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A NOVEL DESIGN OF RECTANGULAR MICROSTRIP PATCH ANTENNA FOR BLUETOOTH APPLICATIONS

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ABSTRACT

Bluetooth is a protocol used for data transmission in short range communication from fixed or mobile devices. This technology is designed for low power consumption having short range based on low cost transceiver microchip in each device. Bluetooth devices use Radio communication system, so it is possible for these devices to communicate even when they are not in line of sight of each other but residing in the defined range. Like other wireless devices, Bluetooth device needs to have antenna in order to transmit data signals through the air to the destination and receive transmitted signals from the source. In this paper, the antenna has been designed by substrate of Fire Resistance 4 (FR4) material having dielectric constant of 4.4 with a conducting radiating patch on the substrate and a conducting ground plane on the bottom side of substrate. The ground plane has been partially reduced to improve the antenna bandwidth. The antenna has been analyzed in terms of various antenna parameters such as return loss (Db), gain (Db), directivity (dBi) and return loss by Vector Network Analyzer. The antenna has been designed utilizing Microwave Studio (CST) and also fabricated by Network analyzer E5071C. The antenna design is appropriate to be utilized to Bluetooth applications. It has been noticed that the practical outcomes got through analysis the fabricated antenna that matches with the CST simulator outcomes.

Keywords: CST, bluetooth, return loss.

1. INTRODUCTION

The microstrip patch antenna is typically fabricated on a insulate substrate that works such as a middle among a ground plane in the substrate lowest side and a radiating patch on the substrate highest [1]. It able to become planned at several forms such as rectangular, rotating, triangular, elliptical, circle, quadrate and several more but the rectangular form is extensively utilized [1] due to the easily connected by the scheme. The substrate choice is the best significant measurement whereas scheming an antenna. It contains of a dielectric material that troubles the transport route and electric for antenna execution. The antenna size is backward proportionate for insulator fixed such as greater is the insulator fixed, lesser is the antenna size [2].

There are substrates set obtainable with various insulate fixed; however, in the scheme of antenna and FR4 item with insulate fixed of 4.4 has been utilized. The antenna able to be feed through different approaches such as coaxial provision and proximity coupled microstrip provision [3].

The providing able to become definite as a tool for transmission the capacity from the supply link to the splint, that itself works as a radiator. The microstrip antenna provide line is usually utilized in MPA scheme in order to it is comparatively straightforward to manufacture [3]. It has been usually utilized for wireless communication applications due to size of tiny antenna, low eighth, best capacity, facility of inauguration, mobility of facility, and is comparatively cheap for industry of particular features and dimensions. Nevertheless, regardless from its feature and there are several disadvantages of MPA. It grips lower capacity and has restricted bandwidth [4].

The bandwidth of MPA able to be better through either utilizing an insert spot [5][6] or via utilizing decrease ground plane [7]. The methods mentioned able to be utilized for optimize the return loss over the bandwidth increase. Various forms of incision have various impact on antenna measurement. Inserting includes for optimize the antenna execution whence return loss and bandwidth. In this paper, it proposed a new design of microstrip antenna for Bluetooth applications. In addition, it has been foreman which the workable results requested through experiment the antenna of fabricated utilizing Network analyzer E5071C carefully connects with the theoretical outcome acquired through simulating the antenna scheme by CST software.

2. MICROSTRIP ANTENNA

The antenna type which is our interest is called Microstrip antennas. Microstip circuits use a thin flat conductor being parallel to a ground plane. This able to be made through having a strip of thin conductor on one side of dielectric called substrate while the other side is a continuous ground plane. The side view of a Microstrip circuit is shown in Figure-1.

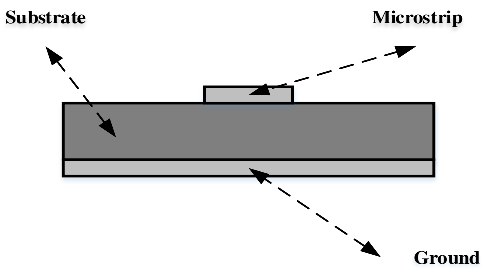

Figure-1. Side view of a microstrip circuit.

