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A Stub Loaded Dual Band Microstrip Patch Antenna for WLAN Application

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***Abstract*— In the rapid progress of commercial communication application, the development of compact antenna has an important role. This work present a stub loaded dual band microstrip patch antenna for wireless local area network (WLAN).The antenna consist of L- Shaped and E-Shaped radiating elements to generate two resonant modes for dual-band operation. The L-element fed directly by a 50-Ω microstrip line is designed to generate a frequency band at around 6.0 GHz to cover the higher band 5.8 GHz of the WLAN system. The E-element is coupled fed through the L-element and designed to generate a frequency band at around 2.4 GHz to cover the lower band 2.44 GHz of the WLAN system. In addition a microstrip stub is introduced for impedance matching causes more uniform electric field on the radiation aperture and thus improve the gain and aperture efficiency. The proposed antenna is designed on an FR4 substrate having dielectric constant 4.4 and a loss tangent of 0.02. The antenna design and simulation is performed using Ansoft HFSS.**

***Index Terms*— Dual band, WLAN, L-shaped radiating element, E-shaped radiating element, Stub**

I. Introduction

Currently, the wireless local area network (WLAN) is one of the most popular networks for accessing the internet. The WLAN uses a lower frequency band, 2.4–2.484 GHz, for the 802.11b/g standards, and two higher frequency bands, 5.15–5.35 GHz and 5.725–5.825 GHz, for the 802.11a standard. As the demand for smaller sizes of wireless devices increases, antennas designers are making tremendous efforts in attempts to reduce the physical sizes of the antennas, yet covering all the three operation bands.

A number of antenna have been proposed for WLAN application, perhaps the size of an antenna and multiband operation was a major problem [5]-[9].

However, significant advancement in wireless communication needs antennas having light weight, low profile, superior performance, and multiband operation. For these requirements, a micro strip antenna is a good candidate due to thin profile, light weight, low cost, and easy fabrication. Wideband and multiband antennas are preferred to avoid using multiple antennas for different operating frequencies.

Microstrip patch antenna is a key building in wireless communication and Global Positioning system since it was first demonstrate in 1886 by Heinrich Hertz and its practical application by Guglielmo Marconi in 1901. Microstrip patch antennas are increasing in popularity for use in communication systems due to their miniaturized size and cost effectiveness. They offer good compatibility for embedded antennas in hand-held devices.

The main disadvantage associated with microstrip antennas (MSAs) is their narrow bandwidth. Many efforts and techniques have been developed for enhancing the bandwidth of these antenna [12] [13]. One popular technique is the utilization of parasitic patches. But the addition of parasitic patches causes enlarge geometry with increased complexity in array fabrication. This is particularly inconvenient for a co-planar case [14]. Alternatively, bandwidth can also be enhanced by employing a substrate of sufficient thickness which allows the penetration of field lines in it. Such a technique requires a coaxially fed method that usually causes increased cross-polarization in H-plane [15]. This also limits the useful bandwidth of an antenna which is usually less than 10% of the central frequency. This limited bandwidth is associated with increased inductance caused by the longer probe [16].

Many researchers have proposed different shapes of microstrip antennas for different applications with a specific feeding mechanism [17]. One of the most popular mechanisms is the coupling slot. Various slot shapes have been designed and proposed like C-shaped [18], U-shaped [19], E-shaped [20], L-shaped [21], H-shaped [22], P-shaped [23], W-shaped [24], the size and selection of a shapes is dependent upon a specific application and frequency of interest. Among them E & L shaped proved to be most popular shaped.

U-shaped and V-shaped microstrip antenna provides bandwidth up to 25% while E-shaped patch antenna can increases bandwidth above 30% compared to a regular rectangular patch antenna. Comparing both designs, the E-shaped is much simpler to construct by only adjusting length, width and position of slots.

The L shape slot in the radiating element tends to have wideband characteristics. Also an L shape introduces the capacitive component in the input impedance to counteract the inductive component of the probe. Also to compensate the

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increasing inductive effect due to the slots, thickness of the substrate is increased, as thickness increases the bandwidth increases accordingly. L Shape patch broadband Microstrip antenna experimentally increase bandwidth up to 23.7% - 24.43% [26].

