V.Manoj Kumar, P.Venu Madhav, V. Nagaraju / International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com
Vol. 3, Issue 1, January -February 2013, pp.1988-1994

Multi-Band Fractal Antenna for WiMAX Application

V.Manoj Kumar*, P.Venu Madhav, V. Nagaraju*****
*,**,***(Department of Electronics & Communication Engineering, PVPSIT, Kanuru, Vijayawada)

ABSTRACT

The fractal antennas that have the multiband operation due to the self-similar property in fractal geometry, which plays a key role to create a fractal circular monopole patch antenna. The other important property that is, Space-filling property which actually determines the reduction in the size of the antenna. This property adds more electrical length in less volume which reduces the size of the antenna. Based on these two properties the fractal antennas are designed. These two properties of fractal geometry making the fractal antenna to apply for several advanced applications. The CPW feed also helps the antenna to achieve the bandwidth in the ratio of 6:1.Though it is difficult to construct a CPW feed for an antenna, but it exhibits wider bandwidth. The proposed antenna is designed by using the CPW feed for fractal antenna that is, Crown shaped CPW-fed circular monopole fractal antenna and implemented to effectively support mobile worldwide interoperability for microwave access (Mobile WiMAX), and WiMAX which operate in the 2.3/2.5 GHz (2.305–2.360 GHz/2.5–2.69) GHz.

Keywords **–Microstrip Patch Antennas, CPW-Fed, Fractal Antennas, Circular Monopole antenna, WiMAX.**

I. INTRODUCTION

To provide the Wireless technologies like WiMAX and other advanced applications through the antennas by using Fractal technology to the microstrip antennas. By using the fractal technology on the microstrip antennas we can get several advantages like wide band operation, less power consumption, less return loss and many more. To handle the most advanced wireless technology like WiMAX it's better to have the more flexible antennas like Fractal antennas. The two properties of the fractal antenna such as Self-similarity and Space-filling are making the fractal antennas for wide application. At GHz frequency the antenna which gives maximum gain with less return loss & VSWR. The design of the fractal antenna for such a practical applications should be made carefully so as to exhibit the desirable characteristics of the antenna like gain, bandwidth, directivity, return loss, VSWR etc. To have the maximum gain, bandwidth, directivity etc it's better to design the antenna by using the fractal technology. To increase the bandwidth a Co-Planar Waveguide (CPW) feed is used. By using such feeding technique the bandwidth of the antenna can be increased to the ratio of 6:1. The new compact Multi-Band antenna has been presented and implemented successfully by fractal technology. So that the most advanced wireless applications like WiMAX can be achieved by proper selection of substrate, feeding technique and proper design procedure.

II. MICROSTRIP PATCH ANTENNAS

Microstrip antennas (also known as printed antennas) the most common of which is the Microstrip patch antenna or patch antenna. A patch antenna is a narrowband, wide-beam antenna fabricated by etching the antenna element pattern in metal trace bonded to an insulating dielectric substrate, such as a printed circuit board, with a continuous metal layer bonded to the opposite side of the substrate which forms a ground plane. Common Microstrip antenna shapes are square, rectangular, circular and elliptical, but any continuous shape is possible. Because such antennas have a very low profile, are mechanically rugged and can be shaped to conform to the curving skin of a vehicle, they are often mounted on the exterior of aircraft and spacecraft, or are incorporated into mobile radio communications devices.

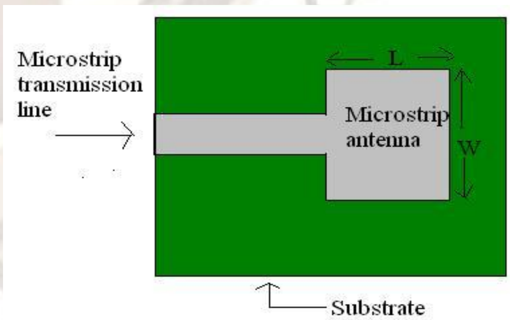


Figure 2.1: Top View of Patch Antenna

The frequency of operation of the patch antenna of Figure 3.1 is determined by the length *L*. The center frequency will be approximately given by:

$$f_c \approx \frac{c}{2L\sqrt{\varepsilon_r}} = \frac{1}{2L\sqrt{\varepsilon_0 \varepsilon_r \mu_0}}$$

2.1 Microstrip Antenna - Feeding Methods:

There are several feeding techniques to excite an antenna. These are:1)Inset Feed, 2) Fed with a Quarter-Wavelength Transmission Line, 3) Coaxial Cable or Probe Feed, 4) Coupled (Indirect) Feed 5) Aperture Feed, 6) CPW Feed.

