A Metamaterial-inspired Miniaturized Dual-Band Printed Directive Dipole Antenna for GSM/Bluetooth/WLAN Applications

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Abstract

In this paper, a miniaturized design of printed dual-band directive dipole antenna is proposed. Loading with complementary split ring resonators introduces an additional lower-order resonance in the reference directive dipole. This enables the proposed antenna to operate around 1.7 GHz and 2.42 GHz, covering the GSM/Bluetooth/WLAN application bands. Furthermore, defected partial ground structure is employed to improve impedance matching in the lower order CSRR-induced band. Full-wave simulations in Ansys HFSS show that the proposed dual-band antenna has satisfactory far-field gains of 1.83 dBi and 3.76 dBi in the two respective operating bands.

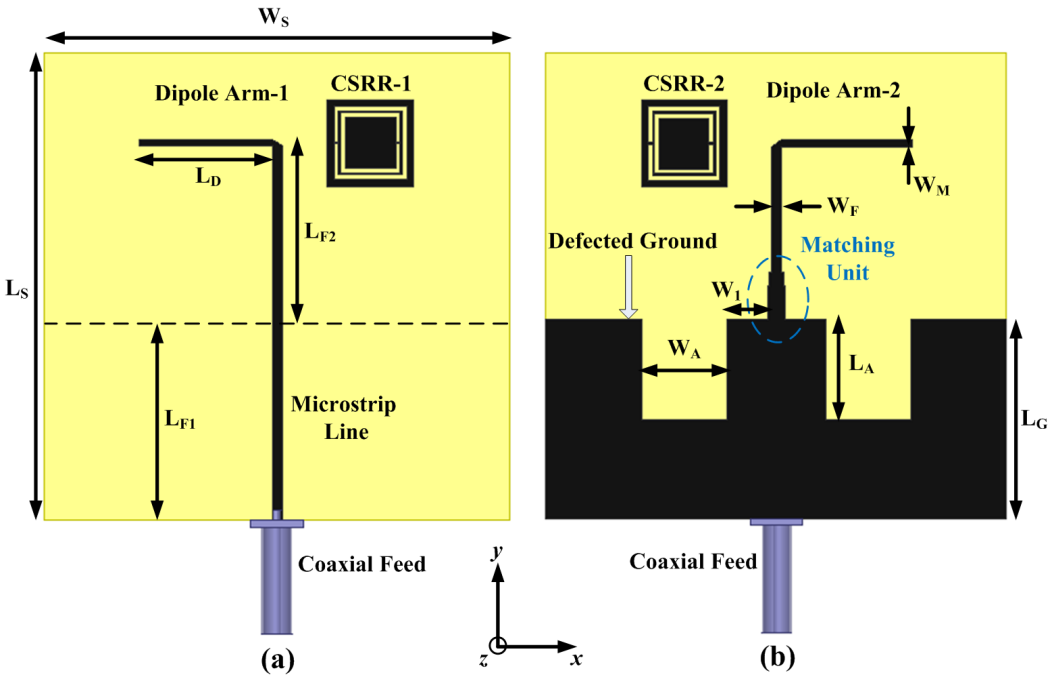

Fig. 1. Schematic Diagram of the proposed antenna (a) Top-view and (b) Bottom-view: L_S = 70 mm, W_S = 70 mm, L_{F1} = L_G = 30 mm, L_{F2} = 27 mm, L_D = 20 mm, W_F = 1.5 mm, W_1 = 6.2 mm, W_A = 13 mm, L_A = 15 mm, W_M = 1 mm.

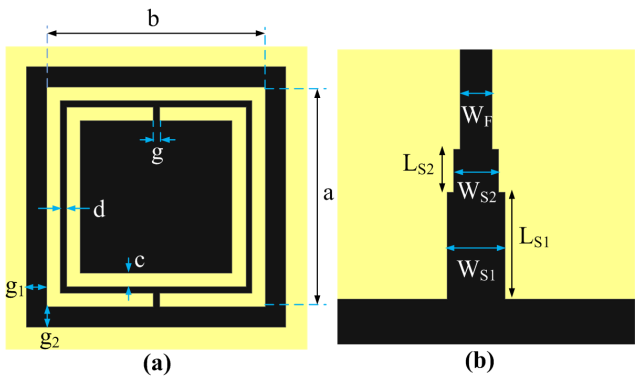

Fig. 2. (a) Rectangular Complementary Split Ring Resonator (CSRR): a = b = 11 mm, c = 0.7 mm, d = g = 0.3 mm, g_1 = g_2 = 1 mm. (b) Matching unit (Zoomed view): W_{S1} = 2.7 mm, L_{S1} = 5 mm, L_{S2} = 2 mm , W_{S2} = 2.1 mm.

