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# Metamaterial- Inspired Dual- Mode Antenna using Rectangular Type CSRR

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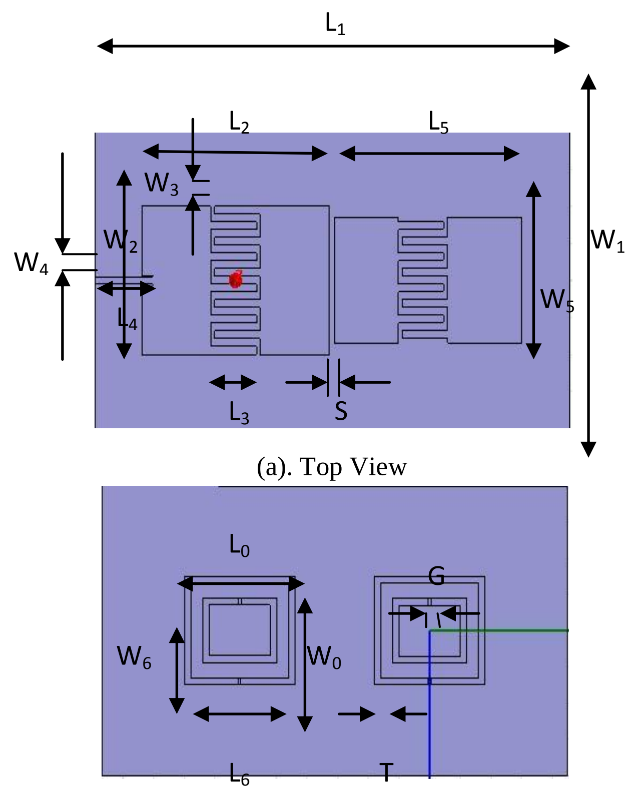
***Abstract*-In this paper a metamaterial-inspired dual-mode antenna using rectangular type CSRR is proposed, Here it is seen that an increase in series capacitance will decrease the resonant frequency at which ZOR mode is achieved using rectangular type CSRR .The resonant frequency of antenna is 2.10 GHz with reflection coefficient up to 21 dB. The electrical size of antenna is 0.531λ0× 0.272$\lambda_0$× 0.010$\lambda_0$and ZOR mode is observed at 1.25 GHz. The proposed antenna has gain of 0.8 dB with radiation efficiency of 63%.**

## I. INTRODUCTION

ZOR is an attractive feature of CRLH transmission line to miniaturize the antenna size [3, 4].MTM antenna is a class of antennas which use the properties of metamaterial to enhance antenna performance and size reduction. A lot of research is reported based on CRLH TL's in [6, 9] and It is observed that bandwidth can be increased by combining different radiating modes. Several CPW-fed ZOR antennas with extended bandwidth are demonstrated. A compact ZOR antenna using CSRR was proposed which includes an interdigital capacitor loaded on patch of antenna and rectangular type CSRR etched on ground plane [5].

## II. ANTENNA DESIGN AND ANALYSIS

The geometry of the proposed MTM antenna using interdigital capacitor and rectangular type CSRR as shown in Figure 1. This structure comprises a patch on which interdigital capacitor loaded and arectangular CSRR etched on the ground plane. The entire structure is implemented on an FR4 epoxyglass substrate ($\varepsilon_r$= 4.4, tan $\delta$ = 0.02) with 1.6mm thickness. Analysis is carried out inorder to achieve optimized design dimensions of the proposed antenna. The optimal design parametersof the proposed MTM antenna are shown in Table1.




(b). Bottom View

Figure 1: Geometry of proposed antenna, (a) Top view, (b) Bottom view

**Table 1**: Dimensions of proposed antenna

| Parameter | Unit(mm) | Parameter | Unit(mm) |
|---|---|---|---|
| $L_1$ | 76 | $W_5$ | 17 |
| $W_1$ | 40 | $L_6$ | 12 |
| $L_2$ | 30 | $W_6$ | 9 |
| $W_2$ | 20 | $L_0$ | 18 |
| $L_3$ | 7.3 | $W_0$ | 15 |
| $W_3$ | 1 | G | 0.4 |
| $L_4$ | 9.25 | S | 0.8 |
| $W_4$ | 1 | H | 1.6 |
| $L_5$ | 30 | T | 1 |

