A Compact Microstrip Fed T –Shape Patch Antenna with Swastika Ground

Komal Garg
Department of Electronics and Communication
JCDMCOE
Sirsa, India
komal.9126@gmail.com

Sukhdeep Kaur
Department of Electronics and Communication
JCDMCOE
Sirsa, India
ersukhdeepkaur@gmail.com

Abstract: A highly compact triple band patch antenna with dimensions 14×14×1mm^3 is presented in this paper. The antenna is fed by a 50Ω microstrip line. The antenna mainly consists of T shape radiating patch and defected ground plane in swastika shape. The proposed antenna is simulated using HFSS simulator and return losses of the antenna at resonant frequencies of 13.1GHz, 15.8GHz and 18.8GHz are -22dB, -23dB and -37dB respectively. The bandwidth of the proposed triple band antenna is (12.7-13.4) GHz, (15.5-16.1) GHz and (18.4-19.2) GHz. The radiation pattern of antenna is bi directional and suitable for satellite and radar applications.
Keywords: *Swatika ground, T shape patch, HFSS, triple band.*

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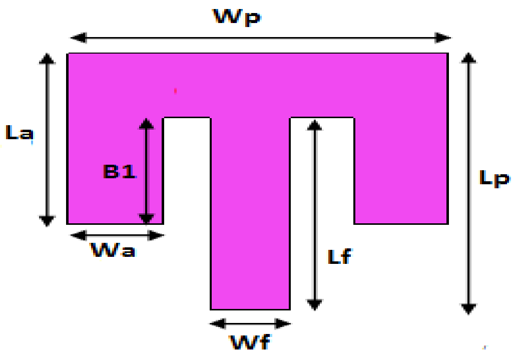
I. INTRODUCTION

To fulfil the increasing demand of compact antennas for various applications such as WLAN, Satellite and radar the field of printed microstrip patch antennas have gained researcher's attention [1-2]. The difficulty in designing antenna challenges engineers when the size of the antenna reduces and the number of operating frequency band increases. A lot of work has been done to design the compact antennas with multiband operation[3-4]. So far, for size reduction, bandwidth enhancement and resonance-mode increment numerous monopole antennas have been proposed by employing various techniques. The most unique technique used to enhance the bandwidth and reduce the size of the patch is to defect the ground[5]. DGS is found to be a simple and effective method to reduce the size of the antenna as well as excite additional resonance modes [6-8]. DGS is realized by etched periodic or non-periodic defect in the ground plane[9-12]. Defected ground structure changes shielded current distribution in the ground plane, which depends upon the shape and dimensions of the defect.

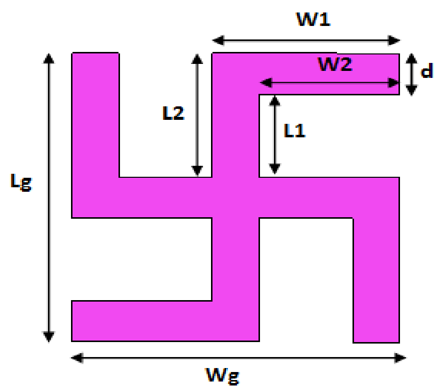
The goal of this paper is to design a compact microstrip patch antenna for triple band applications. The technique employed in this paper to reduce the size of an antenna is defected ground structure. The ground is designed in Swastika shape to enhance the bandwidth and increase the resonance-modes. The proposed antenna is printed on an FR4 epoxy substrate with dielectric constant of 4.4 and fed by a 50Ω microstrip line. The overall dimensions of proposed antenna are 14×14×1 mm^3. The main radiating element of an antenna is designed in T-shape having two arms. The antenna design and simulated data are carefully examined and discussed in the next sections.

II. GEOMETRY Of PROPOSED ANTENNA

Fig. 1 shows the schematic configuration of the proposed antenna with Swastika ground. The substrate used for the antenna is FR4 epoxy with dielectric constant of 4.4, thickness of 1mm and overall dimensions of 14×14mm^2. The dimensions of the antenna are given in table 1. The main radiating element printed on the top of the antenna is designed in T-shape consists of two arms as shown in Fig (a). The length (L_a) of each arm is 8 mm and width (W_a) is 3 mm. The defected ground structure is located on back side of the dielectric substrate and consists of Swastika shape ground as shown in Fig. (b). The length of the ground (L_g) is 14 mm and width of ground (W_g) is 14mm. The antenna is fed by a 50Ω microstrip line having length (L_f) =10mm and width (W_f) = 2.5mm.



