

Structural Analysis and Design of Micro Strip Antenna for S-Band Applications

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Abstract—This paper presents the design and implementation of a two 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. Due to its low profile structure Micro strip antenna consists of small conducting patch made of copper or gold which are placed on a dielectric material. In this paper two antennas are designed one is the Microstrip antenna is fed by inset feeding technique for linear polarisation and other is circular polarised corner truncated MPA fed by coaxial feeding technique for getting circular polarization. This work also studies the effect of antenna dimensions length, width and the substrate parameters dielectric constant, substrate thickness on radiation parameters. This antenna is useful in Wi-Fi and mobile applications over a frequency range of 2-4 GHz. The radiation characteristics such as VSWR which gives nearly 1, bandwidth 180 MHz, and scattering parameter -18 dB, is obtained and are simulated using FEM Tool Software

Index Terms—Micro strip Patch Antenna, Frequency bands, S-band, 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 [1]. 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 [3]. Most wireless communication systems use either linear (vertical, horizontal) or circular

polarization. Knowing the difference between polarizations can help maximize system performance for the user.

II. MICRO STRIP PATCH ANTENNA

A Micro strip antenna consists of a small radiating patch on one side of a dielectric substrate which has a ground plane on one side. The radiating patch and feed lines is usually photo etched on a dielectric substrate [2]. 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 [4]. The dielectric material used for design of Microstrip Antenna is FR4 whose dielectric constant varies from $2.2 \leq \epsilon_r \leq 12$. 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.

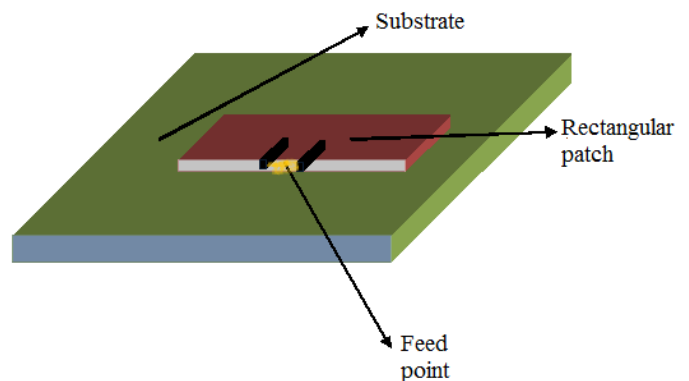


Figure 1: Micro strip antenna

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 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 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 WIFI 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

II. THEORETICAL ANALYSIS

The substrate with high dielectric constant is taken in account as it reduces the antenna dimensions i.e. the dielectric constant increases the length and width of the ground plane decreases[6]. This leads to the increase in the performance of a patch antenna. The input impedance can be improved by using inset feeding technique because it feeds antenna by choosing an optimum point which exists between center and edge [7]. 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 .They are

Gain [8] is defined as the ratio of the radiation intensity in a given direction to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically Or Gain is the ratio of the power required at the input of a loss-free reference antenna to the power supplied to the input of the given antenna to produce, in a given direction, the same field strength at the same distance and it is given by

$$G_{dBi} = 10 \log_{10}(\eta \ 4 \ \pi A / \lambda^2) \tag{Eq.-1}$$

The bandwidth of an antenna refers to the range of frequencies over which the antenna can operate correctly

$$\text{Bandwidth} = f_2 - f_1$$

Where f_2 is upper cut off frequency
 f_1 is lower cut off frequency

The Directivity is the measure of power density that antenna radiates in the direction of strongest emission Directivity of a MPA is

$$D = \frac{2h^2 E_0^2 W'^2 K_0^2}{P_r \pi \eta_0} \tag{Eq.-2}$$

Where h is the height of the substrate, $W' = w+h$, E_0 is the magnitude of the z-directed electric field intensity.

