

# Investigation of Minkowski Patch Antenna with Meander Line Split Ring Resonator (ML-SRR) Structure

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**Abstract**—The objective of this paper is to investigate the effect of the meander line split ring resonator on the modified Minkowski patch antenna. In this work, a modified Minkowski patch antenna with meander line split ring resonator (ML-SRR) and quadruple-P shaped split ring resonator (QPS-SRR) structure is presented. This proposed modified patch antenna with SRRs structures achieved remarkable 2.644 dB of gain at the frequency of 2.402 GHz compared to the normal Minkowski antenna without SRR structures with only 2.348 dB. This antenna had been simulated in the CST Microwave Studio simulation software.

**Index Terms**—Minkowski antenna, split ring resonator, metamaterial

## I. INTRODUCTION

In recent years, there are many works to enhance the gain performance of the patch antenna design. The metamaterial or left-handed media (LHM) structure is one of the technique improve this problem. In 1968, Veselago had been proposed this technique by implementing split ring resonator (SRR) structure with metal wires [1]. Many researchers have studied patch antenna that adds this SRR structure, especially in wireless local area network (WLAN) range of 2.4 GHz. This paper had been investigating the effect of the meander line split ring resonator (ML-SRR) and the quadruple-P shaped split ring resonator (QPS-SRR) structure of the modified Minkowski patch antenna. The parameters that are considered in this work are return loss, gain, directivity, and the radiation pattern of the patch antenna [2].

The geometry Fractal methods can include in many types such as Sierpinski carpet [3], Koch Fractal [4], Minkowski Fractal [5-6] Hilbert Fractal [7] and 3/2 Curve Fractal [8]. The Minkowski Fractal antenna is one popular technique to miniaturize the size of the patch antenna [9]. This Minkowski Fractal also can affect the multiband of frequency [10].

The Minkowski curve can be characterized by the iteration factor [11]. Zero iteration is represented by the normal patch without any scraped out of copper [12]. First iteration show

that four rectangular or square shape of copper had been cut from the patch, shown in Figure 1.

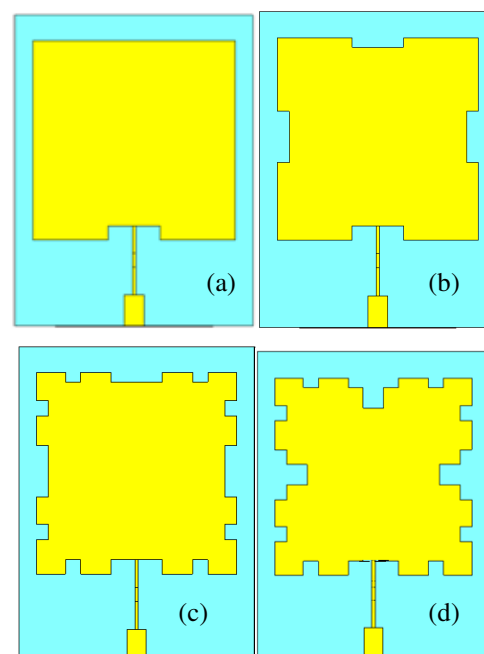


Figure 1. Modified Minkowski patch antenna iteration stage ; (a) Zero iteration; (b) First iteration; (c) Second iteration (d) Third iteration

## II. PROPOSED SRR

Split ring resonators (SRRs) design is used to produce the negative dielectric constant (permittivity) and negative permeability [13]. From the previous work, this structure can increase the gain and miniaturize the size of the patch antenna and have the capability to improve the gain performance [14-15]. This SRR structure also has potential to increase the reflection loss performance of the pyramidal microwave absorber [16]. Figure 2 and Table I shows the proposed meander line split ring resonator (ML-SRR) while Figure 3 and

Table II shows the Quadruple-P shaped split ring resonator (QPS-SRR). The dimension of the ML-SRR is 8.29 mm x 10.33 mm. The dimension of the larger QPS-SRR is 1.68 mm x 2.49 mm while the dimension of the smaller QPS-SRR is 1.37 mm x 2.03 mm.

