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Design and implementation patch antenna with different fractal shape

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Abstract. This work presents the effect of fractal shapes on the patch antenna. It is a conventional rectangular patch antenna with dimension of 9.2 mm x 6.94 mm. It is implemented on FR-4 lossy substrate material with relative permittivity of εr = 4.3, thickness of 1.6 mm and loss tangent of 0.025. It is feed through a microstrip line with dimension of 6 mm x 3.11 mm. The overall dimension of the antenna is 35 mm x 30 mm x 1.6 mm. It operates over a frequency band from 8 GHz to 12 GHz with central frequency 10 GHz. Application of Pythagorean tree Sierpinski gasket, and Koch curve is to decrease the bandwidth and increase the gain of the designed antenna. The performance properties of the antenna such as resonant frequency, radiation pattern, and gain were examined by simulation. The design is implemented through CST microwave studio and measured through network analyser.

1. Introduction

Antenna makes possible communication between two or more stations by sending or receiving signals from stations in wireless communication. There are different types of antennas but patch antennas are chosen due to low profile and simple manufacturability. Patch antennas are low profile, conformable to planar and non-planar surfaces, simple and inexpensive to manufacture using modern printed-circuit technology, mechanically robust when mounted on rigid surfaces, compatible with Monolithic Microwave Integrated Circuits (MMIC) designs, and when the particular patch shape and mode are selected, they are adaptable regarding resonant frequency, polarization, pattern, and impedance. Furthermore, through adding loads between the patch and the ground plane, adaptive elements with varying resonant frequency, impedance, polarization, and pattern could be designed.

Main performance disadvantage of microstrip antennas are their low efficiency, low power, high Q (sometimes in excess of 100), poor polarization purity, poor scan performance, spurious feed radiation and very narrow frequency bandwidth. Although there are methods to increase the height of the substrate to increase the efficiency and the bandwidth, surface waves extract the power available [1-4]. In this paper, a microstrip feed patch antenna is designed at 10 GHz and 5GHz. The effect of fractal shapes is presented.

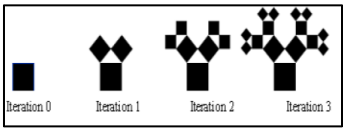


Figure 1 Fractal Shape Proposed

2. Microstrip Feeding

The most common methods of analysis are transmission line, cavity, and full wave. Transmission line model is used in which a conducting strip is connected directly to the edge of the microstrip patch. The conducting strip is slighter in width as compared to the patch. Transmission line method is simple, easy, and gives good insight, but not accurate and more difficult to model coupling.

3. Fractal Shapes

There are various types of fractal shapes but in this paper Pythagorean tree, Sierpinski gasket, and Koch curve are used. In Pythagorean tree, square patches only are used. In Sierpinski Gasket, triangular shape only used for cutting and filling patch with different various dimensions. In Koch curve, line segment keeps divided into four equal length line segments [5-8].

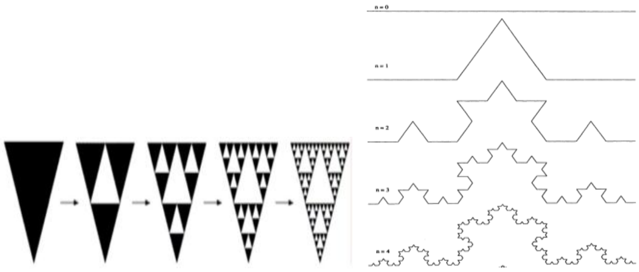


Figure 2 Pythagorean tree, Sierpinski gasket, and Koch curve

4. Antenna Design

4.1 Design

The conventional patch antenna is designed using FR4 substrate with dimension 35mm x 30 mm and its relative permittivity of 4.3, loss tangent of 0.0025 and thickness 1.6 mm. The overall dimension of the antenna is 35 x 30 x 1.6 mm. the feeding line dimensions are 6 mm x 3.11 mm. The patch dimensions are 6.94 mm x 9.2 mm. the patch cuts dimensions are 2.3 mm x 0.4 mm as shown in figure 3.

