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Design of UHF-band Microstrip patch Antenna for Wind Profiler Radar

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Abstract: *This paper presents the design of rectangular microstrip patch antenna which operates in UHF-band at a frequency 445-MHz, used as an Antenna Array element in radar for wind profiling application. Therefore, Finite Element Method (FEM) based High Frequency Structure Simulator (HFSS) software is used to compute return loss (S_{11}), gain, VSWR,bandwidth of Rectangular Microstrip Patch Antenna. For cost effective design, air is used as a dielectric substrate which has zero loss tangent and leads to light weight Antenna. Aluminium metal as a patch and ground which are separated with support of hinges for giving better radiation efficiency.*

keywords –*wind profiling, FEM, HFSS, VSWR, return loss.*

I. INTRODUCTION

Introduction: Modern Atmospheric Radar Systems require low profile, light weight, high gain and simple structure antennas to assure reliability, mobility and high efficiency. Microstrip patch antenna has been received tremendous attention since the last two decades and it becomes a major component in the development of wind profiler Radars [1] [2] which are vertically directed pulsed Doppler Radar, operates on the principle of scattering of electromagnetic energy by minor irregularities in refractive index of air .wind profiler radars are capable of analysing the back –scattered signals to determine wind velocity at heights ranging typically from 150 m to 18 km along the beam[3].

Rectangular Microstrip patch Antenna consists of a sandwich of two parallel conducting layers separated by dielectric substrate[4]. The lower conductor functions as a ground plane, the upper conductor is a rectangular patch as radiator and associated coaxial-probe feed, where the inner conductor of coax is attached to radiation patch while the outer conductor is connected to ground plane. Rectangular microstrip patch has been modelled as a pair of slots separated by a transmission line.

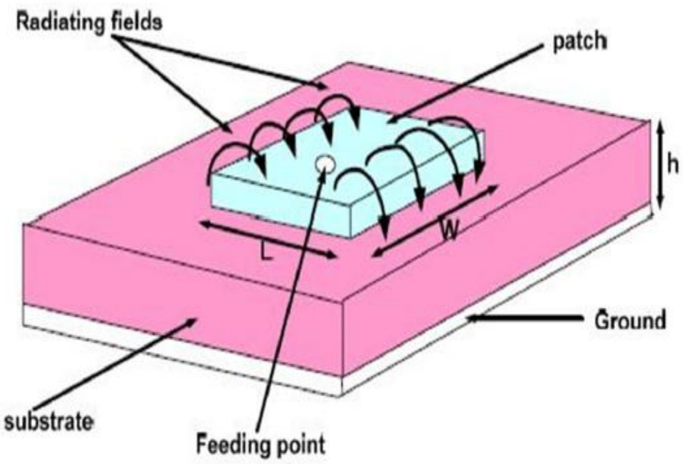


Fig. 1 Rectangular Microstrip Antenna

II.MICROSTRIP ANTENNA DESIGN

The rectangular microstrip patch antenna can be modelled as an array of two radiating slots, each of width w and height h, separated by a distance L. Because the dimensions of the patch are finite along the length and width, the fields at the edges of the patch undergo fringing[7]. The amount of fringing is a function of the dimensions of the patch and height of substrate.

The proposed antenna is shown in fig2. For rectangular microstrip patch antenna, the length L of rectangular patch is usually in the range of $0.3333\lambda_0 < L < 0.5\lambda_0$. Where λ_0 is the free space wavelength. The patch is selected to be very thin such that $t << \lambda_0$ (where t is patch thickness). The height h of the dielectric is usually $0.003\ \lambda_0 < h < 0.05\lambda_0$

(Balanis, 2005)[5]. For low frequencies the effective dielectric constant is essentially constant. At intermediate frequencies its values begin monotonically increases and eventually the approach the values of dielectric constant of the substrate.

