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Design and Development of Micro-strip Patch Antenna for Wi-Fi Applications

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ABSTRACT: The design of dual band (2.400 – 2.488 GHz) microstrip patch antenna for Wi-Fi application is presented in this paper. The antenna is designed using a copper strip having dimensions 39.5 mm (length) x 9.75 mm (width) x 0.5 mm (thickness). The center portion of the strip is shorted with a strip. Two L- slots are cut into both the arms to create two radiating dipole arms. Dimensions of the two dipole arms are adjusted to 15.25 mm (length) x 1.85mm (width) and 13.25 mm (length) x 4.25 mm (width) for optimal performance. The antenna is fed using a SMA connector, connected to a 50Ω coaxial cable. The results show significant improvement over the existing designs.

KEYWORDS: Wi-Fi, Bandwidth, Micro-strip patch, Slots, SMA connector.

I.INTRODUCTION

Antenna (radio), also known as an aerial, a transducer designed to transmit or receive electromagnetic (e.g. TV or radio) waves. (N. Cohen, 1997). Television antenna (or TV aerial), is an antenna specifically designed for the reception of broadcast television signals. The Institute of Electrical and Electronics Engineers (IEEE) defines an antenna as “that part of a transmitting or receiving system that is designed to radiate or receive electromagnetic waves”. (N. Cohen, 1997).

With the continuously increasing number of users who connect to the Internet wirelessly, it has become a challenge to provide connectivity everywhere and that too with high data rates. Several measures have been taken to meet this increasing need of high speed connectivity. In 2009, IEEE defined the 802.11n standard for wireless data connections. According to this standard, the maximum possible speed for WLAN was increased to 600Mbps (IEEE, 2009). This standard also permits use of MIMO to improve data rate (IEEE, 2009), along with the high data rate, there is also the requirement of providing connectivity at the places like hotels, offices, college campuses etc. with high quality service. To solve this problem, best solution is to install sector antennas within these areas. But the problem involved with installing sector antennas is that the locations, at which the antennas are to be placed, are not always suitable to place multiple antennas at desired positions. To overcome this problem dual band micro-strip patch antennas are designed which are capable of accepting input from multiple sources and work on a wide band of frequency.

A micro-strip patch antenna (MPA) consists of a patch on side of a dielectric subsrate and a ground plane on other side. They are compact, light in weight, posses planar geometry and has low fabrication cost. The patc is made of conducting material such as copper, gold, tin, nickel. These metals are widely used because they are quite easy to solder. A feedline is used for excitation. There are four main feeding techniques used which are coaial probe feed, micro-strip line feed, aperture couplingh and proximity coupling. Among all the feeding techniques micro-strip line feed is the most common and widely used technique.

Micro-strip slot antennas are created by cutting slots on the metal surface. There are varieties of shapes of slots available such as T slot, U slot, C slot, S slot etc. With the introduction of slots, there is improvement in bandwidth, gain, reduction in size etc. Both micro-strip patch antenna and slot antennas have thin profile. Both are easy to fabricate. The bandwidth of micro-strip patch antennas is 2-50% whereas of micro-strip slot antennas are 5-30%. Thus how to downsize an antenna without degrading its bandwidth is the design policy while designing compact antennas.

II.ANTENNA TECHNOLOGY

- Antenna tower, a tall tower designed to support antennas (also known as aerials in the UK) for telecommunications and broadcasting.
- Dipole antenna, a simple antenna usually constructed from two wires in opposite phases placed end to end.
- Horn antenna, a type of directional antenna shaped like a horn.
- Metamaterial antenna, a class of antenna incorporating metamaterials to increase performance of miniaturized (electrically small) antenna systems.
- Parabolic antenna, an antenna shaped like a parabola in one or both planes.
- Power antenna (automotive) is an electrically motorized automotive radio antenna that raises and lowers either manually with a dash mounted switch or automatically by turning the radio on or off.
- Antenna (film), a satirical 1969 Dutch film directed by Adriaan Ditvoorst.
- “Antenna”, an episode of the Adult Swim animated television series, Aqua Teen Hunger Force.
- Antenna Awards, an annual awards ceremony that recognizes outstanding community television programs broadcast on Australia’s Channel 31 stations.

