Microstrip Patch Antenna Design for X Band Applications & Military Satellite Communication

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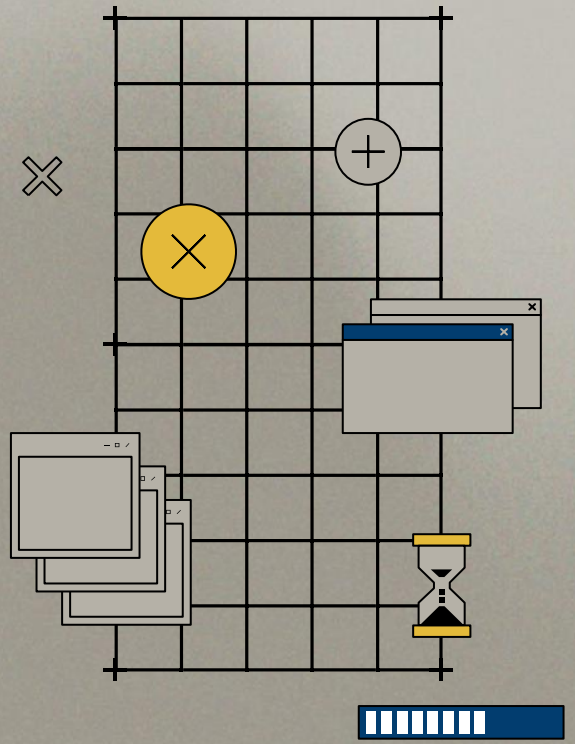


INTRODUCTION

- Advanced virtual technology gadget needs compact, well matched and low priced antennas. Microstrip patch antennas (MPAs) are popular due to their compact size, affordability, and low profile.

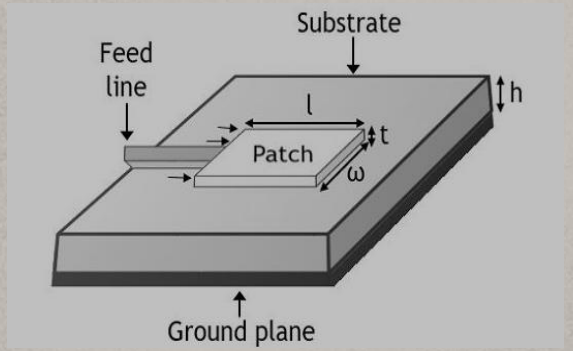
- Microstrip antennas are compatible with MMIC designs with easy production and low cost using modern printing technology and due to the need for low profile antennas in application satellites, aircraft, missiles, microstrip antennas with small dimensions are actively used in these areas.

- However, microstrip antennas have narrow bandwidth and low gain compared to other antennas thus a substrate with high thickness and low dielectric constants is often used to achieve good design performance.

Calculation for Design Parameters

Design Specifications :-

1. Frequency of Operation
2. Substrate material
3. Relative Permittivity of the Substrate (ε_r)
4. Height of the Substrate



Width of Patch: $$w = \frac{C}{2f_0\sqrt{\frac{\varepsilon_r + 1}{2}}}$$

Effective Dielectric constant of Substrate:

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\left(\frac{h}{w}\right)\right]^{-1/2}$$

Effective Length: $$l_{eff} = \frac{C}{2f_0\sqrt{\varepsilon_{eff}}}$$

Extension of Length: $$\Delta l = 0.412h\frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.265\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

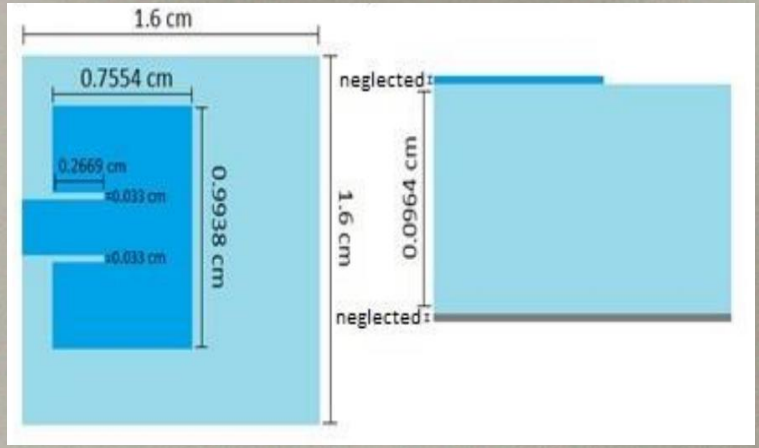
Actual Length of Patch: $$l = l_{eff} - 2\Delta l$$