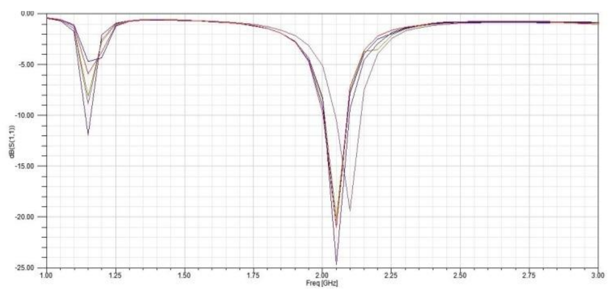


Figure2: Simulated input reflection coefficients of proposed antenna by varying interdigital capacitor finger length $L_3$

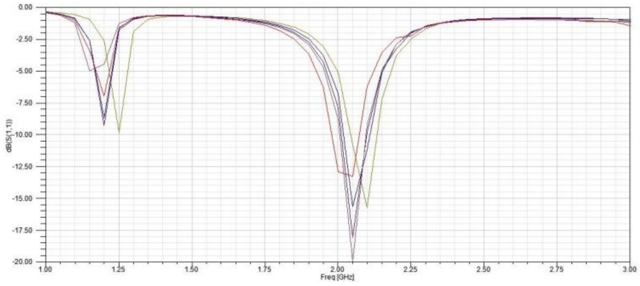


Figure 3: Simulated input reflection coefficients of proposed antenna by varying CSRR thickness T

This antenna design is based on CRLH metamaterial transmission line structure which has two modes by using IDC and CSRR. By using analysis get that n=0 mode is found due to rectangular type CSRR as shown in Figure 2 and n=1 mode is due to coupling between interdigital capacitor and rectangular type CSRR. Figure 3 shows that first order resonant frequency can be tuned by varying the length of inter-digital capacitor while ZOR frequency remains unchanged. This is because increase in length of interdigital capacitor responds to decreases our antenna resonant frequency (increase series capacitance, decrease series inductance). Similarly, by increasing CSRR thickness, ZOR frequency increased (decreases the shunt capacitance, increases shunt inductance) .coupling capacitance act between patch and ground also play a great role in varying the ZOR frequency.

## III.ANTENNA THEORY

Equivalent circuit model of the proposed antenna is shown in Figure4 in which Interdigital capacitor is modeled by series capacitance, $L_R$ is modeled by inductance associated with Interdigital capacitor and feed line, which make series LC circuit. CSRR forms the parallel LC tank circuit. $C_C$ represents the coupling capacitance between patch and ground. These parameters are used in tuning the resonant frequency and electrical size of the antenna. It is realized that ZOR frequency can be tuned by $C_C$ , $L_L$ and $C_R$ while first order frequency can be controlled by series parameters i.e. $L_R$ , $C_L$ and $C_C$ .Therefore, it can increase the bandwidth of antenna by introducing a high shunt inductance and a small shunt capacitance.

Generally it has been seen, ZOR antennas have narrow bandwidth; this is because Q-factor of a ZOR antenna is depends only on $C_R$ and $L_L$ .The narrow bandwidth is due to small $L_L$ and large $C_R$ ,To solve this problem or to extend bandwidth a thick substrate having low permittivity is used but this causes more complex fabrication and reduces design freedom. All these can be overcome by proposed antenna design which is based on large $L_L$ and small $C_R$, which enhanced bandwidth without decreasing radiation efficiency. This structure provides easy fabrication and offers more design freedom. The dispersion relation for proposed antenna can be obtained by [13]

$$\beta_d = \cos^{-1}\left[\frac{1-S_{11}S_{22}+S_{21}S_{12}}{2S_{21}}\right] \quad (1)$$

Figure 5 shows dispersion diagram of the proposed antenna based on $\beta_d$ variation with respect to frequency .dispersion diagram has two regions 1. RH region (β>0),2.LH region (β<0). It is found that RH modes achieve after 2.10 GHz and LH modes may be achieved below 1.25 GHz.

