DESIGN AND STUDY OF COMPACT SIZED PLANAR INVERTED-F ANTENNA FOR Wi-MAX APPLICATION

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ABSTRACT

A Planar Inverted-F Antenna for WiMAX applications (3.3-3.8 GHz) has been presented in this paper. The proposed structure has a dimension of 18 x 13 mm^2 over the ground plane of size 100 x 50 mm^2 which can easily be implanted in the small space available within the mobile device. The proposed structure is having a impedance bandwidth ranging from 3.198 GHz to 4.158 GHz covering WiMAX band. The antenna has a resonating frequency at 3.68 GHz frequency. For getting the impedance bandwidth we are taking -6 dB as the reference return loss. The VSWR, input impedance plot along with parametric study of some key parameters is presented. The radiation pattern and current density plots of the antenna at 3.55 GHz and 3.68 GHz are also presented. The peak realized gain of the proposed antenna varies from 4.15 dB to 5.2 dB in the desired operating band.

Keywords: Broad Frequency Bands, Impedance Bandwidth, Low-Profile Geometry, Planar Inverted-F Antenna, Wimax,

1. INTRODUCTION

The rapid decrease in size of personal communication devices has lead to the need for more compact antennas. At the same time, expansion of wireless systems has increased the applications for multi-functional antennas that operate over broad frequency bands or multiple independent bands. In the past few years, new designs based on planar inverted-F antennas (PIFA) have been used for handheld wireless devices because of its low-profile geometry. The PIFA can be considered a direct extension of the inverted-F antenna that has the horizontal wire radiating element replaced by a plate to increase its usable bandwidth. PIFA designs invoke the quarter-wavelength operation. Additionally, the PIFA offers very high radiation efficiency and sufficient bandwidth in a compact antenna.

Technique like use of reduced ground plane can to be employed to further increase the bandwidth [1], [2]. Multi-frequency capability with the antenna structure can be achieved by exciting various resonant modes using branched structure, created by cutting slots in the radiating element [3]-[6]. Several PIFA structures have been developed in the past to cover various communication frequency bands [7]-[15].

In this paper a Planar Inverted-F Antenna for WiMAX applications (3.3-3.8 GHz) has been presented. The proposed structure is having a impedance bandwidth ranging from 3.198 GHz to 4.158 GHz covering WiMAX band. The antenna has a resonating frequency at 3.68 GHz frequency. Section 2 of the paper gives the details of the proposed structure. Results and discussion is included in section 3 of this paper.

II ANTENNA DESIGN

The antenna structure is designed with Ansoft's HFSS. The antenna is designed at the top right corner of FR4 substrate of size Ws x Ls mm^2. The antenna element is at a height of 4 mm above the substrate. At the bottom side of the substrate, ground plane is placed. The antenna element is connected to the ground plane by a shorting strip of width Wsh. The shorting strip is placed along the width of the substrate.

In order to get the resonance at the desired frequency, slot loading is done by an L-shaped slot in the antenna patch. The antenna is fed by a coaxial cable at a place where impedance matching is proper. The top view and side view of the proposed antenna structure is given in Fig. 1 and Fig. 2 respectively. Fig. 3 shows the detailed dimensions of the antenna patch. The optimized parameters of the proposed structure are given in Table 1.
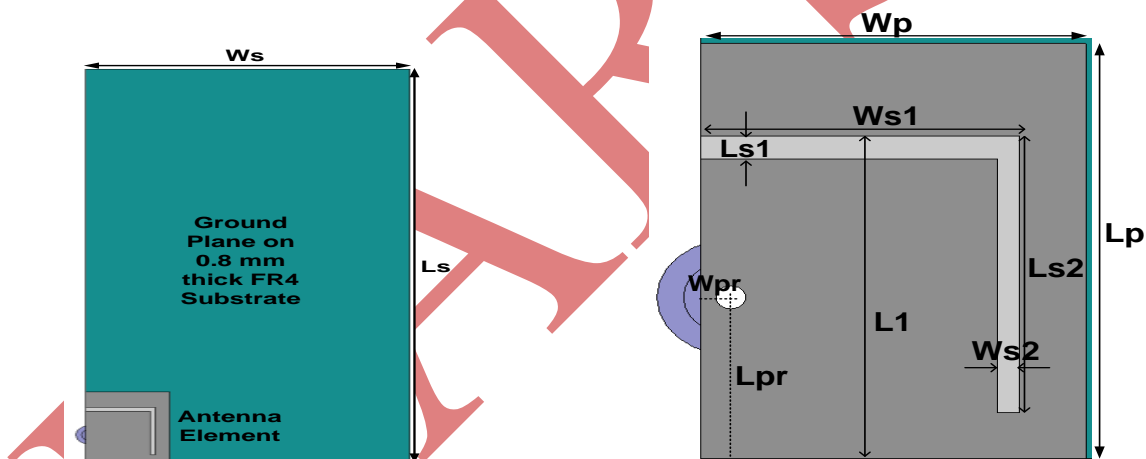

