CHAPTER 5

A MULTIFRACTAL CANTOR ANTENNA FOR MULTIBAND WIRELESS APPLICATIONS

5.1 INTRODUCTION

Realizing multi-standard transceivers with maximum hardware reuse amongst the emerging wireless standards is of great importance to minimize the increased power consumption, the integration problems, and the manufacturing cost (Pan et al 2008).

Typical block diagram of 4G multistandard receiver is shown in Figure 5.1. The diagram shows single receiver architecture capable of operating for multiple standards such as GSM, Wavelength Code Division Multiple Access (WCDMA), WLAN and WiMAX.

This architecture has a common signal path from antenna followed by a reconfigurable duplexer. Most of the blocks of this receiver such as Low noise amplifier, Mixer and filter are shared by the different standards by adjusting their configuration through the means of digital controls.

As a consequence of concurrent multiple services of multistandard wireless systems, there is a need for developing a compact, low profile, multiband planar antennas operating at amidst closely separated multi band frequencies with good radiation characteristics (Agnelli et al 2006).
Various approaches have been reported in the literature to create wireless multiband antennas for personal communication systems such as Printed inverted-F antennas (PIFA), slotted monopole (Liu et al 1997, Delavaud et al 1998, Hee et al 2003, Lee et al 2006). These antennas have lead to improved multiband performance from a single antenna but with complex structure.

Recently, novel antenna designs that exploited the self similar properties of fractals to meet the demands of modern antennas with a desire to achieve maximum shrinkage with multiband performance have been reported (Sundaram et al 2007, Sinha and Jain 2007). Design of multiband antennas using fractal structures such as Sierpinski gasket, Hilbert curve, Appollonian packing monopole and Koch fractal have also been reported (Puente et al 1996c, Song et al 2003, Tsachtsiris et al 2004, Liu et al 2006). Sierpinski

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**Figure 5.1 Multistandard Receiver Architecture**

LNA-Low Noise Amplifier, DC Direct Current, VGA-Voltage Gain Amplifier, ADC-Analog to Digital Converter, DAC-Digital to Analog Converter
gaskets have been investigated extensively for monopole and dipole configurations (Vinoy 2002). Modified form of Sierpinski gasket geometry has been done by Tsachtsiris et al (2004) for controlled multiband operation. Recently, conventional fractal antenna that can achieve maximum shrinkage for a given performance has been reported (Rmili et al 2007). Most of the fractal antenna designs including Cantor set fractal antenna reported have the periodic resonance behavior (Tsachtsiris et al 2004, Liu et al 2006). This resonant behaviour can be flexibly controlled by introducing multifractals in the design of conventional fractal antenna.

Multifractals are mathematical generalizations of fractals, objects displaying "fractional dimension," "scale invariance," and "self-similarity." Many natural phenomena such as meteorological conditions, population distribution, financial time series have been found to be well-represented by multifractals. Multifractal measures were introduced and pioneered by Mandelbrot (Mandelbrot 1972, Evertsz and Mandelbrot 1992) and have since been applied in the physical sciences to describe the distribution of energy and matter, e.g. turbulent dissipation, stellar matter, fractional Brownian motion minerals, stock markets, fluid dynamics and economics (Parisi and Frisch 1985, Mandelbrot et al 1997). Multifractals have found applications in the modeling of asset returns in finance and recently in the study of behaviour of the exchange rate variations (Mandelbrot et al 1997, Norouzzadeha and Jafaria 2005).

Hence, in this chapter, multifractality concept is introduced in the design of fractal antenna element that may permit a richer variety of behaviors to suit the simultaneous operation requirement at multistandard wireless frequencies.
5.2 MULTIFRACTALITY

A self-affine random process satisfies the simple scaling rule:

\[ X(ct)^d = c^H X(t) \] \hspace{1cm} (5.1)

for \( H > 0 \), and all \( c, k, t \geq 0 \), where \( H \) is the self affinity index and \( c \) is the scaling factor.

