

A CPW-Fed Metamaterial Loaded Monopole Antenna for Multiband Operation

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Abstract: The hexagonal shaped patch antenna loaded with hexagonal complementary split ring resonator is presented for multiband characteristics. The better impedance matching is achieved by employing the HCSRR, the metamaterial element in the main radiating patch. The proposed antenna resonates at 2.1 GHz, 6.5 GHz, 10 GHz frequency bands due to the loading of metamaterial element Hexagonal Complementary Split Ring Resonator (HCSRR). The entire size of the antenna is $20 \times 21 \times 0.8 \text{ mm}^3$. The dielectric material used for fabricating the antenna is FR-4 having the dielectric constant of 4.4 (ϵ_r) respectively. The proposed antenna offers better impedance matching, multiband and good radiation pattern characteristics. Parametric study is done for various width of HCSRR slots and by split gap for scrutinizing several characteristics of the proposed antenna. The HCSRR offers negative permittivity characteristics by its pass band behavior. The designed antenna is desirable for L, S and C band applications.

Keywords: Multiband, HCSRR, Negative Permittivity, Metamaterial

I. INTRODUCTION

In communication field, the wireless communication is the emerging and widely used technology and acquired a great area of interest. In air, the electromagnetic signals were broadcasted mainly through the allowable devices which act as transmitter and receiver. This is how the wireless communication mainly operates or the principle of wireless communication. The major advantages of this wireless communication are reliability, ease of installation and mobility. Antenna plays a vital role in wireless communication since it provides better communication. The productivity of business can be improved by the usage of Wi-Fi antennas. Antenna which operates over multiple bands of frequencies is referred as multiband antenna.

In this multiband antenna various frequency bands were coalesced in a single antenna [6]. The slot in the design can be used for bandwidth improvement [6]. Metamaterials are the artificial structure which provides the negative permittivity as well as negative permeability characteristics. The antenna loaded with metamaterial can have the unique effect on the electromagnetic waves characteristics [5]. The Split Ring Resonator (SRR), the Complementary Split Ring Resonator (CSRR), Electric Field Coupled Resonator (ELC) were some of the widely used metamaterial structures utilizing for improving the antenna characteristics and performances [5]. The radiation and matching characteristics of the electric and magnetic dipole antenna has been improved by utilizing metamaterial coating.

The Split Ring Resonator (SRR) offers the negative permeability characteristics by its stop band behavior as well as Complementary Split Ring Resonator (CSRR) offers negative permittivity characteristics by its pass band behavior [7]. The negative refractive index, the reverse Snell's law and the Doppler Effect has been provided by the metamaterial structures [8]. SRR offers dual band at [9]. The microstrip antenna with different patch shapes can be analyzed by using Artificial Neural network (ANN) model, the recent model used in communication system [1]. The unique frequencies from a desired signal can be selected by using the resonator. Frequency Selective Surfaces (FSS) are mainly focused for its bandwidth improvement and frequency stabilization properties [10].

The unique frequencies from a desired signal can be selected by using the resonator. The pass band behavior of the designed antenna is managed in desired range by using dual mode loop resonator and two stepped impedance resonator at [4]. The SRR and CSRR were widely used for fabricating the planar microwave components and for improving the antenna performances [2]. Wearable antenna now attained great area of research in communication field [3,15]. Stacked patch utilized for bandwidth improvement, F shaped slots improve impedance matching, array technique improves gain, the reconfiguration method improves gain, impedance matching and bandwidth [11,14]. The GPS resonant frequency can be used to identify the location [13]. The multiband characteristics are widely used for ultra wide band applications [12].

In this paper, the HCSRR laden antenna has been presented for L, S and C band applications. This design achieved the multiband characteristics which has great significance in wireless communication. Negative permittivity characteristics have been achieved by HCSRR slot.

II. ANTENNA DESIGN AND SIMULATED RESULTS

The proposed antenna is developed first by conventional hexagonal patch antenna fed through coplanar waveguide structure acts as full ground as shown in configuration (A) of Figure 1.

