# A Compact Fractal Monopole Antenna with Defected Ground Structure for Wideband Communication

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***Abstract*** **─** A compact fractal monopole antenna with defected ground structure has been investigated in this paper. A wide bandwidth of 3.13 GHz (3.42 GHz to 6.55 GHz) has been obtained, which covers the IEEE 802.11 WLAN bands (5.2 GHz and 5.8 GHz) and WiMAX bands (3.5 GHz and 5.5 GHz). The dimension of the structure is 14.50 X 27.25 mm$^2$ covering an area of only 395.125 mm$^2$. The realized antenna gain is ≥ 2 dBi at the frequencies of interest. The compactness of the proposed structure and the simplicity of design makes it easy to be fabricated and incorporated in devices suited for wireless communication purpose.

***Index Terms*** **─** Defected ground structure, fractal geometry, monopole antenna, wideband communication

## I. INTRODUCTION

With the advent of portable mobile devices, there is a huge need for compact, low-profile patch antennas for space conservation and also for wideband communication purpose. From literature survey, it has been found that though several wideband antennas have been proposed for wideband applications particularly for WLAN and WiMAX microwave frequency bands; there still exists an issue regarding compactness in shape and size and also in realized gain of the antennas. A dual band antenna with fractal based ground plane has been proposed in [1]. The dimension of the structure is almost equal to 104 X 30 mm$^2$. A perturbed Sierpinski carpet antenna with CPW feed for IEEE 802.11 a/b WLAN application has been presented in [2]. The dimension of the antenna is 45 X 67.8 mm$^2$. A microstrip line fed printed wide slot antenna has been investigated in [3]. The antenna dimension is 70 X 70 mm$^2$. A broadband circularly polarized Spidron fractal slot antenna has been presented in [4]. The dimension of the proposed structure is 40 X 40 mm$^2$. A wideband fractal antenna with combination of fractal geometries has been presented in [5] for WLAN and WiMAX applications. The dimension of the structure is 25 X 66 mm$^2$. Similar types of investigations have been studied in [6] and [7], but in each case there arises an issue regarding the compactness of the proposed antenna structure. In this article, a compact fractal monopole antenna with defected ground structure has been investigated. A wide bandwidth of 3.13 GHz (3.42 GHz to 6.55 GHz) has been obtained, which covers the IEEE 802.11 WLAN bands (5.2 GHz and 5.8 GHz) and WiMAX bands (3.5 GHz and 5.5 GHz). The dimension of the structure is 14.50 X 27.25 mm$^2$ covering an area of only 395.125 mm$^2$. The realized antenna gain at the frequencies of interest are 2.5 dBi, 3.5 dBi, 3.5 dBi and 3.6 dBi at 3.5 GHz, 5.2 GHz, 5.5 GHz and 5.8 GHz respectively.

## II. ANTENNA DESIGN

The objective of this work is to design a low-profile antenna, compact is shape and size with standard gain limits for wideband operations. The dimension of the proposed structure is 14.50 X 27.25 mm$^2$ covering an area of only 395.125 mm$^2$. Repeated square fractal geometry has been applied in design of the patch structure. The width of the feed line has been chosen to match 50 Ω impedance using (1) and (2).

For the proposed design, substrate dielectric constant, $\varepsilon_r = 4.3$, substrate height, $h = 1.5$ mm and width of feed line, $Fw = 3.0$ mm:

$$\varepsilon_{eff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2} \frac{1}{\sqrt{(1+12h/Fw)}}, \tag{1}$$

$$Z_o = \frac{120\pi}{\sqrt{\varepsilon eff}\left[\frac{Fw}{h} + 1.393 + 0.667 ln\left(\frac{Fw}{h} + 1.444\right)\right]}, \tag{2}$$

where $Zo$ is the characteristic impedance and $\varepsilon_{eff}$ is the effective dielectric constant of Substrate.

FR-4 substrate, which is commonly available in the market is used as the substrate for the proposed design.