Among all these feeding techniques the CPW-feed is widely used because of its wider bandwidth and many more advantages.

2.2 CPW-Feed

There are two types of excitation techniques in CPW-feed mechanism. They are:

1. Coplanar Waveguide feed.
2. Grounded Coplanar Waveguide feed.

Here we are using CPW -Feed and it is formed from a conductor separated from a pair of ground planes, all on the same plane on a dielectric medium. In the ideal case, the thickness of the dielectric is infinite; in practice, it is thick enough so that EM fields die out before they get out of dielectric.

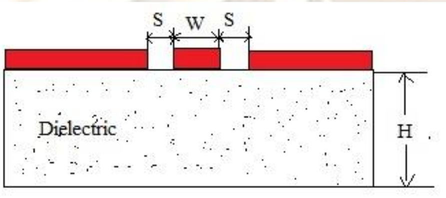


Figure 2.2: Coplanar Waveguide feed.

Where,

W=width of the center conductor,

H=height of the substrate.

S=Slot width made between center conductor and ground plane.

The current distribution when exciting the CPW-feed is produced across the slot which is made between inner conductor and ground plane. Slots are useful to control the path of surface current. This is shown in figure 2.3.

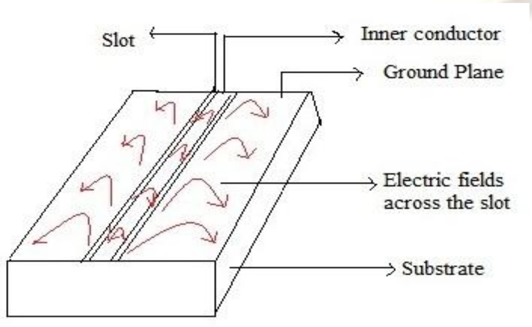


Figure 2.3: Current distribution across the slot.

Advantages of CPW-feed:

1. Active devices can be mounted on top of the circuit, like on Microstrip.
2. It can provide extremely high frequency response (100GHz and more).
3. In terms of circuit isolation, great isolation can be achieved by using CPW, because there are always RF grounds between traces.

Disadvantages of CPW-feed:

1. It is potentially lousy heat dissipation (this depends on the thickness of the dielectric and weather it makes constant to a heat sink).
2. To make compact circuits using narrow transmission lines, there should be tradeoff RF loss.CPW circuits can be lossier than comparable Microstrip circuits, if needed compact layout.

III. Fractal Antennas

A fractal antenna is an antenna that uses a fractal, self-similar design to maximize the length, or increase the perimeter (on inside sections or the outer structure), of material that can receive or transmit electromagnetic radiation within a given total surface area or volume. Such fractal antennas are also referred to as multilevel and space filling curves, but the key aspect lies in their repetition of a motif over two or more scale sizes,[1] or "iterations". For this reason, fractal antennas are very compact, multiband or wideband, and have useful applications in cellular telephone and microwave communications.

3.1 Features of fractal structure

- Self-similarity, which may be manifested as:
- Exact self-similarity: identical at all scales; e.g. Koch snowflake
- Quasi self-similarity: approximates the same pattern at different scales; may contain small copies of the entire fractal in distorted and degenerate forms; e.g., the Mandelbrot set's satellites are approximations of the entire set, but not exact copies.
- Statistical self-similarity: repeats a pattern stochastically so numerical or statistical measures are preserved across scales; e.g., randomly generated fractals; the well-known example of the coastline of Britain, for which one would not expect to find a segment scaled and repeated as neatly as

the repeated unit that defines, for example, the Koch snowflake.

