International Journal Of Advance Research, Ideas And Innovations In Technology

ISSN: 2454-132X
Impact Factor: 6.078
(Volume 7, Issue 3 - V7I3-1482)
Available online at: https://www.ijariit.com

Design and Simulation of Circular Microstrip Patch Antenna Array (2×2) for S-Band Wireless Applications

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ABSTRACT

Latest trends and advancements in wireless communication require high performance antenna designs with low profile characteristics like low cost, ease of fabrication/ handling/ maintenance, simple design, light weight etc. A microstrip patch antenna is best suitable for such applications due to its low-profile characteristics. A wireless local area network (WLAN) is a short-distance communication network mostly used for linking two or more wireless devices within a limited range. WLANs follow the IEEE802.11 standards which have listed the frequencies used in five different frequency bands i.e., 2.4 GHz, 3.6 GHz, 4.9 GHz, 5 GHz, and 5.9 GHz. This paper consists of the design and simulation of high gain antennas for 2.4GHz frequency band applications using High Frequency Structure Simulator (HFSS) software.

Keywords— *Wireless Local Area Network (WLAN), High Frequency Structure Simulator (HFSS), S-11, VSWR, Gain, Directivity, S-band*

1. INTRODUCTION

An antenna is an equipment used for connecting two or more devices by means of a wireless medium. It is used for radiating or receiving radio waves by using air as the medium. In antenna design, there are several considerations that must be considered to be implemented in the system. The advantages for the implementation of antennas in the S-band are lightweight. The antenna has the advantage of circular polarization, while most other antennas are linearly polarized antenna (horizontal or vertical). The advantages of a circular polarized antenna are that they are able to capture the signal under any circumstances, either vertical, horizontal, or oblique.

The basic WLAN architecture comprises the wired LAN network, wireless devices, and an access point that acts as the bridge between the two. To serve the purpose of bridging between wired and wireless mediums, an access point is equipped with an antenna. Each access point can serve only those devices within its range. Higher the gain of the antenna, more will be the range that can be covered. Hence, high gain of the antennas plays a vital role in WLAN applications. By considering the above facts, we proposed the design and

simulation of a high gain 2x2 microstrip antenna array with circular shape patches in the present work as shown in Fig-1. In this study, we have carried out the design and implementation of a microstrip antenna which works in the S-band (2.4 GHz) microwave frequency in HFSS software.

2. DESIGN THEORY

Circular patches are assumed for ease of fabrication. The most widely used dielectric substrate material FR4 of height (h) 1.6mm is used with dielectric constant $\varepsilon r = 4.4$.

Here, we have chosen Resonant frequency $fr = 2.4$GHz, Dielectric constant of air $\varepsilon = 1$.

Radius of the circular patch is given by:

$$a = \frac{F}{[1 + \frac{2*h}{\pi*\varepsilon r*F}\,(ln(\frac{\pi*F}{2*h}) + 1.7726)\,]^{0.5}}$$

where, F denotes Fringing Field, given by the formula

$$F = \frac{8.791 \;*\; 10^{9}}{1.265 * \;10^{9} * \sqrt{4.4}}$$

The inter-element spacing between the antenna array elements i.e., patches is chosen to be between λ/2 and λ to avoid mutual coupling. The impedance is minimum at the centre of the patch and is the maximum at the edges of the patch.

Ideally, inter-element spacing should be λ/2. Frequency of operation is 2.4GHz. Therefore, we calculate

$$\lambda = c/f$$

So, the inter-element spacing = 62.5mm.

Corporate feed networks with quarter wave transformers are employed for the purpose of impedance matching between the high edge impedance of patches and the 50ohm impedance of input.

The corresponding widths of each of the feedlines which are dependent on their impedance values for 2x2 antenna arrays are calculated using the formula:
To calculate width (w) of the feedline:

$$\frac{w}{h} = \frac{2}{\pi}\left[B - 1 - ln(B-1) + \frac{(\varepsilon r - 1)}{(2 * \varepsilon r)}\{l\,(B-1) + 0.39 - \frac{0.61}{2 * \varepsilon r}\}\right]$$

…for w/h>2

where, $B = \frac{377 * \pi}{2 * Zo * \sqrt{\varepsilon r}}$ and,

Characteristic impedance Zo= 50Ω.

