INVESTIGATION OF SINGLE STAGE λ/4 TRANSFORMER MATCHING NETWORK TO THE X-CIRCULAR POLARIZED ANTENNA

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Abstract

This technical paper present 2 design of x-circular polarized with slanted rectangular slot microstrip patch antenna. 4 different circular polarized wave is feed by using single port in X-form is at 450, 1350, 2250 and 3150. The combination of 4 patches for design 1 is without using quarter wave impedance matching technique and design 2 refer to the design x-circular polarized with slanted rectangular slot microstrip patch antenna with single stage transformer. The designs are simulated using Computer Simulation Technology (CST) with dielectric constant, εr=4.3, loss tangent, tan δ=0.019 and thickness of substrate, t=1.6mm. The simulation results for ther return loss, bandwidth, gain, directivity and polarization have been compared. The λ/4 transformer matching network can improve the antenna performance especially the gain and efficiency.

Keywords: *About four key words or phrases in alphabetical order, separated by commas.*

I. INTRODUCTION

The development of wireless communication system has been rapidly growth in this era with increasing demand in the level of enhancement and performance. The concepts of Multiple Input Multiple Output (MIMO) system have been used since 1980's. They were first investigated by using computer simulation [1] and later many researchers explore about MIMO system [2]. In features, MIMO can be very important technology in wireless systems which is require high data rates such as wireless local area network(WLAN's), broadband wireless access network (WiMaX) and third and fourth generation cellular networks (3G and 4G) [1].

Most of the polarizations used in the wireless communication today are linear polarization, circular polarization and multi-polarization. Linear polarization can be obtained by using methods such as coupled patch, slot and single fed method [3] [4] [5]. Circular polarization can occur when two excitation signals of equal amplitude but have 900 phase shifted. Usually, circular polarization can be obtained by using techniques such as slot, double layer, aperture coupled patch, single feed and double feed method [6] [7] [8] [9] [10]. Dual polarization operation has been important in polarization diversity because the capability to enhance the system performance and combat multipath effect in wireless communication especially for wireless MIMO system. Design of compact dual polarized microstrip antenna fed by two probe feed has been reported by G.S. Row [11] and design of dual polarization using single port inset feed can been found in [12]. Polarization diversity is combination of antennas with orthogonal polarization either in horizontal or vertical combination, ±45 degree combination or left or right hand combination [13] [14].

II. DESIGN

A. Design 1 (without λ/4 transformer matching network)

Design 1 show the x-circular polarized with slanted rectangular slot without λ/4 transformer matching technique. *D* is diameter of the circular patch 15.58mm. The rectangular slant slot is placed at the center of the circular patch with length and width of the slot are L = 7.8 mm and w = 1 mm respectively. A_1 and A_2 is length and width of 50Ω microstrip feedline where A_1 is 43.7mm or equal to and A_2 is 3mm. While, B_1 and B_2 is transmission line length and width connecting the coaxial probe and 50Ω microstrip feed line. The optimized value of B_1 is 18mm and B_2 is 1.3mm.

B. Design 2 (with λ/4 transformer matching network)

Figure 2 below show antenna structure for x-circular polarized with slanted rectangular slot design together with λ/4 transformer matching technique. The x-circular polarized microstrip patch in Figure 2 used single feeding point of 50Ω coaxial port. The diameter of the circular patch, *D* is 32mm. Length of the 50Ω microstrip feedline, A_1 is 43.7mm or and width, A_2 is 3mm. Similar to Design 1, the center of circular patch consist of rectangular slot slanted at 450 with length of slot, l is 7.8mm and width slot w is 2mm. The microstrip transmission line is create to connect the probe feed and the λ/4 transformer at each branch. The optimized length, D_1 and width, D_2 of the microstrip transmission line is 16mm and 1.3mm respectively. In order to improve the impedance matching, B_1, B_2, C_1 and C_2 is quarter wavelength binomial transformer is implemented. B_1 is 2.2mm, B_2 is 16mm, C_1 is 1.1mm and C_2 is 16mm.