III.WLAN FREQUENCY BANDS FOR DESIGNED ANTENNA

The IEEE 802.11 standard has been designated for wireless local area network (WLAN) service in 2.4 GHz (2400~2484 MHz).

IEEE standards 802.11a, b, g, n are designated for WLAN applications with the following standards (IEEE notes, 2009).

- IEEE 802.11b : Wireless network bearer operating in the 2.4 GHz ISM band with data rate up to 11 Mbps
- IEEE 802.11g : Wireless network bearer operating in the 2.4 GHz ISM band with data rate up to 54 Mbps

- IEEE 802.11n: Wireless network bearer operating in the 2.5GHz ISM band with data rate up to 600 Mbps and use of multiple antennas.

IV.ANTENNA DESIGN

To manufacture the required microstrip patch antenna, first of all an elementary metal plate dual band antenna is fabricated which radiates efficiently at required frequency bands of WLAN standard. Using this antenna, two designs of fractal antennas are created. Four sections of these fractal antenna designs are then placed inside a single radome to create the required microstrip patch antenna. The required resonance frequencies are obtained by parameter variation such as changing the bridge width or position (2).The rectangular patch antenna can be designed (5) using the equations as shown in Equations (1)-(5).

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+12\frac{W}{h}\right)^{0.5} \quad (1)$$

$$\Delta L = 0.412h\frac{(\varepsilon_{eff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{eff}-0.258)(\frac{W}{h}+0.8)} \quad (2)$$

$$L_{eff} = L + 2\Delta L \quad (3)$$

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}} \quad (4)$$

$$W = \frac{c}{2f_r\sqrt{\frac{\varepsilon_r+1}{2}}} \quad (5)$$

The following are the details of notations used in all the above Equations (1) - (5).

f_r - Resonant frequency(GHz)

c - Speed of light (m/sec)

a_e - Effective radius(mm)

ε_r - Relative permittivity.

ε_{eff} - Effective permittivity

h - Thickness of the substrate (mm)

a - Radius of patch (mm)

W - Width of the patch (mm)

L - Extension of the length (mm)

L_{eff} - Effective length of the patch (mm)

Table 1- Design Parameters

Antenna	**Parameters**	**Dimensions**
	Resonant Frequency	2.4GHz, 5.5 GHz
	Dielectric Constant	4.4
Rectangular Patch	Length of the patch	12.4mm
	Width of the patch	16.59mm
Connecting Strip	Length of horizontal strip	6.5mm
	Length of vertical strip	3.25mm
Feed-	Length of the strip	15mm
	Width of the strip	2mm
Ground/Substrate plane	Length of the plane	40mm
	Width of the plane	50mm

