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Design of Square Patch Antenna with a Notch on FR4 Substrate

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Abstract: **The simulation and experimental results of square patch antennas having a notch and designed on FR4 substrate are reported in this paper. The notch angle is varied and different radiation properties of antennas are tested. It is found that on reducing the notch angle θ from 180° to 164°, the patch resonates at a single frequency. However on reducing notch angle further, the patch starts resonating at two different frequencies. The f_2/f_1 ratio almost linearly increases on decreasing the notch angle. The 10dB impedance bandwidth (VSWR 2:1) of antenna increases up to notch angle 151° but thereafter that antenna behaves simply as a dual frequency antenna with narrow bandwidth at each resonance frequency.**

I. Introduction

Microstrip antennas have a number of attractive features because of their small size, lightweight, low profile and conformability over host structure. Although the conducting patch of the microstrip antenna can have any arbitrary shape but in practice, rectangular, circular, triangular and square-ring shapes are commonly employed for their investigations. A simple patch antenna of regular shape resonates only at a single resonance frequency and its bandwidth is also very poor (1 to 2%) [1-3]. The recent advancements in wireless communication systems particularly in cellular phones and wireless data communication, have increased the demand for wide band, multi frequency and multi band patch antennas. Microstrip antennas for dual frequency applications may be realized by exciting patch geometry by using a single [4] or dual feed [5]. In this paper we propose a single feed square patch antenna with a notch for dual frequency wide band applications. The notch is designed on one side of the square patch as shown in figure -1. The notch angle (θ) is varied and different radiation properties are simulated and also obtained experimentally. The simulation analysis of these antennas is carried out by applying an e.m. simulation software before actual designing of the patch geometries.

II. Antenna Geometry and Simulation Results

The antenna geometry used in the present investigations is shown in figure – 1. The antenna is designed on glass epoxy FR4 substrate ($\epsilon r = 4.4$, $\tan\delta = 0.002$, substrate thickness 0.158 cm) with copper as its ground plane.

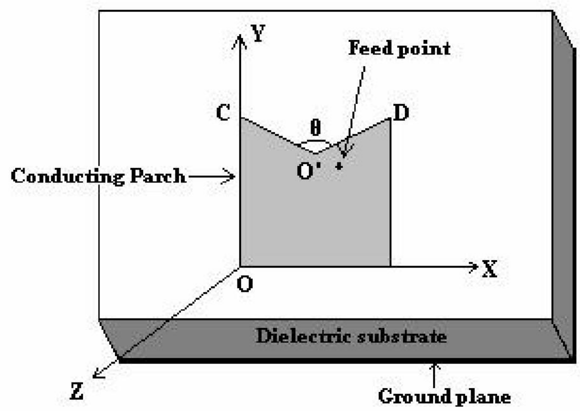

Figure 1. Geometry of a square patch with a notch

The patch size of 3cm x 3cm is considered for the present work lying in xy-plane. The theoretical analysis of square patch antenna without notch is carried out by applying cavity model based modal expansion technique [6] and results are verified by simulation analysis carried out by applying an e.m. simulation software. These analyses reveal that the square patch antenna without notch resonates at a single frequency 3.46 GHz. Since it was designed on a high permittivity substrate having high loss tangent, antenna radiation efficiency was found low (38%) through simulation analysis. The feed location (x_0, y_0) to match input impedance of antenna with connecting cable is shown in the table-1. After its testing, a notch is designed on one side of square patch with notch angle CO'D = θ. Based on the simulation analysis, patch geometries with different notch angles varying from θ = 180° to 132° are designed and tested experimentally.

The simulation results indicate that the square patch with a notch resonates at a single resonance frequency till notch angle varied from as notch angle θ = 180° to 164°. However this resonance frequency increases marginally with decrease in notch angle. On decreasing notch angle further, antenna start resonating at two different frequencies (f_1 and f_2). One of these frequencies (f_1) is lower than the resonance frequency of square patch without notch while other one (f_2) is higher than the resonance frequency of square patch. The ratio of these frequencies (f_2 / f_1) increases significantly as notch angle decreases.

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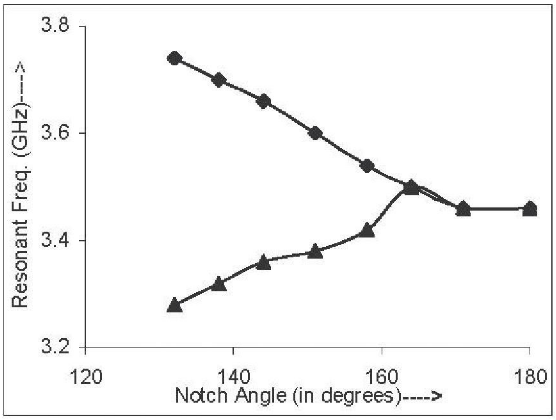

