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Design and Development of 1.575 Ghz Quarter-Wave Patch Antenna with Feed Line

S. Sindhuja, E. Kanniga

Abstract*: *This paper presents a quarter-wave patch antenna for GPS application which is realized by using shorting pins. The impact of the shorting relies upon the distance between the shorting posts, the radius of each shorting post, the number of shorting posts used and the height of the shorting posts which is determined by the thickness of the substrate used (which is 1.6mm for FR-4 substrate). A Right Hand Circularly Polarized Microstrip patch antenna with feed line for GPS frequency (1.575 GHz) is designed, simulated and fabricated. Simulation is done using ADS (Advanced Design System) and a fabricated prototype of the both the shorted and unshorted proposed antenna have been measured using Agilent Vector Network Analyzer.

Index Terms*: *GPS, Microstrip patch antenna, Quarter-wave, Rectangular Patch.

I. INTRODUCTION

Compact MSAs have been realized by using either shorting posts (pins) or shorting wires between the patch and ground [2]-[8]. The shorted microstrip patch antenna is a compact antenna but it suffers from the disadvantage that more number of shorting pins is required thereby making fabrication process harder especially when manufactured in larger quantities [11]. Shorting pins are inserted between the patch and the ground plane generally perturbs the surface current distribution on the patch [14].

A rectangular micro strip antenna operating in the fundamental TM10 mode has a resonant length which is equal to $\lambda/2$ [1]; the voltage distribution along its length is shown in figure 1. The zero potential field is along the line OO to the ground plane, and by using only 50% of the patch a shorted RMSA with reduced size is obtained with resonant length equal to $\lambda/4$. The rectangular patch antenna so far is a half-wave rectangular patch. The electric field distribution under the patch is given by $E_o\cos(\pi x/L)$. At the radiating edge which is on the right the electric field is minimum, zero in the middle (i.e. at $x = \lambda/2$), becomes maximum at the left radiating edge with a phase reversal of 180º (i.e. the field distribution keeps on changing in amplitude and sign).

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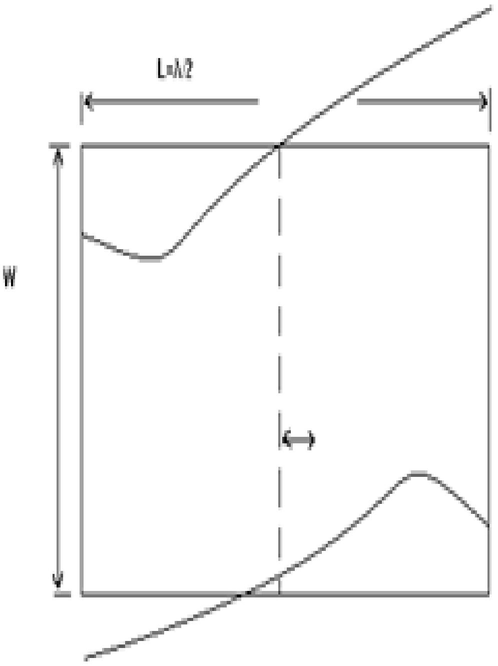

Fig. 1. Field distribution of the fundamental TM10 mode of RMSA

Since the electric field is zero at the plane $x=L/2$, an electric wall is formed there by means of the shorting posts. This phenomenon however does not change the field distribution under the patch. One-half of the patch antenna can now be discarded. [10, 12-15]

The resonating frequency of quarter-wave and that of the half-wave rectangular patch antenna are more or less the same. Rectangular patch geometry of this type is called a quarter- wave patch because the separation between the radiating edge and the electric wall is about $\lambda_g/4$. The characteristics of the quarter wave patch geometry are derived from the half-wave patch and are more or less the same. A quarter-wave patch can be used in applications where small-sized antennas are needed and deterioration in cross polarization characteristics can be tolerated. The major differences are that the quarter wave patch has one radiating edge compared to two for the half-wave patch. This physical difference is responsible for all the differences in antenna characteristics:

1. The E-plane pattern of the quarter-wave patch becomes broader because the array effect of two radiating edges for a half-wave patch is absent here. Also the half-length nature of the patch gives rise

to a cross-polarized Eθ component in the H plane.
2. The radiation conductance Gr of a quarter-wave patch is due to radiation from a single edge. Its value is lowered by a factor of 2 compared to that obtained for half-wave patch. Therefore the radiation resistance at resonance will be two times. Numerical calculations show that ξr is not equal to 1.
3. The stored energy in quarter–wave patch is exactly one half of that of the half-wave patch because of identical field distribution over half the area.
4. The bandwidth is same for both the quarter-wave patch and the half-wave patch.

