INVESTIGATION ON ORTHOGONALLY ALIGNED METAMATERIALS INSPIRED MIMO ANTENNA FOR ULTRAWIDEBAND APPLICATIONS

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***Abstract*— This work proposed a dual band MIMO diversified antenna inspired from metamaterial techniques. proposed antenna has identical two elements strip shaped patch kept orthogonally to each other. Based on simulated riddles the antenna is working at ultra-wide-band region i.e. from 3.01 GHz to 10.6 GHz. The influence of metamaterial is very clear that the proposed antenna transmission coefficient is <-15 dB. At proposed working bands in addition to that the antenna has a stable gain of 3.5 dB over the band and efficiency of 80% is observed. With available limited spectrum Ban allocation the Prabodh antenna can be used for beyond 5G applications in ultra-wide-band region.**

I. INTRODUCTION (*HEADING 1*)

In recent years, the use of wireless antennas applications increased widely Because of their working regions and performance capabilities. Key factors such as bandwidth, gain, and antenna size are evaluated to achieve optimal performance. Many studies have aimed to create a single antenna that can cover all specified frequencies. The properties of Metamaterials will play a vital role in the electromagnetic environment. The [1] split ring resonators (SRRs) and complementary split ring resonators (CSRRs) structures are employed in the antenna design to achieve the WLAN and WiMAX operating frequencies. Splitting resonators are proposed by D.R smith et.al [2], which are having negative permeability or permittivity. The WLAN and WiMAX frequency bands were achieved through the implementation of a slotted ground structure combined with a metamaterial rectangular split-ring resonator. In [3] achieving electromagnetic characteristics, a artificial material consists of systematically arranged small artificial units and difficult to found in natural substance. Metamaterials with negative permeability and permittivity are well-known and valuable in telecommunications research. Compared to traditional narrowband antennas, UWB antennas offer improved channel capacity, diversity gain, high data transmission rate and easy integration. The UWB [6] frequency range, specified by the Federal Communication Commission protocol, spans from 3.2 to 10.6 GHz, supporting indoor applications and Handheld gadgets. To achieve UWB [4] characteristics, conventional techniques include modifications in the feeding line, defects in the ground plane, direct modification of the radiating elements, and slot antennas. They are more number of applications for UWB such as mobile communication, WIFI, WIMAX, Bluetooth, UMTS, WLAN, 4G, 5G and space communication [5].

Multiple-input, multiple-output (MIMO) has been widely utilized in different systems. A reconfigurable MIMO antenna for WLAN and UWB applications has been reported in [7]. The antenna will be impacted by the wideband mutual coupling between UWB MIMO elements [8]. A wideband parasitic element, inserting a tree shape, was positioned between two monopoles in [8]. For diverse applications, MIMO antennas [9] operate across lower ranges as well as high frequencies. Improving isolation between antennas is essential for both UWB performance and MIMO elements. [8] By placing isolation element between the elements, reducing mutual coupling among MIMO elements achieve UWB applications. As designed in [10], the UWB monopole antenna operates from 2.3–7.7 GHz, with a T-shaped reflector placed between the two radiators to reduce mutual coupling. The antenna in [9] operates within the 3.1 to 5 GHz range, missing coverage for the full 3.1 to 10.6 GHz band, despite offering good isolation and having compact dimensions of 37x45 mm in the introduced UWB multi-antenna system.

In this paper, we proposed a dual band MIMO diversified antenna inspired from metamaterial technique, the antenna is simulated on Rogers RT/Duroid 6803 material. To minimize the mutual coupling between the elements incorporating the SRR structures in the proposed antenna which results the enhanced bandwidth. To obtain the circular polarization effect Asymmetrical ground technique is used. Subsequently CSRR is cut in the Asymmetrical ground to get the desired characteristics. The UWB ranges from 3.02 GHz to 10.6 GHz, in addition the antenna operates up to 11.25 GHz. In the rest of the paper, three sections are Showcased, in section II antenna design, geometry, and antenna evolution are explored. The simulated results are in Section III, the

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comparison of the proposed antenna with recent literature is included. In section 4 final conclusion is presented.

