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A NOVEL BROADBAND FRACTAL SIERPINSKI SHAPED, MICROSTRIP ANTENNA

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Abstract—As wireless communication applications require more and more bandwidth, the demand for wideband antennas increases as well. One of the most applicable frequency bands is X-band (8–12 GHz). X-band frequencies are used in satellite communications. Radar applications, terrestrial communications and networking, motion detection and etc. Fractal passive Microstrip antennas are simple and novel structures that attract much attraction recently. In this paper, new Microstrip sierpinski modified and fractalized antenna using multilayer structure for achieving wideband behavior in X-band which in 7–10.6 GHz portion overlaps UWB working range. Using fractal defection in patch, multi higher order modes are inspired for coupling a much wider bandwidth. Roggers TMM3 ($\varepsilon_r = 3.38$) is used in this antenna as substrate. Working range for this antenna is from 7.7 GHz to 16.7 GHz (BW = 9 GHz). This antenna has simple structure, small size and 4 resonance frequencies. This fabricated and tested antenna is designed by Ansoft Designer software.

1. INTRODUCTION

Fractals are geometric shapes, which are self similar, repeating themselves at different scales. With the development of fractal theory, the nature of fractal geometries in antenna design has led to the evolution of a new class of antennas, called fractal shaped antennas. The main weakness of an ordinary Microstrip element is its narrow bandwidth. There are several ways to overcome this problem. A well known way is based on the introduction of an additional stack or coupled patch. The patches can be fabricated on different substrates and accordingly the patch dimensions are to be optimized so that the resonance frequencies of the patches are close to each other to yield broad bandwidth.

1.1. History of MSAs

The numerous advantages of MSA, such as its low weight, small volume, and ease of fabrication using printed circuit technology, led to the design of several configurations for various applications [12, 15]. Deschamps first proposed the concept of microstrip antenna (MSA) in 1953 [8]. However practical antennas were developed by Munson [9, 10] and Howell [11] in 1970. With increasing requirements for personal and mobile communications, the demand for smaller and low-profile antennas has brought the MSA on the forefront. An MSA in its simplest form consists of a radiating patch on one side of a dielectric substrate and a ground plane on the other side. The top and side views of a rectangular MSA (RMSA) are shown in Figure 1. MSAs might have various shapes such as the square, Circular, triangular, semicircular, sectoral, and annular ring shapes are also used.

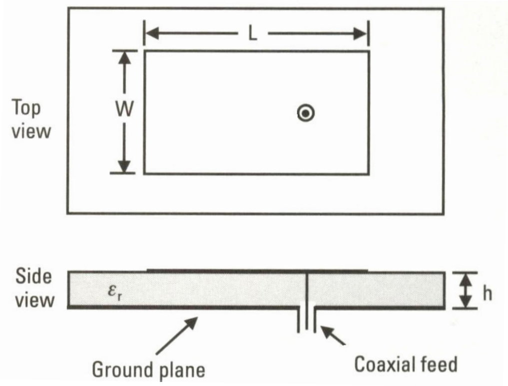


Figure 1. Top and side view or RMSA.

2. FRACTAL PATCHES

Fractal meaning broken or fractured derived from Latin word "fractus" dates back to 19th century as a branch of classical mathematics. Fractals are geometrical shapes that are self similar, and can generate almost any complex structure in nature, through iterating of certain simple geometries. Figures 2 and 3 show examples proposed by Sierpinski (1916), and Koch (1904).

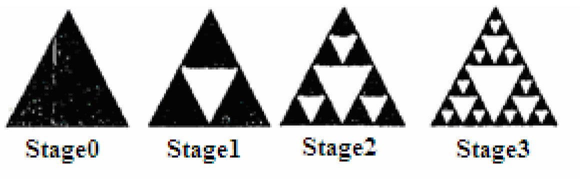


Figure 2. Sierpinski gasket fractal.

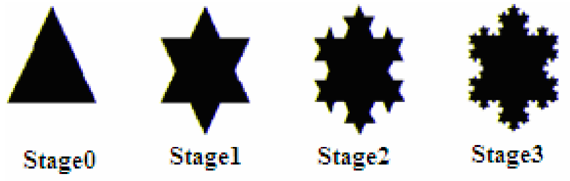


Figure 3. Koch fractal.

3. EFFECTS OF SUBSTRATE PARAMETERS ON BW

Impedance BW of a patch antenna varies inversely as quality factor Q of the patch antenna.

