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Dual Band Z-slotted Rectangular Micro-Strip Patch Antenna Loaded with metamaterial

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Abstract

Objectives: To design of a Dual Band Z-slotted rectangular micro-strip patch antenna loaded with metamaterial. **Methods/Statistical Analysis:** Three MSRR (Multiple Split Ring Resonator, no of rings(N=2)) are used for loading. The structure is having one Z-slotted rectangular micro-strip patch and three SRR at the top, bottom and front side of patch. The entire proposed structure is implemented on a substrate having permittivity (ε_r=2.2) with thickness (h=2.1mm). **Findings:** When patch is loaded with metamaterial, it resonates at two bands 4.9GHz and 5.3GHz with a good impedance bandwidth. The electrical size of this antenna is 0.317 λ x 0.3551 λ x 0.0364 λ at lower resonant frequency. The antenna gain is 6.67 dB and 7.53 dB at the first and second band respectively. Thus conclusion is that MSRR improve the radiation pattern of slotted antenna. **Application/Improvements:** Antenna is suitable for public safety wireless communication system and WLAN application.

Keywords: Dual Band Antenna, metamaterial, Rectangular Micro-Strip Patch Antenna(RMPA), Slotted Antenna

1. Introduction

Micro-strip patch antenna is nothing but a metallic strip placed above the ground at a height which is a fraction of wavelength. Its input resistance and bandwidth depends on the patch width, and its resonant frequency depends on its length. Its design equation has been discussed in antenna handbook[1]. Due to various shapes (triangular, square, circular, elliptical etc.) and its conformable feature of rectangular patch it is widely used. Performance of the patch antenna can be improved by various methods like slotting, metamaterial loading etc. Slotting technique is majorly used for bandwidth and return loss improvement[2]. Size reduction also takes place by slotting. Metamaterial concept was theoretically predicted first by Veselago in 1968[3] and was demonstrated first in[4] 2001. By the use of metamaterial properties like anti-parallel phase and group velocity[5], micro-strip patch antenna can be made more compact. Among all bandwidth enhancement techniques metamaterial loading is the most advantageous one, because by this not only bandwidth improves with sub wavelength resonance but it also enhances the radiation pattern of the patch also. Myriads of designs have been studied for a single antenna to work in dual band such as stub feeding[6], CPW-feed monopole antenna[7], I and U slotted antenna by using CSRR(Complementary Split Ring Resonator) structure[8] etc. Conclusion is that, it is possible to achieve multiband by the combination of radiating elements with the different shapes of metamaterial. In 2002, FCC (Federal Communication Commission of US) allocated a band 3.1 to 10.6 GHz for commercial purposes[9]. This paper presents a compact dual band planer antenna using Metamaterial loading. Out of the two bands we get, highest resonant band resulted due to the patch and the lowest resonant frequency band is due to coupling between patch and meta-material(MSRR).

Design and Analysis: Geometry of the proposed antenna loaded with rectangular SRR (Split Ring Resonator) is shown in figure1. The structure is having one Z-slotted rectangular micro-strip patch and three SRR at the top, bottom and front side of patch. The entire proposed structure is implemented on a substrate having

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permittivity(ε_r=2.2) with thickness (h=2.1mm). Length and width of RMPA for f=5.21 GHz has been calculated by given equation.

$$W=\frac{c}{2f\sqrt{\frac{\varepsilon_r+1}{2}}} \tag{1}$$

$$\varepsilon_{reff}=\frac{(\varepsilon_r+1)}{2}+\frac{(\varepsilon_r-1)}{2\sqrt{1+\frac{12h}{w}}} \tag{2}$$

$$L=\frac{c}{2f\sqrt{\varepsilon reff}} \tag{3}$$

Where, "ε_{reff}" denotes the effective dielectric constant of substrate and "c" is the speed of light in air.

The optimized dimensions of RMPA are; length (L=18.28mm), width (W=20.45mm), width of feed line (k=3.696mm) and depth of feeding (M=7.1mm). Slotting length and width are (L1=12mm) and (w1=2mm) respectively. Width of each SRR ring is (D=0.5mm) and gap between the ring is also 0.5mm. Inset feeding is provided by 50Ω impedance copper wire at a point so that reflection losses should be minimized.