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1. Introduction

Split-ring resonators (SRRs) and their complementary counterparts (CSRRs) have found extensive use in design of multi-band and band-notched ultrawideband printed monopole/dipole antennas [1]-[4]. On the other hand, the concept of using one or more unit-cells of negative refractive index transmission line (NRI-TL) or composite right/left handed (CRLH) metamaterials, as loading elements in printed dipole or monopole antennas to achieve multi-band operation is becoming increasingly popular [5]-[7]. In [8] a via-less CRLH unit-cell comprising of a series-gap and CSRR, is loaded on a double-sided printed dipole antenna to obtain dual-band characteristics. Further studies have revealed that the introduced lower order band is primarily governed by the shunt resonance induced by the CSRR.

In this paper, a microstrip-fed planar dipole antenna is loaded with only CSRRs to achieve the dual-band response. The presence of partial ground plane acts as reflector, making the antenna more directive. Further the ground-plane is defected to get better impedance matching in the CSRR-induced lower frequency band.

2. Antenna Design and Results

Fig. 1 shows the schematic diagram of the proposed CSRR loaded printed dipole antenna with defected ground plane. Low cost FR4-epoxy substrate ($\varepsilon_r = 4.4$, $\tan\delta = 0.02$) of thickness 0.8 mm is chosen for the antenna design. As evident from the top and bottom views (Fig. 1(a) and Fig. 1(b)), the planar dipole utilizes both sides of the substrate symmetrically. It is fed by a 50 Ω microstrip feedline over a partial ground plane. Rectangular patches are placed below each dipole arm, from which CSRRs of suitable dimensions are etched out. To control the impedance matching of the radiating bands of the proposed antenna, the partial ground plane is defected by cutting two rectangular regions of dimensions ($L_A \times W_A$), as shown in Fig. 1(b). For further tuning of the impedance bandwidth, stepped microstrip matching units as shown in Fig. 1(b) are used. The design parameters of the CSRR and the matching unit are shown in Fig. 2(a) and Fig. 2(b) respectively.

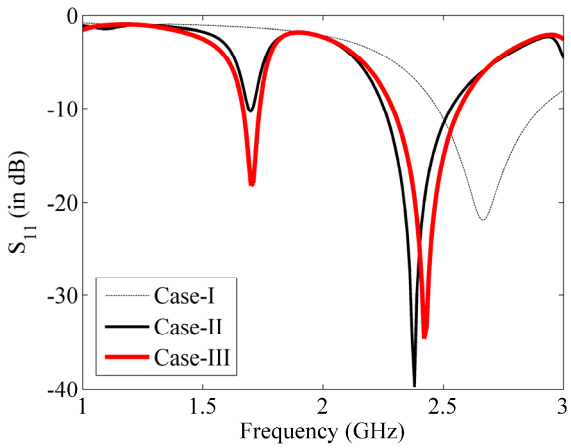
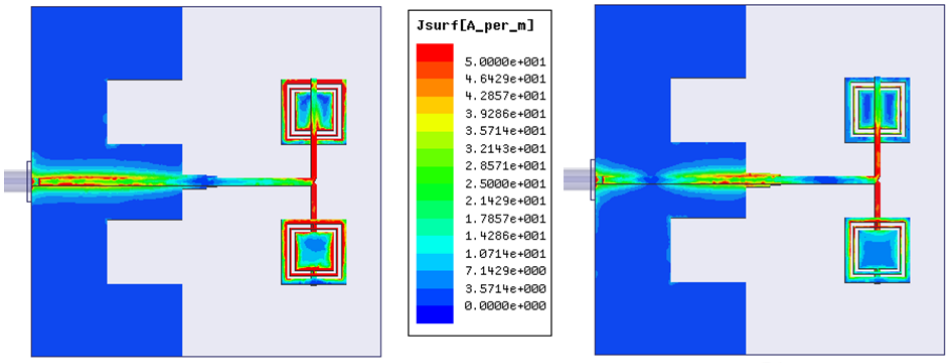


