Pentagonal Shaped Fractal Antenna with Modified Ground and Enhanced Bandwidth for Wireless Applications

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Abstract— **This paper presents the structure, simulation, fabrication and tested results of pentagonal shaped fractal antenna. The antenna is simulated using FR4 substrate of dielectric constant εr 4.4 and thickness h= 1.6 mm. The proposed antenna is excited using microstrip feed. The simulated result of pentagonal shaped fractal antenna exhibits the excellent wideband (WB) wireless application. Federal Communication Commission (FCC) frequency range with a return-loss performance S11 =-10 dB. The simulated radiation patterns of this pentagonal shaped fractal antenna are omni-directional in H-plane and bidirectional in E-plane. This proposed antenna can be useful for WB system, microwave imaging and vehicular radar.**

Keywords— Monopole antenna; Multiband antenna; Fractal geometry; Microstrip feed; Bandwidth enhancement.

I. INTRODUCTION

The rapid progress in wireless and dramatic development of a variety of wireless applications have remarkably increased the demand of multiband and wideband (WB) antennas with smaller dimensions than conventionally possible.

The proposed antenna gives a bandwidth of 4.17 GHz(3.281-7.45GHz) which is small bandwidth[1].The antenna exhibits features such as high data transmission rate, compact and wide impedance bandwidth. Several UWB antennas have been reported in open literature [2–4]. These antennas have been fed directly with the coaxial probe, which required very large ground plane [2, 3]. These antennas are also fragile and not suitable to integrate with the microwave integrated circuit (MIC) and monolithic microwave integrated circuit (MMIC) devices. Liang et. al. [5] has reported the circular disc monopole antenna with coplanar waveguide (CPW) feed. Recently, various UWB fractal antennas have also been reported for UWB applications [6–9]. In Ref. 6,crown square microstrip antenna is proposed to reduce the size. The frequency notched UWB microstrip slot antenna with a fractal tuning stub is proposed to achieve frequency notched function [7,8]. Ding et al. [9] and Kumar and Sawant [10] have proposed a new UWB fractal antenna by adopting the fractal concept on the CPW feed. It is reported in literature that the circular and elliptical shape of the antenna is more suitable for ultra-bandwidth (UBW) characteristic in comparison to conventional square monopole antenna. The square planar monopole antenna has the drawback of providing a relatively smaller impedance bandwidth [11, 12]. To improve the impedance bandwidth of the square planar monopole antenna, several bandwidth enhancement techniques have been reported, such as the use of a double feed [12] and a semi-circular base [13], and so on. The square-shaped fractal antenna with modified ground is reported in this article for UWB characteristics.

This paper presents the simulation of fractal antenna with microstrip feed for the wide bandwidth. This antenna has been simulated using HFSS18. The modification in the ground plane helps in achieving the WB characteristics

a) b) c) d) e)

Figure 1: Pentagonal-shaped fractal antenna with each iteration.

This antenna has advantages of lightweight, low profile, low cost, ease of fabrication, and easy to integrate with radio frequency devices. The proposed antenna has been characterized in term of impedance bandwidth and radiation patterns.

II. ANTENNA GEOMETRY

The printed monopole antennas are adapted and have been widely developed, as it is simple and easy to fabricate. In this paper, a printed pentagonal-shaped fractal monopole antenna for WB application is proposed. The proposed fractal antenna is shown in Figure 1 with four iterations. The Figure 1 shows the shape of pentagon inscribed in pentagon monopole antenna with its zeroth, first, second, third, and fourth iterations. The zeroth iteration consists of pentagonal patch of 7 mm, this is called zeroth iteration as shown in fig 1 (a). In first iteration the second pentagonal patch of 5mm and is rotated by 90̊ , which is subtracted from zeroth iteration. This is known as first iteration as shown in fig 1(b).In second iteration we have scaled first iteration 0.6 mm is called as second iteration which is shown in fig 1 (c). In third iteration we have scaled first iteration 0.4 mm is called as third iteration which is shown in fig 1 (d). In fourth iteration we have scaled first iteration 0.25 mm is called as fourth iteration which is shown in fig 1

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(e).This fourth iterative structure is fed with microstrip feed of 50Ω line width. The antenna has been simulated and optimized. It is observed that impedance matching for wide bandwidth required the modification in the ground plane. The proposed antenna with modified ground is shown in Figure 2 with optimized dimension. In this, rectangular slot inserted with a dimension Wg and Lg is inserted in ground plan as shown in fig 2.In this, the feed of antenna and radiating elements are printed on the substrate. It has been found that microstrip feed offers less dispersion at higher frequency and broader matching [9, 10].

