Communications on Applied Electronics (CAE) – ISSN : 2394-4714
Foundation of Computer Science FCS, New York, USA
International conference on Computing, Communication and Sensor Network, CCSN 2015

Compact-Sized Ultra Wideband Circularly Polarized Microstrip Patch Antenna

T. Dutta
Department of Electronics
and Communication Engineering
National Institute of Technology,
Rourkela – 769008, India

ABSTRACT
A compact-sized single-fed circularly polarized single-layered microstrip patch antenna at X-band is proposed.The antenna is a modified form of the previously developed E-shaped rectangular patch with two parallel unequal slots. For improving the impedance matching performance,the circular reformations are introduced on each of the slot's end.The circles make the fields on the slots uniform without any tangible effect on the axial ratio.The antenna is designed on a thin ROGERS RT/DUROID 5880(tm) substrate with dielectric constant (ε_r) of 2.2 and thickness of 1.6mm. At the operating frequency of 10GHz, the overall size of the antenna is 15.43mm x 8.21mm x 1.6mm.The simulated result shows that the antenna achieved an ultra wideband impedance bandwidth(S_{11}<-10dB) ranges from 9.16GHz to 10.25GHz.

General Terms
Simulation of Microstrip patch antenna.

Keywords
UWB antenna, Circular polarization, E-shaped patch, Microstrip patch antenna.

1. INTRODUCTION
Ultra wideband(UWB) technology enables high-speed data transmission rate with short pulse duration.It is cost effective and low power level transmission across a very wide spectrum at the same time.UWB antennas are desirable for various applications such as communication systems with broadband and spread spectrum features in radar systems.

Microstrip antennas are low profile,light weight,easily mounted and having broadband characteristics.But the major drawback of the conventional microstrip antennas is narrow impedance bandwidth.The bandwidth of the microstrip antenna usually ranges from less than 1% to several percentages [1-2].A lot of techniques have been developed to enhance the impedance bandwidth.But each of them has some limitations.

Circularly polarized antennas have more advantages over linear polarized antennas.Because circular polarization can reduce the misalignment between the antenna of the stationary terminal and the antenna of the mobile terminal.Thus better mobility,weather penetration, and system performance are achieved in circularly polarized microstrip antennas.There are different conventional techniques used to obtain the circular polarization with single-feed single-layer structure by giving feed along the diagonal,chamfering opposite corners, cutting a narrow slot at 45^{o} to a square or circular patch or attaching tab to the elliptical patch.[1-2].There are also some other techniques by introducing asymmetry on the square or rectangular patch or square ground plane of the microstrip antenna.But all of the techniques used the substrate with very high thickness(upto 11mm) or high dielectric constant.These techniques can enhance the impedance bandwidth more than 15% [3-6,8-9].But the overall size of the antenna becomes larger.To overcome this limitation the substrate is chosen with low thickness(H=1.6mm) and low dielectric constant (ε_r=2.2).The operating frequency is taken 10GHz to make the proposed antenna size more compact[7].

In this article, the UWB technique has been used with single-layered coaxial probe-fed E-shaped rectangular patch antenna to achieve circularly polarized radiation.

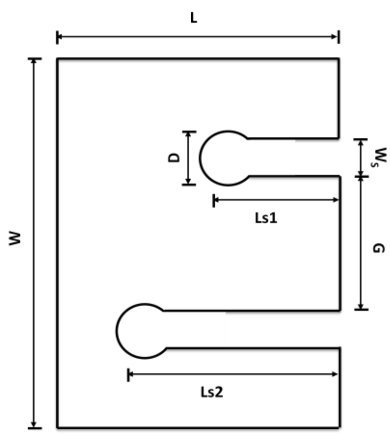

Fig 1: Antenna Geometry

Table 1. Dimensions of the circularly polarized Patch in mm

ε_r	H	W	L	D
2.2	1.6	15.43	8.21	3
W_S	L_{S1}	L_{S2}	G	L_F
1	2	6.61	4.9	2

2. ANTENNA GEOMETRY AND DESIGN PROCEDURE
2.1 Antenna Geometry
Figure 1. shows the geometry of the proposed antenna.The location of the antenna is in the xy plane and the normal direction is z-axis.It consists of an asymmetrical E-shaped rectangular patch antenna with two unequal slot length of L_{S1}

Communications on Applied Electronics (CAE) – ISSN : 2394-4714
Foundation of Computer Science FCS, New York, USA
International conference on Computing, Communication and Sensor Network, CCSN 2015

and $L_{S2}$and of same width (W_S) .The circular perturbations on each of the slot's end are of same diameter D.The patch of width W and length L is placed at a height H from the ground plane with dimension (λ_0 x λ_0) at the operating frequency of 10GHz.The patch dimension taken for the proposed antenna is ($0.51\lambda_0$ x $0.27\lambda_0$).The microwave substrate used between the patch and the ground plane is ROGERS RT/DUROID 5880(tm) with dielectric constant 2.2.The feeding probe connected to the patch passes through the ground plane and the substrate from the back of the antenna. The probe is offset from the right edge of the patch by L_F.

