IMPROVEMENT IN CUBESAT COMMUNICATION USING PATCH ANTENNA

I. ANIRBAN BANERJEE
STUDENT, DELHI PUBLIC SCHOOL, DURGAPUR

Abstract:

In this paper, I have shared how to make the patch antenna of a CubeSat more efficient. Patch antennas are non-deployable (fixed) antennas. They are a part of CubeSat communication due to their compact and lightweight design and ease of fabrication and integration. Path Antennas are a major reason for the increased success rate of CubeSat missions, as many CubeSat missions fail due to the failure to deploy their deployable antennas such as turnstile antennas.

However, there are certain limitations in the functionalities of the Patch Antenna that can hinder the performance of the CubeSat such as Patch antennas facing only one direction, frequency dependency, and low bandwidth leading to low gain.

I. Introduction:

In this, I will use a 1U CubeSat (12cm x 12cm x 12cm) and will use a Patch Antenna for its communication. About 40% of CubeSat communication failures are due to improper deployment of the antenna, these communication failures often lead to whole mission failure. Using the patch antenna will remove the risk of mission failure due to deployment failure of the antenna and it is easy to integrate it into the CubeSat.

I will make the Patch antenna more powerful with greater performance by altitude management to maintain or adjust the orientation of the antenna according to needs, proper material selection with lower weight, good electric conductivity, and low thermal expansion, and modifying the patch antenna dimensions in order to control and improve electromagnetic performance.

II. Project Overview:

i. Material selection-

To be used in a CubeSat the material should be lightweight, have good conductivity, and less thermal conductivity, and should be resistant to space radiation.

- **Borophene** is a material that can help increase the antenna's radiation efficiency and bandwidth. It is about 6.5 times lighter than copper in weight for the same volume. It can be used to make the Patch antenna's ground plane. It has the potential for anisotropic higher conductivity, tuning of its structure can modulate its electrical conductivity.

- **Borophene has more electrical conductivity when doped with Carbon** than Borophene. It also increases stability, but careful control over the doping concentration is required. Borophene is lighter in weight than silver and more corrosion-resistant than Silver. It can be used to make the Patch antenna's patch.

	Borophene	**Copper**
Conductivity to electricity	Potential for anisotropic higher conductivity	Excellent conductivity (~5.96×10^7 S/m)
Density	Lighter (2.3-2.5 g/cm³)	Heavy (8.96 g/cm³)
Mechanical properties	Highly flexible	Rigid
Resistance to thermal expansion	Higy resistant to thermal expansion	Higher thermal expansion than Borophene
Resistance to corrosion	Highly resistant to corrosion (When doped with carbon, the resistivity to corrosion increases)	Less resistance to Corrosion
Resistance to Space radiation	More resistant to space radiation	High chances of degradation under space radiation

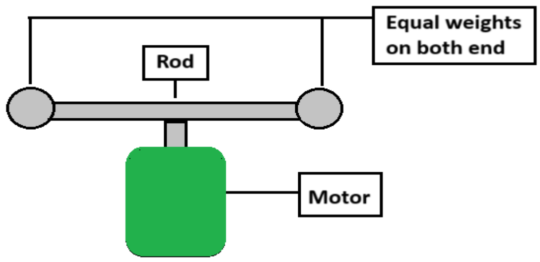
The material used to make the Substrate of the Patch antenna needs to be highly dielectric. It should have a low Dielectric Constant (εr), high mechanical strength, low weight, corrosion resistance, thermal stability, and space radiation resistance.

- **Expanded Polypropylene (EPP) Foam** can be used to make the substrate of the patch antenna of the CubeSat.
    - It has a dielectric constant of ~1.03 to 1.05
    - It has a loss tangent close to 0.002 to 0.005
    - It is lightweight

ii. Orientation management using the Attitude Control System –

The Path antenna is situated on only one side of the CubeSat, which can lead to the loss of signal. For consistent communication, the CubeSat should always be facing toward the antenna present on the Earth. Gyroscopes are present in a CubeSat which provides the orientation of the CubeSat body with respect to the X-axis, Y-axis, and Z-axis. This information can be used to keep the antenna oriented toward the antenna present on the Earth. Using three reaction wheels to move the CubeSat will increase its weight of the CubeSat and three reaction wheels will take up a lot of space in a 1U CubeSat not leaving space for other components and will not perfectly fit in a 1U CubeSat, leading to further mission problems. In spite of using three reaction wheels, we can use:-

- I will use a small rod with equal weights at both ends and will rotate it at a very high velocity using a motor. Its rotation will produce angular momentum and to conserve that angular momentum the CubeSat body will rotate in the opposite direction. We will use 3 sets of this to move it about the three axes.



Advantages of using this system: -

- This decreases the overall weight of the CubeSat body.
- Save space in the interior of the CubeSat for other payloads.
- Cost effective

iii. Effect of ionosphere and how to reduce it -

The ionosphere is the layer of the Earth's atmosphere that has a very high concentration of free electrons and ions, these affect the ability of transmissions and receiving of the patch antenna of the CubeSat.

