Design & analysis of Compact T – shaped microstrip fractal patch antenna for multiband applications

[1] **Naveen Kumar**, [2] **Bhojraj Agrawal**

[1]Student, DC (M.Tech), [2]Associate Professor
[1]Department of Electronics and Communication,
[1]Vivekananda Global University, Jaipur, India

Abstract : ***Many areas of science and engineering, viz. antennas, have been significantly impacted by the application of fractal geometries. A number of microstrip patch antennas using different fractal geometries are available commercially for variety of military, telecommunication and other applications. By applying fractal geometries to patch antennas, improvisation of several antenna parameters and features can be achieved to varying extent.***

In this paper, T-shaped microstrip fractal patch antenna for multiband applications has been proposed. This antenna have been designed and simulated using IE3D software, fabricated and hardware testing has been performed on VNA. The proposed antennas is coaxial probe fed and its structures is based on fractal geometry where iteration techniques have been applied to achieve the multiband operation. The fabricated antennas have low profile, are light weight, very compact and easy to be fabricated & have successfully demonstrated multiband operation characteristics

IndexTerms – Microstrip, IE3D, VNA, Coaxial prob.

I. INTRODUCTION

This fractal antenna is a compact modified T-shaped fractal patch. It operates efficiently on four different frequencies of 3.28GHz, 4.42GHz, 6.00GHz and 8.64GHz; thus making a suitable candidate for multiband applications. A return loss well below -10dB and a positive and closer to 1 VSWR has been measured at all these frequencies. A good agreement has been observed between the simulated and measured results.[1]

This fractal antennas can be used for WiMAX (middle- 3.2 to 3.6 GHz and upper- 5.2 to 5.8 GHz bands), IoT, WLAN, WiFi applications; they operate well in the S [2 – 4GHz], C [4 – 8GHz] and X-band [8-12GHz] band.

These fractal antennas are basically microstrip fractal patch antenna. For designing, IE3D simulation software has been used. FR4 epoxy is used as substrate with height 1.6 mm, loss tangent 0.025 and dielectric constant 4.4. For feeding, Probe feeding method has been used. Iterations of 3rd order have been performed for both the designs to enhance efficiency, improvise antenna parameters like return loss, VSWR, directivity, etc. and achieve multiband operation. In both the antennas, successive iterations have been performed to accomplish the objective of multiband operation.[2][3]

In this work, a compact T-shaped Microstrip Fractal Patch Antenna is designed for multiband applications at8.0GHz frequency. The design steps for the proposed design are described as follows:

1.1: Designing Of Conventional Rectangular Micro-Strip Patch Antenna

The conventional rectangular patch antenna consisting of conducting patch is designed on one side of FR4 glass epoxy substrate with thickness of 1.6 mm, dielectric constant $\mathcal{E}_r$=4.4 and its loss tangent δ=0.025 and ground plane on the other side. The patch dimensions are 16mm x 18mmx1.6mm. The resonating frequency used for the conventional rectangular patch antenna is 8.0 GHz. Other design specifications are same as that of the Modified Sierpinski Carpet. [4]

L = 16mm, W = 18mm

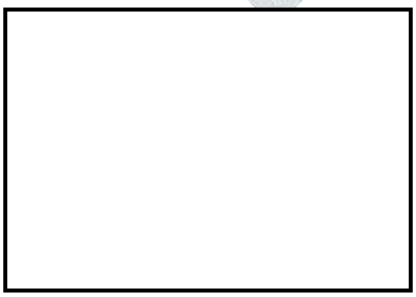


Fig.1 Rectangular Patch Antenna

Fig. 2 Software based Rectangular Patch Antenna

1.2: Performing First Order Iteration

To improvise various antenna parameters like S_{11}, VSWR, gain, etc., for the resonant frequency and obtain efficient UWB operation, first order iteration is performed on the base shape. In first iteration, a T-shaped slot is removed from the centre of the base, as shown in figure 3. Other design specifications are same as that of the base shape.[5][6]