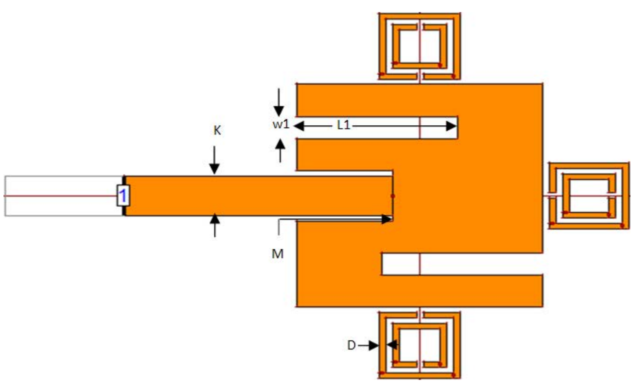

Figure 1. Proposed metamaterial loaded Z- slotted patch antenna.

2. Results and Analysis

2.1 Metamaterial Parameter Extraction

Here characteristics of metamaterial of the MSRR have been verified. S-parameters (reflection coefficient S_{11} and transmission coefficient S_{12})variation of MSRR is shown in figure 2.

These coefficients are used along with equation (4) and (5) to get MATLAB code in order to verify the characteristic of metamaterial.

$$\mu_r=\frac{2}{jk_0h}\frac{1-v2}{1+v2} \tag{4}$$

$$\varepsilon_r=\frac{2}{jk_0h}\frac{1-v1}{1+v1} \tag{5}$$

Where, μ_r(relative permeability), ε_r (relative permittivity), k_0 =2π/λ is wave number and V_1 and V_2 are related with reflection and transmission coefficient as below:

$$V_1=S_{21}+S_{11} \tag{6}$$

$$V_2=S_{21}-S_{11} \tag{7}$$

For a structure to behave as metamaterial either "μ_r" or "ε_r" any one should be negative. Figure 2 shows that at resonant frequency maximum power is transmitted because reflection losses are minimum at resonant frequency. Figure 3 verifies that MSRR structure is behaving as metamaterial as its μ_r is negative.

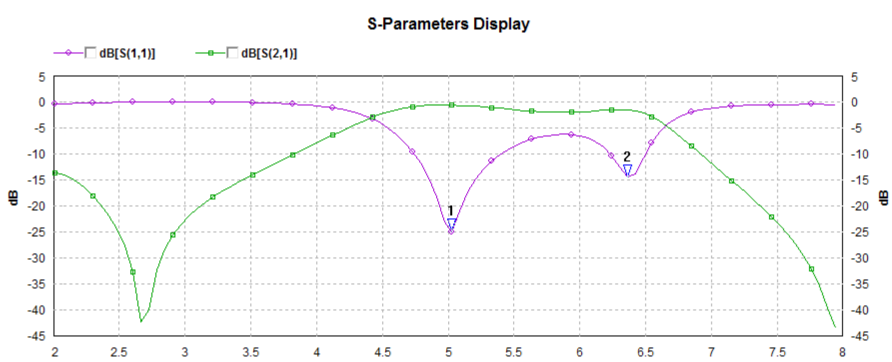

Figure 2. S- Parameters (S_{11}, S_{21}) characteristic of MSRR.

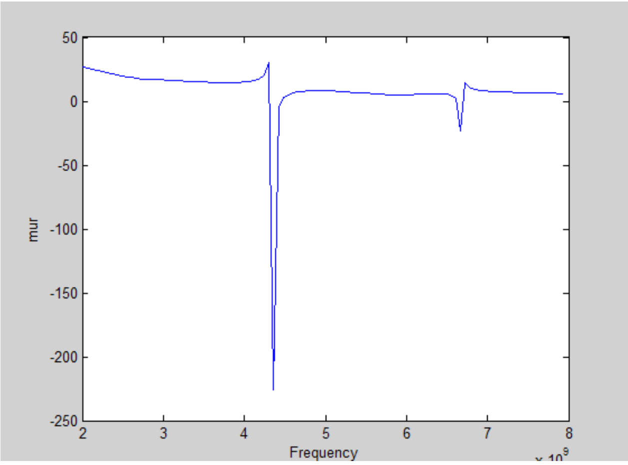

Figure 3. μ_r vs. frequency (GHz) plot for MSRR shows (μ_r = negative).

