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EFFECT OF QUADRUPLE P-SPIRAL SPLIT RING RESONATOR (QPS-SRR) STRUCTURE ON MICROSTRIP PATCH ANTENNA DESIGN

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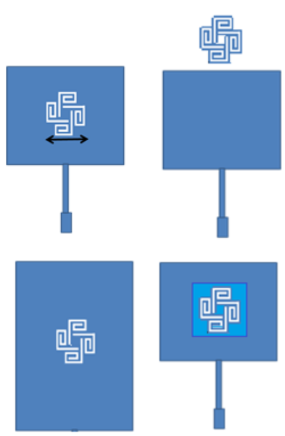
Graphical abstract



Abstract

In this project, the different locations of the quadruple P-spiral split ring resonator (MI-SRR) structure are embedded in the basic rectangular patch antenna. It started with a basic rectangular microstrip patch antenna that simulated in CST Microwave Studio software. After that, four different locations (Location A, Location B, Location C and Location D) of QPS-SRR had chosen to compare its performance of return loss, resonant frequency, surface current radiation pattern, and gain. Location A is representing the antenna with the QPS-SRR at the center part of the patch while Location B has the QPS-SRR at the upper part of the FR-4 substrate. For the Location C and Location D represent the antenna with MI-SRR at the ground at antenna with MI-SRR at the other layer, respectively. Compared with the basic rectangular antenna with only – 27.082 dB, the best return loss was reached by Location A with - 34.199 dB with resonant frequency at 2.390 GHz, while the Location C only shifted the minor value to 2.394 GHz with only - 25.13 dB.

Keywords: Color system, character segmentation, image processing, monitoring console, lighting conditions

1.0 INTRODUCTION

Microstrip patch antenna is one of the antenna types that can be design using the flat surface printed circuit board (PCB) of FR-4. Basically, this types of antenna had been used for many microwave range frequency applications in Malaysia such as Global System for Mobile Communications for 1.80 GHz [1] Wireless Local Area Network (WLAN) applications at 2.4 GHz and 5.2 GHz [2-4], Worldwide Interoperability for Microwave Access (WiMAX) applications at 3.5 GHz [5] or Long-Term Evolution (LTE) applications at 2.6 GHz [6].

The idea of split ring resonator (SRR) structure were from [7-10] actually the simple technique to improve the performance of the microwave range application, especially in microstrip patch antenna design. Basically, this is the popular way is to embedded this structure on the infront side (patch side) of the antenna. There are also the researches on different location of SRR on the patch antenna such as at the ground plane, using multi-layer SRR or designed at the substrates itself. Besides that, there are other techniques to improve the microwave range application such as using the defected microstrip structure (DMS) [11], substrate integrated waveguide (SIW), artficial magnetic conductor (AMC), and defected ground structure (DGS),

This SRR structure can cater the antenna miniaturized problems such in these several papers on [12-18]. These structures also have potential to create the new resonant frequency at the microstrip patch antenna.Beside microstrip patch antenna design, this SRR structure also can be improve the several performance of the microwave range application such as microwave filter, oscillator frequency selective surface or FSS, microwave absorber, and also RF amplifier.

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2.0 ANTENNA DESIGN

The initial design is the rectangular microstrip patch antenna in that designed based on calculation. Figure 1 and Table 1 represent the schematic diagram and the dimension design of the basic rectangular microstrip patch antenna. The second column on

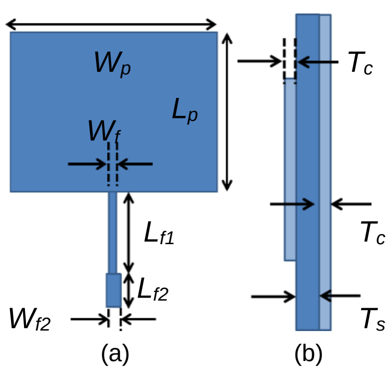

Figure 1 Rectangular microstrip patch antenna, (a) front view of rectangular patch shape, (b) side view

Table1 The dimension of the basic microstrip patch antenna (calculated and optimized)

Symbol	Calculate dimension (mm)	Optimized dimension (mm)
W_p	33.7	32.3
L_p	31.0	29.0
W_f	-	0.5
L_{f1}	-	16.5
W_f	-	3.0
L_{f2}	-	2.72
T_c	0.035	0.035
T_s	1.6	1.6

Table I showed the optimized dimension, which was enhanced based on the calculated dimension, shown at the first column. It presented that the optimized dimension is 32.2 mm width x 29.0 mm length with 0.035 mm of copper thickness and 1.6 mm substrate thickness. This microstrip patch antenna used the full ground with the same dimension of the substrate. The tangent loss of this FR-4 substrate was 0.019.Then, the embedded of QPS-SRR are done at the different location of the antenna. The four different locations were at the center of the microstrip patch (Location *A*), upper part of the FR-4 substrate (Location *B*), back part of ground plane (Location *C*), and the split ring resonator with gap (Location *D*). Figure 2 represents the microstrip patch antenna with quadruple P-spiral split ring resonator at four different locations. Table 2 illustrated the dimension of the microstrip patch antenna with quadruple P-spiral split ring resonator structure. The dimension of this split ring resonator was 5.0 mm in width and 5.0 mm in length.

