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Design of Self-Similarity Multi-Fractal Antenna for WiMAX Application

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Abstract

A novel multifractal self-similarity microstrip-fed monopole fractal antenna is designed. Self-similarity property fractal is implemented in the conventional rectangular patch. As a result, broad bandwidth and resonance frequencies are obtained. The proposed multifractal antenna has a compact size of 19.8*27.8 mm and the operating frequency band of the antenna is 3.4 GHz to 3.6 GHz. The proposed multi-fracal antenna is printed on the FR5 dielectric material with 1.6 mm thickness. It is observed that incremental iterations generate new resonant frequencies. The results shows that the proposed design creates monopole antenna malleable in order to controlling bandwidth and radiation characteristics.

Keywords: Low Profile, Multi-Fractal Antenna, Small Size, Self-Similarity Antenna, Wimax, Wideband

1. Introduction

The tremendous development of wireless system stimulates the growth of different IEEE standards such as IEEE 802.16 WiMAX standard in 3.5 GHz (3.4-3.6 GHz) and 2.4 GHz (2.3-2.75 GHz) bands[1,2], hence then antenna needs to operate at specified frequency bands in the WiMAX[3]. The most present antenna based on the make use of self-similarity property of fractal geometry. Numerous novel antennas described in the literature.

Fractals are expanding symmetry and entity that shows self-similarity in shapes but having irregular arrangements. These are collected after several iterations of a solitary fundamental geometry, which describes a family of multi-fractal shapes[4-6]. The fractal iterations factor determines the size of the original patch[5,6]. By reducing size it is possible to maintain good radiation characteristics[5,6].

A self-similar structure gives a maximum amount of iterations by scaled down. Thus, geometry size shrinks down to its width and length by retaining originality[6]. A self –similarity construction contracts down by diverse aspects hence that it's affords malleable in conniving miniature fractal antenna[6-9]. More than one frequency can be resonated by choosing suitable scaling factors and adjusting feed point of the antenna[10,11].

Basil K Jeemen , Shambavi examined multi-fractal antenna designed for dual band and fabricated with microstrip feeding[12]. Sinha examined self-similarity fractal antenna for multiband applications with microstrip feeding method[13]. Srivatsun and Subha Rani analysed self-affine fractal antenna for telemedicine applications with microstrip feeding method[14]. C. Purente, J. Romeo, R. Pous analyzed self-similarity property and evaluated for UWB characteristics[15,16].

This paper inspects the self-similar property and multi-fractal concept of fractal by applying self-similarity property and multi-fractal into the single rectangular patch increases the discontinuity in terms of rectangular cuts which produce enhanced radiation characteristics. By retaining return loss more than -20 dB in all iterations and made to produce broad bandwidth.

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2. Proposed Antenna Geometry

The multifractal self-similarity geometry comprises the combination of more than four fractals structures into arectangular patch. By Introducing the multi-fractal technique into a single conventional rectangular patch can be introduced more discontinuities in the form of various rectangular and square cuts, that produce better radiation characteristics[15,16]. The self-similarity multi-fractal rectangular patch monopole antenna is simulated by Advanced design system momentum. The self-affine property applied for multifractal geometry in this paper. This proposed antenna designed by scaling a square by factor of 3 in the vertical and by 2 in the horizontal direction, gives 5 rectangles. This process is the recurring process and continued up to Nth iteration. The matrix of the iteration function system described by Equation[15,16]

$$W\begin{pmatrix} w \\ y \end{pmatrix} = \begin{pmatrix} a & b \\ c & d \end{pmatrix}\begin{pmatrix} x \\ y \end{pmatrix} + \begin{pmatrix} e \\ f \end{pmatrix}$$

IFS conversion coefficients of the self-affine multi-fractal given Table 2. The proposed structure are developed at each iteration of equal dimensioins, hence, the proposed geometry lead an antenna to resonate at a resonant frequency of 3.5 GHz. Antenna is printed on the FR5 dielectric material with dielectric contsant (εr) of 4.5. The proposed multi-fractal antenna started with dimensions of 25.8 mm* 19.8 mm which resonates at 3.5 GHz. Maximum return loss and better radiation characteristics can achieve at design frequency by optimizing the different factors such as microstrip stub length, position of the aperture and atmosphere air gap between the dilectric substrate. The proposed geometry is very low in size and has better performance. The structure of proposed antenna shown in the Figure 1, Figures 2, Figure 3, Figure 4 and dimensions of an antenna geometry given in Table 1.

