Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 3, March : 2023

DESIGN AND ANALYSIS OF RECTANGULAR PATCH ARRAY ANTENNA USING HFSS

[1]Dr. R PRASAD RAO, [2]S. PHANI VARAPRASAD, [3]R RAMANA BABU, [4]N MANASA

[1]Associate Professor, Department of ECE, Avanthi Institute of Engineering & Technology, Narsipatnam.

[2,3]Assistant Professor, Department of ECE, Avanthi Institute of Engineering & Technology, Narsipatnam.

[4] Student, B.Tech. Department of ECE, Avanthi Institute of Engineering & Technology, Narsipatnam.

Abstract: Microstrip 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. The major considerations of this work are to enhance the bandwidth, efficiency, Directivity of a Microstrip patch antenna fabricated with corporate feed rectangular patch array antenna and also use cutting holes or slots in the patch. The resonant frequency is chosen at 2.25GHz which is suitable for Wireless Communication Application. HFSS is used to the software environment to design and compare the performance of the antennas. Based on the result analysis, it is noted that corporate feed rectangular patch array antenna offers higher bandwidth, higher radiation efficiency and directivity as compared with the rectangular Microstrip antenna. In addition the rectangular Microstrip antenna shows smaller than the return loss of corporate feed rectangular patch array.

Keywords: Rectangular patch Array antenna, cutting of holes in patch array, FR4_Epoxy substrate material, HFSS tool.

I. Introduction to Rectangular Microstrip Antenna:

Microstrip antennas are low in profile, conformable to planar and non planar surfaces, simple and inexpensive to manufacture using modern printed circuit technology, mechanically robust when mounted on rigid surfaces, compatible with MMIC (Monolithic microwave integrated circuit) designs. Microstrip antennas are among the most widely used types of antennas in the microwave frequency range and they are often used in the milli-meter wave frequency range as well.

Microstrip antennas are made from patches of conducting material on a dielectric substrate above a ground plane and fed by microstrip or coplanar transmission line is called microstrip antenna or patch antenna. This antenna is mostly used with microwave integrated circuits.

For a rectangular patch, the length 'L' of the element is usually $\lambda_0/3 < L < \lambda_0/2$. The strip (patch) and ground plane are separated by a dielectric sheet called substrate as shown in fig. (1a). The design of microstrip antennas and their dielectric constants are usually in the range of $2.2<\varepsilon r<12$. For a rectangular patch, the thickness of patch $t \ll \lambda_0$ and height of the substrate $h \ll \lambda_0$. The radiating elements and the feed lines are usually photo etched on dielectric substrate. The wide use of printed circuits leads to the constructions of radiating elements and inter connecting transmission lines using similar technology. The side view of a patch antenna as shown in fig. (1b). The major operational disadvantages of microstrip antennas are their low efficiency, very narrow frequency bandwidth, low power, high Q, poor polarization purity.

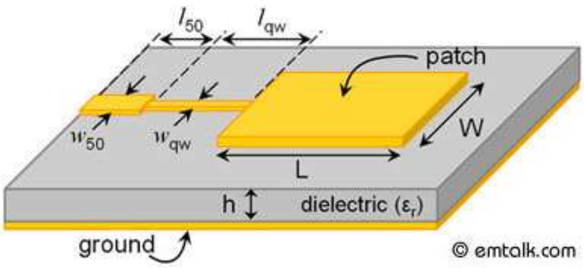

Fig. (1a) Microstrip Antenna

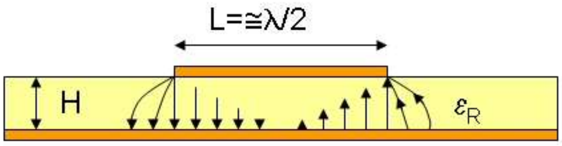

Fig. (1b) Side View

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

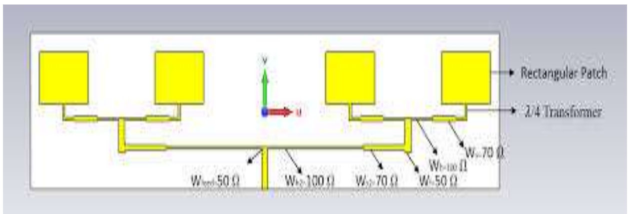

Fig. (1c) Microstrip array antenna

II. Designing of Rectangular Microstrip antenna:

To design a Rectangular microstrip patch antenna the Essential parameters are

1. The operating frequency (f_0).
2. Dielectric Constant of substrate (εr).
3. The height of the dielectric substrate (h).

