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A Circularly Polarized Square Patch Antenna with a Filter at 2.45GHz for Wireless Power Transfer

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***Abstract*—In the new era of designing of a novel circularly polarized (CP) antenna and a butterworth low pass filter at 2.45 GHz for wireless power transfer application. For new applications like WPT the antenna reducing its parameters such as dimensions weight to improve the results which is desired. In this paper a wideband CP antenna L slot antenna which is fed by the feed structure having the L shape and a butterworth low pass filter is discussed. This wideband CP is gained by truncating the one of the edge corner of the patch. The whole arrangement may introduce the quadrature phase difference between the orthogonal E and H fields, which results the generation of circularly polarized wave. The butterworth low pass filter is used to reduce the harmonics and give a best result. The antenna and filter are simulated on the High Frequency Structure Simulator (HFSS) software. The design is implemented using Roger's 3003 TM dielectric substrate having dielectric constant (ε_r=3) and h=1.524mm and resonate at frequency 2.45GHz.**

Keywords-CP, WPT, HFSS, Wireless Communication, SPS, LHCP , RHCP, Butterworth Low Pass Filter

I. INTRODUCTION

The concept of the WPT using microwave was come into picture, when W.C. Brown demonstrated his invention of lifting the helicopter without the fuel energy. The swift growth in the satellite communication has grown the rapid investigation in the field of planar antenna. These antennas are considering as the prompt choice for the design as they are low profile, lighter in weight and low cost. The CP is the common polarization method used in the wireless communication such as WPT, SPS (Space Power Satellite) radar and satellite as they have best weather penetration ability than the linear one. Some basic CP antennas are microstrip spiral dielectric resonator and slots. The basic magic behinds the circular polarization is to excite the two orthogonal E& H field components with equal amplitude but quadrature phase difference. The substrate considered to be having low dielectric constant as to increase the maximum radiation in desired direction. The butterworth LPF is basically used to reduce the non-wanted signals which may reduce the efficiency of the system. The Butterworth filter mainly used as it will have the maximally flat response. In this design a square patch antenna is designed with the dielectric substrate Roger's 3003TM, the structure simulated on the HFSS platform and the parameters are calculated. In order to verify the polarization we calculate the gain LHCP and gain RHCP in dB, the value which have the greater positive magnitude shows the polarization as it is LHCP or RHCP and the graph between Axial Ratio and frequency as (Axial Ratio<3dB) show the overlapped bandwidth in which the antenna behaves like the CP. To achieve the wide axial ratio, one of the method is to make all the structure in such a manner that they have arrange sequential rotation array configuration, due to this the AR BW is increased up to 20% and more, but for this we have wideband power divider which is not suitable for some application such as satellite communication and this may also increase the complexity in the design. In this wideband CP slot antenna with L shaped is modified from the design in [5] which have the asymmetric L-slot designed on square metallic layer. In our design a symmetric L-slot, this is designed on a metallic layer with truncated corner. A wider BW and more gain are achieved. As we know the antenna is characterized by its length, width, Input Impedance, gain and radiation pattern. Antenna and filter design are presented in section II and in the section III we have simulated results of the proposed design, in last section we have some parametric studies of proposed antenna and filter finally acknowledgement and conclusion is made.

A. Microstrip Feed Slot Antenna

The slot structure is made using narrow slots, by cutting the ground plane conductor. The antenna can be excited by microstrip lines which are etched on the dielectric substrate's bottom side resulting in a very compact structure. The main feature of a narrow width slot antenna is its flexible shape so that slot can be bent to any shape to accommodate it in the available space or achieves the desired polarization.

B. Butterworth Low Pass Filter

The main purpose of choosing the butterworth is as it has phase linearity, waveform distortion is minimum, for single input frequency rather than other type of filter. The magnitude of this filter deceases as operating frequency increases from zero to infinity; the transition band is more in butterworth.