II. ANTENNA EVALOUTION

A. *Selecting a Template (Heading 2)*

The proposed antenna is constructed using Rogers RT/Duroid 6803 as substrate material with overall size antenna 25x45x0.1mm and dielectric constant of the substrate is 2.2 and loss tangent is 0.008 with the thickness of 0.1 mm. For the proposed antenna the HFSS software is used for design and simulation. The both elements are fed by 50-Ω microstrip line.

The following design equations are used for the calculation of antenna dimensions

A. The operating wavelength $\lambda_0 = {}^{c}\!/_{f_r}$

where "C" is the speed of the light and "fr" is the resonant frequency

B. Guide wavelength $\lambda_g = {}^{\lambda_0}\!/_{\sqrt{\varepsilon_r}}$

Relative dielectric constant ε_r

C. Thickness of the substrate $h_s \leq \dfrac{0.3^{*} c}{2\Pi f_r \sqrt{\varepsilon_r + 1}}$

B. *Iterations of single element*

Initially in the 1st iteration as shown from figure 2 (a) where the elements of antennas are orthogonally aligned one vertically oriented and other is horizontally placed for polarization diversity and Asymmetric stubs are incorporated of varying length on either sides of feedline. Both elements failed to operate at threshold level with a minimum reflection Coefficient -10dB. To get operational working ranges Figure 2(b) in 2nd iteration introduced the asymmetrical ground planes on either sides of both antennas, working at 4.38GHz . In 3rd iteration double-ring Split Ring Resonators (SRRs) were integrated as show in figure 2(c), resonates at 3.87 to 9.03GHz. In the 4th iteration the CSRR rings are placed on asymmetric ground plane. The EM signal traveling through the feed line creates an EMF in the SRR, causing oscillating currents between its rings. This effect changes resonant

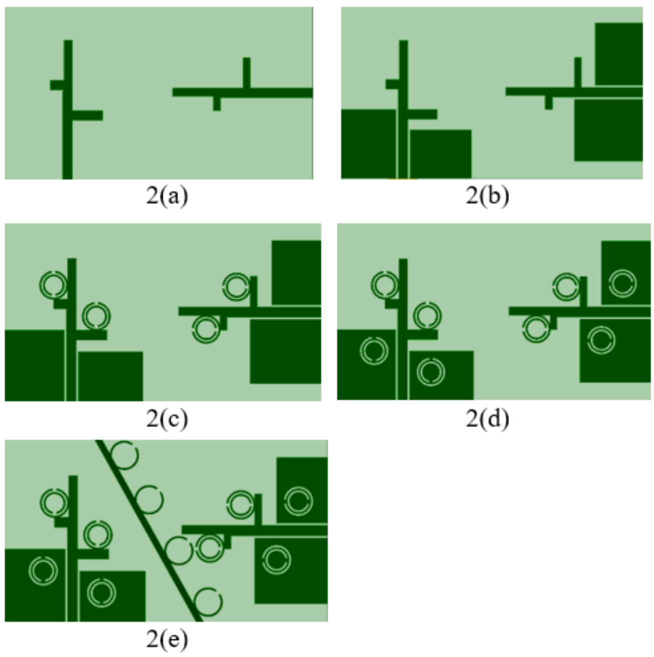


Fig.2 Different Iterations 2(a), 2(b), 2(c), 2(d) and 2(e)

working frequency from 3.87 GHz to 10.66 GHz. To Lessen the Cross-coupling between elements introducing a stub 45 degree slant as shown in the figure 2(e), where SRR rings are incorporated on orthogonal side of the stub, Which give a working range of 3.68GHz to 11.02 GHz.