II. CALCULATION OF THE PATCH ANTENNA DIMENSIONS

The geometry of a single antenna element is shown in the Fig. 2.
The width and length of the radiating surface is given by,

$$W = L = \frac{c}{2f\sqrt{\xi r}} \qquad (1)$$

Where,
Velocity of light, c = 3 x 10^8 m/s
Frequency, f = 1.575 GHz
Relative Permittivity, ξr = 4.6

So substituting the values in equation (1) we get W = L = 44. 4mm. The depth of the feed line into the patch is given by the formula

$$H = \frac{0.822 * L}{2} \qquad (2)$$

Substituting the value of L in equation (2) we get H = 18.25 mm. The value of H is directly proportional to the reflected power S11.

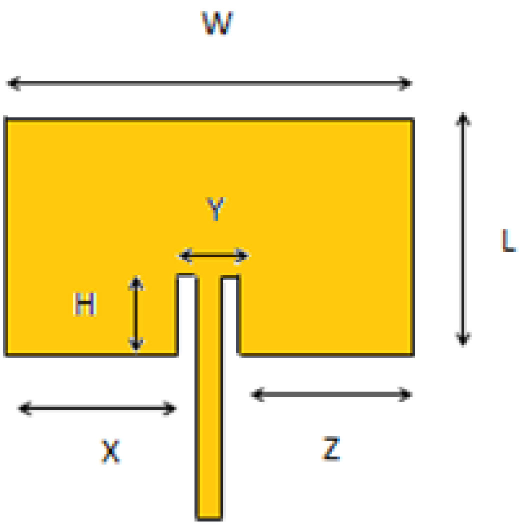

Fig. 2. Top view of the Microstrip patch antenna with feed line

The other dimensions are,

$$Y = \frac{W}{5} = 8.88mm \qquad (3)$$

$$X = Z = \frac{2w}{5} = 17.76\ mm \qquad (4)$$

he value Y is inversely proportional to the coupling between the antenna and the Microstrip.

A. Design of the Quarter-wave patch antenna with shorting posts

Compared to other miniaturization techniques, the proposed shorting technique is much simple and is mechanically robust.

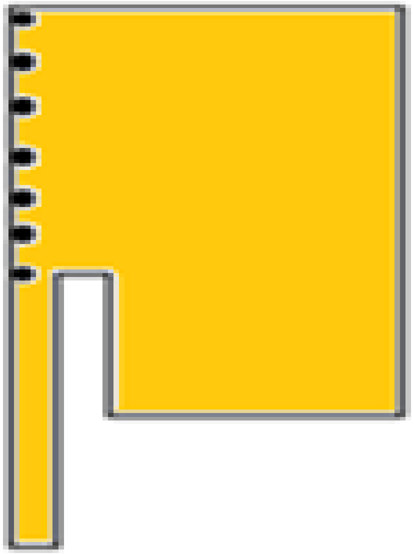

Fig. 3. Top view of proposed shorted antenna

In the proposed design seven equally spaced shorting pins have been used and hence one half of the microstrip patch antenna is discarded. Besides realizing compactness, the shorting technique has also been used to improve gain, directivity, impedance matching [9], radiation pattern and bandwidth. Therefore, short circuited microstrip antennas have created much interest among the researchers because both the short circuited antenna and the conventional microstrip antenna resonate at the same frequency. However the harmonics might be present with a minimum shift.

