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Design of Modified Hexagonal UWB Slot Antenna with Dual Band Notched Characteristics

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***Abstract*—Printed modified hexagonal slot ultra-wideband micro strip-fed antenna with dual band rejection characteristics is presented. The antenna comprises U-shape radiating patch on one side of substrate and ground plane with modified hexagonal slot on other side of substrate with compact size of 28 x 28 mm^2. By inserting symmetrical L-form parasitic ends at the upper edge at the modified hexagonal slot and C-shape parasitic stubs at the both arms of the patch to obtain the desired stop band characteristics for WiMAX and WLAN respectively. The designed antenna is operate in between 3.02~ 15GHz with a dual stop band from 3.15~4.06GHz (for Worldwide Interoperability for Microwave Access) and 5.13~6.2GHz (for Wireless Local Area Network). To mitigate the possible interference in between UWB and these narrow bands (Worldwide Interoperability for Microwave Access and Wireless Local Area Networkbands) will help. The designed antenna is made-up on a FR-4 glass epoxy substrate having dielectric constant of 4.4. Parametric studies have been conducted by changing length L_2 (symmetrical L-shape stubs) and L_3(C-shape stubs) and it is directedwith the help of FEKO-EM simulation software.Performance of this antenna studied in terms of VSWR, efficiency, radiation pattern,time domain analysis.Forthe total ultra-wideband excluding for Worldwide Interoperability for Microwave Access and Wireless Local Area Network frequency,Proposed antenna shows efficiency more than 75%.**

Keywords*—*Modified hexagonal slot antenna, Symmetrical inverted L-shape parasitic stubs, C-shape parasitic stubs.

I. INTRODUCTION

For UWB communication as per the Federal Communication Commission (FCC),the 3.1 to 10.6 GHz is unlicensed frequency band [18].Printed micro strip antennas are useful for UWB communication due to its ease of fabrication, simple structure, compact size and light weight [2]. Other applications of UWB antennas are in wireless communications, imaging and wireless sensor networks mobile and wireless dongles with smaller size and lighter weight [3].Theinterference occurs in between the narrow band and UWB system because of the tremendously large bandwidth of UWB which is major challenge. Slot antenna is made up of slot in the ground of the antenna which is applicable for different application [18]. Recently different techniques have been introduces to design band notch construction in antenna by inserting slots, slits and parasitic element.

The antenna is operative within entire ultra-wideband with triple band stop characteristics [4].In [5], a printed dual band antenna for Bluetooth and UWB applications with Wireless Local Area Network,Worldwide Interoperability for Microwave Access, C-band satellite downlink and DSRC notched characteristics is proposed and investigated.By using rotated C-shaped strip around the inverted T-shaped conductor back plane, WLAN Frequency band notch is obtained [6]. An Ultra-wideband (UWB) antenna with a frequency rangefrom 3.1 GHz to 10.6 GHz, and a bandelimination from 5GHz to 6GHz.Notch-band characteristic is achieved by inserting a slot at the center of the patch [6].