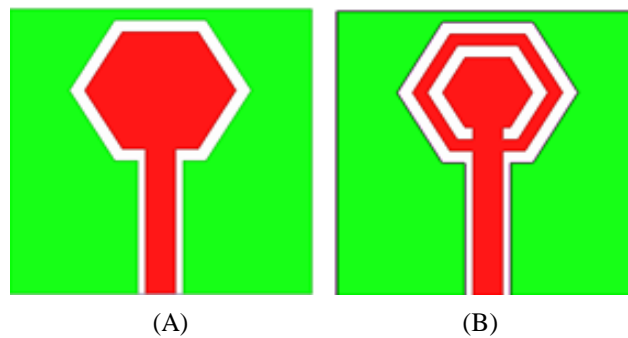


Figure 1: Design steps of proposed antenna

In the second stage, the hexagonal complementary split ring (HCSRR) is laden in the main radiating hexagonal patch as shown in configuration (B) of Figure 1. Here the HCSRR act as metamaterial element. Thus by the inclusion of HCSRR, the multiband with better impedance has been achieved. Added to this HCSRR provides negative permittivity characteristics due to its pass band behavior. Figure 2 shows the design of proposed antenna. Parameters of proposed antenna are shown in Table 1.

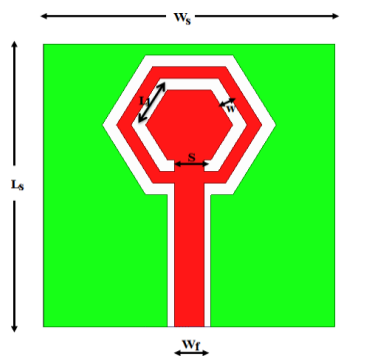


Figure 2: Design of proposed antenna

Table 1: Design parameters of antenna

Parameters	Dimension (mm)
LS	21
WS	20
L	10.75
Wf	2
L1	5
s	1
w	6

The designed antenna is simulated by using the Finite element model based electromagnetic software Ansys HFSS V.15.0. for analyzing the return loss S_{11} (dB) characteristics. In structural mechanism the Finite Element model (FEM) is referred as Dominant discretization approach. Figure 3 shows the simulated S_{11} (dB) characteristics of the conventional hexagonal antenna (A) and the Hexagonal complementary split ring resonator (HCSRR) laden monopole antenna (B). It shows that the conventional antenna (A) resonate at 5.5 GHz. When the metamaterial HCSRR is loaded, the proposed antenna provides tri-band resonant frequency of 2.1 GHz, 6.5 GHz and 10 GHz suitable for L, S and C band applications. Hence from the figure 3 we can infer that the HCSRR loaded monopole antenna offers better impedance matching and multiband characteristics.

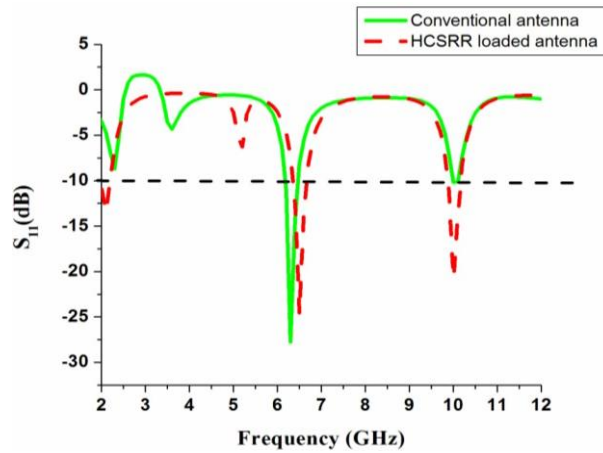


Figure 3: Simulated S_{11} (dB) of conventional and proposed antenna.

III. PARAMETRIC STUDIES

The multiband characteristics are mainly influenced by the split gap effect in HCSRR. By increasing or decreasing the split gap there will be great variation in the return loss characteristics. There is a shift to lower resonance when the split gap decreased. The multiband will be obtained by increasing split gap respectively.

