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New Antenna with Fractal Shaped DGS for Emergency Management Applications

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Abstract— An analysis and design of a novel planar antenna in corporation with fractal shaped defected ground structure (DGS) for emergency management has been presented in this paper. The conventional ground plane can be replaced by a Fractal DGS ground plane to get miniaturization and better resonating characteristics. Particle swarm optimization (PSO) has been used to identify the geometrical descriptors of the structure. The analyses from simulations revealed the effectiveness of varying scale factor that contributes 68% size reduction of ground plane.

Keywords— Antenna, DGS, Fractal, Ground planes, PSO,

I. INTRODUCTION

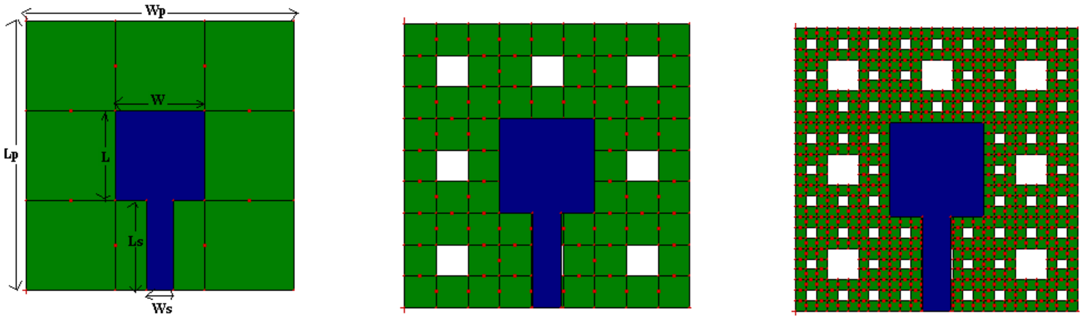
Fractal geometries have been implemented in several science and technologies, such as antennas and radiators [1]. Generally, the utilization of fractal geometries in antennas tends to miniaturize their physical sizes and produce multiband response in their resonating characteristics [2-4]. The generations of fractal configurations have an iterative procedure; they can achieve long paths and high surface areas in a limited volume [5, 6]. However, like conventional microstrip antennas, the bandwidth of microstrip fractal antenna is small. In [7] authors have proposed a new microstrip fractal antenna for high impedance matching and bandwidth. Another method to improve the antenna performance is by using the Defected Ground structure (DGS) on microstrip antenna [8, 9]. DGS is realized by etching off a simple shape defect from the ground plane, depending on the shape and dimensions of the defect, the shielded current distribution in the ground plane is disturbed resulting a controlled excitation and propagation of the electromagnetic waves through the substrate layer [10-12]. Any defect in the ground plane can give rise to increase in effective capacitance and inductance. Defected ground structures, either in a single configuration or periodic form that is frequently referred to as a photonic band gap (PBG) show slow-wave effects leading to considerable size realization [13]. By combining with a defective ground plane, the bandwidth is augmented and the resonant frequency is lowered simultaneously [14, 15]. In this paper, fractal DGS antenna is aimed at proposing a multiband fractal antenna suitable for wireless communication systems devoted to emergency management. A fundamental element of an emergency system is a reliable communication infrastructure allowing rescue operators to be connected and able to support the collection and the elaboration of data coming from monitoring devices distributed in the area of the disaster [17]. The antenna is synthesized with an iterative procedure based on the PSO to identify a structure exhibiting a good impedance matching in the required frequency bands with smaller dimensions.

II. ANTENNA GEOMETRY

Fig. 1 shows the first three iterations of the fractal geometry (sierpinski carpet) used to form the defects in the ground plane. Fractal antenna of different iteration orders can be designed by dropping same structured elements on the patch, whose scale factor is 1/3 without changing the physical parameters of the patch. In this paper only the first, second and third iterations are considered since high order iterations do not make significant effect on antenna properties. The antenna is designed on FR4 substrate of thickness, h = 1.6 mm with dielectric constant, $\epsilon_r = 4.4$. A 50Ω transmission line which consists of a single strip having width, W_s of 3 mm is used to feed the antenna. The patch size is characterized by the length L, width W and thickness, h. The length of the designed antenna, L = 10 mm and width, W = 10 mm, Length of the ground plane, $L_p = 30$ mm and width of the ground plane, $W_p = 30$ mm.