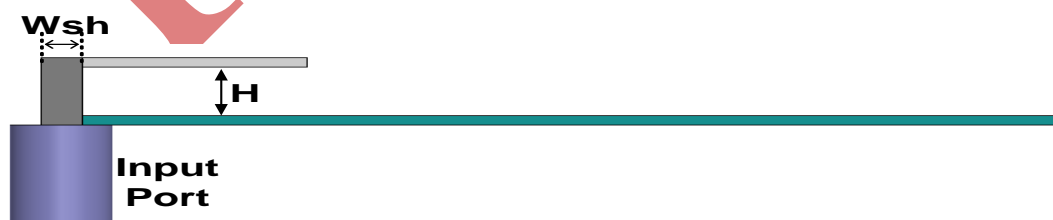**Figure 1: Top View of the Proposed Antenna Structure. Figure 3: Detailed Dimensions of Antenna Patch.**

Figure 2: Side View of the Proposed Antenna Structure.

Table 2.1: Optimized antenna dimensions

Parameter	Size (mm)	Parameter	Size (mm)
Ws	50	Ws1	10.75
Ls	100	Ls1	1
Wp	13	Ws2	0.75
Lp	18	Ls2	12
Wsh	2	Wpr	1
H	4	Lpr	7
L1	14		

III RESULTS AND DISCUSSION

The simulations are performed in Ansoft's HFSS [16] (considering SMA connector) to optimize the shape parameters of the antenna for the desired operating bands.

3.1 Return loss: Fig. 4 shows the return loss characteristics of the proposed antenna. For impedance bandwidth -6 dB return loss is taken as a reference, which is acceptable for the antennas of portable devices. The impedance bandwidth of the antenna ranges from 3.198 GHz to 4.158 GHz covering WiMAX band (3.3-3.8 GHz). The resonant frequency of the antenna is at 3.68 GHz.
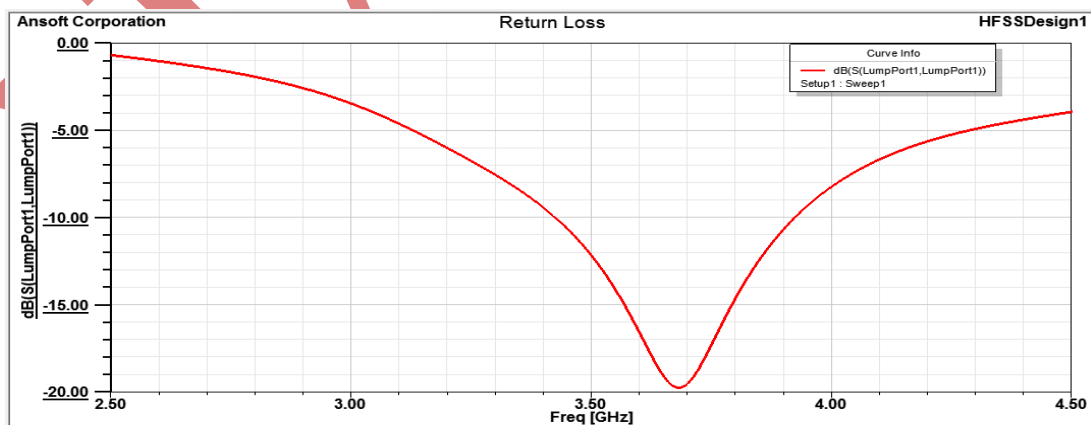

Figure 4: Return Loss Characteristics of the Proposed Antenna.

