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Triple-band Planar Monopole Antenna for WLAN/Wi MAX Applications

[1] Ch.Raghavendra [2] Sujith A [3] Taraka Srikrishna K
[1][2][3] Department of ECE, V. R Siddhartha Engineering College, Vijayawada

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***Abstract:* -- A triple-band micro strip-fed printed monopole antennais designed for Wireless Local Area Network (WLAN) and Worldwide Interoperability for Microwave Access (WiMAX). The proposed antenna consists of a rectangular radiating patch with slots and ground plane that enables proper adjusting of the resonant bands.**

A parametric study on the lengths of the slots of the proposed antenna is provided to obtain the required operating frequency bands-namely, WLAN (2.4/5.2/5.8 GHz) and WiMAX (2.5/3.5/5.5 GHz).The proposed antenna can be an excellent choice for WLAN/WiMAX applications due to its small size, simple structure, good multiband characteristics, omni directional radiation pattern, VSWR and return loss are achieved over the operating bands.

***Index Terms*: Monopole antennas, Multiband antennas, Triple band antennas**

I. INTRODUCTION

The set of legally allowed wireless local area network channels using IEEE 802.11 protocols, mostly sold under the trademark Wi-Fi. 802.11 workgroup currently documents use in five distinct frequency ranges: 2.4 GHz, 3.6 GHz, 4.9 GHz, 5 GHz, and 5.9 GHz bands. Each range is divided into a multitude of channels. Countries apply their own regulations to the allowable channels, allowed users and maximum power levels within these frequency ranges. In some countries, such as the United States, licensed Amature Radio operators may use some of the channels at much higher power for long distance wireless access.

Wireless local area network (WLAN) is a local area network (LAN) that doesn't rely on wired Ethernet connections. A WLAN can be either an extension to a current wired network or an alternative to it. WLANs have data transfer speeds ranging from 1 to 54Mbps, with some manufacturers offering proprietary 108Mbps solutions. The 802.11n standard can reach 300 to 600Mbps.Because the wireless signal is broadcast so everybody nearby can share it, several security precautions are necessary to ensure only authorized users can access your WLAN.

WLAN signal can be broadcast to cover an area ranging in size from a small office to a large campus. Most commonly, a WLAN access point provides access within a radius of 65 to 300 feet. WiMAXis one of the hottest broadband wireless technologies around today. Wi MAX systems are expected to deliver broadband access services to residential and enterprise customers in an economical way. WiMAX would operate similar to WiFi, but at higher speeds over greater distances and for a greater number of users. Wi MAX was formed in April 2001, in anticipation of the publication of the original 10-66 GHz IEEE 802.16 specifications. WiMAX is to 802.16 as the WiFi Alliance is to 802.11

II. FEEDING TECHNIQUES

Micro strip patch antennas can be fed by a variety of methods. These methods are given into two categories contacting and non-contacting. In Contacting method, RF power line for a micro strip patch radiating through the link element is placed directly. Electromagnetic field energy coupler among the micro strip line and the radiating patchis placed on the assignment. Four of the most standard methods to feed micro strip line, coaxial probe (both contacting schemes), near the entrance to the combining and mixing

III. TYPES OF FEEDING

***Micro strip line feeding*:**

In this method, a conducting strip is joined directly to the edge of the Micro strip patch as displayed in Figure. The conducting strip is lesser in breadth as associated to the patch and this feed has the benefit that the feed can be imprinted on the identical substrate to offer a planar construction.

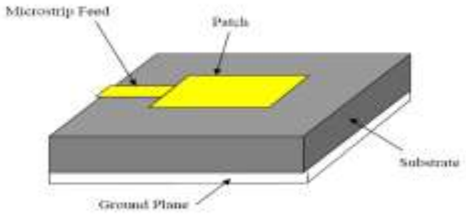

Fig: 1.Micro strip line feed

Determination of the insert cut in the patch is to match the impedance of the feed line to the patch lacking the need for any further matching element. Therefore this is a cool feeding scheme mean while it offers easiness of fabrication and straightforwardness in modeling as well as impedance matching. On the other hand if the depth of the dielectric substrate grows bigger, surface waves and forged feed radiation also increases, which disturbs the bandwidth of the antenna.

