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DESIGN AND ANALYSIS OF MICROSTRIP PATCH ANTENNA FOR RADAR ALTIMETER

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ABSTRACT

The most important parameter for any flying vehicle is altitude. Different techniques and methods are available for altitude measurement; one of these methods is RADAR Altimetry. In this technique altitude measurement of an in-flight vehicle is measured by using RF waves and RADAR. RADAR Altimeter transmits low-power radio waves, these waves incident on the earth and get reflected back with a shift of about 40 Hz/feet. The altitude is determined as per the time delay between the signals which is measured by differentiating the broadcast and received signal for a specific time period. The RADAR altimeter operates on a frequency range of 4.2 to 4.4 GHz in the C-Band. Different shapes of microstrips are tested and used for this application. In this article, a rectangular microstrip antenna is designed and simulated at 4.2GHz and its performance and characteristics are analysed using ANSYS HFSS.

Keywords: antenna, RADAR, altimeter, gain.

1. INTRODUCTION

A microstrip antenna having a magnitude 18mm x 12mm x 1.6 mm with a rectangular shape made with FR4 substrate is suggested for radar altimeter applications in [1]. Dual-band operation can be achieved if the position is changed. The Antenna can operate for a frequency range of 3.98 GHz - 4.47 GHz with a sonorous frequency i.e. 4.22 GHz, it was designed &investigated using HFSS. In [2], a microstrip patch antenna has been designed with a scalene triangular shape that can operate at three resonating frequencies. The measurements of a triangular patch of the antennae are 35mm x 45mmx 55mm. The radiating patch has an L-shaped slot, optimization of this slot with the probe position can result in the generation of desired resonant bands for triple-band application. This antenna can operate at different bands hence applications are wide.

In [3], for RADAR Altimetry, a patch antenna with a rectangular slot is introduced which has one film air membrane with two L probe feed aligned at 90^{o}aside from each other, this antenna incorporates a shorting pin for the purpose of impedance equalling. As per the dimensions the antenna has a reflection coefficient of less than 20dB with a bandwidth of 4.2GHz to 4.4 GHz a center frequency of 4.3 GHz and a gain of 5.95 dB. The article [4] presents a concave-shaped antenna with a slotted patch operating in the C band which has dimensions 32mmx 38 mm with RT-Duroid 5880 substrate. To get direct contact excitation, coaxial feeding is used. In this paper reflection coefficient of -22dB, a gain of the antenna as 10dB, VSWR of 1.1was obtained at a center frequency of 4.3GHz.

The paper [5] aims at the design, development, optimization, and realization of a microstrip patch antenna that has linear polarization and proximity-coupled feed technique operating in the C-band. Initially, a patch antenna was designed with some plot equations and modelled in HFSS software and then compared with tested fabricated results. In [6] to power low-powered sensors from the side lobes of aircraft altimeter radar, a power harvesting system is presented. The design of the antenna is done by full wave field and congruous balance circuit simulations. The presented harvesting system can generate a direct current yield of -21 dBm with 2 micro W/cm2 incident power density. Which is enough for low-power sensor operation and substantiates the rectifier and antenna design. In [7] for pent band application a simple Star-shaped microstrip patch antenna that can operate on 5 resonant frequencies between 1 to 5 GHz has been designed and its performance characteristics such as reflection coefficient, Radiation pattern, Gain, & input impedance are evaluated by doing simulations. Optimizing the location and placement of the co-axial probe can lead to the making of five sonorous frequency bands by the created antennae.

The 2x2 array antenna having four single circular antenna elements with resonance frequency 4.3 GHz was proposed in [8]. This array antenna gives -12.41dB of return loss and a gain of 7.34 dBi for the operating frequency. The proposed antenna in [9] is an mm wave-type working on a very high frequency. The band is not in the C-band; hence a dipole antenna was designed for the operating frequency. The performance characteristics of the novel antenna were mediocre and not efficient for the operating application. Various approaches for Altimeter antenna and rectangular patch antenna for a variety of applications are studied in [10-15].

Most of the antennas presented in different articles give better performance when complex geometries are prepared, which incurs more cost and time. A simple geometry of a rectangular-shaped patch that can provide optimum performance is presented in this paper. The proposed geometry is designed and simulated in a simulation environment using HFSS.

In Section 1, general aspects of a patch antenna used for RADAR altimeter are given and a Literature survey is discussed. Section 2 discusses the design methodology opted for geometry development and states the dimensional parameters of the design. Section 3 contains the results of the simulation along with the analysis based on the obtained results.