Table 2 The dimension of the microstrip patch antenna with different locations of QPS-SRR structure

		Optimized dimension (mm) with different locations			
Parameter	**Symbol**	**A**	**B**	**C**	**D**
SRR width	W_x	5.0	5.0	5.0	5.0
SRR length	L_x	5.0	5.0	5.0	5.0
SRR gap	D_x	0.5	0.5	0.5	0.5

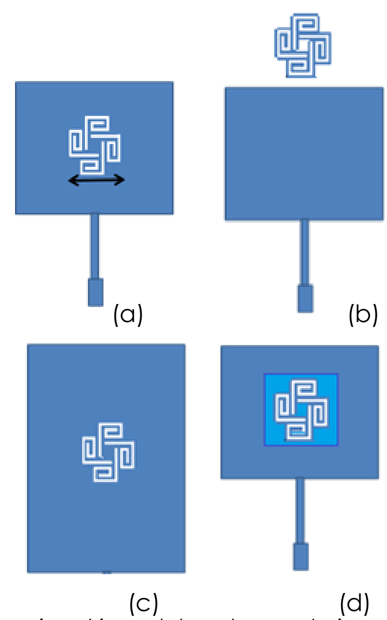

Figure 2 The microstrip patch antenna design with different locations of QPS-SRR structure (a) at the center of the microstrip patch (Location *A*), (b) at the upper part of the FR-4 substrate (Location *B*), (c) at the ground plane (Location *C*), and (d) the split ring resonator with layer gap (Location *D*)

3.0 RESULTS AND DISCUSSION

This section shows the several performance of the microstip patch antenna with QPS-SRR structure. The parameters that taken place in this work are resonant frequency, return loss, bandwidth and antenna gain. Figure 3 and also Table 3 represent the return loss performance for rectangular microstrip patch antenna in CST Microwave Studio.

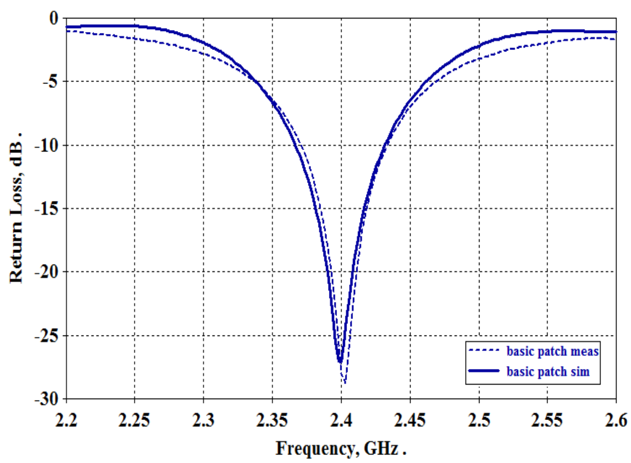

Figure 3 Comparison of return loss for basic rectangular microstrip patch antenna, (simulation and measurement), with lower frequency, f_L, higher frequency, f_H, and resonant frequency, f_r, value at 2.40 GHz

The simulation result of the return loss performance resonant frequency, f_r for this antenna at 2.40 GHz is - 27.082 dB. Compare with the measured value, it shows at 2.403 GHz, the resonant frequency of – 28.68 dB. The bandwidth of this patch antenna is 65.0 MHz in the frequency range between of 2.367 GHz and 2.432 GHz. It's also shows the narrow bandwidth that follows the concept of the antenna theory. The bandwidth achieve of 65 MHz and 64 MHz for simulation and measurement, respectively.

Table 3 Different results for parameters in the basic microstrip patch antenna

Parameter	Antenna type	
	Basic antenna (simulation)	**Basic antenna (measurement)**
Resonant frequency, f_r (GHz)	2.400	2.403
Return loss (dB)	- 27.082	- 28.608
Bandwidth (MHz), f_1-f_2 (GHz)	65, 2.367 – 2.432	64, 2.370 – 2.434
Gain (dB)	3.031	2.980

The return loss for the microstrip patch antenna with different locations of quadruple P-spiral split ring resonator shown in Figure 4. The different locations of the split ring resonator structure can shifted resonant frequency (to the lowe or to the higher frequency). The Location *D* of QPS-SRR shifted the resonant frequency from 2.40 GHz to 2.540 GHz with return loss of - 23.169 GHz, while for Location *B*, it shifted from 2.40 GHz to 2.450 GHz with return loss of - 22.545 GHz.