- Multifractal scaling: characterized by more than one fractal dimension or scaling rule.
- Fine or detailed structure at arbitrarily small scales. A consequence of this structure is fractals may have emergent properties.
- Irregularity locally and globally that is not easily described in traditional Euclidean geometric language. For images of fractal patterns, this has been expressed by phrases such as “smoothly piling up surfaces” and “swirls upon swirls”.
- Simple and “perhaps recursive” definitions.

3.2 Applications of Fractal Antennas

1) Fractals in astrophysics
2) Fractals in the Biological Sciences
3) Fractals in computer graphics

IV.DESIGN OF CIRCULAR MONOPOLE ANTENNA

The fractal structure is used to obtain ‘Wide Band Structure’. The fractal structure is the self-similar design to maximize the length, or increase the perimeter (on inside sections, or the outer surface), of material that can receive or transmit EM radiation within a given total surface. The CPW-fed antennas gives larger bandwidth of 6:1.The CPW-fed fractal antennas are widely used for multi-Band operation. MB (Multi-Band) antennas are intensively used for wireless communications such as transmitting and/or receiving EM energy in shorter durations and avoiding frequency and space dispersive.

A crown-square Microstrip fractal antenna produces a pair of circularly polarized bands in large bandwidths at high frequency modes.

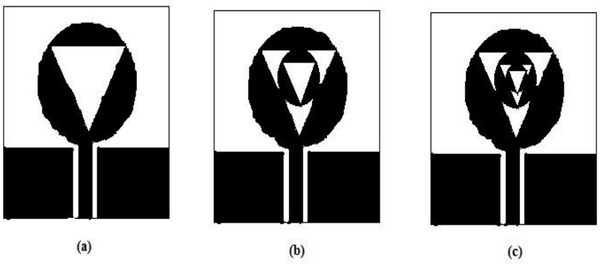


Figure 4.1: Geometries of the CPW-fed ultrawideband fractal antennas (black: copper; white: substrate)
(a) The original structure, (b) the first order iteration, (c) the second order iteration.

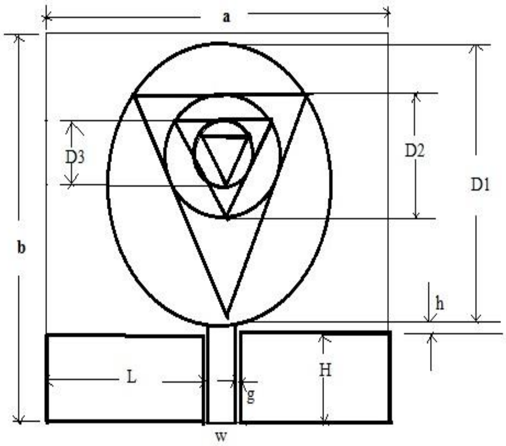


Figure 4.2: Structure of the fabricated monopole antenna.

Table4.1: Dimensions in Millimeters (mm) of fabricated monopole antenna

a	39.2
b	43.5
D1	25
D2	12.5
D3	6.25
L	18.6
H	15.5
w	1.36
g	0.32
h	0.52

Where,

a=Length of the fabricated monopole antenna
b=Height of the antenna

D1=Diameter of the outer circle in the square patch.

D2=Diameter of the first inner circle

D3=Diameter of the second inner circle.

L=Length of the ground plane.

H=Height of the ground plane.

w=Width of the center conductor.

g=Width of the slot made between center conductor and ground plane.

h=Height of the space between radiating patch and ground plane.

4.1ANTENNA CONFIGURATION

A CPW-fed circular disc monopole antenna for MB applications is designed, in which the current of proposed antenna is mainly distributed along the circumference of circular disc antenna. As a result, the current density is low in the middle area of the circular disc antenna. The current will not be affected if the middle part of the circular disc antenna is cut, and the effective path of surface current will become longer. But the first resonant frequency will be decreased and the size of antenna will be reduced and also the bandwidth becomes smaller.

The characteristics of these antennas is relevant to D1, L, H, h.It is also relevant to dielectric constant and thickness of substrate. Here, the substrate used is FR4 with thickness of 1mm, dielectric constant 4.5 and the electric tangent delta or loss tangent of 0.002 are used.

