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DESIGN OF DUAL BAND ANTENNA FOR WIRELESS MIMO COMMUNICATION SYSTEMS

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ABSTRACT
This paper presents the design of dual band antenna by using C-shape slot technique. There are three design of different combination C-slot. The antenna is design at operating frequnecy of 2.4 GHz and 5.2 GHz ISM band. All antenna are design based on microstrip structure element and simulated by using Microwave CST Studio software. Then, the designed antenna was fabricated on FR4 board with dielectric constant of 4.7 and tangent loss of 0.019. All antenna can work at dual band frequency band with 90 % efficiency. The Three shape slot design has the widest bandwidth at both frequency band. Besides that, C shape slot technique can reduce the physical size of the antenna up to 50 %.

Keywords: wireless MIMO system, compact antenna, slot antenna.

INTRODUCTION
High capacity is very crucial in wireless as it is required for future application. It is because; the data transferred by users are becoming larger nowadays. For example, in the early years the data transferred consists of only text or voice only. As time goes by, the user is demanding higher channel capacity as they wish to send voice with picture or text with video or text, picture, and video at the same time. These data are required more capacity to be transferred One of the main challenges in wireless communication is to gain high capacity in order to fulfil future application necessities. It is important in increasing the data transferred simultaneously. Today's channel suffers from attenuation due to multipath in the channel (Z. Daud *et al.,* 2008). The increasing demand for capacity in wireless systems has motivated considerable research aimed at achieving higher throughput on a given bandwidth. It is proven in (G. Stuber *et al*., 2004)(A. Nasr *et al*., 2006) that wireless communication systems using multiple antennas at both transmitter and receiver sides, denoted as Multiple Input Multiple Output (MIMO) antenna systems, enable great enhancements of channel capacity compared to the single input single output (SISO) system.

From (Z. Daud *et al.*, 2008) and (J. Winter 1987) (M. Ozdemir *et al*., 2003), it is mentioned that multiple antennas at both transmitter and receiver can improve the wireless channel capacity within the same bandwidth and power received. Besides improving performance in terms of higher channel capacity which enables a wireless device to transfer and receive data with higher data rate, MIMO also proven to reduce the multipath fading. Also, it is mentioned that multiple antennas are proven to introduce robustness against channel fading and interference.

Current communication devices are portable and multi-applications supported such as Bluetooth, Wi-Fi, GPS, and so much more. These applications are used different operating frequencies in order to avoid interferences between them. The conventional way to support this demand is by placing two or more antennas with different resonant frequency in that device. Clearly, this method is not efficient because integrating two or more antennas proves difficult as they are likely going to couple to each other causing degradation of the received or transmitted signals (M. Matsunaga *et al*., 2011).

Placing two antennas in a device also bring in the space issue since it is usually designed to be a portable device and by placing multiple antennas in the device required more spaces. Another way to support multi-frequency demand without facing any of those problems is by using multi-band antennas which consist only one simple structure antenna that can support dual frequency ranges and it is clearly being more efficient.

Another demand for current communication device design is to be compact in size and low-profile structure since nowadays communication devices are usually portable. It is very crucial to make sure the antenna size is compact enough since the size of the device are depends on the size of the antenna itself. Besides, as mentioned before, in MIMO system, at least two antennas for each operating frequency should be placed in the wireless device in order to support the requirement of the multi-application device. This is quite challenging since generally, according to (Q. Luo *et al*., 2010), placing two antennas at the distance of half wavelength is necessary to achieve good isolation. Then, if the antennas are in large size, more space required for the spacing and for the antennas itself which are not practical and inefficient. Then, an efficient antenna especially for MIMO application is an antenna that compact and can support multi-frequency operation.

ANTENNA DESIGN
There are several design steps that has been done in designing the multiband antenna in this project. Dual-band antenna which is Design A is designed first and the method approached in designing a dual-band antenna in this project is by embedding a pair of slots on the antenna's patch. There are several slot shapes that designed and studied and they are divided to three designs which are

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Design A1 (i), A1 (ii), and A1 (iii). All of the designs are founded by the shape of slot in Design A1 (i) which is C-shaped slots. Design A1(ii) is the Three-shaped slot which are double-up the C-shaped slots and Design A1(iii) is continuous from the Three-shaped slot, but instead of having the equal diameter at both upper and lower slots, this design has a different diameter of the upper and lower slot and produce a pumpkin-like shape, hence named as The Pumpkin-shaped slot.

