Bachelor-Arbeit

Thema: “The Development of a Sierpinski Carpet Antenna with Different Feeding Methods“

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Studiengang: Elektrotechnik und Informationstechnik

Fachrichtung: Automatisierungstechnik

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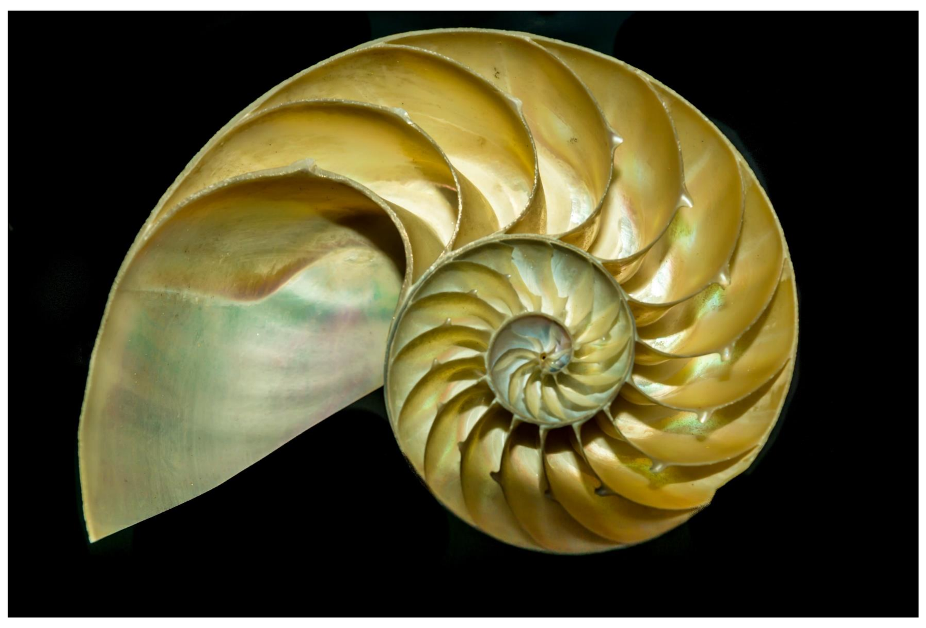
Task

The purpose of this research is to develop a multiband antenna by using fractal geometry and find the most suitable feeding method for it. The Sierpinski carpet antenna is basically a patch antenna with a fractal geometric structure. Fractals allow the antenna to assume different dimensions within it’s original structure. The fractal form can be made through iterating self-similar patterns in the same structure. This creates different dimensions in the structure which can allow the antenna, when assuming a fractal form, to be resonant on these new dimensions. Each iteration creates a similar patch smaller than the original shape by a factor of 3 , hence allowing it to be resonant on a frequency three times larger. The intended resonances are 0.8GHz, 2.4GHz and 7.2GHz. In order to achieve this, different feeding methods shall be tested for optimal performance using CST[1] Studio Suite.

About Fractal Geometry

According to Benoît Mandelbrot geometry is :”often described as cold and dry” [Mandelbrot, 1987]. Fractals are used to describe the best approximation of shapes that are found in nature. Through this self-similar iteration process it divides the shape, hence the use of the word fractal. Fractal antennas have been developed according to this concept. This makes them compact and multipurpose devices. Fractals are used as multiband or wide band antennas in several branches of nowadays microwave technologies.



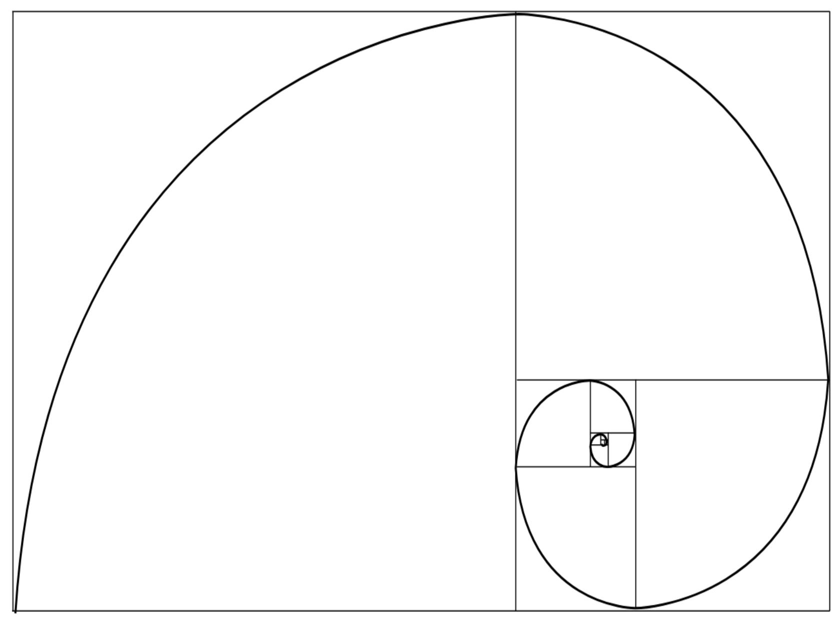


Figure 1: A nautilus shell found in nature (left), A representation of the Fibonacci sequence (right)

Study

The structure was developed to the second iteration level in order to be resonant on the three required frequencies. The main structure is a normal patch antenna with a length dimension equal to approximately the calculated half wave length of the lowest frequency amongst the desired three. $L = \frac{\lambda_{eff}}{2} - 2\Delta L$ where $\lambda_{eff} = \frac{\lambda_0}{\sqrt{\epsilon_{r,eff}}}$, [Kark, 2014], which is the wave length divided by the dynamic efficient permittivity of the substrate.