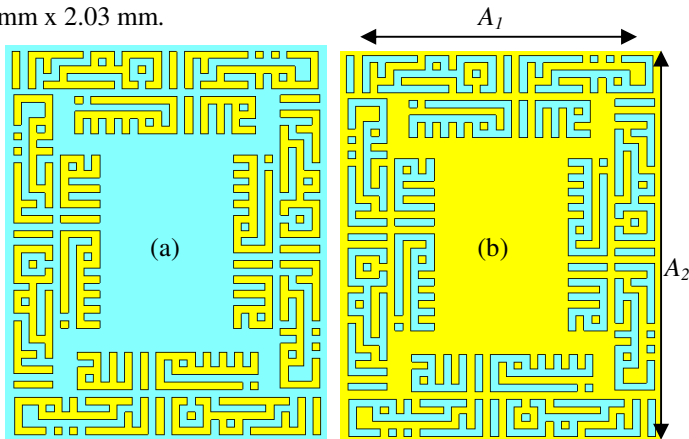


Figure 2. Structure unit of meander line split ring resonator (ML-SRR) (a) normal condition SRR; (b) complimentary SRR condition

TABLE I. DIMENSION OF THE STRUCTURE UNIT OF MEANDER LINE SPLIT RING RESONATOR (ML-SRR)

Parameter part	Dimension (mm)
$A_1$	8.29
$A_2$	10.33

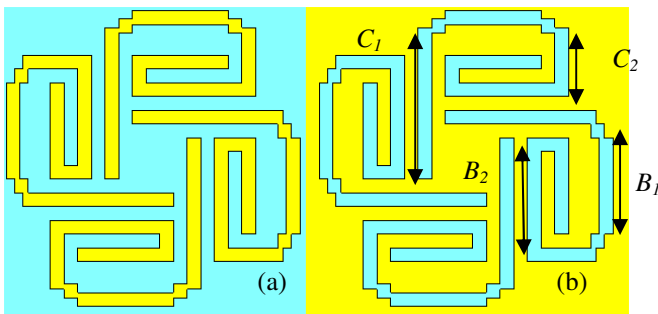


Figure 3. Quadruple-P shaped split ring resonator (QPS-SRR);  $B_1 = 1.68$  mm,  $B_2 = 1.37$  mm,  $C_1 = 2.49$  mm,  $C_2 = 2.03$  mm (a) normal condition SRR; (b) complimentary SRR condition

TABLE II. DIMENSION OF THE STRUCTURE UNIT OF QUADRUPLE-P SHAPED SPLIT RING RESONATOR (QPS-SRR)

Parameter part	Dimension (mm)
$B_1$	1.07
$B_2$	1.29
$C_1$	1.68
$C_2$	0.76

### III. PROPOSED ANTENNA

Minkowski Fractal shape based antenna is designed based on the bigger and smaller size of square shape generator [3]. Figure 4 and Table III shows the modified Minkowski patch antenna (without SRR structure added). This antenna uses FR-4 board substrates with dielectric constant of 4.3, tangent loss of 0.025, and thickness of 1.6 mm.

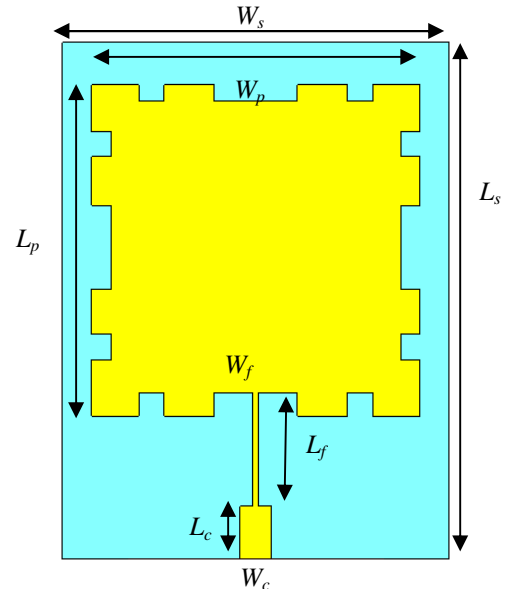


Figure 4. Modified Minkowski patch antenna (without SRR structure added)

