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Minkowski Fractal Geometry based T-shaped Fractal Patch Antenna for wireless applications

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Abstract: One of important concept to design antenna is that antenna have small size. For mobile applications, one may want that antenna must have small size and must be capable to resonate at multiple frequency bands. There are number of techniques that can be useful for designing of antenna which include making use of fractal geometry, use of slot and DGS.. In this paper, T-shaped Patch antenna has been designed and fractal geometry has been applied to it in order to obtain self-similar characteristics. square. Patch length has been taken as square of length 36mm. Dimension of ground has been taken as been taken as 50 mm. The substrate used in this paper is FR-4. Parametric analysis has been applied in terms of changing microstrip line, feed point, thickness and geometry. Antenna resonates at three bands with return loss of 3.9 GHz, 4.5 GHz and 6.1 GHz. This antenna had return loss of -14.34 dB, -14.40 dB and -25.85 dB with bandwidth of 100 MHz, 110 MHz and 200 MHz at resonant frequencies. Further this antenna has good gain of 3.5dBi, 3.6 dBi and 6.1 dBi at corresponding frequencies. This antenna can b useful for Wi-Max and WLAN applications.

Keywords: Wireless applications, WLAN, Fractal Microstrip Patch Antenna

I. INTRODUCTION

Antenna is one of the largest components of the low profile wireless communication. In order to transmit and receive antenna information; modulation is done in which career wave is superimposed over modulating signal. At the required destination, the modulated signal was then received and the original information signal can be recovered by demodulation. Over the years, techniques have been developed for this process using electromagnetic carrier waves operating at radio frequencies as well as microwave frequencies. In the current scenario small, compatible and affordable microstrip patch antennas are developed in wireless communication industries keep on improving antenna performance. A patch antenna is a narrowband antenna with large beam width. It is fabricated by etching the antenna element pattern in metal trace which is 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 known as a ground plane. Fractal geometry is used to reduce the size of patch antenna. Fractal geometries are different from Euclidean geometries which have two common properties: space-filling and self-similarity. It is found that by applying fractal geometry, self-repeating structures are obtained. Fractal geometries that are used in this dissertation are Koch curve, Minkowski fractal geometry and many other self-similar shapes. By applying fractal geometry on patch, area of patch decreases, resonant length increases and number of frequency bands of antenna increases. Also it is good to achieve wideband characteristics apart from multiband characteristics; hence defected ground structure has been applied to antenna. There are different DGS that can be applied to antenna which include H shaped, plus shaped DGS. It is found that by applying DGS to antenna, characteristics of antenna improved. Radio waves and microwaves play an important role in daily life. Television signals are transmitted by satellite using microwaves, military uses microwave for surveillance and navigation purposes. Telephone and data signals are transmitted by microwaves. Also in today's scenario, technology demands such an antenna that can operate on different wireless band and must have different features like low cost, less weight, low profile antenna which are capable of maintaining high performance over a chromatic spectrum of frequencies. Microwave spectrum is usually called as electromagnetic spectrum, since it ranges from 1GHz to 100 GHz. There are different microwave bands which are classified into many frequency bands. Applications most commonly used are of range 1 to 40 GHz. Hence different bands within this range are L band (1-2 GHz), S band (2-4 GHz), C band (4-8 GHz), X band (8-12 GHz), K_u band (12 -18 GHz), K band (18-26.5 GHz) and K_a band (26.5-40 GHz). Different bands together with their applications are mentioned in table 1.1. Microstrip antenna finds applications from 1 GHz to 12 GHz. Hence microstrip antenna can be designed for L band, S band, C band and X band applications. Standard band designations for microwave frequencies listed as per Institute of Electrical and Electronics Engineering (IEEE) is the industry standards.

II. ANTENNA DESIGN

Design Considerations for Fractal Antenna

It is necessary to design antenna in such a way that desired characteristics are obtained. Fractal geometry is applied to antenna so as to obtain multiband characteristics. It is important to take into account size of antenna. If all characteristics are good but size of antenna is large, so antenna will not be much useful. Similarly small size antenna with not good characteristics is not useful. Dimensions of antenna depend on desired frequency of

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application. If antenna is designed for small frequencies size would be large. Size of antenna also depends on dielectric substrate. If substrate has large dielectric constant, size would be small but efficiency and bandwidth decreases.

