Circularly Polarized Rectangular Micro Strip Patch Antenna Design, Analysis for C Band Applications

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Abstract- Now a days the wireless communication system development requires the low cost, low profile, minimal weight antenna development which is accomplished of continuing great presentation completed a wide frequency range. This forward-looking abilities style has supported into the MSPA (Micro Strip Patch Antenna) plan. In this administrative work presents a working recurrence of 4.85 GHz roundabout polarization rectangular miniature strip fix radio wire is planned and mimicked. The proposed rectangular miniature strip fix reception apparatus is double miniature strip-edge-took care of circularly spellbound miniature strip radio wire. The proposed receiving wire can plan and invigorate Left Hand Circular Polarization (LHCP) and Right Hand Circular Polarization (RHCP) with utilizing cross coupler is straight associated with miniature strip radio wire to get polarization of round. The proposed paper work resonant frequency or operating frequency is 4.85 GHz which is mainly used for satellite communications, full-time satellite TV networks or raw satellite feeds. This operating frequency is the IEEE 802.11a version C band frequency and this C band frequency is also used in Wi-Fi devices and Radio LAN. The proposed roundabout polarization rectangular miniature strip fix receiving wire on FR-4 (Flame Retardant and type 4) epoxy substrate material thickness of substrate is 1.6 mm. The dielectric steady of FR4 epoxy is 4.4. The double miniature strip edge took care of round polarization rectangular miniature strip fix radio wire is planned and reenacted utilizing CSTMWS (Computer Simulation Technology Micro Wave Studio) programming. The thunderous or working recurrence of proposed reception apparatus presents at 4.85 GHz for remote correspondences that gives S boundaries (return misfortune), transmission capacity and radiation example of Gain and directivity.

Keywords: Dual-fed, Micro Strip, Circular Polarization, FR-4, TV, LHCP, RHCP, CSTMWS, Gain, Bandwidth.

Introduction

The primary research development satellite technology at Telkom University is involvement on INSPIRE program (Indonesian Nano-Satellite Platform Initiative for Research and Education) (R. H. Chen, 2008). From this involvement, we endure the improvement of satellite system. It is fashioned by students team, lecturer, and collaborate with INSPIRE, LAPAN, ORARI, and AM SAT Indonesia (Syihabuddin, 2011). The primary generation is called TelUSA n, a nano satellite with Remote Sensing Payload (RSPL) mission using optical system. The second generation is called Tel-USAT2 with RSPL Remote Sensing Payload (RSPL) mission using SAR (Synthetic Aperture Radar) as the payload.

A wireless local area setup is a small space communication system greatest frequently used for connecting two or more wireless strategies inside an incomplete assortment (P. A. H. Vardhini 2016). WLANs follow the IEEE802.11 principles which have so far recorded the frequency use in band i.e., 4.85 GHz. The elementary WLAN construction includes of the wired LAN setup, wireless strategies and a contact point which performances as bond between the two. Higher the gain of the antenna additional will be the variety that can be protected. Hence, high gain antennas production vital role in WLAN applications (Prakasam, V. 2018). The proposed antenna has good gain and bandwidth. In interpretation of the above truths, we future the design and simulation of high gain dual-fed circularly polarized rectangular micro strip patch antenna with left half and right half circularly polarization in the present work.

Circular Polarization

The waves are travelling in positive z-direction, the electric field components in x direction and y direction (Krauss, J. D., 1988) are $E_x = E_1 \sin(\omega t - \beta z)$ and $E_y = E_2 \sin(\omega t - \beta z + \delta)$; where E_1 and E_2 are wave magnitudes linearly in x and y directions and δ is the angle of phase. Combining the above two equation we get total electric field expression $E = E_1 \sin(\omega t - \beta z)\, a_x + E_2 \sin(\omega t - \beta z + \delta)$ ay. When the is polarized circularly, the x and y direction magnitudes are equal and $\delta = \pm\pi/2$ [3]. For left hand circularly polarized wave, the phase angle δ is $\pi/2$ and for right hand circularly polarized wave, the phase angle δ is $-\pi/2$ (Krauss, J. D., 1988).

