Microstrip Bowtie Antenna with Patch and Ground-Plane Defects for WLAN Applications

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Abstract: - In this paper, a fractal-based bowtie microstrip antenna with defected ground structure for Wireless Local Area Network (WLAN) applications is proposed and studied. To achieve a dual band operation (i.e., 2.4 GHz and 5.2 GHz unlicensed bands), the initial design of the proposed antenna is based on the Sierpinsky gasket (triangular) fractal geometry. However, it is well known that, at the fundamental resonant frequency of the Sierpinsky gasket, the input impedance match is too poor. To overcome this problem, a circular split ring resonator (CSRR) is used as a defected ground structure to achieve efficient coupling at the fundamental resonant frequency. The proposed antenna is designed and analyzed using the finite element method. To this end, the High Frequency Structural Simulator (HFSS) of ANSYS is employed. The proposed fractal bowtie antenna with CSRR features low profile, high return losses, dual band operation, and moderate coupling bandwidth (around 4 %). Simulation results show that the antenna presents return losses of -19 dB and a coupling bandwidth of 120 MHz at the first resonant frequency (i.e. 2.4 GHz) , while the corresponding values at the second resonant frequency (i.e., 5.2 GHz) are -46 dB and 190 MHz, respectively. These results show that the proposed antenna is suitable for WLAN applications.

Key-Words: - Bow-tie antenna, defected ground structure, Sierpinsky triangular fractal geometry, wireless LAN

1 Introduction

Due to the increasing demand of wireless communication applications requiring high data rates, five generations (5G) technologies will be introduced in the near future developed to achieve superior performance over nowadays wireless and mobile communication systems [1]. In these scenarios, the development of high performance antennas will be of paramount importance.

In this research direction, microstrip antennas has been developed to achieve requirements such as miniaturization, low profile, compatibility with electronic circuits, easy design methodologies, among others [1]-[2]. The performance of microstrip antennas in terms of multiband and wideband behavior has been improved by the use of the fractal geometry [3]-[13]. Multi band antennas are required in cognitive radio networks; also wide band antennas are required in ultra wide band systems. A diversity of fractal geometries has been combined with the microstrip technologies, geometries such as the Sierpinsky gasket, Hilbert curve, snowshape of Knoch, hexagonal, “E”, “T” and “U” shapes, among others. Also, several fractal microstrip antennas with multiband behavior have been proposed for wireless local area network (WLAN) applications. Among these antennas, we found the bowtie microstrip one. The multi band behavior of the bowtie antenna has been improved by the use of the Sierpinsky gasket fractal geometry [9]-[11]. On the other hand the coupling efficiency of the bowtie antenna has been improved by the use of ground-plane defects [11]-[16]. In this paper we propose the use of both patch and ground-plane defects in the structure of the bowtie microstrip antenna to improve both dual-band behavior and return losses. In particular, patch defects are introduced by means of the Sierpinsky gasket geometry [6]-[8], while ground-plane defects are incorporated by means of the circular split ring resonator technique [14]-[16].

The rest of the paper is structures as follows. In Section 2, the methodology for the initial design of the proposed fractal bowtie antenna with circular ring resonator is presented. Section 3, presents the analysis of the simulation results of the proposed antenna. Finally, the conclusions are given in Section 4.

2 Initial Design of the Antenna

The conventional bowtie microstrip antenna is modified using the Sierpinsky triangle fractal geometry to stress its dual band behavior. Thus, the design methodology used for conventional gasket fractal antennas is employed. In this sense, the resonant frequency f_n of the n-th iteration of the gasket can be computed as follows [7]:

$$f_n \approx k \frac{c}{h_1} \delta^n \qquad (1)$$

where k is a constant whose value depends on the substrate type, c is the value of the speed of light in vacuum, h_1 represents the height of the largest triangle, δ is the (log periodic) scale factor (δ≈2), and n is a natural (generally integer) number that corresponds to the n-th iteration. In this work a FR4 substrate with a dielectric constant equals to 4.4 is considered, consequently, k≈0.26. As an example, Fig. 1 illustrates Sierpinsky gasket fractal geometry of five iterations.

