Triple Band Slotted Patch Antenna with a Notch for Wi-MAX Communications

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Abstract: ***A conventional probe fed square patch antenna with a triangular notch & a rectangular slot with perturbation is designed and simulated for triple band operation for applications in communication systems like Wi-MAX systems is presented. The antenna is designed on the glass epoxy FR4 substrate. With the fixed feed point location, the notch angle is varied from 180^0 to 140^0 resulting in single and dual resonance behavior of patch antenna. With the notch angle from 180^0 to 165^0, antenna resonates at a single frequency but on further reduction of notch angle from 165^0 to 140^0, dual resonance behavior is noticed with improved bandwidth. The optimum performance is obtained for a notch angle of 150^0. The maximum radiation efficiency of ~ 40% is obtained. Further, a rectangular slot with perturbation at shorter edges give rise to additional resonant frequency. The other performance parameters of antenna are analyzed by varying notch angle and its position.***

Keywords: Triple band, probe feed, radiation efficiency, Wi-MAX.

I. INTRODUCTION

Microstrip antennas have found immense applications in the field of communication due to its versatile behavior. It can be designed as single band, dual band, wide band planar antenna. Some of its inherent properties like small size, less weight, low cost, easy fabrication and integration with other printed circuit microwave components have made them more popular. Apart from regular shapes of antenna such as rectangular, square, triangular, circular, they can be designed with fractal geometries which makes them for the growth of printed circuit antenna technology. A conventional patch antenna has single resonant frequency with narrow bandwidth & low gain. Therefore, modifications in antenna geometries have reported better performance and wide applications [1]. A normal patch antenna with different notches applied has resulted multi resonance behavior and bandwidth improvement [4-6]. A square patch antenna with probe feed, notch and shorting post has reported higher bandwidth of 13% [6]. Modern communication systems demand antenna with versatile characteristics like multi band, dual feed [7] etc.

The previous work reported are microstrip patch antenna with E-slot and a-slit [10], vertex fed pentagonal slot [11], a square slot and a partial ground plane [12], triple rectangular slot and dual circular slots [13], tapered shaped multi slotted notch cut [14], rectangular & triangular slots and SRR [15], Koch asymmetrical fractal boundary antenna with rotated fractal slot [16] for multi band operation for Wi-MAX communications.

IEEE 802.16 has created Wi-MAX standard with three frequency bands. In this paper, the median band of 3.25-3.85 GHz is considered for antenna design. A triangular notch is applied to a conventional square patch antenna at appropriate position and the depth of notch tip is varied to obtain best performance. Further, a rectangular slot with perturbation at shorter edges is loaded to the patch. The different antenna geometries starting from conventional square patch antenna to the proposed antenna structure are discussed in Section II, the simulated performance parameters of antenna like return loss, VSWR, gain, bandwidth, radiation efficiency and radiation pattern are discussed in section III, conclusions are discussed in section IV.

II. ANTENNA GEOMETRIES

Initially conventional probe fed square patch antenna (SPA) is constructed on a glass epoxy FR4 substrate with dielectric constant ε_r = 4.37, loss tangent tanδ = 0.025 and substrate thickness h = 1.58 mm. A square patch antenna of dimensions 20 x 20 x 1.58 mm^3 with probe feed arrangement is shown in Fig.1.The coordinates of feed location are (x_o, y_o) = (13 mm, 13 mm).

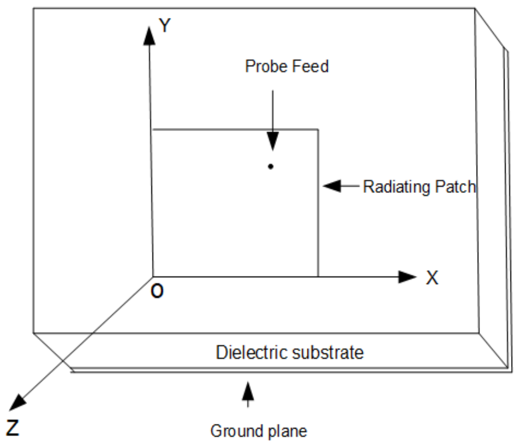

Fig.1: Conventional probe fed square patch antenna (SPA)

In the next step, for the existing patch antenna a triangular notch having notch angle θ is designed as shown in Fig.2. The coordinates of notch tip are O'(a, b)= (10 mm, 14.725 mm).

