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A dual wideband Sierpinski carpet fractal-shaped planar monopole antenna with CPW feed

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A dual wideband design of Sierpinski carpet fractal-shaped planar monopole antenna with a coplanar waveguide (CPW) feed is proposed in this letter. Wide impedance bandwidth of 22% at lower resonance from 4.88 to 6.08 GHz and 41.7% at higher one, which ranges from 9.5 to 14.5 GHz, is obtained. Measured realized antenna gain is around 5 dBi at the lower band centered around 5.5 GHz and are around 4.5 dBi at the higher band. A fabricated prototype is developed with good agreement between simulation and measurement.

Keywords: Fractal antenna, Multiband antenna, Wideband antenna

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I. INTRODUCTION

The efficacy of incorporating fractal geometry in antenna design for multiband operation is well established by researchers for over a decade [1]. The fundamental concept regarding fractal geometry is given in [2]. Walker and James [3] introduced the concept of fractal volume antenna by layering patches comprising of three consecutive iterations of Sierpinski carpet geometry. They reported to have achieved improved impedance bandwidth. Song *et al.* [4] presented a stacked fractal antenna using a square Sierpinski carpet and a diamond Sierpinski carpet configuration with parallel feed arrangement. A good impedance bandwidth of 20:1 was achieved for S11 better than −5 dB and some intermittent mismatch for those better than −10 dB. Ban-Leong Ooi [5] reported a multilayered Sierpinski carpet microstrip patch antenna with electromagnetic band gap ground plane with improvement in input impedance bandwidth. It is desirous to keep the microstrip antenna substrate thickness small for reducing unwanted surface waves and moreover if the ground plane is brought to the same layer of the patch then it has greater compatibility with other electronic components for wireless applications. Simultaneously, it should also radiate and receive over a wide range of frequencies. This letter proposes a technique of achieving dual wide impedance bandwidth by incorporating a Sierpinski carpet planar monopole antenna with coplanar waveguide (CPW) feed.

A) Antenna design and optimization

The antenna is realized on a Taconic substrate of thickness 0.795 mm (1/32″), $\varepsilon_r = 2.2$, and dielectric loss tangent $\delta = 0.0009$. Initial study of the second iteration Sierpinski fractal monopole antenna shows that the side length L_a and the spacing between ground plane and patch h, as shown in Fig. 1(a), influence the resonant frequency and the impedance bandwidth. Therefore, the first design step was to optimize the dimensions that affect the resonant frequency and impedance bandwidth. These dimensions were optimized using an in-house developed real-coded genetic algorithm (RCGA)-based optimization code in MATLAB™ that uses heuristic crossover and non-uniform mutation [6]. In each run the antenna population that emerges is analyzed using CST Microwave Studio™ that is linked with the MATLAB™ based RCGA code. The RCGA parameters constitute a population size of 30 with probability of crossover and mutation depicted by P_c and P_m were chosen to be 0.70 and 0.02, respectively. It took 69 generations to converge to the optimal Sierpinski carpet patch having side length L_a of 21.07 mm and separation between ground plane and patch (h) of 1.73 mm. This is followed by subsequently removing squares of side length 7.02 mm ($L_a/3$) and 2.34 mm ($L_a/9$) as shown in Fig. 1(a) to realize the Sierpinski carpet shape of second iteration. The antenna designed and reported here is of second iteration. The width (W_g) of the ground planes 1 and 2 is 16 mm and length (L_g) is 14.50 mm. Spacing (g) between ground plane and central conductor is 1.15 mm. The CPW center strip is of length ($L_s = L_g + h$) 16.23 mm width (W_c) of 1.50 mm. The fabricated antenna was fed using an SMA connector as depicted in Fig. 1(b) showing the photograph of the fabricated prototype.

