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Dual Band Microstrip Patch Antenna for Wireless Applications

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ABSTRACT

In this paper dual band rectangular microstrip patch antenna using T- slot and capacitive loading is presented for wireless applications. The proposed antenna resonates at 2.50GHz and 4.80GHz, having bandwidth of 137 MHz and 123MHz with gain of 2.07dBi and 1.51dBi respectively. The 'T' shape slot is used on radiator and ground plane to enhance the bandwidth. By using capacitive loading considerable gain enhancement has been achieved. The antenna is design, simulated using CAD FEKO.

***Index Terms*:** Defective ground structure, dual band, T- slot, capacitive loading.

1. INTRODUCTION

Recent improvement of wireless communication requires handheld, portable and high performance multiband antennas. Microstrip patch antennas are the most suitable contender and it is simply integrated in the RF circuits. Microstrip patch antenna has major limitations of less bandwidth and gain. Extensive literature survey shows rigorous research is carried out to improve the bandwidth and gain of patch antenna. Researchers developed different methods such as shorting pin, meandering, stacking or use of high thickness substrates have been implemented to overcome the limitations of microstrip antenna such as use of high thickness substrate is of simple as compared to other techniques. Slotting technique is widely used to achieve multiresonant wideband operation [1]-[7].

A compact dual-band rectangular microstrip patch antenna using L and C shaped structure has been proposed along with defected ground structure is proposed, however, the limitation found related to the packaging of the proposed antenna [1]. A geo-textile fabric material based metamaterial loaded wearable T-shaped microstrip patch antenna for public safety band applications has been presented in [2]. A rectangular slotted microstrip patch antenna with partially loaded metamaterial multiple-split ring resonator (MSRR) loaded in ground plane has been presented. It resonates at multiband applications, researcher have been used two slots to achieve multiband performance [3]. H-shape etched slot on radiating patch has been proposed to improve impedance and bandwidth. While adding a parasitic patch in stacked configuration increases the thickness of the differentially driven microstrip antennas [4]. A new design of microstrip patch antenna by cutting U and half U-slot for broadband operation is proposed. Both designs are implemented using air as a dielectric which occupies more space [5]-[6]. Notch loaded microstrip patch antenna for dual band operation have been presented, it shows resonance frequencies are much more sensitive to slot dimensions. However more optimization of resonance frequencies is possible [7]. This design shows, loading of a pair of right-angle slots and a modified U-shaped slot for

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enhancement of bandwidth has been determined. Design parameters are not optimized and it may increase the bandwidth of the design [8]. A planar dual-band antenna using a very compact radiator to cover all the 2.4/5.2/5.8GHz WLAN operating bands is presented [9]. The radiator consists of L-shaped and E-shaped elements. A slot loaded microstrip patch antenna is proposed to enhance bandwidth. Pair of slits is used to design wide band antenna. Parametric study gives the effect of slot dimensions on performance of antenna [10]-[11]. Tri-band operation of the proposed antenna has been achieved by a pair of symmetrical L and U-shaped slots inside the compact patch. However design represents more complexity [12]. The resonant frequencies are achieved by loading the antenna with non radiating slots along the patch. Dual band patch antenna is presented for use in microwave tomography system for breast imaging. Bandwidth enhancement is essential for breast cancer detection [13]. A method for gain enhancement of a microstrip patch antenna is proposed by removing the substrate which reduces surface waves and reduces dielectric loss [14].

Capacitive loading with microstrip patch antenna is rarely used technique. The main objective of this research work is to discuss the use and effects of capacitive loading technique. In this paper, a T-shape slot loaded microstrip patch is design and effect of slot parameters on performance of antenna is discussed. This design achieves dual band (ISM band & C band) operation useful for many commercial applications. Slot loaded radiating patch shows multi resonance response. By using defected ground structure technique, the enhancement in bandwidth is achieved up to 333 MHz, without disturbing lower resonant frequency. The desired gains have been accomplished using capacitive loading.