Therefore substrate parameters such as dielectric constant and thickness can be varied to obtain different Q, and ultimately the increase in impedance BW. Q of a resonator is defined as

$$Q = \frac{\text{energy stored}}{\text{power lost}}.$$

Figure 4 shows the effect of substrate thickness on impedance BW and efficiency for two values of dielectric constants. Note that the BW increases monotonically with thickness. Also, a decrease ε_r in value increases the BW. This behavior can be explained from the change in Q value.

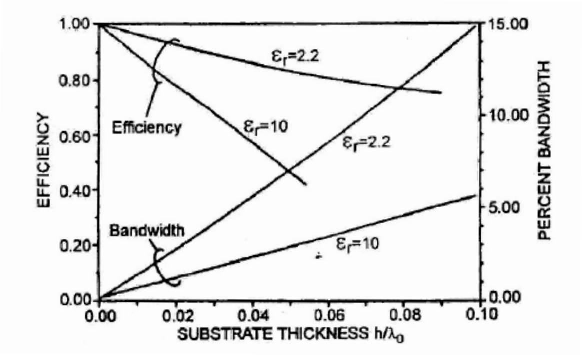


Figure 4. Effect of substrate thickness and dielectric constant on the impedance BW (VSWR < 2) and radiation efficiency.

In conclusion, we can say that the increase in h and decrease in ε_r can be used to increase the impedance BW of the antenna. However, this approach is helpful up to $h \leq 0.02\lambda$ only. The disadvantages of using thick and high dielectric constant substrates are many, including these:

- Surface wave power increases, resulting in poor radiation efficiency.
- The radiation from surface waves may lead to pattern degradation near endfire.
- Thick substrates with microstrip edge feed will give rise to increased spurious radiation from the microstrip step-in-width and other discontinuities. Radiation from the probe feed will also increase.
- Substrates thicker than 0.11λ for $\varepsilon_r = 2.2$ makes the impedance locus of the probe fed patch antenna increasingly inductive in nature, resulting in impedance matching problems.
- Higher order modes along the thickness may develop, giving rise to distortions in the radiation patterns and impedance characteristics. This is a limiting factor in achieving an octave BW.

4. EFFECT OF PARASITIC PATCHES

A patch placed close to the fed patch gets excited through the coupling between the patches [4].

Such a patch is known as a parasitic patch. If the resonance frequencies f_1 and f_2 of these two patches are close to each other, then broad bandwidth is obtained as shown in Figure 5. The overall input VSWR will be the superposition of the responses of the two resonators resulting in a wide bandwidth [7, 8]. If the bandwidth is narrow for the individual patch, then the difference between f_1 and f_2 should be small and if the bandwidth of the individual patch is large, then the difference in the two frequencies should be large to yield an overall wide bandwidth as shown in Figures 5 and 6.

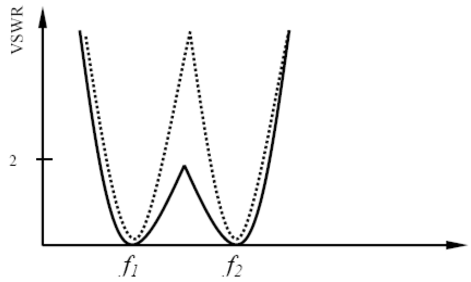


Figure 5. VSWR plot of two coupled resonators having narrow bandwidth (- - -) individual resonators and (__) overall response.

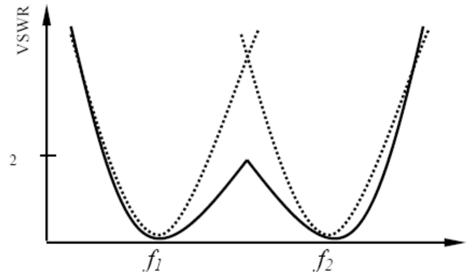


Figure 6. VSWR plot of two coupled resonators having narrow bandwidth (- - -) individual resonators and (__) overall response.

5. MULTILAYER CONFIGURATIONS

In the multilayer configuration, two or more patches on different layers of the dielectric substrate are stacked on each other. Based on the coupling mechanism, these configurations are categorized as electromagnetically coupled or aperture coupled MSA.

In the electromagnetically coupled MSA, one or more patches at the different dielectric layers are electromagnetically coupled to the feed line located at the bottom dielectric layer as shown in Figure 7.