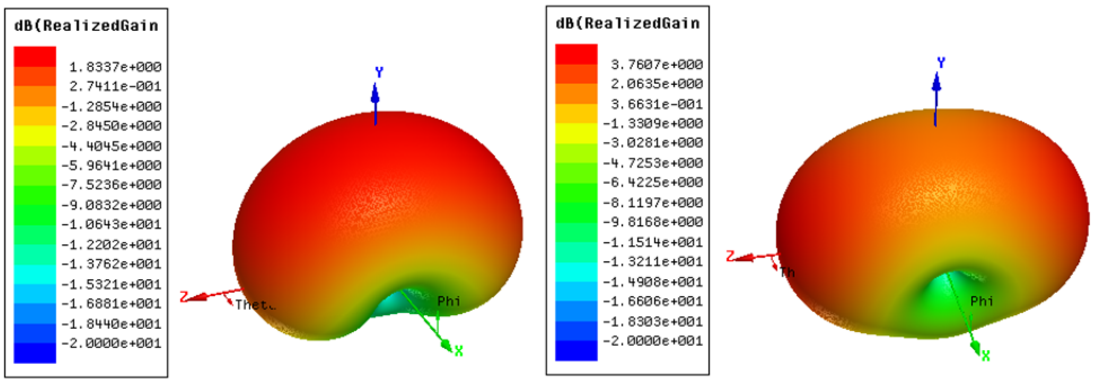
Fig. 3. Comparison of S_{11} (in dB) versus frequency for the three cases, CASE-I: Conventional planar dipole antenna without any CSRR loading and defected ground structure, CASE-II: CSRR-loaded planar dipole antenna without defected ground, CASE-III: Proposed Dual-band Antenna in Fig. 1. Matching unit shown in Fig. 2(b) is used for all the three cases mentioned here.

Full-wave simulations of the proposed antenna structure is done in FEM-based Ansys HFSS. Fig. 3 shows the variation of the S_{11} (in dB) with frequency for the three different cases. It is observed that the reference planar dipole (Case-I) without the CSRR loading and defected ground operates at 2.67 GHz (bandwidth 470 MHz). Loading the dipole symmetrically with CSRR-embedded patches results in shift of the dipole mode to 2.38 GHz (bandwidth 290 MHz). In addition the CSRR loading introduces a new operating mode at 1.70 GHz, but good impedance matching is not achieved (Case-II). The proposed antenna utilizes the defected ground plane to achieve better matching in the miniaturized lower order band. In the final design (Case-III) the value of S_{11} (in dB) at 1.70 GHz comes down to -18.26 dB from -10.38 dB as obtained in Case-II with conventional partial ground. Also impedance bandwidth around 90 MHz is obtained for this miniaturized lower order band. Fig. 4 shows the distribution of surface current magnitude on the dipole antenna, defected ground and the CSRR-embedded patches, for both the operating frequencies.



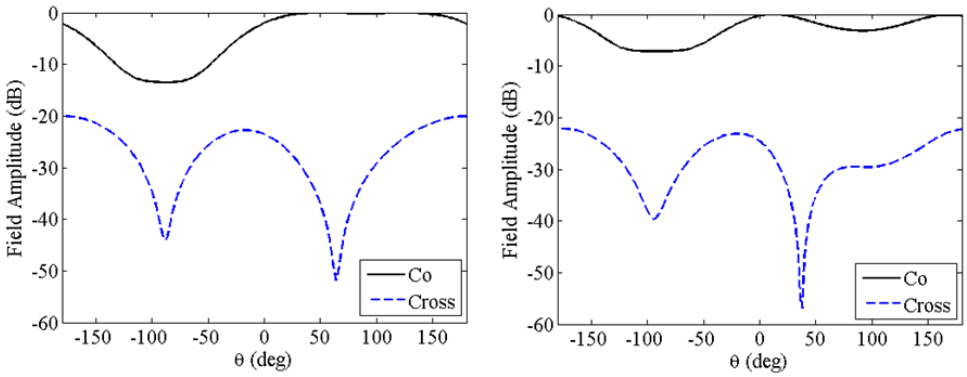
(a) **(b)**

Fig. 4. Distribution of surface current magnitude on the antenna conductors at (a) 1.70 GHz (strong concentration about the CSRRs) and (b) 2.42 GHz.



