DESIGN AND ANALYSIS OF SINGLE AND 2X2 MICROSTRIP PATCH ARRAY ANTENNA FOR SPACE APPLICATIONS

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Abstract:

Microstrip patch antenna arrays play important role in aircraft, spacecraft and missile applications because of their lighter weight, low volume, low cost, low profile, smaller in dimensions besides easy installation and aerodynamic profile are constrains. This project presents a single and 2×2 array antenna of rectangular topology is designed to operate at S Band. The operating frequency of array is from 2 to 4 GHz. The antenna array has been designed and simulated using HFSS. The array antenna design at operating frequency 2.4GHz, FR4 Substrate with dielectric constant of 4.4 and thickness of substrate 1.6mm. The antenna performance using normal patch and with slits on patch are also compared in terms of Bandwidth and Directivity are measured to finalize the antenna design.

The resonant frequency is chosen at 2.4GHz which is suitable for Space Applications. HFSS is used to the software environment to design and compare the performance of the antenna. Based on the result analysis, it is noted that holes on rectangular microstrip patch array antenna offers higher bandwidth, higher radiation efficiency and directivity as compared with the rectangular Microstrip patch array antenna and also noted that holes on single patch antenna offers higher bandwidth, higher radiation efficiency and directivity as compared with the single patch antenna.

Keywords: Single and 2x2 microstrip patch Array antenna, FR4_Epoxy substrate material, HFSS tool.

I. Introduction to Rectangular Microstrip Patch Antenna:

A microstrip antenna consists of conducting patch on a ground plane separated by dielectric substrate. This concept was undeveloped until the revolution in electronic circuit miniaturization and large-scale integration in 1970. Various mathematical models were developed for this antenna and its applications were extended to many other fields. The number of papers, articles published in the journals for the last ten years, on these antennas shows the importance gained by them. The micro strip antennas are the present-day antenna designer's choice. Low dielectric constant substrates are generally preferred for maximum radiation. The conducting patch can take any shape but rectangular and circular configurations are the most commonly used configuration.

Other configurations are complex to analyse and require heavy numerical computations. A microstrip antenna is characterized by its Length, Width, Input impedance, and Gain and radiation patterns. Various parameters of the microstrip antenna and its design considerations were discussed in the subsequent chapters. The length of the antenna is nearly half wavelength in the dielectric; it is a very critical parameter, which governs the resonant frequency of the antenna. There are no hard and fast rules to find the width of the patch.

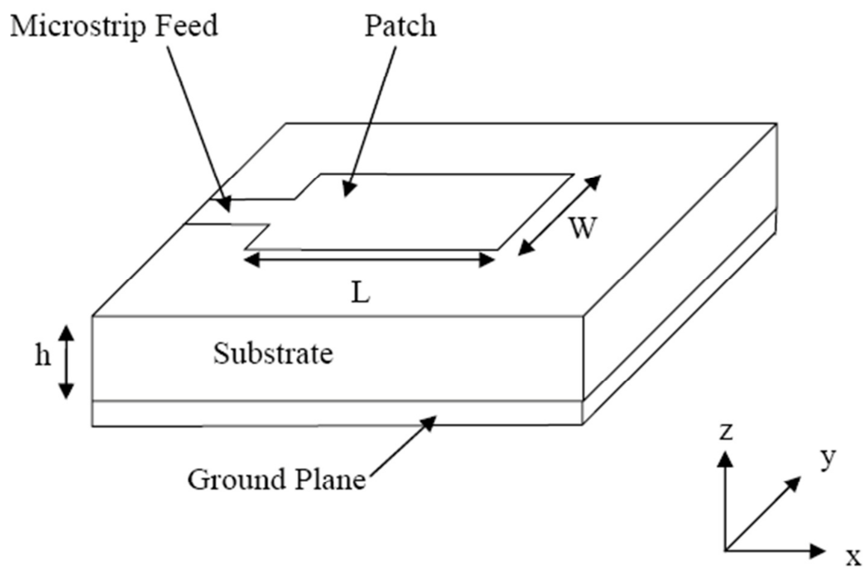


Fig. Single Microstrip Patch Antenna

Microstrip antenna array design: The performance of microstrip antenna increases based on the count of patch elements placed on the substrate.