Some of these problems: -

- Scintillation
- Faraday Rotation of Polarization
- Plasma noise
- Refraction and loss of signals

Ionospheric monitors should be used to collect data and the data shall be used to control the CubeSat position and altitude and also control the working of the patch antenna so that the efficiency of the antenna is not disturbed by the ionosphere.

Using higher frequency bands (S-band, X-bands) will decrease Scintillation problems. Using circular polarization or dual polarization in patch antennas will reduce the faraday rotation problems. Using Bandpass filters will filter out Plasma noises.

iv. Reducing the electromagnetic interference –

Electromagnetic interference (EMI) is a factor that affects the CubeSat's patch antenna by causing noise and distortion. It can disturb the operating frequency range and even mask the signal the CubeSat antenna is trying to receive.

The sources of electromagnetic interference are the on-board electronics, space weather, and launch vehicle electronics

- **Using Faraday cages** of materials with higher electrical conductivity, proper thickness, and very lightweight will help to reduce electromagnetic interference. A metallic netted box with proper dimensions in terms of the CubeSat used should be installed inside the CubeSat body. It will function as a Faraday cage and the sensors, and on-board electronics of the CubeSat will be placed inside the metallic netted box. This will reduce the electromagnetic interference from the onboard electronics and the electromagnetic interference from the outer environment.

- **Using Noise Cancellation Techniques,** to reduce the effect of plasma noises and small electromagnetic interference of the solar flares, we will first measure the frequency, amplitude, and waveform of the electromagnetic wave or the plasma noise using sensors and then create and produce the counter wave of its opposite nature to cancel out that wave.

III. Conclusion:

In this Research paper, I have shared methods, procedures, materials, and ideas on how to make the patch antenna of CubeSats more efficient and reliable to work with by choosing better materials to make the patch antenna and by solving problems such as orientation management, bad effects of the ionosphere electromagnetic interferences that disturb the Patch Antenna of the CubeSat resulting in lower gain, by keeping in mind about the weight constraints and size constraints of the CubeSat and the other systems working in it.

Material named Borophene should be used to make the patch and the ground plane of the patch antenna of the CubeSat, as it has very high electrical conductivity, is lightweight, resistant to corrosion and space radiation has very low thermal expansion, and is flexible. Expanded Polypropylene (EPP) Foam should be used to make the substrate because it has a low dielectric constant, it has a loss tangent close to 0.002 to 0.005 and it is very light weighted.

Despite using three reaction wheels in the CubeSat due to the CubeSat's weight and size constraints, we will use the above-mentioned system to control the CubeSat's orientation.

To reduce the bad effects of the ionosphere on the CubeSat's patch antenna the communication will work on high-frequency bands (S-band, X-band), and usage of dual polarization or circular polarization of the antenna will be done to omit the problem of Faraday rotation and bandpass filters to reduce the plasma noises.

Faraday cages made of lightweight materials and highly conductive metal can be used to reduce electromagnetic interference, Noise cancellation techniques can be used to cancel out electromagnetic waves by measuring the wave and creating a counter wave of the opposite nature to cancel out the wave. This can even be used to reduce plasma noises.

IV. Future Scope:

For Future work, we can modify the Borophene by doping it with other elements or we can use other better-modified artificial or man-made materials that have higher electrical conductivity, are resistant to space radiation and corrosion, and have negligible thermal expansion, lower weight and high flexibility these properties will help to enhance the antenna gain.

We can do more research on Borophene and the procedures of creating it to reduce its cost and difficulties.

We can install AI for real-time tuning of antenna parameters and automated direction and altitude control of the CubeSat.

Miniaturization of Systems can be done, Lower weighted and better materials for Faraday caging can be used, or more different and appropriate methods of reducing electromagnetic interference.

We can study making the systems more cost-effective.

V. REFERENCE :

1) Patch antenna, https://en.wikipedia.org/wiki/Patch_antenna
2) Expanded Polypropylene (EPP), https://www.bpf.co.uk/plastipedia/polymers/Expanded_Polypropylene_EPP.aspx
3) Borophene: A 2D wonder shaping the future of nanotechnology and materials science: RaghvendraKumar Mishra , Jayati Sarkar , Kartikey Verma , Iva Chianella , Saurav Goel , Hamed Yazdani Nezhad, https://www.sciencedirect.com/science/article/pii/S2589965124000412
4) Reaction wheels, https://en.wikipedia.org/wiki/Reaction_wheel
5) Ionosphere, influence on satellite and radio communication, https://www.aeronomie.be/en/encyclopedia/ionosphere-influence-satellite-communication-gps
6) Electromagnetic interference (EMI), Gavin Wright https://www.techtarget.com/searchmobilecomputing/definition/electromagnetic-interference#:~:text=See%20wireless%20network%20configuration%20basics,last%20updated%20in%20March%202022
7) How does Noise Cancelling Work? , Brooke Becher https://builtin.com/hardware/how-does-noise-cancelling-work