IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 9, Issue 4, Ver. II (Jul - Aug. 2014), PP 44-47
www.iosrjournals.org

Design and Simulation of MIMO Elliptical Shaped Micro strip Patch Antenna at 5GHz frequency for Wi-Fi Network

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Abstract: *The growth of portable wireless communication devices has pushed designers to design miniature size micro strip patch antenna as it offers advantages of polarisation diversity, light weight, low manufacturing cost and high reliability. This paper presents the design and simulation of inset edge fed 2X2 MIMO Elliptical shaped micro strip patch antenna at 5GHz frequency for Wi-Fi/802.11a Network. The result of 2X2 MIMO Antenna has been compared with 1X2 Antenna and simple elliptical shaped micro strip patch antenna. High Frequency Structure Simulator (HFSS) software has been used to compare and analyze the performances of antennas in term of return loss and gain and radiation pattern. It has been found that the though return loss and gain of antenna marginally improved but 2x2 MIMO antenna provides high degree of isolation*
Key-words: *2x2 Elliptical shaped micro strip patch antenna, bandwidth, isolation, WLAN*

I. Introduction

An antenna is a device used to transform an RF signal, travelling on a conductor, into an electromagnetic wave in free space. Antennas demonstrate a property known as reciprocity, it means that an antenna will maintain the same characteristics regardless if it is transmitting or receiving. Most of the antennas are resonant devices, which operate efficiently over a relatively narrow frequency band. A Micro strip antenna consists of a metallic pattern on one side of a dielectric substrate and ground plane on the other side of the substrate. The antenna patch can have different shapes like square, rectangular, triangular, circular and elliptical as shown in figure 1.

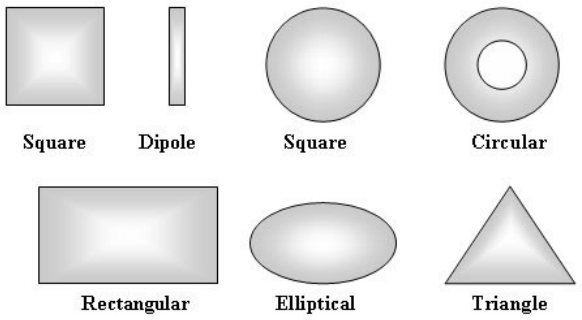

Figure 1: Different types of Micro strip patch

Micro strip 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 low dielectric constant is desirable since this provides better efficiency, larger bandwidth and better radiation but, such a configuration leads to a larger antenna size. Normally for a compact micro strip patch antenna design higher dielectric constants must be used which are less efficient and result in narrow bandwidth. Hence a compromise must be reached between antenna dimensions and antenna performance. It has been found that elliptical antenna may give better return loss, more bandwidth, good directivity and radiation pattern when we are ready to compromise somewhat over the size of antenna.

Multiple-Input Multiple-Output (MIMO) wireless communication system, which is also called Multiple-Antenna system, is well known as one of the most important technologies and widely studied nowadays (Winters, 1987; Foschini & Gans, 1998; Marzetta & Hochwald, 1999; Raleigh & Cioffi, 1998). The main idea of MIMO wireless communication is to utilize the spatial degree of freedom of the wireless multi-path channel by adopting multiple antennas at both transmit and receive ends to improve spectrum efficiency and transmission quality of the wireless communication systems. MIMO technology is able to extremely improve the transmission data rates and alleviate the conflict between the increasing demand of wireless

services and the scarce of electromagnetic spectrum. MIMO is the key technology for future wireless communication systems, such as 3GPP LTE, WiMAX 802.16, IEEE 802.20, IMT-Advanced and so on.

II. Design of Elliptical Micro Strip Patch Antenna

The micro strip inset edge fed technique is used for the design of elliptical shaped micro strip antennas at 5GHz as shown in figure 2.