Table 1. Antenna dimensions of proposed structure

W (mm)	H (mm)	W_a (mm)	H_a (mm)	W_b (mm)
25.8	19.8	8	9	9

Table 2. IFS transformation coefficients for the self-affine multi-fractal

w	a	b	c	d	e	f
1	0.4	0	0	0.6	0.3	0
2	0.4	0	0	0.6	0.3	0
3	0.4	0	0	0.6	0.3	0
4	0.4	0	0	0.6	0.3	0.6
5	0.4	0	0	0.6	0.3	0.6

Figure 1. Antenna geometry for 0th iteration.

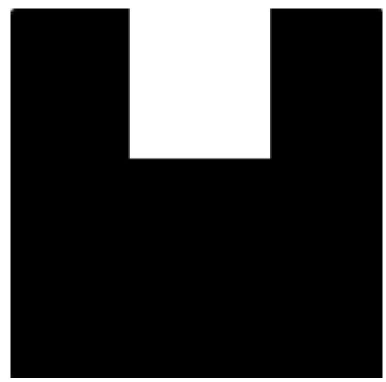

Figure 2. Antenna geometry for 1st iteration.

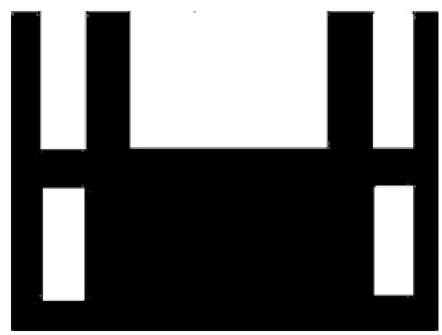

Figure 3. Antenna geometry for 2nd iteration.

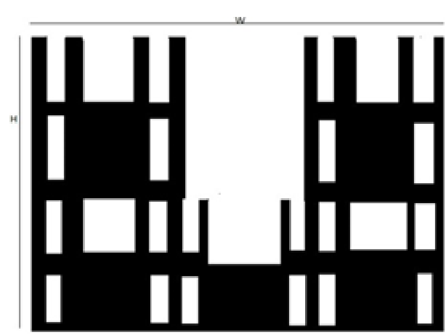

Figure 4. Antenna geometry for 3rd iteration.

3. Result and Discussion

3.1 Return Loss

The proposed Multi-fractal self-similarity antenna is observed to cover the frequency range of 3.4 to 3.6 GHz with a return loss of -22 dB at the opreating frequency of 3.53 GHz for third iterations. The zeroth iterations of the proposed antenna resonate at 3.49 GHz with -21dB return loss and similarly for other iterations K1, K2 and K3 exhibit 3.5 GHz, 3.52 GHz and 3.53 GHz with return loss -20 dB, 21 dB and -22 dB respectively. Figure 5(a), Figure 5(b), Figure 5(c), Figure 5(d) shows the simulated return loss of the three iterations of multi-fractal self-similar structure and Figure 6 shows a comparison plot for the three iterations at 3.5 GHz. It clearly interfered from the return loss plots which the proposed antenna shows better return loss characteristics and better bandwidth for the third iteration, hence, it is suitable for the WiMAX applications. The comparison of the Simulated Return loss at different iterations for self-affine multi-fractal antenna given in Table 3.

Table 3. Simulated returnloss at different iterations for self-affine multi fractal antenna

K0		K1		K2		K3	
Resonant frequency (GHz)	Return loss (dB)	Resonant frequency (GHz)	Return loss (dB)	Resonant frequency (GHz)	Return loss (dB)	Resonant frequency (GHz)	Return loss (dB)
3.498	-21	3.5	-20	3.52	-21	3.53	-22

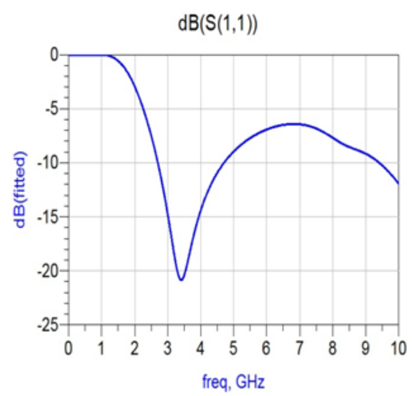

Figure 5(a). Return loss for 0th iteration.

