Tri-Band Microstrip Patch Antenna for S-Band Nano Satellite Application using Co-Axial Feed

Arvind Kumar[1] Shyam Sunder Sonkar[2] Ravindra Kumar[3] R. K. Prasad[4]
[1,2,3]Research Scholar [4]Associate Professor
[1,2,3,4]Department of Electronics and Communication Engineering
[1,2,3,4]Madan Mohan Malviya University of Technology, Gorakhpur

Abstract— It's the generation of tiny satellites which basically needs all its components to be miniature. The product proposed here is one such component, a tri band micro strip patch antenna operating at 2.6GHz, 3.6GHz S-band frequencies and 5.8 GHz. This real-time project work deals with a rectangular patch antenna operating at different frequencies working for various applications. The proposed S-Band Patch antenna is being designed and simulated using HFSS software. Obtaining optimum bandwidth efficiency by choosing suitable size without affecting any other parameters of the antenna is the challenge taken over in this project. The low profile, less weight patch antenna has antenna element of physical dimension 40x40x2.6mm .The substrate material being used is Alumina with dielectric constant 9.6. This antenna is designed to be used for TTC and payload downlink purposes. The designed patch array antenna meets all the parametric needs for a Polar orbiting satellite at Low Earth Orbit (LEO) region.

Key words: Micro strip patch, alumina (9.6), HFSS software, S-band frequency, Nano satellite, payload downlink frequency

I. INTRODUCTION

Microstrip patch antennas are increasing in popularity for use in communication systems due to their miniaturized size and cost effectiveness. They offer good compatibility for embedded antennas in hand-held devices. The basic form of patch antenna consists of a conducting patch printed on aground plane which radiates only at the desired frequency band [1].

The main disadvantage associated with microstrip antennas (MSAs) is their narrow bandwidth. Many efforts and techniques have been developed for enhancing the bandwidth of these antennas [2][3]. One popular technique is the utilization of parasitic patches. But the addition of parasitic patches causes enlarge geometry with increased complexity in array fabrication. This is particularly inconvenient for a co-planar case [4]. Alternatively, bandwidth can also be enhanced by employing a substrate of sufficient thickness which allows the penetration of field lines in it. Such a technique requires a coaxially fed method that usually causes increased cross-polarization in H-plane [5]. This also limits the useful bandwidth of an antenna which is usually less than 10% of the central frequency. This limited bandwidth is associated with increased inductance caused by the longer probe [6].

Many researchers have proposed different shapes of microstrip antennas for different applications with a specific feeding mechanism [7]-[9]. One of the most popular mechanisms is the coupling slot [7]. Various slot shapes have been designed and proposed like E-shaped [8], H-shaped [9], C-shaped [10][11] and U-shaped [12]. The size and selection of shapes is dependent upon a specific application and frequency of interest. In this article, we present a modified H-shaped microstrip patch antenna having a coaxially fed input which operates at nano satellite, wimax and WLAN frequency bands. Considering LEO, the average temperature will be ±150ºC. So, the substrate being chosen must be able to withstand such temperatures. The substrate material chosen is Alumina of dielectric constant 9.6. While considering polarization, Linear Polarization (LP) produces Faraday's rotation and hence Circular Polarization (CP) is preferred .The proposed antenna's geometry is simpler than the one presented in [13], where the authors have combined U and H-shapes to get the antenna functioning at three different frequencies.

II. DESIGN PARAMETERS

Mainly the design of Micro strip patch antenna depends upon three parameters, dielectric constant of substrate, thickness of the substrate and resonant frequency. Depending on the dimension, the operating frequency, radiation efficiency, directivity, return loss are influenced. For the calculation of geometrical dimensions it should be taken in the mind that for a micro strip patch the electrical dimensions are larger than geometrical dimensions This is due to the existence of fringing field beyond the limit, given by the geometrical dimensions of the micro strip patch.

Thus, a rectangular patch of dimension 40mm×40mm is designed on one side of an alumina substrate of thickness 2.6mm and relative permittivity 9.6 and the ground plane is located on the other side of the substrate with dimension 40mm x 40mm. The antenna plate is fed by standard coaxial of 50_ at feeding location of 0.5mm by 20.286mm on the patch. This type of feeding scheme can be placed at any desired location inside the patch in order to match with the desire input Impedance and has low spurious radiation.

