Design of Fractal Based Pentaband Antenna with CPW Feed for Multiband Applications

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Abstract:- Design and development of the fractal based pentaband antenna is presented. The proposed antenna is fed by coplanar waveguide (CPW) – feed. Multiband operation along with miniaturization of the antenna is achieved by applying iteration techniques. Analysis of the designed antenna is done by High Frequency Structure Simulator software. The antenna has low profile and lightweight and easy to fabricate on an FR4 epoxy substrate with dielectric constant of 4.4 and thickness 1.6mm. The proposed antenna is compact with size 25×20mm^2 and is useful for military, satellite, radar and WLAN applications.

***Keywords**:- Coplanar waveguide (CPW), Fractal, Pentaband.*

I. INTRODUCTION

The advancement in wireless communication technologies and UWB systems demands the development in multiband antennas. One of the key technologies in UWB systems is antenna design. A suitable UWB antenna needs to fulfill requirements such as ultra wide bandwidth, directional or omnidirectional radiation patterns, high radiation efficiency and small size. For the efficient utilization of the UWB operational bandwidth it is necessary to design the compact fractal UWB antenna having different operating bands. Proper selection of geometry leads to the advantage of wideband/multiband as well as miniaturization. Fractal geometry provides an excellent solution for designing compact and multiband antennas in a most efficient manner with better antenna performance. The self similarity property of fractal structure gives multi-band performance where as the space filling property results antenna miniaturization by fitting the same electrical length into a compact volume. The electrical length increases with iteration and hence the resonant frequency decreases. Several fractal structures are reported [1]-[6].

The wideband characteristics and bidirectional radiation patterns leads to get more attention to CPW antennas. Many CPW fed antennas are developed recently [7]-[10]. It is easy integrate the CPW antenna and UWB chip.

In this letter, a fractal based pentaband antenna fed be coplanar waveguide is discussed. The antenna resonates in the following five bands 3.07 – 4.01 GHz, 5.30 – 5.77 GHz, 6.57 – 7.81 GHz, 9.77 – 12 GHz and 13.02 – 14.3 GHz and is suitable for the applications in C band, S band, X band and Ku band such as radar, satellite, military and WLAN applications. This letter organizes as follows. A detail of the antenna structure is presented in Section II. Section III discusses simulations and optimizations of antenna performance followed by final results in section IV. Section V concludes this paper.

II. ANTENNA DESIGN

The Figure.1 illustrates the recursive procedure of the proposed fractal antenna. The designed fractal antenna is formed from a circular patch fed by a 50-Ω CPW. The initiator is formed by inscribing a decagon from the circular patch. The first iteration level is achieved by rotating the scaled initiator by 18 degree and is arranged within the decagon slot. The final design layout of the antenna is depicts in Figure.2. The dimensions of the antenna are tabulated in Table.1.

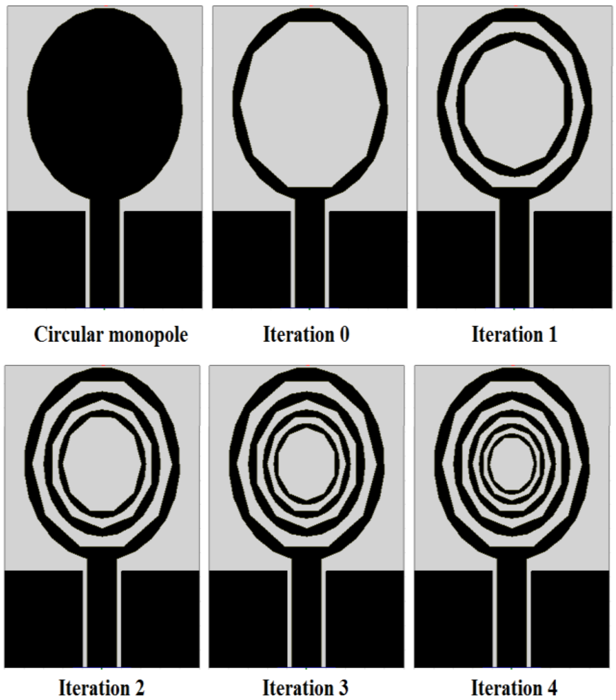

Fig 1:- Recursive procedure of proposed geometry

Parameter	L	W	D	P	P_i
Size(mm)	25	20	16	4.45	3.33
Parameter	L_g	W_g	g	W_f	s
Size(mm)	8	8	0.5	3	1

Table 1. Dimensions of the proposed antenna

The antenna prototype is etched on the FR4 epoxy substrate of relative permittivity 4.4 and loss tangent tan δ= 0.02 with thickness of h =1.6mm.