The theory of multifractals presents a more general relationship:

\[ X(ct)^d = M(c)X(t) \] \hspace{1cm} (5.2)

where \( X \) and \( M \) are independent random functions. Under strict stationarity, arbitrary translations along the time axis allow extension of (5.1) to local scaling rules:

\[ X(t + c\Delta t) - X(t)^c = M(c)\left[X(t + \Delta t) - X(t)\right] \] \hspace{1cm} (5.3)

for all positive \( c \). The scaling factor \( M(c) \) is a random variable, whose distribution does not depend on the particular instant \( t \). Self-similar processes satisfy (5.2),

with \( M(c) = c^H \) \hspace{1cm} (5.4)

To pursue this analogy, we define the generalized index

\[ H(c) = \log_c M(c) \] \hspace{1cm} (5.5)

and rewriting the above relation:

\[ X(ct)^d = c^{H(c)} X(t) \] \hspace{1cm} (5.6)
In contrast to self-similar processes, the index $H(c)$ is a random function of $c$. Multifractality thus permits a richer variety of behaviors than is possible under self-affinity. It also places strong restrictions on the process's distribution. For instance if $c_3/c_1 = c_3/c_2$ and condition (5.1) holds, then

$$\frac{X(c_2t)}{X(c_1t)} \underset{d}{\sim} \frac{X(c_3t)}{X(c_2t)}$$

(5.7)

since both ratios are distributed like $M(c_2/c_1)$.

It is also required that the random scaling factor satisfies the property:

$$M(ab) \underset{d}{\sim} M_1(a)M_2(b)$$

(5.8)

where $M_1$ and $M_2$ are independent copies of $M$. This condition implies the scaling rule namely

$$E\left[|X(t)|^q\right] = c(q)t^{-\tau(q)+1}$$

(5.9)

where $\tau(q)$ and $c(q)$ are both deterministic scaling functions of $q$. In this setting, condition (5.1) characterizes a particular class of multifractals. Multifractality is thus defined as a global property of the process's moments.

A self-affine process $X(t)$ with index $H$ is multifractal, with scaling function $\tau(q) = Hq - 1$. Because of its linearity, the scaling function is fully determined by a single coefficient. It is then called uniscaling or unifractal. Multifractal or multiscaling processes allow more general concave scaling functions (Mandelbrot et al 1997).
The multifractals can also be generated with Iterated function systems (IFS) having spectrum of fractal dimension (Falconer 2003).

5.3 MULTIFRACTAL CANTOR

The multifractality applied to Cantor fractal geometry as discussed in Chapter 4. A typical multifractal set is obtained from the weighted Cantor set, by using two different probabilities \( p_1 = 0.7 \) and \( p_2 = 0.3 \). For canonical Cantor set,

\[
D = \frac{\log 2}{\log \frac{1}{2}(1-h)}
\]

(5.11)

where \( h \) is the relative size of the portion removed.

When the multifractal technique is applied to the Cantor initiator bar, it generates \( 2^n \) number of Cantor set segments of different length. This geometry is generated by using iterated function system with probabilities which is described by the following affine transformation \( w_i \) (Michael Barnsley 1993).

\[
w_i \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} a_i & b_i \\ c_i & p_i d_i \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} e_i \\ f_i \end{bmatrix}
\]

(5.12)

with \( p_1 + p_2 + \ldots + p_N = 1 \) and \( p_i > 0 \) and for \( i = 0,1,2,\ldots,N \).

where \( a_i, b_i, c_i \) and \( d_i \) are scale factors, \( e_i \) and \( f_i \) are translations involved in the transformation and \( p_i \) is the probability associated with the dimension of multifractal geometry in spatial direction with variable probability distribution chosen for the application.
The IFS coefficients for multifractal Cantor set are given in Table 5.1 and the structure generated is shown in Figure 5.2.