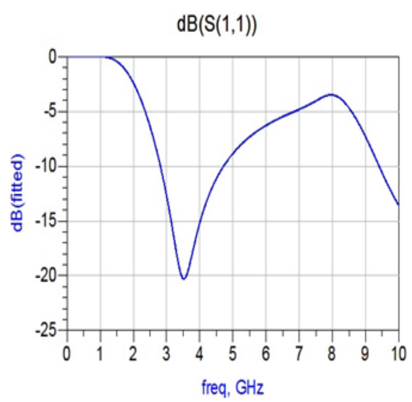

Figure 5(b). Return loss for 1st Iteration.

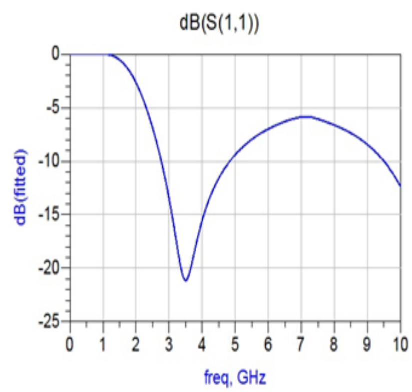

Figure 5(c). Return loss for 2nd Iteration.

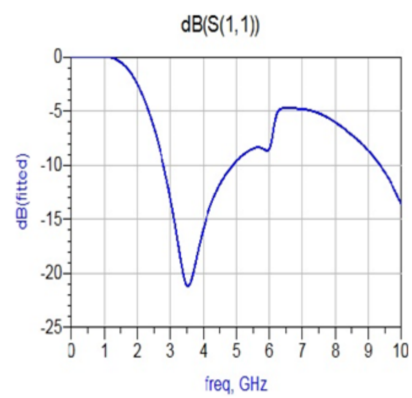

Figure 5(d). Return loss for 3rd Iteration.

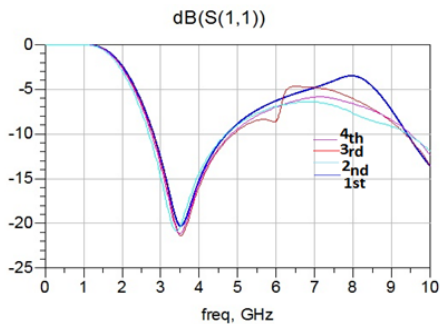

Figure 6. Return loss comparison for three iterations.

3.2 Radiation Pattern

Figure 7 shows the E-Plane polarization and H-plane polarization and circular and Linear polarization for 1st iteration at 3.5 GHz. Figure 8 E-Plane polarization, and H-plane polarization and circular and Linear polarization for 2nd iteration at 3.52 GHz and Figure 9 E-Plane polarization and H-plane polarization and circular and linear polarization for 3rd iteration at 3.5 GHz. It hence, that the radiation patterns in the resonant operating band exhibit better radiation characteristics for the 3.5 GHz. The radiation pattern of the proposed structure is asymmetrical in E-plane and H-plane and it has omnidirectional radiation pattern over the operating band frequencies (3.4 GHz to 3.6 GHz). Figure 9 shows The gain and directivity of a proposed antenna, it has 8 dBi gain at 3.5 GHz.

