Design and Simulation of Patch Antenna Array for 5.4GHz Wi-Fi Application

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Abstract - **In this paper, a microstrip patch antenna array for Wi-Fi 5.4GHZ application has been designed and results are analyzed using Advanced Design System 2009 simulation software. The FR4 glass epoxy with relative permittivity 4.9 and height 1.6 mm is used as substrate material. Our goal is to obtain a high directivity with better gain and reduced losses, to be especially used for C band applications such as WLAN, Wi-Fi, Wi-Max and other wireless systems.**

Keywords: 5.4 GHz, Wi-Fi, patch antenna array, ADS 2009

I.INTRODUCTION

There are different shapes of antenna depending on its application. In general, the Microstrip antenna has many properties which are depending upon its applications. These properties include low profile, light weight, compact and, simple fabrication and Ease of installation. These properties contribute to the application of Microstrip antennas in the military applications, such as aircraft, missiles, space craft, and also in the commercial areas, such as mobile satellite system, cellular mobile communications, broadcast satellite system, wireless communication and global positioning system. The choice of antenna selection is based on the requirements of the application such as frequency band, gain, cost, coverage, weight, etc. Wi-Fi is the most rapidly growing area in the modern wireless communication. This gives users the mobility to move around within a broad coverage area and still be connected to the network. This provides greatly increased freedom and flexibility. For the home user, wireless has become popular due to ease of installation, and location freedom. Portable antenna technology has grown along with mobile and cellular technologies. It is important to have the proper antenna for a device. The proper antenna will improve transmission and reception, reduce power consumption, improved lifetime and improved efficiency of the communication device. In this paper, a single band Microstrip patch antenna for WLAN application is designed and simulated using Advanced Design System.

II. MICROSTRIP PATCH ANTENNA

In its basic form, a Microstrip patch antenna consists of a radiating patch which is built on the dielectric substrate and substrate is attached on the ground plane as shown in Figure 1. The patch is generally made of conducting material such as copper or gold and can take any possible shape.

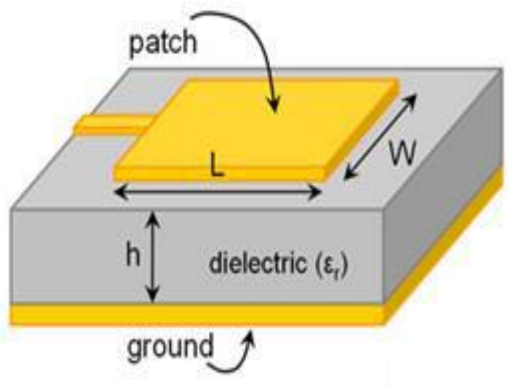

Figure- 1: Structures of Microstrip patch Antenna.

The radiating patch and the feed lines are usually photo etched on the dielectric substrate. The relative permittivity of the dielectric substrate is very important for the calculations of the antenna dimensions. In order to simplify analysis, the patch is generally square, rectangular, circular, triangular, and elliptical or some other common shape. In this paper, the rectangular patch can be used. Micro strip patch antennas radiate primarily because of the fringing fields between the patch edge and the ground plane. For good antenna performance, a thick dielectric substrate having a low dielectric constant is desirable since this provides better efficiency, larger bandwidth and better radiation.

III. MICROSTRIP PATCH ARRAY ANTENNA

Antenna arrays are used to enhance various antenna parameters like bandwidth, directivity, gain, beam width and efficiency. There are a variety of methods to feed the signal into Micro strip patch antennas. The main categories are

Contacting: Radio frequency signal is directly fed to the patch element using metallic feed line.

Non-Contacting: The EM field coupling is used to transfer RF power between the micro strip line and antenna patch element.

IV. ANTENNA FEEDING NETWORKS

A. *Micro strip line feed*

In this case a metallic strip (feed line), which has smaller width as compared to the patch is directly connected to the Micro strip patch. The advantage of this type of feeding technique is that, the feed line can be etched on the same substrate plane and it provides a planar structure.

