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BANDWIDTH ENHANCED MICROSTRIP PATCH ANTENNA FOR UWB APPLICATIONS

V. Bhanumathi and S. Swathi

Department of Electronics and Communication Engineering, Anna University Regional Campus, Coimbatore, India

Abstract

The main aim is to design a compact microstrip patch antenna with bandwidth enhancement for UWB applications by introducing L-Shaped patch with a U-slot. The microstrip patch antenna are having compact profile, simple structure and easy for fabrication. The main disadvantage lies with this is narrow bandwidth. In this paper, an Inverted L-Shaped patch is designed on the top of the substrate and a U-Slot is etched in the infinite ground plane and it is found to be achieving bandwidth enhancement of up to 28% with a compact size of 24×36mm². This structure operates at the frequency of 5.2GHz and 7.4GHz for UWB applications. The performance of the fabricated prototype has also been compared and validated.

Keywords:

Circular Polarization, Monopole Planar Antenna, Triple Band, WLAN, WiMAX

1. INTRODUCTION

Federal Communications Commission (FCC) allocated the range of Ultra Wide Band (UWB) spectrum from 3.1 to 10.6GHz. The growth of the personal communication devices will aim to provide a multimedia data at any time, and anywhere around the world. Hence, the future communication terminal antennas must meet the requirements of multi-band or wideband to sufficiently cover the possible operating bands [1], [2]. Microstrip Patch Antenna (MPA) finds many applications in modern wireless communication due to their ease of fabrication, light weight, compatibility in circuit integration, low profile, and cost. However, the general issue of miniature antenna is fabrication error, directivity, narrow bandwidth, and radiation efficiency. To overcome these issues, H-shaped microstrip patch [3], E-shaped patch [4], U-shaped patch [5], and star shaped MPA [6] were designed. Other techniques in several microstrip slot antennas and planar monopole geometries (such as circular, square, rectangular, elliptical, hexagonal and pentagonal) which provide wide impedance bandwidth have been analyzed [7]. It is observed that the success behind the wireless handheld devices depends on the manufacturing ability [8]. It is found that the UWB antenna will have high impedance matching, stable radiation pattern, and linear phase over the entire UWB frequency range. [9]

The application of UWB technology in wireless [10] has attracted almost all the fields of engineering and industry in the world after the release of 10dB bandwidth of 7.5GHz from 3.1 to 10.6GHz by the FCC. It is also observed that almost all the applications require an antenna having the following features such as, Omni directional radiation pattern, low cost and larger bandwidth [11], [12]. In general, multipath effect exists in wireless communication leading to fading and ISI which degrades the quality of signal. Circularly polarized antenna is used to minimize the losses. The advantage of this is compact profile and multiband operations [13]. It is shown in [14] that it is possible to reduce the resonant length by creating a shorting wall across the center of the patch. It is observed from the literature [15] that the permittivity of the substrate can be increased when the shorting pin is coupled in a capacitive manner to the resonant circuit of the patch.

U-shaped patch antenna with two unequal arms for wideband and dual-frequency quarter-wave is presented in [5] for indoor mobile communications. With the help of two unequal arms of the U-shaped patch, wide impedance bandwidth is obtained in the lower band. Further to enhance, coaxially-fed patch is introduced to realize wide bandwidth in both the bands. Small microstrip patches with shorting posts particularly for mobile communication handset are investigated in [16]. For enhancing the bandwidth with an introduction of a T-shaped stub on top of the substrate is detailed in [17]. It is stated that it can achieve 17% of bandwidth compared to the existing designs. It is shown that the stacked H - shaped microstrip patch is better than single driven microstrip antenna [3]. An asymmetric E-shaped MPA fed with folded patch with shorting pins is also detailed in [4] for bandwidth enhancement.