4.2 FABRICATION

This involves the artwork preparation fabrication as well as etching process and connecting the suitable connector.

Dielectric Substrate: In this project, we used FR4 PCB material which has a layer of copper bonded to a substrate of fiberglass to create the antenna. This FR4 substrate also can be operated until 10 GHz frequency. The thickness of the dielectric available is 1.7 mm.

Connector: 50 ohm SMA connectors were chosen to connect the antenna to the test equipment.SMA connectors have excellent frequency response up to 18 GHz.

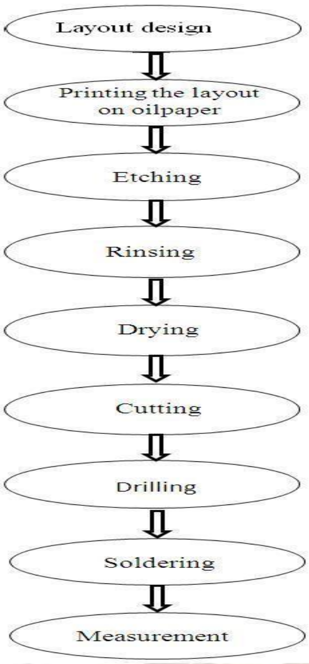
Radiating and Ground Plane: The crown shaped circular monopole fractal antenna of 8.7x9.6 cm was printed on top side of substrate and the two ground planes of size 4.1x3.4 cm with slot width between stripline and ground planes of 0.1cm was printed on the bottom of the patch, as is required to design CPW-fed Microstrip patch antenna. The designed and fabricated crown shaped circular monopole fractal model is shown in figure 5.3 and figure 5.4 respectively.

Table 4.2: Dimensions in Centimeters (cm) of fabricated monopole antenna

a	≈ 8.7
b	≈ 9.6
D_1	≈ 5.5
D_2	≈ 2.8
D_3	≈ 1.4
L	≈ 4.1
H	≈ 3.4
w	≈ 0.3
g	≈ 0.1
h	≈ 0.11

Figure 4.3 :Faricated Circular Monopole patch Antenna.(Dark:copper,Light green:FR4 substrate)

The overall process for fabrication from the beginning to measurement is shown in the below flow chart:



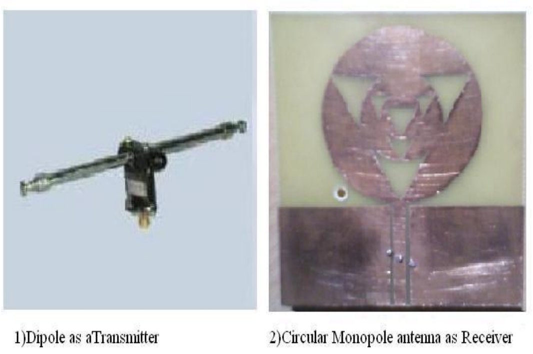


Figure 4.4: Dipole as Transmitter and Fabricated antenna as Receiver.

V. WiMAX

WiMAX (Worldwide Interoperability for Microwave Access) is a wireless communications standard designed to provide 30 to 40 megabit-per-second data rates, with the 2011 update providing up to 1 Gbps for fixed stations.

Speed vs. mobility of wireless systems:

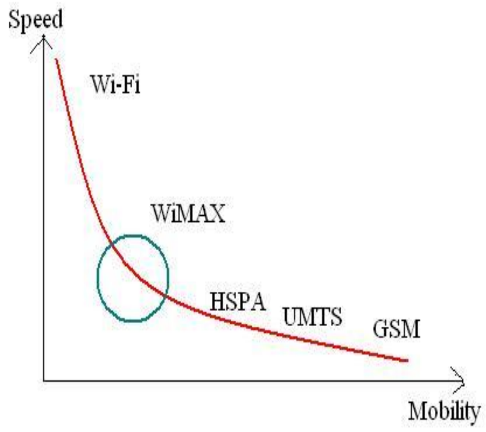


Figure 5.1:Speed vs. mobility of wireless systems: Wi-Fi, High Speed Packet Access (HSPA), Universal Mobile Telecommunications System (UMTS), GSM