This paper is organized as follows. Section II provides design of T slotted microstrip patch antenna. Section III depicts the detailing of DGS and Capacitive loading. Section IV and section V gives results and conclusion respectively.

2. RECTANGULAR MICROSTRIP PATCH ANTENNA DESIGN

The patch antenna (Antenna 1) is a rectangular microstrip patch antenna L_p = 27.20 mm, W_p = 36.70 mm). The FR4 substrate with dimensions of 38.05 mm × 46.86 mm, thickness is of 1.59 mm. Antenna is fed through coaxial probe at x = 6.71 mm, y = 0 from non radiating edge. The physical dimension of the patch has been calculated using equations [16]-[17]. CADFEKO EM simulator is used to simulate the antenna structure.

$$Wp = \frac{c\sqrt{\frac{2}{1+\varepsilon_r}}}{2 f_r} \tag{1}$$

$$\text{Lp} = \text{Leff} - 2\Delta\text{L} \tag{2}$$

where,

$$\frac{\Delta L}{h} = 0.412\frac{\left(\varepsilon_{reff}+0.3\right)\left(\frac{w}{h}+0.2264\right)}{\left(\varepsilon_{reff}-0.258\right)\left(\frac{w}{h}+0.8\right)} \tag{3}$$

$$\varepsilon_{reff} = \frac{\left(\varepsilon_r+1\right)}{2} + \frac{\left(\varepsilon_r-1\right)}{2\sqrt{1+12\left(\frac{h}{w}\right)}} \tag{4}$$

$$L_{eff} = \frac{c}{2 f_r \sqrt{\varepsilon_{reff}}} \tag{5}$$

Where

ε_{reff} = Effective Dielectric constant

C = Velocity of light in free space

L_{eff} = Effective length of the Patch

ΔL = Length Extension of the Patch

To achieve multiband operation T-shaped slot is cut on rectangular microstrip radiating patch antenna. First design frequency kept as it is at 2.45GHz and in addition to that two more bands (Wi-Max and C Band) are achieved. The electrical size of the patch is $0.2196\lambda_0 \times 0.2967\lambda_0$. The electrical dimension for the slot structure is:

For horizontal Arm: $0.06555\lambda_0 \times 0.0164\lambda_0$, For Vertical Arm: $0.0204\lambda_0 \times 0.0655\lambda_0$

λ_0 is free space wavelength.