Figure 2. Variation of resonance frequency with notch angle

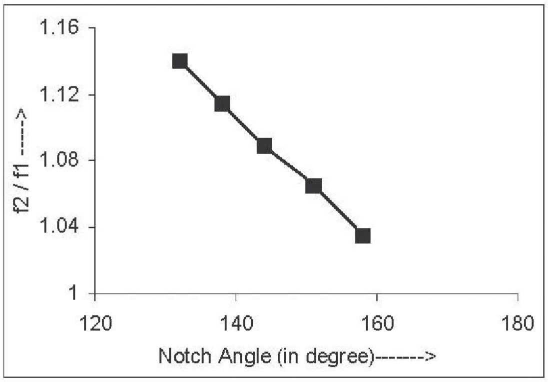

Figure 3. Variation of f_2 / f_1 ratio with notch angle

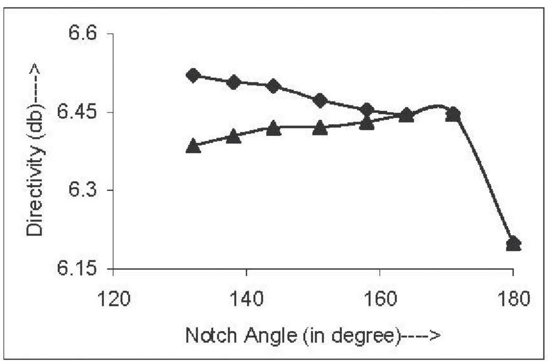

Figure 4. Variation of Directivity of antenna with notch angle

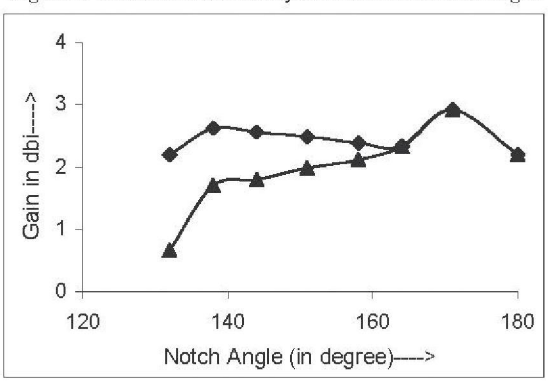

Figure 5. Variation of antenna gain with notch angle

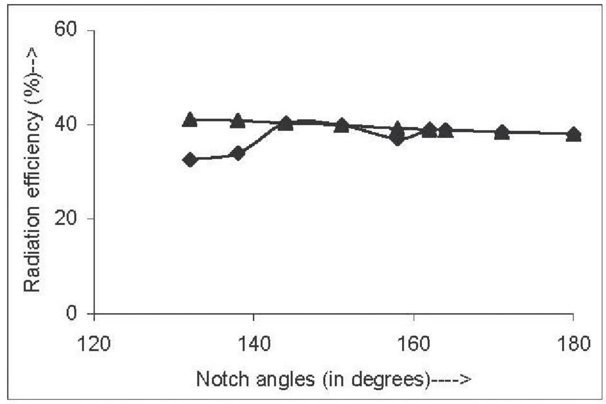

Figure 6. Variation of resonance frequency with notch angle

These results are shown in figure 2 and 3 respectively for different notch angles. The simulation results for directivity and gain of these antennas with notch angle are presented graphically in figure 4 and 5. These variations indicate that directivity of antenna corresponding to f_1 frequency decreases with decrease in notch angle while corresponding to f_2 frequency, it increases with decrease in notch angle. The simulation results indicate that the gain of antenna is quite low. Maximum gain around 2.62dbi is obtained when notch angle θ is 138°, which is obvious as the substrate parameters are sufficiently high. On insertion of a notch, the radiation efficiency of antenna improves marginally at the cost of antenna efficiency. The variation in radiation efficiency of antenna for different notch angle values are shown in figure 6. The radiation efficiency of antenna improves marginally (38.1% at θ = 180° to 40.42% at θ = 144°) on insertion of a notch in a square patch. However antenna efficiency for a square patch without a notch is (38%) which reduces further to 34.44% for an antenna having notch angle θ = 144°.

III. Measured Results

The experimental results of square patch antenna with notch having following design specifications are presented here:

- (i) Substrate material: Glass epoxy FR4 substrate.
- (ii) Dielectric constant: ϵr: 4.4,
- (iii) Substrate loss tangent tanδ: 0.002,
- (iv) Substrate thickness: 0.158 cm,
- (v) Patch dimensions: 2cm x 2 cm,
- (vi) Notch angle θ: 158°,
- (vii) Feed location (xo, yo): 1.36mm, 1.39mm

The experimental results for a square patch antenna with notch angle θ = 158° are presented in this paper. These measured results are also compared with simulation results and are shown in figures 7-9. As shown in figure 7, the measured resonance frequencies of this geometry are 3.385 GHz and 3.53 GHz respectively while corresponding simulated frequencies are 3.42 GHz and 3.54 GHz respectively. A difference of 0.035 GHz for measured and simulated f_1 frequencies (1.04%) and a difference of 0.01 GHz for measured and simulated f_2 frequencies (0.28%) are recorded. The 10dB impedance bandwidth (VSWR 2:1) of this geometry (θ = 158°) is around

