Design of a Novel Wideband Star Shaped Iterated Fractal Antenna For Various Wireless Applications

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Abstract— In this paper, we propose a novel wideband Star Shaped fractal antenna with a defected ground structure. The antenna is designed using the iterations in Triangular – Circular shape with the help of CST (Computer Simulation Technology) and modified partial ground plane. The antenna shows operating bandwidths (referenced VSWR = 2) for covering the range of frequencies 2-6 GHz with cut off frequency 2.5 GHz,3.75 GHz, 5.2 GHz. The present design mainly focuses on the current trends in the development of compact and low profile mobile communication and Ultra Wideband (UWB) applications. for many wireless communications such as RFID,PCS-1900, IMT-2000/UMTS, GPS, ISM (including WLAN), Wi-Fi, Bluetooth and upper UWB band.

Key words: Fractal Antenna, Wide Band, CST Software, Return Loss, Star Shaped

I. INTRODUCTION

The increasing range of wireless telecommunication services and related applications is driving the attention to the design of multi-frequency (multi service) and small antennas. Operators are looking for systems that can perform over several frequency bands which are reconfigurable as the demands on the system changes. Some applications require the antenna to be as miniaturized as possible as can be done [1]. Antenna is a transducer designed to transmit or receive electromagnetic waves. Microstrip antennas have several advantages over conventional microwave antenna and therefore are widely used in many practical applications [2]. Microstrip antennas have low profile, low cost, light weight and conveniently integrated with RF devices. The size of the microstrip antenna becomes too large to be manageable. Reduction of antenna size becomes extremely important in wireless communications and hence it is desired to bring down the size of antenna while achieving the same performance of the large size antenna. Fractal geometry plays a prominent role for these requirements. Fractals have non-integral dimensions and their space filling capability could be used for miniaturizing antenna size [3]. To overcome microstrip antenna limitation of narrow bandwidth by generating more than one resonant frequency many techniques have been used in the past examples- different shaped slots, multilayer, stack, two folded parts to the main radiating patch and use of air gap have been proposed and investigated. The design presented in this paper, uses of air gap i.e. Suspended technique is used.

II. FRACTAL GEOMETRY ANTENNA

Fractal was first defined by Benoit Mandelbrot in 1975 as a way of classifying structures whose dimensions were not whole numbers [4]. A fractal is a rough or fragmented geometric shape that can be subdivided into parts, each of which is (at least approximately) a reduced-size copy of the whole. Fractals are generally self-similar and independent of scale. There are many mathematical structures that are fractals; e.g. Sierpinski's gasket, Cantor's comb, von Koch's snowflake fractals also describe many real-world objects, such as clouds, mountains, turbulence, and coastlines that do not correspond to simple geometric shapes [5]. Fractal geometry is a very good solution to reduce the size of antenna. Fractal shaped antennas show some interesting features which results from their geometrical properties [6]. The unique features of fractals such as self-similarity and space filling properties enable the realization of antennas with interesting characteristics such as multi-band operation and miniaturization [7]. In this paper we used Koch's snowflake fractal antenna [8].

III. ANTENNA DESIGN SPECIFICATIONS

The geometry of the proposed fractal antenna is shown in the Fig (1). This proposed fractal antenna is designed and printed on FR4 (lossy) substrate with size of 40 x 60 x 1.6 mm3, including substrate thickness h= 1.6mm, and dielectric constant ε_r = 4.4 with 0.025 loss tangent. This structure designed by CST (Computer Simulation Technology) microwave studio simulation software. Defected Ground plane structure is shown in Fig (2). The effective reflection coefficient and characteristics impedances calculated with the help of equation (1) and (2).

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r + 1}{2}\left[\frac{1}{\sqrt{1+12\frac{h}{w}}}\right] \quad (1)$$

$$z_0 = \frac{120\pi}{\sqrt{\varepsilon_{eff}}\left[\frac{w}{h}+1.393+0.667\ln\left(\frac{w}{h}+1.444\right)\right]} \quad (2)$$

