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Design of UWB Monopole Antenna with Fractal DGS

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Abstract - *A UWB monopole antenna embedded with plus shape Fractal DGS is proposed in this paper. To enhance the bandwidth of the UWB monopole antenna, plus shape DGS embedded technology has been proposed. After embedding 1st and 2nd iteration of the plus shape DGS, bandwidth enhancement of 93.3% (3.16 - 8.38 GHz) and 117% achieved respectively. The comparison of the gain of the monopole antenna, without DGS and with 1st and 2nd iterations of the DGS is demonstrated. The effects of the embedding of the Fractal DGS on the radiation efficiency of the monopole UWB antenna, without DGS and with different iterations of the Fractal DGS are discussed.*

Keywords- *UWB Antenna; fractal; DGS; Monopole Antenna;*

I. INTRODUCTION

After the declaration of Ultra Wideband (UWB) for unlicensed applications by FCC [1], [2] (Federal Communication Commission) in 1998 for 3.1- 10.6 GHz frequency band, it receives much attraction by the researchers, scientists for research and development. UWB systems transmit and receive information systems by many narrow pulses with extremely low energy levels with low VSWR over a wide frequency band. UWB antenna is an important component in wireless communication systems, which can provide attractive features such as high radiation efficiency, low dissipation power, high transmission rate, compact profile, etc. [3].

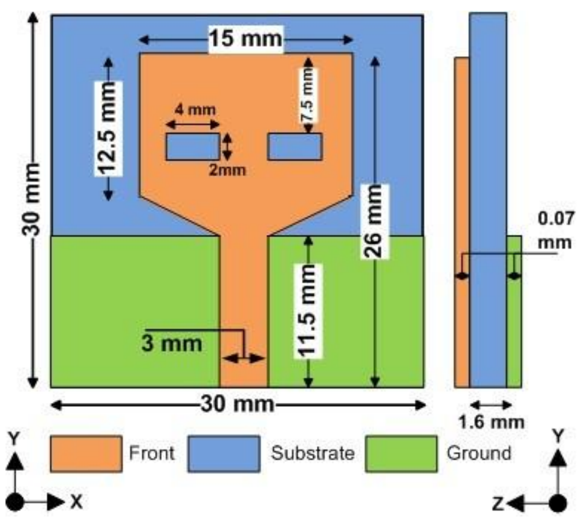

Fig. 1: Top and side views of the 0^{th} iteration of the UWB monopole antenna.

Several UWB monopole antennas have been reported in open literature. These designs have various monopole structures such as Cylindrical Conformal [4] Octagonal-Shaped [5], rectangular [6], moon shaped [7], holly-leaf-shaped [8], semi- circle [9], triangular [10], two steps tapered [11], and circular disc [12], etc. monopole antennas.To enhance the bandwidth of the UWB antenna various techniques such as using Defected ground structure (DGS) [13], stub loading [14], slot embedding [15], EBG structures [16], etc. In DGS technique, a specific shape of the copper has been etched from the ground layer of the antenna, which introduce the lumped equivalent capacitance and inductance and that is responsible for impedance matching [17]–[21]. Thus, by embedding DGS the bandwidth enhancement has been realized. This technique is simple and fabrication is also less complex as compared to the other techniques. Recently using the fractal geometry, design of advanced antennas have been reported [22], [23].

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By the combination of fractal geometry and DGS [20], the enhancement of equivalent electrical length can be achieved, which results the enhanced impedance matching. Thus, the more bandwidth enhancement can be obtained as compared to traditional DGS.

In this paper, the application of the "Fractal DGS" has been shown in a design of the monopole UWB antenna. Section II demonstrates the antenna geometry and design dimensions of the antenna as well as Fractal geometry. The discussion of the simulated results is given in section III. The conclusion of the proposed technique of bandwidth enhancement and future scope of this work are given in section IV.

II. ANTENNA GEOMETRY AND OPERATIONAL MECHANISM

A. Proposed Antenna composition

Fig. 1 exhibits the configuration of the proposed UWB monopole antenna. The inexpensive FR4 material (thickness (h) = 1.5748 mm, dielectric constant (εr) = 4.4, loss tangent ($tan\delta$) = 0.0025) of size $a \times a = 30 \times 30\ mm^2$ was used as substrates. Two rectangular slots are embedded on radiating element with dimensions of $4 \times 2\ mm^2$ to enhance the impedance matching. The antenna design was simulated and optimized using CST Microwave studio V. 16 simulator [24].