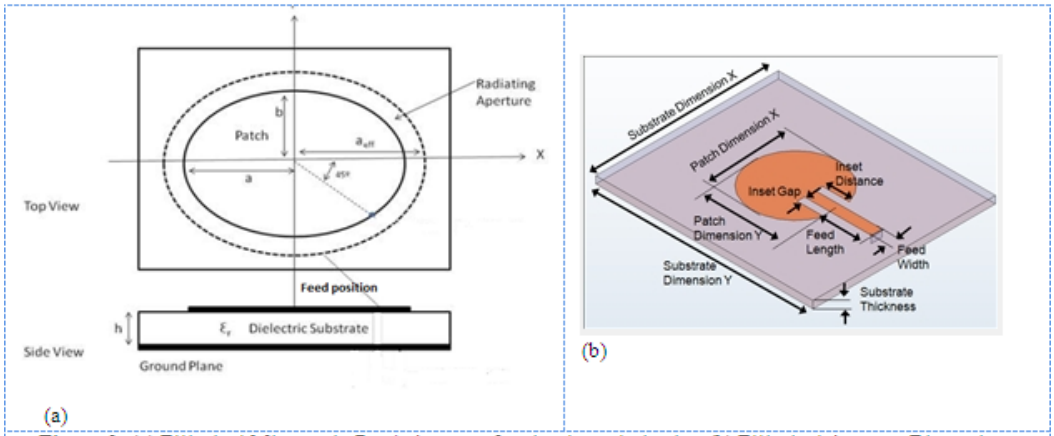

Figure 2: (a) Elliptical Micro strip Patch Antenna for circular polarisation **(b)** Elliptical Antenna Dimensions

Elliptical patch antenna is shown in Figure 2, where 'a' is the semi major axis, 'b' is the semi minor axis and 'a_{eff}' is the effective semi-major axis. The radiated fields cause two modes that are perpendicular to each other and have equal amplitude, but are 90° out of phase. An elliptical patch antenna with optimum dimensions acts as a Circular Polarized wave radiator [2].The patch is excited by a inset edge fed. The empirical formulas for calculation of dual resonance frequency using approximated Mathieu function are listed below.

$$a_{eff} = a\left[1 + \frac{2h}{\pi\epsilon_r a}\left\{\ln\left(\frac{a}{2h}\right) + (1.41\epsilon_r + 1.77) + \frac{h}{a}(0.268\epsilon_r + 1.65)\right\}\right]^{\frac{1}{2}} \quad (1)$$

$$f_{11}^{e,o} = \frac{15}{\pi e a_{eff}}\sqrt{\frac{q_{11}^{e,0}}{\epsilon_r}} \quad (2)$$

$$q_{11}^{e} = -0.0049e + 3.7888e^2 - 0.7278e^3 + 2.314e^4 \quad (3)$$

$$q_{11}^{0} = -0.0063e + 3.8316e^2 - 1.1351e^3 + 5.2229e^4 \quad (4)$$

Where
a= semi major axis, h=height of dielectric substrate, ϵ_r= permittivity of dielectric substrate, a_{eff}= effective semi-major axis, e= Eccentricity of elliptical patch, $q_{11}^{e,0}$= Approximated Mathieu function of the dominant ($TM_{11}^{e,0}$) mode, $f_{11}^{e,0}$= Dual resonance frequency

Micro-strip antenna of circular or rectangular shape usually radiate linearly polarized waves. Circular polarization may be obtained by using multiple feeds or by altering the shape of a rectangular micro strip antenna. An elliptical patch on a microwave printed circuit board can be made to radiate circularly polarized waves. Such an antenna requires only one feed and its geometrical shape is simple enough to permit theoretical analysis to be carried out in standard coordinate system. The effects of the fringe field at the edge of the elliptical patch and those of the dielectric substrate are taken into account in the below mentioned formula.

For an ellipse of semi major axis 'a' and semi minor axis 'b', the foci are at $= \pm c$, where
$c = \sqrt{(a^2 - b^2)}$, $a = \frac{p}{f\sqrt{\mu\varepsilon}}$ (5)
Where $\mu = \mu_0\mu_r$ and $\varepsilon = \varepsilon_0\varepsilon_r$ are the permeability and permittivity of the substrate respectively. p= 0.275.
The eccentricity of the ellipse is defined as E_c=c/a

The specifications used for the design of antenna are mentioned in table 1. The HFSS software tool is used because it is a high performance Full Wave Electromagnetic field simulator for arbitrary 3D volumetric

passive device modelling. It integrates simulation, visualization, solid modelling and automation in an easy to learn environment.

Table 1: Antenna Design Specifications

Substrate material (thickness=62mil)	Rogers RT Duroid 5880(tm) with $\epsilon_r = 2.2$
Patch dimension along X-axis= 2.37cm	Patch dimension along Y-axis= 1.93cm
Substrate dimension along X-axis= 4.5cm	Substrate dimension along X-axis=5.87cm
Inset distance= 0.59cm , Inset gap= 2.43cm	Feed width= 0.485 Feed length=1.828