Dual-band Antenna [Design A]

The method approached in this design is by embedding a pair of slots on the patch. The design of dual band is divided into Design A1, A2, and A3 based on their shapes. Each one of them consists several designs that investigated the performances.

C-Shaped Slot Antenna [Design A1 (i)]

The antenna structure of C-Shaped Slot Antenna and all other designs are similar to the basic rectangular patch antenna which consist patch, substrate (dielectric), and the ground plane and the material of each plane are also similar. The structure of antenna's geometry is as shown in Figure-1. From the Figure, there is a pair of slots that in C-shaped which gives the additional second frequency, then makes the antenna act as a dual-band antenna.

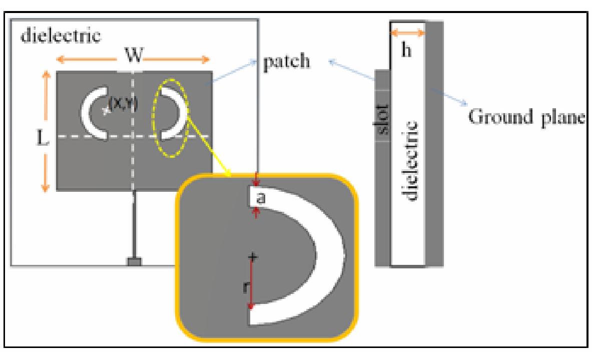

Figure-1. C-Shaped slot antenna design.

The effects of the antenna parameters such as the slot width and the slot radius, position of slots, and the separation between the slots are studied. But, in this section only the studies that give significant impact on the design presented, which are slot width, **a,** distance between slots, **x**, and the slot radius, r.

From Figure-2 and Figure-3, it shows that the parametric study of slot width and distance between slot respectively. The second resonance frequency, f2 tends to shift larger as the slot gets wider and as the slots get further from each other. The parameter of the slot width, a is studied from 0.5 to 2 mm, and the distance between slots, **x** is studied from 1 to 29.5mm as it is the minimum and the maximum value, but the result presented is the one that gives the significant impact on the result. In terms of return loss, it gets smaller as the slots get wider but, conversely become worse when the slots gets further from each other.

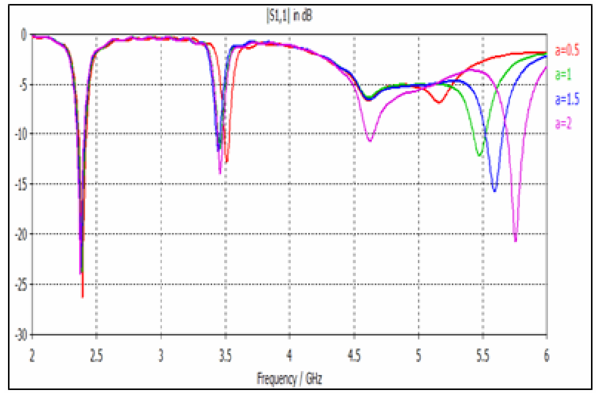

Figure-2. Parametric study of slots width, a.

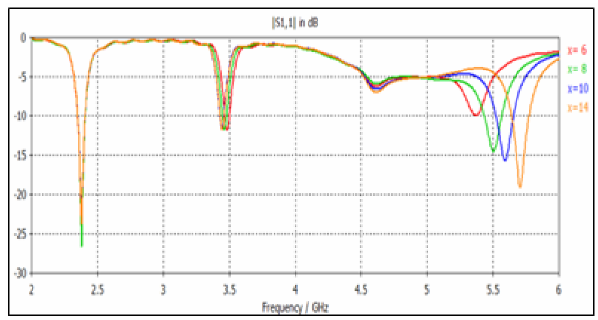

Figure-3. Parametric study of distance between slots, x.

Figure-4 represents the parametric study of radius of the slots, r that embedded on the patch. From the graph, it shows that as the slot radius, r increases, the second resonant frequency, f2 shifting to left, which is smaller, and the return loss becomes increases. The parameter studied included all values that possible, but radius of 3 to 7 mm gives the significance effects to the response. From all the studies, it occurs that all three parameters only affect the second resonance frequency, f2 while first resonance frequency, f1 remain constant or not much difference. Table-1 shows the summary of all three antenna parametric studies.