3.2 Voltage Standing Wave Ratio (VSWR): The VSWR characteristics of the proposed antenna are presented in Fig. 5. It can be seen that for the operating frequency range the VSWR is less than 3. At the resonance frequency, VSWR is 1.23, which shows the perfect matching at the antenna input port.
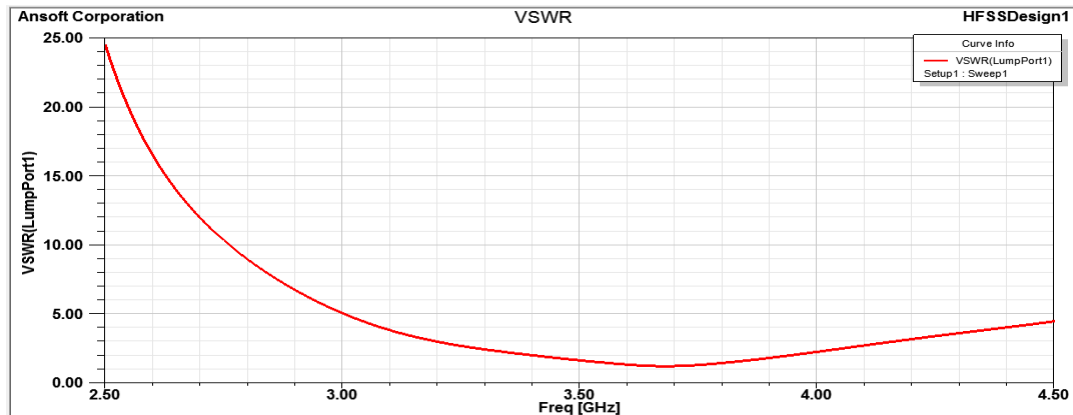

Figure 5: VSWR of the Proposed Antenna.

3.3 Input Impedance (Z_{in}): The input impedance of the proposed structure for the operating frequency range is shown in Fig. 6. It can be seen that the resistive part (real) of the impedance is varying near 50 Ω and the reactive part (imaginary) is varying near 0 Ω. This behaviour is desirable to get proper impedance matching at the port.
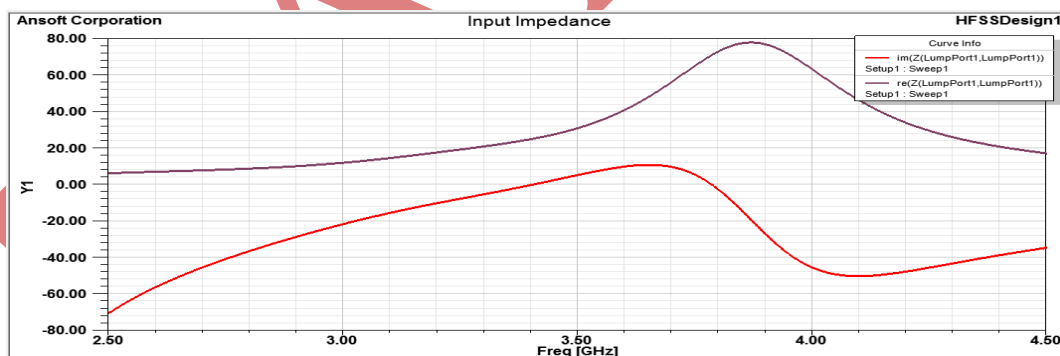

Figure 6: Input Impedance of the Proposed Antenna.

3.4 Parametric Study of the Proposed Antenna

Parametric investigation of some key parameters of the antenna is carried out in order to analyze the effect of various parameters on the operating frequency.

