IOCMA 2026 Conference
The 2nd International Online Conference on Mathematics and Applications
10–12 June 2026 | Online
MDPI

Analysis of Patch Fractal Antenna Design Using Mathematical Modelling

Irsal Djeroud, Habib khouni
Department of electronics, Faculty of technology, LIS Laboratory, Ferhat Abbas University, Setif 1, Algeria
djeroud.irsal@gmail.com

INTRODUCTION & AIM

Fractal antenna geometry can be understood through a mathematical modelling approach based on Iterated Function Systems (IFS). By applying repeated affine transformations, complex self-similar structures are generated from simple initial shapes. Each iteration increases geometric complexity and effectively extends the electrical length, resulting in the appearance of additional resonant frequencies and multiband behavior.

This work aims to demonstrate how recursion and IFS can be used as a systematic framework for generating antenna geometries and analyzing their impact on performance.

METHOD

- The proposed approach is based on the use of Iterated Function Systems (IFS) to generate fractal geometries and apply them to antenna design.

A set of affine transformations is defined by :

$$W(x) = \bigcup_{i=1}^{N} w_i(x) \qquad (1)$$

$$where: \quad w_i(x) = A_i x + b_i \qquad (2)$$

where Ai, represents scaling/rotation and bi, translation.

- **Generation of the Koch Curve**:
- geometry through iterative construction.

- Starting from a simple line segment, the IFS transformations are applied iteratively to obtain a self-similar fractal geometry.

- The Koch fractal geometry is generated through an iterative process, as shown in Figure 1. This geometry is then applied to the segments of a square patch antenna (Figure 2).

Along with the required translations, this yields the following IFS

$$f_1(\mathrm{x}) = \begin{bmatrix} 1/3 & 0 \\ 0 & 1/3 \end{bmatrix} \mathrm{x}$$ scale by **r**

$$f_2(\mathrm{x}) = \begin{bmatrix} 1/6 & -\sqrt{3}/6 \\ \sqrt{3}/6 & 1/6 \end{bmatrix} \mathrm{x} + \begin{bmatrix} 1/3 \\ 0 \end{bmatrix}$$ scale by **r**, rotate by 60°

$$f_3(\mathrm{x}) = \begin{bmatrix} 1/6 & \sqrt{3}/6 \\ -\sqrt{3}/6 & 1/6 \end{bmatrix} \mathrm{x} + \begin{bmatrix} 1/2 \\ \sqrt{3}/6 \end{bmatrix}$$ scale by **r**, rotate by −60°

Where: **r** = 1/3

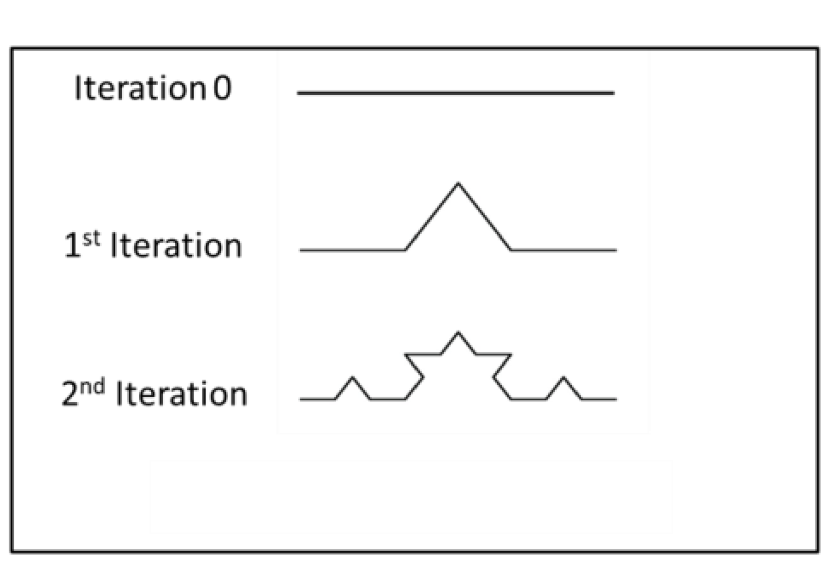

Figure 1: Generation of the Koch fractal geometry through iterative construction.

