A CPW-fed Broadband Swastik Shape PIFA for WiMAX (3.5 GHz) Application

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Abstract

A cpw-fed Swastik shape Broadband planar inverted f antenna (PIFA) for WiMAX application has been proposed. Broadband operation (3.27 GHz to 4.02 GHz) is achieved by proper broadband matching at both the resonances (resonance due to even mode and resonance due to odd mode) due to modified cpw feed. Proposed antenna was simulated using HFSS based on finite element method with genetic algorithm optimization technique. Finally, the proposed antenna was fabricated and some performance parameters were measured to validate against simulation results. The design procedures and employed tuning techniques to achieve the desired performance are presented.

Keywords: Antenna design, PIFA, Modeling and Measurements.

1. INTRODUCTION

The growing demand for mobile Internet and wireless multimedia applications has motivated the development of broadband wireless access technologies in recent years. In recent year wireless standard, worldwide interoperability for microwave access (WiMAX) has been created, defined by the IEEE 802.16 family of standards, with the aim of improving the data rate and/or communication distance, to cater to the increasing consumer demand. WiMAX technology operates at 2.5, 3.5, and 5.5 GHz bands (specifically 2.5-2.69, 3.3-3.7, and 5.25-5.85) with a range that correlates it with the concept of a wireless metropolitan area network [1].

As the demand of portable systems has increased, low profile broadband systems have drawn much interest of researchers. In making such low profile communication system, the antenna size is critical, hence the planar inverted f antenna (PIFA) is a good solution as compare to patch antennas. However to meet the needs of wireless communications, the bandwidth of the traditional PIFA is too narrow to cover multi-frequency bands. In order to get a broadband response, several kinds of broad banding techniques such as patch tapering [2], T shaped ground plane [3], capacitive coupling , and dual resonant patches [4], have been introduced. In addition of all these techniques coaxial antennas [5], cpw-fed Koch fractal slot antennas [6], printed E monopoles and slant slit on patch [8] were shown to provide sufficient impedance bandwidth to cover the required operating frequency for WiMAX and other wireless applications.

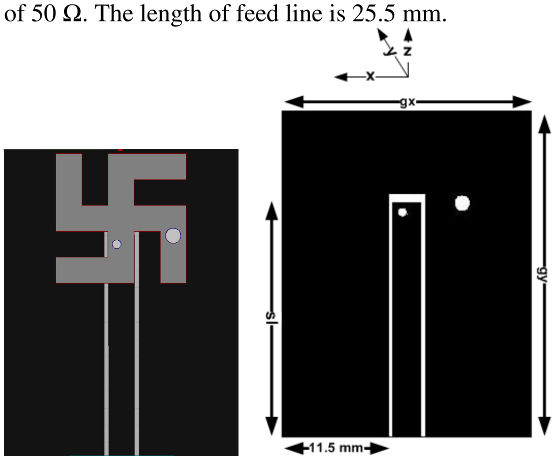
In the present work, a cpw fed swastik shape patch is achieved by inserting pairs of parallel slots on the edges of the PIFA radiating surface to achieve broadband behavior for WiMAX applications. It is found that one resonance is coming due to even mode excitation and another is due to odd mode excitation. Lower resonance is coming due to odd mode while upper resonance is due to even mode. Modified cpw feed gives proper broadband matching at both resonant modes. Antennas fed by a cpw feed have the advantages of being compatible with other microwave integrated circuits (ICs) and also easier to provide short circuit vias between the patch and the ground.

2. ANTENNA GEOMETRY AND SIMULATION

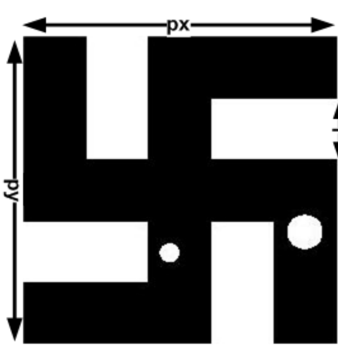
The antenna configuration of proposed cpw fed structure is shown in Fig. 1. The substrate used has relative permittivity $\varepsilon_{r\,=\,4.4}$ and thickness 1.524 mm. The size of substrate used is 27 mm × 35.5 mm. The resonant frequency of a simple rectangular patch is calculated using the formula as shown below:

$$\mathbf{f_r = \frac{c}{4(L+W)}}\;; \qquad (1)$$

Where, c is the free space velocity of light (3×10^8 m/Sec); f_r is frequency of operation; L is the length of radiating element; and W is the width of the radiating element. The optimized design parameters for the proposed antenna are gx = 27 mm, gy = 35.5 mm, patch length px = 15 mm, patch width py = 15 mm, l = 3 mm, diameter of feed pin is 1.0 mm, diameter of short pin is 1.75 mm, the distance between swastik arm edge to center of feed pin is fx = 0.5 mm , the distance between arm edge and center of short pin is scx = 1.5 mm, height between ground and patch is h = 6 mm. The width of feed line and cpw gap are set to achieve line impedance of 50 Ω. The length of feed line is 25.5 mm.



(a) (b)



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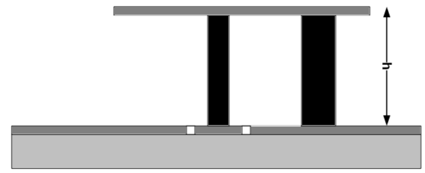
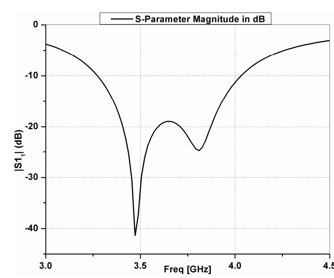


(d)

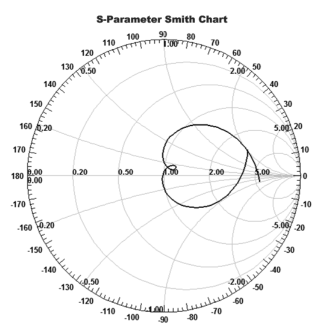
Fig. 1. (a) Proposed antenna configuration (b) top view of ground plane (c) top view of patch (d) side view of antenna

2.1. *Return loss and Smith chart*

The proposed antenna was designed and simulated in finite element method based HFSS V.13. To simulate the antenna driven modal solver was chosen with tetrahedral mesh cell. Port impedance was adjusted to obtain 50 Ω. The simulated return loss and smith chart plot are shown in Fig. 2. The antenna covers WiMAX standard IEEE 802.16 with adequate broad bandwidth of 750 MHz. Single loop in the smith chart corresponds coupled resonances. After fabrication, the return loss of the antenna was tested on the HP Network analyzer.



(a)



(b)

Fig. 2. The simulated (a) |S11| dB and (d) Smith chart

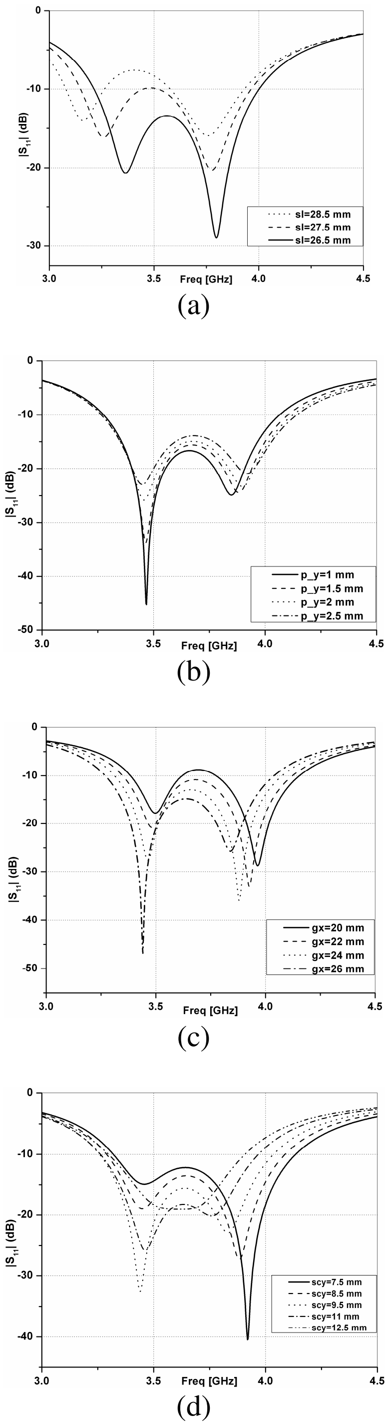


Fig. 3. (a) Variation of feed line length (sl) (b) Variation of patch position along y axis (p_y) (c) Variation of ground length (gx) (d) Variation of shorting pin position

