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Research paper

Folded monopole antenna with CSRRS for tri-band applications

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Abstract

In this paper, a miniaturize folded monopole antenna with complementary split ring resonator (CSRR) is proposed for tri-band applications. In the design procedure of the antenna, first a single band monopole antenna is designed for 2.88 GHz. For design a single band to dual band, the both arms of the radiating element (i.e. Monopole) is folded then it is resonated at 2.68GHz and 5.15GHz resonance frequencies, the resonance of the lower frequency is based on length of the monopole and higher order resonance is excited due to its folding effect. In order to extend its resonances for tri-band operation, the two identical size CSRRs (one on the left and another on the right from the feed line) are placed on the ground plane of the edge of the folded monopole, thus the entire structure is resonated at 2.47 GHz, 3.46GHz and 4.36 GHz frequencies. A simplified equivalent circuit model is developed for understanding its electrical behavior. Therefore, the proposed antenna has been suitable for WLAN, WiMAX and C-band applica- tions.

Keywords: *Tri-Band; CSRR; Monopole Antenna; Equivalent Circuit.*

1. Introduction

In today's wireless communication era, planar monopole antenna is an attractive candidate due to its low profile, light weight with Omni-directional radiation pattern and easy to integrate [1]. At a time, when miniaturized multiband antennas are in a great demand, however, their size reduction is a challenging task. Although, a miniaturized multiband antenna has been designed by cutting slot, which is suitable for WLAN application [2]. Similarly, a multiband reconfigurable antenna [3] has been designed by embedding three pairs of slot dipoles for achieving three bands of operation (2.4/3.5/5.2GHz). However, as we know there are various techniques by which we can reduce the size of the antenna such as cutting slots, using meandered line and using fractal [1-5]. In this antenna the size is reduced by folding the both arms of the monopole. For multiband antenna design, there are various techniques such as by cutting slots and using metamaterial [1]-[6]. In all of these techniques metamaterial is most widely used. There is various type of metamaterials for antenna applica- tions, the most widely used among them are electromagnetic band gap (EBG), different resonators such as split ring resonator (SRR) and complementary split ring resonators (CSRRs) [6-8]. In this paper a miniaturized multiband antenna has been designed by folding monopole with CSRR. Furthermore, an equivalent circuit model has been developed for understanding its resonance behavior in terms of lumped components. The lumped compo- nents (R, L and C) have been determined using the technique given in [1]-[9] and they are further optimized in Keysight ADS
[10] For best return loss (S11) results.
The paper is organized as follows. The design of single, dual and triband antenna is investigated in Section 2, the equivalent circuit model of folded monopole antenna is investigated in Section 3 and in the Section 5, we discussed about the results and finally all works are concluded.

2. Proposed antenna design

The proposed monopole antenna is designed on glass epoxy FR4 substrate with a dielectric constant of 4.4, height 1.6mm and loss tangent 0.02. The size of the antenna is 24×36×1.6 mm3 as shown in Figure 1. For designing the multiband monopole antenna, first a simple monopole antenna is designed as shown in Figure 2 (a), which is resonated at 2.88 GHz frequency band and the length of the radiating monopole antenna is equal to 24mm, which is approximately equal to quarter wavelength of resonant frequency. For designed the single band antenna to dual band, the both arms of the monopole are folded as shown in Figure 2(b). The folded monopole antenna is resonated at two frequencies (2.68 and 5.15 GHz) as shown in Figure 3. In this dual band antenna, first band is occurring due to length of the monopole and the second band is achieved due to its higher order mode, which is mainly achieved due to its folding effect. Now for designing the dual band antenna to triband antenna, we used complementary split ring resonator (CSRR) at ground plane below edged of the folded monopole. The proposed triband antenna is resonated at 2.47 (IBW 9.70%),
3.46 (IBW 3.7%) and 4.36 (10.34%) GHz as shown in Figure 3. The simulated peak gain (radiation efficiency) of the triband antenna at 2.47, 3.46 and 4.36 GHz are 2.47dBi (95.63%), 1.90dBi (78.84%) and 4.10dBi (91.12%), respectively. The resonance behavior of the triband antenna can be understanding with the help of current distribution diagram as shown in Figure 4. The geometrical parameters of the triband monopole antenna are

Ls=24, Ws=36, LG=11, WF=3.6, LF1=8.2, LF2=7.5, LM1=11.6, LM2=12.4, WM=2, a=b=8.3, c=d=g=0.5, w=0.8 (all in millimeters).