Design of Fractal Microstrip Patch Antenna

Design of T-shaped fractal microstrip patch antenna has been obtained by applying fractal geometry. Patch is taken is known to be square whose dimensions has been calculated as per antenna specifications. Although length of antenna had been rectangular but by parameter optimization, length of antenna has been taken as square. Patch length has been taken as square of length 36mm. Dimension of ground has been taken as been taken as 50 mm. The substrate used in this dissertation is FR-4. This substrate has been chosen to reduce antenna dimension of antenna. Substrate used for this antenna is FR-4 with dielectric constant of 4.4 and loss tangent of 0.02. Table 1 shows dimensions of antenna.

In order to design T-shaped fractal patch antenna for wireless applications, square patch of length 36 mm is taken and operational analysis is applied to it. The geometry corresponding to it is shown in figure 1.(a). This antenna is fed by coaxial feed at point (x=0, y=6) as shown in figure 1(a). Results corresponding to it are analyzed. T shape antenna is designed by making use of cantor fractal and Minkowski fractal geometry. First of all, square of 36 mm is divided into half and one section of 18 mm is taken and 36 mm is divided into 3 parts.

Variable	Value
Dimensions of Square Patch	36 mm
Dimensions of Square Ground	FR-4
Substrate Used	50 mm
Thickness of substrate	2.4 mm
Feeding technique used	Coaxial Feeding Technique
Substrate used	FR-4
Feed Length of Probe	4mm
Dimensions of Microstrip Feed	2X 7 mm
Feed point	(0, 6, 0)
First Geometry Algorithm	Minkowski Fractal Geometry
Simulation Software	HFSS

Table 1: Dimensions of Antenna

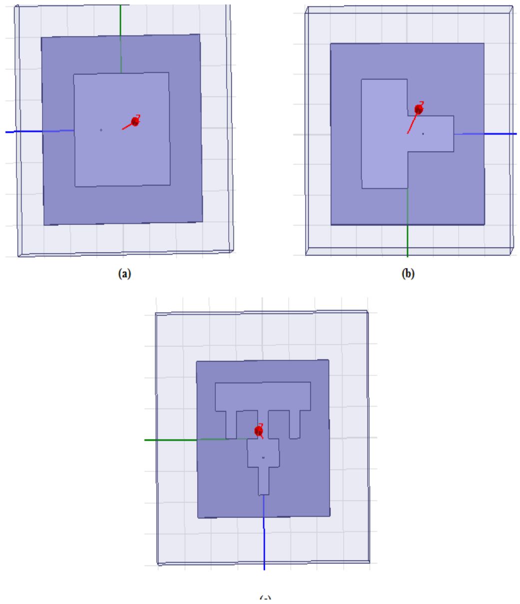

Fig 1:T- Shaped FMPA **(a)** 0^{th} Iteration,**(b)** 1^{st} Iteration and **(c)**2^{nd} Iteration

Hence two a rectangle of 18 mm in length and 12 mm in width are removed to form T-shaped patch as shown in figure 1(b). Now four rectangles of dimension 12 X 18 mm are formed hence x axis is divided into three parts and anf y into two and two rectangles of dimension 4 by 9 mm are removed from rectangle to form self similar structure as shown in figure 1(c). Geometry shown in figure 1(a), 1(b) and 1(c) shows self similar structures geometry. From above geometries, it is found that as number of iterations increases, self-repeating characteristics are obtained. These also show as number of iterations increases, area decreases. Beyond a certain level of iteration, it is difficult to fabricate antenna as cuts become small which cause difficult for antenna to make practically.

Parametric Analysis of Proposed Antenna

It has been analyzed that by applying two iterations of fractal geometry, characteristics of antenna improves a lot. Parametric analysis includes making use of feed point change, substrate selection and thickness of substrate. It is found with help of parametric analysis, one may obtain best configuration that has better result. It is also found that results can also be analyzed by changing feed to microstrip line

- Effect by changing coaxial feeding point
- Effect of changing substrate of antenna
- Effect of Changing feeding technique to microstrip line
- Effect of changing thickness of antenna
- Comparison with E-shaped Fractal antenna

Effect of changing Dielectric Substrate

In this dissertation, substrate used is FR-4, but there are many substrates that can also be used in order to analyze results. FR-4 is having dielectric constant of 4.4

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and loss tangent of 0.02. There are many other substrate that can be used for analyzing results. One of substrate that has been used is Rogers RT-duroid 5880. This antenna has dielectric constant of 2.2 and loss tangent of 0.0009. Feed to antenna has not changed. It has been found that when dielectric constant of antenna has been changed then dimension of antenna changes or resonant frequency changes. Geometry corresponding to it has been shown in figure 2.

