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Design of Tl Shape Rectangular Patch Antenna for Global Positioning System (GPS) Applications

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Abstract: In today's modern communication industry, antennas are the most important components required to create a communication. Microstrip antennas are the most suited for aerospace and mobile applications because of their low profile, light weight and low power handling capacity. A design of a rectangular microstrip patch antenna is developing for GPS applications. The GPS is an aeronautics system provides a location and time information in all conditions of weather and anywhere on or near the Earth. The proposed antenna is designed like a TL shape in a microstrip rectangular patch with a transmission line to obtain a linear polarization. The copper substrate with a relative permittivity of 1 is used as a ground plane which has high power density, low weight and low fabrication cost. The Ansoft HFSS simulation software is used to design the antenna with input frequencies "6 GHz" and "10 GHz" and the resultant graphs are obtained. The output results are obtained with ADS software for the two center frequencies "3 GHz" and "5 Ghz". The proposed antenna increases the gain to "9.879 dBi", reduces bandwidth and gives better radiation in both horizontal and vertical direction. The antenna can be used for vehicle communication, aircraft tracking, cellular telephony, navigation etc.

Key words: Global positioning System · Microstrip patch antenna · Rectangular patch · Transmission line · Planar polarization

INTRODUCTION

Microstrip patch antenna [1] is chosen nowadays than other antennas available in a modern world scenario for their compatibility in Mobile Aircraft, Satellites because of very small sizes. Hence design and development of cost effective microstrip rectangular patch antenna has become an important research area. Microstrip antennas are inexpensive to manufacture and they offer high performance with low profile and these antennas are ideal for GPS [2] and tracking devices. The proposed antenna is designed like TL shape with two rectangular patches and the antenna provides planar polarization with a transmission line by connecting the two patches. Low cost and high performance antennas are required for commercial and automotive [3] industry application. To meet these requirements for GPS applications, authors are focused on low profile and compact size conventional patch antennas [4]. The conventional patch antenna used a higher permittivity substrate to reduce the bandwidth. In this study, a rectangular patch is presented with dielectric substrate and copper substrate to provide rectangular polarization for GPS applications. The patch antenna operates in a input frequency of "6GHz". The effectiveness of proposed antenna is verified by designing a patch antenna with different ground plane and simulated. Finally, the desired compact size and inexpensive antenna is designed with no complex feeding and matching circuits are required. The details of design, performance and results are discussed below.

Antenna Design Process: Proposed antenna's configuration is represented in Fig. 1. The dimensions of the antenna are listed below in the table I. The proposed micro strip Patch antenna [5] includes a radiating patch on one side of a dielectric substrate which has a ground plane on the other side. Conducting materials are made by patches such as copper and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate with a thickness equal to "1.27 mm" and relative permittivity is "10.8". The layer

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of dielectric substrate is placed in the copper layer named as ground with dimensions Length L_1, Width W_1 and Height H_1. The Length L, Width W, Height H of a ground plane is shown in table I, which has relative permittivity of 1. A two rectangular patch named as wave port is printed perpendicularly in the two sides of the substrate layer with a Length L_2, Width W_2 and a transmission line is connected between them. A radiation box is etched on the top of the substrate and rectangular patch to produce excitation which is filled up with air material and the dimensions of the box is Length L_3, Width W_3 and Height H_2.

