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Fractal Fork Shape UWB Monopole Antenna with Ground Deformities

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Abstract

This paper presents a compact size ultra wide band antenna for wide range of wireless applications. The antenna is designed on 18x12x1.6 mm^3 substrate using FR4 material with wide band characteristics using fractal structure of fork shape antenna. The ground is deformed and slots are cut in the broader dimension of antenna. These cuts enables antenna to produce band gaps and optimizing the impedance matching for complete range of operation. The proposed antenna is consisting of a fork shaped repeated geometry patch as a dominating mode of a frequency function. In addition to avoid spurious feed radiations the ground dimensions are optimized to force the antenna structure with in specific range of frequency of 2.4 GHz. On other hand the slotted structure matches the impedance width of the antenna. The proposed structure is simulated and fabricated on commercially available FR4 (4.4) substrate. The Measured and simulated results has good match and operates in frequency range of frequency from 1.55GHz to 13.33 GHz. Therefore the antenna is suitable for ultra wide band applications as referred by IEEE standards and FCC.

Keywords: Fork Shape, fractal, bandgap, ultra-wideband (UWB), impedance matching.

INTRODUCTION

The fast development of communication devices in the wireless systems generated the need of Ultra Wide Band antenna with compact geometry. WPAN is an example of such highly desirable applications. UWB communication is excited to fulfill the requirements the FCC approved 3.1GHz to 10.6 GHz band of frequency. Many researchers' has their keen interest to develop such antenna to receive all of its application opportunities within the same compact area. A wide range of UWB printed antennas with multiple structures and shapes are reported in literature. These antennas require a good control in bandwidth, desired radiation pattern, cheap and simple design structure. In the article [1] improvements are made to the simple elliptical monopole antenna by varying the axial ratio of the ellipse in form of a patch to increase bandwidth, while a circular hole helps patch to enhance the effect of the matching of impedance, [2]-[3], also by reshaping of ground plane to suppress the lower edge of frequency and supports the impedance matching, hence impedance bandwidth in the upper band of frequency [3].

At the same time, many techniques gives a wide range of impedance bandwidth in specific function of cutting notches to corners of the square planar monopole at two side [4], by creating U slot [5], to have a small strip like bar [6], moreover the combinations of multiple type slots [7], more specific even W-shape slot [8], another interesting combination of J& L slots [9] and creatively deforming ground plane structure [10].

In principle UWB is defined by Federal Communications Commission (FCC) for a signal having 500MHz bandwidth. The issued bandwidth from 3.1 to 10.6 GHz for unlicensed use in UWB wireless communications has given an opportunity to develop ultra wideband devices and hence a suitable antenna [11].The main feature of the UWB systems is to use short pulses to have a wide bandwidth with very low power transmitted which makes it more compatible for personal devices in modern world like every day wireless systems around us [12].

Meanwhile most important to maintain the basic characteristics of the antenna as low profile , cheap and easy to fabricate [13].In this paper the proposed antenna is developed from a basic square shape patch by modifying the patch as well as ground geometry to obtain desirable impedance bandwidth.

DESIGN METHOD

In this part, the antenna for the full UWB band is developed which has equivalent to a parallel LC oscillating circuit. Specifically at low frequencies, the main distribution of current is more at the center of patch as compared to the corners of the patch. In fact, the effective length of the patch is responsible to total current distribution as well as the resonating frequency. Therefore, any increase in the length of the patch length is equal to increase in equivalent current element length and decrease in the dominant resonant frequency. The basic design structure can be obtained from the equations given below [13]

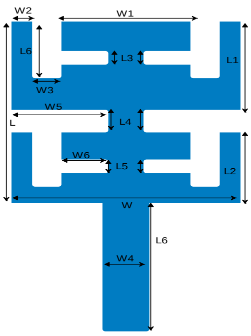
$$W = \frac{c_0}{2f_r}\sqrt{\frac{2}{\epsilon_r+1}} \qquad (1)$$

$$\epsilon_{reff} = \left(\frac{\epsilon_r+1}{2}\right) + \left(\frac{\epsilon_r-1}{2\sqrt{1+12\frac{h}{w}}}\right) \quad \text{W/h >1} \qquad (2)$$

$$\frac{\Delta L}{h} = 0.412\,\frac{(\epsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\epsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \qquad (3)$$

