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Dual Band 'I' Shaped MSA with Diffracted Ground Plane

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ABSTRACT: A dual-band characteristic of single layer 'I' shaped rectangular microstrip slot antenna with differacted ground is presented. It is a probe-fed- mechanism based antenna for matching impedance with 50Ω coaxial line. The antenna geometry is simulated using IE3D software. Antenna works good in the frequency range 3.75 GHz to 4 GHz. It is a light weight, low cost antenna, which can be used for wireless communication in UWB band. The antenna structure involves comparison of same antenna structure with three different heights. Final antenna geometry is designed with 'I' slot on dielectric plane and diffracted ground plane, shows better improvement in the radiation characteristics. Also the effects of slot implementation show the change in resonant frequency. MSA is with 'I' slot and diffracted ground plane, improves properties like resonance frequency, gain, return loss and bandwidth (substantially), which may affect the antenna performance. This structure uses single layer configuration; 'I' shape slot on the dielectric patch and finite diffracted ground plane. The antenna simulation yields -17 dB and -25.79 dB return loss at 4.034 GHz and 4.552 GHz resonant frequency with 7.31% and 9.42% bandwidth with a size of 18.375x39.7x1.5mm^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), Microstrip patch antenna (MPA), Microstrip antenna (MA).

I. INTRODUCTION

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 antenna needs both good impedance matching and low signal distortion within the relative frequency range. Mpas are mostly involved with wireless and cellular mobile communication systems because of their merits, like compactness, low 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 diffracted ground plane. Concepts of MPA and slot antenna are successfully used to get the required antenna performance. The coaxial-feed is used as a feeding mechanism. In this paper, geometry is simulated with sameconfiguration but with three different heights. As we know that by implementing slots, bandwidth and returnloss characteristics can be enhanced therefore, the proposed geometry utilizes 'i'shape slot on dielectric layer and diffracted ground layer. The proposed design can effectively reduce the overall-size of antenna. Concept of impedance matching is presented using feed point variation,and slot implementation. The geometry is so simple but yet so effective, hence can acheive better radiation characteristics.

II. RELATED WORK

Research work is being carried-out in the field of MPAs. The development in the context of MPA is our focus area. The following review emphasised on comparative study of several research works based on microstrip patch antenna. Hang Wong et al. designed an antenna with vertical polarization for WLAN communications in [1]. Designed geometry has equilateral-triangular patch with certain shorting pins. The design of V shaped slot was equivalent to a capacitance loading, which was used to lower the resistance and the reactance of the antenna, resulted in a larger bandwidth. The proposed antenna had the impedance bandwidth of 32.20%, with the peak gain of 6.50 dBi over the operating bandwidth. The return loss of the mounted antenna was measured around -20 dB. The antenna could be easily mounted on the car roof. These characteristics made the designed antenna suitable for C2C and WLAN communications.

In [2] Alexander ye. svezhentsev et al. designed a wide-band omnidirectional cylindrical MA with two new E shapes. The geometry was designed on a low permittivity flexible textile substrate. Designed antennas had presented Omni directional radiation in the horizontal plane, wide-band characteristics (for the first antenna) and low sidelobe 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 and for the antenna 2 was -19 dB. This paper concludes that textile substrate is a good candidate to be used in WBAN applications.

Keisuke Noguchi et al. proposed a new model for ESPA using the multi-conductor modal theory in [3]. It prenented transmission line and radiation-modes were generated on the E Shaped Patch Antenna and an equivalent circuit was derived from the modal theory. The equivalent circuit was designed to obtain wideband and multi-band characteristics. The simulated and measured return loss value was around -25 dB and -22.5 dB. The impedance bandwidth for the wideband design was evaluated 27.7%.

In [4] Alireza motevasselian et al. presented an effective approach for reducing patch size by inductively loading the patch using a cuboid-ridge. The cuboid-ridge dimensions were 29x7x1.6 mm. The fabricated antenna was resonateing at 2.35 GHz. Cuboid-ridge was inserted as the part of the transmission line model of the patch antenna. The results were generated using CST studio simulation tool. The simulated and measured return loss value was around -15 dB and -21.5 dB respectively. The designed geometry was fed by 50 Ω characteristics coaxial line.