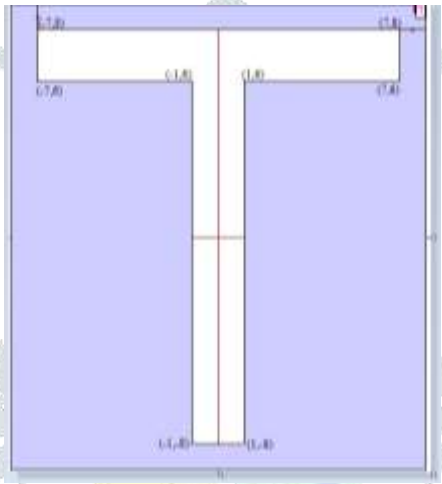


Fig.3 Proposed first order iteration

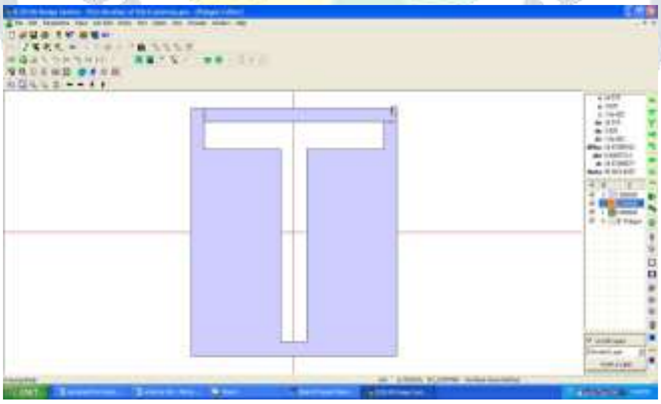


Fig.4 Software based first order iteration

1.3: Performing Second Order Iteration

In order to improvise the return loss and VSWR at the resonant frequency and also to achieve a further enhancement in the operating band, second order iteration is performed. In second iteration, two T-shaped slots are removed from each side as shown in figure 5. Other design specifications are same as that of the base shape. [7][8]

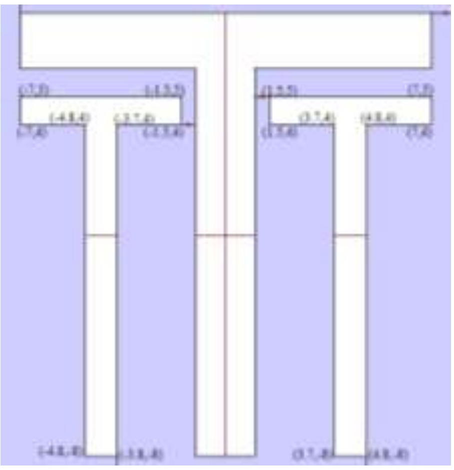


Fig.5 Proposed second order iteration

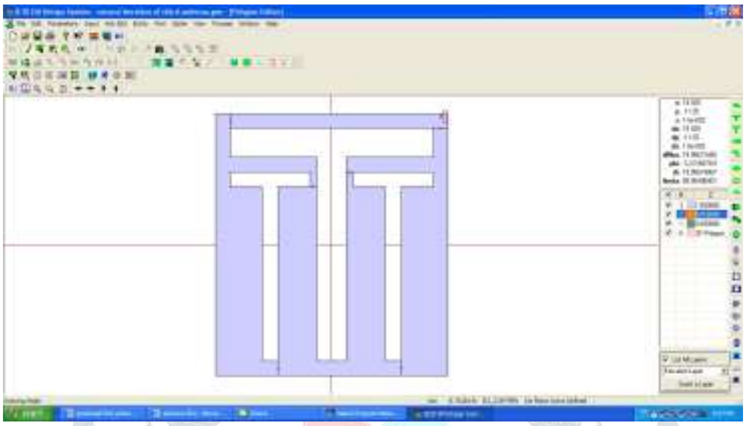


Fig.6 Software based second order iteration

1.4: Performing Third Order Iteration

The main objective of the third order iteration is to improve the overall performance of the T-shaped fractal antenna in the UWB. In third iteration, total four T – shaped slots are removed from both the sides of T slots of second iteration, as shown in figure 7. Other design specifications are same as that of the base shape.[9][10]

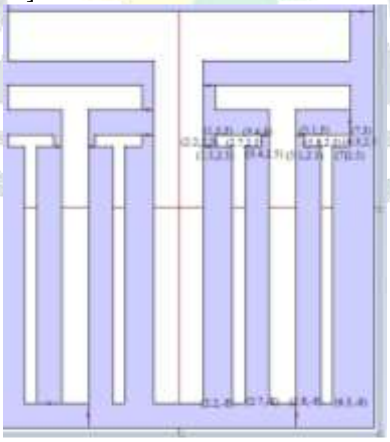


Fig.7 Proposed third order iteration

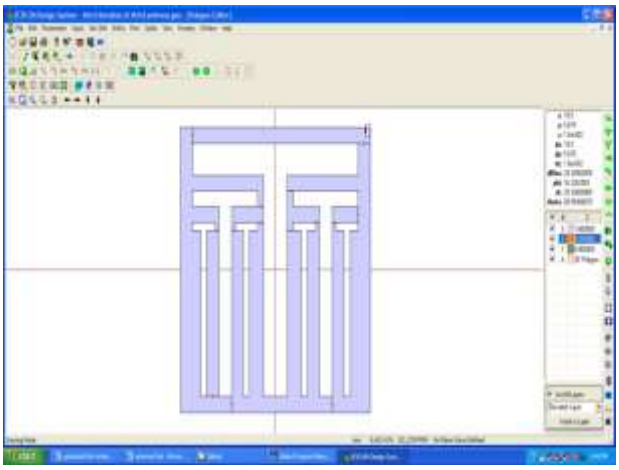


Fig.8 Software based third order iteration

II. RESULTS AND SIMULATION

2.1 Return Loss (S_{11})

The simulated return loss curves of all four geometries are plotted in Fig. 9(a), (b), (c) and (d) respectively.