RESULTS & DISCUSSION

- A square patch antenna is considered as the initial geometry. The segments are modified using the Koch fractal rule, where each segment is recursively transformed using affine mappings

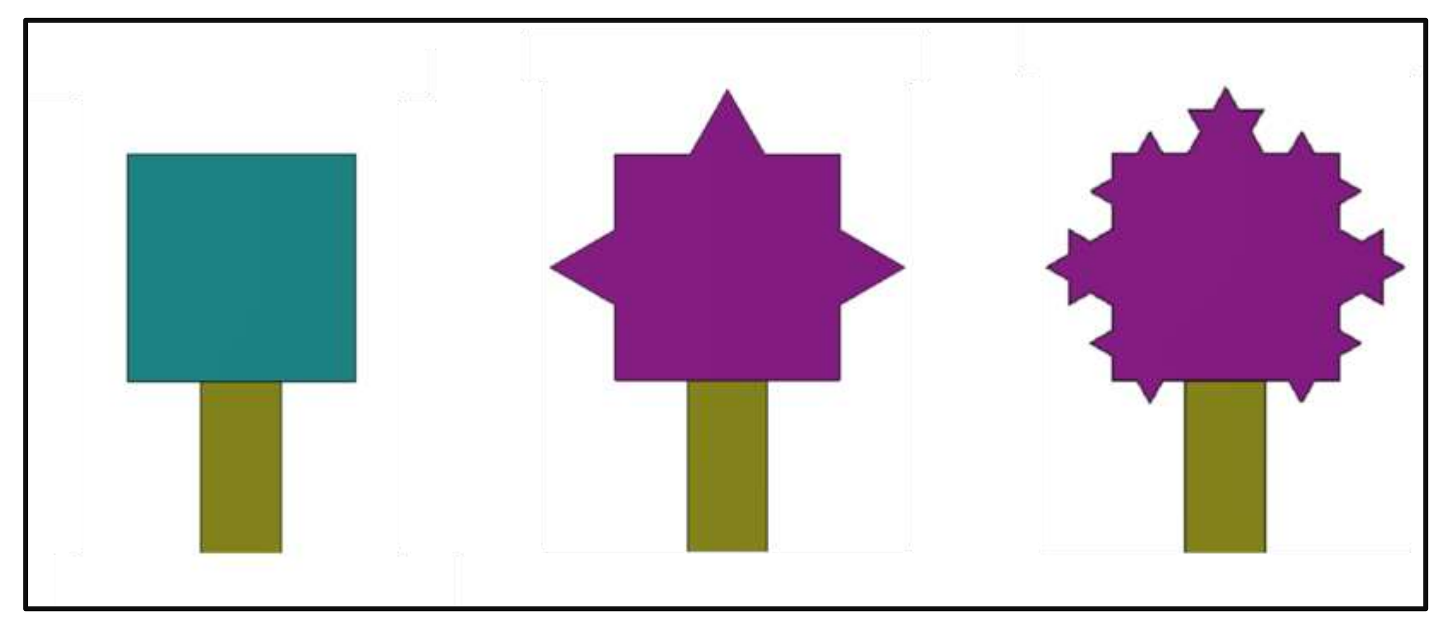

Figure 2: Application of the Koch fractal geometry to a square patch antenna, illustrating the modification for 2 iterations.