To calculate Effective Dielectric constant (Ee) of Microstrip line:

$$Ee = \frac{1}{2}[(\varepsilon r + 1) + (\varepsilon r - 1) * [\frac{1}{(1 + 12 * \frac{h}{w})^{0.5}}]]$$

To calculate length (l) of the Microstrip line:

$$l = \frac{270° * (\pi/180)}{\sqrt{(Ee)} * ko}$$

where, $ko = \frac{2 * \pi * fr}{c}$
ko is a constant for a given frequency.

Table 1: Width of Feedline for corresponding Zo values

Width of 100Ω feedline	0.7mm
Width of 70.7Ω feedline	1.6mm
Width of 50Ω feedline	3mm

3. RESULTS AND ANALYSIS

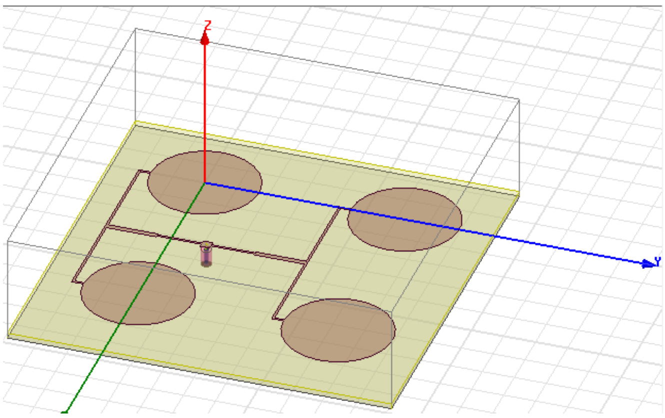

Fig. 1: 2x2 circular microstrip patch antenna with coaxial probe feed

The following results were obtained after simulation using HFSS. The return loss and VSWR of the 2x2 circular microstrip patch antenna array is shown in Fig-2 and Fig-3 respectively.

3.1 Return loss of 2x2 CMPA array(S11)

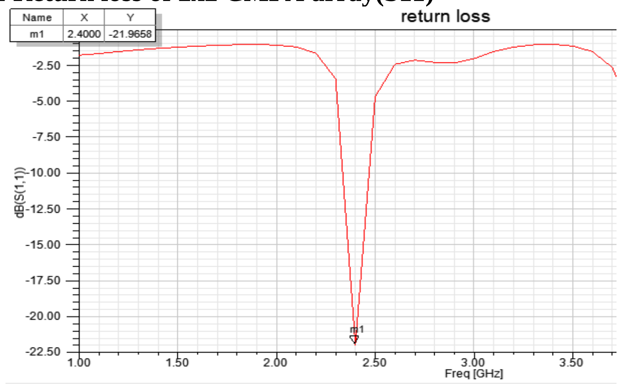

Fig. 2: Return Loss of 2x2 CMPA array

3.2 VSWR of 2x2 CMPA array

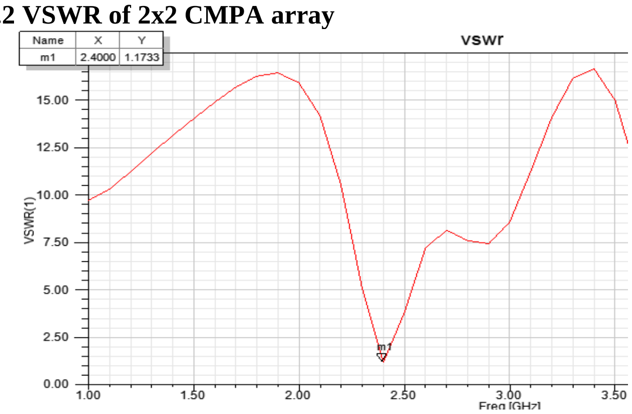

Fig. 3: VSWR of 2x2 CMPA array

The gain, directivity and bandwidth of the antenna array are depicted in Fig-4, Fig-5 and Fig-6 respectively.