Various designing parameters are as follows:

A. Width of patch is given by:-

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

B. Effective dielectric constant is given by:-

$$\epsilon_{reff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left[1+\frac{12h}{w}\right]^{-1/2}$$

C. Effective length of patch:-

$$L_{eff} = \frac{c}{2f_0\sqrt{\epsilon_{reff}}}$$

D. Due to fringing fields present extension of length is calculated by:-

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

E. Effective length of patch is given by:-

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

F. Ground plane dimensions are calculated by:-

$$L_g = 6h+L$$
$$W_g = 6h+W$$

Representations used are as follows:

ϵ_{reff} = EFFECTIVE DIELECTRIC CONSTANT

ϵ_r = DIELECTRIC CONSTANT OF SUBSTRATE

h = HEIGHT OF DIELECTRIC SUBSTRATE

f_0 = RESONANT FREQUENCY

L_g = LENGTH OF GROUND PLANE

W_g = WIDTH OF GROUND PLANE

C = VELOCITY OF LIGHT

III. GEOMETRICAL SPECIFICATIONS OF MICROSTRIP PATCH ANTENNA

In this antenna the relative permittivity = 9.6 of alumina has the thickness h=2.6mm. The length and width of the patch are given as L=40 mm and W=40mm. Now the patch is cut from rectangular patch. The front view and the 3D view of proposed antenna is shown in Fig-1 and Fig-2 respectively.

The antenna is fed by a micro strip line at feeding location of 20mm x 20 mm on the patch.

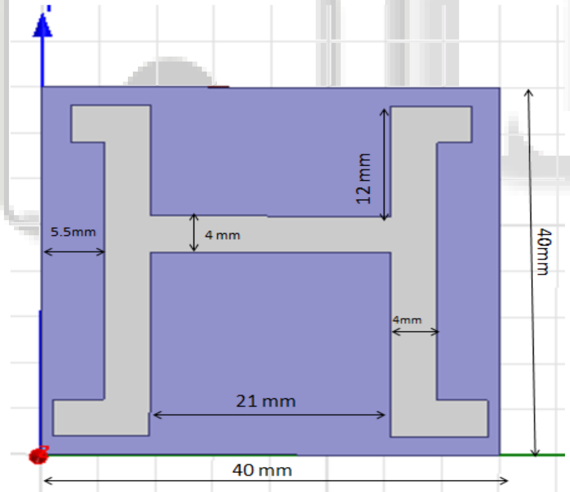

Fig. 1: Micro strip Patch antenna with co-axial feeding.

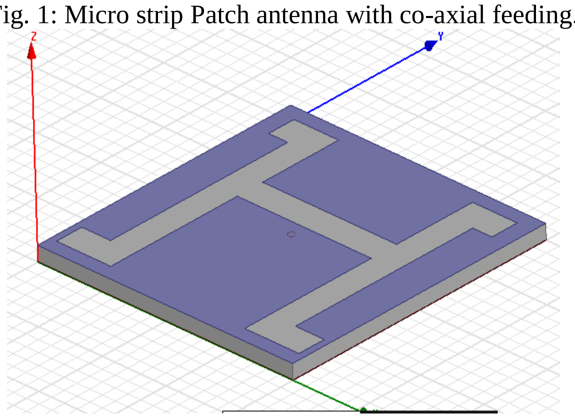

Fig. 2: 3-D View of microstrip patch antenna

IV. SIMULATIONS AND RESULTS

A. Bandwidth and Return Loss:

The scattering parameters S11 for the designed antenna are calculated and the graph of return loss is shown in Fig 3.The proposed bandwidth is about 22%.