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The thickness of the substrate is kept equal to 1.5 mm. The patch and the ground plane are built of 0.5 mm thick copper plates. The patch and the ground plane is composed of Copper (annealed). The ground plane is not continuous throughout the design. A portion of the ground plane has been etched from the top. Two L-shaped slots have been introduced in the ground plane along with an I-shaped slot in the middle. The dimension of these slots have been chosen after parametric optimization. This type of etched ground structure is known as Defected Ground Structure (DGS) in antenna engineering and research. Incorporation of DGS in antenna design has an effect on frequency response of the antenna, which has been discussed later. Repeated square structures have been used in design of the patch as shown in Fig. 1.

The proposed repeated square fractal carpet geometry used to design the patch structure (Fig. 1.). The proposed antenna has been shown in Fig. 2.

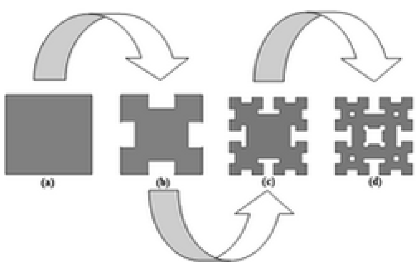


Fig. 1. Proposed fractal carpet geometry: (a) basic geometry, (b) $1^{st}$ iteration, (c) $2^{nd}$ iteration, and (d) $3^{rd}$ iteration.

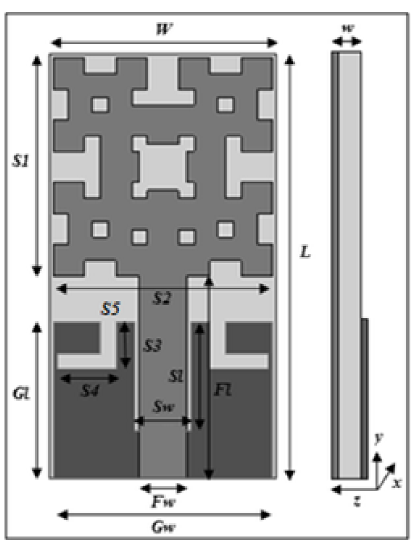


Fig. 2. Proposed fractal antenna with side view.

Genetic Algorithm (GA) has been applied for parametric optimization. The detailed parameter dimensions are provided in Table 1. It may be noted that, the overall area of proposed structure is only $W$ X $L$ = 14.50 X 27.25 = 395.125 mm$^2$.

Table 1: Parameter dimensions (in mm)

| Parameter | Dimension | Parameter | Dimension |
|---|---|---|---|
| *W* | 14.50 | *Fw* | 03.00 |
| *L* | 27.25 | *Fl* | 13.00 |
| *S1* | 14.00 | *Gw* | 14.00 |
| *S2* | 14.00 | *Gl* | 10.00 |
| *S3* | 03.00 | *Sw* | 03.50 |
| *S4* | 03.75 | *Sl* | 07.00 |
| *S5* | 01.00 | *w* | 02.50 |

## III. RESULTS AND DISCUSSION

The proposed antenna structure with different patch shapes in successive iterative stages has been simulated and the results have been displayed in Fig. 3.

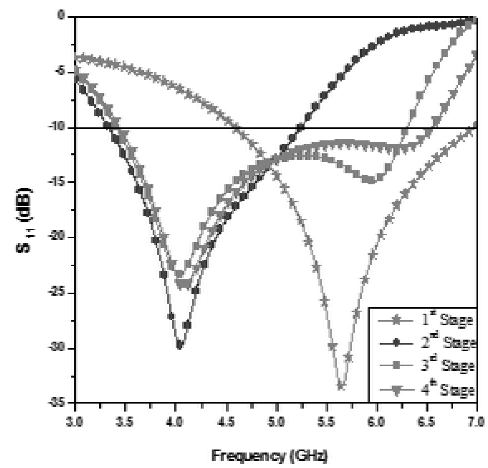


Fig. 3. Return loss of antenna at various iterative stages.

