CHAPTER 4

A CANTOR BASED PREFRACTAL TRIBAND ANTENNA

4.1 INTRODUCTION

The rapid growth of wireless technology demands integrated components including antennas. Dual-band and triband antennas with small physical size and good performance are nearing challenge to meet the needs of integration, cost and efficiency of the emerging wireless world. The major part of the literature dealing with compact antennas for multiband operation is based on planar inverted F antenna (Garg et al 2001). The reasons that made this configuration popular for wireless applications are its increased bandwidth relative to a microstrip antenna and its small size that can be achieved by capacitive loading (Rowell and Murch 1997). However, its higher cost and difficulty in manufacturing relative to a printed antenna make the field of multifrequency antennas for wireless applications an open challenge. One of the solutions in fulfilling the requirement of multiband behaviour is the use of fractal geometries in the design of compact antennas (Puente et al 1996b, Vinoy et al 2001, Werner and Ganguly 2003).

Cantor set is one of the widely studied fractal geometry for antenna array applications due to its simplicity and compactness. So far, Cantor set geometries has been investigated for fractal array configuration such as Cantor linear array, target aperture arrays and random arrays (Kim and Jaggard 1986, Jaggard and Spielman 1992, Jaggard and Jaggard 1998). Cantor ring arrays based on polyadic Cantor set have been found to posses sub-fractal, fractal and super-fractal radiation regimes which have a tight

In this chapter, Cantor set fractal is proposed in the design of miniaturized printed monopole antenna. Various types of Cantor antenna such Triadic, Pentadic and non uniform Cantor fractal antenna are also examined for their multiband performance.

4.2 CANTOR FRACTAL GEOMETRY

Cantor fractal geometry was first proposed by Georg Cantor (1883). A Cantor set is best characterized by describing its generation (Addison 1997). A geometric triadic cantor bar can be generated from a bar of length \( L \) (initiator) into \( R \) number of segments by repeatedly removing the middle \( L/R \) of each existing bar. Each part of the bar layers at a given stage of growth, when magnified, appears as the set in the previous stage. Any arbitrary cascaded removal of portions of the bar may also form a repetitive structure. Prefractal triadic cantor bars at different stages of growth are shown in Figure 4.1.

![Cantor bar fractal structure](image)

**Figure 4.1** Cantor bar fractal structure (a) Initiator K0 (b) First iteration K1 (c) Second iteration K2 (d) Third iteration K3
At $M^{th}$ stage, the prefractal consists of $2^M$ segments having the same length $D^{(M)}$ where

$$D^{(M)} = L \left( \frac{R-1}{2R} \right)^M$$  \hspace{1cm} (4.1)

where $L$ is the length of the initiator bar and $R$ is the number of segments generated in each fractal iteration.

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

$$d^{(M)} = \frac{2L}{R-1} \left( \frac{R-1}{2R} \right)^M$$  \hspace{1cm} (4.2)

Affine transformations, of which similarity transformations form a convenient sub-class, are important characteristics of fractal geometries. These involve scaling, rotation and translation.

These transformations ($w_i$) on the points $(x_i, x_2)$ can be expressed in the mathematical form as:

$$w_i \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} a_i \cos \theta & b_i \cos \varphi \\ c_i \cos \theta & d_i \cos \varphi \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} e_i \\ f_i \end{bmatrix}$$  \hspace{1cm} (4.3)

where, $a_i$, $b_i$, $c_i$ and $d_i$, are scale factors, $\theta$ and $\varphi$ correspond to rotation angles and $e_i$ and $f_i$ are translations involved in the transformation. If the scale factors are reduction or magnifications coefficients, then the transformation yields *self-affine* structure. If the scale factors are equal and $\theta = \varphi$, the transformation yields *self-similar* structure.
The Iterated function system (IFS) coefficients for the generation of Cantor set as shown in Figure 4.1 are given in Table 4.1.

Table 4.1  IFS transformation coefficients for Cantor set fractal

<table>
<thead>
<tr>
<th>wi</th>
<th>ai</th>
<th>bi</th>
<th>ci</th>
<th>di</th>
<th>ei</th>
<th>fi</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
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<td>0</td>
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<td>1</td>
<td>0.6</td>
<td>0</td>
</tr>
</tbody>
</table>

4.3  TRIADIC CANTOR MONOPOLE ANTENNA

A monopole configuration is attractive for wireless communication applications because of its wide band characteristics (Agrawall et al 1998). Hence in the present work, a printed monopole is considered for Cantor fractal iteration as shown in Figure 4.2.

