Rectangular Microstrip Patch Antenna with Different Location of Minkowski Island Split Ring Resonator (MI-SRR) Structure

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***Abstract*—In this project, different locations of the Minkowski Island split ring resonator (MI-SRR) structure are embedded in the basic rectangular patch antenna. It started with a basic rectangular microstrip patch antenna that were simulated in CST Microwave Studio software. After that, four different locations (Location A, Location B, Location C and Location D) of MI-SRR were chosen to compare the performance of return loss, resonant frequency, surface current radiation pattern, and gain. Location A represented the antenna with the MI-SRR at the center part of the patch, while Location B had the MI-SRR at the upper part of the FR-4 substrate. Location C and Location D represented the antenna with MI-SRR at the ground at antenna with MI-SRR at the other layer, respectively. The return loss performances of Design of Location A, Location B, Location C, and Location D were - 26.546 dB, - 23.892 dB, - 43.842 dB, - 51.506 dB at resonant frequency of 2.432 GHz, 2.510 GHz, 2.438 GHz and 2.542 GHz, respectively.**

***Index Terms*—Split Ring Resonator; Patch Antenna; Minkowski Island; Fractal Antenna; Return Loss.**

I. INTRODUCTION

Smith [1] based on Pendry's works [2] claimed that the split ring resonator structure is one of the popular techniques to enhancement the patch antenna design. Besides applying it to antenna, it also can be applied in numerous areas of telecommunication devices such as at microwave absorber, radio frequency (RF) filter, and oscillator [3-8]. The microstrip patches using FR-4 substrate is the basic antenna design that has been developed due to their low profiles, easy to fabricate in laboratory and low in cost compared with Rogers and Taconic.

Minkowski Island is the advanced technique of the Minkowski fractal design. In previous work, complementary Minkowski structure is located at the middle of the patch of antenna to generate a new design [9-18]. Previously, it had been found in many designs of the patch antenna. In this work, four different locations of Minkowski Island split ring resonator (MI-SRR) structure at patch antenna had been chosen to compare its performance.

II. ANTENNA DESIGN

The first step was to design the basic structure of the rectangular microstrip patch antenna. Figure 1 and Table 1 show the dimension and the schematic diagram of the basic rectangular microstrip patch antenna. The optimized result is the change of value from the calculated value to optimize the right location of resonant frequency. It shows that the optimized dimension has the width = 32.2 mm from 33.7 mm and the length = 29.0 mm from 31.0 mm, with copper thickness = 0.035 mm and substrate thickness = 1.6 mm. The tangent loss value of this FR-4 substrate was 0.019.

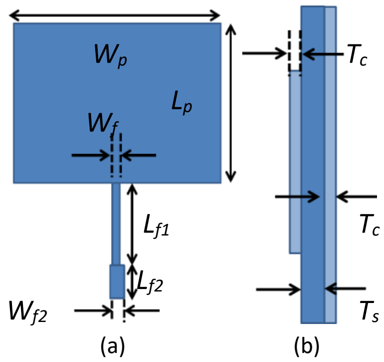

Figure 1: Basic microstrip patch antenna, (a) front view of antenna, (b) side view of antenna

Table 1
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

The next step was to add the MI-SRR at four different locations of the antenna. Location A represents the antenna with the MI-SRR at the center part of the patch, while Location B has the MI-SRR at the upper part of the FR-4 substrate. Location C and Location D represent the antenna with MI-SRR at the ground at antenna with MI-SRR at the other layer, respectively. Figure 2 signifies the microstrip patch antenna with MI-SRR at four different locations (Location A to Location D).

