Circularly Polarized Dual Band Fractal Antenna

Peter Petkov(1) and Ivaylo Nachev(2)

(1) Technical University of Sofia, Sofia, Bulgaria, https://www.tu-sofia.bg
(2) Technical University of Sofia, Sofia, Bulgaria, https://www.tu-sofia.bg

***Abstract*—This paper examines the possibility for the design of a market-oriented antenna with circular polarization. The advantages of the suggested structure are cost-efficiency and production simplicity compared to traditional thick, high-epsilon antennas. The contemplated antenna could potentially be integrated into dual-band Wi-Fi antennas.**

I. Introduction

The main engineering methods to achieve circular polarization are excitation of 2 modes in the printed resonator (H10 и H01). To achieve circular polarization in the design of classic printed antennas, one approach involves beveling two opposing edges. In case 1a, the length of the patch is equal to its width. In the far field a linear polarization will be formed, sloped at 45 degrees. To ensure a circular polarization it is essential to provide a phase shift of 90 deg between these two orthogonal modes. Using non-exact resonant length of the sidewalls ensures this shift, so the L size is a bit longer than the resonant length and the W size is a bit shorter. This nearly square geometry gives +45 and -45 deg phase shift of the resonant modes and guarantees circular polarization in the far field zone of the antenna [1].

In case 1b, the circular polarization is created by two orthogonal modes, excited in the diagonals of the square. This effect (and 90 deg phase shift) can be explained with the reduction of distributed capacity on both sides of radiating edges. The tapered diagonal is characterized by much more inductive impedance. With variation of the area of the cut ΔS, the ratio Ex/Ey can be adjusted [2].

II. Fractal Shapes

The use of a fractal structure is a basic way for reducing antenna size. Given the same frequency fractal antenna,size can be reduced up to less than 45% of the original size. On Fig1. a fractal Koch island form 0-th , fist andsecond order is presented. It is quite easy to see the change in the resonator size, with no change in the frequency.A reduction of 75% appears in fractals of second and third order. The second conclusion is that there is no sizeadvantage from using higher order fractals (Higher than first order) [2, 3].

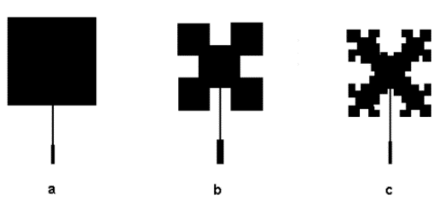

Fig. 1. Generation process of Koch Island.
(a, b, c – zero, first and second order)

Typical frequency response of VSWR of Koch Island is presented at Fig 3. Usually, there is a decrease in first resonant frequency of the patch and excitation of higher order resonances at upper frequencies. In practice there is no advantage in use of higher than second order fractal shapes, because of frequency overlapping or too narrow bandwidth or both. Usually typical frequency response of VSWR of Koch Island, there is a decrease in first resonant frequency of the patch and excitation of higher order resonances at upper frequencies. In practice there is no advantage in use of higher than second order fractal shapes, because of frequency overlapping or too narrow bandwidth or both. One significant drawback of employing fractal shapes is the reduction in bandwidth as the fractal order increases. This could pose a challenge in the specific application, as Wi-Fi signals are not sufficiently narrowband, and there is a concern that antenna properties may, in rare cases, impact system performance.

III. Results

To form a circular polarization in a fractal antenna, a higher order fractal is used for changing corner capacity. Actually, in that case the capacity increases, in spite of the trend described in the case on Fig. 2b. By changing the fractal order and fractal dimension the desired axial ratio can be achieved. The proposed model is investigated through ANSYS HFSS.

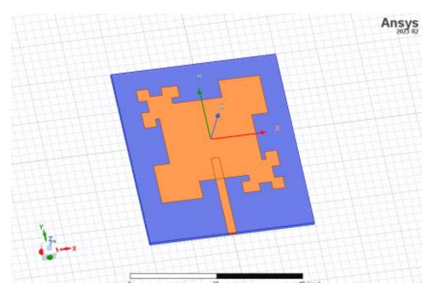

Fig. 2. Proposed design of Circular polarized fractal antenna.

The frequency response of proposed antenna design is displayed figures 3 and 4. As anticipated, there are two resonant frequencies, namely 2.4GHz and 5.8GHz. Within these resonant regions, the S11 parameter exhibits values indicative of the antenna's operational capability. Changing the fractal dimension it is possible to "fine-tune" the second resonant frequency to the desired value. A new resonant frequency can be achieved by increasing the order of fractalization. However experiments show that third and higher order resonances are not suitable for practical use – because of narrowband, poor matching and improper shape of the pattern.

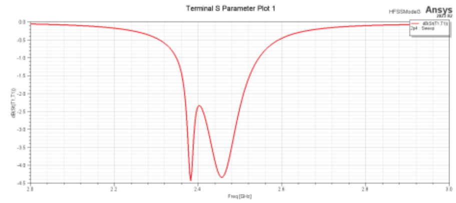

Fig. 3. S11 parameter of proposed antenna on 2.4GHz.