Alternatively, one of the patches is fed by a coaxial probe and the other patch is electromagnetically coupled. The patches can be fabricated on different substrates, and accordingly the patch dimensions are to be optimized so that the resonance frequencies of the patches are close to each other to yield broad BW. These two layers may be separated by either air gap or foam [8].

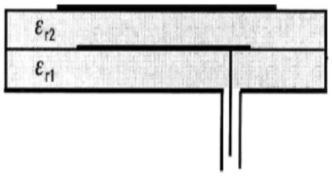


Figure 7. Multilayer MSA.

The multilayer broadband MSAs, unlike single layer configurations, show a very small degradation in radiation pattern over the complete VSWR BW. The drawback of these structures is the increased height; which is not desirable for conformal applications and increased back radiation.

6. ANTENNA DESIGN

As it is shown in Figure 8 planar and stacked multi resonators techniques are combined to yield a wide bandwidth with a higher gain.

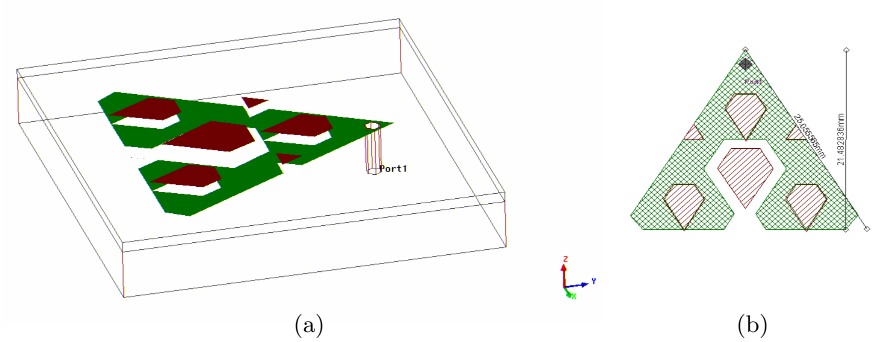
The antenna has two layers with different heights-first layer height is 3.5 mm and the second layer height is 1 mm. The modified Sierpinski shape fractal patch is on the first layer.

Only the bottom patch is fed and the other patches electromagnetically coupled as shown in Figure 8.

There are 6 parasitic patches on the top layer to decrease the antenna gain variation through the band width.

The antenna is designed, optimized and simulated using Ansoft designer software. The band-width obtained for the antenna is 9 GHz. The radiation is in the broad side direction, and the variation in the pattern is very small over the entire bandwidth. At 4.3 GHz, the gain is 7.5 dB.

As shown in Figures 9–13 the bandwidth and return loss are proper for ultra wideband applications and antenna dimensions are suitable for mobile devices.



(a) (b)

Figure 8. One Sierpinski fractal patch on the bottom layer and six patches on the top layer (a), the dimensions of antenna (b).

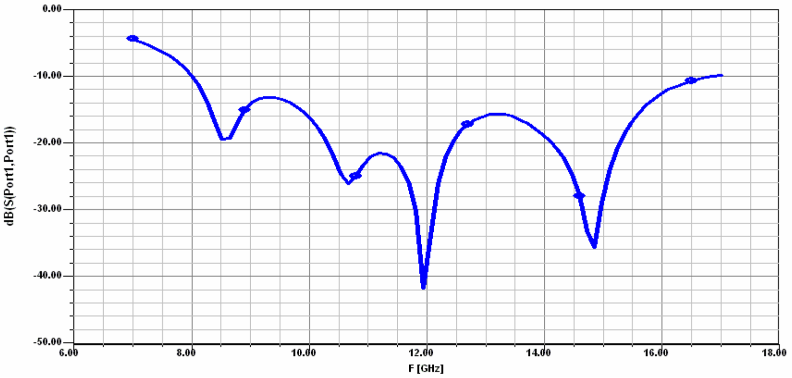


Figure 9. Return loss plot of antenna for stage2 edge cut sienpinski with six patches on top layer.