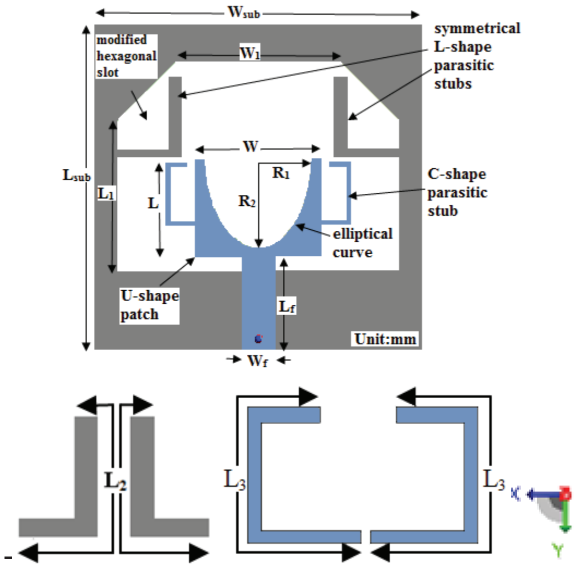


Fig.1. Geometry of proposed antenna

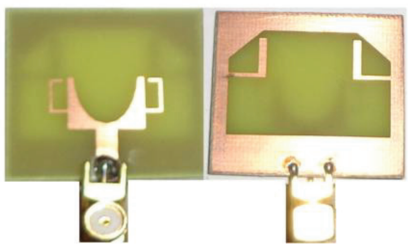


Fig 2.Fabricated antenna

In [8],antenna is designed for Multiple Input Multiple Output applications. Band rejection property is attained by etching two split-ring resonator slots on the patch. In [9],WiMax, WLAN and X-band communication band notched antenna for ultra-wideband (UWB) application is designed .All the three notched bands are obtained by etching a bent and folded slot and a dipole like resonator slots on the antenna radiating patch.In [10], triple band notched characteristics are achieved by using pair of L-shape slots in the ground plane , quarter wavelength slots and inverted L shaped slots along with UWB antenna.UWB slot antenna with dual band rejection is designed [11]. Band rejection can be simplycreated by inserting double parasitic slits [11].By introducing PI shape notchWireless Local Area Network frequency band rejection is obtained [12].In [13], triple band rejection is achieved.Half wavelength slot, open ended quarter wavelength slot in the patchand ground plane are used for notching three different bands. Dual band notch antenna uses L and U- shape slots[14].The antenna functions over the frequency range of 2.75GHz to 15.3GHz with two band stop characteristics of Wireless Local Area Network,Worldwide Interoperability for Microwave Access. Even L-shape slots and Inverted U-shape slot are used to achieve band rejection [15].U-NII band notching is achieved by two reversed L-shaped slots [15].

II. ANTENNA DESIGN, CONFIGURATION ANDANALYSIS

A. Design Equations

To manufacture the geometry,Substrate (FR4) is used with its properties [18].In [17],the simpleformularies for design of the micro-strip antenna are as follows:
Patch width is given by[18],

$$W = \frac{C}{4f_r} \times \sqrt{\frac{2}{\varepsilon_r + 1}} \tag{1}$$

Where, C is the speed of light in free space.
Effective Dielectric Constant:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2\sqrt{1 + \frac{12h}{W_P}}} \tag{2}$$

Length Extension: Normalizedextensionof length is given below,

$$\frac{\Delta L}{h} = \frac{0.412(\varepsilon_{reff} + 0.3)\left(\frac{W_P}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W_P}{h} + 0.8\right)} \tag{3}$$

Effective Length is:

$$L_{reff} = \frac{C}{4f_r\sqrt{\varepsilon_{reff}}} \tag{4}$$

Patch Length: Actual length of patch is L_P[18]

$$L_p = L_{eff} - 2\Delta L \tag{5}$$

B. Band Notched Stub Analysis

To create notch in WiMAX, Symmetrical L- mirror shape stubs are inserted on the upper edge of the modified hexagonal slot and C-shape parasitic stubsat both the arms of the radiating patch for Wireless Local Area Networkband rejection. Even L-shape stubs on ground plane and C- shape parasitic stubs on patch element are responsible to make notch at both WiMAX and Wireless Local Area Network band respectively.

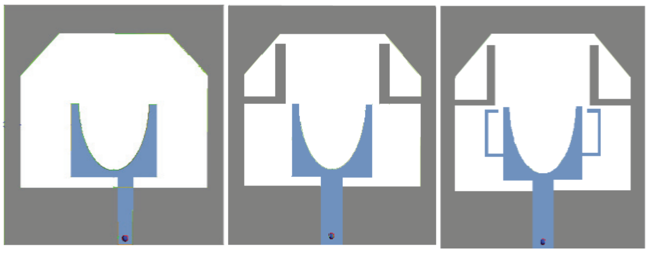
The length of parasitic elements (L_{notch}) are calculated by following formula,

$$\frac{C}{4F_{notch} \times \sqrt{\frac{\varepsilon_r + 1}{2}}} \tag{6}$$

Optimized value of L_{2notch}=13.28mm, L_{3notch}=10.5mm

C. Development of Geometry

Initially, the UWB antenna is designed withfrequency range of 2.76 ~ 11.07 GHz as shown in Fig.3(a).It is printed on FR4 substrate of permittivity 4.4,thickness 1.6mm, loss tangent 0.02[18].It is fed by 50Ω micro-strip line. Antenna structure contains a U-shape radiating patch with elliptical shape having radius of 4.5 and 8mm, ground plane along with modified hexagonal slot [18]. The patch has a width W and length L and it is coupled to feed line of width W_f and length L_f[18]. In[18], By inserting symmetrical L-shape parasitic stubs on a ground plane, band stop function for WiMAX is achieved as shown in Fig.3(b). Lastly, dual band stop characteristics for Worldwide Interoperability for Microwave Access and Wireless Local Area Network bands are appeared by inserting symmetrical L-shape parasitic stubs on ground plane and C-shape parasitic stubs at the both arms of radiating patch. The proposed geometry is shown in Fig.3(c).