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ARPN Journal of Engineering and Applied Sciences

Microstrip circuits are used in microwave components like antennas, filters, coupler and etc. where entire device exists as a pattern of metallization on the substrate. There are several types of Microstrip antennas which can be implemented in Bluetooth devices. Followings are the most common ones used: Microstrip Patch Antenna, Microstrip Monopole Antenna, and Printed Inverted F Antenna (PIFA).

3. MICROSTRIP PATCH ANTENNA

This type of antenna can be fabricated through drawing the antenna style in metal follow bonded to the substrate with a constant metal layer bonded for the reverse side of the substrate that shapes the ground plane. There are several patterns used in patch antennas which are square, rectangular, and circular, but usage of any continuous shape is possible. The top view of a Microstrip rectangular antenna is illustrated in Figure-2.

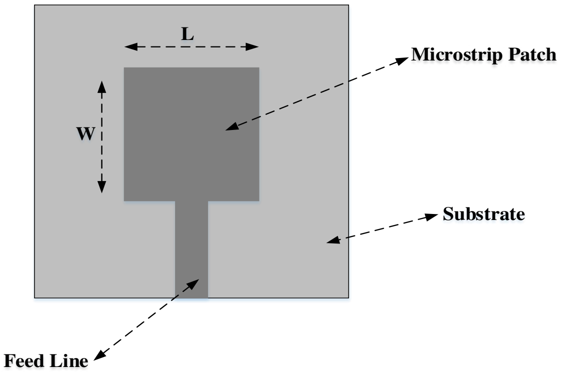

Figure-2. Top view of microstrip rectangular antenna.

Where the unknown variable of width in Figure-2 can be calculated using the below form

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

Where constant C is the light velocity, f_o is the resonance frequency, and ε_r is the dielectric constant of substrate.

The radiating patch length can be calculated using the following calculation: -

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

Where L_{eff} and ΔL can be calculated using the following equations: -

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}} \quad (3)$$

$$\epsilon_{reff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}[1 + 12\,\frac{h}{w}]^{-1/2} \quad (4)$$

$$\Delta L = 0.412h\,\frac{(\varepsilon_{reff}+ 0.3)(\frac{w}{h}+ 0.264)}{(\varepsilon_{reff}- 0.258)(\frac{w}{h}+ 0.8)} \quad (5)$$

Each type of the Microstrip patch antenna has its own calculation method where the above formulas are only applicable in Microstrip rectangular patch antennas.

4. RELATED WORK

This section presents an overview of the use of antenna design for Bluetooth applications. It offers proposed patch antenna for Bluetooth applications at 2.4GHz frequency with inset feeding technique. The patch is design with different parameters like return loss, VSWR, directivity along two directions, radiation pattern in 2-D and 3-D, smith cart, impedance matching is simulated using CST Microwave Studio simulation software [8].

On the other hand, it presents a microstrip star patch antenna on a FR4 substrate (glass epoxy) having thickness of 3.2mm. This antenna consists of a star shape radiating patch along with a partial ground plane [9].

In addition, it proposed the design and analysis of a small size, low profile, inexpensive and high gain microstrip patch antenna. The new designed antenna has operating frequency of 2.45 GHz which issue full in WLAN or Bluetooth applications. This antenna is directly feed by 50Ωcoaxial connector. The suggested model is simulated and various antenna parameters such as radiation pattern, standing wave ratio(SWR), Impedance of the antenna model are analyzing during Numerical Electromagnetic Code (4NEC2) software package [10].

Furthermore, it suggested microstrip patch antenna working on L band for satellite communication which resonates at 2.4GHz frequency. For this antenna coaxial feeding method is used. Parameters like Bandwidth, Gain and Return loss are analysed for this antenna. The HFSS 13.0 software is used for design and simulation [11].