3.3 Gain of 2x2 CMPA array

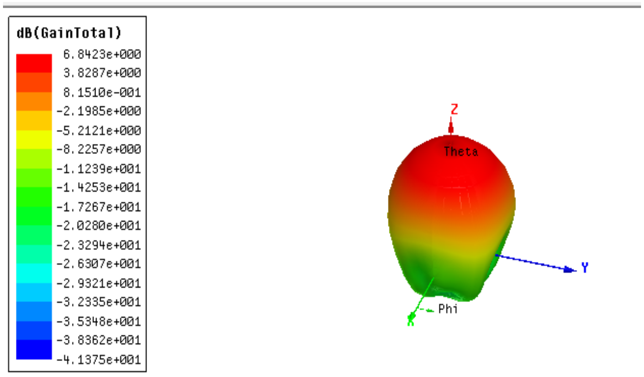

Fig. 4: 3D gain pattern of 2x2 CMPA array

3.4 Directivity of 2x2 CMPA array

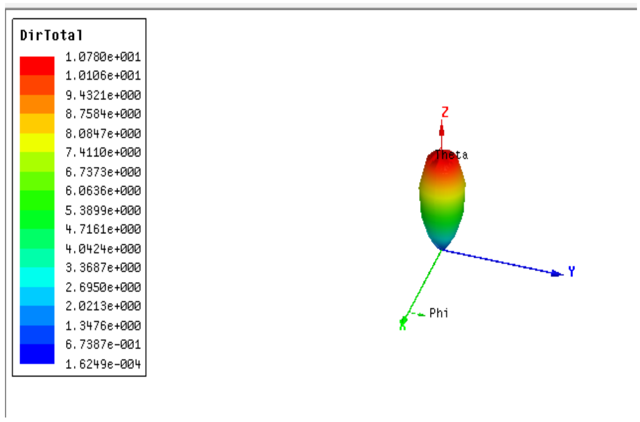

Fig -5: Directivity of 2x2 CMPA array

3.5 Bandwidth of 2x2 CMPA array

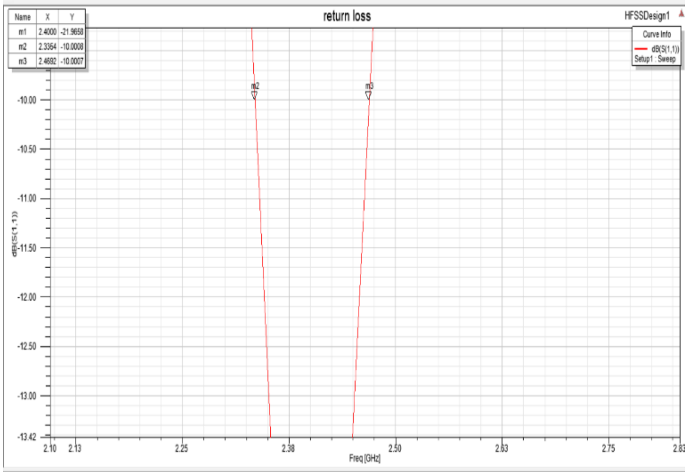

Fig -6: Bandwidth of 2x2 CMPA array

To find the bandwidth, we draw a horizontal at -10dB. The difference between the frequencies gives the bandwidth.
Bandwidth = 2.4692GHz – 2.3354GHz
Bandwidth in % = (0.1338/2.4) * 100

3.6 Efficiency

We know that G = k * D
where, G is the gain of antenna,
D is the directivity, and
k is the efficiency of the antenna.
Therefore, k=G/D

3.7 Radiation Pattern of 2x2 CMPA array

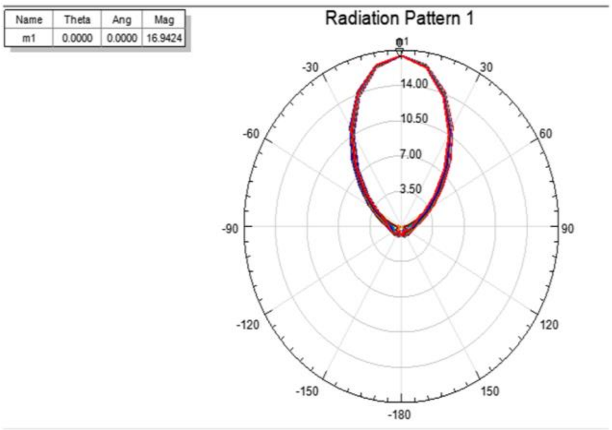

Fig -7: 2D radiation pattern of 2x2 CMPA array

The figure Fig-7 depicts the 2D radiation pattern of the 2x2 CMPA

Table 2: Simulation Results

Design Parameters	Values
Frequency	2.4GHz
Return loss (S11)	-21.9658dB
VSWR	1.1733
Gain	6.8423dB
Directivity	10.78dB
%Bandwidth	5.575%
%Efficiency	63.45%

4. CONCLUSIONS

The 2x2 circular microstrip patch antenna was simulated using HFSS and we conclude that the obtained VSWR is less than 2, which is the ideal value. The obtained return loss is as the ideal value which i.e., less than -10dB. The Radiation Pattern shows the Main lobe, and there is no Side lobe which implies that the antenna array is directive.

5. REFERENCES

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