III. FRACTAL ANTENNA

A fourth iterative inscribed pentagonal fractal antenna with modified ground has been proposed as shown in Figure 2. It is understood that current distribution of the proposed antenna is mainly along the edges of the pentagon. The current density is low in the middle area of the solid pentagonal patch antenna. Therefore, the current will not be affected if the middle area of the solid patch monopole antenna is removed.

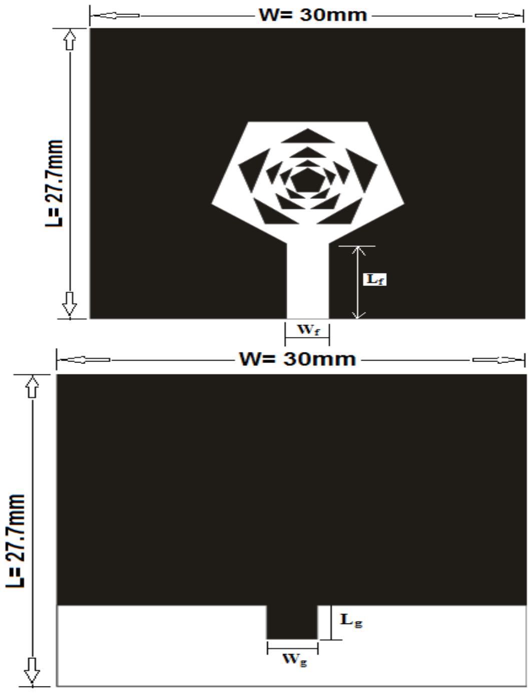

Figure 2: Pentagonal-shaped fractal antenna with modified ground

In this way, the effective path of the surface current will become longer. In this antenna, the effective length of current path is increased by inscribing pentagon in various pentagonal as shown in Figure 1. This results into, the decrement of first resonance frequency and reduction in antenna size. To achieve the WB characteristic, the fractal structure can be added to increase the resonance frequency in high frequencies by adding resonance elements as well as modification ground plane for proper matching. The dimensions of antenna: Substrate size 30mm X 27.7mm X 1.6 mm, W_f = 2.9mm, L_f = 7.16mm,W_g = 3.2mm, L_g = 3mm.

IV. SIMULATED RESULT WITH AND WITHOUT MODIFIED GROUND

This antenna has been simulated using FR4 substrate with ε_r 4.4 and thickness h=1.6 mm. The pentagonal-shaped fractal antenna has been simulated using HFSS18 simulator. First, the fractal antenna has been optimized without modifying ground with respect to design parameters and modified ground length and ground width.

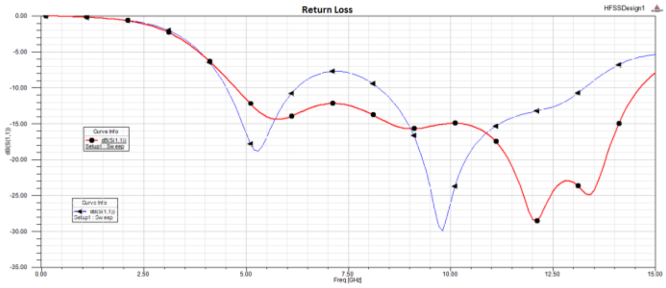

Figure 3: Simulated results pentagonal-shaped fractal antenna with and without modified ground plane