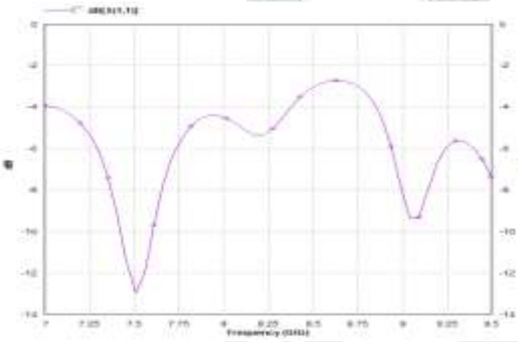


Fig. 9 (a) Simulated return loss of the Base shape

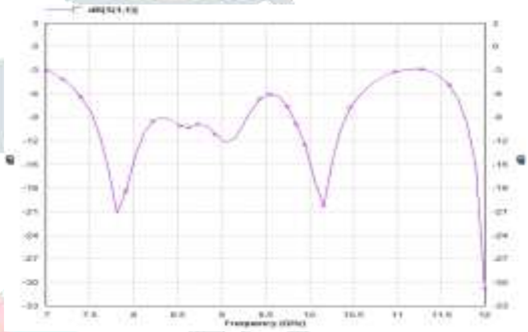


Fig. 9 (b) Simulated return loss of first order iteration

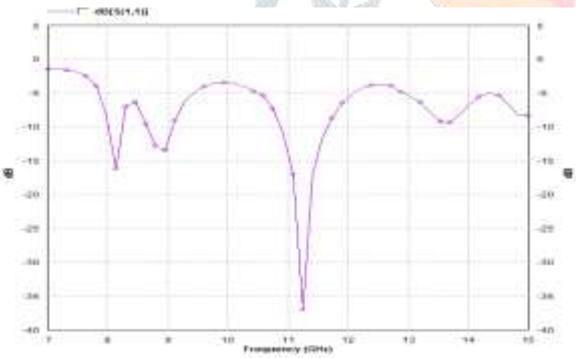


Fig. 9 I Simulated return loss of Proposed second order iteration

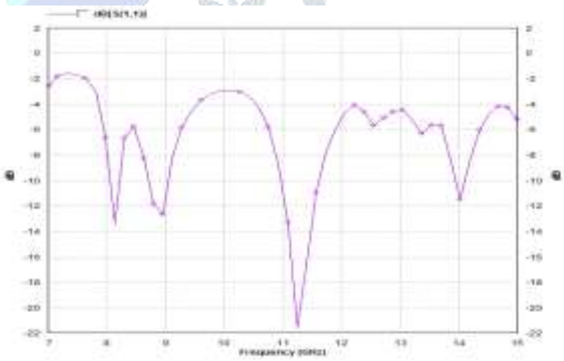
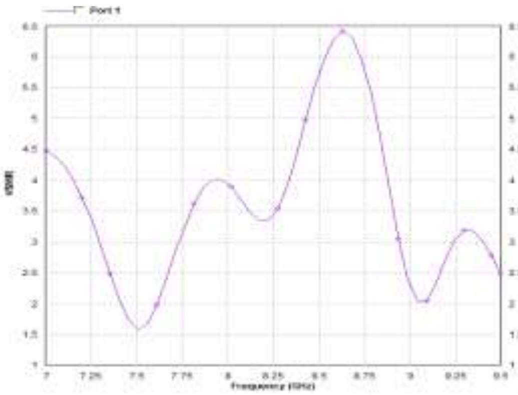


Fig. 9 (d) Simulated return loss of proposed third order iteration

The base shape provides S_{11}< -10dB for frequency range of 7.43GHz to 7.6GHz. By performing first order iteration, we get the value of S_{11}< -10dB for three frequency ranges, i.e. from 7.6GHz to 8.2GHz, 8.83GHz to 9.24GHz and 9.9GHz to 10.37GHz. The second order iteration provides S_{11}< -10dB for three frequency ranges, i.e. from 8.0GHz to 8.2GHz, 8.65GHz to 9.0GHz and 10.90GHz to 11.6GHz. With the third order iteration, frequency ranges for which the designed antenna provides S_{11}< -10dB have been significantly increased. A return loss less than -10dB, i.e. S_{11}< -10dB; is observed from 8.1 to 8.25GHz, 8.7GHz to 9.08GHz, 10.98GHz to 11.6 GHz and 13.9GHz to 14.1GHz.