Design Aspects of Dual-Fed (MSPA)

In order to design any MSPA, we need some set of parameters. The first and foremost thing is operating frequency or resonating frequency f_0 or f_r, in this proposed work the resonating frequency is 4.85 GHz, the second thing is height of the substrate normally the height of the substrate (h) is consider as 1.6 mm and third thing is type of the substrate material, here the type of the dielectric substrate material value is 4.4 (Prakasam, V., 2019).

Formulation of MSPA (Dual-fed Antenna Design)

The design parameters of the proposed RMSPA are Operating frequency, f_r = 4.85 GHz. Generally, FR4 value varies from 4.3 to 4.7, here, ε_r = 4.4 and h or hs or Hs = 1.6 mm.

Step 1: The width of the patch antenna is given by $W = \frac{c}{2f_r\sqrt{\frac{\epsilon_r+1}{2}}}$ (1)

Where c is the velocity of light which is 3×10^{11} mm

Step 2: The length of the patch antenna is given by $L = L_{eff} - 2\times\Delta L$ (2)

Where, Effective length, $L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}}$ (3)

Where Effective Dielectric Constant, $\epsilon_{reff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}[1+12\frac{h}{W}]^{-1/2}$ (4)

The Length Extension, $\Delta L = 0.412h \times \left\{\frac{(\epsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\epsilon_{reff}-0.258)\left(\frac{W}{h}-0.8\right)}\right\}$ (5)

Step 3: Determine the ground plane width and lengths

Length of Ground plane, $L_g = 2 * L$; Width of Ground plane, $W_g = 2 * W$ (6)

Step 4: Determine the Feed line parameters

The length of feed line is Fi = 6h/2; Speed of light, C = $3*10^8$ m/s;

Z_i= 50 Ohms; Width of MS feed line, W_f = 2.932 (where, Z_i = 50)

Manual calculation of MSPA (Dual-fed Antenna)

Using equation (1), the calculation of proposed rectangular patch width is

$$W = \frac{c}{2f_r\sqrt{\frac{\epsilon_r+1}{2}}} = \frac{3\times10^{11}}{2\times4.85\times10^9\sqrt{\frac{4.4+1}{2}}} = 18.83\ mm \quad (7)$$

The calculation of h/W and W/h are $\frac{h}{W} = \frac{1.6\ mm}{18.83\ mm} = 0.085\ \ And\ \ \frac{W}{h} = \frac{1}{\frac{h}{W}} = \frac{1}{0.085} = 11.763$ (8)

The calculation of effective dielectric constant is $\epsilon_{reff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-1/2}$

$$\epsilon_{reff} = \frac{4.4+1}{2} + \frac{4.4-1}{2}[1+12\frac{1.6\ mm}{18.83\ mm}]^{-1/2} = 3.986 \quad (9)$$

The calculation of length extension is $\Delta L = 0.412h \times \left\{\frac{(\epsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\epsilon_{reff}-0.258)\left(\frac{W}{h}-0.8\right)}\right\}$

$$\Delta L = 0.412 \times 1.6\ mm \times \left\{\frac{(3.986+0.3)(11.763+0.264)}{(3.986-0.258)(11.763-0.8)}\right\} = 0.834 \quad (10)$$

The calculation of effective length is $L_{eff} = \frac{c}{2f_r\sqrt{\epsilon_{reff}}} = \frac{3\times10^{11}mm}{2\times4.85\times10^9\times\sqrt{3.986}}$

$$L_{eff} = 15.668\ mm \quad (11)$$

The calculation of proposed patch length is $L = L_{eff} - 2\times\Delta L$

$$L = 15.668\ mm - 2\times0.834\ mm = 14.0005\ mm \quad (12)$$

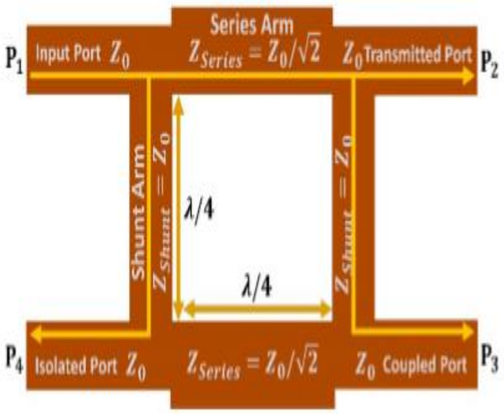
Design parameters of RMSPA

The above calculations can be represented below table. The table 1 shows the design specification of circular polarized rectangular MSPA antennas with corporate feed network.

