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Return Loss and Bandwidth Improvement using Single layer 'I' shaped microstrip slot Antenna with slotted ground

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ABSTRACT

A single-band characteristic of single layer 'I' shaped rectangular microstrip slot antenna with slotted ground is presented. It is a probe fed mechanism based antenna for impedance matching with 50Ω coaxial cable. The antenna geometry is simulated using IE3D simulation tool. Antenna works well in the frequency range 3.95 GHz to 4.45 GHz. It is basically a light weight, low cost antenna, which can be used for wireless communication in UWB band. The antenna structure involves comparison of three different antennas layers with differently located slots on a single layer with finite ground plane. Final antenna geometry i.e. with 'I' slot, shows better improvement in the radiation characteristics. Also the effects of slot implementation show the change in resonant frequency. Microstrip antenna is with 'I' slot and finite ground plane with a vertical slot, improves properties like resonance frequency, gain, return loss and bandwidth, which may affect the antenna performance. This structure uses single layer configuration; 'I' shape slot on the dielectric patch and a rectangular slot on the finite ground plane. The antenna simulation yields -32.15 dB return loss at 4.2 GHz resonant frequency with 11.9% bandwidth with a size of $36.75 \times 39.7 \times 1.5mm^3$. The proposed antenna design presents a good choice for compact and low-cost microwave integrated systems.

Keywords: Rectangular patch, microstrip antenna (MSA), ultra wideband (UWB), Slot antenna, Return loss (RL), Bandwidth (BW).

1. INTRODUCTION

Ultra wideband (UWB) wireless communication allows high rate data transmissions with low power level have embarked great research interests for wireless communications applications in the 3.1Ghz –10.6Ghz frequency band. High-performance UWB antennas need both good impedance matching and low signal distortion within the relative frequency bands. Microstrip patch antennas are mostly used in wireless and cellular mobile communication systems because of their merits, like compactness, light weight and ease of fabrication and LPDAs also have a reasonable gain with a very large bandwidth.

In the design we have presented a single layer microstrip patch antenna configuration. Which consist of 'I' slot on its dielectric plane and a finite ground plane with a vertically located rectangular slot. Concepts of microstrip patch antenna and slot antenna were successfully used to achieve the required antenna performances. The coaxial feed is used as source for the antenna. In this paper, a compact antenna is simulated with three different configurations. As we know that by implementing slots, bandwidth and return loss characteristics can be improved therefore, the proposed geometry invokes slots on dielectric layer and on the ground layer. The proposed design can effectively reduce the overall size of an antenna. Concept of impedance matching is presented using feed point variation, slot implementation. The proposed geometry is very simple but yet so effective, hence can get better radiation characteristics.

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Immense research work is being carried out in the field of microstrip patch antennas. The development in the context of microstrip patch antenna is our focus area. The following review emphasised on comparative study of several research works based on microstrip patch antenna. U. Chakraborty et al. designed a compact dual-band microstrip patch antenna in [1] to support the IEEE 802.11system. Initially, two -10 dB impedance bands were generated by two different designs with same sized slotted ground-plane structures. Afterword, these two designs were combined to form the geometry of the dual-band antenna. The design technique used for the dual-band antenna using two separate single-slotted RMSAs was successfully implemented for the application in IEEE 802.11a WLAN band (5.15–5.35 and 5.725–5.825 GHz). In [2] Jigar M. Patel et al. presented a comparative analysis in between S-shaped microstrip patch antenna using metamaterial and common S-shaped multiband microstrip patch antenna, defected ground structure S-shaped microstrip patch antenna using Complementary split ring resonator. This research comfirms that metamaterial generates more bands than the proposed simple s shape microstrip Patch Antenna. The antenna could be used for L Band and S Band Applications. Further design could be modified to have multiband for other applications in C band, X band and other bands. Xiao Lei Sun et al. designed and studied a dual-band monopole antenna with a very compact area of only for 2.4/5.2/5.8-GHz WLAN applications in [3]. The antenna consisted of an L – shaped and E - shaped elements having resonances at about 2.44 and 5.5 GHz respectively. In [4] Chih-Yu Huang and En-Zo Yu proposed a coplanar waveguide fed dual-band slot-monopole antenna suitable for WLAN operation. The designed antenna provides two separate impedance bandwidths of 124 MHz (about 5.1% cantered at 2.45 GHz) and 1124 MHz (about 22.4% centered at 5.5 GHz); both the bandwidths are large enough for the required bandwidth of the 2.4 and 5.2/5.8 GHz WLAN bands. The two frequency bands can be tuned separately.

