Circular Patch Antenna with Enhanced Bandwidth using Narrow Rectangular Slit for Wi-Max Application

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Abstract

Since the inception of Microstrip Patch antenna constant efforts are being made to modify the overall performance of this class of antenna field .Although the microstrip antenna has some of shortcoming till this date such as low gain, narrow operating bandwidth, poor radiation efficiency, yet it has been one the most suitable candidate for modern wireless communication technology. This paper focus on the bandwidth enhancement of microstrip circular patch antenna by introducing a narrow rectangular slit of length 12 mm and width 0.6 mm and thickness 0.2 mm on the conventional circular patch. The proposed antenna is excited through the microstrip feed line technique and the antenna design and the parametric studies has been executed using Ansoft's HFSS (High Frequency Structure Simulator) The antenna resonate at two frequencies 2.7GHz and 5.4GHz having gain1.215dBi & 5.37dBi at respective frequency, these bands cover the lower and upper band of Wi-Max application.

Keywords

Microstrip Circular Patch Antenna, Miniaturization, Narrow slit, Gain, Bandwidth.

I. Introduction

Microstrip patch antenna has gain extensive application in present scenario of wireless communication due to their light weight, small size, ease of fabrication and integrability with circuitry. However these antennas are less suited to modern communication [1,2] as they efficiently resonate at single frequency and shows narrow bandwidth and low gain especially at lower microwave frequencies. As they are compact in nature and hence are popular structures in modern wireless communication system.

There are varieties of patch structures available but the rectangular, circular and triangular shapes [3] are most frequently used. The performance of antenna is affected by patch geometry, substrate property and feed technique. In circular structure the mode TMz (where z is taken perpendicular to the patch) is supported by circle shape on substrate with height (h < < λ) very small as compared to wavelength. There are different model to analyze the microstrip patch antenna. The basic model to analyze the patch antenna is the cavity [4] model. This model provides the method that the normalized field within the dielectric substrate can be found more accurately and does not radiate any power the effective dimension of antennas are greater than the actual dimension due to the fringing[5] [6] field between the patch and the ground plane. With the development of mobile and wireless communication system the demand for broad band, multiband patch antennas are desired.

II. Antenna Structures and analysis:

Due to limited bandwidth of the microstrip patch antenna several designs of the patch antenna have been proposed. Broadband can be achieved by embedding a u slot [7] on patch of various shapes or wider arc shaped slot in a circular patch. In this paper a circular patch antenna with narrow rectangular slit of specific dimension is designed and simulated on ansoft HFFS. The circular patch is excited through the microstrip feed line which is directly connected to the patch antenna. Since for microstrip antennas the substrate [8] height h is very small (h = 0.05λ0), the field along z are essentially constant [9]. Therefore the resonant frequencies for the TMz mn0 can be written as,

$$\frac{1}{2\pi\sqrt{\mu\epsilon}}\left(\frac{\chi_{mn}}{a}\right)\frac{1}{2\pi\sqrt{\mu\epsilon}}\left(\frac{\chi_{mn}}{a}\right)$$

χmn represents the zeroes of the derivatives of the bessel function Jm(x) and they determine the order of the resonsnt frequencies.

III. Design Parameters of conventional patch

In present case of study coparision analysis of circular patch withuot any slit and circular patch with narrow rectangular slit is investgated under similar conditions. A planer geometry of conventional patch of radius Rp = 14.5 mm is printed on the substrate of the dielectric material FR-4 havig length l×w = 55 mm×55 mm and thickness (h) = 1.59 mm. the dielectric constant for substrate is εr = 4.4 and has loss tangent 0.002. the antenna is excited through microstrip feed line having dimension L=13.15 mm and width, w= 1 mm.The circular patch antenna is design based on cavity model to obtain the best output in term of return loss and VSWR. Fig.1 shows the structure of conventional circular patch antenna.