A. PSO Implementation

In PSO each particle is treated as a point in an N dimensional space which adjusts its "flying" according to its own flying experience as well as the flying experience of other particles. Each particle maintains track of its coordinates in the solution space which are associated with the best solution that has achieved so far by that particle [16]. This best value is called personal best (Pbest). Another best value is the value obtained so far by any particle in the neighbourhood of that particle. This value is called global best (gbest). Each particle tries to change its position using the information of the current positions, the current velocities, the distance between the current position and the Pbest position, the distance between the current position and the gbest position [16]. The role of PSO optimization is to find the optimized scaling factor that defines the best proposed antenna for the desirable frequencies of operation. In the PSO loop, a swarm is initialized with population of random positions and velocities of antenna parameters with their lower and upper bounds in solution space.



(a) (b) (c)

Fig. 1 Geometry of the proposed antenna (a) first iteration (b) second iteration (c) Third iteration

The below given equation (1) is taken as a fitness function for PSO to find the designed parameter of the proposed structure:

$$\text{Fitness function} = (2.40- f_1)^2 + (4.95- f_2)^2 \qquad (1)$$

The particle position (S^N) and velocity (V^N) was changed according to the equations (2) and (3). The particles position can be modified according to the following equations [15]:

$$S^{N+1} = S^N + V^{N+1}, \qquad (2)$$
$$V^{N+1} = w\, V^N + c_1 r_1\, (Pbest - S^N) + c_2 r_2\, (gbest - S^N) \qquad (3)$$

III. RESULTS AND DISCUSSIONS

A. Resonating Characteristics of Proposed Geometry

The simulation tool adopted for evaluating the performance of the fractal antenna is IE3D software, which is based on the method of moment's technique. Fig. 2 shows the reflection coefficients for all the three iterations of proposed fractal antenna that is first, second and third iteration. As expected, it was demonstrated that with increase in the iterations, resonant frequency shifts towards lower side. The simulated resonant performance characteristics of the proposed antenna are reported in Table. 1. It can be noticed that there is an increase in the impedance bandwidth of the proposed structure when the iterations of the fractal antenna increases, with considerable improvement in the impedance matching of the antenna.

TABLE.1

RESONANT PERFORMANCE CHARACTERISTICS OF PROPOSED ANTENNA

No. of Iterations	Resonant Frequency (GHz)	Reflection Coefficient (dB)	Bandwidth (GHz)	Input Impedance (ohms)
First	5.29	-11.29	0.58	42.03-j25.66
	7.05	-22.89	0.98	61.50-j6.62
Second	5.25	-11.05	0.50	62.10-j0.64
	7.03	-19.32	0.77	41.56-j25.26
Third	1.95	-13.05	0.04	44.72+j2.93
	3.94	-11.89	0.68	51.64-j6.68
	5.25	-13.20	0.86	43.16-j9.69
	7.03	-20.61	0.95	59.81-j2.93

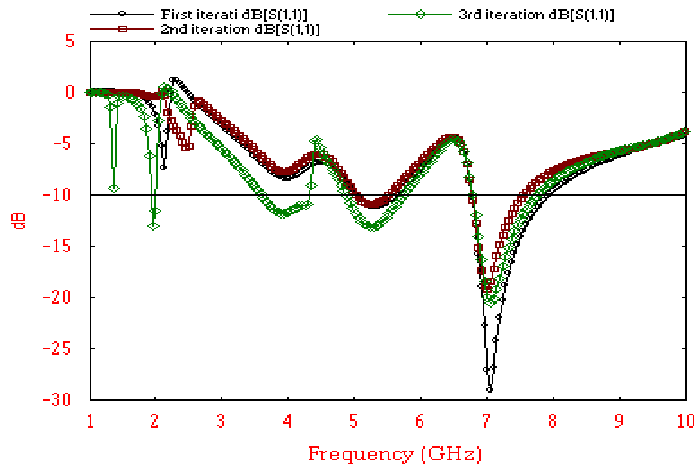


Fig. 2 Simulated s-parameters of all the three iterations

B. Optimization Results

In order to enable the operability in the frequency bands {2.41 GHz, 4.95 GHz}, while miniaturizing the radiating structure, the antenna has been required to exhibit a good impedance matching over the working frequencies .The PSO-based optimization procedure has been applied to identify the geometrical descriptors of DGS for required frequencies. To obtain a database from simulator for obtaining fitness function, the scaling factor of the DGS fractal has been varied. Using the data; the equations representing the relationship among different parameters of ground plane are generated by Curve-fitting method in MATLAB software. This relationship has been used to generate the fitness function of PSO to optimize the ground plane structure in order to obtain the required frequencies. From the presented results it is clear that the proposed antenna with defected ground plane is an efficient radiator and outperformed in terms of occupied PCB area, electrical size and bandwidth. Moreover the results after optimization illustrate that the for getting required working frequencies scaling factor of the proposed structure should be 1/6 as shown in Fig. 3 and this scaling factor provide 68% size reduction to ground plane. The optimized structure resonates at 2.41 GHz and 4.95 GHz with –16.1 and -14.71 dB reflection coefficient respectively, as given in Fig. 4.