(a) (b) (c)

Fig.3. (a) The Ultra Wideband antenna, (b) Even L-shape parasitic elements, (c) the U-shape patch with embedded C-shape parasitic elements and symmetrical L-shape parasitic stubs on ground plane.

The geometrical structure is shown in Fig.1.In this, the antenna with U-shape patch and modified hexagonal slot-backed plane with inserted symmetrical L-shape parasitic stubs and C-shape parasitic stubs at both the arms of the radiating patch are designed to notch Worldwide Interoperability for Microwave Access and Wireless Local Area Networkfrequency band respectively from UWB[18].

TABLE I. DIMENSIONS OF FABRICATED ANTENNA

Configuration	Parameter	Value(mm)
Substrate	L_{sub}	28
	W_{sub}	28
	h (thickness of	1.6
Radiating element-Patch	W	10.87
	L_p	8.5
U-shape slot	R_1	4.5
	R_2	8
Modified Hexagonal Slot	W_1	24
	W_2	14
	L_1	13
Symmetrical L-shape parasitic stub	L_2	13.28
C-shape parasitic stubs	L_3	10.5
Feed Line	W_f	3
	L_f	8

In this section, dual notched band modified hexagonal slot UWB antenna with various design parameters is constructed. By using FEKO-EM simulation software,the simulated results are obtained.Fig. 3.shows the various antenna geometries used for simulation studies. Voltage Standing Wave Ratio characteristics for the UWB antenna Fig. 3.(a), symmetrical L-shape parasitic stubs Fig. 3.(b) and Fig. 3.(c) are correlated in Fig.4.

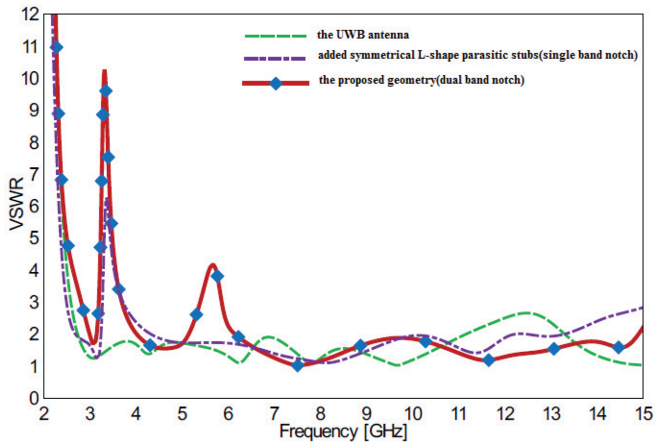


Fig.4. Simulated VSWR for different antenna geometries

From the illustrated Fig .3, symmetrical L-shape parasitic stubs are used to provide band stop function for WiMAX whereas C-shape parasitic stubs provide WLAN notching. It indicates the VSWR characteristics of proposed geometry. It shows that antenna operates over entire UWB with dual band notch. The parametric study has been conducted using the CADFEKO 7.0 simulation software. Further to study the detail analysis of L and C shape parasitic stubs parametric studies are conducted. The ideal value of each parameter (L_2, L_3) was selected except remaining parameter. The values of other parameters are fixed by optimization technique.

Initially, the graph of length L_2 of the proposed geometry is varied by keeping L_3 fix is shown in Fig. 5.

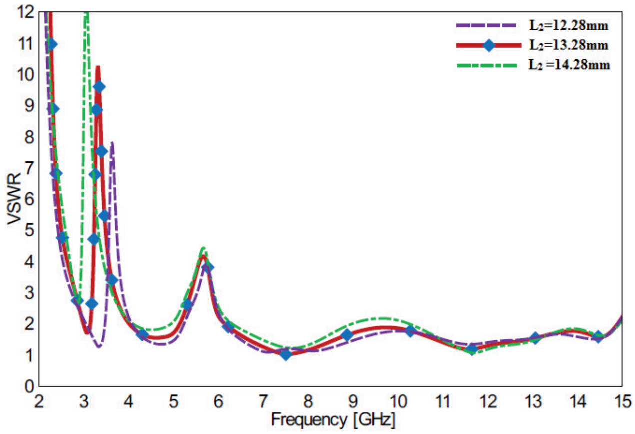


Fig .5.Variations in parameter L_2 of symmetrical L-shape parasitic stubs

Asshown in Fig.5,changing length(L_2),effects on the higher edge frequency which move to lower side. At L_2=13.28mm, the band rejection property satisfies well at WiMAX.

