Dual Circular-Polarized Slot Antenna Design for Wireless MIMO System at 2.4 GHz

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***Abstract*—This work proposed a dual circular-polarized slot antenna for wireless local area network (WLAN) application at 2.4 GHz. The proposed design is simulated by using FR-4 as is substrates. In this work, three stages of antenna had been simulated in CST Microwave Studio. First two antenna, Design *1-A* and Design *1-B* is containing a single polarized antenna with different feedline port location. An X-shaped structure is located at the middle of the patch at angle of 42.5 degrees. Then, dual feedline port antenna, Design *B1* are designed to create dual circular-polarized effect. The return loss S_{11} results at 2.4 GHz of Design *2-A* antenna are -21.511 dB and – 28.48 dB for simulation results and measurement results, respectively. For axial ratio for Port 1 and Port 2 are 0.63 and 1.12, respectively. In the end, the simulation and measured antenna design are compared.**

***Keywords*—wireless MIMO system, circular-polarized antenna, patch antenna, wireless LAN**

I. Introduction

Wireless communication plays an important role and obstructed people in numerous behaviours. People needs improve quality communication system for technologies with high data transmission rate is required such examples like voice call, video call and data.

In order to achieve improvement in communication system, the transfer speed of information need to be upgraded by increasing the data capacity where it can be achieved through the implementation of Multiple Input Multiple Output (MIMO) system. The MIMO system had been considered as a significant foundation to build the next and future generation of wireless network due to its advantages of high capacity and spectral efficiency.

The use of multi polarized antennas help to overcome space restraint in employing MIMO system due to big number of antennas. The lessen the multipath effect in wireless communication while to advance the system performance can be done by using dual polarized antenna that effect the polarization diversity. Several works on MIMO antenna had been shown in these papers [1-8].

There are many research work had been done on realizing circular polarization. For the first technique is use annular-ring slot antenna, shows in paper by Falade [9]. This antenna is created by from two truncated annular ring slots where the truncation in the inside patch attached with irregular stubs acquaint with the dual orthogonal mode. It shows the below 3 dB axial ratio bandwidth between 2.243 GHz - 3.253 GHz of frequency band.

The second technique is applying different two orthogonal port that feed to a single antenna design such in paper of Wang [10]. In this paper, the antenna is containing of two main part with the microstrip with dual lines ended with circular patches. In other hand, the H-shaped slots is positioned at the upper layer of the antenna. The main patch is on the highest aspect of third layer whereas the diverging patch is on the bottom of first layer.

Another technique is using three metallic layers broadband with circular patch, shown is al-Saedi [11]. At the top layer part, the circular part is acts as the radiating segment while and two altered L-shaped slots are stamped on the central ground. It shows that also every slot in the antenna creating a sense of circular polarization. At 30.0 GHz of frequency, the antenna displays a 3-dB axial-ratio of 13.9 %.

In other work by Torres-García [12], circular polarization had been creating by using a circular patch design by applying two feeds with equal amplitude with phase = 90^0 different. In this case, a 3-dB axial-ratio bandwidth of 100 MHz or 4% at midpoint frequency of 2.4 GHz are exist by the performance of the antenna design. There are others work that implement the circular polarized method in their patch antenna design, refer to these several papers – Theunis [13], Zainol [14], Asmeida [15], Rahim [16], Elshikh [17], and Ismail [18].

In this work, a step of different of a dual-polarized antenna design with blend of a dual circular polarization for wireless MIMO system had been done. The return loss (S11), resonant frequency, gain and radiation pattern of the antenna had been considered in this paper.

II. Antenna Design

This antenna is design by CST Microwave Studio. The dual-polarized antenna is design for wireless LAN at 2.4 GHz system with Port 1 and Port 2. The project is containing 3 different design of antenna Design *1-A*, Design *1-B* and Design *2-A*.

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The first two design of Design *1-A* and Design *1-B* is constructed on the previous work of the same authors, while the Design *2-A* is the improvement work that been done in this paper [11].