3.4.1 Effect of Varying 'H'

The effect of variation in air gap between the antenna patch and ground on the return loss characteristics are given in Fig 7. It can be seen that with the increase in H, resonant frequency of the antenna is shifting towards the lower frequency side, and better resonance is obtained. However the impedance bandwidth remains almost constant with an increase in H. The selected value of H is taken 4 mm to keep in view of the small space available inside the mobile device.
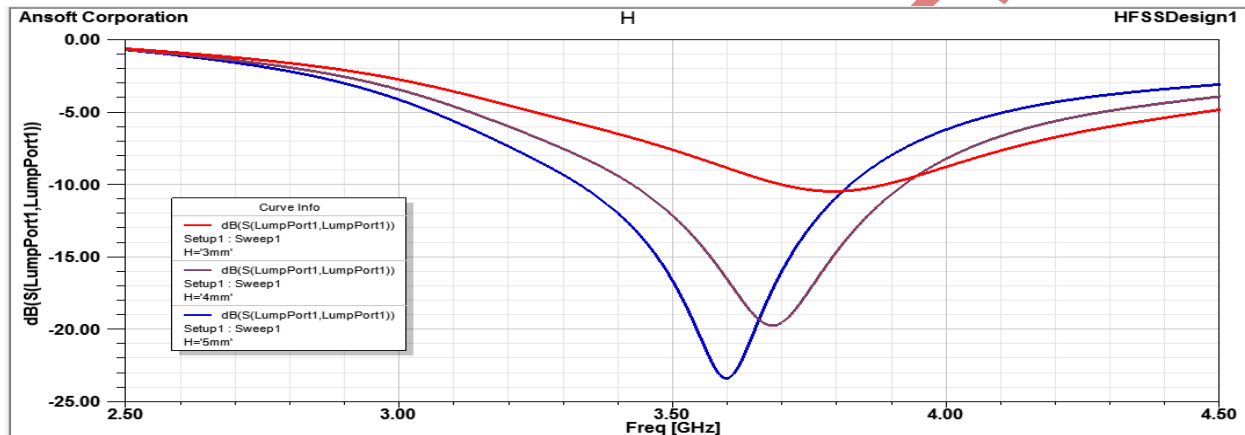

Figure 7: Effect of Varying 'H' On the Antenna Characteristics

3.4.2 Effect of Varying 'Wp'

The effect of variation in width of the patch is shown in Fig. 8. It can be seen from the figure that with an increase in Wp, the resonant frequency is shifting towards the lower frequency side of the frequency spectrum. This is because with an increase in Wp, wavelength increases and hence frequency decreases. The optimized value of Wp is 13 mm.
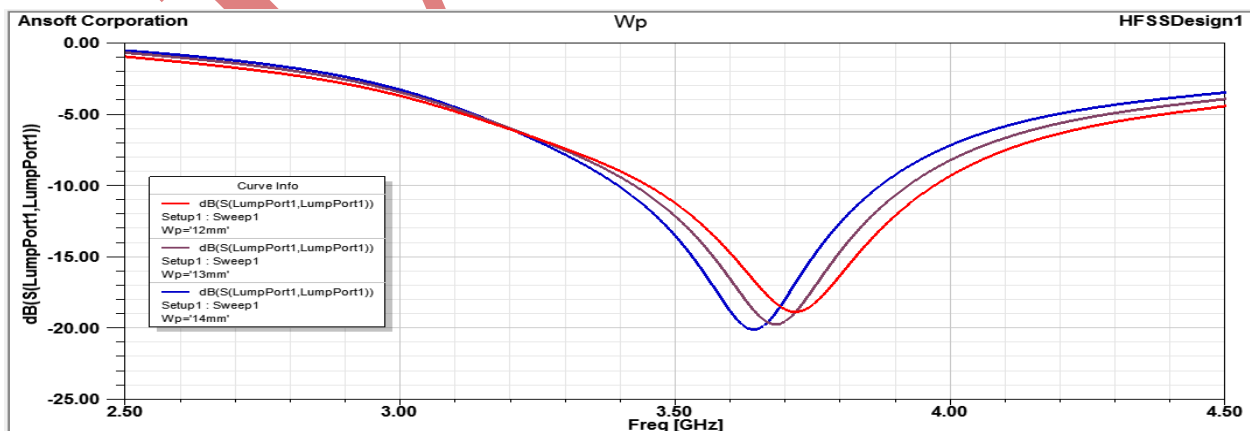

Figure 8: Effect of Varying 'Wp' On the Antenna Characteristics.