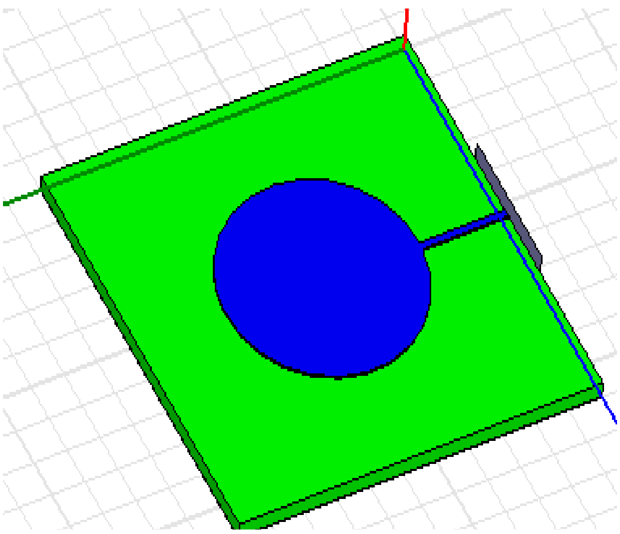

Fig.1: Strucrure of Circular Patch Antenna without slit

The return loss of conventional circular patch antenna without any slit, simulated on HFSS is shown in the fig.2,which indicates that the antenna shows resonance essentially at two frequencies i.e. 2.8 GHz and 5.4 GHz, though resonance is also observed at 4.3 GHz but shows poor impedance matching with feed network.

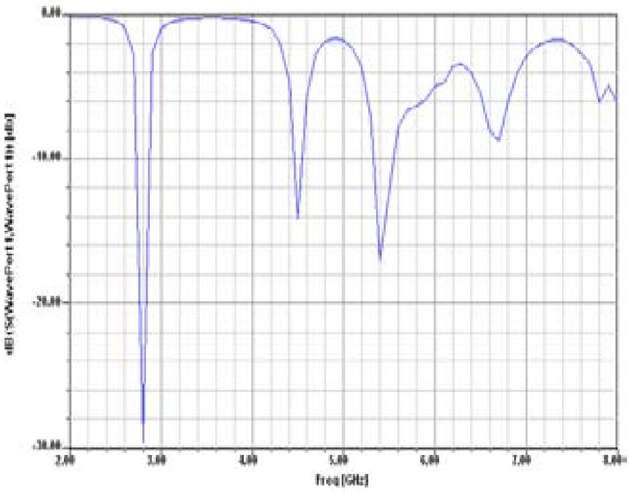

Fig.2 : Variation of return loss of circular patch antenna with frequency

The VSWR characteristics of circular patch without any slit is shown in the fig. 3

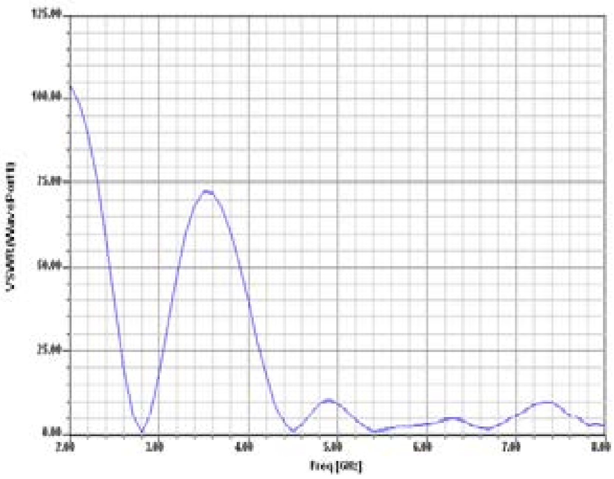

Fig.3 : VSWR for circular patch without any slit

The fig.3 indicates that antenna shows good impedance matching with feed network at 2.8 GHz & 5.4 GHz and has VSWR values 1.06 and 1.36 at respective frequencies. The radiation characteristics of antenna without any slit for 2.8 GHz & 5.4 GHz are shown in fig.4 and fig. 7 respectively. The gain of antenna at 2.8 GHz is 1.47 dBi and at 5.4 GHz the gain is 2.57 dBi. Fig 5 and fig 6 shows the elevation and azimuth pattern of patch antenna without slit.