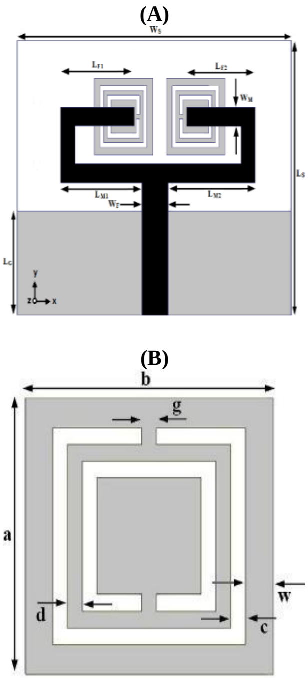


Fig. 1: Proposed Antenna A) Geometry of Proposed Antenna B) Zoom View of CSRR.

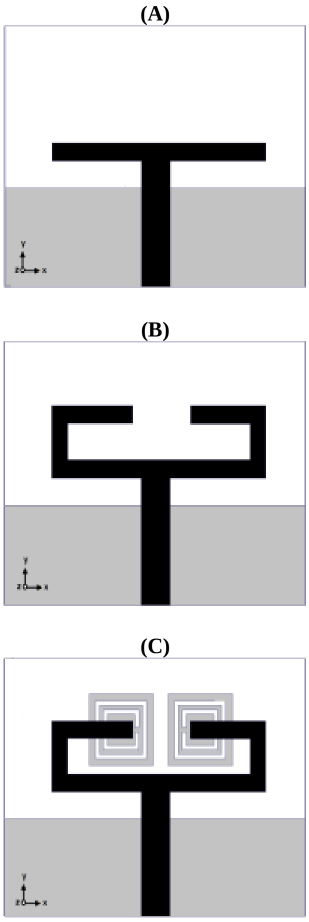


Fig. 2: Evolution of the Proposed Antenna A) Monopole Antenna (Anten-Na1) B) Folded Monopole Antenna (Antenna 2) C) Folded Monopole with CSRR Antenna (Antenna 3).

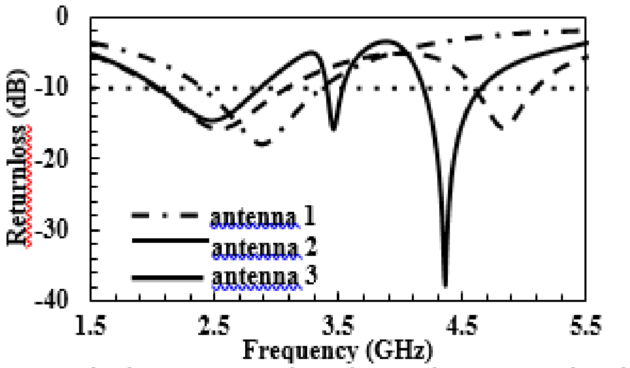


Fig. 3: Simulated Return Loss, Single Band Monopole Antenna, Dual Band Folded Monopole Antenna and Triband Folded Monopole with CSRR.

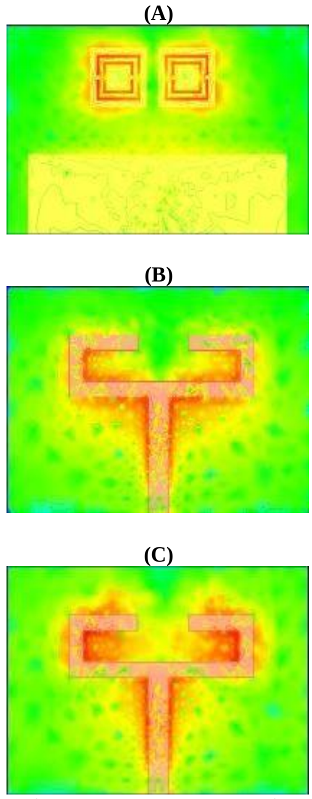


Fig. 4: Simulated Surface Current Distribution of Folded Monopole Antenna A) 3.46 GHZB) 2.47 GHZ C 4.36 GHZ.

3. Equivalent circuit modelling

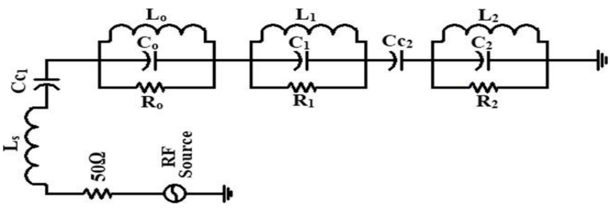


Fig. 5: Equivalent Circuit Model of Proposed Antenna.

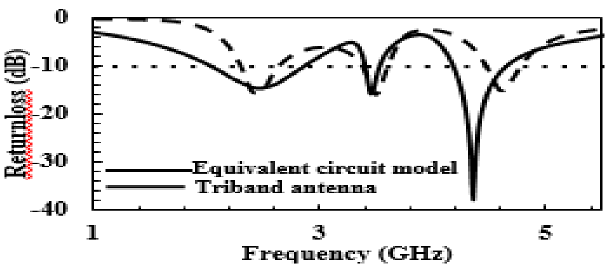


Fig. 6: Comparison of Return Loss of Triband Antenna with Equivalent Circuit Model.

