Desing and Simulation of Characteristics of Sierpinski Triangle Fractal Geometry for Multiband Applications

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***Abstract*— Current wireless communication systems demand various types of antennas that can operate in multiple frequency bands that must be adapted to large requirements without affecting performance and other antenna configurations. In this article, a sierpinski fractal antenna for multiband applications is proposed. The structure is given from a factual and similar design to maximize the effective length of a material. The dimension of the antenna to be made has a dimension of 102 mm at the base and 137 mm in height with a dielectric substrate of the FR4 type (ϵr =4.4) with a thickness of 1.6 mm. An opening angle of 60 degrees and four iterations using Sierpinsky geometry.**

Keywords*— *Sierpinski, Multiband, Antenna, Fractal, Iteration

I. Introduction

The fast development of wireless communications and their wide band demand imposes customs antennas design also taking advantage of the dimensions in an optimum way. The classic antennas, designed based on Euclidean Theory, do not satisfy this requirement. A possible solution to the stated problem is using microstrip antenna whit fractal's patch.[1][3][12]

Since its evolution, fractals have stolen a major role, satisfying the immense need of dual frequency antennas in WLANS since the release of a complete ISM band.[8][4]

The term fractal is derived from latin word fractus which means broken, was first coined by Benoit Mandelbrot, the pioneer of classifying this geometry. Soon the field found an extensive application in statistical analysis, nature modeling, compression, computer graphics and of course antennas.[3] In the recent years and with the multiplication and miniaturization of telecommunications systems and their integration in restricted environments, such as Smart-phones, tablets, cars, airplanes, and other embedded systems.[7] The design of compact multi-bands and Ultra Wide Band (UWB) antennas becomes a necessity.

One of the interesting techniques to provide this kind of antenna is the use of fractal structures giving a considerable reduction of the antenna area.[6]

These antennas are multiband, that means that different bands are active for different frequency ranges and bands of work. This property can be fulfilled by adding slots in patches, and fractals in antennas.[2-5]

This design is used because of its advantages as compact size, broadband, independent frequency and low mutual coupling. The fractal antennas are formed by a triangular right-angle isosceles triangle with Sierpinski structure, although not the method is applied to triangles as we have seen in some papers that there are Sierpinski fractals applied to rectangles called carpets. The software used for the simulation are HFSS and Designer.[6][7]

The antenna covers all wireless LAN bands, i.e. LAN / WLAN / GSM / LTE / WiMAX / UWB, so its use in these applications is very popular with antenna designers.

II. Fractal Geometry

The original inspiration for the development of fractal geometry came largely from an in-depth study of the patterns of nature Fig 1.The term "Fractal" means linguistically "broken" or "fractured" from the Latin "fractus." This term was created by Benoît MANDELBROT 40 years ago in 1974. Fractals are geometric shapes, which cannot be defined using Euclidean geometry, are self-similar and repeating themselves on different scales like clouds, mountains, coasts,lightning, etc.[13]

Also, fractal geometry has been used in the electromagnetic, and especially in the design of antennas. Several studies have adopted fractal structures and showed that this technique can improve the performances of the antenna and it is one of the techniques to design antennas with multi-band and broad-band behavior.

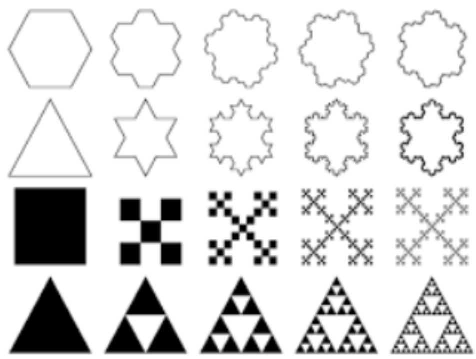


Fig. 1. The fractal geometry(Balanis)

A. The Sierpinski Structure

This structure was invented by Polish mathematician SIERPINSKI. There are several variations of this structure

The construction of this triangle is made from a solid equilateral triangle and applying the following steps:

- An equilateral triangle is built and has be taken as a base.
- Subdivide it into four smaller congruent equilateral triangles and remove the central one.
- Repeat step 2 with each of the remaining smaller triangles.

Fig 2 shows the first four iterations of the SIERPINSKI triangle, applied to the antenna once it has already been coupled to the transmission lines.

