On the Design of CPW- Fed Ultra Wideband Triangular Wheel Shape Fractal Antenna

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***Abstract*- The new triangular wheel shape (TWS) fractal antenna with CPW – fed is presented. This antenna has been designed on dielectric substrate ε_r = 4.3 and thickness h = 1.53 mm with radius a=40mm. The fourth iterative TWS fractal antenna has been fabricated and tested. The antenna exhibits the excellent ultra wide bandwidth from 0.86 to 11.49 GHz corresponding 172.15 % at S11 < -10 dB. The lower end usable frequency of TWS antenna is shifted to 0.86 GHz in comparison to resonant frequency 1.442 GHz of simple microstrip patch. This reveals the size reduction of the antenna due to fractal properties. The experimental radiation pattern of antenna has been observed nearly omni – directional. The cross polarization of TWS fractal antenna has also been measured. Such type of antenna can be useful for UWB system, mobile and radar applications.**

***Index Terms* – Patch Antenna, Resonant Frequency, Fractal Geometry, Multiband, CPW-fed**

I. INTRODUCTION

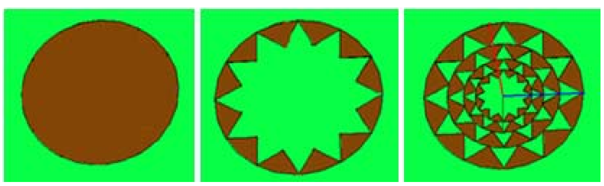
The ultra wideband (UWB) antennas have become emerging research topic in the field of modern wireless communications due to its unique features such as transmitting and/or receiving electromagnetic energy in shorter durations and avoiding frequency dispersive and space dispersive [1]. Several schemes have been suggested in recent years for designing the ultra wide band antennas. Some UWB antennas are much more complex than other existing single band, dual band and multi-band antennas [2-4]. Most of the UWB monopole antennas investigated till today is non-planar [3-4]. Due to their protruded structure, they can not be integrated with MMIC/MIC and they are fragile.

In recent years, the fractal technology has been used extensively to realize the planar multiband antennas. These fractal antennas are based on self-similar and space filling properties of fractal geometry. The self-similar properties of fractal antennas are useful for multiband band features [5-6]. The space filling property leads to the miniaturization of antennas [7-8] because it adds more electrical length in less compact physical space. Very few work have been reported so far on fractal antennas with UWB characteristic [9].

In this paper, a new fractal antenna has been realized with UWB characteristic to meet the demand of FCC (Federal Communication Commission) as well as others bands. This antenna is less fragile and can be easily integrated with MMIC/MICs.

II. GEOMETRY OF FRACTAL ANTENNA

The fractal antenna has been constructed with triangular wheel shape. The initial geometry of antenna has been taken a circular patch of radius 40 mm. This initial geometry is called 0^{th} iteration as shown in Fig. 1a. The triangular wheel fractal antenna has been made with four iteration. The first iteration of antenna has been curved from 0^{th} iteration by subtracting the overlap portion of four equilateral triangles with center of initial circle at 0^0, 90^0, 180^0 and 270^0 as shown in Figure 1b. In the second iteration, a circle is made with radius touching the inner tip portion of first iteration. The four equilateral triangles with the center of inner circle are again constructed at 0^0, 90^0, 180^0 and 270^0 angle and overlap portion is subtracted from inner circle metallization. Similarly, third and fourth iteration are achieved with the reduced scale and overlapping portion is subtracted from the inner circular metallization respectively. This process can be repeated infinite times. But infinite iterative structure is impossible to realize because of fabrication constraints. The final fourth iterative fractal antenna has been finalized for design and fabrication as shown in Fig. 1c. The each iterative radiating element has been made in such as way that each iterative radiating element metallization should touch each other to have connectivity for current distribution. This fourth iterative TWS fractal antenna with CPW-fed has been shown in Fig. 2. This antenna was fabricated with the compensation of 15 µm keeping in mind the fabrication constraints.