$$E_z = E_0 \cos \frac{m\pi x}{L} \cos \frac{n\pi y}{W} \tag{Eq.-3}$$

VSWR gives a quick way of estimated how much power is reflected by an antenna and it can be calculated as

$$SWR = \frac{1 + abs(emw.S_{11})}{1 - abs(emw.S_{11})} \tag{Eq.-4}$$

The calculation of width is accomplished by using this formula

$$W = \frac{c}{2f_0 \sqrt{\frac{\epsilon_r + 1}{2}}}$$

The length of the patch can be calculated as

$$L = \frac{C}{2f_0 \sqrt{\epsilon_{reff}}} - 0.824h \left(\frac{(\epsilon_{reff} + 0.3) \left(\frac{W}{h} + 0.264\right)}{(\epsilon_{reff} - 0.258) \left(\frac{W}{h} + 0.8\right)} \right) \tag{Eq.-5}$$

The frequency of operation of the patch antenna is determined by the length L. the central frequency F_c approximately equal to

$$F_c \cong \frac{1}{2L \sqrt{\epsilon_0 \epsilon_r \mu_0}} \tag{Eq.-6}$$

Where c is the velocity of the light, ϵ_0 and μ_0 are the permittivity and permeability of the free space, ϵ_r is the permittivity of the dielectric substrate. The actual length of an antenna is

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

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \frac{1}{\sqrt{1 + 12 \frac{h}{w}}}$$

The characteristic impedance [11] of inset feed micro strip patch antenna can be calculated as

$$Z_0 = \frac{120\pi}{\sqrt{E_{reff} \left(1.33 + \frac{w}{h} + \frac{2}{3} \ln \left(\frac{w}{h} + 1.444 \right) \right)}} \tag{Eq.-7}$$

Cmsol automatically generates variables for the S-parameters. The port numbers determine the variable names. the software generates the variables S11_emw. S11_emw is the S-parameter for the reflected wave variables for the S-parameters on a dB scale, S11dB_emw, is also defined using the following relation:

$$S_{11dB} = 20 \log_{10}(|S_{11}|) \tag{Eq.-8}$$

III. PROPOSED PATCH ANTENNAS

It is necessary to design antennas with very high directive characteristics to meet the demand of long distance communication Inset feed excitation technique provides more gain and perfect impedance matching as compared to the other feed excitation technique. Also the main advantage of this

feeding technique is that feed can be given anywhere inside the patch which makes easier fabrication compared to other feed technique.

Polarisation is an important design consideration. The polarisation of each antenna in a system should be properly aligned.

- Maximum signal strength between stations occurs when both stations are using identical polarization.
- In linear polarisation the view is not clear; so most users prefer circular polarization as they are not fully educated on the benefits or the price sensitivity towards equipment.
- It increases the signal strength reliability, resistance to weather conditions, and ease of installation but technically circular polarisation is better than linear polarisation.
- But linear polarisation has its own criteria i.e. the specific equipment costs are marginally less and in this work the inset feed MPA gives linear polarization.

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 such as a microstrip line. In the non-contacting scheme, electromagnetic field coupling is done to transfer power between the microstrip line and the radiating patch.

A. INSET FED BASED LINEAR POLARISED ANTENNA

In Inset feed technique, a conducting strip is connected directly to the edge of the Microstrip patch The conducting strip is smaller in width as compared to the patch and this kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure.

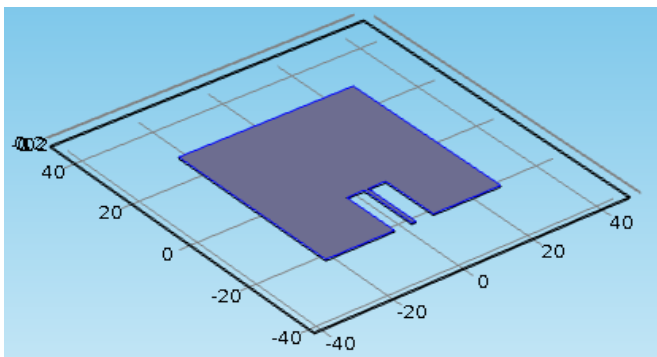


Figure 2: Inset feed Linear Polarised Microstrip Antenna

B.COAXIAL FEED CIRCULAR POLARISED ANTENNA

For getting circular polarisation radiation [14], a patch must support orthogonal fields of equal magnitude but in-phase quadrature. This requirement can be accomplished by

single patch with proper excitations or by an array of patches with an appropriate arrangement and phasing.

