A Cantor based Prefractal Multiband Antenna

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Abstract—This paper proposes a design of new fractal monopole antenna using Cantor bar fractal geometry. The antenna exhibits multiband characteristics with reduction in dimension compared to traditional Sierpinski fractal antenna.

Index Terms— Fractal antenna, Cantor bar, multiband antenna.

I. INTRODUCTION

The emergence of global wireless communication standards has induced a rapid technological push towards the development of miniaturized multiband antennas. Fractal antennas with multiband characteristics have been reported in the literature [1]-[4]. Sierpinski monopole, Hilbert curve dipole, Koch monopole, Minkowski patch are some of the popular fractal antennas [5]-[6].

Recently, Cantor set based Fractal array antennas have been studied and found to possess multiband characteristics with lower side lobe level [7]-[8]. This paper presents the design of a monopole antenna using Triadic Cantor bar fractal geometry for multiband applications.

II. CANTOR FRACTAL MONOPOLE ANTENNA DESIGN

A. Cantor fractal geometry

A geometric triadic Cantor bar can be generated from a bar of length \( L \) (initiator) by repeatedly removing the middle \( L/R \) of each existing bar.

\[
D^{(M)} = L \left( \frac{R - 1}{2 R} \right)^M
\]  
(1)

At the \( M \)th step of growth, \( 2^M - 1 \) new gaps are generated whose lengths \( d^{(M)} \) are

\[
d^{(M)} = \frac{2 L}{R - 1} \left( \frac{R - 1}{2 R} \right)^M
\]  
(2)
B. Antenna Design

The geometry of the proposed antenna is based on the Cantor bar fractal geometry. First the initiator (K0) is considered as a radiator of length 19mm and height 2.3mm. Then the successive iterated Cantor segments are grown on the initiator to get the different stages (K1, K2 and K3) of antenna. Fig. 2 shows the Cantor fractal antenna at different stages with the dimension. In this design, the initiator monopole antenna has a vertical strip as feedline and a symmetric horizontal strip on the top of the substrate. This operates as quarter-wavelength radiator which resonates at 7.2 GHz [9]. In successive iteration of the Cantor bar fractal antenna, the structure grows vertically with different width as shown in Fig. 2. This results in lengthening of path current resulting in a reduction of resonant frequency. The self similar property of the prefractal Cantor bar structure makes it a multiband antenna. A small triangular conductor section has been added in to the vertical feed line to improve the impedance matching.

II. EXPERIMENTAL CHARACTERIZATION

The dimension and the prototype of the prefractal Cantor monopole antenna are shown in Fig. 3. The antenna is printed on the front of an inexpensive FR4 substrate with a thickness of 1.6mm and a relative permittivity of 4.4 and loss tangent of 0.0027. A finite ground plane of dimension 23.3mm × 41mm has been used. The feed line is positioned symmetric to the radiator. The ground plane is away from the radiator by a small gap of 1mm. The overall height of the prefractal antenna is 9.2mm.

Fig. 3. Prefractal Triadic Cantor fractal monopole antenna (a) Geometry and dimension of antenna (b) prototype

Fig.4. Return loss of the Cantor fractal monopole antenna at different iterations K0, K1 K2 and K3

The Cantor fractal antenna is simulated at different stages using ADS momentum, and a prototype of the third iterated Cantor antenna is constructed and tested. Fig. 4 shows the simulated return loss of the Cantor fractal monopole antenna at different stages K0, K1, K2 and K3.
The initiator monopole antenna shows strong resonance at 7.2GHz. It also exhibits small resonances at lower frequencies because the dimension of the antenna is small relative to wavelength. As fractal iteration increases, the resonance frequency is further lowered and the fractal iteration leads to stronger multiband resonances. Fig.5 shows the comparison of simulated and measured return loss of the third iterated Cantor fractal antenna.

Fig.5. Measured Return loss of the Third iterated Cantor monopole

![Graph showing the comparison of simulated and measured return loss](image)

Details of the resonant frequencies with return loss better than -10dB are given in Table 1. The simulated value of return loss for the first iteration Cantor antenna is -11dB at 7.1GHz and around -13dB at the operating frequency of 5.6GHz with maximum bandwidth of 200MHz. For the second iterated Cantor antenna, the measured return loss is about -13.5 dB at the operating frequency of 7GHz, -15 dB at 5.5GHz, -11dB at 3.75GHz and -11dB at 2.15GHz. The maximum bandwidth of 300MHz is obtained at 5.5GHz. The third iterated antenna shows strong resonances at 6.9, 5.5, 3.8, and 2.1GHz with the return loss greater than -12dB.

Frequencies of each resonance band of the prefractal antenna with return loss better than -10dB can be estimated from [10],

\[
f_n = \frac{c \times 0.24}{h} \left( \frac{1}{\delta^n} \right)
\]

where \( c \) is the speed of light in vacuum, \( h \) is the height of the largest finger of the monopole, \( n \) a natural number and \( \delta \) is the scale factor equal to 1.6 for this structure.

The radiation patterns for the third iterated Cantor antenna as shown in Fig.6 are obtained experimentally at four resonant frequencies 2.1GHz, 3.8GHz, 5.5GHz and 6.9GHz respectively in both Z-X and X-Y planes. The pattern exhibits similarity in Z-X plane throughout the operating band and the configuration proves omni directional radiation in X-Y plane.

### III. CONCLUSION

A compact monopole antenna has been designed using Cantor bar based fractal structure and tested experimentally. The Cantor based monopole antenna provides a significant size reduction relative to the traditional Sierpinski gasket antenna. With a miniature size and functions of multiband operations, the proposed antenna can be applied to wireless communications.

<table>
<thead>
<tr>
<th>n</th>
<th>K1</th>
<th>K2</th>
<th>K3</th>
</tr>
</thead>
<tbody>
<tr>
<td>( f_n ) (GHz)</td>
<td>( S_{11} ) (dB)</td>
<td>BW (MHz)</td>
<td>( f_n ) (GHz)</td>
</tr>
<tr>
<td>1</td>
<td>7.1</td>
<td>-11</td>
<td>50</td>
</tr>
<tr>
<td>2</td>
<td>5.8</td>
<td>-13</td>
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<td>3</td>
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<td>100</td>
</tr>
<tr>
<td>4</td>
<td>2.15</td>
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<td>100</td>
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REFERENCES


Fig. 6. Measured radiation patterns of prefractal Cantor monopole antenna at 2.1GHz, 3.8GHz, 5.5GHz and 6.9GHz respectively in Z-X plane and X-Y plane, where \( \theta \), \( \varphi \) are standard polar coordinates (E\( \theta \) co pol, E\( \varphi \) cross pol)