Theoretical Analysis, Design, Simulation, Fabrication and Characterisation of Microstrip Patch Antenna for Wi-Fi Applications

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Abstract - This paper presents the design and simulation and fabrication of a Micro strip antenna which is suitable for S-Band applications. Different antennas are existed, but microstrip based patch antennas are used mostly in IC and PCB technologies which are required for the modern applications. Micro strip antenna consists of small conducting patch made of copper or gold which are placed on a dielectric material. The Microstrip antenna is fed by microstripinset feeding technique and studies the effect of antenna dimensions length, width and the substrate parameters like dielectric constant, substrate thickness on radiation parameters. The mode of operation is quasi TEM mode because the radiation is distributed in air and dielectric medium. This antenna is useful in applications over a frequency range of 2-4 GHz. The radiation characteristics are stimulated using HFSS17.0 Software.

Index Terms—*Microstrip Patch Antenna, Frequency bands, TEM mode, Antenna characteristics*

I. INTRODUCTION

An antenna means a transporting signal from one end to other producing EM field consisting of electric field and magnetic field. The physical radiation mechanisms can be obtained by using Maxwell's equations. The Micro strip patch antennas are present day Antenna designer's choice as it is very advantageous in weight, cost, size and its fabrication. The patch antenna is a one type of transducer that converts the electrical energy in the form of Electro Magnetic waves. These antennas are used by any radio receiver or transmitter to couple its electrical connection to the EM field. Microstrip Antennas are undeveloped until the current revolution of a miniaturized of an electronic circuits and large scale integration in 1970s.The early work of Bob Munson on Microstrip Antennas for use of low profile flush mounted antennas on missiles, rockets shows the usage in several antenna problems. In 1886 radio antenna at shorter wavelength was assembled by Heinrich Hertz and further improved over long distances by Guglielmo Marconi. In modern applications a variety of array configurations such as rectangular and circular patches on a Microstrip Antenna using enormously than conventional antennas because they are bulky and costly.

II. DESIGN OF RECTANGULAR MICROSTRIP PATCH ANTENNA

A Microstrip patch antenna consists of a small radiating patch on one side of a dielectric substrate which has a ground plane on other side. The radiating patch and feed line are usually photo etched on a dielectric substrate. The patch acts as a resonating cavity (short circuit walls on top and open circuit on the sides) made of copper and generally it is square, triangular, circular or elliptical in shapes. The dielectric material used for design of Microstrip Antenna is FR4 whose dielectric constant varies from $2.2 \leq \varepsilon_r \leq 12$. For a rectangular patch, the patch length L is usually $0.33\lambda_0 < L < 0.5\lambda_0$.The height h of the dielectric substrate is $0.033\lambda_0 < h < 0.055\lambda_0$ usually.

In cavity, only certain modes exist at different resonant frequencies i.e. if an antenna is excited at a resonant frequency a strong field set up inside a cavity and strong current on surface of patch. This produces a significant radiation due to fringing fields exist between patch and ground for achieving good antenna performance. Microstrip Antennas is fed by microstrip inset feeding technique. The purpose of inset cut in patch is to match the feed line `impedance without need for using any additional matching element. This can be achieved by controlling the position of an inset properly.

The transmission line model represents microstrip is a non -homogeneous line of two dielectrics, typically the substrate and the air. The electric field lines reside in the substrate and some parts of lines in air then it does not support TE, TM and pure TEM mode of transmission since the phase velocities are different in air and substrate. Instead of all these modes a quasi TEM mode of operation is taken in to consideration because radiation is distributed in dielectric medium and air.

Depending upon the applications and frequency of operation the antenna has to be chosen. The antenna may be in different shapes, size and even sometimes they have different configurations and logarithmic variations. For communication systems particularly in Wi-Fi and s-band applications the patch antenna is taken because its fabrication is compatible with microwave monolithic integrated circuit (MMIC) and opto electronic integrated circuit (OEIC) compared to other antennas.