Rectangular microstrip antenna designed based on the following equations

1. To find the width (W).

$$\text{Width}(W) = \frac{c}{2f_0\sqrt{\frac{(\varepsilon_r+1)}{2}}}$$

2. To find the effective dielectric constant (ε_{eff}).

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\sqrt{\frac{1}{\left[1 + 12\frac{h}{W}\right]}}$$

3. To find the fringing length (ΔL):

$$\Delta L = 0.412h\frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.813\right)}$$

4. To find the effective Length (L_{eff}):

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}}$$

5. To find the actual length (L):

$$L = L_{eff} - 2\Delta L$$

Table 1 Data sheet of microstrip antenna

S No.	Parameters	mm
1	F_0	2.25GHz
2	Ɛr	4.4
3	h	1.6
4	W	40.57
5	ΔL	0.7344
6	L_{eff}	33.67
7	Radius of Cutting of hole	5

III. Simulation Results of Rectangular Patch Antenna

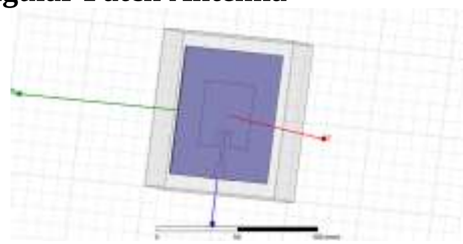

Fig. 2 Designed Rectangular patch using HFSS

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.

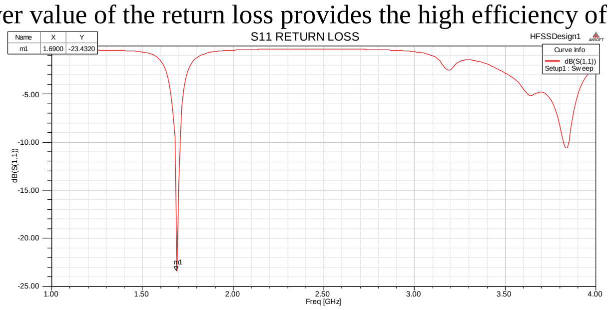

Fig. 2a Return losses for Single patch MSPA

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.

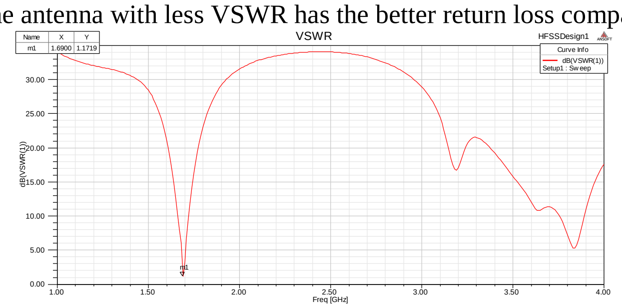

Fig.2b VSWR for Single patch MSPA

iii). Beamwidth:

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 3, March : 2023

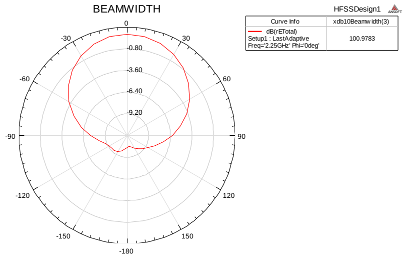

Fig. 2c Beamwidth for Single patch MSPA

iv). Directivity:

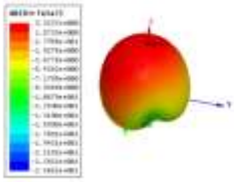

Fig. 2d Directivity for Single patch MSPA

v). Bandwidth:

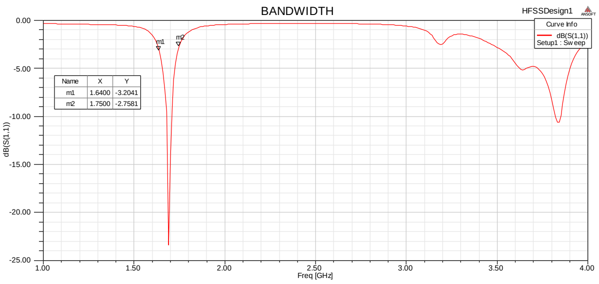

Fig. 2e Bandwidth for Single patch MSPA

IV. Simulation Results of Corporate feed Rectangular Patch Array Antenna

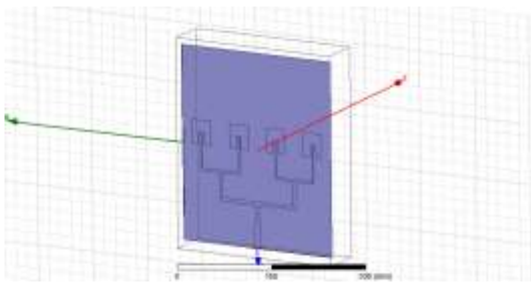

Fig. 3 Designed Corporate feed Rectangular Patch Array Antenna

i). Return Losses:

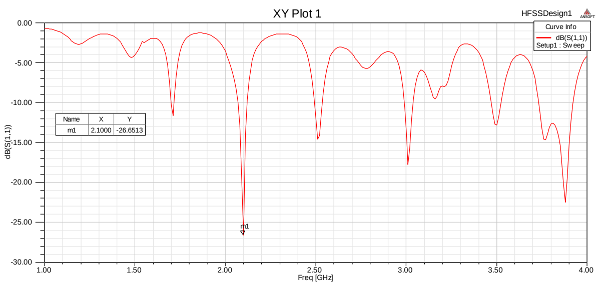

Fig. 3a Return losses for Microstrip Antenna Array

ii). VSWR:

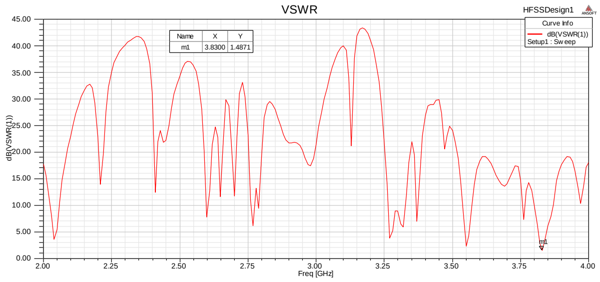

Fig. 3b VSWR for Microstrip Antenna Array

iii). Beamwidth:

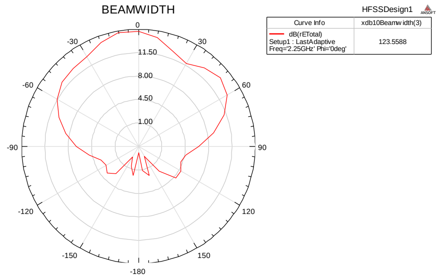

Fig. 3c Beamwidth for Microstrip Antenna Array

iv). Directivity:

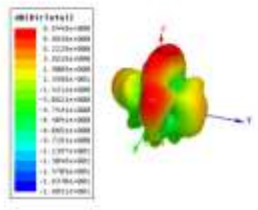

Fig. 3d Directivity for Microstrip Antenna Array

v). Bandwidth:

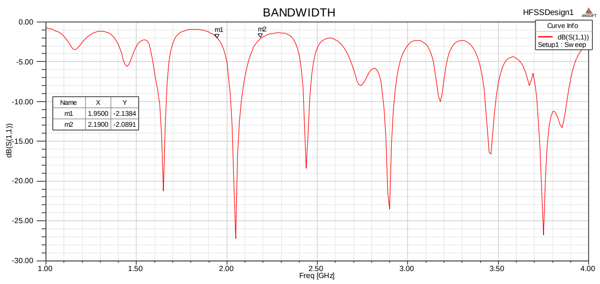

Fig. 3e Bandwidth for Microstrip Antenna Array

V. Simulation Results of cutting holes in patch Array Antenna

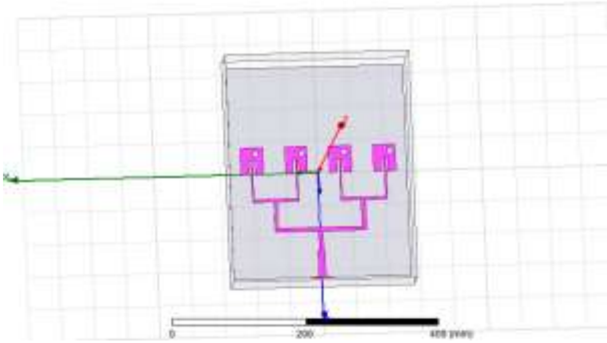

Fig. 4 Designed cutting holes in patch Array Antenna

i). Return Losses:

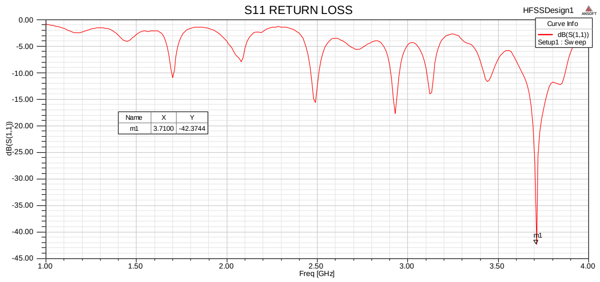

Fig. 4a Return Losses for Circle cut MSPA Array

ii). VSWR:

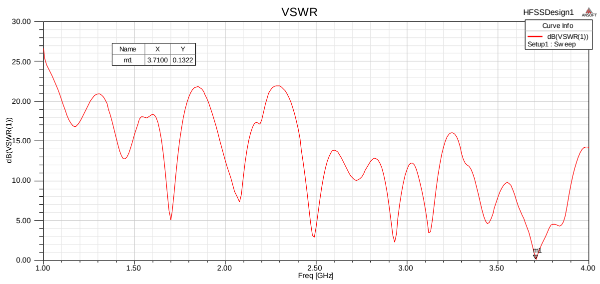

Fig. 4b VSWR Losses for Circle cut MSPA Array

iii). Beamwidth:

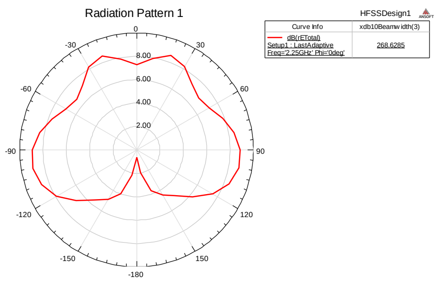

Fig. 4c Beamwidth for Circle cut MSPA Array

iv). Directivity:

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 3, March : 2023

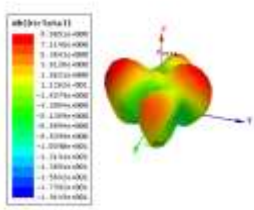

Fig. 4d Directivity Losses for Circle cut MSPA Array

v). Bandwidth:

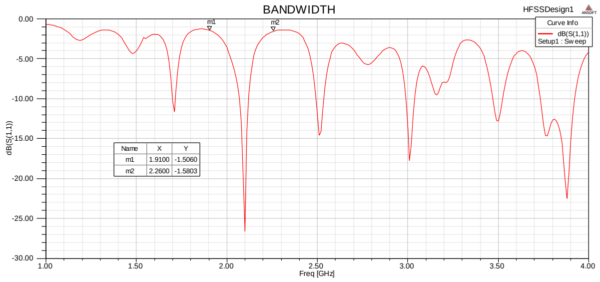

Fig. 4e Bandwidth Losses for Circle cut MSPA Array

VI. Results and Discussions

PARAMETER	SINGLE PATCH	MICROSTRIP ARRAY	CUTTING HOLES IN PATCH ARRAY ANTENNA
RETURN LOSS (S11)	-23.432	-26.6513	-42.37
BEAMWIDTH	100.973	123.5588	268.6285
DIRECTIVITY (dB)	3.3237	8.5448	8.8651
VSWR (dB)	1.1719 (value 1.14)	0.3205 (value 1.04)	0.1322 (value 1.05)
BANDWIDTH	110 MHz	240 MHZ	350 MHZ
RADIATION EFFICIENCY	0.13893	0.3205	0.33206