DIMENSIONS OF MICRO-STRIP PATCH ANTENNA

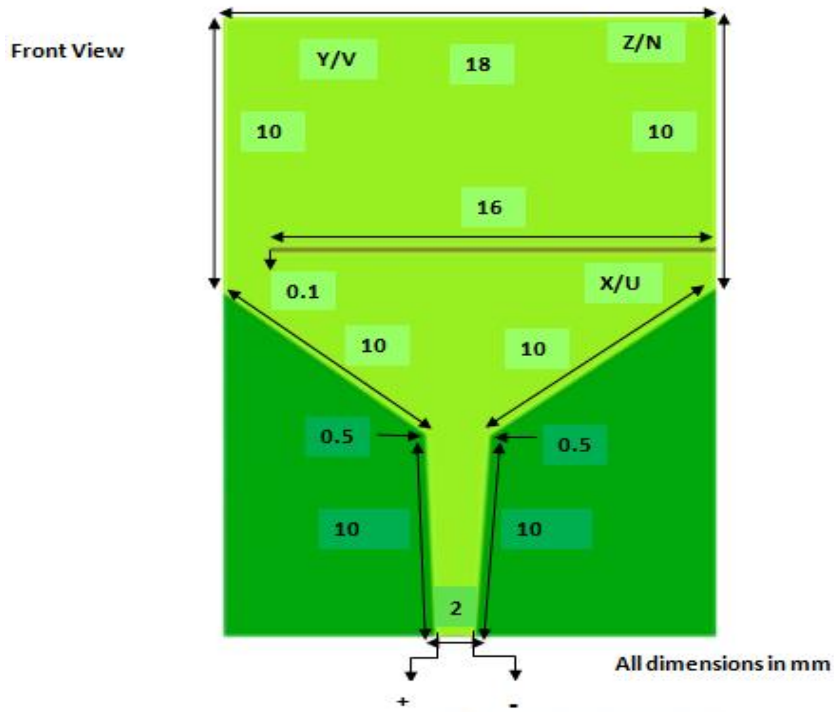

Fig. 1- Front View

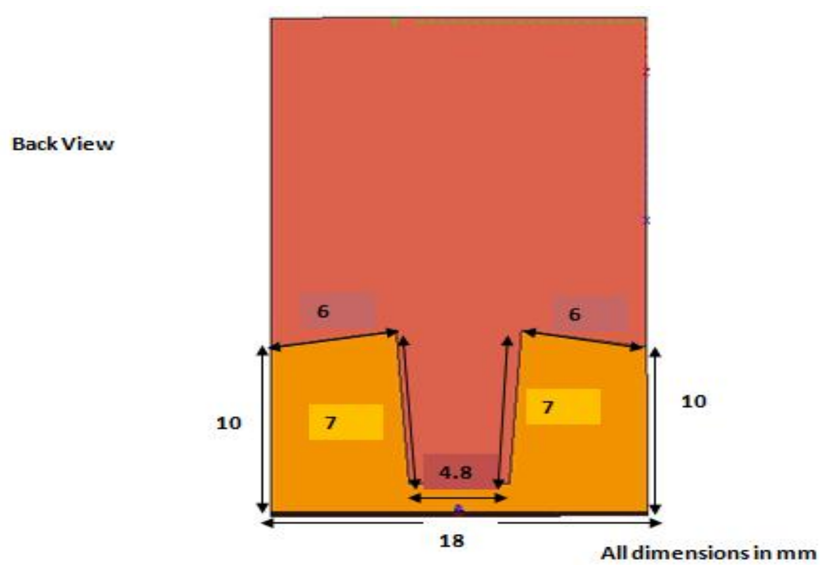

Fig.2- Back View

V.SOFTWARE DESIGN

The elementary antenna is designed and simulated using EMSS FEKO v 6.1. The software has different modules for designing and result analysis. CADFEKO is used for designing of the antenna and POSTFEKO is used to view the simulation results.

EMSS FEKO

FEKO is a comprehensive electromagnetic simulation software tool, based on state of the art computational electro-magnetic (CEM) techniques. It enables users to solve a wide range of electromagnetic problems.

The multiple solution techniques available within FEKO make it applicable to a wide range of problems for a large array of industries. Typical applications include:

- Antennas: analysis of horns, microstrip patches, wire antennas, reflector antennas, conformal antennas, broadband antennas, arrays
- Antenna placement: analysis of antenna radiation patterns, radiation hazard zones, etc. with an antenna placed on a large structure, e.g. ship, aircraft, armored car
- EMC: analysis of diverse EMC problems including shielding effectiveness of an enclosure, cable coupling analysis in complex environments, e.g. wiring in a car, radiation hazard analysis
- Bio-electro-magnetic: analysis of homogeneous or non-homogeneous bodies, SAR extraction
- RF components: analysis of waveguide structures, e.g. filter, slotted antennas, directional couplers
- 3D EM circuits: analysis of microstrip filters, couplers, inductors, etc.
- Radomes: analysis of multiple dielectric layers in a large structure.
- Scattering problems: RCS analysis of large and small structures.