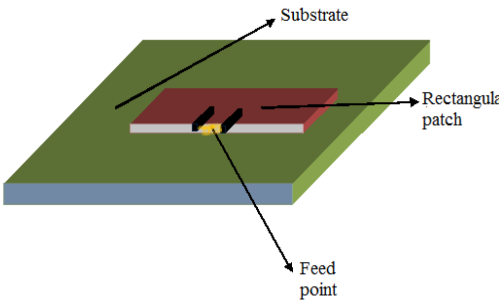

Fig.1: Microstrip Patch Antenna

2.1 Theoretical analysis for design of basic antenna

The basic antenna is designed for a resonating frequency of 2.4GHz.The material used for the substrate is FR4Eproxy which has the relativity permittivity of 4.4. The substrate thickness is designed as 1.5mm. The material for the patch is copper and material for Radiation box is Air.

The dielectric materials play important role in antenna designing process. The thick substrate with low dielectric constant gives good performance and provides better efficiency, larger bandwidth, but large antenna element. While thin substrate with higher dielectric constant provides smaller element size however because of their greater losses they are less efficient and have relatively smaller bandwidth. The performance of antenna improves when the value of dielectric constant reduces. The input impedance can be improved by using micrstripinset feeding technique because it feds antenna by choosing an optimum point which exists between center and edge. The length can be chosen of a microstrip antenna to minimize the reflected power. It is important to discuss the parameters which are analyzed during stimulation

The dimensions of the antenna can be calculated by using the following equations

1. Width (*W*):

$$W = \frac{\text{C}}{2\text{fo}\sqrt{(^{\varepsilon}\text{r}+1)/2}}$$

W= 38.03mm

2. Effective Dielectric constant (*εreff*):

$$^{\varepsilon}reff = \frac{(^{\varepsilon}r+1)}{2} + \frac{^{\varepsilon}r-1}{2}[1+12\left(\frac{h}{w}\right)]^{\wedge}(\frac{1}{2})$$

*E*reff = 4.4

3. Effective length (*Leff*):

$$Leff = \frac{\text{c}}{2\text{fo}\sqrt{^{\varepsilon}\text{reff}}}$$

$Leff$=29.795

4. Length Extension (Δ*L*):

$$\Delta L = 0.412h * \frac{(^{\varepsilon}reff+0.3)\left(\frac{W}{H}+0.264\right)}{(^{\varepsilon}reff-0.258)\left(\frac{W}{H}+0.8\right)}$$

=0.79mm

5. Actual length of patch (*L*):

The actual length is obtained by:

$$L = Leff - 2\Delta L$$

L=29mm

6. Ground Plane Dimensions (*Lg*and *Wg*):

Lg = 6h + L

Lg= 41 mm

Wg = 6h + W

Wg= 47.2mm

7. Resonant frequency

$$f_c = c/2L\sqrt{^{\varepsilon}r}$$

f_c=2.4GHz

2.2 Design of Basic Antenna

The basic antenna is designed by using copper as a conducting material and FR-4 Epoxy as a dielectric material. Here we are using microstripinset feeding technique.

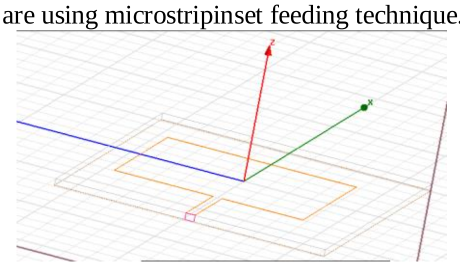
Fig.2: Basic Microstrip Patch Antenna with Inset Feed Technique

Table 1: Practical values of Inset Feed Technique

Antenna Characteristics	Inset Feed Antenna Value
Patch Length	29.46mm
Patch Width	38.01mm
Substrate Thickness	1.5mm
Substrate Length	41mm
Substrate Width	47.2mm
S-Parameter	-17.6dB
VSWR	Nearly 1
Bandwidth	100 MHz