Amit A. Deshmukh and K. P. Ray proposed a new geometry by integrating a half-U-slot and a rectangular slot inside the rectangular microstrip patch antenna in [5]. The proposed antenna design shows better bandwidth enhancement with gain of more than 7 dBi for the entire BW with the broadside radiation pattern. M.Ali et al. presented a wide-band/dual-band packaged antenna for wireless local-area network (WLAN) applications in the 5.15–5.35 GHz and 5.725–5.825 GHz frequency range in [6]. The effects of coupling between the ground plane and antenna were shown. Fabricated antenna dimensions were of 28x9x3 mm^3 on FR4 substrate. In [7] D.K. Shrivastava et al. proposed stack configuration of a wideband U-slot loaded rectangular patch and a horizontal slot loaded rectangular patch antenna. The designed antenna performed wideband operation due to its dual resonance nature. The designed antenna configuration has shown bandwidth enhancement. The resonance operation effect depends upon substrate thickness and slot parameters. The impedance bandwidth of 54.6 % is obtained. The half power beamwidth was found to be approximately 68 and radiation pattern was found to be almost constant throughout the entire bandwidth. In [8] Alireza motevasselian et al. presented an effective approach to reduce the size of patch in rectangular microstrip antennas. The approach was based upon inductively loading the patch using a cuboid ridge and the cuboid ridge is included in the transmission line model of the patch antenna. Mahdi moosazadeh et al. proposed a novel microstrip-fed monopole antenna for a triple-band operation in [9]. The proposed antenna consisted of a pair of symmetrical L and U shape slots inside the rectangular patch that enables proper adjusting of the resonant bands. Proposed antenna geometry was simulated and fabricated on FR4 substrate. Designed antenna covers the desired operating bandwidths, gain, and radiation patterns for WLAN (2.4/5.2/5.8 GHz) and WiMAX (2.5/3.5/5.5 GHz) applications. The antenna had relatively small dimensions of 15x15x1.6 mm^3. In [10] Ali Foudazi et al. presented a compact microstrip line fed multi-band monopole antenna. The base of the designed antenna was a diamond-shaped patch that covered the UWB frequency range. For achieving multi-band characteristics, several narrow strips, could be integrated with the antenna. The designed geometry had a substrate size of 16x22x1 mm^3 and covers the frequency bands 1.3, 1.8, 2.4 and 3.1–10.6 GHz. which could be used for GPS, GSM, WLAN and UWB applications. The antenna had omnidirectional and stable radiation patterns across all the relevant bands. A quad-band antenna is simulated using HFSS and fabricated a prototype on FR4 substrate. In [11] Zi-Xian Yang et al. proposed a rectangular patch antenna for bandwidth enhancement, in which polarization could be reconfigured. The antenna had stair-slots on the ground and two p-i-n diodes were used for switching the antenna's polarization (linear polarization, left-hand circular polarization and right-hand circular polarization). The 3-dB axial-ratio bandwidths and return loss enhancement were achieved. The asymmetrical slotted ground acted as an excitation plane and modes with different resonant frequency to generate CP radiation, and due to the stair-slots, the lower resonant frequency decreased and the higher one increased. Thus, the overall bandwidths were improved. The proposed antenna could be used for wireless local area network (WLAN) in the range of 2.4GHz – 2.5 GHz in wireless communication systems.

In the proposed design, we will investigate the effects of slot implementation and impedance matching using movement of slots with a constant feed point. In this paper, the configuration of proposed antenna consist of 'I' slot on dielectric plane and slotted ground is described in detail. Design parameters are discussed, by considering the effects of different dimensions on antenna performances. The proposed antennas as described in Fig. 1 is Simulated with the IE3D version 9.0, and the work is finally concluded.