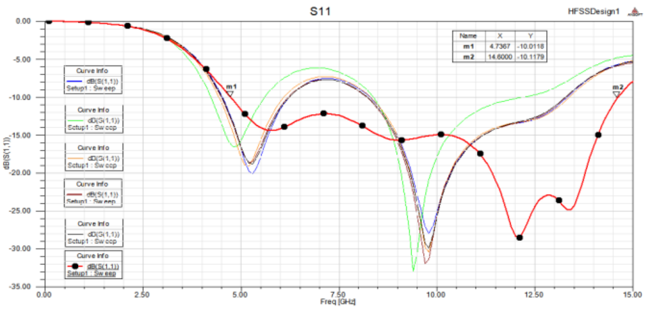

Figure 4: Simulated results of each iteration of pentagonal-shaped fractal antenna with modified ground

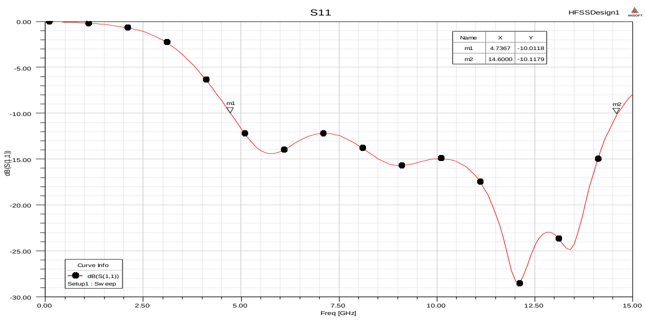

Figure 5: Return loss of pentagonal-shaped fractal antenna with modified ground plane.

After optimization, it is observed that impedance matching has not been achieved with return loss S11= -10 dB as shown in Figure 3. As, it is known that shape of the ground plane plays the important role in the design of WB antenna. This is because the current distribution is along the edge of the ground plane near the radiation. To achieve the impedance bandwidth, one rectangular slot is added into ground. Width and length of rectangular slot W_g = 3.2mm, L_g = 3mm respectively. It is observed from the result that a drastic improvement is achieved throughout the band with modified ground plane.

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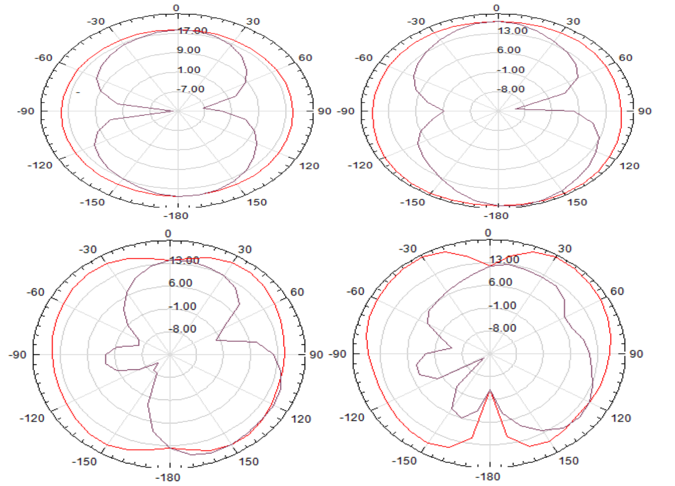

Figure 6: Simulated radiation patterns of Pentagonal-shaped fractal antenna in 5GHz, 7GHz, 9GHz and 11GHz with modified ground plane.

The antenna with modified ground has been optimized with respect to these parameters. The ground plane length and width of the proposed antenna with modified are also optimized to the value of 30mm and 7.2 mm respectively for impedance matching throughout the band. The simulated results of each iteration with modified ground and optimized design parameters are shown in Figure 3, and proposed antenna with optimized dimension is shown in Figure 2. The proposed antenna with modified ground has also been simulated with respect to each iteration. The simulated results of each iteration are shown in Figure 4. It each iteration are shown in Figure 4. It is clear from the simulated results that impedance matching is very poor throughout the band for first iteration. The impedance matching improves marginally for the second iteration. The impedance matching throughout the band is improved almost throughout the band for third and fourth iteration. It is also observed from the simulated results as the iteration increases the first resonant frequency shifted slightly towards lower frequency side. It is also found that as the number of iteration increases, the lower-edge of the impedance bandwidth is moved to the low frequency and the level of the impedance matching over the higher frequency side is also improved slightly.

