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Broadband Rectangular Patch Antenna with Orthogonal Crossed Slits

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***Abstract*- A compact rectangular patch antenna with narrow crossed slits is proposed in this communication. The proposed antenna resonates at two closely spaced frequencies (3.55 GHz and 3.76 GHz) with improved operational bandwidth (9.3%). The measured bandwidth value is nearly two times higher than that of a conventional rectangular patch antenna (~3.9%) having identical patch size and operating under similar conditions. The simulated gain and efficiency of proposed antenna are little higher than that of a conventional rectangular patch antenna but these are still lower than desired values. The E-plane co and cross polar radiation patterns are drawn at two resonance frequencies which are almost identical in shape and nature. Obtained radiation parameters suggest that proposed antenna may be proved useful for modern communication systems**

***Index Terms*- Microstrip antenna, broadband, dual frequency operation, gain, radiation patterns**

I. INTRODUCTION

Microstrip antennas have attracted scientific community to find their possible applications in modern communication systems due to their small size, light weight, low cost on mass production, low profile and easy integration with other components [1-2]. However three major limitations of microstrip patch antennas are their inherent narrower bandwidth, low gain in comparison to other microwave antennas and their capability to operate at a single resonance frequency. Due to these limitations, conventional single frequency regular shape microstrip antennas are not found suitable for modern communication systems. With recent advancements in cellular phones, mobile and wireless communication systems particularly for data communication, need for compact broad band, dual / multi frequency patch antennas was realized. These antennas after several alterations in their geometry [3-8] are found extremely useful in wireless, satellite and mobile communication systems. Some of recent advancements related with broadband microstrip patch antennas may be found in available literature [9-12]. Use of slots in antenna design provides a simple and efficient method for obtaining the desired compactness multi-band and wide band properties since these shapes radiate electromagnetic energy more efficiently [3, 8]. In the present communication, design of a broadband rectangular microstrip patch antenna modified in two steps is systematically presented.

II. ANTENNA STRUCTURE & SIMULATED RESULTS

(a) Conventional rectangular patch antenna

First the performance of a conventional rectangular patch antenna having length and width *L* (= 3.429 cm), *W* (= 2.07 cm) respectively is reported which is designed on glass epoxy FR-4 substrate having substrate relative permittivity

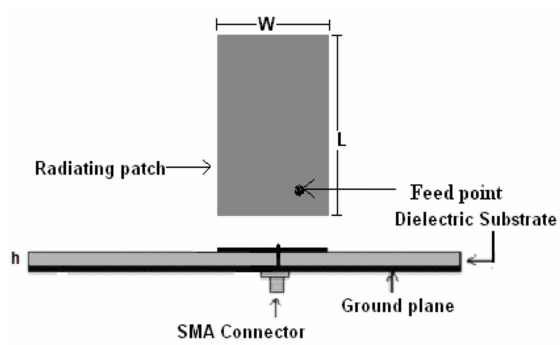

Fig 1: Geometry of regular rectangular patch antenna

ε_r = 4.4, substrate height h = 0.159 cm and loss tangent = 0.025. The simulation analysis is carried out by using IE3D simulation software [13] and measured results are obtained at ISRO, Bangalore by using available vector network analyzer and anechoic chamber. These measured results reveal that in the frequency range 3.4GHz to 4.2 GHz, antenna resonates at a single frequency 4.06GHz as shown in fig. (2). This measured resonance frequency is in good agreement with the calculated resonance frequency 3.98GHz for the TM_{11} mode of excitation [14]. The measured impedance bandwidth of antenna (corresponding to 10dB return loss) with central frequency 4.066GHz is 161MHz or 3.9%.

The input impedance variation of antenna with frequency is shown in figure 3. This antenna under present condition presents circularly polarized radiations which can be realized with the presence of a very small loop in impedance variation with frequency. The size of loop decides the purity of circular polarization. If the two degenerate modes which are necessary for obtaining circular polarization are very close to each other then the loop area becomes almost zero and axial ratio approaches to zero. For the considered geometry, both simulated and measured impedance results presents a small loop and the simulated axial ratio under the present case is close to 0.61dB. The simulated input impedance of antenna at resonance frequency is (52.30- j3.74) ohm which is in fair agreement with the input impedance of feed network (50ohm). The measured input impedance of antenna at resonance frequency is (31.67 – j 2.83) ohm which needs improvement.