2. ANTENNA DESIGN CONSODERATION

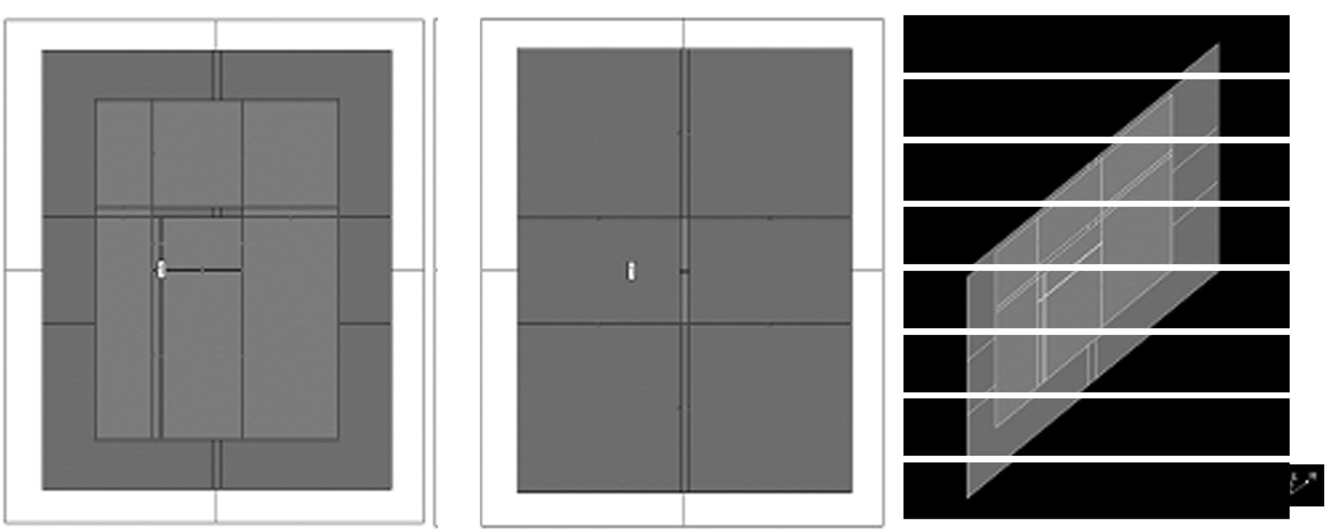
The configuration of single layer microstrip antenna, which consist of 'I' slot on its radiating patch and a slotted finite ground plane, the comparison is made between three geometries. First of all a horizontal slot is designed of 9.46×0.946 mm^2 size at the centre of the dielectric patch and on ground plane a vertically located slot of same size is designed. The whole geometry is located at the centre (i.e. x_f= 0 mm, y_f= 0 mm). The feeding technique used in the design is probe feeding. Feed point is calculated as (x_f= -5.84 mm, y_f= 0 mm). Now for impedance matching, the horizontal slot is shifted toward the feed and situated at (x_f= -2 mm, y_f= 5.2 mm). The simulated geometry is shown in Fig. 1. Dielectric layer and ground plane dimensions are given in table.1. The substrate is chosen to be FR4 having dielectric constant ε_r= 4.3 with the height h=1.5 mm. and loss tangent as 0.019. The location of the feed point is obtained from the equation given below;

$$X_f = \frac{L}{2\sqrt{\varepsilon_{reff}}} \text{ and } Y_f = \frac{W}{2}$$

For the patch designing certain calculations have been done with the help of following equations;

Width and Length of patch is given by;

$$W = \frac{V_0}{2*f_r}\sqrt{\frac{2}{\varepsilon_r+1}}, \quad L_{eff} = \frac{V_0}{2*f_r\sqrt{\varepsilon_{reff}}}$$



(a) (b) (c)

Figure 1: Antenna 1, 1(a) Top view of antenna, 1(b) Bottom view of antenna, 1(C) 3d view of antenna

The return loss characteristic is shown in figure 2. It shows that antenna 1 initially does not radiate due to its impedance mismatching.

