Comparison of some configuration for multiband antennas using Sierpinski fractal geometry

Rodrigo de Oliveira Matos
Instituto Nacional de Telecomunicações - INATEL
Santa Rita do Sapucaí, Brasil
diasoliveira@gmail.com

José Antônio Justino Ribeiro
Departamento de Telecomunicações
Instituto Nacional de Telecomunicações - INATEL
Santa Rita do Sapucaí, Brasil
justino@inatel.br

Abstract– **In this article will be presented the comparison of two configurations for antennas using Sierpinski fractal geometry for multiband operation. In adopted geometry, with the successive generation of the triangles with predefined angle, it has a logarithmic spacing among the operation frequencies. These projects were built with a fiberglass substrate FR4 and provide acceptable performance in terms of return loss at different frequencies. Simulations and measurements of the fabricated prototypes and the antenna parameters like bandwidth, directivity, gain, radiation efficiency and radiation pattern are shown.**

Index Terms– **Antennas, Fractal, Multiband, Sierpinski.**

I. INTRODUCTION

Modern systems and wireless communication technologies such as the cognitive radio [1], occupy high bandwidths, demand different frequencies and require adaptable antennas to these applications. In this scenario, appeared fractal antennas with desirable behaviors in multiple frequency bands. Its applications began in the middle of 1980s, with the creation of Nathan Cohen [2]. In its proposal, developed the theory of antennas applied to structures that maintain self-similarity in their progressive geometries. The structure that adopts the Sierpinski fractal geometry was discussed in other papers [3] and some developments are presented in order to improve its performance. For this, the use of printed geometry parallel to the ground plane on a dielectric substrate FR4 [4], in a configuration similar to some conventional structures, was studied. After that, a configuration with a vertical structure over a finite ground plane was analyzed.

II. ANTENNA PARALLEL TO THE GROUND PLAN

In another publication [5] it was presented a printed plate structure using Sierpinski fractal geometry with a multiband behavior and logarithmic spacing among successive bands. From the results, in higher operating frequencies the radiation efficiency of the antenna with a 1.5mm thick substrate is similar to the traditional triangular microstrip. Once the excitation occurred in the triangle associated with the higher frequencies, the action of very narrow path for the current in the triangles connections was not observed. For lower frequencies the efficiency drops, severally affecting the antenna gain. One reason is that the connections generated at each iteration present electrical resistance and, consequently, power losses. Thus, improvements in the antenna structure with better triangles coupling are suggested. [6].

III. ENHANCEMENT FOR THE PARALLEL PRINTED ANTENNA

With numerous tests, it was found that in the first iteration would be desirable to introduce a chamfer of 0.6cm at the vertices of the triangle to be removed. In the second iteration, there will be a chamfer of 0.4cm and 0.3cm in the third iteration. Furthermore, the antenna was mounted on square substrate with 60cm side. The changes in the structure of the radiator are in Fig. 1. Fig. 2 presents the return loss obtained from the simulations with the HFSS® [7]. A summary of the antenna main characteristics at frequencies of interest is in Table I.

TABLE I.
SUMMARY OF THE CHARACTERISTICS OF THE SIERPINSKI MICROSTRIP ANTENNA WITH CHANGED IRRADIATOR

Frequency	Bandwidth	Directivity	Gain	Radiation Efficiency
750MHz	1.34%	8.34dB	–7.36dB	2.69%
1.53GHz	1.82%	10.89dB	–0.54dB	7.21%
1.62GHz	1.91%	10.47dB	0.31dB	9.25%
3.6GHz	10.80%	13.10dB	9dB	39.30%

