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Wideband Rectangular Patch Antenna for X-Band Applications

B.Nataraj, K.R.Prabha

Abstract*: In this paper, a wideband rectangular patch antenna for X-band applications is proposed. The antenna is printed on an FR4-epoxy substrate with thickness 1.58 mm and the patch dimensions are 9.13 mm by 6.27 mm. The design is simulated using Advanced Design System software to yield a return loss of -33.53 dB at 10.58 GHz resonant frequency. The drawbacks of patch antenna such as narrow bandwidth and low gain are improved through this design to provide good gain characteristics. The benefits of microstrip patch antenna including low profile, low weight, ease of fabrication etc. makes it an ideal choice for design optimization to effectively support mobile, military requirements, wireless and satellite communication

***Index Terms*: Microstrip, patch, bandwidth, X-band, return loss.**

I. INTRODUCTION

An antenna acts as an interface between propagating radio waves through electric currents and space moving in a metal conductors which is generally a transmission line, used along with a transmitter or receiver. Microstrip antenna is one amongst the foremost common forms of printed antenna or planar antenna. Polarization diversity is an integral advantage of patch antennas. Patch antennas can easily be designed to have linear and circular polarizations. This property helps in implementing patch antennas in various forms of communication links having various requirements. The patch antenna can be of the following common shapes such as elliptical, square, circular, rectangular, triangular, etc. The parameters like dielectric material, resonant frequency and height of the dielectric material is chosen properly for an effective radiation. Rectangular patch antennas have different advantages like light weight and low profile and disadvantages associated with them are meagre gain and narrow bandwidth. Patch antennas are used for applications of sub-bands of X-band radar frequency like government associations for weather audit, civil, non-civil, air traffic control, defence tracking and vehicle speed detection for law enforcement rendering finer efficiency and bulkier bandwidth.

II. TRANSMISSION LINE

A microstrip patch antenna embodies a radiating patch off-centered to the dielectric substrate which has substrate typically made of conducting material like gold or copper taking any possible shape. It is fabricated by a photolithographic method with a ground plane on the rear of the board being the same.

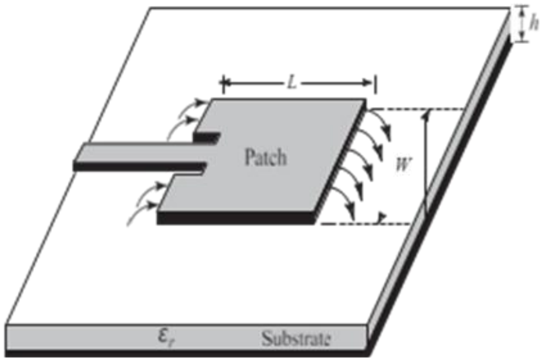

Figure 1. Microstrip patch antenna

Microstrip antennas are comparably less expensive to construct and the design is also mounted on lesser volume. They are routinely employed at ultra-high frequency and greater frequencies owing to the proportionality of the antenna size to the frequency of resonance wavelength. An individual patch antenna equips a 6-9 dB of paramount directive gain.With air as dielectric substrate, the patch antenna is half wavelength long. The substrate of the antenna being a dielectric, cut-back of the antenna length happens with increase in relative permittivity. The "fringing fields" of the protracted electric field increases the electrical antenna length slightly which marginally shortens the resonant length of the antenna.

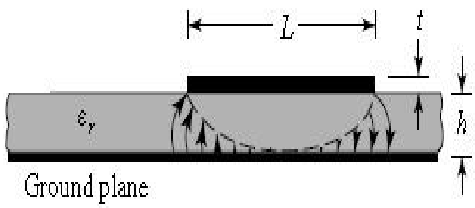

Figure 2. Side view

For peak performance of antenna, to provide better radiation, higher efficiency and larger bandwidth, a thick dielectric substrate with a minimum dielectric constant is selected. Design of a compressed patch antenna depends upon a substrate with a higher dielectric constant. Excitation guides the electromagnetic energy source to the patch, generating negative charges around the feed point and positive charges on the other part of the patch.The patch antenna radiations are produced owing to the generated electric field due to the difference in charges.

