

Improvement in Gain and Bandwidth of Rectangular Patch Loaded with Orthogonal Crossed slits

¹Gian Chand, ²Ramesh Kumar, ³Monish Gupta, ⁴Dinesh Gupta

^{1,3}Maharishi Markandeshwer University, Mullana, Ambala, Haryana, India

²Kurukshetra University, Kurukshetra, Haryana, India

E-mail: ¹gian1354@gmail.com, ²rameshbaba311@gmail.com, ³monish_gupta1976@yahoo.com, ⁴dinesh_radaur@yahoo.com

Abstract

A new reduced size Rectangular Patch Antenna with two Narrow Orthogonal Crossed slits is proposed. This Antenna resonating at two closely spaced frequencies i.e. 3.5 GHz and 3.7 GHz. The Gain, The Directivity and The bandwidth of proposed antenna has been improved by 10 dB, 2, 3.5 GHz. The Gain, The Directivity and The bandwidth of simple patch antenna was 10 dB, 2, 3.5 GHz. The Gain, The Directivity and The bandwidth of proposed patch at frequency f_1 is 10 dB, 2, 3.5GHz. The Gain, The Directivity and The bandwidth of proposed patch at frequency f_1 is 10 dB, 2, 3.5 GHz. These obtained parameters indicate that proposed Antenna is suitable antenna for Modern communication system.

Keywords

Microstrip Patch Antenna, Antenna miniaturization, dual frequency operation, Return loss, gain, bandwidth, radiation pattern, VSWR.

I. Introduction

The microstrip antenna concept dates back about 56 years in the U.S.A by Deschamps [1] and in France by Gutton and Baissinot [2]. In late 1960's additional studies were undertaken by Kaloj, who studied basic rectangular and square configurations. Microstrip Antennas have attracted much interest due to their low profile like compact in size, light weight, low cost on mass production, ease of installation, compatible with MMIC designs. However major two limitations in their applications are narrower bandwidth and low gain in comparison to that of other Microwave Antennas. In recent past conventional single frequency regular shape microstrip antenna have been studied [3-4], these antennas fail to serve their purpose because of complex demand in modern communication systems specially for data communication, reduced size compact broad band, dual frequency operation patch Antenna was realized. These modified Antennas are originates from conventional regular shape patch antenna structure [5]. Introducing slot or slit in radiating patch is simple and efficient method for obtaining the desired compactness, multiband and broadband properties since these shapes radiates electromagnetic energy efficiently [5, 6]. Further introducing crossed slit is best method than using single slit for size compactness and reducing resonant frequencies lower value. Based on similar concept, a new Rectangular microstrip patch Antenna loaded with orthogonal crossed slits [7] is proposed and carefully examined in this study. These orthogonal crossed slits are introduced in this patch one by one. Because the proposed Antenna structure is simple and compact, the Antenna can be easily constructed.

II. Optimization Procedure and Simulated results.

(a) Conventional Rectangular Patch Antenna:-

A Conventional Rectangular Microstrip Patch having Dimensions length $L=34.3\text{mm}$, width $W=20.7\text{mm}$ and glass-epoxy FR-4

substrate having substrate relative permittivity $\epsilon_r=4.4$ height $h=1.59\text{mm}$ and loss tangent = 0.02 is considered. HFSS simulation software is taken as electromagnetic simulation and simulated results are presented sequentially. Ground plane dimension is derived by formula:

$$\text{Length of Ground plane} = 6h+L$$

$$\text{Width of Ground Plane} = 6h+W$$

Structure of the Conventional Rectangular Patch Antenna is shown as in figure 1.

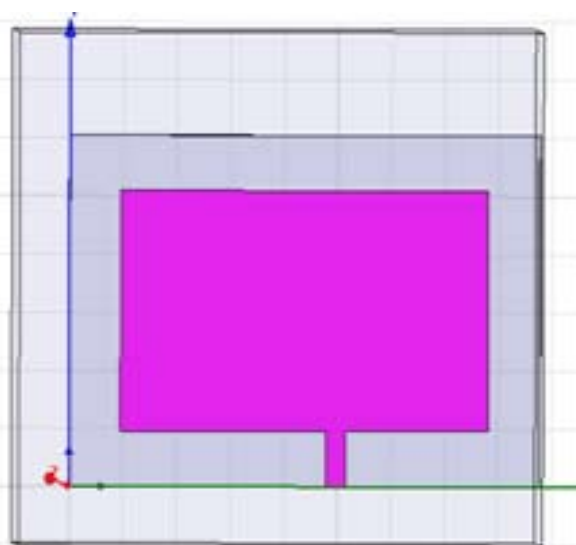


Fig.1: Structure of conventional patch.

