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Compact Dual Band Microstrip Patch Antenna for Wi-Fi/Bluetooth/ Wi-Max Applications

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Abstract

In today's world of wireless communication, recent developments in wireless communication industry continue to derive requirement of small, compatible and affordable microstrip patch antennas. Several types of microstrip multiband antennas are being proposed by researchers and the process still goes on. For ease of fabricating mobile handsets, printed planer internal antennas have been designed to be integrated with ground planes and system circuits on the same substrates. Along with the several advantages of microstrip patch antenna it shows some limitaion like narrow bandwidth.Therefore, multiband antennas offers best option to overcome these drawbacks by using several techniques to enhance bandwidth of microstrip patch. This paper presents a compact dual band microstip patch antenna with S-shaped band pass filter. The designed antenna had 40mm width and 40mm length and is designed using a substrate material FR-4 with thickness of 1.6mm. Patch dimensions of 20mm by 15mm is designed at a resonating frequencies 2.4 GHz and 5.1 GHz. Simulation is carried out using CST Microwave Studio. In the simulation process different feed positions are optimized to the individual patch to get the appropriate results. Simulated design shows a maximum magnitude of 5.94 dBi for 2.4 GHz and 5.41dBi for 5.1 GHz.

Keywords: Microstripe patch antenna, Multiband, Compatible, Affordable, Band pass filter

I. INTRODUCTION

This current age of Science and Technology has developed the wireless communication system that demands for multiband operating antenna capable to be embedded in portable devices because of their advantageous features like light weight, high gain and high efficient characteristics. A patch antenna is a narrowband, wide beam antenna fabricated by etching the antenna element pattern in metal trace bonded to an insulating dielectric substrate such as a printed circuit board with a continuous metal layer bonded to the opposite side of the substrate which forms a ground plane. The electromagnetic waves is produced by an antenna which is so called transducer because it transform electric current in to EM waves and by receiving vice versa. Radiation of antenna by changing the current inside a conductor wire is the concept of radiations of antenna. By accelerating or decelerating the current in a straight wire, the current will create a flow which makes the antenna radiate, if current will not flow, antenna never radiate. Common microstrip antenna shapes are square, rectangular, circular and elliptical, but any continuous shape is possible. The resulting structure is less rugged but has a wider bandwidth because such antennas have a very low profile, are mechanically rugged and can be shaped to conform to the curving skin of a vehicle. They are often mounted on the exterior of aircraft and spacecraft or incorporated into mobile radio communication devices. Microstrip antennas are the best choice for wireless devices because of their structured characteristics like low profile, ease of fabrication and low cost. Since it is common practice to combine several radios into one wireless and use single antenna, microstrip antenna suffers from disadvantages like they have less bandwidth and gain. In this paper a compact dual band microstrip patch antenna with S-shaped band pass filter has been designed for wireless applications such as WiFi, Bluetooth, WiMax, etc.

The fundamental specifications used in the patch antennas are,

i. Gain

Gain of an antenna 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.

ii. Radiation Pattern

Radiation pattern is a mathematical function or graphical representation of the radiation properties of the antenna as a function of space co-ordinates. The term radiation pattern refers to the directional dependence of the energy of the radio waves from the antenna or different source.

iii. Antenna Efficiency

It is a ratio of total power radiated by an antenna to the input power of an antenna. Antenna efficiency means how effectively the antenna receives or transmit the signal.

$$\text{Efficiency}, \eta = P_{radiated}/P_{input}$$

where,

η = Antenna efficiency

$P_{radiated}$= Total radiated power

P_{input} = Total input power

iv. Resonant Frequency

Frequency at which the response amplitude of a device is maximum is known as the system’s resonant frequency. At these frequency, even small periodic driving forces can produce large amplitude oscillations, because the system stores vibration energy. Resonance occurs when a system is able to store and easily transfer energy between two or more different storage modes.

v. Bandwidth

Bandwidth is the range of frequencies over which the antenna maintains its characteristics and parameters. i.e. bandwidth is the difference between the highest frequency signal component and the lowest frequency signal component.

vi. Voltage Standing Wave Ratio

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Voltage standing wave ratio is the ratio of maximum voltage to the minimum voltage in a standing wave. $VSWR = V_{max} / V_{min}$

Generally it is a measure of how efficiently radio frequency power is transmitted from a power source, through a transmission line, into a load. The value of VSWR should lie between 1 and 2.

vii. Return Loss(S_{11})

Return loss is the loss of power in the signal returned/reflected by a discontinuity in a transmission line or Return loss is the reflection of signal power from the insertion of a device in a transmission line. This discontinuity can be a mismatch with the terminating load or with a device inserted in the line. Return loss is a measure of how well devices or lines are matched.The antenna is one port device. Hence the scattering parameter S_{11} acts as return loss.