Besides, it presents a design of compact size slot loaded micro strip patch antenna with inset fee transmission line. Antenna is designed to operate on frequency of 2.45 GHz. This band of frequency is occupied by the applications of Bluetooth and GSM. The graphical and numerical results of return loss, input impedance VSWR and radiation pattern are calculated [12]. Moreover, it offered a multi resonant MPA eligible of processing capable in the frequency range of 2.39 GHz to 5.79 GHz have been suggested. It has been schemed utilizing substrate of FR4 tool having dielectric fixed of 4.4 with a direct radiating patch on the substrate and a direct ground plane on the lower side of substrate. The antenna performance has been investigated whence different antenna parameters for example impedance bandwidth, gain, return loss, directivity, half power Beam width and VSWR [13].

5. DESIGN SPESIFICATIONS

The performance of an antenna able to be measured from a number of parameters. The parameters of critical are as follows: Antenna tuning, Gain, Directivity and Return loss.

5.1 Directivity

One of the major parameters used in the analysis of the performance of a radio frequency communication system is the amount of power that the transmitter is able to direct toward the receiver using its antenna. This power is obtained from the transmitted power and the ability of the antenna to direct that power toward the receiver.

The directivity of antenna is determined by the design of the antenna. A reference antenna is needed to compare it with one antenna performance and determine the directivity of that antenna. Nowadays isotropic radiator is preferred as the reference antenna for comparison. When the directivity of an antenna is converted to decibels, it is called the antenna gain relative to isotropic source (dBi), using the following formula:

$$Gain\ (dBi) = 10\log(Directivity) \tag{6}$$

5.2 Input impedance

It is recognized through as the impedance presented via an antenna at its terminals. Therefore, the antenna impedance able to be written as:

$$Z_{in} = R_{in} + jX_{in} \tag{7}$$

Where Zin represents the impedance of antenna in the terminals, R_{in}represents the reactance of antenna in the terminals, and X_{in}represents the reactance of antenna in the terminals.

The imaginary part, $X_{in}$of the input impedance represents the capacity kept in the near field of the antenna. As the resistive part, R_{in}represents the power radiated by the antenna. The standard value of input impedance for a practical antenna is 50 ohms since most radio equipment's are built for this impedance value.

5.3 VSWR

An antenna is called efficient that it has the maximum power transfer among the sender and the antenna. This case only occurs when the input resistance of the antenna is corresponded to that of the sender. In addition, it is based on the extreme capacity transport theorem, extreme capacity able to be transport only if the resistance of the sender is a complex conjugate of the antenna impedance under consideration and vice-versa. Consequently, the case for suitable is:

$$Z_{in} = Z_s^* \tag{8}$$

Where $Z_{in} = R_{in} + jX_{in}$, and
$Z_s = R_s + jX_s$

If the above situation is not pleased, then some of the power will be reflected back and this will create standing waves which can be characterize through the parameter named Voltage Standing Wave Ratio (VSWR).

VSWR is given as follows:

$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|} \tag{9}$$

$$\Gamma = \frac{\text{Zin}-\text{Zs}}{\text{Zin}+\text{Zs}} \tag{10}$$

Where Γ is called the reflection coefficient.

The VSWR is essentially an amount of the resistance incompatibility among the sender and the antenna. The advanced the

VSWR, the better is the incongruity. The lowest VSWR that agrees to a faultless match is unity.

5.4 Return loss

It is the variance in dB among the forward and reverse capacity gauged at each point in the RF method. Typically, but not always this point is the input of the antenna.

In general, both return loss and VSWR are used as a performance parameter to quantify the percentage of the power that will be reflected at the input to the antenna. In other word, return loss and VSWR are both parameters of quality of match checking, where the quality of match is how good the antenna is matched; A mismatched antenna reflect some of incident power back to the transmitter causing the creation of the standing waves. Return loss is given as:

$$RL = -20\log|\Gamma| \tag{11}$$

If the perfect match occurs among the antenna and the transmitter then$\Gamma = 0$, which cause $RL = \infty$ means no incident power is replicated back, while a $\Gamma = 1$ will cause the $RL = 0\ dB$ means all the case power is reversed back.