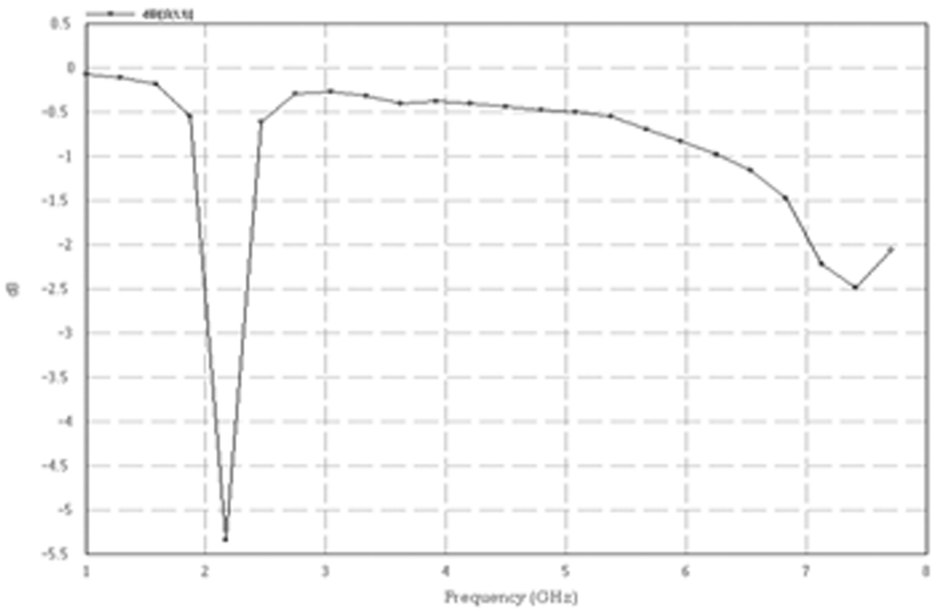


Figure 2: Return loss vs frequency (Antenna 1)

Table 1
Dimensions of antenna 1
(All dimensions are in mm.)

L (length of dielectric plane)	25.75
W(width of dielectric plane)	30.7
L_g (length of ground plane)	36.75
W_g (width of ground plane)	39.7
L_s (length of slot)	9.46
W_s (width of slot)	0.946

Effective dielectric constant is given by;

$$\varepsilon_{reff}=\left(\frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\right)*\frac{1}{\sqrt{1+\frac{12h}{w}}}$$

Practical approximate relation for normalized extension of length;

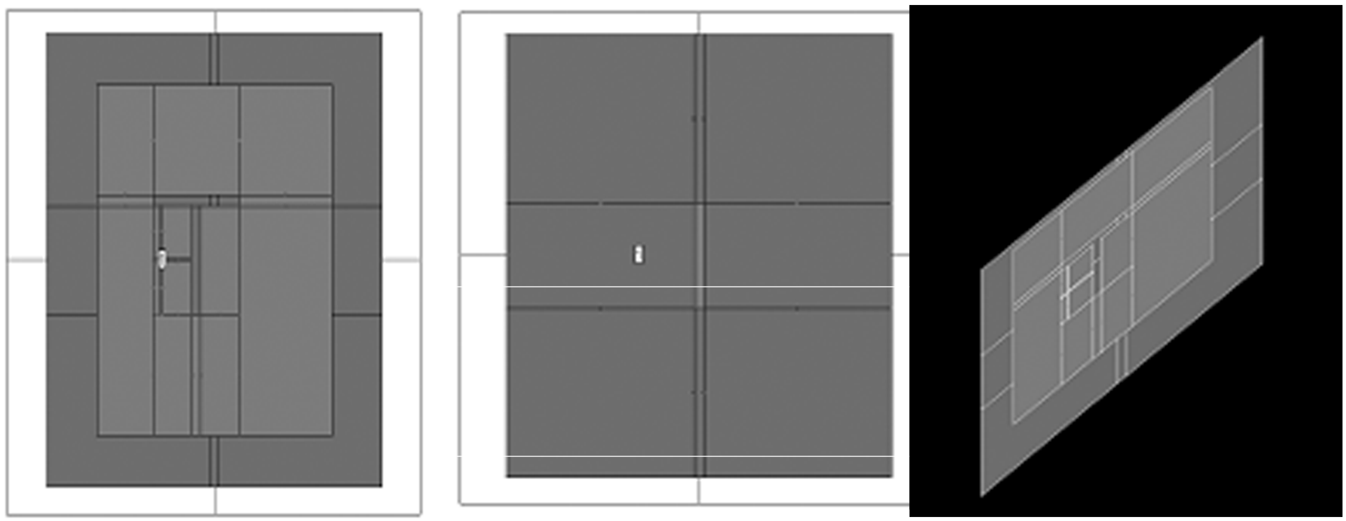
$$\frac{\Delta L}{h}=0.412\frac{\left(\varepsilon_{refff}+0.3\right)\left(\frac{W}{h}+0.264\right)}{\left(\varepsilon_{refff}-0.258\right)\left(\frac{W}{h}+0.8\right)}$$