Length of Substrate: $$L_S = 6h + l$$

Width of Substrate: $$W_s = 6h + w$$

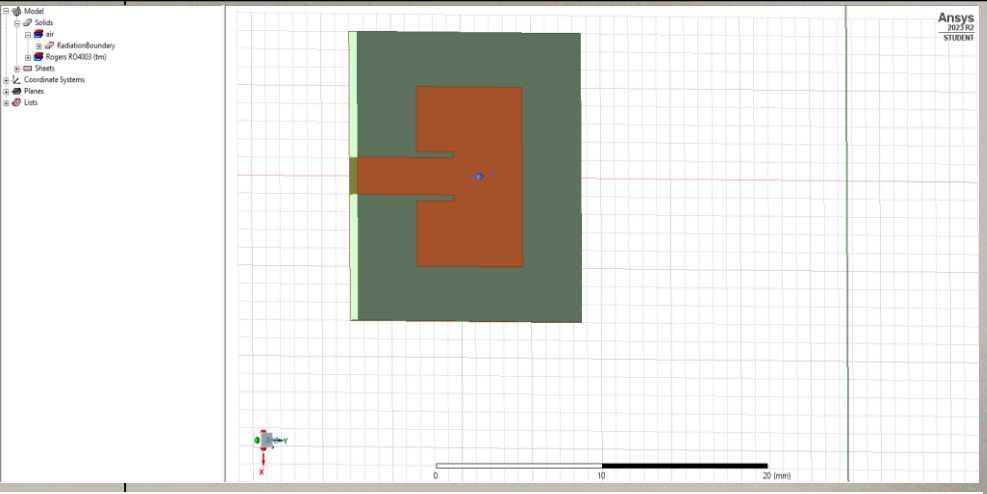
MPA design for X Band Application

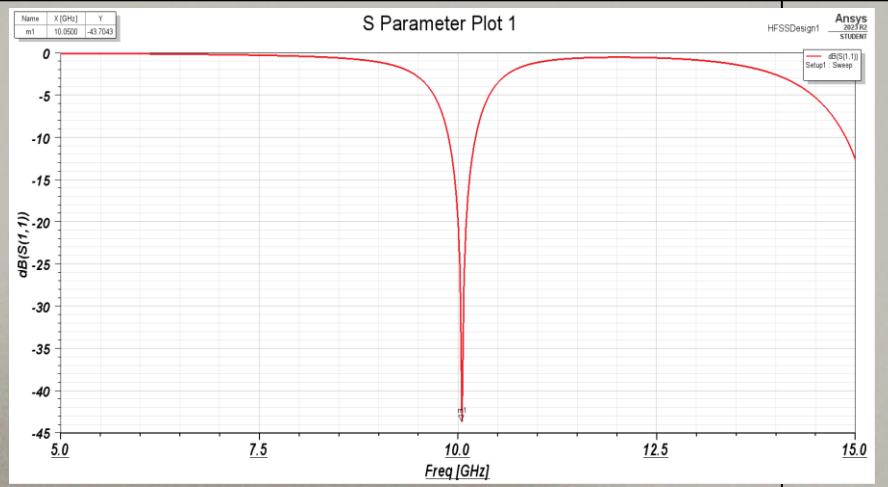
Design Parameters	Values
Operating Frequency	10 GHz
Substrate Material	RO4003
Length of Substrate	1.6 cm
Width of Substrate	1.6 cm
Height of Substrate	0.0964 cm
Relative Permittivity of Substrate	3.4
Patch Length	0.7554 cm
Patch Width	0.9938 cm
Embedded feed Length	0.2669 cm
Embedded feed Width	0.03313 cm