Amandeep Kaur Sidhu et al. proposed an RMPA with circular slot applicable for S band and X band applications in [5]. Rogers RT/Duroid material was used as design substrate with εr =2.2. Probe feed is used to provide the excitation. This paper is based Miniaturisation of antenna structures. Proposed geometry size of conventional antenna was reduced to 48%. The maximum return loss was obtained in the second iteration as -16.20 dB. The gain of the antenna was calculated 8.32 dBi. Proposed antenna was designed and simulated using HFSS. The proposed antenna design shows bandwidth enhancement with gain of more than 7 dBi for the entire BW with the broadside radiationpattern.

M.Ali et al. presented a wide band or dual-band packaged antenna for WLAN applications in the 5.15–5.35 GHz and 5.725–5.825 GHz frequency range in [6]. The effects of coupling of ground plane and antenna were presented. Antenna size was 28x9x3 mm3 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 patchantenna. The designedantenna performed wideband-operation due to its dual resonance -nature. The designed antenna configuration has shown bandwidthenhancement. The resonanceoperation effect depends upon substrate thickness and slot parameters. The impedancebandwidth of 54.6 % is obtained. The half power beamwidth was approximately 68o and radiation pattern was almost constant throughout the entire bandwidth.

In [8] Alireza motevasselian et al. proposed an effective approach for size reduction of patch in rectangular microstrip antennas. The approach was based upon inductivelyloading 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. designed a novel microstrip-fed monopole antenna for a triple-band operation in [9]. The proposed design had 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 and WiMAX applications. The antenna had small dimensions of 15x15x1.6 mm3.

In [10] Ali Foudazi et al. presented a compact microstrip-line fed multi-band monopole antenna. The base of antenna was a diamond-shaped patch that covered the UWB frequency range. For achieving multi-band characteristics, narrow strips, could be appended with the antenna. The geometry had a size of 16x22x1 mm3 and covers the frequency bands 1.3, 1.8, 2.4 and 3.1–10.6 GHz. which could be utilized for GSM, GPS, WLAN and UWB applications. Antenna had omnidirectional and stable radiation patterns across all the relevant bands. A quad-band antenna was simulated using HFSS and fabricated 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 design on the ground and 2 PIN 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 RL enhancement were achieved. The asymmetrical slotted ground behave as an excitation plane and modes with different resonant frequency to generate CP radiation, and due to the stair-slots, the

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lower resonant frequency decreased and the higher one increased. Thus, the overall bandwidths were improved. The antenna could be used for WLAN in the range of 2.4GHz – 2.5 GHz in wireless communication systems.

In our design, we will investigate the effect of slot implementation and impedance matching using movement of feed point and diffracted ground plane. In paper, the configuration of proposed antenna consist of 'I' slot on dielectric plane and finite diffracted ground is described in detail. Design parameters are discussed, by considering the effect of various dimensions on antennaperformances. The proposed antennas as described in Fig. 1, Simulated using IE3D version 9.0, and the work is finally concluded.

III. Antenna Design Consideration

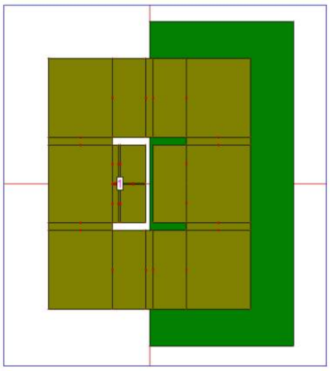
The configuration of single layer microstrip antenna, which consist of 'I' slot on its radiating patch and a finite diffracted ground plane, the comparison is made on three different heights of geometries. First of all a 'I' slot is designed of 9.46x0.946 mm^2 size at the centre of the dielectric patch with the diffracted ground plane of size (18.375x39.7 mm^2). 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 feed point is shifted toward the 'I' slot and situated at (x_f=-3.84 mm, y_f=0 mm). The simulated geometry is shown in Fig.1. All the dimensions are given in table.1. FR4 substrate is chosen having dielectric constant ε_r = 4.3 with height h=1.5 mm. and loss tangent= 0.0019. The location of feed point is calculated from the equation given below;

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

For the patch designing certain calculations have been done using following equations;

Width and Length of patch is given by;