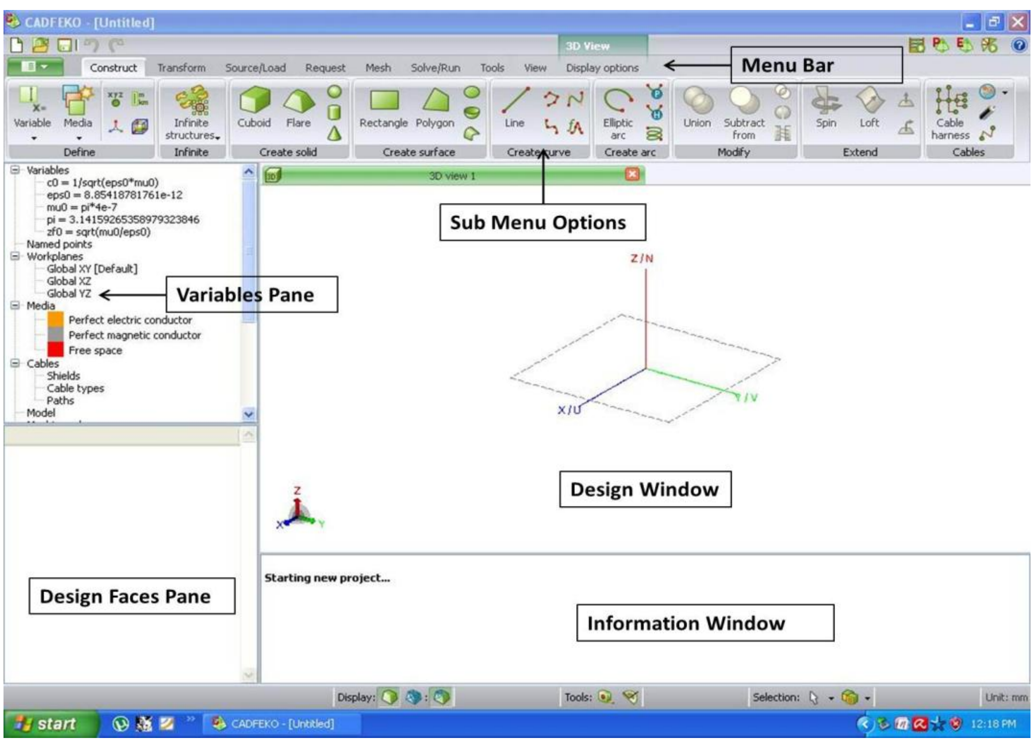

Fig.3: Screenshot of EMSS CADFEKO with various interface units

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Fig. 3 shows the screenshot of EMSS CADFEKO. The CADFEKO v6.1 Window can be divided into following parts

a) Menu Bar: The bar at the top with all the menu options. Clicking on these options will open subsequent submenu options.
b) Sub Menu Options: Just below the Menu bar, lies the sub menu pane. Here we can select all the options for creating, meshing and solving antenna designs.
c) Variables pane: This pane contains definition of all the variables in a design, including the voltage, frequency and other design variables
d) Design Faces Pane: This pane displays the edges and faces of the antenna, which is designed in the design window. This pane is used to access properties of faces and edges of the antenna.
e) Information Window: This pane gives the information about processing and error messages while designing and simulating the antenna.
f) Design Window: This window is the workspace to create the required design. The design can be rotated in 3 dimensions with proper scaling features.

VI.ANTENNA FABRICATION

The simulated designed is fabricated as shown in Fig. 4The antenna is fabricated using FR-4 substrate of thickness 1.6 mm. The desired shape is achieved by preparing the mask of the simulated design and then the prepared mask is printed on the PCB for etching process and finally the SMA port is soldered for power supply

Fig. Front View Back View

VII.RESULT AND DISCUSSIONS

The simulated results of the proposed micro-strip patch antenna design are discussed here. The results of the fabricated antenna obtained after VNA testing are also discussed here in this section.