Figure 4.2  Basic monopole Initiator antenna

The initial geometry (K0) operates as quarter-wavelength radiator (Girish Kumar and Ray 2003). The resonant frequency $f_n$ is
\[ f_n \approx \frac{c \times 0.24}{\sqrt\varepsilon_r} \left( \frac{1}{L + r + p} \right) \]  

(4.5)

where \( r = W/2\pi \), \( W \) is the width, \( L \) is the height of the initiator strip and \( p \) is the gap between the radiator and the ground plane. The Cantor fractal monopole antenna can be constructed by applying a Cantor geometric transformation on the initiator metallization (K0) of length \( L \) and width \( W \) on a FR4 substrate. The first three iterations of the Cantor bar leads to structures namely K1, K2 and K3 respectively.

Figure 4.3 shows the Cantor fractal antenna at different stages with the dimension. In this design, the initiator monopole antenna has a vertical strip as feed line and a symmetric horizontal strip on the top of the substrate. In successive iteration of the Cantor bar antenna, the structure grows vertically with different width.

![Cantor Bar Antenna Iterations](image)

**Figure 4.3** Prefractal Triadic Cantor bar fractal based antenna K0 – Initiator bar, K1–First iterated Cantor bar, K2 – Second iterated Cantor bar, K3 – Third iterated Cantor bar antenna
4.4 SBTD ANALYSIS OF CANTOR FRACTAL ANTENNA

Figure 4.4 shows the side view and the top view of the prefactal Cantor monopole antenna along with the boundary region. The antenna system consists of two metallic layers, the radiator on the top of the substrate and the ground plane printed on the bottom of the substrate. The feed line is positioned symmetric to the radiator to get symmetric radiation. A small triangular conductor section acting like a tapered impedance transformer is added to the top of the vertical feed line to improve the impedance matching. A finite ground plane has been used and it is away from the radiator by a small gap.

4.4.1 Antenna Structure Discretization

The structure is discretized in all three direction x, y and z respectively with specified SBTD cell size. Then the numerical analysis is carried out using SBTD technique.

Figure 4.4 Geometry of Prefractal Triadic Cantor fractal monopole antenna
4.4.2 Boundary Conditions

In the proposed antenna,

(i) The Cantor antenna structure does not lie on the ground plane whereas the feed line lay on the ground plane,
   $E_x$ and $E_y$ are zero for cells covering only the ground metallization and $E_z$ exists in the substrate.

(ii) On the monopole metallization, $E_x$ and $E_y$ are zero for cells covering only the ground metallization and $E_z$ exists in the cells above the metal (i.e, in free space) and the cells below the monopole, (i.e, substrate).

The basic governing equations for SBTD are Maxwell’s curl equations given by

\[
\nabla \times \vec{E} = -\mu \frac{\partial \vec{H}}{\partial t} \quad (4.1)
\]

\[
\nabla \times \vec{H} = \varepsilon \frac{\partial \vec{E}}{\partial t} + \sigma \vec{E} \quad (4.2)
\]

where $\vec{E}$ and $\vec{H}$ are electric and magnetic field, $\varepsilon$ is the permittivity, $\mu$ is the permeability and $\sigma$ is the conductivity of the medium.

The structure under analysis is terminated by a Perfectly Matched Layer (PML) absorbing boundary conditions and a Gaussian pulse $f(t)$

\[
f(t) = A \exp \left( \frac{t-T}{\sigma_0} \right)^2 \text{ is used as excitation field.}
\]
The updated Maxwell’s equations based on Daubechies wavelet supported SBTD scheme are as follows:

\[
K+1/2 \bar{H}^x_{\ell,m+1/2,n+1/2} = k -1/2 \bar{H}^x_{\ell,m+1/2,n+1/2} + \frac{\Delta t}{\mu_{\ell,m+1/2,n+1/2}} \left[ \frac{1}{\Delta x} \sum_{i=-3}^{2} a_{i,k} E^z_{x_{\ell+i+1/2,m+1/2,n}} \right] \\
- \frac{1}{\Delta y} \sum_{i=-3}^{2} a_{i,k} E^z_{y_{\ell,m+i+1/2,n+1/2}} \\
\]