Table 2 Comparison of Microstrip antenna, Rectangular patch array antenna and Cutting of holes in patch array antenna

From the table 2 rectangular patch array antenna has good results compared to rectangular microstrip antenna. More negative values of return loss give better results. Closer to value to 1, better is the VSWR. From the table 2 cutting holes in patch antenna array has good results compared to rectangular patch array antenna.

VII. Conclusion:

In this paper, comparison between a single patch rectangular antenna and corporate feed rectangular patch array antenna and also cutting holes in patch array antenna using the simulation results obtained from HFSS has been carried out. These three antenna configurations show quite good results on perspectives of bandwidth, radiation efficiency, directivity, return loss, VSWR, angular width for wireless communication applications. However, from the perspectives of bandwidth, radiation efficiency, directivity, return loss, angular width for cutting holes in patch array antenna configuration show better results.

References:

[1] Constantine A. Balanis, Antenna Theory Analysis and Design, Wiley Publications, 2005

[2] a paper on " Design and Analysis of Microstrip Antenna Array Using CST Software K. Karuna Kumari1, Prof.P.V.Sridevi2", Department of ECE GITAM University, Visakhapatnam, A.P., India

[3] Prof.P.R.Chadha, Amit kumar,"Rectangular Microstrip Patch Antenna Design for WLAN Application using Probe Feed" IJETAE, Volume 2,Issue 12, December 2012.

[4] Design of an S-Band Rectangular Microstrip Patch Antenna by K. O. Odeyemi, D. O. Akande, E. O. Ogunti European Journal of Scientific Research

[5] R. Prasad Rao, Budumuru Srinu and C. Dharma Raj, "Design and Analysis of Multi Substrate Microstrip Patch Antenna", Springer India 2016 S.C. Satapathy et al. (eds.), Microelectronics, Electro magnetics and Telecommunications, Lecture Notes in Electrical Engineering 372, DOI 10.1007/978-81-322-2728-1_70.

[6] Neha Parmar, Manish Saxena, Krishnkant Nayak "Review of Microstrip Patch Antenna for WLAN and WiMAX Application" Int. Journal of Engineering Research and Applications Vol. 4, Issue 1(Version 1), January 2014.

[7] Prof.P.R.Chadha, Amit kumar,"Rectangular Microstrip Patch Antenna Design for WLAN Application using Probe Feed" IJETAE, Volume 2,Issue 12, December 2012.

[8] Dr. Max Ammnan, "Design of Rectangular Microstrip Patch Antennas for the 2.4 GHz Band"Dublin Institute of Technology

[9] G. Breed, "The fundamentals of patch antenna design and performance," From High frequency electronics Summit technical media, LLC, March 2009

[10] H. Pues, A. Van de capelle, "Accurate transmission line model for the rectangular microstrip antenna", IEEE Microwave, Antenna and Propagation Proceedings, Vol.131,Pt.December 1984.

[11] K. A Michalski and D. Zheng, "Analysis of microstrip resonators of arbitrary shape," IEEE Trans. Microwave Theory Tech., vol. 40. pp. 112-199, Jan. 1992.

[12] Modern Antenna Design, Thomas A. Milligan, IEEE Press, John Wiley & sons Publications ©2005.

[13] Modern Antenna Design, Thomas A. Milligan, IEEE Press, John Wiley & sons Publications ©2005.

[14] Hoi-Shun LUi, Han Tat HUi, and Mook Seng Leong, "A Note on the Mutual-Coupling Problems in Transmitting and Receiving Antenna Arrays" IEEE Antennas and Propagation Magazine, Vol. 5 1, No.5, October 2009.

[15] Samir Dev Gupta, MC Srivastava, Amit Singh, "Design and Performance Analysis of Cylindrical Microstrip Antenna and Array using Conformal Mapping Technique", IJCEA, vol. 02, Issue 03, pp 1 66-1 80, Jul. 201 1.