Design Specifications:

Essential parameters for the design are:

- Operating frequency f_0= 445 MHz
- Dielectric Substrate is air $\varepsilon_r = 1$
- Height of substrate = *2.5 cm.*

Step 1: calculation of width (*W*):

The Width of Rectangular microstrip antenna is

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

Substituting $C = 3*10^8$ m/s (speed of light in free Space), $\varepsilon_r = 1$ (for air dielectric) and $f_o = 445$ MHz (operating frequency of microstrip patch antenna)

then

W=0.3371 m =33.71 cm

Step 2: Calculation of Effective dielectric constant (ε_{reff}):

The effective dielectric constant is

$$\varepsilon_{r\,eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2}$$

Substituting $\varepsilon_r = 1$ for air dielectric, $W = 33.71$ *cm* and $h = 2.5$ *cm*

Then $\varepsilon_{reff} = 1$

Step3: Calculation of Effective length (L *eff*):

The effective length is

$$L_{eff} = \frac{C}{2f_0\sqrt{\varepsilon_{reff}}}$$

Substituting $\varepsilon_{reff} = 1$, $C = 3*10^8$ m/s (speed of light in free Space), and $f_o = 445$ MHz (operating frequency of microstrip patch antenna).

Then $L_{eff} = 33.70$ *cm*

Step 4: Calculation of length extension (ΔL):

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

Substituting $\varepsilon_{reff} = 1$, $W = 33.71$ *cm* and h =2.5 cm

Then $\Delta L = 1.736$ cm

Step 5: calculation of actual length of Rectangular microstrip patch (L):

Actual length (physical) of Rectangular patch is given by

$$L = L_{eff} - 2\Delta L$$

Substituting $L_{eff} = 33.70$ *cm and* $\Delta L = 1.736$ *cm* *Then L= 30.228 cm.*

Step 6: calculation of ground plane dimensions (L_g and W_g):

Design the Ground plane is finite instead of infinite ground plane due to practical considerations .dimensions of ground plane are greater than the patch dimensions by approximately six times the substrate thickness along length and width.

$L_g = L+6h = 45.23$ *cm*

$W_g = W+6h = 48.71$ *cm*

III OVERVIEW OF HFSS SOFTWARE

High Frequency Structure Simulator (HFSS) uses Finite Element Method to solve Electromagnetic structure. hfss is extremely useful for antenna design and design of complex RF electronic circuit elements including filters, transmission lines , etc. HFSS is essential for designing high frequency and/ or high speed components used in modern electronics devices.

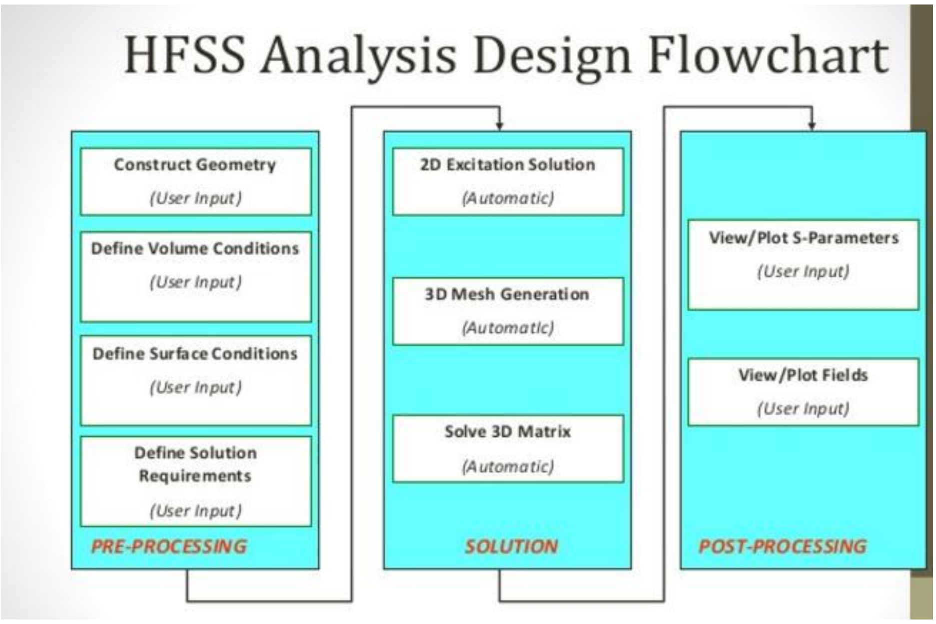
3.1 The important features of HFSS Software version 15

(a) Powerful drawing capabilities to simplify design entry.
(b) Computes S-parameters and 3D passive structures
(c) Advanced material selecting options are included

(d) Calculate far-field pattern patterns
(e) It consists an option for wideband fast frequency sweep.
(f) It creates parameterized cross section models.