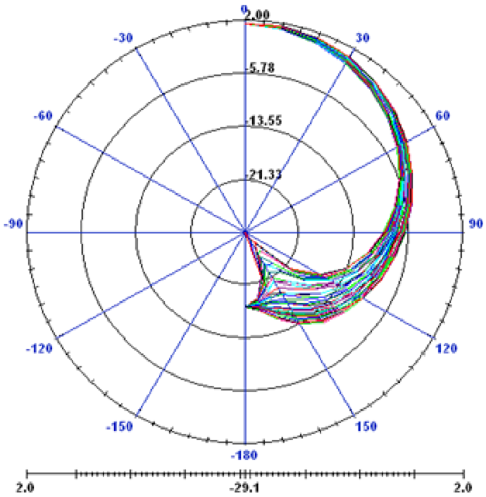

Fig.4 : 2D radiation pattern at 2.8 GHz

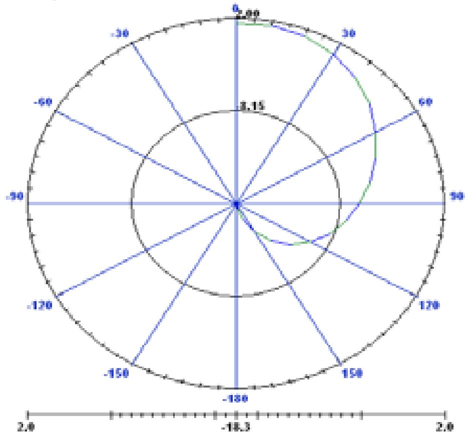

Fig.5 : Elevation gain pattern at 2.8 GHz for circular patch.

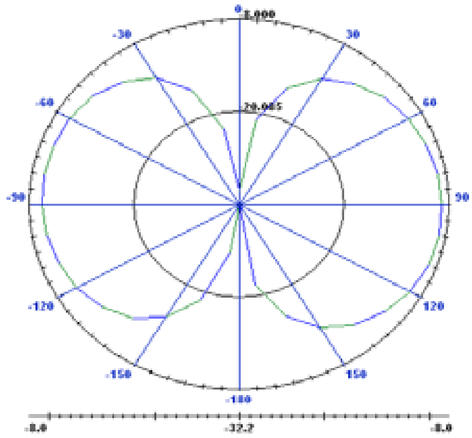

Fig.6 : Azimuth gain pattern at 2.8 GHz for circular patch

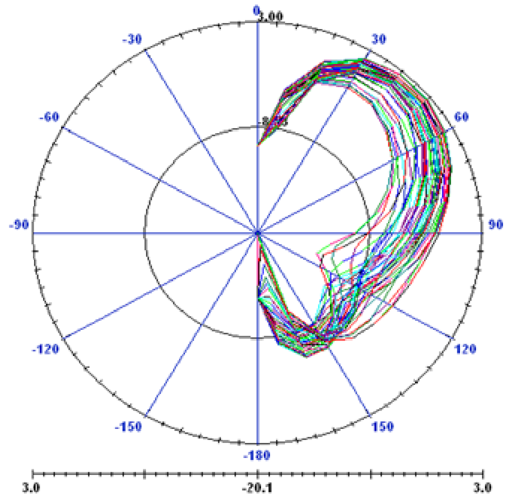

Fig.7 : 2D radiation pattern at 5.4 GHz

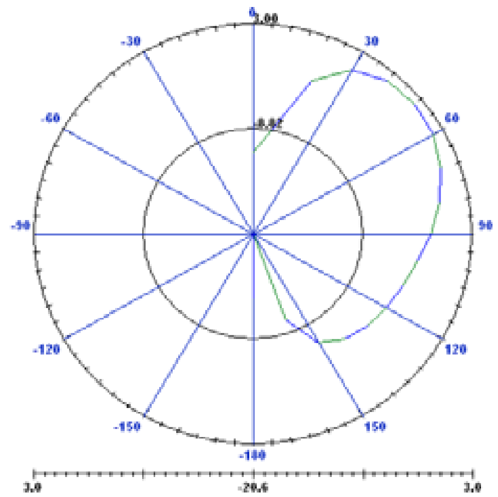

Fig.8 : Elevation pattern at 5.4 GHz for circular patch antenna.

