Coplanar Waveguide-fed Printed Monopole Antenna in 0.5-3 GHz Range

Gurpreet Singh Gosal (*Author)*

Research Undertaken at - Center for Applied Research in Electronics (CARE), Indian Instituteof Technology Delhi, New Delhi

Student at - Punjab Engineering College, Chandigarh

Abstract—This study presents a coplanar waveguide (CPW)-fed planar monopole antenna. The proposed antenna is designed to operate from 0.5 to 3 GHz. The goal was to reduce the dimensions of the antenna through various design variations in the geometry of the Square Planar Monopole Antenna . Final Design consists os a Central Hole, Step Notches at the edges and Curved Base where radiating element is fed by the CPW.The Impedence and Radiation characteristics(Calculated and Measured) of the proposed monopole are presented and effect of the design variations are analyzed.

I. Introduction

In recent times wireless systems are putting greater demands on antenna designs. Many systems now operate intwo or more frequency bands, requiring dual or triple band operation of fundamentally narrow band antennas. These include, satellite navigation systems, cellular systems, wireless LAN etc. One of the most employed in mobile communication systems is the monopole antenna and its family. They can be developed with to cover frequency extremities from GSM900/NADC, IMT-2000, the 2.45 GHz ISM bands further on. If radiation pattern over the bandwidth is tolerated then single broad band monopole antenna, instead of dual or triple band response can be used for the same purpose. The impedence bandwidth(BW) achievable for the quarter wave monopole antenna dependent on the radius of the cylinder tube. The BW increases with radius of the cylinder. A simpler cost effective technique is to replace the cylindrical stub of a conventional monopole antenna with a printed element. Many regular shaped configurations, such as, circular, rectangular, elliptical, rectangular etc have been investigated for larger impedence bandwidth. Maximum impedence bandwidth for VSWR=2 has been achieved for a printed elliptical monopole antenna. Recently it has been proposed that, although the square monopole provides smaller impedence BW than circular or elliptical monopole, its radiation pattern suffers less degradation within the impedence BW.

For achieving the design of modified monopole antenna in the frequency range of 0.6 to 3 GHz CPW feed was finalized such that metallic geometry is on the same plane and can be easily realized in the printed circuit structures. A modified Square Planar configuration has been presented with a Semi- circular Base, Central slot and Edge Notches. Modifications are made so that required operation is possible with small size, light weight, low cost antenna and ease of its integration with other Microwave components. The theoretical study of this configuration has been carried out using CST Microwave Studio(MWS). This configuration covers all the wireless communication bands.

The Paper is organized as follows: Section 2 describes the antenna design and its geometry . Section 3 presents the effects of modification in the geometry of the antenna. In Section 4, some practical results are presented. Finally a conclusion summarizes the main characteristics of the proposed antenna.

II. Antenna Geometry

For a planar monopole antenna, the lower frequency corresponding to VSWR=2 can be approximately calculated equating its area to that of an equivalent cylindrical monopole antenna of same height L and equivalent radius r, as described below:

$$2 \pi r L = W L \quad (1)$$

Therefore,

$$r = W / (2 \pi) \quad (2)$$

The length of the monopole can be obtained using

$$L = 0.24 \lambda A \quad (3)$$

Where,

$$A = L / (L + r) \quad (4)$$

For a thin flat sheet of width, L , the equivalent radius is given by

$$r = L/2\pi \quad (5)$$

Therefore,

$$A = 0.86 \quad (6)$$

The frequency corresponding to the lower edge of the BW(f_L) can thus be calculated as follows:

$$f_L = 61.9 / L \quad (7)$$

where L is the side length in mm.
and f_L is lower edge cut off frequency.

For the f_L = 0.5 GHz, L = 123.8 mm using [7]. Now to reduce this dimension design enhancements need to be performed through some modifications in the geometry. Therefore a Central slot, Semi-circular base and Edge notches are introduced which result in reduced radiating elements area with the same impedence BW. Final design is implanted on a substrate of thickness 0.5 mm and μ = 2.2.