Though circular polarization with the proposed geometry is realized but the presence of single resonance frequency with narrow bandwidth and low gain (~1.5dBi) restricts application of this antenna for modern communication systems. Therefore this patch antenna is modified in two steps. In the first step, a single narrow rectangular slit of length '*l*' and width '*w*' is applied which touches the periphery of narrow side of the rectangular patch. Location

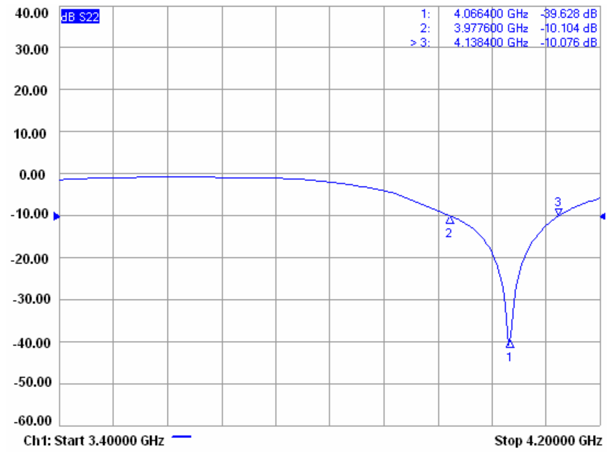

Fig 2. Variation of reflection coefficient (S_{11}) of conventional rectangular patch antenna with frequency

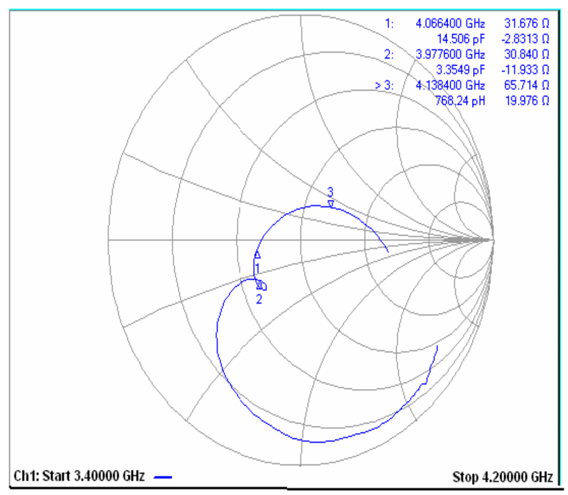

Fig. 3 Variation of input impedance of conventional rectangular patch antenna with frequency

of slit, its length and width are selected after extensive optimizations. In the second step, another narrow slit orthogonal to first slit is applied in such a way that the two slits intersect each other. Location of this additional slit, its length and width are again selected after extensive optimizations. The performances of these two structures are reported in this communication.

(b) Rectangular patch antenna with narrow slit

One of the important requirements from antenna geometry in modern communication systems are that antenna must show broad band

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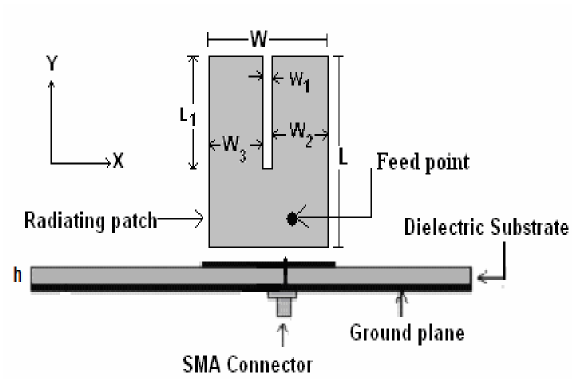

Fig. 4: Geometry of rectangular patch antenna with single slit

dual frequency performance. For achieving this goal, we first introduced a single narrow rectangular slit of length 'L_1' and width 'W_1' touching periphery of narrow wall of the rectangular patch. The geometry of antenna with inset feed arrangement is shown in figure 4. The narrow slit parallel to Y-axis is not located at the center of narrow wall of the patch but located at distances W_2 = 10.45mm from right broad wall and W_3 = 9.75 mm from left broad wall as shown in figure - 4. The optimization of design parameters through simulation suggest that on making length L_1 = 13.8 mm of the slit with width W_1 = 0.5mm, antenna resonates at two frequencies 3.64GHz and 4.08GHz in the frequency range 3.4GHz to 4.2GHz. The presence of narrow slit has excited an additional mode bearing lower resonance frequency than TM_{11} mode which is already present for the considered geometry. The proposed slit is cut precisely along the patch length to make cross-polar field component quite low.

