A Compact Metamaterial inspired Dual-band SRR loaded Antenna for Wireless Applications

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Abstract
*In this study, a compact antenna inspired by metamaterial loaded with two split ring resonator (SRR) having dual band characteristics has been presented. The proposed antenna offers compact size with total antenna dimensions as 22.95λ_0*18.70 λ_0*0.013λ_0, where λ_0 is the free space wavelength at 2.55 GHz. Because of double SRRs, the presented antenna has dual band behaviour with first band centered at the resonance frequency of 2.55 GHz and the other band centered at the resonance frequency of 3.48 GHz having input impedance bandwidth (S_{11}<-10 dB) for the first resonance band as 7.05% and for the second resonance band as 3.73% respectively.*

The SSRs also provided the optimal matching and increased the gain of proposed antenna in working band. The radiating rectangular patch is slotted to maximize the current flowing through it. This configuration achieved maximum performance of antenna properties. The designed antenna has a radiation nature with gain of 1.42 dB and .73 dB for first and second resonance band respectively. From the radiation pattern, this designed antenna shows the omnidirectional in xz-plane and in yz-plane it shows the dipolar type radiation pattern.

Keywords: Split ring resonator, metamaterials, dual-band.

Introduction

Metamaterials are homogeneous structure whose size of the cell is much smaller than the guided wavelength.[1] For a material to be called as metamaterial, it should have both negative μ_r and ε_r, where μ_r and ε_r are the relative permeability and permittivity. Therefore, they are called as Left-handed materials as they have double negative parameters. MTMs are distributed structures made of lumped elements which mean S<λg/4 where S is size of the component. In this case the phase difference between the signals from the input to the output is negligible. Therefore, the lumped elements are considered as size less element.

Design of compact antenna[3,6] has good applications in transmission line-based Metamaterials. Multiband antenna having compact size increases its value in wireless applications. Day by day research is going on to make antenna more compact in size, having good gain and radiation efficiency. To full fill this purpose, Metamaterials are in demand due to its properties like negative η where η is refractive index of material.

SRR is made by using two concentric metallic rings having split in both the ring at the opposite side of each other. For designing multiband LC loaded SRR is used. In proposed antenna to generate dual-band with extended bandwidth, rectangular split ring resonator is used.

In this study, a compact size antenna inspired from metamaterial has been presented. The proposed antenna is a combination of CPW-fed,[2] two SRR and slotted radiating rectangular patch antenna. The total physical size of proposed structure is 27*22*1.6 mm^3 and shows dual-band characteristics. The proposed antenna has impedance bandwidth (S_{11}<-10 dB) of 7.05% (2.46-2.64 GHz) for the first band and impedance bandwidth (S_{11}<-10 dB) of 3.73% (3.42-3.55 GHz) for the second band respectively. In addition, the presented antenna shows good peak gain and radiation efficiency in the working band. The designed antenna shows dipolar radiation pattern in *xz*-plane and omnidirectional radiation pattern in *yz*-plane which is more suitable for wireless applications.

Antenna Design

For SRR[7] structure design, positive-ε/negative-µ MTM is considered as shown in fig. 1. Here two concentric metal rings are considered having split at both the opposite side which act as capacitor. There will coupling between these ring.one is capacitive coupling (C_m) because of the gap between the two concentric ring and the other will be inductive coupling represented by transforming ratio n as shown in the fig. 1. For a single ring, resonance frequency is given by $\omega = \sqrt{LC}$.

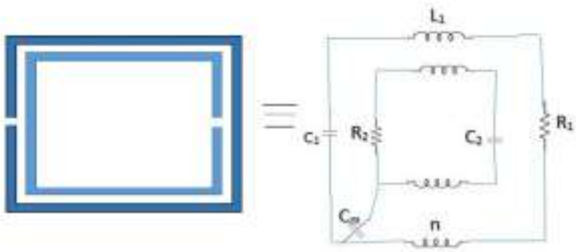

Fig. 1: Double SRR with its equivalent circuit

The presented antenna considered in this study is designed on FR4 substrate with height = 1.6 mm with dielectric constant (ε_r) of 4.4 and the thickness of copper layer is 0.035 mm. Here, two square types SRR have been used on the FR4 substrate having outer length = 6 mm and inner length = 4.8 mm and outer width = 6 mm and inner width = 4.8 mm. The geometry of SRR strongly affects the lower impedance bandwidth and also improves matching and gain of proposed antenna. Here square type SRRs are used to compare circular SRRs to have a lower magnetic resonant frequency.

