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Design A Square Microstrip Patch Antenna for S-Band Application

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Abstract: *In recent years there is a need for more compact antennas due to rapid decrease in size of personal communication devices. This paperdeals with the problem of size and performance of antenna. This paper presents design and simulation of a square micro strip patch antenna at 2.6 GHz for S- Band communications that provides a radiation pattern along a wide angle of beam and achieves a good gain. The square micro strip patch antenna was analyzed using Ansoft/Ansys HFSS. The proposed inset feed square patch antenna provide good Resonant Frequency, Return Loss, VSWR, Radiation Pattern and the antenna Gain.*

Index Terms: *Micro strip antenna, Inset feed, Return Loss*

I. Introduction

Micro strip patch antennas (also just called patch antennas) are among the most common antenna types in use today, particularly in the popular frequency range of 1 to 6 GHz. This type of antenna had its first intense development in the 1970s, as communication systems became common at frequencies where its size and performance were very useful. At the same time, its flat profile and reduced weight, compared to parabolic reflectors and other antenna options, made it attractive for airborne and spacecraft applications. More recently, those same properties, with additional size reduction using high dielectric constant materials, have made patch antennas common in handsets, GPS receivers and other mass-produced wireless products. This tutorial article is intended to provide basic information on patch antenna design and operation, directed to engineers who are mainly designers of RFmicrowave circuits. The paper hope that this information will assist them as they design circuitry connected to these antennas, or as they are called on to evaluate and specify a vendor's antenna product for their current project.

Antennas are indispensable elements of any wireless communication systems. There are several type of antenna are available they are wire antenna, log periodic antenna, travelling wave antenna, micro strip antenna, aperture antenna, reflector antenna. The wire antenna comprises of several antenna they are short dipole antenna, dipole antenna, half wave dipole, broadband dipole, monopole antenna and loop antenna. In spite of this antenna, in this project micro strip antenna is designed with frequency of 2.6GHZ.Micro strip antenna comprises of 2 antennas theyare rectangular micro strip (patch) antenna and planar inverted-F antenna Micro strip or patch antennas arebecoming increasingly useful because they can be printed directly onto a circuit board. Micro strip antennas are becoming very widespread within the mobile phone market. Patch antennas are low cost, have a low profile and are easily fabricated. Micro strip antennas find many applications as they are low profile, light weight, conformable to surface and inexpensive to manufacture using printed-circuit technology. For a patch, the length L of the element is usually the $L < \lambda g/2$ (where λg is the guide wavelength on the substrate). Thicker substrates with lower dielectric constant provide better efficiency and larger bandwidth but at the expense of larger element size. Thin substrates with higher dielectric constants lead to smaller element sizes, minimize coupling, but are less efficient and have relatively smaller bandwidth.

Micro strip patch antennas have enjoyed proliferated use in many circularly polarized applications due to their low-profile and useful radiation characteristics. In the last decade, the development of modern wireless systems has prompted increased investigation on micro strip radiators, with particular attention paid to improving performance and miniaturization. Compared to a circular patch for a given frequency the square geometry is smaller in size. In modern communication system requires low profile, light weight, high gain, and simple structure antennas to give surety reliability, mobility, and high efficiency characteristics. Due to the existence of growth in development of low cost, less weight, highly reliable, minimal profile antennas for wireless devices, it poses a new challenge for the design of antenna in wireless communications. This paper presents design and simulation of a square micro strip patch array antenna at 2.6 GHz for wireless communications that provides a radiation pattern along a wide angle of beam and achieves a good gain.

The rest of the paper has been divided into Fiveparts.Section 1 describes overview of antenna. Section 2 describes an overview of the Micro strip patch antenna. Section 3describesdesign consideration of antenna.Section 4 describes simulation results. Section 5 describesthe conclusion and future work respectively.