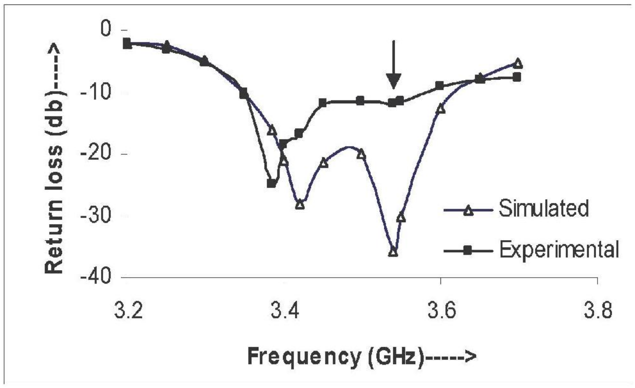

Figure 7. Comparison between simulated return loss of antenna

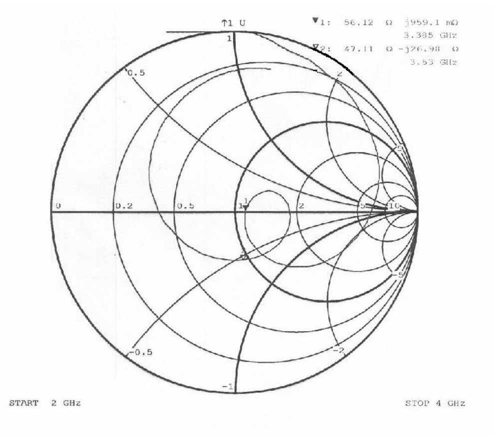

Figure 8. Measured input impedance of antenna

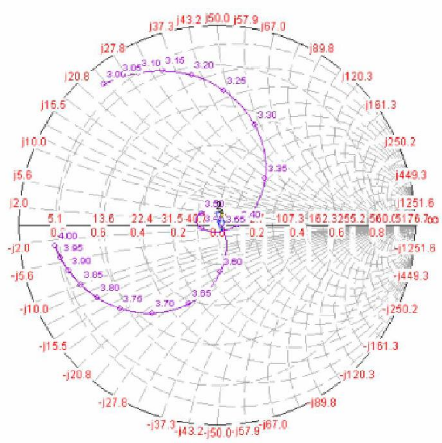

Figure 9. Simulated input impedance of antenna

7.01%, which is much higher than that recorded for a square patch antenna without notch (1.09%) designed on same FR4 substrate.

A large difference in measured and simulated return loss values at f_2 = 3.53GHz frequency can be seen though a fairly good agreement at f_1 = 3.385GHz frequency was obtained. The measured input impedance of proposed antenna with frequency is shown in figure 8. Figure 9 shows its simulation results. If we compare these two results we will find that the measured

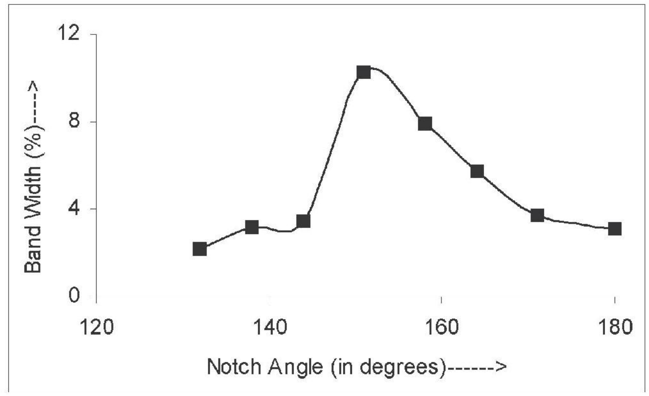

Figure 10. Variation of bandwidth with notch angle

input impedance Z_{in} at frequency 3.385GHz is 56.12 + j 0.959 ohm which is in fairly good agreement with the simulated input impedance Z_{in} = 52.11 - j 3.42 ohm at same frequency. However a large difference in measured input impedance Z = 56.12 + j 0.959 ohm and simulated input impedance Z = 52.11 - j 3.42 ohm at resonance frequency 3.53GHz is recorded. This indicates that further improvement in antenna geometry is necessary at this second resonance frequency. The variation in bandwidth of antenna as a function of notch angle is shown in figure 10. This figure indicates that at notch angle $\theta = 151^o$, maximum bandwidth up to 10.29% may be achieved. On further reducing notch angle θ, the bandwidth of antenna starts decreasing. $\theta = 151^o$ is the optimum value of notch angle obtained for the proposed antenna.

Due to the lengthening of the excited surface current path, the square microstrip antenna with a notch possesses a smaller size as compared to the square microstrip antenna for a given frequency. Therefore, the square patch microstrip antenna with a notch is a considerable candidate for compact wireless communication applications.

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