2.2 Return Losses Characteristics

Return loss of Z-slotted patch without loading and with loading is shown in figure4 and figure5 respectively. Value of Return loss less than -10dB shows how well power is received by antenna. At 5.2 GHz return loss for Z-slotted antenna is -20.67dB and bandwidth of 147 MHz for the optimized structure. MSRR loading produces two bands one at 4.9 GHz and the other at 5.3 GHz with good return loss -18.8dB (bandwidth=45MHz) and -21.995dB(bandwidth=172 MHz) respectively. Highest resonant band is resulted due to the patch and the lowest resonant band is due to the coupling between patch and metamaterial (MSRR). Figure 6 shows the VSWR characteristic of proposed antenna. The acceptable value of VSWR for a good antenna should lies in the range of

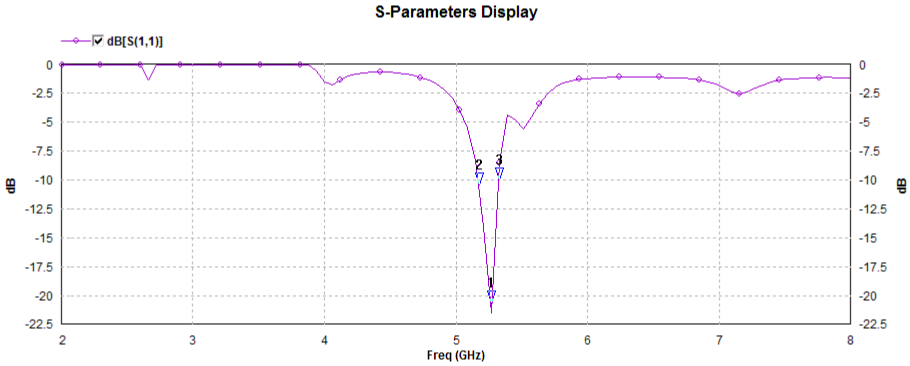

Figure 4. Return loss (S_{11}) characteristics of Z-slotted RMPA.

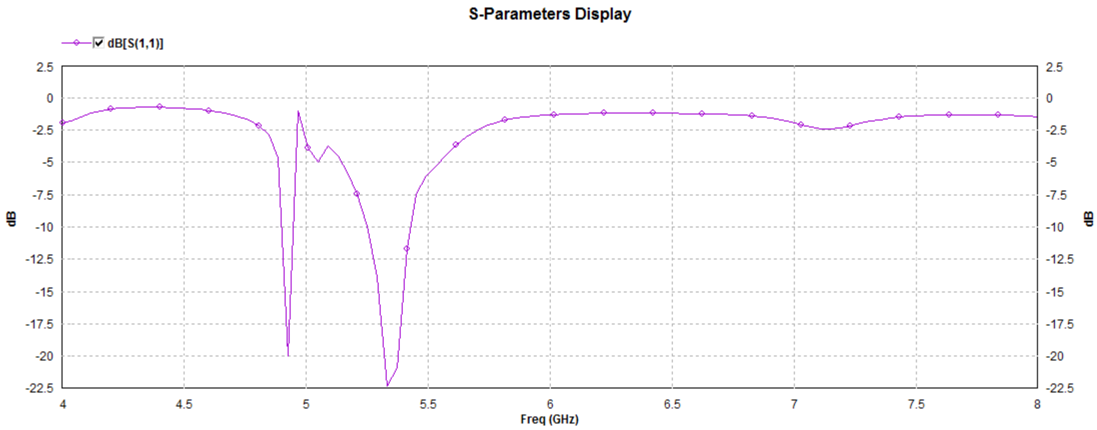

Figure 5. Return loss (S_{11}) characteristics of RMPA loaded with MSRR.

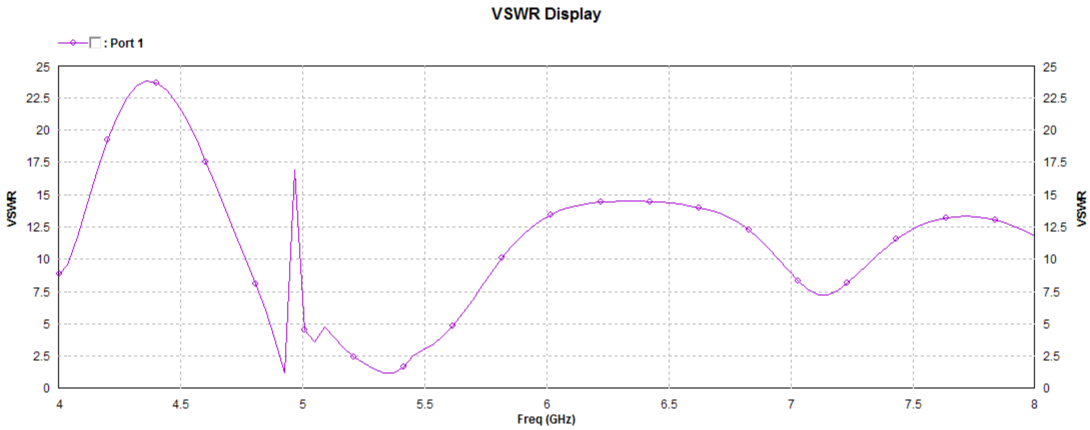

Figure 6. VSWR characteristics of RMPA loaded with MSRR.