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III. ANTENNA DESIGN

The antenna characteristics is predominantly dependant on the shape of the patch. Since patch width is dependent on the bandwidth which in turn is analogous to the efficiency and radiated power. Similarly the resonant frequency is reliant on the patch length. The patch length is given by,

$$L = \frac{c}{2 f_r \sqrt{\varepsilon_r}} \qquad (1)$$

Due to fringing effects, the length of the patch is given by,

$$L = \frac{c}{2 f_r \sqrt{\varepsilon_{reff}}} - 2\Delta L \qquad (2)$$

where ΔL is given as,

$$\Delta L = 0.412 h \frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} + 0.258)\left(\frac{W}{h} + 0.8\right)} \qquad (3)$$

On account of the fringing effect, the effective dielectric constant of the substrate is given by the following equation,

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12\frac{h}{W}\right)^{-\frac{1}{2}} \quad \frac{W}{h} \rangle\rangle 1 \qquad (4)$$

The width of the patch is,

$$W = \frac{c}{2 f_r \sqrt{\frac{\varepsilon_r + 1}{2}}} \qquad (5)$$

Here fr is the resonant frequency, ε_r is the dielectric constant of substrate and c is the free-space velocity of light (C=3×10^{8} m/s).

The proposed antenna has the dimensions as 16 mm by 16 mm with the patch length and width as 6.27 mm and 9.13 mm. The substrate involved is FR4-epoxy with 1.58 mm as thickness and a relative dielectric permittivity of 4.4 and 0.02 as loss tangent. The length of the inset feed is at 6.85 mm and width is 2.5 mm with the impedance matching done at 50Ω. With the above dimensions, basic layout of the patch is drawn and simulated using Advanced Design System (ADS) software and the results are obtained.

IV. SIMULATION RESULTS

The proposed antenna layout is designed using Advanced Design System where analysis is done by Method of Moment (MoM). The simulated and observed results are provided below. One of the key highlight of ADS is that it supports momentum and 3D EM simulator which helps in creating full standard based design and verification. The return loss of -33.53dB is obtained at a resonant frequency 10.58GHz as shown in the figures 5 and 6 which depicts the graph plot of its magnitude and phase with frequency. Bandwidth is measured at 790MHz which effectively covers the frequency range for satellite communications. The figures 3 and 4 shows the layout as well as the 3-dimensional view of the patch layout.