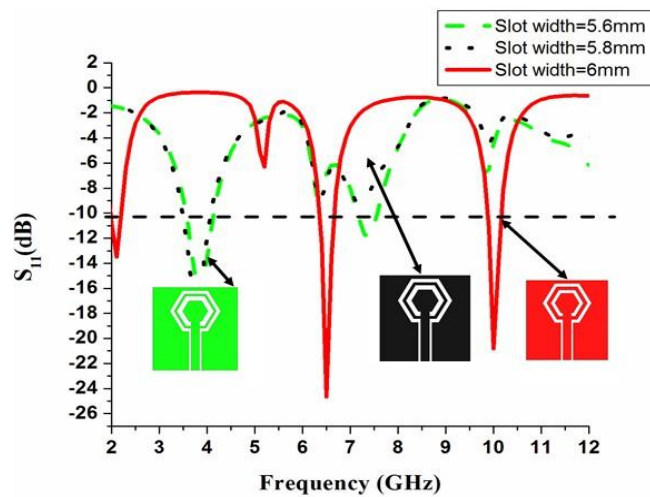


Figure 4: parametric study of slot width

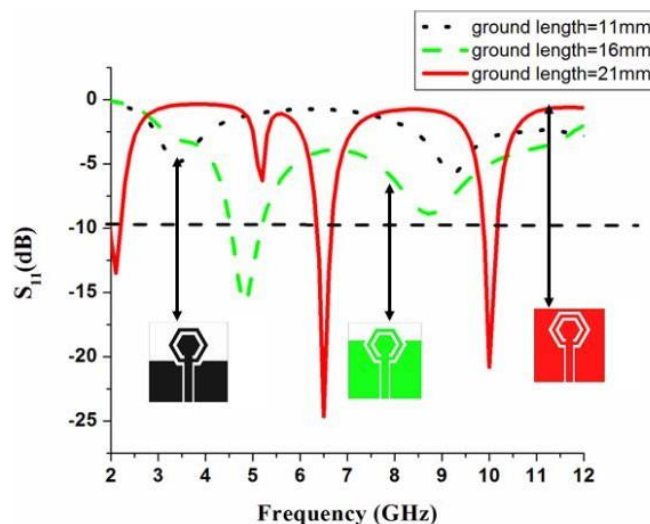


Figure 5: Parametric analysis of ground length

The parametric analysis of ground length is shown in Figure 5. In this the ground length is decreased in the order of

5mm from 21mm to 11mm. Thus in steps of 21mm, 16mm and 11mm. From these steps we can infer that the optimum result achieved at 21mm.

IV. RESULTS AND DISCUSSION

From figure 3 it is inferred that the designed antenna offers better impedance matching with multiband characteristics. Hence the antenna is highly efficient. The resonant frequencies with corresponding return loss of the proposed antenna are 2.1 GHz at -13.48 dB, 6.5 GHz at -24.68 dB and 10 GHz at -20.80 dB respectively desirable for L, S and C band applications.

The designed antenna offers an simulated -10 dB impedance bandwidth of 222.6 MHz (1.9774 GHz to 2.2000 GHz) at 2.1 GHz, 315.7 MHz (6.3502 GHz to 6.6659 GHz) at 6.5 GHz and 296 MHz (9.8727 GHz to 10.1687 GHz) at 10 GHz respectively.

The radiation pattern (E-plane and H-plane) for the all resonant frequencies such as 2.1 GHz, 6.5 GHz and 10 GHz are shown in Figure 6 (a), 6 (b) and 6 (c) respectively. For all the resonant frequencies, it is inferred that the E-Plane is at bi-directional pattern and H-Plane at omnidirectional pattern.