5.5 Gain

The power gain is a key performance number that merge the antennas directivity and electrical capacity. It is normally knowing in the maximum radiation direction each unit area. In addition, it represents how well the antenna change input

$$G(\theta,\phi) = e_{cd}\,D(\theta,\phi) \tag{12}$$

Where e_{cd} is the antenna radiation efficiency and is given as follows:

$$e_{cd} = \frac{R_r}{R_r+R_L} \tag{13}$$

Where R_r is the radiation resistance, and R_L is loss resistance.

5.6 Bandwidth

The bandwidth of an antenna is the range of frequencies which the performance of the antenna is expected to a specific standard. In this range which can be on either side of the center frequency all the antenna characteristics like input impedance, radiation pattern and gain are very near to those values that have been measured at center frequency. The range of the frequencies for Bluetooth application is about 2.40 GHz to 2.50 GHz. With these frequencies the bandwidth is calculated to be 100 MHz [14].

6. MATERIALS AND METHODS

6.1 Simulation tools

In this paper, the simulation was used CST simulation software and fabrication to design and simulate a microstrip patch antenna. It is a useful tool for modelling electromagnetic structures.

6.2 Proposed design

In this paper, a new antenna is designed, modification, and simulation were done using the CST Microwave Studio software. CST Microwave Studio (MWS) is a professional tool for the three dimensional Electro Magnetic simulation of high frequency components. CST unparalleled performance makes it first select in mechanism leading research and improvement departments. Applications contain ideal microwave and radio frequency such as in mobile connection, wireless designs, signal integrity and EMC/EMI.

Users of CST Microwave Studio are offered unmatched elasticity in attempting an extensive application range by a set of obtainable solver mechanisms. In addition, the main structure, the largely applicable Time Domain solver and the Frequency Domain solver that simulates on hexahedral CST MWS presents then solver structures to specified applications. Filters for the specified import CAD files and the extraction of SPICE parameters increase scheme possibilities and keep time.

After that, it is to establish the working plane properties to make the sketch plane large enough for out device. Because our PIFA antenna is 30 mm by 30 mm so our structure has maximum extension of 15 mm along coordinate directions. The working plane should be set to at least 20 mm to fit our device. In addition, the material chosen for substrate is loss FR-4 with dielectric constant of 4.7.

The antenna needed some modification to reduce the value of input impedance to get as close as possible to the value of 50 Ω. The first step is to calculate the width of the input feed line. This was done using the CST Microwave Studio software itself in the calculation of Input Impedance part where it is possible to get the input impedance by entering the width of substrate, dielectric constant of substrate and the width of the input feed line. 2.8 mm was chosen as the width of the input feed line which cause the input impedance to be 50.42 Ω. The design of the Inverted F antenna was done on the top of this feed line. Figure-3 illustrate the top view of the inverted F antenna.

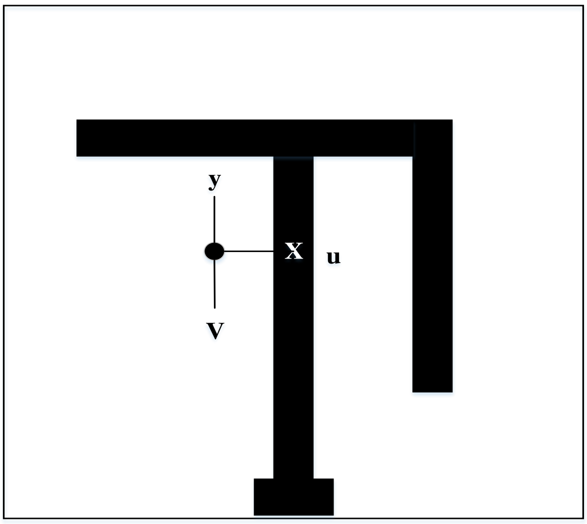

Figure-3. Overall view of the PIFA.

