
A. Surface current distribution

The sense of polarization vector is understood using Surface current distribution is shown in figures 11(E field at 4.8, 9.2, 11.7 GHz), 12(H field at 4.8, 9.2, 11.7 GHz), 13(J field at 4.8, 9.2, 11.7 GHz). As to know the extent of mutual coupling effects in the proposed antenna elements, E-field, H-field and current distribution plots are taken. These plots show there is a good agreement considering the less mutual coupling and high isolation due to the placement of SRRs. The T-shaped stub that is extended from the top edge of the ground plane prevents the mutual coupling between element 1 and element 2 and thus the isolation is maintained which can be observed through the field distribution plots when each element excited individually by terminating other with a matched load.



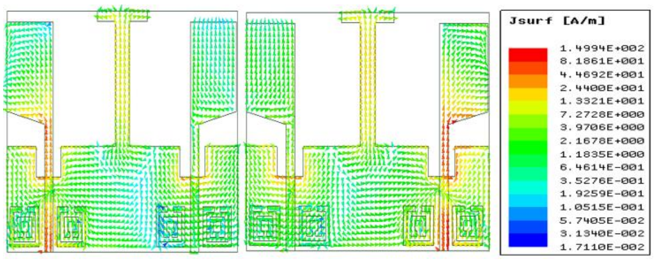
(A) (B)

Figure.11 (A) Simulated E field at port-1 (B) Simulated- E field at port 2



(A) (B)

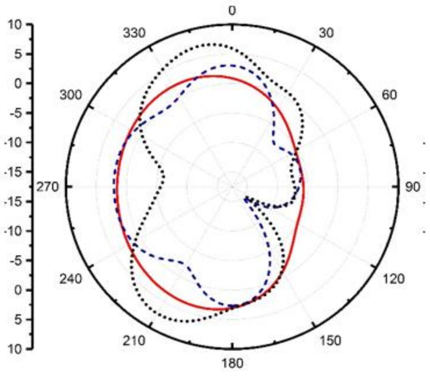
Figure 12. (A) Simulated- H field at port1; (B) Simulated-H field at port 2



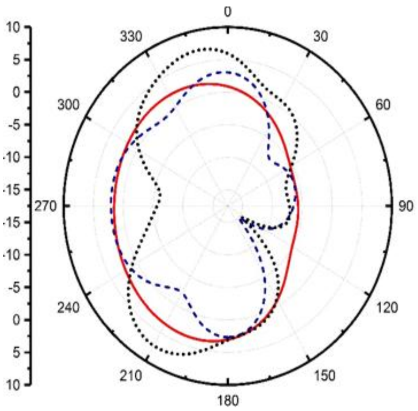
(A) (B)

Figure 13. Simulated surface current distribution (A) at port-1 (B) at port-2

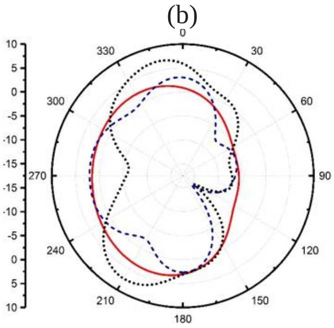
B. Radiation Pattern



(a)



(b)

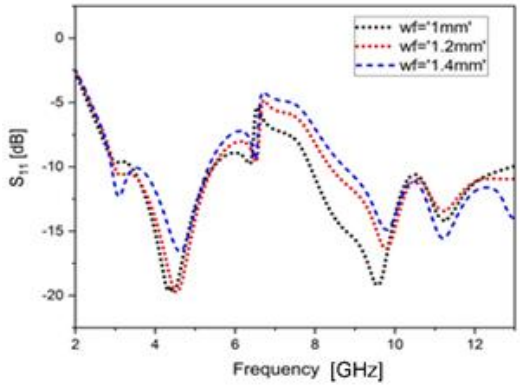


(c)

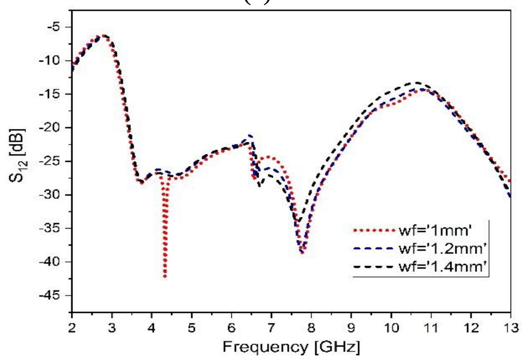
Figure.14 2D-Radiation patterns (a) XY-plane, (b)YZ-plane, (c)ZX-plane

C. PARAMETRIC ANALYSIS

The parametric analysis as for the antenna measurements are exhibited in this section. The reduced dimensions are recognized and utilized in the antenna fabrication process.

