Manually Fabricated Patch Antenna

Simulating the patch antenna on IE3D to fabricating it manually

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***Abstract*—with the ever growing advancement in antenna design and fabrication, the need to infuse in new concept within the domain has become a high key note necessity for telecom engineers. The Micro-strip patch antenna is one a kind of antennas where compactness, economical aspects are taken into consideration. In 2016, Amazon released the World's Smallest Android Smart Phone at the cost of $70.99 with dimensions of 90x45x11mm(L x W x D). This paper shows the concept of the patch design using the IE3D software through its calculated dimensions, to finally fabricate it manually.**

Keywords—Feed point, WLAN, UMTS, Return loss, 2.4 GHz

I. Introduction

By definition, an antenna is a device that is used to transform an RF signal travelling on a conductor into an electromagnetic wave in free space. The IEEE standard definition of Terms for Antenna (IEEE Std 145-1983) defines the antenna or aerial as a mean for radiating or receiving radio waves [2]. One the best radio frequency band that can be used for the designing of the antenna is the unlicensed 2.4GHz which is also called as the ISM (Industrial, Scientific & Medical) band, making it easy to certify with FCC (Federal Communication Commission) or maybe its counterparts in various other countries.

What's so special about the 2.4 GHz? There are many ISM bands, some at higher/lower frequencies but not all of these are internationally recognized bands. It's only the 2.4 GHz that's offers this recognition, having majority of applications in the field of Wireless Communication. With the development of high frequency semiconductor devices and MIC, micro strip has drawn maximum attention towards the antenna community in recent years. In spite of its multiple attractive features of being light weight, cheap, easily fabricated, conformability on curved surface as well as compatibility, the micro strip antenna suffers from an inherent limitation of narrow impedance bandwidth and presently research is on the go by antenna engineers & scientists, making the micro strip antenna a present day antenna designer's choice. This antenna supports a range of body centric applications such as WLAN, Wi-Fi, Wi-MAX, BAN, HYPER LAN, GSM, UWB, UMTS-LTE, Bluetooth, Mobile communication and Telemedicine [6].

IE3D is a Moment of Method Simulator which solves the Maxwell's Equations in an integral form through the use of Green's functions. The results are analyzed and discussed in terms of return loss, bandwidth, 3D radiation pattern, Smith Chart [2]. Thus depending on the type of radiated field of the antenna, its shape is decided to be either rectangular or circular; linear, circular or elliptical polarized. The most common of all patches is the rectangular patch as it is used to simplify analysis as well as perform prediction. The circular, square and dipole are also used frequently due to their ease of analysis, fabrication and excellent radiation pattern but of all; the dipole patch displays properties of a large bandwidth and minimum space requirement. The conventional antenna methods use linearly polarized wave. Circular/ elliptical polarized are obtained from various feed arrangement by slightly modifying the patch. The micro strip is also called as a paper thin antenna.

II. Selection before Designing

Remember as a young child, the type of fascination that we would get on figuring an antenna. Whentravelling through hilly regions coming across mobile towers or even on top building dish antenna right up to the old analog radios at home. All this seemed to be an interest and dream but now what if this so called complicated antenna could be made right at the comfort of your home except for the testing and analyzing of it. Seems interesting right? This is exactly what this paper is all about. This project was developed in the following stages:

A) Designing of the antenna dimensions mathematically

The proposed micro strip antenna is capable of operating in a dual frequency band, i.e. WLAN (2.4 – 2.48GHz) & UMTS (2.1 – 2.3GHz) in the frequency range 1.8 GHz to 3GHz for wearable applications making the antenna to multipurpose.

B) Simulation on IE3D

Electromagnetic stimulation is an advanced technology to yield high accuracy analysis and design for complicated microwave and RF printed circuits, antennas, high speed digital circuitsand other electronic components. Since, its formal introduction in 1993; IEEE International Microwave Symposium (IEEE IMS 1993), IE3D has adopted an industrial standard in planar and 3D electromagnetic stimulation. It is a closed source application, and one of the simplest platforms for designing an antenna.