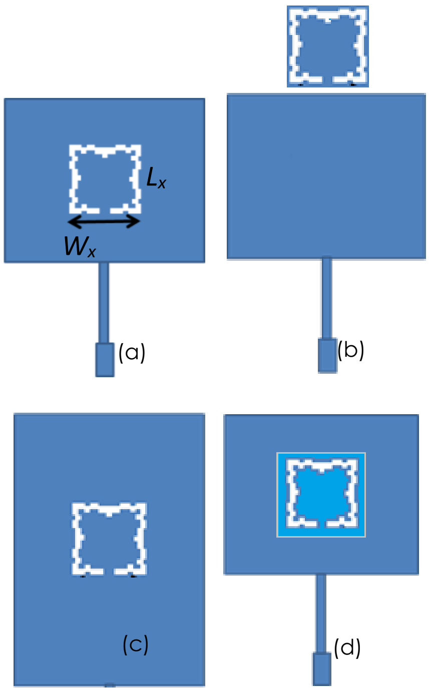

Figure 2: The rectangular patch antenna with four different locations of Minkowski Island split ring, (a) Location A - center of the microstrip patch, (b) Location B - upper part of the FR-4 substrate, (c) Location C - back part of ground plane, (d) Location D - the split ring resonator with gap

Table 2 shows the dimension of the basic rectangular patch antenna with MI-SRR structure at different location. The same dimension of this split ring resonator was used at all four different designs with 5.0 mm width x 5.0 mm length. The split gap at the ring was only 0.5 mm, which are the same for all designs.

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

Parameter	Symbol	Optimized dimension od MI-SRR (mm)			
		Location *A*	Location *B*	Location *C*	Location *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

III. Results and Discussion

This segment displays the numerous simulated and measured performance results of the microstip patch antenna with different locations of the MI-SRR structure. The results of the resonant frequency, return loss, bandwidth and antenna gain are presented. Figure 3 with Table 3 shows the simulated return loss performance for basic rectangular microstrip patch antenna in CST Microwave Studio simulation software.

The simulated result of the return loss performance resonant frequency for basic antenna was - 27.082 dB at 2.40 GHz of resoanat frequency. For the measured result, it shows the shift of resonant frequency to 2.403 GHz with – 28.68 dB, with 65.0 MHz of narrow bandwidth in between 2.367 GHz and 2.432 GHz. Compared with the simulated, the measured result achieved the bandwidth of 64 MHz.

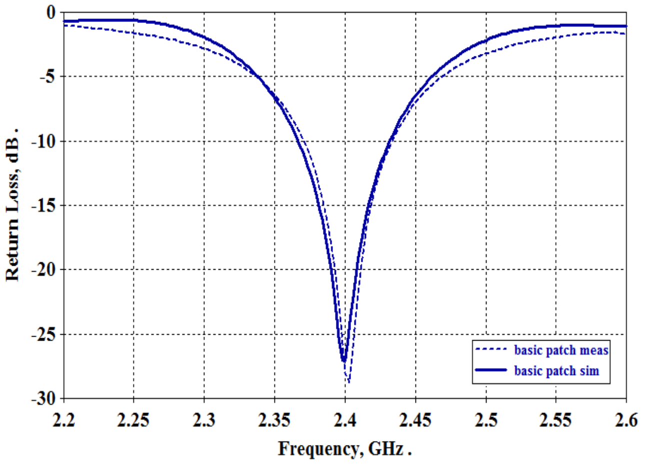

Figure 3: Simulated and measured result of return loss for basic rectangular microstrip patch antenna with lower frequency

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

Figure 4 shows the return loss for the microstrip patch antenna with different locations of Minkowski Island split ring resonator structure. All types of split ring resonator shifted the resonant frequency to a higher level compared with the basic patch antenna that resonated at 2.4 GHz. The best reflection coefficient was achieved by Location D with - 51.506 dB compared to the basic antenna with only – 27.082 dB.

The resonant frequency for this split ring resonator location was at 2.542 GHz, while Location C was shifted to 2.438 GHz with - 43.842 dB. As for bandwidth, the locations for all split ring resonators shared nearly similar bandwidth between 61 MHz to 65 MHz, like the basic microstrip patch antenna. Table 4 represents the comparison of different parameters between the basic patch antenna and the microstrip patch antenna with different locations of Minkowski Island split ring resonator structures.

