This full-text paper was peer-reviewed and accepted to be presented at the IEEE WiSPNET 2016 conference.

High Gain Patch Antenna for CubeSat

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***Abstract*: A design of high gain patch antenna system suited for inter-satellite and earth observatory is presented. The antenna consists of four patch antenna array designed for maximum gain, this antenna is suitable for CubeSat structure. A 96mm square antenna substrate is designed and fixed to one of the faces of CubeSat. The design of antenna array is executed using CST software, simulation results shows that antenna has maximum gain 9.6 dB, directivity 10.06 dBi, beam width 54.8^0 and antenna achieves good impedance matching in the S-band at 2.46 GHz.**

***Index Terms*-- CubeSat, Patch Antenna, Array.**

I. INTRODUCTION

A CubeSat is a small type of space mission satellite with 10x10x10 cm cubit units or in multiples of its cubic units with a mass of just over 1 kg per unit, often has been used for commercial off the shelf (COTS) are continuously increasing nowadays [2]. These satellites are widely used by many developing countries, Universities and private owners to gain experience in satellite technology and subsequent research works. Due to the use of modern technology for the development of the satellite and its compact size, the CubeSat can be designed, developed and implemented with low cost.

The services of CubeSat may be utilized for the complex missions such as earth observation [4], remote sensing, earthquake detection, inter-planetary mission and inter-satellite mission purposes. Even as a minor research project, the satellite must satisfy the requirement to withstand harsh space environment. So, the design of every hardware device should be rigid and this is a real challenge to the designers.

One of the key subsystems of every CubeSat is communication system. About 17% of satellite failed due to communication system failure. This communication system ensures the data transmission between the satellite and the ground station [2]. In communication system, the design of an antenna is a vital process. The CubeSat rely on Very High Frequency / Ultra High Frequency (VHF/UHF) with deployable monopole and dipole antenna, it provide low bit rate in order to provide high bit rate. The S-band, whose frequency lies between 2 to 4 GHz is considered for antenna design [1].

The new design proposed by A. Babuscia *et al* as inflatable parabolic antenna for maximum gain, where it produces backward radiation and this will affect the entire CubeSat system [3]. The patch antenna is found suitable for *S-band* frequency and it is compact in size with low cost and it can be fixed on the CubeSat surface. In addition, this antenna emits negligible backward radiation which does not affect the overall CubeSat system.

There is a need for satellite mapping and a real time monitoring of hostile environments, as about 17% satellite lost signal during operation due to communication hardware failure in the past. In order to provide the continuous signal transmission, more research is required at all ends. In this context, the paper addresses the design issues and evaluation by simulation of a high gain patch antenna in S- band for the applications in CubeSat and discusses its performance.

II. ANTENNA DESIGN

The CubeSat satellite ranges from 10×10×10 to 30×30×30 cm cubic units. So, the design of patch antenna is deemed to be compact, to be fixed on the CubeSat. Due to geometrical constraints on CubeSat, a 96 mm square substrate is designed for the patch antenna array. For high reliable antenna Rogers RT 5870 ($\varepsilon = 2.3$ and $h = 1.52mm$) substrate is used with substrate dielectric constant the dimension of the single patch antenna is calculated analytically by using formula [8].

Width of the patch antenna:

$$w = \frac{\vartheta_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (1)$$

Length of the patch antenna:

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{reff}\sqrt{\mu_0\varepsilon_0}}} - 2\Delta L \quad (2)$$

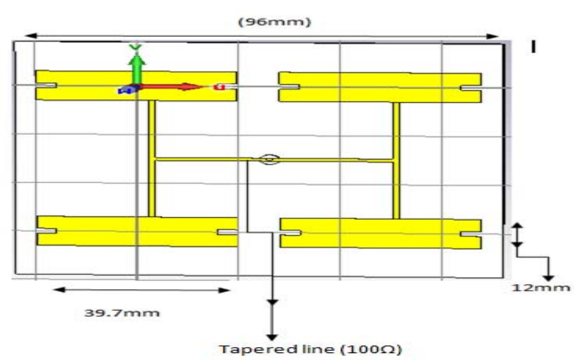

Fig. 1 Proposed antenna geometry dimension

The final dimension are L=39.7mm and w =12mm. which is optimized at 2.46GHz and designed using the microwave studio (MWS) by computer simulation technology (CST), for particular single patch antenna measurement the substrate is designed as 48 mm square plan.

