Design & Performance Analysis of Triple Band Micro Strip Patch Antenna for Wireless Applications

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Abstract - **There is a growing demand for a multiband terminal antenna that is capable of receiving multiple services introduced by different wireless technology networks. These networks include Bluetooth, WiMAX, and WLAN which operate at different frequency bands. Micro strip antennas are widely used in many applications due to their low Profile, low cost and ease of fabrication. In some applications it is desired to have a dual band or multiband characteristics. This paper presents the design and simulation of a Multiband Microstrip patch antenna with operating frequencies 2.25GHz, 3.4GHz and 5.64GHz for wireless applications. The shape will provide the broad bandwidth which is required in various wireless applications. An Edge-Fed microstrip with substrate FR4epoxy having dielectric constant 4.4 and substrate height of 1.57mm is designed and analyzed with different parameters like VSWR, Gain, Peak directivity, Return losses, Bandwidth etc,. This antenna design is an improvement from previous research and it is simulated using HFSS (High Frequency Structure Simulator) version 13.0 software.**

Keywords - **Microstrip,Tri-Band,Wi-Fi, Wi-MAX,, WLAN, Edge-Fed, HFSS Software 13.0**
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I. INTRODUCTION

Wireless operations permit services, such as a long-range communications, that are impossible or impractical to implement with the use of wires. The term is commonly used in the telecommunications industry to refer to telecommunications systems (e.g. radio transmitters and receivers, remote controls etc.) which use some form of energy (e.g. radio waves, acoustic energy, etc.) to transfer information without the use of wires. Information is transferred in this manner over both short and long distances.

Usually broadband wireless access networks are considered to be enterprise level networks providing us with more capacity as well as coverage. We have seen that in remote inaccessible areas wired networks are not at all cost effective. Wireless networking has offered us an alternative solution for such problem of information access. They have definitely changed the way people communicate and share information among themselves by overcoming problems nowadays associated with distance and location.

Wi-Fi stands for "wireless fidelity". However since most of our WLANs are based on those standards, the term Wi-Fi is used generally as a synonym for WLAN. Wi-Fi is a popular technology which allows any electronic device to exchange and transfer data wirelessly over the network giving rise to high speed internet connections. Any device which is Wi-Fi enabled (like personal computers, video game consoles, Smartphone, tablet etc.) can connect to a network resource like the internet through a wireless network access point. Now such access points also known as hotspots have a coverage area of about 20 meters indoors and even a greater area range outdoors, this is achieved by using multiple overlapping access points. However with all such features, Wi-Fi also suffers from certain shortcomings. Wi-Fi is known to be less secure than wired connections (such as Ethernet) because an intruder does not need a physical connection. The operating frequency bands 2.4GHz-2.48GHz and 5.15GHz-5.85GHz.

WiMAX stands for "World Interoperability for Microwave Access". It is a standard typically based on global interoperability including ETSI HIPERMAN, IEEE 802.16d-2004 for fixed, and 802.16e for mobile high-speed data. WiMAX is gaining popularity as a technology which delivers carrier-class, high speed wireless broadband at a much lower cost while covering large distance than Wi-Fi. It has been designed to be a cost effective way to deliver broadband over a large area. It is intended to handle high-quality voice, data and video services while offering a high QoS[3]. The operating frequency bands 3.3GHz-3.8GHz and 5.15GHz-5.85GHz.

In this paper, a Triple band microstrip patch antenna using epoxy substrate excited with edge feed has been designed, simulated, optimized and analyzed using HFSS (High Frequency Structure Simulator) software version 13.0. A microstrip patch antenna with three arms[1] of different shapes, substrate of epoxy material and ground plane is fed with Edge-feed system is developed on Ansys HFSS platform and analyzed to observe the different antenna performance parameters at different frequencies of operations.

This paper is structured as follows. Section II describes methodology followed for design of microstrip patch, design parameters and geometry. Section III shows the results explaining antenna parameters like Radiation pattern, Return loss, VSWR, Gain with specifications tabulated and finally Section IV is conclusion.