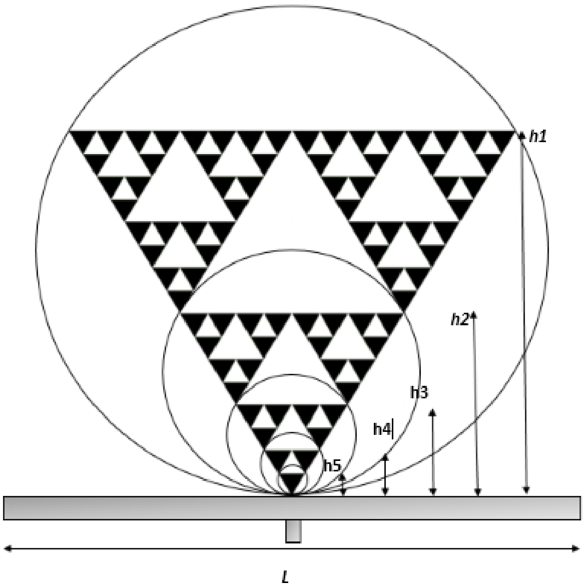

Fig. 1. Sierinski fractal geometry of five iterations.

The fractal microstrip bowtie antenna is obtained by joining two Sierpinsky gaskets as it is shown in Fig. 1. Fig. 1 also shows that a λ/4 feed transmission line that corresponds to the fundamental resonant frequency is employed. Notice that three iterations gaskets are employed for the fractal microstrip bowtie antenna.

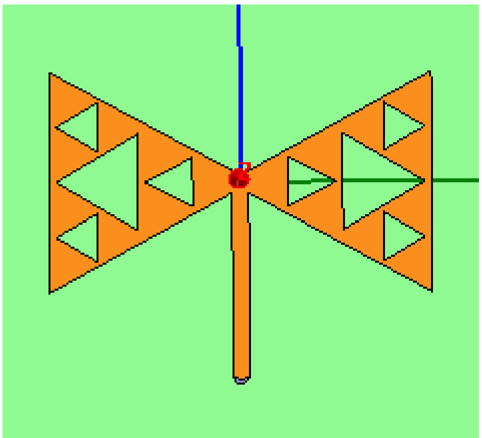

Fig. 2. Fractal microstrip bowtie antenna with λ/4 transmission line feeder.

Thus, the initial design of the fractal bowtie antenna is as follows. Given the fundamental resonant frequency f_1=2.5 GHz, the second resonant frequency f_2=5 GHz, δ≈2, and k≈0.26, from (1) it is obtained that the height of the largest triangle h_1=31.2 mm and h_i= h_{i-1}/2 (for i=2, 3,…) for the subsequent iterations.

Notice that this is an approximated design methodology and the performance of the bowtie antenna is optimized using the simulation tool for high frequency electromagnetic structures HFSS of ANSYS.

As it is well known, the Sierpinsky gasket presents poor impedance match at the fundamental resonant frequency. This is the reason why the development of Sierpinsky gasket based antennas employs the second resonant frequency as the operating one. However, this approach results in larger antenna systems (i.e., the low profile requirement for modern antennas is not reached). To overcome this inconvenient aspect, a defected ground structure is employed. In particular, a circular split ring resonator (CSRR) technique is used here to achieve efficient coupling at the fundamental resonant frequency of the gasket fractal based bowtie microstrip antenna.

A circular ring in the vacuum is matched to a frequency given by the following equation [16]:

$$f = \frac{1}{2\pi\sqrt{LC}} \qquad (2)$$

where f is the resonant frequency of the circular ring, L is the approximated inductance of the closed ring and it is given by

$$L = \mu_0 R_m \left(\ln \frac{8R_m}{h+w} - 0.5 \right) \quad (3)$$

where μ_0 is the magnetic permeability of the vacuum, R_m is the average value of the inner and outer radius of the circular ring, h is the height of the ring, and w is the difference between the inner and outer radius of the ring. C is the sum of capacitances between the gap and the surface of the ring and it is given by

$$C = C_{gap} + C_{surf} \quad (4)$$

where

$$C_{gap} = \varepsilon_0 \left[\frac{wh}{g} + \frac{2\pi h}{\ln \frac{2.4h}{w}} \right] \quad (5)$$

$$C_{surf} = \frac{2\varepsilon_0 h}{\pi} \ln \frac{4R_m}{g} \quad (6)$$

ε_0 is the electric permittivity of the vacuum, and g is the value of the aperture of the ring.
As stated above, equations (2) to (6) corresponds to a resonant circular ring operating in the vacuum and are used for the initial design of the defected ground structure of our proposed antenna.
Thus, during the simulation process, the original dimensions of the gasket and the dimensions of the circular ring resonator are changed in order to adjust, as near as possible, the first two resonant frequencies at 2.4 GHz and 5.2 GHz, respectively, and at the same time obtain reasonable values for the return losses.