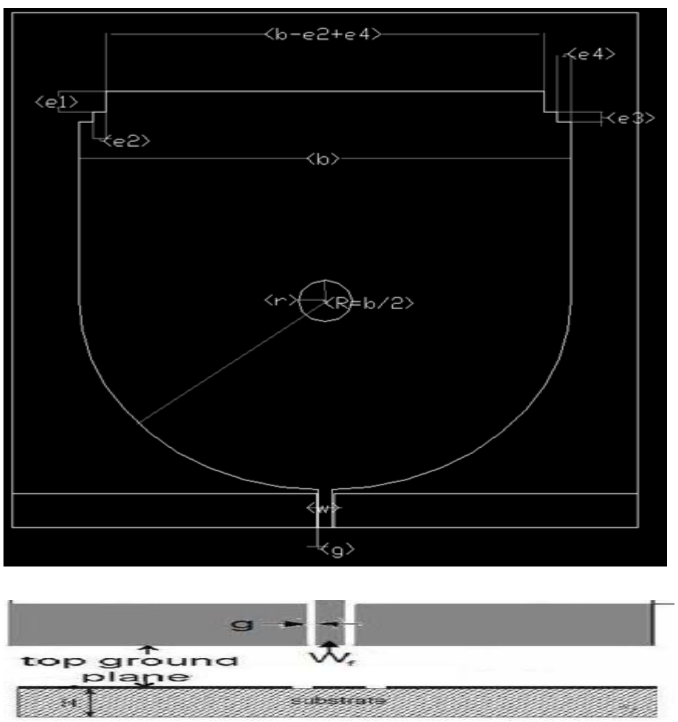

Fig. 1 Modified square Planar monopole antenna with CPW feed.

TABLE 1
Dimensions of Radiating Element

Symbol	Quantity	Value (mm)
b	Radius of base and width of square	110
r	Radius of Slot	6
R	Radius of Semi-circular base	55
g	Ground plane to feedline gap	0.2
w	Width of feedline	5
h	Substrate height	0.5
e1	Notch length	6
e2	Notch length	3
e3	Notch length	3
t	Feedgap	2.7

CPW feed is used as the feedline since both the ground planes are chosen very close to the conducting strip so there is very tight coupling between the ground and conductor and therefore very less radiation losses as compared to microstrip feed lines. Here, fields are more confined in the dielectric hence the effective dielectric constant for the CPW feedlines is slightly higher. This reduces the f_L. Semicircular base is introduced instead of square base which provides continuity between feedline and radiating element thus increase coupling.

III. Effect of Various Parameters

Modifications in the Antenna geometry were made one parameter at a time and rest were kept according to the final values and the effect of that single parameter is analyzed.

A. Feedgap

Feedgap t= 2.7 mm gave the best BW response.

B. Effect of variations in b(side of square and radius of the base)

As we have seen f_L is inversely related to the area of radiating patch thus reduction in the dimensions of the antenna would increase lower edge frequency as shown below for b= 85 mm.

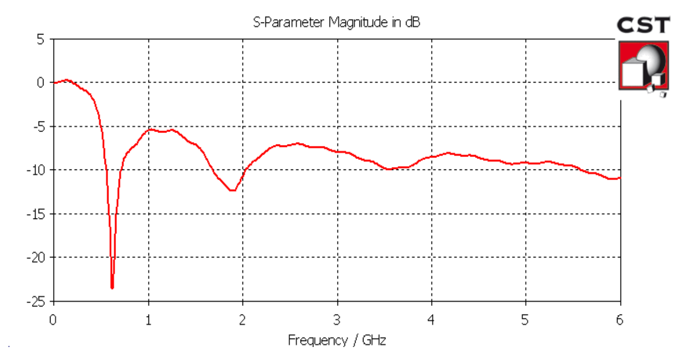

Fig. 2 Return loss for b= 85mm

C. Effect of variation in slot radius

Radiating element with variable slot radii were analyzed and finally r = 6mm was implemented in the final design. Now if no slot is made in the antenna following return loss characteristics are obtained.