Effect of Changing Feed Point

Proposed T –shape fractal patch antenna has been designed using FR-4 as substrate. It has been found that feed point plays an important role in design characteristics. The T shape fractal patch antenna is analyzed by varying feed point.

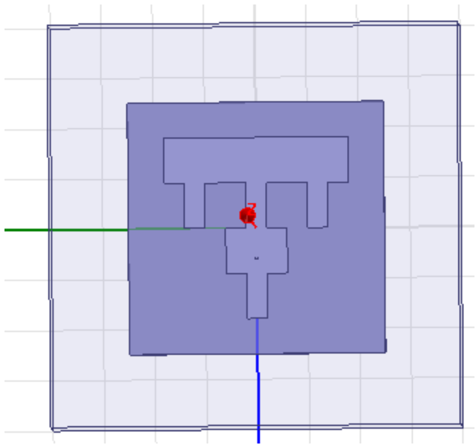

Figure 2: Antenna with DGS using Different Substrate

Feed point is important characteristics. Coaxial feed is varied by varying feed at (0, 4), (0, 6) and (0, 8). Variation of feed point has been shown in figure 3(a), 3(b) and 3(c).

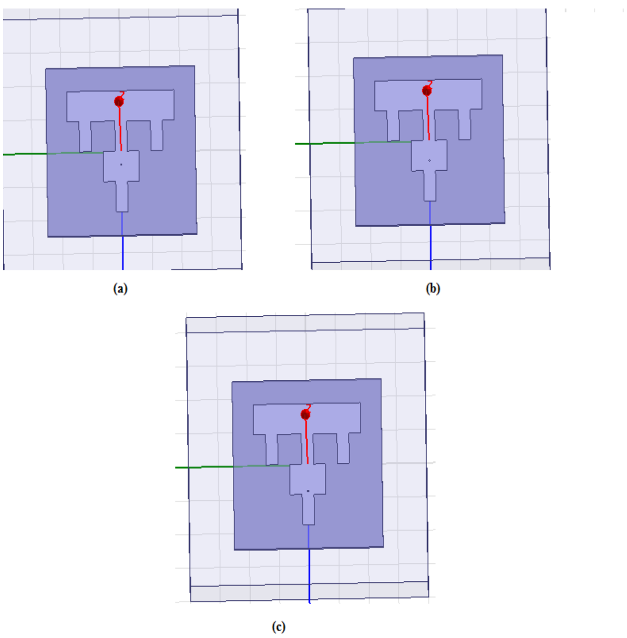

Figure 3:T-shaped Fractal Antenna with (a) Feed Point at (0,4), (b) Feed point at (0,6) and Feed Point at (0, 8).

III. RESULTS & DISCUSSION

T-Shaped Fractal Patch Antenna

In this section, simulation results of different iterations of fractal geometry are compared. T shape fractal antenna is made by cutting slots as shown in figure 4.2. These cause self-similar T-shaped structure. Return loss vs. frequency for various iteration of T-shaped fractal geometry are shown in figure 5.1.