The simulated resonance frequencies are in close agreement with measured resonance frequencies 3.60GHz and 4.09GHz shown in fig. 5(a). The circular polarization realized in the previous section is no more present for this geometry as may be seen from input impedance variation. The measured impedance bandwidths corresponding to 10dB return loss at both resonance frequencies are still low (2.8% and 2.45%) and therefore further improvement in this antenna is applied in the next step.

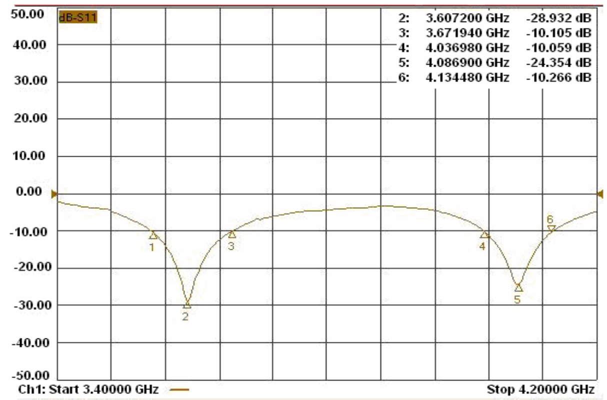

Fig 5(a). Simulated variation of reflection coefficient (S_{11}) of single slit loaded rectangular patch antenna with frequency

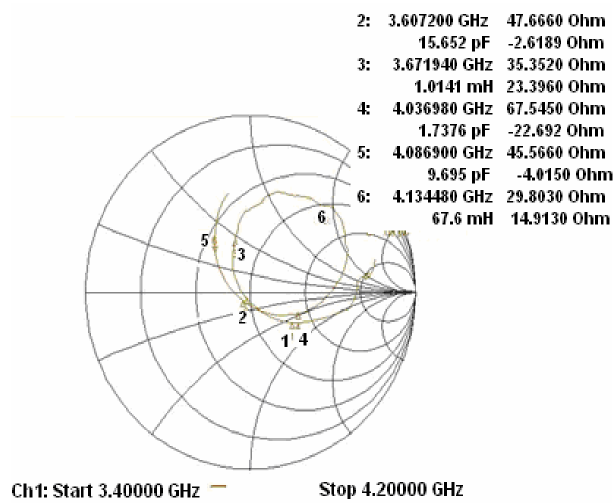

Fig 5(b): Measured variation of input impedance of single slit loaded rectangular patch antenna with frequency

(c) Rectangular patch antenna with orthogonal crossed slits

In the next step, an additional narrow slit orthogonal to first slit is applied as shown in figure 6. This second narrow slit is parallel to X-axis and it is located as a distance 'L_1' = 9.24mm from the upper narrow wall. The length of this second slit (w_1 + w_2 + w_3) is 12 mm while width 'L_2' is 0.5mm. The length of horizontal arms 'w_1' and 'w_3' of horizontal arms are identical and equal to 5.75mm while length 'w_2' is 0.5mm. Under this modified condition, the simulation analysis of proposed rectangular patch antenna with two orthogonal slits reveals that in the

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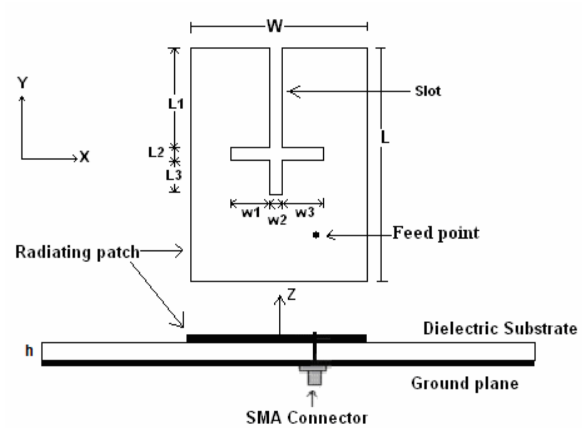