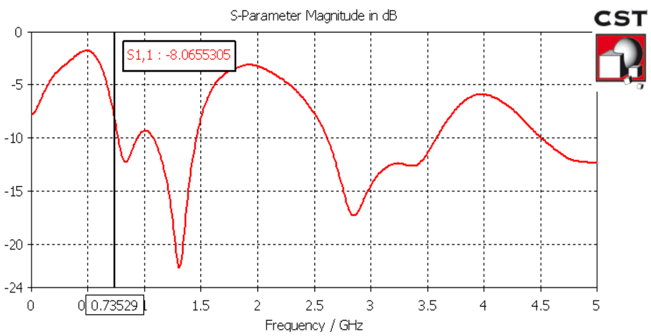

Fig. 3 Return Loss for r = 0mm

D. *Effect of edge notches' dimensions*

Incorporation of edge notches further reduced the lower edge frequency and various dimensions were simulated but e1=6, e2=3, e3=3 and e4=3 gave optimum results.When no edge notches are placed there is right shift in the lower edge frequency.

IV. MEASUREMENT AND RESULTS

A. *Return Loss*

Return Loss of the final design simulatedand measured is represented in Fig. 6 and Fig. 7 respectively.The f_L(simulated)= 0.56 GHz and f_L(Measured) = 0.6 GHz. So there is slight shift in the measured result which owe to fabrication errors.

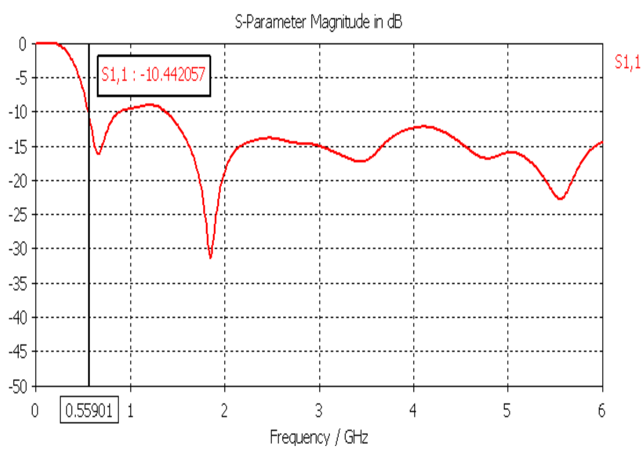

Fig. 4 Simulated Return Loss plot for Modified Square Planar Antenna

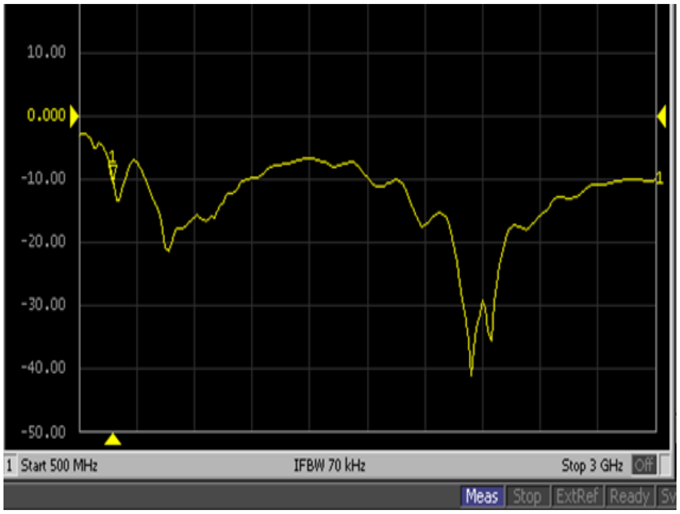

Fig.5 Measured Return Loss plot for Modified Square Planar Antenna

B. *Radiation Pattern*

Radiation Patterns were simulated and measured at six different frequencies(0.8, 1, 1.5, 2, 2.4, 2.8) GHz as shown.