The design is start with the Design *1-A*, that contain of single circular-polarized slot antenna, shown in Figure 1(a). This antenna has a single feedline for Port 1 with 50 Ohm characteristics impedance. In order to get the circular polarization condition, a X-shaped patch is located into the middle of the slot of length, L_S at angle of 42.5 degrees and therefore the corners of the antenna area unit truncated.

The next design, Design *1-B* is showing the same shaped with Design *1-A* but with different location of the feeding method. In this case, 45^0 of feedline from the above part of truncated corner of the antenna are used. This single circular-polarized antenna is shown at Figure 1(b). At this time, the coaxial probe had been implemented as waveguide port to connect the feedline because this connecter cannot be positioned at the truncated corner in simulation situation.

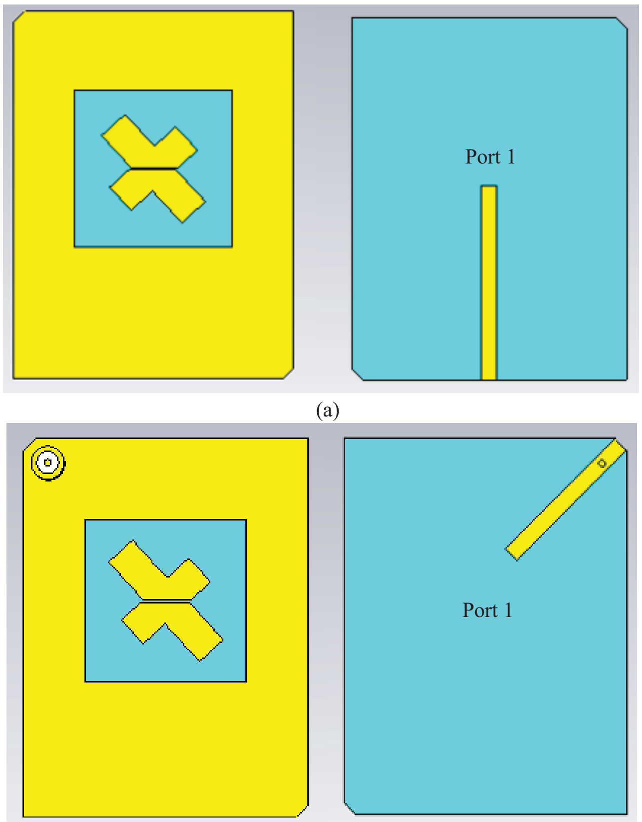


Figure 1: Antenna design (a) single circular-polarized slot antenna, Design *1-A*, (b) single circular-polarized slot antenna, Design *1-B*

The antenna structure of forward-facing view and opposite view of Design *2-A* is illustrated in Figure 2. Design *2-A* is a mixture of Design *1-A* and Design *1-A* with the combination of left-hand polarization and right-hand circular polarization system. In this design, different feedlines had been done with two different ports location to creates a dual polarized antenna. The dimensions of the X-shaped patch, size of the slot and the feedlines' is then optimized to achieve wanted frequency application of at 2.4 GHz with return loss is better than - 10 dB and axial ratio below targeted value of 3.0. Table I represent the optimum dimension of all antenna design.

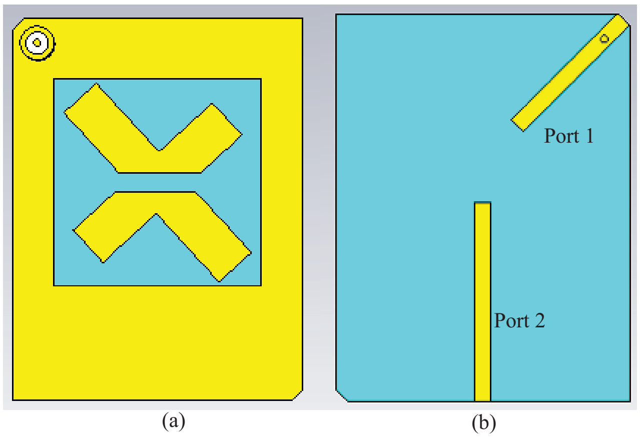


Figure 2: Dual circular-polarized slot antenna, Design *2-A* (a) Forward-facing view (b) Opposite view

TABLE I. OPTIMUM DIMENSIONS FOR DESIGN *1-A, 1-B* AND *2-A*.