II. RESULTS AND DISCUSSION

Impedance characteristic of the designed antenna was predicted using finite integration technique based 3D electromagnetic field solver CST Microwave Studio. The fabricated prototype was tested using an HP 8722C vector network analyzer. The return loss obtained from simulation and

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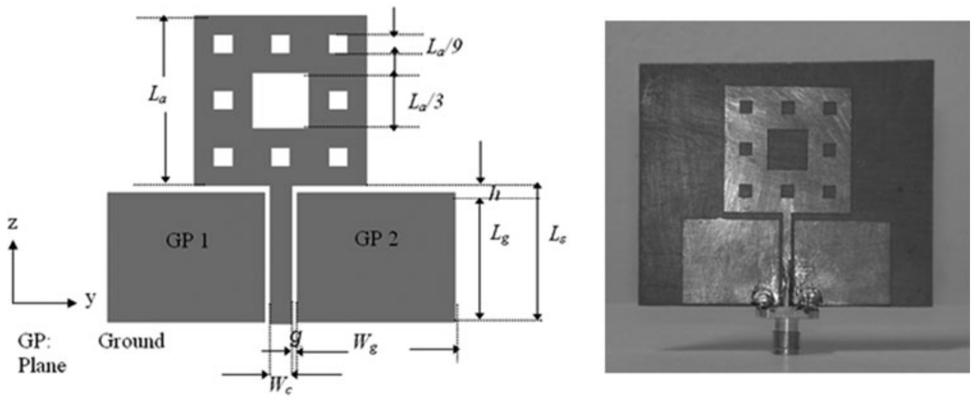


(a) (b)

Fig. 1. (a) Sierpinski carpet shaped planar monopole antenna with CPW feed. (b) Photograph of the fabricated prototype.

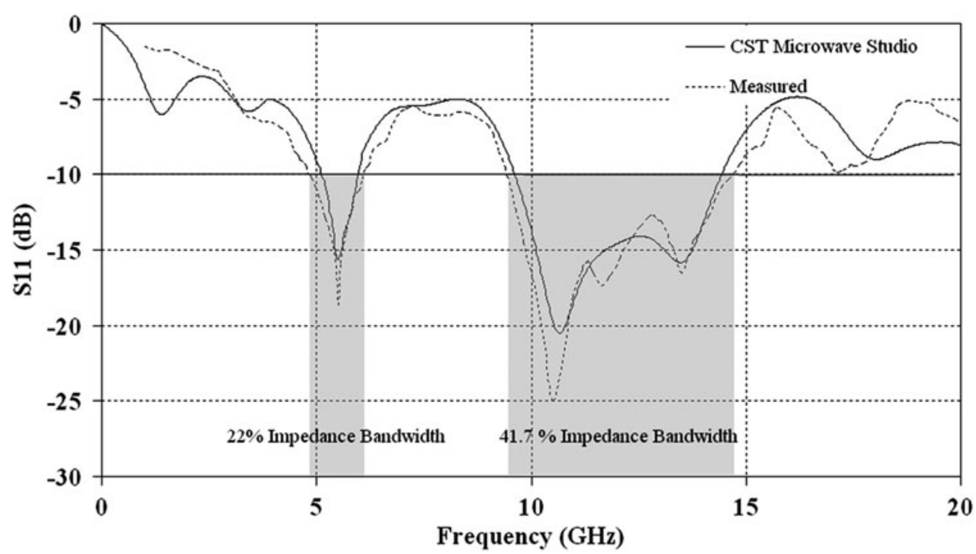
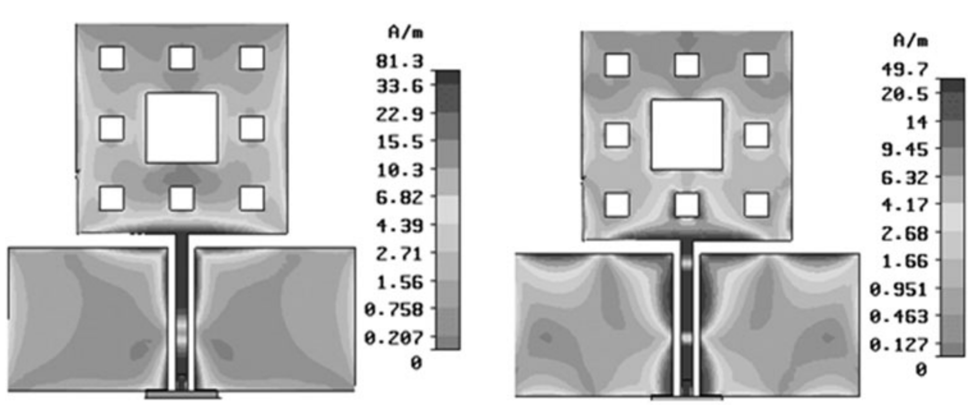


Fig. 2. Simulated and measured S11 (dB) characteristics of the antenna. Also shown is the impedance bandwidth at the two bands.