A proximity coupled V-slot MPA fed by a Y shaped stub is presented to have an impedance bandwidth of 21% and high gain of 9dBi [18]. Our paper is designed based on the idea given in [17] and the simulation results show a better enhancement in bandwidth with respect to the existing. A compact dual-frequency antenna with bandwidth enhancement is proposed in [19]. A compact triangular microstrip antenna for enhancing the bandwidth is studied in [20] and it can operate in the frequency of 8.3GHz. A triple band monopole antenna is designed and analyzed in [21].

Here, the realization of dual-frequency operation in the proposed design is achieved by cutting a slot in the elliptical patch and a partial ground plane is used for realizing the bandwidth. The antenna is found to be having a compact size of 24×20 mm². It is proved based on the simulation that the antenna with a partial arc-shaped ground can obtain a larger bandwidth for two bands than that with a partial rectangle ground. This paper presented a new microstrip patch antenna design for bandwidth enhancement with a compact size particularly for UWB applications. The designed antenna is fabricated and tested for validity.

The antenna configuration has been presented in section 2. The measurement and testing of the proposed prototype is provided in section 3. Section 4 concludes the paper.

2. ANTENNA CONFIGURATION

Initially, the T-shaped antenna given in [12] is realized in simulation. To shorten the non-radiating side, the antenna element with dual feed line structure is proposed based on the signal-interference concept given in the existing work. A T-Shaped stub is introduced at the top of the substrate in order to reduce the narrow bandwidth.

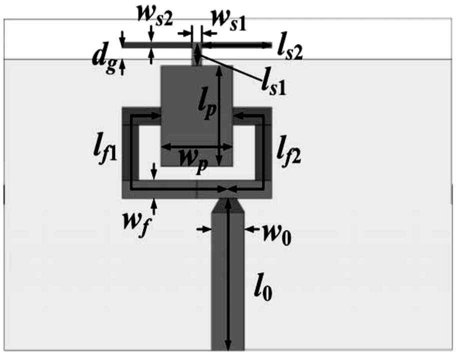


Fig.1. Structure of T-Shaped patch antenna

The enhanced bandwidth antenna is used for wideband application as shown in Fig.1. The feeding structure of 50Ω microstrip line etched on an inexpensive FR-4 substrate with a dielectric constant of 4.4 and substrate thickness of 1.6mm.

2.1 PATCH ANTENNA

The patch is inserted at the top of the substrate of monopole antenna as shown in Fig.2 as dual feed line structure. Two feed line paths of different lengths are used in the patch antenna by using the principle of signal interference feed.

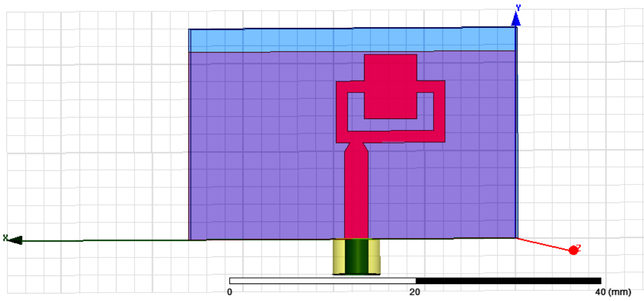


Fig.2. Design of Patch Antenna

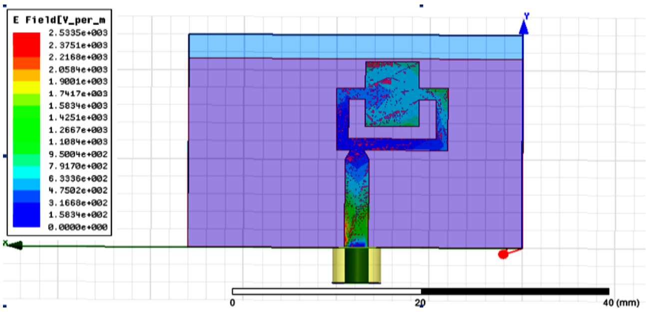


Fig.3. Current distribution of Patch Antenna

The surface current distributions of patch antenna operating at the frequency of 5.2GHz is shown in Fig.3. The reflection coefficient is shown in Fig.4, which has operating bands at 5.2GHz which is applicable for WLAN application.