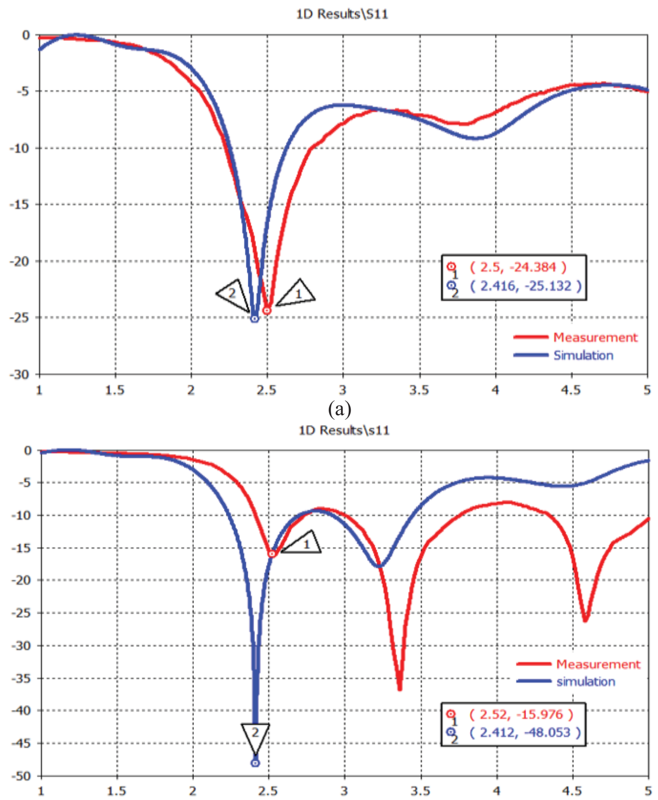
Parameter	Description	Value (mm)		
		1-A	*1-B*	*2-A*
W_s	Width of substrate	53	53	53
L_s	Length of substrate	70	70	70
W_f	Width of feedline	3	3	3
L_f	Length of feedline port 1	37.5	30	27
L_g	Length of feedline port 2	-	-	36
L	Length of square slot	30	30	38
W	Width of square slot	30	30	38
G	Gap	0.5	0.5	3.5
L_a	Length of long arm	30	30	42
W_a	Width of arm	6	6	8
L_b	Length of short arm	17	17	34.5

III. RESULT AND DISCUSSION

This segment comprises the several outcomes performances of the design, starting from the important parameter of return loss and resonant frequency. The other parameters are gain, axial ratio, radiation pattern and surface current.

The simulated reflection coefficient graphs in Figure 3 shows that all Design *1-A*, Design *1-B* and Design *2-A* accomplished resonant frequency near to 2.4 GHz by return loss better than – 10 dB where design *1-A* achieved 2.416 GHz while design *1-A* achieved 2.412 GHz. Design *1-B* has a better simulated reflection coefficient result with better return loss of - 48.053 dB as compared to that of design *1-A* and - 25.132 dB.