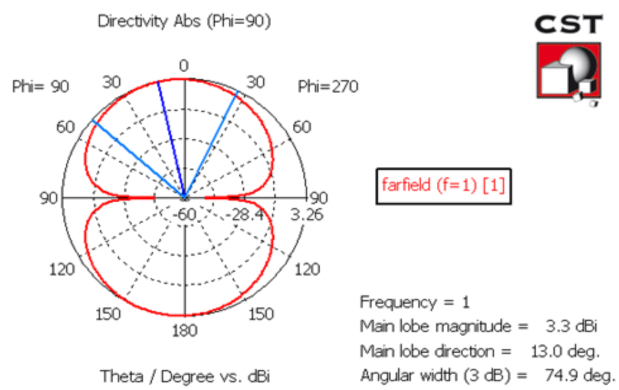

Fig. 6 Simulated Radiation Pattern in E-Plane at f = 1GHz

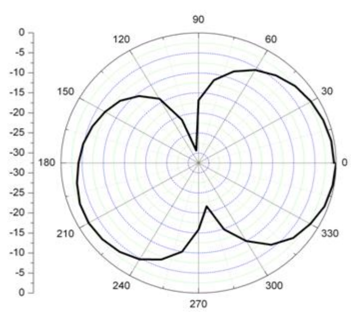

Fig. 7 Measured Radiation Pattern in E-Plane at f = 1GHz

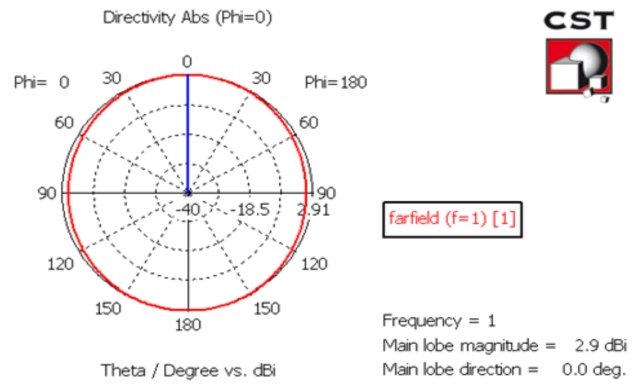

Fig. 8 Simulated Radiation Pattern in H-Plane at f = 1GHz

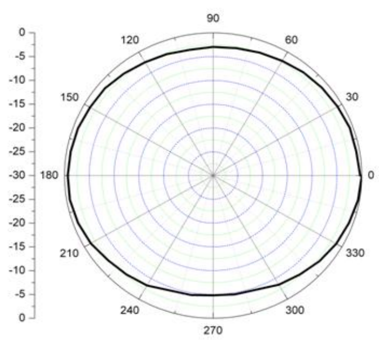

Fig. 9 Measured Radiation Pattern in H-Plane at f = 1GHz

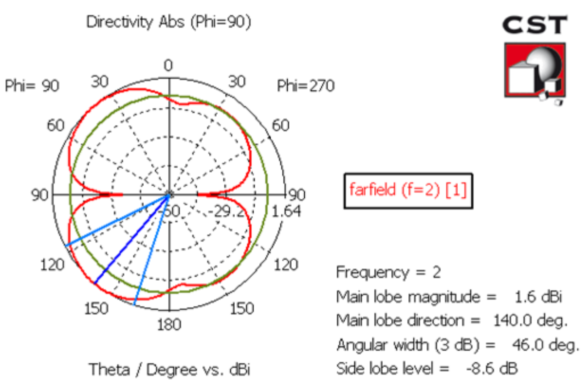

Fig.10 Simulated Radiation Pattern in E-Plane at f=2 GHz

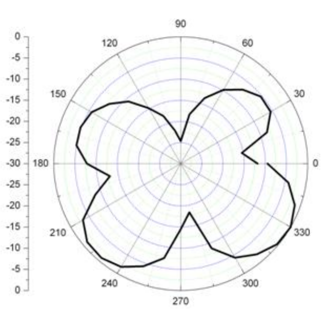

Fig.11 Measured Radiation Pattern in E-Plane at f=2 GHz

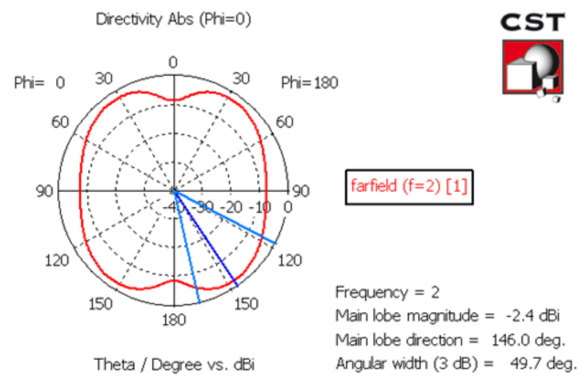

Fig. 12 Simulated Radiation Pattern in H-Plane at f=2 GHz

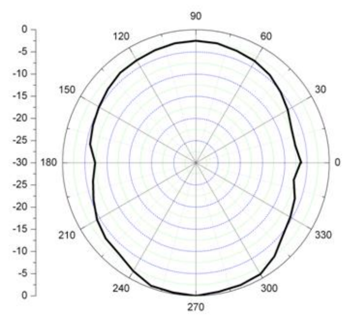

Fig. 13 Measured Radiation Pattern in H-Plane at f=2 GHz

C. *Gain Measurements*

Gain was measured using Friis equation by employing a reference horn antenna and is plotted as follows:

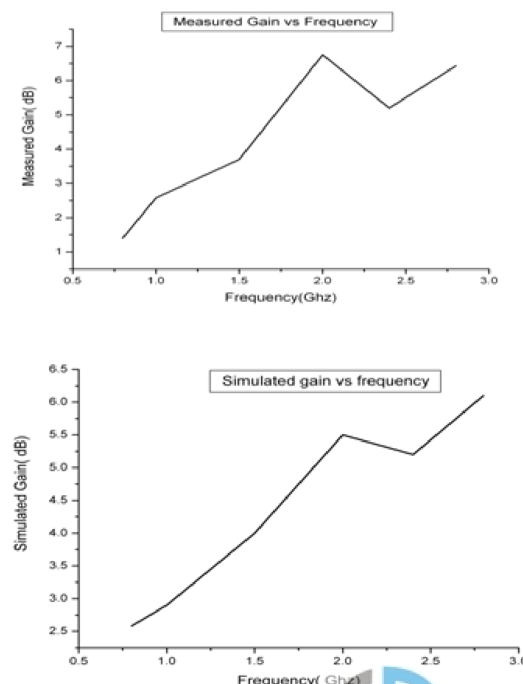

Fig. 14 Plots for measured and simulated gain

D. Cross Polarization

The designed Planar Monopole Antenna should be linearly polarized thus the cross polarization components are calculated in CST MWS . Axial ratio is found out to be 40 dB in both azimuthal and elevation plane. The Cross Polarization E-Field components were analyzed at all the six frequencies and is presented for f = 2 GHz:

The designed Planar Monopole Antenna should be linearly polarized thus the cross polarization components are calculated in CST MWS . Axial ratio is found out to be 40 dB in both azimuthal and elevation plane. The Cross Polarization E-Field components were analyzed at all the six frequencies and are presented for f = 0.8 GHz and 2 GHz:
As plots indicate E-field(Cross-polar) received component power is -141.9 dBW/m⍰ which is insignificant as compared to Co-polarized component = -8.4 dBW/m⍰. Therefore, antenna is linearly polarized at 0.8 Ghz