II. MICROSTRIP PATCH ANTENNA

Microstrip patch antenna a kind of radio antenna with a low profile, which can be mounted on a flat surface. It comprises of a flat rectangular sheet of metal, mounted over a larger sheet of metal called a ground plane. It is a single-layer design which consists generally of four parts. They are patch, ground plane, substrate, and the feeding part. Patch antenna is shown in Figure 1.

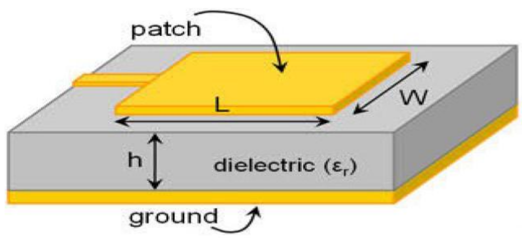

Figure 1: Patch Antenna

Patch antenna is a single element resonant antenna. It consists of a conducting patch of any planar or nonplanar geometry on one side of a dielectric substrate with a ground plane on other side. It is a popular printed resonant antenna. They are mostly used at microwave frequencies. The rectangular and circular patches are the basic and most commonly used microstrip antennas. These patches are used for the simplest and the most demanding applications.

i. Multifunctional Microstrip Patch Antenna

Multifunctional Microstrip Patch Antenna for Linear Polarization is presented by N.Mithilesh[3]. The proposed antenna is suggested to be used in a mobile phone handset that covers dual frequency bands which include GSM 1900 (1850-1990MHz) and Bluetooth(2400-2483.5MHz). The simulation of the antenna is performed using a High Frequency Selective Surface (HFSS) software. Analysis for return loss, VSWR, gain and radiation pattern were carried out. The proposed antenna

shows return loss of -34dB at 1.9GHz (Horizontal polarized) and -24dB at 2.4GHz (Vertical polarized) which implies[3] good results. The impedance matching is good at the desired frequencies. The overall simulation results shows that the antenna worked well at the desired

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two frequencies and hence making the antenna suitable for use at same time for wireless applications.

iii. Circular Shaped Microstrip Patch Antenna

Sachin Kumar Jain and Atal Rai (2014) proposed a circular shaped microstrip antenna through an inset feed. Simulation results show that the designed antenna can be used as a dual frequency antenna with effective return loss of -33.43 dB and -35.90 dB at 1.609GHz and 2.239GHz respectively. The dual band operation of the proposed antenna[8] is due to two exited modes (TM01& TM11) for the proposed antenna TM11 is the fundamental as well as the dominant mode. The two modes have the similar broadside radiation characteristics and same polarization planes.

ii. Rectangular Microstrip Patch Antenna

Design of dual-band rectangular microstrip patch antenna with defected ground plane[11] is presented. The design concept is to have two slots etched out from the ground plane of a microstrip patch antenna designed for 2.5 Ghz operation to enable second frequency band 3.5 GHz operation. The positions of etched slots are determined using parametric analysis to meet the objectives of large impedance bandwidth and high gain in the desired bands and mismatching in the undesired bands. The proposed antenna provides wide impedance bandwidths of 13.56% (2.3-2.7 GHz) and 10.36% (3.3-3.7 GHz) at centre frequencies of 2.5 GHz and 3.5 GHz, respectively. The gains in E-Plane are 6.7 dB and 5.1 dB, and the gains in H-Plane are 6.5 dB and 4.88 dB, for 2.5 GHz and 3.5 GHz, respectively. The proposed dual-band antenna shows monopole-like radiation patterns with higher gains as compared to monopole antennas.