Probe Feed:

Probe feed method is used for nourishing Micro strip patch antennas. It is shown in Figure. It found that the outer conductor is connected to the ground plane, mean while the inner conductor of the coaxial connector integrated radiating patch. The most important advantage of this method is no need to match with its input impedance of the patch can be located inside a place of wanting to feed. The feed to make the process easier and less radiation is bogus.

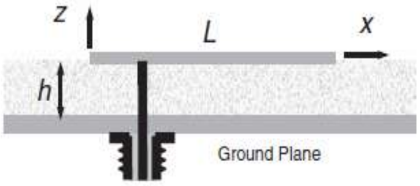

Fig:2.Probe feed

The main drawback is the narrow bandwidth, and a hole is bored in the substrate and the connector juts out of the ground plane is a problem from the model. It offers a wide bandwidth, the power of a dense surface, for, micro strip line feed and coaxial feed will notice that many of the risks of sorrow.For the ground plane, the outer conductor of Coaxial cable is connected and the center will be extended up to patch antenna.

***Aperture Coupled Feed*:**

Feed circuitry is shielded from the antenna with the help of a conductor with hole,for the purpose of transmitting energy to antenna.In the aperture united feeding method the radiating patch and the micro strip feed line are unglued by the ground plane as shown in Figure 5.1.3 Coupling between the patch and the feed line is completed over a slot or an aperture in the ground plane. The coupling aperture is typicallyfixed under the patch, important to lower crosspolarizationdue to regularity of the shape. The quantity of coupling from the feed line tothe patch is strong-minded by the shape, dimensions and position of the aperture.

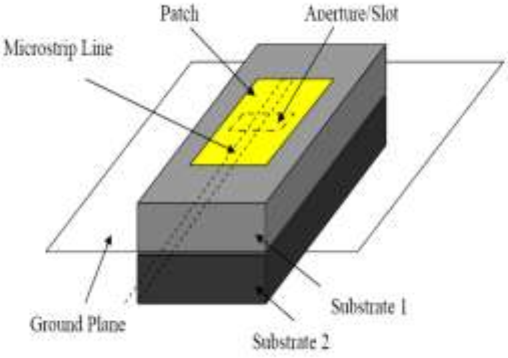

Fig:3.Aperture-coupled feed

The key drawback by this feed method is that it is problematic to manufacture due to numerous layers, which also increases the antenna chunkiness. This feeding arrangement also offers narrow bandwidth.

Proximity Coupled Feed:

The proximity coupled feeding method is also termed as the electromagnetic coupling arrangement. In this the two dielectric substrates are used in such a way that the feed line is among the two substrates and the radiating patch is on top of the upper substrate as shown in figure.

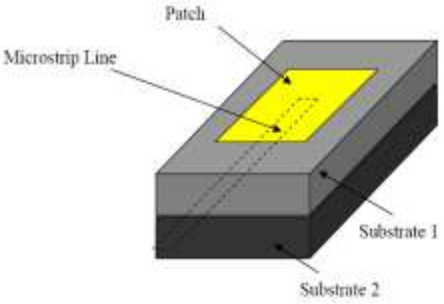

Fig:4.Proximity Coupled Feeding

The most important benefit by using this feed method is that it eradicates bogus feed radiation and makes available a very high bandwidth. Matching can be accomplished by governing the length of the feed line and the width-to-line ratio of the patch.