An equivalent circuit model for the folded monopole antenna with CSRR is developed in advanced design system (ADS) to analysis the working principle of the proposed antenna. The proposed circuit model is obtained by combination of operating mode plus higher order mode. The resonance behavior of the folded antenna is represented by parallel RLC circuit and resistance R0, inductance L0 and capacitance C0 represents the lumps parameters of the monopole. The value of resistance and reactance are computed by ADS for its optimum value. For the feed line there are also additional inductance LS and capacitance Cc1.There are also additional resistance (R1) and reactance (C1 and L1) due to higher order resonance by the folded monopole and one another lower order resonance is occurred due to complementary split ring resonator (CSRR) having another resistance R2, capacitance C2 and inductance L2 [9]-[11]. There is also mutually coupling between the folded dipole to CSRR. which was represented by capacitor Cc2 [6]. The final optimized circuit parameters are as follows

LS=0.822 nH, CC1=0.74 pF, RO=490Ω, LO=0.618 nH, CO=2.72 pF, R1=172.30Ω, L1=1.68 nH, C1=1.64 pF, CC2=1.67pF, R2=300Ω, L2=1.24 nH, C2=0.72 pF

Are shown in Figure 5. Figure 6 depicts return loss of triband antenna and its equivalent model.

4. Results and discussion

The simulation of proposed folded monopole antenna is performed using the finite element method (FEM) based advanced design system (ADS) simulation software [10]. From the parametric study, the optimum value of the parametric are obtained. The effect of the value of L=LM1+LM2+WF on the magnitude of reflection coefficient of the antenna can be seen in Figure 7. As shown in Figure 7, when L increase from 27.6 to 31.6mm than the first resonance frequency is shifted from 2.43 to 2.26 GHz, while the third higher order resonance frequency is decreased due to increase the physical size of the monopole. As we know that the second resonance frequency is generated due to CSRR and its resonance frequency mainly depends on its size. The length and width of the CSRR is equal (l=a=b) as shown in Figure 1. If we increased its size from 7.7 to 8.9 mm, the second and third resonance frequency are decreased as shown in Figure 8. In this figure the second resonance frequency decrease from 3.82 to 3.13 GHz, while the third higher order resonance frequency is decreased because the electrical length of the monopole is increased. The antenna is design on low cost FR4 substrate and its simulated return loss is shown in Figure 9. The 2D radiation pattern of the antenna consists bi-directional radiation pattern in the E-plane and omnidirectional radiation pattern in the H-plane at all the three resonance frequencies as depicted in Figure 10 and the 3D radiation pattern at all three resonance frequencies are shown in Figure 11.

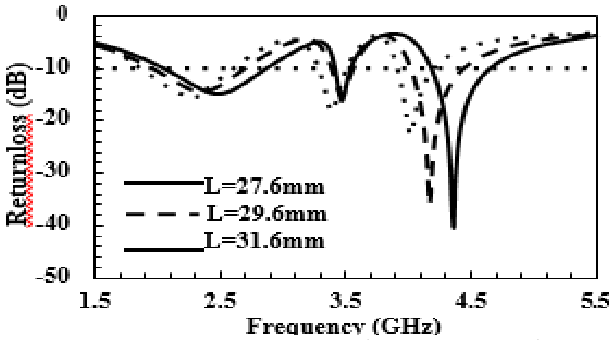


Fig.7: Simulated Return Loss (S11) for Various Value of L.

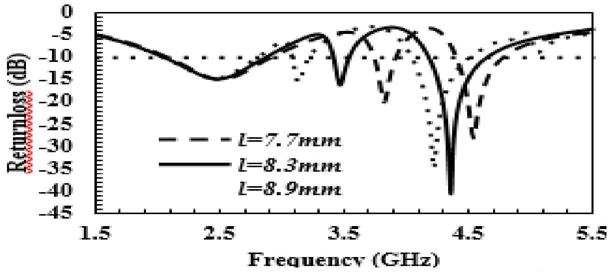


Fig. 8: Simulated Return Loss (S11) for Various Value of L.

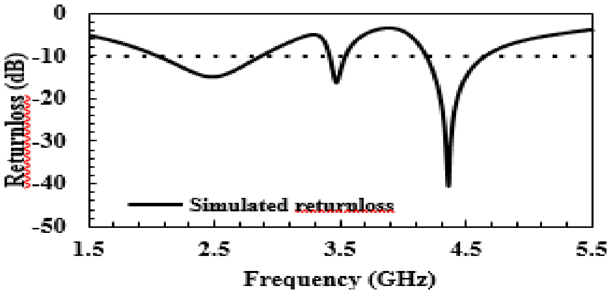


Fig. 9: Simulated Return Loss of the Proposed Antenna.