6.3 Fabrication

As mentioned earlier fabrication of Microstrip antennas are done using the FR-4boards. The steps to fabricate an antenna are stated below:

- The modified Inverted F antenna shape was exported from the CST Microwave studio software into AWR Microwave Studio software where it is possible to print the layout of the antenna onto the transparent papers.
- The layouts of the modified Inverted F antenna were printed on the transparent paper and cut to the size of the substrate used in the antenna. This piece of transparent paper with the layout of antenna is called a Mask. Figure-4 shows the mask of the antenna and the FR-4 board.

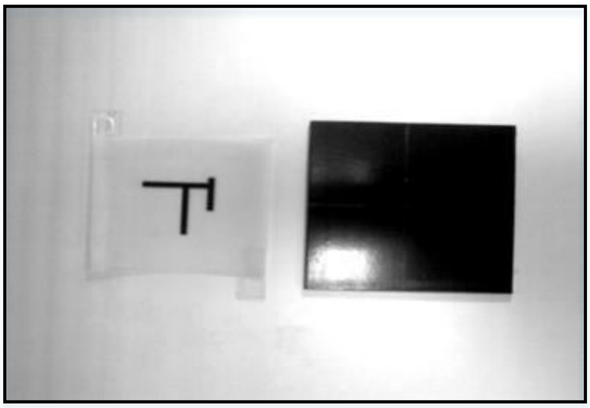

Figure-4. The mask on the left and Fr_4 board on the right.

- FR-4board was cut into two 30 mm by 30 mm separate boards using the cutter.
- The masks were placed on the top of the FR-4boards.
- Boards were then placed under the UV machine for 10 – 11 minutes.

ARPN Journal of Engineering and Applied Sciences

Figure-5. FR4 boards on the UV machine.

- The mask was removed from each Fr_4 boards.
- Boards were placed in the Etcher machine where the extra copper around the layout of antenna was etched out of them using the graphic chemical liquid in the machine. Figure-6 shows the etcher machine.

Figure-6. Etcher machine.

- The port was then soldered to the feed of each antenna.

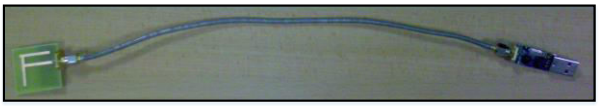

Figure-7. Inverted F antenna connected to bluetooth dongle using wire connector.

7. RESULTS

This paper is proposed a new design of three most common type of microstrip antenna was done and after simulation based on CST software. The most effective one was chosen to be fabricated and to be used in the Bluetooth device.

7.1 Return loss

This antenna was simulated using CST Microwave studio. Figure-8 shows the return loss graph of this antenna. The drop in this graph occurs on exactly 2.45 GHz which is our central frequency with the return loss value of -24.84 dB which is acceptable. Bandwidth in this design has been increased to more than 200 MHz which is a better design compare to previous studies which was around 50 MHz.

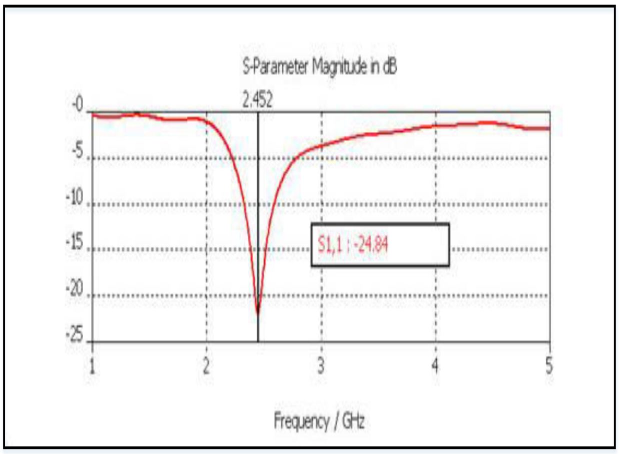

Figure-8. S11 graph of PIFA with 49.69 Ω input impedance.