IV. ANTENNA CONFIGURATION AND DESIGN APPROACH:

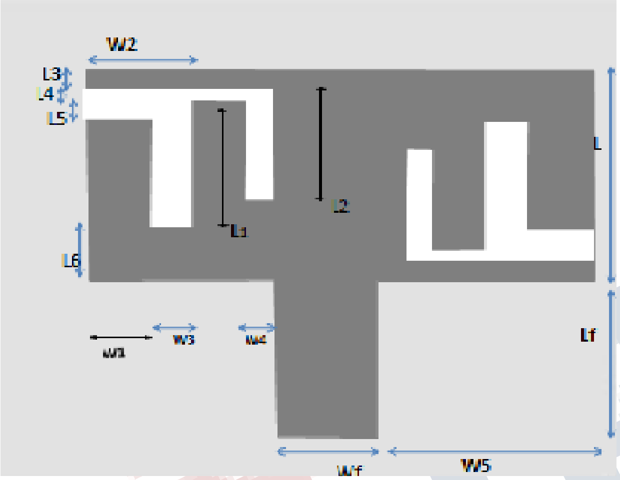

Fig:5. Antenna Design

The above figure illustrates the geometry and dimensions of the proposed triple band antenna for WLANand WiMAX triple-band operation. The proposed antenna is fabricated on the FR4 dielectric substrate of thickness1.6mm, relative permittivity of4.4, and dielectric loss tangent of 0.02. The over all size of the proposed antenna is only 19mm×25mmor about $0.152\lambda_0 \times 0.2\lambda_0$, where λ is the free-space wavelength at the desired first resonant frequency 2.4GHz.

Antenna is composed of a rectangular shaped radiator with two F shaped slots of equalize, formed by dimensions W$_1$, L$_1$,W$_2$, and L$_2$, are etched on the left and right side of the radiator. A circular shaped patch is printed with a rectangular ground plane on the back side of the dielectric substrate. Ansoft's HFSS commercial software are used to optimize parameters for triple-band operation of the proposed compact antenna ,and the dimensions are listed in the TableI.

Dimensions of Antenna (Table I):

Parameters	Units(mm)	Parameters	Units(mm)
L	15.0	Lf	9.0
L1	9.0	W1	1.25
L2	8.8	W2	5.25
L3	0.6	W3	1.0
L4	1.0	W4	0.4
L5	1.0	W5	6.25
L6	1.2	Wg	19.0
Lg	3.9	Wf	3.0

The antenna design evolution process to achieve the triple band operation for WLAN/WiMAX applications. The antenna design starts by a conventional rectangular patch and ground plane, and it can be observed that in this case a single resonant mode seems to form at about 3.0 GHz [see Ant 1)]. The Ant 2 (Fig. 2) illustrates that two modes are resonating at 2.8 and 4.2 GHz due to the modification of the radiating patch by etching two L-shaped slots each on either boundaries of the patch. Ant 3 indicates that inclusion of an additional L-shaped slot on the radiating patch of the antenna provides another additional resonance. Finally, ground plane is modified patch to improve the impedance matching.

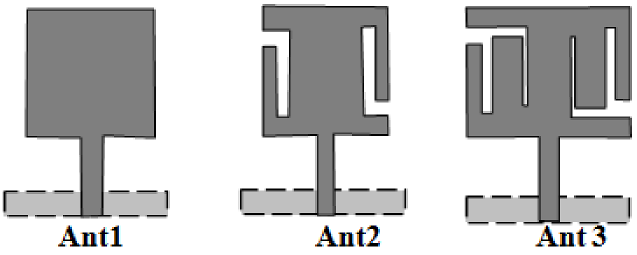

Fig: 6.Evolution for Antenna Geometry

WLAN resonance occurs at the 2.4/2.5 GHz WLAN resonance occurs due to the middle and right side of the patch. For the 3.5 GHz operation it is observed that the resonance occurs due to L-shaped slot on the left hand side of the patch. The third (highest) resonant mode of the antenna, by considering the current distribution of the antenna arises from the currents on the upper and lower strip formed due to the F-shaped slots on the radiating patch and feed line. This clearly indicates the importance of the embedded slot on the proposed antenna resonance.