II. ANTENNA AND FILTER GEOMERTY DESIGN

The structure of antenna is shown in fig.1. The antenna is designed on the dielectric material Roger's 3003TM having the dielectric constant ε_r=3 and thickness of 1.524mm with the

ISSN 2348 – 7968

loss tangent 0.0017. The patch structure is of square shape having dimensions (L) of 82mm and thickness of metal cladding is of 0.135mm. The upper left corner of the patch is perturbated and having length of (L_C=35mm). The L shape slot is designed on bottom layer of the substrate. The substrate is symmetric to Phi=135^o diagonal axis and having width of (W_S=54mm) and a length of(L_S=18.3) the lower right corner of the slot is (a= 14mm) from the lower right corner of the substrate, the feed line is also have the L shape which is designed on the upper layer of the substrate. The feed line having the two side one is the vertical side (wider side) which have the dimensions L_H=18mm and W_H=2mm and horizontal side (narrow side) have the dimension of L_X =14mm and width of W_X =1mm L_L=29mm and W_L=2mm. The Feed Line is designed in such a way that it will achieve the maximum BW at the horizontal side of the feed line, there is a cylindrical coax is place, so that feed line and the radiating patch is properly connected. As we know that the maximum radiation in slot is bidirectional i.e. it may radiate the RF wave in major lobe as well as in side lobe and in back lobe around the slot. So to overcome this disadvantage or to increase the radiation in one particular direction i.e. in major lobe side so that the gain , efficiency and HPBW is increase so we use a metallic reflector of the dimension same as the patch placed 25mm below the slot antenna . It also reduced the back lobe radiation; its position is just quarter wavelength (at 2.45GHz) below the slots.

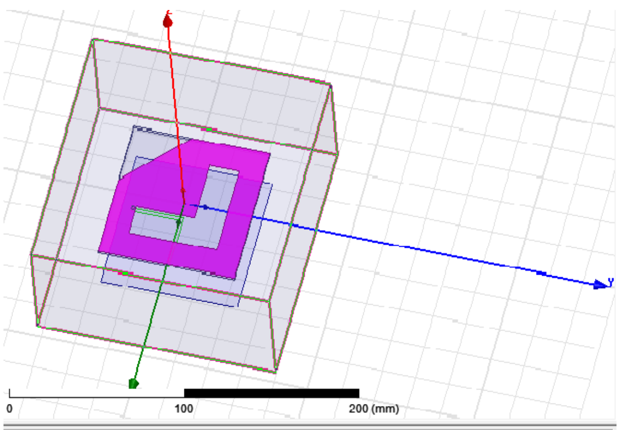

Fig.1. The Square Patch CP antenna structure.

In this we discuss the important parameters through which we design our structure for a particular application.

C. Choice of Substrate

As in different design the different materialis used to design the structure . The dielectric constant of substrate affects the antenna performance as a thick dielectric substrate which has a low dielectric constant will give better radiation then the substrate has a high dielectric constant as

$$BW \, \alpha \text{ antenna dimension}$$

$$BW \, \alpha \, \frac{1}{\in_r}$$

D. Choice of Feed Type

The antenna can be excited by mainly two type one is the Contacting feed and other is Non Contacting feed . In contacting feed there is two type ie. Microstrip feed and coaxial feed in these the Rf Power is fed directly to the patch by connect the feed and the radiating patch on other hand the non contacting feed also have the two type Proximity feed and Aperture coupled feed in these feed the RF Power is fed by coupling the feed and the radiatng patch. In our dsign we use the microstrip feed due to its advantage that it is etched on the same substrate to provide plannare structure.

A. The designing Equation For Slot

The Effective Dielectric constant and characteristic impedance of Feed line
W/h< 1

$$E_{reff} = \frac{Er+1}{2} + \frac{Er-1}{2}\left[\frac{1}{\sqrt{1+\frac{12h}{w}}} + 0.04\left(1-\frac{w}{h}\right)^2\right]$$

...(1)

$$Z_o = \pm\frac{60}{\sqrt{E_{reff}}}\ln\left(\frac{8h}{w}+\frac{w}{4h}\right) \ldots(2)$$

$$\frac{w}{h} > 1$$

$$\in_{eff} = \frac{\in_r +1}{2} + \frac{\in_r -1}{2}\left[\frac{1}{\sqrt{1+\frac{12h}{w}}}\right] \ldots(3)$$

$$Z_c = \frac{120}{\sqrt{\in_{eff}}} \frac{1}{\left[\frac{w}{h}+1.393+\left(0.677\times\ln\left(\frac{w}{h}+1.44\right)\right)\right]}$$