II. METHODOLOGY

A. Design of Microstrip Slot

In this section there is presented a design with the use of –Microwave HFSS simulation software. First of all we have to choose a dielectric constant and substrate height to design an antenna as these are the basics for the design an antenna. They were chosen according to the design frequency. There was chosen substrate material is air with dielectric constant.

1. Substrate Height =1.57 mm
2. Dielectric Constant=4.4

Two L-shaped stepped impedance components are designed to operate at 900/1800 MHz bands [15]. Thereafter, a third resonant element is added for operation at the third band of 3500MHz. Height = 1.57mm is used to demonstrate the design concept. The width of middle arm antenna and left arm antenna is equal to 10mm to provide a suitable radiation aperture at the 900/1800MHz bands. The length of most right antenna is equal to 32mm and length of bottom arm is equal to 25 mm[8].

B. Designing parameters:
- Calculation of the Width (W)
- Calculation of Effective dielectric constant (ε_{reff})
- Calculation of the Effective length (L_{reff})
- Calculation of the length extension (ΔL)
- Calculation of actual length of patch (L).

C. Designing Equations
The below equations are used to find out the length and width of patch.The width of the patch is found by

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}} = \frac{v_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (1)$$

Where the v_0 is the free-space of velocity of light

The effective dielectric constant can then found by

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

Where the dimensions of the patch along its length have been extended on each end by a distance ΔL, which is a function of the effective dielectric constant εreff and the width to- height ratio (W/h), and the normalized extension of the length, is
The extension length has been adapted into the form

$$\Delta L = 0.412\, h\, \frac{(\varepsilon_{eff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{eff}-0.258)(\frac{W}{h}+0.8)} \qquad (3)$$

The actual length of patch(L) can be determined as

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{reff}}\sqrt{\mu_0\varepsilon_0}} - 2\Delta L \qquad (4)$$

D. Geometry of Antenna
The geometry of the designed antenna is shown in the Figure 1.The antenna is made of a single patch on top, one layers of dielectric and a edge feed slot connected to the upper patch.

Table.1: Antenna specifications

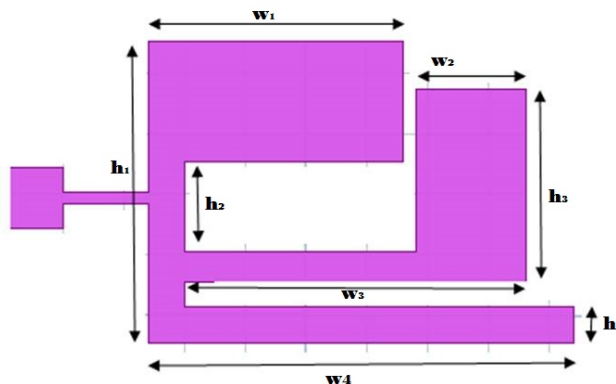| Dimension	W1	W2	W3	W4	h1	h2	h3	h4
Specification(mm)	17.5	10	23	32	25	07	14	05

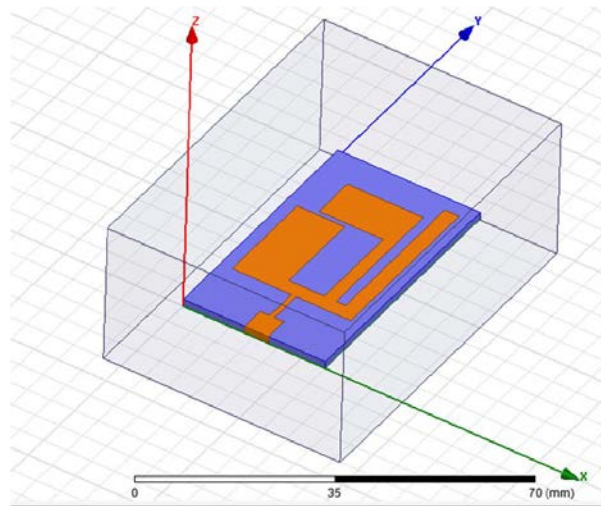Figure1: Design geometry of proposed micro strip patch.