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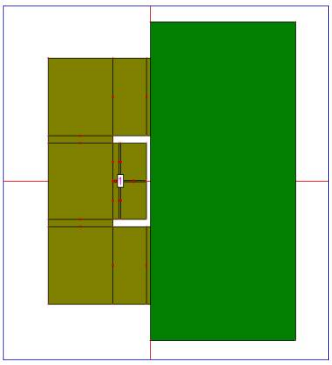
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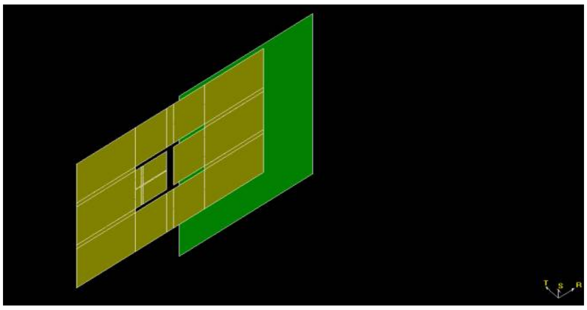

1(c)
Fig. 1 Antenna 1, 1(a) Top view of antenna, 1(b) Bottom view of antenna, 1(C) 3d view of antenna

The return loss characteristic of Antenna-I is shown in figure.2. It shows that antenna 1 is radiating at 4.034GHz and 4.552GHz in the range of 3.8 to 4.85GHz.

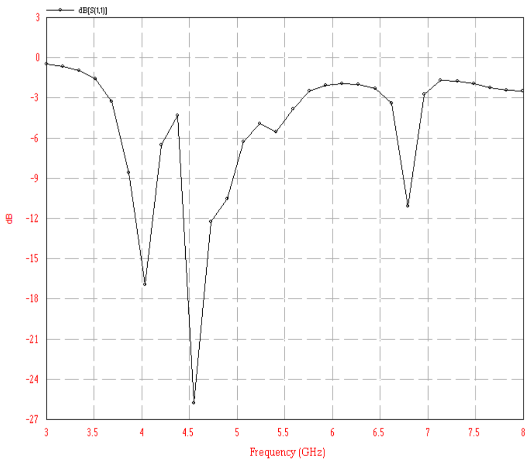

Fig.2. Return loss vs frequency (Antenna 1)

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

Parameters	Dimensions	Result RL
L (length of dielectric plane)	25.75	
W(width of dielectric plane)	30.7	-17 dB @4.034 GHz & -25.79 @4.552 GHz
L_g (length of ground plane)	18.375	
W_g (width of ground plane)	39.7	
L_s (length of slot)	9.46	
W_s (width of slot)	0.946	
Height b/w Ground and Dielectric plane	1.5	

Effective dielectric constant is given by;

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

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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, same design has been implemented onto the dielectric plane with the same dimension of finite diffracted ground plane but with h=2.5 mm. Geometry dimensions are shown in table.2.

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

Parameters	Dimensions	Result RL
L (length of dielectric plane)	25.75	
W(width of dielectric plane)	30.7	-22 dB @ 3.8 GHz
L_g (length of ground plane)	18.375	
W_g (width of ground plane)	39.7	
L_s (length of slot)	9.46	
W_s (width of slot)	0.946	
Height b/w Ground and Dielectric plane	2.5	

The return loss characteristic of Antenna-II is shown in figure.3. It shows that designed antenna radiates at 3.8 GHz and can be concluded as increasing height b/w the two planes results in improved bandwidth but consequently return loss will reduce.

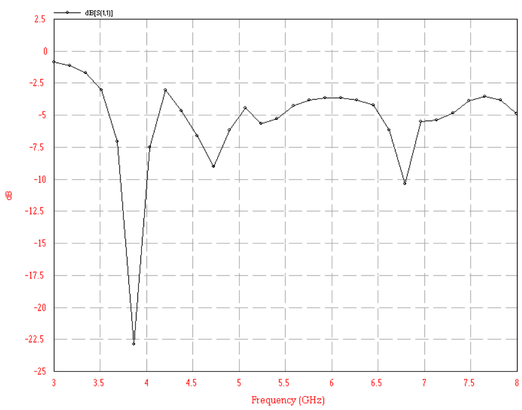

Fig.3. Return loss vs frequency (Antenna 2)

The last variation is taken with height of 3.5 mm (i.e; h=3.5 mm), same design has been implemented onto the dielectric plane with the same dimension of finite diffracted ground plane. Geometry dimensions are shown in table.3.