C) Manual Fabrication

After designing the antenna on IE3D, the fabrication of it is important so as to test the antenna practically. IE3D has the feature of converting this design to Geber file so as to fabricate it precisely on a CNC machine but now what if you want to make it as a DIY project then why not fabricate it on your own at home. The advantage is that its fabrication is similar to that of PCB (Printed Circuit Board) board.

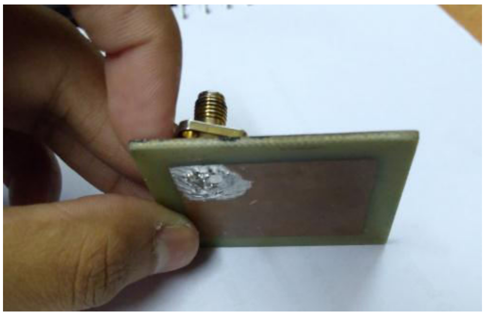


FIG II: MANUALLY FABRICATED PATCH ANTENNA

III. MICROSTRIP ANTENNA

The parameters taken into consideration for this antenna are as follows; it is a 3.9mm X 4.7mm rectangular substrate having patch dimensions of 2.8mm X 3.7mm. These calculated values were determined from the below formulae that determine the width and length. The selected dielectric constant is 4.36, hence glass epoxy i.e. FR4 is the dielectric material that is 1.59mm thick. Its loss tangent is 0.016 with ground conductivity as 0.

The coaxial feed point is of radius 0.5mm with a simple ground plane arrangement considered at points (7.25, 6.35) when the plane is considered at point (0, 0). The range for the frequency band is from 0.8GHz to 3GHz which comprises for the UMTS and WLAN frequency bands. The total no of point's frequencies taken in this range is of 88 frequencies.

The feed point and length/width of the antenna can be varied as per the antenna designer depending on the type of radiation pattern needed for its desired application.

A. Mathically calculate the dimensions through the following formulae.

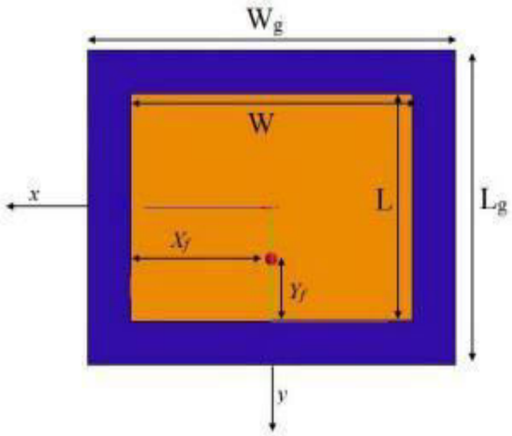


Fig III. A: Dimensions needed for patch designing

Step 1: Calculation of patch Width (W)

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

Substitute, c = 3.00e+008 m/s and f0 = 2.4GHZ Range of dielectric constant lies in between 2.2 to 12

Step 2: Calculation of patch Length (L)

$$L_{eff} = \frac{c_o}{2f_o\sqrt{\varepsilon_{reff}}} - 2dL$$

Substitute,c = 3.00e+008 m/s and f0 = 2.4GHZ

Step 3: Effective Dielectric constant

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-1/2}$$

Substitute, εr=2.2 to 12, h=1.59mm

Step 4: Length extension

$$dL = 0.412h\frac{(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)}$$

Substitute, h=1.59mm

Step 5: Calculation of Ground Dimensions

Width of the ground: Wg = W + 6h
Length of ground: Lg = L + 6h

Step 6: Feeding Technique & Location

The impedance match depends on the feed point location of the patch. The feed point location has to match 50 ohm.

Along the width of patch:

$$X_f = \frac{W}{2}$$

Along the length of patch:

$$Y_f = Y_0 - dL$$

$$\text{Where } Y_0 = \frac{L}{\pi}\cos^{-1}\sqrt{\frac{50}{Z_0}}$$

$$Z_0 = \sqrt{50 * Z_{IN}}$$

$$Z_{IN} = 90 * \frac{\varepsilon_r^{\,2}}{\varepsilon_r - 1}\left(\frac{L}{W}\right)^2$$

B) Technically simulating on IE3D

In this the proposed antenna parameters were considered and analyzed such as its gain, return loss pattern, radiation pattern, etc. Along with it investigation was also done on its gain, bandwidth and return loss performance so as to improve the limitations of the microstrip antenna to finally realize the fact that another antenna (meta material antenna) features to the disadvantage of the microstrip antenna.