Actual length of the patch is given by;

$$L_{eff}=L+2\Delta L$$

Secondly, the ‘T’ shaped slot has been implemented onto the dielectric plane with the same dimension and a slotted finite ground plane. Designed geometry is shown in fig. 2. All the dimensions of antenna 2 are given in table 2.

Whole geometry is located around the origin (0, 0) while ‘T’ shape has been implemented around (-2, 0).



(a) (b) (c)

Figure 3: Antenna 2, 3(a) Top view of antenna, 3(b) Bottom view Of antenna, 3(C) 3d view of antenna

Table 2
dimensions of antenna 2
(All dimensions are in mm.)

L (length of dielectric plane)	25.75
W(width of dielectric plane)	30.7
L_g (length of ground plane)	36.75
W_g (width of ground plane)	39.7
L_{hs} (length of horizontal slot)	9.46
W_{hs} (width of horizontal slot)	0.946
L_{vs} (length of vertical slot)	0.946
W_{vs} (width of vertical slot)	9.46

The return loss characteristic of antenna 2 is shown in fig. 4. It shows that due to ‘T’ slot implementation antenna 2 creates a band around 5.96 GHz with -12.92 dB return loss value and 5.8 % of bandwidth. Also it confirms that vertical slot implementation shifts the resonant frequency towards higher level frequency. The dielectric constant for the designing substrate is chosen to be FR4 having $_r$ = 4.3 with the height h = 1.5 mm. and loss tangent as 0.019.

Atlast, the final geometry is made with ‘I’ shape slot onto the dielectric plane with a slotted ground is show in fig. 5. Dimensions of the antenna 3 are given in the table.3.

Whole geometry is simulated using FR4 substrate parameters such as; dielectric constant $_r$ = 4.3, height h = 1.5 mm. and loss tangent as 0.019. All the dimensions of antenna 3 are given in table.3. Return loss characteristic shown in fig. 5. On comparing all the three geometries, we come know that results of the final geometry with the ‘I’ shape slot are far better than the previous geometries. Return loss and bandwidth characteristic of antenna 3 are abruptly enhanced shown in fig.6. Antenna 3 is simulated with the 1.5 mm