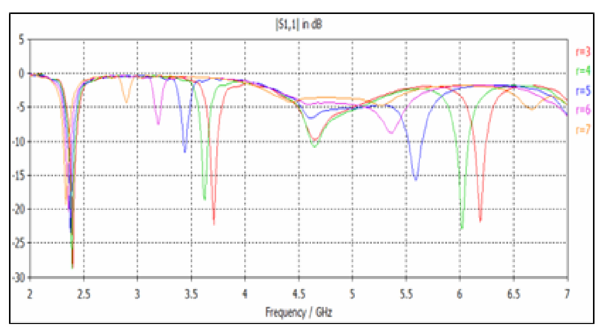

Figure-4. Parametric study of slot radius, r.

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Table-1. Summary of the parametric studies of design A1 (I).

Parameters		f1 (GHz)	Return Loss (dB)	f2 (GHz)	Return Loss (dB)
Slot Width, a (mm)	0.5	2.392	-26.33	5.158	-6.86
	1.0	2.386	-23.81	5.480	-12.13
	1.5	2.380	-23.38	5.590	-17.72
	2.0	2.374	-24.03	5.752	-20.77
Distance between Slots, x (mm)	6	2.380	-23.25	5.368	-9.94
	8	2.380	-26.69	5.500	-14.52
	10	2.380	-23.38	5.590	-15.72
	14	2.380	-23.78	5.704	-19.11
Slot radius, r (mm)	3	2.404	-28.59	6.190	-21.84
	4	2.392	-28.77	6.022	-22.86
	5	2.380	-23.38	5.590	-15.72
	6	2.356	-20.56	3.196	-7.57
	7	2.338	-19.34	2.896	-4.29

Three-Shaped Slot Antenna [Design A1 (ii)]

Three-Shaped Slot Antenna is the continuous design from the previous one as the shape of the slots is determined by combining two of the C-shaped slots in the previous design and creates a slot that looks like the shape of the number three. It also has the same structure and material used as the dielectric and conductor material which are FR-4 and copper respectively. Figure-5 shows the antenna's structure and in this design, all the antenna parameters that studied are the same as the Design A1 (ii). However, only two of them are considered giving the significance effects to the response, which are slot width, a and the slot radius, r.

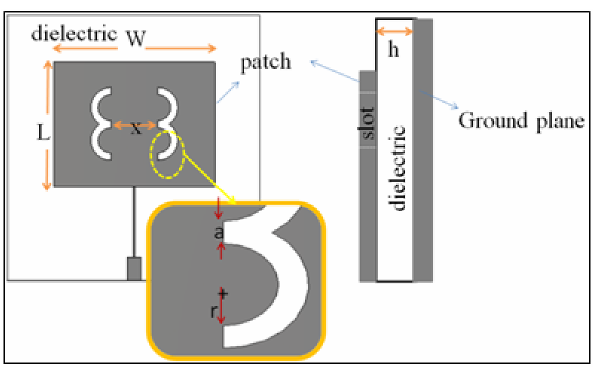

Figure-5. Three-shaped slot antenna design.

Figure-6 represents the analysis study of slot width, a that embedded on the patch and the studied are started with a equal to 0.5 until a equal to 2.0 mm. From Figure, it shows that as slot width increases, the second resonance frequency, f2 also increases, contrary to the return loss which decreases as the slots get wider.

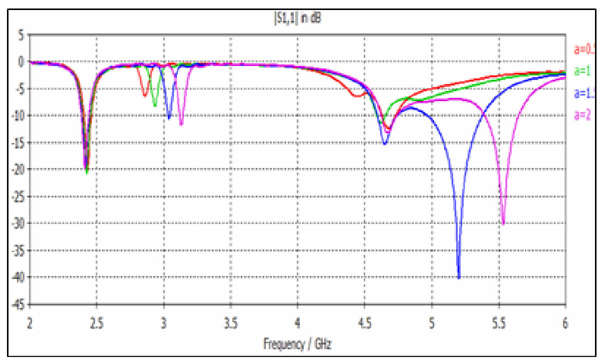

Figure-6. Parametric study of slots width, a.

Figure-7 shows the analysis study for the parameter of slot radius, r and from the Figure, it shows that the second resonant frequency, f2 will be increased as the radius increases. Noticed that the same effects occurred in the frequency of Design A1 (i). As for the return loss parameter, it will decrease as the slot radius, r increases. All parameters are affecting only the upper frequency and not much impact to the lower one. Table-2 shows the summary of all parametric studies.