The graph of variation in parameter L_3 of C-shape parasitic stubs are shown in Fig.6.It is observed that as the length and the band rejection are interrelated to each other. The results are better at L_3=10.5mm.

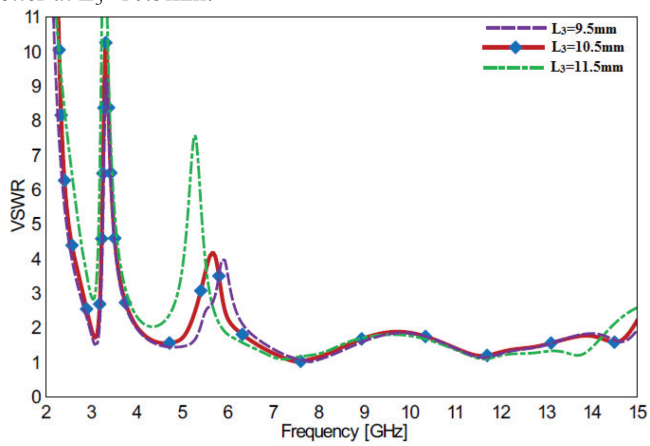


Fig .6.Variations in parameter L_3 of C-shape parasitic stubs of the proposed geometry

From Fig (5,6), doesn't shows any effect on bandwidth of antenna even though L_2 and L_3 are changed. This parametric analysis clearly shows the effect of symmetrical L-shape parasitic stubs and C-shape parasitic stubs on band stop characteristics for Worldwide Interoperability for Microwave Accessand Wireless Local Area Network respectively.

Fig.7 shows current directions at various frequencies when L and C-shape parasitic stubs inserted.At un-notched frequency (4.16GHz) current distribution is dense as shown in Fig.7.(e-f).In Fig.7.(a-b),at notch frequency(3.54GHz) current distribution is stronger and concentrated more along the symmetrical L-shape parasitic stubs. At 5.40GHz, the maximum current is concentrated along the C-shape parasitic stubs which are embedded at both arms of the radiating patch as shown in Fig.7.(c).This shows that, both L and C-shape parasitic stubs are responsible for band notching characteristics.

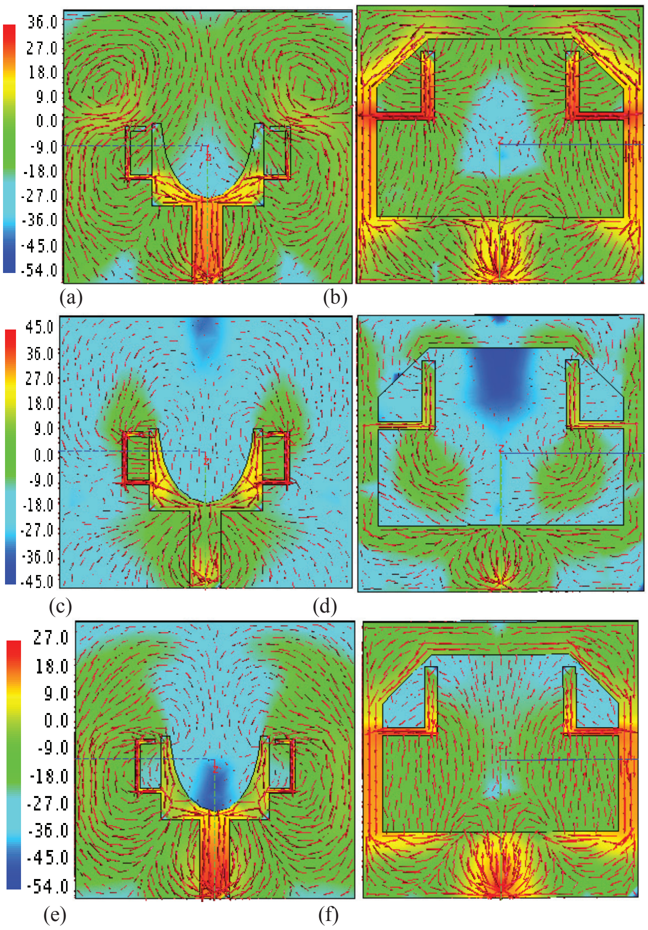


Fig .7.current distribution (a)-(b) top and bottom layer at 3.54GHz, (c)-(d) top and bottom layer at 5.40GHz, (e)-(f) top and bottom layer at 4.16GHz