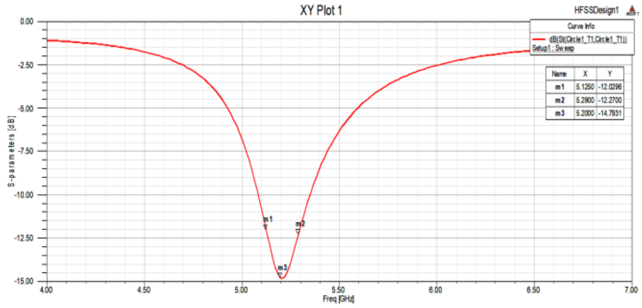


Fig.4. Reflection coefficient of Patch Antenna

It is seen that from the Fig.4 that the bandwidth is enhanced by 3.2% approximately from around 5.1 to around 5.8GHz with reflection coefficient less than -10dB. The 2-D radiation pattern of a dual feed line in patch antenna at 5.2GHz frequency of zero gain UWB planar antenna ($\Phi = 0^0, 90^0$) is shown in Fig.5.

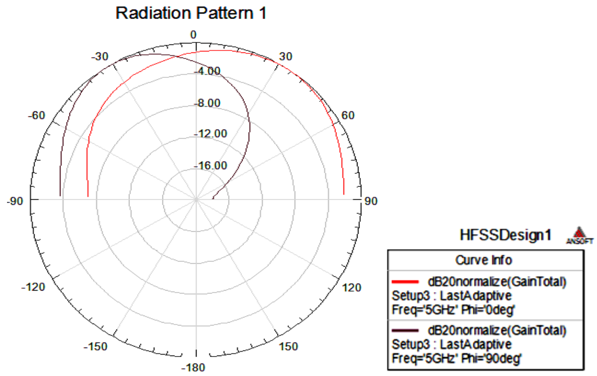


Fig.5. Gain of Patch Antenna

2.2 T-SHAPED PATCH ANTENNA

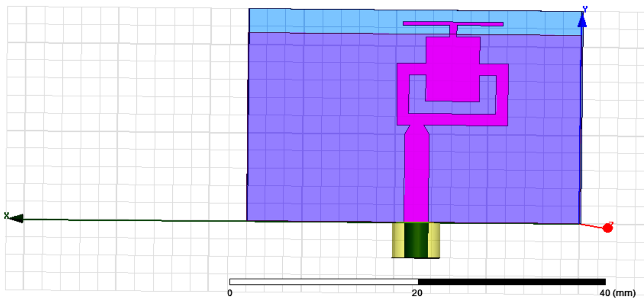


Fig.6. Design of T-Shaped Patch Antenna

The T-shaped patch is inserted at the top of the substrate by using the dual feed line structure and it is found that the bandwidth of the patch antenna is narrow due to the frequency dependence of the transmission-line feed and the design is shown in Fig.6. The antenna design was etched on the same side of the substrate with a dielectric constant of 4.4 and substrate thickness of 1.6mm. The dimensions of the substrate are 24×36mm^2. These antennas enhance the bandwidth up to 17.0% approximately with overall frequency of 5.1-5.8GHz respectively.