Return Loss: This is the best and convenient method to calculate the input and output of the signal sources. It can be said that when the load is mismatched the whole power is not delivered to the load there is a return of the power and that is called loss, and this loss that is returned is called the 'Return loss'. This Return Loss is determined in dB as follows.

$$RL = -20\log |\Gamma| \text{ (dB)}$$

The Return loss value is -39 db at resonant frequency 4.03 GHz as shown in Fig. 2. This shows that this antenna has single band.

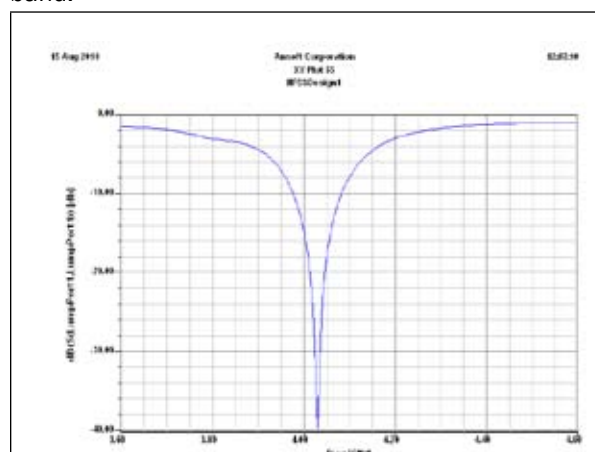


Fig.2: Return loss variation of Rectangular Patch Antenna with frequency.

Radiation pattern: The radiation patterns of an antenna provide the information that describes how the antenna directs the energy it radiates. Radiation patterns also show the gain of the antenna.

All antennas, if 100% efficient will radiate the same total energy for equal input power regardless of pattern shape. Radiation patterns are generally presented on a relative power dB scale. It is a measure that takes into account the efficiency of the antenna as well as its directional capabilities.

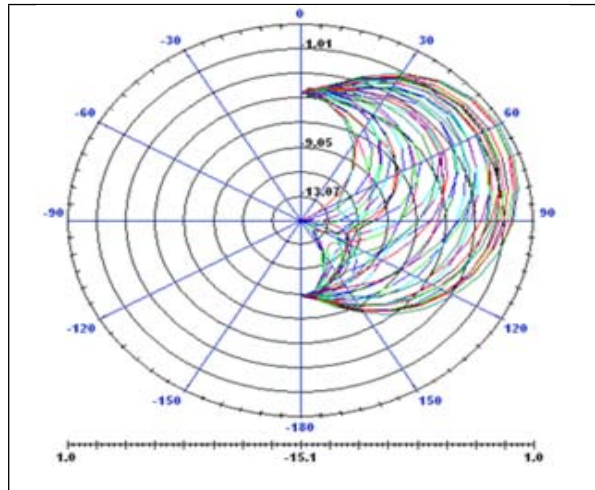


Fig.3: Radiation pattern at 4.03 GHz. Radiation pattern in Fig. 3 shows that gain value is .71 dBi which indicate very low value.

This antenna is the basic or regular rectangular patch. Presence of single frequency with narrow bandwidth and low gain restricts application of this antenna in modern communication systems. So its modification is must for improvement in its overall performance. There are various method which modify this conventional antenna one of them is introducing slit or slot in the radiating patch. Therefore a single narrow rectangular slit of length 'l' and width 'w' is introduced in the patch. The location, length and width of slit are optimized to achieve improved performance.

(b) Rectangular patch antenna with single slit:
When a narrow rectangular slit having dimension:
Length= 15mm
Width= 0.5 mm

This slit is loaded in the radiating patch of the Rectangular patch antenna.

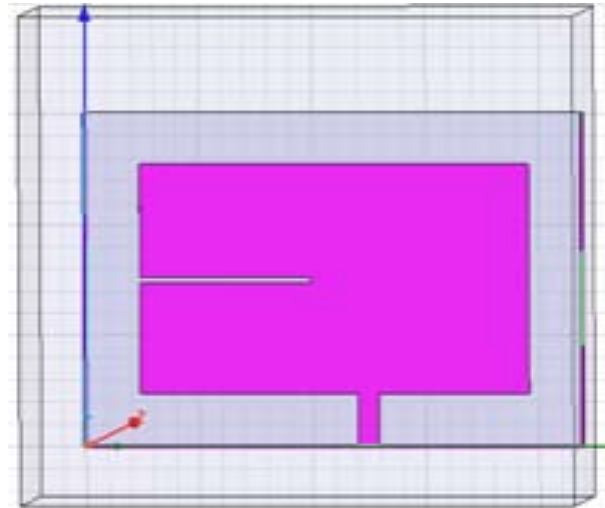


Fig.4: Structure of Rectangular patch Antenna with single slit on simulator.