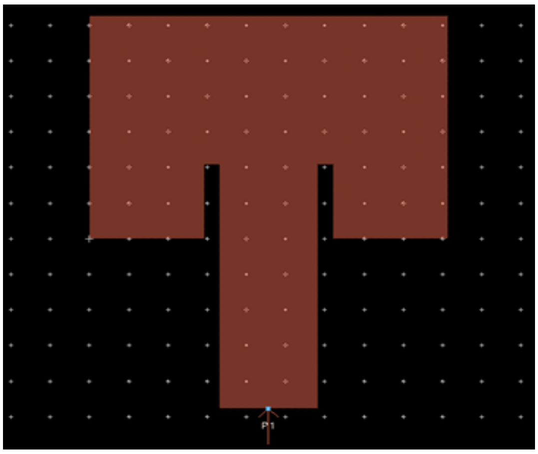

Figure 3. Layout of the patch

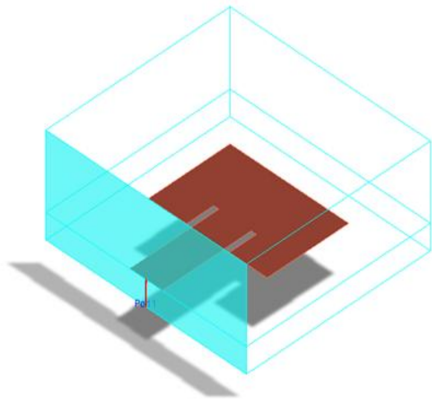

Figure 4. 3-Dimensional view of layout

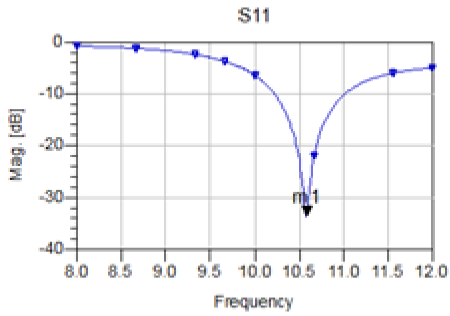

Figure 5. Plot of return loss magnitude vs frequency

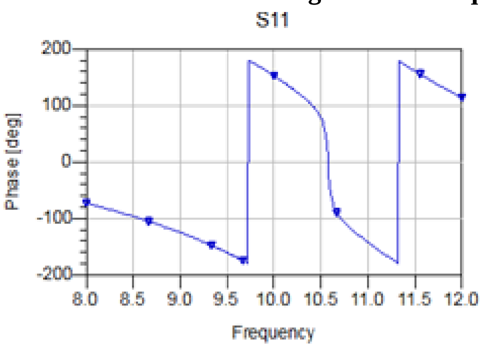

Figure 6. Plot of return loss phase vs frequency

The acquired radiation pattern at 10GHz is seen in figure 7.

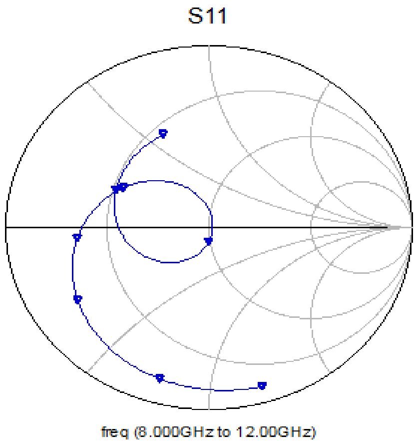

Figure 7. Radiation Pattern

The antenna is omnidirectional and has a broad radiation pattern which is clearly seen in the 3-dimensional bottom and top view in figures 8a and 8b.

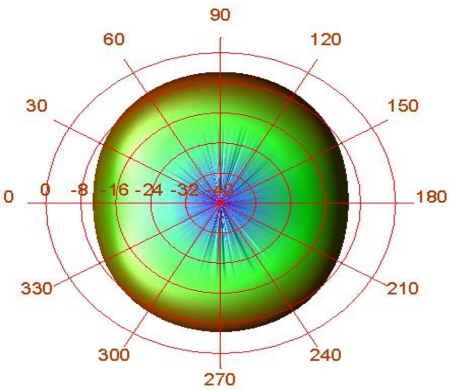

Figure 8a. 3-Dimensional bottom view of radiation pattern

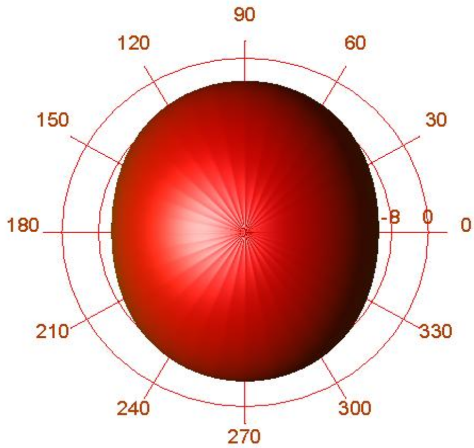

Figure 8b. 3-dimensional top view of radiation pattern

The polarisation of the radiated field is defined in terms of its far field. The linear and circular polarisation graph plot in 2-dimensonal view is given in figures 9a and 9b.