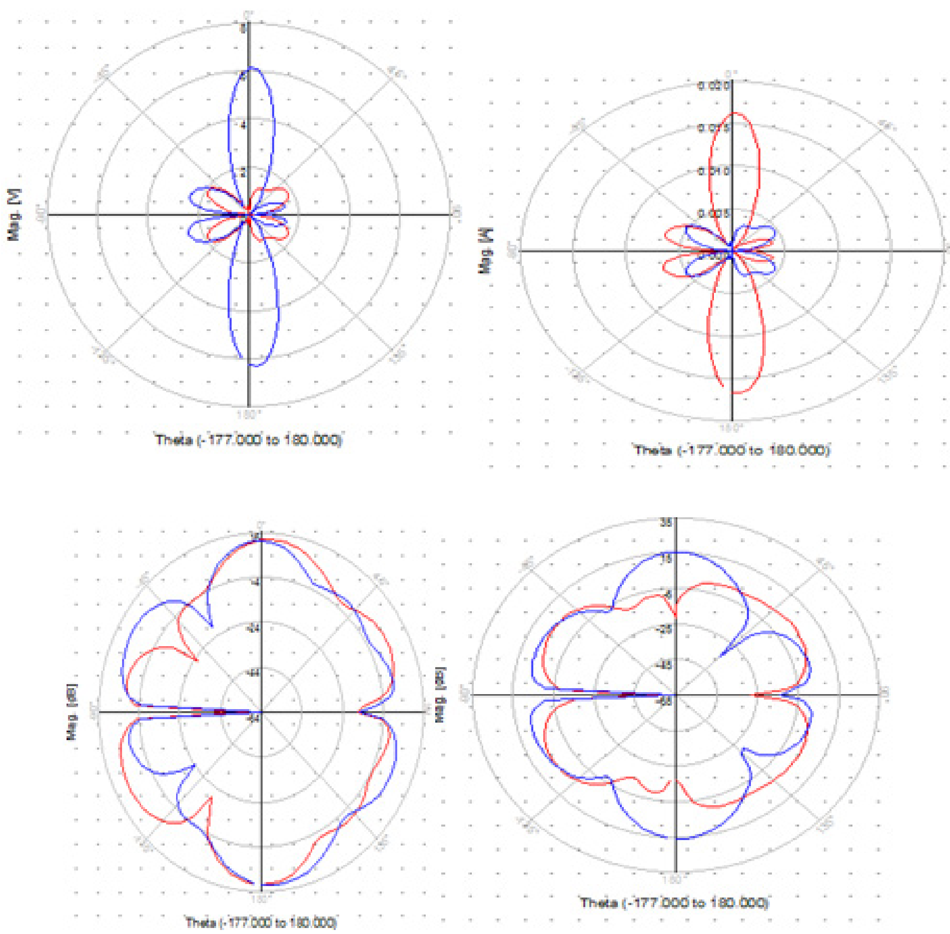

Figure 7. E-plane and H-plane polarization, circular polarization and linear polarization for 1st itereation at 3.5 GHz.

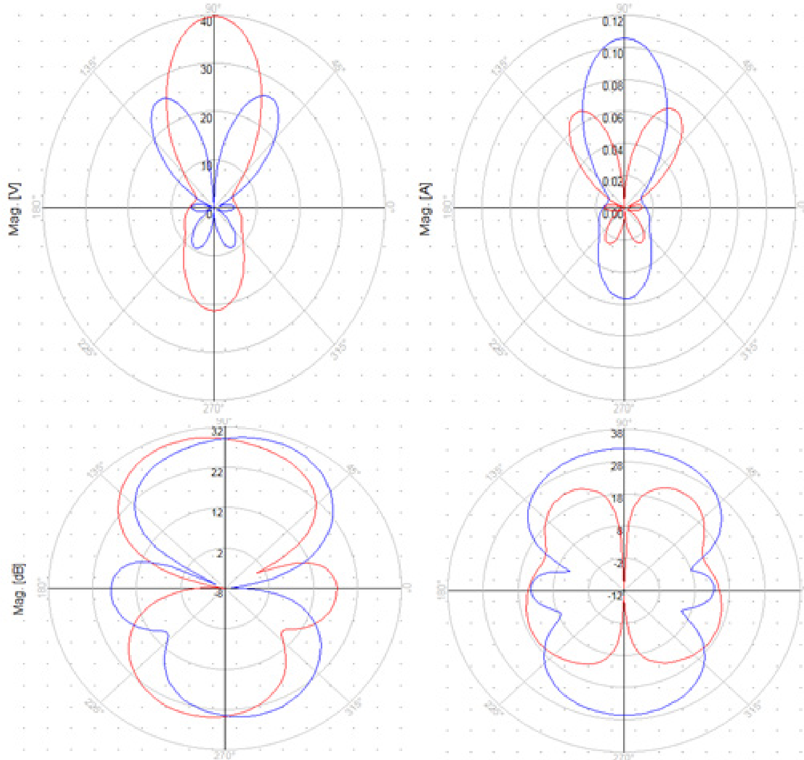

Figure 8. E-plane and H-plane polarization, circular polarization and linear polarization for 2nd itereation at 3.52 GHz.