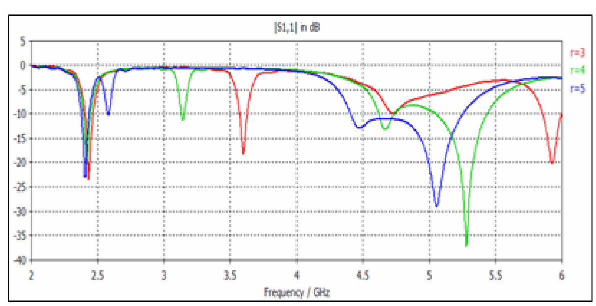

Figure-7. Parametric study of slot radius, r.

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Table-2. Summary of the parametric studies of design A1 (Ii).

Parameters		f1 (GHz)	Return Loss (dB)	f2 (GHz)	Return Loss (dB)
Slot Width, a (mm)	0.5	2.434	-20.35	4.678	-12.42
	1.0	2.428	-20.89	4.634	-11.38
	1.5	24.160	-19.72	5.200	-40.26
	2.0	24.160	-20.04	5.530	-30.35
Slot Radius, r (mm)	3	2.434	-23.60	5.926	-20.21
	4	2.422	-20.48	5.278	-37.30
	5	2.404	-23.08	5.056	-29.17

Pumpkin-Shaped Slot Antenna [Design A1 (iii)]

The Pumpkin-Shaped Slot Antenna is also the continuously design of the previous one which is Three-Shaped antenna. The only difference is the lower and upper part of the slot is not in the same radius which makes it looks like a pumpkin-shaped slot. This design has the same geometry of design structure and the same material used in the previous designs. Figure-8 shows the geometry of the design.

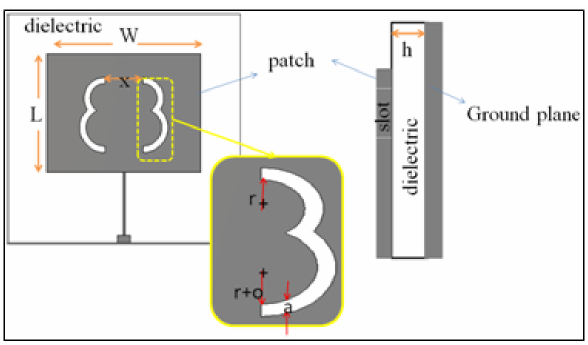

Figure-8. Pumpkin-shaped slot antenna design.

In this design, the parameters that give the significance impact to the response are the distance between the slots, **x** and the differences of slots radius, r.

As shown in Figure-9 and Figure-10, it shows that the same results are occurred as the slots get further from each other and the differences of slots radius become larger because both of them makes the second resonance frequency, f2 shifting and become larger. But, it is not the same case for the return loss as it gets increased when the distance between slots, x increases and decreases when the differences of slots radius, r increases. The return loss of the first resonance frequency f1 is slightly increased as the differences of slots radius, r become larger, but still not affected by the distances between slots, x. Table-3 shows the overall analysis of all both parameters.

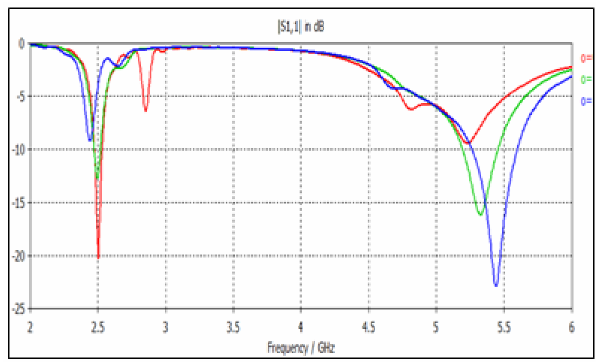

Figure-9. Parametric study of differences of slots radius, r.