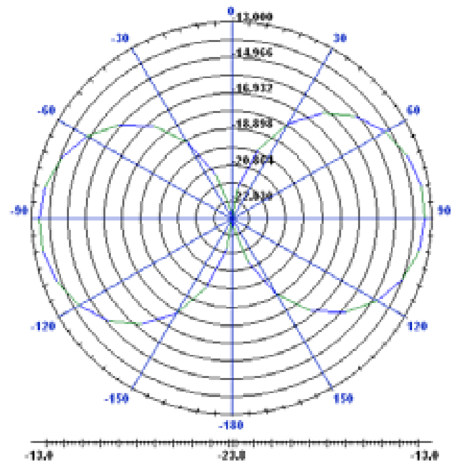

Fig. 9 : Azimuth gain pattern at 5.4 GHz for circular patch.

The graphs shown above indicates the gain characteristic of circular patch antenna without any slit at 2.8 GHz & 5.4 GHz with the decibel gain of 1.52 dBi and 2.57 dBi respectively. To achieve the improved performance of planar circular patch, a narrow rectangular slit of dimension L=12mm and W=0.6mm and thickness t=0.2 mm is etched in x-y plane on circular patch having same dimension as that of conventional circular patch as shown in fig. The antenna is then simulated under the conditions similar to circular patch without any slit.

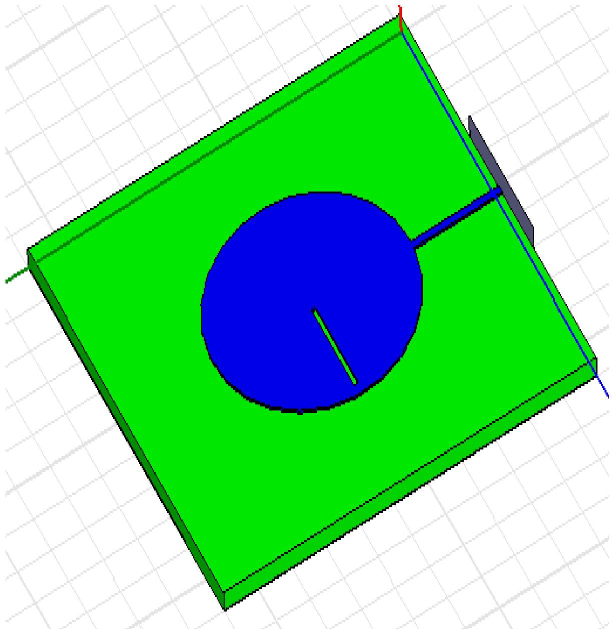

Fig.10 : Structure of Circular patch antenna with narrow slit.

The optimum performance of antenna is obtained by adjusting slit on the patch which in turn excites the other mode as the electrical length of the antenna is increased. The simulated results show that the antenna resonates efficiently at two frequency i. e. at 2.7 GHz and 5.4 GHz as shown in Fig. 11

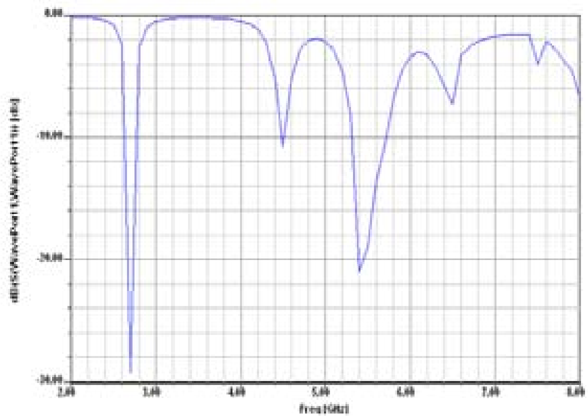

Fig.11 : Variation of return loss with frequency for circular patch antenna with narrow slit

In the presence of narrow rectangular slit the dominant mode of circular patch are affected that perturb the uniform current distribution on the patch surface and the electrical length of the antenna is increased, which cause the antenna at lower frequency and the first band is obtained at 2.7 GHz as shown in fig.8. At second band some higher modes are excited which shows good matching with feed network and also bandwidth improvement at this band is observed. The antenna now has the % bandwidth values at 2.7 GHz and 5.4 GHz as 5.5% and 7.5% respectively. The VSWR of circular patch antenna loaded with narrow rectangular slit is shown in fig.12

 ISSN : 2230-7109(Online)