Table 1 RMSPA Specifications and Proposed Dual-Fed Antenna Specifications

Description & Short Name	**VALUE**	**Description & Short Name**	**VALUE**
Operating frequency (f_r)	4.85 GHz	Port1 length (Lm_1)	8.841 mm
Dielectric Constant (ε_r)	4.4	Port1 width (Wm1)	0.2051 mm
Width of the patch (W)	18.83 mm	Port1 feed length (Lt_1)	8.214 mm
Length of the patch (L)	14.00 mm	Port1 feed width (Wt_1)	3.059 mm
Loss tangent (tanδ)	0 mm	Port2 length (Lm_2)	8.841 mm
Feed line width (W_f)	3.102 mm	Port2 width (Wm_2)	0.2051 mm
Feed line length (L_f)	8.302 mm	Port2 feed length (Lt_2)	8.214 mm
Input impedance	50 ohms	Port2 feed width (Wt_2)	3.059 mm

Directional coupler



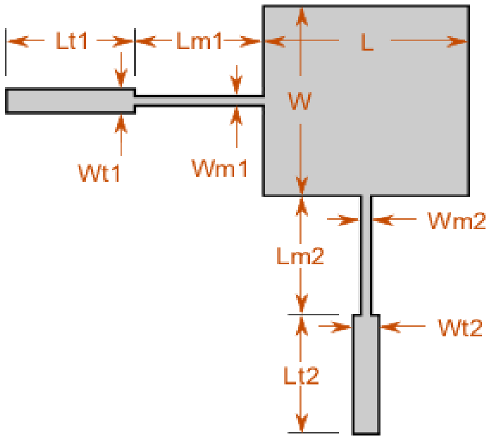


Figure 1 Conventional branch line coupler geometry. **Figure 2 P**roposed dual-fed antenna geometry.

The division streak cross coupler is a 3-dB directional coupler with a phase shift of 90 degrees between through outputs and coupled port and port number 4 is isolated port. The mathematical expressions are:

$$\frac{w_2}{h_2} = \frac{2}{\pi}\left[B - 1 - \ln(2B-1) + \frac{\varepsilon_r - 1}{2\varepsilon_r}\left\{\ln(B-1) + 0.39 - \frac{0.61}{\varepsilon_r}\right\}\right] \text{ And } \frac{w_2}{h_2} = \frac{8e^A}{e^{2A}-2} \quad (13)$$

Where $B = \frac{377\pi}{2z_0\sqrt{\varepsilon_r}}; \frac{w_2}{h_2} > 2$ & $1 = \frac{90^0(\pi+180^0)}{\sqrt{\varepsilon_{reff}*k_0}}$; $k_0 = \frac{2\pi f}{c}$; Where l is the hybrid length.

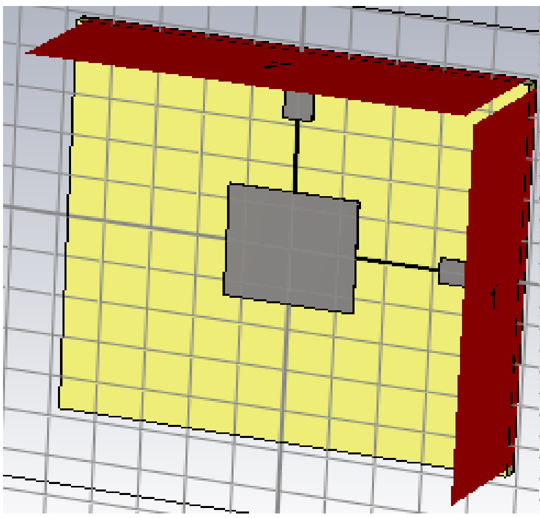
The branch line coupler s-matrix is given by

$$[S] = -\frac{1}{\sqrt{2}}\begin{bmatrix} 0 & j & 1 & 0 \\ j & 0 & 0 & 1 \\ 1 & 0 & 0 & j \\ 0 & 1 & j & 0 \end{bmatrix} \quad (14)$$

Design of Micro Strip Antenna Polarization

In circular polarization, the energy can be radiated into two planes that are horizontal plane and vertical plan. The left hand circular polarization can be defined as two signals or waves has equal magnitude values but 90^0 phase shift. In left hand circular polarization wave is rotating in anti-clock wise or counter clock wise direction. On the extra indicator, in the RHCP the wave is rotating in clock wise direction.