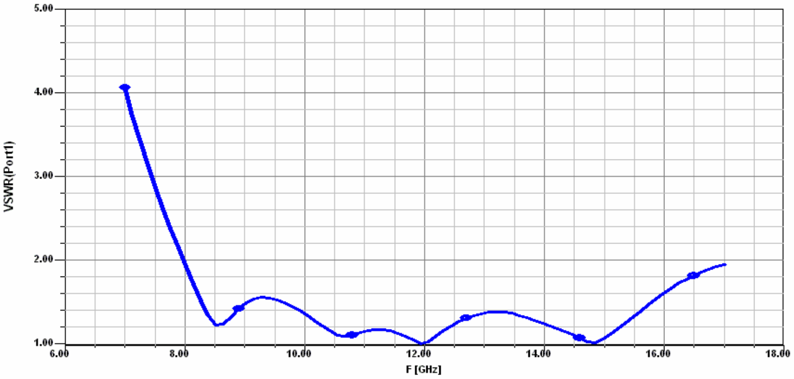


Figure 10. VSWR plot of antenna for stage2 edge cut sienpinski with six patches on top layer.

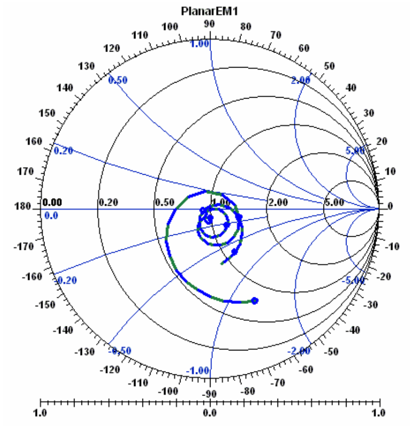
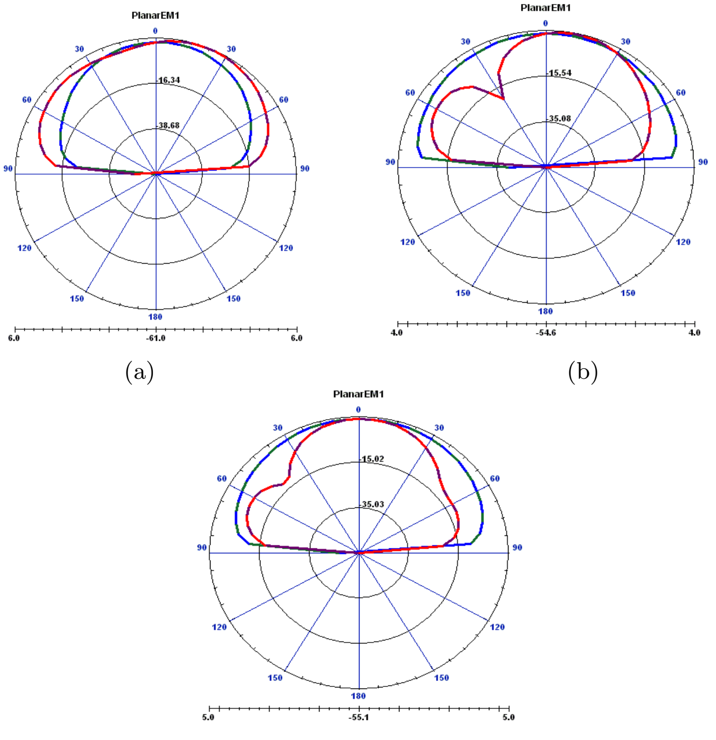


Figure 11. Impedance characteristic of the antenna with six patches on the top layer.

