Comparative Analysis of dual 'L' shaped microstrip slot Antenna with slotted flinite and infinite ground plane for return loss enhancement

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Abstract* - A single-band characteristic of dual 'L' shaped rectangular microstrip slot antenna with finite and infinite 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. Antenna1 (with infinite ground plane) works well in the frequency range 6.8 GHz to 7.1 GHz whereas Antenna2 (with finite slotted ground plane) works well in the frequency range 6.7 GHz to 7.35 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 two different antennas structures with oppositely located 'L' slots on a single layer with infinite ground plane (in Antenna1) and with slotted finite ground plane (in Antenna2). Antenna geometry i.e. with dual 'L' slot, shows better improvement in the radiation characteristics. Also the effects of slot implementation show the change in resonant frequency. Microstrip antenna is with 'L' slot and finite ground plane with a horizontal slot, improves properties like resonance frequency, gain, return loss and bandwidth, which may affect the antenna performance. This structure uses single layer configuration; dual 'L' shape slot on the dielectric patch with infinite ground plane (in Antenna1) and dual 'L' shape slot on the dielectric patch with finite ground plane (in Antenna2). The antenna simulation yields -25.58 dB return loss at 6.966 GHz resonant frequency (Antenna1) and -25.82 dB at 6.966 GHz with 4.31% and 9.25% bandwidth respectively with a maximum size of 24.68x27.42x1.5mm^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).

I. 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.

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. different research works; in a recent study Jin-dong zhang et al. proposed a single layer microstrip line fed patch antenna that could be used for bandwidth improvement and harmonic suppression in [1]. λ/4 microstrip line resonators were introduced nearby rectangular patch. Wideband properties were obtained using resonator implementation. The designed antenna shows size reduction, light weight since it was designed using electrically thin and light substrate. Also on reviewing paper λ/4 resonator and capacitive feeding was found a good candidate for harmonic suppression. The designed antenna resonated at 4.9 GHz. The antenna was operating in the range of 4.69 to 5.10 GHz and return loss and bandwidth was obtained -25 dB and 8.4% respectively. The measured bandwidth was 2.7 times wider than that of the traditional insert-fed patch. In [2] alexander ye. svezhentsev et al. designed a wide-band omnidirectional cylindrical MPA with two new E shapes. The geometry was designed on a low permittivity flexible textile substrate. Both antennas (Fig.3 and Fig.5) had shown Omni directionality in the horizontal plane, wide-band behavior (for the first antenna) and low side-lobe levels (for the second antenna). The antenna was designed to have 33% and 21% bandwidth, and 2.98 dBi and 4.56 dBi gains, respectively. The return loss values obtained from antenna 1 -25.15 dB (in Fig.4) and for the antenna 2 was -19 dB (in Fig.6). This paper concludes that textile substrate is very promising to be used in WBAN applications. Keisuke Noguchi et al. proposed a new model of ESPA using the mode theory in [3]. Paper described that transmission line and radiation modes were generated on E shape patch antenna and an equivalent circuit was derived, it helped in obtaining wideband and multi-band characteristics. Maximum bandwidth was derived for the ESPA. The simulated and measured return loss value was around -25 dB and -22.5 dB. The bandwidth for the wideband design was evaluated 27.7%. In [4] Alireza motevasselian and william G. whittow presented an approach for the reduction in patch size by loading patch using a cuboid ridge. The cuboid ridge dimensions were 29x7x1.6 mm (in fig.7). The fabricated antenna was found to be resonated at 2.35 GHz. Cuboid ridge was inserted as the part of the transmission line of the patch antenna. The results were generated using CST studio simulation tool. The simulated and measured return loss value was found to be around -15 dB and -21.5 dB respectively. The designed geometry was fed by 50 Ω characteristics coaxial line. Amandeep kaur sidhu and jagtar Singh Sivia proposed an RMPA with circular slot for S band and X band communication in [5]. RT Duroid material was used as design substrate with $\varepsilon_{r\,=}$ 2.2. Probe feeding was used for excitation of patch. This paper is based Miniaturisation of antenna structures. Designed geometry size shows 48% size reduction by conventional antenna. The maximum return loss was obtained in the second iteration as -16.20 dB (in fig.12). The gain of the antenna was calculated 8.32 dBi. Proposed antenna was simulated HFSS. 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^o and radiation pattern was found to be almost constant throughout the entire bandwidth. Mahdi moosazadeh et al. proposed a novel microstrip-fed monopole antenna for a triple-band operation in [8]. 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 [9] 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 [10] 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. 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 [11]. The proposed antenna design shows better bandwidth enhancement with gain of more than 7 dBi for the entire BW with the broadside radiation pattern.