TABLE III. DIMENSION OF THE MODIFIED MINKOWSKI PATCH ANTENNA (WITHOUT SRR STRUCTURE ADDED)

Parameter part	Dimension (mm)
$W_s$	34
$L_s$	45
$W_p$	28.86
$L_p$	28.86
$W_f$	0.5
$L_f$	9.95
$L_c$	4.55
$W_c$	2.81

Figure 5 shows the different location of ML-SRR and QPS-SRR structure of the modified Minkowski patch antenna. Type A antenna had been representing the attached 4 pair of ML-SRR and QPS-SRR at the patch antenna to improve the gain performance. In Type B, a rectangular stripline had been added to control the location of the resonant frequency of the antenna.

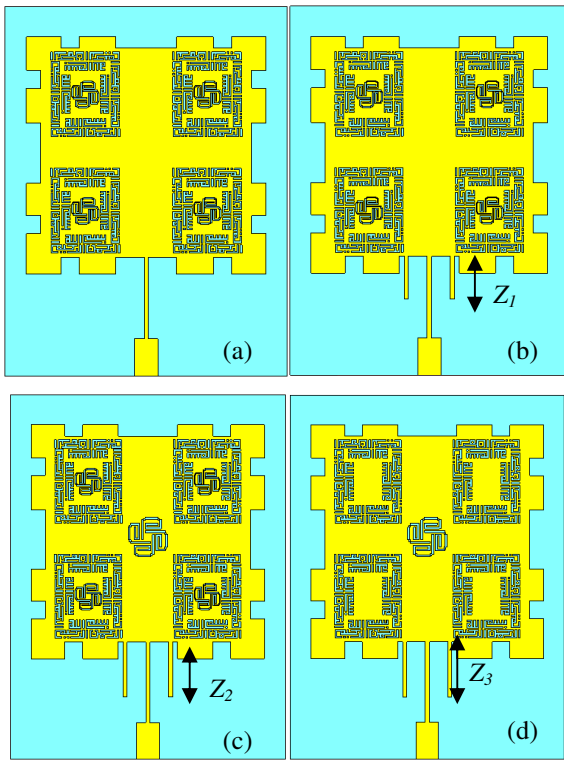


Figure 5. Modified Minkowski patch antenna with different variation ; (a)Type A; (b) Type B; (c) Type C (d) Type D

For the Type C antenna, a larger version of QPS-SRR antenna had been added at the center location of patch antenna to enhance more gain of the antenna. In the Type D, 4 smaller versions of QPS-SRR had been removed from the design. Table IV shows the adjustment Stripline length to optimize the resonant frequency to 2.402 GHz

TABLE IV. THE ADDITION OF STRIPLINE TO ADJUST THE FREQUENCY RANGE TO 2.402 GHz

Minkowski Antenna type	Rectangular strip length added (mm)
Without SRR	-
Type A	-
Type B	5.2
Type C	6.8
Type D	6.8

IV. RESULT

Figure 6 shows the return loss performance of the modified Minkowski patch antenna with ML-SRR and QPS-SRR (in different iteration stage). From the graph, it shows that, the different type of stage will control where is the resonant

frequency. The best reflection loss had been shown by second iteration of the Minkowski patch antenna. This antenna had been resonating at 2.402 GHz of frequency. The third iteration shows the worst return loss performance but it had been shifted from 2.402 GHz to the 2.202 GHz, the different frequency point of 200 MHz.