B. Design steps involved in the miniaturization of microstrip patch antennas

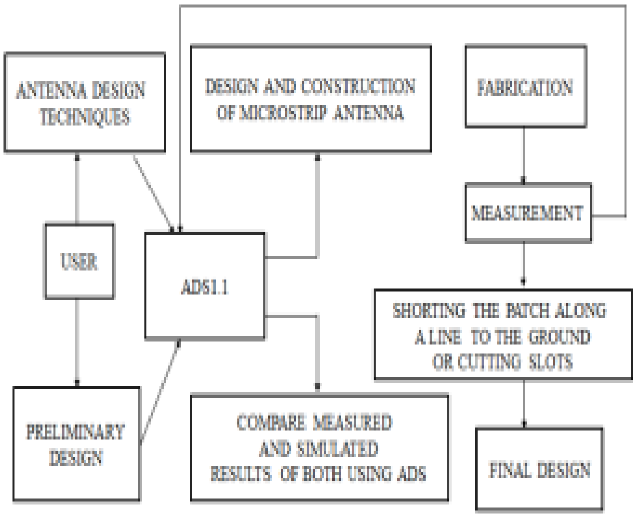

Fig. 4. Design steps

C. Simulation using ADS

In this study, Advanced Design system software was used for computing the radiating characteristics of the shorted microstrip patch antenna. In order to match the impedance of the feed line to the patch an inset cut is introduced which eliminates the need for any additional matching element. It is necessary to properly control the inset position to match the impedance.

Table I. Design Parameters of the Antenna

Design Parameter	**Value**
Substrate material	FR4
Relative Permittivity of the substrate	4.6
Thickness of the dielectric substrate	1.6 mm
Design Frequency	1.575 GHz