…..(4)

Where w= width of feed line

Characteristic Impedance of slot and Guided Wavelength of Slot

ISSN 2348 – 7968

$$Z_o = 60 + 3.69\sin\left[\left(\frac{\in_r - 2.22}{2.36}\right)\pi\right] +$$

$$133.5\ln\left(10\in_r\right)\sqrt{\frac{w}{\lambda_o}}$$

$$+2.81\left[1 - 0.011\in_r\left(4.48 + \ln\in_r\right)\left(\frac{w}{h}\right)\ln\left(\frac{100h}{\lambda_o}\right)\right]$$

$$+131.1\left(1.028 - \ln\in_r\right)\sqrt{\frac{h}{\lambda_o}} +$$

$$12.48\left(1 + 0.18\ln\in_r\right)\left[\frac{\frac{w}{h}}{\sqrt{\in_r - 2.06 + 0.85\left(\frac{h}{\lambda_o}\right)^2}}\right]$$

…(5)

$$\frac{\lambda_g}{\lambda_o} = 1.045 - 0.365\ln\in_r + \frac{6.3\frac{w}{h}\in_r^{0.945}}{238.64 + 100\frac{w}{h}}$$

$$-\left(0.148 - \frac{8.81\left(\in_r + 0.95\right)}{100\in_r}\right)\ln\left(\frac{h}{\lambda_o}\right) \quad \text{…(6)}$$

Where h= substrate height

W=width of slotBased on the antenna simulation results a filter has to be designed to reject the higher order bands. The filter order and the corresponding **‘g’** values are chosen from that of an elliptic function low pass prototype filter. These filter is decided to have a pass band cut off (Ωc)at 2.45 GHz and based on the below highlighted prototype values , it should provide Ω_s at 4.08 GHz and is of the order 7.that means the filter requires seven elements to design a low pass filter. The specification of the filter is as pass band cut off frequency is 2.45GHz and stop band cut off is 4.08GHzand maximum pass band attenuation is 0.003 dB and minimum stop band attenuation is -30dB, characteristic impedance is 50Ω, material used is Roger’s 3003 same used in antenna design.

The specification of the filter as this is a Stepped Impedance filter in which the series inductor and shunt capacitor is placed. The length of inductor and capacitor are calculated by these equations .

$$l_L = \frac{\omega_c L}{Z_H \beta} \quad (7)$$

$$l_C = \frac{\omega_c C Z_L}{\beta} \quad (8)$$

After calculating all the values of length and width with the help of line calculator we get

Impedance(ohm)	Width(W)(mm)	Length(L)(mm)
Z_l =18	14.9816	1.8025
Z_h =130	0.4503	6.259824
Z_l =18	14.9816	6.130908
Z_h =130	0.4503	6.4047
Z_l =18	14.9816	7.2987
Z_h =130	0.4503	5.3964
Z_l =18	14.9816	1.8025

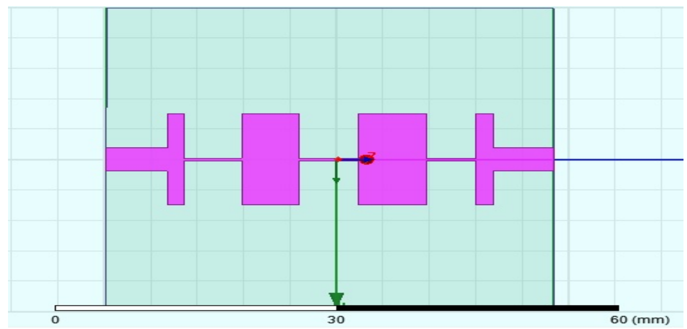

Fig.2. The Butterworth Low Pass Filter

And when we merge the filter on the input of the antenna to get maximum efficiency as the filter removes the higher harmonics at our center frequency i.e. 2.45GHz.