In this article, we present a very low cost compact stub loaded dual-band antenna using a having a microstrip fed input which operates at WLAN frequency bands. The radiator consists of an L-shaped and E-shaped elements resonating at around 2.4 GHz and 6.0 GHz respectively.

This work is organized as follows. In Section II, information about wireless standards is provided. Section III describes the proposed antenna geometry, this is followed by Section IV where Parametric Study of the antenna has been given. Section V discussed on the results and Section VI shows the experimental verification of antenna using VNA. Finally, Section VII concludes the work

II. WIRELESS TECHNOLOGY STANDARDS

The proposed antenna is compatible with the following Wireless Technology Standards.

WiMAX: WiMAX (Worldwide Interoperability for Microwave Access) is a wireless communication standard widely used as an alternative to cable and DSL. IEEE std 802.16 defines the frequency bands for WiMAX usage. Three WiMAX bands 2.3/2.5/3.5GHz (2300-2400, 2500-2700, 3400-3600 MHz) are widely used. WiMAX is deployed all over the world and the usage of bands differs from each country.

Bluetooth: Bluetooth is a wireless communication standard used for communication over short range distances. Bluetooth is a very popular technology standard and can be find in many electronic devices. Bluetooth operates in the range of 2.4GHz (2400-2483.5MHz).

WLAN: WLAN systems represent an attractive way of setting up computer networks in locations where cable installation may be expensive or impossible. They provide high data applications and this is one of the reasons why big attention is paid to WLAN equipment manufacturers. WLANs operate in the unlicensed 2.4 GHz (2400-2484 MHz) and the 5GHz band- 5.2GHz (5150-5350 MHz) and 5.8GHz (5725-5825MHZ). Some of the popular WLAN standards as follow:

1) 802.11a

This is a 5 GHz radio band physical layer standard which specifies eight available radio channels with a maximum link rate of 54 Mbps per channel. As the distance between the radio access point and the user increases, the data rate decreases.

2) 802.11b

This is 2.4 GHz radio band physical layer standard which specifies three available radio channels and a maximum link rate of 11 Mbps per channel. Again, the data rate decreases with an increasing distance between the access point and the user.

3) 802.11g

This physical layer standard for WLAN specifies three available radio channels in the 2.4 and 5 GHz radio band with a maximum link rate of 54 Mbps per channel and with the use of Orthogonal frequency-division multiplexing (OFDM). Now-a-days, dual band WLAN systems combining the IEEE 802.11a/b/g standards are be- coming more attractive. Hence, to satisfy the need of wireless communications, it is necessary to design compact high performance antennas with 2.4/5 GHz dual band operation and excellent radiation characteristics.

III. ANTENNA GEOMETRY

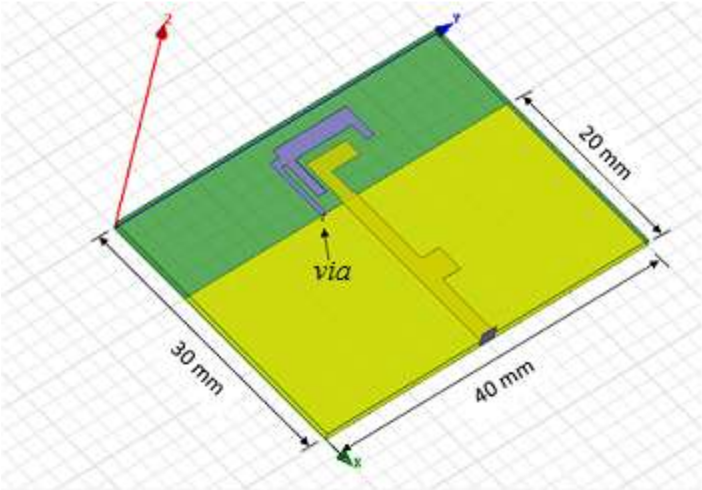
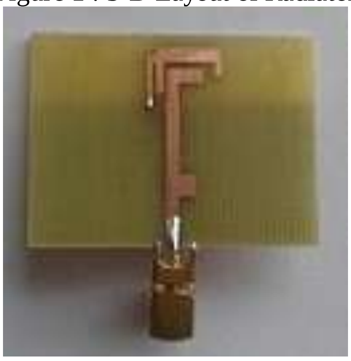
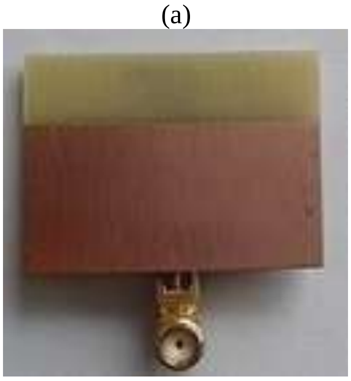