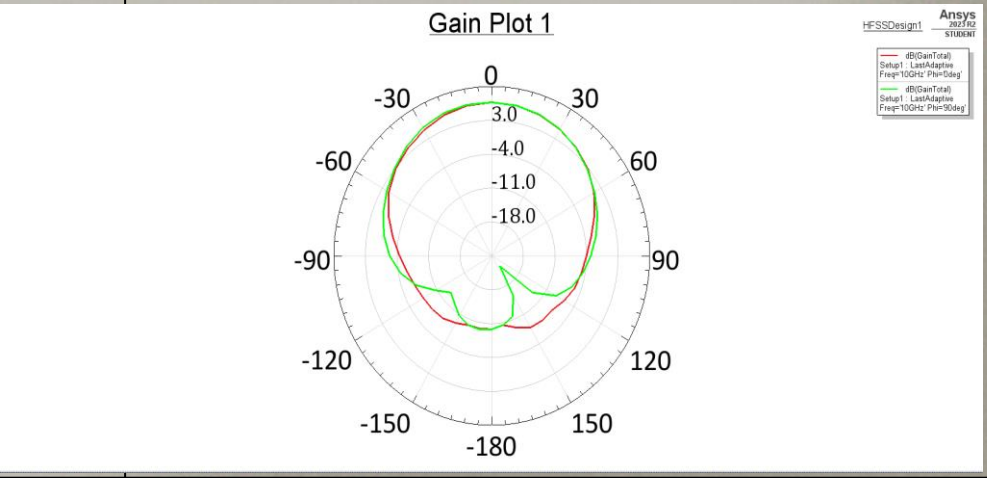


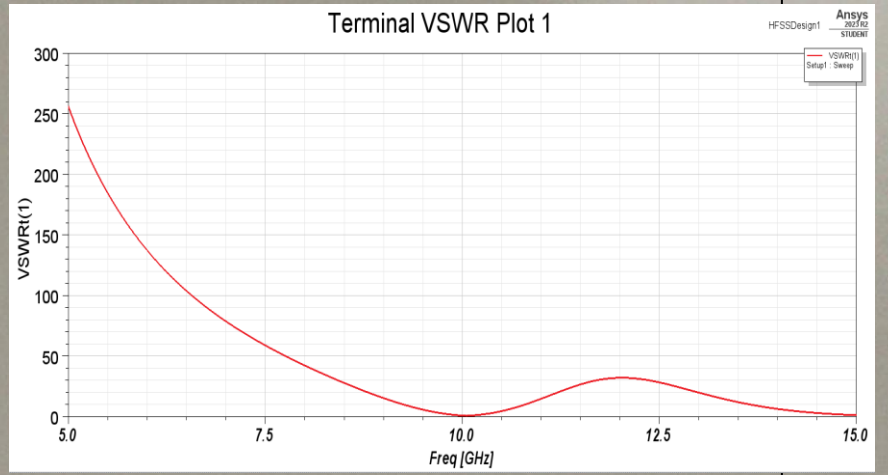
Bandwidth at -10dB = 0.35 GHz
Bandwidth % = 3.5 %

Results of MPA of frequency 10 GHz :