The different feeding methods that were tested are four: The thin microstrip feed, the direct coaxial cable feed, the aperture coupling method, and the coplanar waveguide feed. All three iteration levels of the carpet were simulated with each feeding method and the results were compared.

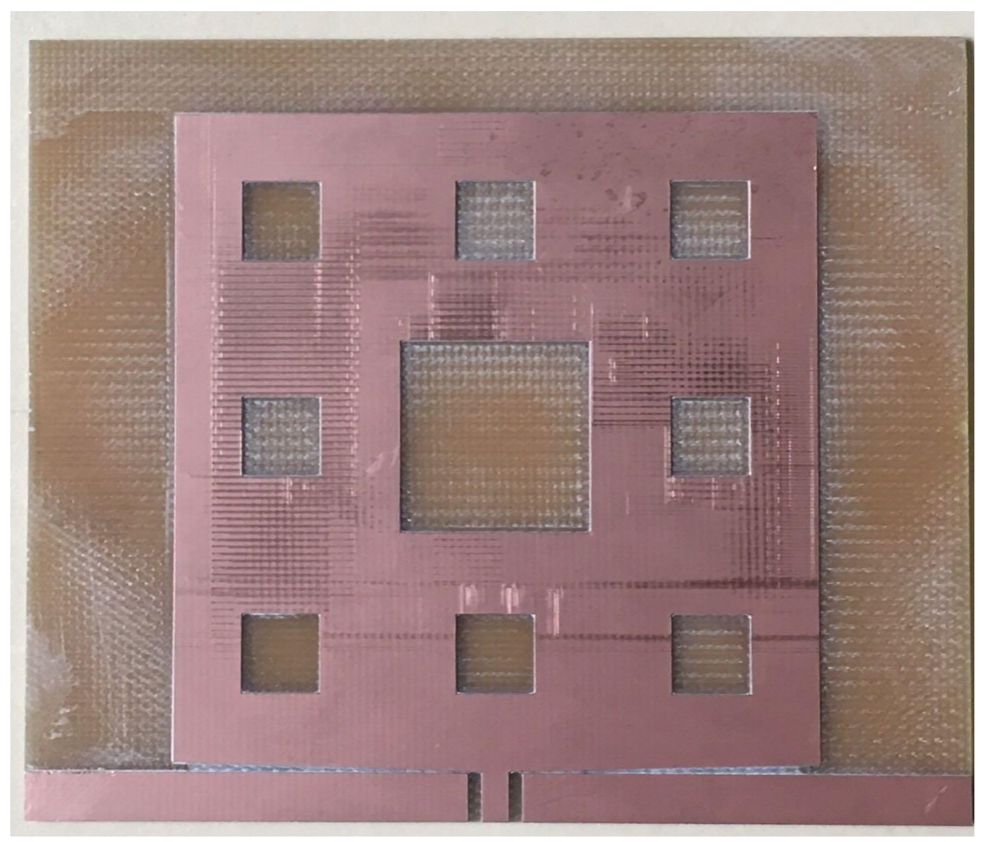


Figure 2: A manufactured Sierpisnki carpet to the 2nd iteration with coplarwaveguide feeding method

Conclusion

Due to the fixed surface area of the antenna, by trying to achieve higher frequencies while still satisfying the dimension conditions for all resonances. The Sierpinski carpet with an FR-4 substrate, has proven to be a lossy structure in this specific frequency range. The surface are of the Sierpinski carpet in relation to iteration level i, is as follows [Semaan, 2018]:

$$f(i) = a - \sum_{n=0}^{i} 8^n \left(\frac{a}{9^{n+1}}\right) \quad ; \quad \alpha = \frac{\omega}{c\sqrt{2}} \cdot \sqrt{\epsilon_r' \mu_r'} \cdot \sqrt{\sqrt{1 + tan\delta_d} - 1}$$

The other equation describes the power attenuation through a substrate. The area decreases with each iteration, however not as fast as the power attenuation, which is represented in Np/m. Therefore it has been found that with higher frequencies under the substrate and desired frequencies’ restraints, the power loss increases in a way that hinders resonance. The direct coaxial cable feed has proved to be the best feeding method and yielded the best results. That is fathomable because of the coaxial cable’s power preserving characteristics.