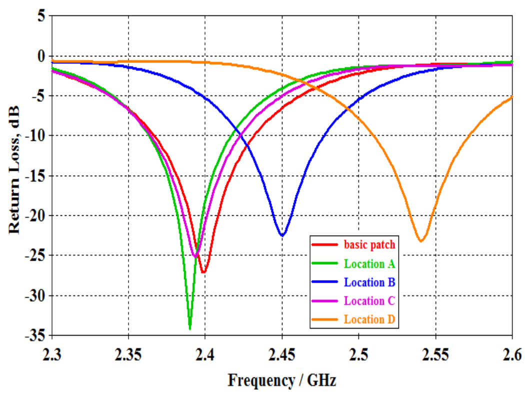

Figure 4: Return loss of bow-tie patch antenna with different SRR distance from the center part of the bow-tie patch

Table 4
Comparison of different parameters between the patch antennas with different locations of Minkowski Island split ring resonators

Design Antenna	Resonant frequency, f_r (GHz)	Return loss (dB)	Bandwidth (MHz), f_{High} - f_{Low} (GHz)	Gain at f_r (dB)
Basic	2.400	- 27.082	65, 2.367 – 2.432	3.031
Location *A*	2.432	- 26.546	61, 2.401 – 2.461	2.406
Location *B*	2.510	- 23.892	63, 2.479 – 2.542	2.844
Location *C*	2.438	- 43.842	65, 2.406 – 2.471	2.836
Location *D*	2.542	- 51.506	62, 2.511 – 2.573	3.336

Figure 5 shows the performance of gain for the patch antenna with different locations of Minkowski Island split ring resonators. Only Location D was improved for its performance, in which it gained by 3.336 dB. The performance of gain for Location A, B, and C were 2.406 dB, 2.844 dB, and 2.836 dB, respectively.

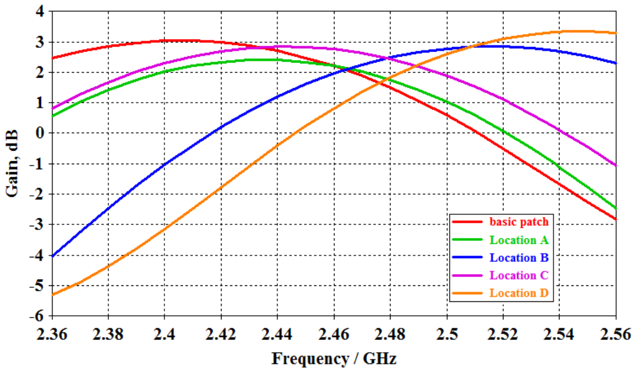

Figure 5: The gains of microstrip patch antenna with different locations of Minkowski Island split ring resonators

Figure 6 represents the comparison of radiation in the microstrip patch antenna with different locations of Minkowski Island split ring resonators. It shows that Location C experienced minor changes in the radiation pattern compared to the basic microstrip patch, while the others remained with the same circular shape.

Figure 7 shows the contribution of surface current in the microstrip patch antenna with different locations of Minkowski Island split ring resonators. It shows that different types of surface current depended on the location of the split ring resonator. The surface current of Location A and C were focused at the center of the patch.

IV. Conclusion

The results of the simulation work conducted in CST Microwave Studio simulation software show that the split ring resonator affected several parameters of the microstrip patch antenna. The resonant frequency of the antenna can be considered using different dimensions of the length, width and the location of the split ring resonator structure. From the result, the shifted of resonant frequency, f0 affects that the increment of capacitance, C. This situation exists due to the addition of split ring resonator structure in the antenna. The value of capacitance is proportional with the resonant frequency. Therefore, this situation affects the decrement of resonant frequency of the patch antenna.