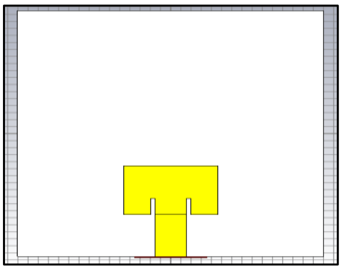
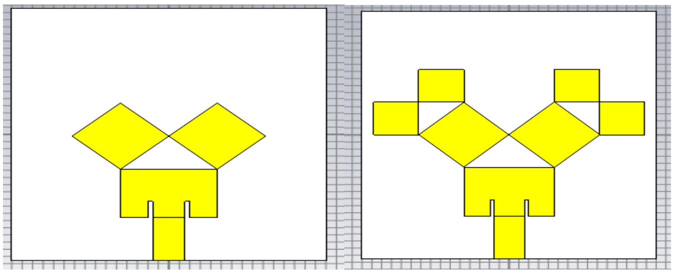


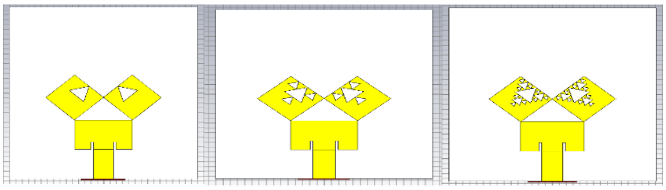
Figure 3 Conventional patch antenna

Figure 4 shows the Pythagorean iteration applied on the conventional patch antenna. The patch dimensions in figure 4a are 6.66 mm x 9.2 mm and the new squares lengths is 6.505 mm. In figure 4b the patch dimension are 6.94 mm x 9.2 mm and the four new square lengths is 4.6 mm.

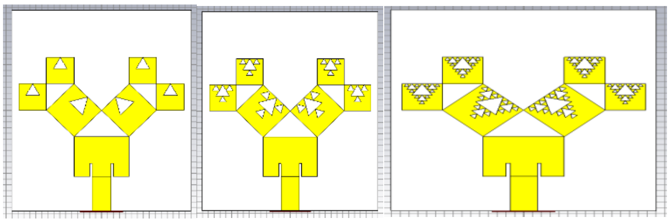


(a) (b)

Figure 4 Pythagorean first and second iteration applied on the conventional patch
(a) First iteration Pythagorean (b) Second iteration Pythagorean



(a) (b) (c)



(d) (e) (f)

Figure 5 shows the Sierpinski gasket iterations applied on the Pythagorean iterations

In figure 5a, figure 5b, and figure 5c the patch length equals to 6 mm and the patch cuts length equals to 1.8 mm, while in figure 5d, figure 5e, and figure 5f the patch length equals to 6.94 mm and the patch cuts length equals to 2.3 mm.

Moreover, another configuration is illustrated in figure 6 which represents the Koch curve on the conventional patch. The patch length equals to 5.65 mm and the patch cuts length equals to 1.2 mm.

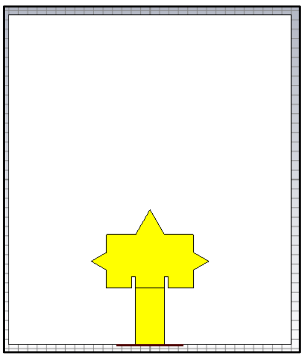


Figure 6 Conventional patch with Koch on the sides

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4.2 Results

Concerning the conventional patch antenna, the simulated return loss results are illustrated in figure 7. It is clear that the bandwidth equals to 671 MHz with a gain of 3.45 dB. Furth more, the return loss of first and second Pythagorean iterations is shown in figure 8.