III. RESULTS AND DISCUSSIONS

To measure the bandwidth, Agilent Field-fox VNA (30KHz to 14GHz, Model No: N9916A) is used, while radiation pattern measurements are carried out in anechoic chamber. The simulated and measured Voltage SWR of the proposed antenna is demonstrated in Fig.8. The proposed antenna displays a band stop function for WiMAX and Wireless Local Area Network having wide impedance bandwidth of 3.02~15GHz for Voltage SWR less than 2. Simulated and measured results are in good agreement. The efficiency of designed antenna is more than 75% in whole Ultra Wideband except WiMAX and WLAN band as shown in Fig. 8. At notch frequency antenna efficiency drops sharply to 10%[18].

Hence designed antenna is good applicant in different applications.

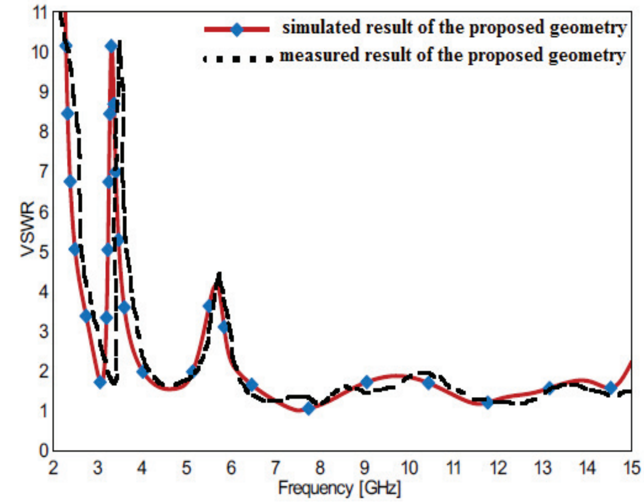


Fig .8.Simulated and measured VSWR characteristics for proposed geometry.

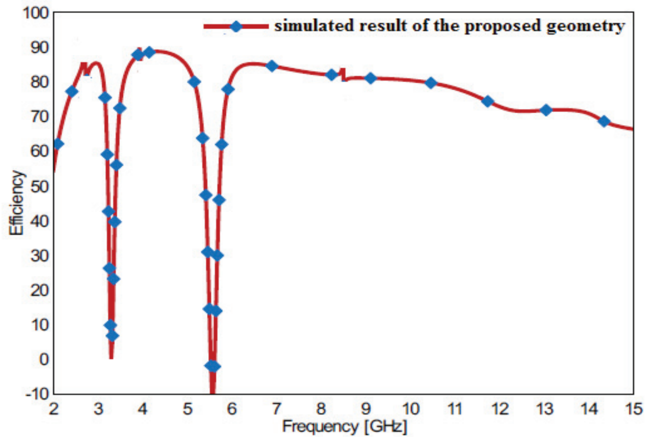
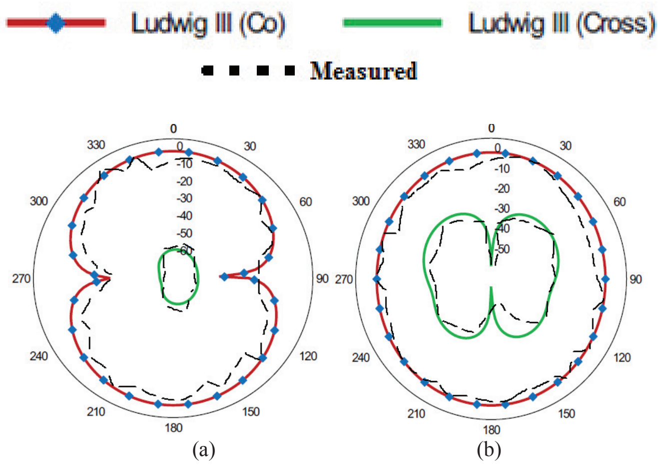


Fig.9. Simulated efficiency characteristics for designed antenna.