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 two oppositely placed 'L' slot on dielectric plane (in Antenna1) and slotted ground is described in detail (in Antenna2), basically Antenna2 design is an extension of Antenna2 design. 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.

II. ANTENNA DESIGN CONSODERATION

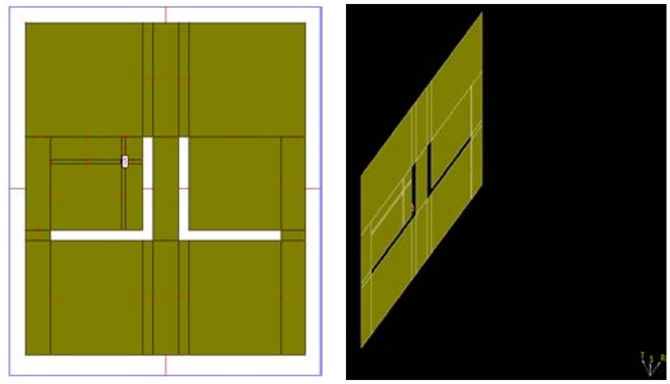
The configuration of presented microstrip antenna consists of two oppositely placed 'L' slot on its radiating patch (in Antenna1) and a slotted finite ground plane (in Antenna2) with same dielectric plane as designed in Antenna1. The comparison is made between two geometries. First of all a vertical slot is designed of 5.76x0.576 mm^2 size at (x=1mm, y=0mm) from the centre of the dielectric patch (in Antenna1) with infinite ground plane and on ground plane three horizontal equidistant slots along y-axis are located of 9.07x0.907 mm^2 size is implemented. 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 =-3.35 mm, y_f =0 mm). Now for impedance matching, the horizontal slots are placed on ground plane (in Antenna2) and middle slot is shifted upward along y-axis and situated at (x_f =-2.35 mm, y_f =1.5 mm). The simulated geometry (Antenna1) is shown in Fig.2.1. 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;

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



1(a) 1(b)

Fig. 2.1 Antenna 1, 1(a) Top view of antenna, 1(b) 3d view of antenna

The return loss characteristic is shown in figure.2.2. It shows that antenna 1 initially does not radiate due to its impedance mismatching.

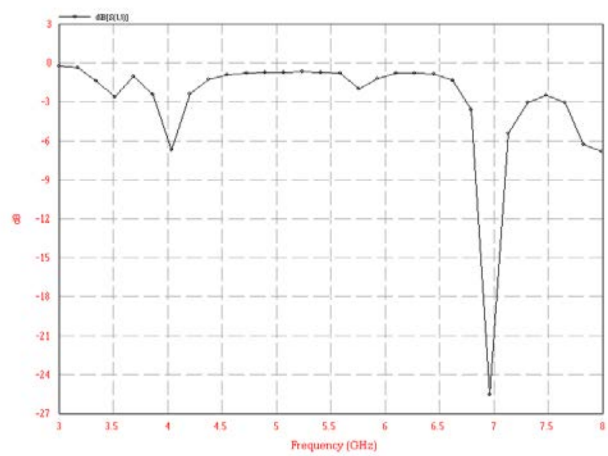


Fig.2.2 Return loss vs frequency (Antenna 1)

TABLE.1. DIMENSIONS OF ANTENNA 1
(All dimensions are in mm.)

S.No.	Antenna Parameters	Measurement
1.	L (length of dielectric plane)	15.68
2.	W(width of dielectric plane)	18.42
3.	L_g (length of ground plane)	24.68
4.	W_g (width of ground plane)	27.42
5.	L_s (length of slot)	5.76
6.	W_s (width of slot)	0.576

Effective dielectric constant is given by;

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

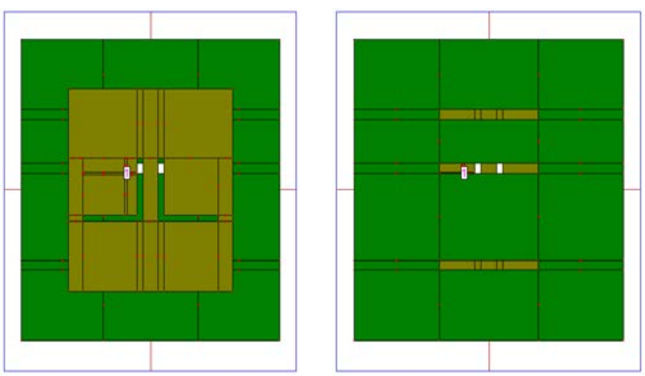
Practical approximate relation for normalized extension of length;