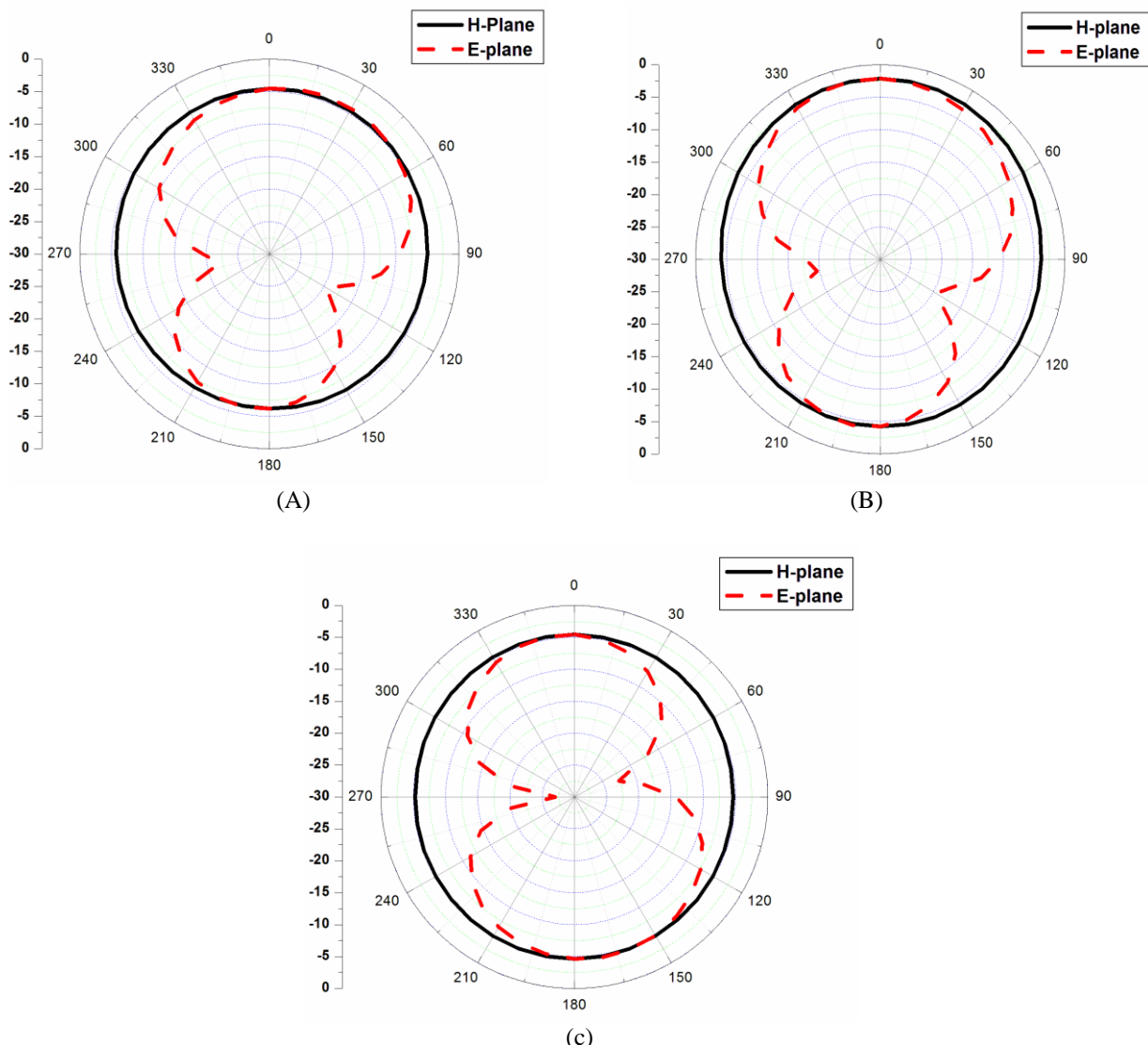


Figure 6: Far Field Radiation Pattern

The simulated VSWR of the designed antenna is shown in Figure 7. Thus the antenna offers VSWR in the range between 1 to 2 i.e., $VSWR \leq 2$. Thus the antenna is efficient.