II. Micro Strip Patch Antenna

As communication devices become smaller due to greater integration of electronics, the antenna becomes a significantly larger part of the overall package volume. This results in a demand for similar reductions in antenna size. In order to simplify analysis and performance prediction, the patch is generally square, rectangular, circular, triangular, elliptical or some other common shape. The square micro strip patch antenna is the widely used of all the types of micro strip antennas that are present The substrate material, dimension of antenna, feeding technique will determines the performance of micro strip antenna. Hence among different feeding techniques, inset fed technique is used for the design of square micro strip patch antenna at 2.6GHz.Themicro strip patch antenna is shown in fig 1.Micro strip patch antenna has a ground plane on the one side of a dielectric substrate which other side has a radiating patch as shown below in Figure 1.

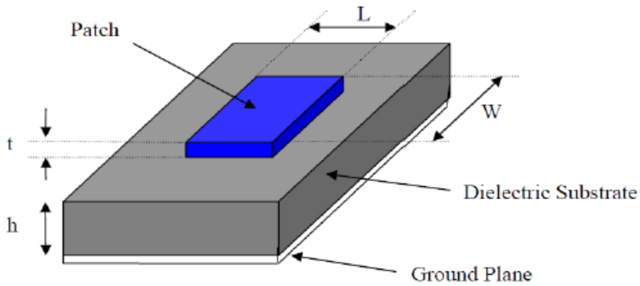

Figure 1 Micro strip antenna

A square patch is used as the main radiator. The patch is generally made of conducting material such as copper or gold and can take any possible shape. Dielectric constant of the substrate (ϵr) is typically in the range $2.2<\epsilon r <12$. For good antenna performance, a low dielectric constant with thick dielectric substrate is desirable, as it provides better radiation, better efficiency and larger bandwidth.

A. Inset Feed Method

This typically yields high input impedance. Since the current is low at the ends of a half wave patch and increases in magnitude toward the center, the input impedance could be reduced if the patch was fed closer to the center. One method of doing this is by using an inset feed (a distance R from the end) as shown in the figure 2. Since the current has a sinusoidal distributions, moving in a distance R from the end will increase the current by cos (π*R/L) - this is just nothing that the wavelength is 2*L, and so the phase difference is 2*π*R/(2*L) =π*R/L

Transmission line model depicts the micro strip antenna by two slots of width W and height h separated by transmission line of length L.Themicro strip is a non-homogeneous of two dielectrics, typically, substrate and the air. Most of the electric field lines reside some part in the air and rest in the substrate. This results that transmission line does not support transverse electric magnetic (TEM) mode of transmission, as phase velocities would be different in substrate and in the air.

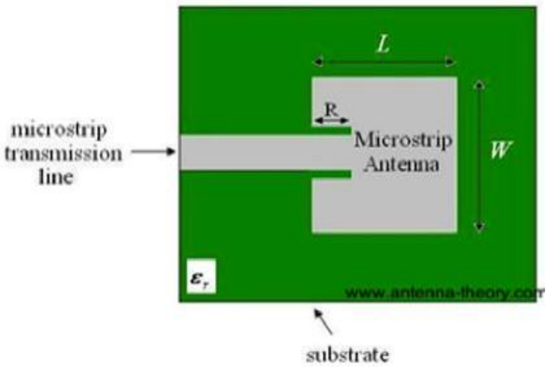

Figure 2. Patch antenna with insert feed

B. Micro Strip Patch Antennaanalysinng Method

Assume a square micro strip antenna of width W, length L resting on the height of a substrate h. The coordinate axis was selected as the height along z direction, length along x direction and width along y direction. In order to operate in the fundamental mode, length of the patch should be slightly less than $\lambda/2$, where λ is the wavelength equal to $\lambda 0 /\sqrt{\epsilon_{reff}}$ .The TM10 implies that field varies a cycle of $\lambda/2$ along the length, and width of the patch has no variation. The micro strip patch antenna is represented by two slots, separated by a transmission line of length L and open circuited at both the ends as shown in Figure 3.