One of the significant advantages of advanced wireless systems such as WiMAX is spectral efficiency. For example, 802.16-2004 (fixed) has a spectral efficiency of 3.7 (bit/s)/Hertz, and other 3.5–4G wireless systems offer spectral efficiencies that are similar to within a few tenths of a percent. The notable advantage of WiMAX comes from combining SOFDMA with smart antenna technologies. This multiplies the effective spectral efficiency through multiple reuse and smart network deployment topologies. The direct use of frequency domain organization simplifies designs using MIMO-AAS compared to CDMA/WCDMA methods, resulting in more effective systems.

Advantages and disadvantages of WiMAX:

Advantages:

1) Single station can serve hundreds of users.

2) Much faster deployment of users compared to wired networks.

3) Speed of 10Mbps at 10Km with LOS.

Disadvantages:

1) Line-of-Sight is needed for longer connections.

2) Weather conditions like rain could interrupt the signal.

3) Other wireless equipment could cause interference.

4) It is very powerful intensive technology and requires strong electrical support

5) Big installation and operational cost.

6) It is very expensive.

VI.EXPERIMENTAL RESULTS

The fabricated antenna with dimensions (8.7 × 9.6 ×0.17 cm) is shown in figure , the radiation patterns at 600MHz and at 1500MHz with relative and absolute ON are observed. The Cartesian graph of Level vs. frequency also seen.

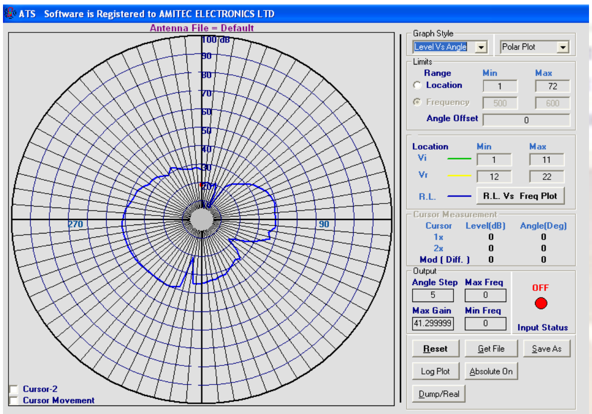


Figure 6.1: Radiation pattern(Level vs Angle polar plot) at 600MHz

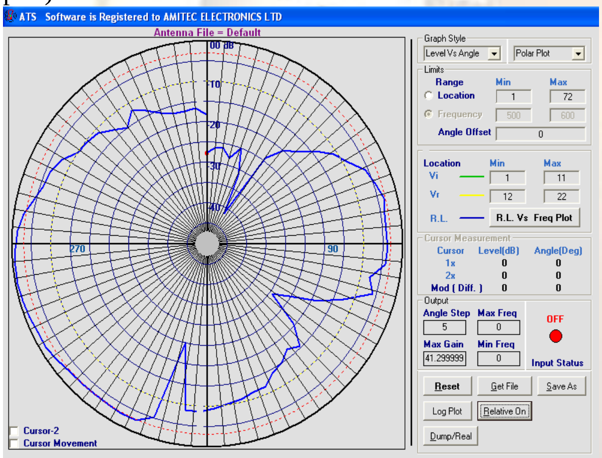


Figure 6.2: Radiation pattern(Level vs Angle polar plot) at 600MHz with absolute ON

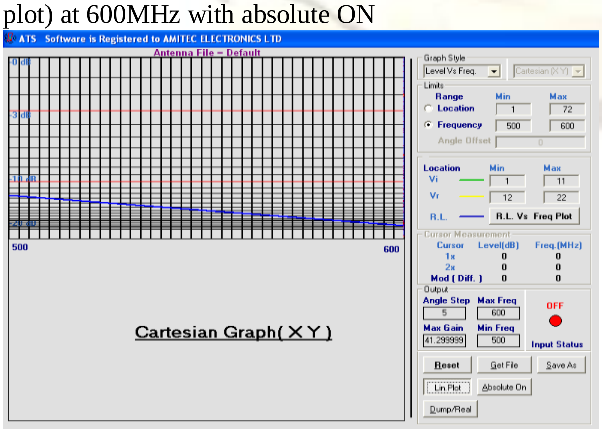


Figure 6.3: Cartesian Graph(Level vs Frequency) of the antenna at 600MHz.