More over at this frequency a strong current distribution is noticed on the finite ground plane.

First Resonance

First resonance in the proposed antenna is excited due to the middle and right side of the patch. At the resonance, this length would be half of the wavelength in the medium. The boundary condition for the first resonance can be seen in which the maxima of the current occurs at the main radiating patch and right side L-slot patch, therefore, the length of the radiating patch responsible for first resonance can be calculated as

$$\mathbf{Lr1 = (L - L5) + (Wf + W5) + (L2 + L6 - L4)}$$

From the data presented in Table-I, Lr1= 32.25mm. Here the effective dielectric constant of the antenna is calculated based on the equation. Therefore, the effective dielectric constant(Δreff), due to the circular patch and the radiating patch, is 3.86. At the resonance, Lr1 should be λg/2. Therefore,

$$\mathbf{Fr1 = C\ /2\ Lr1\sqrt{reff}}$$

The effectiveness of the design method is further validated by predicting the first resonance frequency for the data presented in the Table- III, the first resonant frequency as a function of L2 is compared with the full-wave simulated data, the effect of L2 of the F-shaped slot onthe right hand side of the radiator on return loss of the antenna. By varying the slot length L2, thereis no significant change in the second and third resonance, whereas the first resonance is very sensitive to this dimension. As the length is increased from 6.8 mm to 10.8 mm, the first resonance shifts towards lower frequency side. Further increase in length spoils the boundary condition necessary for the first resonance. Hence, to cover the triple-band accurately, the value of L2 is selected to be 8.8 mm. From Table-II, it can be seen that the resonant frequencies calculated from the design method are agreeing well with the simulated data.

Second Resonance:

The second resonance is excited due to the F-slot on the left hand side of the radiating patch, However, for the boundary condition in this case, the electric field maxima occurs at the slot edges are shown. From the data given in the Table-II, the length ofthe slot is 23.05 mm, as

$$\mathbf{Lr2 = L1 + L2 + W2}$$

$$\mathbf{Fr2 = C\ /2\ Lr2\sqrt{reff}}$$

Therefore, fr2 = 3.31 GHz for reff = 3.86. However, thefull-wave simulation shows that the resonance is occurred at 3.43 GHz, which is much close to the predicted value. The effectiveness of the design method is further validated by predicting the second resonance frequency for the data presented. In the Table- III, the second resonant frequency as a function of L1 is compared with the full-wave simulated data. Table-III, it can be seen that the resonant frequencies calculated from the design method are a greeing well with the simulated data.

***Third Resonance*:**

The third resonance occurs due to the narrow strips, formeddue to the F-shaped slot at the bottom and right hand side on the radiating patch, respectively. This can also be established by studying the current distribution as shown in Fig.. it is clearly illustrated that one of the current minima occurs at the end of the edge and the other on the feed line. At resonant frequency, the length of the current path would be half of the guided wavelength. Therefore,

$$\mathbf{Lr3 = L2 + W2 - W4}$$

$$\mathbf{Fr3 = C\ /2\ Lr3\sqrt{\varepsilon reff}}$$

Here the effective dielectric constant of the medium is 3.86.The effectiveness of the design method is further validated by predicting the third resonance frequency for the data presented in Fig. 8. In the Table- IV, the third resonant frequency as a function ofW2 of the right side is compared with the full-wave simulated data.

V. SIMULATION RESULTS

The micro strip patch antenna was designed using HFSS simulator. The performance of the antenna has been studied by comparing the Return loss, VSWR, radiation patterns.