2.3 Simulated Results of Basic Antenna

The Parameter S11 is shown in figure 3

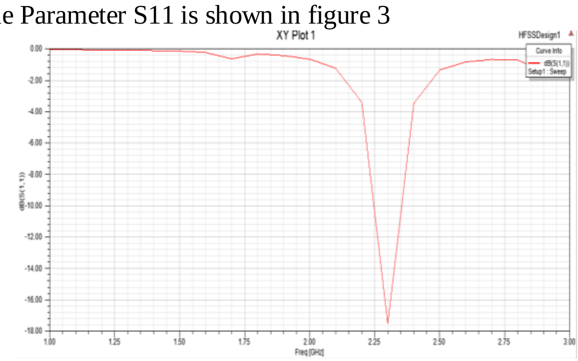

Fig.3:S11 Parameter

The parameter VSWR for designed antenna is shown figure 4

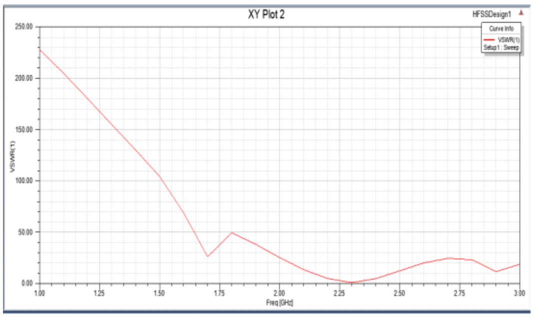

Fig.4: VSWR Measurement

The radiation pattern for designed antenna is shown figure 5

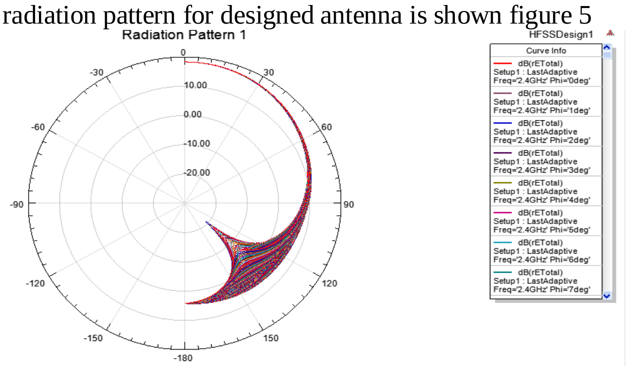

Fig.5: Radiation pattern

III. PROPOSED ANTENNA

The proposed antenna is designed for Wi-Fi applications which has resonant frequency of 2.4/5.2GHz.The material used for Substrate is FR-4 Epoxy and the material used for Patch is Copper.

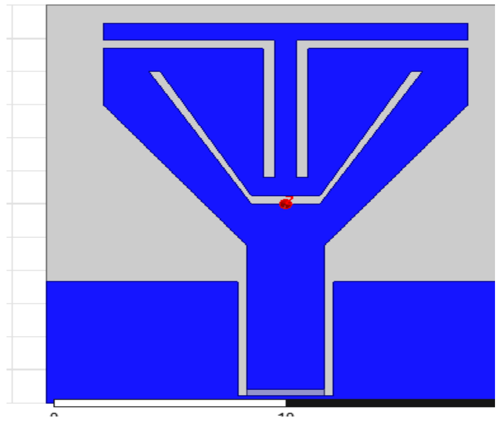

Fig.6: Proposed Antenna with CPW Feed Technique

3.1 Material Analysis

For designing of proposed antenna, the patch is generally made of conducting material such as Copper, Aluminum or Gold. We used the copper as a conducting material because copper has higher conductivity and able to with stand load surges and it is low cost compared to the other materials.

Table.2: Comparison of Different Patch Materials

Materials	**Conductivity**	**Cost**
Copper	Excellent	Medium
Aluminum	Very good	Low
Gold	Good	High

The dielectric materials are FR-4, RogersRo4350, TaconicTLE, and RTDuroid. We used FR4 material as a dielectric material because FR-4 has a low dielectric constant, thick substrate, easily available, it retain its high mechanical values and electrical insulating qualities in both dry and humid conditions.

Table 3: Comparison of Different substrate materials

Substrate	**Dielectric constant** (ε_r)	**Loss tangent (δ)**
FR-4 Epoxy	4.4	0.002
Rogers R04350	3.66	0.004
Taconic TLE	2.95	0.0028
RTDuroid 5880	2.2	0.0009

Table 4: Different types of Feeding Techniques

Characteristics	Micro strip line feed	Co-axial feed	Aperture coupled feed	Proximity coupled feed	Co-planar waveguide
Spurious feed radiation	More	More	More	Minimum	Less
Reliability	Better	Poor due to soldering	Good	Good	Good
Ease of fabrication	Easy	Soldering and drilling needed	Alignment required	Alignment Required	Alignment Required
Impedance matching	Easy	Easy	Easy	Easy	Easy
Band width	2-5%	2-5%	21%	13%	3%

3.3 SIMULATED RESULTS FOR PROPOSED ANTENNA

The Three analytical parameters, S11, VSWR and Radiation pattern were observed and compared for both simulation results and laboratory measurements. The return loss (S11) was simulated for the proposed patch over a frequency range from (0 to 10GHz). As seen in figure.7, the best results were achieved at different frequencies corresponding to the return loss magnitude which are below -10db. The lowest return loss magnitude at -19.50db.This satisfy standard antenna return loss criteria for any Particular operating frequency.