IV. DEVELOPMENT MODEL FOR RECTANGULAR MICROSTRIP ANTENNA

A model is developed for Rectangular Microstrip Antenna with help of HFSS Software by using following flow chart



In the designing of antenna ,aluminium metal is used as patch and ground, air is used as substrate, utilized coaxial probe feed Technique, for mechanical support, hinges are used at all corners of patch and ground ,is shown in figure 3

TABLE 1. Antenna parameters

Length	*30.228 cm*
Width	*33.71 cm*
(X_f, Y_f)	(0, 6.3 cm)
L_g	*45.23 cm*
W_g	*48.71 cm*

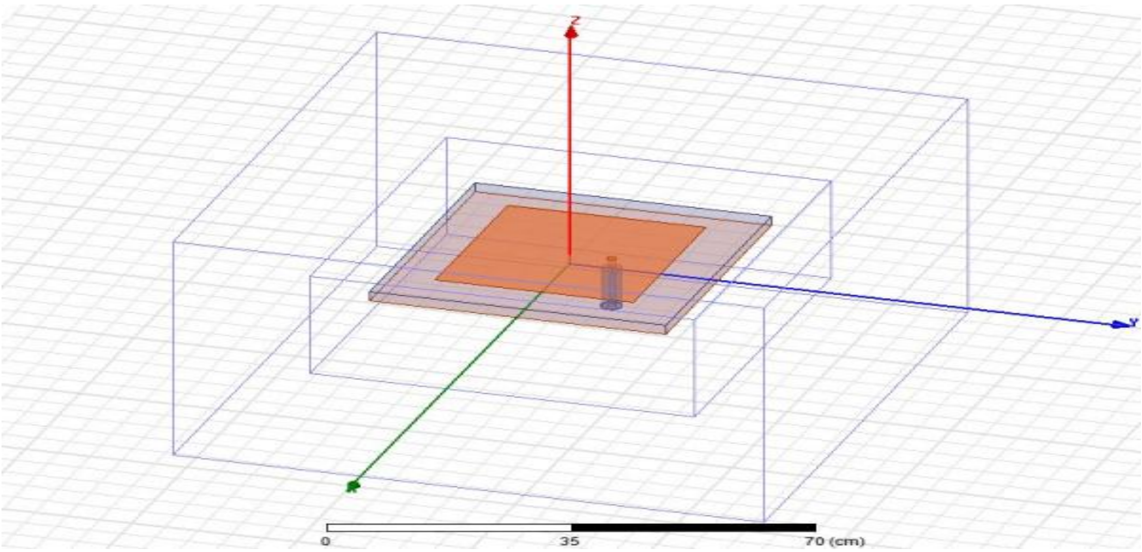


Fig2. Rectangular Microstrip Patch antenna simulated model

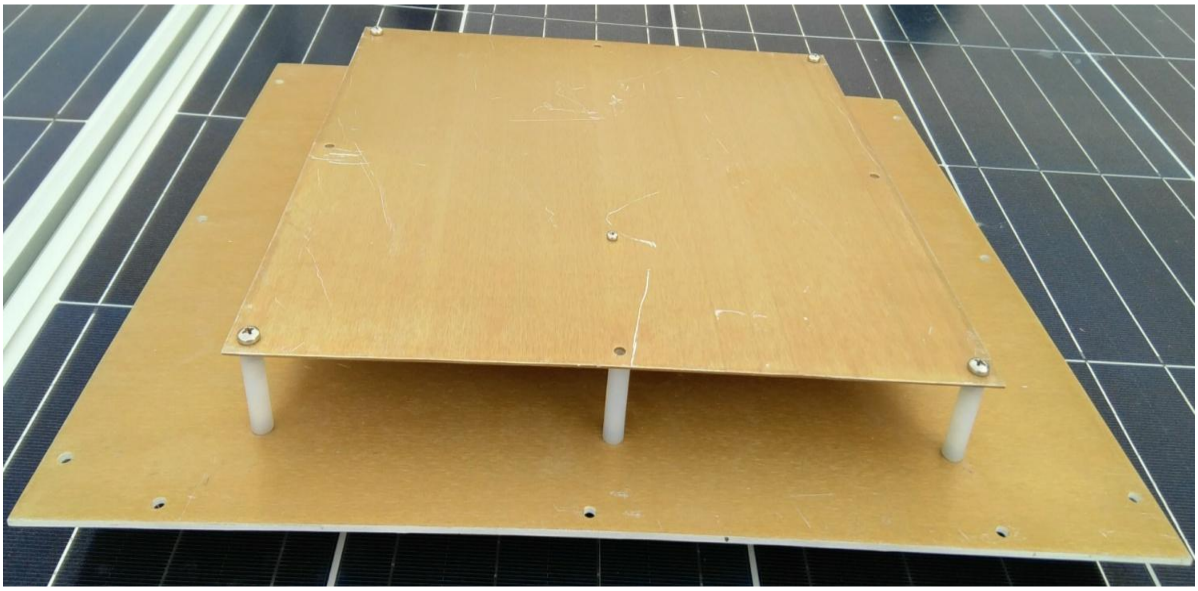