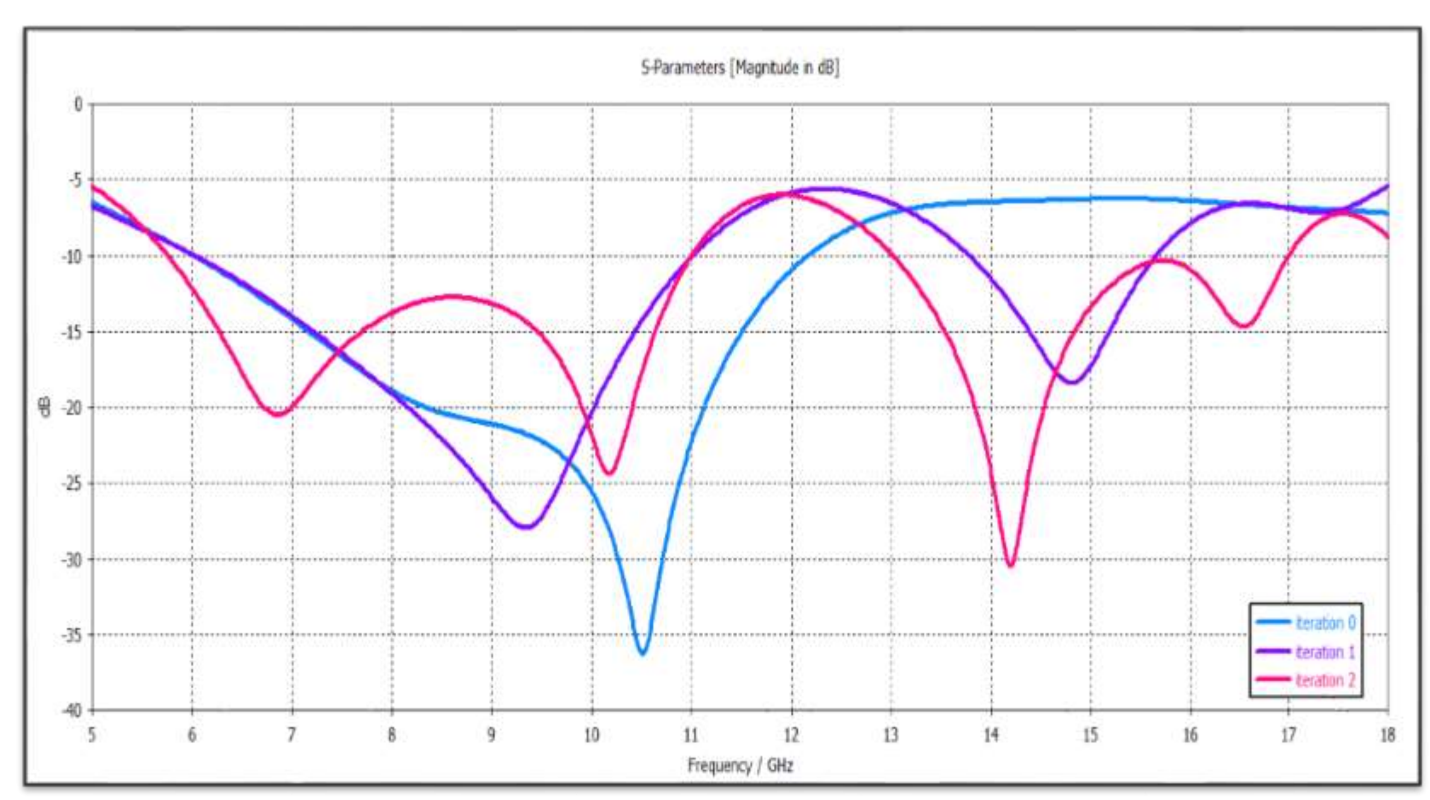

Figure 3: Simulated S_{11} parameter showing the effect of fractal edge modification on antenna performance.

- The simulated S_{11}, shows improved performance, with the emergence of new resonant frequency compared to the initial geometry and a wider bandwidth for the second iteration.

Using IFS, the Koch curve is generated through recursive transformations, increasing geometric complexity and electrical length, which directly impacts antenna performance by introducing new resonant frequencies for multiband communication applications.

CONCLUSION

The obtained results demonstrate that the **iteration order can be used as a design parameter**, allowing control over antenna characteristics through a mathematical approach.
The application of the Koch curve to a square patch antenna increases the electrical length without increasing its physical size, leading to **enhanced multiband performance**.

FUTURE WORK / REFERENCES

[1]. C. A. Balanis, Antenna Theory: Analysis and Design, 4th ed., Hoboken, NJ, USA: Wiley, 2016.

[2]. Long Y. Research on Flexible Antennas for Partial Discharge Monitoring of Transformers and Distributed Deep Learning Pattern Recognition. Chongqing University; Chongqing, China: 2023.

[3]. A. S. A. Jafar, M. A. Al-Hadi, and A. M. A. Shakoor, "Design and Optimization of a Dual-Band Microstrip Patch Antenna for Wireless Communication," in Proc. IEEE Int.Conf. on Antennas and Propagation (ICAP), 2021, pp. 129-133.