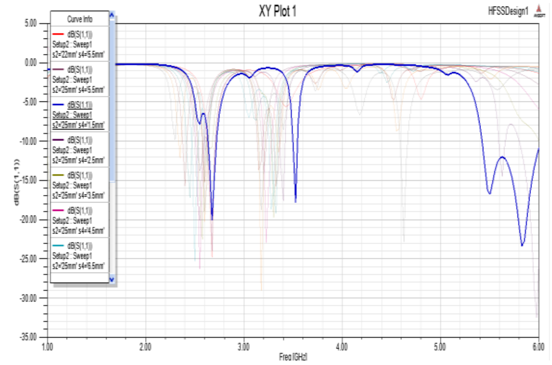

Fig. 3: RETURN LOSS

B. VSWR:

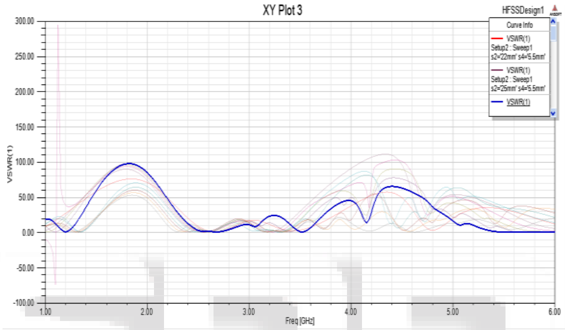

Fig. 4: VSWR PLOT

C. Current Distribution in Antenna:

Current distribution in a micro-strip antenna plays an important role in reducing the return loss and VSWR

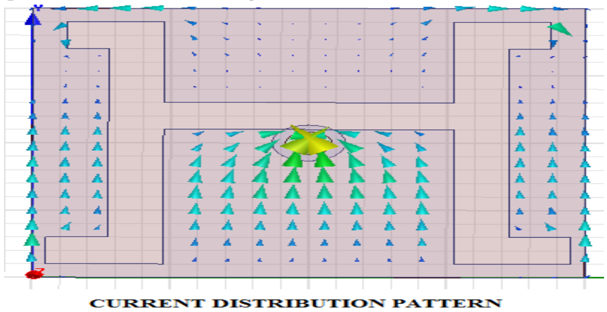

Fig. 5: Current Distribution Pattern

D. Radiation Pattern :

The plot of radiation pattern is shown in figure 8.

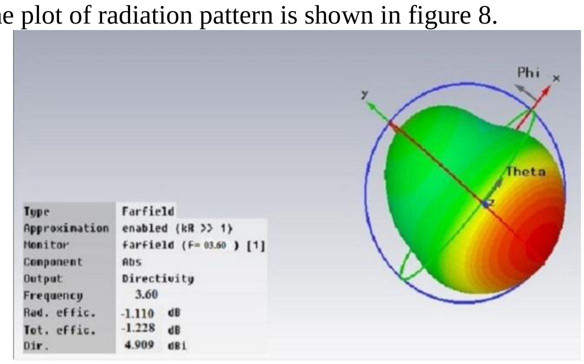

Fig. 6: Radiation Pattern At 3.6 Ghz

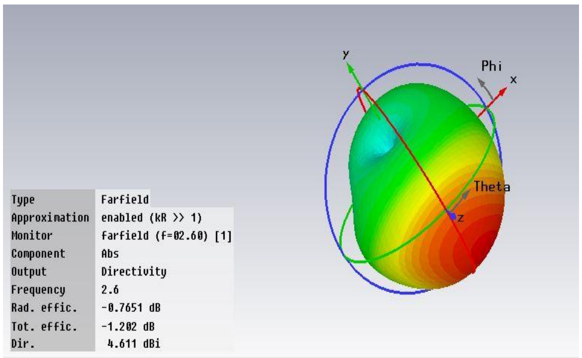

Fig. 7: Radiation Pattern At 2.6 Ghz

V. CONCLUSION

A tri-band modified H-shaped antenna for WIMAX, nano satellite and WLAN applications has been presented. The return loss *S*11 at 2.6GHz, 3.6 GHz and 5.8 GHz are -20.05db,-18.51 dB and -25.65 dB respectively. It is observed that the antenna offers improved characteristics at 5.8 GHz and its general performance for all the three reported bands is within acceptable range. Further, the VSWR of the fabricated antenna is ≤ 1.5 which is well within acceptable margins. From the results, it is clear that the above designed antenna is much suitable for S-Band Nano satellite applications. It is providing better gain and directivity and operates at 2.6GHz and is dimensionally apt to be installed on tiny satellites.

The substrate chosen has better temperature coefficient and hence the antenna can operate at varying temperatures in LEO region. Yet, a smaller patch with different substrate material, with better performance is our near future vision.

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