From the geometrical design view Lm1 is the port1 length which is the length of matching transmission line, Wm2 is the width of port 1 which is the transmission line width, Lt1 is the port 1 feed which is transmission line feed, Lm2 is the port2 length which is the length of matching transmission line, Wm2 is the width of port 2 which is the transmission line width, Lt2 is the port 2 feed which is transmission line feed.



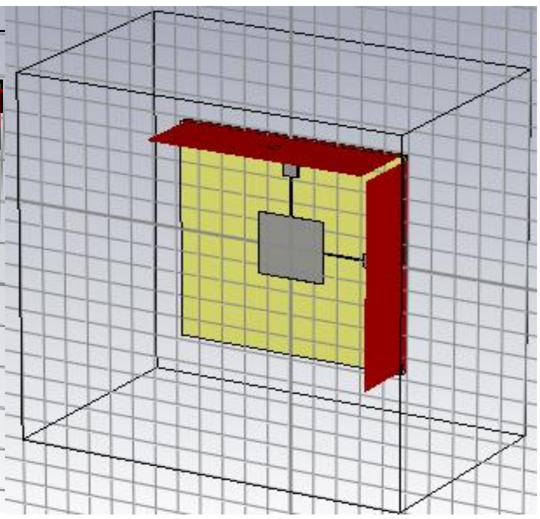


Figure 3 3D view Dual-Edge-Fed LHCP. **Figure 4** 3D view Dual-Edge-Fed RHCP.

The left-hand circular polarization and right hand circular polarization rectangular patch width and length are same that are 18.83 mm × 14.00 mm. The width and length of port 1 and port 2 are same, the feed line width and feed line length of port 1 and port 2 are same. The 3D view of dual-edge-fed LHCP rectangular micro strip patch antenna presented in figure 3. The figure 4 shows the dual-edge-fed RHCP rectangular micro strip patch antenna 3D view.

Simulation Results and Discussion

Present days, the design and simulation results are very important exercise to estimate the performance of system through software simulation tools before the real time execution. CST MWS simulator software supports to decrease the cost of fabrication since only the antenna through the greatest performance would be fabricated. Here, simulate and discuss the proposed antenna design performance, the reproductioneffects of s-parameter, bandwidth, gain and directivity are estimated at 4.85 GHz operating frequency. The proposed antenna has FR-4 epoxy substrate, which $\varepsilon_r \rightarrow 4.4$, thick ness of the substrate is 1.6 mm and 0 mm loss tangent. In this paper work, we select the minimum frequency range is 3 GHz and maximum frequency range is 7 GHz. Select the time domain solver parameters that are Mesh type is Hexahedral, Accuracy is -40 dB, Source Type is all ports, Mode is all type, normalized to fixed impedance value is 50 ohms and finally click the start button.

S Parameters

The general representation of scattering parameter is S_{ij}. In this general representation, the first subscript indicate the output of the port and second subscript indicate the input of the port. The theoretical reflection coefficient value should be not more than -10 dB. In this paper work the reflection coefficient (S_{11}) value is -15.985891 dB at 4.85 GHz, this return loss value delivered at port 1 when the input is applied at port 1. The insertion loss (S_{21}) value at port 2 is -14.13546 dB at 4.85 GHz when the input is applied at port 1. According to return plot or reflection coefficient plot for LHCP has excellent value than -10 dB in the selected operating frequency. The return loss plot of dual-edge-fed LHCP is shown in figure 5. From the LHCP return loss plot maximum return loss output value at port 1 is -16.35 dB at 4.86 GHz and at port 2 is -14.497 dB at 4.84 GHz.