Fig. 6: Geometry of rectangular patch antenna with orthogonal crossed slits

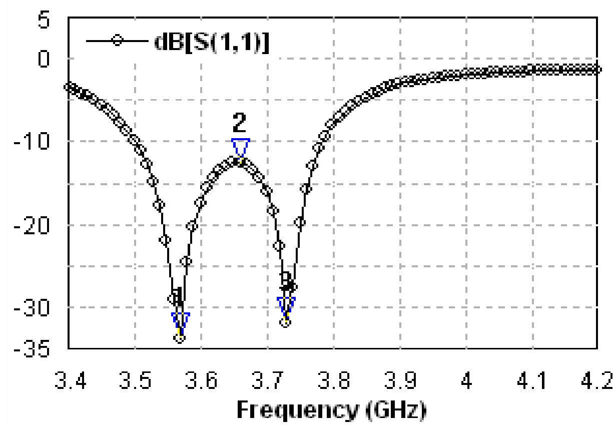

Fig 7(a): Simulated variation of reflection coefficient (S_{11}) with frequency

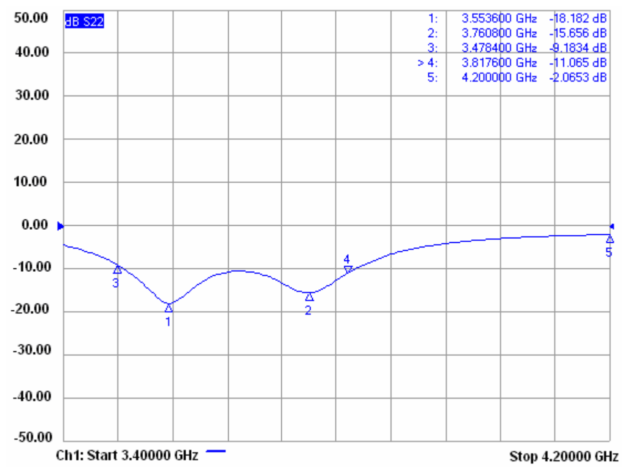

Fig 7(b): Measured variation of reflection coefficient (S_{11}) with frequency

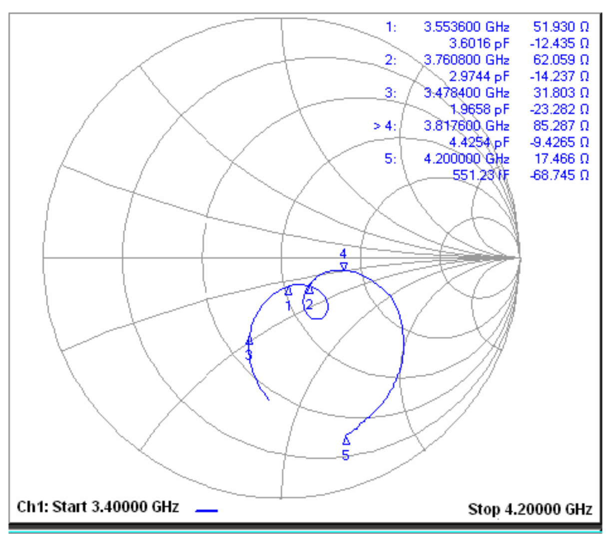

Fig. 8 Measured variation of input impedance of proposed antenna with frequency

frequency range 3.4GHz to 4.2GHz, antenna resonates at two frequencies 3.56GHz and 3.73GHz as shown in fig. 7(a). With introduction of second slit in the geometry as shown in figure 6, the electrical length of the entire slit structure is increased hence the second resonant frequency is lowered creating an overlap with the first resonance that results an increased operational bandwidth. This behavior is similar to that analyzed with the U-slot reported earlier [5]. Since the additional slit supports an electric field orthogonal to the electric field in the initial slit, the resulting antenna produces a considerable cross-polar radiation that may be realized from radiation patters of antenna presented later.

The two simulated resonance frequencies are in very close agreement with measured resonance frequencies 3.55GHz and 3.76GHz as shown in fig. 7(b). The measured impedance bandwidth (9.3%) is improved significantly in comparison to that attained in two previously discussed geometries. The variation of input impedance of antenna as a function of frequency is shown in figure 8. This variation still has a loop but the size of loop is large that makes axial ratio more than 3dB. This suggests that the circular polarization is still absent in this modified geometry which we realized earlier in section (a) of this paper. The measured input impedances at frequencies 3.55GHz and 3.76GHz are (51.93 – j12.44) ohm and (62.1 – j 14.24) ohm respectively which are quite close to simulated input impedance of antenna.