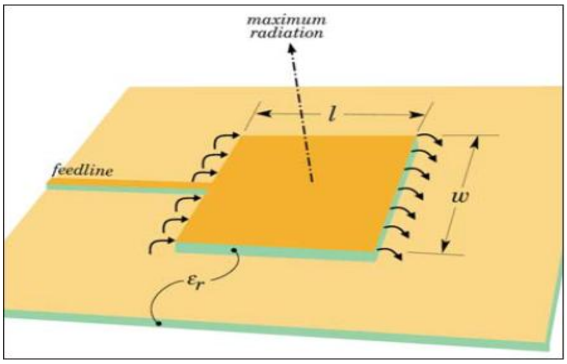

Figure 3 square patch antenna

The normal components of the electric field at the two edges along the width are in opposite directions and thus out of phase as seen in Figure 4. Since the patch is λ/2 long and hence they cancel each other in the broadside direction. The tangential components which are in phase, means that the resulting fields combine to give maximum radiated field normal to the surface of the structure.

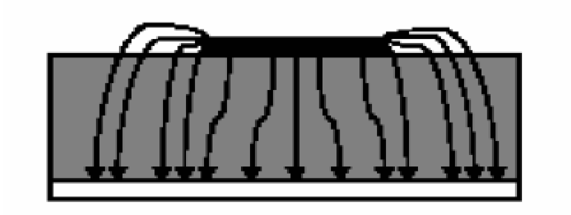
Figure 4. Electric field lines

III. Design Consideration Of Antenna

The paper has designed a Square patch antenna of the center frequency 2.6 GHz. Gain required as 11.5dBi. The antenna has employed a hybrid structure and using Rogers RT duroid 5880 as a substrate.

The three essential parameters for the design of micro strip patch antenna are:

1) Frequency of operation (f_0).
2) Dielectric constant of the substrate (ϵ_r).
3) Height of dielectric substrate (H).

For the micro strip patch antenna the height of the dielectric substrate is critical since the antenna should not be bulky. The resonant frequency of the antenna must be selected appropriately. The transmission line model will be used to design the antenna. The edge type feed is used in this design.

C. Antenna Design Calculations

1) Frings factor:

$$\Delta_L = 0.412\, h \frac{(\epsilon_{reff} + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\epsilon_{reff} - 0.258)\left(\frac{w}{h} + 0.8\right)}$$

2) Calculation of length:

$L = L_{eff} - 2\Delta_L$ Where, $L_{eff} = \frac{c}{2Lf_0\sqrt{\epsilon_{reff}}}$

3) For a Micro strip patch antenna, the resonance Frequency is given as

$$f_0 = \frac{C}{2\sqrt{\epsilon_{reff}}}\sqrt{\left(\frac{m}{L}\right)^2 + \left(\frac{h}{w}\right)^2}$$

Where m and n are modes along L and W respectively.

4) Calculation of width:

For efficient radiation, the width W is given as

$$W = \frac{C}{2f_0\sqrt{\frac{\epsilon_r+1}{2}}}$$

5) Calculation of height of dielectric substrate (H):

The equation to determine the height of the dielectric substrate is

$$H = \frac{0.3\,C}{2\pi f\sqrt{\epsilon_r}}$$

6) Calculation of the ground plane dimensions (L_g and W_g):

The transmission line model is applicable to infinite ground planes only. However, for practical considerations, it is essential to have a finite ground plane. It has been similar results for finite and infinite ground plane can be obtained if the size of the ground plane is greater than the patch dimensions by approximately six times the substrate thickness all around the periphery. Hence, for this design, the ground plane dimensions would be given as:

$L_g = 6h+L$

$W_g = 6h+W$

Hence after calculating all the parameters using the above formulae, the micro strip patch antenna was designed.

7) Determination of feed point location:

The feed co-ordinates were calculated $Y_f = W/2$ and $X_f = X_0 - \Delta_L$ where, $X_0 = \frac{L}{\pi}\cos^{-1}\sqrt{\frac{50}{Z_0}}$

and $Z_0 = \sqrt{50 * Z_{in}}$

8) Dielectric Substrate

It was found suitable to select a thin dielectric substrate with low dielectric constant by considering the trade-off between the antenna dimensions and its performance. Thin substrate permits to reduce the size and also spurious radiation as surface wave, and low dielectric constant for higher bandwidth, better efficiency and low power loss. The simulated results were found satisfactory.

