DESIGN AND ANALYSIS OF MICROSTRIP PATCH ARRAY ANTENNA FOR KU BAND APPLICATIONS

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Abstract:

Micro strip 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. In this study, we designed single and 2x2 array antennas operating at the resonant frequency of 15 MHz within the KU band. Through extensive analysis, we obtained key performance metrics including gain, VSWR, S11, and directivity for both antenna configurations. Our results showcase the efficacy of these antennas in high-frequency applications, particularly within the KU band spectrum. The single antenna design demonstrates commendable performance in terms of gain and directivity, with acceptable VSWR and S11 values. Meanwhile, the 2x2 array configuration exhibits enhanced gain and directivity, albeit with potential trade-offs in VSWR and S11 characteristics. These findings provide valuable insights for optimizing antenna designs to meet specific requirements within the KU band frequency range. Further investigations may focus on refining the array configuration to balance performance metrics and address specific application demands effectively.

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.

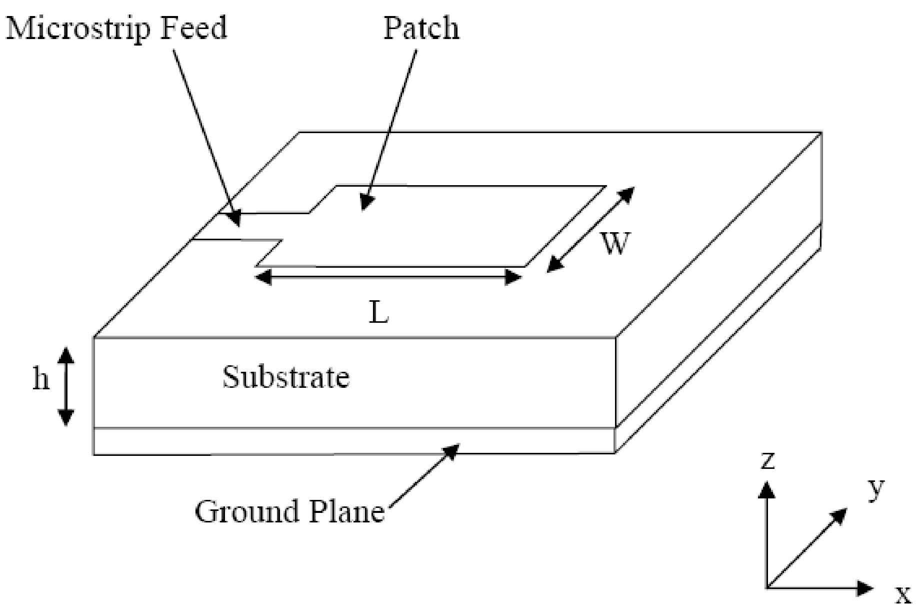


Fig. Single Microstrip Patch Antenna

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

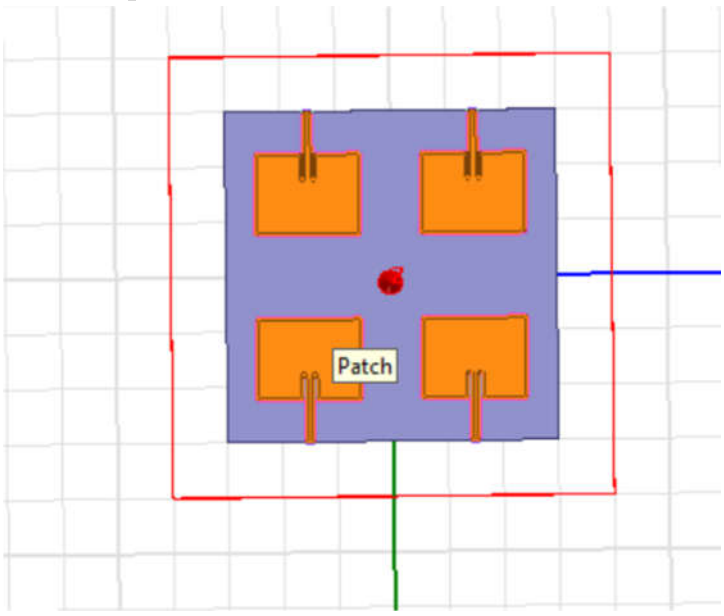


Fig. 2x2 Microstrip Patch Array Antenna

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):