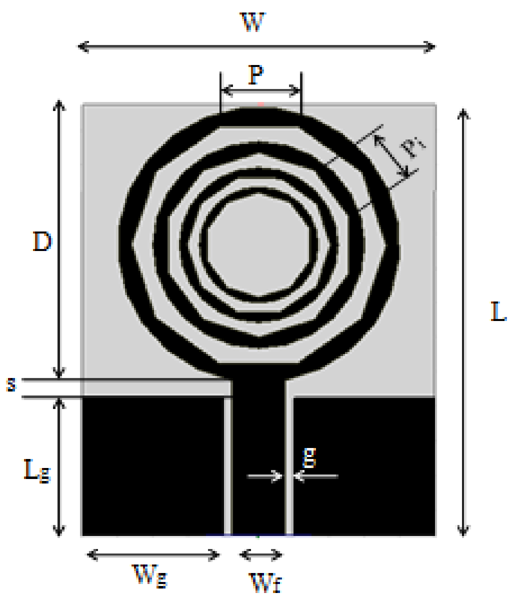

Fig 2:- Proposed antenna structure.

III. SIMULATIONS AND OPTIMIZATIONS

The finite element method (FEM) based Ansoft High Frequency Structure Simulator (HFSS v13) software is used for the simulation and optimization. The basic circular patch antenna provides wideband characteristics. The circular patch dimension is optimized by the parametric study carried out by varying the diameter of the circular patch and the results are shown in Figure.3. Better impedance matching is obtained for the diameter of 16mm. The simulated return loss curves for different iterative stages are depicts in Figure.4.

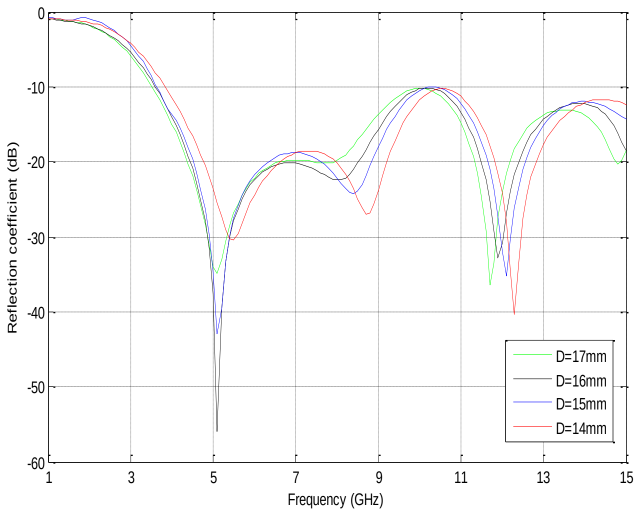

Fig 3:- Reflection coefficient versus frequency curves of the circular patch for various diameters.

The iteration 0 structure gives the dual band performance. The number of bands in which the antenna can operate increased on further level of iterations. The results get stabilized after a few iterations. Here Iteration 3 structure is chosen as the final design layout since this level shows better impedance matching than the succeeding level.

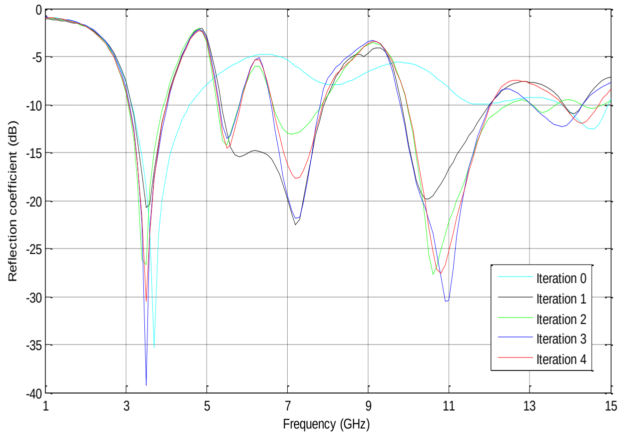

Fig 4:- Return loss curves for different iterations.

The scaling factor for the proposed design was optimized by simulating the return loss curves for different scaling factors and results are illustrates in Figure. 5. To get desired penta-band operation the iteration factor for the fractal geometry is chosen to be 0.75.