The good circularly polarized radiation can be achieved by adjusting the lengths of the two parallel unequal slots of the E-shaped patch antenna to the optimum position.When the lengths of both slots are equal,linear polarization occurs.For circular polarization,one of the slot's length should be reduced such that the x-directed current and y-directed current are equal in magnitude and 90^o out of phase. When $L_{S1}<L_{S2}$, the antenna is left-hand circularly polarized(LHCP) and for right-hand circular polarization(RHCP), $L_{S1}>L_{S2}$.

2.2 Design Procedure

Step 1. Start with a symmetrical E-shaped rectangular patch

At 10GHz.

Step 2. Create asymmetry by shortening L_{S1}/L_{S2} for LHCP/RHCP.

Step 3. Introduce circular reformations on each of the slot'send of E-shaped patch to enhance the impedancebandwidth of the circularly polarized patch antenna.

Step 4. Change feed position to obtain the Axial Ratiominimum as well as enhancement of impedancebandwidth with reduction of S_{11}(return loss due to he misalignment between the antenna and the transmission line).

Figure 2 shows the flowchart of the antenna design procedure.

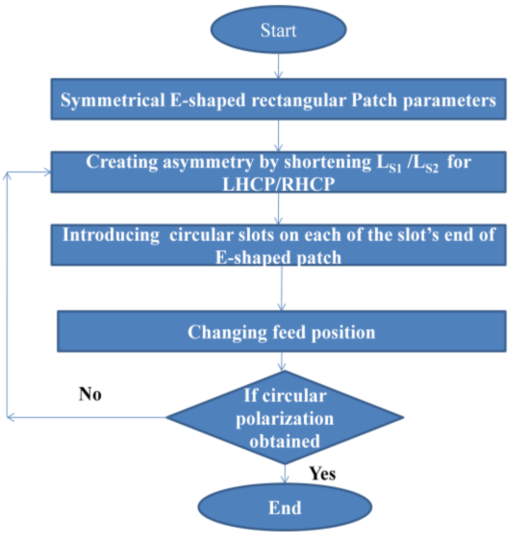

Fig 2. Flowchart of antenna design procedure

3. RESULTS

The simulation is carried out by using ANSYS/HFSS. For comparison purpose,the same antenna structure has also been studied with substrate height H = 6.7mm at operating frequency 2.45GHz(S-band). As a result, impedance bandwidth increases from 12% to 21.75% and return loss(S_{11}) reduces from -22dB to -32.5dB.But the overall patch size becomes (63mm x 33.5mm x 6.7mm).It is too large at 2.45GHz.The return loss(S_{11}) plot for the antenna with thick substrate at S-band is shown in Figure 3.

Impedance Bandwidth = $[(f_U - f_L)/f_C]$ x 100%

Where f_U and f_L are upper and lower frequency respectively defined at -10dB return loss, f_C is center frequency.

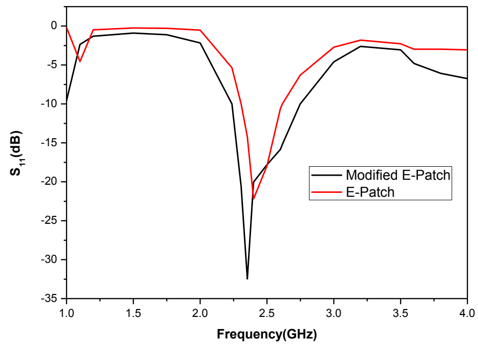

Fig 3. S_{11} for the modified E-Patch and E-Patch without modification with thick substrate(H=6.7mm) at 2.45GHz.

For small sized antenna design,the size of the ground plane can also vary the impedance bandwidth response of the antenna [6]. Figure 4 illustrates the return loss(S_{11}) responses for the proposed compact sized circularly polarized antenna with square-shaped ground plane of different length (G) at 10GHz.The impedance bandwith of this antenna becomes increased for larger ground plane. When G=35mm,the impedance bandwith is 12% with return loss of -18.01dB.The bandwidth is decreased to 11% with return loss of -15.17%for G=25mm.