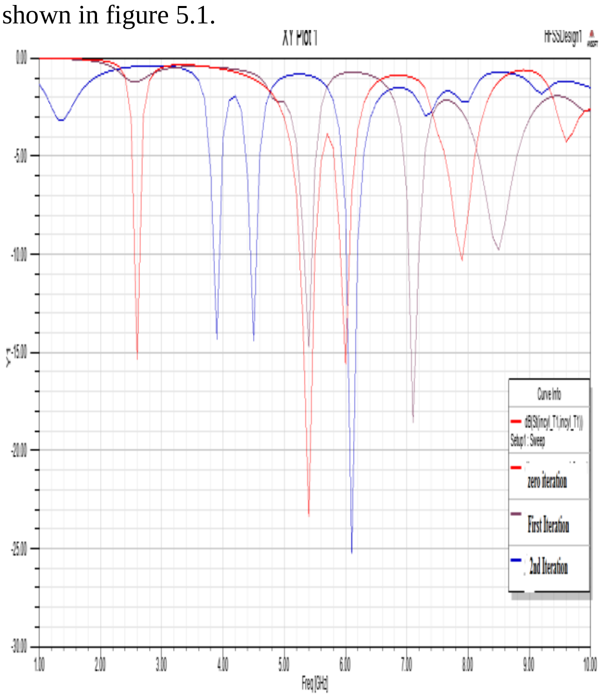

Figure 5: Return Loss Vs. Frequency for Different Fractal Iterations of T-shaped FMPA

From figure 5 it is found that characteristics of antenna increases as number of iterations increases, initially square antenna resonates at 2.6GHz, 5.4GHz and 6 GHz with return loss of -16 dB, -23 dB and -16 dB and bandwidth of 110 MHz, 100 MHz and 125 MHz. since characteristics of antenna at zeroth iteration are not good so fractal geometry has been applied to improve characteristics. Two slots are cut as shown in figure 1(b). This antenna resonates at two bands at 5.4 GHz and 7.10 GHz with return loss of -16 dB and -14.72 dB. This antenna had bandwidth of 180 MHz and 170 MHz at resonant frequency. As results obtained are good but resonant frequency bands are having more return loss hence second iteration of fractal geometry is applied. When second iteration of fractal geometry is applied as shown in figure 1(c), antenna resonates at three bands with return loss of 3.9 GHz, 4.5 GHz and 6.1 GHz. This antenna had return loss of -14.34 dB, -14.40 dB and -25.85 dB with bandwidth of 100 MHz, 110 MHz and 200 MHz at resonant frequencies. Further this antenna has good gain of 3.5dBi, 3.6 dBi and 6.1 dBi at corresponding frequencies. Further radiation patterns at 3.9 GHz, 4.5 GHz and 6.1 GHz have been shown in figure 6(a), 6(b), and 6(c).It is found that when one wants to have radiations, there must be acceleration or deceleration of

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charges, these currents have been refer to time harmonic applications where most charge has been mentioned in transients. In order to have acceleration or deceleration, patch must be having non regular conduction path. It has been found that by making more and more non regular path to antenna, characteristics of antenna become improved. When first iteration of fractal geometry has been applied, effective length of patch increases which result better antenna characteristics.

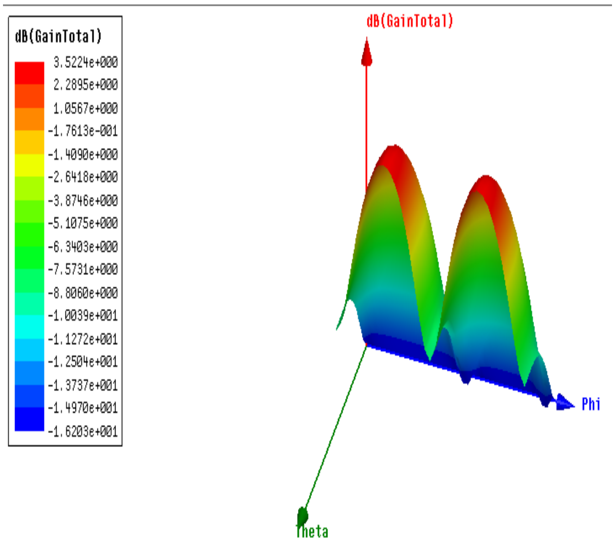

Figure 6(a): Radiation Pattern of T-shaped FMPA at 3.9 GHz

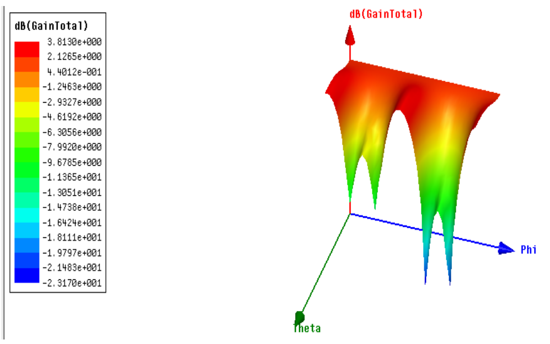

Figure 6(b): Radiation Pattern of T-shaped FMPA at 4.5 GHz

When second iteration is applied, number of fractal cuts increases which caused effective length to increase more and more, hence T-shaped fractal antenna in second iteration as shown in figure 1 has good characteristics in terms of return loss, gain and bandwidth. This radiation pattern show s that antenna is having maximum energy corresponds to that in particular direction. There are different radiation patterns like fan based, pencil based radiation pattern.