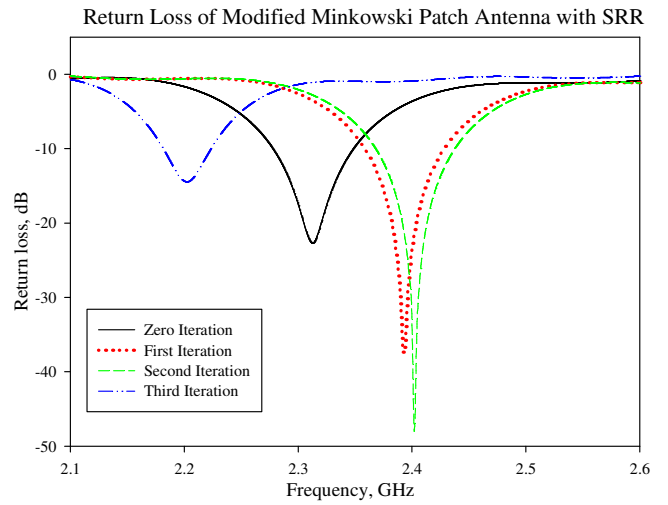


Figure 6. Return loss performance of modified Minkowski patch antenna with ML-SRR and QPS-SRR (in different iteration stage)

Table V shows return loss, resonant frequency and the bandwidth of the Minkowski patch antenna. It shows that the second iteration Minkowski patch antenna had been achieved the best reflection loss with - 47.990 dB at a frequency of 2.402 GHz. The worst return loss performance had been achieved by third iteration by only - 14.665 dB but it has the wider bandwidth compared to the other iteration stage. This antenna (at third iteration stage) has a bandwidth of 100.7 MHz.

TABLE V. RETURN LOSS PERFORMANCE OF MODIFIED MINKOWSKI PATCH ANTENNA WITH ML-SRR AND QPS-SRR (IN DIFFERENT ITERATION STAGE)

Minkowski Antenna stage	Resonant frequency	Return loss (dB)	Bandwidth (MHz)
Zero iteration	2.312	- 22.680	70.7
First iteration	2.392	- 36.925	69.6
Second iteration	2.402	- 47.990	60.8
Third iteration	2.202	-14.665	100.7

Table VI represents the result of the gain and the directivity of the antenna (in different iteration stage). The first iteration shown the best gain performance with 2.495 dB while the worst gain had been shown by third iteration with only 0.775 dB.

TABLE VI. GAIN AND DIRECTIVITY PERFORMANCE OF MODIFIED MINKOWSKI PATCH ANTENNA WITH ML-SRR AND QPS-SRR (IN DIFFERENT ITERATION STAGE)

Minkowski Antenna iteration stage	Gain (dB)	Directivity (dBi)
Zero iteration	2.332	5.441
First iteration	2.495	5.505
Second iteration	2.348	5.539
Third iteration	0.775	5.434

Figure 7 and Table VII shows the resonant frequency, return loss and bandwidth of the different type of modified Minkowski patch antenna. From the graph, it shows that the best performance of the return loss is the modified Minkowski patch antenna (without SRR structure) with  $-47.999$  dB at 2.402 GHz of frequency.

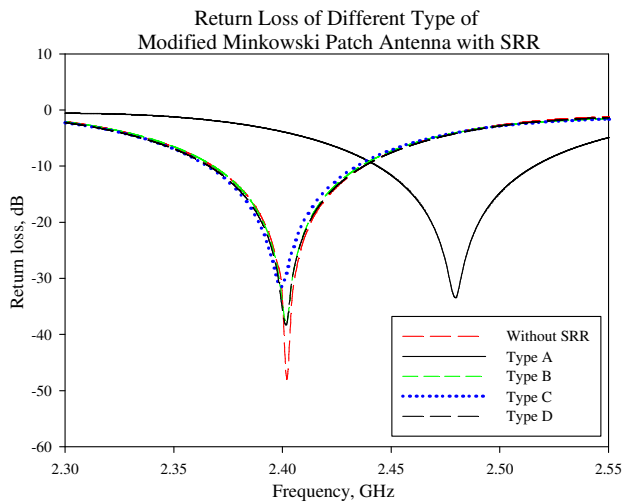


Figure 7. Return loss performance of the different type of modified Minkowski patch antenna with ML-SRR and QPS-SRR