V. SIMULATED RESULTS AND DISCUSSION

The proposed modified ground pentagonal-shaped fractal antenna has been shown in Figure 2 with optimized dimension. The simulated result of proposed antenna acquired from the HFSS 18 has been shown in Figure 5. The fractal antenna exhibits the excellent WB characteristic in frequency range from 4.73 GHz to 14.6GHz at voltage standing wave ratio (VSWR) 2:1. It is observed during simulation that as the number of iteration increases, the lower-edge of the impedance bandwidth is moved to the low frequency and the level of the impedance matching over the operating frequency band is improved. The simulated results are in good agreement as shown in Figures 3 and 5, respectively. The radiation patterns of modified ground of pentagonal-shaped fractal antenna have been simulated in HFSS18. The simulated radiation patterns at selective frequencies, i.e., 5GHz, 7GHz, 9GHz and 11GHz as shown in Figure 6. The nature of radiation pattern in H-plane is nearly omnidirectional and in E-plane is bidirectional. The gain of this fractal antenna is less than 7 dBi. The peak gain at high frequency increases because effective area at higher frequency increased. This fractal antenna is exceeding the bandwidth than reference antenna [1].

VI. EXPERIMENTAL VERIFICATION

After obtaining simulated results, the proposed antenna is manufactured using FR4 (ε_r =4.4,h=1.6mm) with said dimensions. Figure 7.a) gives the patch layout where as 7.b) gives the ground plane structure as shown in figure.

Figure 7: Patch and Ground plane layout of manufactured antenna

After manufacturing, the antenna is tested for its return loss and VSWR by using ROHDE & SCHWAARZs (9KHz to 13.6GHz)Vector Network Analyzer. It is found that there is excellent correlation between simulated and tested results.

Figure 8 gives return loss of tested antenna. Antenna transmits almost all frequencies above 6.02 GHz. till 14 GHz showing its wideband range. Figure 9 gives VSWR which is lesser than 2 for all frequencies in wide pass-band.

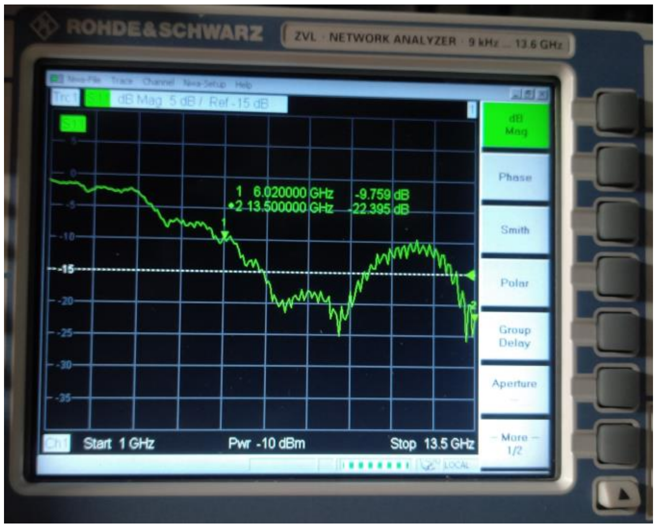

Figure 8: Measured Return Loss(S11) for tested antenna

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Figure 9: Measured VSWR

VII. CONCLUSIONS

The proposed pentagonal-shaped fractal antenna with modified ground has been successfully simulated and WB characteristics. The proposed fractal antenna has been simulated with fourth iteration. The simulated result of this antenna exhibits the excellent WB characteristics in the wide range from 4.73 GHz to 14.6 GHz. The measured radiation of proposed antenna in azimuth plane is nearly omnidirectional and bidirectional in E-plane. The proposed antenna is simple to design and easy to fabricate and integrate with MMIC devices. The proposed antenna is useful for wireless local area communications, radar, ground penetrating radar, medical imaging, and other military applications.

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