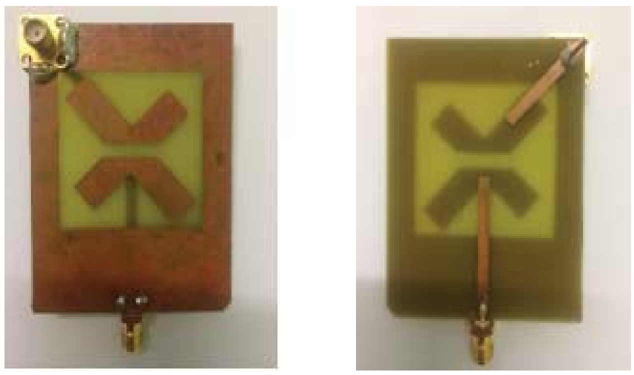
In addition, there is no substantial return loss graph pattern compared between simulation results and measurement results for Design *1-A* and Design *1-B*. Nevertheless, the measured return loss and resonant frequency graphs for Design *1-A* and Design *1-B* a little lifted to the right. The measured resonant frequency for Design *1-A* is 2.499 GHz, design *1-B* is 2.52 GHz. Both antennas for Design *1-A* and Design *1-B* achieved experimental return loss result improved than - 10 dB at their resonant frequency. Design *1-A* have a better experimental return loss of - 24.384 dB as compared to design *1-B* with - 15.976 dB only.



(b)

Figure 3: S_{11} parameter performance of the design (a) Design *1-A*, (b) Design *1-B*

The prototype (fabrication) of optimized dual circular-polarized antenna is shown in Figure 4. To achieve dual polarization by using a single antenna structure, two feedlines are fed by using two ports where both the ports shared the same ground.



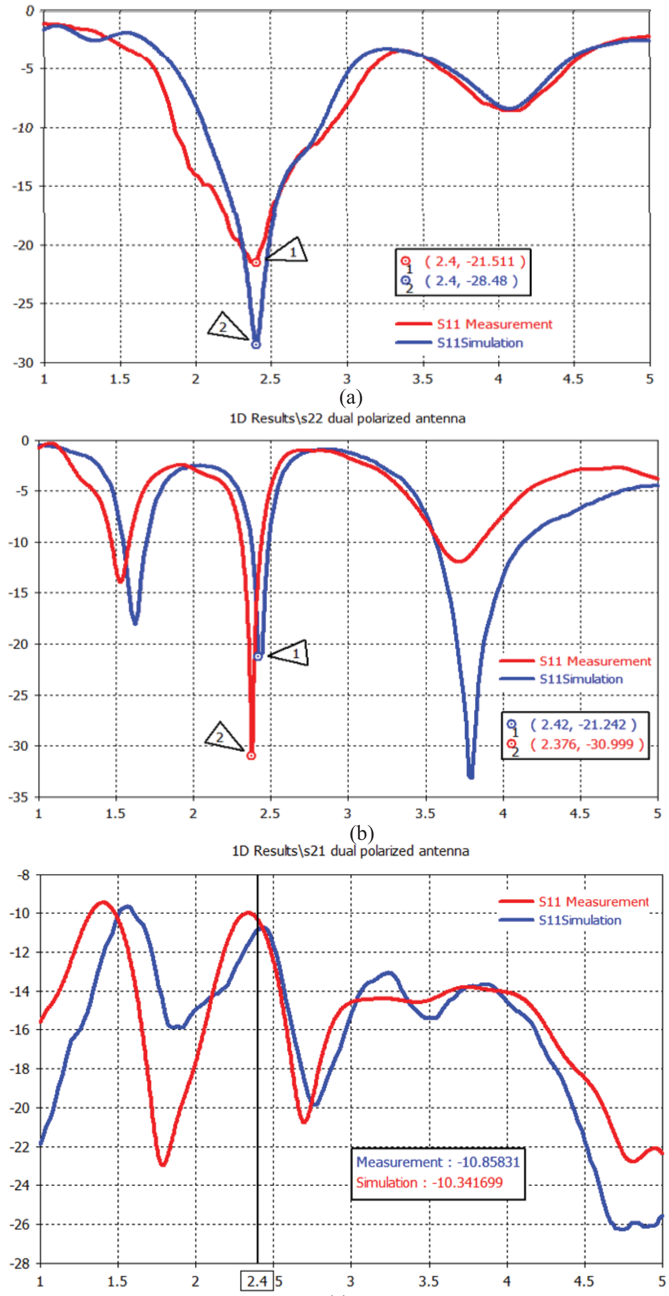
(a) (b)

Figure 4: Prototype of antenna Design B (a) Front view (b) Back view

In Figure 5, the simulation and measurement performance of the S_{11} parameter results for antenna Design *2-A* for Port1 and Port 2 are compared. Comprised on the simulated S_{11} and S_{22} outcomes, Port 1 managed to achieve resonant frequency at exact 2.40 GHz with return loss of -- 28.480 dB. Port 2 on the other hand achieved slightly at 2.420 GHz of resonant frequency with – 21.242 dB performance.