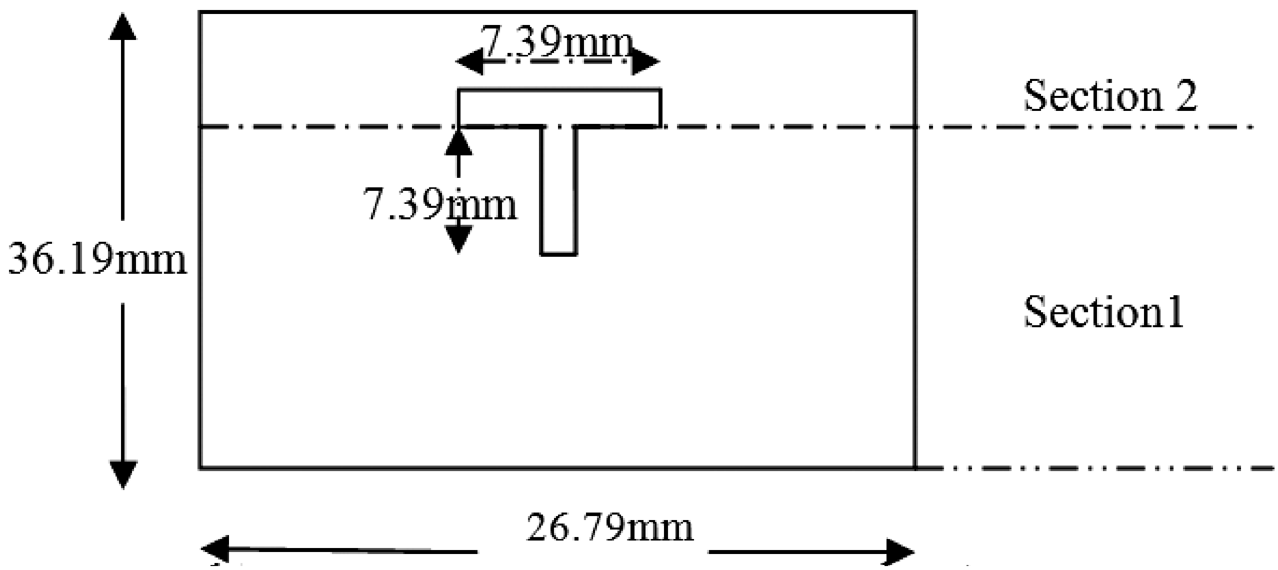

Figure 1: T-Slot rectangular microstrip patch antenna

T-Slot loaded patch is analyzed by considering two sections in the patch. Section 1 is analyzed as a patch in which single vertical notch is incorporated. This perturbation in the patch changes the surface current length which is accounted for by an additional series inductance ΔL and series capacitance ΔC. So the equivalent circuits of section 1 have been modified in which

$$L_2 = L + \Delta L \tag{6}$$

$$C_2 = C + \Delta C \tag{7}$$

The additional inductance is given as

$$\Delta L = \frac{Z1 + Z2}{16\pi \cos^{-2} \frac{\pi Z0}{L}} \tan\left(\frac{\pi fls}{c}\right) \tag{8}$$

The additional capacitance is given by,

$$\Delta C = 2ls\frac{\in 0}{\pi}\left[\ln\left(\frac{2\left(1+\sqrt{k'}\right)}{1+\sqrt{k'}}\right)+\ln\coth\frac{\pi d}{4h}+0.013c\frac{h}{d}\right].\cos^{-2}\frac{\pi y0}{Le} \tag{9}$$

The second section is considered as two microstrip bend line and the equivalent impedance of the shape is given as,

$$Z_{b=j}WLB+\frac{1}{\frac{1}{jwLb}+jwCb} \tag{10}$$

$$\frac{Cb}{Wb}=\left(9.5\in r+1.25\right)\frac{Ws}{h}+5.2\in r+7.0\,pf\,/\,m \tag{11}$$

And

$$\frac{2Lb}{10}=100\left(4\sqrt{\frac{Wb}{h}}-4.21\right)nH \tag{12}$$

Combining the above two sections, consider T-slot loaded patch .Antenna parameters changed due to change in slot length and width. Observations indicate that resonant frequency mostly depends on the length of the patch and the horizontal arm of cut T-slot on radiating patch. It results in change in inductance due to insertion of slot on a radiating patch. Introduction of slot changes current length and it cause to tuned antenna in dual band (2.44GHz and 4.50GHz) having considerable impedance bandwidth with respect to antenna 1. S_{11} plot of antenna 1 and 2 shown in Fig. 3 (a) and Fig. 3(b). It is observed that lower resonating frequency shifted towards lower side due to decrease in vertical arm length of T-slot. It has been also observed that lower resonating frequency shifted towards higher side due to increase in horizontal arm length. Along with T-slot vertical and horizontal arm length, if the length and width of the patch varies, results on enhancement of bandwidth and helps to achieve desire resonating frequency.

3. DEFECTIVE GROUND STRUCTURED RMPA WITH T-SLOT

First two structures of reference patch antenna and T shaped slot loaded antenna are combining together and cut a T shape slot on ground plane (Antenna 3). Addition of defective structure reduces dimension of patch. The dimensions of the patch are given by $0.2172\lambda_0 \times 0.3\lambda_0$. Electrical dimension of slot is given by:

Horizontal arm: $0.073\lambda_0 \times 0.016\lambda_0$, Vertical Arm: $0.020\lambda_0 \times 0.081\lambda_0$

Simulated results of T-Slotted and ground slotted rectangular microstrip patch antenna are compared. Simulated -10dB impedance bandwidth of Antenna 3 are 2.458-2.529GHz and 4.374GHz-4.809GHz.