**Table 5.1** IFS transformation coefficients for the Multifractal Cantor set

<table>
<thead>
<tr>
<th>( w_i )</th>
<th>( a_i )</th>
<th>( b_i )</th>
<th>( c_i )</th>
<th>( d_i )</th>
<th>( e_i )</th>
<th>( f_i )</th>
<th>( p_i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.3</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1/3</td>
</tr>
<tr>
<td>2</td>
<td>0.3</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.6</td>
<td>0</td>
<td>2/3</td>
</tr>
</tbody>
</table>

**Figure 5.2** Multifractal Cantor set structure (a) Initiator \( K_0 \) (b) First iteration \( K_1 \) (c) Second iteration \( K_2 \) (d) Third iteration \( K_3 \)

The existence of probabilities in the table leads to non uniform growth of Cantor set fractal structure which has the advantage of compressing multi bands to smaller spectral interval.
5.4 MULTIFRACTAL CANTOR MONOPOLE ANTENNA

In the Cantor set fractal structure, segments generated at every iteration are of same dimension. The antenna design based on such self affine fractal design exhibits a multiband behavior with similarity and periodicity owing to its self similar shape (Sinha and Jain 2007). In the proposed structure, multifractal technique is applied to the initiator monopole that generates 2^n number of Cantor set segments of different length. This makes the antenna operates at the lower wireless frequency applications with reference to wireless standards such as GSM, DCS, PCS and WLAN.

The multifractal Cantor antenna structures at different iteration are shown in Figure 5.3.

![Multifractal Cantor monopole structure](image)

Figure 5.3 Multifractal Cantor monopole structure (a) Initiator K0 (b) First iteration K1 (c) Second iteration K2 (d) Third iteration K3

The design of initial geometry (K0) follows the design equation given below (Girishkumar and Ray 2003).


\[ f_n \approx \frac{c \times 0.24}{\sqrt{\varepsilon_r}} \left[ \frac{1}{L + r + p} \right] \]

(5.13)

where \( r = \frac{L}{2\pi} \), \( f_n \) is the resonant frequency, \( W \) is the width, \( L \) is the height of the initiator strip and \( p \) is the ground plane gap. Then the successive iterated segments are generated as per the multifractal concept and added on to the initiator repeatedly for multiple lower resonances.

The structure of the third iterated prefractal Cantor multifractal antenna is shown in Figure 5.4 The vertical height of the third iterated monopole fractal antenna is \( h \). The radiator is fed through a microstrip feed line. The feed line position is optimized to improve impedance bandwidth.

Figure 5.4 Structure of third iterated Multifractal Cantor monopole antenna
5.5 SBTD ANALYSIS OF MULTIFRACTAL CANTOR ANTENNA

Figure 5.5 shows the side view and top view of the Multifractal Cantor antenna under consideration. This antenna structure is numerically analysed using Sampling bi-orthogonal time domain method (SBTD). The relevant theory and mathematical equations have been presented in Chapter 2. PML absorbing boundary conditions are considered for the analysis.

Figure 5.5 Top view and side view of the Multifractal monopole antenna for the analysis

5.5.1 Antenna Discretization

The multifractal antenna is discretized three dimensionally with suitable cell size along X, Y and Z axis such that the field computation is carried out using SBTD based Maxwell’s updated equations in a leap frog manner.
5.5.2 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 SBTD scheme based on biorthogonal sampling method has the following updated Maxwell’s electric and magnetic field component equations in terms of wavelet coefficients $a_i$:

\[
\begin{align*}
K+1/2 H^\chi_{\ell,m+1/2,n+1/2} &= k-1/2 H^\chi_{\ell,m+1/2,n+1/2} + \frac{\Delta t}{\mu_{\ell,m+1/2,n+1/2}} \left[ \frac{1}{\Delta z} \sum_{i=-3}^{2} a_i \cdot k E^y_{\ell,m+1/2,n+i+1} 
- \frac{1}{\Delta y} \sum_{i=-3}^{2} a_i \cdot k E^z_{\ell,m+i+1,n} \right] \\
K+1/2 H^\nu_{\ell+1/2,m,n+1/2} &= k-1/2 H^\nu_{\ell+1/2,m,n+1/2} + \frac{\Delta t}{\mu_{\ell+1/2,m,n+1/2}} \left[ \frac{1}{\Delta x} \sum_{i=-3}^{2} a_i \cdot k E^z_{\ell+i+1/2,m,n+1} 
- \frac{1}{\Delta z} \sum_{i=-3}^{2} a_i \cdot k E^x_{\ell+i+1/2,m,n+i+1} \right] \\
K+1/2 E^z_{\ell,m,n+1/2} &= k E^z_{\ell,m,n+1/2} + \frac{\Delta t}{\epsilon_{\ell,m,n+1/2}} \left[ \frac{1}{\Delta x} \sum_{i=-3}^{2} a_i \cdot k^{+1/2} H^y_{\ell+1/2+i,m,n+1/2} 
- \frac{1}{\Delta y} \sum_{i=-3}^{2} a_i \cdot k^{+1/2} H^x_{\ell,m+1/2+i,n+1/2} \right]
\end{align*}
\]
where the wavelet coefficient $a_i$ are given by

$$a_i = \int_{-\infty}^{\infty} Q_i(x) \frac{\partial S_{1/2}(x)}{\partial x} dx$$

(5.17)

where $S(x)$ and $Q(x)$ are Dabechies wavelet based sampling and testing functions

5.5.3 Results and Discussion

The antenna has the dimension of height $h = 65.9$ mm and total horizontal $W_t = 38.5$mm. The mesh specification for SBTD technique is $73 \times 125 \times 8$ cells and cell size of $\Delta x=0.5274$mm, $\Delta y=0.5272$mm and $\Delta z=0.15$mm are chosen. The coding for SBTD is written in MATLAB. To validate the numerical analysis of the proposed multifractal Cantor antenna, the return loss is obtained using FDTD, Empire 3D simulation and the measurements. The numerical and simulated results show good agreement with the measured results as shown in Figure 5.6.

![Figure 5.6](image)

Figure 5.6 Comparison of theoretical simulated and measured Return loss of the Multifractal Cantor monopole
5.6 PERFORMANCE EVALUATION OF MULTIFRACTAL MONOPOLE ANTENNA

5.6.1 Effect of Fractal Iteration Levels

In order to investigate the performances of the antenna at different iteration and the effectiveness of the fractal geometry, the structures are simulated using ADS momentum. The resonant behavior of multifractal Cantor antenna is shown in Figure 5.7. It can be noted that a significant shift in resonant frequency is observed for the first iterated multifractal antenna when compared to that of simple monopole.

![Simulated return loss of the Multifractal Cantor monopole](image)

**Figure 5.7 Simulated return loss of the Multifractal Cantor monopole**

As iteration increases, the number of fingers and the length of the fingers increase. This leads to multiple resonances without much perturbation in the higher resonance. The dimension of the finger and the coupling between the fingers generate the other resonant modes. The resonating bands are dependent on the size of the ground plane. This is due to the fact that the
electrical size of the ground plane is comparable with the one in the resonating band.

Figure 5.8 shows the photograph of multifractal antenna in different stages of fractal iterations. The comparison of simulated and measured return loss characteristics at different stages of multifractal antennas are shown in Figures 5.9 to 5.12.

![Figure 5.8 Prototype of the Multifractal Cantor monopole antenna](image)

![Figure 5.9 Return loss of the simple monopole antenna](image)
Figure 5.10  Return loss of the first iterated Multifractal Cantor antenna

Figure 5.11  Return loss of the second iterated Multifractal Cantor antenna
Figure 5.12 Measured return loss of the third iterated Multifractal Cantor antenna

The measured results are presented in Figure 5.13 and the resonance frequencies at different stages of fractal iterations K0, K1, K2 and K3 are tabulated in Table 5.2.