$$L = \frac{c_0}{2f_r\sqrt{\epsilon_{reff}}} - 2\Delta L \qquad (4)$$

The proposed model is shown in figure 1 having both side modified with repeated fractal fork geometry along with significant modification in the ground plane. The design evolution of the proposed antenna is shown in figure 2. The antenna is first structured on 12x18x1.6 mm^3 substrate of glass epoxy FR4 material. The basic structure has been developed from the square shape antenna of 10x10 mm^2 and it is found to resonate at 2.4 GHz. Structure on modified ground deformities. This has given a crux to modification and evolution of proposed geometry from multiple design structures as shown in figure 2(a), 2(b) and 2(c) respectively. Descriptively, square patch first be converted into fork shaped geometry on the optimized geometry of ground plane in association slotted band gap structures along the broader side of the ground plane. The structure is further modified through iterative process to develop fractal structure of fork shape architecture on patch side using the same geometry of ground. The design satisfaction appears on the proposed model for extending the ground structure along with the same band gap symmetry with fractal fork shape on patch. This design geometry is found suitable from each parametric aspect, the design specifications are mentioned in table1. It is observed that further change in the band gap slots would not have UWB properties due to non-generative suppression electric field through corners. Hence the proposed model is modeled and simulated on high frequency structure simulator for design validation process. The patch is feed with the microstrip line to obtained 50 ohm impedance for good impedance matching.



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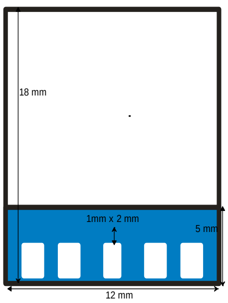

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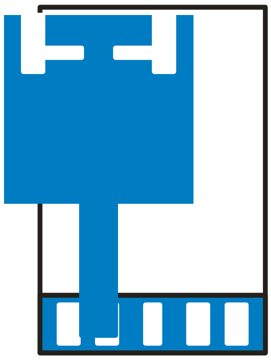
Figure 1. Proposed antenna design (a) patch (b) ground



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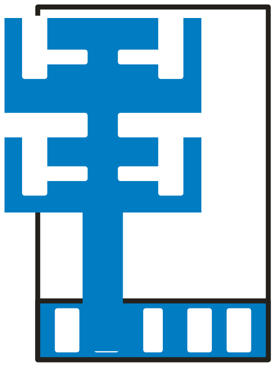

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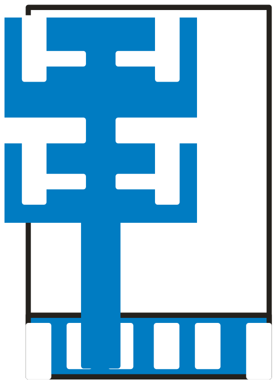


(c)

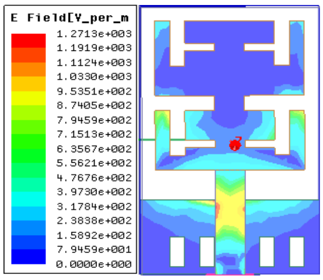
Figure 2. Antenna Geometry (a) Fork shape (b) fractal fork shape (c) corner edged EBG ground with fractal fork

Table 1: Design measurements

parameter	(mm)	parameter	(mm)
L	10	W	10
L1	5	W1	6
L2	4	W2	1
L3	0.5	W3	1
L4	1	W4	2
L5	0.5	W5	4
L6	3	W6	2