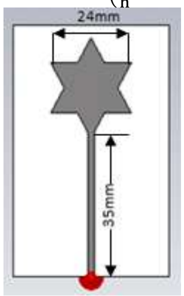

Fig. 1: Front view of Star shaped Fractal Antenna

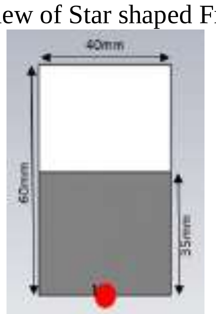

Fig. 2: Back view of Star shaped Fractal Antenna

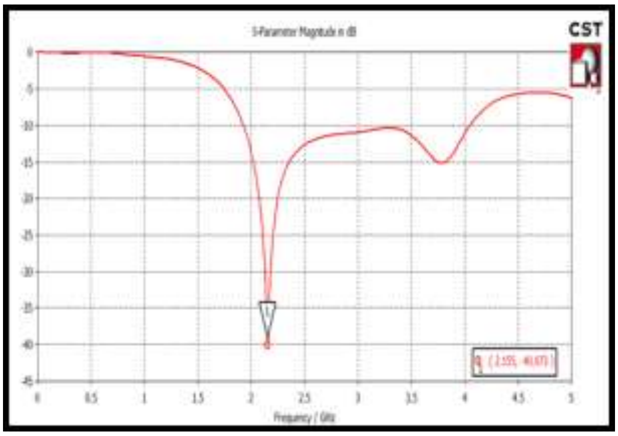

Fig. 3: Simulated Return loss of Star shaped Fractal Antenna

Basic star shaped fractal antenna structure is shown in Fig (1) & (2). Reflection coefficient or result loss curve s-parameter v/s frequency curve is shown in above Fig. (3), which has maximum peak at 2.155 GHz. Iterations applied in this basic star shaped antenna structure.

Fig (4) shows the front view of star shaped star slotted fractal antenna structure after 1st iteration and back surface of star slotted antenna structure remain same .

IV. SIMULATION RESULTS AND DISCUSSION

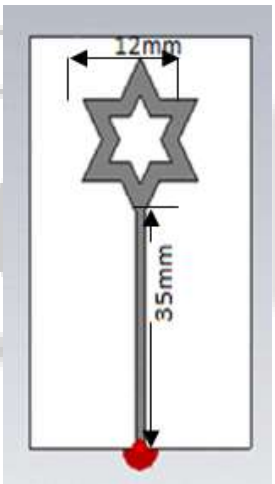

Fig. 4: Front view of Star shaped Fractal Antenna after 1st iteration

Fig. 5: Front view of fabricated Star shaped Fractal Antenna after 1st iteration

Fig. 6: Back view of fabricated Star shaped Fractal Antenna after 1st iteration

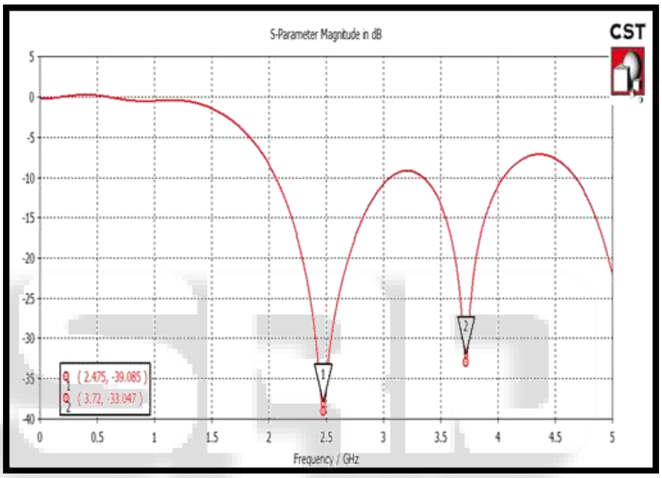

Fig. 7: Simulated Return loss of Star shaped star slotted Fractal Antenna after 1st iteration

Fig. (5) & (6) shows the fabricated front and back view of 1st iterated star shaped star slotted fractal antenna which is very compact in size . simulated return loss of antenna star shaped star slotted fractal antenna after 1st iteration is shown in Fig (7) which has two cut off frequencies at 2.47 GHz and 3.72 GHz. And maximum return loss about - 39 db at 2.47 GHz and – 33 db at 3.75GHz.

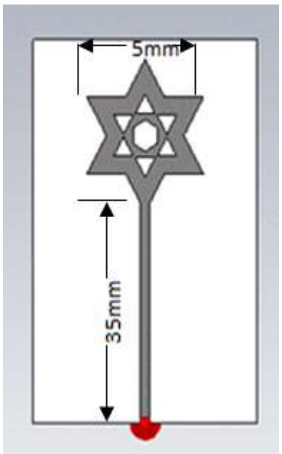

Fig. 8: Front view of Star shaped Fractal Antenna after 2nd iteration

Fig. 9: Fabricated Star shaped hexagonal iterated Fractal Antenna after 2nd iteration