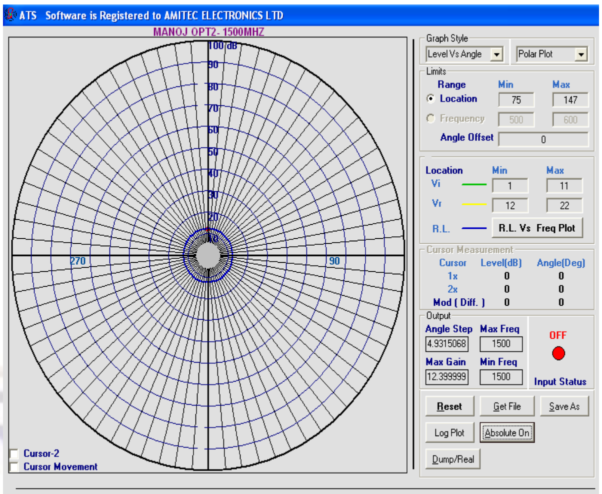


Figure 6.4: Radiation pattern(Level vs Angle polar plot) at 1500MHz.

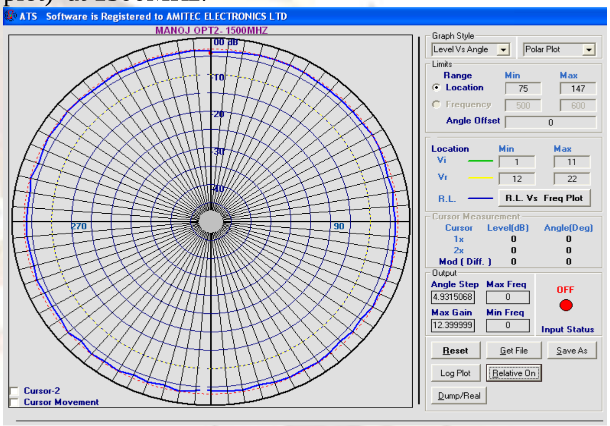


Figure 6.5 : Radiation pattern(Level vs Angle polar plot) at 1500MHz with absolute ON.

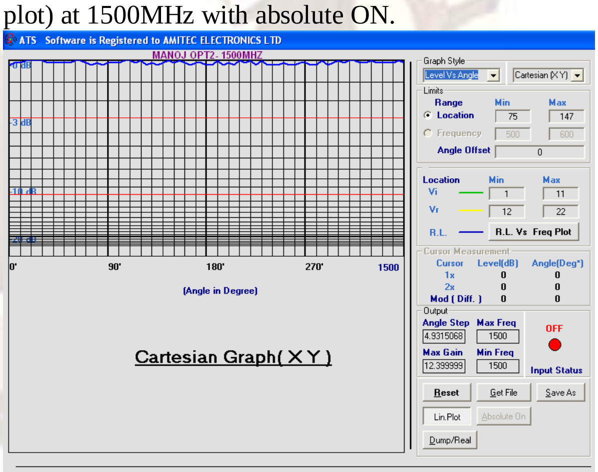


Figure 6.6 : Cartesian Graph(Level vs Angle) at 1500MHz.

Figure 6.1 shows the Radiation pattern(Level vs Angle polar plot) at 600MHz whose maximum gain is 41.29dB. Figure 6.2 shows the Radiation pattern(Level vs Angle polar plot) at 600MHz with absolute ON which indicates the clear detail of the radiation pattern.Figure 6.3 shows the Cartesian Graph(Level vs Frequency) of the antenna from 500MHz to 600MHz. Figure 6.4 shows the

Radiation pattern(Level vs Angle polar plot) at 1500MHz whose maximum gain is 12.39dB. Figure 6.5 shows the Radiation pattern(Level vs Angle polar plot) at 1500MHz with absolute ON indicates the clear detail of the radiation pattern. Figure 6.6 shows the Cartesian Graph(Level vs Angle) of the antenna from 0 to 360 degrees.so as the frequency is increased from 600MHz to 1500MHz the maximum gain is reduced and at 3 GHz it is still reduced.so as the frequency is increased the propoed antenna can have degradation in its characteristics.so to overcome this problem,the antennas substrate thickness,dielectric constant value,thickness of the metal,characteristic impedance of the antenna etc should be optimum to get desirable characteristics at higher frequencies.