Return Loss: Return Loss of this antenna is lower at frequencies 3.58 GHz and 4.04 GHz.

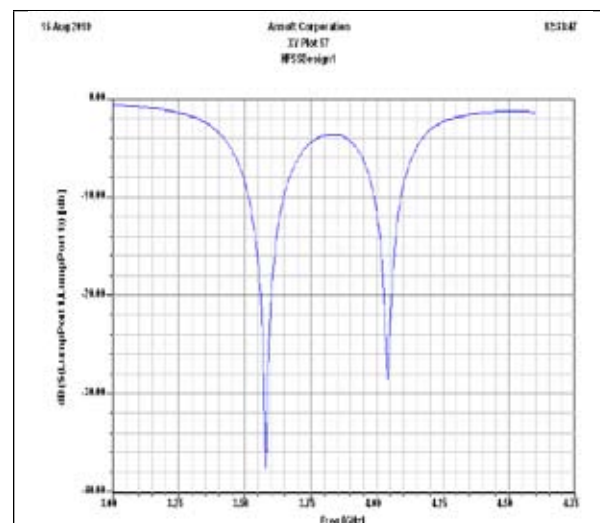


Fig.5: Return loss (S11) of Patch with single slit Antenna. Fig. 5 shows that the resonant frequencies is 3.58 GHz and 4.04 GHz. At these frequencies the return loss has -37 db and -29 db. Which shows that this antenna has dual frequency band. Radiation patterns of this structure: Radation patterns at these resonant frequencies shows that the value of gain has negative value.

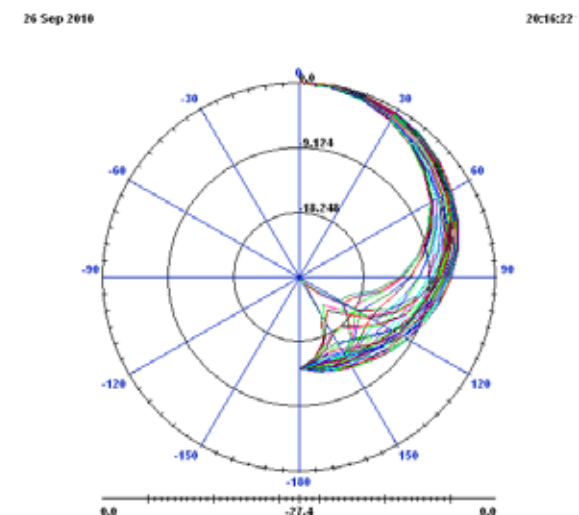


Fig.6: Radiation patterns at 3.58 GHz.

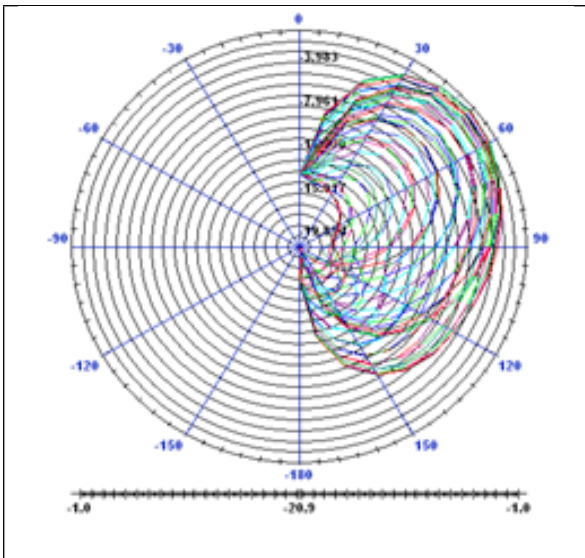


Fig.7: Radiation patterns at 4.04 GHz. Performance of this antenna has little higher than conventional rectangular patch but these are lower than desired value. So further modification is required in this structure. To achieve this modification a second slit is introduced on the radiating patch. This second slit is orthogonal to the first one but have same dimension.