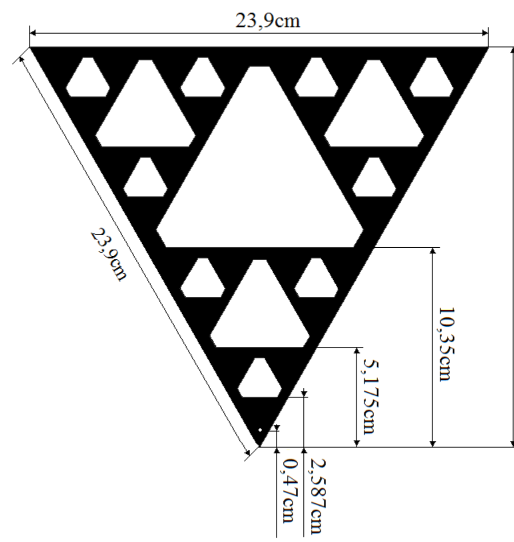

Figure 1. *Modifications to the irradiator of Sierpinski microstrip antenna with opening angle of 60° by introducing bevels at the vertices of triangles excluded at each iteration*

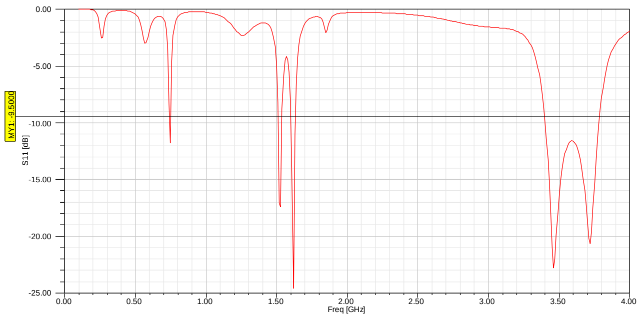

Figure 2. *Simulated result for the return loss in dB from 100MHz to 4GHz for modified Sierpinski microstrip antenna.*

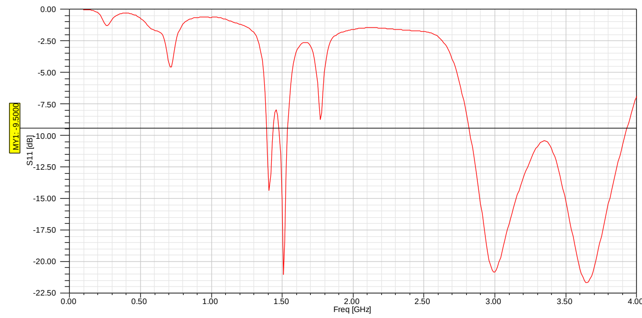

Figure 4. *Simulated result for the return loss in dB from 100MHz to 4GHz for the antenna over a dielectric with thickness h = 6.6 mm.*

As seen in Table I, the triangles connections couplings are not enough to improve the radiation efficiency significantly. This means that, besides introducing better coupling, one should employ a low loss tangent dielectric and/or apply a thicker dielectric laminate [8]. Aiming to achieve this improvement in efficiency at higher frequencies, an antenna on a square substrate with 60cm side, with the same dielectric FR4, but with h = 6.6mm thickness was analyzed. The idea was, beyond better radiation efficiency, to obtain a higher bandwidth. Changes in radiator are in Fig. 3. The return loss obtained from calculations is in Fig. 4 and Table II is a summary of the main characteristics at the frequencies of interest. According to theoretical predictions, a thicker dielectric led to a wider bandwidth and better radiation efficiency. A bandwidth of about 30% and radiation efficiency exceeding 70% around higher operation frequency were achieved

TABLE II

SUMMARY OF THE MAIN CHARACTERISTICS OF SIERPINSKI MICROSTRIP ANTENNA USING THICKER DIELECTRIC

Frequency	**Bandwidth**	**Directivity**	**Gain**	**Radiation Efficiency**
1.41GHz	3.18%	10.56dB	5.75dB	33.03%
1.51GHz	3.97%	11.22dB	7.74dB	44.97%
3.38GHz	32.89%	10.98dB	9.53dB	71.60%