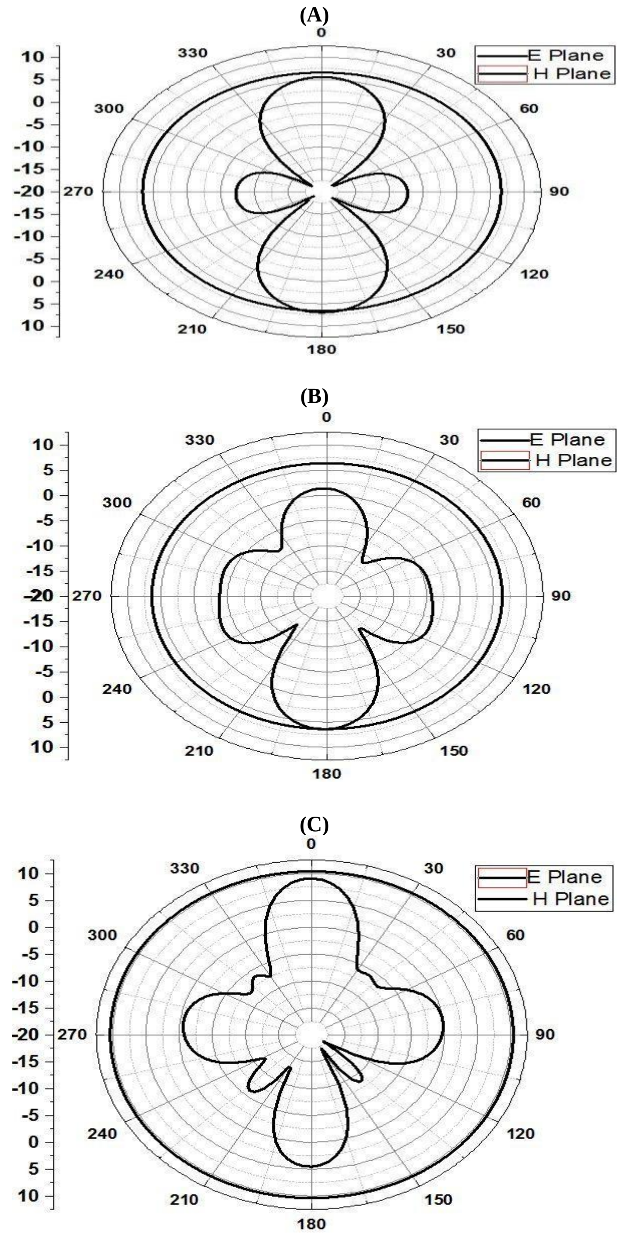
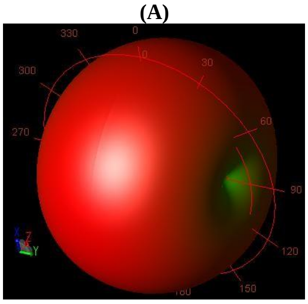
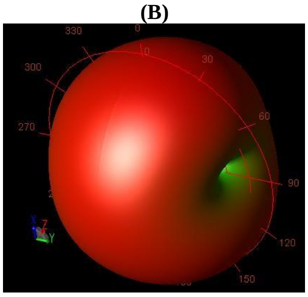


Fig. 10: Simulated 2D Radiation Pattern of Proposed Triband Antenna A) 2.47 GHz B) 3.46 GHz C) 4.36 GHZ.

(A)



(B)



(C)

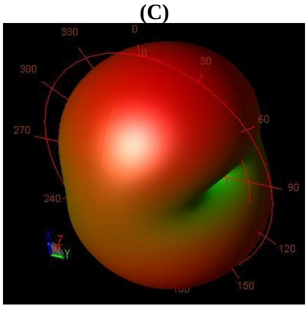


Fig. 11: Simulated Third Radiation Pattern of Proposed Triband Monopole Antenna A) 2.47 GHZ B) 3.46 GHZ C 4.36 GHZ.

5. Conclusion

The proposed miniaturized multiband antenna has been designed for WLAN, Wi-MAX and C-band applications. Which consists Omni-directional radiation pattern at all the three resonance frequencies. The antenna is designed on FR4 substrate with the size of 24×36×1.6 mm3. It consists two fundamental modes and one higher order mode for desired applications. The gain and efficien- cy of the antenna are 2.47dBi (95.63%), 1.90dBi (78.84%) and 4.10dBi (91.12%) at resonance frequencies of 2.47 GHz, 3.46 GHz and 4.36 GHz respectively. For better understanding for occurrence of fundamental modes and higher order mode, an equivalent circuit model is further developed. The small size, sim- ple structure, good gain with Omni-directional radiation pattern antenna is suitable for modern communication system

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