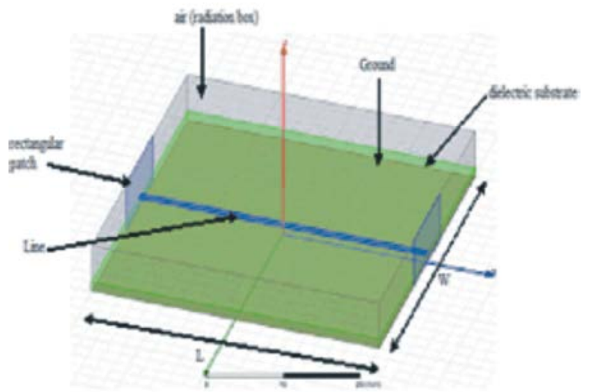

Fig. 1: Geometry of the polarized [6, 7] rectangular patch antenna

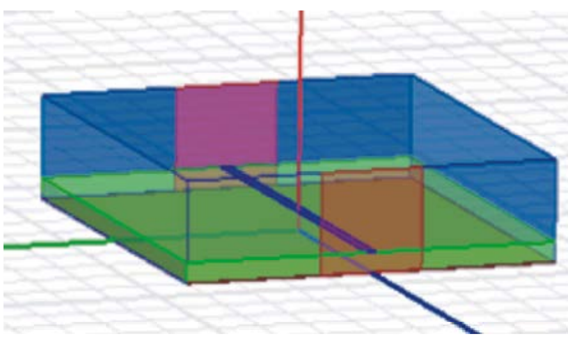

Fig. 1(a): Side view of the antenna

Parametric Values of the Antenna:

Parameters	Values (mm)	Parameters	Values (mm)
W	40	L	40
W_1	40	L_1	40
W_2	11	L_2	-6.35
W_3	40	L_3	40
H	1.27	H_1	1.27
H_2	6.35		

The overall design of patch antenna is meshed with vacuum as shown in Fig. 2 named as mesh. Excitation is provided by a copper line to the rectangular patch, which is shown in Fig. 3.

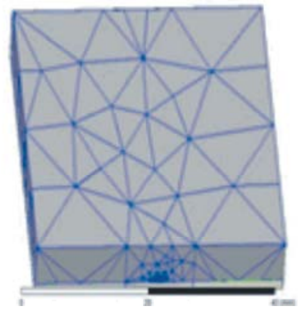

Fig. 2: Overall mesh of the antenna

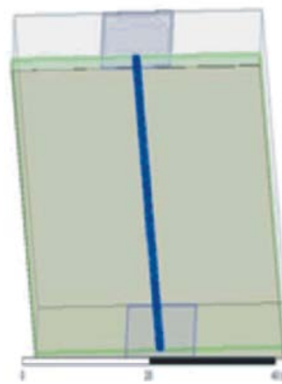

Fig. 3: Excitation analysis of rectangular transmission line

Antenna Analysis: The ξeff the effective permittivity of the substrate and is the correction factor considering the presence of the different dielectric materials used on the two sides of the folded patch [8].

$$\varepsilon_{eff} = 1 + q(\varepsilon_r - 1) \quad (1)$$

The frequency of proposed antenna is calculated by using formula given as

$$f_c = \frac{1}{2L\sqrt{\varepsilon_0 \varepsilon_r \mu_0}} \quad (2)$$

RESULT AND DISCUSSION

The proposed antenna is designed to operate in the center frequency of “3 GHz” and “5 GHz” for GPS [9] applications. The result is obtained in both HFSS and ADS software for proposed antenna and it is discussed below. The design of an antenna is done by HFSS software and antenna parameters are calculated by using ADS software. The variation of both is discussed below.

Polar Plot: Fig. 4.1(a) and Fig. 4.1(b)shows the polar plot of direction and time, the output of designed antenna is simulated in the plot with direction in one axis and time in another axis. The arrow mark indicates the direction of antenna and it is obtained in "270 degree". Fig. 4.1(a) is simulated in acosh function and y parameter asy(p1,p2). Fig. 4.1(b) is simulated in polar function as z parameter as z(p1,p2).