Two SRR are placed closed to radiating slotted patch antenna and coupled with it magnetically. Because of coupling, the radiating patch antenna fields interact with that of two SRRs, which in turn excite both inner and outer ring of two SRRs and make it behave like a metamaterial, thus giving a radiating mode that corresponds to two bands one at 2.55 GHz and one at 3.48 GHz. Here patch is slotted for maximum radiation efficiency as it will allow more current to flow through it.

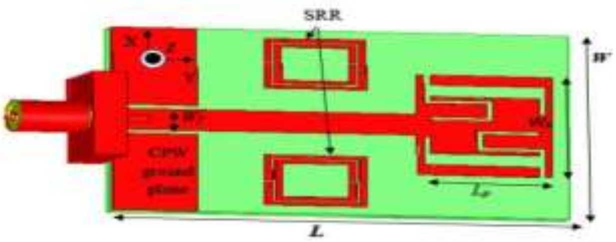

Fig. 2: Dual-band SRR loaded Metamaterial inspired antenna (*L*= 27mm, *W* = 22 mm, W_F = 2.5 mm, L_P = 8 mm and W_P = 12 mm).

Results and Discussion

The simulated input impedance bandwidth for dual-band characteristic of proposed SRR loaded metamaterial inspired antenna having slotted rectangular patch is presented in fig. 3. The designed antenna depicts input impedance bandwidth 7.05% (2.46-2.64 GHz) for the first band and for the second band 3.73% (3.42-3.55 GHz) respectively as shown in fig. 3.

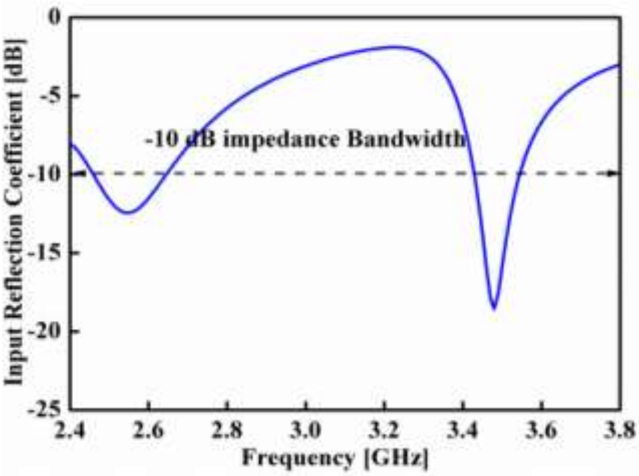

Fig. 3: $|S_{11}|$ of presented dual-band MTM antenna.

Fig. 4 depicts the peak gain versus frequency of the designed dual-band MTM antenna. With reference to fig. 4, designed antenna shows 1.42 dB at first resonance frequency, 2.55 GHz, while it shows 0.73 dB at second resonance frequency 3.48 GHz respectively. The proposed antenna shows radiation efficiency in broadside direction as shown in fig. 5. From fig. 5 it is found that the radiation efficiency is 90.66% at first resonance frequency (2.55 GHz) while 70.40% in the second resonance frequency (3.48 GHz) respectively. Fig. 6 and fig. 7 depict the co- and cross-polarization of designed dual-band MTM antenna at two different resonance frequencies of 2.55 GHz and 3.48 GHz respectively.

It is found from fig. 6 that the difference between co- and cross-polarization levels is 27.39 dB at 2.55 GHz in broadside direction. The difference between co- and cross-polarization at 3.48 GHz frequency in broadside direction has been found to be -5 dB. Because of high cross polarization, the proposed antenna shows low gain in the second band. But the pattern is useful for the wireless communications.

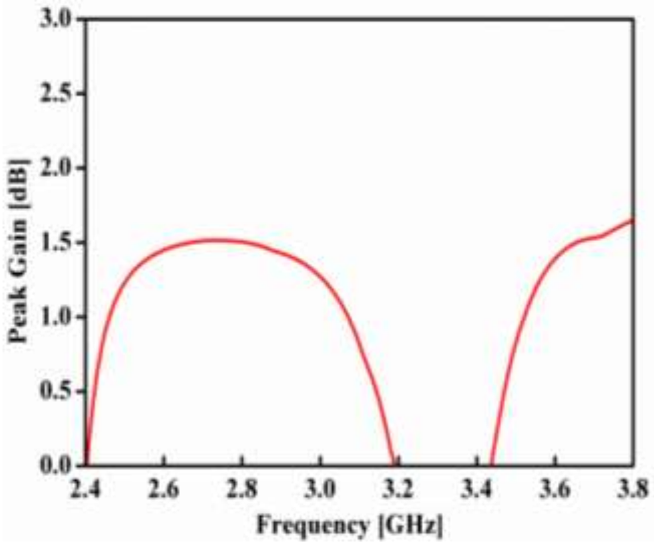

Fig. 4: Peak Gain of proposed dual-band MTM antenna.