3.2 Methods of feeding

Microstrip patch antennas can be fed by a variety of methods. These methods can be classified into two categories- contacting and non-contacting. In the contacting method, the RF power is fed directly to the radiating patch using a connecting element. In the non-contacting scheme, electromagnetic field coupling is done to transfer power between the feed and the radiating patch. Feeding technique influences the input impedance and polarization characterization of the antenna. There are four most common structures that are used to feed planar printed antennas. There are co-axial feed, microstripline feed, co-planar waveguide and proximity coupled feeds. For designing of proposed antenna, we are using co-planar waveguide as a feeding technique because it has less spurious feed radiation and reliability is good

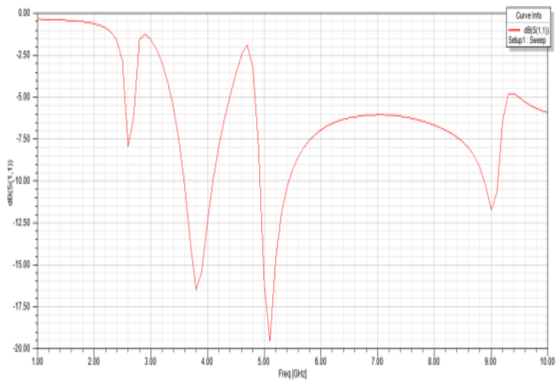

Fig.7: S11 parameter

The voltage standing wave ratio (VSWR) is a measure of how efficiently radio frequency power is transmitted from a power source, through a transmission line in to a load. The VSWR for the proposed antenna as shown figure 8

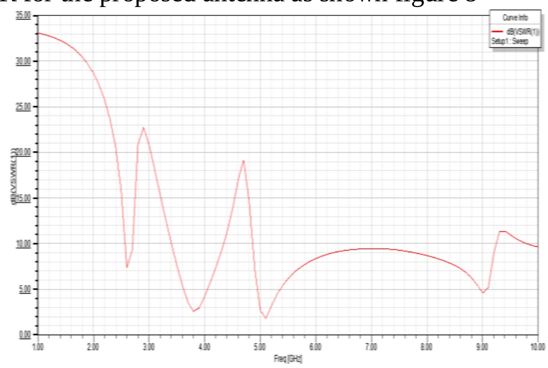

Fig.8: VSWR Measurement

The radiation pattern refers to the direction of the electromagnetic waves radiates away from the antenna. The radiation pattern for the proposed antenna as shown figure 9

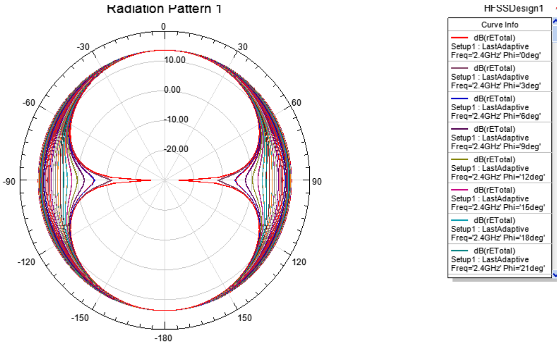

Fig.9: Radiation Pattern

3.4 FABRICATION OF PROPOSEDANTENNA

As the design of the proposed antenna is analyzed and simulated on the HFSS17.0 simulation software. That design is to be converted into another format which may include many format s such as Gerber, AutoCAD DXF, BMP file and many more. We have used DXF file format and given it to the automatic antenna fabricating machine (LPKF Protomat S100 PCB plotter) and thus machine as shown figure 10

Fig.10: PCB Plotter

Fig.11:Fabricated Antenna

3.5 CHARACTRISATION OF PROPOSED ANTENNA

The combinational analyzer is an instrument used for analyzing the graphs for the fabricated antenna. The fabricated antenna is connected to the probe of the combinational analyzer