A single point feed patch capable of producing Circular Polarised radiation is very desirable in situations where it is difficult to accommodate dual-orthogonal feeds with a power divider network.

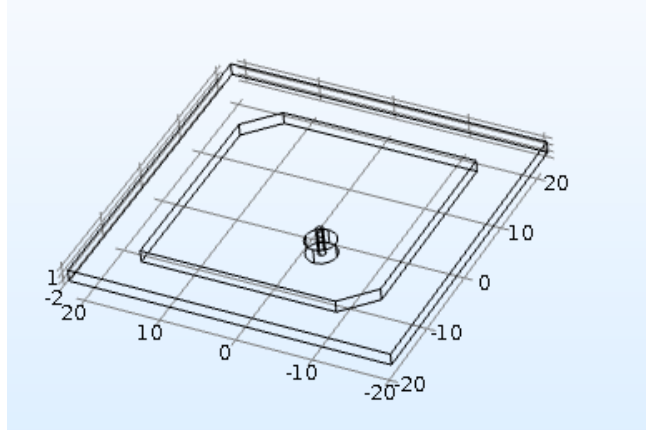


Figure 3: Circular polarised Microstrip antenna in FEM Tool

This can be accomplished by slightly perturbing a patch at appropriate locations with respect to the feed. Figure 3 show the circular polarised antenna truncated at corners and the feed is placed on the diagonal axis of the patch. Note that the feed is always located diagonal to perturbation segments that are appropriately selected to produce two orthogonally degenerate modes in the patch for Circular Polarised radiation.

IV. DESIGN AND SIMULATION

In this paper we designed and simulated two types of patch antennas one is linear polarized patch antenna and other one is circular polarized patch antenna.

A. DESIGN OF LINEAR POLARISED ANTENNA

In theoretical calculations the operating frequency is 2.4GHz and also in practical 2.4GHz is obtained and it is in the S-band range i.e.2-4GHz.By observing below table the operating frequency is depends upon the dimensions and the dielectric constant ϵ_r .

Table 1: Effect of dimensions on Antenna operating frequency

Microstrip Length (L)& Width(W) in mm	Height (mm)	ϵ_r	Operating Frequency, f_0 (GHz)
50,50	0.5	3.38	1.63
34,30	0.5	3.38	2.403
34,30	2	3.38	2.38
34,30	4	3.38	2.3238
34,30	0.5	2	3.104
34,30	0.5	4	2.21
34,30	0.5	6	1.81

By comparing both practical and theoretical values the proposed antenna have length $L=34\text{mm}$ and width $W=30\text{mm}$ is which gives about 2.35GHz in practical but in theoretical 2.32GHz obtained suitable for S-band frequency range. This antenna can be easily fabricated on substrate due to its small size and thickness [9].

Table 2: Dimensions of Inset feed linear polarised Antenna

Dimensions For proposed antenna	Inset feed linear polarised MPA
Patch Length	36.609mm
Patch Width	29.158mm
Substrate thickness	1.6mm
Substrate width	47.20mm
Substrate length	47.20mm

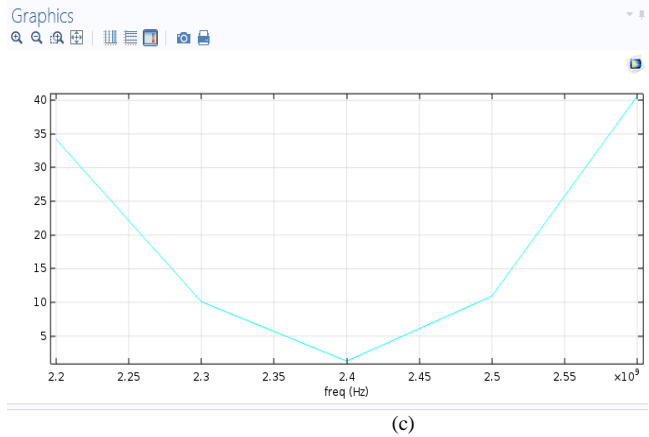
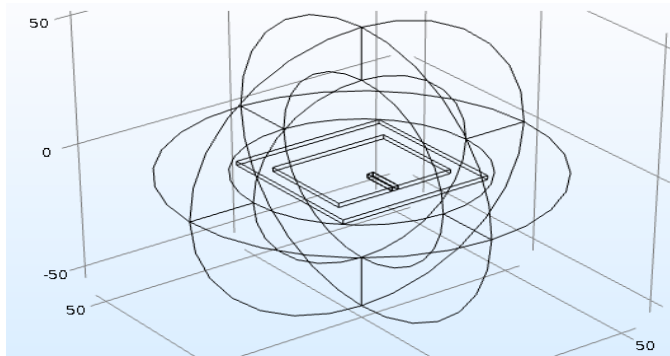