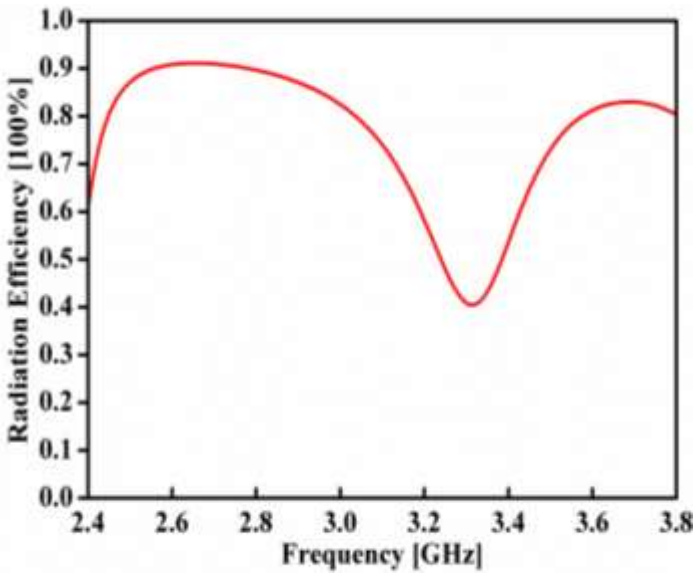

Fig. 5: Radiation Efficiency of designed dual-band MTM antenna at θ =0º and ϕ = 0º.

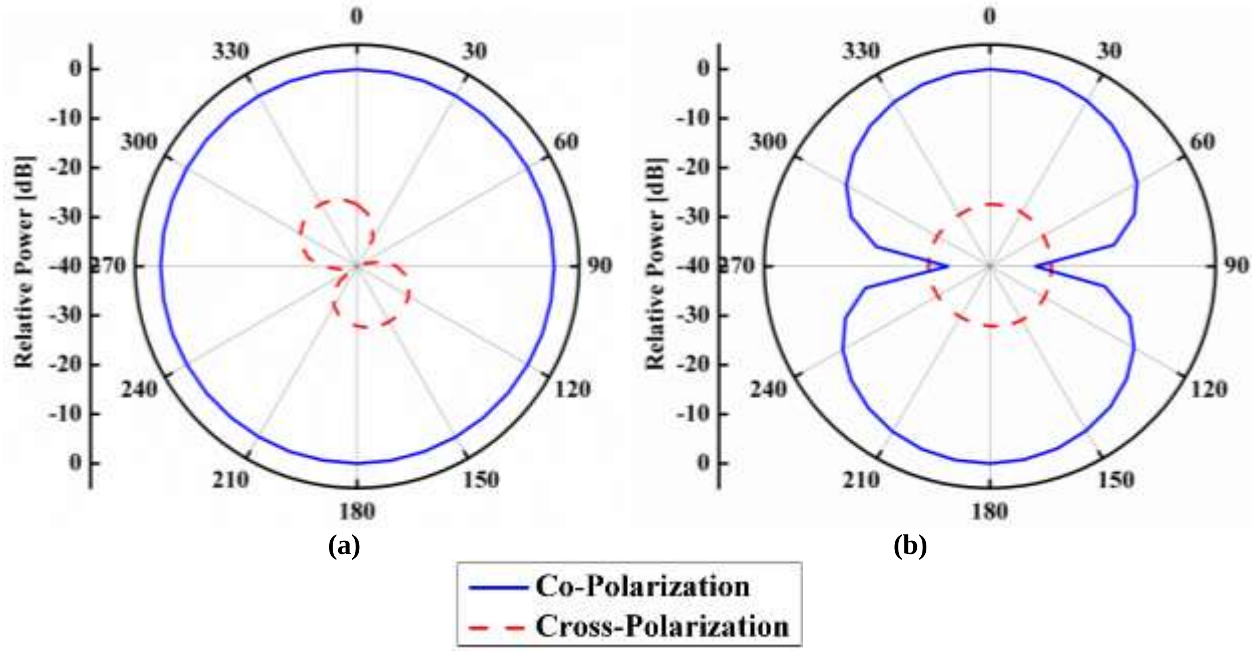

Fig. 6: Normalized radiation patterns of designed dual-band MTM antenna (a) In *xz*-plane at 2.55 GHz, (b) In *yz*-plane at 2.55 GHz.