Fig.11: Combinational Analyzer

The graphs for proposed antenna are shown in Figure12

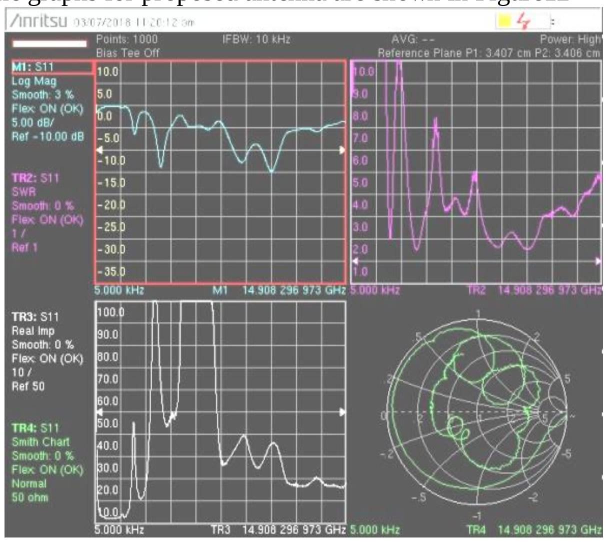

Fig.12: Different Parameters of Antenna

Table 5: Present work Comparison with Literature

Parameter	Reference1	Reference2	Reference3	Reference4	This Work
Dielectric material	Rogers R04350	Rogers 5870	RogersDuroid 5880,FR4	Rogers/RT Duroid 5870	FR4-Epoxy
Feeding	Microstripline feeding	Aperture coupled feeding	Capacitive feeding	Printed meandering probe feeding	Co-planar waveguide feeding
Connector	Co-axial	-	-	SMA	Co-axial
Return loss	-14,-19.7dB	-13.5dB	-20,-18dB	-30dB	-19.50dB
Gain	8.3dBi,7.8dBi	8.2dBi	6.2dBi	6.7dBi	5dBi
Resonant frequency	1.95GHz,2.4GHz	5GHz	1.575GHz,2.4GHz	5.2GHz	2.4GHz,5GHz
Software	CST microwave studio	HFSS	CST microwave studio	HFSS	HFSS
Band	Dual band	Single band	Dual band	Single band	Dual band
Fabrication	Done	Done	Done	Done	Done

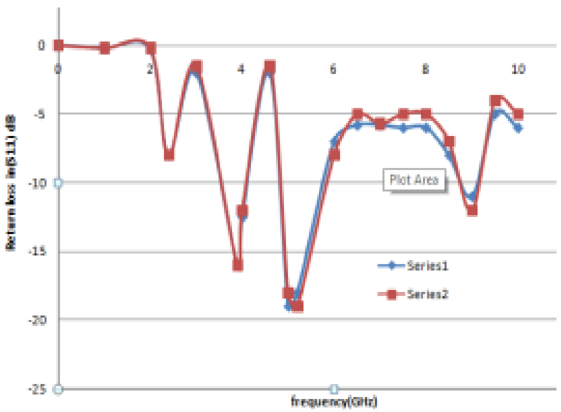

Fig.13: S-11 Parameter

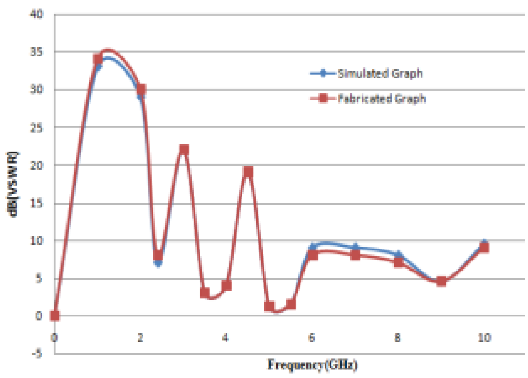

Fig.14: VSWR Measurement

IV. CONCUSION

Based on the analysis done in this paper, it is clear that the proposed patch antenna gives an operating frequency range of nearly 2.4GHz/5.2GHz in both simulation and fabrication process and in analysis we got the return loss -8dB at 2.4GHz and -19dB at nearly 5.2GHz and VSWR is 1.3 at 5.2GHz. It is suitable in s-band applications like Wi-Fi modules.

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