iv. E–Shaped Microstrip Patch Antenna

E–Shaped microstrip patch antenna using different substrate materials is presented in[10] by Sohaib Abbas Zaidi and Tripathy M.R. They designed a patch antenna using FR4- epoxy and epoxykevlar

material. The permittivity of FR4-epoxy and epoxy-kevlar was 4.4 and 3.6 respectively. The return loss, radiation pattern and gain of the proposed antenna showed that it has promising characteristics for various wireless communication applications. The effect of changing the permittivity of the substrate was also studied. It was analysed that how antenna performance[12] varies while changing the value of dielectric constant. The proposed antenna was coaxially fed. The design was simulated using HFSS (High Frequency Selective Surface) software.

v. Circularly Polarized Microstrip Patch Antenna

Novel design of a circularly polarized linear patch antenna array fed [13] by a coplanar waveguide (CPW) is presented. The array elements are placed in the direction transverse to the feeding CPW line and are excited by a couple of 100 slotlines, which are combined to form the 50 feeding CPW. A novel circularly polarized patch array [14] fed by a slotted waveguide is proposed. Optimized circular polarization is achieved with a split truncated patch flexibly. Improved bandwidth and efficiency are obtained by utilizing the feeding waveguide.

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III. DESIGN METHODOLOGY

Conventional microstrip antennas suffer from narrow bandwidth. Increasing frequency results in larger size. This is a challenge for this type of antenna. Make one better results in degrading the other. From other side, compact antenna is a need for portable mobile devices. These make researchers to improve the antenna's methods have been suggested for upgrading size and bandwidth of antenna. Increasing substrate thickness, using low dielectric substrate, using impedance matching and feeding techniques and using slot geometry in antennas are some methods for improvement of bandwidth and size. The main objective is to improve the bandwidth of the microstrip antenna while retaining other desired parameters. Filter is used for this purpose. The designed antenna is resonate at 2.4GHz and 5.1GHz.

i. Antenna Design

The proposed antenna comprises a rectangular patch with S-shaped filter. It was simulated using CST Microwave Studio. The designed structure of antenna had width of 40mm and length 40mm. For optimal simulation, the width was taken as 50mm and length was taken as 50mm. The substrate thickness is calculated as 1.6mm for chosen material FR-4. The patch dimensions are carefully chosen for the frequency bands 2.4 GHz and 5.1 GHz as length of 20mm and width as 15mm. Filter consists of two hairpin structures. Both the resonators form a single S-shaped filter that filters 2.4GHz and 5.1 Ghz. The top view of the simulated antenna is shown in figure 2.

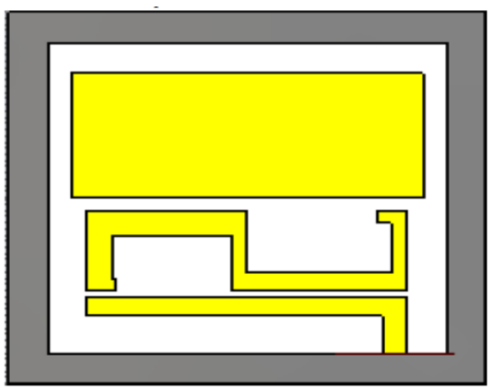

Figure 2: Designed Antenna

Filter section is chosen in such a way that it is non-contacting the patch but coupled with patch through proximity coupling. Dimensions of the filters are matched with the patch for optimum scaling. Upper resonator has length of 20mm and width of 2mm for each strip. Similarly the lower resonator has the same length and width of the upper resonator itself. The width of the feed line is 2mm and length is 6mm.

ii. Design Equations

The dimensions of the rectangular microstrip antenna are calculated using the equations (1) to (5).

Patch Width,

$$W = \frac{c_0}{2f_r}\sqrt{\frac{2}{\xi_r+1}} \qquad (1)$$

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where,

c_0 – velocity of light
f_r – resonant frequency
ε_r – relative permittivity

Effective length,

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

Patch length,

$$L = \frac{c}{2f_r\sqrt{\xi_{reff}}} - 2\Delta LE \quad (3)$$

Effective permittivity,

$$\varepsilon_{ref} = \left\{\frac{\varepsilon_r+1}{2}\right\} + \left\{\frac{\varepsilon_r-1}{2}\right\} * \frac{1}{\sqrt{1+\frac{12*h}{w}}} \quad (4)$$

Changing length to hight,

$$\frac{\Delta L}{h} = 0.412\frac{(\xi_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\xi_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad (5)$$

iii. Calculations for the Required Specification

The above equations are used for designing the patch antenna with desired specifications. Before starting the calculations it is necessary to assume three essential parameters.

