CHAPTER 6

DESIGN AND PERFORMANCE OF A COMPACT BROADBAND CIRCULARLY POLARIZED RECTANGULAR RING ANTENNA

6.1 INTRODUCTION

This chapter focuses on the design and performance of a compact circularly polarized CPW feed broadband rectangular ring antenna. This antenna is simulated and fabricated on a glass epoxy FR4 substrate with a thickness of 1.6 mm and relative permittivity of 4.4 and loss tangent of .025. By introducing a square slot in the centre of the patch an impedance bandwidth nearly 10.3 GHz is achieved. The presented antenna has been designed, simulated and measured successfully. The simulation analysis of designed antenna is carried out using HFSS software and measurements are performed using Vector Network Analyzer. The obtained results with this antenna make it a suitable antenna for UWB systems and portable applications.

A traditional microstrip antenna has drawback of narrow impedance bandwidth, low gain and single operating frequency corresponding to its dominant mode [16]. Many techniques have been studied and reported in recent years to increase the impedance bandwidth of printed antenna [17]. There have been reports of insertion of various shapes of slots to enhance the impedance bandwidth of antennas which includes quarter-wavelength line slot resonator [20], asymmetrical CPW slot [20], compact disc monopole antenna [29] and U-shaped slot [43]. However most of these antennas are either large in size or do not have sufficient bandwidth required for many practical applications particularly for ultra wide band applications. Several other techniques including parasitic elements near externally excited element [28], and excitation of patch element through an aperture coupling [33] are also reported for enhancing the impedance bandwidth of antennas. In most of these cases bandwidth improves but limited up to 3 to 3.5 GHz.

Federal Communications Commission (FCC) allowed a band from 3.1GHz to 10.6 GHz for ultra wideband (UWB) wireless communications, for the implementation of UWB systems we have to develop a suitable antenna with extremely wide bandwidth of 7.5 GHz, for return los less than -10dB with omni-directional radiation pattern. This will present low directivity with uniform gain and high radiation efficiency. However for
achieving further higher bandwidth from antenna required in UWB communication systems, aforementioned techniques are unsuitable. In this chapter, design of compact CPW feed square ring patch antenna is proposed for bandwidth enhancement. This antenna resonates at two frequencies and provides nearly 10.3 GHz bandwidth with covering almost entire frequency range desired for UWB communication systems.

6.2 ANTENNA DESIGN AND RESULTS
Initially a rectangular ring patch antenna having patch dimensions outer patch dimension 14 mm x 14 mm and inner square slot with dimension 6mm x 6mm is considered with infinite ground plane. The centres of patch and slot coincide with each other as shown in figure 6.1. The performance of this antenna simulated using HFSS simulation software considering presence of glass epoxy FR4 substrate material with dielectric constant $\varepsilon_r = 4.4$ and loss tangent 0.025 between the patch and the ground plane.

![Fig. 6.1 The top view of the rectangular patch antenna with a slot](image)

This antenna is excited by a 50Ω microstrip feed line (line width 3mm and line length 8mm) and feed through a SMA connector. The variation of return loss with frequency suggests that antenna resonates at frequency 10.2 GHz and provides excellent matching with feed line.
In the above return loss graph shown in figure 6.2 we observe that this antenna resonant at 10.3 GHz having a band from 8.7 GHz to 11.1 GHz but this band does not cover the range required for ultra wide band system. So iteration is required based on formulae shown in equation 1.1-1.6.

In the next step, shown in figure 6.3, keeping patch dimension and feed technique same as considered in previous case, the ground plane of antenna is modified by reducing its size in steps based on the formulae shown in equation 1.1-1.6. In each step of modification, performance of antenna is optimized and finally the size of ground plane equal to 6mm x 30mm is selected.
The simulated antenna resonates at 5.5 GHz frequency and provides impedance bandwidth from 1.4 GHz to 8.1 GHz as shown in figure 6.4 but still it is not sufficient for ultra wide band system because it is not covering the complete ultra wide band frequency range which is from 3.1GHz to 10.6GHz. Therefore further iterations on changing slot size are required in order to fine tune the results.

Fig 6.4 Variation of the reflection coefficient ($S_{11}$) with frequency of design shown in Fig.6.3

The final antenna is modified by replacing finite ground plane with coplanar waveguide (CPW) arrangement but the patch and feed line dimensions are retained as it is reported earlier. The antenna structure is simulated with HFSS simulation software keeping dimensions of ground plane equal 6 mm x 30 mm on both sides of feed line. The gap between feed line and considered ground plane is optimized and final value of the gap $w_1$ = .5 mm is selected.

Fig 6.5 (a) Rectangular patch antenna with cpw feed
6.5 (b) Top view of the fabricated antenna
(c) Side view of the fabricated antenna

The selected antenna is designed using glass epoxy FR4 substrate material as shown in figure 6.5. This antenna is measured using vector network analyser. The simulated antenna structure as well as the fabricated structure is shown in the figure 6.5. The variation of the reflection coefficient with frequency is shown in Fig. 6.6. From the figure 6.6 we observe that the antenna resonant at two frequencies 5.10 GHz and 9.9 GHz and having impedance bandwidth 10.3 GHz or 159.6%. The measurements of reflection coefficient, VSWR were carried out with a vector network analyser.
Fig. 6.6 The reflection coefficient v/s frequency graph.

The variation of measured reflection coefficient with frequency is shown in Fig. 6.7. From this graph we observe that the measured result is close to the simulated result so we can use this antenna for practical purpose also.

Fig 6.7 The reflection coefficient v/s frequency graph.

The variation of the simulated and measured VSWR with frequency is shown in Fig. 6.8(a), (b). The value of the VSWR in both the cases is less than 2 which tell us about the perfect matching between the antenna and the transmission line.
Fig 6.8 (a) variation of the simulated VSWR with frequency
(b) variation of measured VSWR with frequency

The variation of the simulated and measured value of smith chart is shown in Fig.6.9 (a), (b). From the smith chart we see it cross the real line at 1 which shows the perfect matching between the antenna and the transmission line.
The radiation pattern of the proposed antenna at different frequencies is shown in the Fig. 6.10 (a), (b), (c) given below. The pattern shows the omni directional behaviour of the proposed antenna. Omni directional pattern suggests us that this antenna can be used for broadcasting purpose.
Fig 6.10 (b) The radiation pattern at frequency 5GHz

Fig 6.10 (c) The radiation pattern at frequency 6.7GHz

In the figure 6.11 the axial ratio with frequency is shown in figure which tells us that the proposed antenna is circularly polarized.
6.3 RESULTS AND DISCUSSION
The Antenna exhibits 10.3 GHz bandwidth which is suitable for ultra wide band applications. The antenna is having good impedance matching i.e. maximum energy will be transferred.

The Antenna is having omnidirectional radiation patterns means this antenna can be used for broadcast purpose.

6.4 CONCLUSION
The designed antenna is of bandwidth of 10.3 GHz which covers complete ultra wide band. A novel compact circularly polarized antenna for ultra wide band applications has been presented and investigated. We found that by cutting a square in the centre of the patch with proper dimensions and with coplanar waveguide feed, large impedance bandwidth can be achieved in a very small size. The radiation pattern of the antenna is omnidirectional so this antenna has applications in mobile and wireless network.