7.2 Directivity and gain

Input impedance calculated by CST Microwave Studio is 49.696 Ω which is very close to 50 Ω and is acceptable for an antenna in any application. Three dimensional Theta and Phi component view of antennas Directivity and Gain is shown in Figures 9, 10, 11, and 12 respectively. The ability of the antenna to direct the power toward receivers is illustrated in these figures. The absolute Directivity and Gain of the antenna is 2.113 dBi and 0.8977 dB respectively.

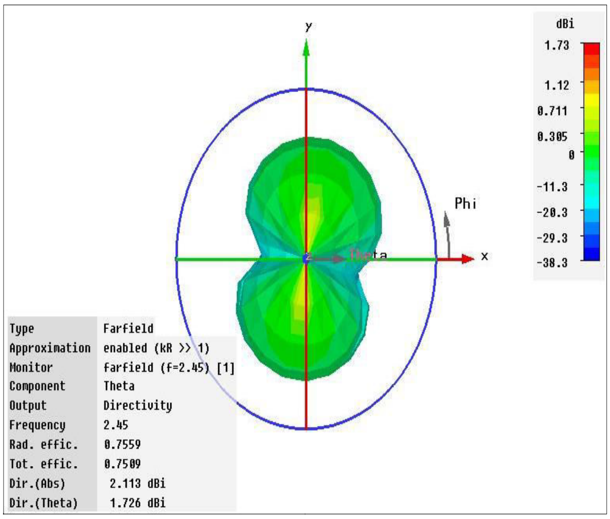

Figure-9. Three dimensional view of Theta component of directivity.

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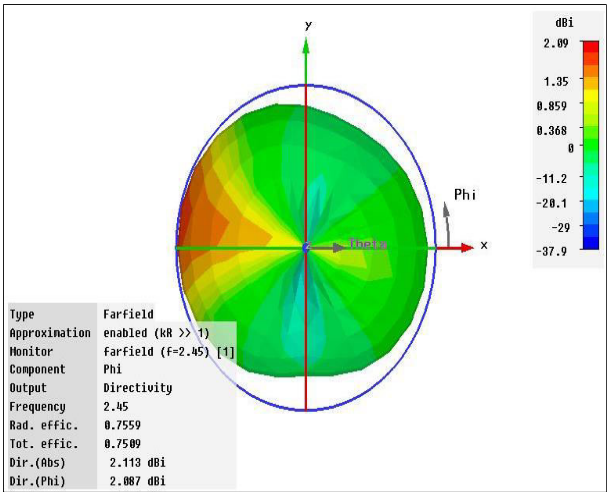

Figure-10. Three dimensional view of Phi component of directivity.

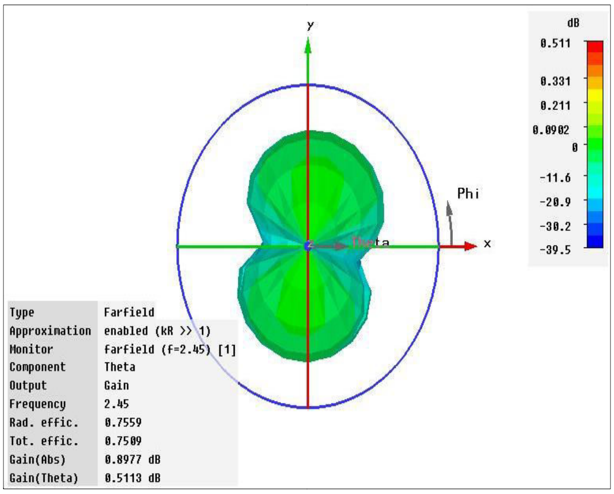

Figure-11. Three dimensional view of theta component of gain.