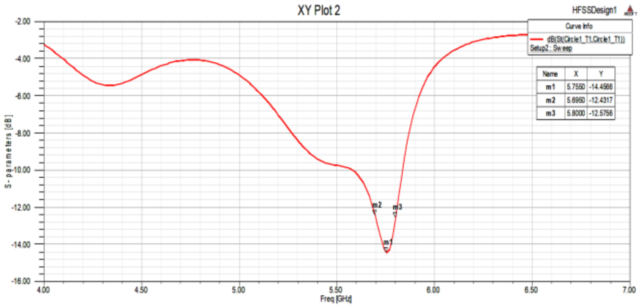


Fig.7. Reflection coefficient of T-Shaped Patch Antenna

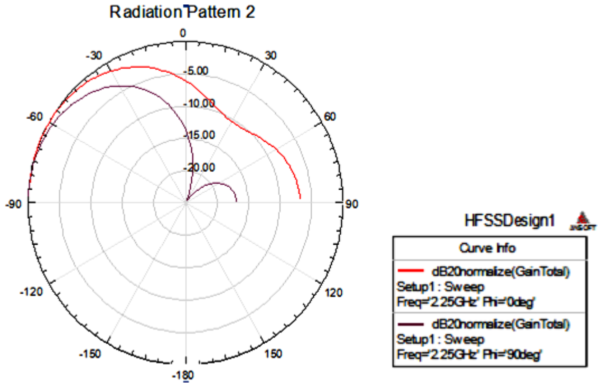
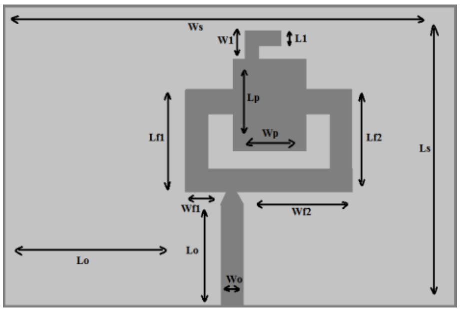


Fig.8. Gain of T-Shaped Patch Antenna

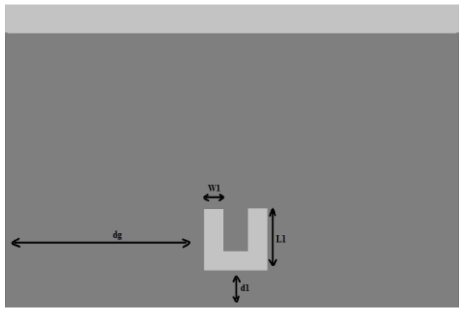
The reflection coefficient of T-shaped patch is shown in Fig.7 and the operating frequency band is 5.4GHz. The 2-D radiation pattern of a dual feed line in T-shaped patch antenna at 5.4GHz frequency of zero gain UWB planar antenna ($\Phi = 0^0, 90^0$) is shown in Fig.8. It is observed that the bandwidth is enhanced up to 17.0% approximately for the frequency range of 5.1 to 5.8GHz with reflection coefficient less than -10dB. Where, f_H is the higher frequency, f_L is the lower frequency and f_C is the centre frequency.

$$Bandwidth(\%) = \frac{f_H - f_L}{f_c} \times 100 \quad (1)$$

The bandwidth is calculated in percentage by using Eq.(1) and is used for only wideband antenna. The existing methods of dual feed line antenna are a major technological advance in enhancing bandwidth for UWB applications. Further we enhance the bandwidth by using the Inverted L-shaped patch at the top of the substrate and U-Slot are etched in infinite ground plane as shown in Fig.9. With this, it is possible to enhance the bandwidth up to 28% for the overall frequency of (5-7.8GHz). The design parameters of the proposed antenna were optimized using commercially available software Ansoft HFSS version 13.0. The dimensions such as total width, length of the feed as well as the substrate (in mm) considered for the design of antenna is tabulated in Table.1.



(a) Front view



(b) Back view

Fig.9. Structure of Inverted L-shaped patch with U-Slot antenna

Table.1. Design Parameters of the U-Slot Antenna

Material	Width (mm)	Length (mm)	Height (mm)
Substrate	W_s=36	L_s=24	T=1.6
Dual-feed line	W_0=2.6	L_0=10	T=0
	W_{f1}=1.3	L_{f1}=15.6	
	W_{f2}=1.3	L_{f2}=10.6	
Rectangular Patch	W_p=5.8	L_p=7.3	T=0
T-Shaped Patch	W_{s1}=0.8	L_{s1}=1.7	T=0
	W_{s2}=0.4	L_{s2}=5.6	
	d_g=0.8	d_g=0.8	
Invert L-Shaped Patch	W_l=0.8	L_l=1.7	T=0
U-Slot	W_1=1	L_1=4	T=0
	d_1=1	d_g=16	