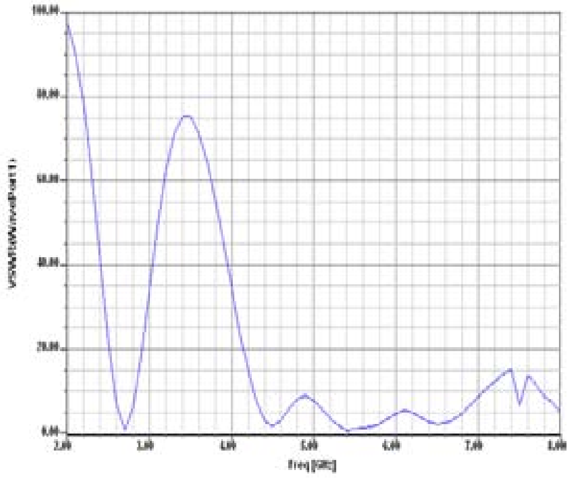

Fig.12 : VSWR for circular patch antenna with narrow rectangular slit

Fig. 12 indicates that that antenna with narrow rectangular slit shows good matching at both the resonances i.e. at 2.7 GHz & 5.4 GHz with considerable improved bandwidth and gain as compared to antenna without narrow slit.

The gain patterns of microstrip circular patch antenna with slit, at two resonating frequency are shown in the following fig.13 and fig.16. The gain values of this antenna at 2.7 GHz and 5.4 GHz are 1.215 dBi and 5.37 dBi respectively.

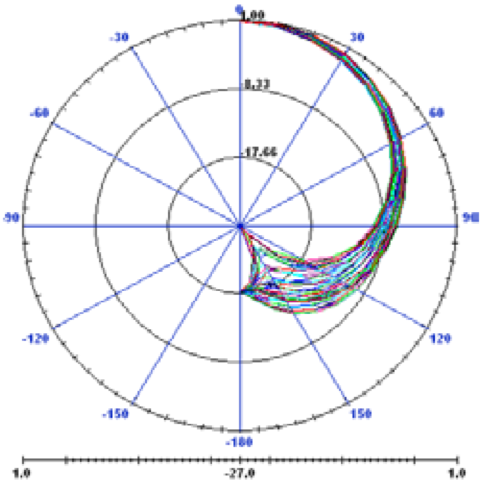

Fig.13 : gain characteristics of circular patch antenna with narrow slit at 2.7 GHz

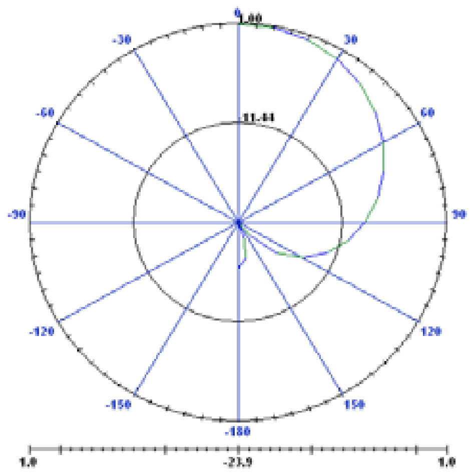

Fig.14 : Elevation gain pattern at 2.7 GHz for circular patch with slit

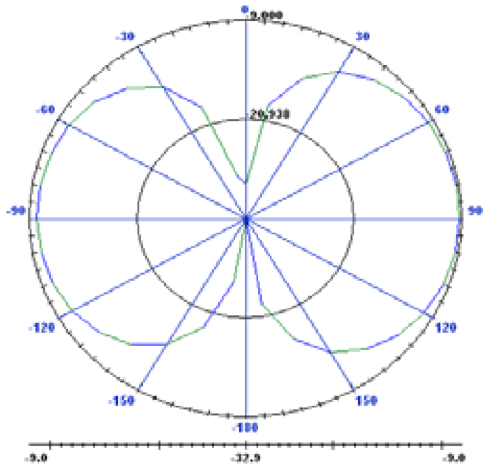

Fig.15 Azimuth gain pattern at 2.7 GHz

Fig. 14, Fig. 15, Fig. 17 and Fig. 18 shows the elevation and azimuthal gain pattern at 2.8 GHz and 5.4 GHz respectively.