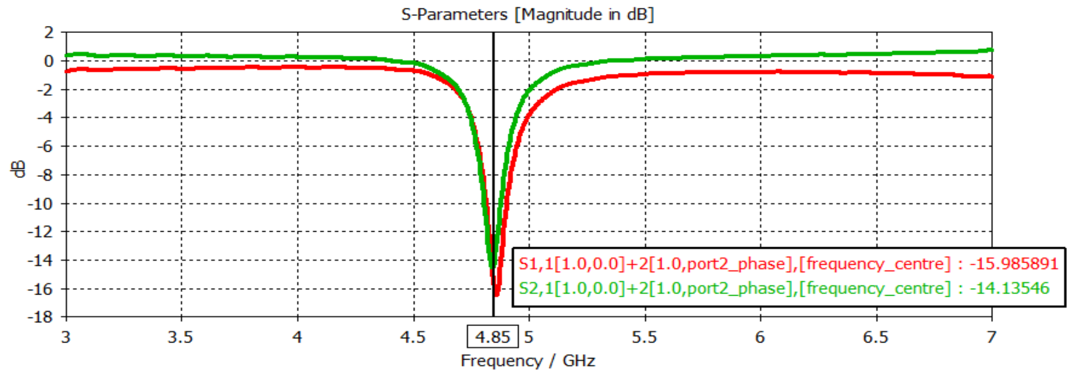


Figure 5 Return Loss plot of dual-edge-fed LHCP

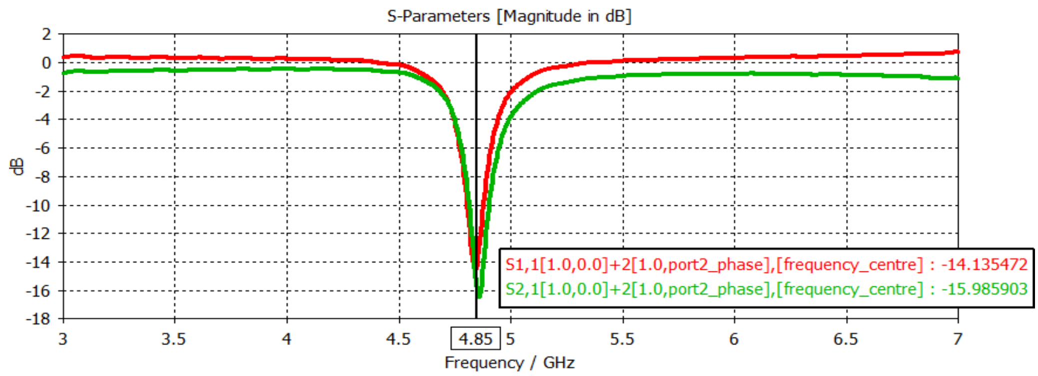


Figure 6 Return Loss plot of dual-edge-fed RHCP

The proposed dual-edge-fed rectangular micro strip antenna delivered at port 1 when the input is applied at port 1. The insertion loss (S_{21}) value at port 2 is -15.985903 dB at 4.85 GHz when the input is applied at port 1. According to return plot or reflection coefficient plot for right hand circular polarization has excellent value than -10 dB in the selected operating frequency. The return loss plot of dual-edge-fed RHCP is shown in figure 6. From the RHCP return loss plot maximum return loss output value at port 1is -14.471 dB at 4.83 GHz and at port 2 is -

16.363 dB at 4.86 GHz. Simulation part is done. The S_{11} value is -14.135472 dB at 4.85 GHz, this return loss value.

Table 2 Return loss for LHSP and RHCP

Frequency in GHz	Type of Circular Polarization	Input	Output Port 1 (RL) & Port 2 (IL)
4.85	Left Hand	Port 1	-15.985891 & -14.13546
4.86 & 4.84	Left Hand	Port 1	-16.35 & -14.497
4.85	Right Hand	Port 1	-14.135472 & -15.985903
4.83 & 4.86	Right Hand	Port 1	-14.471 & -16.363

Band Width

The % of bandwidth is given by $BW = \frac{f_H - f_L}{f_c} * 100$------ (15)

From the LHCP bandwidth plot the return loss value is -15.985891 dB at 4.85 GHz, the lower cut-off frequency value is 4.8415 GHz at -10.001 dB, upper cut-off frequency value is 4.9036 GHz at -10.008 dB and bandwidth and % of bandwidth is 62.1 MHz and 1.2804 %. The bandwidth plot of dual-edge-fed left hand circular polarization micro strip patch antenna as shown in figure 7.