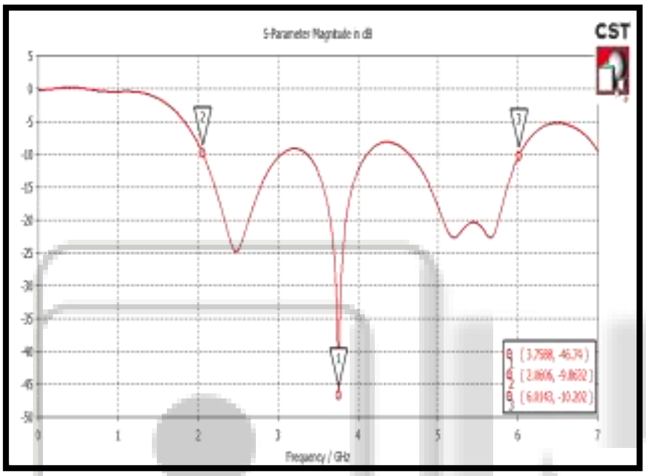

Fig. 10: Simulated Return loss of Star shaped star slotted Fractal Antenna after 2nd iteration

Fig. (8) shows the second iterated star shaped hexagonal shaped antenna and its iterated view is shown in above Fig. (9).Whose shape is similar to basic star shaped antenna shown in Fig. (1) and back surface is similarly defected. Finally simulated return loss (magnitude Vs. frequency curve is shown in Fig. (10) which is a wide band antenna and having maximum peak at 3.75 GHz about 46.7 db antenna gain. This antenna covers frequency range from 2- 6 GHz. So it is a wide band antenna and bandwidth is very large.

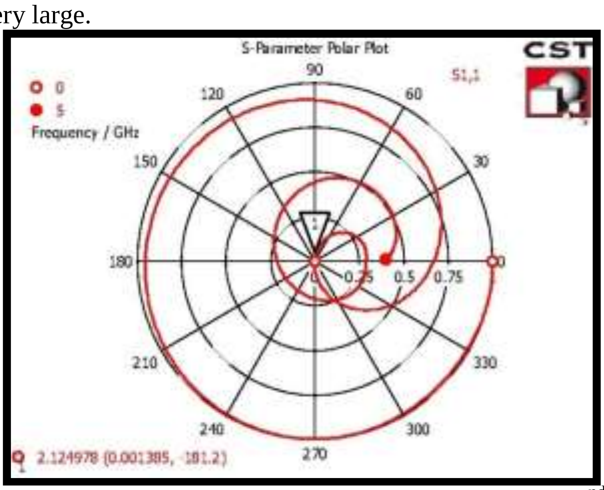

Fig. 11: Polar plot of star shaped fractal antenna after 2nd iteration

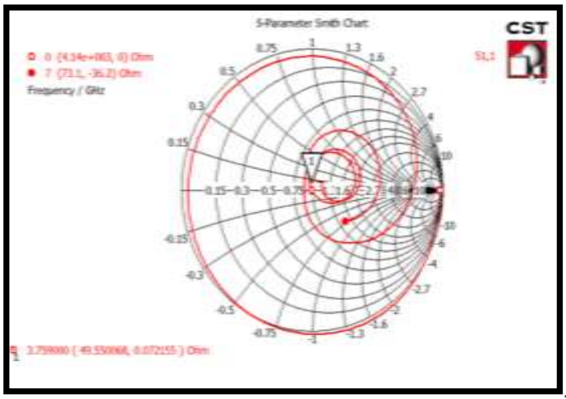

Fig. 12: Smith chart of star shaped fractal antenna after 2nd iteration

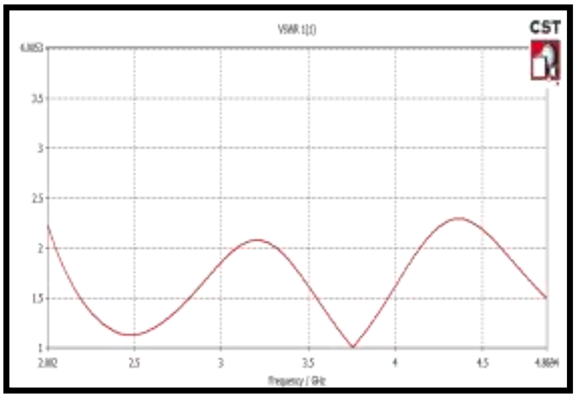

Fig. 13: VSWR curve of star shaped fractal antenna after 2nd iteration

Fig. (13) shows the voltage standing wave ratio with antenna design of star shaped star slotted iterated fractal antenna with defected ground structure.