2.3 T-SHAPED PATCH WITH U-SLOT ANTENNA

In T-Shaped patch, U-Slot is etched in infinite ground plane in order to make the antenna resonate at another frequency range of 7.2GHz for Satellite applications. The dual feed line antenna resonating at a resonant frequency of (4.6-7.8GHz) for Satellite and WLAN applications is designed in HFSS as shown in Fig.10.

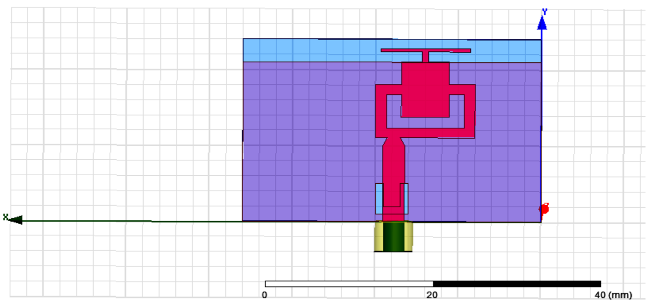


Fig.10. Design of T-Shaped patch with U-Slot Antenna

The simulation results of T-Shaped patch with U-Slot antenna for reflection coefficient is shown in Fig.11 which achieves an operating bands of 5 GHz and 7.2 GHz.

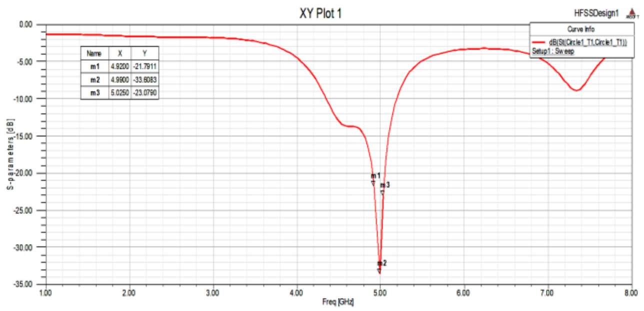


Fig.11. Reflection coefficient of T-Shaped patch with U-Slot

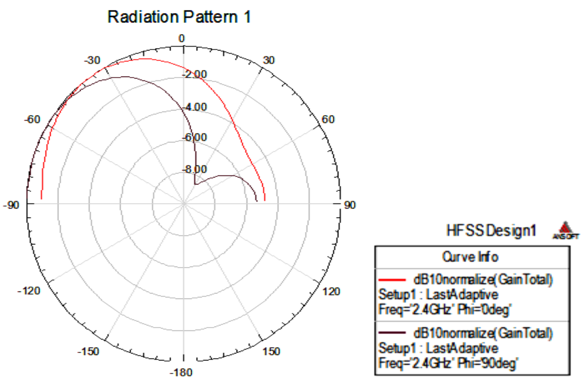


Fig.12. Gain of the T-Shaped patch with U-Slot Antenna

It is seen from the Fig.12 that the bandwidth is enhanced by 19.0% approximately from around 5 to 7.4GHz with reflection coefficient less than -10dB.

2.4 INVERTED L-SHAPED PATCH ANTENNA

Here, an inverted L-Shaped patch is inserted on the top of the substrate. The shape is changed from T patch to an inverted L patch without using any slot in the ground plane. The dual feed line antenna resonating at 4.6-5.8GHz for WLAN application is designed in HFSS as shown in Fig.13.