(4.6)

\[
K+1/2 H^y_{\ell+1/2,m,n+1/2} = k -1/2 H^y_{\ell+1/2,m,n+1/2} + \frac{\Delta t}{\mu_{\ell+1/2,m,n+1/2}} \left[ \frac{1}{\Delta x} \sum_{i=-3}^{2} a_{i,k} E^z_{x_{\ell+i+1/2,m+1/2,n}} \right] \\
- \frac{1}{\Delta y} \sum_{i=-3}^{2} a_{i,k} E^z_{y_{\ell+i+1/2,m+1/2,n+1/2}} \\
\]

(4.7)

\[
K+1/2 H^z_{\ell+1/2,m+1/2,n} = k -1/2 H^z_{\ell+1/2,m+1/2,n} + \frac{\Delta t}{\mu_{\ell+1/2,m+1/2,n}} \left[ \frac{1}{\Delta x} \sum_{i=-3}^{2} a_{i,k} E^x_{x_{\ell+i+1/2,m+1/2,n}} \right] \\
- \frac{1}{\Delta y} \sum_{i=-3}^{2} a_{i,k} E^x_{y_{\ell+i+1/2,m+1/2,n+1/2}} - \frac{1}{\Delta z} \sum_{i=-3}^{2} a_{i,k} E^x_{z_{\ell+i+1/2,m+1/2,n+1/2}} \\
\]

(4.8)

\[
K+1/2 E^x_{\ell+1/2,m+1/2,n} = k E^x_{\ell+1/2,m+1/2,n} + \frac{\Delta t}{\varepsilon_{\ell+1/2,m+1/2,n}} \left[ \frac{1}{\Delta y} \sum_{i=-3}^{2} a_{i,k+1/2} H^z_{\ell+i+1/2,m+1/2,n} \right] \\
- \frac{1}{\Delta z} \sum_{i=-3}^{2} a_{i,k+1/2} H^y_{\ell+i+1/2,m+1/2,n+i+1/2} - \frac{1}{\Delta z} \sum_{i=-3}^{2} a_{i,k+1/2} H^y_{\ell+i+1/2,m+1/2,n+i/2} \\
\]

(4.9)

\[
K+1/2 E^y_{\ell+1/2,m+1/2,n} = k E^y_{\ell+1/2,m+1/2,n} + \frac{\Delta t}{\varepsilon_{\ell+1/2,m+1/2,n}} \left[ \frac{1}{\Delta z} \sum_{i=-3}^{2} a_{i,k+1/2} H^x_{\ell+i+1/2,m+1/2,n+i} \right] \\
- \frac{1}{\Delta x} \sum_{i=-3}^{2} a_{i,k+1/2} H^z_{\ell+i+1/2,m+1/2,n+i+1/2} - \frac{1}{\Delta x} \sum_{i=-3}^{2} a_{i,k+1/2} H^z_{\ell+i+1/2,m+1/2,n+i} \\
\]

(4.10)
\[ k+1 E_{\ell,m,n+1/2}^z = k E_{\ell,m,n+1/2}^z + \frac{\Delta t}{\varepsilon_{\ell,m,n+1/2}} \left[ \frac{1}{\Delta x} \sum_{i=-3}^{2} a_{i+1/2} H_{\ell+1/2+i,m,n+1/2}^y \right. \]

\[- \frac{1}{\Delta y} \sum_{i=-3}^{2} a_{i+1/2} H_{\ell,m+1/2+i,n+1/2}^x \left. - \frac{1}{\Delta y} \sum_{i=-3}^{2} a_{i+1/2} H_{\ell,m+1/2+i,n+1/2}^x \right] \quad (4.11) \]

where the wavelet coefficient \( a_i \) is given by,

\[ a_i = \int_{-\infty}^{\infty} Q_{-i}(x) \frac{\partial S_{1/2}(x)}{\partial x} dx \quad (4.12) \]

where \( S(x) \) is the Daubechies scale based sampling function and \( Q(x) \) is the testing function.