(a) **(b)**

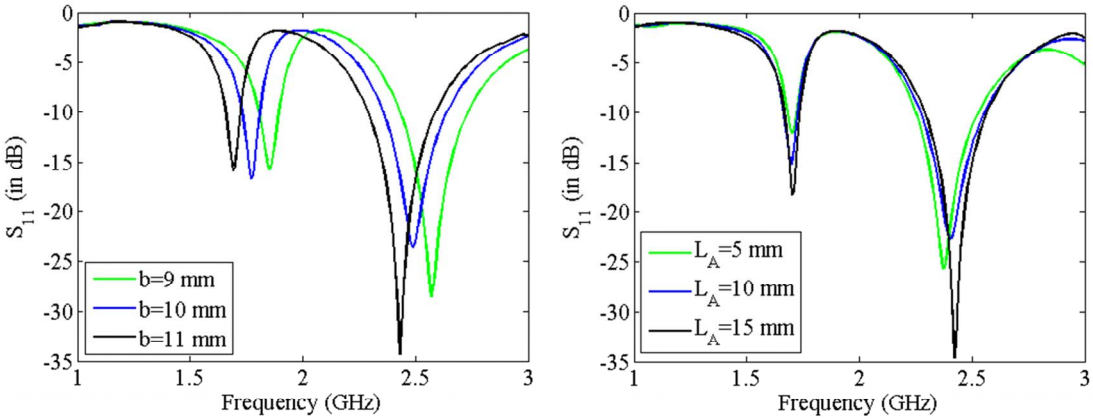
Fig. 5. 3D Radiation Pattern for the Proposed Dual Band Antenna (Fig. 1): (a) 1.70 GHz and (b) 2.42 GHz.



(a) **(b)**

Fig. 6. Relative magnitude of simulated co-polarized and cross-polarized E-fields for $\varphi = 90^o$ plane at (a) 1.70 GHz and (b) 2.42 GHz.

Fig. 5 shows that the proposed dual-band antenna exhibits good peak far-field realized gains of 1.83 dBi and 3.76 dBi at 1.70 GHz and 2.42 GHz respectively. For both the bands in the *x*-directed planar dipole, nulls are observed in $\varphi = 0^o$, $\theta = 90^o$ direction. Also the presence of partial defected ground along *xy*-plane as shown in Fig. 1(b), suppresses the radiation along $180^o \leq \varphi \leq 360^o$, making the *x*-directed dipole along $0^o \leq \varphi \leq 180^o$. Furthermore, significantly low value of cross-polarized components as compared to the co-polarized components of the E-field for $\varphi = 90^o$ plane (Fig. 6), confirm the linearly polarized nature of the proposed antenna. Fig. 7 shows the results of parametric analysis of the proposed antenna. It is evident from Fig. 7(a) that the bands of the proposed antenna can be tuned by simply varying the width b of the rectangular CSRR. Fig. 7(b) shows that the length of the rectangular slot has considerable effect on the impedance matching on both the bands.



(a) **(b)**

Fig. 7. Parametric study on the return loss of the proposed antenna (a) Effect of CSRR width b. (b) Effect of ground slot length L_A.

3. Conclusion

A dual band printed dipole antenna with directive radiation pattern is designed by loading with metamaterial-inspired CSRR-embedded patches. Good impedance matching at the lower order frequency band is achieved by use of a defected partial ground plane. The return loss characteristics and far-field patterns of the proposed antenna are analyzed via full-wave HFSS simulations. The proposed antenna is a good candidate for wireless communication devices working in GSM/Bluetooth/WLAN range.

4. Acknowledgement

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5. References

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