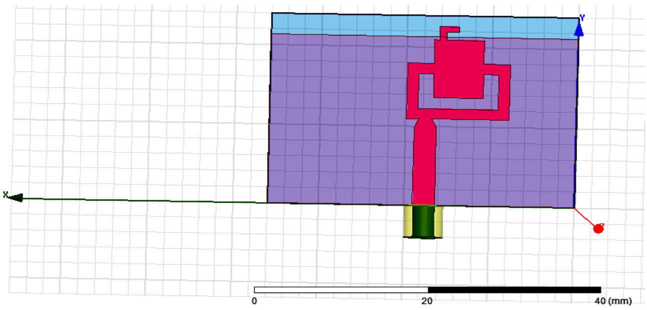


Fig.13. Design of Inverted L-Shaped patch Antenna

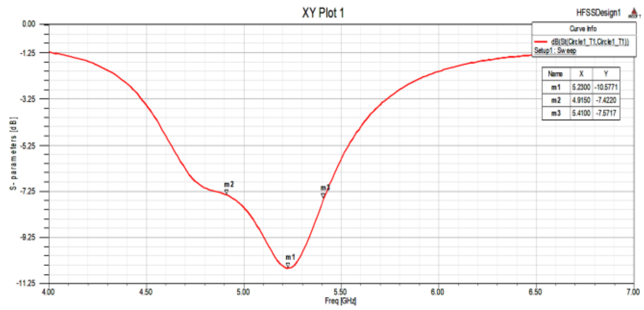


Fig.14. Reflection coefficient of Inverted L-Shaped patch

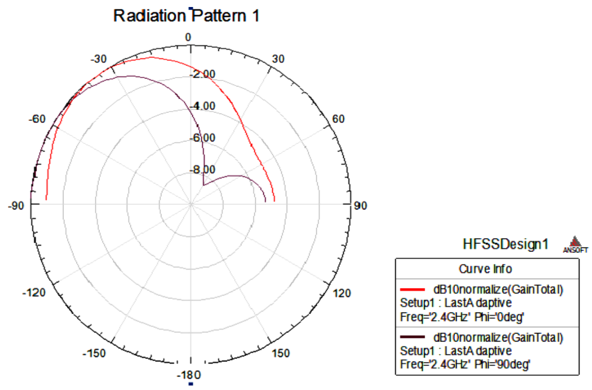


Fig.15. Gain of the Inverted L-Shaped patch Antenna

The simulation result for the reflection coefficient of the Inverted L-Shaped patch antenna is shown in Fig.14 which has an operating band of 5.2GHz. The bandwidth is enhanced up to 22.0% approximately for the frequency range of 4.6 to 5.8GHz with reflection coefficient less than -10dB as shown in Fig.15. The 2D radiation pattern of a dual feed line in Inverted L-Shaped patch antenna at 5.2GHz frequency is zero gain.

2.5 INVERTED L-SHAPED PATCH WITH U-SLOT ANTENNA

In the Inverted L-Shaped patch antenna, U-Slot is etched in infinite ground plane in order to make the antenna to resonate at the frequency range of 7.4GHz for Satellite. The dual feed line antenna resonating at a resonant frequency of 4.6-7.8GHz for Satellite and WLAN applications is designed in HFSS as shown in Fig.16.