(c) Rectangular Patch antenna with Orthogonal crossed slits: When an additional narrow slit orthogonal to first one is applied therefore the resulting structure of the proposed antenna is shown below.

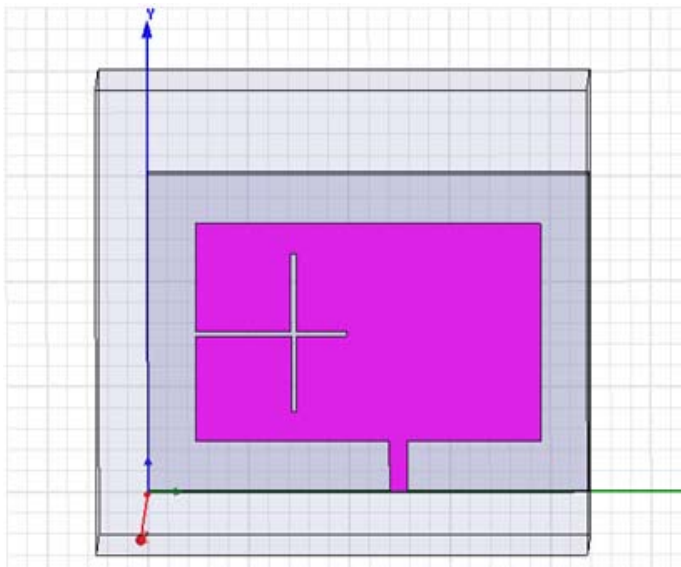


Fig.8: Geometry of Rectangular Patch With Orthogonal Crossed Slits.

Second slit has same dimension as that of first slit i.e. “l”=15 mm and w =0.5 mm. This slit is parallel to y-axis and located at a distance 9.49 mm from the narrow wall and equal divided by first slit having length “l1” and “l2” are identical and equal to 7.5 mm. This is modified structure of the Conventional Rectangular Patch having compact size as well as high gain and bandwidth. Proposed Antenna resonates at two resonant frequencies 3.51 GHz and 3.7 GHz.

Return Loss: Return loss value in Fig. 9 shows that at resonant frequencies i.e. 3.5 GHz and 3.7 GHz has -29 db and -22 db. These value shows that this antenna is not single band.

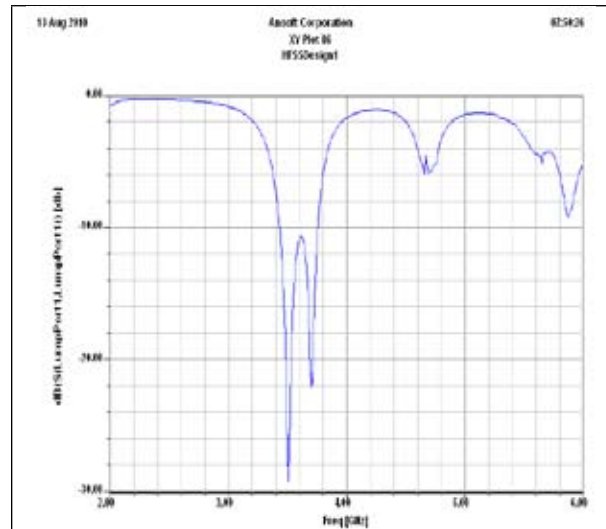


Fig.9: Return loss variation of Orthogonal crossed slits loaded Rectangular Patch.

The Simulated results shows that when slit or slot is introduced in the radiating Patch. The slit is operated to do magnetic wall. Meandering the excited surface current path in the antennas radiating Patch [8]. This results resonant frequencies drops or shifted towards lower values side and size of this antenna is also reduced effectively. This reduction in size is due to on inserting orthogonal slits on the conventional rectangular patch structure.

The VSWR of the antenna:

Voltage standing wave ratio (VSWR) is the ratio between the maximum voltage and minimum voltage along transmission line. A decrease VRWS means good matching with minimum VSWR is one. If VSWR is given by:

$$VSWR = \left(\frac{1 + S_1}{1 - S_1} \right)$$

VSWR is shown as in the Fig. 10 shows that at resonant frequencies the graph value is 1 for both frequencies i.e. 3.5 GHz and 3.7 GHz. This value is less than 2 which is required condition.