Figure 1 : 3-D Layout of Radiator



(a)



(b)

Figure 2 Prototype Antenna (a) Top view (b) Bottom view

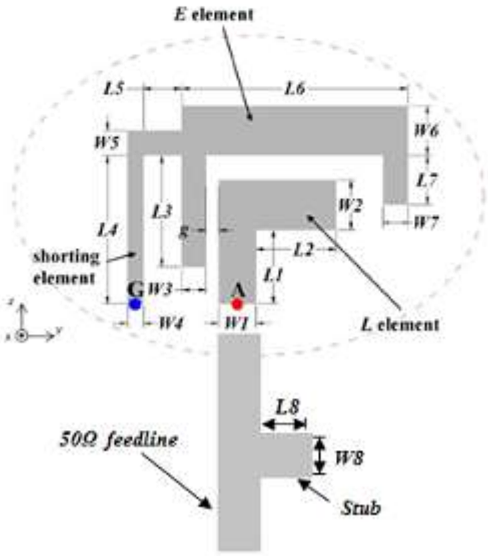


Figure 3: Geometry of Radiator

Figure 1 shows the 3-D view of the proposed dual-band antenna which has a radiator with an area of $8.5 \times 10.4\ mm^2$, a ground plane of $40 \times 20\ mm^2$ and overall dimension of $40 \times 20 \times 0.8\ mm^3$, the microstrip-feed line has a width of 1.8 mm to achieve a characteristic impedance of 50Ω.

The geometry of the radiator is shown in Figure 3 which consists of two radiating elements. These elements look like the letters E and L rotated by 90° and so are denoted here as an E –element and L -elements, respectively. The prefixes W and L used to indicate the dimensions of Figure 3 denote the widths and lengths, respectively, in different parts of the elements. The L-element is direct-fed by the feed line at "A" marked on Figure3. It generates a wide frequency band at 6.0GHz for the higher WLAN bands at 5.8 GHz. The E-element, placed very close to the L–element having a modified inverted F structure, is coupled-fed from the L-element via the small gap "g" and is shorted to ground using a via with diameter of 0.3 mm marked as "G" on the shorting element of Figure 1(b). It generates a band at around 2.4 GHz for the lower band 2.44 GHz of the WLAN system. Thus the antenna has dual-band operation to cover all the 2.44 /5.8 GHz WLAN bands. Since only one feed point is required for the two separate elements which are closely packed together, the radiator size is very compact.

The analysis to study the effects of stub on the dual band response in stub loaded antenna is presented. The stub reduces the resonance frequency of second order $TM_{3/4,0}$ mode of the shorted patch and along with the fundamental $TM_{1/4,0}$mode yields dual frequency response.

In order to reducing the frequency ratio of two frequency bands of the antenna and also for the impedance matching a microstrip stub having volume $3 \times 2.3 \times 0.02\ mm^3$ is etched on one of the side of the fed line as shown in Figure 3.Loaded stubs causes more uniform electric field on the radiation aperture and thus improves the gain and aperture efficiency. When a stub introduce to one of the end of the feed line, one can make an antenna with two resonant frequencies. The first resonant frequency is approximately the same as that in the initial design, but the second frequency depends on the stub's length, the stub's location, and the location of the feed point across the patch's width.