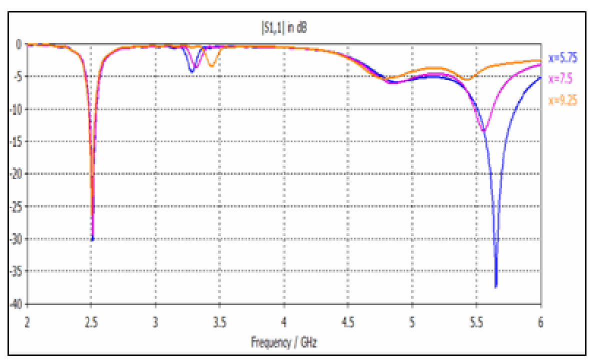

Figure-10. Parametric study of distance between slots, x.

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Table-3. Summary of the parametric studies of design A1 (Iii).

Parameters		f1 (GHz)	Return Loss (dB)	f2 (GHz)	Return Loss (dB)
Slot Radius, r (mm)	0	2.506	-20.28	5.230	-9.47
	1	2.500	-12.74	5.326	-16.17
	2	2.500	-9.25	5.440	-22.99
Distance between Slots, x (mm)	5.75	2.512	-30.34	5.650	-37.51
	7.50	2.512	-29.40	5.554	-13.45
	9.25	2.506	-26.40	5.422	-5.58

SIMULATION AND MEASUREMENT

In this section, the result of all dual-band antenna designs are presented and discussed. It is divided to three sections, which are Design A1, A2, and A3.

Design A1

As mentioned in the previous chapter, there are three designs that fall in Design A1 which are Design A1(i), Design A1 (ii), and Design A1(iii) and the geometry of all of the designs are as shown in Figures 11, 12, and 13 respectively. The optimised dimension of the design is presented in Table-4. Despite the dual-band effects, the slots embedded also affects the size of the patch on the antennas. From the Table, it shows that the size of the patch of Design A1 (i) and Design A1 (ii) are reduced compare to the basic rectangular patch antenna whereas for Design A1 (iii), the patch size is increases by 13.16 percent.

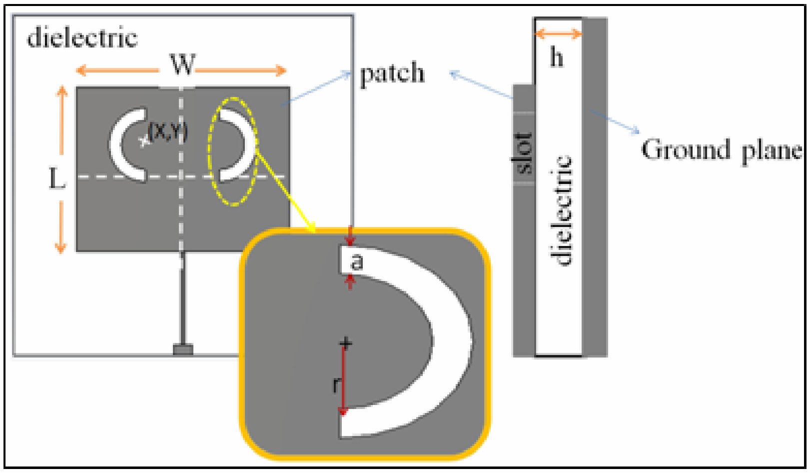

Figure-11. Design A1 (i).

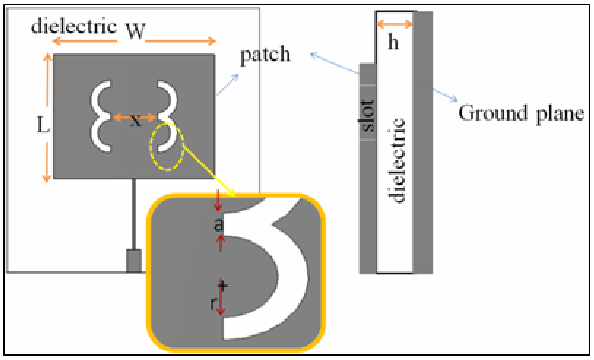

Figure-12. Design A1 (ii).

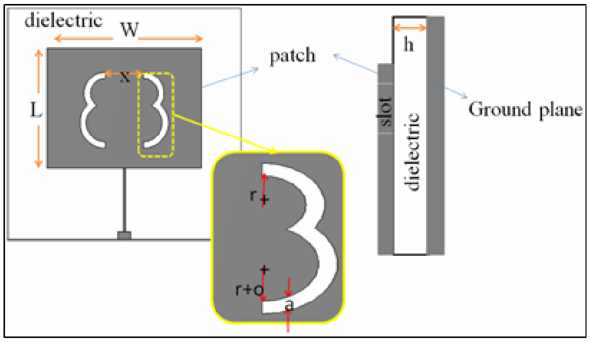

Figure-13. Design A1 (iii).