(a) Fig. 1. Circular Microstrip Patch

(b) Fig.1. 1st iterative Antenna

(c) Fig.1 4th iterative Fractal Antenna

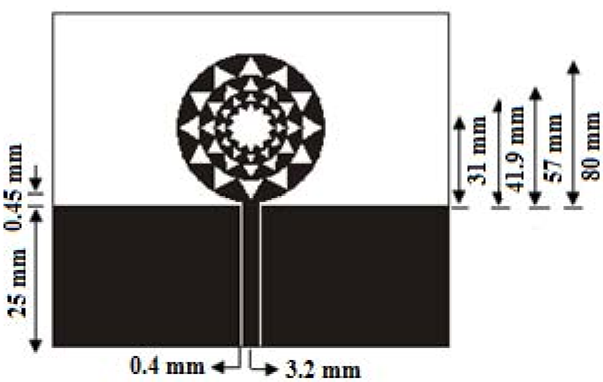


Fig. 2. Triangular Wheel Shaped Fractal Antenna with CPW – Fed

III. DESIGN EXPRESSION OF CIRCULAR MICROSTRIP ANTENNA

The design expression of simple circular Microstrip antenna for calculating the resonant frequency is given below;

$$f_r = 1.841 v_o / 2\pi r_{eff} \sqrt{\epsilon_{eff}} \qquad (1)$$

where v_o is the velocity of light. The effective radius r_{eff} can be calculated by following expression [10]

$$r_{eff} = r_o[1+2h/\pi r_0 \epsilon_r\{\ln(r_0/2h)+(1.41\,\epsilon_r +1.77) + h/r_0(0.268\,\epsilon_r+1.65)]^{1/2} \qquad (2)$$

The dimension of the solid circular patch is taken as a = 40 mm. This simple patch has been fabricated on FR4 substrate dielectric constant ϵ_r = 4.3 and thickness h = 1.53 mm. The antenna was coaxially feed from the bottom. The experimental resonant frequency of this patch has been observed at 1.442 GHz as shown in Fig. 3.

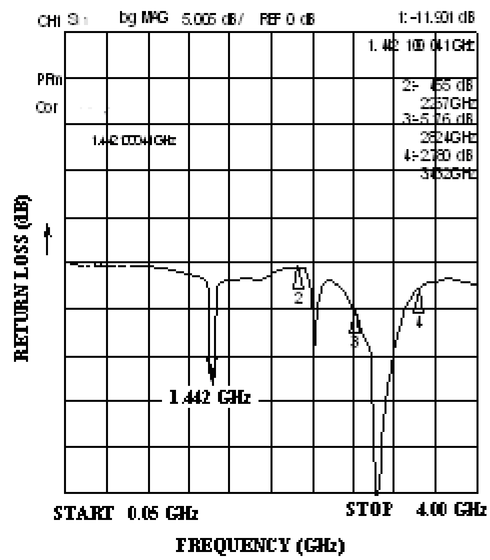


Fig.3. Experimental Result of Conventional Microstrip Patch Antenna

IV. DESIGN OF TRIANGULAR WHEEL SHAPE FRACTAL ANTENNA

The final structure of the fractal antenna of fourth order iteration is shown in Fig. 2. The antenna is fed with CPW- fed. The advantage of coplanar feed is that the feed and radiating elements are printed on the same side of the substrate. In the Coplanar technology, no via is required for ground purpose. So, this technique is less costly. It is known that CPW-fed antenna performs better in respect of bandwidth [10]. In CPW configuration, the 50 Ω impedance is achieved by adjusting the width (*w*) of the inner conduct and the gap width (*g*) between the ground plane and the inner conduct. It depends to the relative permittivity and the thickness of the substrate. The width of coplanar line, gap between ground plane and feed line, gap between ground and radiating patch, width and length of ground plane effects the lower end frequency as well as ultra wide bandwidth. The most crucial parameter is the gap between ground plane and patch. It is optimized for proper coupling of field from feed to patch.