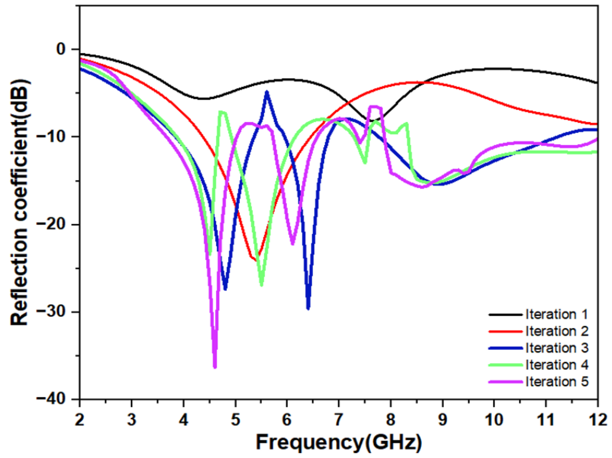


Figure 3 Reflection coefficient

These geometric factors directly influence the antenna's performance metrics, such as bandwidth, frequency and radiation pattern. The designed antenna is operates within ultrawide band range where 3.02GHz to 10.06GHz and it has been noted that the antenna functions up to 11.03GHz.

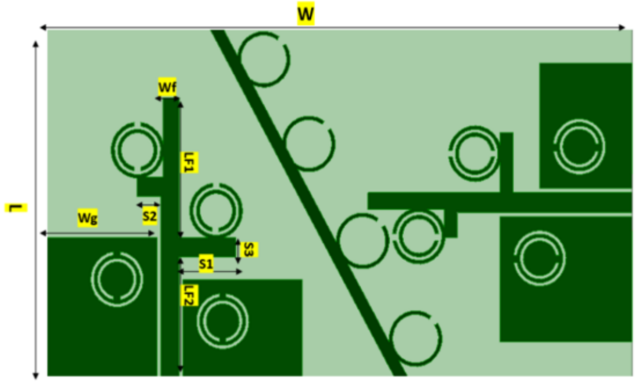


Figure 1 Evaluation process of Flexible UWB MIMO antenna

In the construction of the UWB MIMO antenna, Dimensions are same for antenna1 and antenna2 only change is placement of the antenna on the substrate. Attached to the feed line are pair horizontal stubs with asymmetrical way and width of 1.6 mm. For better impedance matching, the feed line width is made similar to the horizontal stubs' width. To further enhance circular polarization (CP), the ground plane is intentionally made asymmetric, complementing the asymmetry of the stubs. The Double SRRs are strategically placed on pair of horizontal projections and CSRR are cut in the ground plane. An SRR consisting of two concentric rings with radii 'r1' and 'r2' is designed, with a gap 'G' separating the two rings. To subpress mutual coupling in the elements of MIMO antenna, a inclined 45 degrees stub is inserted in between the elements. The right side of stub is incorporated with rings to maintain the isolation. The dimensions for the proposed MIMO antenna are shown in the table 1.

Description of the Parameter	*Value (in mm)*
Width of the Feed (Wf)	1
Lengths of the Feed (Lf)	35
Length of the substrate (Ls)	45
Width of the substrate (Ws)	25
Thickness of the substrate (h)	0.1
Width of horizontal strip1 (W1)	1
Width of the Ground (Wg)	10
Length of the Ground (Lg1/Lg2)	14/12
Gap (G)/G1	0.5/1
Radii of the circles R1/R2/R3/R4	1.5/2/2.5/3
Length of stubs S1/S2/S4/S5	1/1.5/2/2.5
Stub	2
CSRR	3.5