By comparing the simulated and measured results, there is no significant difference shown by the graph outline. The measured S_{11} results show that Port 1 managed to achieve same resonant frequency as the simulated results which is 2.40 GHz but with a wider bandwidth. However, the measured return loss for Port 1 is - 21.511 dB which is higher than that of simulated. On the other hand, the measured resonant frequency for Port 2 is slightly moved to the right on 2.42 GHz with performance - 30.999 dB of return loss.

Meanwhile, the simulated and measured S_{21} for antenna Design *2-A* is - 10.34 dB and - 10.86 dB respectively at frequency 2.4 GHz. The isolation between port 1 and port 2 is considered good as the it managed to achieve S_{21} of – 10 dB and below.



(c)

Figure 5: S_{11} parameter results of the antenna Design *2-A* (a) S_{11}, (b) S_{22}, (c) S_{21}

Table II shows the simulation and experimental results for antenna design *1-A*, *1-B* and *2-A* on return loss, resonant frequency, axial ratio and gain.

TABLE II. SIMULATION AND EXPERIMENTAL PERFORMANCE FOR ANTENNA DESIGN *1-A, 1-B* AND *2-A*.

Antenna		Resonant frequency	Return loss	Axial ratio	Gain
Design *1-A*	Simulation	2.416	- 25.132	1.21	3.15
	Measurement	2.499	- 24.384	NA	2.56
Design *1-B*	Simulation	2.412	- 48.053	0.90	3.95
	Measurement	2.520	- 15.976	NA	2.67
Design *2-A* (Port 1)	Simulation	2.400	- 28.480	0.63	2.66
	Measurement	2.400	- 21.550	NA	1.56
Design *2-A* (Port 2)	Simulation	2.420	- 21.242	1.12	2.56
	Measurement	2.376	- 30.999	NA	1.57

Figure 6 displays the simulated axial ratio graph for antenna Design *2-A*. The simulated axial ratio results show that all two ports is radiating in circular polarization at frequency 2.4 GHz as both ports achieved axial ratio below 3. The axial ratio for Port 1 is 0.63 while that of Port 2 is 1.12.

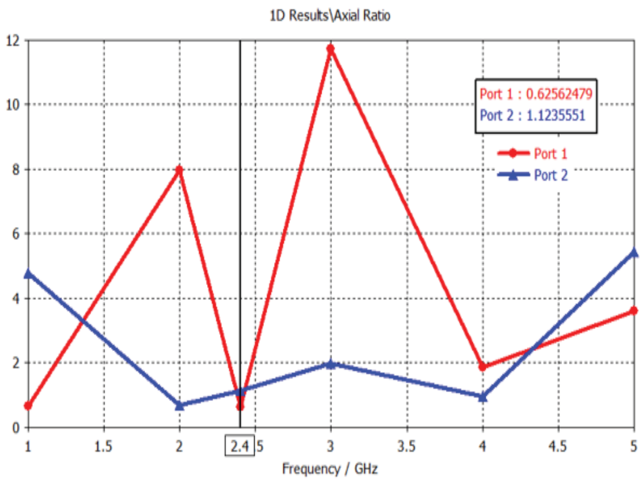


Figure 6: Simulated axial ratio for antenna Design *2-A*.

Meanwhile, the simulated gain results are shown in Figure 7 where both Port 1 and Port 2 achieved a similar gain at 2.4 GHz of resonant frequency. The simulated gain for Port 1 is 2.66 dB while Port 2 is 2.56 dB. However, the measured gain for both ports displays the values of – 1.56 dB and – 1.57 dB, respectively at the resonant frequency.