TWS fractal antenna has designed based on self - similarity and space filling fractal properties. This Fractal antenna has been truncated with the finite iteration. The 4th iterative of fractal antenna has been taken because fourth iterative structure is found comfortable to achieve impedance matching for the UWB characteristic. It is seen that effect of fractal geometry shifts the resonant frequency because of removal of metallization. It is because, the current is mainly distributed along the circumference of the antenna. This results low current density in the middle area of the antenna. So, the current will not be affected if the middle area of the TWS antenna is slotted. This increases the effective path of the surface current. In other sense, the first resonance frequency will be decreased and the size of the antenna will be reduced. To achieve the UWB characteristic, the fractal structure has been added to increase the resonance frequency in high frequencies by adding four resonance elements.

V. DISCUSION AND RESULTS

The TWS fractal antenna has been fabricated on FR4 substrate $\varepsilon_r = 4.3$ and thickness 1.53 mm with coplanar feed. The photograph of fractal antenna is shown in Fig. 4. The coplanar feed line length has been taken 25 mm, width 3.2 mm and gap between feed line and ground 0.4 mm. The gap between ground and antenna has been taken GP = 0.45 mm. The antenna has been simulated using Electromagnetic simulator based on FDTD method. The simulated result has been shown in Fig. 5. The antenna has been fabricated and tested using vector network analyzer (VNA40). The experimental result of antenna shown in Fig. 5, reveals that the antenna is working in ultra wide bandwidth from frequency 0.86 GHz to 11.49 GHz at –10 dB return loss points, which corresponds to impedance bandwidth of 172.15%. The behavior of input impedance versus frequency of this fractal antenna has been shown in Fig. 6. The lower end usable frequency of TWS fractal antenna is shifted to 0.86 GHz in comparison to simple coaxially feed circular patch 1.44 GHz of same dimension. This indicates the size reduction of antenna. The variation in the simulated and experimental results are because the antenna has been simulated in ideal condition. The practically SMA connector of VSWR = 1.3 has been used to test the antenna. The antenna is covering all the important band of wireless communication system including FCC band from 3.1 GHz to 10.6 GHz.