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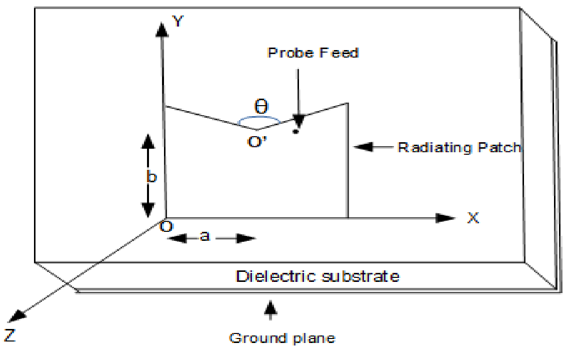


Fig.2: Square patch antenna with a triangular notch (SPAN)

In the next step, for the existing square patch antenna with a notch, a rectangular slot of dimensions 6 mm x 2.6 mm with perturbation at shorter edges is introduced at the center of the patch, which is the proposed structure as shown in Fig.3.

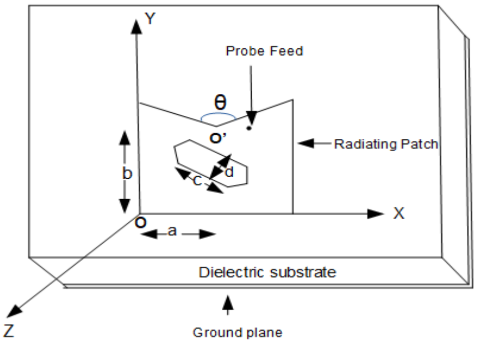


Fig.3: Square patch antenna with a triangular notch & a slot (SPANS)

III. SIMULATION RESULTS

The conventional probe fed square patch antenna (SPA) resonates at a single frequency 3.44 GHz and shows a narrow bandwidth corresponding to – 10 dB is 2% with radiation efficiency of 38%. The plot of S11 v/s frequency is shown in Fig.4. The return loss of -46.8 dB is obtained at resonant frequency of 3.44 GHz.

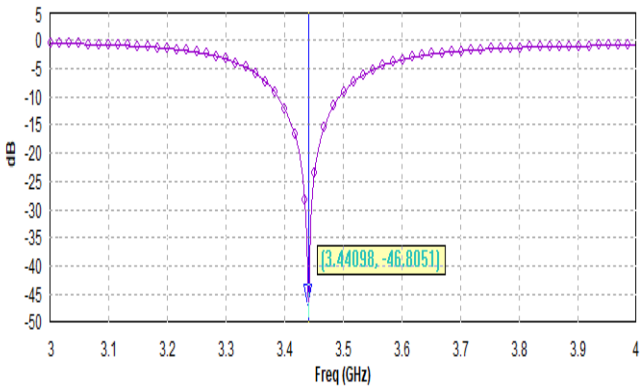


Fig.4: Return loss v/s frequency variation for a square patch antenna.

For the antenna design shown in Fig.1, notch angle θ is applied. By decreasing notch angle from 180^0 to 165^0 , the antenna resonates at a single frequency till the notch angle is varied. With further reduction of notch angle, antenna resonates at two frequencies one above the resonant frequency of conventional patch without notch and other below the resonant frequency of conventional patch without notch. The variation of resonant frequency with notch angle is shown in Fig.5.

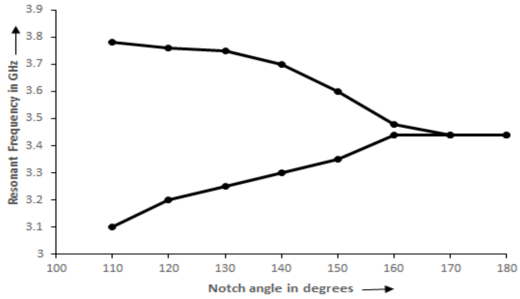


Fig.5: Variation of resonant frequency with notch angle.

The optimum results are obtained for coordinates of notch tip O'(a, b) = (10 mm, 14.725 mm) for a notch angle θ = 150^0. Fig.6 shows the two resonant frequencies f_1 = 3.25 GHz and f_2 = 3.77 GHz with return loss of – 17.48 dB and – 21.83 dB respectively.