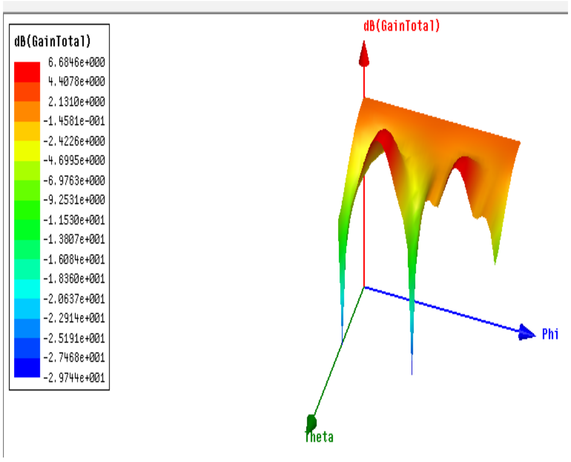

Figure 6(c): Radiation Pattern of T-shaped FMPA at 6.1 GHz

Table2 shows comparison of results of different iterations of T-shaped fractal geometry applied on square patch as shown in figure 1. Results are analyzed in terms of return loss and bandwidth. It is found from results that antenna characteristics improves as number of iterations increased.

Iteration Number	**Resonance Frequency (GHz)**	**Return Loss (dB)**	**Bandwidth (MHz)**
0^{th} Iteration	2.6	-16	100
	5.4	-23	200
	6	-16	110
1^{st} Iteration	5.4	-14.72	180
	7.10	-18.60	170
2^{nd}	3.9	-14.34	100
	4.5	-14.40	110
	6.1	-25.85	200

Table 2: Comparison Results of Different Iterations of T-shaped FMPA

It is found from results that as dimension of antenna increases, result become better. Further it is also found that as one move from first to third iteration, number of bands and bandwidth increases. Voltage standing wave ratio is measure of reflection occur. When any incident wave travel from input side then at impedance terminal, because of improper matching, waves get reflected hence maxima's and minima's are formed. VSWR is ratio of voltage maxima to voltage min ima and must be greater than one. This antenna has VSWR of 1.91, 1.17 and 1.91 at 3.9 GHz, 4.5 GHz and 6.1 GHz at corresponding frequencies.

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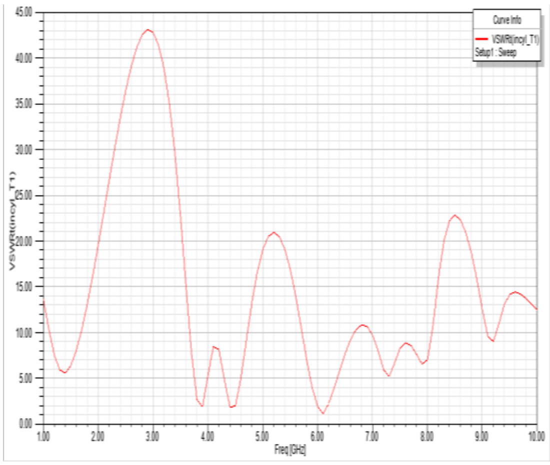

Figure 7: VSWR **Vs**. Frequency for Proposed Antenna

One of important parameter is smith chart. By using smith chart one can have obtained reflection coefficient, maxima location, impedance matching and many other things. Figure 8 shows smith chart of proposed antenna.