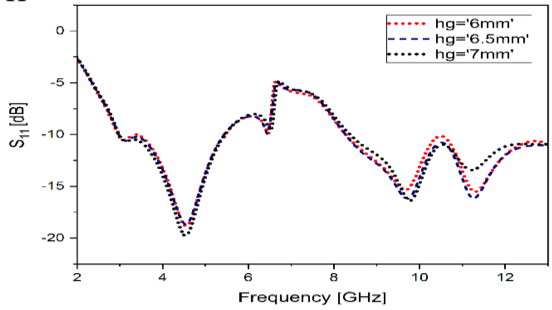


(a)

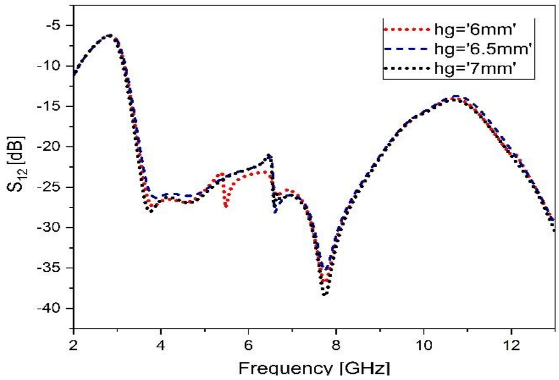


(b)

Figure.15 reflection coefficients for change in feed width (a) S_{11} parameters, (b) S12 parameters

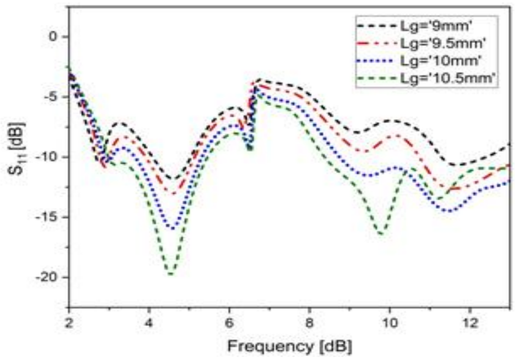


(a)

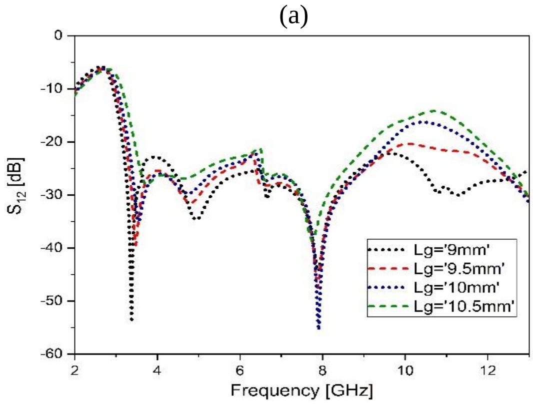


(b)

Figure.16 reflection coefficients for change in height of ground (a). S_{11} parameters, (b).S12 parameters



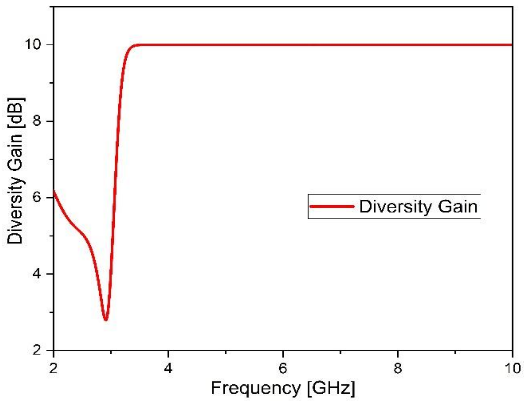
(a)



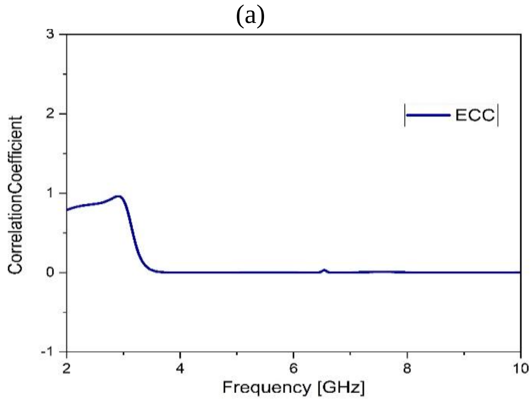
(b)

Figure.17 reflection coefficients for change in length of the ground
(a). S_{11} parameters, (b).S12 parameters

D. MIMO Performance



(a)



(b)

Figure.18 MIMO Performance
(a) Diversity gain, (b) ECC

IV. CONCLUSION

A simple SRR loaded, dual band-notched Ultra-Wide Band (UWB) MIMO antenna for IoT applications is proposed and discussed in this paper. The prototyped antenna of size 32mm×24mm having T-Shaped ground plane and tapered microstrip feeding lines with a flag shaped patch is proposed to enhance impedance matching and isolation characteristics. The simulated and practical results show that the antenna works in UWB (3.1 GHz -10.6 GHz) except at two bands, 5.43 GHz to 8.54 GHz (C-band) and 10.4 GHz to 10.7 GHz (super extended X-band). The ECC, diversity gain, peak gain indicates that it has all features to work as a good radiating element for UWB diversity enabled communication systems.

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