2. DESIGN METHODOLOGY

The geometry of the recommended microstrip patch antenna for the RADAR Altimeter is shown in Figure-1. As a substrate for patch antenna FR4 with dielectric permittivity 4.4 is selected. The geometry of the substrate is 40 mm x 40 mm and the thickness is taken as 1.6 mm. A rectangular microstrip is put on one side of the substrate with dimensions 16.5 mm x 21.7 mm to operate at a frequency range of 4.2-4.4 GHz. The measurement of the patch is calculated using the equations given below.

$$Wi = \frac{v}{2f_{rel}}\sqrt{\frac{2}{e_{rel}+1}} \tag{1}$$

$$e_{eff} = \frac{e_{rel}+1}{2} + \frac{e_{rel}-1}{2}\left[1 + 12\frac{he}{W}\right]^{-1/2} \tag{2}$$

$$\frac{\Delta Le}{he} = 0.412\frac{(e_{eff}+0.3)\left(\frac{Wi}{he}+0.264\right)}{(e_{eff}-0.258)\left(\frac{Wi}{he}+0.8\right)} \tag{3}$$

$$Le = \frac{v}{2f_{rel}\sqrt{e_{eff}}} - 2\Delta Le \tag{4}$$

Where Le and Wi are the length & width of the patch individually, v is the velocity of light in free space, he is height of the substrate, e_{rel} and e_{eff}i s comparative and effective dielectric constant of the material respectively.

For impedance matching a cut of 4.125 mm x 4 mm is made on the patch. The width of the port for feed is kept at 3 mm. A radiation box of measurement 80 mm x 80 mm x 40 mm made of air is also defined for simulation purposes.

Table-1. Calculated parameters.

Parameter	Measurement (mm)
Wi	21.7
Le	16.5
he	1.6
Port Width	3
Substrate	40 X40
Radiation Box	80 X80X40

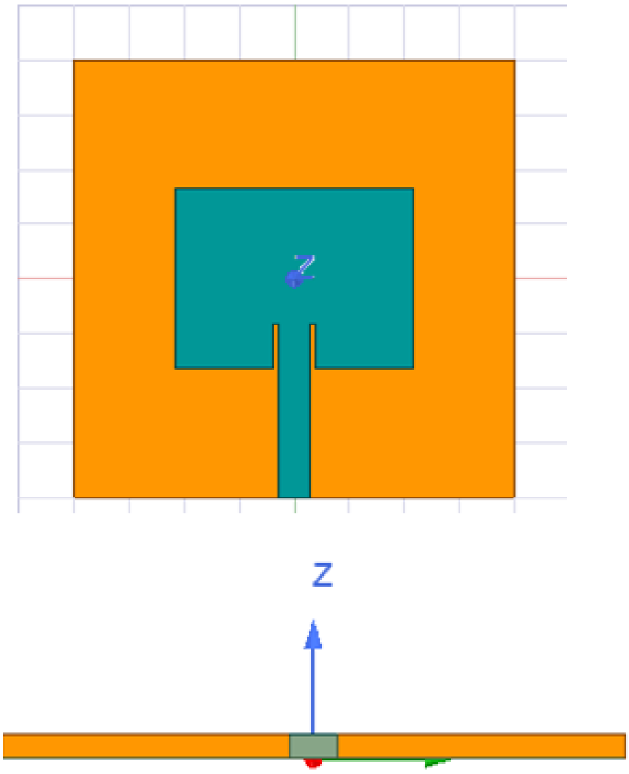

Figure-1. Configuration of the proposed antenna (a) Top View (b) Side View.

3. RESULT AND ANALYSIS

The suggested antenna geometry is designed and analyzed. The S11 parameter of the simulated antenna is described in Figure-2. S11 is plotted for 2 to 6 GHz, but according to the value in dB, the operating frequency is 4.2 to 4.4 GHz with a sonorous frequency of 4.22 GHz.

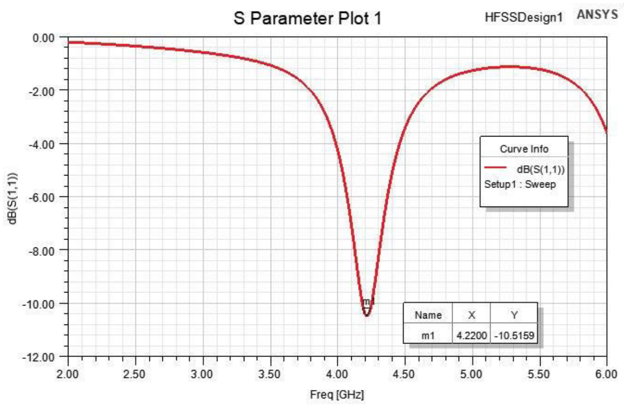

Figure-2. Reflection coefficient (S_{11} parameter) of proposed antenna.