TABLE VII. RETURN LOSS AND BANDWIDTH OF DIFFERENT TYPE OF MINKOWSKI PATCH ANTENNA WITH SRR

Minkowski Antenna type	Resonant frequency	Return loss (dB)	Bandwidth (MHz)
Without SRR	2.402	- 47.990	69.8
Type A	2.480	- 33.340	72.3
Type B	2.402	- 38.128	68.1
Type C	2.402	- 31.328	68.7
Type D	2.402	- 38.086	71.3

The addition of the SRR structure had been reduced the return loss performance. The addition of the SRR had been enhanced the gain of the Minkowski patch antenna. It shows that in Type B antenna, it increases the gain of the Minkowski

patch antenna from the 2.348 dB to 2.644 dB. The addition of the rectangular stripline had been located back the resonant frequency from the 2.480 GHz at the Type A to 2.402 GHz in Type B antenna. This SRR structure did not give the big impact of the bandwidth performance.

Figure 8 shows the 3D radiation pattern of the modified Minkowski antenna with SRR structure. Table VIII represents the gain and directivity performance of the different type of modified Minkowski patch antenna.

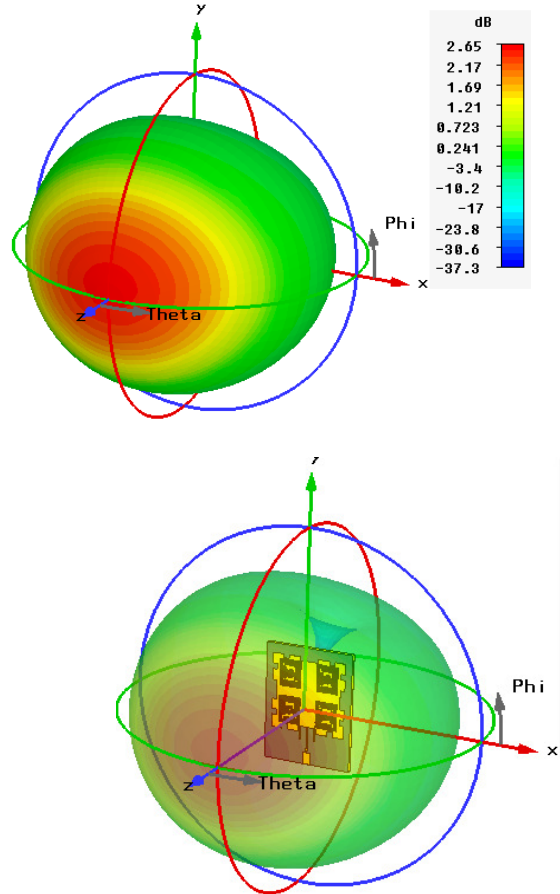


Figure 8. 3D radiation pattern of the antenna

TABLE VIII. GAIN AND DIRECTIVITY OF DIFFERENT TYPE OF MINKOWSKI PATCH ANTENNA WITH SRR

Minkowski Antenna type	Gain (dB)	Directivity (dBi)
Without SRR	2.348	5.539
Type A	2.627	5.644
Type B	2.644	5.506
Type C	2.629	5.501
Type D	2.486	5.522

## V. CONCLUSION

After simulation done, it shows that the gain had been enhanced by the addition of the ML-SRR and QPS-SRR on the modified Minkowski patch antenna. An improvement of the gain by 0.296 dB from 2.348 dB to 2.644 dB. The SRR has the capability can control the resonant frequency. The proposed antenna design can be integrated with RF transmitter [17] and RF receiver [18] to form a complete WLAN front-end system.

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