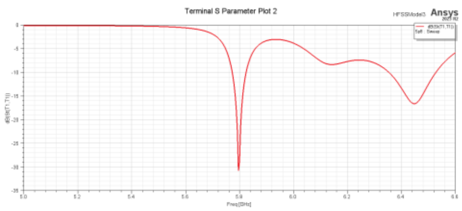

Fig. 4. S11 parameter of proposed antenna on 5.8GHz.

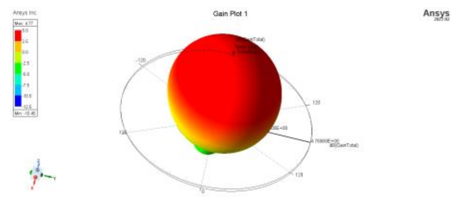

Fig. 5. Linear polarization RP at 2.4GHz.

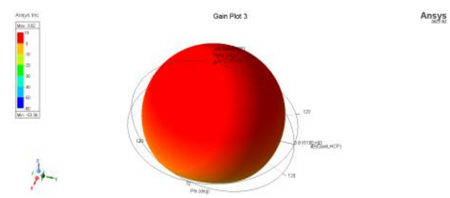

Fig. 6. LHCP RP at 2.4GHz.

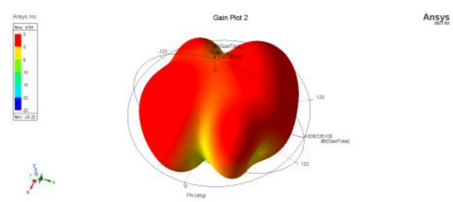

Fig. 7. Linear polarization RP at 5.8GHz.

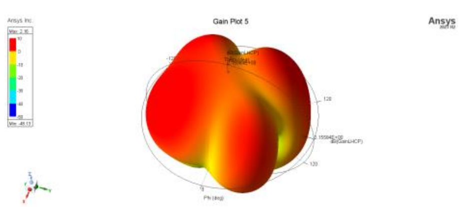

Fig. 8. LHCP RP at 5.8GHz.

In other words, the proposed structure gives opportunity to work on two different bands and with oppositecircular polarizations. Such a combination of properties is not typical of printed antennas and probably notachievable in other ways. Increase of axial component on the lower frequency is caused because of the change indistributed capacity, mentioned above. By varying the size of filled and fractalized corner squares, an acceptableaxial ratio can be achieved. However, this variation causes a change in the main resonant frequency. So fine-tuning of this antenna is a process that also includes a change of the antenna size. The fractalized squares perform as independent radiators with electrical size bigger than physical (because of fractal shape). The LHCP is caused by the phase shift, invoked by the difference in the length of the paths, from the microstrip feed. Aditional space shift is given by the orientation of fractal squares against the microstrip line. The combination of these two factors gives almost pure LHCP even on non-optimized and not tuned antenna. However this path differences gives a slope in the pattern (against normal axes), which is a significant disadvantage for antennas intended to work in mobile satellite communications. Optimization of pattern and polarization purity is a subject for

There are two additional advantages of the fractal structure. The direct result of applying of fractal shaping is size reduction (or resonant frequency, with the same antenna size). The analysis performed shows that usual patch antenna with size ot 22x22 mm (as proposed) has resonant frequency of 2.4 GHz. There is a 15% advantage as regards the antenna size. The second advantage is in the antenna efficiency. Other properties being equal (size 22x22 mm, $\varepsilon r = 3.55$, and substrate thickness = 1 mm) square patch will have efficiency of about 84%. The proposed design hasradiation efficiency of 98%.

IV. Conclusion

This paper introduces a possible design o the Koch island microstrip patch antenna. Fractal shape is used in order to reduce antenna size and maintain dielectric permittivity in reasonable range. This patch antenna has a lower resonant frequency compared to the zero-th iteration patch, and this property contributes to the reduction in antenna size. The main advantage of the proposed design is the possibility for operation on two different circular polarizations on two frequency bands. Additional benefits are the reduced size and improved radiation efficiency. All these features give this antenna the possibility for mass production from inexpensive substrates that are readily available on the market. The use of substrates with lower dielectric permittivity will also cause a decrease in fringing fields and edge leaking of surface waves. This antenna is intended mainly for the automotive industry.

Acknowledgment

This study is financed by the European Union-NextGenerationEU, through the National Recovery and Resilience Plan of the Republic of Bulgaria, project № BG-RRP-2.004-0005.

References

[1] Bancroft, Randy. "Microstrip and printed antenna design." (No Title) (2009)..

[2] Garg, R., et al. "Microstrip Design Antenna Handbook, Artech House." (2001).

[3] Bangi, Inkwinder Singh, and Jagtar Singh Sivia. "Minkowski and Hilbert curves based hybrid fractal antenna for wireless applications." AEU-International Journal of Electronics and Communications 85 (2018): 159-168.