(a) Radiating patch



(b) Ground plane

Figure 1. Design specification of proposed antenna

TABLE I GEOMETRIC DESIGN VALUES OF ANTENNA

Parameter	Value (mm)	Parameter	Value(mm)
W_p	12	W_g	14
L_p	12	L_g	14
W_a	3	W_1	8
L_a	8	W_2	6
W_f	2.5	L_1	4
L_f	9	L_2	6
B_1	5	D	2

III. SIMULATION RESULTS

A. Return Loss

Fig.2 presents the simulated return losses for the proposed antenna. The antenna resonates at three frequencies, hence can be used for triband applications. The resonant frequencies are 13.1GHz, 15.8GHz and 18.8GHz and return loss at these frequencies are -22dB,-23dB and -37dB. The return losses are below -10dB in the operating frequency bands of (12.7-13.4) GHz, (15.5-16.1) GHz and (18.4-19.2) GHz. The operating frequencies lie in K and Ku bands thus suitable for satellite and radar applications.

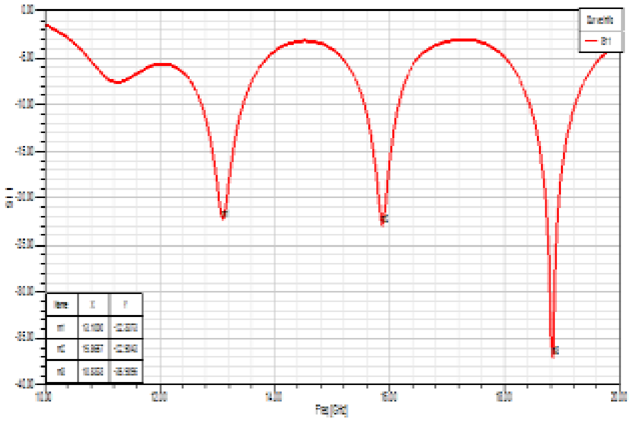


Figure 2: Simulated return losses of the proposed antenna

B. VSWR

Fig. 3 shows the simulated VSWR for the proposed antenna. Voltage standing wave ratio (VSWR) is an antenna parameter which tells about the impedance matching. VSWR should be less than 2 for good impedance matching. It is clear from the figure that VSWR value for the operating frequency band is below 2. VSWR value at the resonant frequency of 13.1GHz, 15.8GHz and 18.8GHz is 1.1, 1.1 and 1.02 respectively.

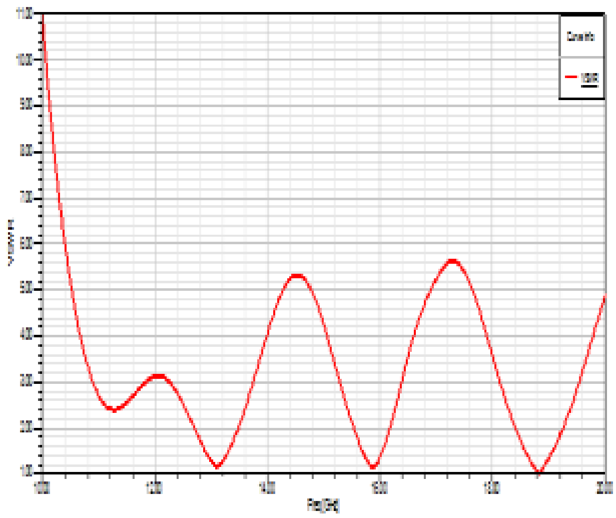
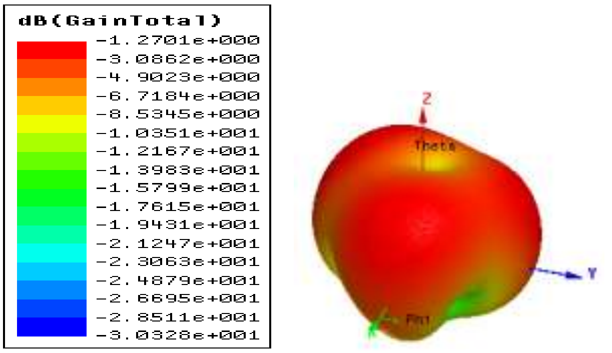