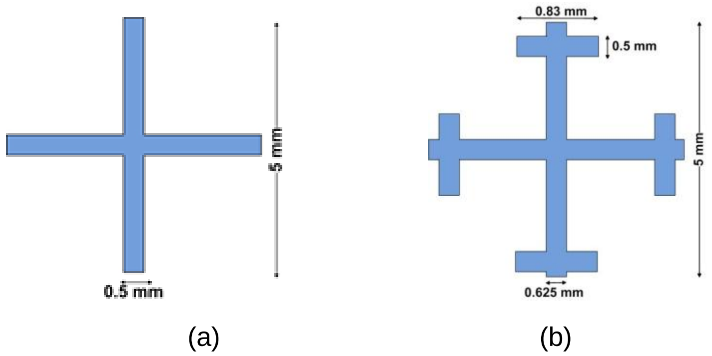
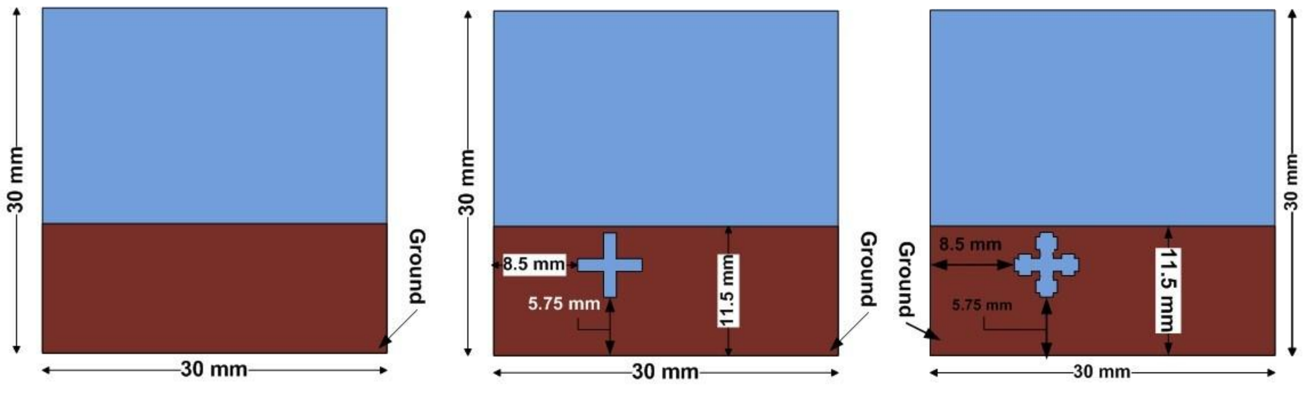


Fig. 2: Design dimensions of the iterations: (enlarge view) (a) 1st iteration of the plus shape fractal DGS (b) 2nd iteration of the plus shape fractal DGS.



(a) 0^{th} iteration (b) 1^{st} iteration (c) Proposed 2^{nd} iteration

Fig. 3: Design geometry of back side of the monopole antenna embedded with different iterations of fractal DGS.

B. Design of Fractal DGS

The generation procedure of design of plus shape fractal DGS is shown in Fig. 2.

Step:1 Select shape of the DGS, which add equivalent capacitance and inductor such that maximum impedance matching can be achieved. Here, plus shape DGS has been chosen.

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Step:2 Optimize the dimensions of the DGS, (length and width, etc.) such that maximum enhancement of the bandwidth can be achieved. Consider this as the first iteration of the DGS.

Step:3 Optimize the location of the DGS by parametric sweep using the simulator.

Step:4 To enhance electrical length, add second iteration and optimize its design dimensions.

III. RESULTS AND DISCUSSIONS

The antenna has been simulated and optimized with CST Microwave Studio V. 2016. Fig. 4 shows the comparison of the return loss characteristics of the UWB monopole antenna without DGS and with all iterations of the fractal DGS. It is seen that without embedded of the DGS, bandwidth of 2.7 GHz (3-5.7 GHz) is achieved. After embedding 1^{st} and 2^{nd} iteration of the plus shape DGS, bandwidth enhancement of 93.3% (3.16 - 8.38 GHz) and 117% achieved respectively. The comparison of the gain of the monopole antenna without DGS and with 1^{st} and 2^{nd} iterations of the DGS is shown in Fig.5. The disadvantage of the DGS is that it radiates backside, so it reduces the front to back radiation ratio and which leads to decrement in the gain. From the result shown in Fig. 5, it is concluded that, at a frequency of 7.5 GHz, the gain of the antenna reduced from 4.61 dB to 3.97 dB (i.e. 13.89%) and 3.62 dB (i.e. 21.48%) with embedding of the 1^{st} and 2^{nd} iterations of the DGS respectively.

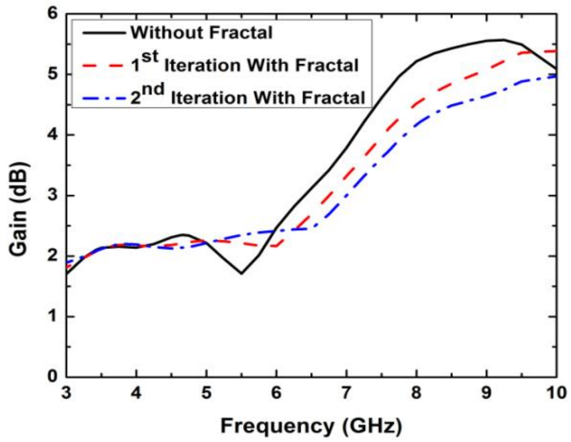

Fig. 4: Comparison of the S_{11} characteristics of the antennas (without DGS and with different iterations of the Fractal DGS).