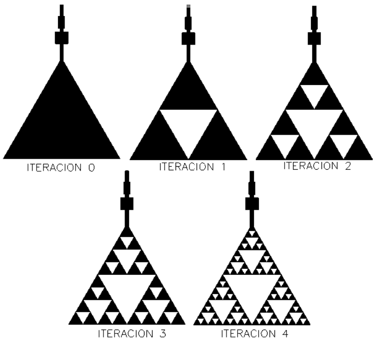


Fig. 2. Iterations applied to the antenna

III. Antenna Design

A. The Scale Factor

The scale factor Ψ is very important, since it is related to the heights of the consecutive triangles in the iterations, figure 3, equation 1.[14]

$$\Psi = \frac{h}{b} = \frac{b}{a} \quad (1)$$

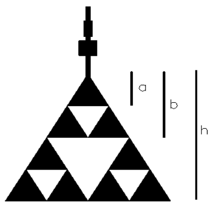


Fig. 3. Scale factor applied for the serpinski antenna

Table 1 shows the substrate specification of proposed antenna. The proposed antenna is a broadband operation. The return loss of the antenna must be below -10dB to make sure the proposed antenna can achieve at least 90% matching efficiency [10]. The antenna is designed by using a FR4 epoxy dielectric substrate with dielectric constant, εr= 4.4, tangent loss, tan δ = 0.019 and the thickness, *t* of substrate, *h* = 1.6mm.

TABLE I. Substrate Specification

substrate	FR4
Relative permittivity,εr	4.4
Tangent loss, δ	0.019
Substrate thickness, h	1.6mm
Copper thickness, t	0.035mm

Table 2 and Fig 4 shows the dimension of the antenna.The black region represents the copper layer of antenna while the white region represents the substrate of the antenna.

TABLE II. Dimension Of The Antenna

Symbol	Description	Value(mm)
Ha	Triangle height	90
Hl	Triangle length	102
Hat	Total height of antenna	137

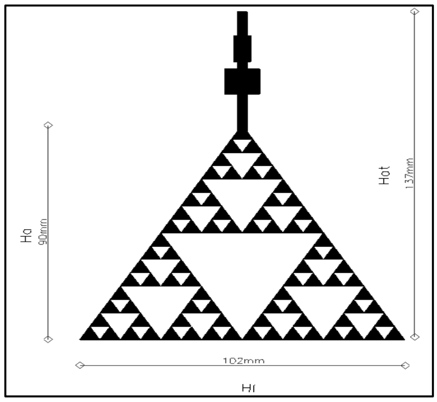


Fig. 4. Simulation of Proposed Antenna

IV. Analysis Of Results

The number of operating frequencies depends on the number of iterations that the antenna has. [2]

The simulation and measured S(1,1) and transmission gain match to some extent,these errors are mainly due to SMA connectors and the actually processing of manufacture wich can be considered within the allowd range,besides that the measurements are not made in a closed area,this also affects our measuments a bit.

The results obtained from the simulation in the Ansoft Designer software are shown below.

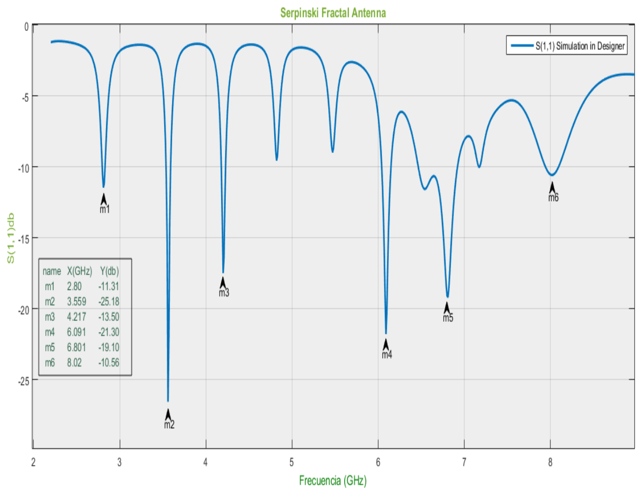


Fig. 5. Simulated return loss vs frequency simulated for the Serpinski Antenna.