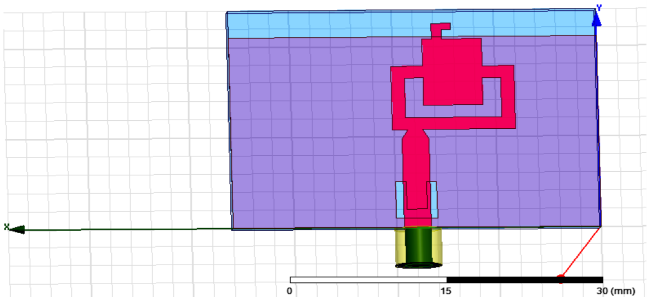


Fig.16. Design of Inverted L-Shaped patch with U-Slot

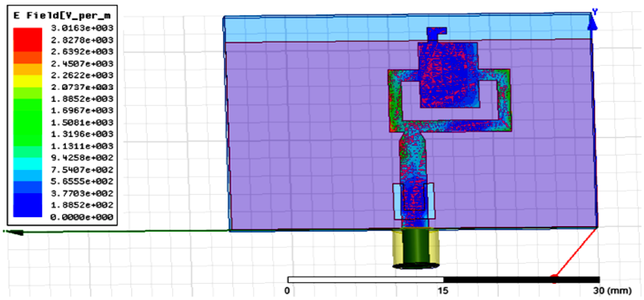


Fig.17. Current distribution of Inverted L-Shaped patch with U-Slot

The surface current distributions of Inverted L-shaped patch with U-slot antenna operating at the frequency of 5.2GHz and 7.4GHz is shown in Fig.17. The reflection coefficient is shown in Fig.18 which has operating bands at 5.2GHz and 7.4GHz. The corresponding antenna's gain is shown in Fig.19.

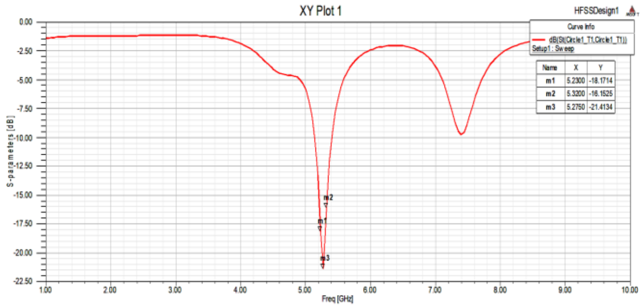


Fig.18. Reflection coefficient of Inverted L-Shaped patch with U-slot

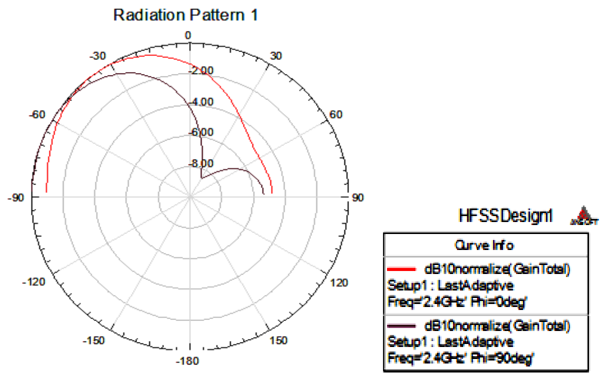
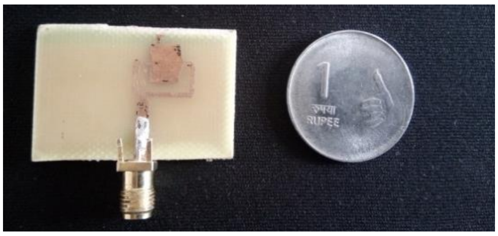


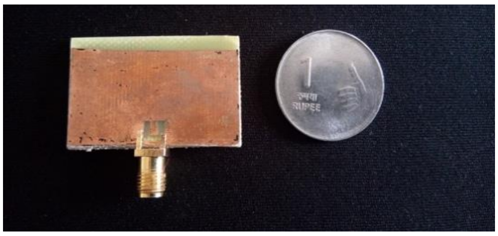
Fig.19. Gain of the Inverted L-Shaped patch with U-Slot

3. RESULT ANALYSIS

The designed L-shaped antenna with U-slot is fabricated using FR4 substrate with a thickness of 1.6mm. "FR" refers to Flame/Fire Retardant which is a glass-reinforced epoxy laminate sheets, tubes, rods and printed circuit boards. FR4 substrates are mostly widely used and it is of low cost with excellent mechanical properties. The Fig.20 shows the top and bottom view of the fabricated antenna.