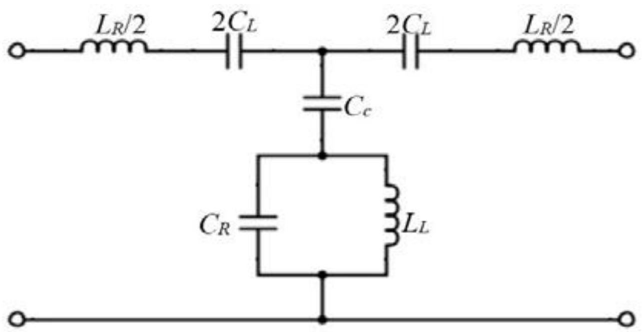



Figure 4: Equivalent Circuit of proposed antenna

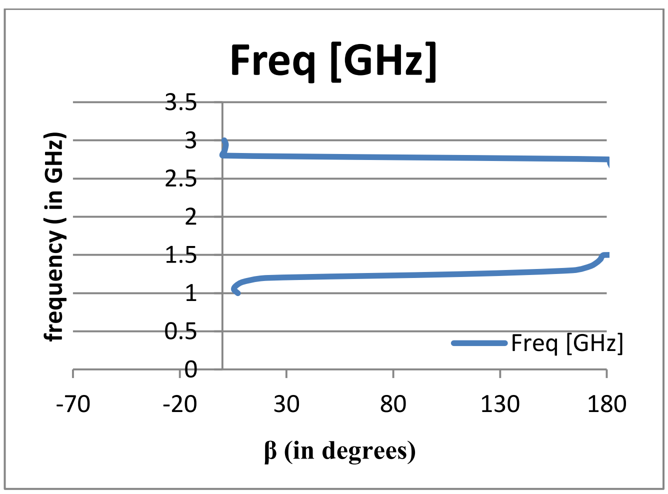


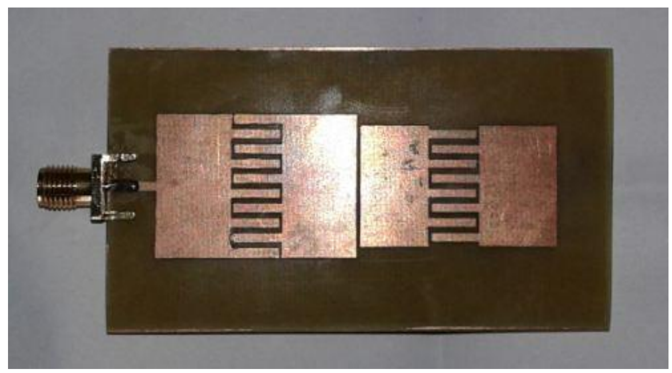

Figure5: Dispersion diagram of the proposed MTM antenna

## IV.RESULTS

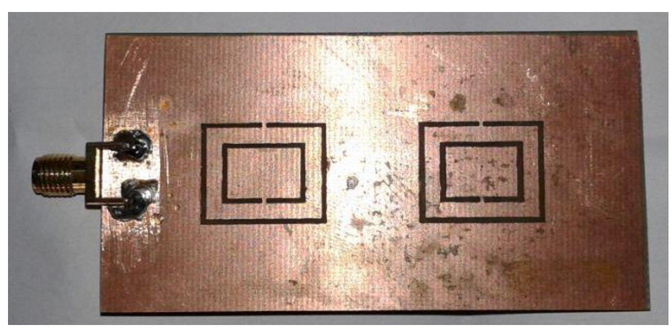
The simulated reflection coefficient of the proposed antenna is shown in Figure 7. Showing fractional bandwidth of 5.9 % (at the centre frequency 2.08GHz) is found with an extension from 2.02GHz to 2.14GHz. Figure 9 shows the E-field distribution of the proposed MTM antenna at 2.10GHz.It can be clearly seen that first order resonating frequency is due to coupling between Interdigital capacitor and ground plane. It is also seen that ZOR frequency is due to the rectangular type CSRR. The overall electrical size of the antenna is $0.531\lambda_0\times 0.272\lambda_0\times 0.010\lambda_0$.Figure 6 shows the simulated reflection coefficients where the resonant frequency is at 2.10 GHz.

Moreover, the bandwidth, radiation efficiency and gain are 5.9%, 63% and 0.8 dBrespectively. From Figure 7, the resonance frequency is 2.10 GHz, the frequencies $f_1$ and $f_2$ are given by 2.0210GHz and 2.1440 GHz respectively. Then, the fractional bandwidth can be calculated as 5.9% by using the expression