Figure 5.13 Comparison of return loss of monopole antenna at different iteration
The table conveys increase in number of resonant frequency and slight change in resonant frequencies as iteration increases. The simple monopole (K0) resonates at single frequency 5.75GHz. The first iterated multifractal antenna (K1) resonates at 6.9, 5.7 and 4.8GHz respectively. The second iterated antenna (K2) resonates at 6.98GHz, 5.9GHz, 4.7GHz and 3GHz respectively. The third iterated antenna (K3) resonates at 6.9GHz, 5GHz, 3GHz and 2.2GHz respectively. The bandwidth also increases with respect to iteration. This implies as fractal iteration increases, the electrical length of the antenna increases and hence reduction of resonant frequency. The presence of discontinuity in the fractal structure and the self similarity the antenna leads to multiband performance.

5.6.2 Effect of Changing Feed Location

The feed line position is varied from one end of the monopole to the other to study the impact on bandwidth. Figure 5.14 shows the simulated return loss with respect to various feed line position of the Cantor antenna. The improvement in bandwidth for d=13mm is visible from the graph.
Figure 5.14 Simulated return loss of the Multifractal Cantor antenna with respect to variation in feed line position

The radiation patterns are shown in planes parallel and normal to plane of geometry. For all fractal iterations, the simulated radiation patterns and the measured patterns at 5.7GHz are compared in Figures 5.15 and 5.16.

There is no significant change in the first iteration and patterns show perturbation for second and third iteration of the antenna. Figure 5.17 shows the radiation patterns of the multifractal Cantor antenna at different stages of fractal iteration (K0, K1, K2, K3) at resonant frequencies 2GHz, 3GHz 4.25GHz, 5GHz and 6.9GHz respectively. Patterns show similarity throughout the band of operation the plane of the geometry and omni directional radiation in the normal plane.
Figure 5.15 Radiation patterns of first and second iterations of Multifractal Cantor monopole antenna at the resonant frequencies 5.7GHz
Figure 5.16 Radiation patterns of third and final iterations of Multifractal Cantor monopole antenna at the resonant frequency 5.7GHz
Figure 5.17  Radiation patterns of three iterations of Multifractal Cantor monopole antenna at resonant frequencies 2.2 GHz, 3 GHz, 5GHz and 6GHz respectively
5.6.3 Effect of Dielectric Substrate

The proposed multifractal Cantor antenna is analyzed with the substrates namely, RT Duroid, FR-4 and Alumina. High dielectric constant results in lowering of resonance due to increase in electrical dimension, but the bandwidth are reduced due to increase in quality factor. The thickness of the dielectric substrate material also affects the tuning of the antenna. For implementation, low cost substrate FR4 with $\varepsilon_r = 4.4$ and $h=1.6\text{mm}$ is chosen. The influence of dielectric constant on the performance of multifractal Cantor monopole antenna is depicted in Figure 5.18. SBTD analysis is used to study the effect of dielectric support on the behavior of monopole antenna.

![Graph showing return loss of the Multifractal Cantor antenna for various dielectric substrate material RT Duroid 5880 ($\varepsilon_r = 2.2$), FR4 (4.4) and Alumina (9.8)](image)

**Figure 5.18** Return loss of the Multifractal Cantor antenna for various dielectric substrate material RT Duroid 5880 ($\varepsilon_r = 2.2$), FR4 (4.4) and Alumina (9.8)
5.6.4 Influence of Multifractal Structure Parameter Variation

The multifractal antenna structure in third iteration with probabilities $p_1 = 1/3$ and $p_2 = 2/3$, shown to have wideband characteristics. This can also be made multiband antenna by varying the probabilities $p_1$ and $p_2$. Figure 5.19 shows the input characteristics of third iterated Multifractal Cantor monopole antenna for the multifractal monopole antenna for various probabilities $(p_1, p_2) = (0.33, 0.66), (0.25, 0.75) \text{ and } (0.45, 0.55)$. The curves show shifting of multiple resonances as the values of $p_1$ and $p_2$ changes. Hence in order to meet the frequency specification of required applications, the probabilities in the design of multifractal antenna are to be suitably chosen and hence the need for optimization.