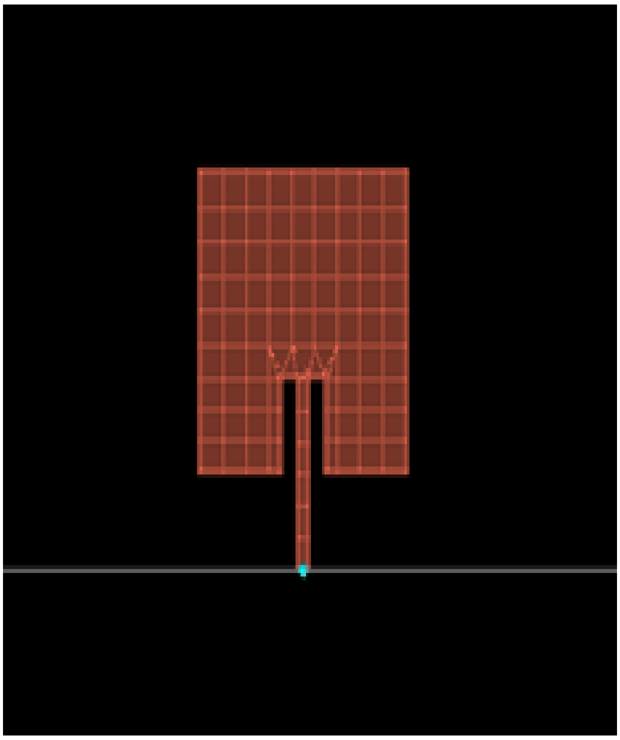

Fig. 5. Design of unshorted microstrip patch antenna

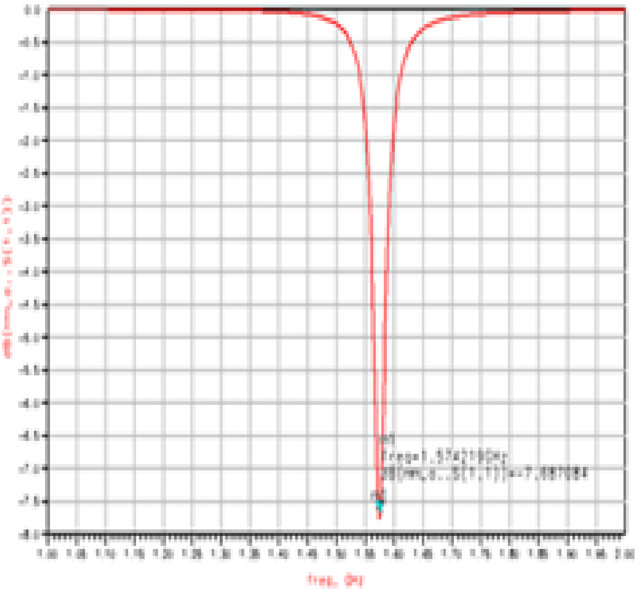

Fig. 6. Simulation result for unshorted microstrip patch antenna

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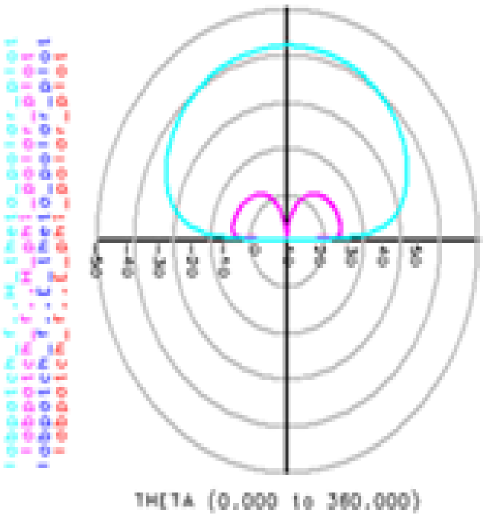

Fig. 7. Radiation pattern for unshorted microstrip patch antenna

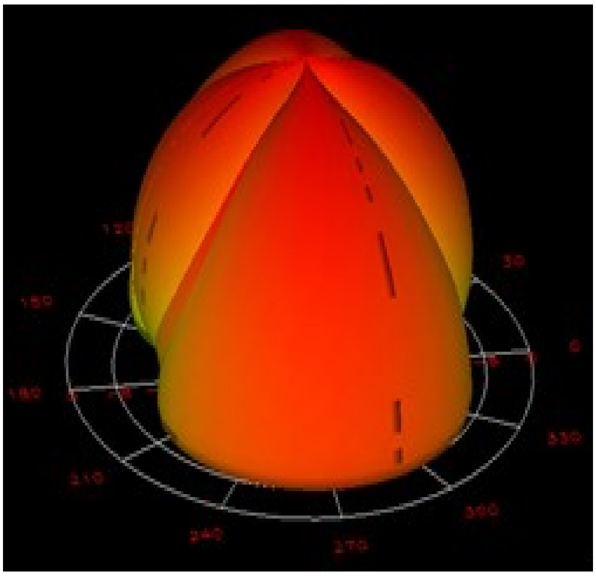

Fig. 8. Radiation pattern for unshorted microstrip patch antenna (3D)