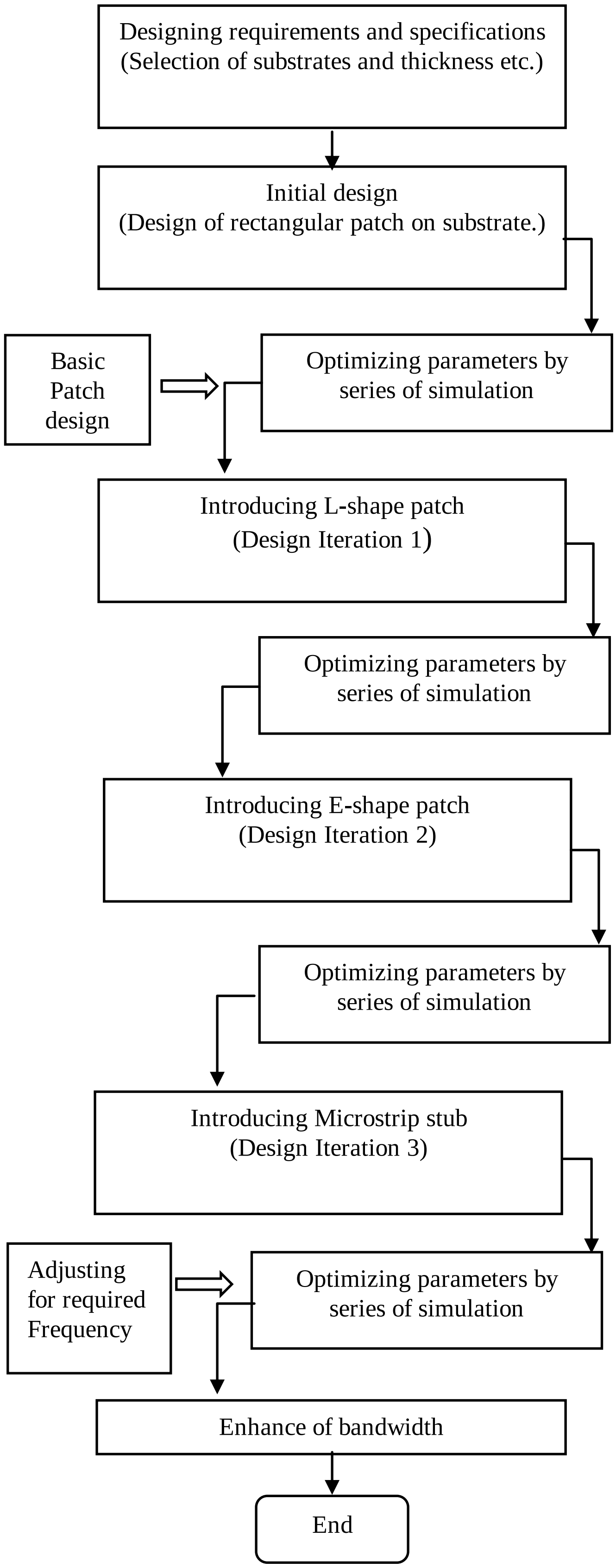


Figure 4: Flow diagram of designing Procedure

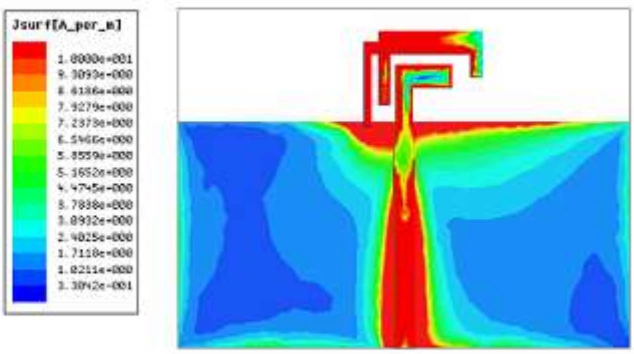
FR4 substrate of thickness 0.8 mm is used on which the total structure is mounted. Dielectric constant of substrate material is chosen as 4.4 while loss tangent is 0.02. The dimension of substrate material is taken as 40 mm × 30 mm. The opposite side of the substrate is covered by the copper plate that acts as ground plane for excitation signal. This enhanced the directivity of antenna to a desired level. Copper metal was also used as radiating element. The optimized dimensions are listed in Table1.