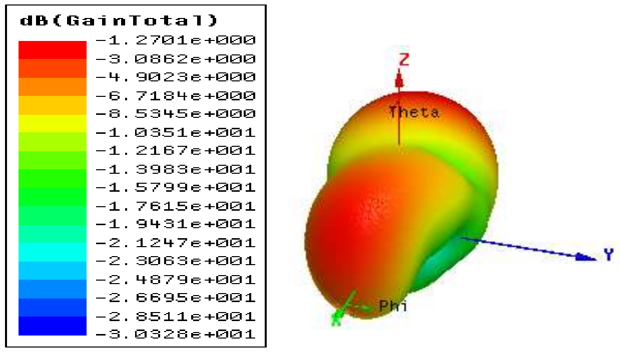
Figure 3. Simulated VSWR of proposed antenna

C. 3D polar plot

Fig. 4 shows the simulated 3D polar plot showing gain of the proposed antenna at different resonant frequencies of 13.1GHz, 15.8GHz and 18.8GHz. In plots red portion shows the maximum gain and blue shows the weaker gain. The proposed antenna showing good gain in all directions.



(a)



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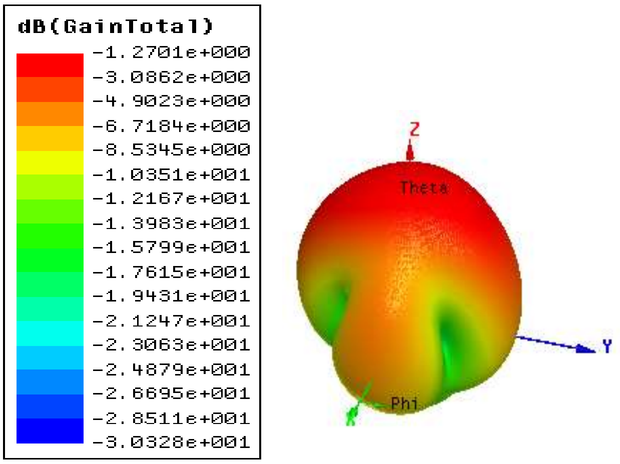
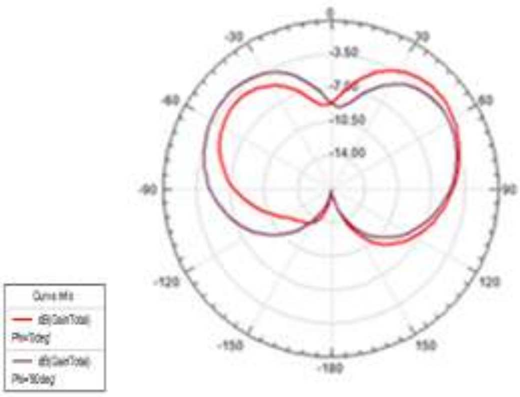


(c)

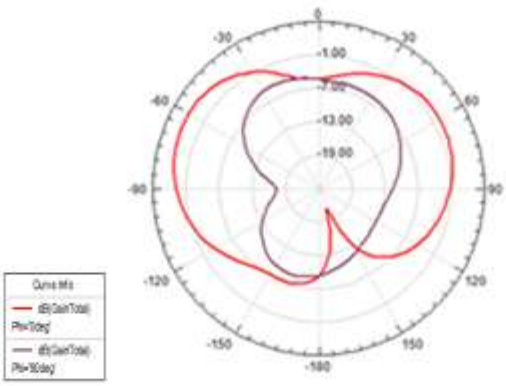
Figure 4. 3D polar plot showing gain of proposed antenna (a) 13.1GHz (b) 15.8GHz (c) 18.8GHz

D. Radiation Pattern

Fig. 5 shows the simulated radiation pattern at different resonant frequencies of 13.1GHz, 15.8GHz and 18.8GHz of the proposed antenna. The patterns are bi-directional in both E-plane and H-plane.