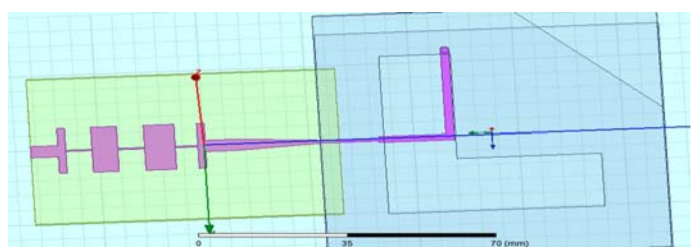

Fig.3. The Antenna with Filter

III. RES ULTS

The simulation is done on the HFSS version 14.0. The Return loss achieve at 2.44 GHZ is -36.6162 dB without filter and the Return loss with filter is-34.225dB. The VSWR of the antenna without filter and with filter is same i.e. 1.0375, but the main advantage of merging the filter with antenna is that the input impedance of antenna without filter is 60.51 Ω and with filter is 52 Ω , which near to the characteristic impedance. The Axial Ratio< 3dB which show the antenna is circularly polarized. The Peak Gain is 7.8464dB. As the magnitude of gain LHCP is negative i.e. -10 dB and the magnitude of the gain RHCP is positive i.e. 6.6287 dB, so the antenna attains the Right Hand Circular Polarization. The obtain graphs shows that the higher order harmonics which may decrease the efficiency of the system is remove.

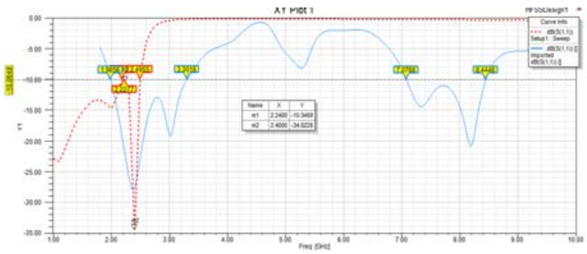

Fig.5. Combined frequency of antenna & filter in term of Return Loss

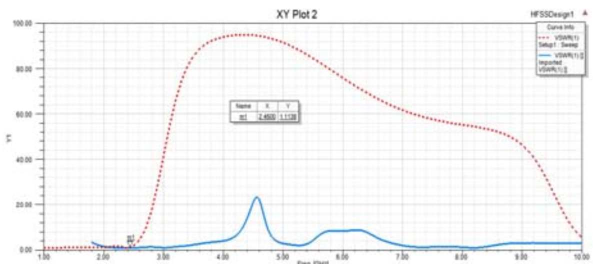

Fig.6. VSWR of antenna(dotted) and antenna with filter(solid)