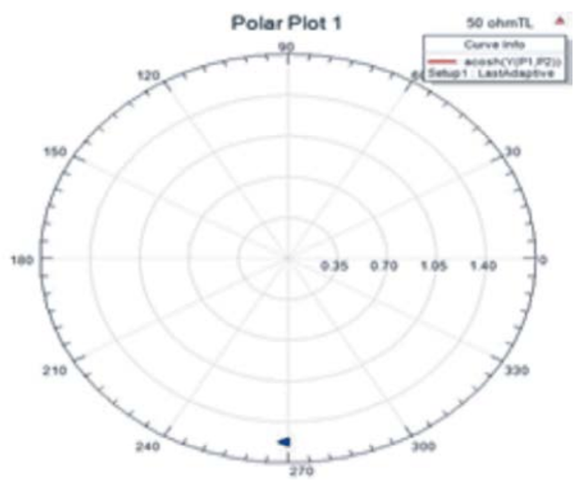

Fig. 4.1(a): Polar plot of direction and time

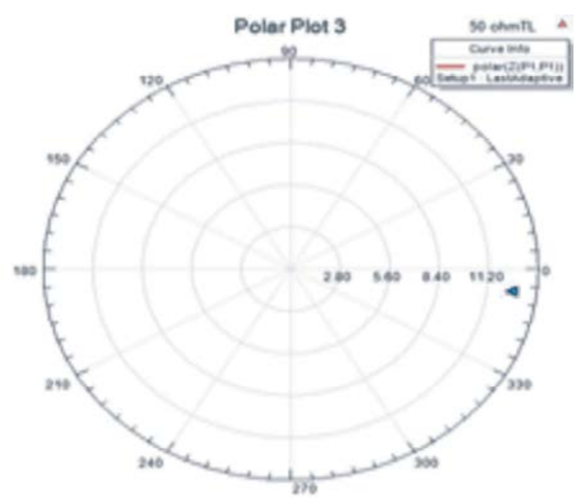

Fig. 4.1(b): Polar plot of direction and time

3D Pattern of Antenna: The 3D pattern of the antenna is shown in Fig. 4.2 with different magnitude values. Normally the antenna contained various shapes but in 3D view of the antenna is obtained in the following diagram. The proposed antenna is view with respect to frequency and time.

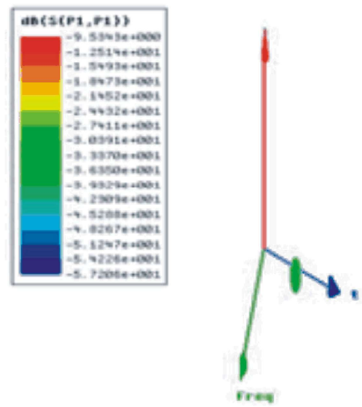

Fig. 4.2: 3D pattern of antenna

Smith Chart: The impedence of the antenna is explained by using smith chart. The variation in impedence can be shown by using different direction parameters which is shown in Fig. 4.3(a), Fig. 4.3(b) and Fig. 4.3(c). The three different function are used to simulate the output of the proposed antenna.