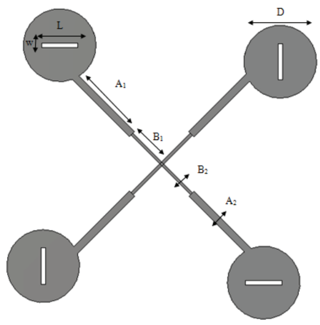


Figure 1: Antenna structure for Design 1

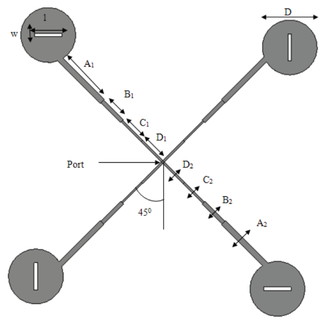


Figure 2: Antenna structure for Design 2

III. RESULTS

A. Design 1

1) *Return Loss*

Figure 3 show the return loss for x-circular polarized with slanted rectangular slot without matching network. The return loss obtained is not less than -10dB. Thus, the bandwidth for circular patch is 0MHz since the return loss is not more than -10dB for 90 % total efficiency.

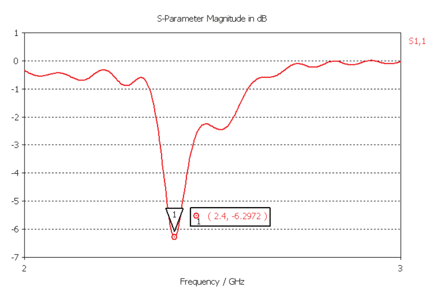


Figure 3: Return loss

2) *Gain and Directivity*

Gain and directivity of Design 1 is 5.5dB and 6.1dBi respectively. It can be seen that, the gain of the x-circular polarized antenna is bigger compared to the single patch circular polarized antenna. This may be due to mutual effect of each element at far field.

3) *Impedance and Total efficiency*

The input impedance for Design 1 is -23.47-j18.55Ω. Thus, the total efficiency for Design 1 is -1.9 dB which can be consider not at the best condition.

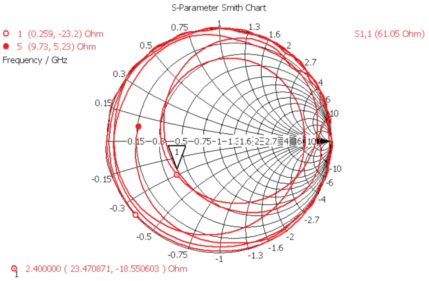


Figure 4: Smith chart

4) *Surface Current*

Figure 5 show a surface current which is the current flow through antenna at angle of 0^0, 45^0, 90^0, 1350, 225^0, and 315^0.

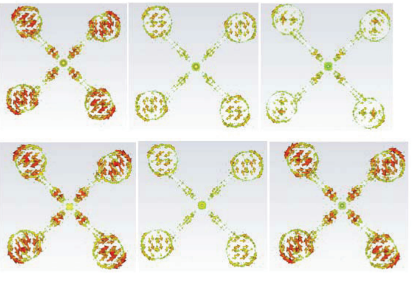
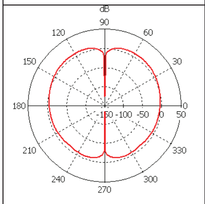
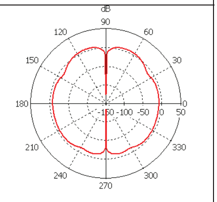


Figure 5: Surface current

5) *Radiation pattern*

Table 1 below show the radiation pattern for Design 1 at principle cutting plane of 0^0 and 90^0. The principle cutting plane of -45^0 and 45^0 which are align with feed direction also presented.

Table 1: Radiation pattern

0^0 & 90^0	45^0 & -45^0
	

B. Design 2

1) *Return Loss*

Figure 6 show the return loss for x-circular polarized with slanted rectangular slot plus λ/4 transformer matching network. The simulate return loss is -34.85dB and the bandwidth is 32MHz.