a. Frequency of operation

The resonant frequency of the antenna must be selected appropriately. Most of the wireless applications run on ISM band. Because the band is free to use without any restrictions. Only the transmitting power has to be limited within the specified prescribed limit 2.4 GHz is the common frequency for Wi-Fi and Bluetooth, 5.1 GHz for Wi-Max technologies. Nowadays for increasing the bandwidth it is necessary to go for higher frequencies. Increasing the frequency further reduces the interference so 5.1 GHz is selected.

b. Dielectric constant of the substrate

The dielectric material selected for this design is FR-4 which has a dielectric constant for 4.4. A substrate with high dielectric constant has been selected since it reduces the dimensions of the antenna.

c. Height of dielectric substrate

For the microstrip patch antenna to be used in wireless applications it is essential that the antenna is not bulky. Hence, the height of the dielectric substrate is selected as 1.6mm. Hence the essential parameters for the design are,

f_r = 2.4 GHz and 5.1 GHz

$\varepsilon_r = 4.4$

h = 1.6mm.

The following Table 1 presents the dimensions of the designed patch antenna.

Parameters	Dimension
Length of the patch	20 mm
Breadth of the patch	15 mm
Dielectric constant	4.4
Feed strip length	6mm
Feed strip width	2mm
Thickness	0.2mm

Table 1: Dimensions of the designed patch antenna

IV. RESULT AND DISCUSSION

In accordance with the procedure explained in the previous chapters, a single antenna that operates on frequencies 2.4GHz and 5.1 GHz was designed using CST Microwave Studio. For simulation copper annealed is chosen for strip lines and patch. FR-4 is chosen for the substrate.The results obtained from the simulation are demonstrated and discussed in this chapter.

i. Fabricated Antenna

The overall design provides a better mechanical support for the patch and also gives better radiation pattern. Since the radiation is perpendicular to patch, filtering of undesired frequencies by the filters because some amount of radiation loss. The loss can be reduced by introducing optimized layouts. Optimization can cause changing of substrate this in turn increases the cost of the antenna. Figure 3 shows front view of the fabricated antenna.

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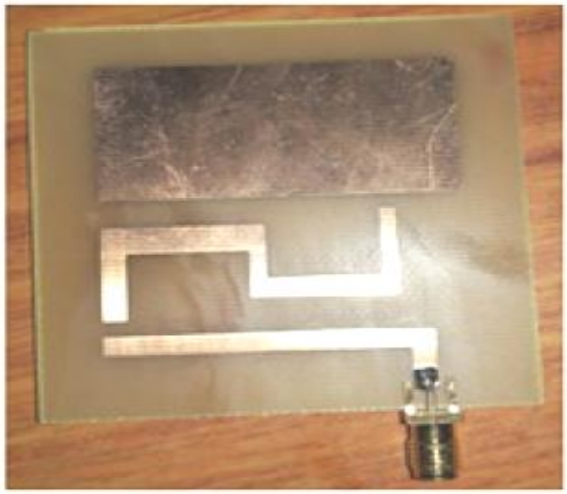

Figure 3: Front View of Fabricated Antenna

ii. Simulation Results

a. Return loss

Return loss is the difference in decibel power between power sent towards antenna under test and power reflected. The acceptable value for reflection coefficient for wireless devices is to be less than or equal to -10dB. The designed antenna's return loss is shown in Figure 4.