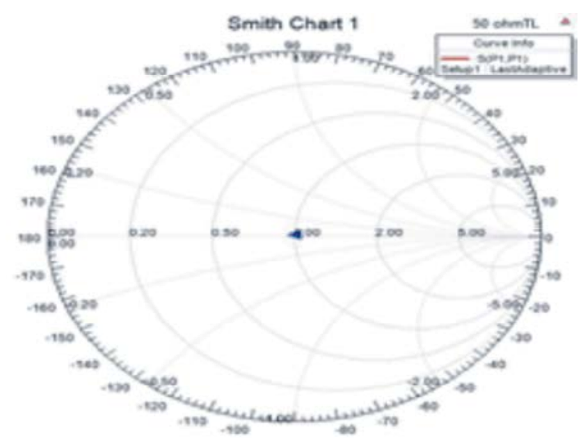

Fig. 4.3(a): Impedance of the antenna

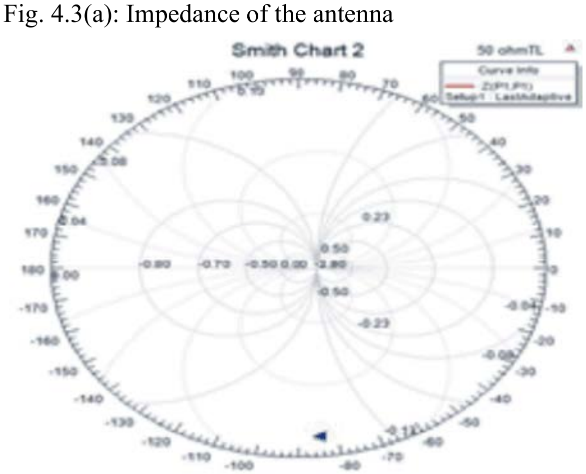

Fig. 4.3(b): Smith chart in z parameter

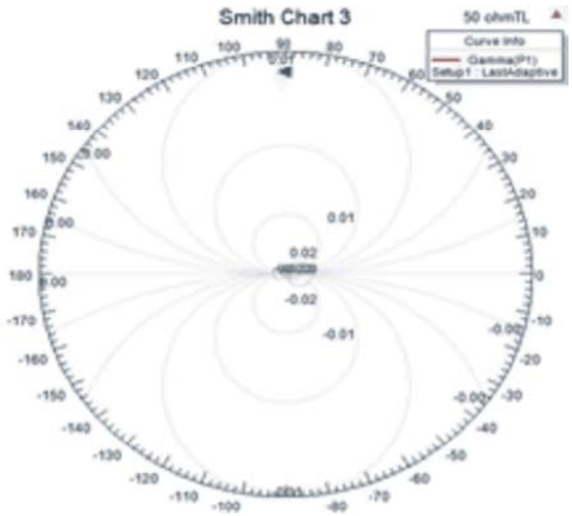

Fig. 4.3(c): Smith chart in gamma direction

Radiation Patternt: The plot describes the radiation pattern of the proposed antenna, the horizontal and vertical axes are angle (degree) and gain(dB) respectively. The Fig. 4.1(a) shows the radiation pattern of antenna in polar plot. For the center frequency "3 GHz", the waveform obtain in the plot with a gain "9.89 dBi", the wavefrom in the plot represent the gain and it obtain in the angle of "0 degree". Fig. 4.1(b) also shows the radiation pattern but with the center frequency of "5 GHz". The same results is obtained in this frequency. The comparison of two frequencies is shown with two different plots such as polar plot and rectangular plot. By comparing these two, the gain of "9.89 dBi" is obtained by both the frequencies.

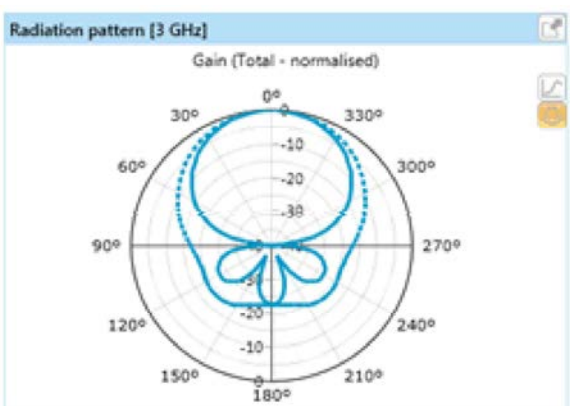

Fig. 4.4(a): Polar plot

Gain: To direct or concentrate radio frequency energy in a particular direction or pattern is named as a relative measure. The measurement is typically measured in dBi (isotropic radiator) or in dBd (dipole radiator [10]). In the above plot gain vs degree is used to show the obtained gain of proposed antenna. Here, the gain of the proposed antenna is shown with frequency with a linear graph. Fig. 4.2(a) shows the gain of the antenna with a center frequency "3 GHz" as "9.89 dB". The waveform in the plot increase linearly from minimum frequency of "2.5GHz" to maximum frequency of "3.5 GHz". The Fig. 4.2(b) shows the gain of both center frequencies of "3 GHz" and "5 Ghz".