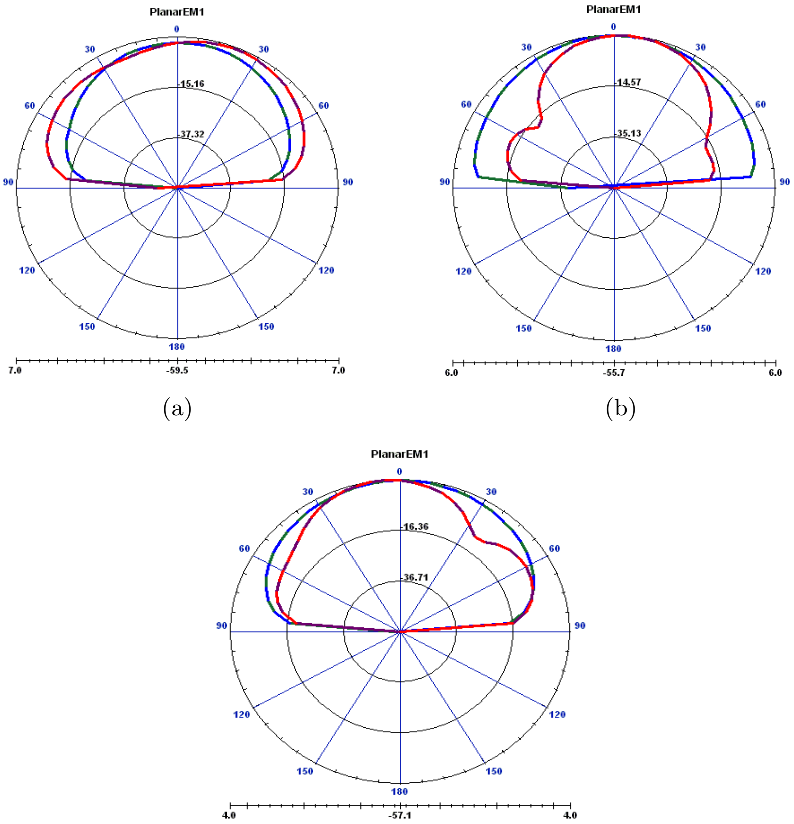


(a)

(b)

(c)

Figure 12. Radiation patterns for 11.9 GHz (a), 10.6 GHz (b), 8.6 GHz (c) before adding parasitic patches.



(a) (b)

(c)

Figure 13. Radiation patterns for 11.9 GHz (a), 10.6 GHz (b), 8.6 GHz (c) after adding parasitic patches.

7. SIMULATION RESULTS

The antenna is designed, optimized and simulated using Ansoft designer software. The bandwidth obtained for the antenna is 9 GHz. The radiation pattern is in the broad side direction, and the variation in the pattern is very small over the entire bandwidth. The return loss, VSWR and smith chart at range of 7 till 17 GHz are shown in Figures 9 to 11.

As it is showed in Figs. 12 and 13, adding parasitic patches reduces the variation of radiation pattern. This antenna is fabricated and tested in Khajenasire university antenna lab. The numerical results are compared in Fig. 14 using Matlab software.

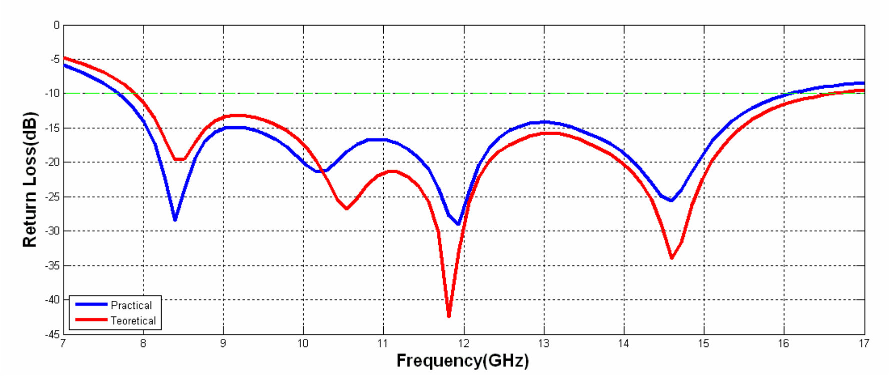


Figure 14. Comparing the practical and theoretical results.

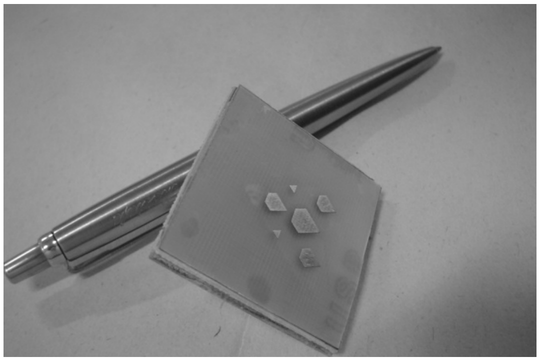


Figure 15. The fabricated antenna.

8. CONCLUSION

In this paper, a new small microstrip antenna for ultra wideband applications is designed, optimized and simulated. There was a great success in finding a suitable structure for mobile applications. Also obtaining bandwidth about 50% and maximum gain about 7.5 dB shows that this structure can be mentioned as a useful design for ultra wideband products. However acquired results show that the antenna design and structure need more refinement in order to achieve the ultimate design with a smaller physical profile and better performance.

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