RESULTS AND DISCUSSIONS

The multiple design aspects are observed on simulation of different geometry on high frequency structure simulator.A UWB fractal shaped antenna with electromagnetic band gap enabled ground structure is designed. A prototype of the proposed antenna was also fabricated and testing is done on Vector network analyzer. The fabricated antenna is shown in figure 4. As an important aspect of obtaining ultra wide band characteristics of the antenna, the square patch is modeled on reduced ground geometry of 3 mm. The observations, for the formed structure of fork shape at the upper edge of patch and simultaneous modification in ground by inserting band gap structure of 1x2 mm ^{2,} to vary impedance bandwidth, are found to make antenna resonating at 2.4 GHz. This makes the structure more interesting to be resonated at much compact size. The EBG structure could be able to make antenna to have its lower edge of cut off frequency at significantly reduced level on horizontal axis as 1.55 GHz. As a next stage the fork shape geometry is being made as a repeated structure of modified fractal patch. This fractal has made antenna to be matched over the wide range of impedance bandwidth under -10 dB return loss characteristics. Therefore the antenna structure is highly matched at wider side of the patch geometry, while the fractal limbs resonate at comparatively high edge of frequency. In addition to above the any further improvement in band gap structure shows band rejections in upper half of frequency spectrum. Thus for the UWB properties, the ground geometry is found perfectly resonating in extended version of ground dimensions (5 mm) with the previously depicted same band gap structures. Figure 3 shows the variation of electric and magnetic field strength for the proposed antenna geometry, clearly indicates that lower part of antenna has effective current distribution in its first phase and later on the repeated fork structure is extended the distribution. Figure 4 shows the comparative study among the multiple design evolution in terms of return loss in dB with respect to frequency in GHz. on the basis of simulated results the fractal geometry with enabled EBG structure is fabricated and measured on VNA. The Measured results of the proposed antenna has a-10dB impedance bandwidth from 1.55 to more than 13.33 GHz, covering the above said WLAN (2.4 GHz), WiMAX (2.5 GHz), and complete UWB(3.1–10.6 GHz). In test, the impedance parameters are also shown in figure 8, giving perfect match over the real edge of frequency. The isolation at the port at maximum impedance is observed -36 dB and most of the band is matched at an average of -18 dB. From the classical theory, the x-z plane also termed as E-plane, has complete plot at a particular azimuth angle of phi and the primary sweep of Theta. Obviously, the x-y plane termed as H-plane at a particular elevation angle Theta and the primary sweep is Phi. Figure 9 & figure 10 shows, the simulated and measured normalized far-field radiation patterns in E-plane and H-plane at frequencies at 2.5, 5, 7.5,10 and 9.34 GHz. The resulted E-plane is found highly directional with unidirectional properties. The H-plane has bidirectional properties at port 1 showing good polarization characteristics.



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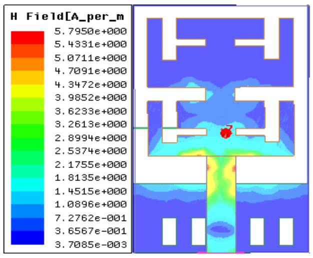

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Figure 3. (a) Electric and (b) Magnetic field distribution