Table 1: Optimized dimension of antenna

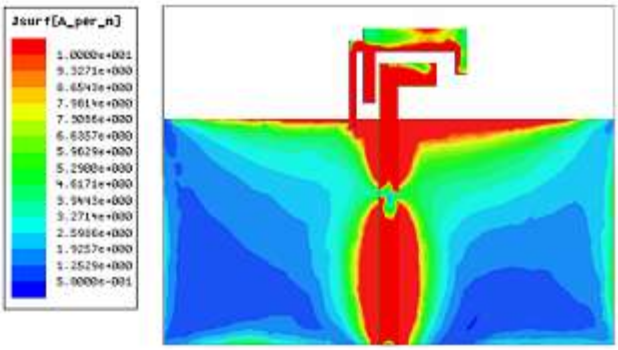
(L1,W1)	(3,1.5)
(L2,W2)	(3.45,2)
(L3,W3)	(4.5,1)
(L4,W4)	(6.5,0.6)
(L5,W5)	(0.65,1)
(L6,W6)	(9.15,2)
(L7,W7)	(2,1)
(L8,W8)	(2.3,3)
g	0.5

IV. PARAMETRIC STUDY

To observe the effect of various dimensions of the antenna on the two resonant frequencies a detailed parametric study was performed using Ansoft HFSS. To understand the impact of the radiating elements on the resonating frequencies, the design is simulated with the L-shape element alone and a single band was obtained at 6.2 GHz. The S11 plots have been shown in Fig. 6. When the E-element was added, a second resonant mode was obtained at 2.4 GHz also shifting the higher frequency to around 5.4 GHz. The Current distribution results are shown in Fig. 5. It shows that at 2.4 GHz, the current was mainly on the E-element which show that E-element is the resonating element at 2.4 GHz. At 5.4 GHz, a high current was observed on the L-element which confirms that L-element is responsible for that band.



(a)



(b)

Figure 5: Current distribution plot at (a) 2.4 GHz (b) 5.4 GHz

When a stub is introduced to one of the end of the feed line, the first resonant frequency is approximately the same as that in the initial design, but the second resonance frequency get shifted. Shifting in a resonance depends on the stub's length, the stub's location, and the location of the feed point across the patch's width.

For a radiator without stub S_{11} yields around $-18.88\ dB$ at resonance frequency around 2.4 $GHz\ and\ -24.85dB$ at resonance frequency around 5.4 GHz.

For a radiator with stub S_{11} yields around $-38.08\ dB$ at resonance frequency around 2.4 $GHz\ and\ -40.7dB$ at resonance frequency around 6.0 GHz. here, s_{11} improved for the lower band at around 2.4 GHz and the resonance frequency of upper band 5.4 GHz get shifted to resonance around 6.0 GHz

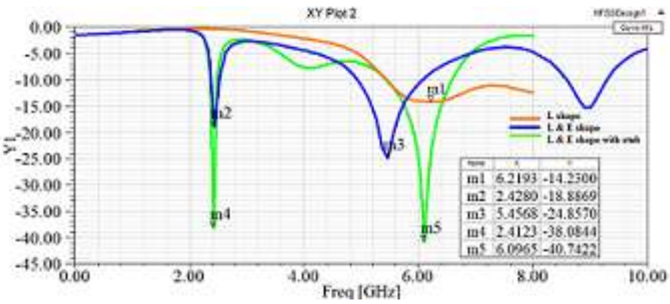


Figure 6: S_{11} *Parameter plot*

	Resonance Frequency (GHz)	Return Loss (S_{11}) in dB
L-element only	6.2	-14.23
L & E element	2.4	-18.88
	5.4	-24.85
L & E element with stub	2.4	-38.08
	6.0	-40.74

Table 2: Simulated S_{11} at various design iteration

V. RESULTS & DISCUSSION

The proposed antenna is designed and simulated in Ansoft HFSS. It provides excellent characteristics which demonstrate a clear indication that proposed antenna can be used in 2.44 / 5.8 GHz wireless applications discussed above. The designed antenna is excited with a microstrip feeding in order to extract its electromagnetic characteristics. The normalized impedance of the input excitation source is selected as 50 Ω which is worldwide accepted for WiMAX, Wi-Fi application.

According to the conventional circuit theory as well as electromagnetic wave propagation theory, maximum amount of the input excitation will be radiated in air when perfect impedance matching between source and radiator would be achieved. Voltage standing wave ratio commonly known as VSWR measures the amount of mismatch between source and antenna. In case of antenna design and wireless application VSWR must be less than 2; and expected as close to 1.The 50Ω source impedance resulting in a VSWR of 1.02 and 1.07 respectively for 2.4 GHz and 6.0 GHz band depicted in Fig.7.