134 | P a g e

3.4.3 Effect of Varying 'Wsh'

The effect of variation in width of the shorting strip is shown in Fig. 9. It can be seen from the figure that with an increase in Wsh, the resonant frequency is shifting towards the higher frequency side of the frequency spectrum. Better return loss is obtained with an increase in Wsh. The optimized value of Wsh is 2 mm.
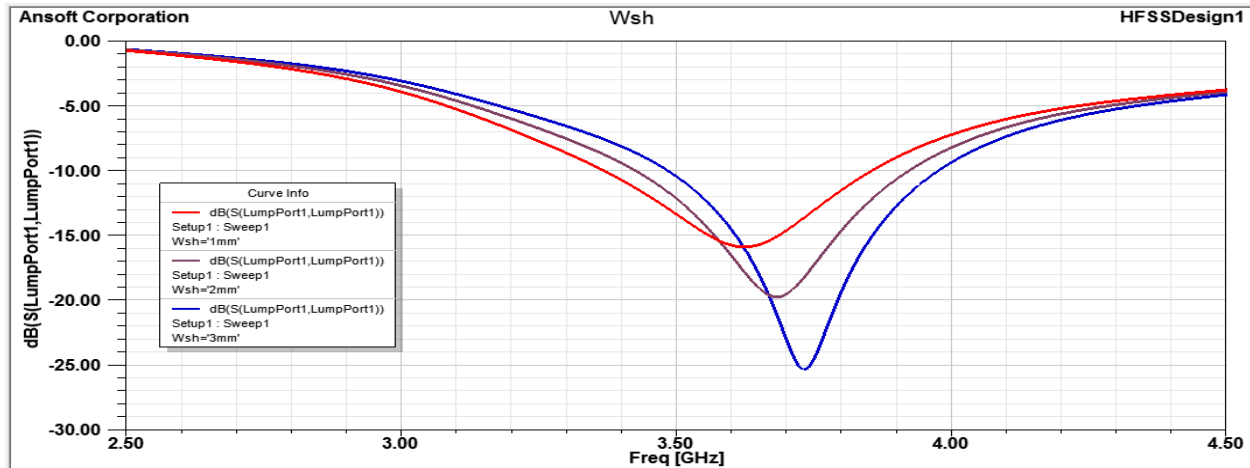

Figure 9: Effect of Varying 'Wsh' On the Antenna Characteristics.

3.4.4 Effect of Varying 'Lpr'

The effect of variation in position of the coaxial probe 'Lpr' is shown in Fig. 10. It can be seen from the figure that with an increase in Lpr, the resonant frequency is shifting towards the higher frequency side of the frequency spectrum. The variation in return loss value is not much with an increase in Lpr. Thus this parameter is providing an ease to shift the operating band as per the requirement. The optimized value of Lpr is 7 mm.
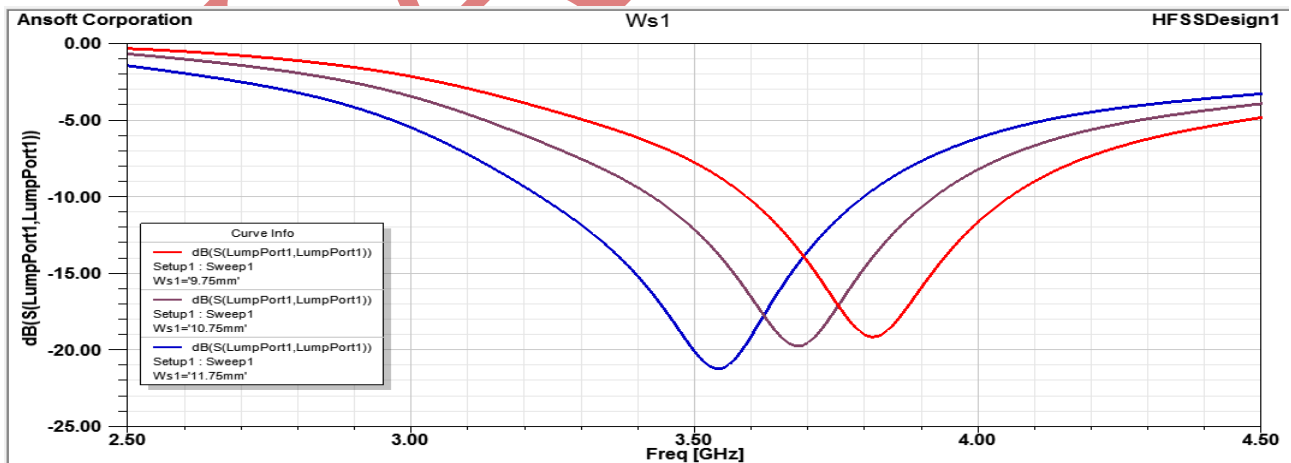

Figure 10: Effect of Varying 'Lpr' On the Antenna Characteristics.