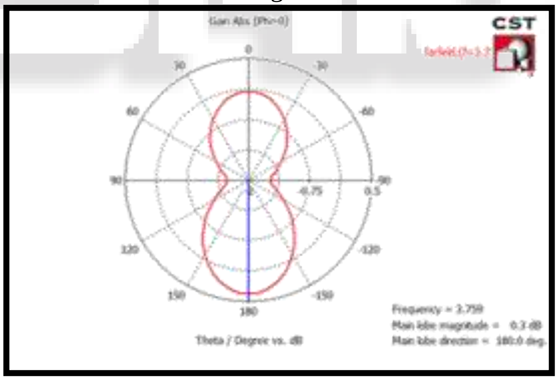

Fig. 13: Polar radiation pattern of star shaped fractal antenna after 2nd iteration (simulated)

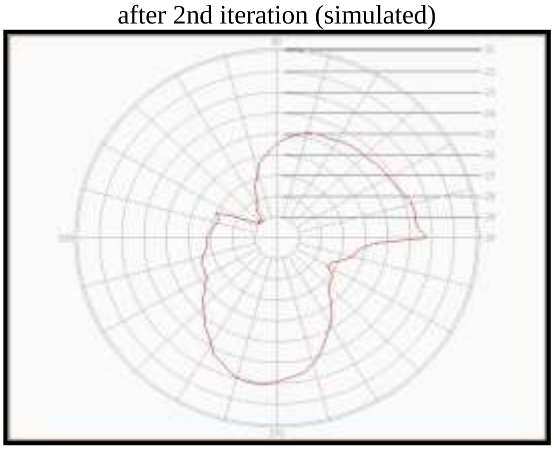

Fig. 14: Polar radiation pattern of star shaped fractal antenna after 2nd iteration (measured)

To understand the behaviours of the fractal antenna's structure and to determine the different parameters, the antenna was simulated using CST (computer simulation technology) Microwave studio software 2010. This Fabricated star shaped iterated fractal antenna is very compact in size . The return loss curve of fractal antenna (s-parameter versus frequency) is shown in Fig. (10) which has very wide frequency band from 2 GHz to 6 GHz and gain about 46.255 db . Polar plot and smith chart curve is shown in Fig (11) and (12) respectively. Fig (12) shows the simulated radiation pattern of star slotted iterated fractal antenna and measured radiation pattern of the antenna is shown in above Fig. (13)

Fig 15: Antenna under measurement using antenna measurement system

Three dimensional radiation pattern of this proposed star shaped iterated fractal antenna is shown Fig. (16) & Fig. (17) both are in far field region. It is wide band type fractal antenna. it is clear that this star shaped fractal antenna is multi and wide band both type. and this antenna is simulated with the help of CST-MWS (computer simulation technology- microwave studio software).

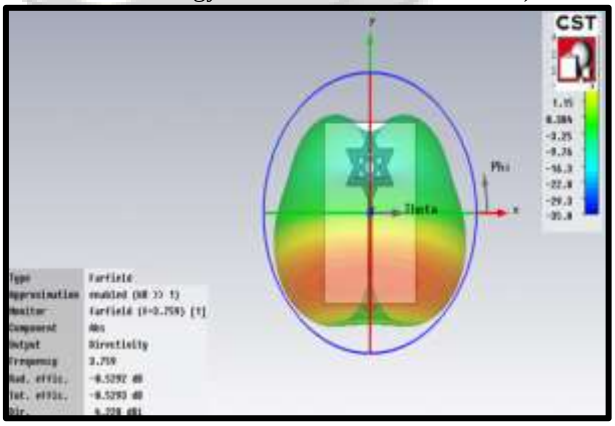

Fig 16: Absolute Radiation pattern of proposed fractal antenna

Fig. (16) shows the transparent absolute three dimensional radiation pattern with transparent antenna structure of star shaped star slotted iterated fractal antenna with defected ground structure. In this antenna maximum directivity is about the horizontal axis. Reflection coefficient is measured with the help of spectrum analyzer. Proposed fractal antenna has antenna efficiency about 88.5 %. Polar radiation pattern determine with the help of antenna measurement system which is shown in above Figures.

V. CONCLUSION

It is observed that as the resonant frequencies decreased after each iteration gain is increased. The iteration is increased by introducing number of triangle which form star shape and length of one antenna reduced then again rotating whole antenna 90° counter clockwise with specific dimension improves the antenna gain as well as its bandwidth. The proposed antenna have some favorable characteristics such as; compact size, almost symmetrical radiation pattern , higher gain, satisfactory return loss less than 10 db and acceptable bandwidth in desired frequency (2 – 6 GHz) ISM(Industrial scientific medical) band. This proposed antenna has high gain about 46.775 db. The proposed antenna is capable of covering the WLAN communication standard (2.4-2.484 GHz) and other wireless communications.

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