Fig3: Fabricated Rectangular Microstrip Patch Antenna element

V SIMULATED RESULTS FOR DIFFERENT PARAMETERS

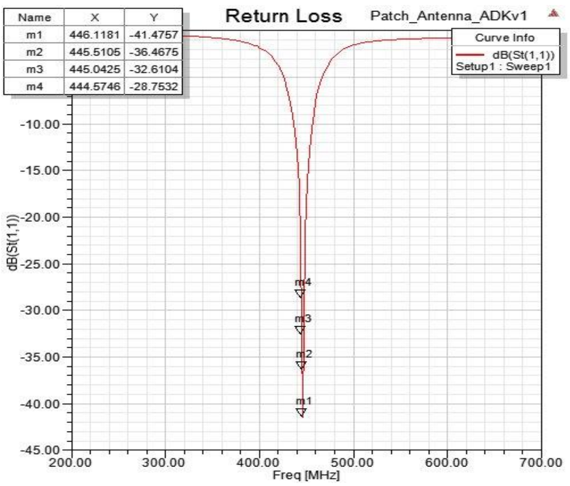


Fig 4: Return Loss vs frequency plot

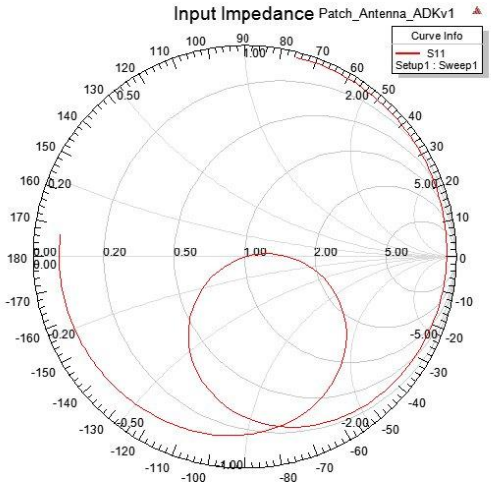


Fig5: input impedance of patch element plot

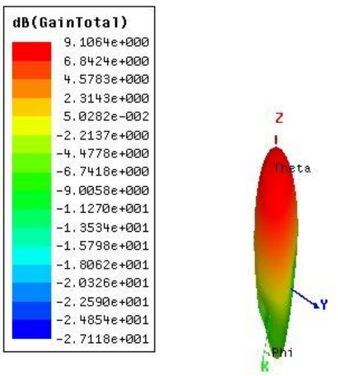


Fig 6: 3D Radiation pattern of patch antenna

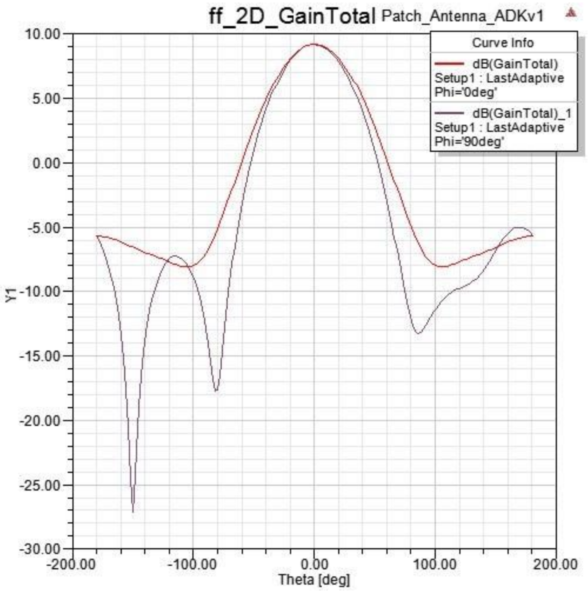


Fig 7: 2D Radiation pattern of patch antenna.

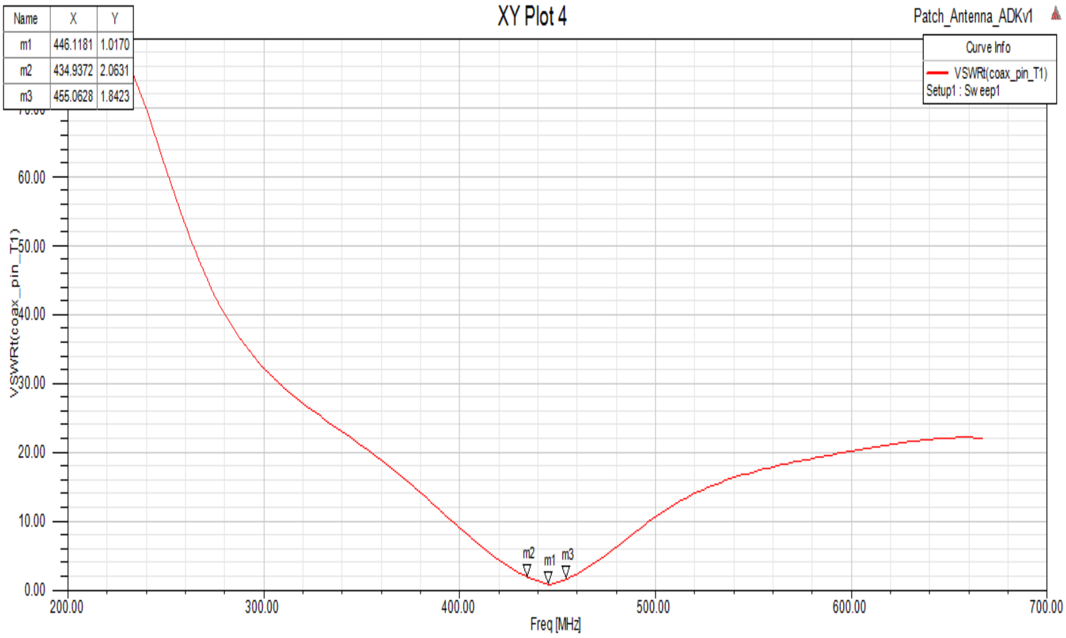


Fig8: VSWR vs frequency

V. CONCLUSION

The research motivation of this paper is to design Rectangular Microstrip Antenna at 445MHz for atmospheric wind profile Radar application with coaxial probe feed technique. HFSS Software is used for designing and simulation of rectangular microstrip antenna. the directivity of the designed antenna is 9.01dB, return loss(S11) -32dB, impedance bandwidth is 20 MHz, VSWR at 445Mhz is 1.0170.the radiation Efficiency at 445MHz is about 95% and antenna efficiency is about 82.5 %. from the radiation pattern. It is observed that the use of air as dielectric and aluminium as patch and ground plane, which reduces the weight in the fabrication of antenna array of wind profiler Radar and also it is cost effective design.

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