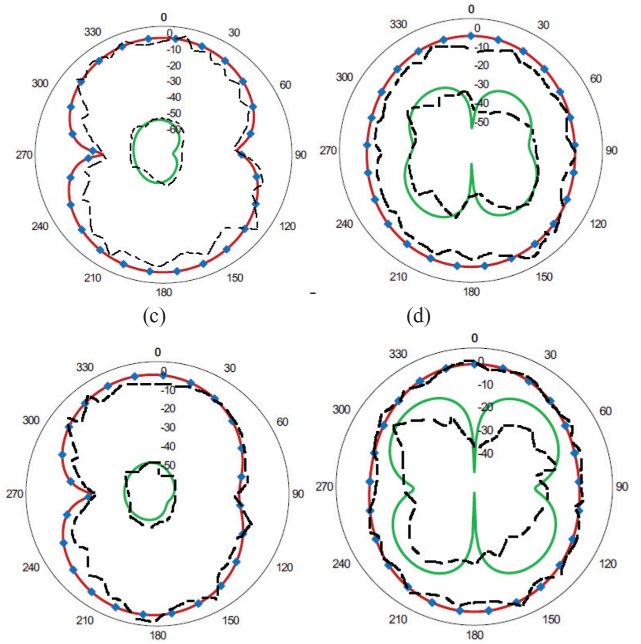


Fig .10.Simulated and measured radiation pattern of the proposed antenna at (a)E-field co and cross polarization at 4.47GHz (b)H-field co and cross polarization at 4.47GHz(c) E-field co and cross polarization at 5.09GHz (d) H-field co and cross polarization at 5.09GHz(e) E-field co and cross polarization at 6.95 (f)H -field co and cross polarization at 6.95

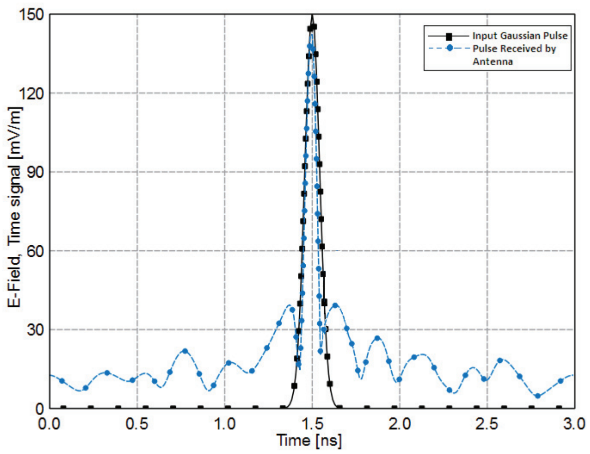


Fig.11. Time Domain Analysis

Fig.10.shows the simulated and measured radiation patterns of designed antenna at various frequencies of 4.47GHz,5.09GHz and 6.95GHz.The cross-polarization is less as compared to co-polarization. It helps to prove that whether antenna radiate properly or not over the overall frequency range. [18]. As the frequency increases the cross-polarization goes on increasing however it is less than -20db. Fig.11. shows time domain analysis of the designed antenna. It is used to obtained pulse spreading behavior of the designed antenna using FEKO-EM simulation software spreading behavior of the proposed antenna using CAD FEKO software 7.0.Received signal for double stop band Ultra Wideband slot antenna and input Gaussian pulse is shown in Fig.11.

IV. CONCLUSION

A slot antenna has been designed whose shape is modified hexagonal. It is useful for UWB applications along with dual stop band characteristics. The antenna offers 11.98GHz bandwidth (3.02 - 15GHz) for Voltage SWR is less than 2 excluding for Worldwide Interoperability for Microwave Access (3.15~4.06GHz) and Wireless Local Area Network (5.13~6.2GHz).Antenna filter out Worldwide Interoperability for Microwave Access and Wireless Local Area Network band by inserting symmetrical L-shape parasitic stubs in the ground plane and C-shape parasitic stubs at both arms of the radiating patch respectively. It shows good suppression ability at Worldwide Interoperability for Microwave Access and WLAN band. The antennashows efficiency greater than 75%, omnidirectional and directional radiation pattern in H & E plane respectively excluding the stop band showing the appropriateness of the designed antenna for UWB applications.

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