All this process of data collection is done with an Anritsu MS2724C equipment which is a spectrum analyzer in addition to a microwave signal generator, we need 2 antennas a receiver and a transmitter which are connected by coaxial

50 ohm to the equipment (fig. 6) , we set a central frequency and so we can continue with either the gain measurements or with the radiation diagram. For the latter it varies ,in both phi and theta 10 ° to collect data

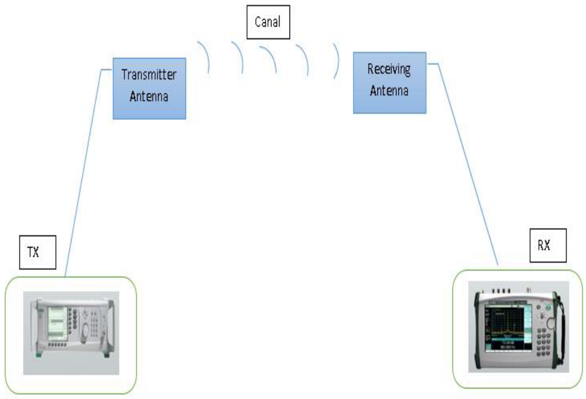


Fig. 6. Diagram of blocks for measurement

For these measurements in the spectrum analyzer, the transmission gain is analyzed. The data collection was done in parts, because only a single frequency is generated with the RF generator, and because the spectrum analyzer would need a very high range and this would become slow.

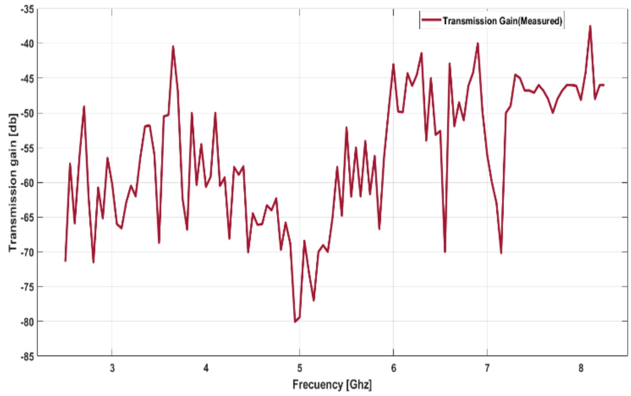


Fig. 7. Measured of the Transmision Gain

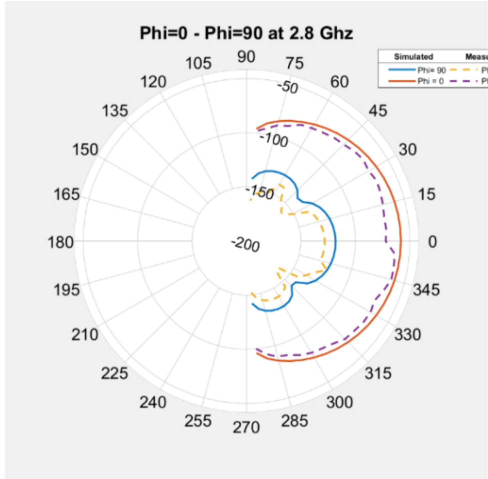
The radiation pattern is observed in the antenna's far field [9]. The far field is defined by Equation (1) , where (D) is the end-to-end length of the antenna, (λ) is the wavelength of the antenna, and (R) is the distance from the antenna.

$$R > \frac{2D^2}{\lambda} \quad (1)$$

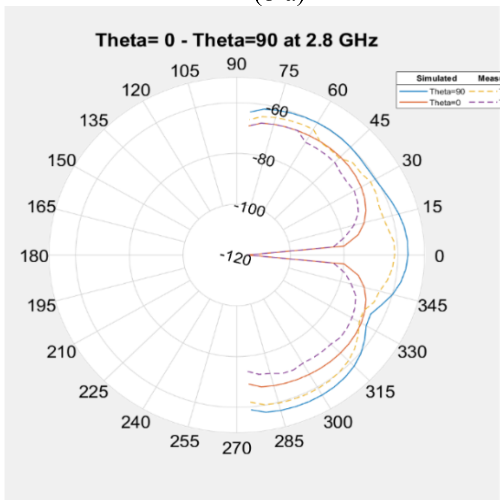
To understand the multifrequency characteristics of an antenna a study of the reflection coefficient curves alone is not sufficient it may show a very low reflection coefficient in some modes with exhibiting the desired radiation pattern.

To check the operation of the antenna shown graph different patterns of radiation in Phi = 0°-90° and theta = 0°-90° to the specified frequencies which are: 2.8 GHz, 3.56 GHz, 4,217 GHz, 6,091 GHz, 6.8 GHz, 8.01 GHz

To support the same, radiation pattern reports are generated at the resonant frequencies as shown in the following Figures.