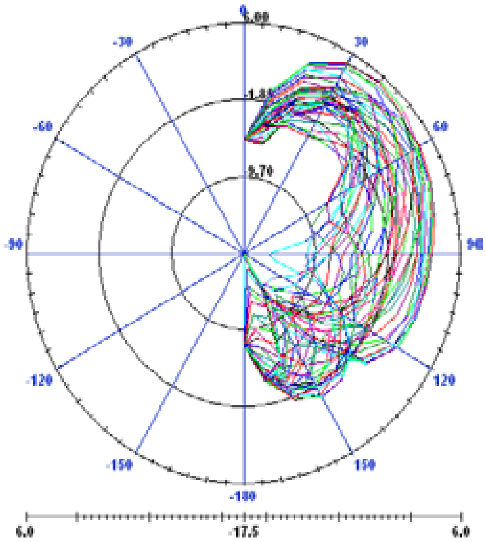

Fig.16 : Gain characteristics of circular patch antenna at 5.4 GHz having narrow slit .

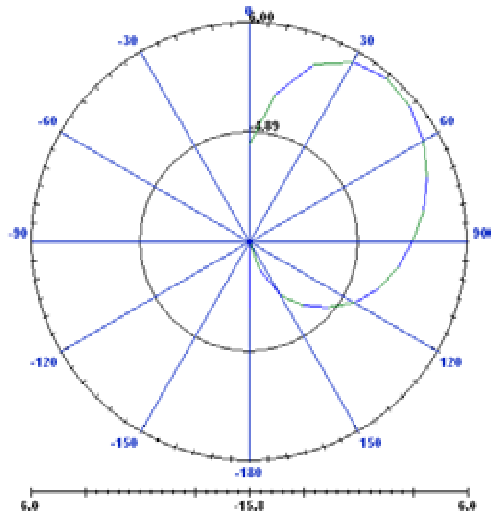

Fig.17 : Elevation gain pattern at 5.4 GHz for circular patch with slit

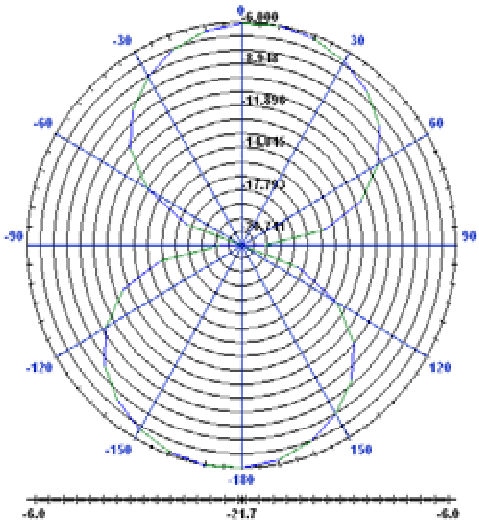

Fig. 18 : Azimuth gain pattern at 5.4 GHz

IV. Discussion

The performance characteristics of two antenna i.e. circular patch antenna without any slit and the circular patch antenna with a narrow rectangular, simulated under similar condition has been tabulated in the table 1. In order to improve the performance of planner circular patch a narrow rectangular slit of specific dimension has been located at different position on the circular patch and the each time the resulting antenna has been optimized. The antenna performance degrades if the slit is located at other position rather than for this design in this paper. It is clear from table.1, the overall performance of circular patch antenna with narrow rectangular slit is higher than the circular patch antenna without any slit. Although the decibel gain of circular patch antenna with narrow rectangular slit at first resonance has almost same value this may be accounted due to the lower frequency as patch antenna suffer from low gain, bandwidth and efficiency at lower microwave frequencies. The operating bandwidth at this resonance has considerable higher than the antenna without any slit.

