Jurnal
Teknologi

Full Paper

Minkowski Island Fractal Patch Antenna With Different Size of Complimentary Quadruple P-Spiral SRR (QPS-SRR) Structures For Broadband Applications

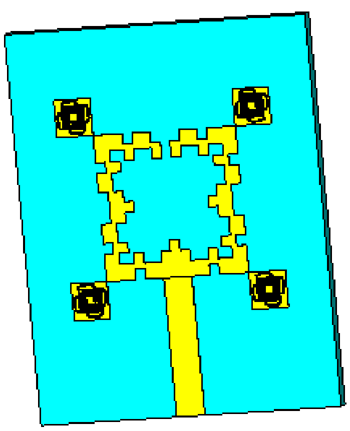
Article history
Received
27 August 2015
Received in revised form
23 December 2015
Accepted
3 January 2016

Nornikman Hassan*, Muhammad Syafiq Noor Azizi, Mohamad Hafize Ramli, Mohammad Hanif Mazlan, Mohamad Ariffin Mutalib, Thailis Bounya Ngelayang, Mohd Hafiz Sulaiman, Muhammad Zuhair Bolqiah Edris

Centre for Telecommunication Research and Innovation (CeTRI), Faculty of Electronics and Computer Engineering, Universiti Teknikal Malaysia Melaka (UTeM), 76100 Durian Tunggal, Melaka, Malaysia

*Corresponding author
nornikman84@utem.edu.my

Graphical abstract



Abstract

A wideband Minkowski fractal antenna with complimentary quadruple P-spiral split ring resonator (QPS-SRR) is proposed in this paper. Four minis complimentary QPS-SRR structure had been connected to the corner of the main Minkowski Island fractal to investigate the effect to the resonant frequency, return loss, bandwidth and gain of the antenna. Firstly a basic Minkowski Island of Design A is simulating. Then 2-N of complimentary QPS-SRR (Design B1 and Design B2) is added to the antenna. Lastly, five different sizes of complimentary 4-N QPS-SRR (Design C1, Design C2, Design C3, Design C4 and Design C5) is added in the antenna to compared its effect. Design C is effect to resonate at two different frequencies of 2.28 GHz and 3.336 GHz with return loss of – 13.252 dB and – 19.296 dB. This antenna also can be applies at 2.4 GHz of WLAN application and 3.5 GHz WiMAX application with return loss performance of – 13.252 dB and -12.26 dB, respectively. It shows the single bandwidth of the 4.8 mm width x 4.8 mm length QPS-SRR (Design C3) is 1.218 GHz.

Keywords: Minkowski Island, microstrip patch antenna, fractal antenna, split ring resonator, resonant frequency

1.0 INTRODUCTION

Smaller dimension design of microstrip antenna and broadband effect to the antenna is two main significant demands from consumers. These consumer requirements can be realized with the use of various techniques for create smaller dimension with broadband application. Fractal geometry structure based is use to reduce the size of the microstrip patch antenna. Minkowski [1], Minkowski Island, Hilbert [2], Sierpinski [3], Koch [4], are the example of the fractal geometry structures. This fractal geometry exists by the similarity shaped with different dimension.

Minkowski Island is the subdivision geometry of the Minkowski fractal structure. This structure had been use in several antenna designs such as in [5-6]. Beside antenna, this Minkowski Island structure are also founded in the reflectarray antenna [7], RF filter design [8] and frequency selective surface design [9].

In this works, the Minkowski fractal antenna with four minis quadruple P-spiral structures (QPS-SRR) had been design to reduce the size of the antenna and create a broadband condition to cater multiband effect of resonant frequency. The different configuration of the complimentary QPS-SRR is done in this work. This is to investigate the effect to the return loss, resonant frequency, bandwidth and the gain of the Minkowski fractal antenna.

Split ring resonator structure is the example of the metamaterial that function to reduce the size of the antenna. In the year of 1999 and 2000, Smith and Pendry successfully introduced this SRR technique by implementing split ring resonator (SRR) structure with metal wires [10-11].

2.0 ANTENNA DESIGN

This section shows the dimension and configuration structure of the proposed antenna. Firstly it shows the complimentary QPS-SRR. Then it followed by the different stage of the Minkowski Island fractal with complimentary QPS-SRR of Design A, Design B, and Design C.

Figure 1 shows the complimentary quadruple P-spiral split ring resonator. The dimension of the complimentary QPS-SRR is 4 mm x 4 mm.

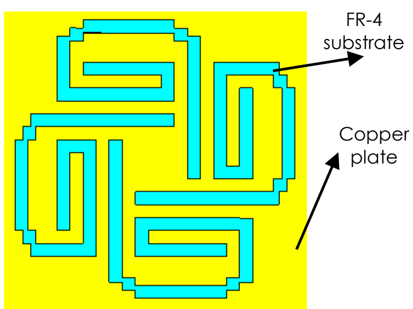


Figure 1 Complimentary quadruple P-spiral split ring resonator structure in copper patch

Figure 2 shows the basic Minkowski Island fractal antenna with quadruple P-spiral split ring resonator structure (Design A). This Minkowski Island is designed on a FR-4 substrate (dielectric constant, εr = 4.3) with a substrate thickness of 1.6 mm, width of 30 mm and length of 38 mm and copper thickness of 0.035 mm. These copper plates are located at the front part and the back (ground) of the substrate. This antenna has a ground plane of 21 mm width x 7.0 mm length. The dimension of the Minkowski Island fractal is 14.2 mm x 14.2 mm.