Return loss:

The Return Loss (RL) provides the info about the quantity of power that is dissolute to the load and does not return as reflection. For practical applications, a VSWR of 2 is acceptable, since this agrees to a RL of -10dB

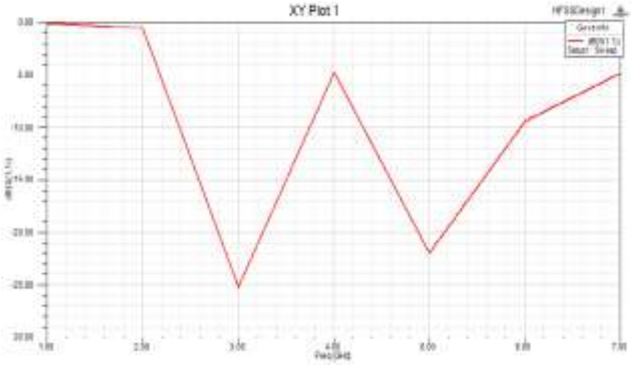

Fig:7. Return loss

The simulation results for the return loss for the frequency ranges of WLAN 2.4/5.2/5.8 GHz and for WiMAX of2.5/3.5/5.5 GHz are shown in the figure .

Return loss at different frequencies(Table II):

Proposed antenna	Return loss <-10db	Frequency range(GHz)
FR4	-10	2.4
FR4	-13	2.5
FR4	-12	5.8
FR4	-13	5.2
FR4	-14.5	3.5
FR4	-15	5.5

VI. VOLTAGE STANDING WAVE RATIO (VSWR):

For the practical antennas the VSWR has to be less than 2 i.e. 90%of the power has to be radiated in to space and only 10% of the power has to be reflected back. So the value of VSWR can be seen to be within 1 to 2 in the operating range.The simulation results for VSWR for the frequency range of WLAN 2.4/5.2/5.8 GHz and for WiMAX of 2.5/3.5/5.5 GHz are shown in the figure

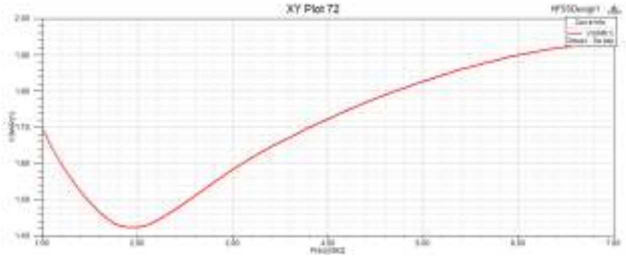

***Fig :8.** VSWR*

VSWR at different frequencies(Table III)

Proposed antenna	VSWR(<2)	Frequency range(GHz)
FR4	1.49	2.4
FR4	1.50	2.5
FR4	1.65	3.5
FR4	1.86	5.5
FR4	1.89	5.8

Radiation patterns

Radiation pattern is a function of the observer's position along a path or a surface of a constant radius and goes through a direction at which maximum radiation occurs. A two dimensional pattern is used to represent the radiation pattern and this may be function of the elevation angle θ at a constant azimuth angle φ or a function of azimuth angle φ at a constant elevation angle θ. The radiation patterns of azimuth and elevation are shown below.

Radiation plots are most often shown in either the plane of the axis of the antenna or the plane perpendicular to the axis and are referred to as the azimuth or "E-plane" and the elevation or "H-plane" respectively.

A drop of 1 dB means that the power is decreased to about 80% of the original value while a 3 dB drop is a power decrease of 50% or one-half the power. The beam width specified on most data sheets is usual0ly the 3 dB or half-power beam width.

A 10 dB drop is considered a large drop, a decrease to 10% of the original power

At 2.4GHz:

Radiation plots are most often shown in either the plane of the axis of the antenna or the plane perpendicular to the axis and are referred to as the azimuth or "E-plane" and the elevation or "H-plane" respectively.

Radiation pattern for the frequency of 2.4GHz which is given the 0 dB Gain.