1 to 2, here it is1.16 at 4.9Ghz and 1.24 at 5.3Ghz ,which means antenna is reflecting back minimum power at the resonant frequency.

2.3 Radiation Pattern(gain) Characteristics

Radiation pattern of Z-slotted antenna without and loaded with metamaterial are shown in figure 7 and figure 8(a and b) respectively. When Z-slotted patch is loaded with metamaterial, it shows an increase in gain by an amount around 2 dB. From figure 7 gain without MSRR loading is 5.2dB. But while loaded with MSRR it splits in two bands, first band is having gain of 6.67dB and second band is having gain of 7.53dB.

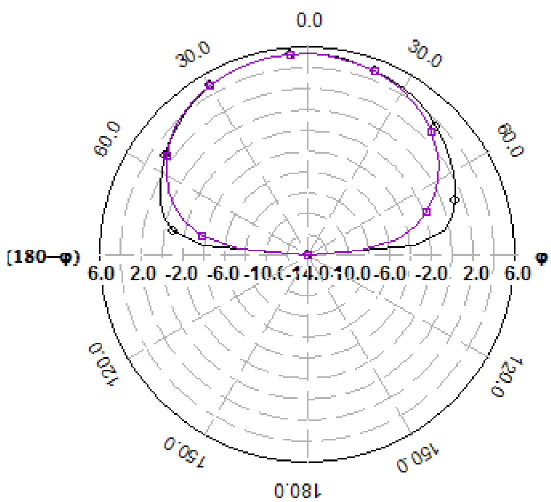

Figure 7. 2-D radiation pattern of Z-slotted patch (gain=5.2dB at phi=0°, 60°).

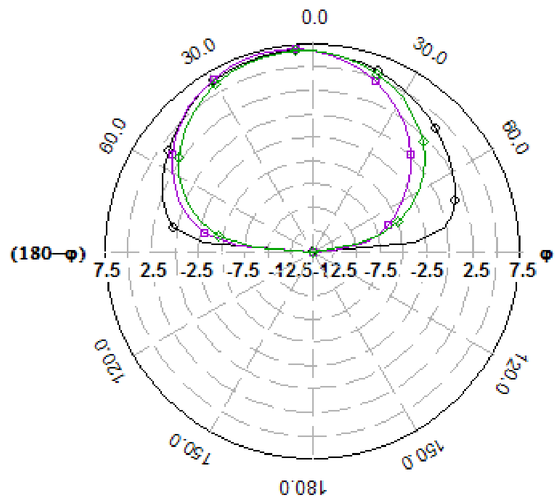

Figure 8a. 2-D radiation pattern (gain=6.67dB) of MSRR loaded antenna at 4.9 GHz (with phi=0°,60°,120°).

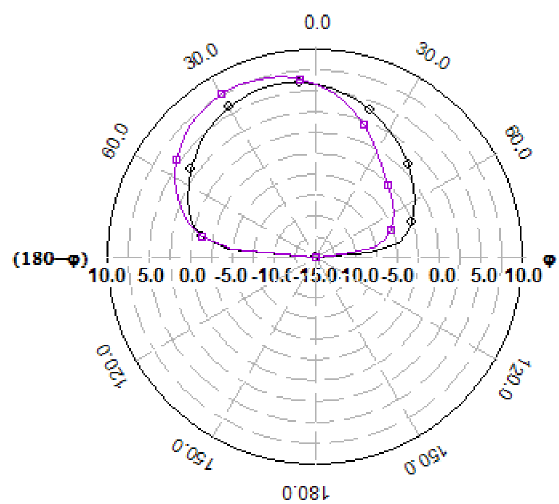

Figure 8b. 2-D radiation pattern (gain=7.53dB) of MSRR loaded patch at 5.3 GHz (with phi=0°, 60°).

3. Conclusions

This paper proposes a dual band Z-slotted RMPA antenna loaded with metamaterial. Slotting is used to reduce the area and to improve bandwidth and reflection coefficient of normal RMPA. Due to metamaterial loading two extra bands are found with the antenna gain of 6.67 and 7.53 dB for the first and second band respectively. Due to two bands antenna is used for different application. It is suitable for modern public safety wireless communication system.

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