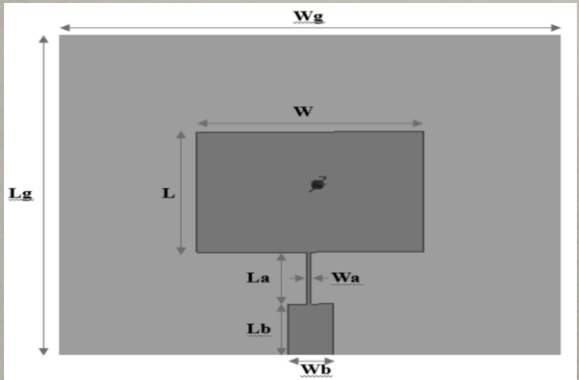






MPA design for Military Satellite Communication

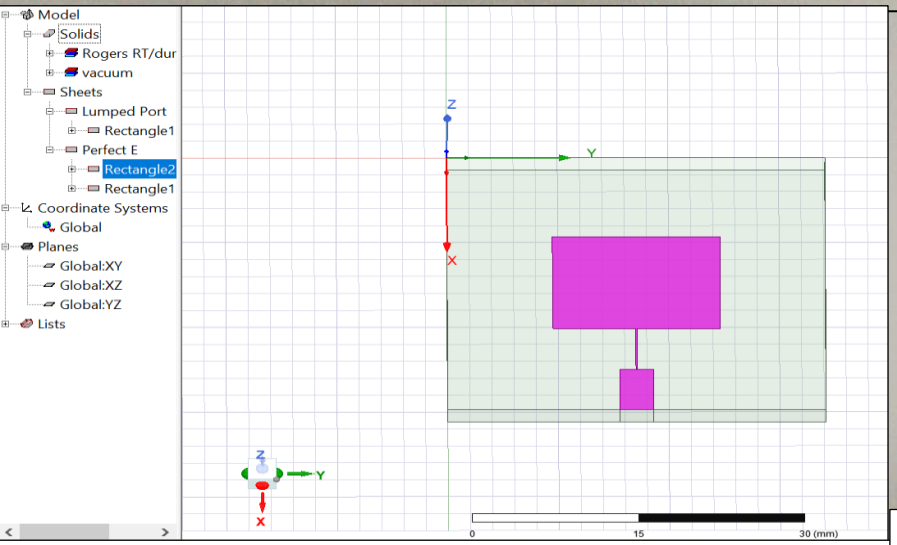
First Antenna

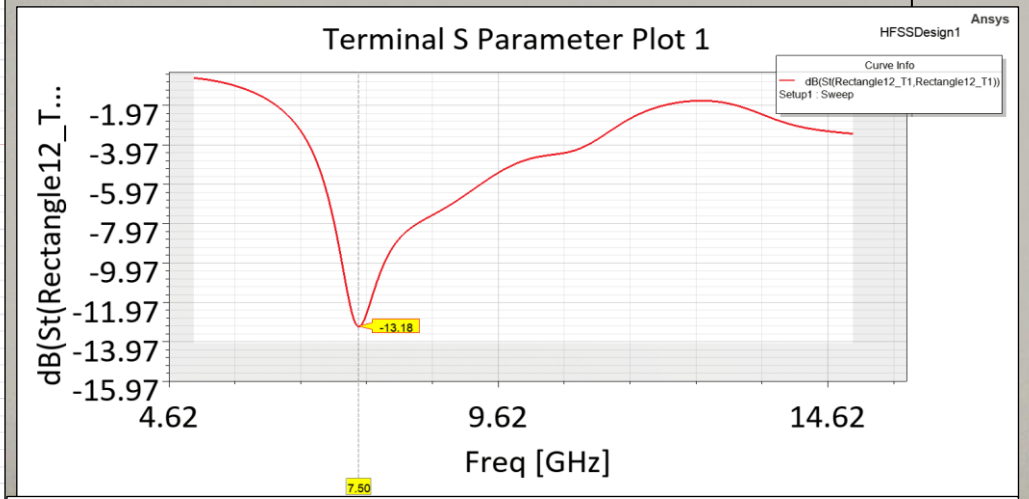


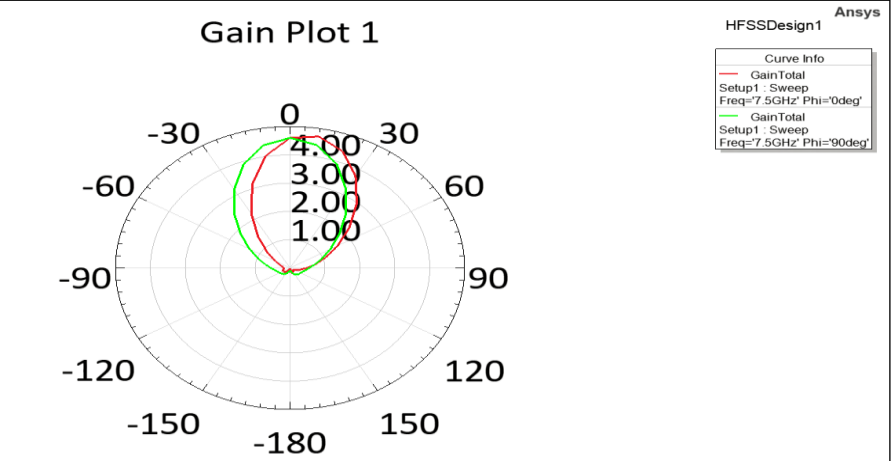
This Antenna operates in the frequency ranges of 7.06 - 8.41 GHz. The 7.8 GHz center frequency has -34.5 dB return loss.