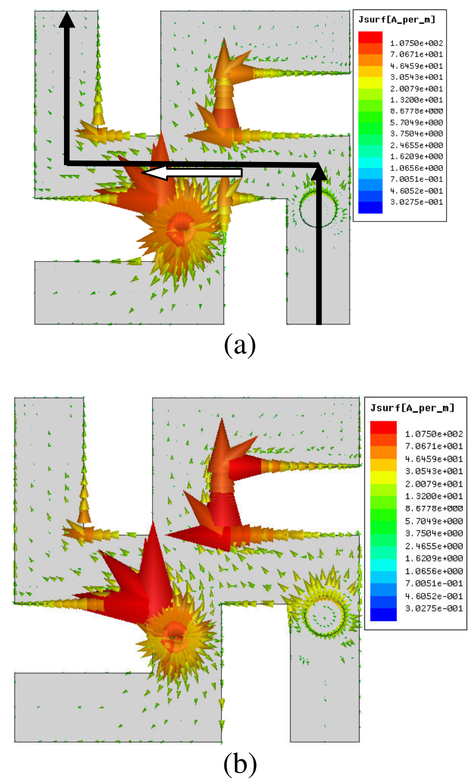


Fig. 4. Surface current densities at (a) 3.47 GHz and (b) 3.8 GHz bands

2.2. *Variation of return loss with parametric analysis of design parameter*

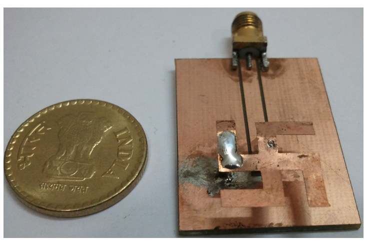
A detailed parametric analysis of the proposed antenna structure was done. From Fig. 3(a) it can be observed that changing the feed line length (sl) has a prominent effect on the lower resonant mode. Changing the feed line length (sl) has no effect on the resonance frequency in upper resonant mode except the change in magnitude of return loss. From Fig. 3(b) One can see the variation in patch position (p_y) from ground edge (along the y axis) on the upper resonant mode. As p_y increases shifting of upper resonant mode towards higher frequency achieved. Figure 3(c) shows the ground plane effects of antenna structures, as ground plane length (gx) decreased, broadband behavior of antenna going towards dual band response and also both resonance shifted towards higher frequency. Fig. 3 (d) shows that, due to variation in shorting pin position, prominent change in even resonant modes occurs, in the sense of resonant frequency as well as magnitude of return loss.

2.3. *Current distribution*

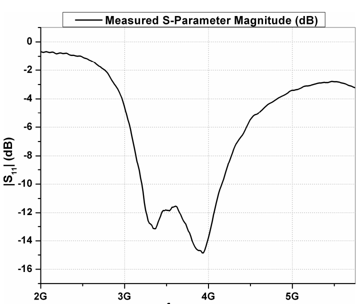
The current distributions for the swastik patch at 3.47 GHz and 3.8 GHz are shown in Figs 4(a) and 4(b). From the Fig. it can be concluded that at both lower as well as higher frequency of resonance only one path branch is going to resonate. And due to higher current path the miniaturization on patch size is also achieved.

3. FABRICATION AND MEASUREMENT

The simulated antenna was fabricated using photolithography process; thereafter its return loss was measured with HP network analyzer (HP 8720B). Fabricated antenna's result was found to be good agreement with the simulated result. The measured bandwidth is 755 MHz. Shifting of return loss level upward was observed, which may be due to fabrication errors.