B. Micro strip Pin Feed

In this case the coaxial connector is used to feed the RF power to the patch element. The coaxial connector consists of an inner conductor and an outer conductor. The inner conductor is drilled through the substrate plate and is soldered to the metallic patch element. The outer conductor is connected to the metallic ground plane. The advantage of this feeding technique is that the feed can be placed at any desired location.

C. Micro strip Series Feed

In this technique the individual patch elements are connected in series using a transmission line from which the desired proportion of RF energy is coupled into the individual element propagated along the line. Here the input power is feed at the first element. Quarter wavelength transformer method is used in this method.

D. Corporate Feed

A corporate feed is most widely used feeding techniques to fabricate the antenna arrays. In this case the incident power is equally splitting and distributing to the individual antenna elements. The corporate feeding technique can provide power splits of 2k (where k= 2; 4; 8; 16…..).

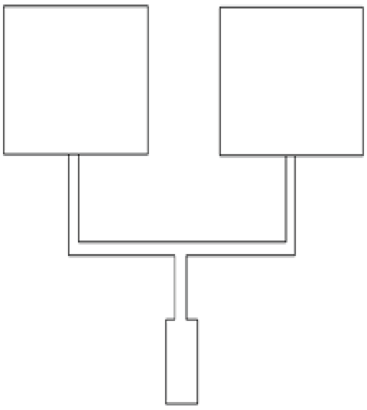

Figure-2: Corporate Feed Network

V. ANTENNA DESIGN

The proposed antenna is designed for a resonating frequency of 5.4 GHz. The substrate material FR-4 which has the relative permittivity of εr=4.9. The substrate thickness is designed as 1.6mm. The dimensions of the antenna can be calculated by using the following relationship.

i. *Width of the Patch:*

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}}$$

Where,
c =free space velocity of light.
fr = resonating frequency.
ε_r= relative permittivity of substrate.

ii. *Effective dielectric Constant:*

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

Where,
h = Thickness of the substrate.
W= Width of the patch.

iii. *Effective Length:*

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

iv. *Patch length extension:*

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{W}{h}+0.8)}$$

v. *Length of the patch:*

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

vi. *Width of the substrate:*

$$L_g = 6h + L$$

vii. *Length of the substrate:*

$$W_g = 6h + W$$

VI. ANTENNA SPECIFICATION

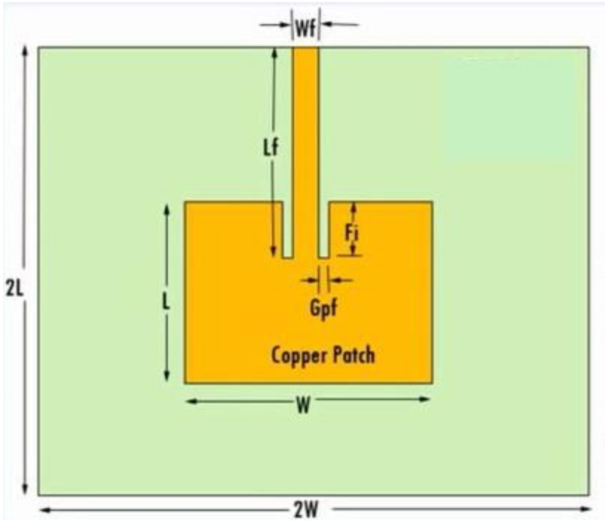

TABLE I
Design specification of the proposed antenna

DESIGN PARAMETER	VALUE
Dielectric constant	4.9
Length	13 mm
Width	16.79 mm
Feed length	9.5 mm
Feed Width	8 mm
Feed insertion(Fi)	4 mm
Feed gap(Gpf)	1 mm
Thickness(h)	1.6 mm
Operating frequency	5.4 GHz

VII. ANTENNA ARRAY DESIGN

A.1 X 1 antenna array design:

The width of the patch is 16.79 mm and length is 13mm. The length of the feed line is 9.5mm, feed width is 8mm and feed insertion of 4mm, feed gap of 1mm.