Compared with the basic rectangular antenna with only – 27.082 dB, the best return loss was reached by Location *A* with - 34.199 dB with resonant frequency at 2.390 GHz, while the Location *C* only shifted the minor value to 2.394 GHz with only - 25.13 dB.

As for bandwidth performance, all split ring resonator at locations of Location A, Location B and Location C has a narrow the bandwidth between 54 MHz to 58 MHz, except for Location D with better performance of 62 MHz. Table 4 below shows the comparison of different parameters between the basic rectangular patch antenna and the microstrip patch antenna with different locations of quadruple P-spiral split ring resonators.

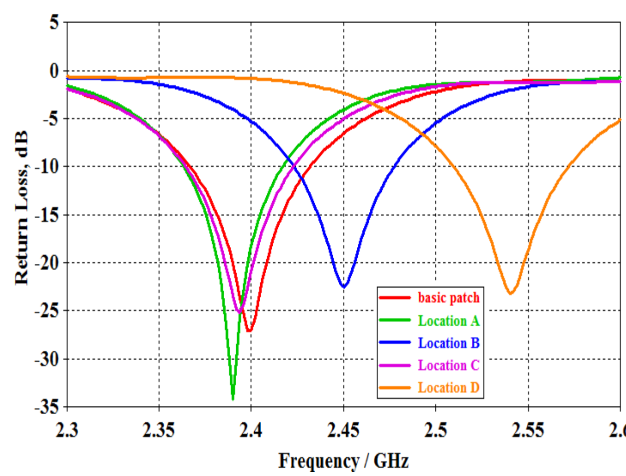

Figure 4 Return loss of the microstrip patch antenna with different locations of quadruple P-spiral split ring resonators

Table 4 Comparison of resonant frequency and return loss performance between the basic rectangular patch antenna and the microstrip patch antenna with different locations of QPS-SRR

Antenna Design	Resonant frequency, f_r (GHz)	Return loss (dB)
Location *A*	2.390	- 34.199
Location *B*	2.450	- 22.545
Location *C*	2.394	- 25.131
Location *D*	2.540	- 23.169

Figure 5 shows the gain for the microstrip patch antenna with different locations of quadruple P-spiral split ring resonators at the range between 2.36 GHz and 2.56 GHz of frequency. All split ring resonator structures show the improvement of antenna gain performance, except for Location *A* with only 2.648 dB. The antenna gain performance for Locations *A*, *C*, and *D* were 3.118 dB, 3.033 dB, and 3.139 dB, respectively.

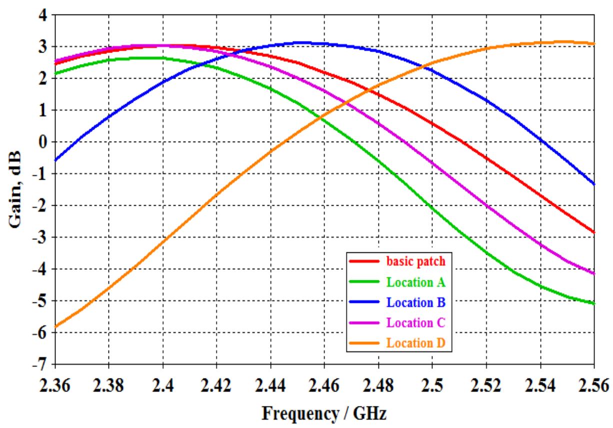

Figure 5 The gain of microstrip patch antenna with different locations of quadruple P-spiral split ring resonators at the range between 2.36 GHz and 2.56 GHz of frequency