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Table-4. Optimised dimension of design A1.

Parameter	A1(i)	A1(ii)	A1(iii)
Patch Width, W	31.5 mm	33.8 mm	36.5mm
Patch Length, L	26.6 mm	26.12 mm	28.45mm
Slot Width, a	0.5 mm	1.5 mm	1.5 mm
Radii of slot, r	6.0 mm	4.2 mm	5 mm
Distance between slots, x	12 mm	5 mm	4.5 mm
Slot radius differences, o	NA		1 mm
Patch Size changes	8.70% (reduce)	3.80% (reduce)	13.16% (increases)
Coordinate of Centre of Circle, (X,Y)	(6,4)	NA	

The simulation and measurement results of these designs also discussed in this section. Figure-14 shows the fabricated designs of Design A1 and Figure-15 shows the frequency Response of all designs that fall under Design A1 and Figures 16, 17, and 18 shows the radiation pattern of Design A1 (i), Design A1 (ii), and Design A1 (iii) respectively. Please note that from all of the designs, only several of them are selected to be fabricated and in Design A1 category, Design A1 (i) are not selected. Hence, there are no data of the measurement result of Design A1 (i).

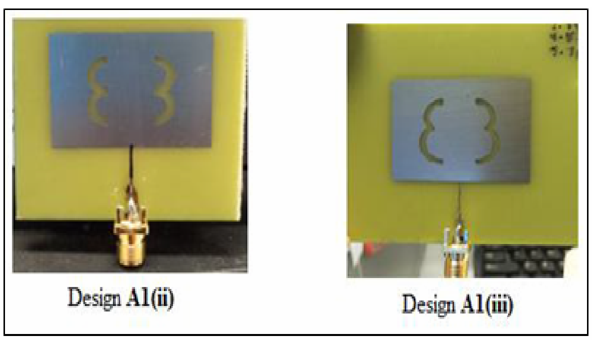

Figure-14. Fabricated design of design A1.

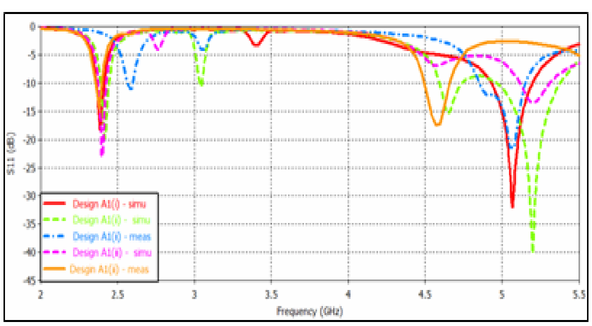

Figure-15. Frequency response of design A1.

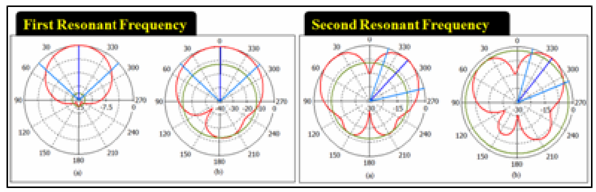

Figure-16. Simulation radiation pattern of design A1 (i) (a) E-plane (b) H-plane.

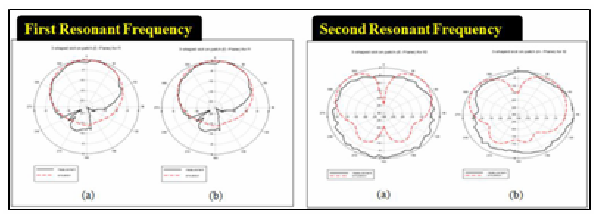

Figure-17. Simulation and measurement radiation pattern of design A1 (ii) (a) E-plane (b) H-plane.

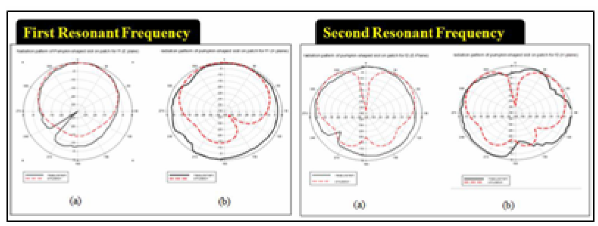

Figure-18. Simulation and measurement radiation pattern of design A1 (iii) (a) E-plane (b) H-plane.