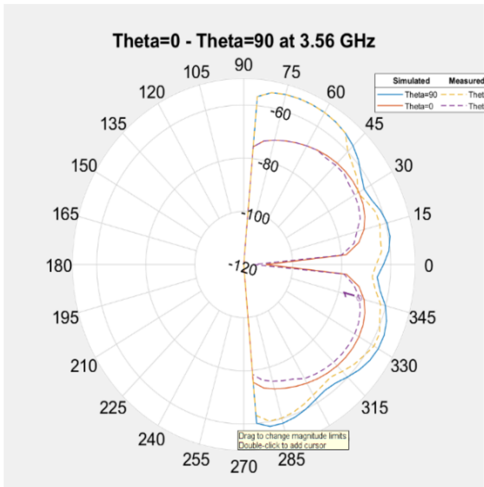


(8-a)

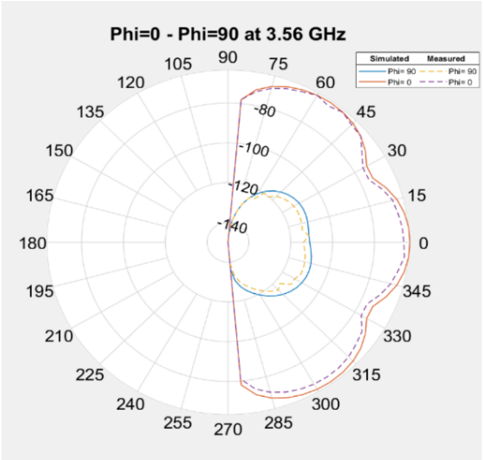


(8-b)

In Figs 8-a and 8-b the frequency of 2.8 Ghz it can be seen that in phi = 0° and theta = 90° behaves like an isotropic radiation, instead in thetha = 0° its behavior is omnidirectional, phi = 90° has a directive compotation which its lateral lobes resemble the main lobe .

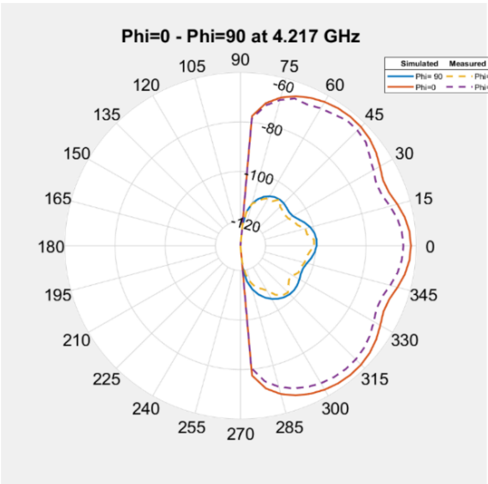


(8-c)

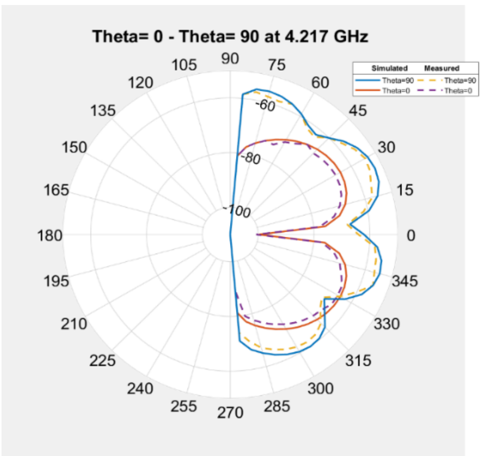


(8-d)

In Fig 8-c and 8-d the frequency 3.56 GHz it is observed that both phi and theta (0° and 90°) have a very even omnidirectional radiation behavior, only with the difference that phi = 90 their radiation is very low in comparison with the others.

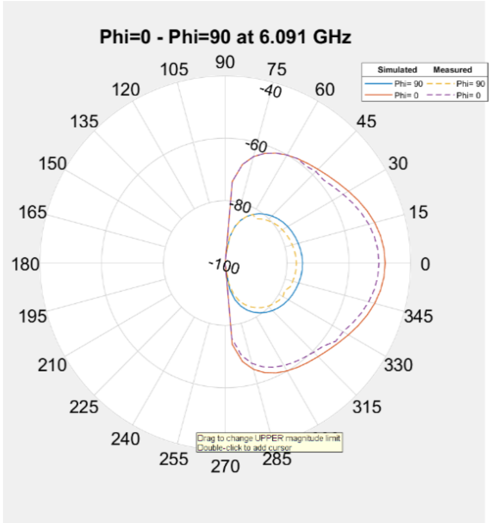


(8-e)