Table 1: Comparison between two antennas

Sr. No.	Resonant Frequency (GHz)	Return Loss (dB)	Gain (dBi)	Directivity (dB)	BW (MHz)	%BW	VSWR
Circular Patch without Slit	2.8	-29.59	1.45	5.980	140	5	1.06
	5.4	-17.10	2.57	5.162	230	4.25	1.36
Circular Patch with Narrow Slit	2.7	-29.08	1.215	3.131	150	5.5	1.09
	5.4	-21.08	5.35	8.503	410	7.59	1.38

V. Conclusion

In this paper the performance of circular patch antenna with a narrow rectangular slit has been discussed. Microstrip feed line has been used to excite the antenna. Theoretically the use of microstrip feed line may impact on the cross polarization performance of the antenna since high modes are generated by connection of the feed line that produce spurious radiation. The narrow slit etched on patch shifts the first resonance toward lower side of frequency as well as improves the bandwidth of second band, when compared to conventional circular patch the slotted antenna shows good impedance matching for both 2.7GHz and 5.4GHz. Gain pattern of slotted antenna corresponding to 2.7GHz and 5.4 GHz is 1.215 dBi and 5.37 dBi respectively. Proposed antenna is perfect a candidate for lower and upper band of Wi-max application.

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3Dimensional gain patterns of circular patch antenna with and without any slit are shown in the following Fig.s.

Gain characteristics of circular patch antenna without any slit at 2.8 GHz having gain 1.45dBi

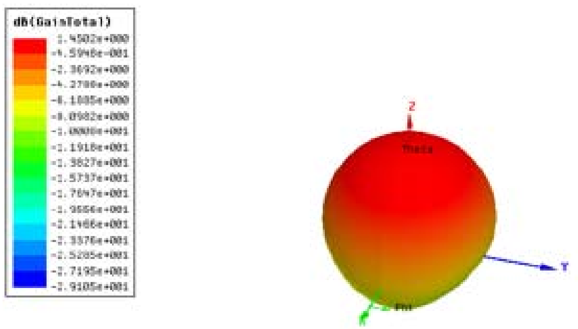

Fig. (a) 3D Gain pattern at 2.8 GHz

Gain characteristics of circular patch antenna without any slit at 5.4 GHz having gain 2.57 dBi

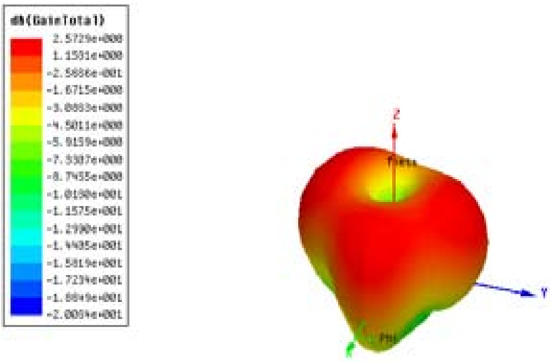

Fig. (b) 3D Gain pattern at 5.4 GHz

Gain characteristics of circular patch antenna without any slit at 2.7 GHz having gain 1.215dBi

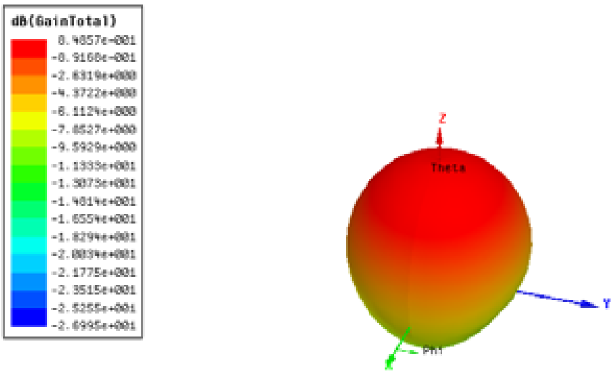

Fig. (c) 3D Gain pattern at 2.7 GHz

Gain characteristics of circular patch antenna without any slit at 5.4 GHz having gain 5.37dBi

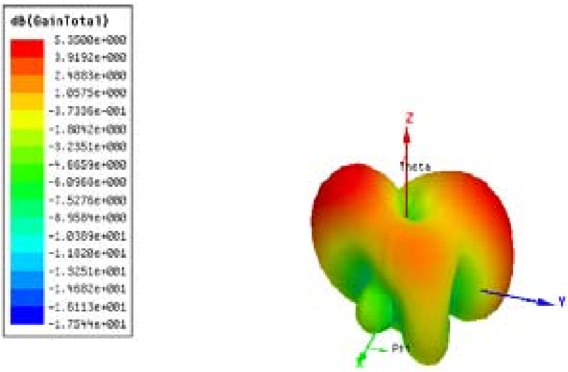

Fig. (d) 3D Gain pattern at 5.4 GHz