3.4.5 Effect of Varying 'L1'

The effect of variation in position of the slot loading of the patch 'L1' is shown in Fig. 11. It can be seen from the figure that with an increase in L1, the resonant frequency is shifting towards the lower frequency side of the frequency spectrum. The variation in return loss value is not much with an increase in L1. Thus this parameter is providing an additional degree of freedom to shift the operating band as per the requirement. The optimized value of L1 is 14 mm.
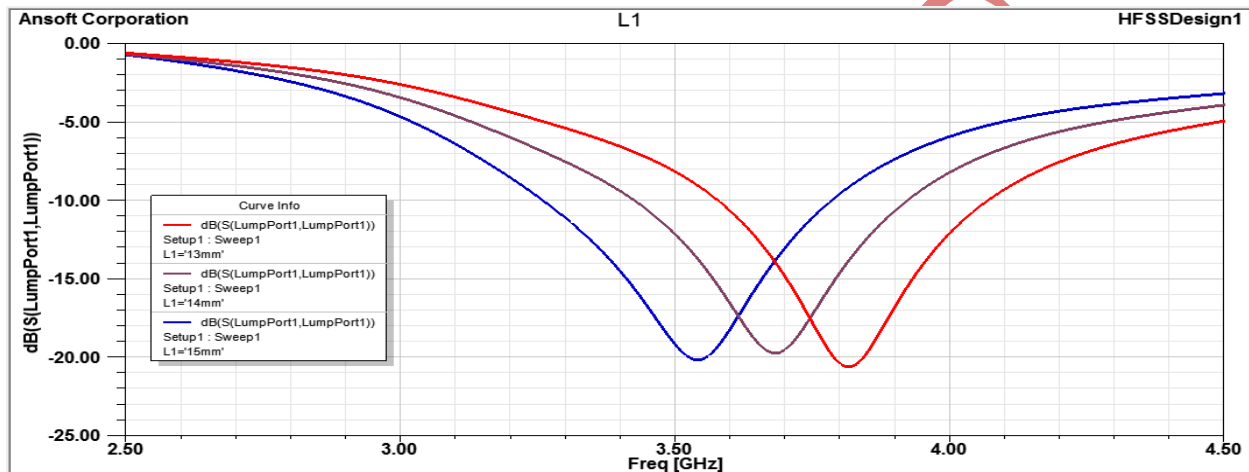

Figure 11: Effect of Varying 'L1' On the Antenna Characteristics

3.4.6 Effect of Varying 'Ws1'

The effect of variation in length of the slot 1 is shown in Fig. 12. It can be seen from the figure that with an increase in Ws1, the resonant frequency is shifting towards the lower frequency side of the frequency spectrum. The variation in return loss value is not much with an increase in Ws1. The optimized value of Ws1 is 10.75 mm.
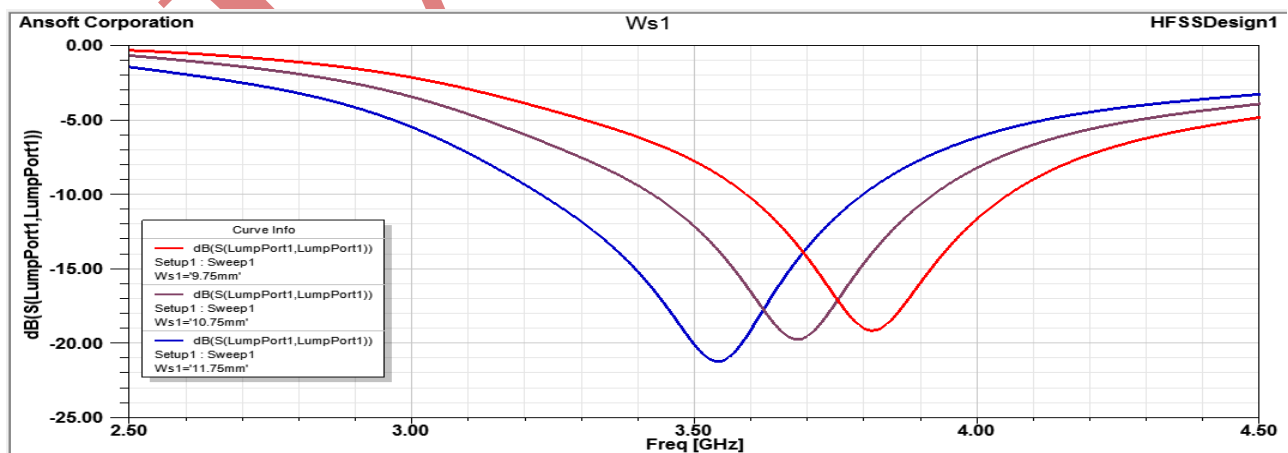