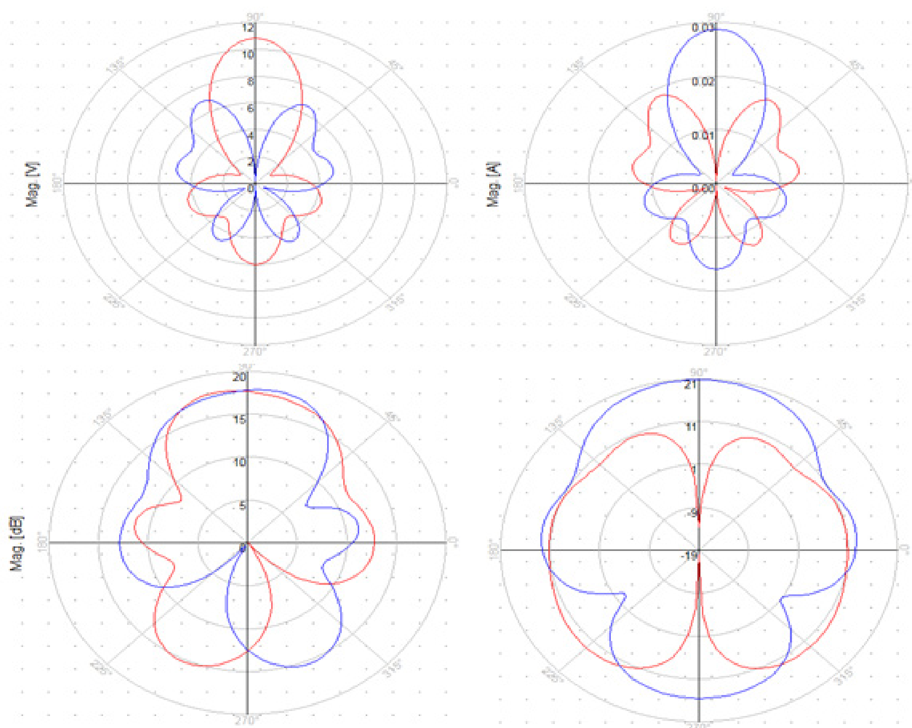

Figure 9. E-plane and H-plane polarization, circular polarization and linear polarization for 3rd itereation at 3.5 GHz.

3.3 Current-distribution

The radiator plane current distribution of the proposed multi-fractal self-similarity antenna is shown in Figure 10. It can be observed, which has more current distributions of a rectangular patch and, therefore, improving the radiation efficiency of the proposed antenna.

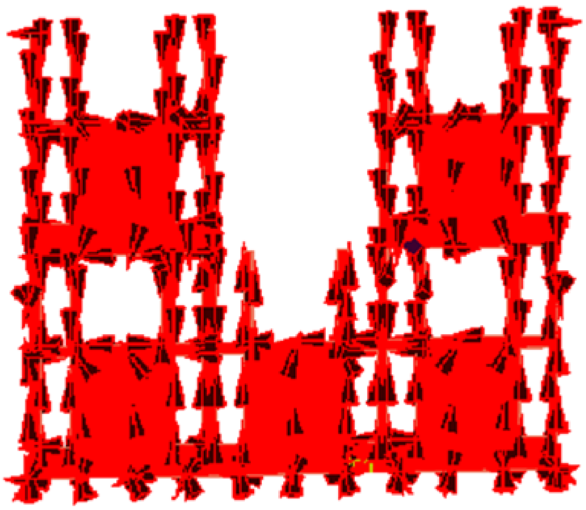

Figure 10. Current Distributions of an antenna for 3rd iteration.

4. Conclusion

The low profile, the compact and low cost multi-fractal self-affine fractal antenna is simulated. The simulated results in terms of return loss, directivity, gain evaluated. The simulated current distribution of the proposed antenna shows a good correlation between radiating elements and resonant frequencies. It possesses better return loss characteristics (S11) at 3.5 GHz and bandwidth. It has -22 dB return loss for 3.5 GHz, hence the multi-fractal self-similarity antenna can use for WiMAX applications since the proposed antenna exhibits the broadband width, better radiation characteristics.

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