(a)



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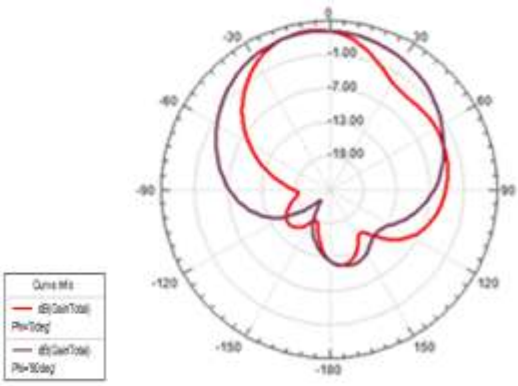
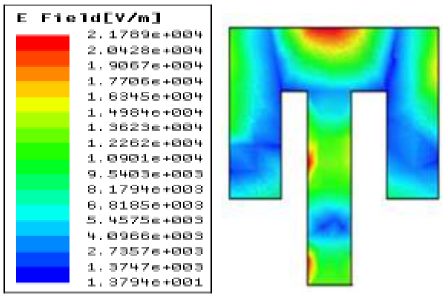


(c)

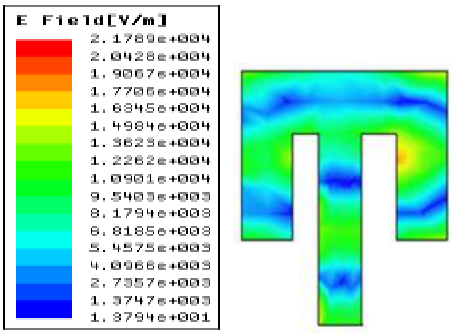
Figure 5. 2D radiation Pattern of proposed antenna (a) 13.1GHz (b) 15.8GHz (c) 18.8GHz

E. Electric Current Distribution

Fig.6 shows the simulated electric current distribution of the proposed antenna at 13.1GHz, 15.8GHz and 18.8GHz. It is clear from the figure that the current radiates maximum in the arms of T-shape radiator and direction of current is from feedline to radiator.



(a)



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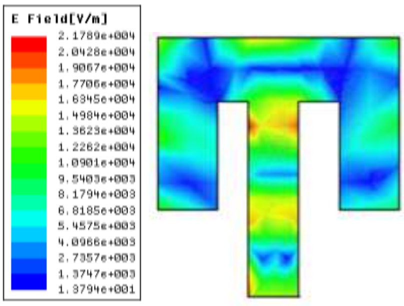

(c)

Figure 6. Simulated current distribution of proposed antenna (a) 13.1 GHz (b) 15.8 GHz (c) 19.8GHz

F. Effect of DGS

Fig. 7 shows the comparative analysis of return losses of the proposed antenna with and without DGS. It can be seen that the impedance matching with normal ground plane is poor especially at higher frequencies. The antenna with simple ground has maximum return loss around -27dB whereas using Swastika shape ground return losses get improved and reaches upto -37dB hence the proposed antenna with Swastika shape ground has a better impedance matching and resonant frequencies.

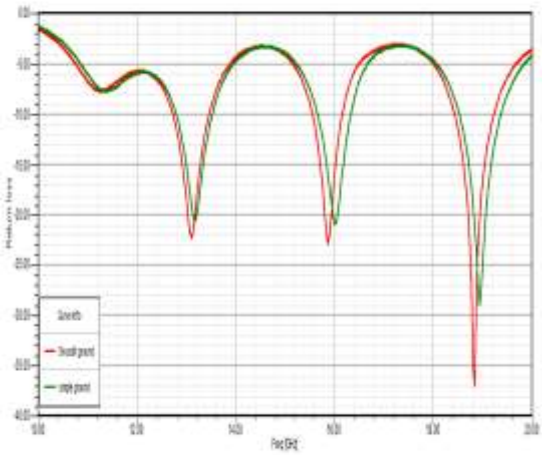

Figure 7. Simulated return losses against frequency to study the effect of DGS

G. Effect of arm width

Fig. 8 shows the simulated return losses for different arm widths. The proposed antenna consists of T shape patch having two arms. In this part, the effect of arm width on the performance of an antenna is studied. The lower resonant frequency does not vary greatly when W_a decreases from 3mm to 2mm but upper resonant frequency shifted toward the high frequency. As the arm width increases from 2mm to 3mm, the surface area of the patch increases hence the return losses get improved. The optimized arm width is 3mm for the proposed antenna.