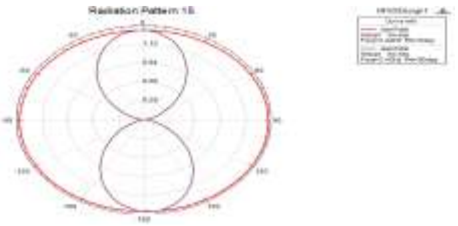

Fig: 9.Radiation pattern of 2.4GHz

At 2.5GHz

Radiation plots are most often shown in either the plane of the axis of the antenna or the plane perpendicular to the axis and are referred to as the azimuth or "E-plane" and the elevation or "H-plane" respectively. Radiation pattern for the frequency of 2.5GHz which is given the gain of 0.5 dB

Fig:10. Radiation pattern of 2.5GHz

At 3.5GHz:

Radiation plots are most often shown in either the plane of the axis of the antenna or the plane perpendicular to the axis and are referred to as the azimuth or "E-plane" and the elevation or "H-plane" respectively.Radiation pattern for the frequency of 3.5GHz which is given the gain of 0.85 dB

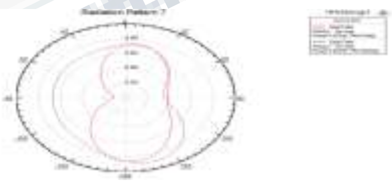

Fig :11.Radiation pattern of 3.5GHz

At 5.2GHz:

Radiation plots are most often shown in either the plane of the axis of the antenna or the plane perpendicular to the axis and are referred to as the azimuth or "E-plane" and the elevation or "H-plane" respectively. Radiation pattern for the frequency of 5.2GHz which is given the gain of 1.98 dB

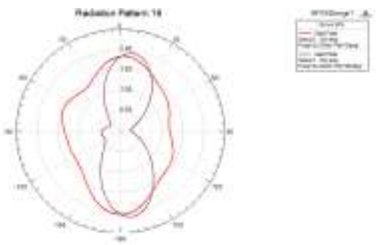

Fig :12. Radiation pattern of 5.2 GHz

At 5.5GHz :

Radiation plots are most often shown in either the plane of the axis of the antenna or the plane perpendicular to the axis and are referred to as the azimuth or "E-plane" and the elevation or "H-plane" respectively.Radiation pattern for the frequency of 5.5GHz which is given the gain of 2.40 dB

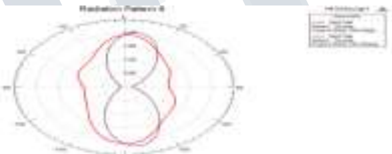

Fig :13.Radiation pattern of 5.5GHz

At 5.8GHz

Radiation plots are most often shown in either the plane of the axis of the antenna or the plane perpendicular to the axis and are referred to as the azimuth or "E-plane" and the elevation or "H-plane" respectively. Radiation pattern for the frequency of 5.8GHz which is given the gain of 2.40 dB

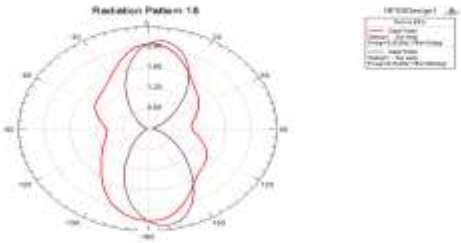

Fig :14.Radiation pattern of 5.8GHz

VII. ANTENNA FABRICATION PROCESS

The Micro strip patch antenna is fabricated by using the photolithographic technique in which a chemical etching process is done. In this etching process the unwanted metal regions are removed so that the required design is obtained. Depending upon the antenna design a substrate is placed. Here bi-planar or uni-planar dual or single side substrates are used.By using diverse types of substrate materials the antenna is designed. The selection of a proper substrate material is the essential part in antenna design.