4. CAPACITIVE LOADED T-SLOTTED RMPA

It is observed from the simulated result higher resonating frequency bandwidth is of 435 MHz but negative gain. Inductive effect on gain of defective ground structured slot loaded microstrip patch antenna. Capacitive loading reduces inductive effect of by adding capacitance in parallel with capacitance of slot loaded microstrip patch antenna.

Five antenna designs are shown in figure 3, simulation results of reflection coefficient with frequency plot is presented in figure 4. Simulated results for resonant frequency, bandwidth and gain are presented in Table I. Good matching between simulated and analytical results

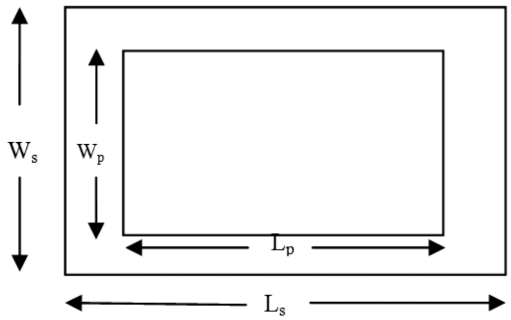

Figure 2(a): Antenna 1

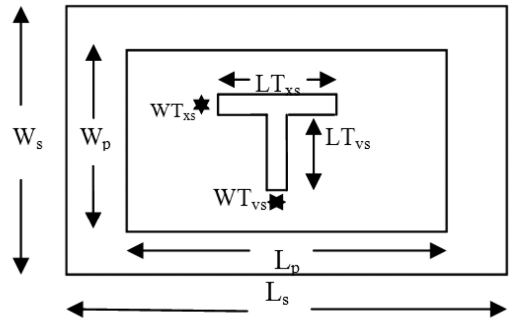

Figure 2(b): Antenna 2

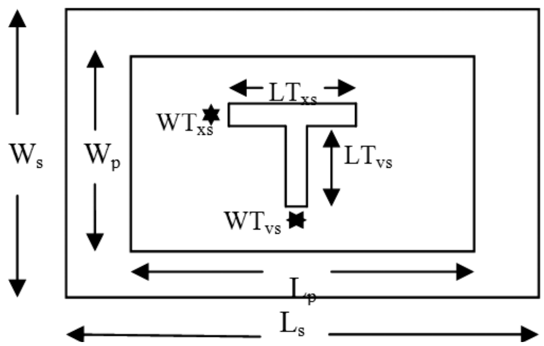

Figure 2(c): Antenna 3

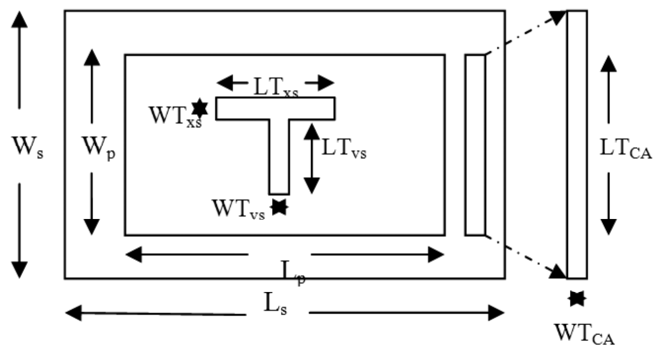

Figure 2(d): Antenna 4 WT_{CA}

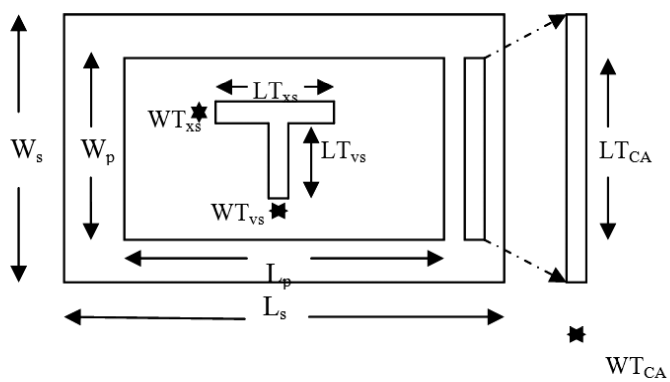

Figure 2(e): Antenna 5 WT_{CA}

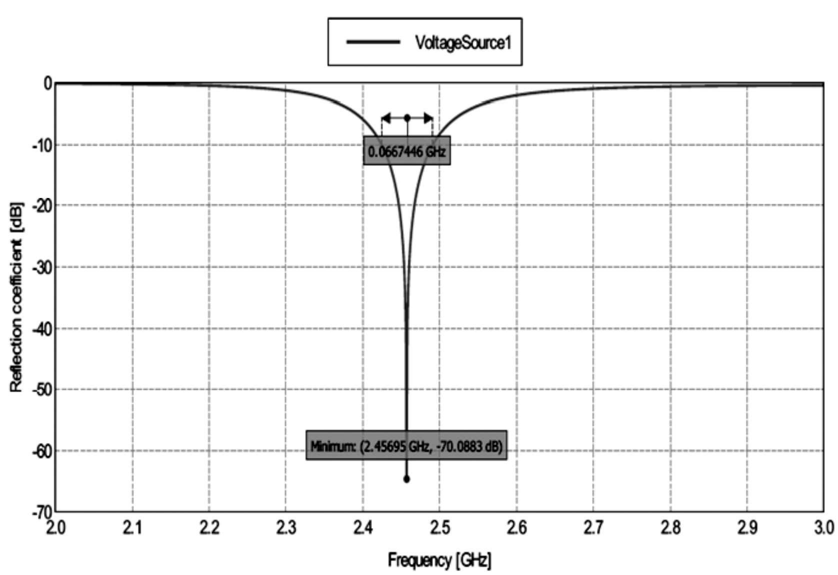