From Fig. 3, it has been observed that the resonant frequency near 5.6 GHz in the $1^{st}$ stage gradually shifts towards the left near 4.0 GHz in the $2^{nd}$ iterative stage with gradual interment in bandwidth in the successive stages. A maximum bandwidth of 3.13 GHz (3.42 GHz to 6.55 GHz) has been obtained, which covers the IEEE 802.11 WLAN bands (5.2 GHz and 5.8 GHz) and WiMAX bands (3.5 GHz and 5.5 GHz) in the $4^{th}$ or final iterative stage.

Defected Ground Structures (DGS) are used now-a-days by antenna researchers to improve the frequency response characteristics of the antenna. A fraction of the propagating energy is stored by the ground plane, which has an effect on overall frequency response of the antenna structure. Figure 4 shows the $S_{11}$ vs. frequency plot for the antenna with and without the presence of DGS.

The proposed structure has been fabricated as shown in Fig. 5. The front view (Fig. 5 (a)) shows the fractal square patch and the 50 Ω feed line. The rear view (Fig.

5 (b)) shows the DGS ground plane. The dimension of the structure is comparable to a "1 Rupee Indian Coin". The dimension of the structure is 14.50 X 27.25 $mm^2$ covering an area of only 395.125 $mm^2$. Due to its low-profile structure, the proposed antenna has a very small coverage area and can easily be integrated in compact and low-profile devices supporting wideband operations.

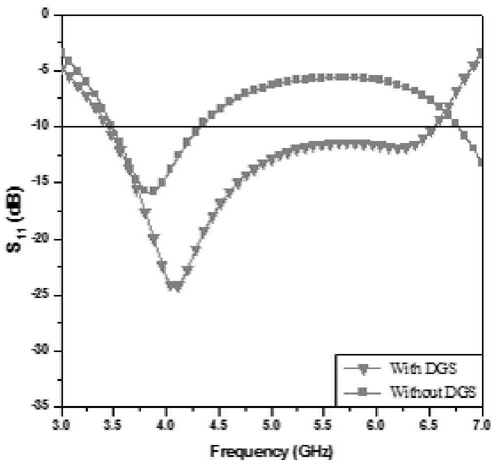


Fig. 4. Return loss of antenna with and without DGS.

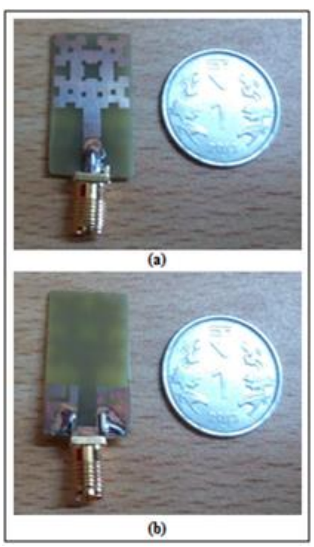


Fig. 5. Fabricated prototype: (a) front view and (b) rear view.

Simulated and measured return losses have been shown in Fig. 6. The results bear a good agreement. Slight discrepancy in result may be due to the effect of soldering. 2D polar plot of the antenna has been shown in Fig. 7. Isolation level between co and cross-polarizations greater than 100 dB has been maintained with almost omni-directional H-plane patterns (Fig. 7.). The simulated and measured antenna gains are plotted in Fig. 8. The realized antenna gain (measured) at the frequencies of interest are 2.5 dBi, 3.5 dBi, 3.5 dBi and 3.6 dBi at 3.5 GHz, 5.2 GHz, 5.5 GHz and 5.8 GHz respectively; which is quite decent for wideband operation. Figure 9 shows the antenna surface current distribution pattern. It can be observed from that, the current originates from the feed and distributes itself uniformly at the edges of the patch. The resonant modes thereby generated, come closer resulting in a wider bandwidth.