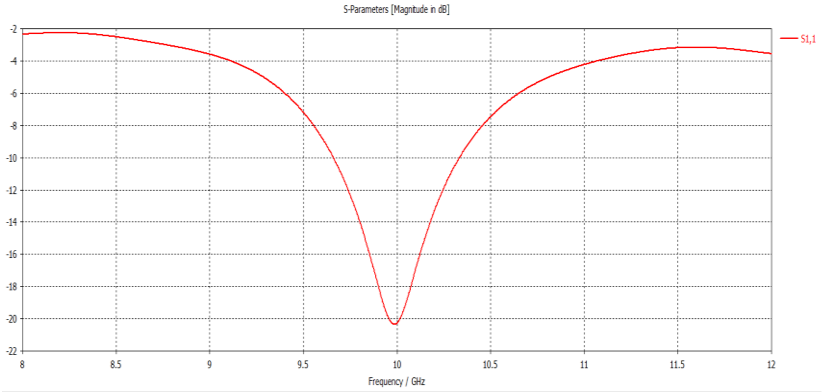

Figure 7 Return loss of the conventional patch

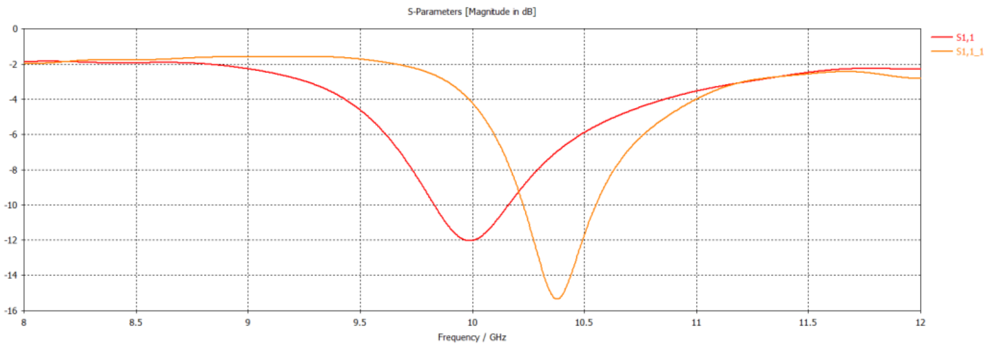

Figure 8 return loss of first and second Pythagorean iterations, the red is iteration one and the orange is iteration two

The return loss of first Pythagorean iteration equals to -12 dB while the second Pythagorean iteration equals to -20.3 dB.

The bandwidth of iteration one equals to 336 MHz and iteration two equals to 331 MHz. The gain equals to 5dB and 3.02 dB respectively. Figure 9 shows the return loss of three Sierpinski iterations on the first Pythagorean iteration.

The return loss of second and third Sierpinski equals to -11.6 dB, while the first iteration's return loss equals to – 13.85 dB. The gain values respectively are 4.8 dB, 4.7 dB, and 4.7 dB.

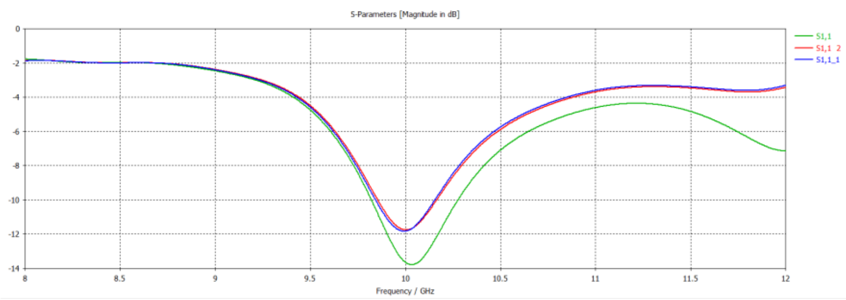

Figure 9 return loss of first, second, third iteration Sierpinski on first iteration Pythagorean

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The return loss of first, second, third of Sierpinski applied on the second iteration Pythagorean equals to – 15.8 dB with bandwidth of 320MHz and gain value of 2.9 dB, 2.8 dB and 2.66 dB respectively as shown in figure 10.