Figure 2: Design of Triple Band micro strip patch in HFSS software

III.RESULTS AND EXPLANATIONS

A. Return Losses

Figure 5 illustrates both the simulated and experimental results of the antenna return loss. Here, return loss is defined as

$$R = 20\log10 \ | \ \Gamma \ | \qquad (5)$$

where Γ is the reflection coefficient. As shown in this figure, simulated values of the first and second resonant frequencies are 2.31 GHz and 3.78 GHz, respectively. Current paths of the 1st and2nd modes are shown. Dash-dot lines show the average length of current paths for each mode. The resonant frequencies can be calculated approximately as follows:

$$f_1 = \frac{c}{2\sqrt{\varepsilon_{eff}}L1} \qquad (6)$$

$$f_2 = \frac{c}{2\sqrt{\varepsilon_{eff}}L2} \qquad (7)$$

$$f_3 = \frac{c}{2\sqrt{\varepsilon_{eff}}L3} \qquad (8)$$

Where L1, L2 and L3 are the average lengths for current paths of the 1st and 2nd resonant modes and c is the free space velocity of light. The effective permittivity is also given by

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1 + \frac{10h}{W}\right)^{-0.555} \quad (9)$$

Where **h** and W are height of the substrate and width of the patch. The return losses are shown in the below Figure 3.
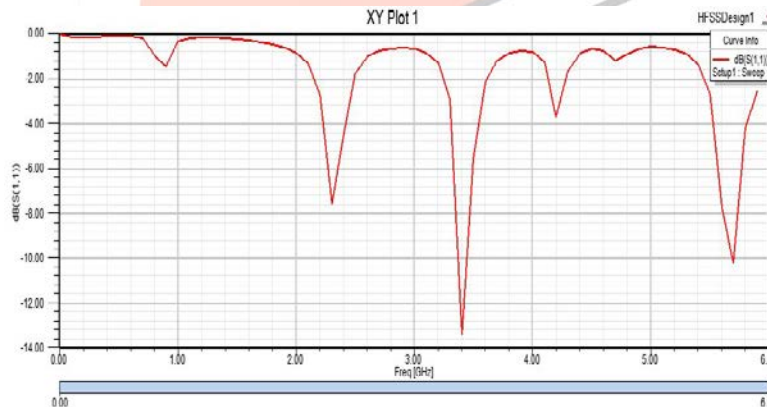

Figure 3: Return losses

B. Radiation Pattern

The radiation field of the micro strip antenna may be determined using either an electric current model or a magnetic current model. In the electric current model, the current is used directly to find the far-field radiation pattern. The electric current for the (1,0) patch mode. If the substrate is neglected (replaced by air) for the calculation of the radiation pattern, the pattern may be found directly from image theory. If the substrate is accounted for, and is assumed infinite, the reciprocity method may be used to determine the far-field pattern. In the magnetic current model, the equivalence principle is used to replace the patch by a magnetic surface current that flows on the perimeter of the patch[9] [7].
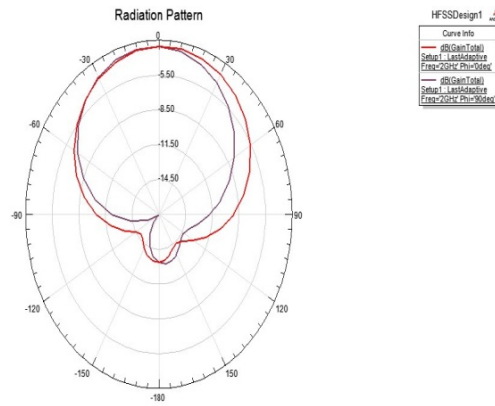The radiation Pattern of antenna is shown in below figures 4

Figure 4: Radiation pattern

C. 3-D View of Radiation Pattern

The radiation pattern is main concentration for the wide band application [12]. For wide band application the effect of the radiation up to 30 miles. The gain must be high for this type of application the radiation pattern is

