Design of Line of Star Patterned on Microstrip Patch Antenna for Linear Polarization

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ABSTRACT
A probe-fed, rectangular patch antenna has been proposed. Dual frequency has been achieved by suitably cutting stars along the x axis slots into the rectangular patch cut to form a square patch. It is demonstrated that the proposed antenna exhibits two resonant frequencies of 2.268GHz and 2.35GHz with a peak gain of 6.5dBi. The software used to model and simulate the microstrip patch antenna is Zeland Inc's IE3D software. IE3D is a full-wave electromagnetic simulator based on the method of moments. The antenna structure is described and simulation results are presented.

General Terms
EMDC- Electronics, Microwave devices & circuits.

Keywords
MSA (Microstrip antenna), RMSA (Rectangular microstrip antenna), LP (linear Polarization)

1. INTRODUCTION
Microstrip Patch antennas play a very significant role in today's world of wireless communication systems. This paper presents linearly polarized microstrip antenna for wireless communications systems which is suitable for the 2.268GHz and 2.35GHz of operations. The prospect of this design is to obtain a small size, light weight and low cost miniaturized antenna with good antenna characteristics and ease of integration using feed-network. A RMSA is design for a resonant frequency of 2.4 GHz. This RMSA is cut into square patch having line of stars patterned on it. An RMSA operating at frequency *fo* = 2.4 GHz with length (*l*) = 39mm, width (*w*) = 48mm, *tan δ* = 0.001, total area = 1872mm^2 is designed. There are numerous methods to increase the bandwidth of antennas, including increase of the substrate thickness and the use of a low dielectric substrate, hence duoroid having $\mathcal{E}_r$ = 2.4, thickness (*h*) = 1.58mm is selected.

2. ANTENNA PROTOTYPE PARAMETERS
The antenna has a simple rectangular structure as shown in Fig. 1. The dielectric chosen is Duroid substrate having εr =2.4 and a thickness of 1.58 mm. The dimensions of patch are approximated by using basic design approach described for microstrip patch antenna as listed below –

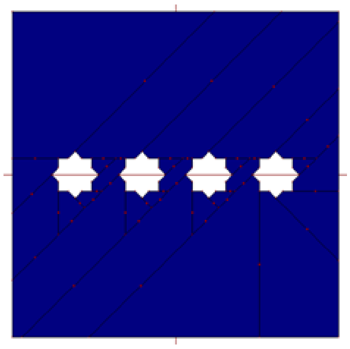


Fig.1 Structure of Proposed Antenna

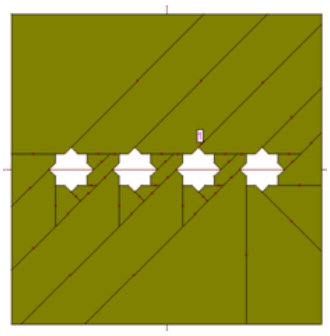


Fig.2 Antenna with probe feed

Width of patch:

$$W = \frac{c}{2f0\frac{\sqrt{\varepsilon r+1}}{2}} \quad (1)$$

Effective dielectric constant:

$$\varepsilon e = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}[1+\frac{10h}{W}]^{\wedge}(-0.5) \quad (2)$$

$$fo = \frac{c}{2\sqrt{\varepsilon r}}[\left(\frac{m}{L}\right)^{\wedge}2+\left(\frac{n}{W}\right)^{\wedge}2]^{\wedge}0.5 \quad (3)$$

Effective length is given by

$$Le = L + 2\Delta L = \frac{\lambda}{2\sqrt{\varepsilon e}} \quad (4)$$

Where;
c = 3x10^8 m/s.
h = height of substrate.
ε_r = dielectric constant of the substrate.
This rectangular patch is than cut in the form of a square patch having length Ls = 39mm and width Ws = 39 mm reducing the surface edges. The square patch integrates four stars in a single line pattern on the x axis. For the rectangular patch cut into square patch the area reduces by 18.75%. Furthermore, stars are etched in the square patch reduces the surface area of the proposed antenna. The calculation of patch dimensions is based on the transmission line model. A substrate of low dielectric constant is selected to obtain a compact radiating structure that meets the demanding bandwidth specification.
Coupling of power through a probe is one of the basic mechanisms for the transfer of microwave power. The probe can be an inner conductor of a coaxial line in the case of coaxial line feeding .The coaxial cable is attach to the back side of the printed circuit board and coaxial center conductor after passing through the substrate is soldered to the patch metalisation. The location of the feed is determined for the given mode so that the best impedance match is achieved. Excitation of the patch is achieved through the coupling of the feed current J_z to the E_z field of the patch mode .The coupling constant can be obtained as:

$$\text{Coupling} = \iiint E_z J_z dv \quad (5)$$

$$= \cos(\Pi x_o / L) \quad (6)$$

Where L=resonant length of the patch

X_o= offset of the feed point from the patch edge.

The above expression shows that coupling is maximum for a feed located at a radiating edge of the patch (X_o=0 or L).

After selecting the patch dimensions L and W for a given substrate, the next task is to determine the feed location (x_o, yo) so as to obtain a good impedance match between the generator impedance and the input impedance of the patch element. It is observed that the change in feed location gives change in impedance hence provides a simple method for impedance matching. We see that if the feed is located $x_o = x_f$ and $0 \leq y_f \leq W$, the input resistance at resonance for the dominant mode TM_{10} mode can be expressed as

$$R_{in} = R_r \cos^2(\Pi xf/L) \qquad R_r \geq R_{in} \quad (7)$$

Where xf is the inset feed distance from the radiating edge and R_r is the radiation resistance at resonance when the patch is fed at a radiating edge. The radiation resistance R_r with an estimated accuracy of 10% average for h $\leq 0.03\lambda o$ and $\varepsilon_r \leq$ 10 are given as

$$R_r = V_o^2 / 2P_R \quad (8)$$

$$= \varepsilon_{re} \; \underline{Z_{o/}} \; 120 I_2 \quad (9)$$

Where Z_o is the characteristic impedance of which the patch is a segment.

The inset distance is selected such that R_{in} is equal to the feed line impedance, usually taken to be 50Ω. Although the feed point can be selected anywhere along the patch with, it is better to choose yf = W/2 if W$\geq L$ so that TM_{0n} (n odd) modes are not excited along with the TM_{10} mode. Determination of exact feed point requires an iterative solution for impedance to match .The above equation provides a useful solution for the purpose. Kara has suggested an expression for xf that does not need calculation of radiation resistance .It is approximately given as

$$Xf = L/2 \sqrt{[\varepsilon re(L)]} \quad (10)$$

Where, εre(L) is defined

$$\varepsilon re(L) = [(\varepsilon_r+1)/2]+[(\varepsilon_r-1)/2] \, F(L/h) \quad (11)$$

Radiation Efficiency ε_r: The radiation efficiency is defined as the ratio of radiated power P_r to the input power P_i that is

$$\varepsilon_r = P_r / P_i \quad (12)$$

The input power gets distributed in the form of radiated power, surface wave power, and dissipation in the conductors and dielectric.

It has been observed that radiation efficiency depends on the substrate thickness and permittivity, and is not effected very much either by the patch shape or feed [4].Numerical values indicate that radiation efficiency is almost independent of aspect ratio W/L of the rectangular patch [5].

BANDWIDTH: If the antenna input impedance can be matched to its feeding structure across a certain frequency range, that frequency range will define the antenna bandwidth (BW). The bandwidth can be specified in terms of the return loss or the voltage standing wave ratio (VSWR). The typical values for micro strip antennas are VSWR<2 or return loss (S_{11} in db) < -10db. Furthermore, the BW is inversely proportional to the quality factor (Q) and given by

$$BW = \frac{VSWR - 1}{Q\sqrt{VSWR}} \quad (13)$$

The minimum quality factor is given by

$$Q_{min} = \frac{1 + 3(koR)^2}{(koR)^3 * [1 + (koR)^2]} \quad (14)$$

Where, R is the minimum sphere radius which completely encloses the antenna.