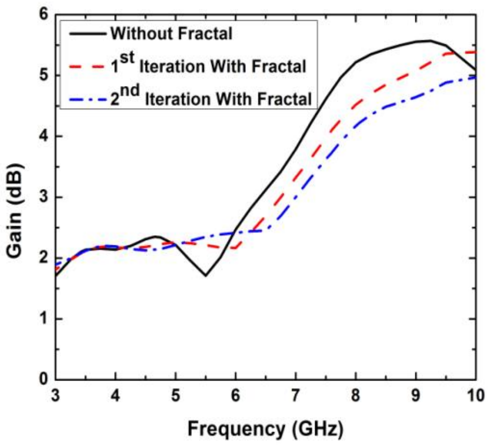

Fig. 5: Comparison of the gain of the antennas (without DGS and with different iterations of the Fractal DGS).

Fig. 6 shows simulated radiation polar plot (E and H plane) of the proposed 2^{nd} iteration fractal DGS monopole antenna at 8.02 GHz. The dipole type radiation is achieved in E plane. It is seen that in E plane, the main lobe of 1.95 dB obtained at 0° angle with 3 dB angular width of 94°. In H plane, the main lobe of 2.4 dB obtained at 13° angle with 3 dB angular width of 69.7°

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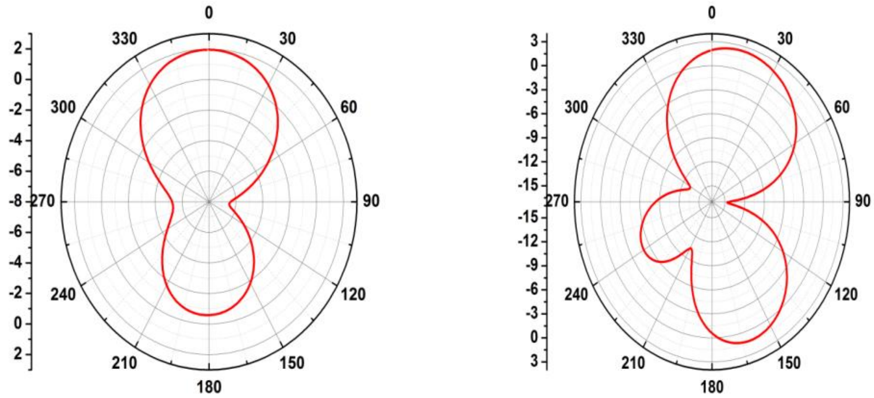

(a) E Plane (b) H Plane

Fig. 6: Polar plot of the 2nd iteration of the UWB monopole antenna at 8.02 GHz.

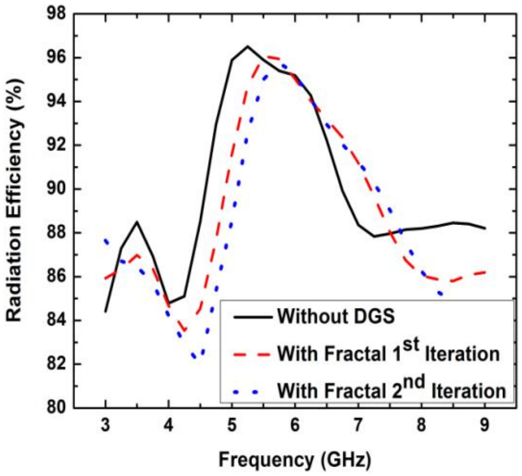

Fig. 7: Comparison of simulated radiation efficiency of the antenna (without DGS and with different iterations of the Fractal DGS).

The effect of Fractal DGS on the radiation efficiency of the antenna is shown in Fig. 7. As Fractal DGS radiates back side, side lobe increases, which the gain and radiation efficiency of the antenna between 4.5 to 5.5 GHz frequency. Between 5.5 GHz to 7.5GHz frequency, the Fractal DGS act as a bandstop filter for surface waves and hence, it block surface waves, which are undesirable and thus radiation efficiency increases.

(b) CONCLUSION

A single feed microstrip line coupled UWB monopole antenna embedded with plus shape 2nd iteration fractal geometry has been proposed for enhancement of the bandwidth of the antenna. The DGS plays a major role for impedance matching by adding equivalent capacitance and inductance and hence enhancement of the bandwidth can be realized. The Fractal geometry enhances this effect and more enhancement of the bandwidth can be achieved. The integration of other specific shape of the fractal defected ground structure, metamaterial, reactive impedance surface for the performance enhancement of the antenna, and to enhance the gain of the antenna, the use of partially reflective surfaces may be the future scope of this work.

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