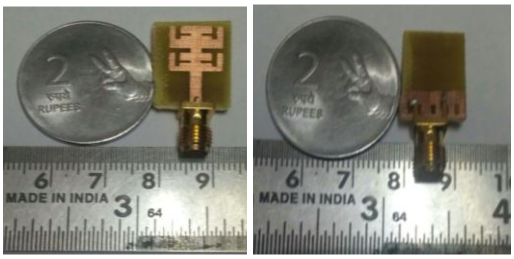


Figure 4. Fabricated antenna patch and ground

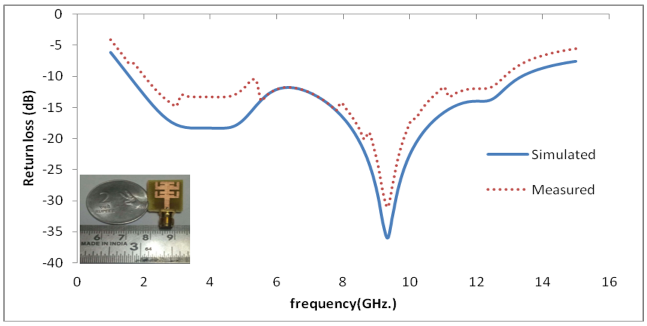


Figure 5. Measured and Simulated Reflection coefficient S_{11} against Frequency

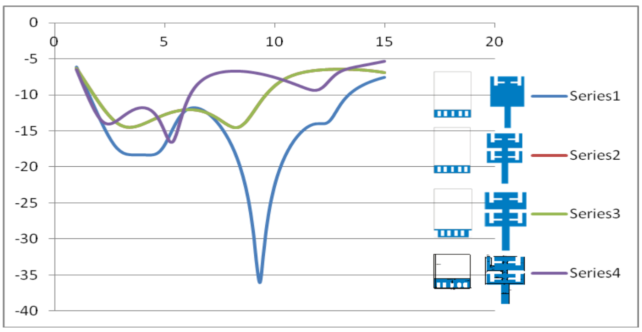


Figure 6. Variation of S_{11} parameters

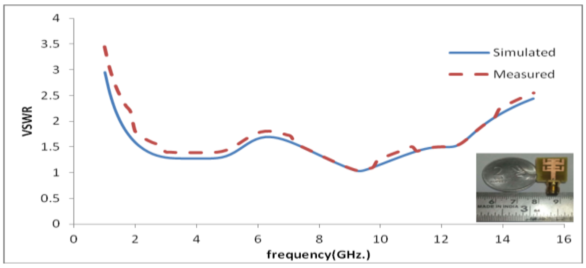


Figure 7. Simulated and measured variation of VSWR

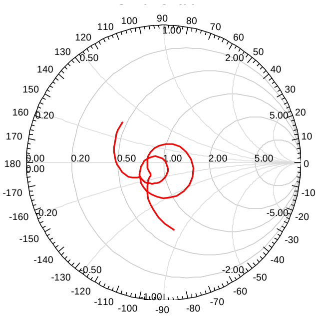
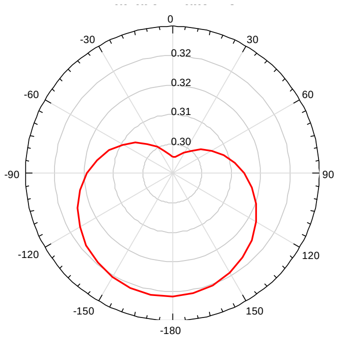


Figure 8. Smith Chart



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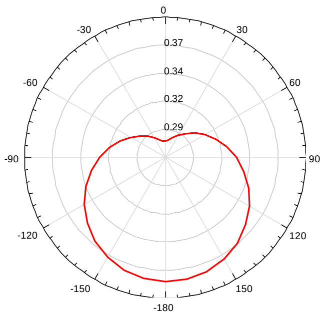

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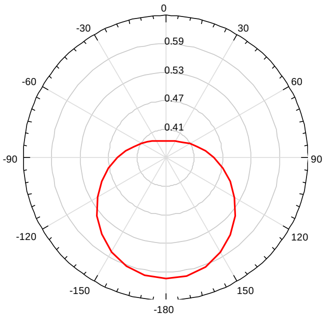

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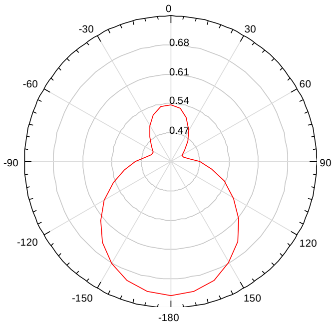
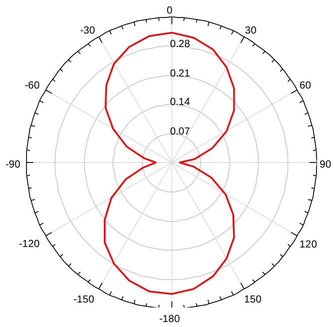


(d)

Figure 9. Simulated E- plane radiation patterns (a) at 2.5 GHz (b) At 5 GHz (c) 7.5 GHz (d) 10 GHz



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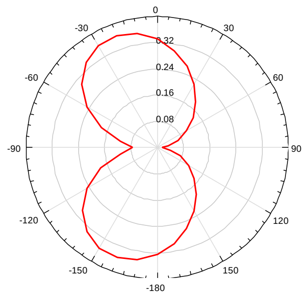

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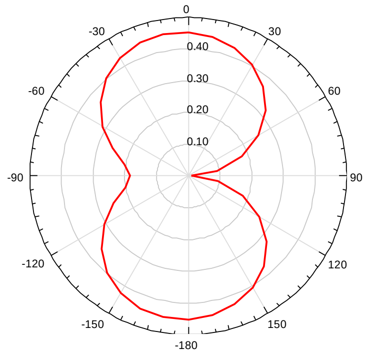

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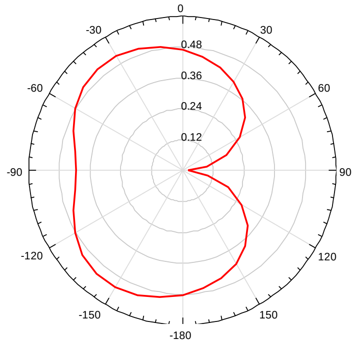

(d)

Figure 10. Simulated H-plane radiation patterns (a) at 2.5 GHz (b) 5 GHz (c) 7.5 GHz (d) 10 GHz

CONCLUSION

As an emerging technology of ultra wide band, the specific requirement of designing of compact size perfectly matched antenna is full filled in this work. The antenna is designed through multiple iteration process through result analysis and necessary modification. The simulation results motivated the fabrication process of the antenna. The measured and simulated results of the antenna over the impedance bandwidth below -10 dB have a good compromise. This has produced the design validation for the practical application feasibility of the proposed model, which has been operating in complete 1.55 to 13.33GHz. huge band of application along with the compact structure. The VSWR and radiation properties of antenna are also observed and analyzed through 50 ohm strip feed matching. The antenna has found with good stability at successive frequency of observation over the complete band of operation. Therefore the proposed structure has compact symmetry and practically suitable to UWB applications as per the standards of FCC and IEEE.

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