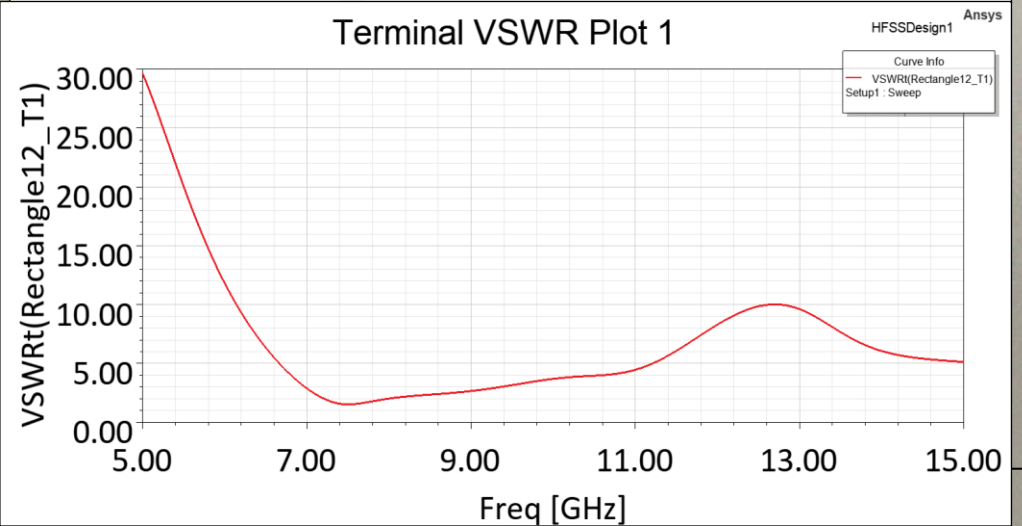
Design Parameters	Values
Wg	34.19 mm
Lg	29.72 mm
W	15.14 mm
L	10.87 mm
Wa	0.125 mm
La	4.7925 mm
Wb	3 mm
Lb	4.7325 mm
Substrate Material	Rogers RT / duroid 5880
Height of Substrate	3.175 mm
Relative Permittivity of Substrate	2.2

Results of First Antenna:

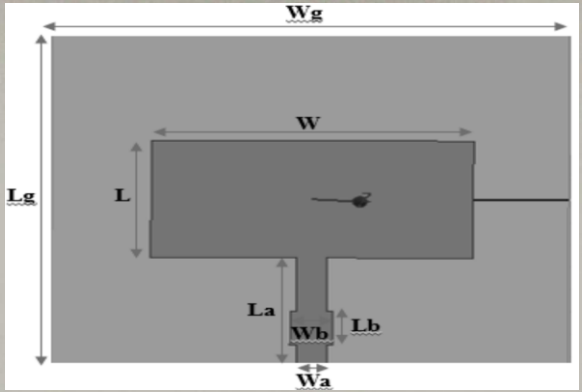








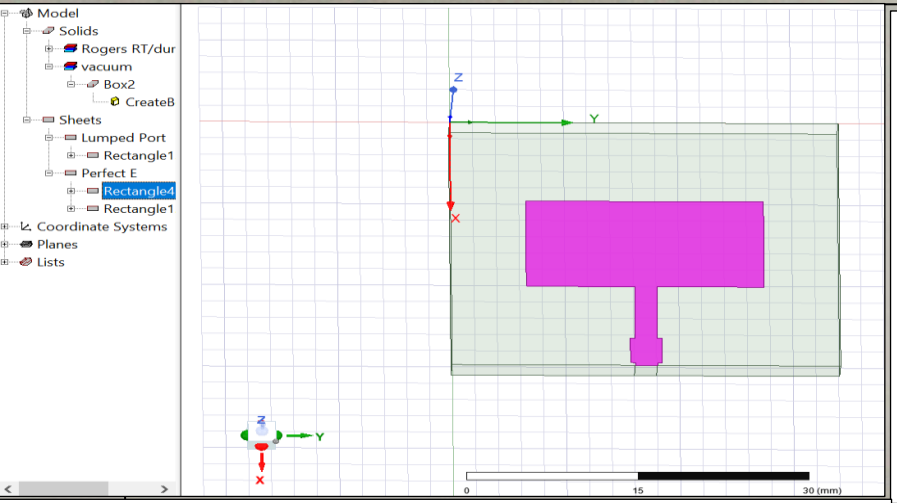
Second Antenna

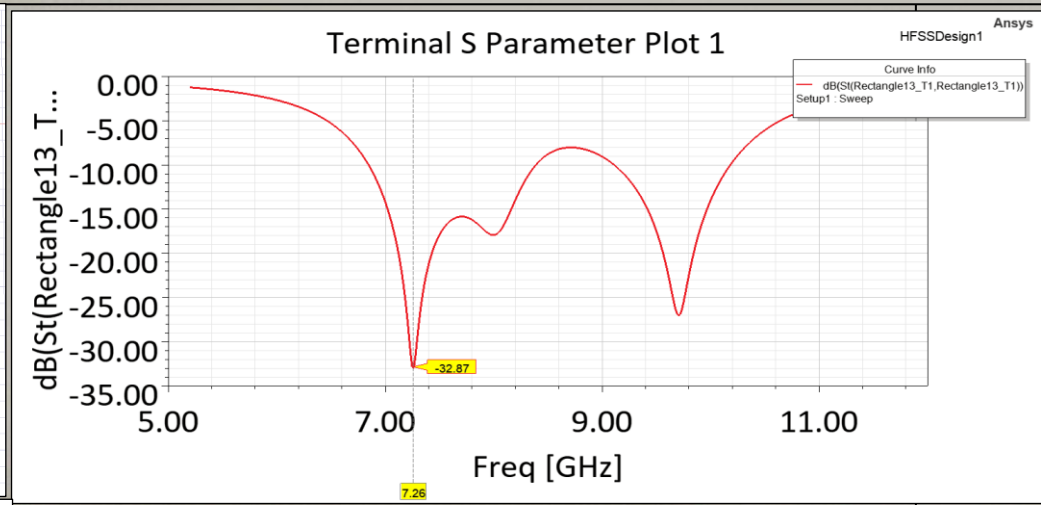


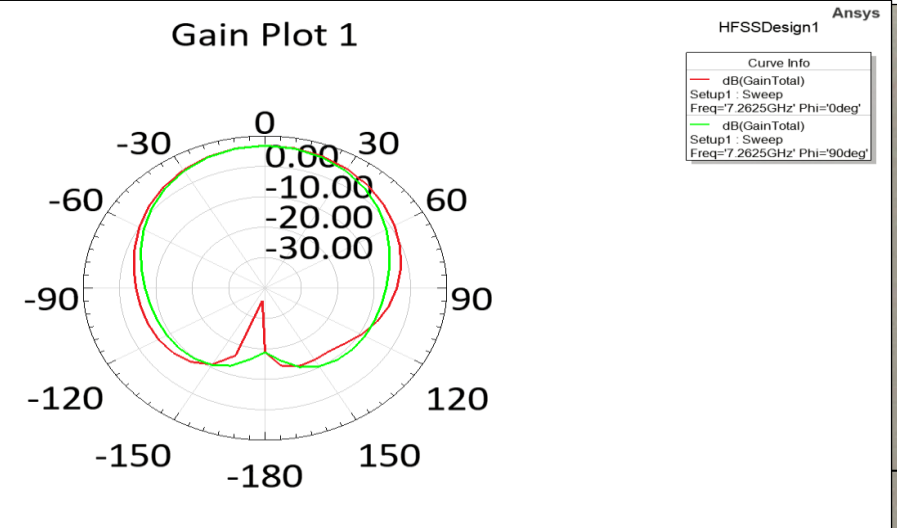
This Antenna operates in the frequency ranges of 6.73 - 9.69 GHz. The 7.8 center frequency has -25.4 dB return loss.