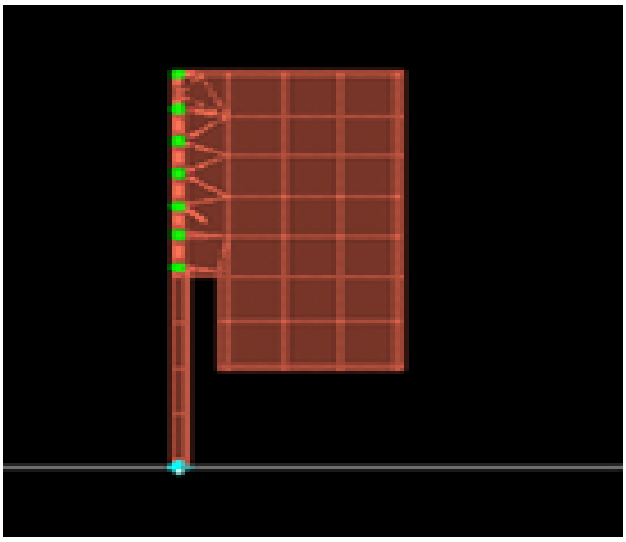

Fig. 9. Design of shorted microstrip patch antenna

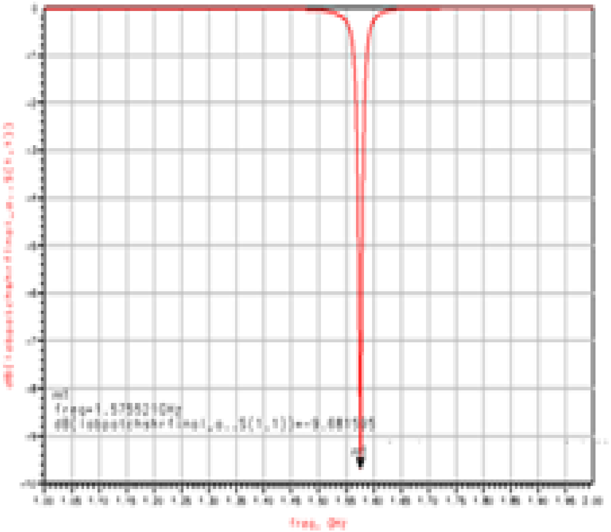

Fig. 10. Simulation result for shorted microstrip patch antenna

The simulation results show Return loss at center frequency, 3D polar plot of gain and directivity in E and H plane.

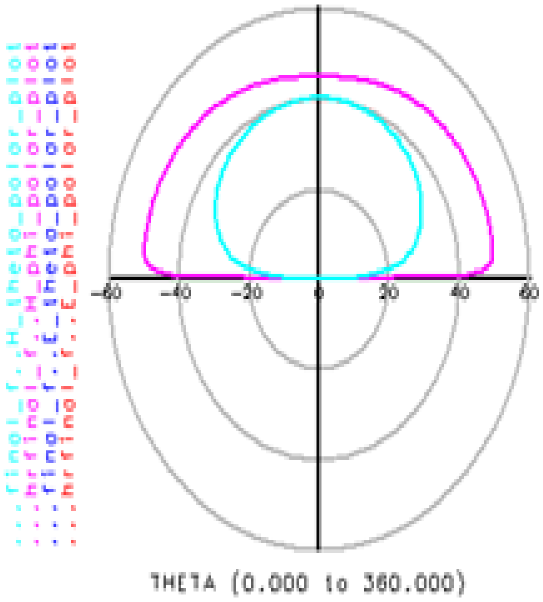

Fig. 11. Radiation pattern for shorted microstrip patch antenna

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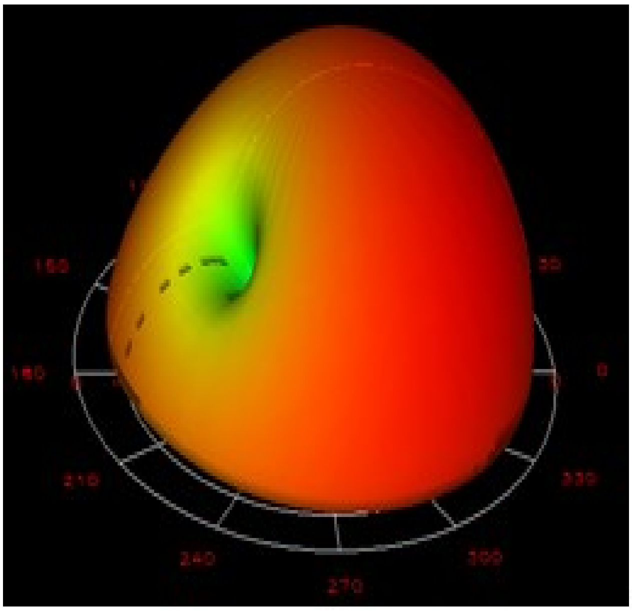

Fig. 12. Radiation pattern for shorted microstrip patch antenna (3D)