1) Return Loss:

Return loss is the loss of power in the signal returned/reflected by a discontinuity in a transmission line or optical fiber. It is similar to VSWR parameter of an antenna which indicates the amount of power that is lost to the load. The value of return loss should be minimum, in order to minimize the reflection wave and ability to maximize the transmitting power enabling the antenna to perform better.

Theoretically, on IE3D as shown in fig III.B.1.1, we obtained the micro strip antenna return loss to be below -10db for WLAN at around -30db with its frequency point at 2.4462 GHz and UMTS as -13.36db at the frequency point 1.90296 GHz.

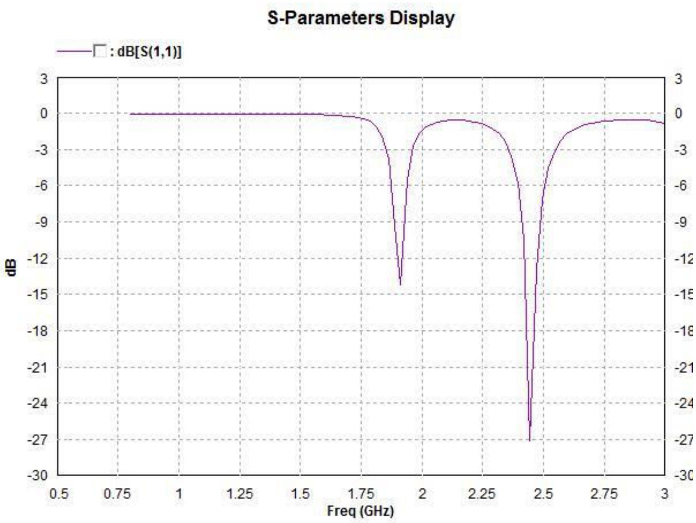


Fig III.B.1.1: Return loss characteristic of the patch

Practically, as shown in fig B.1.2, the range obtained for the dual band micro strip antenna for WLAN is 2.4GHz to 2.248GHz & for UMTS is 2.1GHz to 2.3GHz with the return loss for both the bands being below -10db. Thus with this we realize the antenna to have a good reflection coefficient and high power transfer.

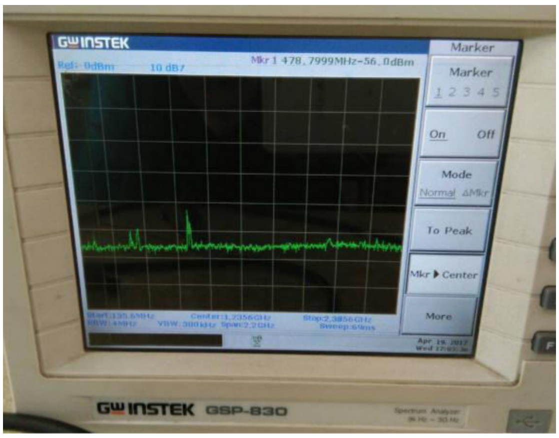


Fig B. 1.2: Return loss on spectrum analyzer

2) Radiation pattern

The radiated energy of an antenna is characterized by the antennas radiation pattern. The radiation pattern of the antenna is the graphical representation of the radiation properties of the antenna as a function of space. It is important to state that an antenna radiates energy in all directions, at least to some extent, so the antenna pattern is actually 3 dimensional. The antenna patterns (Azimuth and elevation plane patterns) are frequently shown as plots in polar coordinates. Thus giving the viewer the ability to easily visualize how the antenna radiates in all directions as if the antenna was "aimed" or already mounted.