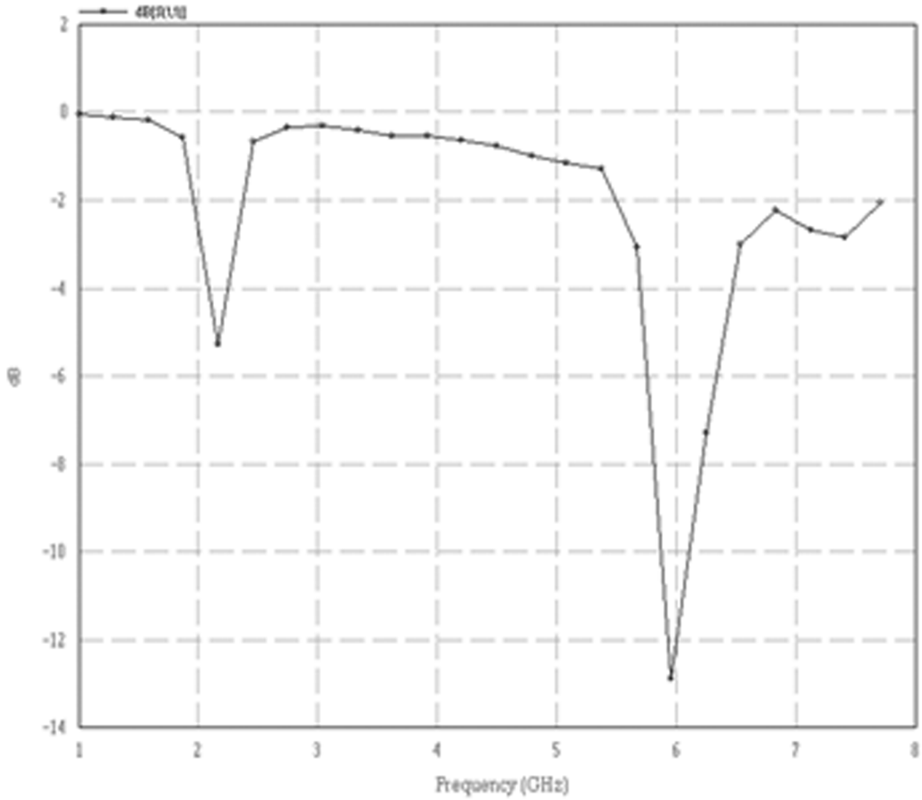
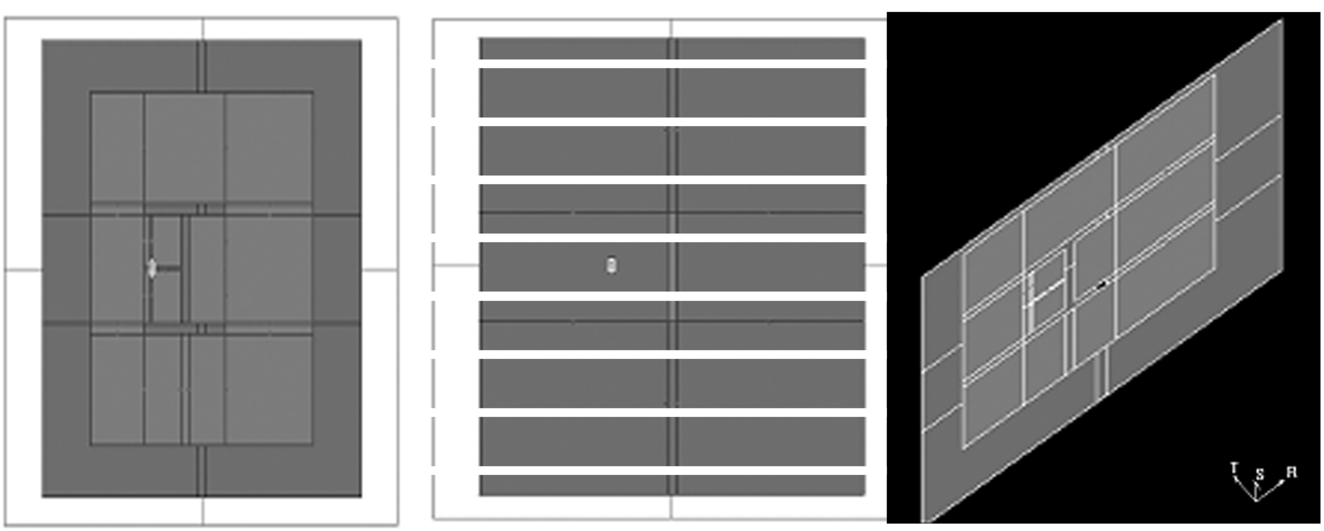


Figure 4: Return loss vs frequency (Antenna 2)



(a) **(b)** **(c)**

Figure 5: Antenna 3, 4(a) Top view of antenna, 4(b) Bottom view of antenna, 4(C) 3d view of antenna

thick FR4 substrate having dielectric constant $_r$ = 4.3 and 0.019 loss tangent. Simulation result shows that impedance is perfectly matched and hence antenna 3 starts radiating at 4.2 GHz resonant frequency. All the dimensions for the designing of antenna 3 are tabulated in Table. 3. Designed antenna works in the range of 3.95 GHz to 4.45 GHz. Designed antenna covers s band partially and c band. As 3.7 GHz to 4.2 GHz is allocated for commercial telecommunications using satellites. So the proposed antenna is a good candidate and can be used easily.