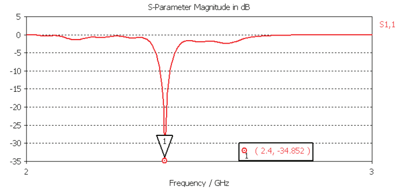


Figure 6: Return loss for Design 2

2) *Gain and Directivity*

The gain and directivity of Design 2 are 6.79dB and 7.54dBi respectively. Similar to Design 1, the gain of the x-circular polarized antenna with matching network give better gain compared to the single element design.

3) *Impedance and Total efficiency*

The input impedance for Design 2 is 63-j0.96Ω. Thus, the total efficiency for Design 2 is -0.76 dB.

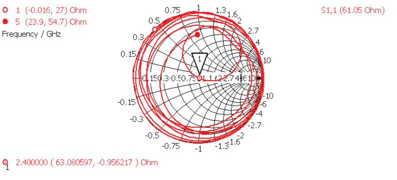


Figure 7: Smith chart

4) *Surface Current*

Figure 8 show the surface current flown through the patch antenna at angle of 0^0, 45^0, 90^0, 135^0, 225^0, and 315^0.

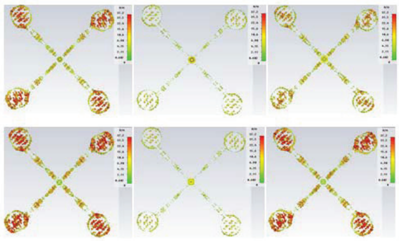
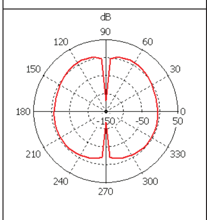
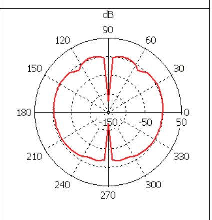


Figure 8: Surface current for design 2

5) *Radiation pattern*

Table 2 below show the radiation pattern for Design 2 with principle cutting plane of 00 and 900. The principle cutting plane at -450 and 450 are shown in Table 2 as well.

Table 2: Radiation pattern for design 2

0^0 & 90^0	45^0 & -45^0
	

IV. COMPARISON

Table 3 below show the comparison between x-circular polarized without matching and x-circular polarized with binomial matching network. The return loss for Design 2 is -34.85 which is better compared to Design 1. This is due to impedance matching improvement provide by $\lambda/4$ transformer matching network. So, more power can be deliver to the circular patches from the probe feed. The bandwidth for Design 1 is 0MHz because the return loss is not less than -10dB which is not achieve the requirement for good antenna performance. Design 2 have a better gain and directivity which are 6.78dB and 7.54dBi respectively compare to Design 1. Total efficiency for Design 2 is much better compare to Design 1.

Table 3 comparison between design 1 and design 2

Parameters	Design 1	Design 2
Return loss (dB)	-6	-34.85
Bandwidth (MHz)	0	32
Gain (dB)	5.5	6.79
Directivity (dBi)	6.1	7.54
Impedance (Ω)	-23.47-j18.55Ω.	63-j0.96Ω
Total efficiency (dB)	-1.9	-0.76
Polarization	Circular polarization	Circular polarization

V. CONCLUSION

Design 1 present x-circular polarized design without matching and Design 2 present x-circular polarized design with single stage quarter wave impedance matching. Both antenna was simulated and designed by using CST software at frequency 2.4GHz. Design 1 has gain and directivity of 5.5dB and 6.1dBi respectively. Total efficiency for Design 1 is -1.9dB. Thus, Design 2 have a good return loss which is -34.85dB and bandwidth of 32MHz. The simulated gain and directivity obtain are 6.79dB and 7.54dBi respectively. Total efficiency for Design 2 is -0.76dB. Overall, the performance of the x-circular polarized antenna with single feed probe can be improve by using $\lambda/4$ transformer.

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