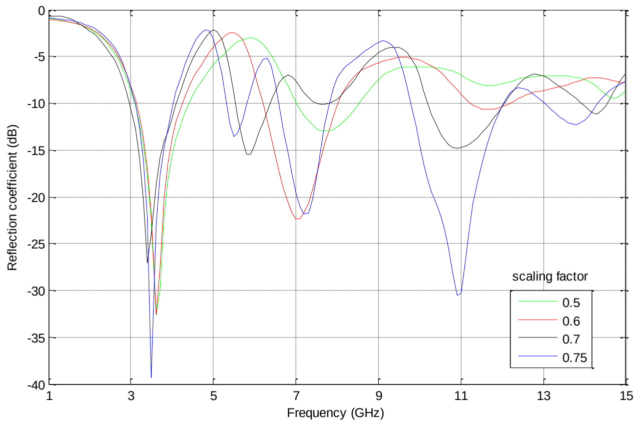

Fig 5:- Return loss for different scaling factors.

The antenna was simulated on different substrates having different dielectric constant and thickness. The simulated S11 is shown in Figure.6. The antenna designed on FR4 Epoxy exhibits penta-band behavior where it shows quad band performance on Arlon25N and RT/duroid 5880.

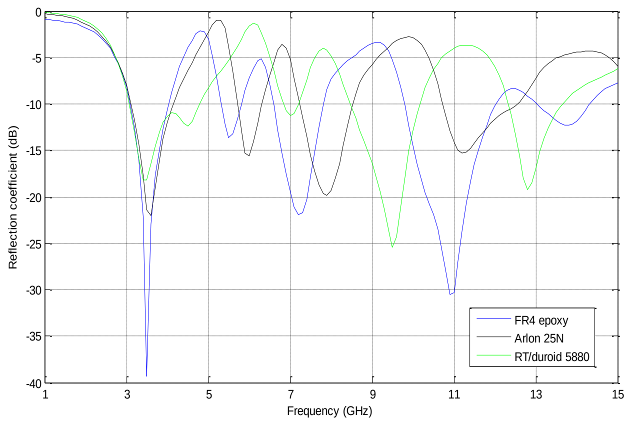

Fig 6:- Return loss of proposed antenna on different substrates.

IV. RESULTS

The designed antenna is fabricated using photolithography technique. The experimental studies are carried out on E5063A vector network analyzer. SMA connector is used to feed the antenna. Simulated and measured return loss of the proposed antenna shown is Figure.7.

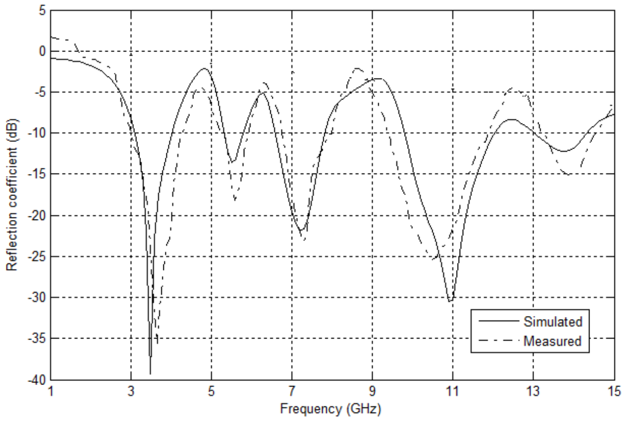

Fig 7:- Return loss of pentaband antenna geometry.

The VSWR of designed antenna is illustrated in Figure. 8.

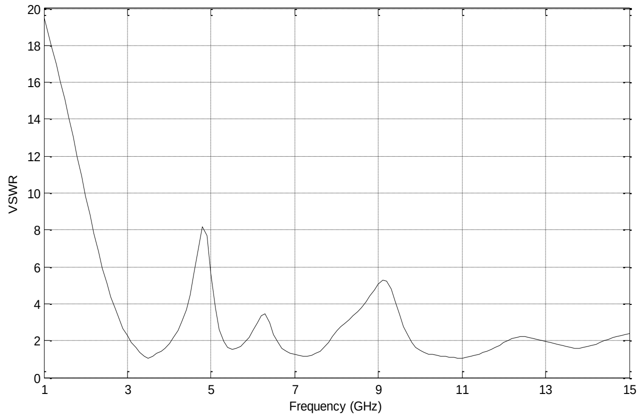

Fig 8:- VSWR of antenna structure

The fabricated antenna prototype is shown in Figure. 9.