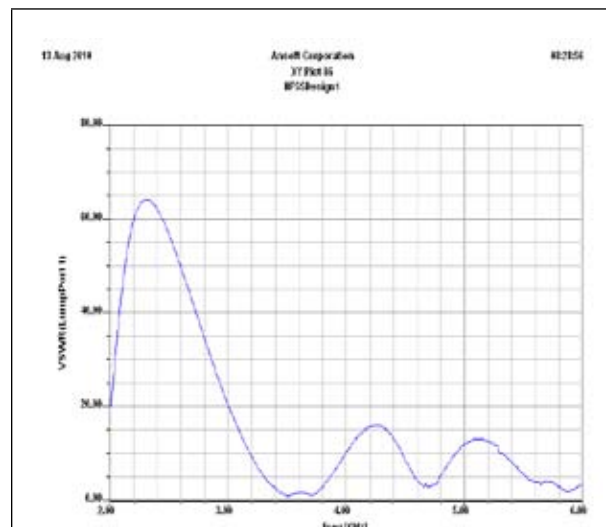


Fig.10: Simulated variation of VSWR Vs frequency of the Proposed Antenna.

Most wireless systems operate at 50 ohm impedance. Hence

the antenna must be designed with impedance as close to 50 ohm possible. A VSWR of 1 indicates an antenna impedance of exactly 50 ohms. Mostly the ratio of VSWR > 1.5:1 is needed for antenna functional.

Radiation patterns:

2-D Radiation Patterns of Rectangular Patch Antenna with orthogonal crossed slits at resonance frequencies i.e. 3.5 GHz and 3.7 GHz is shown respectively in Figs.

These radiation patterns shows that the value of gain is positive in all these Fig.s. The value of gain at 3.5 GHz is 6.65 dBi and at 3.7 GHz value is 4.14 dBi.

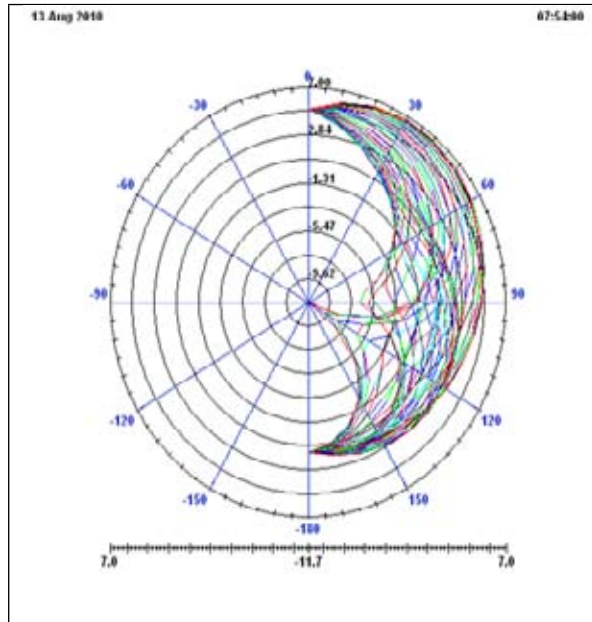


Fig.11: Radiation Pattern at 3.5 GHz.

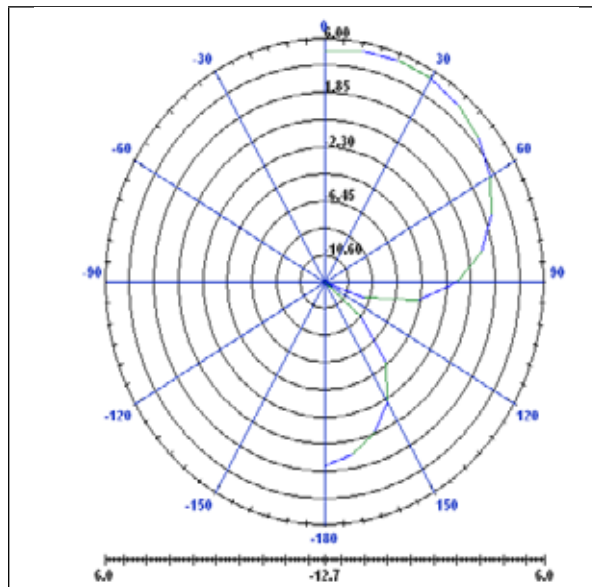


Fig.12: Elevation Gain at 3.5 GHz.