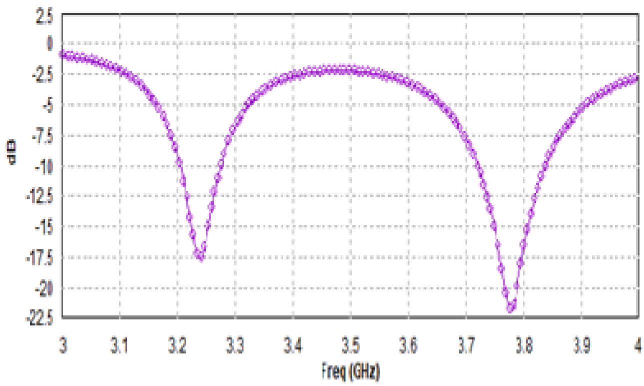


Fig.6: Variation of S_{11} with frequency.

Fig.7 shows the variation of VSWR with frequency. The square patch antenna with a triangular notch (SPAN) excites two modes with one being the dominant TM_{11} mode. Therefore, two resonant frequencies exist within the median band.

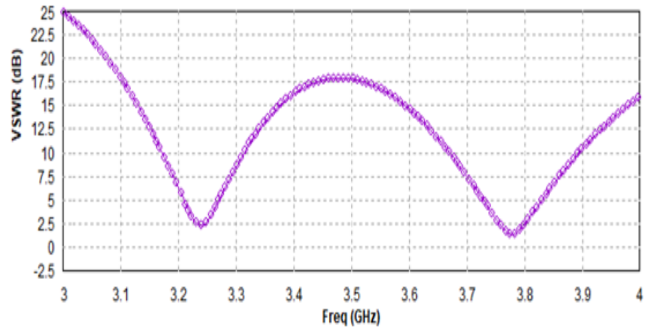


Fig.7: Plot of VSWR v/s frequency.

Fig.8 shows the variation of input impedance with frequency. The simulated input impedance at resonant frequency f_1 = 3.25 GHz is Z_{in1} = 49.2 + j25.2 Ω and at f_2 = 3.77 GHz is Z_{in2} = 49.11 + j16.8 Ω.

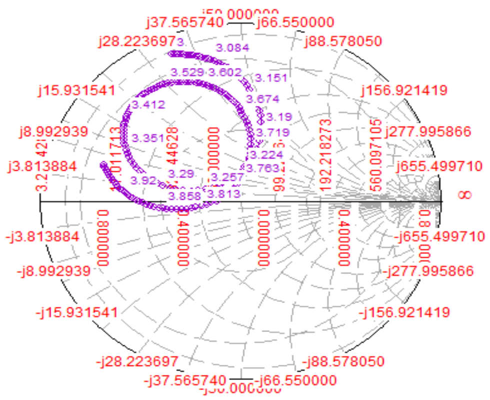
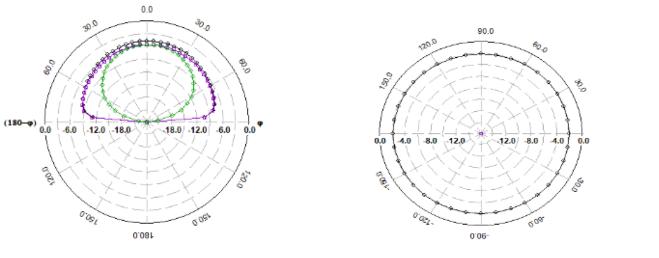


Fig.8: Variation of input impedance with frequency.

The simulated radiation pattern of the square patch antenna with a notch has a beamwidth of 104^0. The radiation pattern of the antenna is not much affected by the presence of notch. The antenna has maximum radiation in broadside direction with a simulated gain of 6.5 dBi. The simulated E-plane & H-plane radiation patterns are shown in Fig.9.



a b

Fig.9: Simulated a) E-plane & b) H-plane radiation pattern.

Fig.10 shows the variation of bandwidth of the antenna as a function of the notch angle. Without notch (θ $=180^0$) applied, the antenna has a very low bandwidth. With the decrease in notch angle, the bandwidth increases. The maximum bandwidth of 10.5% is achieved for a notch angle of 150^0. As the depth of the notch increases, the path for current flow increases. Therefore, the performance of the antenna improves with more current flow. Further reduction of notch angle θ, the bandwidth of the antenna decreases.