Figure 12: Effect of Varying 'Ws1' On the Antenna Characteristics.

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3.5 Radiation Pattern

The radiation pattern of the proposed antenna are plotted in XZ-plane (phi = 0^0) and in YZ-plane (phi = 90^0) at 3.55 GHz and 3.68 GHz, and are shown in Fig. 13 and Fig 14. Respectively. At 3.55 GHz, main beam is located at theta = 15^0 and there is a back lobe. In YZ-plane, beam width is wide and there is null at theta = -150^0. Almost similar radiation pattern is obtained at 3.68 GHz.
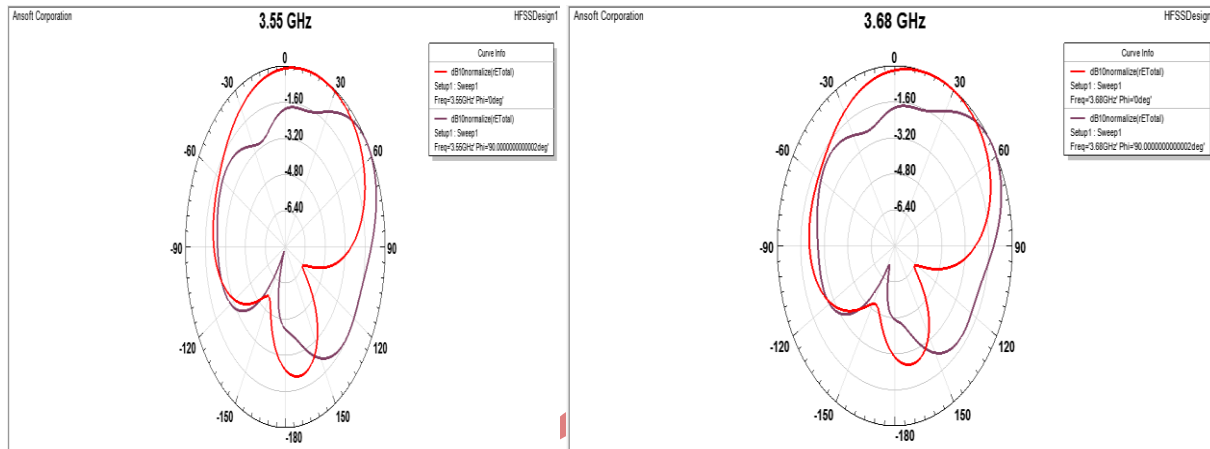

Figure 13: Radiation Pattern of the Proposed Antenna at 3.55 Ghz.   Figure 14: Radiation Pattern of the Proposed Antenna At 3.68 Ghz.

