Wide-Slot Fractal Antenna Design with Improved Bandwidth

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***Abstract*—The present paper focuses on the bandwidth enhancement of a microstrip patch antenna by introducing a fractal shaped slot. By increasing the number iterations, it is possible to increase the bandwidth of the antenna. Simulated results indicate that the impedance bandwidth, defined by -10 dB return-loss, is about 3.5 times higher than that of a conventional microstrip-line-fed printed wide-slot antenna. Proposed design also achieves gain of 4 dB over a frequency range of 2 to 6 GHz.**

Keywords- Fractal antenna, Iteration Factor (IF), Iteration Order (IO)

I. Introduction

By applying fractal geometry in microstrip antennas, many advantages can be achieved. These include: small size, multi-band operation, wide bandwidth and low mutual coupling in case of array [1]-[11]. In recent years several fractal geometries have been designed for various antenna applications. Some of these geometries have been particularly useful in reducing the size of the antenna, a few designs show wideband characteristics, while other designs aim at incorporating multiband characteristics. The fractal antennas are low profile antennas with moderate gain that can be made operative at multiple frequency bands, and hence are multifunctional. Many fractal antenna configurations have been reported in recent years [1]-[11]. Fractal geometries have two common properties, space-filling and self-similarity [1]. Using the self similarity properties, a fractal antenna can be designed to receive and transmit over a wide range of frequencies while space-filling properties of a fractal antenna make it possible to reduce antenna size, reduce radar cross-section and reduce mutual coupling [1]-[11].

In the recent years, the microstrip-line-fed printed wide-slot antennas have received much attention because of their wider operating bandwidth [8]-[11]. In the present paper, three different microstrip fractal geometries have been discussed. It is important to note that, the proposed designs have better impedance bandwidth performance as compared to the designs discussed in [11]. The simulated results obtained for all the fractal iterations have been compared with microstrip-line-fed printed wide-slot antenna with a rectangle slot. The fractal geometries described in the paper are working over a bandwidth of 2.3 GHz to 3.1 GHz. All the fractal designs are discussed in Section II, while the simulated results are summarized in Section III.

II. Fractal Antenna Geometry

Fractal geometry can be created by iterative process, which tends to increase the electrical length of the antenna. The basic rectangular slot microstrip-line-fed printed wide-slot antenna called as a starting structure/initiator (here onwards referred as design-1) is shown in Fig. 1. The patch has been designed on FR4 substrate with relative permittivity (ε_r) of 4.5 and thickness (h) of 1.5 mm. As shown in Fig. 1, the dimension of the slot is 30 mm x 30 mm. The printed wide slot is etched on a grounded substrate and the original wide slot is chosen to be a square in order to excite two modes with close resonant frequencies. The starting structure defines the general shape of the structure with iteration order of zero. The ground plan is chosen to be square with a side length of 75 mm. For designing the antenna with a required resonant frequency, the dimensions of the square slot can approximately be determined using the formula:

$$f = \frac{c}{2L\sqrt{\varepsilon_{re}}} \qquad (1)$$

In (1), c is the speed of light in vacuum, ε_{re} is the effective relative permittivity and L is the length of the square slot. For design simplicity, the width of the tuning stub is chosen to be the same as that of the 50 Ω microstrip line.

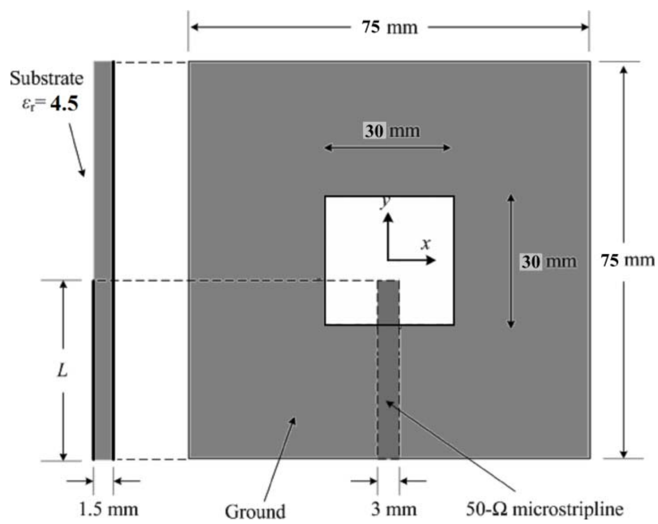

Fig. 1 Geometry and dimensions of the proposed microstrip-line-fed printed wide-slot antenna with rectangle slot (Design-1).

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Simulated results show that the conventional square slot antenna needs optimization of the tuning-stub length of L = 35.5 mm to achieve the optimal performance, while the fractal-shaped square slot antennas requires tuning stub length of L = 37.5 mm. The basic rectangular slot microstrip-line-fed printed wide-slot antennas after the first and the second iterations are shown in Fig. 2 and Fig. 3, respectively. As shown in Fig. 2, the dimension of the slot after the first iteration is 7 mm x 7 mm, whereas, the dimension of the slot after the second iteration is 1.75 mm x 1.75 mm.

III. Results and Discussion

All the three designs, shown in Fig. 1, 2 and 3 have been simulated by considering the finite ground plane and the dimension of the ground plane was kept 75 mm x 75 mm.