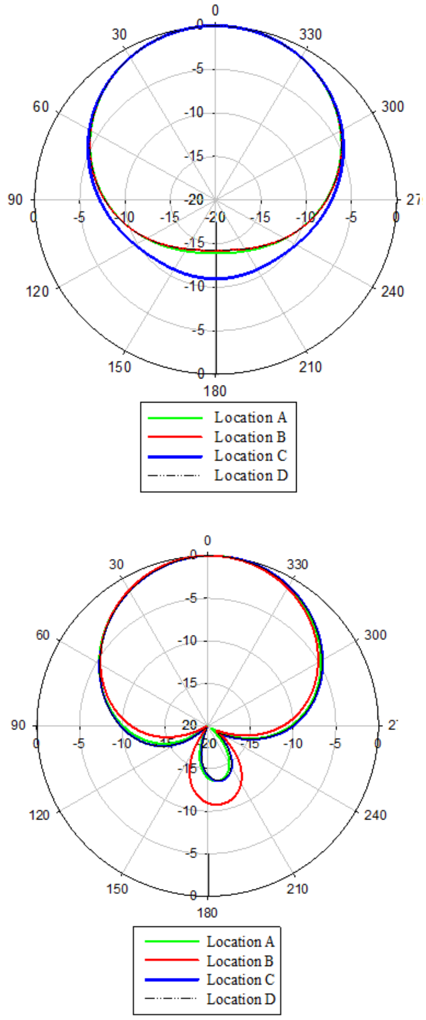

Figure 6: Radiation pattern for microstrip patch antenna with different locations of Minkowski Island split ring resonator, (a) phase = 0, (b) phase 90

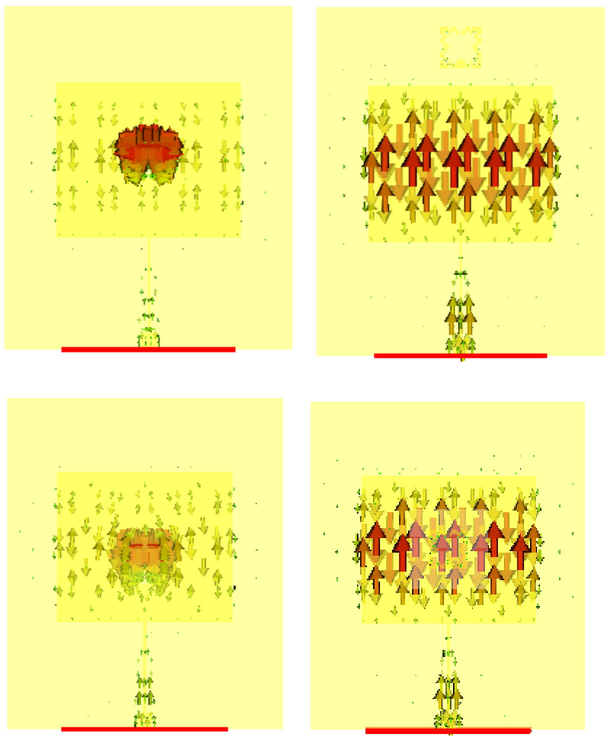

Figure 7: Surface current of microstrip patch antenna with different locations of MI-SRR structures for Locations *A*, *B*, *C*, and *D* at $\phi = 0^0$.

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REFERENCES

[1] Smith, D. R., Padilla, W. J., Vier, D. C., 2000. Nemat-Nasser, S. C., and Schultz, S., Composite Medium with Simultaneously Negative Permeability and Permittivity, *Physics Review* Letter, 84: 4184 – 4187

[2] Pendry, J. B., Holden, A. J., Robins, D. J., and W. J. Stewart, 1999. Magnetism from Conductors and Enhanced Nonlinear Phenomena, *IEEE Transactions on Microwave Theory and Technique*s, 47(11):2075 – 2084

[3] Lee, Y. S., Malek, M. F. B. A., Cheng, E. M., Liu, W. W., You, K. Y., Iqbal, M. N., Wee, F. H., Khor, S. F., Zahid, L., and Haji Abd Malek, M. F. b., 2013. Experimental Determination of the Performance of Rice Husk-Carbon Nanotube Composites for Absorbing Microwave Signals in the Frequency Range of 12.4-18 GHz, *Progress In Electromagnetics Research*, 140:795-812

[4] Mazlan, M. H., Ahmad, B. H., Husain, M. N., Zakaria, Z., Shairi, N. A., 2015. Single and Cascaded Substrate Integrated Waveguide Bandstop Filter for Interference Suppression in X-Band Region, *1st ICRIL-International Conference on Innovation in Science and Technology (lICIST 2015),* 592 – 595

[5] Mahyuddin, N. M., Ab. Kadir, N. F. S., 2014. Design of a 5.8 GHz Bandstop Filter Using Split Ring Resonator Array, The 8th *International Conference on Robotic, Vision, Signal Processing & Power Applications. Lecture Notes in Electrical Engineering*, 291:473 – 482,.