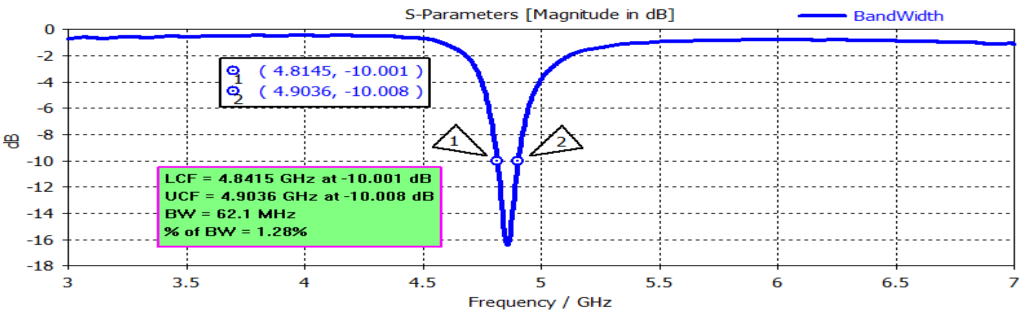


Figure 7 Bandwidth plot of dual-edge-fed LHCP.

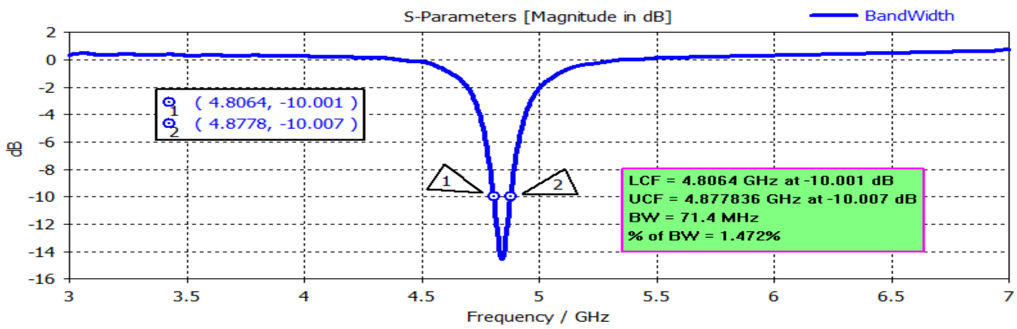


Figure 8 Bandwidth plot of dual-edge-fed RHCP.

From the RHCP bandwidth plot the return loss value is -14.135472 dB at 4.85 GHz, the lower cut-off frequency value is 4.8064 GHz at -10.001 dB, upper cut-off frequency value is 4.8778 GHz at -10.007 dB and bandwidth and % of bandwidth is 71.4 MHz and 1.4722 %. The bandwidth plot of dual-edge-fed right hand circular polarization micro strip patch antenna is as shown in figure 8.

Table 3 Band Width and % of Band Width for LHSP and RHCP

Frequency in GHz	Type of Circular Polarization	Band Width	% of Band Width
4.85	Right Hand	71.4 MHz	1.4722 %
4.85	Left Hand	62.1 MHz	1.2804%

Smith Chart

The smith chart plot of dual-edge-fed LHCP and RHCPMSPA as shown in figure 9.

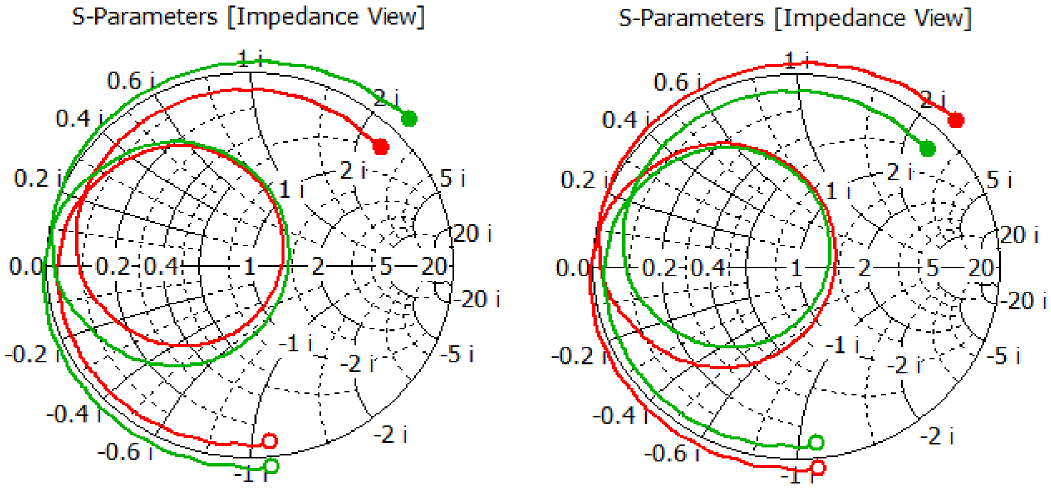
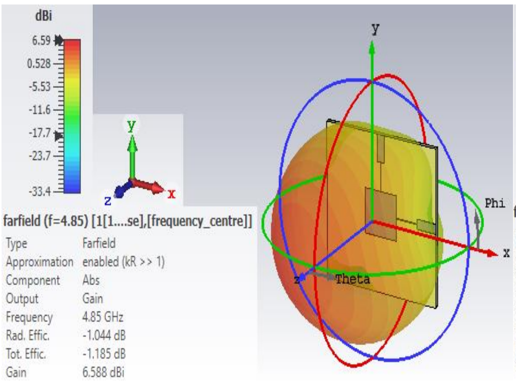