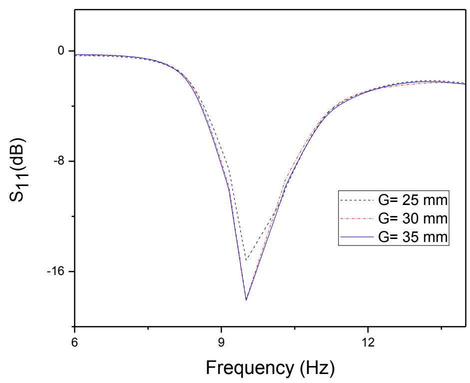

Fig 4. S_{11} of proposed antenna with different size of ground plane at 10GHz.

The probe position has the significant role for impedance matching and improving the axial ratio level,too.Figure 5. Shows the effect of different probe position on S_{11}.When the feed is at 2mm from the patch end then circular polarization occurs with impedance bandwidth maximum and return loss minimum.But for the other feed positions,impedance

Communications on Applied Electronics (CAE) – ISSN : 2394-4714
Foundation of Computer Science FCS, New York, USA
International conference on Computing, Communication and Sensor Network, CCSN 2015

bandwidth decreases, return loss increases and Axial Ratio also changes.

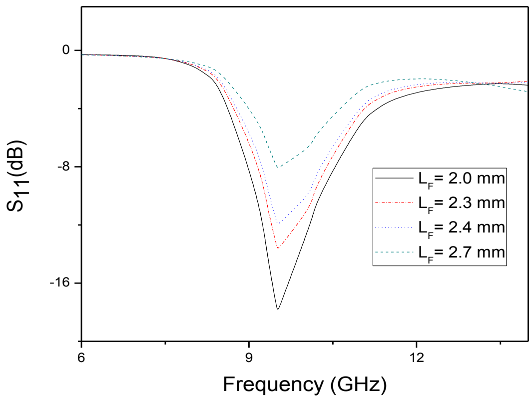

Fig 5. . S_{11} of proposed antenna with different Probe position

From Figure 6. the 3D Polar plot depicts that the Axial Ratio of the antenna is 0dB.Axial Ratio is the ratio of the maximum magnitudes of the y and x components of instantaneous radiated electric field (E_y and E_x respectively).

Axial Ratio = (E_y / E_x)

For circular polarization,Axial ratio is 1(0dB).

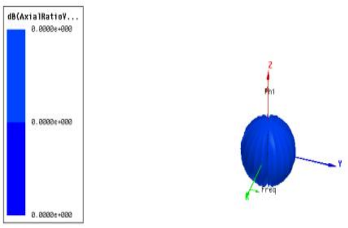

Fig 6. 3D Polar plot for Axial Ratio of the antenna

Figure 7. shows that the GainTotal for the antenna is approximately 7.45dB.GainTotal of the antenna is the gain we account with respect to the total Electric field density including both of RHCP and LHCP.

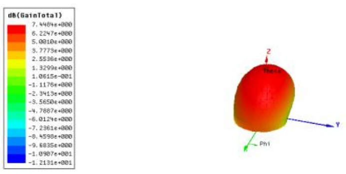

Fig 7. 3D Polar plot for GainTotal of the antenna

The simulated radiation patterns in xz plane (ϕ=0^o) and yz plane (ϕ=90^o) at 10GHz are shown in Figure 8(a). and (b). respectively.Boresight radiation patterns can be obtained.

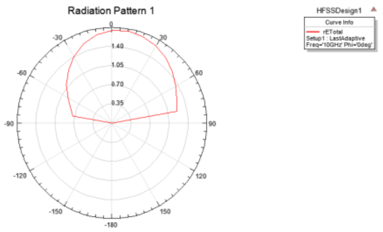

Fig 8(a). Radiation pattern of the proposed antenna at 10GHz at ϕ=0^o

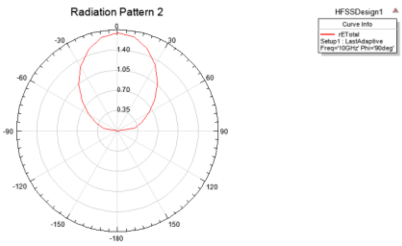

Fig 8(b). Radiation pattern of the proposed antenna at 10GHz at ϕ=90^o

Figure 9 shows the surface current flow on the proposed microstrip patch antenna.The shorter arm of the E-patch generates higher orthogonal mode providing shorter surface current and the circles at the end of the slots make the electric fields on the slots uniform.Thus the circular reformations enhance the impedance bandwidth of the circularly polarized E-shaped patch antenna.