3. GEOMETRY AND DESIGN PROCEDURE

The proposed design structure incorporates four star shaped pattern providing linear polarization with single feed. The table 1 shows the parameter of the proposed patch antenna.

Table 1.Parameters of the proposed Patch Antenna

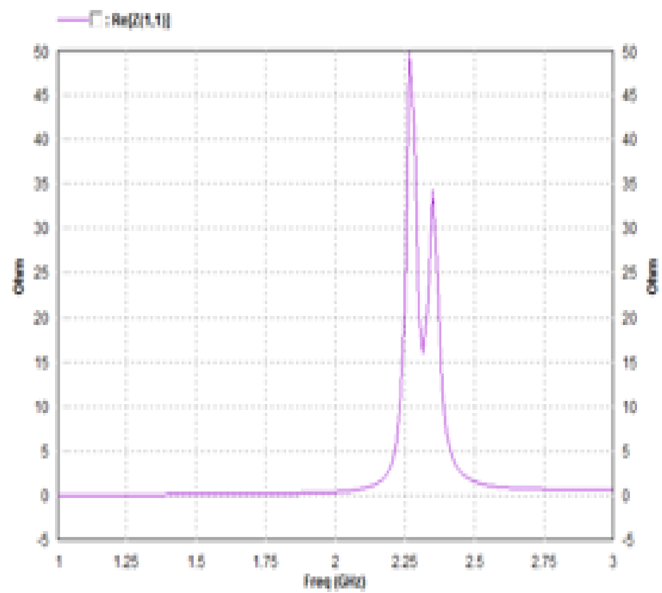
Parameter	Value in mm
L	39
W	48
Ls	39
Ws	39
Area of rectangular Patch	1872mm^2
Area of Square Patch	1521mm^2

4. Simulated Results

The antenna is simulated and optimized using Zeland IE3D software. The IE3D (Zeland Software) is an integrated full wave electromagnetic simulation and optimization package for the analysis and design of microstrip antennas based on method-of-moments and it is used to solve the problems assigned to it [1]. It is a computational power- house that when given an input file performs calculations necessary to obtain the fields and/or currents at each grid point in the model. The simulators offer accurate reflection of how microstrip antennas actually perform.

Simulated results are presented return loss vs. frequency curve shows two bands having return loss better than -10 dB. Correspondingly, VSWR vs. frequency curves also show two bands having voltage standing wave ratio lower than 2:1.

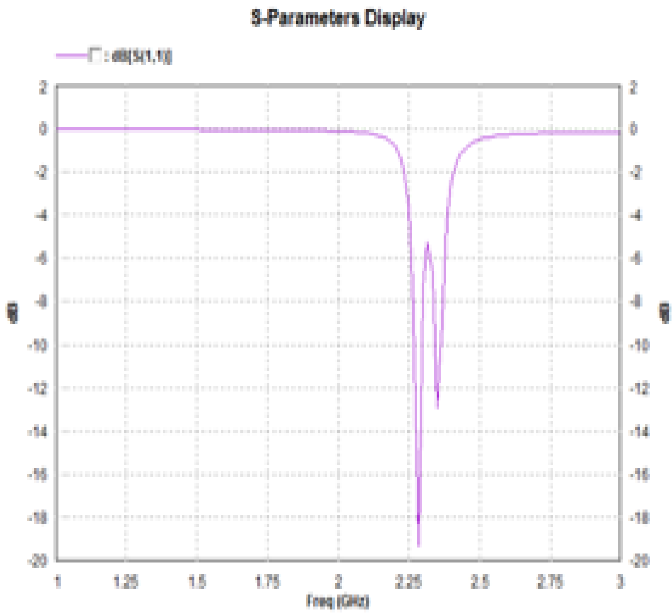
Graph of Impedance vs frequency forAntenna