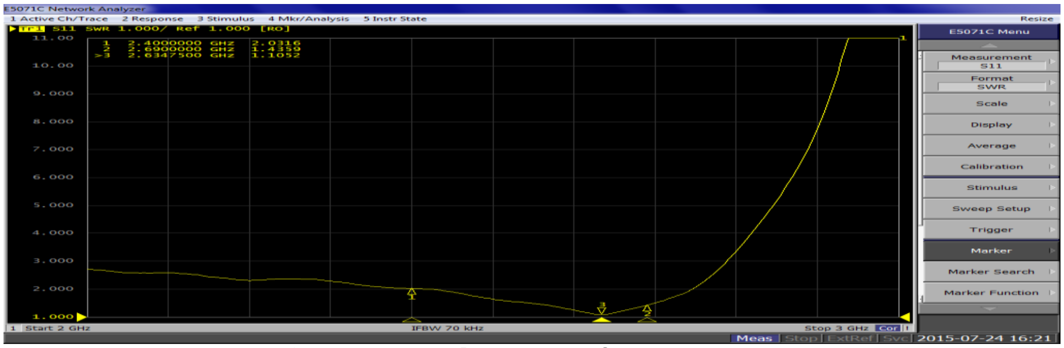


Fig. 5: Measured VSWR vs. frequency curve on VNA

Fig. 6: Measured return loss vs. frequency curve on VNA

Fig 5 and 6 shows the measured radiation pattern of the antenna on Virtual Network Analyzer. The VNA used for measurement is Anritsu make VNA Master MS2025B. The frequency range of VNA is 500 KHz – 6 GHz. The fig. reveals that the measured radiation pattern is in accordance with the simulated radiation pattern. Return loss of -10dB is obtained for both frequency bands. For lower band, the minimum value of return loss is -9.2936 dB at 2.400 GHz and for upper band, it is -25.914 dB at 2.488 GHz.