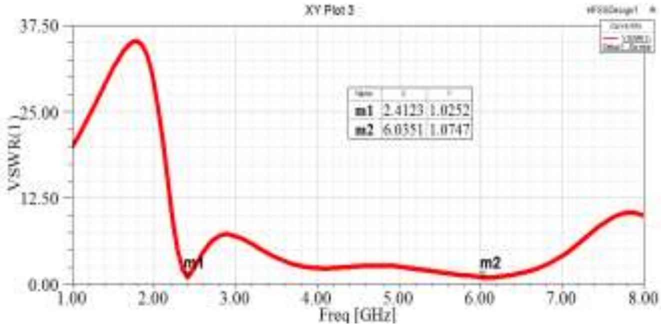


Fig. 7. Computed voltage standing wave ratio of the proposed antenna

Another important electrical behavior of antenna is its scattering parameter, sometimes known as return loss. Return loss must be less than -10dB in case of successful wireless application. Scattering parameter is closely related to the VSWR. It becomes smaller while the VSWR is close enough to 1.The simulated return loss of the proposed antenna obtained as -38.08 dB and -40.74 dB at 2.41 GHz and 6.09 GHz respectively. The impedance bandwidth e.g. the frequency range where the return loss remains below -10 dB obtained around 0.122 GHz from 2.35 GHz to 2.47 GHz and 1 GHz from 5.48 GHz to 6.58 GHz. Hence, the VSWR was found below 2 within the frequency range. The simulated return loss with frequency variation is illustrated in Fig. 8.

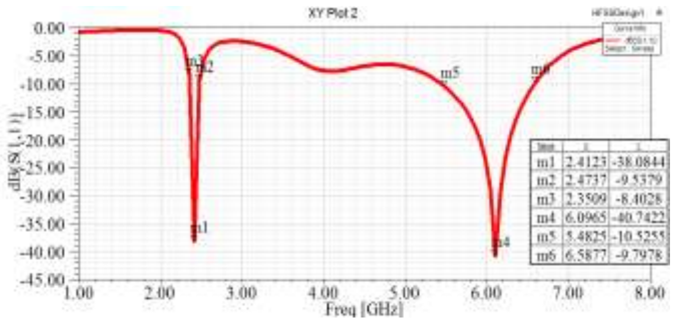


Fig. 8. S-parameter magnitude in dB

The mathematical function or a graphical representation of radiation properties of antenna as a function of space coordinates is called radiation pattern which is the most important property of antenna performance analysis. In most cases the radiation pattern is determined in far field region. Extracted far field radiation pattern are shown in figure 9 and 10.