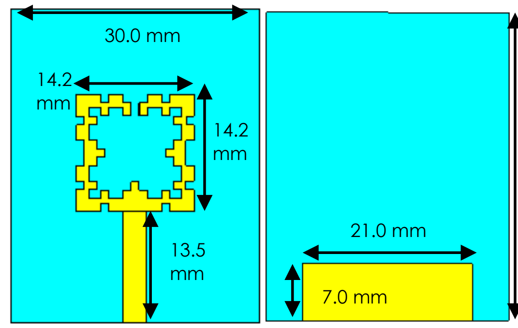


Figure 1 Minkowski Island fractal patch antenna, Design A (a) front view (b) back view.

Figure 3 shows the Minkowski Island fractal antenna with 2-N quadruple P-spiral split ring resonator structure (Design B). Design B1 is the antenna that has QPS-SRR at above patch while Design B2 is the antenna that has QPS-SRR at bottom patch.

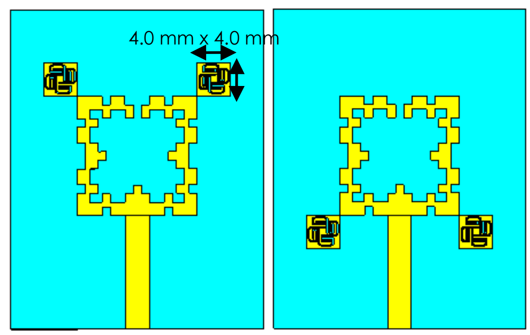


Figure 3 Minkowski Island fractal patch antenna with 2-N complimentary QPS-SRR structure, (a) Design B1 (complimentary QPS-SRR at above patch) (b) Design B2 (complimentary QPS-SRR at bottom patch)

Figure 4 represent the Minkowski Island fractal antenna with 4-N quadruple P-spiral split ring resonator structure (Design C). Five different dimensions of the width and length of complimentary QPS-SRR are done to investigate the effect. The dimension of the Design C1, Design C2, Design C3, Design C4 and Design C5 are 3.2 mm x 3.2 mm, 3.6 mm x 3.6 mm, 4.0 mm x 4.0 mm, 4.4 mm x 4.4 mm, and 4.8 mm x 4.8 mm, respectively.

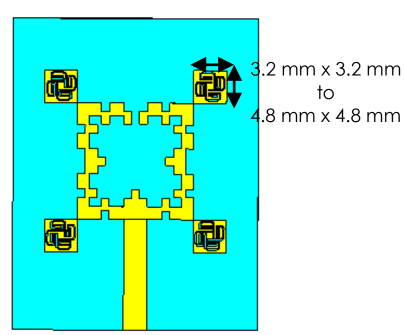


Figure 4 Minkowski Island fractal patch antenna with 4-N complimentary QPS-SRR structure, Design C

3.0 RESULTS AND DISCUSSION

This section shows the several performance of the Minkowski Island fractal patch antenna with QPS-SRR structure. The parameters that taken place in this paper are resonant frequency, return loss, bandwidth and antenna gain.

Figure 5 represent the return loss performance for basic Minkowski Island fractal antenna (Design A) in CST Microwave Studio. It shows that the return loss of –19.81 at resonant frequency of 2.45 GHz with bandwidth between 2.209 GHz to 2.787 GHz and

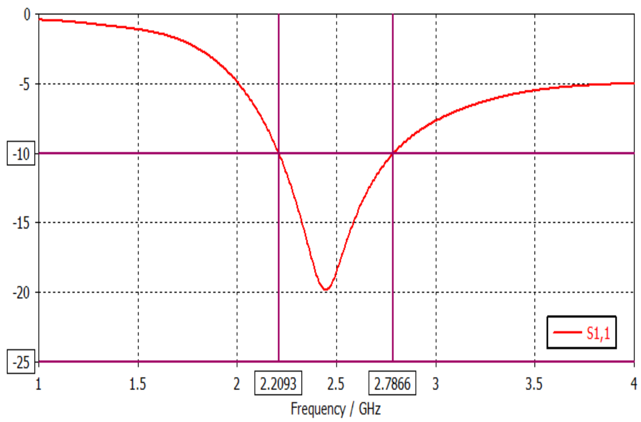


Figure 5 Return losses for basic Minkowski Island fractal antenna (Design A)

The return loss for the Minkowski Island fractal antenna with 2-N quadruple P-spiral split ring resonator structure (Design B1 and Design B2) is shown in Figure 6. The different locations of the QPS-SRR structure can shift the resonant frequency (to the lower or to the higher frequency). The top QPS-SRR structure creates two different resonant frequencies at 2.165 GHz and 5.07 GHz with – 24.802 dB and – 19.534 dB, respectively.