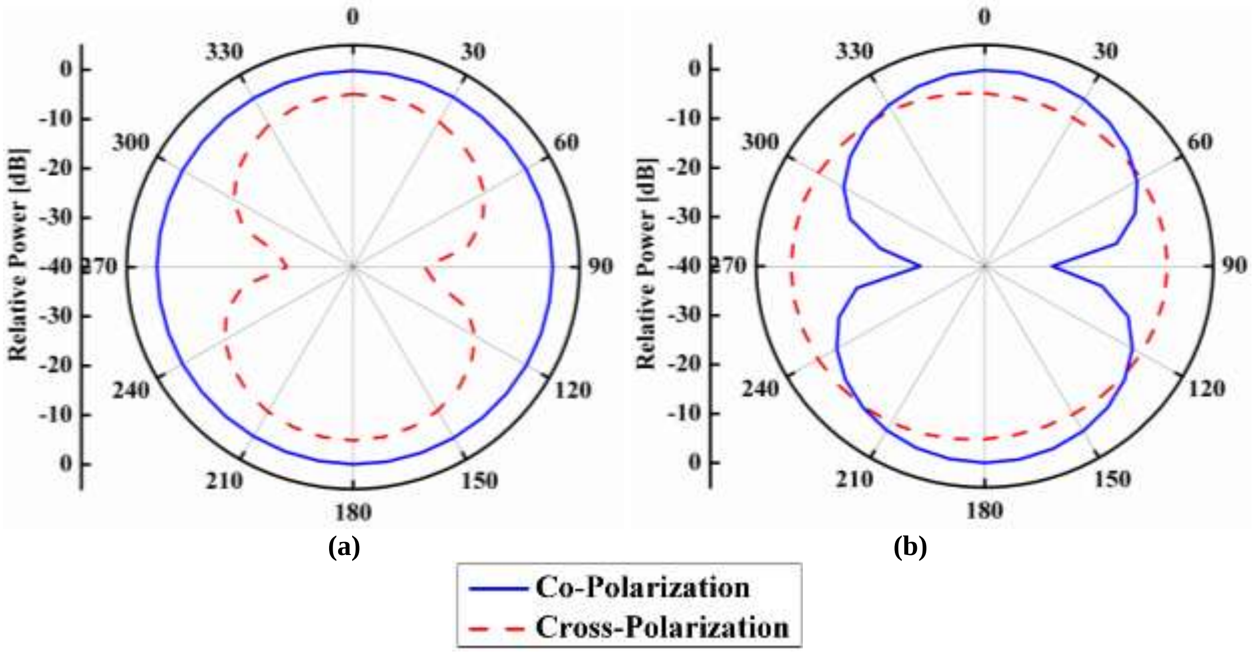

Fig. 7: Normalized radiation patterns of designed dual-band MTM antenna (a) In *xz*-plane at 3.48 GHz, (b) In *yz*-plane at 3.48 GHz.

Conclusion

In this study, a dual band metamaterial inspired antenna based split ring resonator with slotted rectangular radiating patch has been developed. The designed antenna depicts dual band response because of the combination of SRRs and slotted rectangular radiating patch. The SRRs also improve the matching as well as gain of proposed antenna. The presented antenna exhibits dual-band operations and shows -10 dB input impedance bandwidth (S_{11}<-10 dB) of 7.05% (2.46-2.64 GHz) for first band and 3.73% (3.42-3.55 GHz) for second band respectively.

The proposed antenna has an electrical size of $22.95\lambda_0$*$18.70 \lambda_0$*$0.013\lambda_0$, where λ_0 is the free space wavelength at 2.55 GHz. In *xz*-plane the designed antenna shows omnidirectional radiation pattern and in yz-plane it shows dipolar type radiation pattern with a good peak gain and radiation efficiency in the working band. Due to miniaturization and dual-band characteristics of the designed MTM antenna, the proposed antenna can be easily used for the wireless applications.

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