From the graph in Figure-15, it shows that the most optimum design of Design A1(i) resulting resonance frequency of 2.386 GHz and 5.068 GHz whereas the design specification is designing dual-band antenna with resonance frequency 2.4 GHz and 5.2 GHz as f1 and f2 respectively. Because it is hard to achieve the specification using this design, it has been modified and improved as these next designs (Design A1 (ii) and A1 (iii)). From the graph, it also shows that there are shifting between the simulation and measurement resonance frequencies, f1 and f2 for Design A1 (ii). That is may be caused by the dimension of fabricated design which is slightly inaccurate or not exactly same as the simulation. From the parametric studies of Design A1(ii) that have been performed earlier, it is noticed that the f1 is dependence to the dimension of the patch, which is the width, W and the length, L, while f2 is dependence to the dimension and position of the slots. Due to lack of equipment, it is very difficult to maintain the accuracy of the dimension, especially at the slots part which only 1.5mm width. Same case happened to Design A1 (iii) but the frequency shifting are more greatly especially on second resonance frequencies, f2. That is also may be due to the inaccuracy of the slots dimension on the fabricated design. Consistent with the parametric studies that have been performed earlier which proved that f2 is also dependence to the dimension and position of the slots.

As mentioned before, both Design A1 (ii) and A1 (iii) are the improvement and modification of Design A1 (i) as it is hard to achieve the desired resonant frequency which are 2.4 GHz and 5.2 GHz. From Figure-15, it seems like both Design A1(ii) and A1 (iii) gives the similar result in their resonance frequency, but the Three-shaped Slot Antenna is slightly better than the Pumpkin-shaped Slot Antenna in terms of the return loss and bandwidth. The main factor that makes the Design A1 (ii) is better is the size of the patch. Based on Table-4, Design A1(ii) gives size reduction by 3.89 percent but Design A1(iii) which is the Pumpkin-shaped Slot Antenna gives size increment by 13.16 percent which are not fulfilling the design specification that required size reduction at least by 50 percent of the basic rectangular microstrip patch designed earlier.

CONCLUSIONS

This paper presents the design of dual band antenna by using C-shape slot techniques. Three designs has been proposed based on different combination of C-shape slot. The design of double C-shape slot can produce the resonant frequency at 2.4 GHz and 5.2 GHz. Besides that, the size of the double C-shape slot antenna can be reduced up to 50% compared to the microstrip patch antenna. So, this design can be used to develop the compact mobile communication devices.

REFERENCES

Z. Daud, M. Aziz, M. Suaidi, M. Rose, M. Kadir, M. Shah. 2008. MIMO Channel Characterization and Optimization. Telecommunication Technologies 2008 and 2008 2nd Malaysia Conference on Photonics. NCTT-MCP 2008. 6th National Conference on. pp. 132-135.

G. Stuber, J. Barry, S. McLaughlin, Y. Li, M. Ingram, T. Pratt. 2004. Broadband MIMO-OFDM wireless communications. Proceedings of the IEEE. pp. 271-294.

A. Nasr, J. Molina, M. Lienard, P. Degauque. 2006. Optimisation of Antenna Arrays for Communication in Tunnels. Wireless Communication Systems, 2006. ISWCS '06. 3rd International Symposium on. pp. 522-524.

J. Winters. 1987. On the Capacity of Radio Communication Systems with Diversity in a Rayleigh Fading Environment. Selected Areas in Communications, IEEE Journal on. pp. 871-878.

M. Ozdemir, H.Arslan, E. Arvas. 2003. A mutual coupling model for MIMO systems. Wireless Communication Technology, 2003. IEEE Topical Conference on. pp. 306-307.

M. Matsunaga, K. Kakemizu, M. Candotti, T. Matsunaga. 2011. An omni-directional multi-polarization and multi-frequency antenna. Antennas and Propagation (APSURSI), 2011 IEEE International Symposium on. pp. 2765-2768.

Q. Luo, H. Salgado, J. Pereira. 2010. Printed C-shaped monopole antenna array with high isolation for MIMO applications. Antennas and Propagation Society International Symposium (APSURSI), 2010 IEEE. pp. 1-4.