(a) Top View



(b) Bottom View

Fig.20. Fabricated Prototype of the Proposed Antenna

The fabricated antenna is tested using Agilent Technologies Network Synthesizer. The results are measured and are shown in Fig.21. It is observed from the measured results that the reflection coefficient is less than -10dB at the frequency range of 5.0-8.0GHz. It can be seen that at marker 1, the S_{11} value is -24.70dB. At marker 2, the S_{11} value is also -24.70dB.

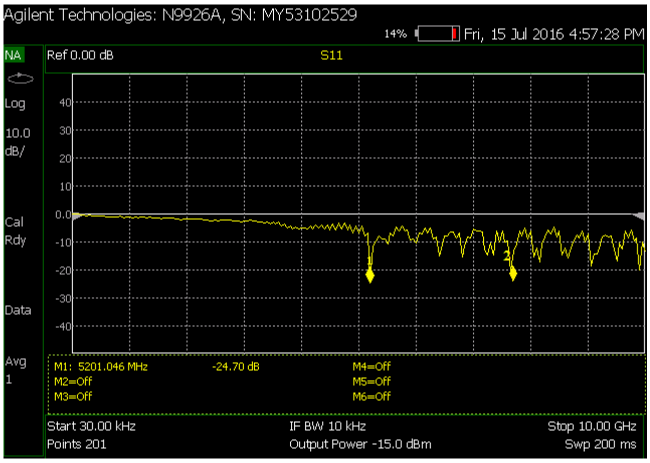


Fig.21. Measured Reflection Coefficient

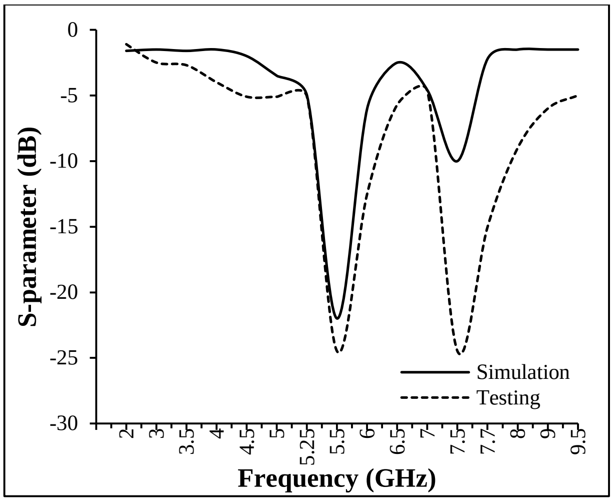


Fig.22. Reflection Coefficient Value-Comparison

The reflection coefficient values of the measured and simulated are compared and it is plotted as shown in Fig.22. It is observed that the S_{11} value is attaining maximum at the frequency range of 5 to 8GHz. The comparison results of the proposed L-shaped patch with U-slot with that of the other existing designs for frequency, bandwidth and return loss are tabulated in Table.2. From this, it is evident that the proposed design achieves a good bandwidth enhancement over the others with compact size.

Table.2. Comparative Analysis of Patch Antennas

Parameters	Frequency (GHz)	Bandwidth (%)	Return Loss (dB)
Patch	5.4	3.2	-14
T-Shaped Patch	5.4	17	-15
T-Shaped Patch with U- Slot	5.2	19	-23
Inverted L-Shaped Patch	5.2	20	-12
Inverted L-Shaped Patch with U-Slot	5.2, 7.4	28	-24

4. CONCLUSION

A compact microstrip patch antenna of size 24×36mm^2 is designed, fabricated and tested for its functionality. It is observed that the design achieves the expected bandwidth. In this design, dual feed line structure is used which can reduce the non-radiating side of the antenna for bandwidth. And further bandwidth enhancement is realized through introducing an Inverted L-shaped patch at the top of the substrate and a U-slot in the infinite ground plane. The fabrication and testing reveals that the proposed antennas are of smaller size with a reduction in bandwidth and also have excellent radiation characteristics. The antenna operates from 4.8 to 7.8GHz which is found to be suitable for UWB applications.

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