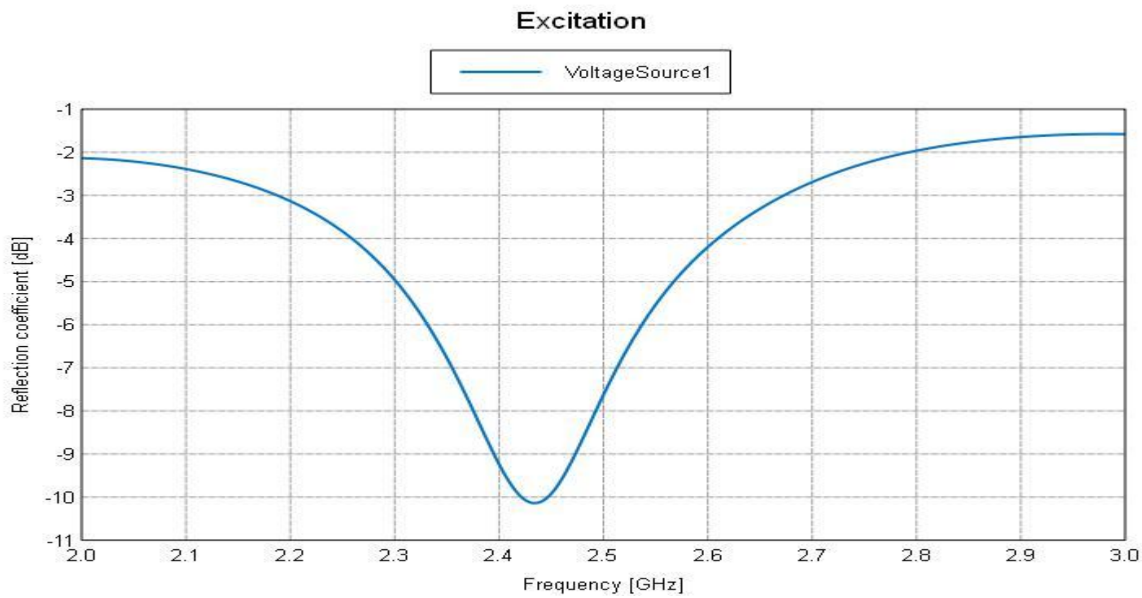
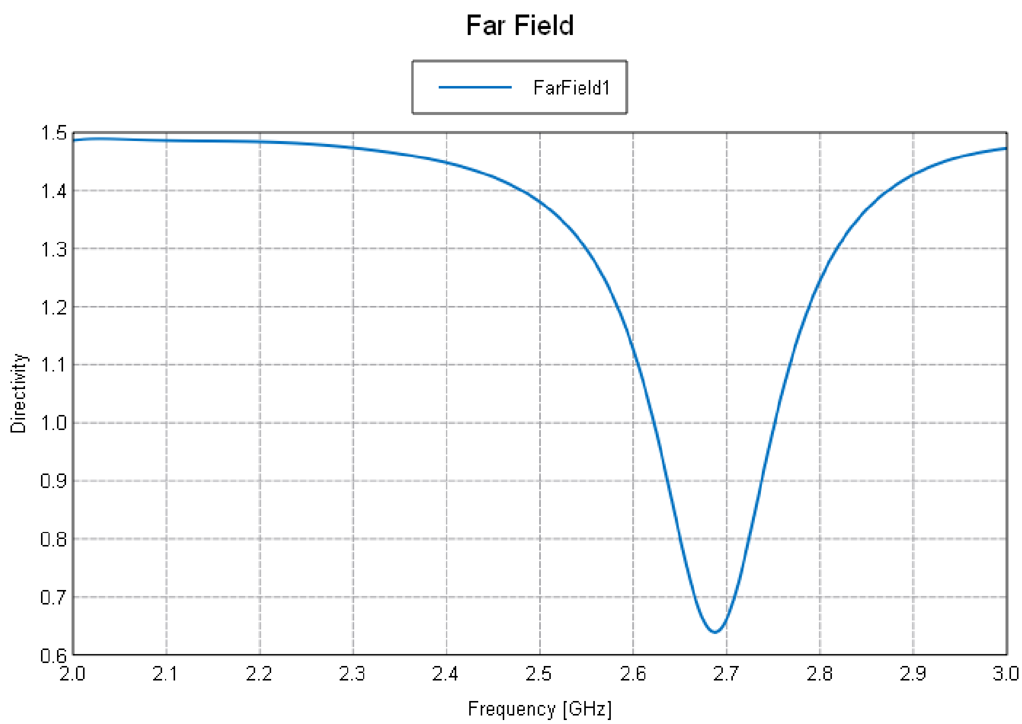


Fig. 7- Return Loss

The proposed antenna achieves return loss >7dB (Fig. 7) for entire frequency range. This corresponds to VSWR <2.6. The Peak value of return lose is 10.2dB at 2434 MHz. The antenna achieves peak gain of -1.6dBi at 2.4GHz which falls to -4.6dBi at 2.488 GHz.



Total Directivity (Theta = 0 deg; Phi = 0 deg.)

Fig. 8 : Directivity XY plane vs. frequency

Fig 8. Shows directivity of antenna on XY plane. It shows that the antenna has directivity of 1.4 to 1.45 in the desired frequency range. This corresponds to the high power front lobe of XY plane. It depicts that antenna is not perfectly omnidirectional.