$$BW\% = \frac{f_2-f_1}{f_c}X100 \quad (2)$$



(a). Top View



(b). Bottom View

Figure 6: Prototype of fabricated antenna, (a) Top view, (b) Bottom view

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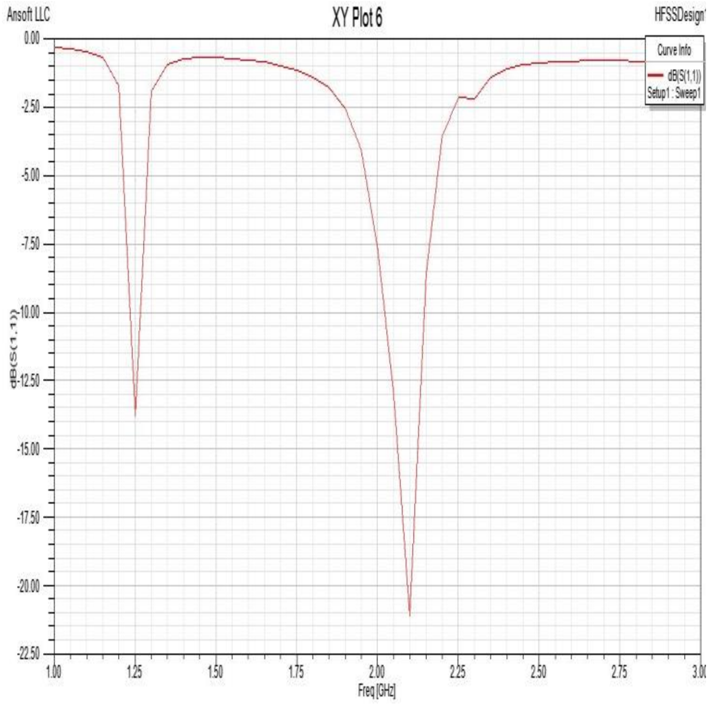



Figure 7: Simulated input reflection coefficient of the proposed antenna

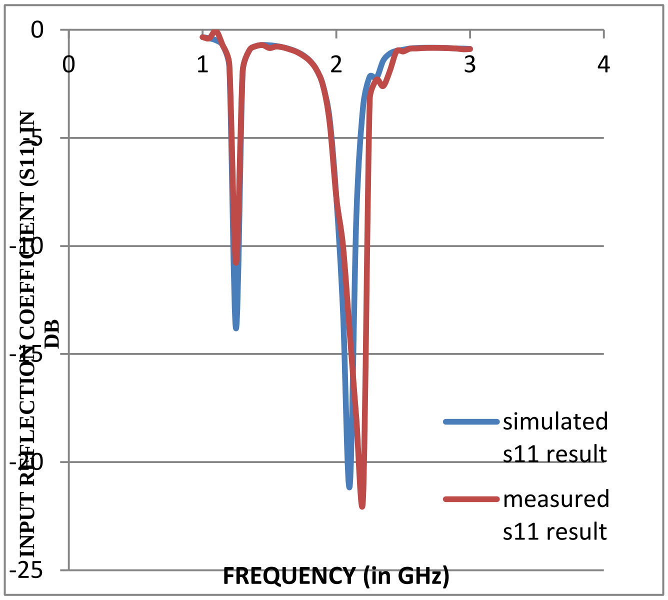
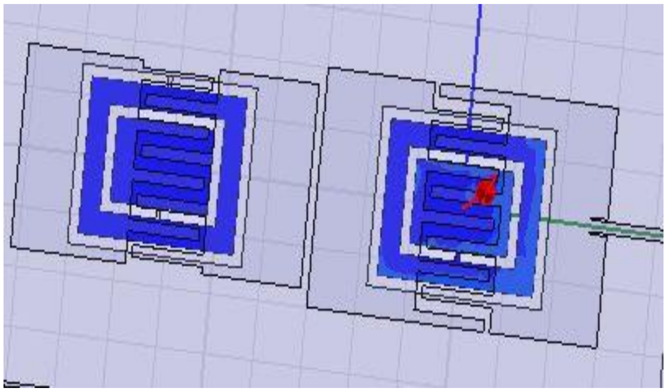


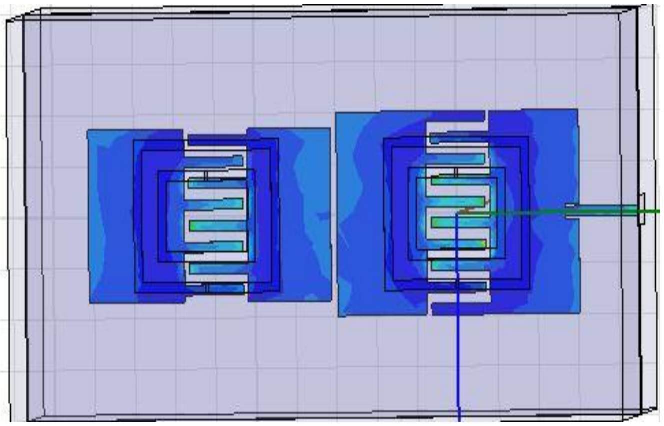

Figure 8: Comparison of simulated and measured input reflection coefficient of proposed antenna