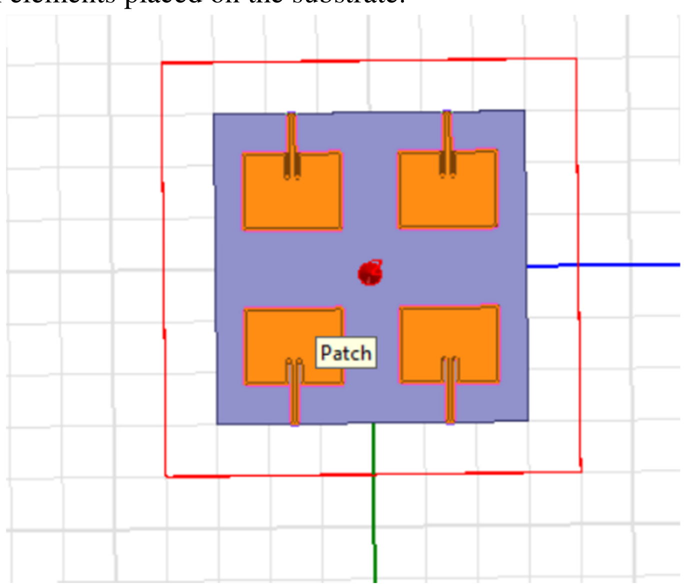


Fig. 2x2 Microstrip Patch Array Antenna

II. Designing of Rectangular Microstrip antenna:

To design a Rectangular microstrip patch antenna the Essential parameters are

1. The operating frequency (f0).
2. Dielectric Constant of substrate (Ɛr)

3. The height of the dielectric substrate (h).
Rectangular microstrip antenna designed based on the following equations

Step 1: Calculation of the width(W): $W = \frac{c}{2fr\sqrt{\frac{\epsilon r+1}{2}}}$

Step 2: calculation of effective dielectric constant ($Eeff$):

$$Eeff = \frac{(\epsilon r+1)}{2} + \frac{(\epsilon r-1)}{2} \sqrt{\frac{1}{\left(1+\frac{12h}{W}\right)}}$$

Step 3: calculation of extension length(ΔL):

$$\Delta L = 0.412h \frac{(Eeff+0.3)(\frac{W}{h}+0.264)}{(Eeff-0.258)(\frac{W}{h}+0.813)}$$

step 4: calculation of effective length (Leff):

$$Leff = \frac{c}{2fr\sqrt{Eeff}}$$

step 5: calculation of original length(L):

$$L = Leff - 2\Delta L$$

Step 6: calculation of length of the ground plane (Lg):

$$Lg = 6h + L$$

Step 7: calculation of width of the ground plane (Wg):

$$Wg = 6h + W$$

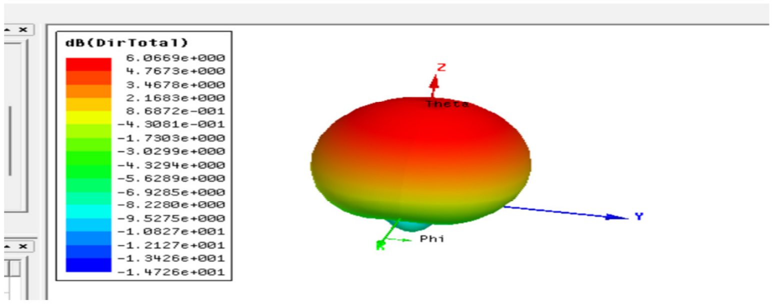
Step 8: Return Loss = -S11 = -10log*(|S11|)

Design Parameters:

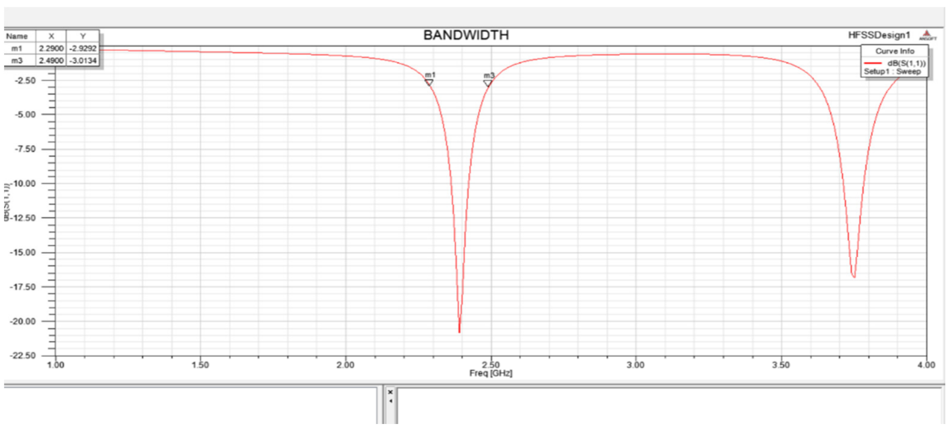
Parameter	Value
Width(W)	38.04 mm
Effective Dielectric Constant (E eff)	4.08 mm
Extension Length(ΔL)	0.73 mm
Effective Length (L eff)	30.92 mm
Original Length(L)	29.44 mm
Length of Ground Plane (L g)	39.04 mm

Width of Ground Plane (W g)	47.63 mm

i) Directivity:



ii) Bandwidth:



SIMULATION RESULTS

PARAMETER	**SINGLE PATCH ANTENNA**	**2x2 MICROSRIP PATCH ARRAY ANTENNA**	**HOLE ON SINGLE PATCH**	**HOLE ON 2X2 MICROSTRIP PATCH ARRAY ANTENNA**
DIRECTIVITY (dB)	6.06	6.05	6.29	6.27
BANDWIDTH	200MHz	203MHz	210MHz	237MHz

Table: Comparison of single Microstrip Patch and 2x2 Microstrip Patch Array Antenna with and without holes

Simulation Results of Single patch Antenna

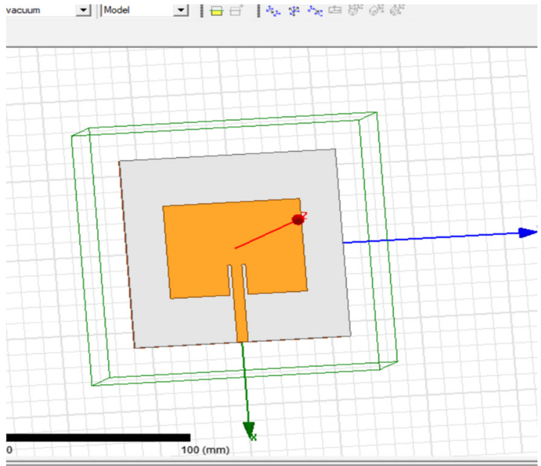


Fig. Designed Rectangular patch using HFSS

i). Directivity:

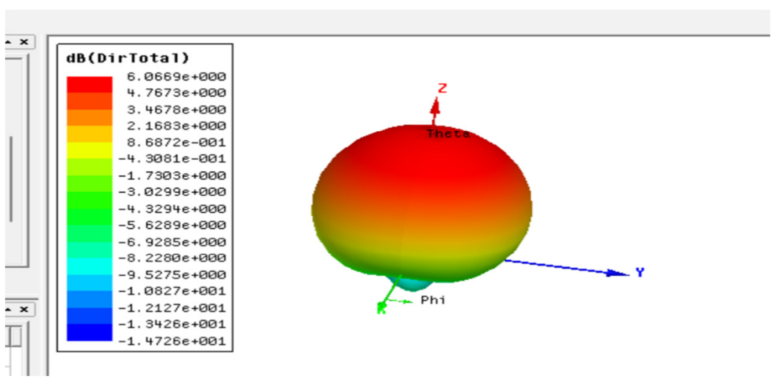


Fig. Directivity for Single patch Antenna

ii). Bandwidth:

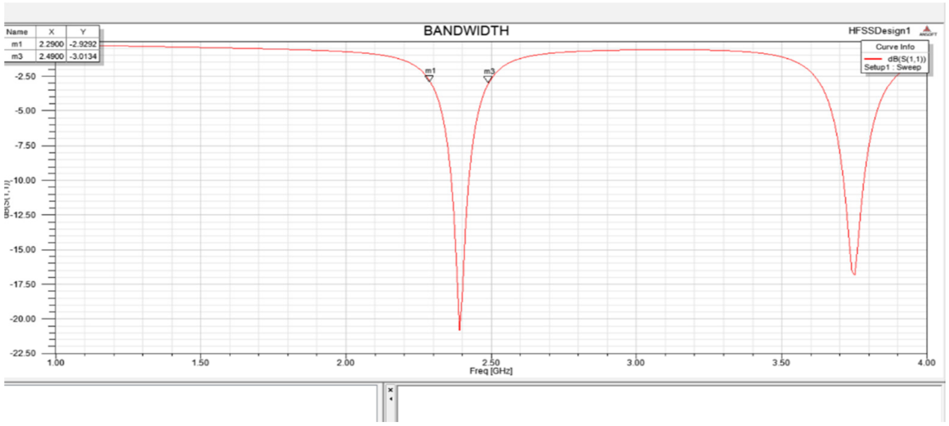


Fig. Bandwidth for Single patch Antenna

Simulation Results of Microstrip feed Rectangular 2x2 Patch Array

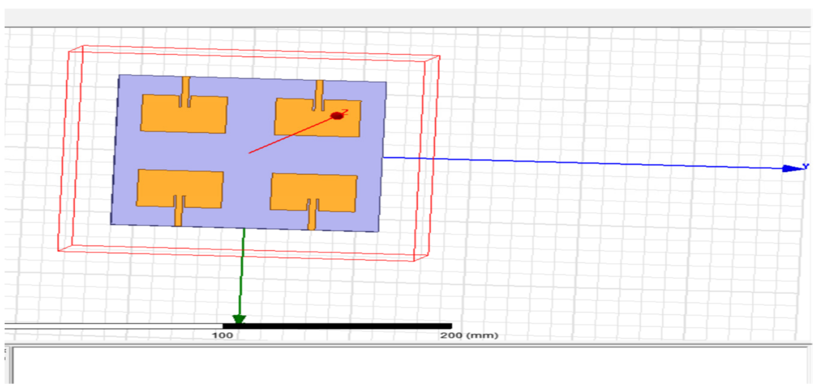


Fig. Designed Microstrip feed Rectangular 2x2 Patch Array

i). Directivity:

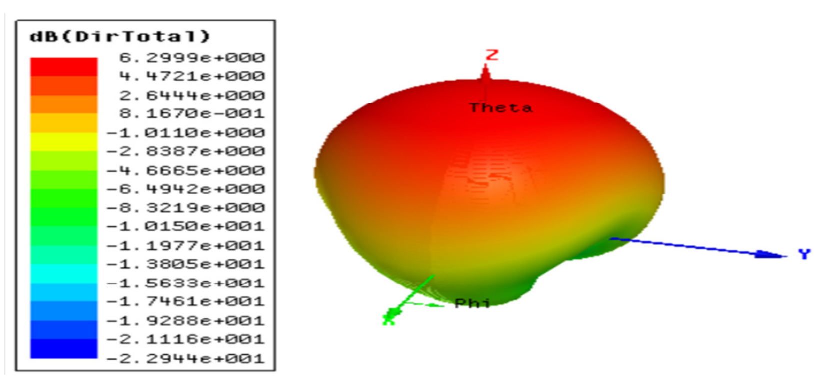


Fig. 5.5 Directivity for 2x2 MSPA Array

ii). Bandwidth:

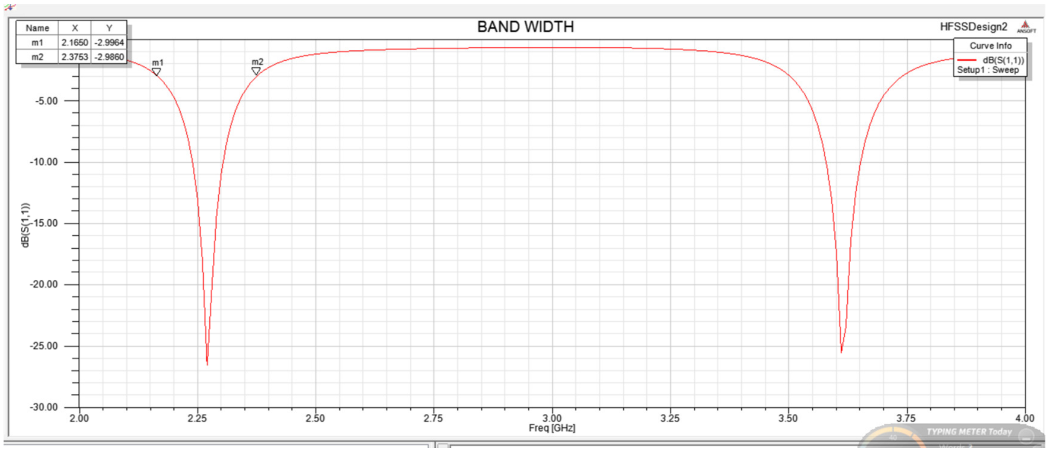


Fig. 5.6 Bandwidth for 2x2 MSPA Array

Simulation Results of cutting hole in Single patch Antenna

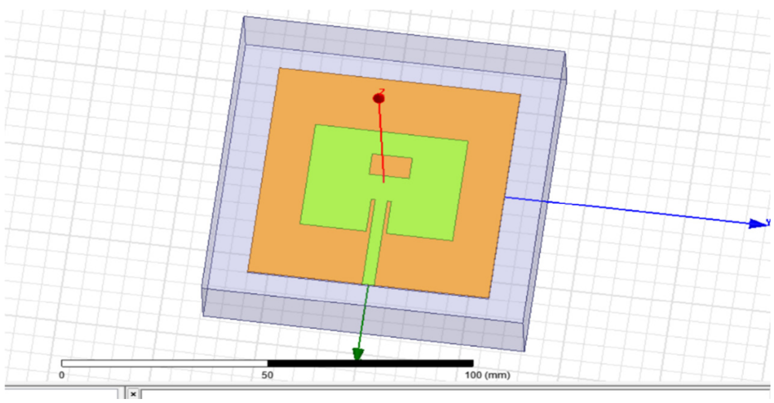


Fig. Designed cutting hole in Single patch Antenna

i). Directivity:

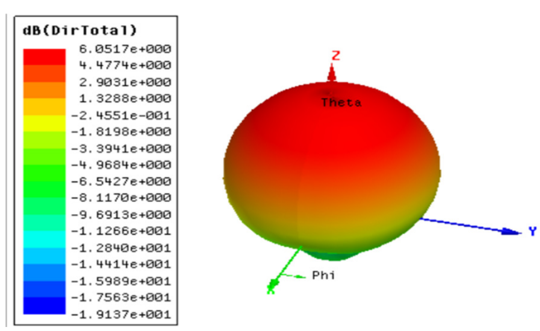


Fig. 5.8 Directivity Losses for Rectangular cut MSPA

ii). Bandwidth:

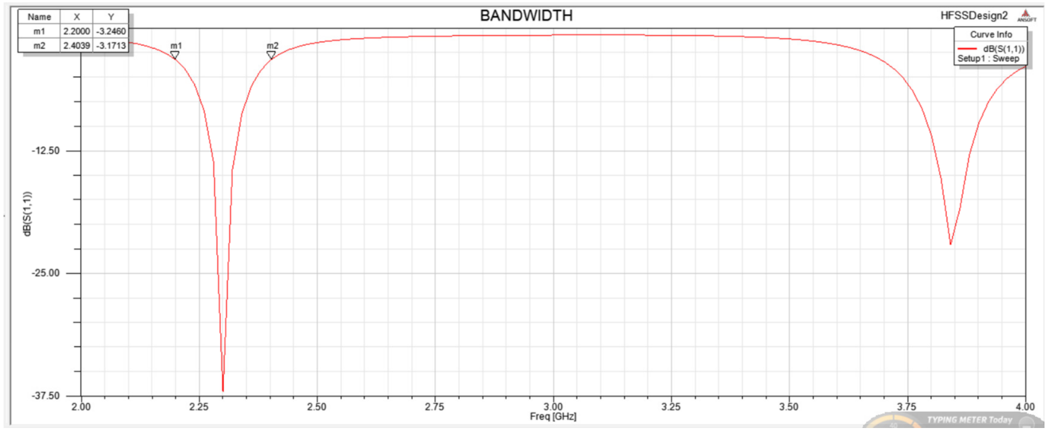


Fig. Bandwidth for Rectangular cut MSPA

Simulation Results of cutting hole in 2x2 MSPA Array

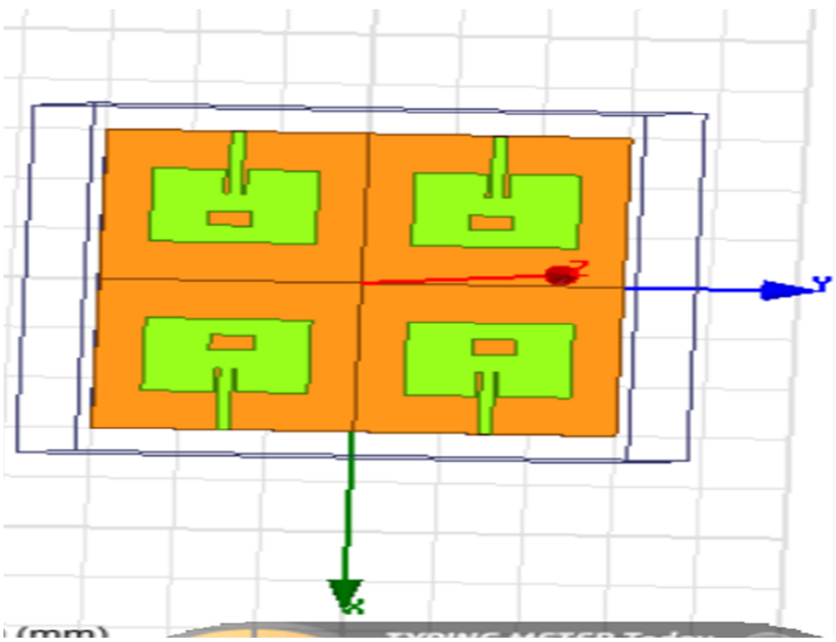


Fig. Designed cutting holes in 2x2 MSPA Array

i). Directivity:

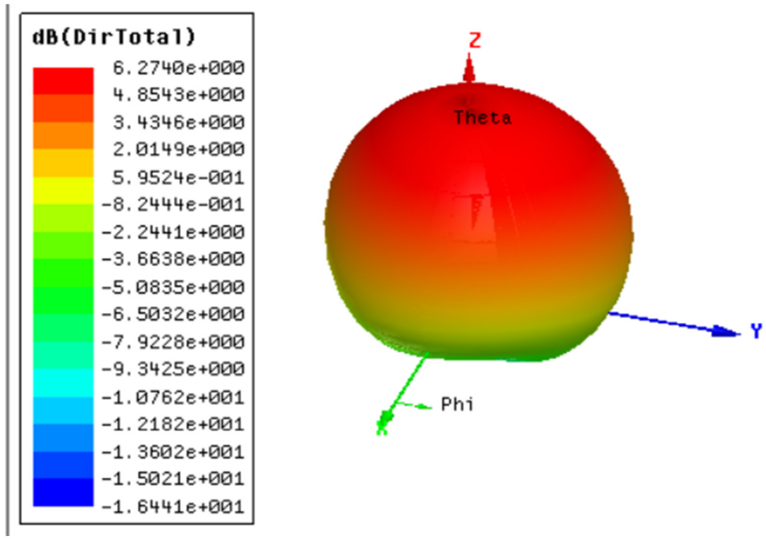


Fig. Directivity Losses for Rectangular cut 2x2 MSPA Array

ii). Bandwidth:

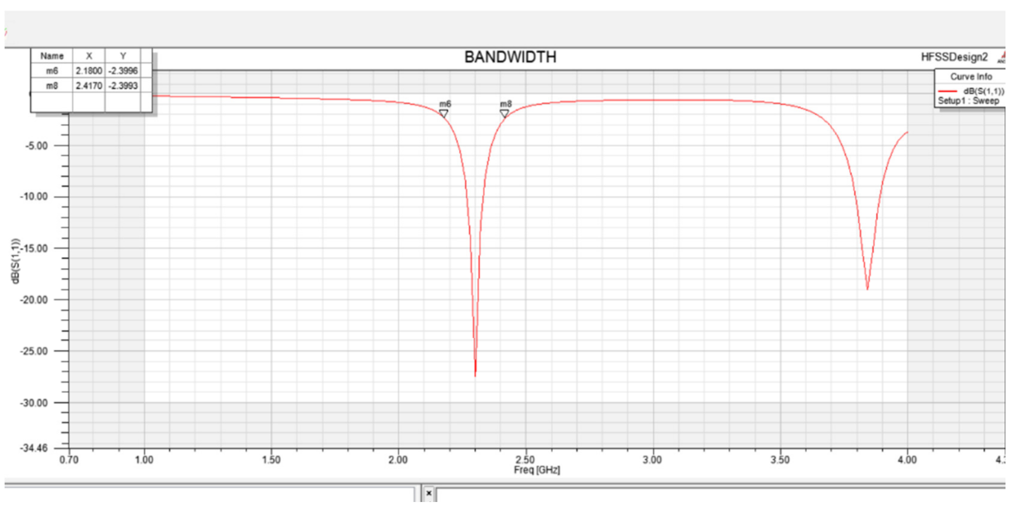


Fig. Bandwidth for Rectangular cut 2x2 MSPA Array

CONCLUSION

In this paper, comparison between a single patch rectangular antenna and 2x2 array antenna and also cutting holes on single patch antenna and also cutting holes on 2x2 patch array antenna using the simulation results obtained from HFSS has been carried out. These four antenna configurations show quite good results on perspectives of bandwidth, directivity for Space Applications. In designing single patch and 2×2 array antennas for Space Applications, the presence of holes on the patch significantly impacts performance. Antennas without holes tend to exhibit lower bandwidth and higher directivity compared to those with holes. However, antennas with holes might offer advantages in terms of size reduction or specific radiation pattern requirements. Ultimately, the choice between the two designs depends on the trade-offs between bandwidth, directivity and other application-specific factors such as size constraints and desired radiation characteristics.

Finally concluded observation of my project is noted that holes on rectangular microstrip patch array antenna offers higher bandwidth, higher radiation efficiency and directivity as compared with the rectangular Microstrip patch array antenna and also noted that holes on single patch antenna offers higher bandwidth, higher radiation efficiency and directivity as compared with the single patch antenna.

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