Figure 4: Linear Polarised Inset feed Microstrip antenna
(a) Radiation plot (b) Bandwidth (c) VSWR



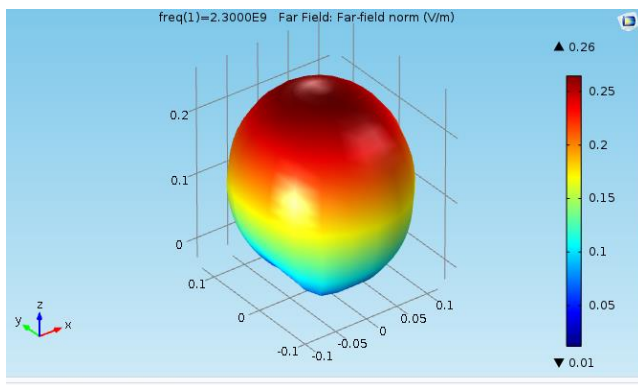
Antenna Radiation plot tells about where the power is being radiated and received and easy to find the antenna characteristics from the plot directly. The outer edge of the plot is the maximum gain of the antenna. These plots are complex in the real world as it is 3D so often Cartesian coordinate system is used.

B. DESIGN OF CIRCULAR POLARISED ANTENNA

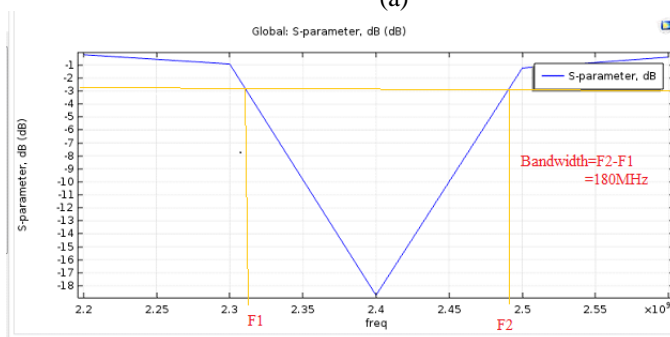
Table 3 shows the practical results of coaxial feed circular polarised micro strip antenna suitable in s-band as it operating frequency is 2.4GHz is presented

Table 3: Results of coaxial feed circular polarised MPA

Parameter	Practical values for circular polarised MPA
Gain	7db
VSWR	1
Operating frequency	2.4GHz
Bandwidth	180MHz
S-parameter	-18dB
Dielectric Constant	3.38



(a)