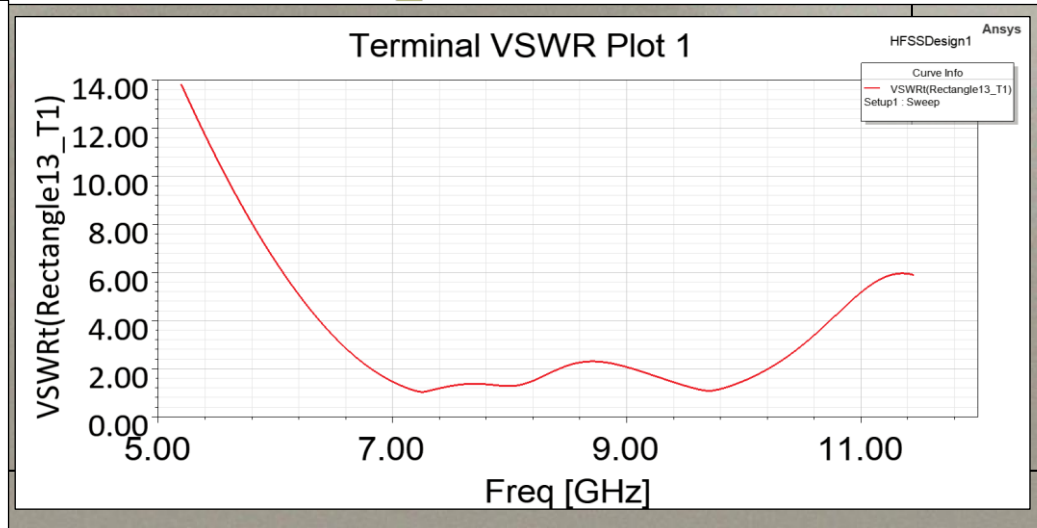
Design Parameters	Values
Wg	34.19 mm
Lg	29.72 mm
W	21 mm
L	10.45 mm
Wa	1.946 mm
La	9.635 mm
Wb	2.8 mm
Lb	3 mm
Substrate Material	Rogers RT / duroid 5880
Height of Substrate	3.175 mm
Relative Permittivity of Substrate	2.2

Results of Second Antenna:









Final Outcomes

- The 1st Antenna designed as a result of the studies, covers all the up and down frequency ranges allocated for military satellite communication and has a bandwidth of 1.35 GHz = 17.25%.

- The 2nd Antenna, designed as a result of the changes made on the 1st Antenna, operates in the frequency ranges of 6.74 - 9.69 and has a bandwidth of 1.6 GHz more than the 1st Antenna.

IMPROVEMENTS IN MPA

- **Bandwidth Improvement:** Stacked Patches, Slots and Modifications, Different Feeding Techniques
- **Radiation Efficiency:** Optimize Substrate, Refine Dimensions, Improved Feeding Mechanism.
- **Directivity and Gain:** Adding a Reflector, Higher Gain Feed
- **Miniaturization:** Advanced Materials, Advanced Manufacturing Techniques
- **Environmental Stability:** Material Selection, Protective Coatings
- Since the antenna sizes calculated by numerical methods are difficult to adjust to operate in appropriate frequency ranges, the dimensions of the antenna can be designed using the genetic algorithm, which is a part of artificial intelligence optimisation algorithms.

CONCLUSION

- First we designed a MPA at 10 GHz frequency for X Band applications and obtained schematic drawings.
- In the simulation section, S11 characteristic graphics, E and H plane radiation patterns and antenna gain graphics were drawn. Simulation results show that the antenna works as desired and meets the X Band design criteria.
- Thereafter we designed a microstrip patch antenna operating in the range of downlink frequency 7.25-7.75 GHz and uplink frequency 7.9-8.4 GHz allocated for military satellite communication.
- Then we designed a 2nd Antenna as a result of the changes made on the 1st Antenna, operates in the frequency ranges of 6.74 - 9.69 and has a bandwidth of 1.6 GHz more than the 1st Antenna.

THANK YOU