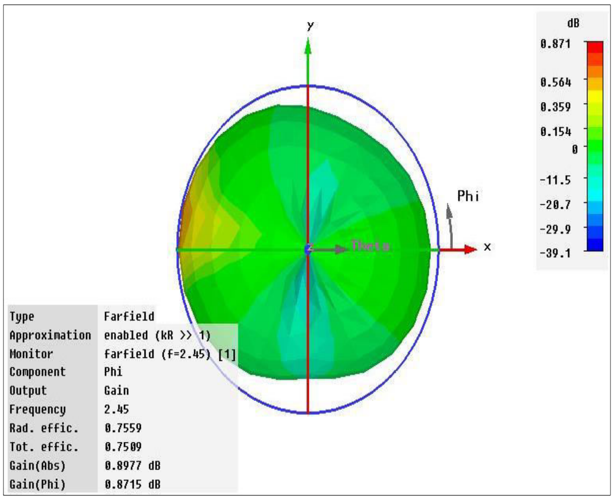

Figure-12. Three dimensional view of Phi component of gain.

Figures 13, 14, 15 and 16 below shows the Directivity and the gain of the antenna at 2.45 GHz for Theta and Phi components in planar plane. These graphs illustrate that the antenna is not only radiating in single direction and the amount of power directed toward receiver is delivered in two directions, which indicate that our antenna is not a directional antenna.

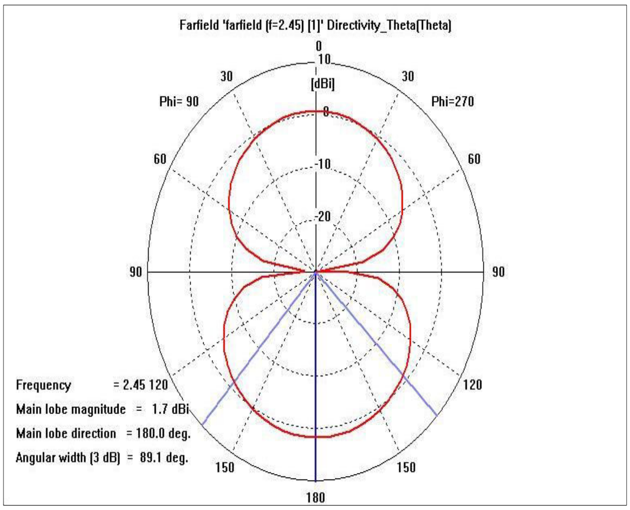

Figure-13. Planar view of theta component of directivity.

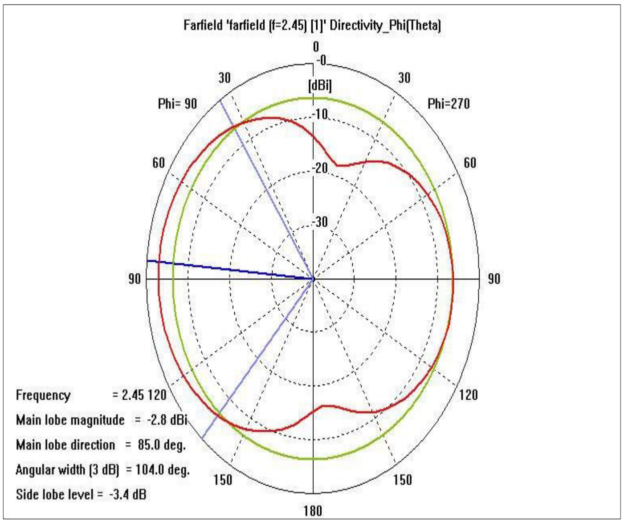

Figure-14. Planar view of Phi component of directivity.