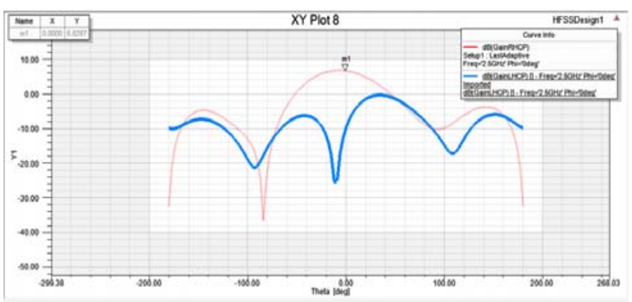

Fig.6. Gain LHCP and RHCP at 2.45GHz with Phi=0º

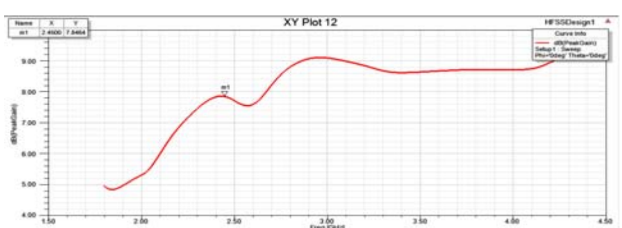

Fig.7. Peak gain of the Antenna

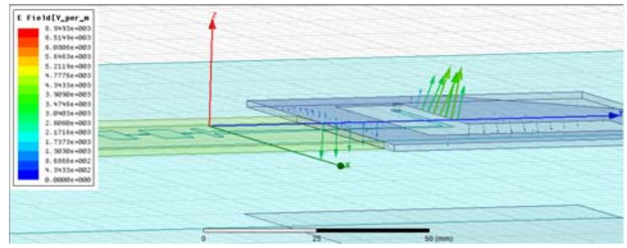

Fig.8. Vector E Field Patterns of antenna with filter

IV. Parametric studies

This is one of the practical interest so that the how the result of any of the designed structure is changed just by changing the value of any particular parameters.

E. Proliferate the truncated corner length(L_C)

If we change the dimension of the upper left perturbated corner, so the Axial Ratio of proposed antenna is change. So to have maximum AR we have to L_C =35mm. As the corner alters the flow of the current around the slots and engender the required Polarization. So as L_C <30 mm so the AR is not acceptable.

F. Proliferate the Slot Width(W_S)

The length of the horizontal feed line is changed as the width of the L slot is changed. The L slot Width is basically determines the lower resonant frequency of the antenna and it is half wave length long (for 2.45GHz =30.6mm).

G. Proliferate the Slot Length(L_S)

As the length of the slot is changed by any value the Return Loss is shifted. So we have to vary the length according to our requirement to shift the Return Loss to Our Resonant frequency. As we decrease the length, AR is shifted towards the lower frequency. The overlapped BW is also tuned by changing this parameter.

V. Conclusion

In this paper the use of L shaped slot and L shaped feed line structure and perturbated upper left corner, a wideband circular polarization antenna is designed. The various parameters of the designed structured is analyzed. The design has the Return Loss of -36.6162dB without filter and with filter -34.225dB, peak Gain is7.8464 and AR <3dB i.e.at 2.46 GHz the AR< 3 dB and overlapped BW ranges from 2.46GHz to 3.2GHz. So the antenna structure is design so that it is used as a receiving antenna in wireless power transfer application and many more wireless and satellite application. As the antenna is CP so it is capable to penetrate any weather condition. As the return loss is decrease slightly as we place the filter in front of the antenna but as the higher harmonics are decrease so the efficiency of the system is increase.

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References

[1] Shing-Lung, StevenYang, Ahmed A. kishk and Kai Fong Lee"WideBand Circularly Polarized Antenna with L shape Slot " IEEE TRANSECTION ON ANTENNA AND PROPOGATION,VOL., 56, NO.6, JUNE 2008.

[2] M. Haneshi and Y. Suzuki"Circular polarization and bandwidth", in handbook of Microstrip Antennas, London, U.K. :Peter Pereginus,1989, J. R. James, P. S. Hall.

[3] J.D.Kraus, Antennas 2nd ed. New York: McGraw-Hill, 1988 Chapter 7.

[4] R.Chair, S.L.S. Yang, a.a. kishk, K.L. Lee and K.M. Luk,"Aperture Fed Wideband Circular polarized rectangular stair shaped dielectric resonator antenna, "IEEE Trans. Antenna and Propag.,Vol.54. No.4, PP. 1350-1352, Apr 2006.

[5] T. Fukusako and L. Shafai,"Circularly polarized Broadband Antenna with L-shape Probe and Wide Slot,"in Proc. ANTEM/URSI,Jul.2006 pp.445-448.

[6] J Huang,"A Technique for an array to generate circular polarization with linear polarized elements," IEEE Trans. Antennas propag.,Vol.34 pp.1113-1124, Sep,1986

[7] Neenansha Jain , Anubhuti Khare, and Rajesh Nema "E-Shape Micro strip Patch Antenna on Different Thickness for pervasive Wireless Communication" International Journal of Advanced Computer Science and Applications, Vol.2, No.4, 2011.

[8] M. Habib Ullah, M.T. Islam, J.S. Mandeep and N. Misran "A new double L-shaped multiband patch antenna on a polymer resin material substrate" DOI 10.1007/s00339-012-7114-0, Springer 2012.