Table I Recommended Antenna Parameters

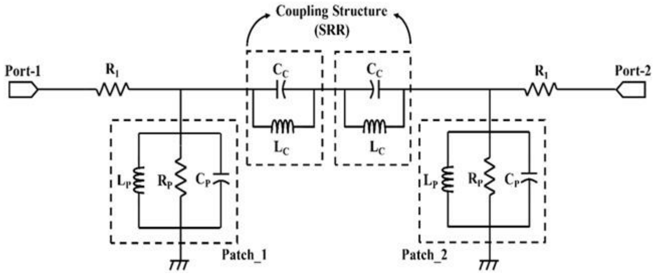


Illustration of proposed model

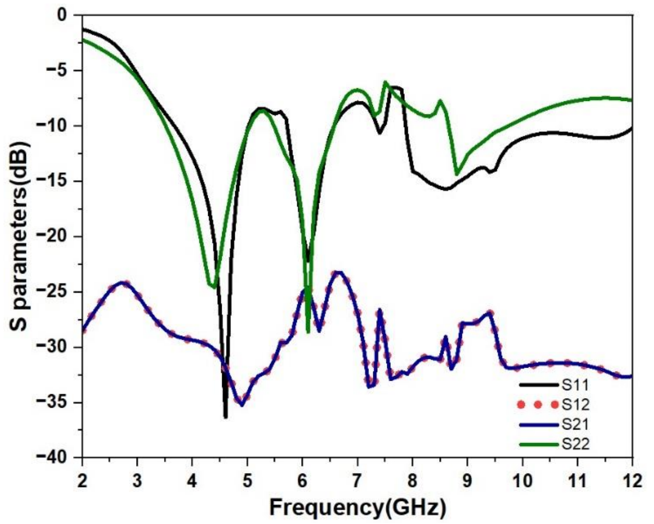
Figure 3 presents the iterations of the reflection coefficient characteristics. 3. Iteration 5, shows the best operating range from 3.68GHz to 12.02 GHz. Thus, it is chosen as the final design for the MIMO antenna.

III. Results And Discussion

This section showcases the simulated outcomes of the proposed metamaterial UWB MIMO antenna.

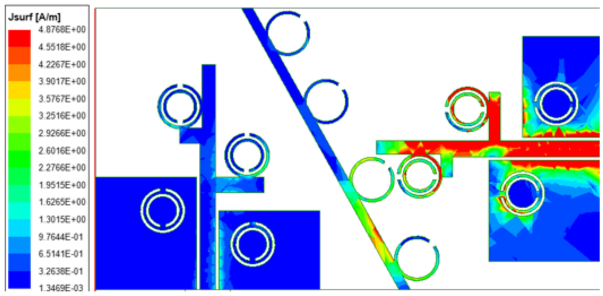
A. *Reflection coefficient characteristics*

Achieving a wide operating range from 3.68 GHz to 12.02 GHz with an impedance bandwidth of 8.34 GHz, the proposed MIMO antenna's simulated reflection coefficient (S11) and transmission coefficient (S22) characteristics are illustrated in Figure 4. Additionally, the coupling between the two elements is sufficiently low and acceptable.

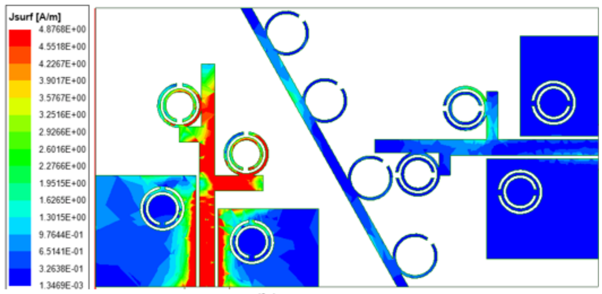


B. *Current distribution*

From figure 5, the current distributions indicates that the absence of the stub effect the port1 from port2. These results



(a)5.8GHz



(b)5.8GHz

Figure.5. Current distribution of MIMO antenna at 5.8GHz

increased coupling between both elements. From the figure 6 a, b shows the current distribution at resonant frequencies 5.8GHz. At 5.8GHz, port 1 is activated and port 2 is closed, it observed that the stub is Hampering the flow of current from port 1 to port

The current distribution plots show both the strength of the currents and the polarization at that frequency.
Hence, the proposed MIMO antenna has good isolation between the elements.