Impedance=50 Ohms a frequency=2.268GHz

Impedance=43.95 Ohms at frequency=2.35GHz

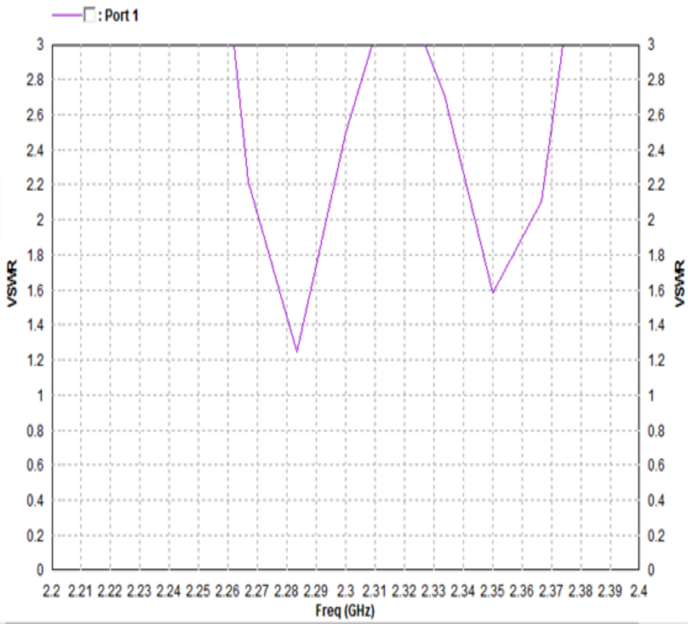
Graph of Return Loss for Antenna

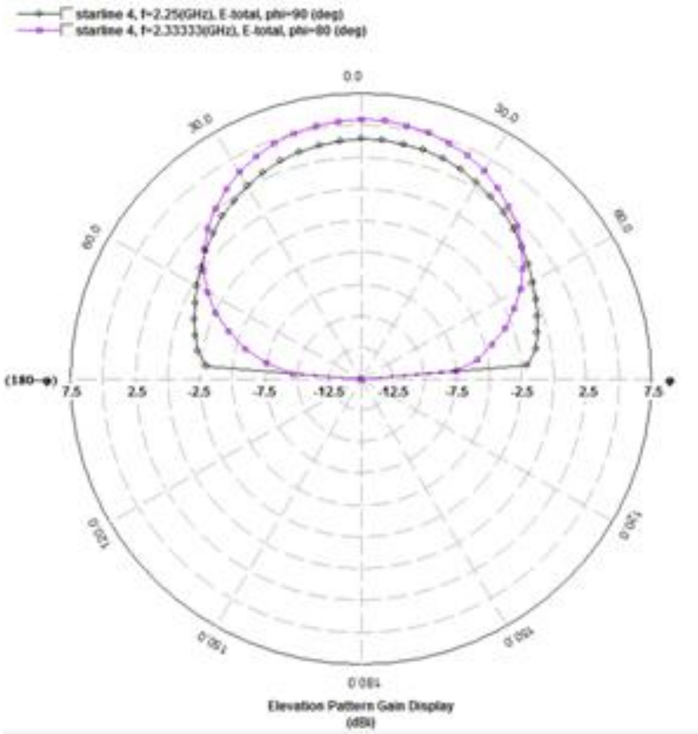


Return Loss=-19.5dB at frequency=2.268GHz

Return Loss=-13dB at frequency=2.35GHz

Graph of Vertical Standing Wave Ratio Patch Antenna