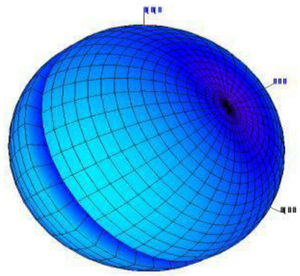
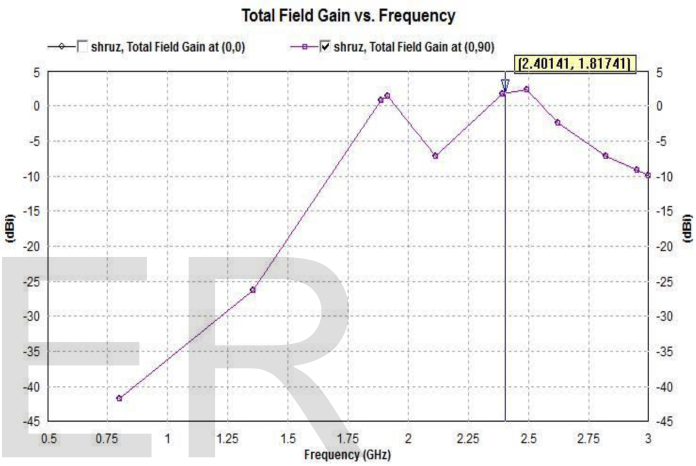


Fig B. 2: True 3D Radiation Pattern of a Rectangular patch

3) Antenna Gain:



Total Field Directivity vs Frequency

Antenna Gain is the ratio of the amount of surface power radiated by the antenna to the surface power radiated by a hypothetical isotropic antenna.

C) Maunual Fabrication

The main requirement to keep in mind before fabrication of the micro strip is the selection of the substrate type and location of the feed point of the antenna.

The dielectric constant of this antenna is 4.36 hence we had to go for the FR4 substrate/ glass epoxy. FR4 dielectric constant lies in the range of 2.2 to 12. Thick substrates with low dielectric constant result in better efficiency, large BW and small antenna size; on the other hand thin substrates with high dielectric constant have reduced efficiency, small BW and small size. In short; for good antenna performance a thick dielectric substrate having low dielectric constant is desirable since it provides better efficiency, large BW and good radiation performance.

The feed point of the antenna is also of equal importance. In this project we have selected the co-axial cable as the medium to the feed point of the antenna. The main advantage is that this feed can be placed at any desired location in order to match its input impedance; along with it; it can be easily fabricated and posses low spurious radiation except for the fact that it has a narrow bandwidth and displays asymmetries which generates the higher order modes to produce cross-polarized radiation.

This manually designed antenna has to be fabricated so precisely that we obtain outputs as that of the simulated design. If not done so then it would be a complete waste of resources and time.

The complete cost of this project went only into the fabrication of the antenna which came to only Rs 400/-. Thus, stating the fact that the micro strip antenna is a very economical and cheap antenna.

D) *Conclusion*

The proposed antenna is a dual band micro strip antenna operating in the frequency range 0.8 GHz to 3GHz for WLAN and UMTS applications having return loss, theoretically and practically below -10 db overall determining the antennas excellent performance in reflection coefficient and power transfer stating to the fact that the Micro-strip patch antenna is the type of antenna where compactness, economical aspects are taken into major consideration for all miniature based devices where an antenna is needed.

E) *Future Scope*

Micro strip antennas provide wide bandwidth, desired polarization and high gain. All these features/ goals were achieved in this project work. In addition to it, more research work can be done in the following areas;

1. Reducing the size of the patch element.
2. Improving cross-polar to co-polar levels.
3. Designing the feed network to avoid unwanted radiations as well as the ability to affect the polarization of the antenna; even when the antenna is designed in an arrayed format it should display minimum errors and losses as much as possible.

F) *Applications:*

Most of the rapid advances in micro strip antennas and array took place in the early 1980's. They were initially driven by defense and space application but today it is growing rapidly in the commercial as well as industrial sector. The specifications in defense and space antennas typically emphasize maximum performance with little constraint on cost. On the other hand commercial applications demand low cost components, at the expense of reduced electrical performance. Thus, the below table specifies the commercial application range that an antenna can be designed for.

Global Positioning Satellite	1575 MHz & 1227 MHz
GSM	890-915MHz & 935-960 MHz
Wireless LAN	2.40-2.48 GHz &5.4 GHz
Cellular Video	28 GHz
Direct Broadcast Satellite	11.7-12.5 GHz
Automatic Toll Collection	905 MHz &5-6 GHz
Collision Avoidance Radar	60 GHz,77 GHz& 94 GHz
Wide Area Computer Network	60 GHz

Table D.1: Micro-strip antenna applications for various frequencies

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