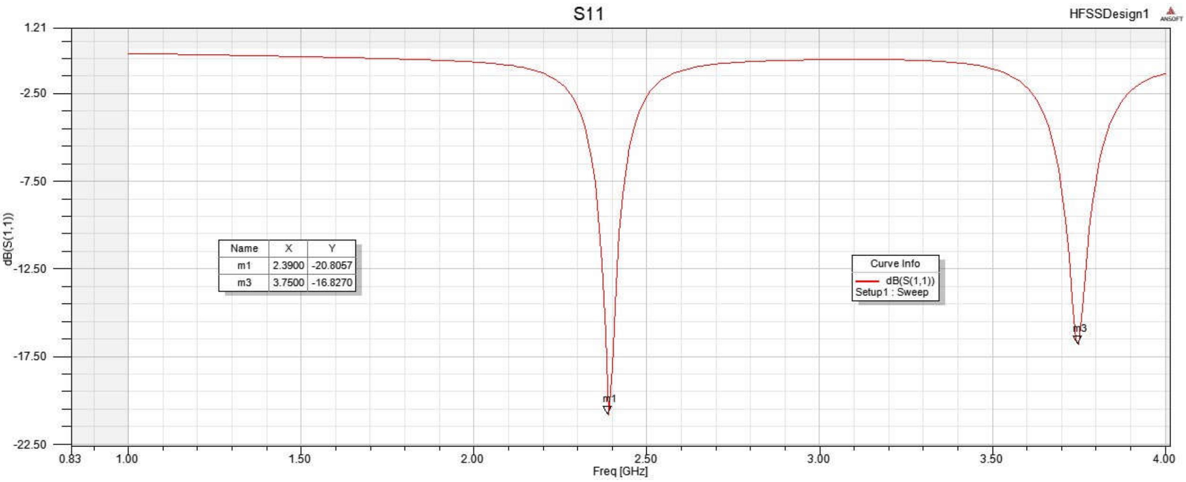
$$Wg = 6h + W$$

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

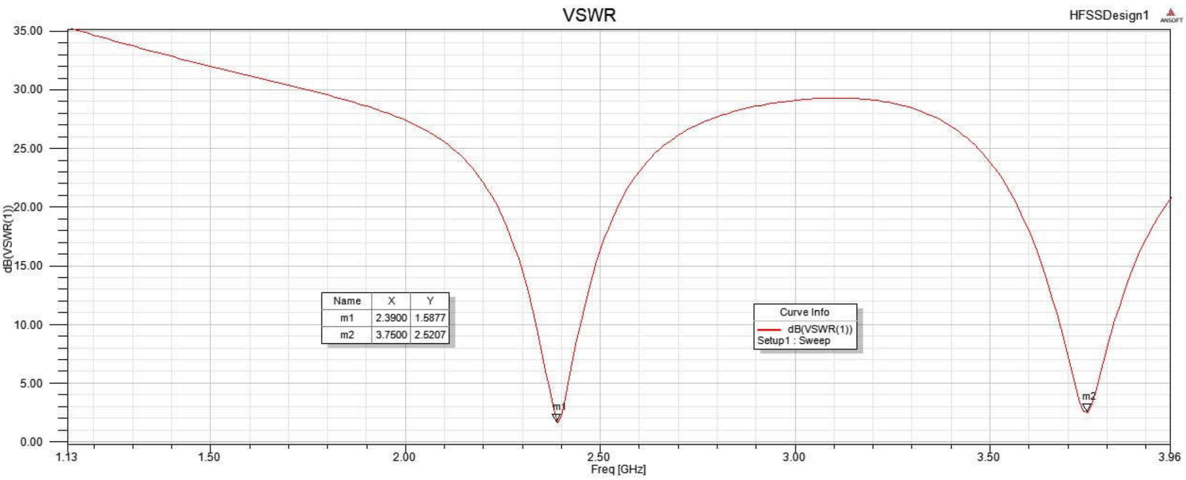
Design Parameters:

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

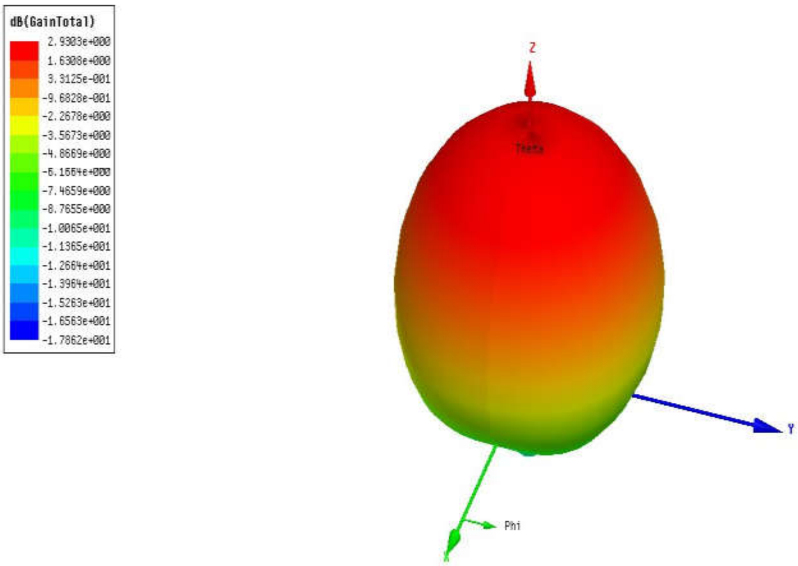
i). Return Losses: It is a parameter used to measure the power reflected by the antenna due to the mismatch of the transmission line and antenna. Lower value of the return loss provides the high efficiency of antenna.2x



ii). VSWR: VSWR stands for voltage standing wave ratio. It is defined as the ratio between the maximum value of standing wave voltage to its minimum value. The antenna with less VSWR has the better return loss compared to the other antenna.



iii). GAIN:



iv). DIRECTIVITY:

SIMULATION RESULTS

PARAMETER	SINGLE ANTENNA	2x2 MICROSRIP ARRAY
RETURN LOSS (S11)	-16.77	-24.74
VSWR (dB)	2.53	1.00
DIRECTIVITY	3.87	5.72
GAIN	3.10	4.77

Table: Comparison of single Microstrip Patch and 2x2 Microstrip Patch Array Antenna

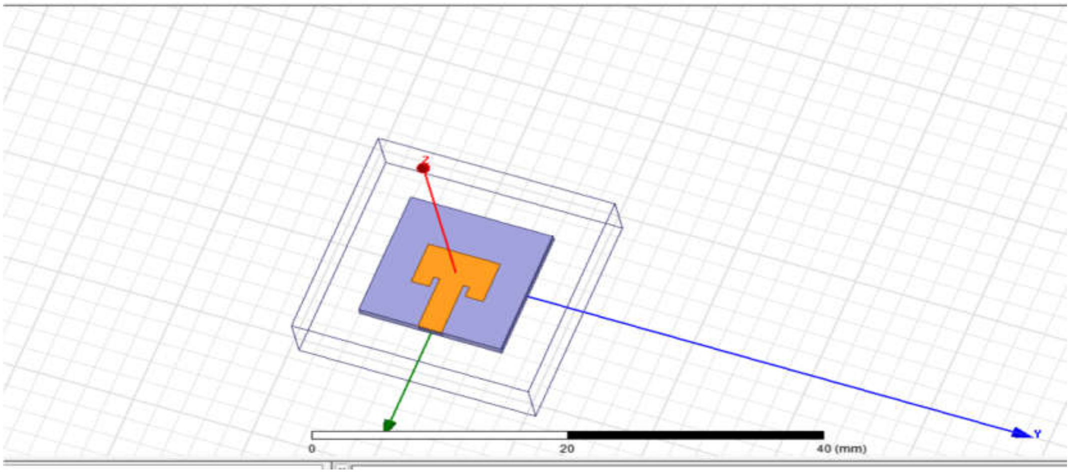


Fig. Designed Rectangular patch using HFSS

i). Return Losses:

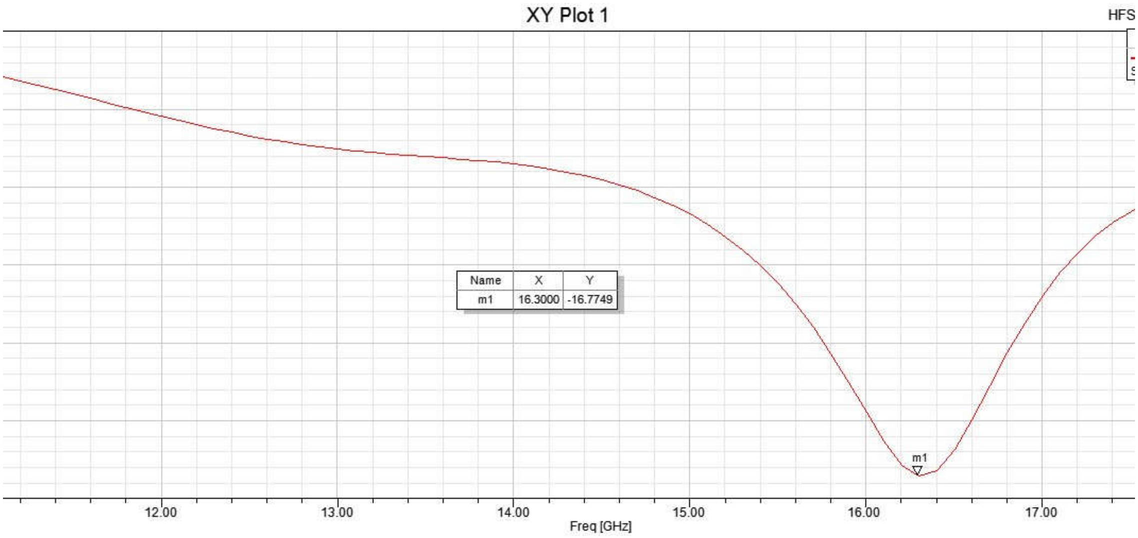


Fig. Return losses for Single patch MSPA

ii). VSWR:

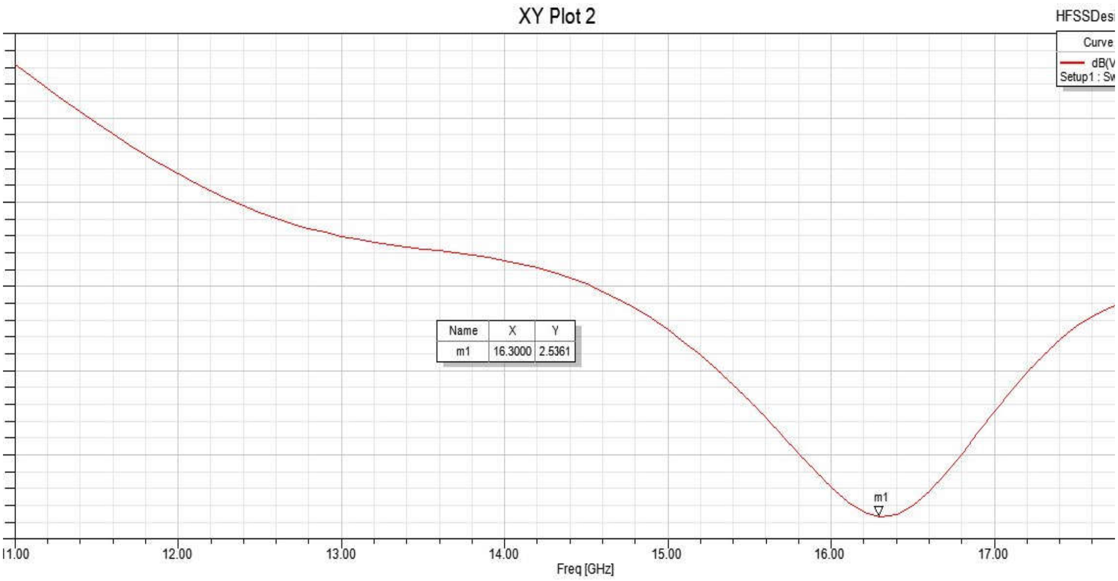


Fig. VSWR for Single patch MSPA

iii) Directivity:

Fig. Directivity for Single patch MSPA

iv) Gain:

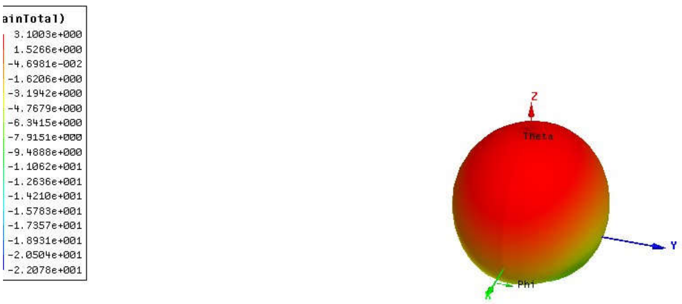


Fig.Gain for Single patch MSPA

Simulation Results of 2x2 patch Array Antenna

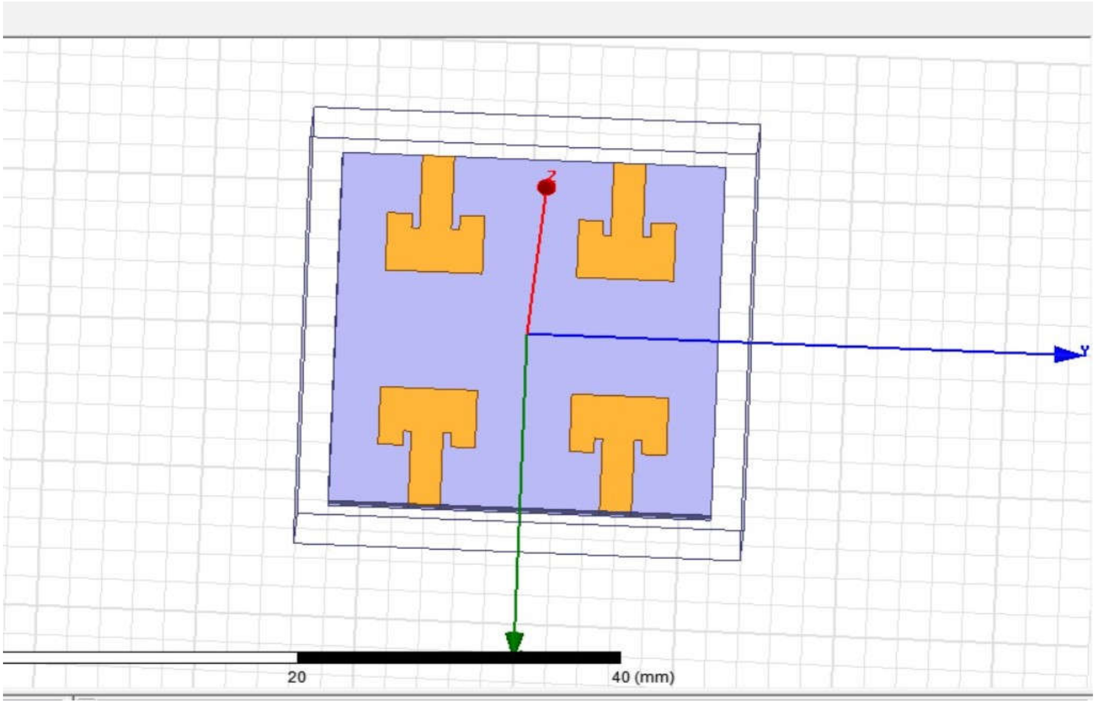


Fig. Designed patch Array Antenna

i). Return Losses:

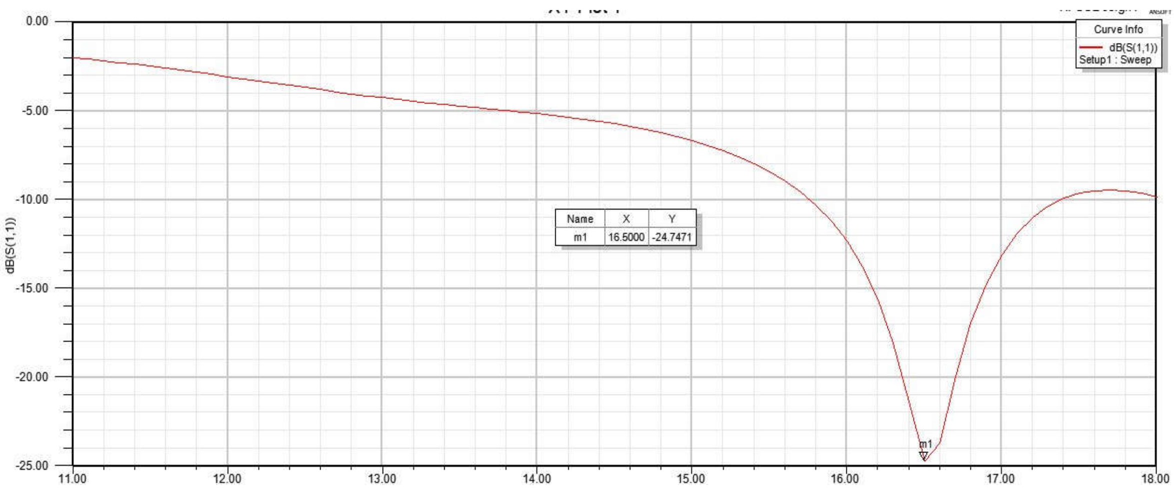


Fig. Return Losses for MSPA Array

ii). VSWR:

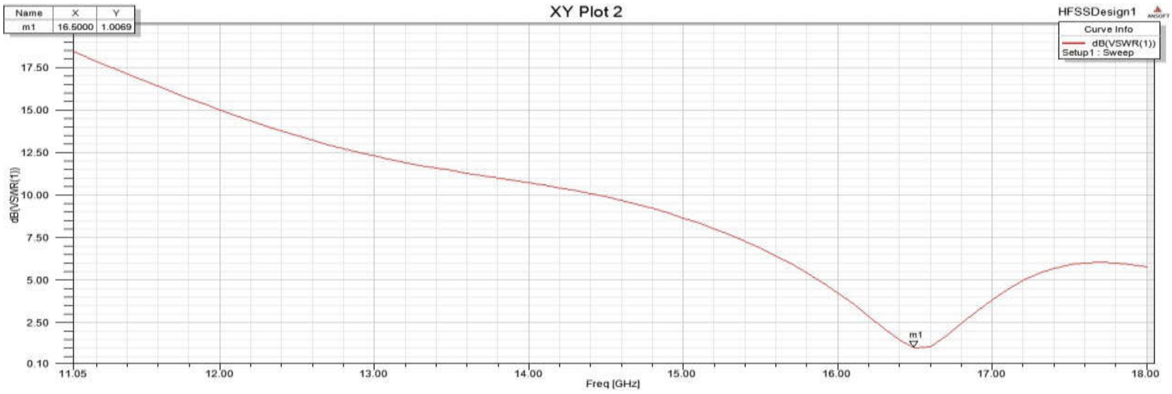


Fig.VSWR Losses for MSPA Array

iii). Directivity:

Fig. Directivity for MSPA Array

iv) Gain:

Fig. Gain for MSPA Array

CONCLUSION

In this paper, comparison between a single Microstrip patch rectangular antenna and 2x2 Microstrip patch array antenna using the simulation results obtained from HFSS has been carried out. Our study presents the design and evaluation of single and 2x2 Microstrip patch array antennas operating at the resonant frequency of 15 MHz within the KU band. The single antenna design demonstrates satisfactory performance in terms of gain, VSWR, S11, and Directivity, making it a viable option for high-frequency applications within this spectrum. Additionally, the 2x2 Microstrip Patch array antenna configuration exhibits enhanced gain and directivity, showcasing its potential for applications requiring higher performance. These findings underscore the importance of tailored antenna designs to meet specific requirements within the KU band frequency range. In addition to the core findings, our study underscores the significance of antenna design parameters such as substrate material, dimensions, and feed network configuration in achieving optimal performance within the KU band. The impact of environmental factors and surrounding structures on antenna performance should also be considered, highlighting the importance of real-world testing and validation.

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