![Comparison of return loss of third iterated Multifractal Cantor monopole antenna for various IFS probabilities](image)

**Figure 5.19** Comparison of return loss of third iterated Multifractal Cantor monopole antenna for various IFS probabilities $(p_1, p_2) = (0.33, 0.66), (0.25, 0.75) \text{ and } (0.45, 0.55)$. 

5.7 OPTIMIZED MULTIFRACTAL CANTOR MONOPOLE ANTENNA

The emerging wireless antenna needs to operate at multiband frequencies such as GSM, PCS, DCS, UMTS, and WLAN. In order to meet the above requirement, the antenna structure has to be optimized. This is done by varying the values of IFS probabilities \( p_1 \) and \( p_2 \) corresponding to the dimension of the fingers of third iterated Cantor multifractal structure.

The resultant geometry of the multifractal antenna is shown in Figure 5.20. This optimized geometry is analysed using SBTD method and simulated in an ADS 2002 platform. This antenna is fabricated and tested in the anechoic chamber. Figure 5.21 shows the prototype of multifractal Cantor antenna.

![Figure 5.20 Geometry of an optimized Multifractal Cantor antenna](image-url)
The results of numerical analysis, simulation and measurements are shown in Figure 5.22. The results of the proposed antenna are in good agreement with each other. The resonant behaviour of the proposed antenna is tabulated in Table 5.3. The center frequency of each band appears in the second column, bandwidth in the third column and the frequency ratio between the adjacent bands is depicted in the fourth column.
Table 5.3  Proposed Multifractal antenna resonant frequencies and scale factor between adjacent bands

<table>
<thead>
<tr>
<th>n</th>
<th>(f_n) (GHz)</th>
<th>(S_{11}) (dB)</th>
<th>BW (MHz)</th>
<th>(f_{n+1}/f_n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.9</td>
<td>-18</td>
<td>900</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>2.75</td>
<td>-26</td>
<td>1200</td>
<td>3.05</td>
</tr>
<tr>
<td>3</td>
<td>3.5</td>
<td>-27</td>
<td>1100</td>
<td>1.27</td>
</tr>
<tr>
<td>4</td>
<td>4.6</td>
<td>-24</td>
<td>1100</td>
<td>1.31</td>
</tr>
<tr>
<td>5</td>
<td>5.7</td>
<td>-34</td>
<td>1300</td>
<td>1.24</td>
</tr>
</tbody>
</table>

The result shows the suitability of multifractal antenna for multiband wireless applications covering GSM 900MHz, GSM 1800MHz, DCS, PCS and WLAN 2.4GHz and WLAN 5.8GHz.

The simulated and the measured gain patterns of both \(E_\theta\) and \(E_\phi\) components of the electric field at the principal plane cuts (Z-X plane and X-Y plane) for the resonant frequencies 0.9 GHz, 1.8 GHz, 2.4 GHz and 5.8 GHz are shown in Figure 5.23. The values are normalized with respect to maximum total electric field and expressed in dB. The radiation patterns are found to be omni directional in X-Y plane with better cross polar level at all resonating bands of operation. The measured values of \(E_\theta\) components in Z-X plane pattern at 1.8 GHz and 5.8 GHz are different from that of the simulated values. This is due to the undesired reflections from the surroundings.
Figure 5.23  Measured and the Simulated radiation patterns of third iterated Multifractal Cantor antenna at 900 MHz, 1.8 GHz, 2.4 GHz and 5.8 GHz respectively. (Z-X plane and X-Y plane polarization comparison) where $\theta$, $\phi$ are standard polar coordinates
5.8 EFFECT OF GROUND PLANE ON THE MONOPOLE CONFIGURATION

The structure could also be interpreted as an asymmetrical dipole, where one of the arms on the top of the substrate is Cantor based structure and the other arm on the bottom of the substrate is the complete rectangle metallization since the dimension of one arm is comparable with that of Cantor structure. The characteristics of Cantor monopole can also be observed with an orthogonal electrically large ground plane. Figure 5.24 shows the multifractal monopole antenna configuration with larger ground plane.