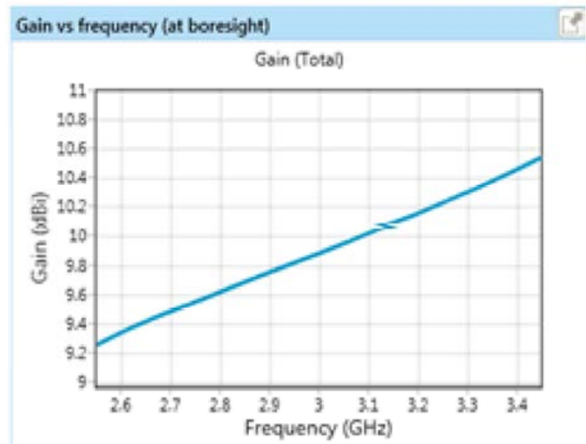

Fig. 4.5(a): Gain with center frequency 3GHz

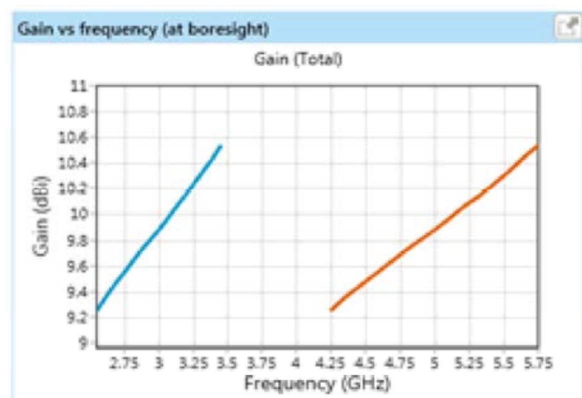

Fig. 4.5(b): Gain of both 3GHz and 5GHz

3D Radiation Pattern: A 3D radiation defines the variation of the power radiated by an antenna as a function of the direction away from the antenna. This power variation as a function of the arrival angle is observed in the antenna's far field.The 3D pattern of frequencies "3 Ghz" and "5 GHz" are shown in Fig. 4.3(a) and Fig. 4.3(b) respectively. The maximum radiation is obtained in the "9.89 dBi" gain in the direction of z-axis, which is shown in the figure.