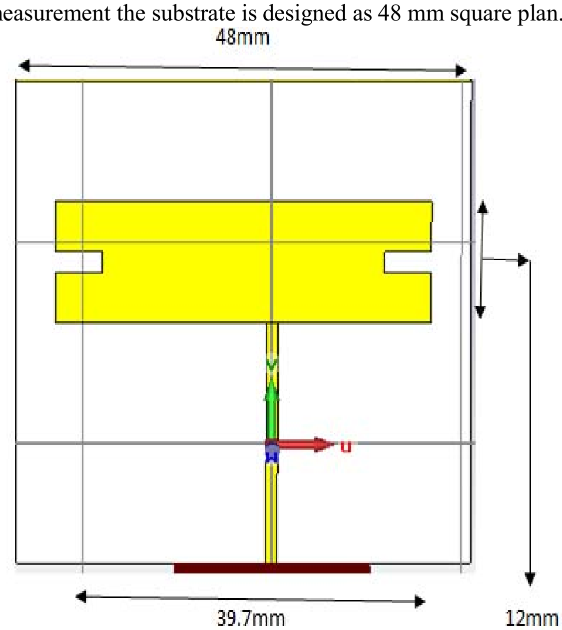

Fig. 2 Single patch antenna geometry

In order to get the best impedance matching the feed point is moved 3 mm away from the centre of patch edge. This single patch design is simulated using CST software, where single patch antenna produce maximum gain of 5.404 db and S_{11} value is -29 db at 2.46 GHz. I second phase the antenna array is designed using 96mm substrate .the four patch antenna are placed based on the first phase design dimension.

In order to feed the antenna array a simple tapered line (100Ω) is designed [8], the feed line width is calculated using analytical line impedance, calculated width of tapered line 1.2mm. This tapered line is negligible in width and also occupy less substrate surface, where remaining surface is utilized for the solar cell deployment.

The 50Ω coaxial feed is designed as the antenna input for tapered lines, this coaxial feed is placed 2.2mm away from the substrate centre in order to divide the power equally among the four patch antenna array. The copper (t=0.035mm) is used for patch and also for ground plane.

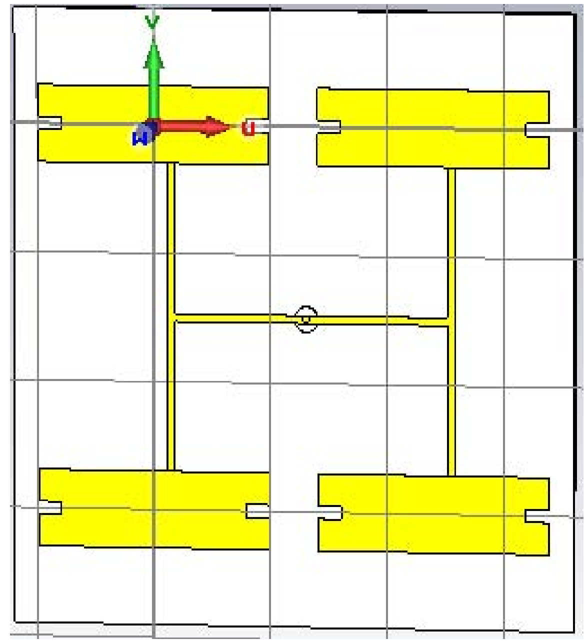

Fig. 3 Antenna array front view

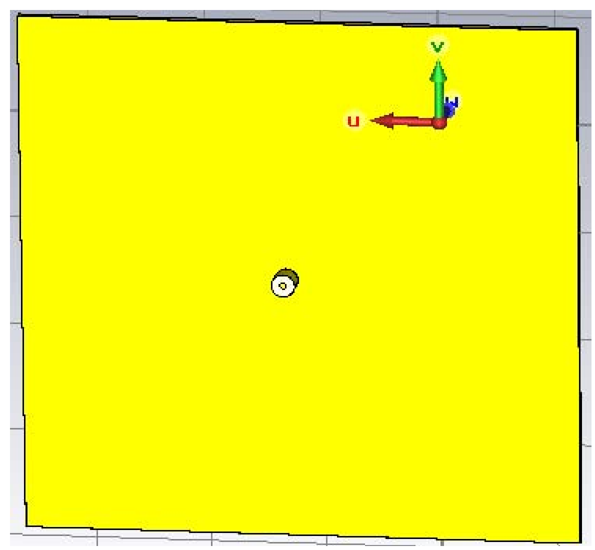

Fig. 4 Antenna array bottom view

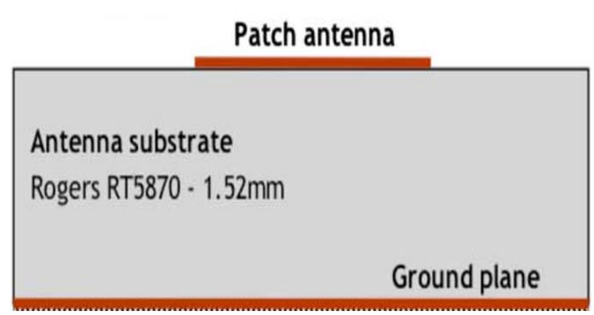

Fig. 5 Antenna side view [1]

III. RESULTS

After the design of the antenna array, it is simulated using CST software. The simulation results show various parameters such as return loss, gain, directivity, beam width, VSWR; these results can be discussed as follows

A. Return loss

The simulation results show that antenna well matched at operating frequency and S_{11} is fall well below -10db at 2.46 GHz. The simulated return loss in figure [6].