### 4.4.3 Results and Discussion

The Cantor antenna having the dimension \( 19 \text{mm} \times 9.2 \text{mm} \) built on FR4 substrate with \( \varepsilon_r = 4.4 \) and thickness=1.6mm as shown in Figure 4.5 is analysed using SBTD method.

![3D view of Prefractal Triadic Cantor fractal monopole antenna in SBTD domain](image)

**Figure 4.5** 3D view of Prefractal Triadic Cantor fractal monopole antenna in SBTD domain
The SBTD coding is developed using MATLAB with the following space steps implemented with computational domain of $44 \times 81 \times 10$ cells with the space size of $\Delta_y = 0.5295\text{mm}$, $\Delta_z = 0.6321\text{ mm}$, $\Delta_x = 0.16\text{mm}$ and the time step is 0.88 ps.

The numerical result shows Cantor fractal antenna resonating at 2.1GHz, 3.8GHz, 5.5GHz and 6.9GHz. The comparison of SBTD numerical results with the measured value is shown in Figure 4.6. The result shows good agreement with the measured results. Compared to FDTD simulation, the use of SBTD technique requires smaller meshes for the computation to get the same accuracy. The SBTD technique gives saving factors 1.6 and 6 of the computer memory and computational time saving respectively.

![Figure 4.6 Numerical analysis of the third iterated Cantor fractal monopole antenna](image-url)
4.5 PERFORMANCE EVALUATION OF TRIADIC CANTOR FRACTAL ANTENNA

4.5.1 Effect of Iteration Levels

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. Figure 4.3 shows the Cantor fractal antenna at different stages with the dimension. In this design, the initiator monopole antenna has a vertical strip as feed line and a symmetric horizontal strip on the top of the substrate.

4.5.2 Experimental Validation

The antenna is fabricated on FR4 substrate having $\varepsilon_r = 4.4$ and thickness=1.6mm. The prototype of the fabricated Cantor fractal antenna is shown in Figure 4.7.

![Prototype of Triadic Cantor monopole antenna](image)

Figure 4.7 Prototype of Triadic Cantor monopole antenna (a) Simple monopole (b) First iteration (c) Second iteration (d) Third iteration

4.5.3 Results and Discussion

Figure 4.8 shows the return loss of Cantor fractal monopole at different iterations (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 electrical length of the antenna increases and hence the resonance frequency is further lowered showing strong multiband resonances. Details of the resonant frequencies with return loss less than -10dB are given in Table 4.2.

![Graph showing return loss for different iterations K0, K1, K2, and K3](image)

**Figure 4.8** Return loss of the Cantor fractal monopole antenna at different iterations K0, K1, K2 and K3

**Table 4.2 Prefractal Cantor monopole antenna resonance**

<table>
<thead>
<tr>
<th>n</th>
<th>K1</th>
<th>K2</th>
<th>K3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>fn (GHz)</td>
<td>Sl1 (dB)</td>
<td>BW (MHz)</td>
</tr>
<tr>
<td>1</td>
<td>7.1</td>
<td>-11</td>
<td>50</td>
</tr>
<tr>
<td>2</td>
<td>5.6</td>
<td>-13</td>
<td>200</td>
</tr>
<tr>
<td>3</td>
<td>3.75</td>
<td>-11</td>
<td>150</td>
</tr>
<tr>
<td>4</td>
<td>2.15</td>
<td>-11</td>
<td>100</td>
</tr>
</tbody>
</table>
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 less than -12dB.

Frequencies of each resonance band of the prefractal antenna with return loss better than -10dB can be estimated from (Girish Kumar and Ray 2003),

$$f_n \approx \frac{c \times 0.24}{h} \left[ \frac{1}{\delta^n} \right]$$

(4.94)

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 approximately equal to 1.2 for this structure.