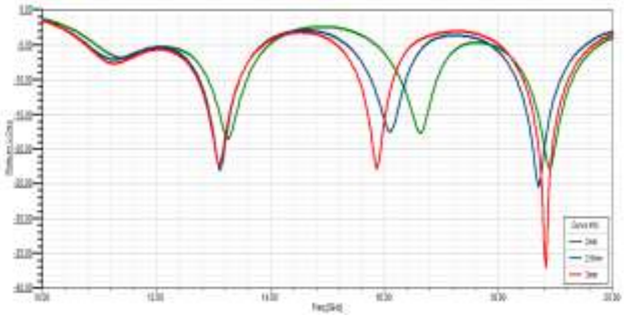

Figure 8. Comparison of return losses for different values of arm width W_a

TABLE II. FREQUENCY BAND AND RETURN LOSSES AT RESONANT FREQUENCIES FOR DIFFERENT ARM WIDTH

Width (Wa) (mm)	**Frequency band (GHz)**	**Center frequency (GHz)**	**Return loss (dB)**
2mm	12.9-13.5, 16.2-16.9, 18.5-19.3	13.2, 16.6, 18.9	-18, -17 -22.8
2.5mm	12.7-13.4, 15.7-16.3 18.3-19.0	13.1, 16.1 18.7	-23, -17.5 -25.5
3mm	12.7-13.4, 15.5-16.1 18.4-19.2	13.1,15.8 18.8	-22, -23 -37

H. Effect of arm length

Fig. 9 shows the comparative analysis of the return losses in the form of XY plot for the different lengths of 6mm, 7mm, 8mm and 9mm. The antenna is optimized with different lengths of the T-shape arms .

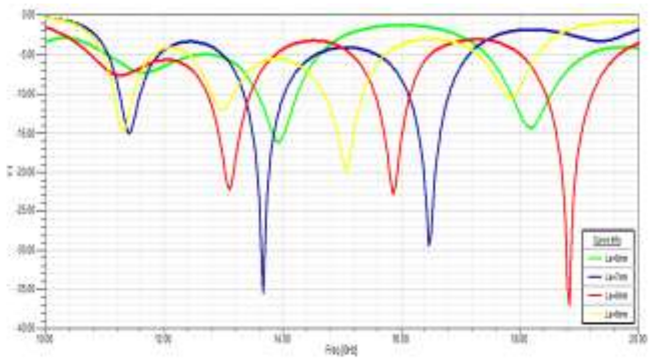

Figure 9. Comparison of return losses for different values of arm width W_a

As the length of arm increases from 6mm to 8mm, results are improving in terms of frequency bands and return losses. Only two bands are achieved for 6mm arm length with return losses of -16dB and -14dB. At 7mm arm length return losses get improved by achieving return losses of -15dB, -29dB and -35dB for the three frequency bands. Again increasing length from 8mm to 9mm the performance of antenna degraded. The best results are obtained at the arm

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length of 8mm which has achieved the triple band operation with the maximum return losses. So, the optimized arm length for the proposed antenna is 8mm.

Table III. FREQUENCY BAND AND RETURN LOSSES AT RESONANT FREQUENCIES FOR DIFFERENT ARM LENGTHS

Length (La) (mm)	Frequency band (GHz)	Center frequency (GHz)	Return loss (dB)
6mm	13.5-14.2, 17.8-18.5	13.9, 18.2	-16, -14
7mm	11.2-11.6, 13.3-14.0, 16.1-16.8	11.4, 13.6, 16.4	-15, -35, -29
8mm	12.7-13.4, 15.5-16.1, 18.4-19.2	13.1, 15.8, 18.8	-22, -23, -37
9mm	11.1-11.5, 14.6-15.4	11.3, 15.0	-14.7, -19.7

V. CONCLUSION

A highly compact T-shape microstrip patch antenna with Swastika ground is proposed. The dimensions of proposed antenna are $14\times14\times1mm^3$. The antenna is printed on FR4 substrate having a dielectric constant of 4.4. Using T-shape patch and Swastik shape ground, three resonant modes with good impedance performance are achieved. The proposed antenna excites at triple frequency of 13.1GHz, 15.8GHz and 18.8GHz with return loss value of -22dB, -23dB and -37dB. The impedance bandwidth of proposed antenna is (12.7-13.4) GHz, (15.5-16.1) GHz and (18.4-19.2) GHz. All antenna parameters are simulated using Ansoft HFSS v.11. The proposed antenna have several advantages such as small size, large bandwidth and good radiation patterns indicating it a good candidate for several K and Ku band applications.

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