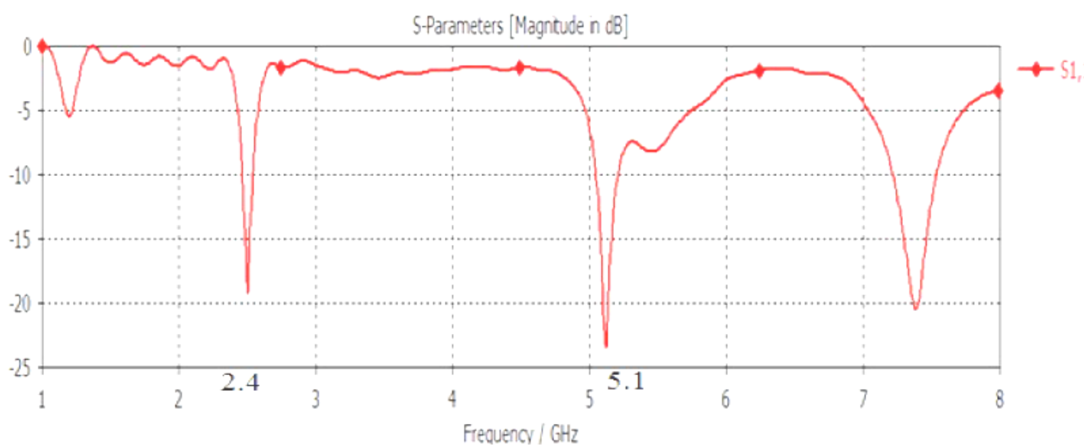

Figure 4: Simulated Antenna's S-Parameter

At the operating frequency 2.4 GHz the return loss is -19dB which is less than -10dB and at 5.1 GHz the return loss is -24dB. At the center frequency the return loss is minimum.

b. Voltage Standing Wave Ratio

Voltage standing wave ratio is a measure of how well the components of the RF network are matched with impedance. In other words, VSWR is defined as the ratio of the maximum

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voltage to the minimum voltage in the standing wave. Figure 5 shows the designed antenna's VSWR.

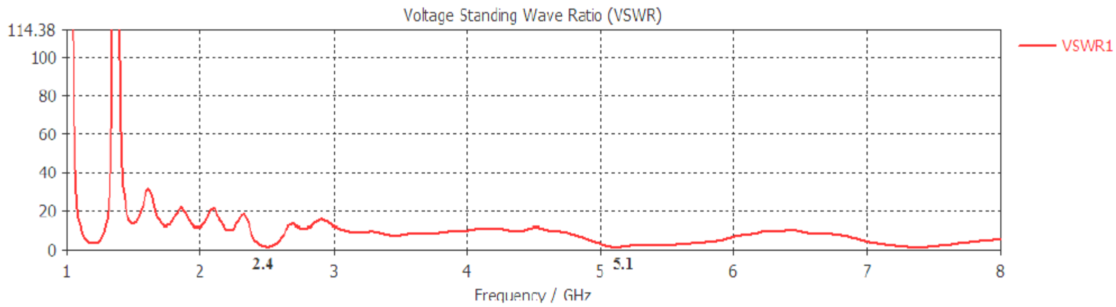

Figure 5: Simulated Antenna's VSWR

The value of VSWR lies between 1.0 to 2.0. The acceptable value is 1.0.In this case, no power is reflected from the antenna, which is ideal. As per the design, the VSWR at 2.4 GHz is 1.25 and at 5.1 GHz is 1.2 respectively.

c. Bandwidth

Bandwidth is the range of frequencies over which the antenna can operate perfectly. It is also defined as the amount of data that can be transmitted in a fixed amount of time. For digital devices, the bandwidth is usually expressed in bits per second or bytes per second. For analog devices, the bandwidth is expressed in cycles per second, or Hertz. Bandwidth diagram is shown Figure 6.