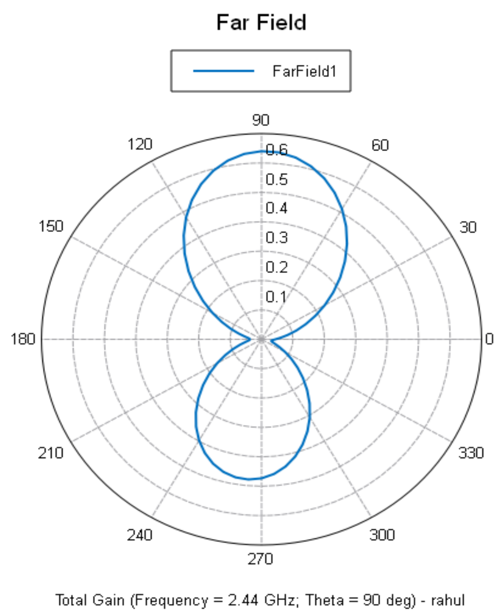


Fig 9: XY plane radiation

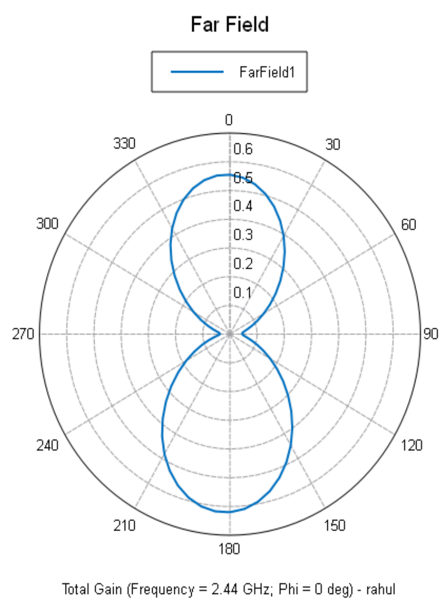


Fig. 10 : XZ plane radiation

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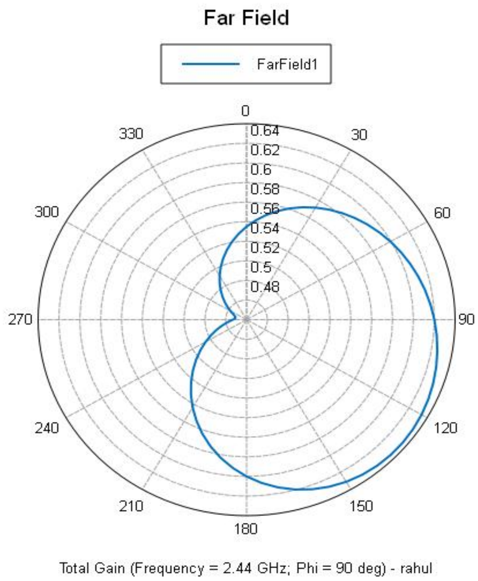

Fig. 11: YZ plane radiation

Fig. 9-11 shows the radiation pattern of the proposed antenna at 2.444 GHz. It shows doughnut like pattern similar to a dipole antenna. The front lobe is slightly bigger than the back lobe which normally occurs that high frequencies. This may be attributed to uneven shape of the antenna which results in current flow variations.

Similarly Fig. 10 shows the XZ plane radiation pattern. Radiation pattern is still doughnut like similar to that of a dipole antenna.

Fig. 11 shows the YZ plane radiation pattern of the antenna at 2444 MHz

The radiation cover right half of the plane. The pattern corresponds to sectorial radiation pattern with beam width of about 120◦.