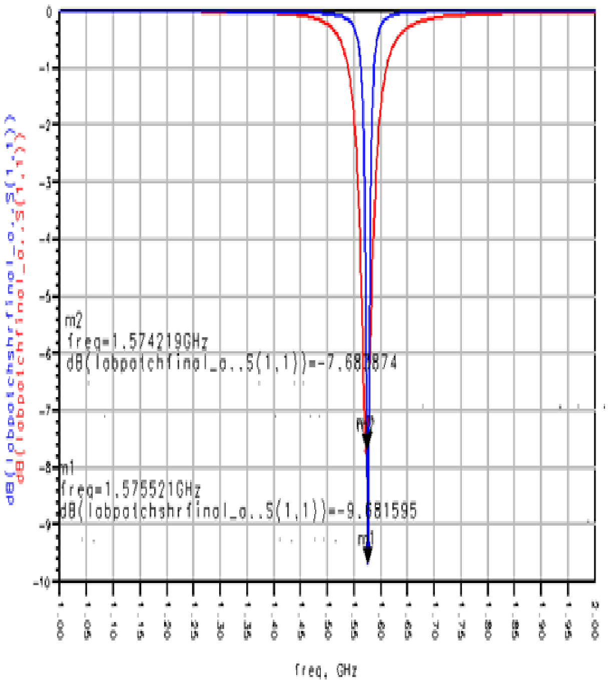

Fig. 13.Comparison of Simulation results for unshorted and shorted microstrip patch antenna

Table II. Simulation Results

Parameter of Study	**Value obtained**	
	Conventional	**Proposed design**
$S_{11,}$ Return loss	**-7.68 dB**	**-9.68 dB**
$A_{e,}$ Effective Antenna Area	**19.71 cm^2**	**9.9 cm^2**

D. Experimental Results

Both the half wave and quarter wave inset-fed microstrip patch antenna have been fabricated and tested using Agilent Vector Network Analyzer. There is a good match between the simulated and experimental results.

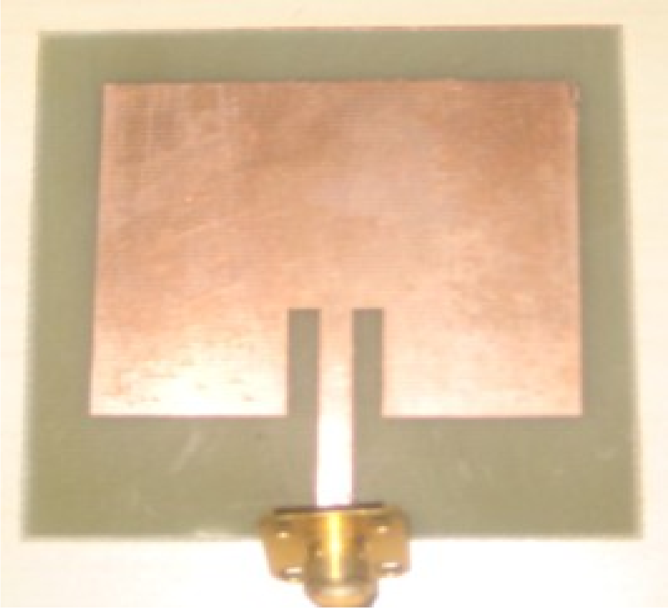

Fig. 14. Comparison of the size of the fabricated prototypes of a conventional microstrip patch antenna and shorted patch antennas

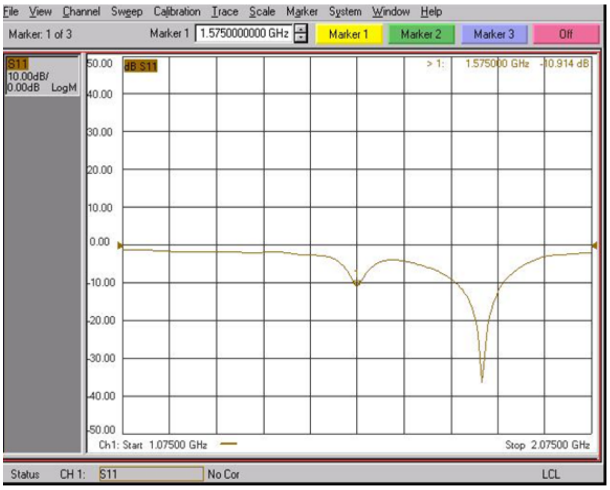

Fig. 15. Measured Results

III. CONCLUSION

In this paper, shorting posts have been used to reduce the input impedance on the periphery of the half of the patch antenna. The fabrication is carried out for both the shorted and unshorted patch antennas with both operating at the same frequency band in their fundamental TM10 mode. The proposed work provides an insight into the functioning of widely used Microstrip patch antenna element with shorting posts. As future work, techniques like introducing slots, truncating of the patch edges and changing of substrate may be done for further improvement of the design.

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