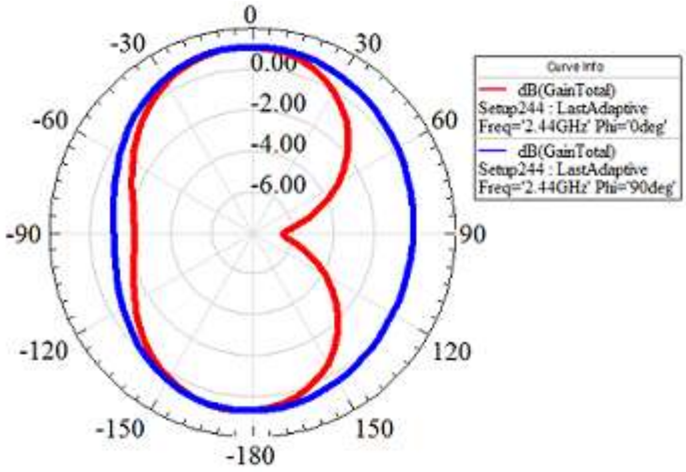


Fig 9: Radiation pattern at 2.44GHz

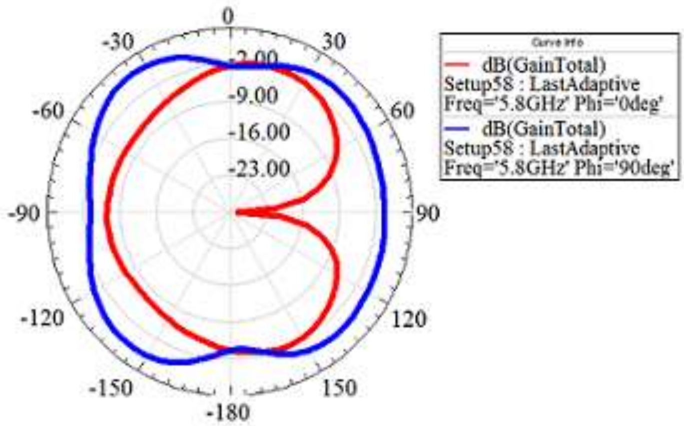
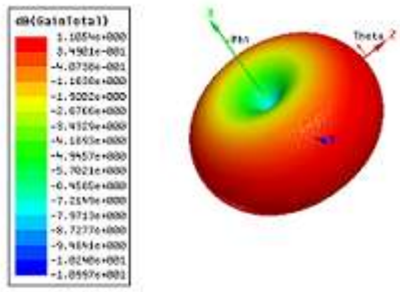
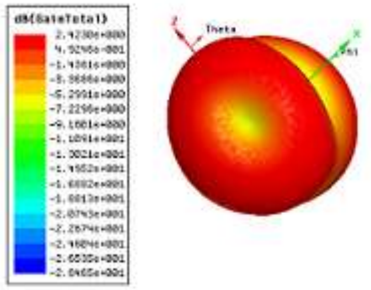


Fig 10: Radiation pattern at 5.8 GHz



(a)



(b)

Fig 11: 3D polar plot at (a) 2.4 GHz (b) 5.8 GHz

From the above pictorial representation it is very feasible to conclude that the proposed antenna consists of a single main lobe of narrow beam width and a very small back lobe as compared to the main lobe. So, maximum power will be radiated in desired direction with a very small power loss. Again the computed far field radiation pattern proves that proposed antenna geometry would result as a highly directional antenna.

VI. EXPERIMENTAL VERIFICATION

The testing of the antenna is done using VNA (Vector Network Analyzer) [ROHDE & SCHWARZ ZVH8 CABLE AND ANTENNA ANALYZER] at wireless communication lab, AISSMS COE, Pune which analyses one or two port networks. The frequency range of VNA is from 100 KHz to 8 GHz.

Figure 12: VNA for Testing

Figure 13: Test setup

Figure 14: Measured Return loss (S_{11}) using VNA

Table 3: Tested Result of Antenna Design at 2.4 and 5.8 GHz

Parameters	Tested Results at 2.4 GHz	Tested Results at 5.8 GHz
Resonance Frequency	2.4 GHz	6.2 GHz
Return loss	-20.13 dB	-21.97 dB
Bandwidth	200 MHz	600 MHz

Practical experiments demonstrate a reasonably good agreement between simulation and measurement results of the S-parameters. Both theoretically and experimentally, it is depicted that the antenna could radiate toward the desired directions within the entire working frequency band, which could lead many practical applications in wireless communication subsystems.

After all these discussion and pictorial representations of extracted antenna performance parameters, it is very convenient to state that proposed compact L & E shaped would be frequently used in WLAN applications at 2.4 / 5.8GHz. This antenna will result in lower fabrication cost due to its compact size, small radiation loss as well as long distance propagation capabilities because of its highly aimed focusing.

VII. CONCLUSION

A low cost compact dual band antenna for 2.4GHz and 5.8GHz band of WLAN applications has been designed and studied. The antenna has a compact radiator of area $8.5 \times 10.4mm^2$ with a stub having area $3 \times 2.3\, mm^2$ featuring an L-element and an E-element resonating around 6.0 GHz and 2.4GHz respectively. A thorough parametric study reveals that these two frequency bands can be tuned independently by adjusting certain dimensions of the radiating elements and also location of stub and its dimensions. Thus, by carefully adjusting the key dimensions of the antenna a dual band performance can be obtained at other frequencies. The reflection coefficient S11, VSWR and radiation pattern plots for the two frequencies have been studied. These results have shown that the design is a very promising candidate for WLAN applications..

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