The measured return loss of the third iterated antenna (K3) is compared with the numerical result and the simulated results as shown in Figure 4.9. The radiation characteristics of the antenna are measured in an anechoic chamber using a network analyzer. These measurements use a sweep frequency source, and the results are almost consistent within the band.
Figure 4.9 Measured Return loss of the Third iterated Contor on monopole

Figure 4.10 shows the radiation pattern of simple, first, second and third iterated Cantor monopole antenna respectively in the parallel and perpendicular plane of the antenna for the frequency 6.9 GHz. The simulated and the measured radiation patterns are plotted at resonant frequency 2.1GHz. In all iterations, the fractal antenna shows omni directional radiation in the perpendicular plane and bidirectional radiation along the parallel plane. There exist a small deviation in the measured pattern and this may be due to the losses in the cables used for measurement.
Figure 4.10 Radiation patterns of Triadic Cantor monopole antenna at different stages of its fractal iteration K0, K1, K2, and K3 at 6.9 GHz
The radiation pattern in co polarization and cross polarization orientation of the third iterated Cantor antenna (K3) is also obtained at four resonant frequencies 2.1GHz, 3.8GHz, 5.5GHz and 6.9 GHz both in the normal plane and in the parallel plane of the antenna and are shown in Figure 4.11. The pattern exhibits similarity in plane throughout the operating band in the parallel (Z-X) plane and the configuration proves omni directional radiation in normal (X-Y) plane.

Figure 4.11 Measured radiation patterns of prefactal Cantor monopole antenna at 2.1GHz, 3.8GHz, 5.5GHz and 6.9GHz respectively. (Z-X plane and X-Y plane polarization comparison) where θ, φ are standard polar coordinates (E_θ co pol, E_φ cross pol)
4.6 PERFORMANCE EVALUATION OF PENTADIC CANTOR FRACTAL ANTENNA

4.6.1 Geometry of Pentadic Cantor

In the Triadic Cantor fractal antenna, the basic Cantor initiator was divided into three sections of same dimension in each iteration level, so as to achieve further miniaturization. The characteristics can be perturbed by changing the fractal growth dimension and the number of segments generated in each iteration level. Generation of Pentadic Cantor fractal structure is shown in Figure 4.12.

![Figure 4.12 Generation of Pentadic Cantor monopole](image)

4.6.2 Experimental Validation

The Pentadic Cantor fractal monopole antenna is constructed by applying a Cantor geometric transformation on the Initiator metallization of length W and height L. 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 \(\times\) 41mm has been used. The ground plane is away from the radiator by a small gap of 1mm. The photographs of these antennas are shown in Figure 4.13. The layout of the third iterated Pentadic Cantor monopole antenna is shown in Figure 4.14. The simple monopole (K0) resonates at 7.2GHz.
4.6.3 Results and Discussion

The simulated and measured return losses of different iterated Pentadic Cantor fractal antenna are reported in Figure 4.15. The Cantor antenna at its first fractal iteration shows weak resonance at 2.2GHz, 3.9GHz and strong resonance at 5.7GHz. As iteration increases, the lower resonance gets stronger particularly at third stages of fractal iteration; the antenna
resonates at 1.45GHz, 2.35GHz and at 3.65GHz. The third iterated Cantor shows drastic reduction in resonant frequency which leads to miniaturization of antenna.

Figure 4.15 Simulated and Measured return loss of Pentadic Cantor monopole

Figures 4.16 to 4.18 shows the simulated electric field distribution in E and H plane of the antenna geometry for first, second and third iterated Cantor fractal antenna. The pattern resembles that of triadic Cantor antenna for lower iteration.
Figure 4.16 Radiation patterns of first iterated (K1) Pentadic Cantor monopole

Figure 4.17 Radiation patterns of second iterated (K2) Pentadic Cantor monopole

Figure 4.18 Radiation patterns of third iterated (K3) Pentadic Cantor monopole
4.7 NONUNIFORM CANTOR SET MONOPOLE ANTENNA

4.7.1 Non uniform Cantor Geometry

The Triadic Cantor structure is perturbed by changing its IFS coefficients during the affine transformation and the change in performance is observed. In successive iteration, the Cantor segments generated are unequal in width. The IFS coefficients for the structure are given in Table 4.3 and the generation of structure is shown in Figure 4.19. Same scaling and transformation are applied in successive iteration.