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ARPN Journal of Engineering and Applied Sciences

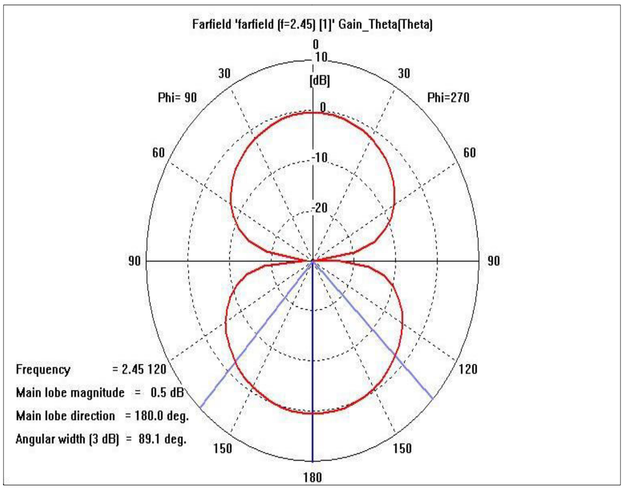

Figure-15. Planar view of theta component of gain.

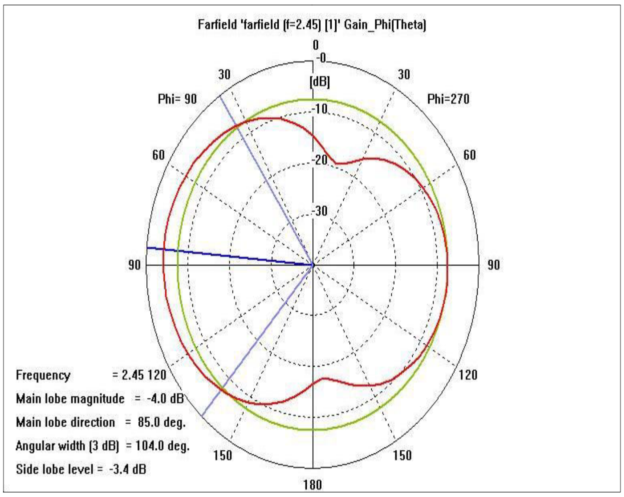

Figure-16. Planar view of Phi component of gain.

7.3 Return loss by vector network analyzer

This antenna was then fabricated using Vector Network Analyzer. Figure-17 illustrates the S11 graph for this antenna. The drop in this graph was occurred on frequency 2.427 GHz which can be caused by connector's loss, soldering fault, and losses in the wire which connects the antenna to Vector Network Analyzer. The value of the return loss on this point is -22.85 dB which is more than -9.5 dB and so it is acceptable to act as an antenna in Bluetooth device.

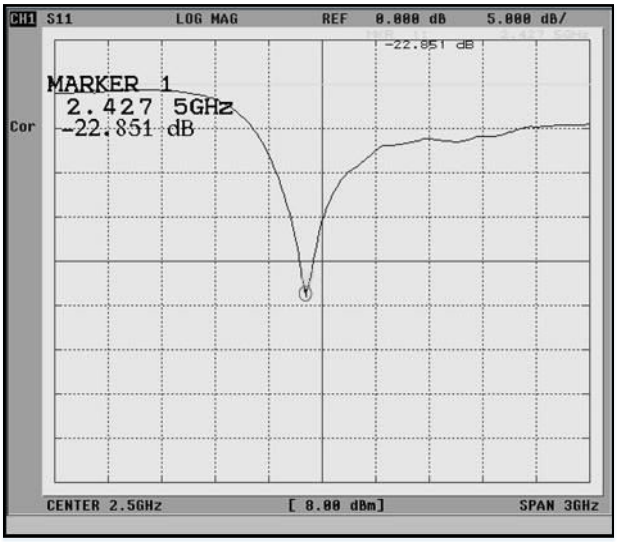

Figure-17. Return loss graph of antenna tested by vector network analyzer.

8. CONCLUSIONS

The aim of this paper was to design and fabricate a microstrip antenna for use in Bluetooth devices. A printed inverted F antenna has been successfully designed having the center frequency of 2.427 GHz. The return loss on center frequency is -22.581 dB. The gain of 0.8977 dB and directivity of 2.113 dBi were measured for the designed antenna. The bandwidth obtained is 250 MHz which is more than sufficient for Bluetooth applications.

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