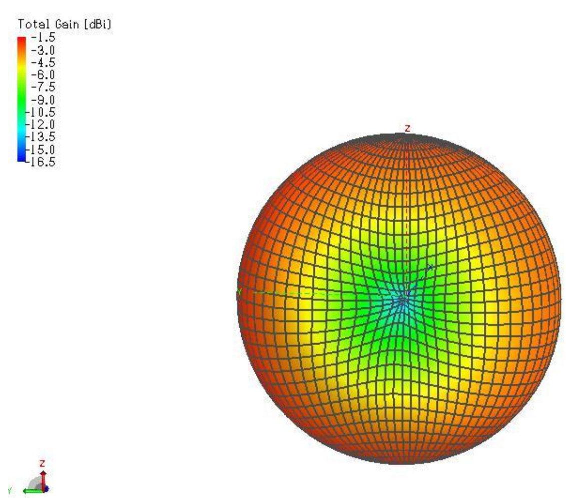

Fig. 12

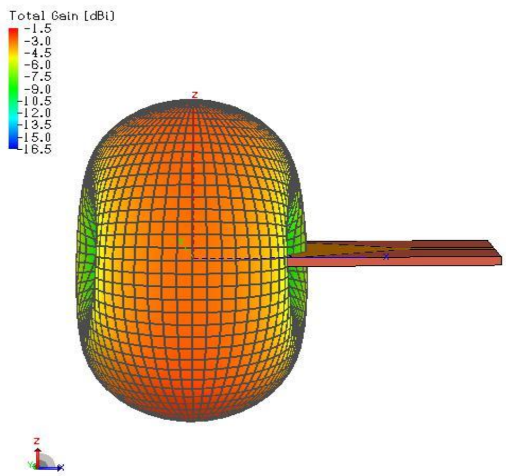

Fig. 13

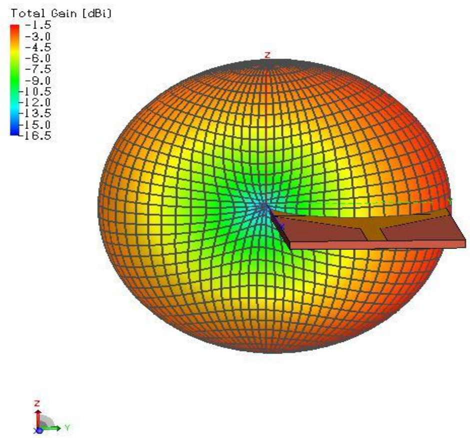

Fig. 14

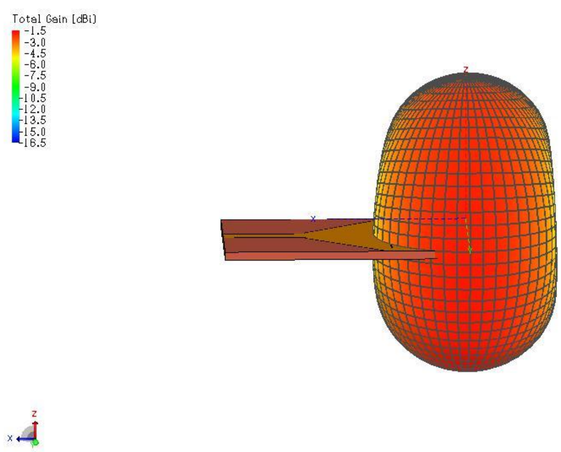

Fig. 15

Fig : (12) (13) (14) & (15) shows 3 Dimensional Radiation Patterns.

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Table 2: Simulation results of the Micro-strip patch antenna

PARAMETER	SPECIFICATIONS
	In 2.4GHz band
Frequency Range	2.400GHz-2.488GHz
Gain	-1.6 dBi at 2.4, -4.6 dBi at 2.488 GHz
VSWR	< 2
Polarization	Circular
Return Loss	>7dB
Impedance	50 Ohms
Size	180 X 160 mm X 100mm

VII. CONCLUSIONS

In this paper, the design of dual band microstrip patch antenna (2.400 GHz – 2.488 GHz) was proposed. The proposed antenna achieves return loss > 7dB for entire frequency range. This corresponds to VSWR < 2. The peak value for return loss is 10.2 dB at 2.4 GHz. The antenna achieves peak gain of -1.6 dBi at 2.4 GHz which falls to -4.6 dBi at 2.488 GHz.

VIII.ACKNOWLEDGEMENT

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