The geometry is simulated using IE3D simulation tool within 1 GHz to 8 GHz operating frequency range. Designed antenna can be used for c band mostly. The comparison of all three antennas is shown in

Table 3
dimensions of antenna 3
(All dimensions are in mm.)

L (length of dielectric plane)	25.75
W(width of dielectric plane)	30.7
L_g (length of ground plane)	36.75
W_g (width of ground plane)	39.7
L_{hs} (length of horizontal slot)	9.46
W_{hs} (width of horizontal slot)	0.946
L_{vs} (length of vertical slot)	0.946
W_{vs} (width of vertical slot)	9.46

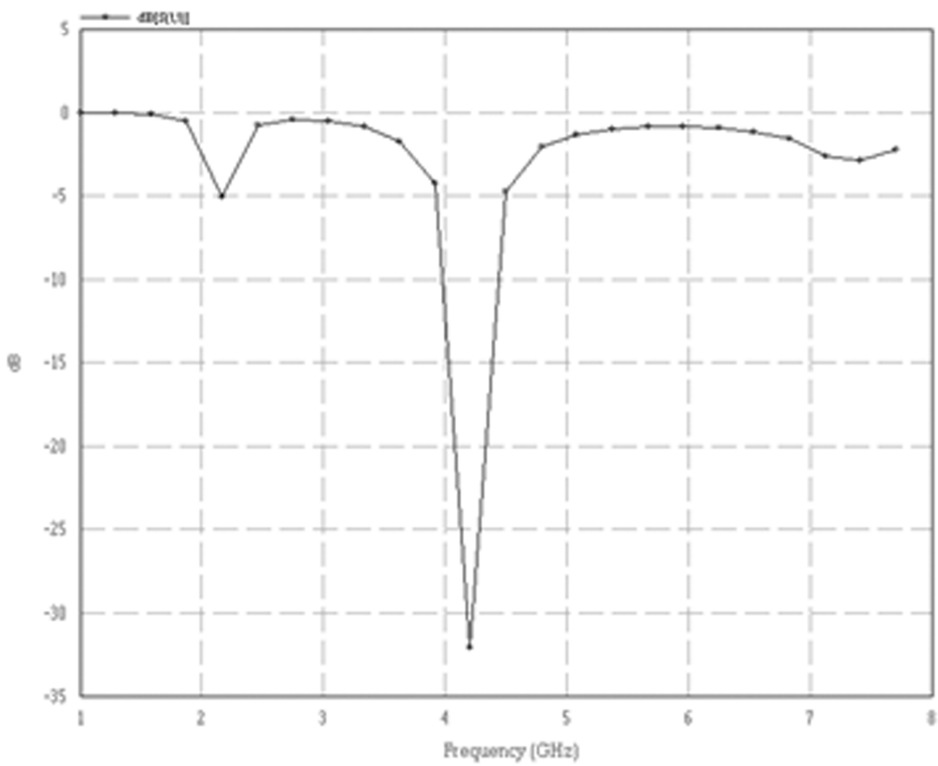


Figure 6: Return loss vs frequency (Antenna 3)