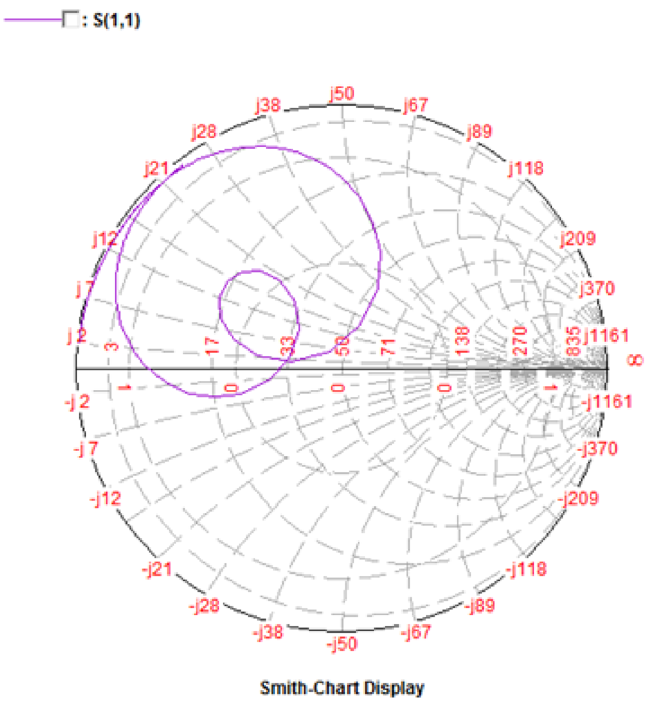


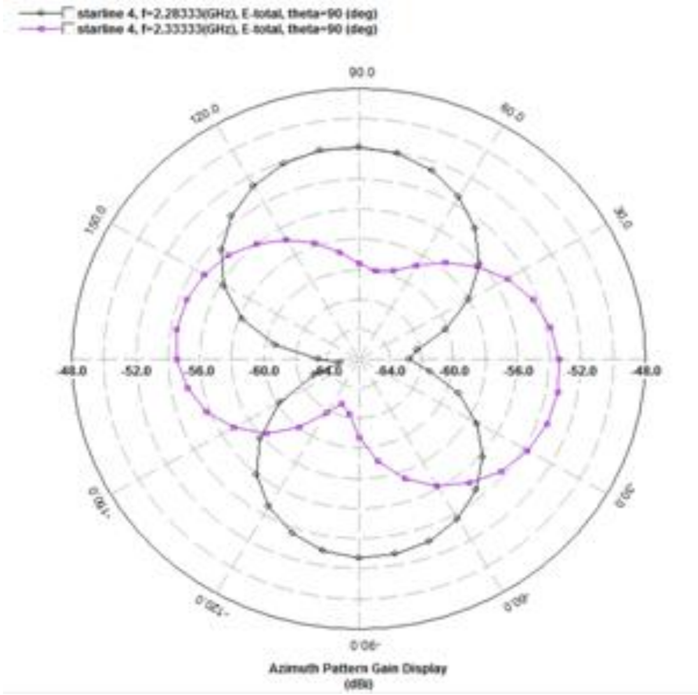


VSWR=1.25 at frequency=2.268GHz

VSWR=1.6 at frequency=2.35GHz

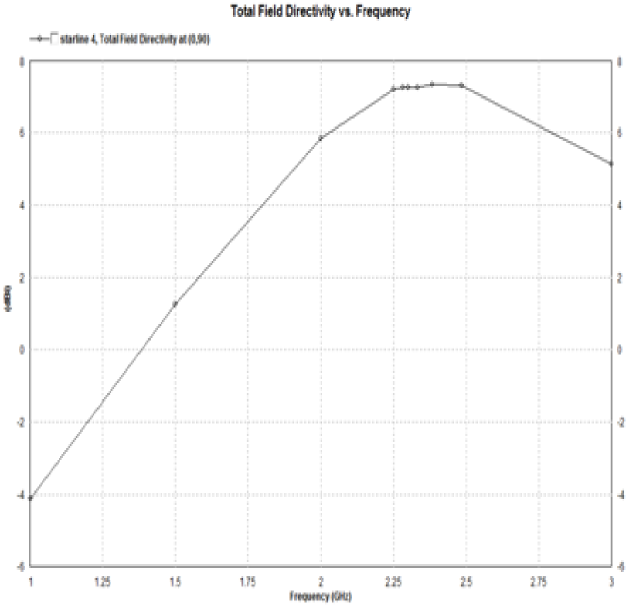
Smith Chart





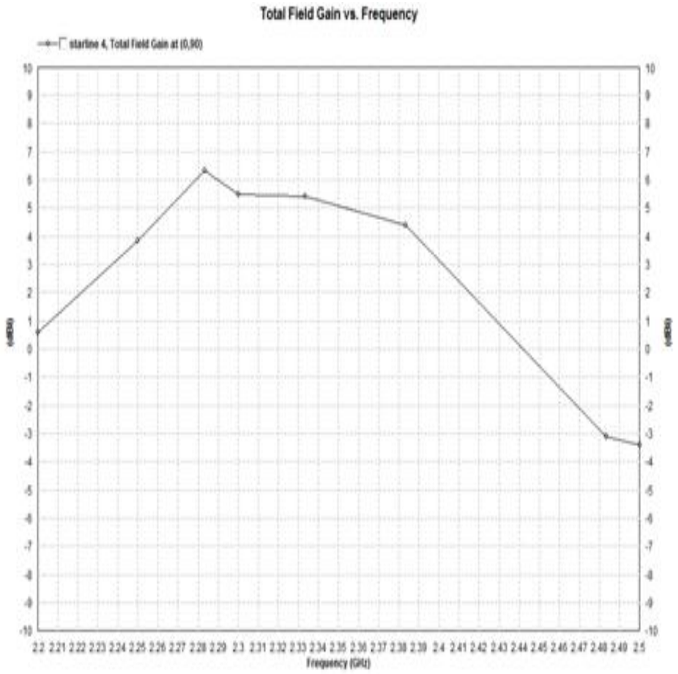
Graph of Directivity vs Frequency for Antenna

2-D Radiation Pattern (Elevation and Azimuth Pattern)