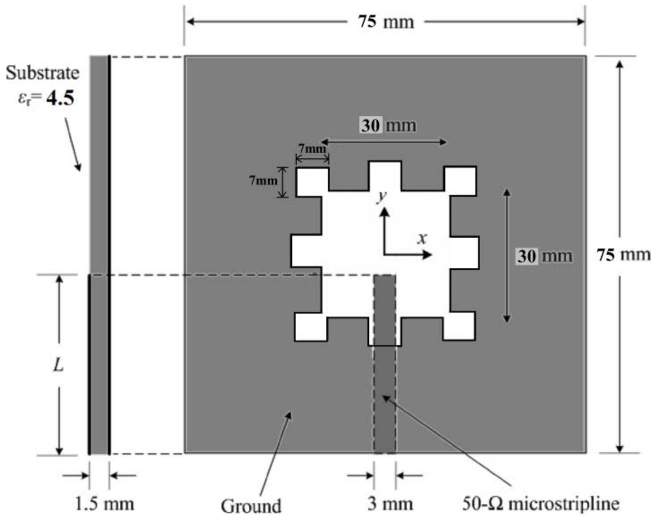

Fig. 2 Microstrip-line-fed printed wide-slot antenna after first iteration (Design-2).

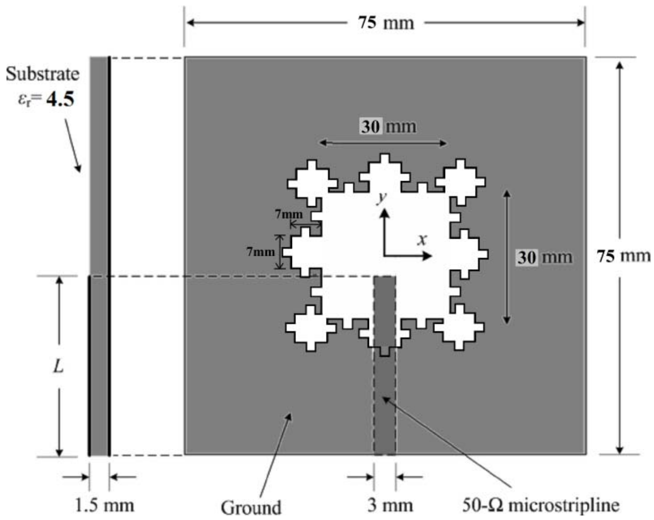

Fig. 3 Microstrip-line-fed printed wide-slot antenna after second iteration (Design-3).

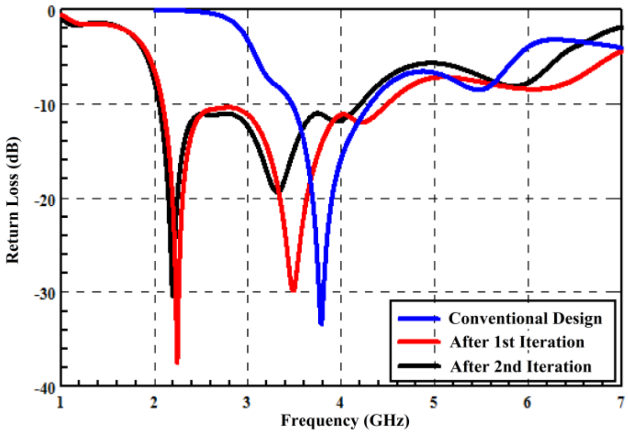

Fig. 4 Simulated return-loss performance of microstrip-line-fed printed wide-slot antenna.

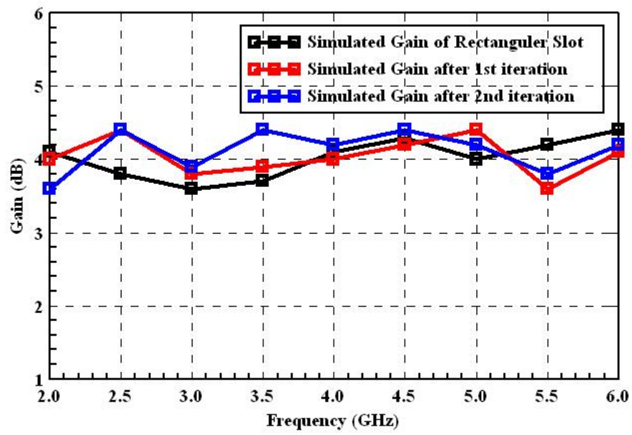

Fig. 5 Simulated Gain (dB) performance of all the three designs.

The simulated return-loss plot is as shown in the Fig. 4 for all the three designs. The return-loss plot of design-1 shows an impedance bandwidth of 0.76 GHz (3.43 - 4.19 GHz), which corresponds to 18.33% of the centre frequency. The return-loss plot of design-2 shows an impedance bandwidth of 2.41 GHz (2.09 - 4.5 GHz), which corresponds to 73.14% of the centre frequency. Similarly, the return-loss plot of design-3 shows an impedance bandwidth of 2.18 GHz (2.05 - 4.23 GHz), which is equivalent to 69.42% of the centre frequency. Fig. 5 depicts the simulated peak antenna gain within the operating bandwidth of the proposed antennas. The simulated antenna gain levels obtained are about 3.9-4.2 dB in the range of 2-6 GHz.

From Table 1, it is evident that the proposed fractal antenna achieves maximum bandwidth of 73.14% and 69.42%, which is quite significant. It is also to be noticed that, the gain of the fractal antenna (Design-2 and Design-3) is better than the basic antenna structure (Design-1).

Table 1 Important antenna parameters

Type	Operating Frequency (GHz)	Gain (dB)	*BW
Basic Antenna (Design-1)	3.43-4.19	3.95	18.33%
After first iteration (Design-2)	2.09-4.5	4.15	73.14%
After second iteration (Design-3)	2.05-4.23	4.05	69.42%

*at -10 dB return-loss

IV. CONCLUSION

In the present paper, the designs of a microstrip-line-fed printed wide-slot fractal antenna operating on wide bandwidth have been discussed. It has been observed that fractal antenna geometry significantly improves the antenna bandwidth, while maintaining the reasonable gain. The antenna is easy to fabricate and can find many practical applications.

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