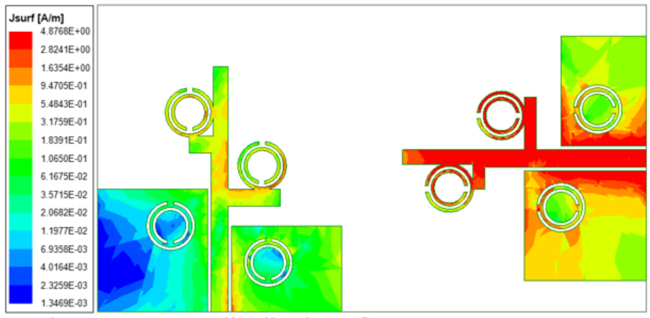


Figure 6 Current distribution of MIMO antenna at 5.8 GHz without stub in between the both ports

C. *Diversity Analysis Characteristics for Proposed UWB-MIMO Antenna*

The channel capacity of the MIMO system is affected by a parameter known as ECC. A minimal envelope correlation coefficient (ECC) is crucial to confirm the efficiency and capability of the proposed UWB-MIMO antenna.

$$\frac{|\,S_{11}\cdot S_{12}^{*}+S_{21}\cdot S_{22}^{*}\,|^{2}}{(1-|\,S_{11}\,|^{2}-|\,S_{21}\,|^{2})(1-|\,S_{12}\,|^{2}-|\,S_{22}\,|^{2})}$$

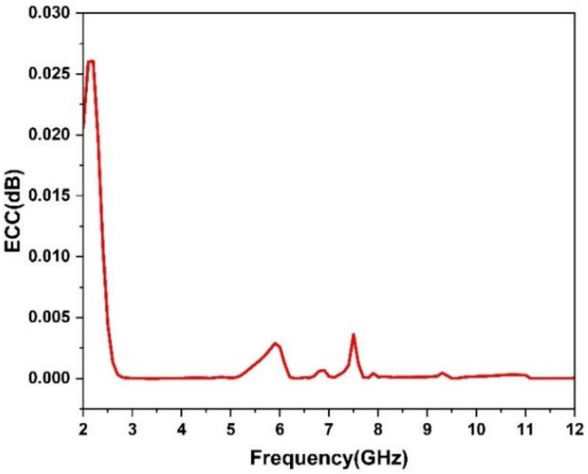


Figure 9. Simulated ECC of the UWB MIMO antenna

Diversity Gain (DG)

$$DG = 10 \cdot \sqrt{1 - ECC^2}$$

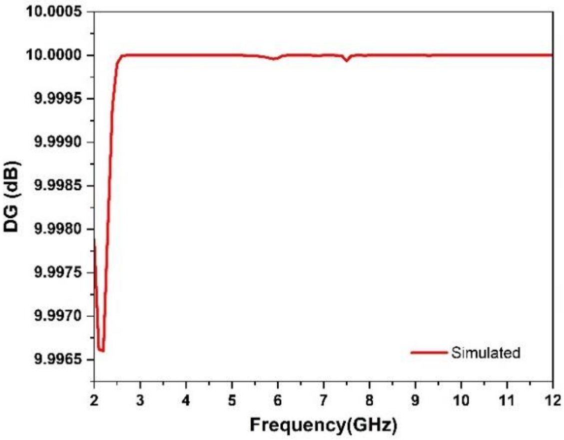


Figure 10. The simulated diversity gain versus frequency.