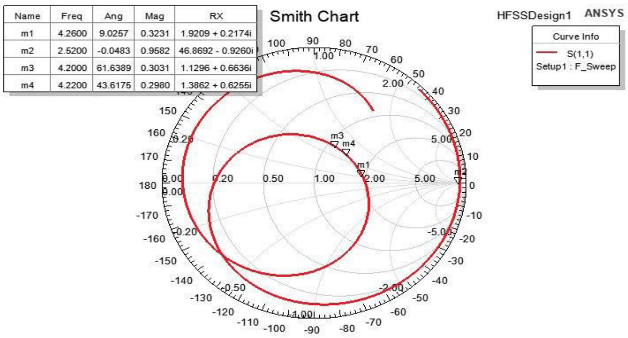

Figure-3. Impedance of proposed antenna.

The smith chart is represented in Figure-3. From the figure, it is seen that the resonance frequency of 4.22 GHz is harmonized as it is in the centre. Figure-4 shows a gain of the designed antenna which has a maximum value of 4.4 dB. Directivity is shown in Figure-5 with a maximum value of 6.8 dB. Figure-6 and Figure-7 show the E field and H field of the suggested antenna. The E-field radiation pattern is taken for 4.22 GHz frequency and phi=0 degree for all Theta values. H field radiation pattern is taken for 4.22 GHz and phi=90 degree for all Theta values.

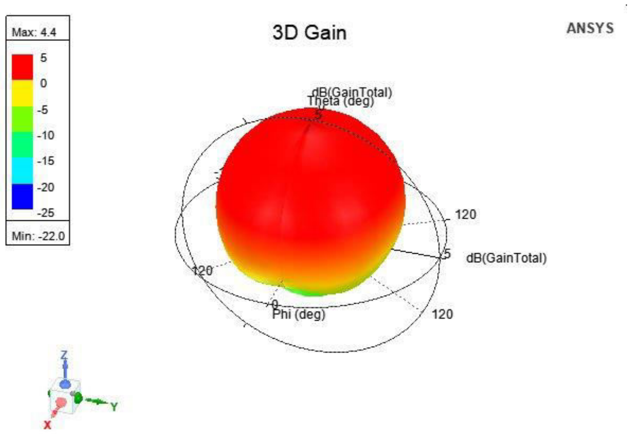

Figure-4. Gain of proposed antenna.

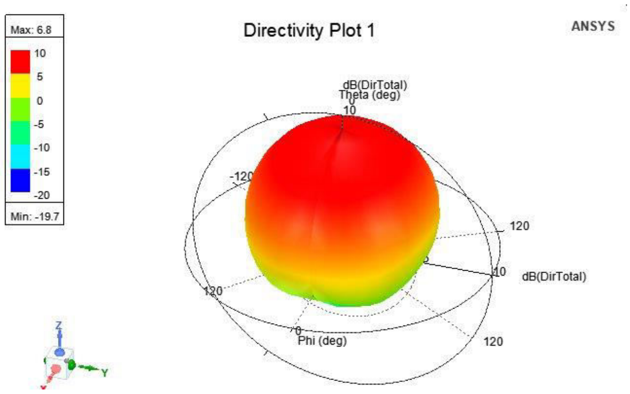

Figure-5. Directivity of proposed antenna.

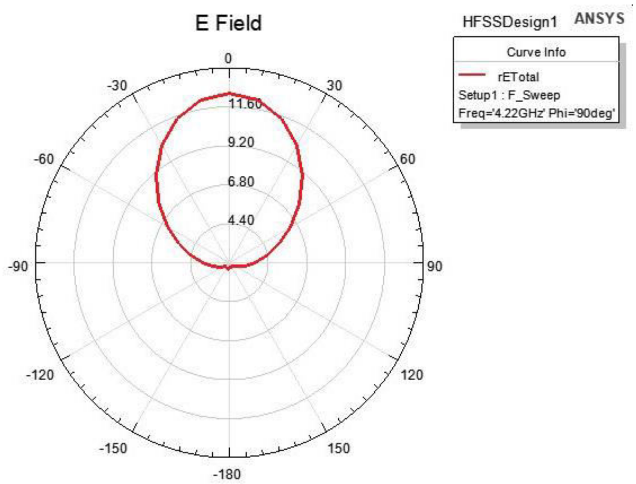

Figure-6. E Field at 4.22 GHz for proposed antenna.