3 Simulation Results

First, the return loss for the Sierinsky fractal based bowtie microstrip antenna without CSRR is presented in Fig. 3. The dimensions of this antenna that gives the best performance in terms of return loss are as follows: h_1=28.36 mm; h_2= h_1/2; length and wide of the feed transmission line equal to 28 mm and 2.4 mm, respectively.
From Fig. 3 it is observed the dual band behavior of the fractal bowtie antenna, however, as it is expected, the input impedance match at the fundamental resonant frequency is too poor, that is, a return loss of -3.67 dB is presented at the 2.47 GHz first resonant frequency. On the other hand, return loss of -9.36 dB is achieved at the second resonant frequency of 5.08 GHz. However, in both cases the return loss are greather that -10 dB (i.e., poor matching).
On the other hand, Fig. 4 presents the structure of the circular ring resonator that improves the performance of the fractal bowtie antenna for WLAN applications. This ring is simulated over a FR4 dielectric substrate instead of over vacuum. The obtained dimensions of the ring are as follows: inner radius 12 mm, outer radius 15 mm, height of the ring 0.035 mm, and gap 1 mm. The frequency response of the circular ring resonator is illustrated in Fig. 5. From Fig. 5, it is observed that the resonant frequency of the ring is at 2.7 GHz with a return loss of -53.738 dB.

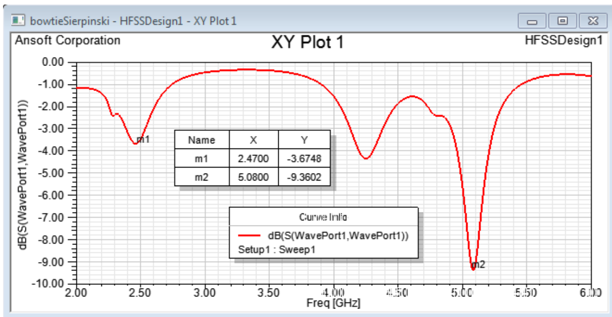

Fig. 3. Return loss for the fractal bowtie antenna without CSRR.

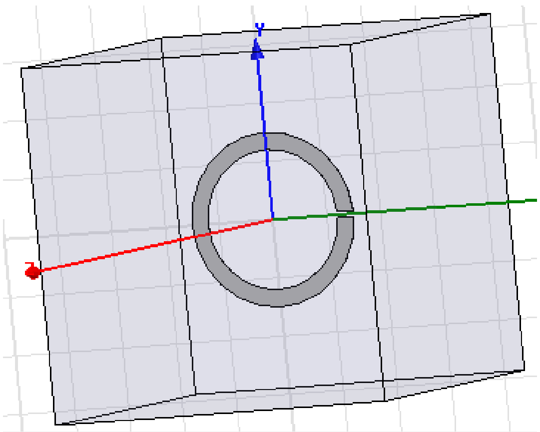

Fig. 4. Circular Split Ring Resonator.

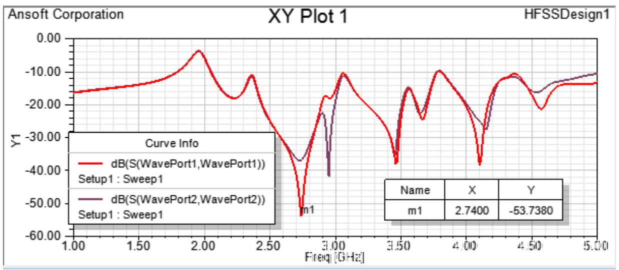

Fig. 5. Return losses for the circular split ring resonator.

The ground-plane defect is now incorporated in the fractal bowtie microstrip antenna structure. Figs. 6 and 7, illustrate, respectively, the front side and the back side of the Sierpinsky fractal based bowtie microstrip antenna with CSRR. The return losses of the simulated and optimized antenna are presented in Fig.8. Very satisfactory results are extracted from Fig. 8: the designed antenna presents return losses of -19.13 dB and a coupling bandwidth of 120 MHz at the first resonant frequency, which is equal to 2.46 GHz. On the other hand, the second resonant frequency is equal to 5.24 GHz with return losses of -45.95 dB and a coupling bandwidth of 190 MHz.

