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DESIGN AND ANALYSIS OF RECTANGULAR & CIRCULAR PATCH ARRAY ANTENNA USING HFSS

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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 and circular 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 & Circular patch Array antenna, cutting of holes in patch array, FR4_Epoxy substrate material, HFSS tool.

A. 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.

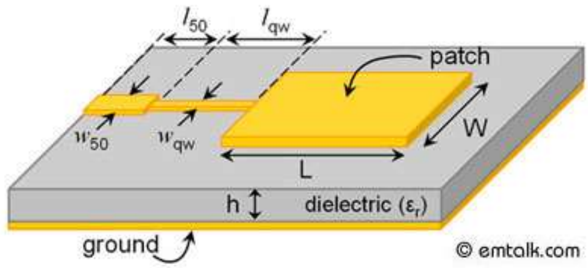

Fig. (1a) Microstrip Antenna

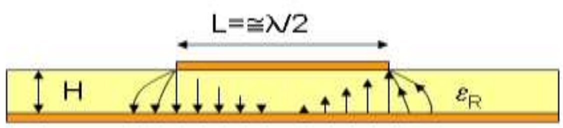

Fig. (1b) Side View

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

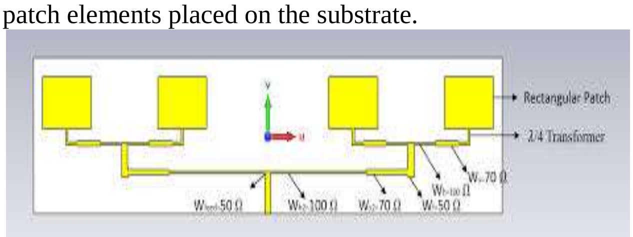

Fig. (1c) Rectangular Microstrip array antenna

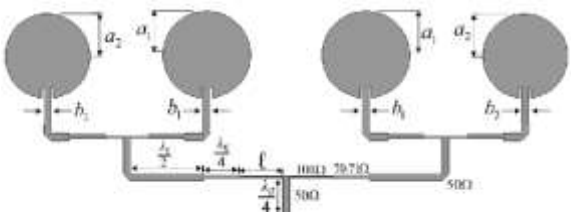

Fig. (1d) Circular Microstrip array antenna

B. Designing of Rectangular Microstrip antenna:
To design a Rectangular & Circular microstrip patch antenna the Essential parameters are

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

Rectangular & Circular 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):

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

6. To find the radius of the circular (a):

$$a = \frac{F}{\left\{1+\frac{2h}{\pi\varepsilon_r F}\left[\ln\left(\frac{\pi F}{2h}\right)+1.7726\right]\right\}^{1/2}}$$

Where

$$F = \frac{8.791 \text{ X } 10^9}{f_{r\sqrt{\varepsilon_r}}}$$

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 (r)	18.28
8	Radius of Cutting of hole	5

C. Simulation Results of Rectangular Patch Antenna:

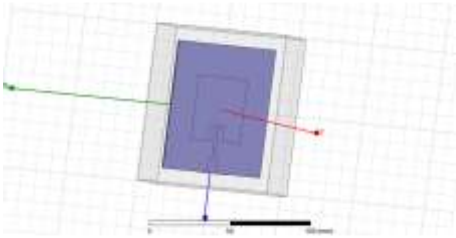

Fig. 2 Designed Rectangular patch using HFSS

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.

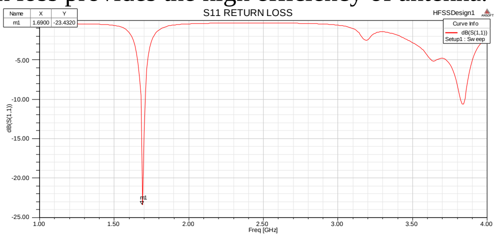

Fig. 2a Return losses for Single patch MSPA

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.

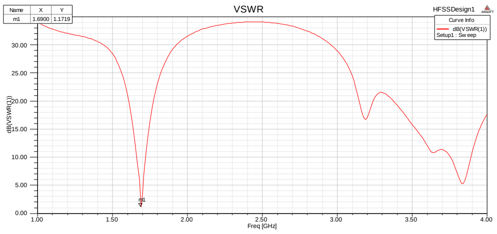

Fig.2b VSWR for Single patch MSPA

iii). Beamwidth:

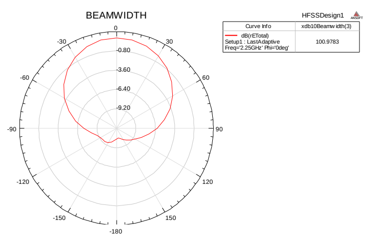

Fig. 2c Beamwidth for Single patch MSPA

iv). Directivity:

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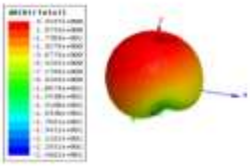

Fig. 2d Directivity for Single patch MSPA

v). Bandwidth:

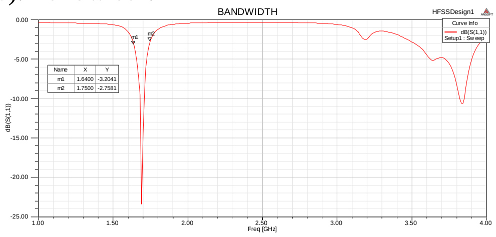

Fig. 2e Bandwidth for Single patch MSPA

D. Simulation Results of Corporate feed Rectangular Patch Array Antenna:

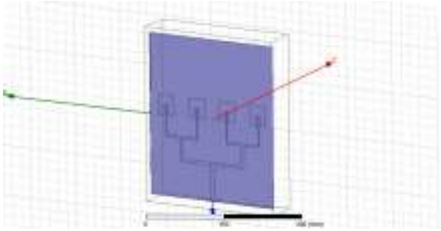

Fig.3 Designed Corporate feed Rectangular Patch Array Antenna

i). Return Losses:

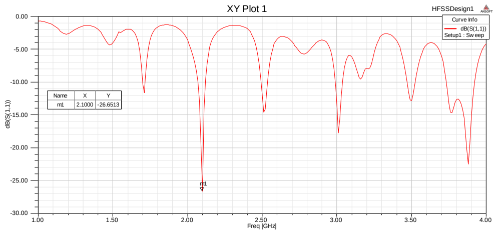

Fig. 3a Return losses for Microstrip Antenna Array

ii). VSWR:

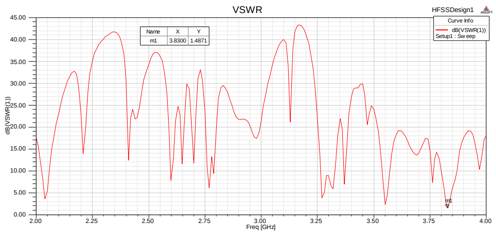

Fig. 3b VSWR for Microstrip Antenna Array

iii). Beamwidth:

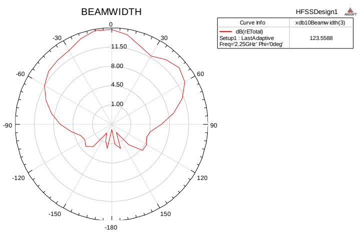

Fig. 3c Beamwidth for Microstrip Antenna Array

iv). Directivity:

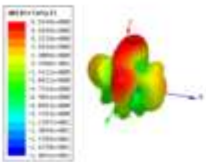

Fig. 3d Directivity for Microstrip Antenna Array

v). Bandwidth:

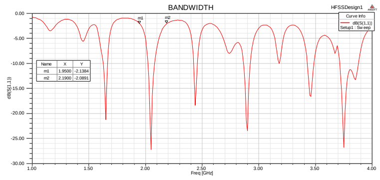

Fig. 3e Bandwidth for Microstrip Antenna Array

E. Simulation Results of cutting holes in patch Array Antenna:

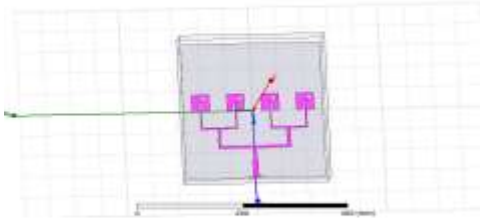

Fig.4 Designed cutting holes in patch Array Antenna

i). Return Losses:

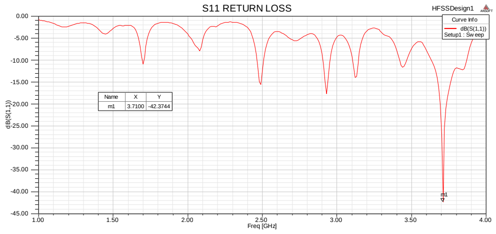

Fig. 4a Return Losses for Circle cut MSPA Array

ii). VSWR:

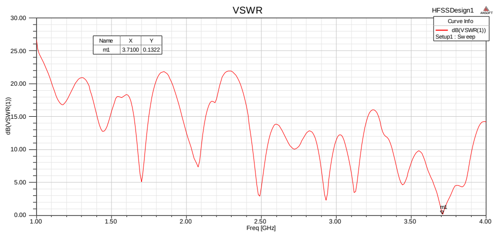

Fig. 4b VSWR Losses for Circle cut MSPA Array

iii). Beamwidth:

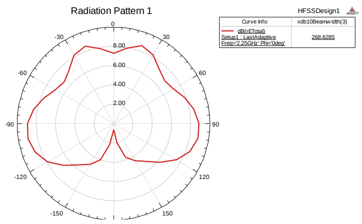

Fig. 4c Beamwidth for Circle cut MSPA Array

iv). Directivity:

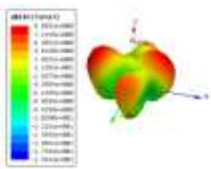

Fig. 4d Directivity Losses for Circle cut MSPA Array

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v). Bandwidth:

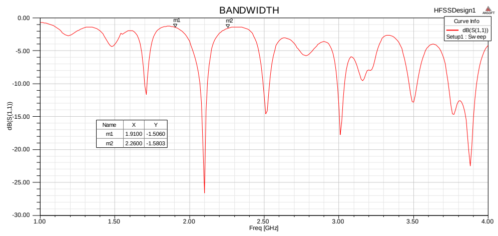

Fig. 4e Bandwidth Losses for Circle cut MSPA Array

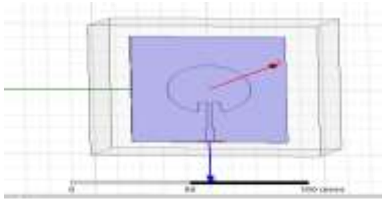

Fig.5 Single patch circular patch antenna without hole on patch

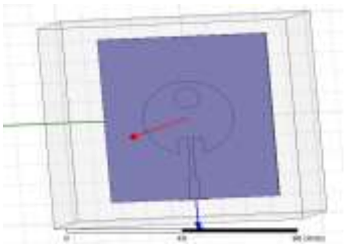

Fig.6 Single patch circular patch antenna with hole on patch

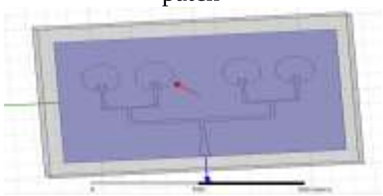

Fig.7 Circular patch array antenna without hole on patch

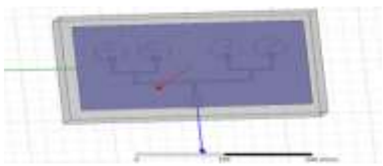

Fig.8 Circular patch array antenna with holes on patch

F. Results and Discussions:

PARAMETER	Without holes on patch	With holes on patch (5mm radius)
RETURN LOSS (S11)	-23.432	-12.1634
BEAMWIDTH	100.973	102.69
DIRECTIVITY (dB)	2.856	3.3237
VSWR (dB)	1.1719	4.3723
BANDWIDTH	110 MHz	190 MHz
RADIATION EFFICIENCY	0.13	0.14

Table 1 Comparison between with and without holes on single Rectangular patch

PARAMETER	Without holes on patch	With holes on patch (5mm radius)
RETURN LOSS (S11)	-26.6513	-42.37
BEAMWIDTH	266.6	268.6
DIRECTIVITY (dB)	8.5448	8.8651
VSWR (dB)	1.4869	0.1322
BANDWIDTH	240 MHZ	350 MHZ
RADIATION EFFICIENCY	0.32	0.33

Table 2 Comparison between with and without holes on rectangular patch array

PARAMETER	Without holes on patch	With holes on patch (5mm radius)
RETURN LOSS (S11)	-24.28	-26.33
BEAMWIDTH	91.31	91.51
DIRECTIVITY (dB)	6.54	6.55
VSWR (dB)	1.06	0.83
BANDWIDTH	170	190
RADIATION EFFICIENCY	0.33	0.34

Table 3 Comparison between with and without holes on single Circular patch

PARAMETER	Without holes on patch	With holes on patch (5mm radius)
RETURN LOSS (S11)	-26.84	-10.08
BEAMWIDTH	19.99	24.04
DIRECTIVITY (dB)	2.45	3.1
VSWR (dB)	0.79	5.6
BANDWIDTH	130MHz	200MHz
RADIATION EFFICIENCY	0.22	0.26

Table 4 Comparison between with and without holes on circular patch array

From the above table 1 to 4 single patch & rectangular, circular patch array with cutting on holes antenna has good results compared to others designs. More negative values of return loss give better results. Closer to value to 1, better is the VSWR. From the table 1 to 4 cutting holes in patch antenna array has good results compared to other patch array antenna.

G. Conclusion:

In this paper, the comparison between a single patch rectangular antenna, corporate feed rectangular patch array antenna, single patch circular antenna, and circular patch array antenna with and without holes has been carried out using the simulation results obtained from HFSS. These eight antenna configurations show quite good results on perspectives of bandwidth, radiation efficiency, directivity, return loss, VSWR, beam width for wireless communication applications. However, from the perspectives of bandwidth, radiation efficiency, directivity, return loss and beam width the configuration of cutting holes in patch array antenna show better results.

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