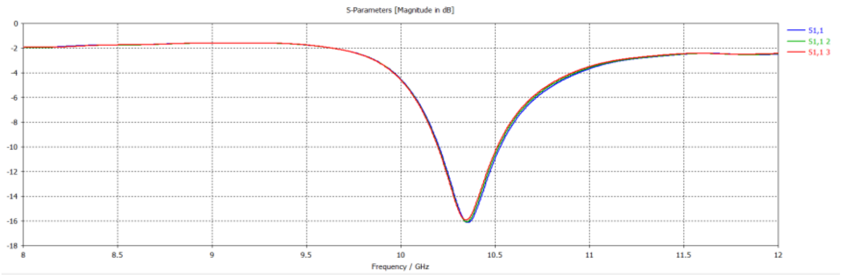


Figure 10 return loss of first, second, third of Sierpinski applied on the second iteration Pythagorean

Finally, Koch curve is applied on the sides of the conventional patch which gives a return loss of -15.68 dB, a bandwidth of 632 MHz and a gain of 2.7 dB as shown in figure 11.

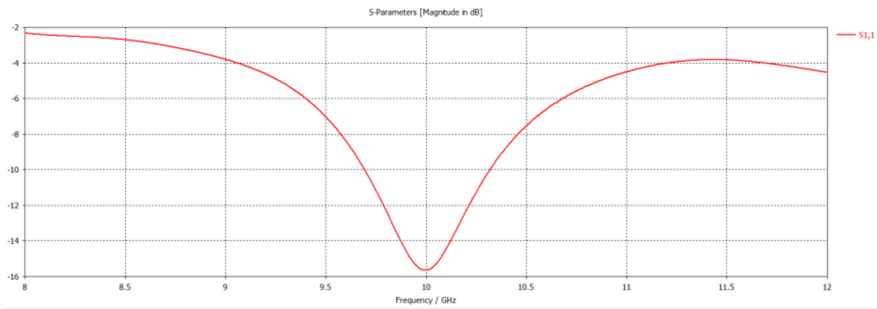
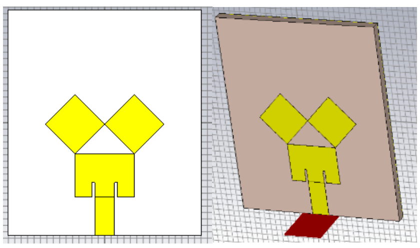


Figure 11 return loss of conventional patch with Koch on sides

For the sake of measurements, first iteration Pythagorean antenna is simulated as shown in figure 12 and measured using network analyzer. The simulated and measured return loss is illustrated in figure 13. The radiation pattern is shown in figure 14. The fabricated antenna is shown in figure 15. The surface current is illustrated in the following figure 16.



(a) (b)

Figure 12 Top and Perspective View of first iteration Pythagorean antenna designed on CST.