The Figure 4 and 5 show the radiation pattern for the antenna at 5.64GHz. HPBW is the angular separation which the magnitude of the radiation pattern from the peak of the main beam decreases by 50% or -3 dB. HPBW (angle) is 70° for Optimum Frequency of 8.73 GHz.
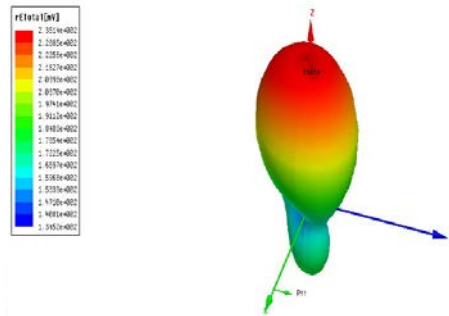

Figure5: 3D-view of radiation pattern

D. Field Distribution

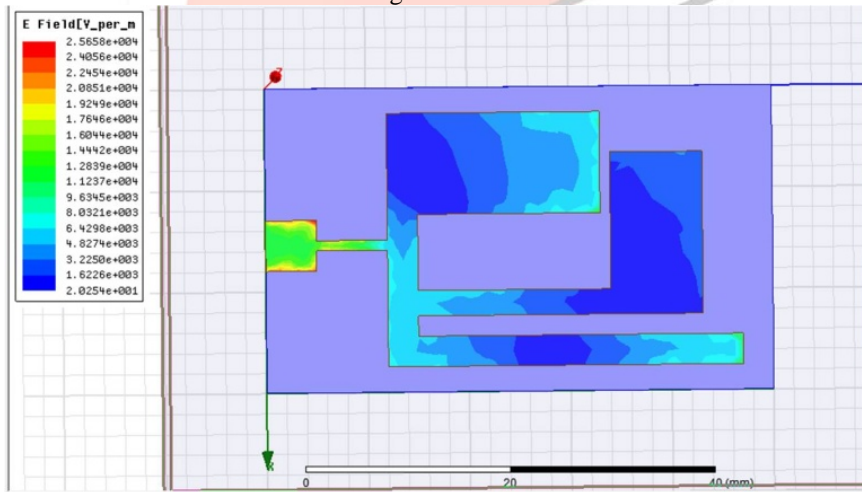The E-field distribution and H-Field distribution for this design is

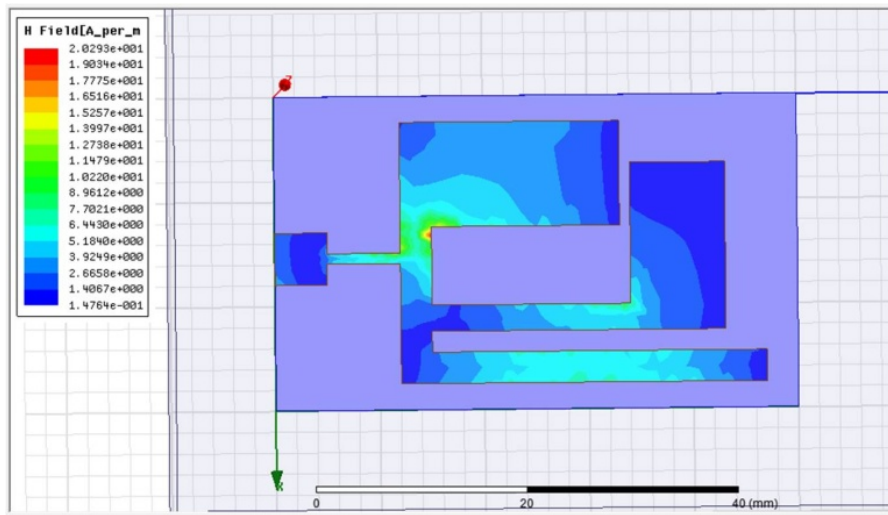Figure 6: E-field distribution for E-shape micro strip patch antenna