Channel Capacity Loss (CCL)

$$CCL = -\log_2(1 - |S_{11}|^2)$$

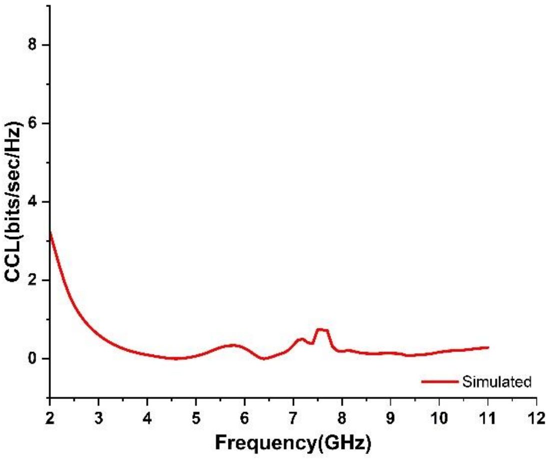
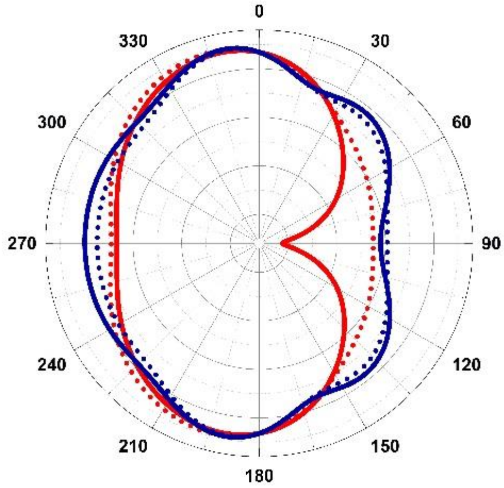


Figure 11. The simulated Channel Capacity Loss versus frequency.

D. Table 2. Comparison of different circularly polarized MIMO antennas.

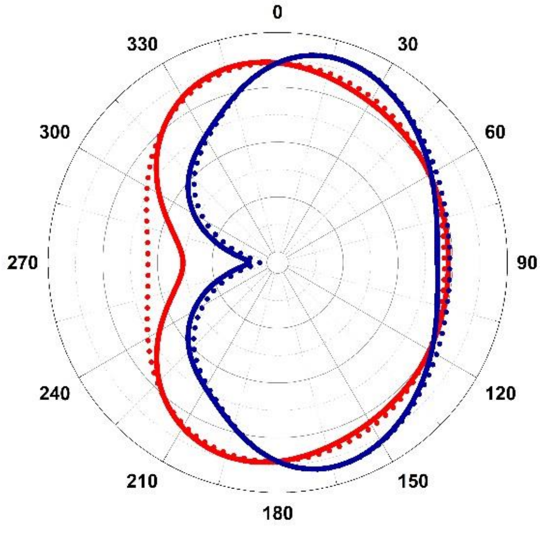
Ref.	*MIMO Element*	*Antenna Size (mm3)*	*Frequency Band (GHz)*	*ECC*	*CCL bits/s/Hz*	*Isolation (dB)*
[11]	2 × 2	24 × 24 × 1.6	3.04–8.11	<0.004	<0.32	<−16
[12]	2 × 2	95 × 49.7 × 1.6	3.15–3.93	< 0.03	<0.10	<−26
[13]	2 × 2	40 × 65 × 1.6	5.16–6.30	<0.112	<0.338	22.284
[14]	2 × 2	22.5 × 50 × 1.6	5.2–6.4	0.001	-	<−20
Proposed model	2 × 2	25x45x 0.1	3.5-11.5	<0.02	<0.3	<-25

E. Radiation patterns



(a)

Illustration 7. Radiation pattern for proposed antenna at (a) 10.0 GHz (b) 11.0 GHz (c) 52.0 GHz at Port 1



(a)

Illustration 8. Radiation pattern for proposed antenna at (a) 10.0 GHz (b) 11.0 GHz (c) 52.0 GHz at Port 2

IV. CONCLUSION

This paper proposes a ultra-wide-band MIMO antenna which is inspired by metamaterial split ring resonator. The simulated results are supporting the proposed model is good candidate for real time wireless communication applications. Having advantage of isolation below -15dB, simple structure, possible flexible nature conversion and fabrication ease. Additionally MIMO parameters are also showing good agreement on proposed antenna that it works with in the limits of MIMO parameter parameters. This Results demonstrates proposed work will suite real time demands of next generation wireless communication system.

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