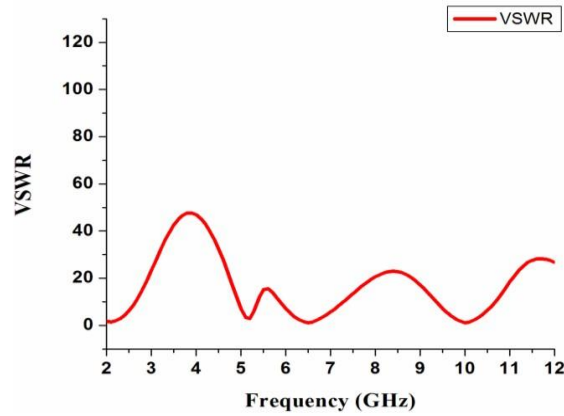
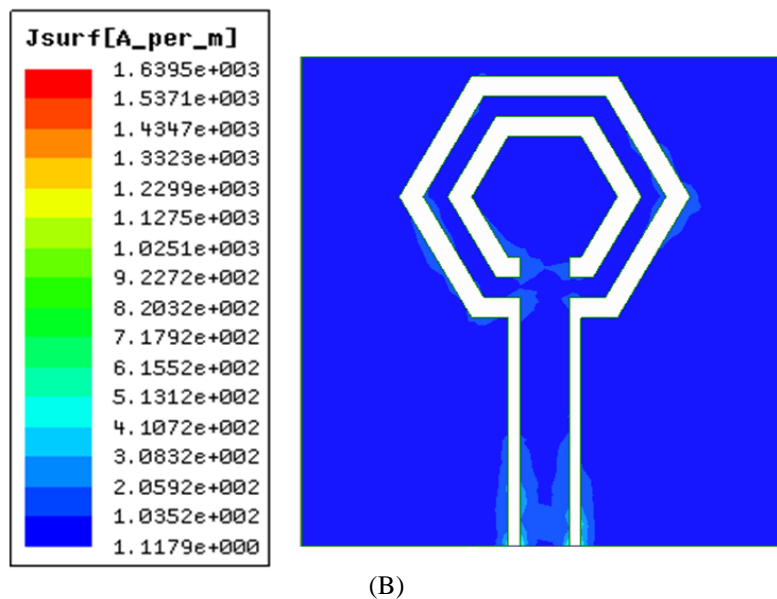
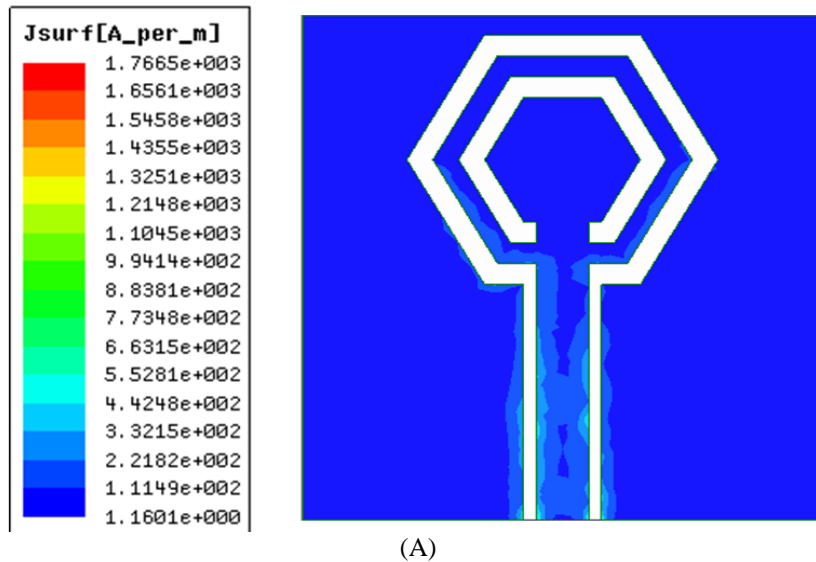
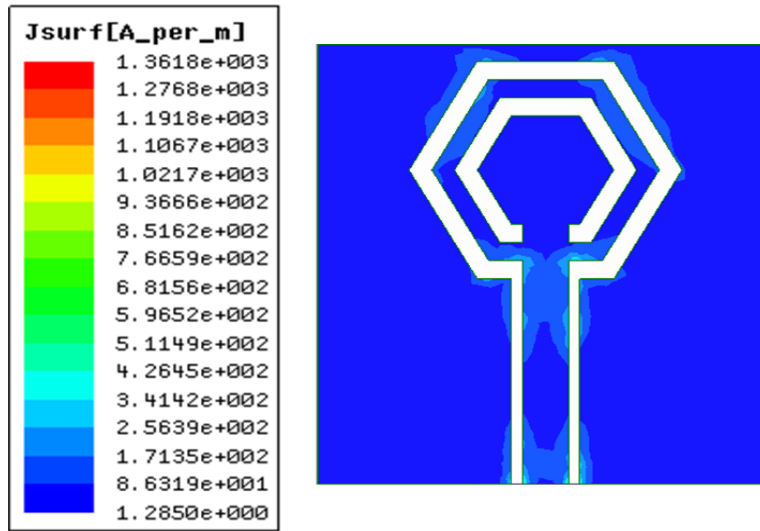


Figure 7: VSWR plot of the proposed antenna

Surface current distribution of the designed antenna is analyzed for learning and formalize the resonant frequencies as shown in Figure 8 (a)-(b)-(c).

The resonant frequency of 2.1 GHz, 6.5 GHz and 10 GHz due to the inclusion of HCSRR with split is desirable for ISM band, S and C band applications.





(C)

Figure 8: Surface current distribution of the designed antenna (a) 2.1 GHz (b) 6.5 GHz and (c) 10 GHz.

Table 2: Progression of simulated parameters

Proposed antenna	Resonant frequency (GHz)	Return loss (dB)	VSWR
Simulated	2.1	-13.48	1.5
	6.5	-24.66	1.1
	10	-20.80	1.2

V. CONCLUSION

The CPW-Fed metamaterial loaded monopole antenna for multiband operation is presented. The total dimension of the designed antenna is $21 \times 20 \times 0.8 \text{ mm}^3$. The inclusion of hexagonal complementary split ring resonator (HCSRR) is responsible for obtaining multiband characteristics. The proposed antenna is applicable for L, S and C band devices. The simulated return loss, radiation pattern and VSWR make the antenna suitable for wireless applications.

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BIOGRAPHIES



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