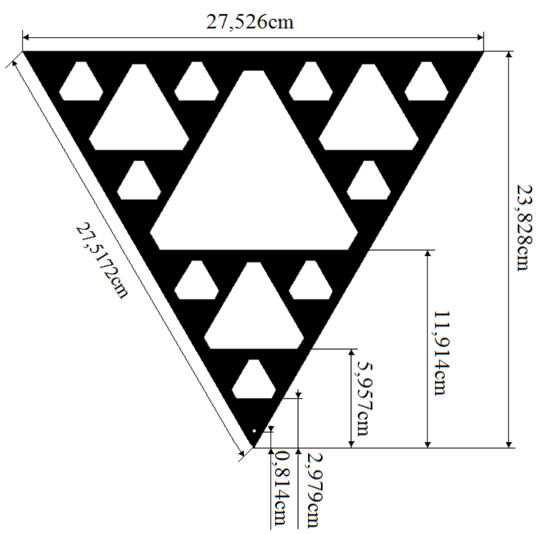

Figure 3. *Dimensions changed on the modified Sierpinski microstrip antenna irradiator with aperture angle of 60° mounted over a dielectric with thickness h = 6.6 mm.*

IV. VERTICALLY MOUNTED ANTENNA

In search to an antenna with broadband and improved radiation efficiency, the printed geometry was vertically mounted over a finite ground plane. In this case, the air-solid dielectric composition has an overall influence on antenna properties. To compare with the model previously developed, the vertically mounted radiating element has the same number of iterations and dimensions as the first microstrip antenna. Fig. 5 exhibits the structure assembly as presented in the program HFSS® and Fig. 6 shows the calculated return loss. Table III summarizes this antenna main characteristics. To validate the simulation, it was built an antenna prototype and performed the measurements. (Fig. 7). It was used a network analyzer Advantest R3765/CG calibrated between 100MHz and 3.7 GHz. The antenna was fed with a coaxial cable of 50Ω. To minimize influences of the workbench, the antenna was mounted on a support that kept her away enough to ensure trustworthiness results. The reflection coefficient (S_{11}) values and the return loss measurement were obtained. (Fig. 8). Table IV compares frequency measurements and those obtained theoretically. There is a good agreement between correspondent results, validating the predicted values through simulation.

TABLE III

SUMMARY OF THE MAIN FEATURES OF THE STRUCTURE MOUNTED VERTICALLY

Frequency	**Bandwidth**	**Directivity**	**Gain**	**Radiation Efficiency**
765GHz	11.34%	4.576dB	4.35dB	95%
1.46GHz	26%	7.36dB	7.14dB	95%
2.96GHz	28.34%	7.92dB	7.70dB	95%

TABLE IV

COMPARISON BETWEEN FREQUENCIES OBTAINED IN EXPERIMENTAL AND SIMULATED RESULTS FOR THE ANTENNA MOUNTED VERTICALLY

Band Order	**Measurement frequency**	**Simulated frequency**	**Difference between frequencies**
0	238MHz	230MHz	8MHz (3.36%)
1	736MHz	765MHz	29MHz (3.94%)
2	1,40GHz	1,46GHz	60MHz (4.28%)
3	2,89GHz	2,96GHz	70MHz (2.42%)

By applying the same printed antenna power, the field distribution is strongly modified, compared to first one. This new field configuration and different induced currents led to smaller connections and dielectric losses, with better radiation efficiency.

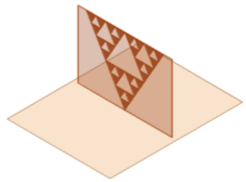

Figure 5. *Aspect of the Sierpinski antenna mounted vertically on a finite ground plane in HFSS® program.*

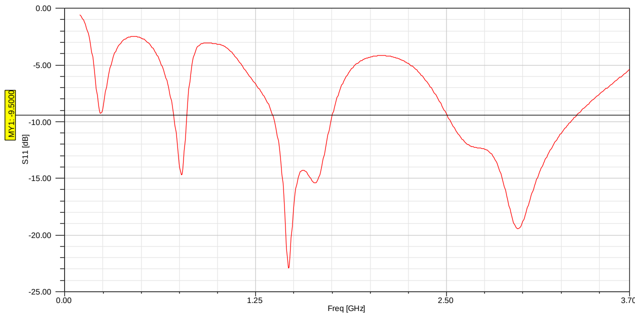

Figure 6. *Theoretical result for the return loss in dB at frequencies between 100 MHz and 3.7 GHz for the antenna mounted vertically.*