Figure 9 Smith chart plot of dual-edge-fed LHCP and RHCP.

Far Field Gain and Directivity

The 3D far field gain radiation pattern and directivity radiation pattern of dual-edge-fed LHCP and RHCPMSPA are shown in figure 10 to figure 13. According to figure 10, the far field gain is 6.59 dBi at 4.85 GHz which is the gain of LHCP.



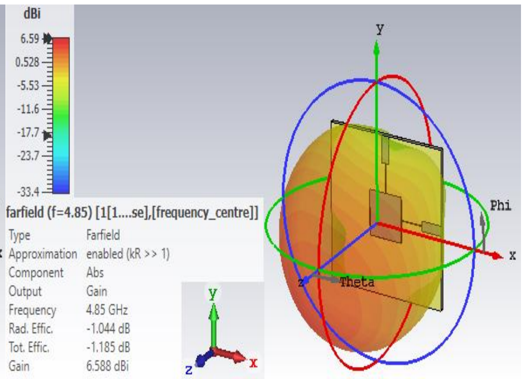


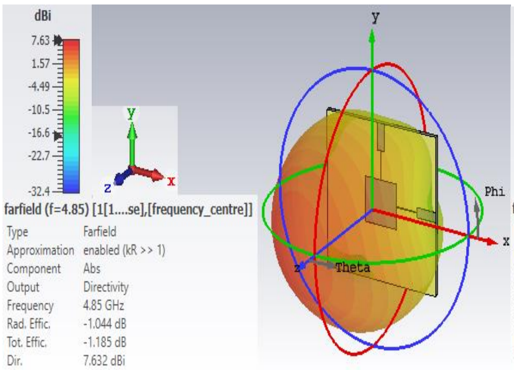
Figure 10 3D Far Field Gain for DEF LHSP. **Figure 11** Far Field Gain for DEF RHSP.

According to figure 11, the far field gain is 6.59 dBi at 4.85 GHz which is the gain of RHCP. According to figure 12, the far field directivity is 7.632 dBi at 4.85 GHz which is the directivity of LHCP. According to figure 12, the far field directivity is 7.632 dBi at 4.85 GHz which is the directivity of RHCP. Observe the LHCP and RHCP figures, the simulated resultant gain and directivity value is same at the specified operating frequency. The proposed antenna gain and directivity is suitable for wireless communication requirements.

The 2D far field gain radiation pattern and directivity radiation pattern of dual-edge-fed LHCP and RHCP MSPA are shown in figure 14 and figure 15. According to figure 14 and figure 15, the foremost part extents are -15.0 deg. And -4.0 deg. And side lobe magnitudes are -12.7 dB & -15.3 dB.

Table 4 Gain and Directivity for LHSP and RHCP

Frequency in GHz	Parameters	LHCP	RHCP
4.85	Gain	6.59 dBi	6.59 dBi
4.85	Directivity	7.63 dBi	7.63 dBi
4.85	Radiation Efficiency	-1.044 dB	-1.044 dB
4.85	Total Efficiency	-1.185 dB	-1.185 dB



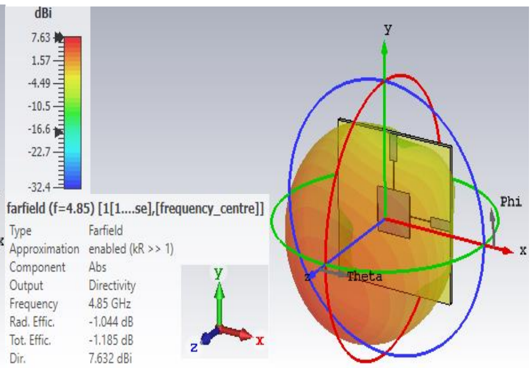


Figure 12 3D Far Field Directivity for DEF LHSP. **Figure 13** 3D Far Field Directivity for DEF RHSP.