The measured E-plane co and cross polar patterns of antenna at two resonant frequencies 3.55GHz and 3.76GHz are shown in fig. 9 and 10 respectively. Radiation patterns at both frequencies are identical in shape and indicate that direction of maximum radiations is normal to the patch geometry. Fig -9 suggest that at frequency 3.55GHz, co polar pattern is nearly 15dB higher than cross polar pattern while Fig -10 suggest that at frequency 3.76GHz, co polar pattern is nearly 6.5dB higher than cross polar pattern.

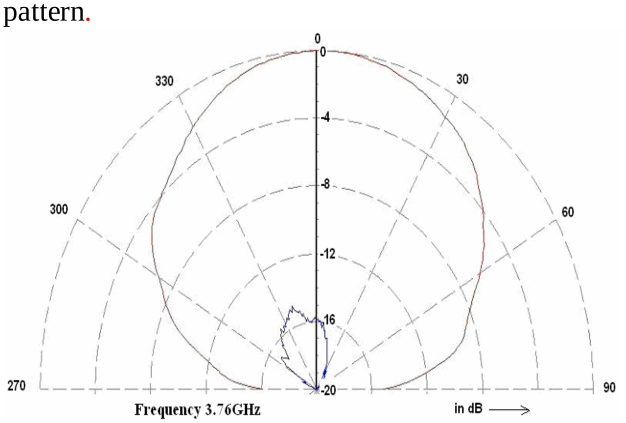

Fig. 9: E plane Co and Cross polar pattern of antenna at frequency 3.55GHz

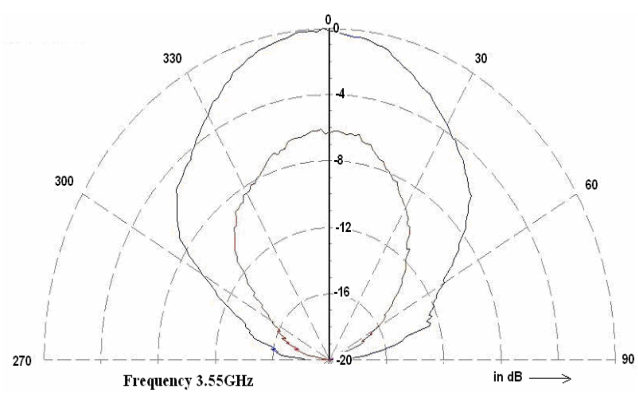

Fig. 10: E plane Co- Cross polar pattern of antenna at frequency 3.76GHz

The performances of three antenna geometries reported in this paper are summarized in table -1. As shown in this table, the gain of antenna even after modifications is still very low. Low gain and efficiency values of these antennas are perhaps due to application of glass epoxy FR-4 substrate material bearing large loss tangent value.

Table-1: Comparison between performances of different antenna geometries

Geometry	Measured Resonant Freq. (GHz)	Measured Band width (%)	Simulated Gain (dB)
Simple rectangle	4.06	3.9	3.47
Rectangle with single slit	(i) 3.60 (ii) 4.08	(i) 2.8 (ii) 2.5	4.19 3.19
Rectangle with orthogonal crossed slits	(i) 3.55 (ii) 3.76	9.3	4.37 3.52

IV. DISCUSSION AND CONCLUSIONS

The radiation performance of a rectangular patch antenna with orthogonal crossed narrow slits is investigated in free space and is compared with that of a conventional rectangular patch antenna excited under similar conditions. The conventional rectangular patch considered here was providing circularly polarized radiations but was operating at a single frequency with narrow operational bandwidth. The modified rectangular patch antenna resonates at two frequencies with much improved impedance bandwidth though circular polarization could not be realized. The efficiency and gain of modified antenna are improved marginally but these are lower than desired values for modern communication systems. The antenna radiation patterns within bandwidth are almost identical in shape. The results obtained with proposed geometry suggest that this compact size antenna with little more improvements may be proved a useful geometry for modern communication systems.

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