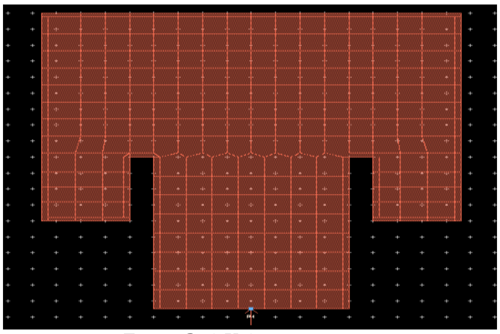

Figure-3: 1 X 1 antenna array

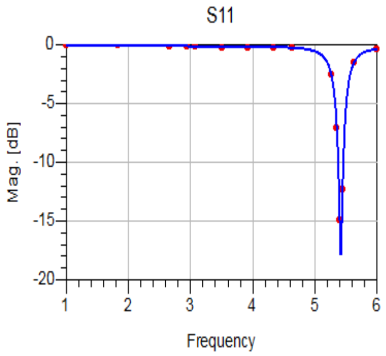

Figure-4: Return loss of 1 X 1 antenna array

B. 1 X 2 antenna array design:

Here 2 elements are used and each element has the same dimensions as mentioned above in order to increase the antenna performance. The length of the power divider is 12 mm and width is 1 mm. Distance between the centers of both the feed line is 24 mm.

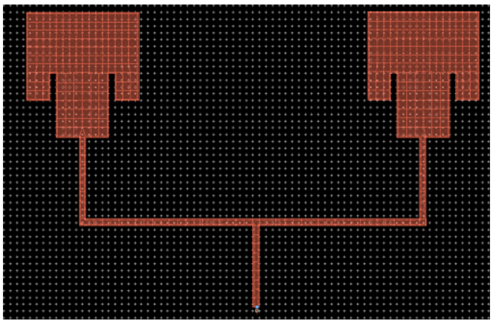

Figure-5: 1 X 2 antenna array

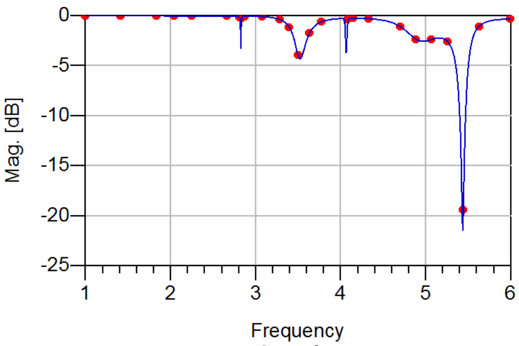

Figure-6: Return loss of 1 X 2 antenna array

c. 2X2 antenna array design:

Here 4 elements are used and each element has the same dimensions as mentioned above in order to increase the antenna performance. The length of the power divider is 12 mm and width is 1 mm. Distance between the centers of both the feed line is 24 mm.

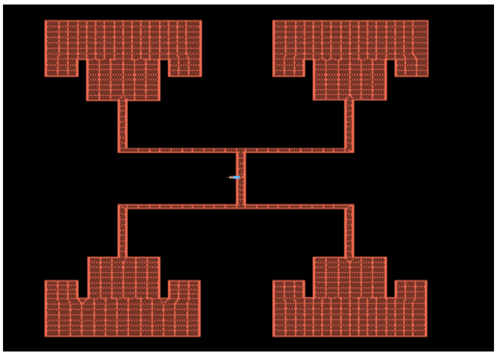

Figure-7: 2 X 2 antenna array

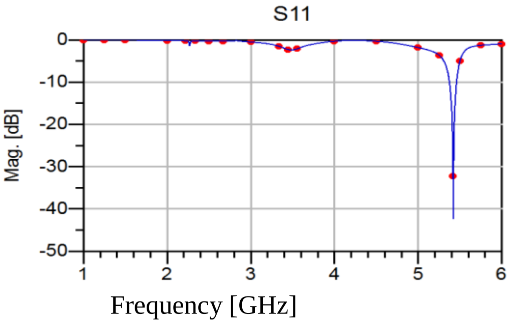

Figure- 8: Return loss of 2 X 2 antenna array.

VIII. RESULTS AND DISCUSSIONS

A. Return loss:

According to maximum power transfer theorem, the maximum amount of power will be transferred when there is perfect match between devices. Transfer between the feed line antenna takes place when the input impedance of antenna must identically match with characteristic impedance of feed line .If any mismatch in impedance results in return of energy back to the source called return loss. An antenna is said to be efficient if the return loss is below -10 dB

The Return loss is determined for 1, 1X2, and 2X2 antenna array and a better return loss were observed in 2X2 antenna array and the results are tabulated table 2.