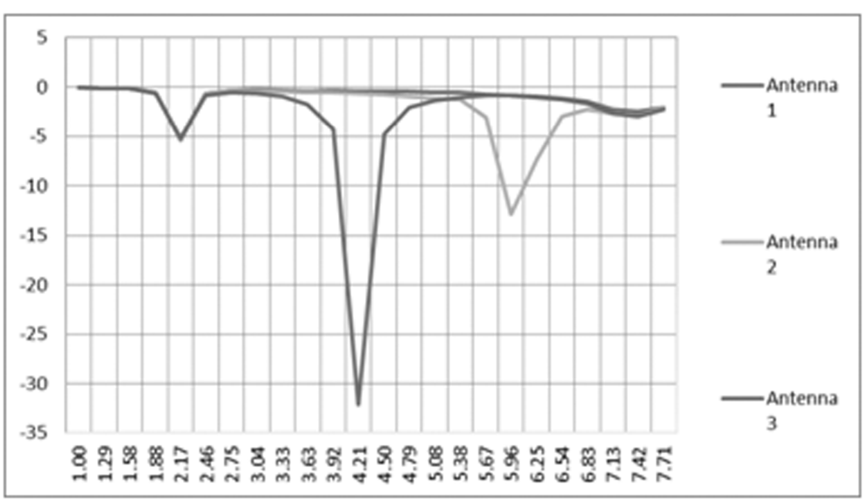


Figure 7: Comparative graph between simulated and measured results

fig.6. It shows that impedance matching can be done easily using slot implementation, which improves the overall performance of the design. Also the finite ground plane acts as a perfect reflector. So that can get maximum radiations in one direction.

4. CONCLUSION

In this paper Single layer 'I' shaped microstrip slot Antenna with slotted ground is presented. Probe feeding is used in this structure as a feeding mechanism. Slot implementation is very easy and effective approach for achieving size reduction and good performance at the demonstrated frequency relatively. By introducing a finite slotted ground plane impedance matching can be achieved, so that we can have better return loss and hence bandwidth. Simulation results show that design antenna is a good candidate for s band (partially) and c band in the range of 3.95 GHz to 4.45 GHz.

REFERENCES

[1] U. Chakraborty et al. "Compact Dual-Band Microstrip Antenna for IEEE 802.11a WLAN Application" IEEE Antennas and Wireless Propogation Letters, VOL. 13, 2014, pp. 407-410.

[2] Jigar M. Patel et al. "Comparative Analysis of S-Shaped Multiband Microstrip Patch Antenna" International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Vol. 2, Issue 7, July 2013, pp. 3273-3280.

[3] Xiao Lei Sun et al. "Dual-Band Antenna with Compact Radiator for 2.4/5.2/5.8 GHz WLAN Applications" IEEE Antennas and Wireless Propogation, Vol. 60, issue 12, December 2012.

[4] Chih-Yu Huang and En-Zo Yu "A Slot-Monopole Antenna for Dual-Band WLAN Applications" IEEE Antennas and Wireless Propogation Letters, Vol. 10, 2011.

[5] Amit A. Deshmukh and K.P.Ray "Compact Broadband Slotted Rectangular Microstrip Antenna" IEEE Antennas and Wireless Propogation Letters, Vol.8, 2009.

[6] M. Ali et al. "Wide-Band/Dual-Band Packaged Antenna for 5–6 GHz WLAN Application" IEEE Antennas and Wireless Propogation, Vol. 52, Issue 2, February 2004.

[7] D.K. Srivastava et al. "Wideband electromagnetically coupled coaxial probe fed slot loaded stacked patch antenna" International Journal of Engineering, Science and Technology, Vol. 3, No. 3, 2011, pp. 154-159.

[8] Alireza Motevasselian et al. "Patch size reduction of rectangular microstrip antennas by means of a cuboid ridge" IET Microwaves, Antennas & Propagation, Vol. 9, Iss. 15, 2015, pp. 1727–1732.

[9] Mahdi Moosazadeh et al. "Compact and Small Planar Monopole Antenna With ymmetrical L- and U-Shaped Slots for WLAN/WiMAX Applications" IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS, VOL. 13, 2014, pp. 388-391.

[10] Ali Foudazi et al. "Small UWB Planar Monopole Antenna With Added GPS/GSM/WLAN Bands" IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, VOL. 60, NO. 6, JUNE 2012, pp. 2987-2992.

[11] Zi-Xian Yang et al. "Bandwidth Enhancement of a Polarization- Reconfigurable Patch Antenna With Stair-Slots on the Ground" IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS, VOL. 13, 2014, pp. 579-582.