2.1: Voltage Standing Wave Ratio (VSWR)

The simulated results for VSWR of all the four geometries are plotted in Fig. 10 (a), (b), (c) and (d) respectively.



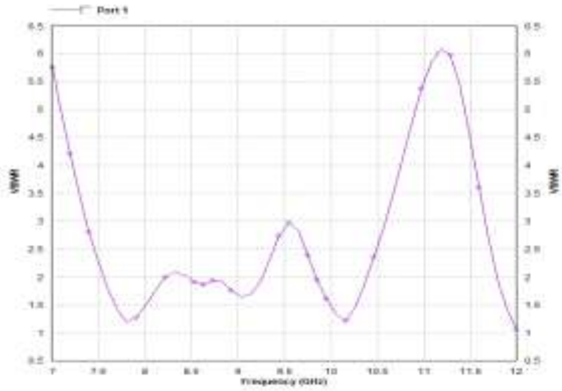
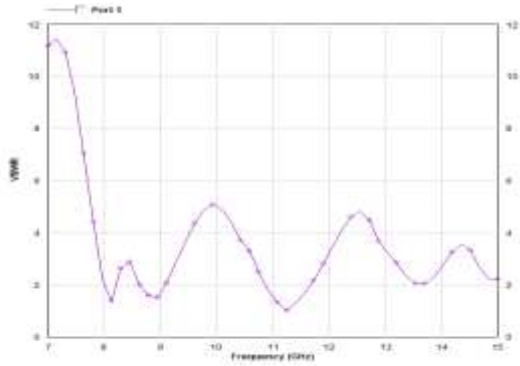


Fig. 10 (a) Simulated VSWR for the base shape Fig. 10 (b) Simulated VSWR for the proposed first order iteration



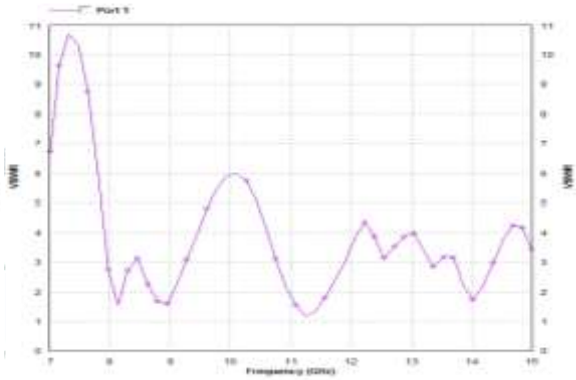


Fig. 10 (c) Simulated VSWR for the Proposed second order iteration Fig. 10 (d) Simulated VSWR for the proposed third order iteration

For the base shape, the frequency range for which VSWR is positive and closer to 1 is from 7.43GHz to 7.61GHz. For first order iteration, the frequency ranges with acceptable VSWR are from 7.61GHz to 8.22GHz, 8.53GHz to 9.24GHz and 9.85GHz to 10.37GHz. In the second order iteration, a positive and less than 2 VSWR is observed from 8GHz to 8.2GHz, 8.65GHz to 9.08GHz and 10.90GHz to 11.6GHz. For the third order iteration, the frequency ranges having positive and less than 2 VSWR are from 8.1 to 8.25GHz, 8.7GHz to 9.08GHz, 10.98GHz to 11.6GHz and 13.9GHz to 14.1GHz.

The main objective is to design a very compact T-shaped microstrip fractal patch antenna capable of operating efficiently at multiple frequencies in S-band, C-band and X-band. Iterations of third order were performed to achieve the desired motive. On increasing the number of iterations, a significant improvement in antenna parameters, viz. return loss, VSWR, fractional bandwidth was observed. The simulated results depict that the designed antenna operates efficiently on four different resonant frequencies in all three bands where S_{11} < -10dB and VSWR < 2; which is the desired condition for an antenna to work efficiently for practical applications. However, certain geometrical modifications can be done to improve gain and return loss. Different feeding techniques like aperture feed can also be experimented to improve bandwidth and overcome generation of higher modes. The designed antenna can be used for various S-band, C-band and X-band applications like in WLAN, WiMAX, wireless communication, IoT, radar applications, terrestrial communications and networking, space communications, etc.

III. Acknowledgment

I am greatly indebted to my guide for his invaluable guidance during the course of the research work. He always gave useful suggestions and also helped me when the work was not moving ahead at times. I wish to express my thank to all in the department who have helped and guided me during this period. Words can hardly express my deep sense gratitude for my report guide **Mr. Bhojraj Agrawal and Mr. Parmeshwar Kumawat (HOD)** without their guidance and help this project would not have been possible. I would like to express my heartfelt gratitude towards my colleagues and friends for their moral and technical support throughout the duration of the report.

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