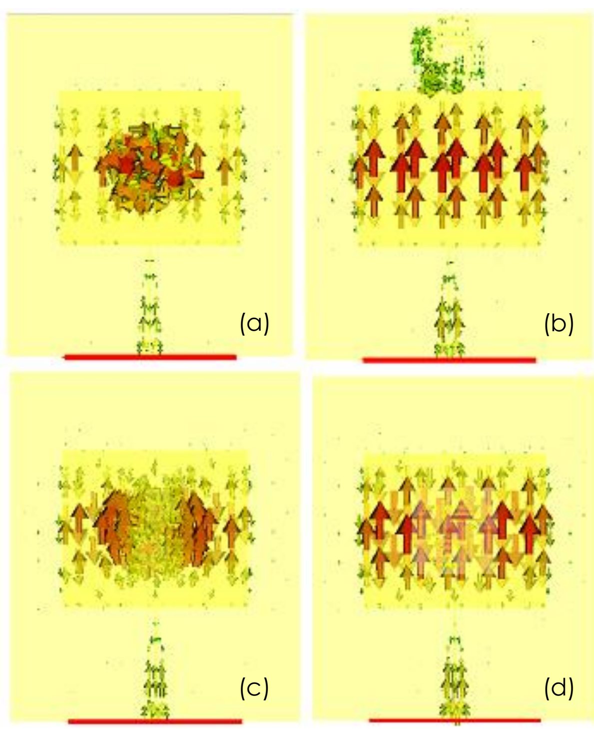

Figure 6 The Surface current distribution of microstrip patch antenna with different locations of quadruple P-spiral split ring resonators structure. Phase at 0^0 for (a) Location *A*, (b) Location *B*, (c) Location *C*, and (d) Location *D*

Figure 6 represents the surface current distribution of the microstrip patch antenna with different locations of quadruple P-spiral split ring resona.tors structure. The red arrow shows the significant high surface current distribution compare with the green arrow. All antenna type had different types of surface current distribution effected, depending on its split ring resonator location. For example, Location *B* affected the upper part of the FR-4 substrate but basically all location had focusing the surface current distribution at the center of the patch antenna.

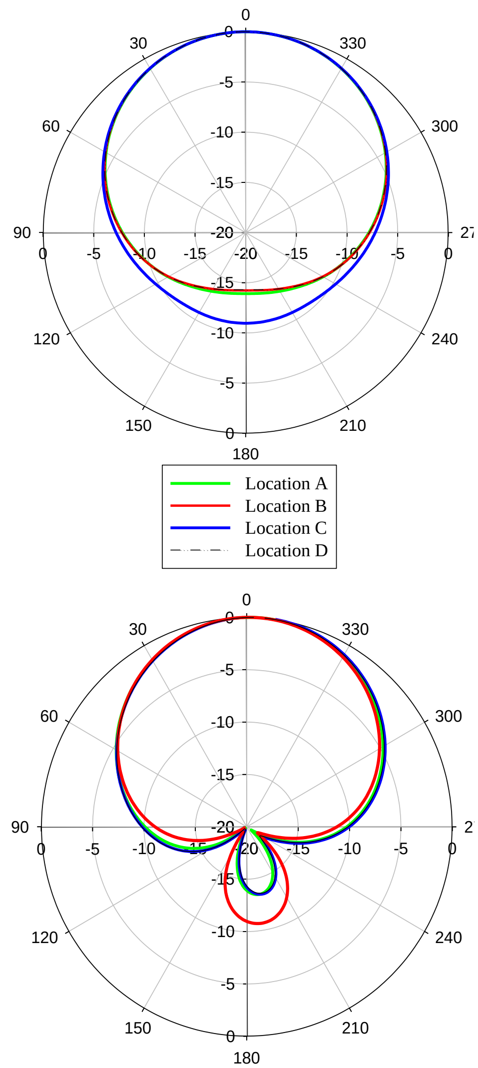

Figure 7 Comparison of 2D radiation pattern for microstrip patch antenna with different locations of quadruple P-spiral split ring resonators, (a) at phase = 0^0, (b) phase = 90^0

Figure 7 shows a comparison of radiation for the microstrip patch antenna with different locations of quadruple P-spiral split ring resonators. Two different phase considered in this work, firstly at phase = 0^0 while another at phase = 90^0. From the graph of phase = 0^0, all designed shows circular shaped accept at Location C. Location *C* had been changed a little of its radiation pattern compared to the basic microstrip patch, while the others remain with the same circular shape.

From the graph of phase = 90^0, all designed remain the circular shaped with minor back loop. The Location *C* design shows larger back loop compare other designed compared with other design

4.0 CONCLUSION

After simulation done in CST Microwave Studio simulation software, it shows that the quadruple P-spiral split ring resonator had been effected the several parameter of the microstrip patch antenna. In this case some design had to improve the performance of the return loss, gain and also bandwidth of the microstrip patch antenna.

Design of Location *A* and Location *C* effect to shifted the resonant frequency into lower frequency band. That mean, this quadruple P-spiral split ring resonator also had been potential to reduce the microstrip patch antenna size. The shifted of resonant frequency, f_0 will effect that the increment of capacitance, *C*. This situation is because of addition of split ring resonator structure in the antenna. From the formula of resonant frequency, the value of capacitance is proportional with the resonant frequency. So, this situation will effect the decrement of resonant frequency of the patch antenna. At other two designs (Design B and Design D) did not effect the reduction size potential.

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