(a) (b)

Fig. 3. (a) Current distribution on the antenna at 5.5 GHz and (b) that at 12.5 GHz.

measurement is shown in Fig. 2. Simulated and measured results are in good agreement. Two distinct bands of frequencies are observed. The lower band that spans from 4.88 to 6.08 GHz can be used for WLAN and HIPERLAN. The other band of frequencies span from 9.5 to 14.5 GHz, which have possible application in military communication. It is observed from Fig. 2 that the benefit of using Sierpisnki carpet geometry results in merging of modes that results in

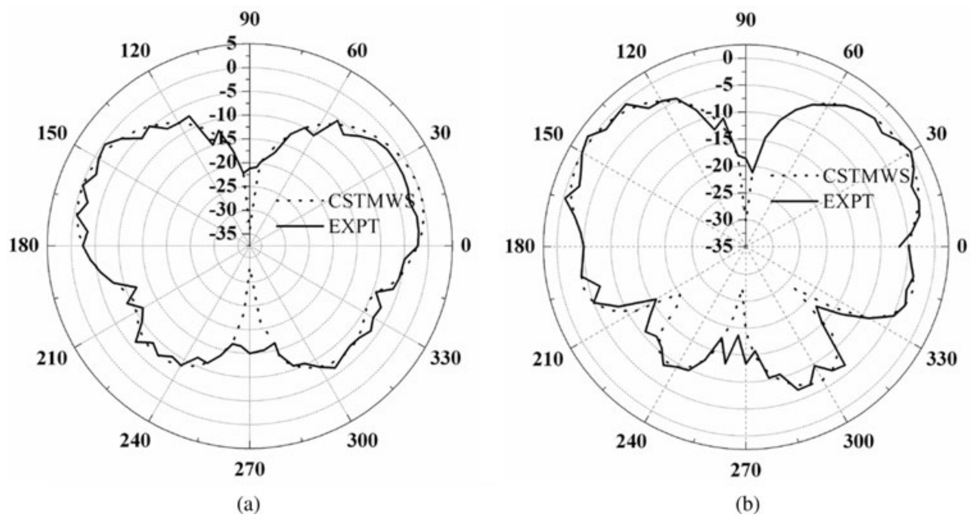


Fig. 4. Normalized elevation plane radiation patterns at frequencies (a) 5.5 GHz and (b) 12.5 GHz.

wide impedance bandwidth of about 22% at the lower band and 41.7% at the upper one, calculated for return loss values better than −10 dB.

Fractals are popular for their self-similar property, which can be put in the other way that things get repeated at different scales. It is also true when we consider the current distribution on fractal antenna. Current distribution at 5.5 and 12.5 GHz is shown in Figs 3(a) and 3(b), respectively. It is observed that interaction between surface currents on central strip of CPW and ground plane increase with increasing frequency. Such effect is also observed at the boundaries between ground plane and patch at the higher band. Thus current distribution is different at the two bands. The pluralism in current distribution manifests itself in slightly undulated pattern at 12.5 GHz as compared to the pattern at 5.5 GHz. Elevation plane patterns at 5.5 and 12.5 GHz are shown in Figs 4(a) and 4(b), respectively. Pattern characteristics remain similar within each band enabling it to be useful for the entire band of frequencies. Measured realized antenna gain remains around 5 dBi at the lower band centered around 5.5 GHz and are around 4.5dBi at the higher band. Due to monopole arrangement the pattern is azimuthally omnidirectional that makes it suitable for application in communication systems.

III. CONCLUSION

A Sierpinski carpet shaped planar monopole antenna with CPW feed has been proposed. Wide impedance bandwidth is obtained with 22% impedance bandwidth at lower band centered on 5.5 GHz and 41.7% impedance bandwidth at higher band with a mid-band frequency of 12.5 GHz. Measured resonance and radiation characteristics are in good agreement. It is observed that a direct consequence of difference in current distribution results in slightly undulated radiation pattern at the higher band. Within a band radiation characteristics remain similar.

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