IV. Simulation Results And Discussion

The three essential parameters for the design of a Square Micro strip Patch Antenna:

1. Frequency of operation (f_o): The resonant frequency of the antenna must be selected appropriately. The resonant frequency selected for the design is 2.6 GHz.
2. Dielectric constant of the substrate (ε_r): The dielectric material selected for our design is Rogers RT duroid 5880 which has a dielectric constant of 2.2.A substrate with a high dielectric constant has been selected since it reduces the dimensions of the antenna.
3. Height of dielectric substrate (h):

For the micro strip patch antenna substrate is selected as 1.6 mm.

Table 1 Dimensions of patch antenna

Solution Frequency	2.6 GHz
Patch Dimension	41.2 mm
Substrate dimension along x	100 mm
Substrate dimension along y	90 mm
Inset feed width	1.8 mm
Inset feed length	20 mm

Table 1.Shows the parameter selected for design a square micro strip antenna. Inset feed value is noted and the different calculation noted for test purpose.

D. Structure Of Patch Antenna Design

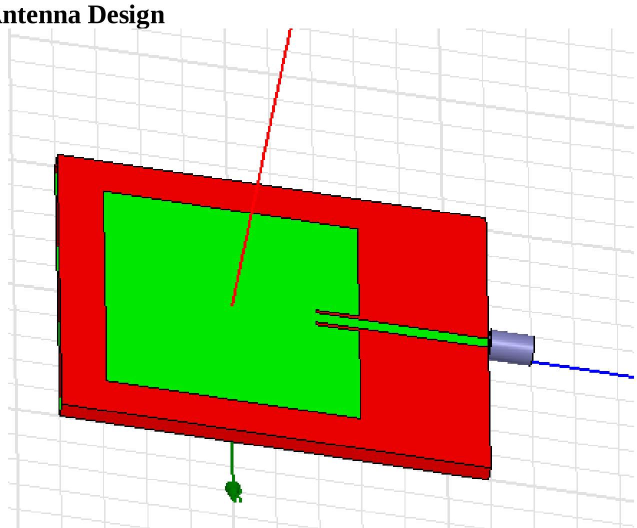

Figure 5. Feed micro strip antenna

Figure 5.Shows the square patch array antenna design is shown in below figure in 3D model. It consists of patch elements on one side of a dielectric substrate and a planar ground on the other side. It was assigned with an air box boundary and virtual radiation to create far field radiation pattern and assigned with a excitation.

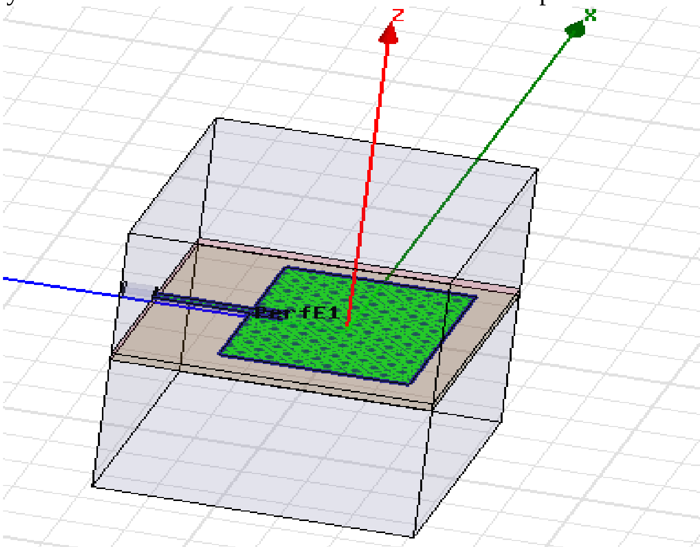

Figure 6. Full view of square patch micro strip antenna

Figure 6 shows the full view of antenna, here the ground is taken as a rectangular and the medium for the ground is E- plan. A rectangular box is covers the antenna.

The square patch micro strip antenna is simulated using Ansoft HFSS. The parameters evaluated were gain, beam width and return loss. Table 2 shows the comparison of proposed system with different frequency range. Here the Proposed system gave a good gain and result is satisfactory.