Table 4.3 IFS transformation coefficients for the non uniform Cantor set

<table>
<thead>
<tr>
<th>w</th>
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<th>b</th>
<th>c</th>
<th>d</th>
<th>e</th>
<th>f</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.6</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0.4</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.7</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 4.19 Layout of non uniform Cantor fractal monopole antenna
4.7.2 Experimental Validation

The Unequal Cantor fractal monopole antenna is constructed by applying a Cantor geometric transformation on the Initiator metallization of length 19mm and height 2.2mm on an 1.6mm thickness FR4 substrate with relative permittivity $\varepsilon_r = 4.4$ and loss tangent, $\tan \delta = 0.0027$. The layout of third iterated non uniform Cantor fractal antenna is shown in Figure 4.20. The antennas are fabricated and the prototype of the triadic Cantor antennas are shown in Figure 4.21 and the measured results are shown in Figure 4.22.
4.7.3 Results and Discussion

The successive iterated prefractal cantor monopole antenna structure does not alter the antenna characteristics significantly. This concludes that perturbation in the width of the Cantor segments exhibits no significant variation in the input characteristics. The antenna is fabricated and the experimented for the return loss and the radiation pattern. The characteristics are compared with that of Triadic and Pentadic Cantor fractal antenna Figure 4.23. The input characteristics do not change with respect to smaller variation in the width of the triadic Cantor segments. Radiation patterns are observed to have self similarity in all iteration and there is no significant variation in the shape of the pattern from that of Triadic Cantor antenna.
In order to investigate the effect of dielectric support on the input characteristics of pentadic Cantor antenna, the proposed designs are simulated for various dielectric support materials such as FR4, RT Duroid and Alumina 9.6. All the substrate are taken with thickness h = 1.6mm. The simulated return loss of the Triadic, Pentadic Cantor antenna on different dielectric materials are depicted in Figures 4.24 and 4.25.

**Figure 4.23** Comparison Return loss of Triadic, Pentadic and Unequal Cantor antenna

### 4.8 EFFECT OF DIELECTRIC PROPERTY ON CANTOR MONOPOLE ANTENNA

In order to investigate the effect of dielectric support on the input characteristics of pentadic Cantor antenna, the proposed designs are simulated for various dielectric support materials such as FR4, RT Duroid and Alumina 9.6. All the substrate are taken with thickness h = 1.6mm. The simulated return loss of the Triadic, Pentadic Cantor antenna on different dielectric materials are depicted in Figures 4.24 and 4.25.
Figure 4.24  Return loss of the Triadic Cantor monopole antenna for various dielectric substrate material RT Duroid 5880, FR4 and Alumina

Figure 4.25  Return loss of Pentadic Cantor set based fractal antenna on various dielectric support FR 4, RT Duroid and Alumina 9.6
The thickness and the dielectric constant of the support material affect the tuning of the antenna. High dielectric constant results in lowering the resonance and increases the bandwidth. For a fixed dimension of the antenna, the existence of material with high dielectric constant lowers the resonance frequency. This leads to further miniaturization.

Figures 4.26 and 4.27 show the radiation characteristics at resonant frequencies of triadic and pentadic Cantor monopole for the dielectric substrate RT Duroid and Alumina respectively. Patterns for elevation planes parallel to and normal to the plane of the geometry are shown here. The radiation characteristics of triadic Cantor antenna are comparable with the conventional monopole antennas. It shows that the pattern sustains the self similarity irrespective of the dielectric support material.

**Figure 4.26** Radiation pattern of Triadic Cantor antenna on RT Duroid at three resonant frequencies, 2.67GHz, 4.78GHz and 6.95GHz
Figure 4.27 Radiation pattern of Pentadic Cantor antenna on Alumina 9.6 at four resonant frequencies, 1.53GHz, 3.99GHz, 5.31GHz and 6.31GHz

4.9 SUMMARY

Monopole antenna configurations of different Cantor fractal geometry have been studied. It has been observed that the input characteristics of triadic Cantor antenna are affected by fractal iteration. The use of Cantor geometry in antenna provides miniaturization compared to conventional multiband antenna. The resonant frequencies of basic Cantor antenna are influenced by fractal translational coefficients. The effect of dielectric supports are investigated and found that increase in dielectric constant lowers the resonant frequency. This antenna provides strong multiband response by a factor of 1.6. The measured radiation characteristics of these antennas are also presented and validated. Hence Cantor set fractal geometry offers the possibility of designing miniaturized, compact and multiband antenna.