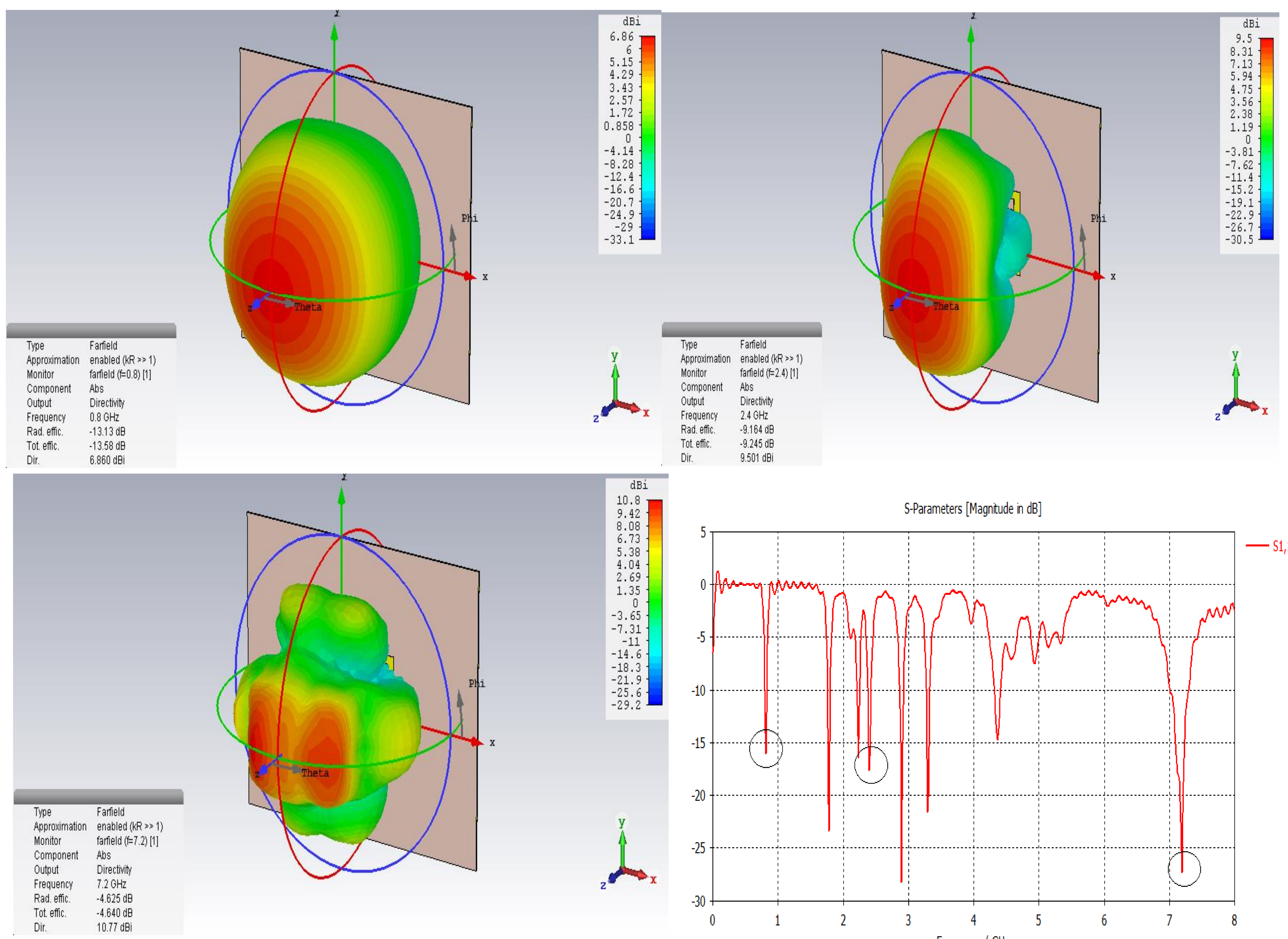


Figure 3: S11 parameters and 3D far field plots of the radiation pattern of a coaxially fed Sierpinski carpet at 0.8GHz, 2.4GHz, and 7.2GHz in it’s second iteration state

	Gain	FWHM (E-Plane)	FWHM (H-Plane)
0.8GHz	6.86 dBi	84.5 deg.	86.1 deg.
2.4GHz	9.5 dBi	71.1 deg.	53.2 deg.
7.2GHz	8.08 dBi	36.5 deg.	26.3 deg.

Figure 4: Gain and 3-dB width of coaxially fed Sierpinski carpet in 2nd iteration state

Notes:
[1]CST: Computer Simulation Technology

Quellen:
[Kark, 2014] Kark, K. W., 2014. *Antennen und Strahlungsfelder.* 5. Auflage Hrsg. s.l.:Vieweg+Teubner Verlag.
[Semaan, 2018] Semaan, A., 2018, The Development of a Sierpinski Carpet Antenna with Different Feeding Methods , HS Ravensburg-Weingarten.