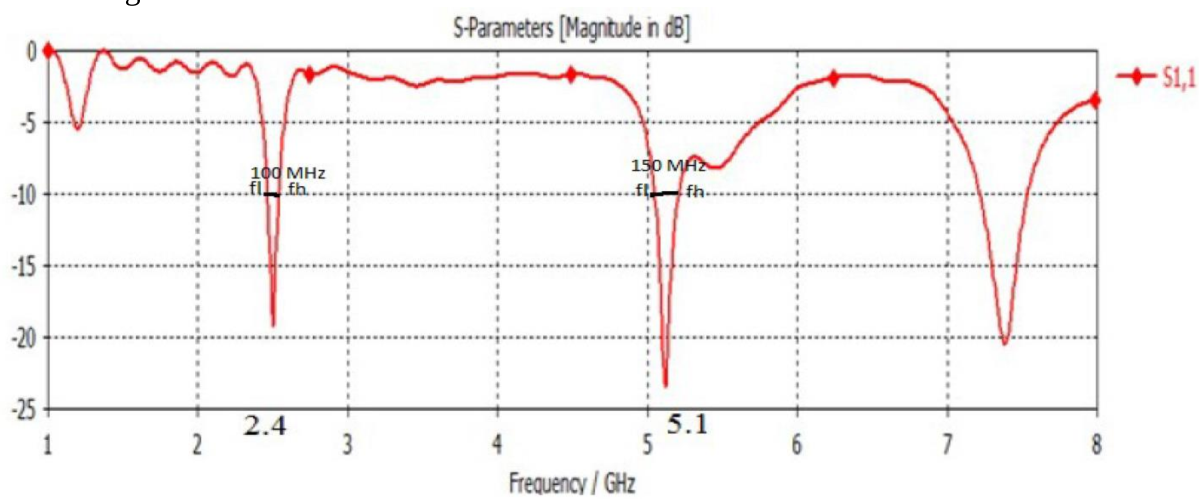

Figure 6: Simulated Antenna's Bandwidth

For an antenna, bandwidth is calculated from the S parameter graph by drawing a line at -10 dB. As per the design, the bandwidth at 2.4 GHz is 100 MHz and at 5.1 GHz is 150 MHz respectively.

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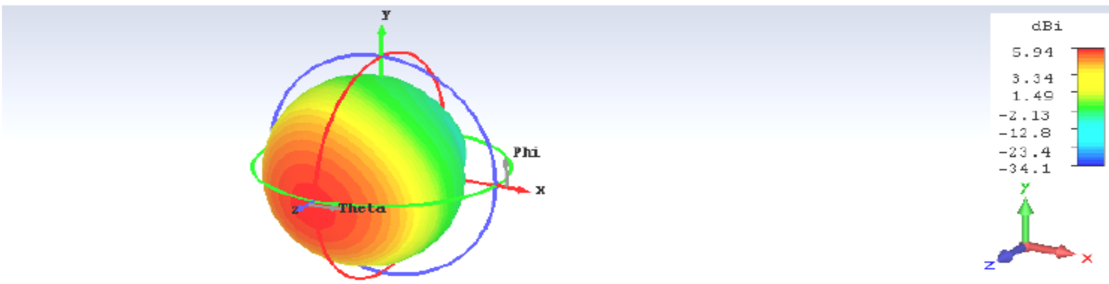
d. Radiation Pattern

The term radiation represent the emission or reception of wave front at the *antenna*, specifying its strength. Radiation pattern refers to the directional dependence of the energy of the radio waves from the antenna or different source. The following Figures 7.1 and 7.2 shows



the 3D view radiation for designed antenna.

Figure 7.1: Radiation Pattern(3D View) for 2.4 GHz

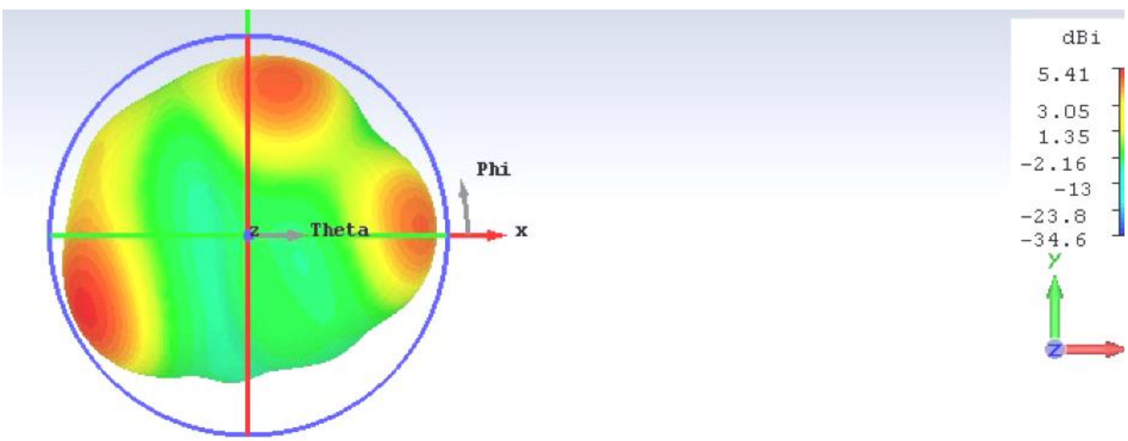


Figure 7.2: Radiation Pattern(3D View) for 5.1 GHz

V. CONCLUSION

Microstrip antenna is one of the most popular types of printed antenna. These play a very significant role in today's wireless communication. In this paper, a compact dual band microstrip patch antenna with S-shaped filter that could be operated in frequencies 2.4 GHz and 5.1 GHz was simulated using the CST Microwave Studio and also the antenna was fabricated. It can be used as a transducer for many wireless applications that operates on those frequencies.

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