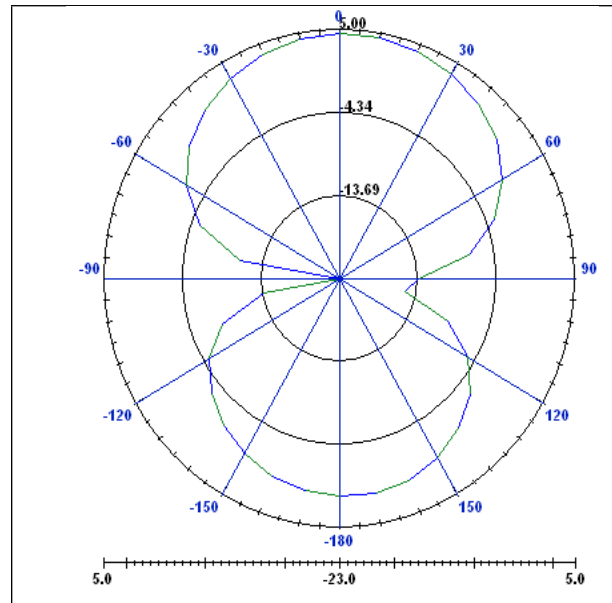


Fig.13: Azimuthal Gain at 3.5 GHz.

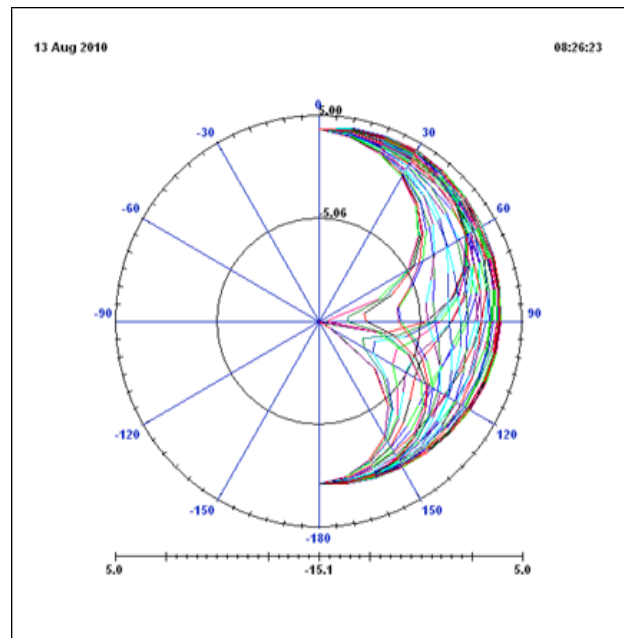


Fig.14: Radiation Pattern at 3.7 GHz.

Elevation and azimuthal values shows the value of gain in a particular direction. These values changes at every point rapidly. Gain has maximum value i.e. 6.65 dBi and 4.14 dBi at 3.5 GHz and 3.7 GHz respectively.

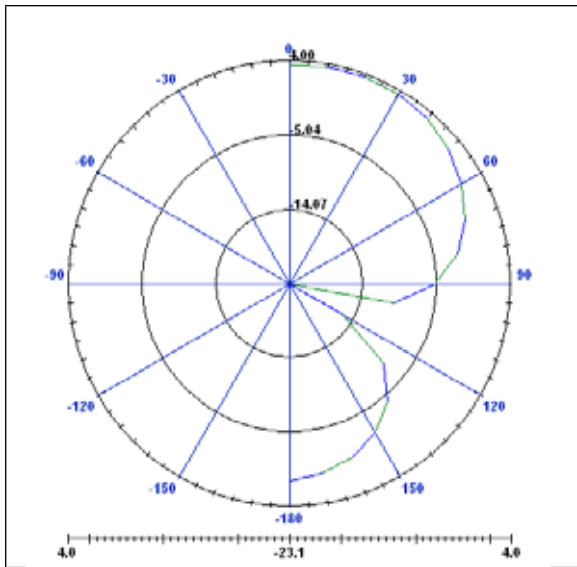


Fig.15: Elevation Gain at 3.7 GHz.