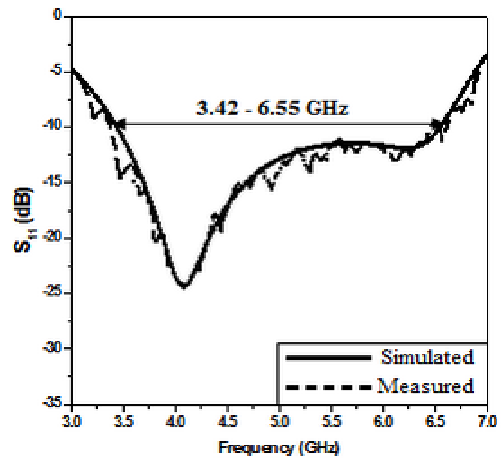


Fig. 6. Simulated and measured return losses.

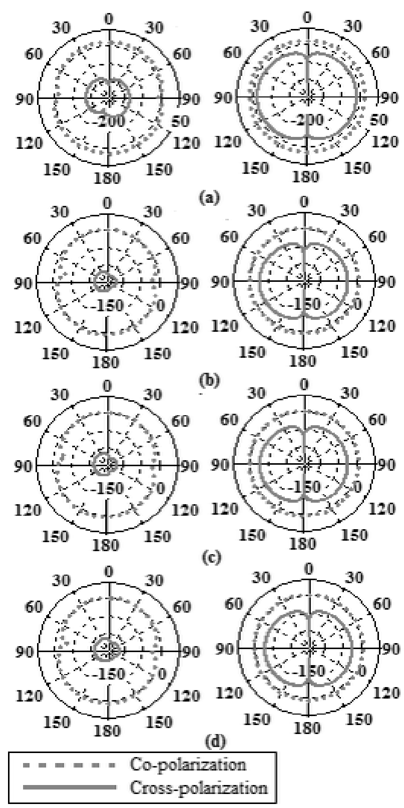


Fig. 7. 2D polar plot of E-plane (left) and H-plane (right) at: (a) 3.5 GHz, (b) 5.2 GHz, (c) 5.5 GHz, and (d) 5.8 GHz.

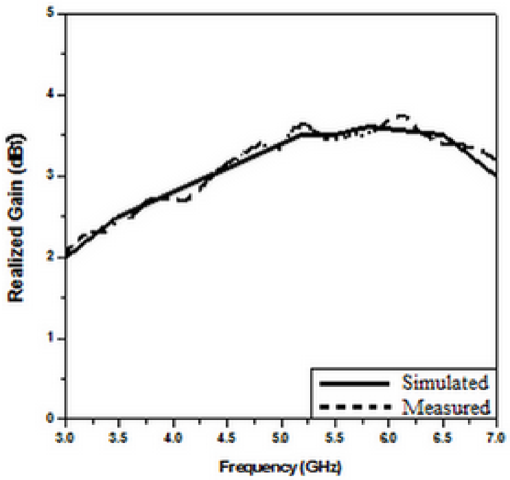


Fig. 8. Realized gain of proposed antenna.

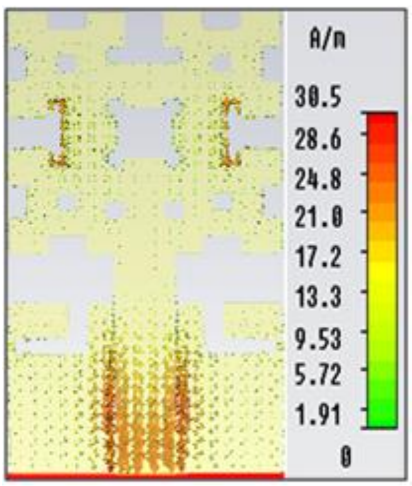


Fig. 9. Antenna surface current distribution pattern.

## IV. CONCLUSION

A compact fractal monopole antenna with defected ground structure has been investigated in this paper. A wide bandwidth of 3.13 GHz (3.42 GHz to 6.55 GHz) has been obtained, which covers the IEEE 802.11 WLAN bands (5.2 GHz and 5.8 GHz) and WiMAX bands (3.5 GHz and 5.5 GHz). The dimension of the structure is 14.50 X 27.25 mm$^2$ covering an area of only 395.125 mm$^2$, which is smaller compared to other compact wideband antennas available in existing literatures. The compactness of the proposed structure with standard gain levels makes the antenna a suitable candidate for wideband communication purpose.

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