**Table 2:** Summary of the proposed ZOR antenna at two resonant frequencies

| | | |
|---|---|---|
| **Frequency (GHz)** | 1.25 | 2.10 |
| **Bandwidth (%)** | 3.2 | 5.9 |
| **Gain (dB)** | -13.66 | -0.81 |
| **Efficiency (%)** | 28 | 63 |



(a)



(b)

Figure 9: E-field distribution of proposed antenna, (a) for CSRR, (b) ) for interdigital capacitor at 2.10 GHz

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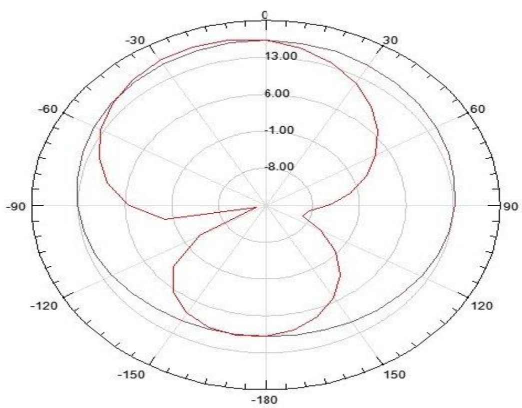
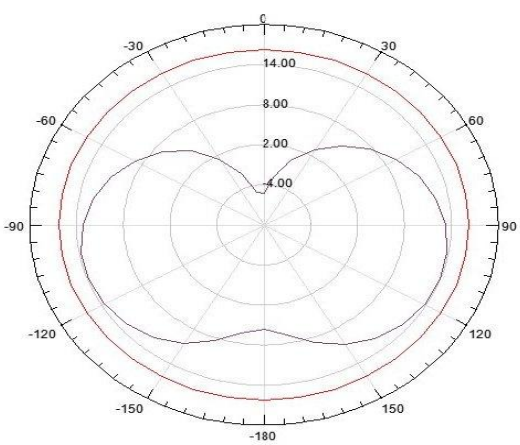
**Table 3:** Comparison with earlier published work

| **Design and feeding technique** | **Frequency (GHz)** | **Bandwidth (%)** | **Electrical size of the whole antenna** | **Feeding Technique** |
|---|---|---|---|---|
| This work | 2.10 | 5.9 | $0.531\lambda0\times0.272\lambda0\times 0.010\lambda0$ | Microstrip |
| [5] | 2.14 | 5.3 | $0.321\lambda0\times 0.285\lambda0 \times 0.011\lambda0$ | Microstrip |
| [10] | 3.82 | 4.9 | $0.505\lambda0 \times 0.442\lambda0 \times 0.02\lambda0$ | Microstrip |
| [19] | 2.66 | 4.1 | $0.35\lambda0 \times 0.35\lambda0 \times 0.013\lambda0$ | CPS-like |




(a)




(b)

Figure 10: Simulated radiation pattern of the proposed antenna at 2.10 GHz, (a) at xz-plane, (b) at yz plane

## V. CONCLUSION

A MTM antenna using rectangular type CSRR and Interdigital capacitor is proposed here. It is seen that dimensions (size) of antenna can be miniaturized by varying the length of Interdigital capacitor. It is observed that operating frequency of antenna can be tuned by varying CSRR thickness. Dispersion relations are found by calculating $\beta_d$. The overall size of the antenna is $0.531\lambda_0\times 0.272\lambda_0\times 0.010\lambda_0$. Impedance matching is achieved at 21 dB with fractional bandwidth of 5.9%. The proposed antenna has antenna gain of 0.8dB with 63 % simulated antenna radiation efficiency at the operating frequency of 2.10 GHz. The proposed metamaterial antenna exhibits dual-band behavior with first band centered at 1.25GHz and second band centered at 2.10 GHz. Radiation patterns of field are consistent throughout the antenna working band shown in Figure 10. With all these features, proposed antenna can be operated at various wireless standards such as GPS, UTMS, and CNSS.

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