Figure 7. *Antenna and equipment used to measure the return loss of the antenna in the range of 100MHz to 3.7 GHz.*

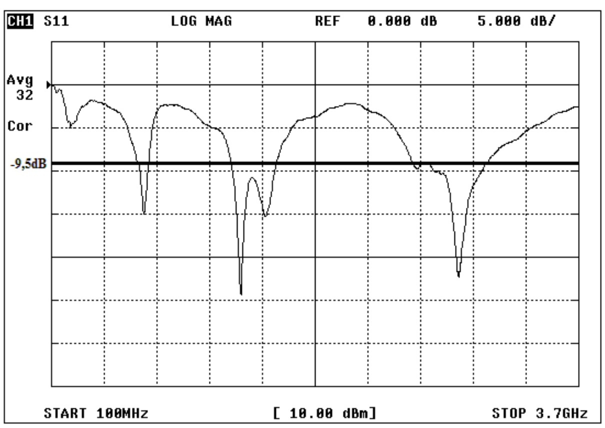

Figure 8. *Measure for return loss in dB to frequencies ranging from 100MHz to 3.7 GHz for the Sierpinski Antenna mounted vertically on the ground plane.*

V. Radiation Characteristics

The radiation pattern in specified frequency was calculated. The graphs for the parallel and normal planes referred to the plane of the radiator are in Fig. 9 to Fig. 11. These represent the component E_θ for $\phi = 0^o$ and $\phi = 90^o$, where θ is the elevation angle measured from the vertical axis through the center of the antenna. By comparing the two presented configurations, they have different performances in terms of bandwidth, gain and radiation efficiency.

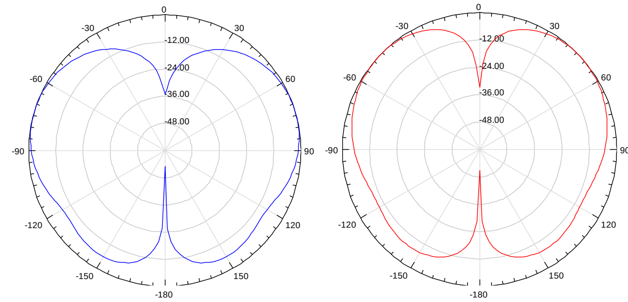

Figure 9. *Radiation pattern to the Sierpinski antenna mounted vertically on finite ground plane, operating at 765MHz (a) in the normal plane (ϕ=0º) and (b) in parallel plane (ϕ=90º).*

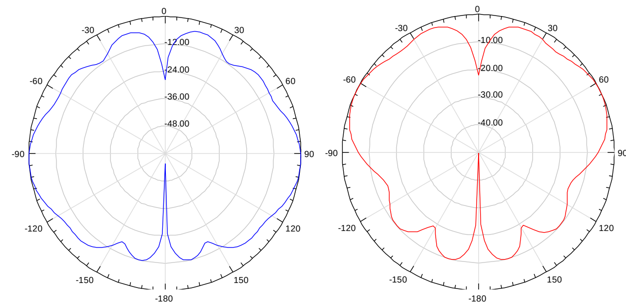

Figure 10. *Radiation pattern to the Sierpinski antenna mounted vertically on finite ground plane, operating at 1.46GHz (a) in the normal plane (ϕ=0º) and (b) in parallel plane (ϕ=90º).*