![Multifractal Cantor monopole with an orthogonal ground plane](image)

**Figure 5.24 Multifractal Cantor monopole with an orthogonal ground plane**

The effect of ground plane on the performance of the monopole antenna is shown in Figure 5.25. As the ground plane dimension increases, the antenna exhibits a noticeable shift in resonant frequency and return loss without affecting the radiation pattern. As the ground plane decreases, the antenna shows a frequency shift towards lower frequencies. But for our requirement the dimension of ground plane is optimized to 32mm × 38.5mm. The change in resonant frequency with respect to ground plane size is tabulated in Table 5.4.
Figure 5.25  Comparison of return loss for the cases namely, a monopole antenna with parallel ground plane and monopole with an orthogonal electrically large (200mm×200mm) ground plane

Table 5.4  Return loss with finite ground plane and Return loss with electrically large ground plane

<table>
<thead>
<tr>
<th>Return loss with finite ground plane</th>
<th>Return loss with electrically large ground plane</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>( f_n (\text{GHz}) )</td>
</tr>
<tr>
<td>1</td>
<td>0.9</td>
</tr>
<tr>
<td>2</td>
<td>2.7</td>
</tr>
<tr>
<td>3</td>
<td>3.5</td>
</tr>
<tr>
<td>4</td>
<td>4.6</td>
</tr>
<tr>
<td>5</td>
<td>5.7</td>
</tr>
</tbody>
</table>
The gain was measured in the X-Y plane for horizontal polarization of the antenna. Figure 5.26 presents the measured gain of the antenna. The maximum measured gain of the multifractal Cantor monopole antenna implemented on FR4 is 4.2 dBi at 5.8 GHz.

Figure 5.26 Gain of the Multifractal antenna in X-Y plane

5.9 EFFECT OF DIELECTRIC SUBSTRATE ON MULTIFRACTAL CANTOR MONOPOLE ANTENNA

The structure have been studied for various dielectric material such as RT Duroid 5880 ($\varepsilon_r=2.2$), FR4 ($\varepsilon_r=4.4$) and Alumina ($\varepsilon_r=9.8$) with dielectric material thickness of 1.6 mm and ground plane $7\text{cm}\times4\text{cm}$. From the simulated result as shown in Figure 5.27, it has been observed that increased dielectric constant of the substrate reduces the dimension of the antenna. In Figure 5.28, radiation patterns for antennas on alumina, RT FR4 and Duroid substrates are plotted. These patterns are plotted at resonant frequencies for these individual cases. Although there is a change in the shape of the radiation patterns in these cases, the overall performances does not appear to vary much.
Figure 5.27  Return loss of the Mutifractal antenna for various values of Dielectric constant of the substrate
Figure 5.28 Radiation patterns of Multifractal Cantor monopole antenna at resonant frequencies with various substrates.
5.10 SUMMARY

The increasing growth in future wireless standard technology demands for reconfigurable RF devices and components. In this aspect, multistandard antenna is expected to play an important role in the reconfigurable transceivers. This chapter presents the design and implementation of multifractal Cantor antenna that finds potential application in multistandard wireless systems. Multifractality is applied in the design of Cantor bar fractal monopole antenna and it has been investigated to give closely separated multiband characteristics.

The multifractal Cantor antenna structure has been optimized to make it suitable for multiband wireless applications covering GSM, PCS, DCS, UMTS, and WLAN. It is observed that the input characteristics of antenna are optimized by multifractal iteration and probability associated with the IFS coefficients. The effect of electrically large orthogonal ground plane and the dielectric support are investigated.

The multifractal Cantor antenna thus offers the possibility of miniaturization, flexibility in respect of controlling the resonance and bandwidth. The simulation and the experimental results show that multifractal antenna is ideally suited for multistandard wireless frequency operation.