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

Parameters	Dimensions	Result RL
L (length of dielectric plane)	25.75	
W(width of dielectric plane)	30.7	-14.02 dB @ 3.89 GHz & -11 dB @ 4.75 GHz
L_g (length of ground plane)	18.375	
W_g (width of ground plane)	39.7	
L_s (length of slot)	9.46	
W_s (width of slot)	0.946	
Height b/w Ground and Dielectric plane	3.5	

The return loss characteristic of antenna-III is shown in fig. 4. It shows that if we further increase the height of the antenna results in poor result in terms of return loss. On the other hand return loss plot of Antenna-III shows the improvement in bandwidth. The return loss vs frequency plot shows -14 dB value in the range of 3.65 to 3.95GHz.

Also it confirms that slot implementation of diffracted ground plane shifts the resonant frequency towards lower level frequency. The dielectric constant for the designing substrate is chosen to be FR4.

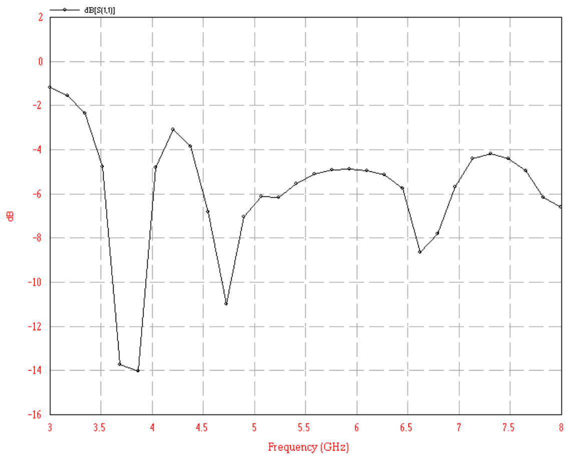

Fig.4. Return loss vs frequency (Antenna-III)

Geometry is simulated with FR4 substrate having dielectric constant ε_r = 4.3, height h=1.5 mm. and loss tangent = 0.0019. On comparing all three geometries, we come to know that result of the geometry with the height of 1.5 mm is far better. Simulation result shows, impedance is perfectly matched and hence antenna-I will radiate at 4.034 GHz and 4.552 GHz resonant frequency. Designed antenna works in the range of 3.8 GHz to 4.9 GHz. Designed antenna covers s band partially and c band and proposed antenna is a good candidate to use in maritime navigation signals, broadcast satellite services.

IE3D simulation tool is used for simulating the design within 3 GHz to 8 GHz frequency range. Antenna can be used in c band mostly. The comparison of all three antennas is shown in fig.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.

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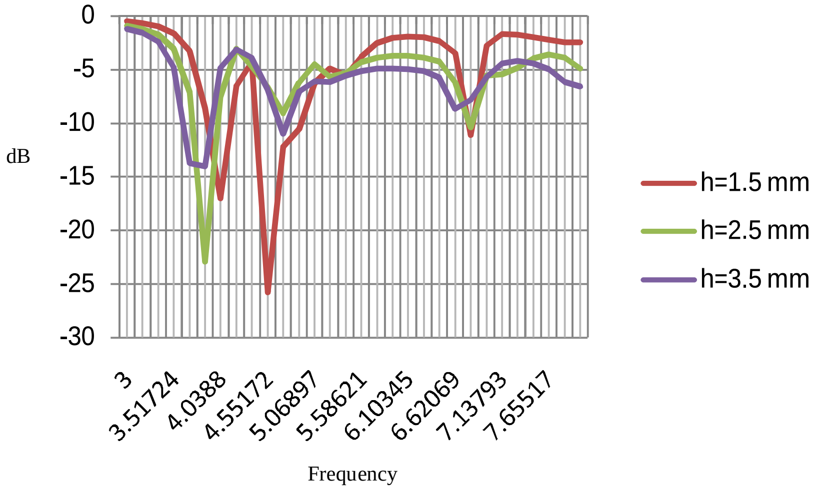

Fig. 5 comparative graph between simulated results with h=1.5 mm, h=2.5 mm, h=3.5 mm.

IV. CONCLUSION

In this paper Single layer 'I' shaped microstrip slot Antenna with diffracted ground plane is presented. Probe feeding is used in this structure as a feeding mechanism. Overall simulation results can be concluded as Slot implementation is very easy and effective approach for achieving size reduction and good performance at the demonstrated frequency relatively. By introducing a finite diffracted ground plane resonant frequency can be shifted towards lower side of the operating frequency range. Better return loss is obtained by impedance matching through feed point movement. Height variation shows improvement in bandwidth but consequently resulted in poor return loss value. 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 4.89 GHz.

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