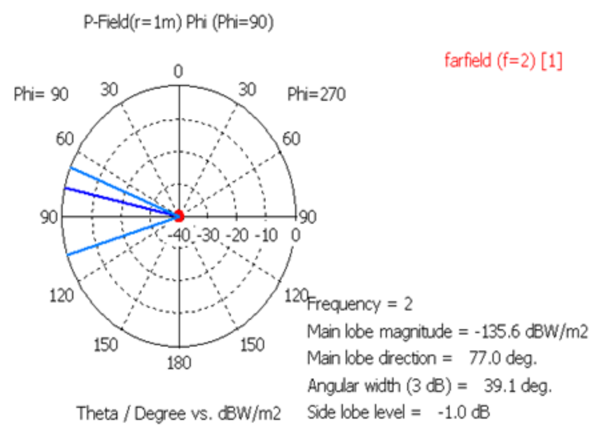

Fig. 15 Cross polariazation pattern in E-Plane at f= 2GHz

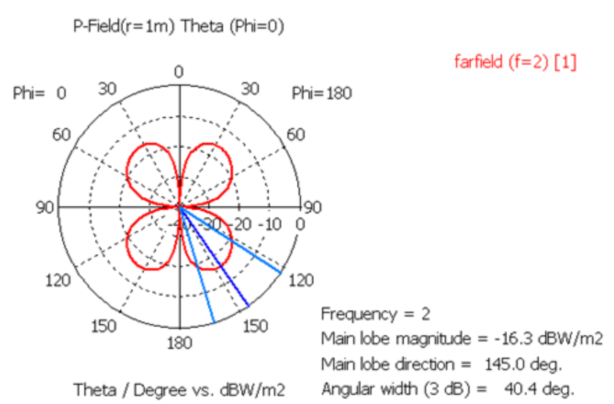

Fig. 16 Cross polarization Pattern for H-Plane at f= 2 GHz

Above two plots depicting Cross Polarization in E and H Plane show that there is considerable cross polarization in H-Plane with Co- polarization E-Field main lobe magnitude of the order of Cross-polarization E-Field main lobe magnitude while in E-Plane there is considerably less Cross polarization. Also the Cross polarization increases wih increase in frequency i.e. least at 0.6 GHz and maximum at 3 GHz.

V. CONCLUSION

The main objective of the design is to achieve a broadband antenna with considerable reduction in dimensions and improved performance and it has been achieved with the incorporation of geometric modifications of the radiating element. Antenna yields larger bandwidth and completely covers all the wireless communication channels as GSM(900-1800 MHz), UMTS(1885-2200 MHz) and WCDMA(1.92-2.17 GHz) etc. The radiation patterns are also studied at six different frequencies which are in accordance with the simulated results. Also Gain and Cross polarization vector is analyzed.

Further reduction of the dimensions can be achieved through geometric variations such as increasing the current path or by employing impedence transformers in the feedline and using tapered CPW feed structures. Moreover as it has been estimated that Elliptical monopole projects maximum impedence bandwidth among all other monopole geometries it can be used in achieving the reduction of monopole dimensions.

ACKNOWLEDGMENT

This work was undertaken at Microwave and RF Lab. Of Center for Applied Research in Electronics(CARE), IIT Delhi by myself as a Research Intern under the guidance of Assoc. Prof. Ananjan Basu.

REFERENCES

[1] Ray, K.P., Anob P.V., Kapur R., and Kumar G., “Broadband Planar Rectangular Monopole Antennas,” in *Microwave optical Letters* , Vol. 28, No. 1, 2001, pp. 55-69

[2] E. Lee, P.S. Hall and P. Gardner,” Compact Wideband Planar Monopole Antenna *”*, Electronics Letters35(1999), 2157-2159

[3] M.John and M.J..Ammann, “*Optimization of impedence bandwidth for the printed monopole antennas,”* Microwaves and Optical Technology Letters, Vol. 47, No.2, pp. 153-154 Oct,2005

[4] Balanis, C.A., *Antenna Theory Analysis and Design*,John Wiley & Sons, Inc., 1997.

[5] Naffal Herscovici and Christos Christoduoloc, “Wideband monopole antennasfor multi-band wireless systems,” *IEEE Trans Antennas and Propagation Magazine, Vol.45 , No.2, April 2003*