3.6 Peak Realized Gain

The Peak Realized Gain of the proposed antenna is plotted against frequency and is shown in Fig. 4.16. The value of Peak Realized Gain varies from 4.15 dB to 5.2 dB in the desired operating band.
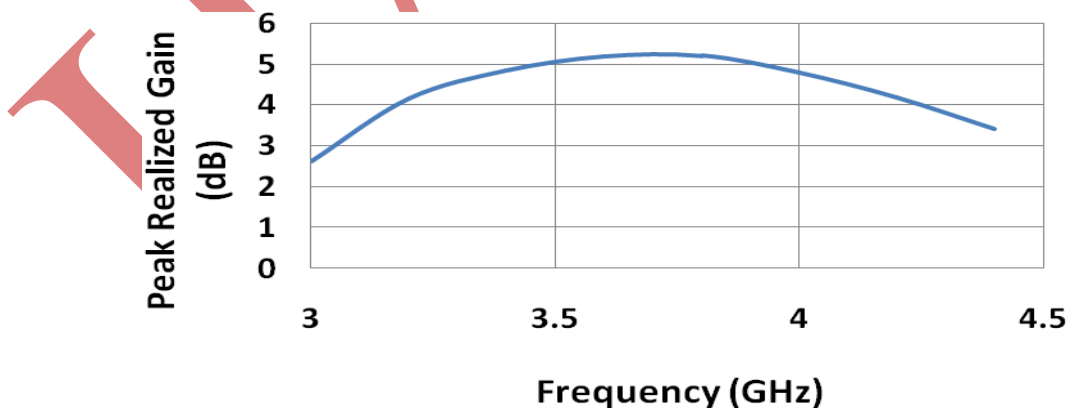

Figure 15: Plot of Peak Realized Gain.

3.7 Current Density Plot

The plot of current density over the antenna patch and ground at 3.55 GHz and 3.68 GHz are shown in Fig. 16 and 17 respectively. It can be seen that maximum current is concentrated near the slot structure present in the patch.
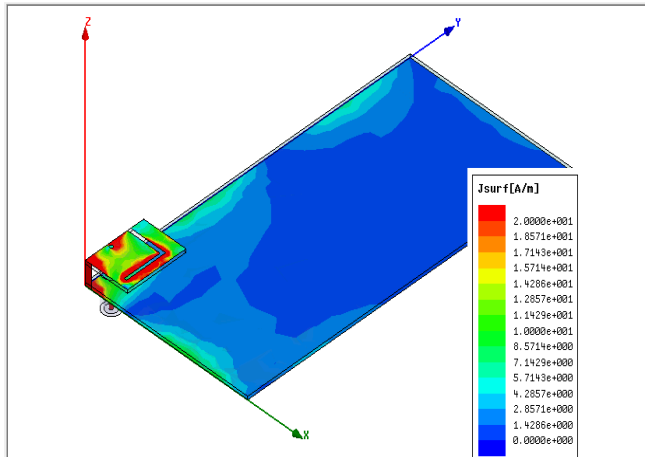

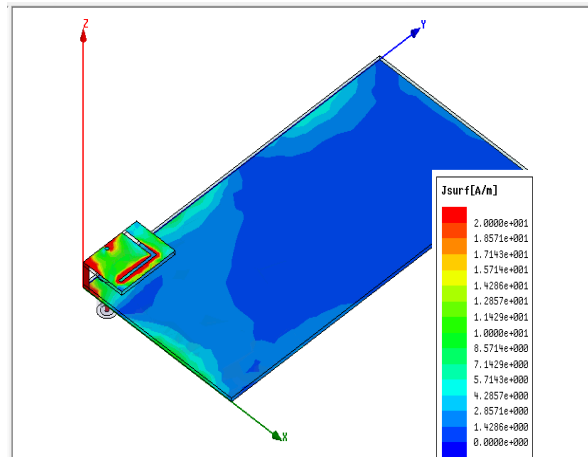**Figure 16: Current Density Plot at 3.55 Ghz.**   **Figure 17: Current Density Plot at 3.68 Ghz.**

IV CONCLUSION

A Planar Inverted-F Antenna for WiMAX applications (3.3-3.8 GHz) has been presented. The proposed structure has a dimension of 18 x 13 mm^2 over the ground plane of size 100 x 50 mm^2 which can easily be implanted in the small space available within the mobile device. The proposed structure is having a impedance bandwidth ranging from 3.198 GHz to 4.158 GHz covering WiMAX band. Antenna has a resonating frequency at 3.68 GHz frequency. For getting the impedance bandwidth we are taking -6 dB as the reference return loss, which is acceptable for mobile phone applications. The VSWR, input impedance plot along with parametric study of some key parameters is presented. The radiation pattern and current density plots of the antenna are also presented. The peak realized gain varies from 4.15 dB to 5.2 dB in the desired operating band.

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