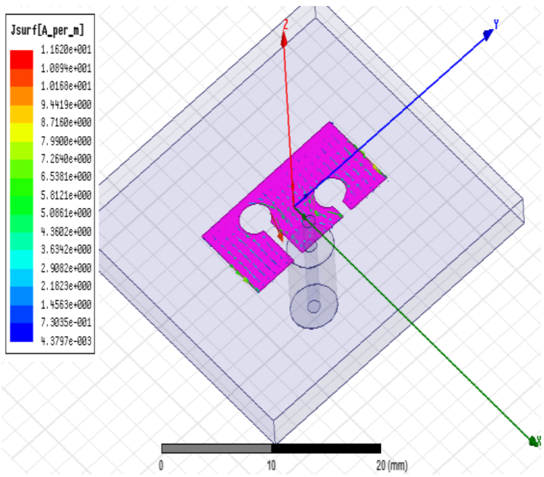

Fig 9. Surface current flow on the proposed microstrip patch antenna.

4. CONCLUSION

Compact sized circularly polarized Ultra Wideband microstrip antenna has been proposed with single-feed single-layer structure.These antennas are simple and easy to fabricate.They do not need larger space or any external circuitry like multi-layer,multi-feed or sequential-feed configurations.The simulated result illustrates that a small change by varying the size of ground plane can also give change in impedance bandwidth of the proposed compact sized antenna. An effective impedance bandwidth of 12% at a minimum workable return loss of -10dB was obtained (9.15-10.27GHz) for the proposed compact sized antenna.The radiation patterns and total gain (7.45dB) are stable across the passband. Due to the wide bandwidth, the proposed antenna can be considered in cost effective Ultra Wideband applications such as communication systems with broadband and spread spectrum features in radar systems. The simulated results can be used for the fabrication of the proposed antenna.

However, The proposed compact structure can also be used for further enhancement of bandwidth.In the proposed compact structure, Defected Ground Structure (DGS) could be introduced for further enhancement of bandwidth by suppressing the cross polarized radiation of the antenna.

5. ACKNOWLEDGEMENT

I would like to thank Prof. S. K. Behera for his guidance and discussion.

6. REFERENCES

[1] C. A. Balanis, Antenna Theory: Analysis and Design, Third Edition,New York, John Wiley and Sons,2005,Microstrip Antennas,p.811.

[2] R. Garg, P.Bhartia, I.Bahl and A. Ittipiboon, Microstrip Antenna Design Handbook, Norwood,MA, Artech House, 2001,Microstrip Radiators,p.2.

[3] Ahmed Khidre,Kai Fong Lee,Fan Yang and AtefElsherberi,"Wideband Circularly Polarized E-shaped Patch Antenna for Wireless Applications",IEEE Antennas and Propagation Magagine,Vol.52,No.5,October 2010.

[4] Kin-Fai Tong and Ting-Pong Wong,"Circularly polarized U-slot antenna",IEEE Transactions on Antennas and Propagation,Vol.55,No.8.August 2007.

[5] Ka Yan Lam,Kwai-Man Luk,Kai Fong Lee,Hang Wong and Kung Bo Ng,"Small Circularly Polarized U-slot Wideband Patch Antenna",IEEE Antenna and Wireless Propagation Letters,Vol.10,2011.

[6] M. Albooyeh, N. Komjani and M. Shobeyri,"A novel cross-slot geometry to improve impedance bandwith of microstrip antennas",Progress in Electromagnetics Research Letters,Vol.4,63-72,2008.

[7] Baskaran Kasi,Lee Chia Ping and Chakrabarty,"A Compact Microstrip Antenna for Ultra WidebandApplications",European Journal of Scientific Research.January 2011.

[8] Anupam Kumar Yadav, Sabyasachi Mukhopadhyay, Pradip Kumar Yadav, "Performance Comparison between U Slotted and Dumbbell Slotted Shaped Rectangular Patch Antenna", IJAREEIE, Vol.4,Issue 4,April 2015.

[9] Ajay Yadav, Bhadrasheela Chauhan, Aanchal Jain, "Microstrip Symmetrical E-Shaped Patch Antenna for the Wireless Communication Systems", IJETAE, Vol.2, December 2015.