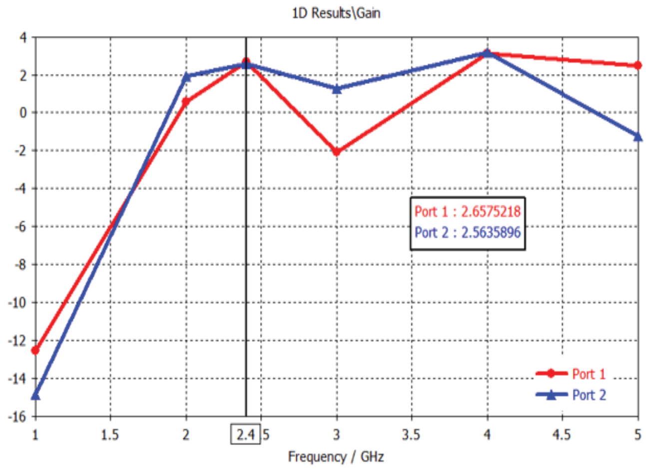


Figure 7: Simulated gain for antenna Design *2-A*.

The comparison between simulated and experimental in the lab for radiation pattern is shown in Figure 8. The radiation pattern is plotted in phi = 0 degree and 90 degrees. Based on the results, it is hard to compare the measured and simulated radiation pattern due to lack of similarity between the measured and simulated results. This might be caused by the interference in the testing environment. Figure 8 shows the radiation pattern for antenna Design *2-A*.

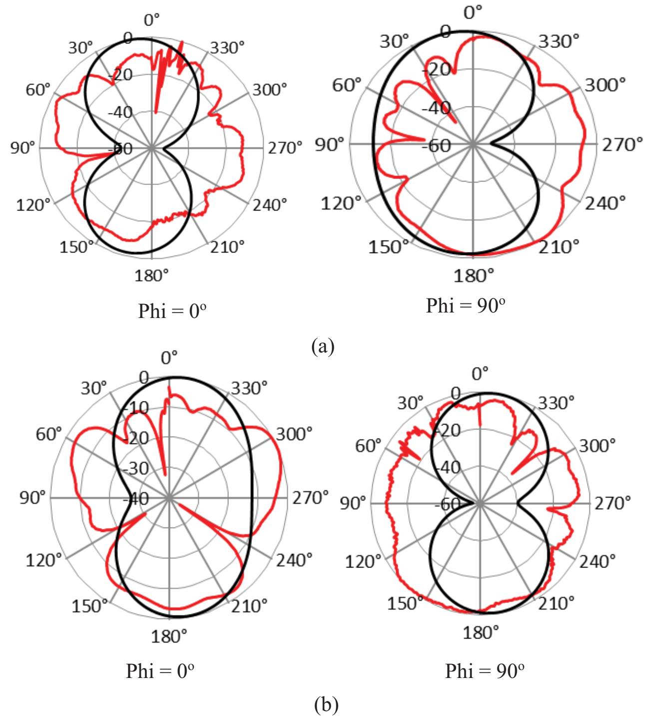


Figure 8: Radiation pattern for antenna Design *2-A* (a) Port 1, (b) Port 2

ACKNOWLEDGMENT

The authors would like to thank Universiti Teknikal Malaysia Melaka (UTeM), Melaka, Malaysia for supportive work in obtained the information and material in the development for our work. Thanksalso to Centre for Research and Innovation Management of Universiti Teknikal Malaysia Melaka (CRIM-UTeM) and the Ministry of Education, Government of Malaysia to support the fees for this manuscript by using a grant of

PJP/2017/FKEKK/HI13/S01542. Thanks also to Center for Telecommunication Research and Innovation (CeTRI), Faculty of Electronics and Computer Engineering (FKEKK), Universiti Teknikal Malaysia Melaka (UTeM). Lastly, we also thank the nameless referees, lecturer and other researcher whose explanations, consultation and observation led to an enhanced appearance of our projects.

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