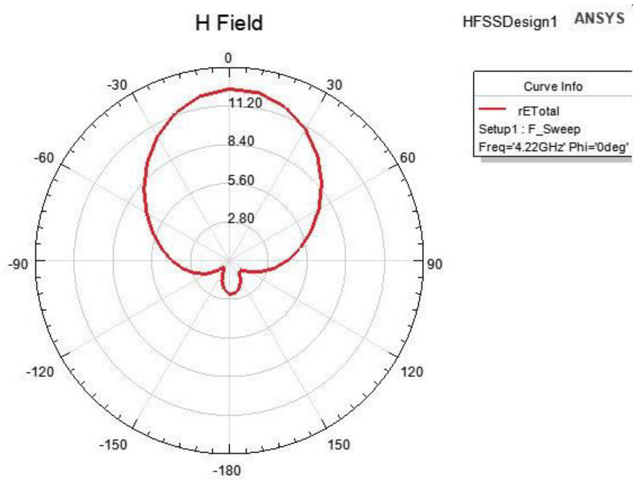

Figure-7. H Field at 4.22 GHz for proposed antenna.

The VSWR is shown in Figure-8. The current density over the patch geometry is shown in Figure-9.

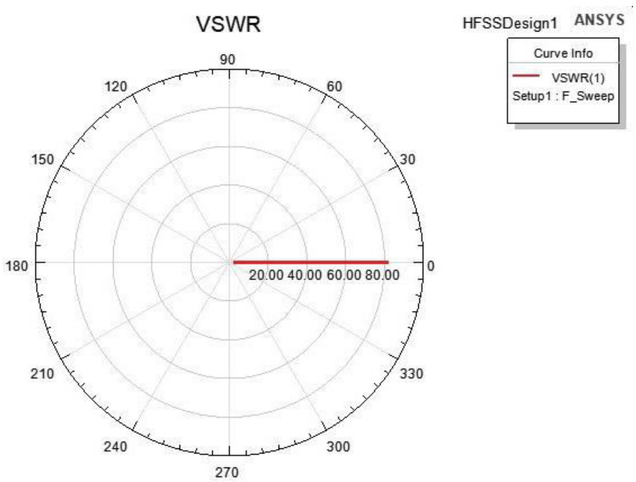

Figure-8. VSWR of proposed antenna.

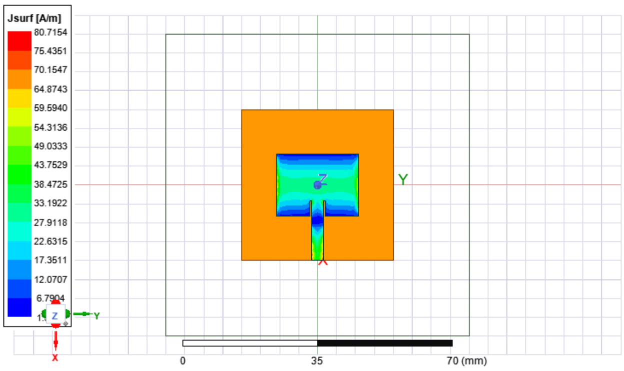

Figure-9. Current Density on proposed antenna.

Table-2. Comparison of Performance Characteristics.

S. No	Reference	Gain	S11	Geometry Complexity
1	[5]	1.3	1	Low
2	[2]	2.05	-	High
3	[1]	3.74	39	Medium
4	[8]	4.3	16	High
5	Proposed design	4.4	10.52	Very Low

As shown in Table-2 proposed antenna gives an acceptable gain and reflection coefficient while keeping the geometry of the antenna very simple. A better gain and S11 parameter can be achieved by incorporating a more complex geometry but it increases the cost and decreases the manufacturability of the antenna.

4. CONCLUSIONS

A closely packed rectangular microstrip antenna is planned for RADAR altimetry which has a resonance frequency of 4.22 GHz. The suggested antenna is drafted and animated in ANSYS HFSS software. The reflection coefficient is -10.52 dB at 4.22 GHz. Good impedance matching is achieved by providing a cut for feed input. The proposed design Gain is 4.4 dB and the Directivity is 6.8 dB. Hence the designed antenna exhibits good performance.

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