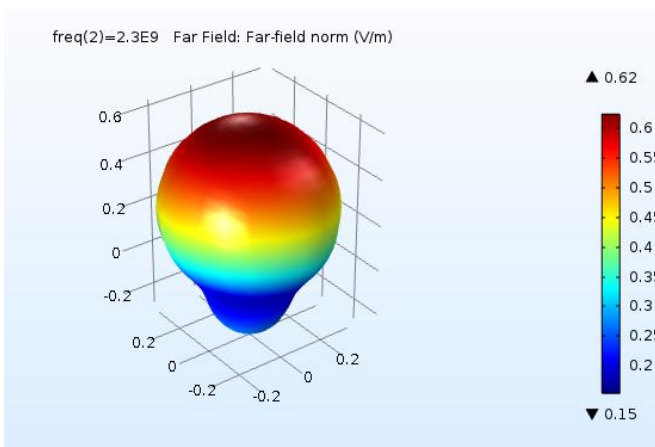
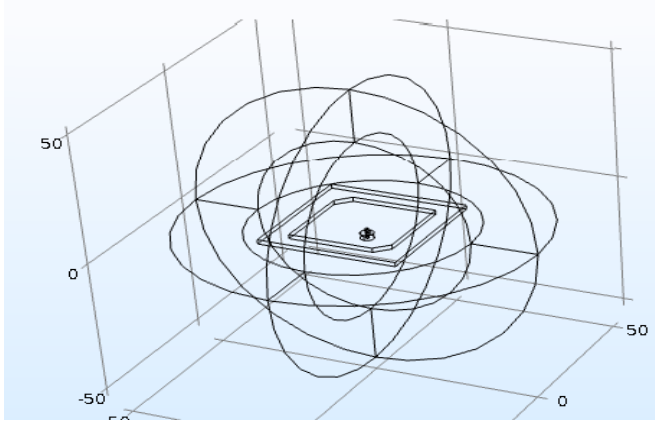


(b)

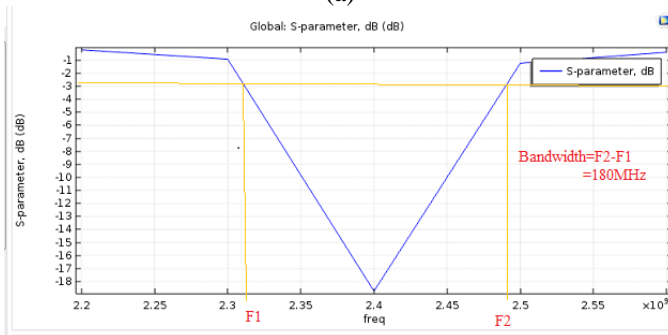
Table 4 shows the Dimensions of inset feed linear polarised and circular polarised coaxial feed antennas

Table 4: Dimensions of coaxial feed circular polarised antenna

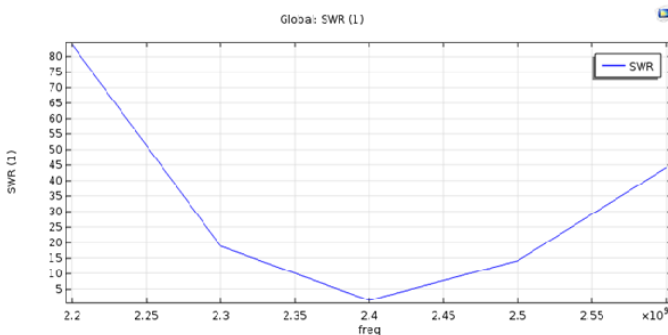
Dimensions For proposed antenna	Coaxial feed circular polarised MPA
Probe Length	29.15mm
Patch Width	37.60mm
thickness	1.6mm



(a)



(b)



(c)

Figure 5: Circular Polarized Coaxial feed Microstrip antenna (a) Radiation plot (b) 3D Polar Plot (c) Band width (d) VSWR

Table 5: Comparison of proposed circular polarised antenna with previous antennas

Antenna	Frequency Band (GHz)	Dielectric material	CP frequency (GHz)
Antenna in ref. [10]	2.453-2.490	FR-4	2.47
Antenna in ref. [13]	1.25-1.575	RO-3006	1.227
Proposed Antenna	2.32-2.49	FR-4	2.4

V. CONCLUSION

The antenna characteristics are simulated using Comsol Multiphysics. It is clear that the Rectangular patch dimensions such as Length (L), Width (W) of 47 mm and Height (H) of 1.6mm gives an operating frequency range of 2.4 GHz and which gives linear polarization and the coaxial fed corner truncated circular polarized MPA operates in 2.4 GHz of frequency, both antenna get s_{11} -18dB which is suitable in s-band. The antenna dimensions such as length and width decreases the frequency may increases. A structural analysis between different patch dimensions is analyzed and shows the effect of dielectric constant leads to slightly variation in the frequency the height doesn't shows much impact on frequency is observed using FEM Tool.

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