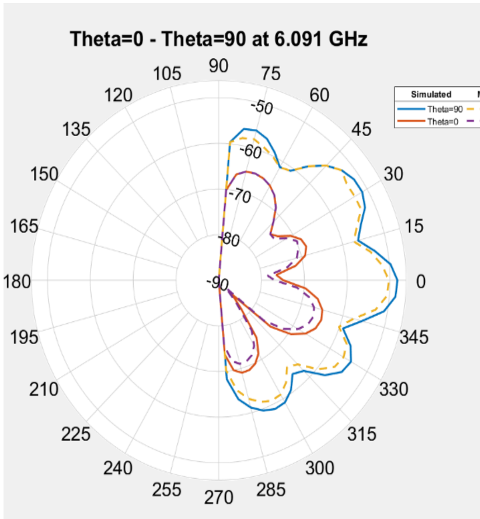


(8-f)

In Figs 8-e and 8-f the frequency of 4.217 Ghz , in this frequency it shows an omnidirectional radiation, but in some cases it has high lateral lobes in the main lobe, theta is almost similar in levels, while in phi there is a big difference between phi = 0°and 90°.



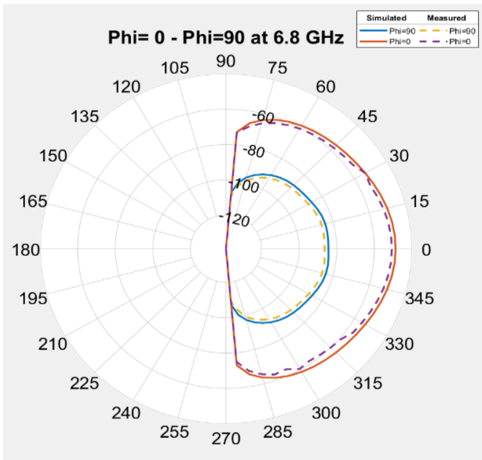
(8-g)



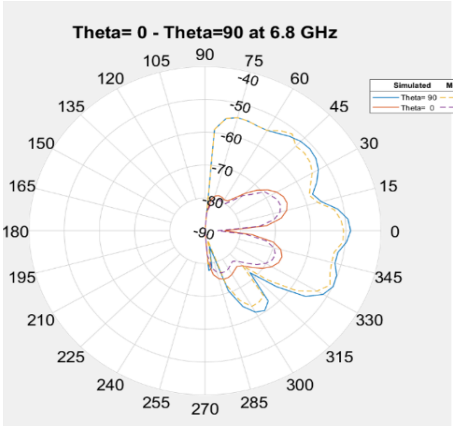
(8-h)

In Figs 8-g and 8-h to 6.09 Ghz in this frequency there is already a great difference, as the frequency increases, this diagram with respect to theta more lateral lobes begin to appear, similar to the classic microstrip antennas.

While phi maintains an omnidirectional radiation at both 0 and 90 °.

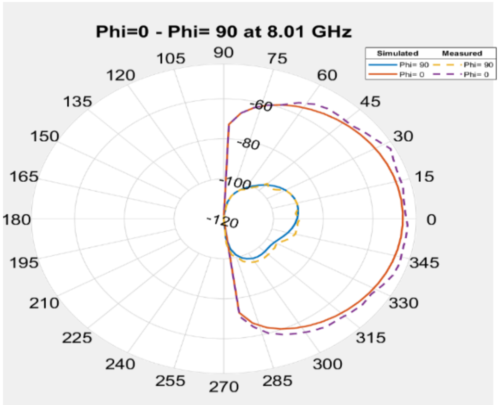


(8-i)

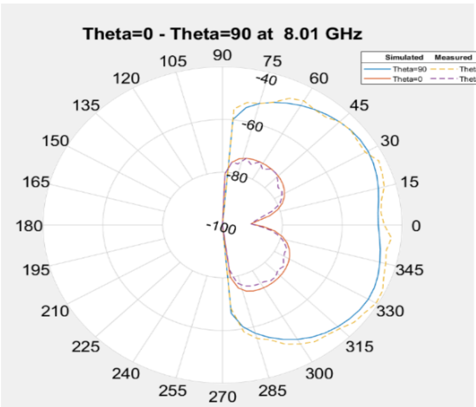


(8-j)

In Figs 8-i and 8-j to 6.8Ghz as explained in the previous case, the occurrence in the theta of lateral lobes is given, while in phi there is an onmidirectional radiation



(8-k)



(8-l)

Fig 8 (a-l). Radiation Pattern for each frequency (simulate vs measured).

In Figs 8-i and 8-j to 6.8Ghz in both cases theta and phi are given onmidirectional radiation, in this case there is no longer the appearance of lateral lobes because, despite being a high frequency, this is a frequency unrelated to the iterations

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