Figure 7: H-field distribution for E-shape micro strip patch antenna

For the view of field distribution there is no uniform distribution in the single u-slot patch antenna. For non-uniform distribution of these fields the return losses are somewhat high. For decrease the return losses there must perfect matching between coaxial system and the radiating element then we can easily remove the return losses.
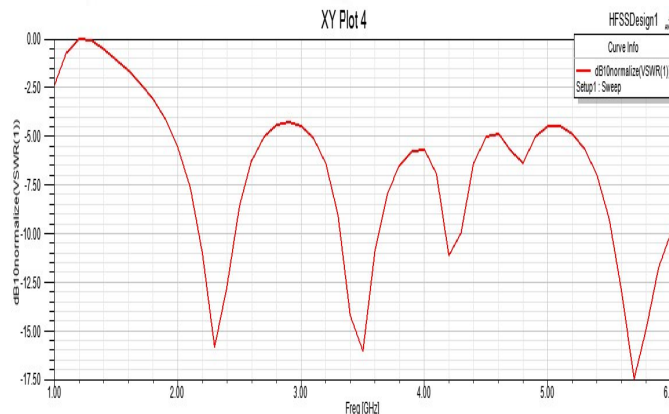
E. VSWR

Figure 8: VSWR for E-shape patch antenna

F. Gain

Another useful measure describing the performance of an antenna is the gain. Although the gain of the antenna is closely related to the directivity, it is a measure that takes into account the efficiency of the antenna as well as its directional capabilities. Remember that directivity is a measure that describes only the directional properties of the antenna, and it is therefore controlled only by the pattern. Gain of an antenna (in a given direction) is defined as "the ratio of the intensity, in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically [5] [7]. The radiation intensity corresponding to the isotropically radiated power is equal to the power accepted (input) by the antenna divided by 4π." In equation form this can be expressed as

$$Gain = 4\pi \frac{radiation\ intensity}{total\ input\ power} = 4\pi \frac{U(\theta,\varphi)}{p_{in}} \qquad (10)$$
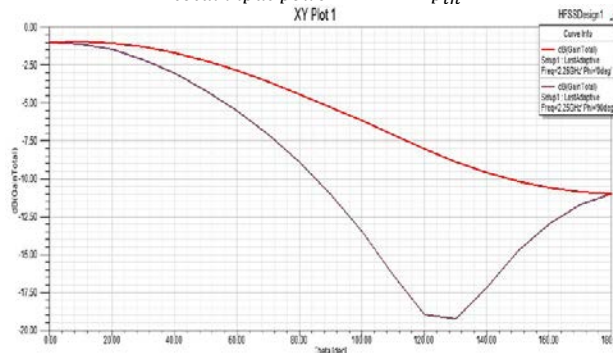

Figure 9: Gain characteristics

G. Different Antenna Parameters at Different Frequencies

Table 2: Values for radiation parameters for each frequency

Frequency(GHz)	2.25	3.4	5.64
Gain (dB)	0.815844	1.02579	1.04352
Radiation Efficiency(dB)	0.383772	0.362633	0.311672
Max U(W/Sr)	0.0414141	0.0322271	0.0392289
Peak Directivity	2.12586	2.82873	3.34812
Radiated Power(W)	0.244813	0.143169	0.14724
Accepted Power(W)	0.637913	0.394804	0.472418
Incident Power(W)	1	1	1

IV. CONCLUSION

In this paper, a Triple band microstrip patch antenna using epoxy substrate excited with edge feed has been designed, simulated, optimized and analyzed using HFSS (High Frequency Structure Simulator) software version 13.0. The performance of the designed antenna was analyzed in term of bandwidth, gain, return loss, VSWR, and radiation pattern. The design was optimized to meet the best possible result. Substrate used was FR4epoxy which has a dielectric constant of 4.4. The results show the multiband antenna is able to operate with 2.25GHz, 3.4GHz and 5.64GHz frequencies. Due to the frequency of operation and compact area occupied, the proposed antenna is promising to be embedded within the different portable devices employing Wi-Fi, WiMAX and in different wireless applications.

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