Design and simulation of microstrip fractal patch antenna

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Abstract. The proposed fractal antenna is designed to operate at the frequency of 7.23 GHz using an FR4 substrate of relative permittivity of εᵣ = 4.4. Different optimization techniques have been used, such as slots, use of meta-materials, fractal design, Feeding Techniques, to improve some antenna parameters. The resulting fractal design provides a gain of 10 dBi and a return loss of -19.8 dB which is about 90% of the input power radiated.

1. Introduction

Microstrip antennas, with their compact size, provide a wide range of advantages over many applications including Satellite Communication, GPS Systems, Mobile Communication, etc. There are many ways to optimize the design of the microstrip patch to obtain the desired results for an application. One of the optimization techniques, this paper concentrate is Fractal Geometry.

The Fractal Design of the microstrip patch brings the space-filling factor into account to give better improvements such as multi-band applications, better radiation pattern, and good bandwidth.

In this paper, we proposed an antenna with fractal design and meta-materials to obtain a gain of 10 dBi and a return loss of -19.8 dB.

2. Description of the proposed fractal design

The paper [1] presents a comparison between three basic designs like circle, rectangular, and triangle. By observing the results of the paper, all these three designs show different advantages. Triangular patch has good gain, Rectangular patch shows good return loss and circular patch gives better directivity. So, we desired to design an antenna with all three designs, and we came up with the resulted design.

It includes a triangle on top of a rectangle, and both combined to circle. This is taken as one branch. The proposed design consists of 6 of these branches rotated at an angle of 60 degrees. This is the basic design of the proposed design or iteration 1 of the fractal geometry of the proposed design. This basic design is symmetric along any given branch.

A study is conducted on optimization techniques to further improve the simulated results.
These techniques include feeding techniques, the inclusion of slots, and the use of meta-materials. The use of fractal geometry is one of the optimization techniques.

Both Microstrip line feeding technique and co-axial feeding technique is implemented. But for a fractal design where fractal geometry is to be retained, the use of microstrip line feed is not very efficient. So, the proposed design used a co-axial feeding technique. The probe is placed on the y-axis on the patch and kept modifying as fractal geometry proceeds. For basic design, the co-axial probe is placed at 15mm from the center.

After obtaining acceptable design parameters and simulated results of iteration1 of the proposed design, we precede iteration 2 part of the design.

All these optimization techniques are implemented, and the designs are compared in the table shown in the conclusion. The patch is contained in a rectangle of dimensions 32 mm × 32 mm. The thickness of the substrate is chosen as 4.2mm. As the fractal design proceeds to the next iteration, there is only a small change in the increase in patch dimension, but the design complication increases. This makes the proposed design compact. The scaling for fractal geometry is chosen as ¼. Fractal design is implemented such as each branch of the basic design will further have part of the basic design. Only part is considered to ensure overlap complications in the design.

The design used Square Split Ring Resonators (SRR) as meta-material cells. Each SRR has 2 rings with a gap of 0.5 mm. The dimension of the outer ring is taken as λ /23. The figure included below shows SRR’s of bigger size to show that SRR’s are used. It is only indicative and the dimension of SRR is smaller. Each cell is replicated and placed at different areas on the substrate to modify the design and check its results. 4 cells are combined as one block. In the proposed design 4 such blocks are placed at 4 corners. Further for future work, we can improve the number of rings in SRR and even the shape of SRR. The final proposed design is shown below.

![Proposed Fractal Design](image)

**Figure 1.** Proposed Fractal Design

### 3. Simulated Results

The proposed fractal design is simulated in FEKO software. FEKO provides different analytic methods to simulate our design. We used the default method that is the Method of Moments (MOM).
There are two designs which gave desired acceptable results upon simulation. One is iteration 1 of the proposed fractal design and the other is the proposed design. Both the designs and their simulated results are explained below.

### 3.1 Basic Design with SRR
This is the basic design or iteration 1 of the proposed design. 6 Square SRR’s are used as shown in Figure 2. There is a co-axial probe towards y-axis with position as mentioned in the Section 2.

![Figure 2. Basic Design with SRR](image)

Figure 3. Polar Plot of Basic Design with SRR

The simulated results – polar plot, return loss vs. frequency graphs are shown in Figure 3 and 4. The polar plot of radiation pattern is at a frequency of 7.45 GHz. The Half-power beam width (HPBW) is around 96.6053 deg. The graph is directive with no side lobes.

![Figure 4. Return Loss vs Frequency graph](image)

An observation can be made to find the operating frequency at 7.45 GHz with -10 dB Bandwidth as 0.47 GHz.

### 3.2 Fractal Design with SRR
The design of this model is shown in Figure 1. In Figure 5, a polar plot of the proposed fractal design can be seen. It has an HPBW of 93.4436 deg.
The return loss vs. frequency graph for the proposed design is as shown in Figure 6. The -3dB bandwidth is about 0.981 GHz. The frequency of operation is around 7.23 GHz.

Theoretical modeling is done by CST Studio Suite. The parameters of the feeding network are tuned to achieve the desired characteristics. The simulated results show a good agreement with the theoretical predictions. The return loss is better than -10 dB in the frequency range of interest. The gain is around 6.98 dBi, which is suitable for most applications.

Table 1. Simulated designs and their results

| Design Modification                        | Gain (dBi) | Return Loss (dB) | Frequency (GHz) |
|-------------------------------------------|------------|------------------|-----------------|
| Microstrip Line Feed                      | 6.98       | -11.7            | 8.625           |
| Co-axial Feed towards y-axis             | 8          | -13.7            | 8.96            |
| Star shaped with meta material           | 9          | -12              | 7.45            |
| Fractal design iteration 2 with meta-material SRR | 10         | -19.8            | 7.23            |
| Fractal design iteration 2 with slots included and meta-material SRR | 9          | -8.83            | 7.28            |
4. Conclusion

The proposed antenna includes fractal design and meta-materials to provide desired improvements. Gain of -10 dBi and Return loss of -19.8 is observed with simulated results. Also, the radiation pattern has directional pattern. This antenna operates at a frequency of 7.23 GHz. Therefore, antenna is efficient, directive and compact. Further improvement can be done with increasing the iteration of fractal design. The design can be fabricated and practically tested to compare practical and simulated results.

5. References

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