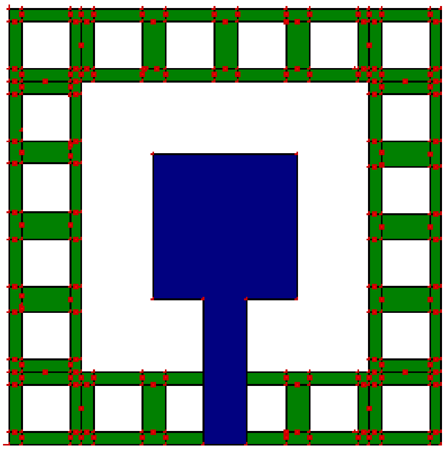


Fig. 3 Geometry of optimized antenna with scale factor, r=1/6

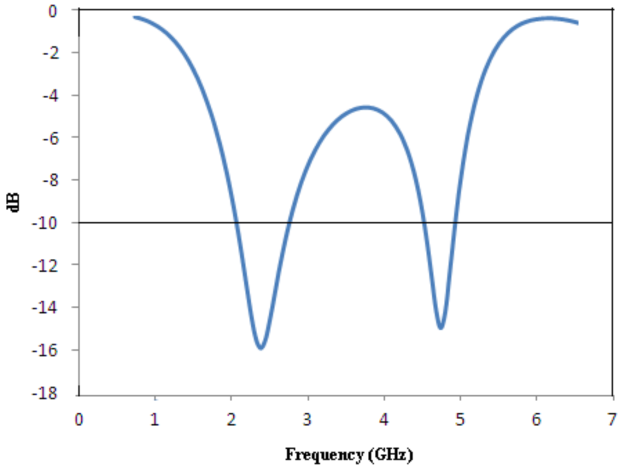
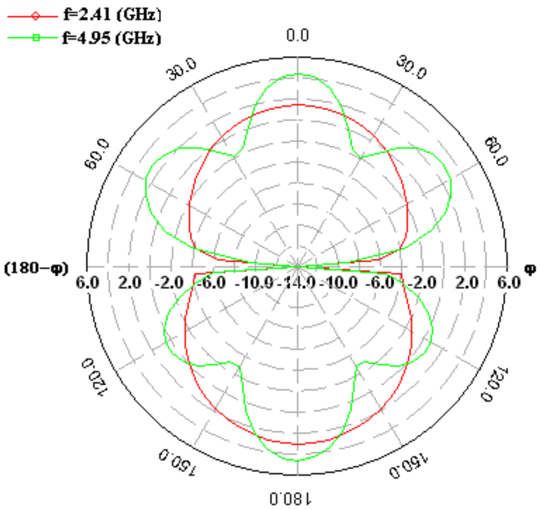


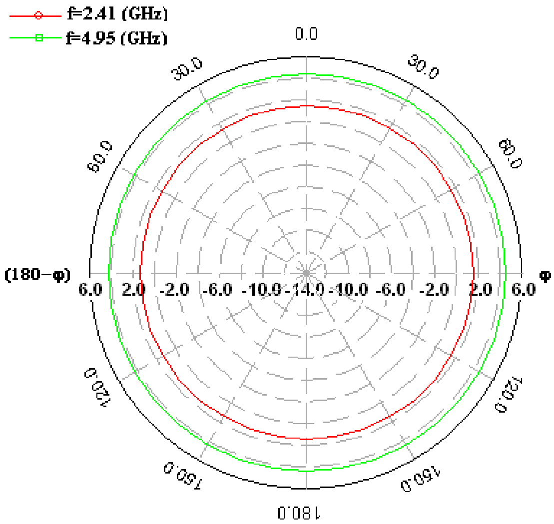
Fig. 4 Simulated s-parameters of optimized antenna

C. Radiation Patterns

Fig. 5 shows the simulated radiation patterns of the proposed structure. It is observed that the proposed antenna exhibits omnidirectional radiation patterns in the y-z plane (H-plane) and "8-shape" radiation patterns in the x-z plane (E-plane), similar to those of an ideal dipole antenna.



(a)



(b)

Fig. 5 Simulated radiation patterns of optimized antenna (a) E-plane (b) H-plane

IV. CONCLUSIONS

An approach for the electromagnetic analysis of self-similar fractal DGS structures is proposed in this paper. In order to assess the efficiency and the effectiveness of the proposed design, the performances of the PSO optimized antenna have been critically evaluated. The antenna enables operate at WLAN standards at 2.41 GHZ as well as in the Public Safety band at 4.95GHz. Moreover, a maximum size reduction of about 68% has been yielded in corporation of DGS. The design is highly feasible for compact, low cost and efficient solution for emergency management applications.

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