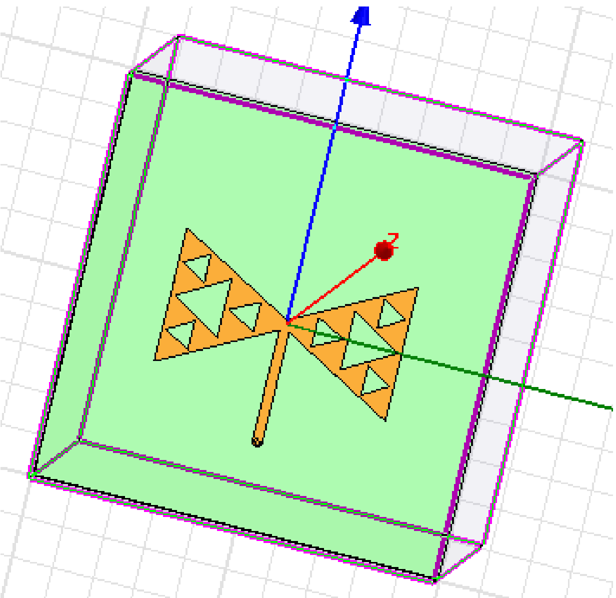

Fig. 6. Front side of the fractal bowtie antenna with CSRR.

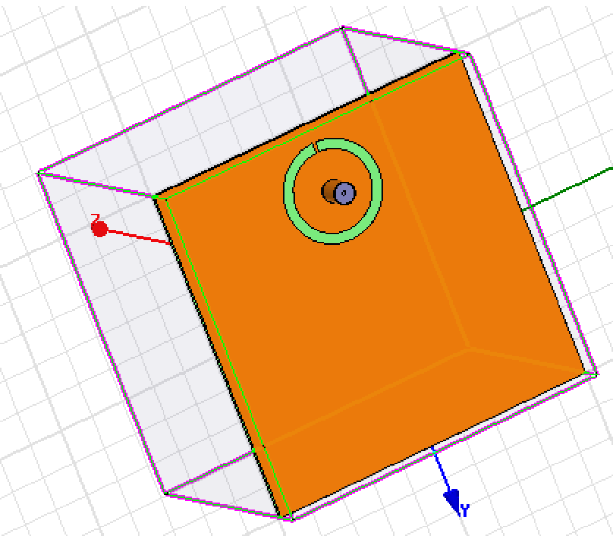

Fig. 7. Back side of the fractal bowtie antenna with CSRR..

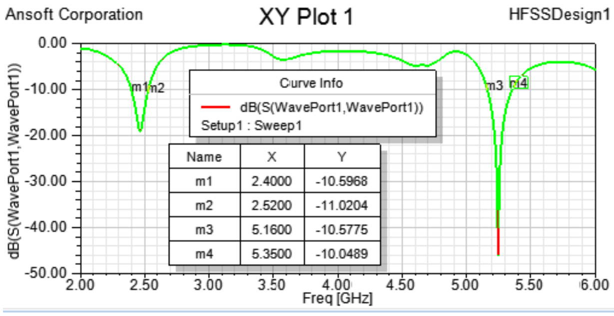

Fig. 8. Return losses for the fractal bowtie antenna with CSRR.

4 Conclusion

In this paper, the conventional bowtie microstrip antenna was modified to improve its performance at the frequency bands used by wireless local area networks (i.e., 2.4 GHz and 5.2 GHz unlicensed ISM bands). In the patch of the bowtie antenna, a defect based on the Sierpinsky fractal geometry was introduced to achieve a dual band behavior. Also, a ground plane defect based on the circular split ring resonator technique was introduced to improve return losses at the first two resonant frequencies; consequently a low profile antenna system was obtained. Simulation results showed that the designed antenna has two resonant frequencies: 2.46 GHz and 5.24 GHz with return losses of -19 dB and -46 dB and coupling bandwidths of 120 MHz and 190 MHz, respectively. Thus, the proposed antenna is an excellent choice for WLAN applications.

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