[6] Abdalla, M. A., and Zihrun, H., 2012. On The Study of Development of X Band Metamaterial Radar Absorber, *Advanced Electromagnetics*, 1(3): 94 – 98,

[7] Bruster A., Zakaria Z., Ruslan E., Mutalib M. A., 2015. A Review of Bandpass with Tunable Notch Microwave Filter in Wideband Application, *International Journal of Engineering and Technology (IJET)*, 7(3): 825-832

[8] Zakaria Z., Mutalib M. A., Sam W. Y., Fadzil M. F. M., 2015. Integrated suspended stripline structure (SSS) with J-shape defected stripline structure (DSS) To Remove Undesired Signals In Wideband Applications, *2015 9th European Conference on Antennas and Propagation (EuCAP),* 1-5.

[9] Lata, S., Kumar, V., 2013. Design and Simulation of Minkowski Fractal Patch Antenna on SOI Substrate for Next Generation Wireless Networks, *International Journal of Emerging Technology and Advanced Engineering*, 8(3): 92 – 95

[10] Moraes, L. B. and Barbin, S. E., 2011. A comparison Between Minkowski and Koch Fractal Patch Antennas, 2011 *SBMO/IEEE MTT-S International Microwave & Optoelectronics Conference (IMOC)*, 17 – 21

[11] Rusu, M., Hirvonen, M., Rahimi, H., Enoksson, P., Rusu, C., Pesonen, N., Vermesan, O., Rustad, H., 2008. Minkowski Fractal Microstrip Antenna for RFID Tags, *38th European 2008 Microwave Conference (EuMC 2008)*, 666 – 669,

[12] Shafie, S. N., Adam, I. and Soh, P. J, 2010. Design and Simulation of a Modified Minkowski Fractal Antenna for Tri-Band Application, *2010 Fourth Asia International Conference on Mathematical/Analytical Modelling and Computer Simulation (AMS),* 567 – 570

[13] Luo Q., Salgado H. M., and Pereira J. R., 2009. Fractal Monopole Antenna Design Using Minkowski Island Geometry, *IEEE Antennas and Propagation Society International Symposium (APSURSI '09),* 1-4,

[14] Liu J. C., Liu H.H., Yeh K. D, Liu C. Y., Zeng B.H., and Chen C.C., 2012. Miniturized Dual-Mode Resonators with Minkowski-Island-Based Fractal Patch for WLAN Dual-Band Systems, *Progress In Electromagnetics Research C (PIER C),* 26: 229-243,

[15] Wahid A., Rahim M. K. A., Zubir F., 2010. Analysis of Dual Layer Unit Cell with Minkowski Radiating Shape for Reflectarray Antenna on Different Substrate Properties. *2010 IEEE Asia-Pacific Conference on Applied Electromagnetics (APACE 2010)*, 1-5,

[16] Liu J.-C., Chiu S.-H., Kuei C.-P., and Zeng B.-H., 2011. A Novel Minkowski-Island-Based Fractal Patch for Dual-Mode and Miniaturization Band-Pass Filters, *Microwave and Optical Technology Letters (MOTL*), 53(3):594-597

[17] Campos A. L. P. S. Olivera E. E. C. d, 2010. Design of Miniaturized Frequency Selective Surfaces Using Minkowski Island Fractal, Journal of Microwaves, *Optoelectronics and Electromagnetic Applications (JMOE)*, 9(1):43-49

[18] Lee E. C., Soh P. J., Hashim N. B. M., Vandenbosch G. A. E., Volski V., Adam I., Mirza H., and Aziz M. Z. A. A., 2011. Design and Fabrication of a Flexible Minkowski Fractal Antenna for VHF Application, *5th European Conference on Antennas and Propagation (EuCAP 2011)*, 521-524.