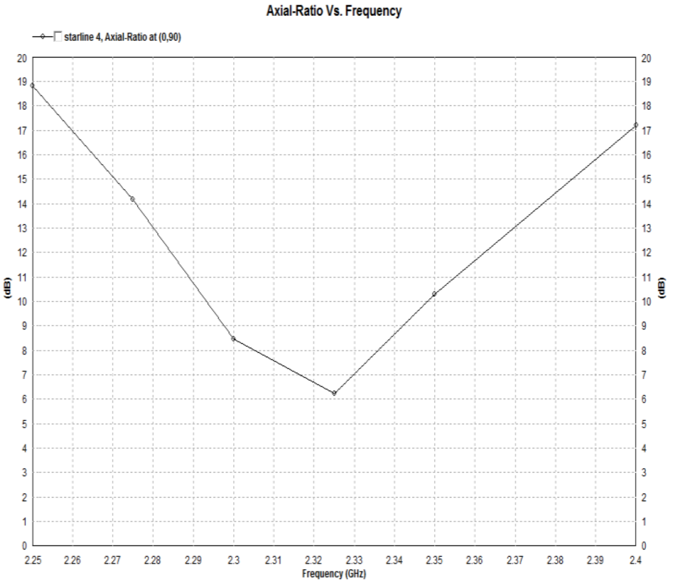
Directivity=7.4dBi at frequency=2.38GHz

Graph of Gain vs Frequency for Antenna



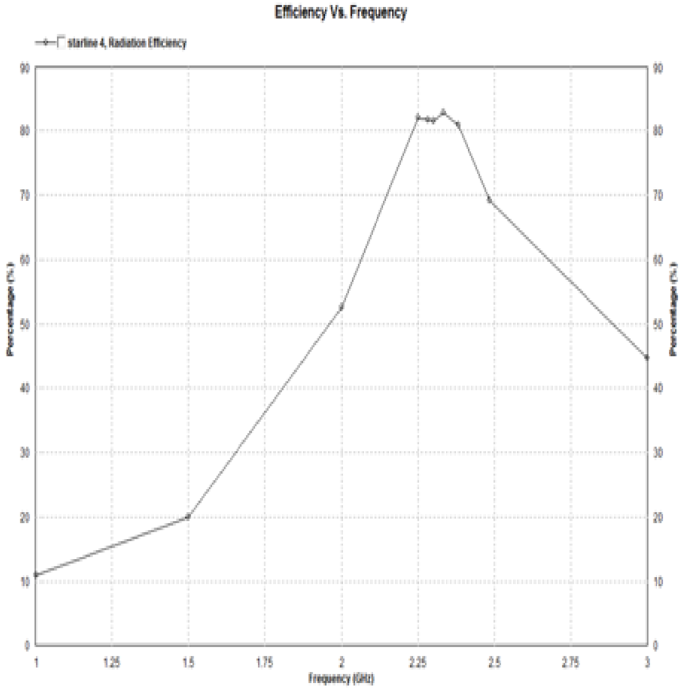
Gain=6.5dBi at frequency=2.285GHz

Graph of Axial Ratio vs. Frequency for Antenna



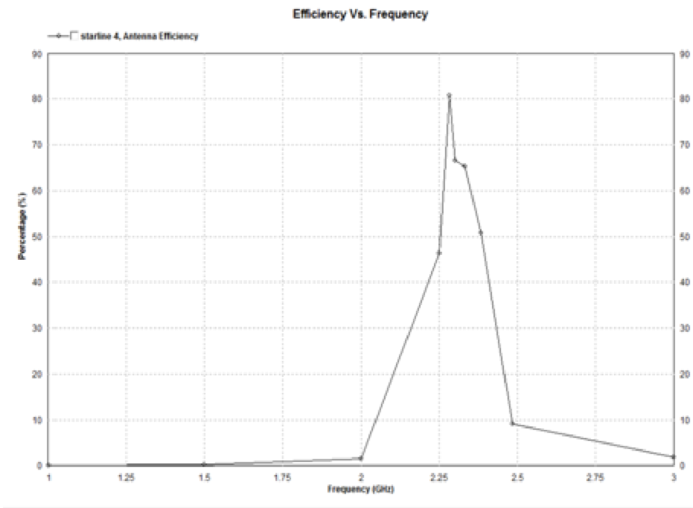
Axial Ratio = 6.1dBi at frequency = 2.325GHz

Graph of Radiation Efficiency vs. Frequency for Antenna



Radiation Efficiency=83% at frequency=2.335GHz

Graph of Antenna Efficiency vs. Frequency for Antenna



Antenna Efficiency=80% at frequency=2.285GHz

3-D Radiation Pattern