Figure 3(a): S_{11} of Antenna 1

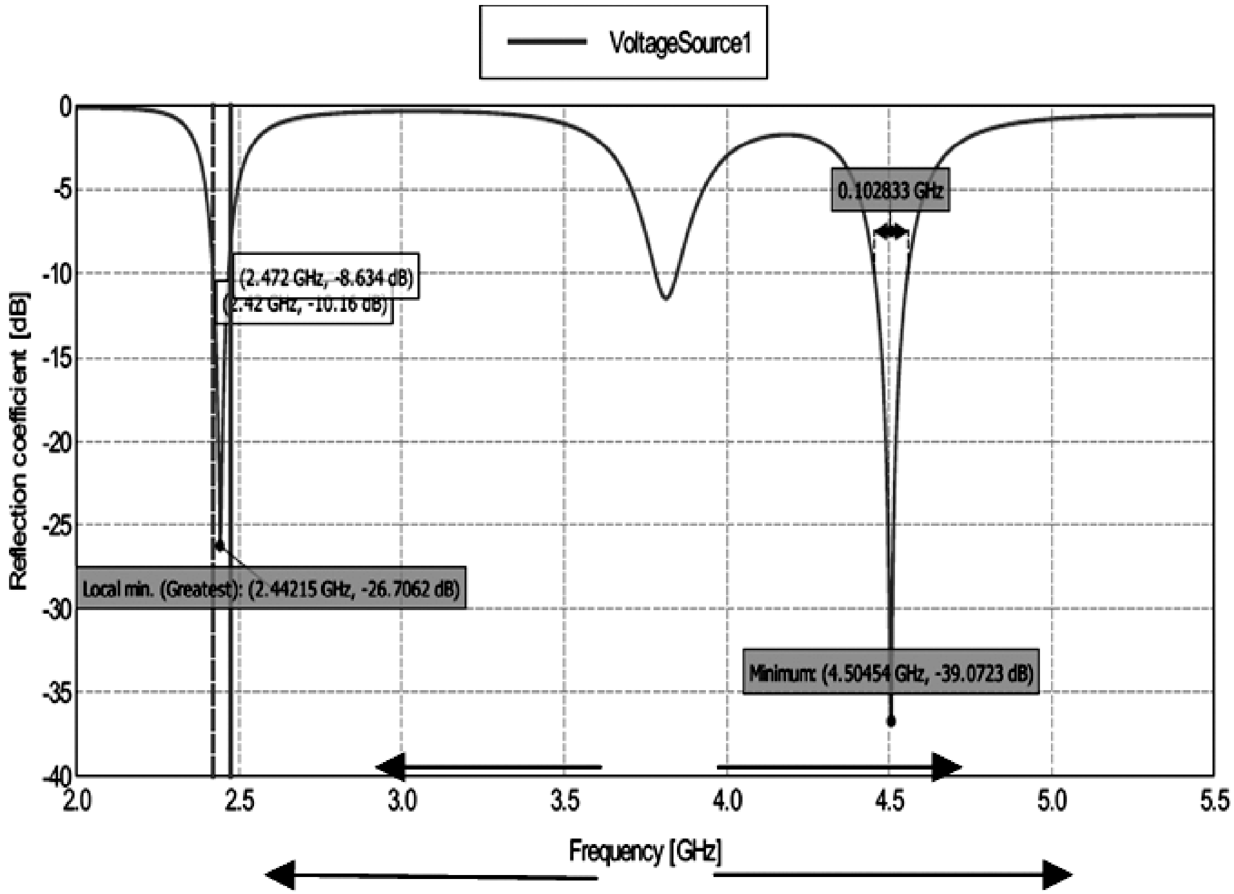

Figure 3(b): S11 of Antenna 2

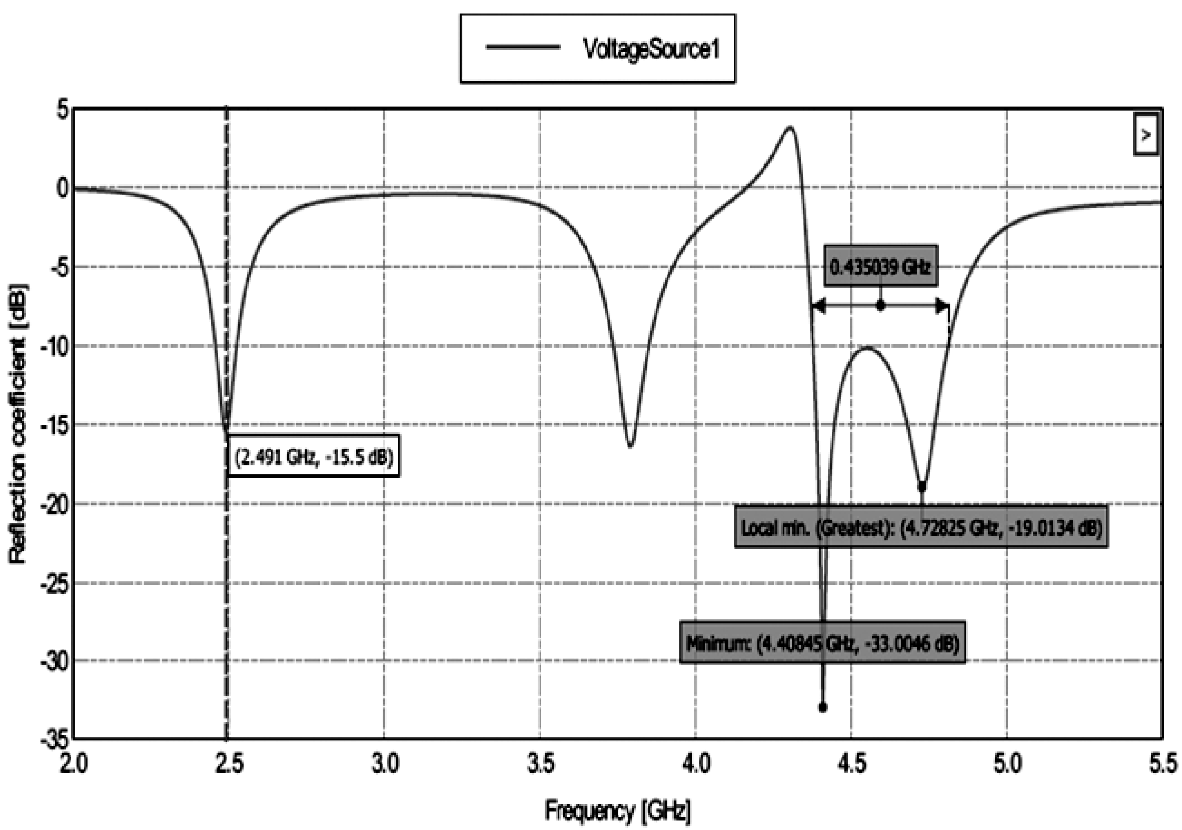

Figure 3(c): S_{11} of Antenna 3

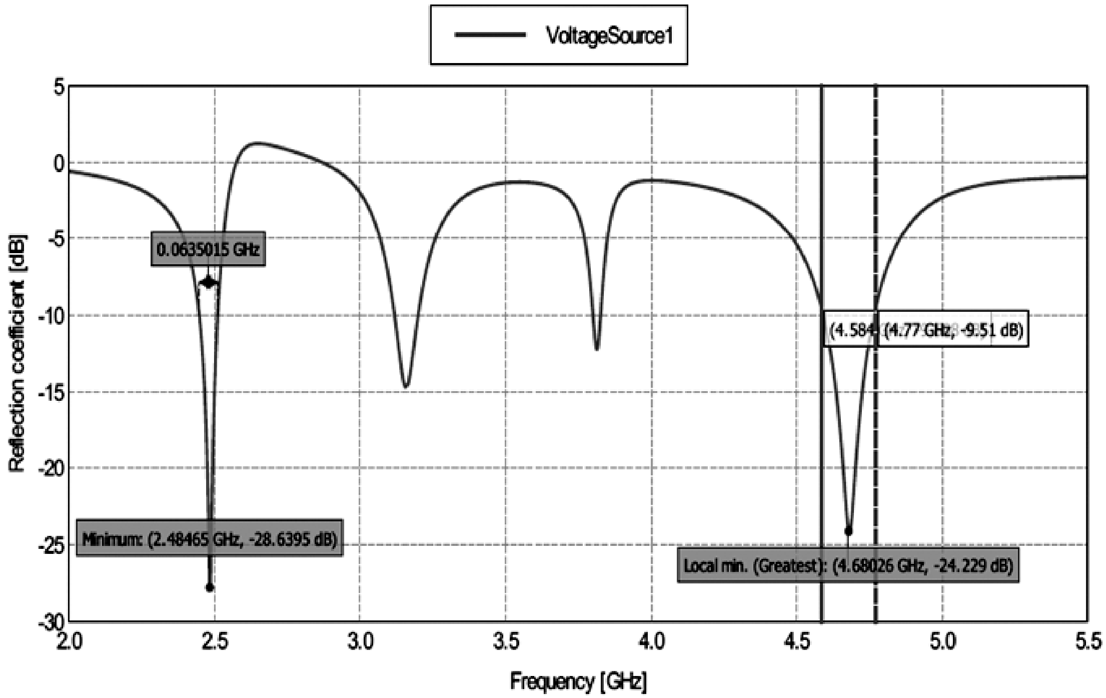

Figure 3(d): S_{11} of Antenna 4

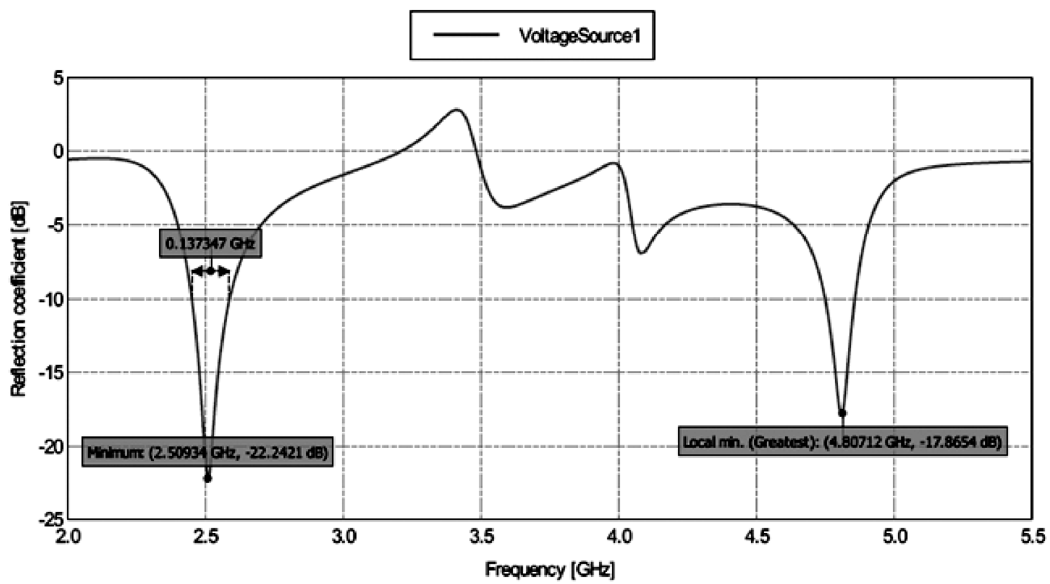

Figure 3(e): S_{11} of Antenna 5

5. RESULTS AND DISCUSSION

Table 1
Simulated Results

Sr. No	*Antenna Configuration*	*Frequency/ Band*	*Return Loss (dB)*	*Gain (dB)*	*Bandwidth MHz*
1	Antenna 1	2.456GHz (ISM Band)	-70.11	2.26	66
2	Antenna 2	2.44GHz (ISM Band) 4.50GHz (C Band)	-26.70 -39.07	11.6	57 102

(contd...Table 1)

Sr. No	*Antenna Configuration*	*Frequency/ Band*	*Return Loss (dB)*	*Gain (dB)*	*Bandwidth MHz*
3	Antenna 3	2.491GHz (ISM Band) 4.40GHz (C Band) 4.72GHz	-15.5 -33.0 -19.01	1.58	59 435
4	Antenna 4	2.48GHz (ISM Band) 4.68GHz (C Band)	-28.63 -24.22	2.69 3.03	63 174
5	Antenna 5	2.50GHz (ISM Band) 4.80GHz (C Band)	-22.27 -17.86	2.07 1.51	137 123

6. CONCLUSION

Dual band rectangular microstrip patch antenna is designed for (ISM and C band). Initially three frequency bands 2.491 GHz, 4.40GHz and 4.72GHz are observed by loading T-slot on radiating patch. Further this structure is modified to defective ground structure and loaded with capacitive slit. This design resonates at two bands 2.48GHz and 4.68GHz with 2.69dBi, 3.03dBi and 63MHz, 174MHz gain and bandwidth respectively. These antenna configurations will be useful for different RF and mobile communication applications.

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