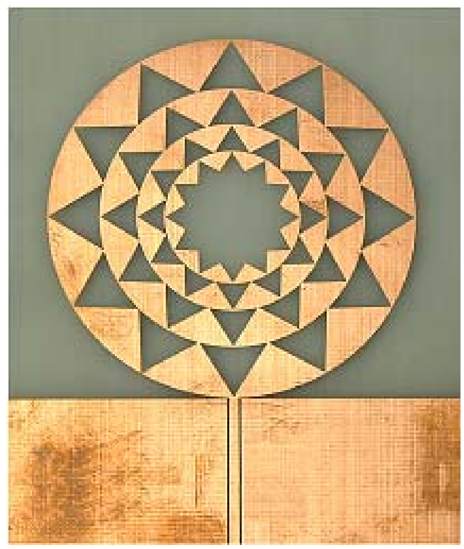


Fig. 4. Photograph of the Triangular Wheel Shape Fractal Antenna

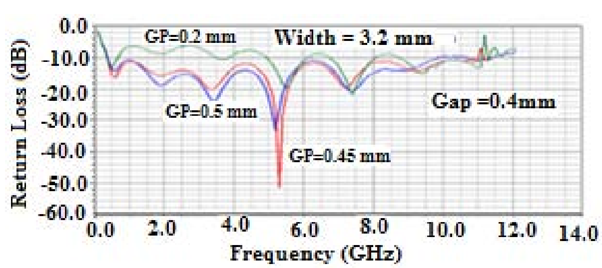


Fig. 5. Simulated Result of Triangular Wheel Shape Fractal Antenna

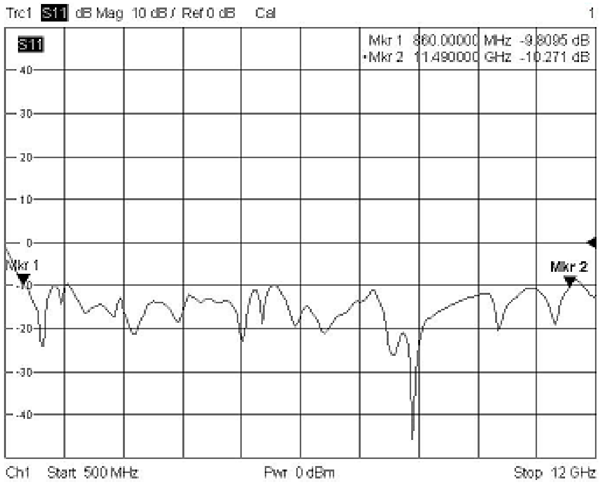


Fig. 6. Experimental Result of Triangular Wheel Shape Fractal Antenna

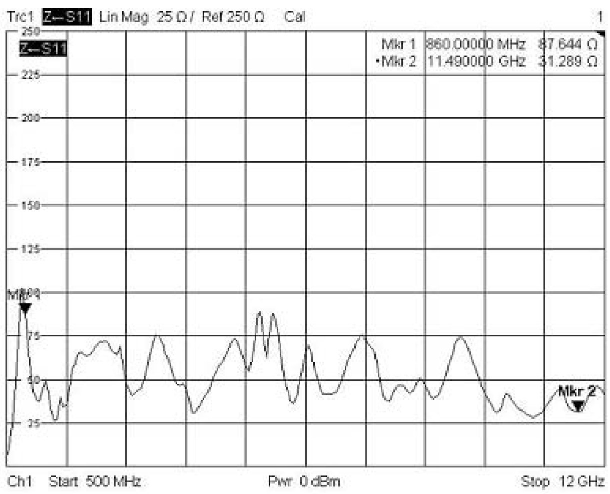


Fig. 7. Input Impedance of Triangular Wheel Shape Fractal Antenna

VI. EXPERIMENTAL RADIATION PATTERN

The radiation pattern was measured in in-house anechoic chamber by a swept frequency measurement. The measured radiation patterns of the proposed antenna are plotted at several frequencies within this band. It has been observed that the radiation pattern of antenna is nearly omni - directional. The radiation pattern of the antenna at frequencies 0.913 GHz, 2.215 GHz, 3.112 GHz and 7.202 GHz are shown in Fig. 8 to 9. The measured radiation patterns in azimuth plane are nearly omni - directional within its impedance bandwidth. The variation in radiation pattern is probably due to the edge reflection. The gain of this antenna is less than about 5 dB throughout the band. The cross polarization of fractal antenna has been plotted at two frequencies 0.913 GHz and 5.202 GHz as shown in Fig. 10a and b. The cross polarization level has been observed better than –15.5 dB at frequency 0.913 GHz. This type of planar antenna can be good for candidates for UWB communications.

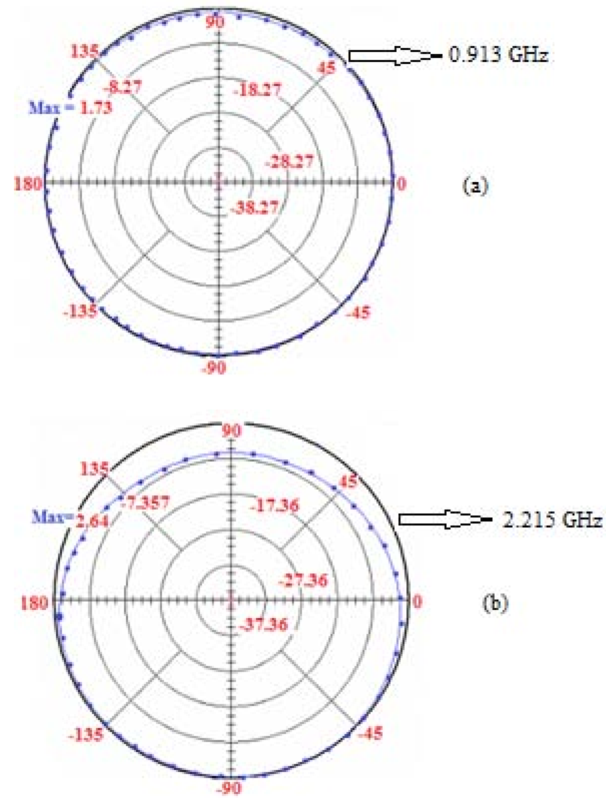
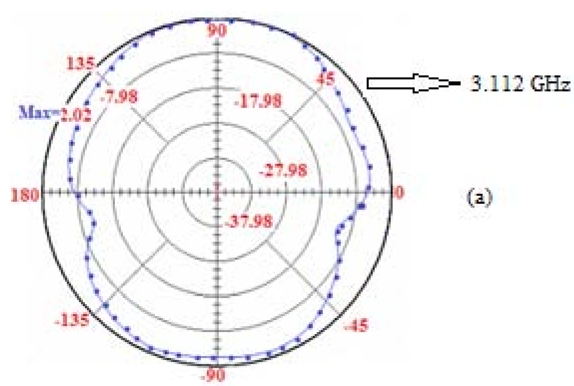