Fig: 15. Prototype of fabricated antenna

A thin layer of negative photo resist solution is coated using rotating method on copper surfaces and is dried. The mask is placed onto the photo resist and exposed to UV light. After the proper UV exposure the layer of photo-resist material in the exposed portions hardens when it is treated with developer solution. The absorbers fixed on the walls are highly lossy at microwave frequencies. They have tapered shapes to attain good impedance matching for the microwave power impinges upon it.

Measured Results of the Antenna:

Return loss:

The Return Loss (RL) provides the info about the quantity of power that is dissolute to the load and does not return as reflection. For practical applications, a VSWR of 2 is acceptable, since this agrees to a RL of -10dB. The fabrication results for the return loss for the frequency ranges of WLAN 2.4/5.2/5.8 GHz and for WiMAX of 2.5/3.5/5.5 GHz are shown in the figure .

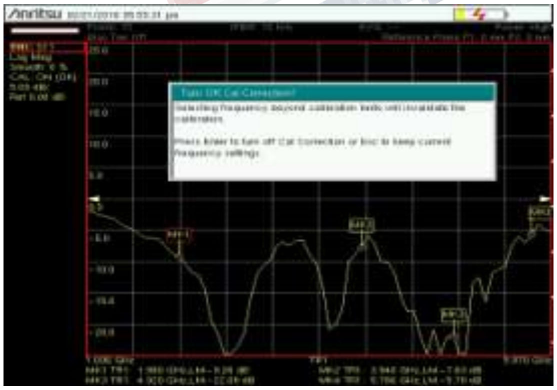

Fig:16. Return loss

(Table IV):Return loss (Fabricated Antenna)

Proposed antenna	Return loss <-10db	Frequency range(GHz)
FR4	-13	2.4
FR4	-13.5	2.5
FR4	-12	5.8
FR4	-13.5	2.5
FR4	-10	3.5
FR4	-11	5.5

Voltage Standing Wave Ratio (VSWR):

For the practical antennas the VSWR has to be less than 2 i.e. 90%of the power has to be radiated in to space and only 10% of the power has to be reflected back. So the value of VSWR can be seen to be within 1 to 2 in the operating range. The fabrication results for VSWR for the frequency range of WLAN 2.4/5.2/5.8 GHz and for WiMAX of 2.5/3.5/5.5 GHz are shown in the figure .

Fig : 17.VSWR for Different frequencies

Proposed antenna	VSWR(<2)	Frequency range(GHz)
FR4	1.57	2.4
FR4	1.6	2.5
FR4	1.65	3.5
FR4	1.8	5.5
FR4	1.72	5.2
FR4	1.7	5.8

(Table V):VSWR for Different frequencies

VIII. COMPARISON OF RESULTS

Table VI Comparison between Simulated and Measured values of VSWR

In this the results of Micro strip patch antenna are been compared both for the simulated and the measured. The values are represented in the tabular form.

Frequency(GHz)	Simulated return loss	Measured return loss
2.4	-10	-13
2.5	-13	-13.5
3.5	-15	-12
5.2	-14.5	-13.5
5.5	-13	-10
5.8	-12	-11

Table: VI Comparison between Simulated and Measured values of Return Loss

From the Table it shows the simulated results of the antenna using HFSS software and measured results of the antenna using vector network analyzer is been compared .By comparing both the results it is clearly observed that the simulated results and measured results are having a change because the losses are more in fabrication and the measurement errors are more while measuring the values in the analyzer.

The position and dimension of the slots are slightly misplaced compared to the simulated antenna design. In fabrication the slits are not exactly inserted so that the losses are more, hence the return loss and VSWR are slightly different compared with the simulated antenna.

IX. CONCLUSION

Optimal micro strip-fed monopole antenna with two L shaped slots radiators is proposed, simulated and fabricated for WLAN/WiMAX operation. Experiments are carried out to validate the design concept and method showing a good agreement between simulated and fabricated values. The proposed antenna features gives good triband operatingbandwidth and stable radiation patterns indicating that it is applicable for WLAN/WiMAX applications.