Table 2: Comparison of return loss for different array antenna

Antenna array	Frequency (GHz)	Return loss S(11), (dB)
1 X 1	5.4	- 15
1 X 2	5.4	- 20
2 X 2	5.4	- 40

B. Radiation Pattern:

The radiation pattern or antenna pattern is the graphical representation of the radiation properties of the antenna as a function of space .That is the antennas pattern describes how the antenna radiates energy out in the space.

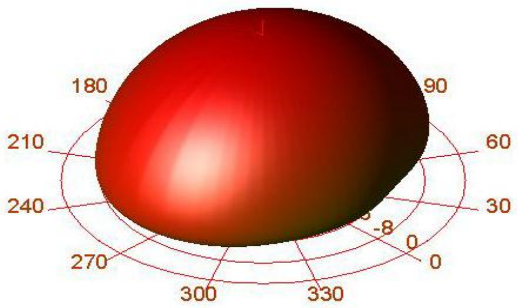

Figure-9: Radiation pattern of 1X1 antenna array

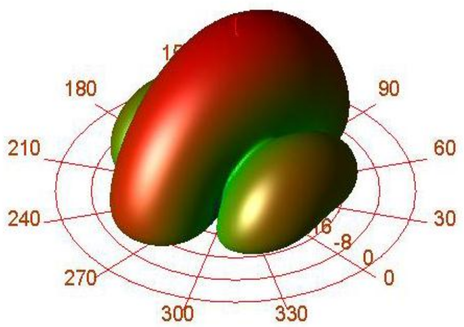

Figure-10: Radiation pattern of 1 X 2 antenna array

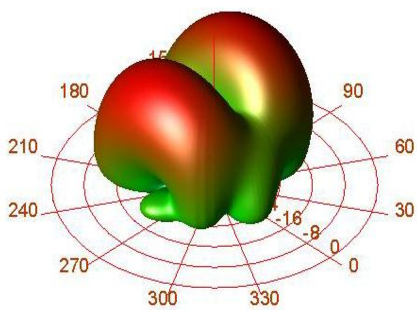

Figure-11: Radiation pattern of 2 X 2 antenna array

From Figure-9, 10and 11 red colour regions specify the maximum radiation and green colour indicates medium level of power radiation.

C. *Gain:*

The gain is determined for the 1 X 1, 1 X 2, and 2 X 2 array antennas respectively and a better gain of 10.23 dB was observed in 2 X 2 antenna array and the results are tabulated in table 3.

Antenna Array	Gain (dB)
1 X 1	4.06
1 X 2	9.34
2 X 2	10.23

Table 3: Comparison of Gain for different array antenna

D. Directivity:

The directivity is determined for the 1 X 1, 1 X 2, and 2 X 2 array antennas respectively and a better directivity of 10.46 dB was observed in 2 X 2 antenna array and the results are tabulated in table 4.

Antenna Array	Directivity (dB)
1 X 1	6.49
1 X 2	10.55
2 X 2	10.96

Table 4: Comparison of Directivity for different array antenna

Comparison between 1 X 1, 1 X 2, and 2 X 2 Antenna array:

Antenna parameter	1 X 1 Antenna array	1 X 2 Antenna array	2 X 2 Antenna array
Operating Frequency [GHz]	5.4	5.4	5.4
Return Loss S11 [dB]	-15	-20	-40
Directivity [dB]	6.49	10.55	10.96
Gain [dB]	4.06	9.34	10.23

IX. CONCLUSION

Microstrip Patch antenna configured in an array format with different number of patch elements has been analyzed. The 1 X 1, 1 X 2, and 2 X 2 Antenna arrays are operating in the frequency of 5.4 GHz Wi-Fi communication in the IEEE 802.11. Return loss up to -40 dB has been achieved by 2x2 arrays at 5.4 GHz. Improved Gain, Directivity, return loss and radiated power is also achieved by implementing more number of patch elements in the arrays.

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