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

Actual length of the patch is given by;

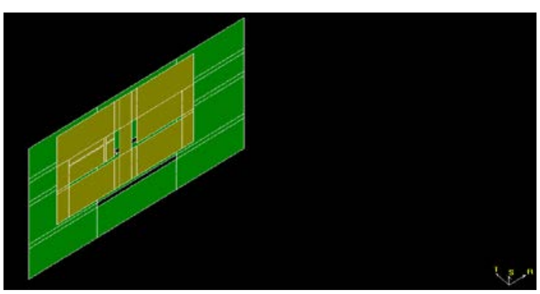
$$L_{eff} = L + 2\Delta L$$

Secondly, the oppositely placed 'L' 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.2.3. All the dimensions of antenna 2 are given in table.2.



3(a) 3(b)

Whole geometry is located around the origin (0, 0) while 'L' shape has been implemented x_f =1mm from (1,0).



3(c)

Fig. 2.3 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.)

S.No.	Antenna Parameters	Measurement
1.	L (length of dielectric plane)	15.68
2.	W(width of dielectric plane)	18.42
3.	L_g (length of ground plane)	24.68
4.	W_g (width of ground plane)	27.42
5.	L_s (length of slot)	9.07
6.	W_s (width of slot)	0.907

The return loss characteristic of antenna 2 is shown in fig. 2.4. It shows that due to oppositely placed 'L' slot implementation with horizontally placed slots on ground plane antenna 2 creates a band around 6.966 GHz with -25.82 dB return loss value and 9.25 % of bandwidth. Also it confirms that movement of horizontal slot implementation shifts the resonant frequency towards lower level frequency. The dielectric constant for the designing substrate is chosen to be FR4 having ε_r = 4.3 with the height h=1.5 mm. and loss tangent as 0.019.

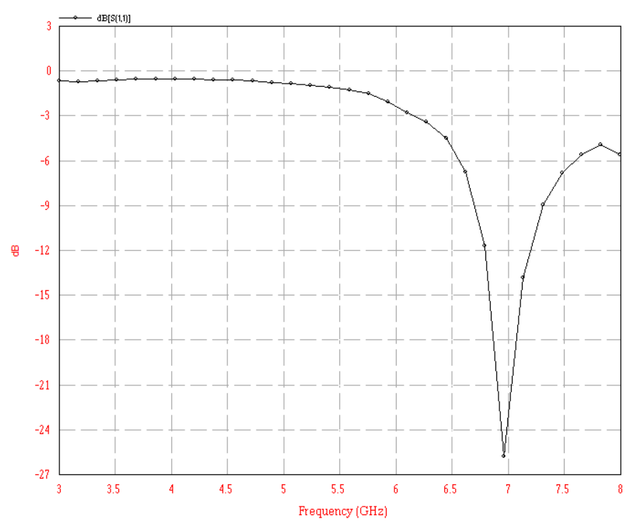


Fig.2.4. Return loss vs frequency (Antenna 2)

On comparing both the geometries, we come know that results of the final geometry with the oppositely placed 'L' shape slot with slotted ground (Antenna2) are far better than the Antenna1 geometry. Designed antenna covers c band. Antenna shows its radiation characteristics in between 6.7 GHz to 7.35 GHz are 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 3 GHz to 8 GHz operating frequency range. Designed antenna can be used for c band mostly. The comparison of all antennas is shown in fig.2.5. 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.

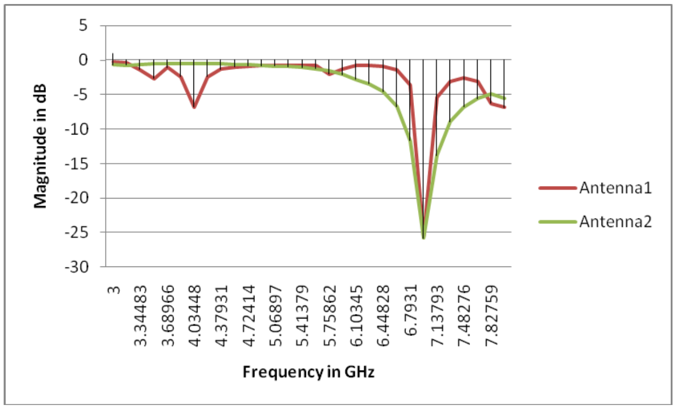


Fig. 2.5 comparative graph between simulated results of Antenna1 and Antenna2

III. CONCLUSION

In this paper oppositely placed 'L' 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 6.7 GHz to 7.35 GHz.

IV. REFERENCES

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