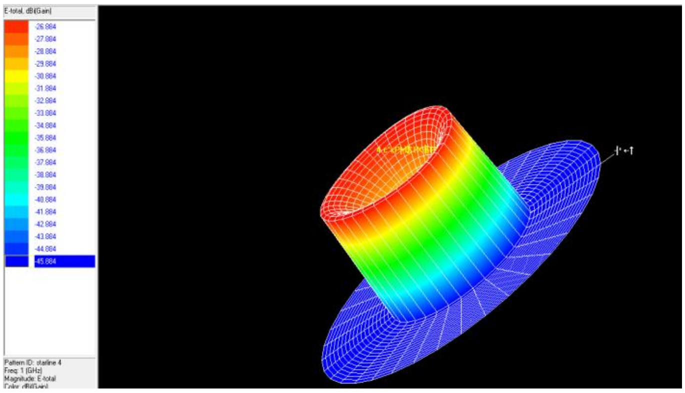


Fig.3 3-D Radiation Pattern (Mapped 3-D)

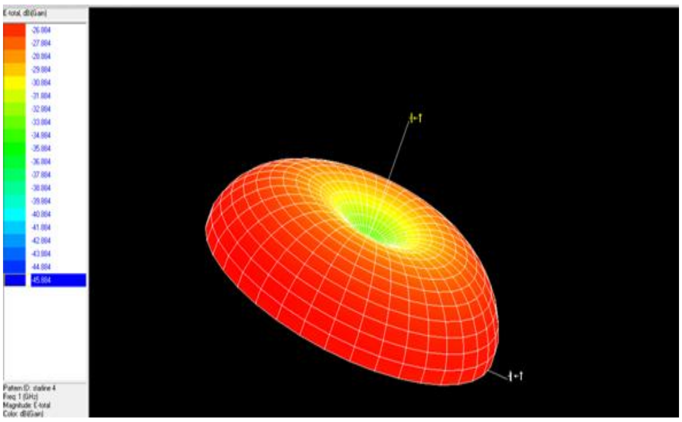


Fig.4 3-D Radiation Pattern (True 3-D)

5. CONCLUSION

A compact microstrip antenna with a single feed placed diagonally is presented. After simulation, the above antenna geometry allows linear polarization of the radiated. Antenna's directivity and gain plots are shown in above achieves considerably high directivity and simulated results show a peak gain of 6.5dBi. These two bands are useful for various wireless applications.

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