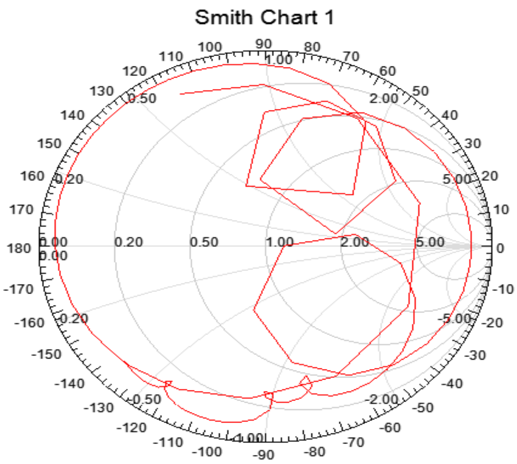

Figure 8: Smith Chart of Proposed Antenna

Effect of changing feed point

Parametric analysis has been conducted so as to vary feed point all along axis. By varying feed point it was found that impedance changes. Impedance change occurs as value of resistance and inductance change take place by varying feed point on peripheral of patch. Feed has given at several point along y axis at (0, 4), (0, 6) and (0, 8). By applying feed to antenna at x=0 and y-6, antenna resonates at 3.9 GHz, 4.5 GHz and 6.1 GHz with return loss of -14.34 dB, -14.40 dB and -25.85 dB. This configuration had good bandwidth of 100 MHz, 110 MHz and 200 Mhz at corresponding frequencies. As feed point shift from y=6 mm to y= 4mm, antenna characteristics changed as now antenna resonates at 4.5 GHz with return loss of -17 dB and bandwidth of 100 MHz. By changing feed point to y=8 mm, antenna resonates at 6.1 GHz with return loss of -16.5 dB and bandwidth of 150 MHz. Analysis of results of different antenna configurations have been shown in table 3. It is found that by making such analysis, antenna characteristics become much well.

Table 3: Antenna Characteristics by Feed Point

Y-Location	Resonant frequency	Return Loss	Bandwidth
Y=6	3.9	-14.34	100
	4.5	-14.40	110
	6.1	-25.85	200
4	4.5	-17	100
8	6.1	-16.5	150

Results of return loss versus frequency loss versus frequency at different feed points have been shown in figure 9.

CONCLUSION

From results it is found that parametric analysis had been carried out in termns of substrate thickness, feed point and number of iterations. It is found that by making use of fractal geometry, characteristics of antenna improves a lot. In this paper, T-shaped Patch antenna has been designed and fractal geometry has been applied to it in order to obtain self-similar characteristics. Patch length has been taken as square of length 36mm. Dimension of ground has been taken as been taken as 50 mm. The substrate used in this paper is FR-4. Parametric analysis has been applied in terms of changing microstrip line, feed point, thickness and geometry.

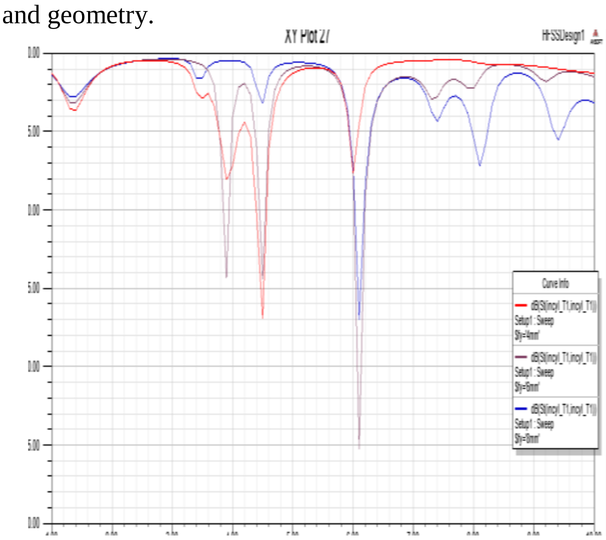

Figure 9: Return Loss Vs Frequency for Antenna with Different Feed Point

Antenna resonates at three bands with return loss of 3.9 GHz, 4.5 GHz and 6.1 GHz. This antenna had return loss of -14.34 dB, -14.40 dB and -25.85 dB with bandwidth of 100 MHz, 110 MHz and 200 MHz at resonant frequencies. Further this antenna has good gain of 3.5dBi, 3.6 dBi and 6.1 dBi at corresponding frequencies. This antenna can b useful for Wi-Max and WLAN applications.

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