VII.CONCLUSION

At 600MHz and 1500MHz the proposed antenna gives maximum gain which is high at 600MHz and somehow less at 1500MHz but whenever the frequency is increased the characteristics are degraded, this is because of the substrate used is FR4 whose dielectric constant is 4.4, the fringing fields exhibited when antenna is excited is less and so the radiated power from proposed antenna is less as the dielectric constant is large. The Omni directional pattern at 1500MHz is formed due to the resonance between transmitter and receiver which is useful for 360 degrees coverage with maximum gain of 12.4 dB and at 600 MHz the antennas pattern is directional which acts as a directional antenna with the maximum gain of 41.3dB.So, if the substrate's dielectric constant value, substrate thickness chosen in optimum then even at higher frequencies the gain can be increased with good radiation pattern with less return loss & VSWR.

The new compact Multi-Band antenna has been presented and implemented successfully by fractal technology. The Experimental results of the gain and radiation patterns demonstrate that the CPW-fed Multi-Band circular Monopole fractal antenna provides good Multi-Band performance with a convenient smaller size. Therefore, the antenna is attractive for Multi-Band applications like WiMAX, mobile WiMAX applications.

REFERENCES

[1] Constantine A. Balanis, (1997),"Antenna Theory Analysis and Design", John Wiley and Sons Inc.

[2] "Hand book of Microstrip Antennas " Edited by JR James and PS Hall, IET.

[3] Pozar, D.M. Microstrip antennas. Proceedings of the IEEE. Volume 80, Issue 1,Jan. 1992 Page(s):79-91

[4] Ramesh Garg, Prakash Bhartia, Inder Bahl, Apisak Ittipon, (2000)," Microstrip Antenna Design Handbook", Artech House.

[5] http://www.antenna-theory.com

[6] N. Behdad and K. Sarabandi, A compact antenna for ultra wide-band applications, IEEE Trans Antennas Propag 53 (2005), 2185–2192.

[7] J. Liang, C.C. Chiau, X. Chen, and C.G. Parini, Printed circular disc monopole antenna for ultra-wideband applications, Electron Lett 40 (2004), 1246–1247.

[8] J. Liang, L. Guo, and C.C. Chiau, CPW-fed circular disc monopole antenna for UWB application, IEEE International Workshop on Antenna and Technology: Small Antennas and Novel Metamaterials, Marina Mandarin, Singapore, March 7–9, 2005, pp. 505–508.

[9] J. Guterman, A.A. Moreira, and C. Peixeiro, Microstrip fractal antennas for multistandard terminals, IEEE Antennas Wireless Propag Lett 3 (2004), 351–354.

[10] J.P. Gianviffwb and Y. Rahmat-Samii, Fractal antennas: A novel antenna miniaturization technique, and applications, Antennas Propag Mag 44 (2002), 20–36.

[11] P. Dehkhoda and A. Avakoli, A crown square microstrip fractal antenna, IEEE Antennas Propag Soc Int Symp Dig 3 (2004), 2396 –2399.

[12] E. Lule, T. Babij, and TimeDerivative, Koch island fractal ultra wideband dipole antenna, IEEE Antennas Propag Soc Int Symp Dig 3 (2004), 2516–2519.

[13] S.-Y. Suh, W. Stutrmmtt, and W. Davistt, A novel CPW-fed disc antenna, IEEE Antennas Propag Soc Int Symp Dig 3 (2004), 2919–2922.

[14] http://www.tutorialspoint.com/wimax/wimax_summary.htm

[15] http://rswcyyw.blogspot.com/2007/06/wimax-disadvantages.html