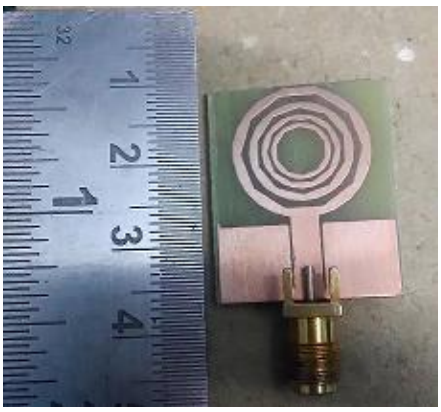

Fig 9:- Photograph of fabricated antenna.

The radiation patterns in the E and the H planes simulated at the five resonating frequencies are shown in Figure 9. At lower frequencies the antenna displays a dipole-like radiation pattern in the E-plane and a nearly omnidirectional radiation pattern in the H-plane. The shape of radiation pattern is somewhat distorted at higher frequencies. This distortion is due to the excitation at higher modes.

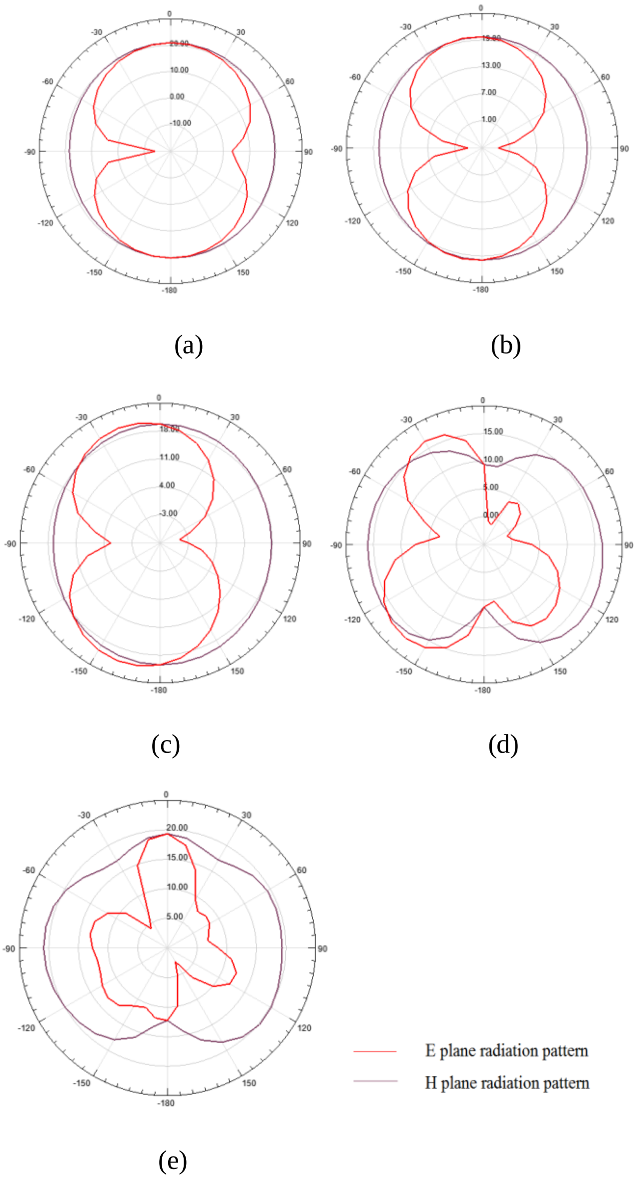

Figure.10. Radiation pattern of proposed antenna at (a) 3.5 GHz (b) 5.5 GHz (c) 7.2 GHz (d) 10.9 GHz (e) 13.7 GHz

Table.2 shows the comparison of the proposed antenna with some of the recently developed antennas. From comparison, it sees that the designed antenna is very compact in its size and design.

Antenna	Number of operating bands	Lowest Resonating Frequency (GHz)	Antenna Size (mm^3)	Feeding Technique
Proposed antenna	5	3.5	20×25×1.6	CPW feed line
[3]	2	1.8	72 ×84 × 1.6	Microstrip feed line
[5]	2	1.41	80×80×1.56	Co-ax probe feeding
[6]	5	0.89	62×89.6×0.78	Microstrip feed line
[8]	3	1.8	34×51×1.6	CPW feed line

Table 2. Comparison between recently reported antennas and the proposed antenna

V. CONCLUSION

Design and development of the fractal antenna has been introduced. The proposed antenna is analyzed in between 1-15GHz using Ansoft HFSS. The antenna structure with fractals of circular patch with decagonal slot gives wideband/multiband characteristics. The antenna designed in this paper is a good candidate for UWB applications such as wireless LAN, radar and satellite communications.

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