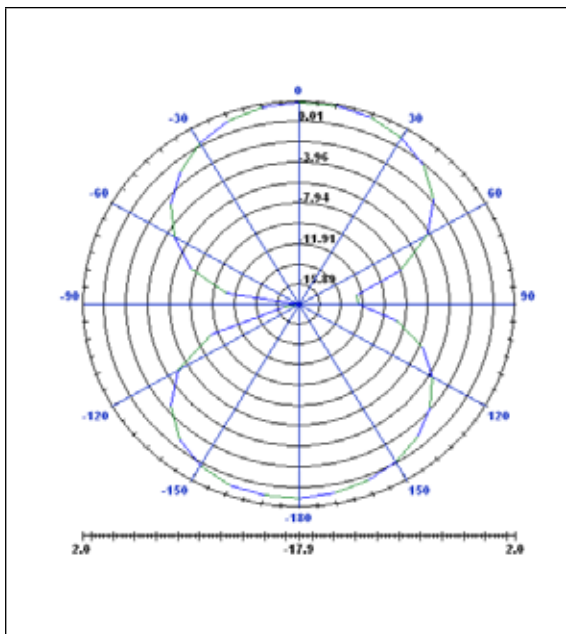


Fig.16: Azimuthal Gain at 3.7 GHz.

3-D Radiation Patterns of the proposed Antenna is also shown below respectively at these resonance frequencies. These Patterns showing Gain 6.549 dBi and 4.4d Bi at there respective frequencies.

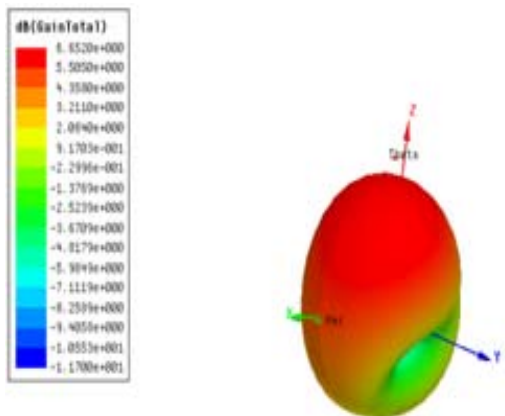


Fig.17: 3-D Pattern at 3.5GHz.

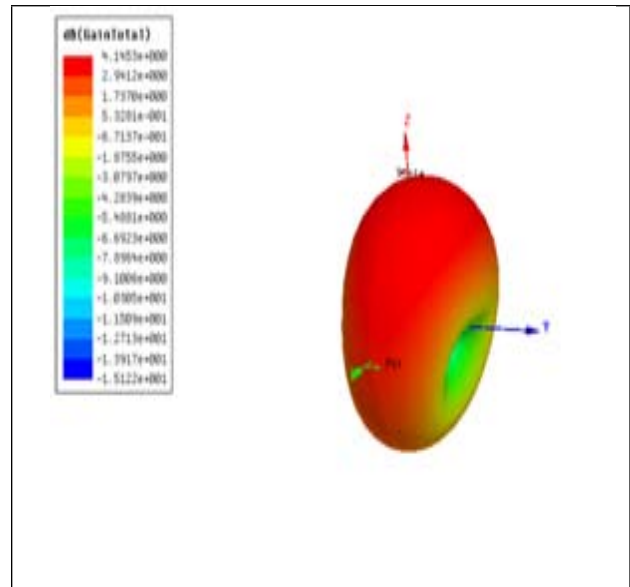


Fig.18: 3-D Pattern at 3.7 GHz.

Directivity of the Antenna at these resonant frequencies:
The ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions.

The average radiation intensity is equal to the total power radiated by the antenna divided by 4π .

If direction is not specified, the direction of maximum radiation is implied.

$$D = \frac{U}{U_0} = \frac{4\pi U}{P_{rad}} D = \frac{U}{U_0} = \frac{4\pi U}{P_{rad}}$$

Directivity of non isotropic source:

$$D_{max} = \frac{4\pi U}{P_{rad}} D_{max} = \frac{4\pi U}{P_{rad}}$$

Although the gain of the antenna is closely related to the directivity but gain is a measure that takes into account the efficiency of the antenna as well as its directional capabilities. Instead Directivity is related to only directional capabilities.

2D Directivity pattern of the antenna at 3.5:

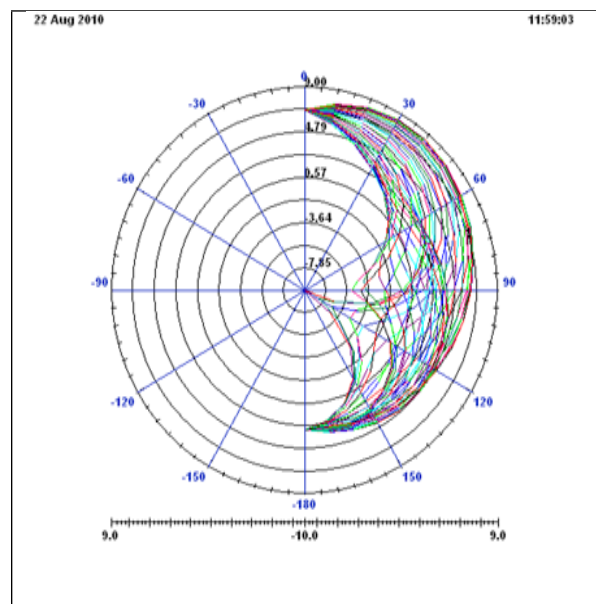


Fig.19: 2D directivity pattern at 3.5

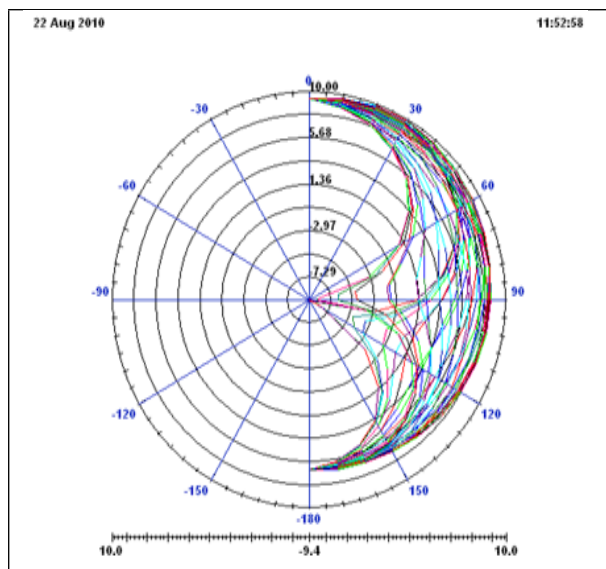


Fig.20: 2D directivity pattern at 3.7.

Calculation of Bandwidth and efficiency coefficient:

The simulation results of the input return loss are shown in fig. The return loss is -29 dBi, -22 dBi for the resonant freq. 3.5 GHz and 3.7 GHz.

Bandwidth: The bandwidth of the antenna is the difference of upper cut-off frequency and lower cut-off frequency.

The bandwidth of the antenna = 3.78 - 3.42 = .36GHz = 360 MHz

The % bandwidth of the antenna

$$\%BW = \frac{3.78 - 3.42}{3.6} \times 100\% = \frac{.36}{3.6} \times 100\% = 10\%$$

Efficiency Coefficient: The power gain of the antenna at frequencies is 6.54 dBi and 4.14 dBi. The directivity is 7.5 dBi and 9.6 at these respective frequencies

$$G = kD$$

Where G is the gain of the antenna, k is efficiency coefficient, and D is directivity.

Efficiency Coefficient for 3.5 GHz:

$$k = 6.54 / 7.5 = .8720$$

So that the efficiency of the antenna at 3.5 GHz is 87.20%

Efficiency Coefficient for 3.7 GHz:

$$K = 4.14 / 9.6 = .4312$$

So that the efficiency of the antenna at 3.7 GHz is 43.12%

Table 1: Results of Proposed Antenna parameters.

Resonant Frequency (GHz)	Return loss (dBi)	Gain (dBi)	Directivity (dBi)	Bandwidth (GHz)	% Bandwidth	VSWR	Efficiency Coefficient "k"
3.5	-29	6.54	7.5	360	10	1	87.20
3.7	-22	4.14	9.6			1	43.12

III. Conclusion

Comparison between performances of different proposed geometries as shown in table:

Table 2: Comparison table

Structure	Resonant Freq. GHz	Band Width (%)	Gain (dBi)
Conventional Structure	4.03	2.48	.73
Rectangle With Single Slit	3.58	3.63	1
With Orthogonal Crossed slits	4.04	2.48	.71
	3.5	10	6.54
	3.7		4.14

The new rectangular patch antenna with narrow orthogonal crossed slit on the radiating patch resonates at frequencies 3.5 GHz and 3.7 GHz. This shows that when the slit is introduced in the radiating patch of the single band antenna then the resulting antenna is found for multiband and resonant frequency tends to lower side. By doing this metal portion is decrease so that the gain deceases.

This table shows that the results obtained with proposed Rectangular patch Antenna with orthogonal crossed slits suggested that the Antenna has compact in size as well as better performance in gain and bandwidth. This is deserving candidate for modern wireless communication systems. From these results shows that antenna is best suited for Wi-max, satellite communication and radar communication.

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