B. Radiation pattern

The antenna radiation pattern showed in 3D structure in fig [7]. The simulated antenna produces the maximum gain of 9.6 dB along the bore side direction at 2.46GHz.

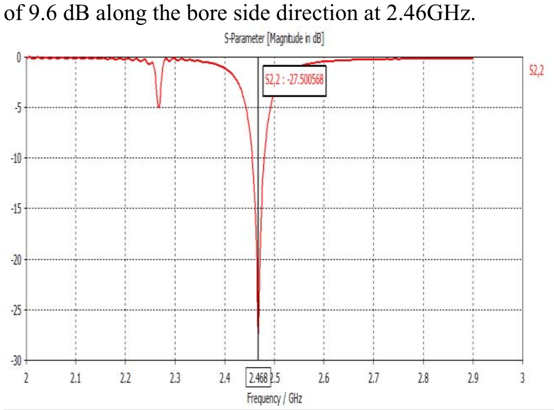

Fig. 6 Simulated reflected coefficient

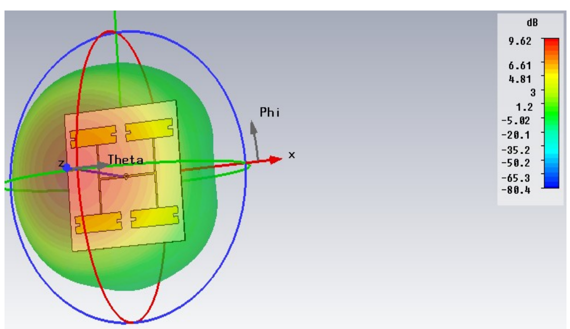

Fig 7.3D plot of simulated gain radiation pattern

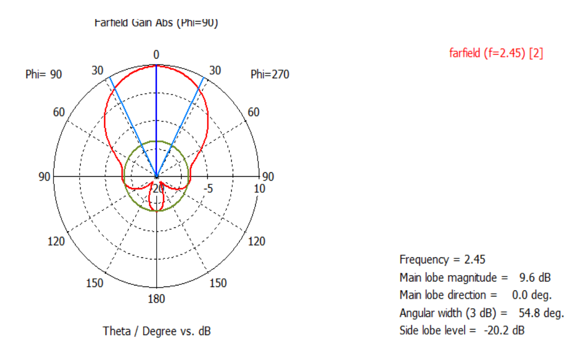

Fig. 8 Simulated beam width pattern

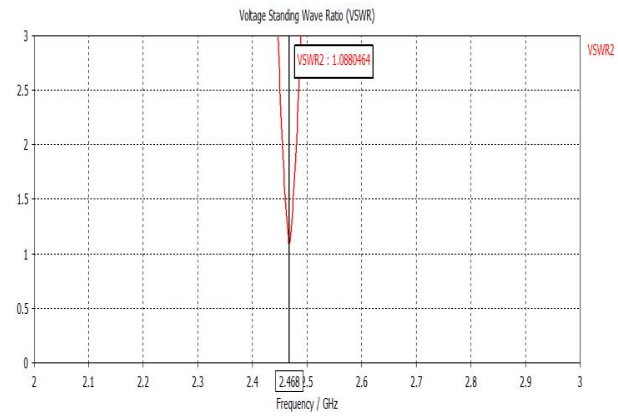

Fig. 9 Simulated VSWR at operating frequency

Directivity of the main lobe is 10.06 dBi with beam width of 54.8^o fig[8] and simulated results shows that VSWR is 1.088 at 2.46GHz fig[9].

IV. CONCLUSION

The design of high gain patch antenna is presented in this paper. In order to provide high data rate the S-band is used and for compact antenna structure the patch antenna is used. The design of antenna array need to provide a gain of 9.6 dB and it should also avoid the communication discrepancy during transmission of signals. This antenna provides maximum directivity on bore site direction of 10.06 dBi, with beam width of 54.8^o and VSWR of 1.088. This antenna is simple and gain has been improved as compared to the antennas being used and reported, such as the patch antenna used in Tigrisat with gain of 7.3db. This antenna can be used for remote sensing, communication, inter-planetary satellite, inter-satellite and it can also be used as a measuring element of atmospheric charged particle.

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