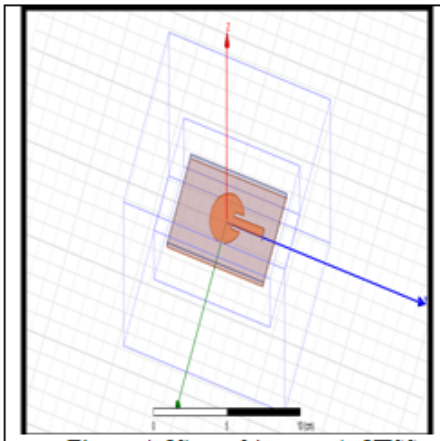

Figure 4: View of Antenna in HFSS

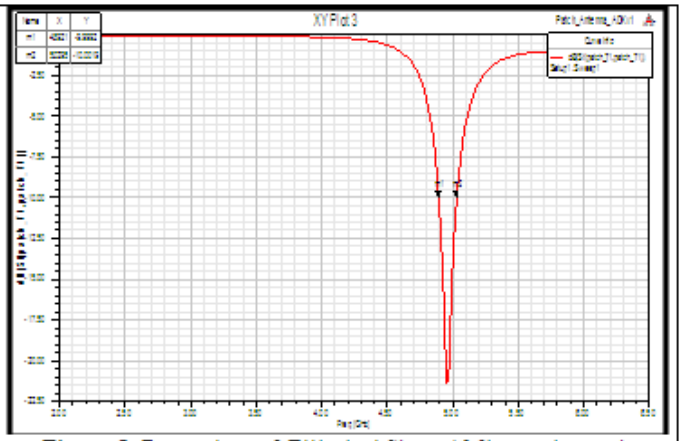

Figure 5: Return loss of Elliptical Shaped Micro strip patch antenna

The elliptical patch antenna design for single patch, 1x2 patches were simulated using Ansoft HFSS. The parameters evaluated were gain, bandwidth and return loss.