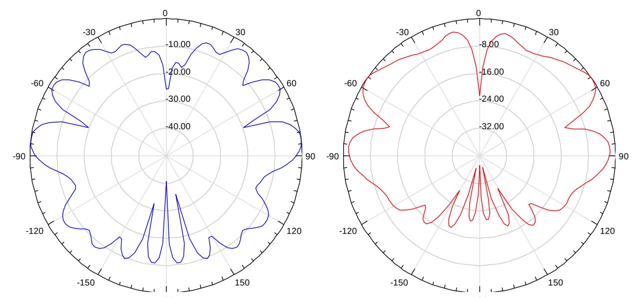

Figure 11. *Radiation pattern to the Sierpinski antenna mounted vertically on finite ground plane, operating at 2.946GHz (a) in the normal plane (ϕ=0º) and (b) in parallel plane (ϕ=90º).*

Both the models possess multiband characteristics, with logarithmic spacing through successive frequency bands. However, the vertically mounted structure shows better bandwidth. The microstrip antenna presented about 2% bandwidths, while in the second configuration is achieved values from 11% to 25%. Another relevant factor is the radiation efficiency, which determines the antenna gain. In microstrip model, the highest efficiency was approximately 35%. It is reduced at lower frequencies, demanding a thicker dielectric substrate with a lower loss tangent. In the vertically mounted antenna, the losses are mainly limited to the radiator element and the ground plane, with radiation efficiency as high as 95%.

VI. Conclusion

The differences between the printed configurations and the vertically mounted stand out on performance in terms of bandwidth, directivity, gain and radiation efficiency. The printed antenna on a dielectric FR4 substrate parallel to a finite ground plane has narrow bandwidth and smaller radiation efficiency. In this situation, it is recommended to use radiator with better coupling between triangles on a dielectric with low loss tangent or on a thicker substrate. Thus, one can achieve wider bandwidth and better radiation efficiency compared with the traditional microstrip antennas.

The vertical radiator has a wider bandwidth and high efficiency, since there is a new field configuration and the solid dielectric composes with the air a global influence on the antenna properties. The new field distributions for the same applied power lead to a smaller induced current in conductors and to lower power loss in dielectric medium.

ACKNOWLEDGEMENTS

The authors acknowledge the support provided by Mr. Antonio Alves Ferreira Júnior in measurement procedures and the financial support provided as a scholarship by the *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* – CAPES.

REFERENCES

[1] J. MITOLA, Cognitive Radio: An integrated agent architecture for software defined radio, Ph.D. dissertation, Royal Institute of Technology (KTH), Stockholm, Sweden, 2000.

[2] N. COHEN, Fractal antennas and fractal resonators, US Patent n. 6 452 553. Issued September 2002.

[3] C. PUENTE, J. ROMEU, R. POUS, X. GARCIA, F. BENITEZ, Fractal multiband antenna based on the Sierpinski gasket, *Electronics Letters*, vol. 32, n. 1, pp. 1–2, January 1996.

[4] Pertech do Brasil. Linha Epoxy: Folha de dados TG 150ºC. Available on : http://www.pertech.com.br/download/boletimtecnico/folha_de_dados_tg 150_fr4.pdf Access on: 02 March 2012.

[5] R. O. MATOS, J. A. J. RIBEIRO, Antena multibanda utilizando geometria fractal de Sierpinski, Proceeding of MOMAG 2012, João Pessoa, PB., August 2012.

[6] J. YEO, R. MITTRA, Modified Sierpinski Gasket Patch Antenna for Multiband Applications, Proceeding of Antennas and Propagation Society International Symposium, vol. 3, pp. 134-137, 2001.

[7] Ansys HFSS, version 14.0, Ansys Corporation, Pittsburgh, PA.

[8] D. C. NASCIMENTO, J. C. S. LACAVA, (2011). Design of Low-Cost Probe-Fed Microstrip Antennas In: NASIMUDDIN, N. Ed Microstrip Antennas. ISBN: 978-953-307-247-0, InTech.

Available on: http://www.intechopen.com/books/microstrip-antennas/design-of-low-cost-probe-fed-microstrip-antennas

Access on: 15 August 2012.