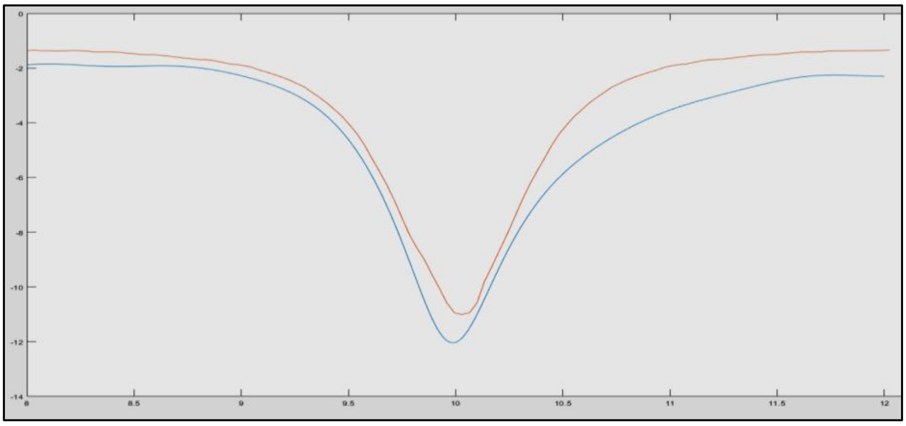


Figure 13 simulated and measured return loss

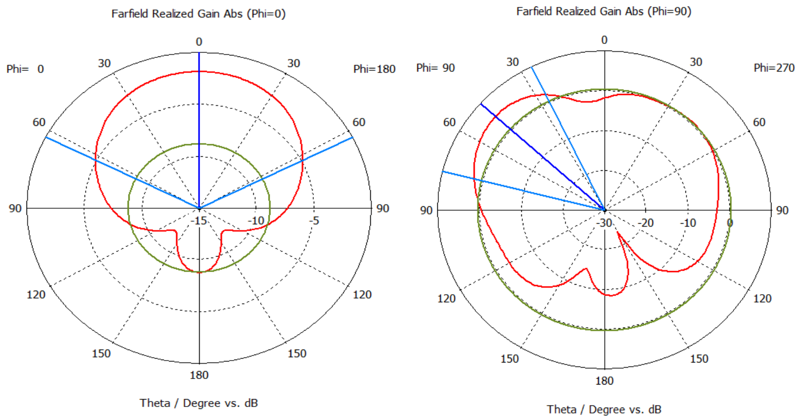


Figure 14 2D radiation pattern of first iteration Pythagorean at resonant frequency of 10 GHz

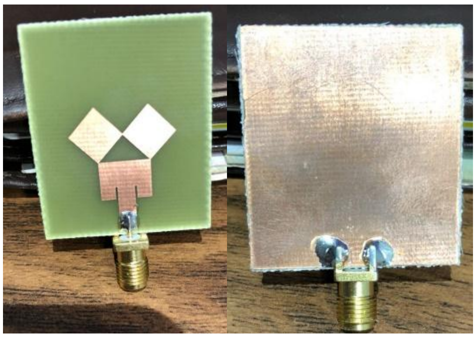


Figure 15 fabricated antenna

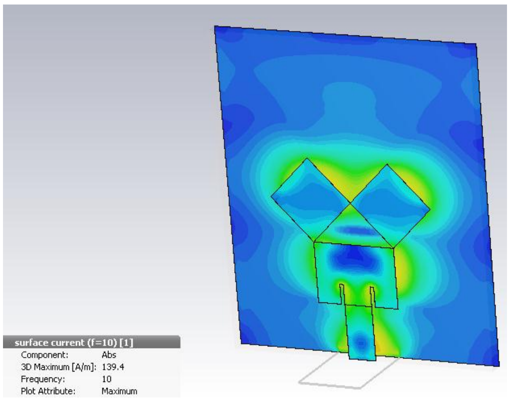


Figure 16 surface current at frequency 10 GHz

5. Conclusion

Patch antenna is presented showing its structure, features, manufacturing, applications and implementation using CST. It includes design of conventional patch antenna using FR4 substrate of relative permittivity 4.3, loss tangent 0.0025 and substrate thickness of 1.6 mm which conducted bandwidth of 0.675 GHz and gain of 3.45 dB at 10 GHz. Applying the Pythagorean first iteration to the conventional patch exhibits high gain of 5dB and lower bandwidth of 0.336 GHz which is fabricated and measured using network analyzer. The paper has 9 designs using fractals and simulated using CST. One notices an agreement between the simulated and the fabricated results. The Sierpinski gasket iterations added to the first Iteration Pythagorean tree exhibits lower bandwidth only. Furth more, Sierpinski gasket iterations are applied on the second iteration of the Pythagorean tree and resulted in lower gain, lower bandwidth, and lower beam width.

6. References

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