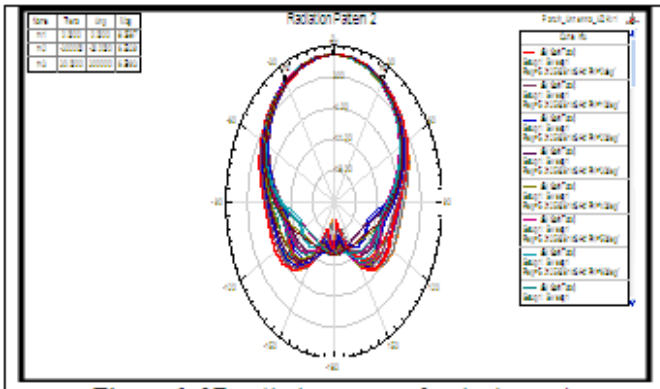

Figure 6: 3D radiation pattern for single patch

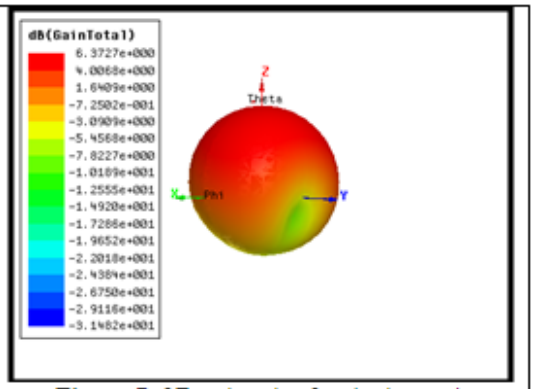

Figure 7: 3D polar plot for single patch

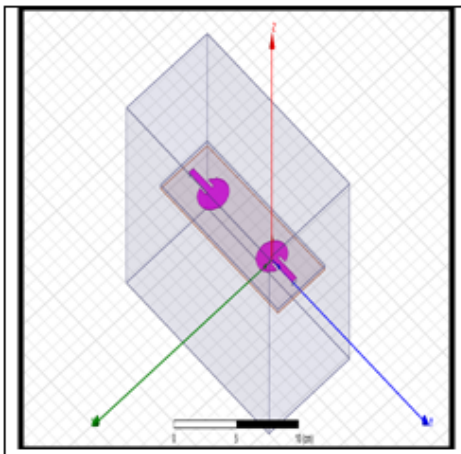

Figure 8: View of Antenna in HFSS

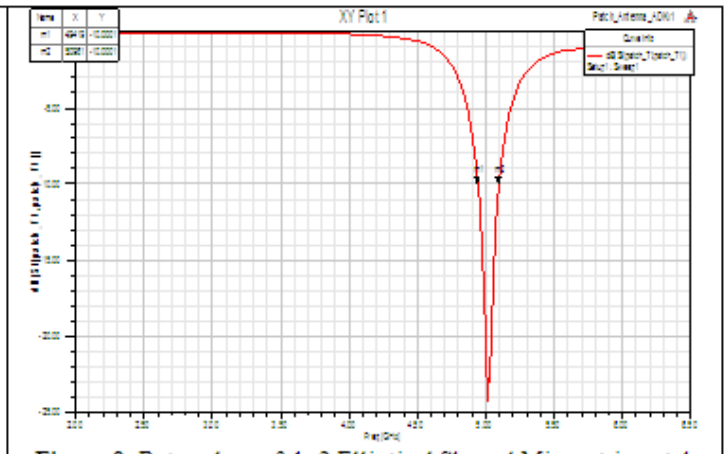

Figure 9: Return loss of 1x2 Elliptical Shaped Micro strip patch antenna

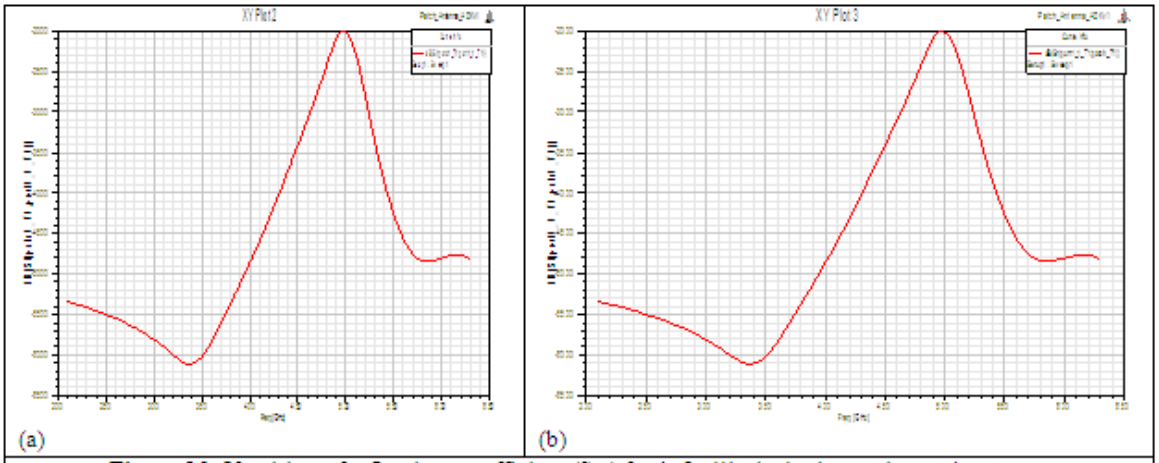

Figure 10: Varaition of reflection co-efficient (S_{11}) for 1x2 elliptical micro strip patch antenna

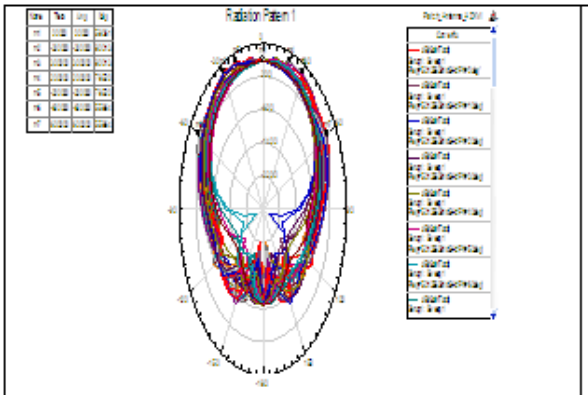

Figure 11: 3D radiation pattern for 1x2 patch

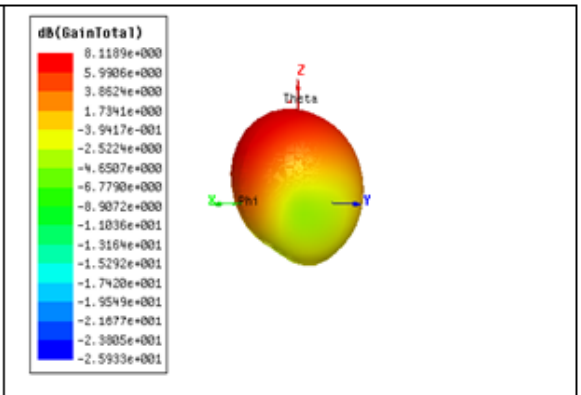

Figure 12: 3D polar plot for single patch

Table 2: Comparison of Elliptical Micro strip patch Antennas

Type of Antenna	Return Loss	Bandwidth	Radiation Pattern
Single Patch	-21.5dB	137.5MHz	Angle 0° Magnitude=8.0587 Angle 30° Magnitude=6.5339
1x2 patch	-24dB	154.2MHz	Angle 0° Magnitude=5.8061 Angle 30° Magnitude=8.0013

III. Conclusion

Elliptical shaped Micro strip Patch Antenna has been analyzed. It has been observed that to improve the bandwidth and gain of elliptical shaped antenna, a MIMO technique is used. Using the MIMO design the return loss and bandwidth had been increased. It has been found that radiation pattern also increases due to increase in number of patches. MIMO antenna also provides a better isolation.

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