(a)

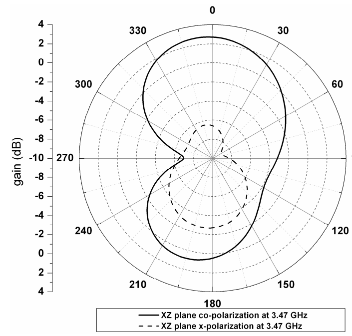


(b)

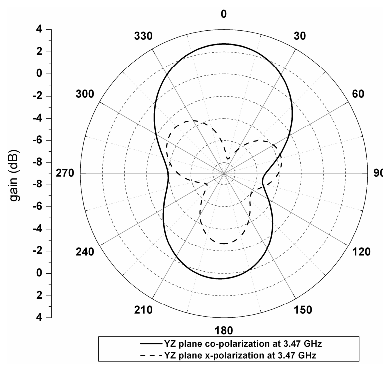
Fig. 5. (a) The fabricated antenna (b) Measured return loss

4. SIMULATED RADIATION PATTERNS AND GAIN PLOTS

Figure 6 shows the simulated Co and Cross polarization radiation patterns of the antenna in both XZ and YZ plane at the frequencies 3.47 GHz and 3.8 GHz. At both 3.47 GHz and 3.8 GHz bands the maximum power was achieved by the antenna in the broadside direction. Consequently, gain plots are taken for the two-frequency bands in the directions of their respective maxima. From Fig. 6(d) it can be concluded that high cross polarization level in YZ plane at 3.8 GHz band occurred.



(a)



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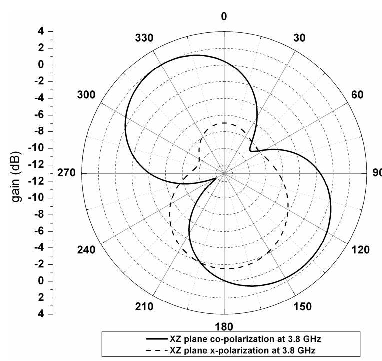

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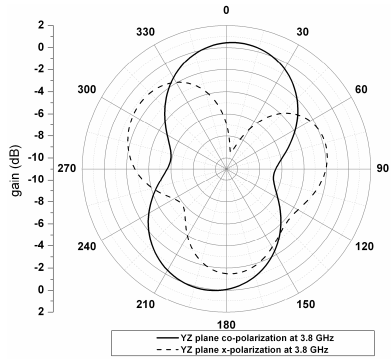

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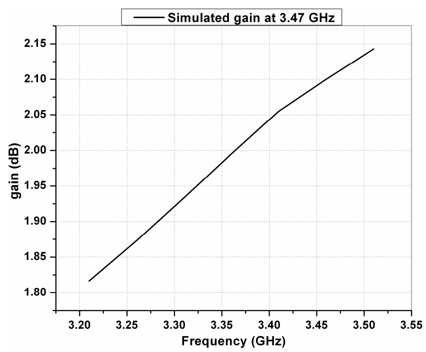

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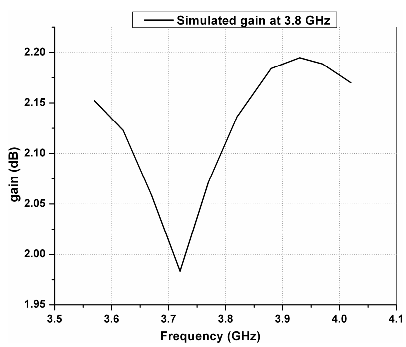

(f)

Fig. 6. (a) XZ-plane pattern at 3.47 GHz (b) YZ-plane pattern at 3.47 GHz (c) XZ-plane pattern at 3.8 GHz (d) YZ-plane pattern at 3.8 GHz (e) Gain plot at 3.47 GHz (f) Gain plot at 3.8 GHz

5. CONCLUSION

A cpw fed swastik shape geometry applied to planar inverted F antenna by introducing paires of parallel slots in the rectangular patch. Due to modified cpw feed broadband mactching have been successfully done to achieve wide bandwidth of 755 MHz. Lower resonance of antenna is coming due to odd mode and higher resonance is due to even mode. The radiation pattern in YZ plane at 3.8 GHz showing high level of cross polarization. Due to Swastik shape patch we get miniaturization is about 33 % as compare to rectangular patch. The antenna is a low profile antenna so that we can utilize it in portable wireless applications.

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