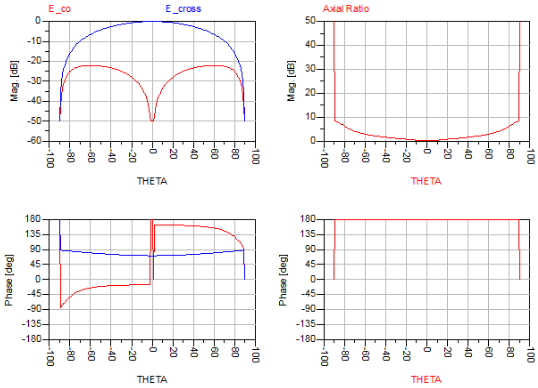

Figure 9a. Linear polarization

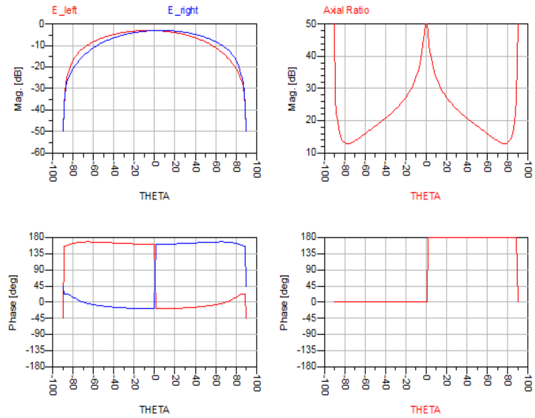

Figure 9b. Circular polarization

The E-plane (vertical) and H-plane (horizontal) radiation pattern of the proposed patch antenna at 10 GHz frequency is presented in figure 10.

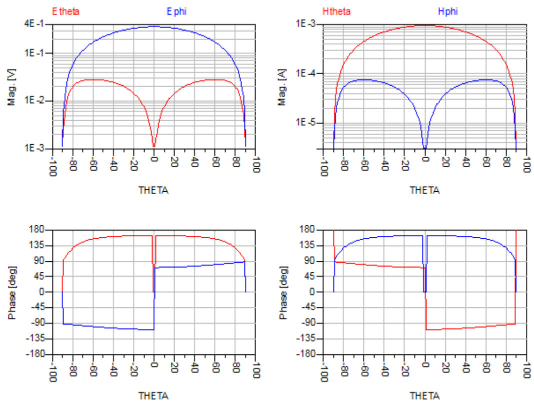

Figure 10. E-plane and H-plane radiation pattern in Cartesian coordinates

Radiation efficiency is expressed in terms of gain, directivity,effective area and power radiated as seen in figure 11.The overall efficiency is around 60-70% in the frequency range of 8-12 GHz.Therefore the antenna characteristics are significantly improved.

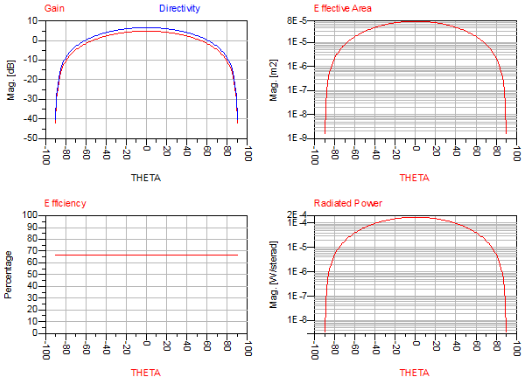

Figure 11. Radiation efficiency

In the figure 12 the current distribution of the proposed antenna is displayed where it is seen that the current is maximum at the centre and minimum at the edges by which impedance is minimum at the centre and goes on increasing towards the edges.

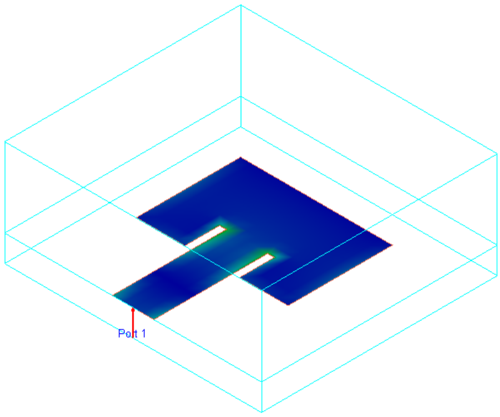

Figure 12. Current distribution

V. CONCLUSION

A rectangular microstrip patch antenna is proposed in this paper. From the results obtained it is observed that the major limitations of low gain and narrow bandwidth are enhanced to make it wideband with high gain. Also the impedance bandwidth has been improved. It is seen that the antenna produces good results according to return loss, bandwidth and radiation characteristics. The design is cost effective and can be fabricated with ease making it to be efficiently used in X-band applications. The proposed antenna can be optimized in order to accommodate various geometric configurations and extend its applications.

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