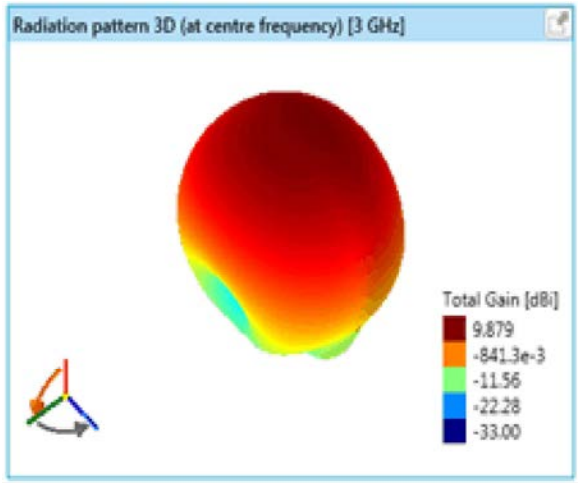

Fig. 4.6(a): 3D pattern of 3GHz

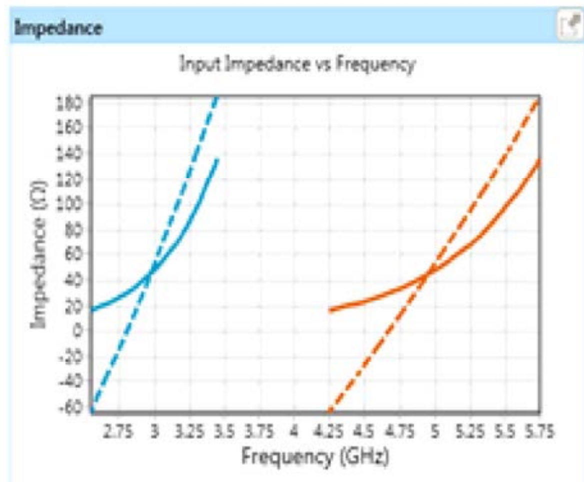

Fig. 4.7(a): Impedance of both 3GHz and 5GHz

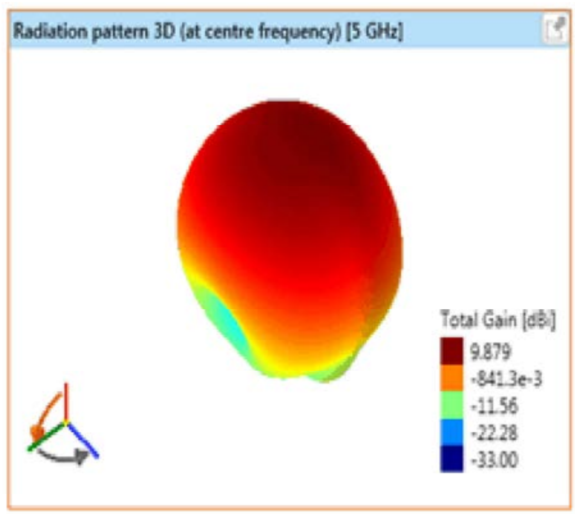

Fig. 4.6(b): 3D pattern of 5GHz

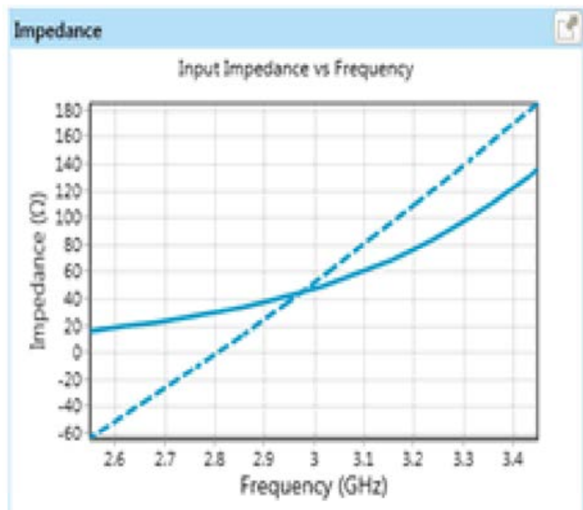

Fig. 4.7(b): Impedence of 3GHz

Impedence: The theory of maximum power transfer states that for the transfer of maximum power from a source with fixed internal impedance to the load, the impedance of the load must be the same of the source. The plot shows input impedance Vs frequency and gives 40 ohm impedance. In Fig. 4.4(a) the impedance of the center frequencies 3 GHz and 5 GHz is shown. It shows variation between two frequencies, the wave shown in blue gives impedance 50 Ω for 3 GHz and the wave shown in orange also gives impedance 50 Ω for 5 GHz. The fig 5.4(b) explains the impedance of 50 Ω for 3 GHz with a linear graph. The dotted line shown the wave from negative impedance the straight line starts from negative impedance.

Comparison Between Existing System and Proposed System:

S.no	Parameters	Existing System	Proposed System
1	Impedance Bandwidth	1.560 to 1.593 GHz	2.600 to 5.750 GHz
2	Center Frequency	1.575 GHz	3GHz
3	Gain	-12 DB to -11 DB	9.89 DB
4	Antenna Volume	$0.08\lambda_o$ x $0.08\lambda_o$ x $0.02\lambda_o$	40mm x 40mm x 7.58mm

The table B shows the comparison between existing system and proposed system. By varying the dimensions and shape of the existing antenna, the proposed antenna measured the impedance bandwidth for 9.89 dBi of ranges from “2.600 GHz to 5.75 GHz” with the simulated results.

CONCLUSIONS

A microstrip antenna is designed and fabricated with low profile and compact size with two rectangular patches and produces a rectangular polarization. Approximate volume of the antenna is approximately “40mm x 40mm x 7.58mm”. The proposed antenna operates in “3GHz” and “5GHz” and it has addition features such as low bandwidth, better radiation and highly efficient because of high positive gain as “9.89 dBi” which gives narrow polarization. The high impedance as “50 ohm” is obtained in the designed antenna. The design of antenna is done by using Ansoft HFSS and the antenna parameters such as radiation pattern, impedance, frequency and gain is calculated by using ADS software. So the proposed antenna is well suitable for GPS application.

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