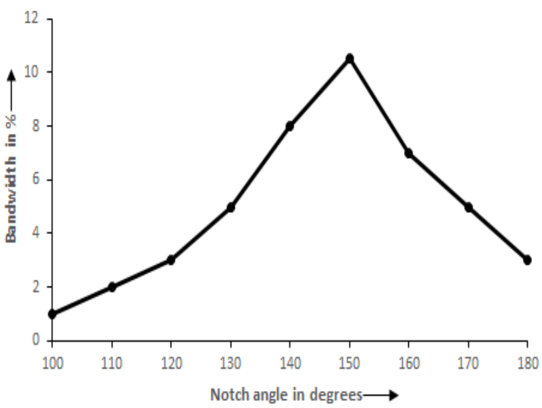


Fig.10: Plot of bandwidth of the antenna v/s notch angle.

The variation of bandwidth of square patch antenna as a function of shifting notch location O'(a, b) along the x-axis is shown in Fig.11. The bandwidth of the antenna is maximum when (a, b) = (10 mm, 14.725 mm).

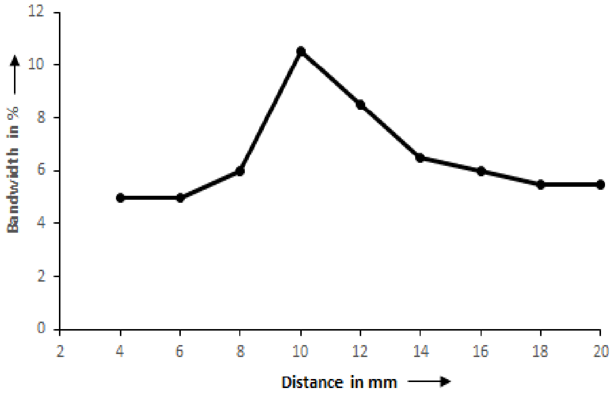


Fig.11: Plot of bandwidth of the antenna with the variation of notch tip O' along x-axis.

The maximum radiation efficiency of the antenna is 38% for notch position of (a, b) = (10 mm, 14.725 mm).

The square patch antenna with a triangular notch and a rectangular slot (SPANS) with perturbation at shorter edges presents additional frequency f_3 at 3.66 GHz with return loss of -41.6 dB. The other two frequencies f_1 and f_2 are unaffected. The variation of S_{11} with frequency for SPANS is shown in Fig.12.The VSWR at f_3 is 0.145 and input impedance of $Z_{in3} = 49.52 + j1.46\ \Omega$.

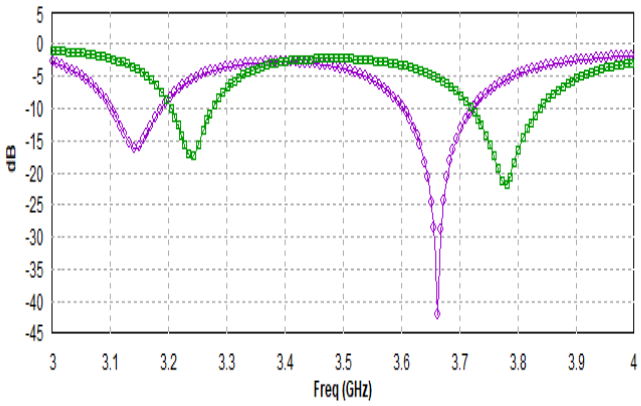


Fig.12: Variation of S_{11} with frequency for SPANS.

The radiation pattern is unaffected. The radiation efficiency decreases to ~ 30% and ~ 35.5% at resonant frequencies f_1 and f_2 respectively and ~ 40% at f_3.

IV. CONCLUSIONS

The triple resonance behavior of conventional square patch antenna is obtained with the application of a triangular notch and a rectangular slot with perturbation at shorter edges. With the decrease of notch angle below 165^0, another mode is excited apart from the dominant TM_{11} mode. Further, with a rectangular slot, additional frequency is observed. All the frequencies lie in the median band 3.25 – 3.85 GHz allotted for Wi-MAX communications. The optimized bandwidth of 10.5% is obtained for the notch angle of 150^0. The average radiation efficiency of ~ 35% is obtained with broadside radiation pattern.

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