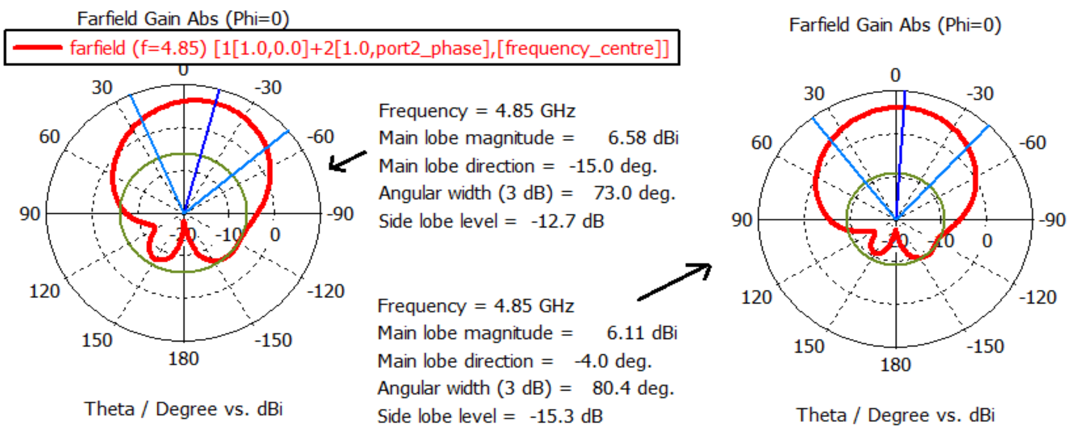


Figure 14 2D Far Field Gain Pattern of LHCP and RHCP.

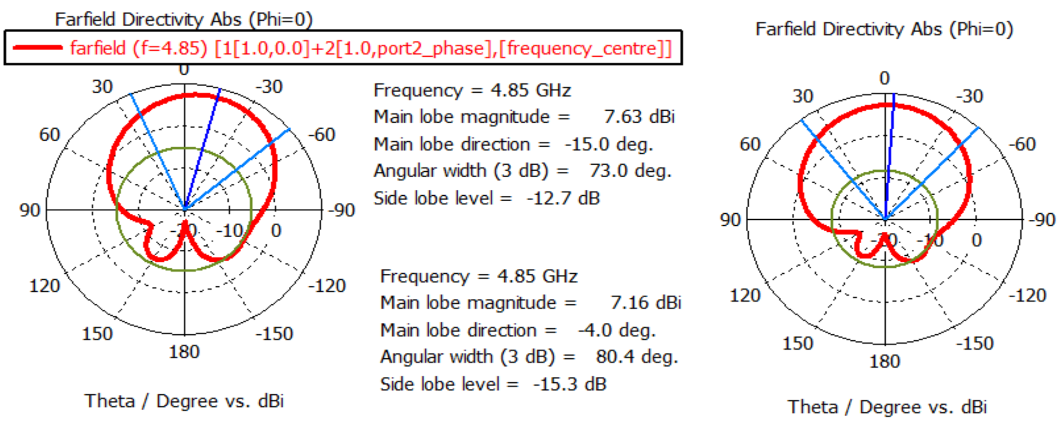


Figure 15 2D Far Field Directivity Pattern of LHCP and RHCP.

Conclusion

There are several categories of micro strip antenna arrangement that are stimulate a circular polarization. In this paper work, we planned a dual-edge-fed polarized rectangular micro strip antenna. This proposed structure has remained second hand for a wireless communications system at 4.85 GHz, the dual-edge-fed left hand and right hand circular polarization micro strip antenna is effectively simulated and got the excellent simulation results at specified operating frequency. The return loss value is -15.985891 dB, Band width is 74.1 MHz, gain value is 6.59 dBi and directivity is 7.632 dBi. According to this good results the circular polarization intellects varieties the proposed construction suitable for practical wireless communication applications needful circular polarization diversity.

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