Table 2. Comparison of measured gain, return loss and bandwidth at two frequencies for single patch antenna.

Frequency in GHz	Substrate	Gain	Return Loss
2.25	Rogers RT RT duroid 5880	8 dB	-42dB
2.4	Rogers RT RT duroid 5880	9 dB	-14dB
2.6	Rogers RT RT duroid 5880	11.5 dB	-32.11dB

E. Radiation Pattern Plots

Since a micro strip patch antenna radiates normal to its patch surface, the elevation pattern for φ = 0 and φ = 90 degrees would be important.

Figure 7.below shows the gain of the antenna at 2.6 GHz for φ = 0 and φ = 90 degrees and shows the radiation pattern of proposed system. The maximum gain is obtained in the broadside direction and this is measured to be 1.87 dBi for both, φ = 0 and φ = 90 degrees.

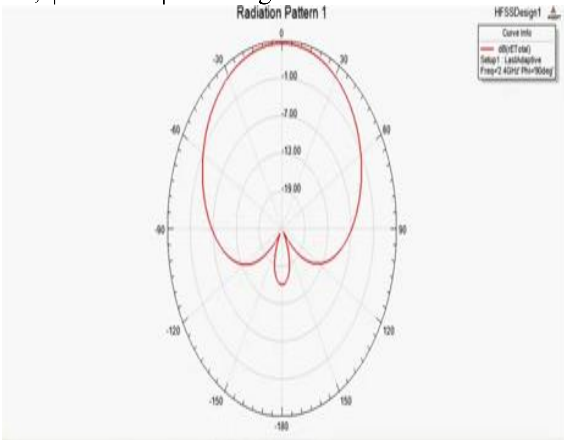

Figure 7. Radiation pattern of proposed system

F. Return Loss

The inset feed used is designed to have an inset depth of 20 mm, feed-line width of 1.8 mm and feed path length of 20 mm. A frequency range of 2.6 GHz is selected and 20 frequency points are selected over this range to obtain accurate results. The center frequency is selected as the one at which the return loss is minimum. The bandwidth can be calculated from the return loss (RL) plot. The bandwidth of the antenna can be said to be those range of frequencies over which the RL is greater than -9.5 dB (-9.5 dB corresponds to a VSWR of 2 which is an acceptable figure). Using PSO, the optimum feed depth is found to be at Y_o = 13.2mm where a RL of -32 dB is obtained. The plot for frequency v/s return loss is shown in Figure 8.

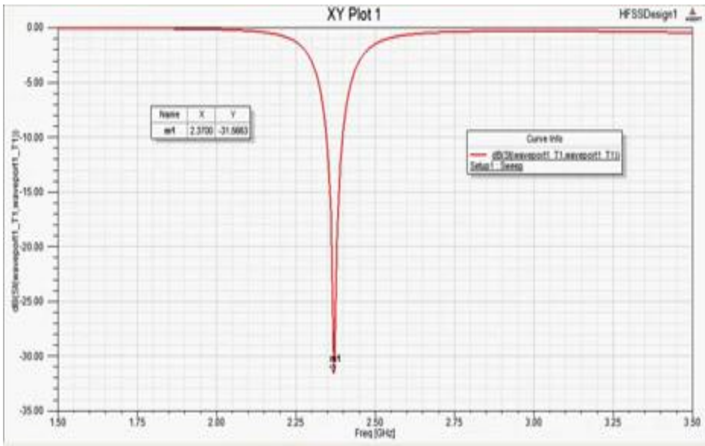

Figure 8. S-parameter plot for frequency v/s Return loss of proposed system

V. Conclusion

The design of square micro strip patch antenna with operating frequency 2.6 GHz suitable for s band application using inset feed feeding technique has been completed using HFSS software. The performance parameters were achieved with gain 11.5 dB and beam width 40 degrees in E-plane and 26 degrees in H-plane for patch antenna. The proposed antenna consists of a single patch for single operating frequency. In future two patches are going to be stacked and slots will be introduced to operate in two operating frequency to achieve high gain and good return loss.

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