Fig. 8. Experimental Radiation pattern of Fractal Antenna at 0.913 GHz and 2.215 GHz



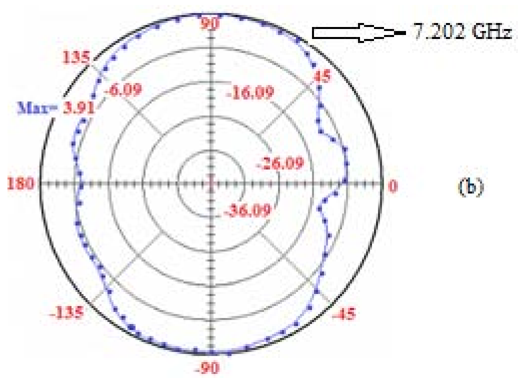


Fig. 9. Experimental Radiation pattern of Fractal Antenna at 3.112 GHz and 7.202 GHz

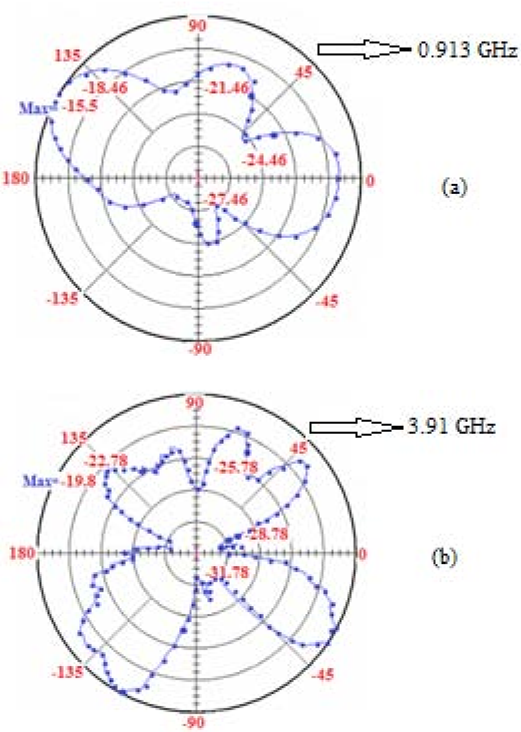


Fig. 10. Cross Polarisation of Fractal Antenna 0.913 GHz at 3.91 GHz

VII. CONCLUSION

The new triangular wheel shape fractal antenna has been designed and tested successfully. The UWB feature of fractal antenna has been achieved using self -similarity property and space filling property of fractal geometry. The experimental result indicates that the CPW – fed provide good impedance matching for UWB performance. The impedance bandwidth has been achieved around 10.63 GHz corresponding to 172.15 %. The antenna has omni – directional radiation pattern across the matching band. This type of antenna can be useful for GSM900, GSM1800, PCS1900, WCDMA/UMTS (3G), ISM, WLANs, WiBro (2.3–2.39 GHz), WLAN (2.4–2.483 GHz), and DMB (2.605–2.655 GHz) and UBW simultaneously as well as mobile and radar communications.

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