Compared with the top 2-N QPS-SRR, the bottom 2-N QPS-SRR shows the worst return loss but still have the accepted return loss performance. It resonates at two different frequencies at 2.479 GHz and 3.70 GHz with only – 10.567 dB and – 11.269 dB, respectively.

As for bandwidth performance, it shows that the top 2-N QPS-SRR has a wider bandwidth compare the bottom 2-N QPS-SRR.

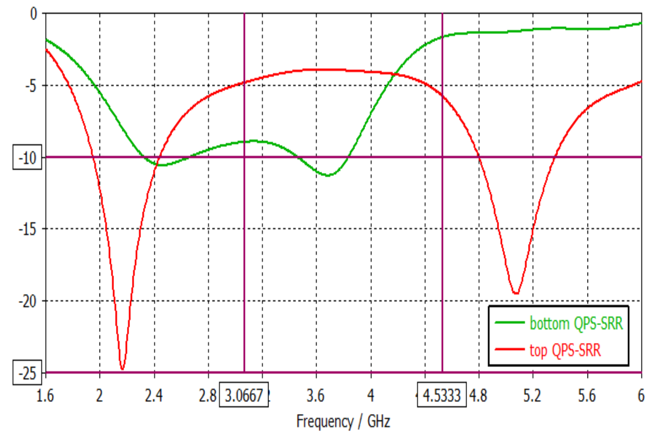
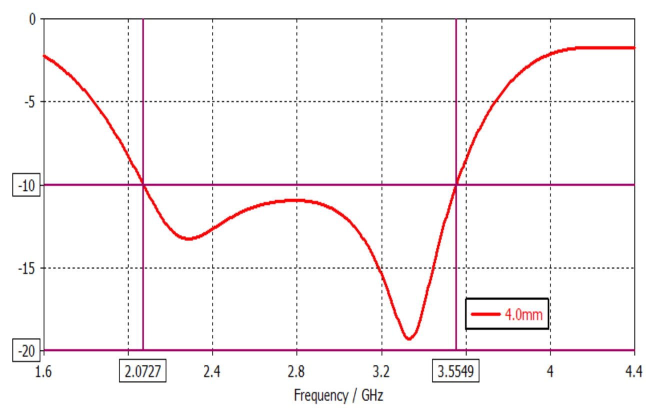
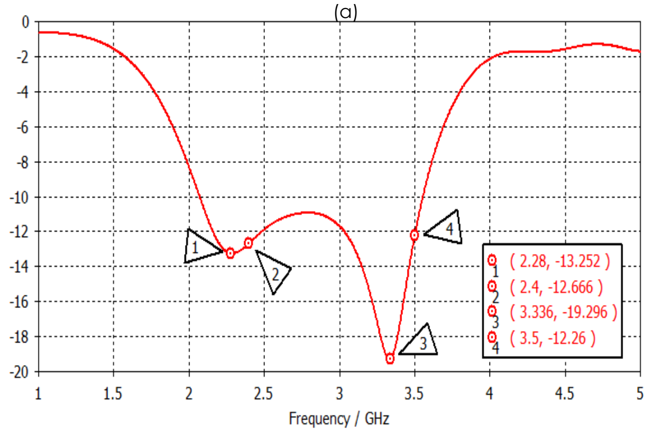


Figure 6 Return losses for Minkowski Island fractal antenna with 2-N complimentary QPS-SRR (Design B1 and B2)

The next section is to compare the size of the 4-N QPS-SRR on the Minkowski Island fractal patch antenna. Figure 7 shows the return loss, resonant frequency and bandwidth of the for Minkowski Island fractal antenna with 4-N complimentary QPS-SRR (Design C3).



(a)



(b)

Figure 7 Return losses for Minkowski Island fractal antenna with 4-N complimentary QPS-SRR (Design C3), (a) bandwidth of the antenna, (b) resonant frequencies

Design C is effect to resonate at two different frequencies of 2.28 GHz and 3.336 GHz with return loss of – 13.252 dB and – 19.296 dB. This antenna also can be applies at 2.4 GHz of WLAN application and 3.5 GHz WiMAX application with return loss performance of – 13.252 dB and -12.26 dB, respectively. Table 1 shows the Frequency, return loss, and gain for the Minkowski Island fractal antenna with 4-N complimentary QPS-SRR (Design C3).

Table 1 Frequency, return loss, and gain for the Minkowski Island fractal antenna with 4-N complimentary QPS-SRR (Design C3)

Frequency (GHz)	Return loss (dB)	Gain (dB)
2.28	- 13.252	0.920
2.40	- 12.666	1.061
3.336	- 19.296	1.835
3.50	- 12.26	1.526

Figure 8 sand Table 2hows the return losses for Minkowski Island fractal antenna with 4-N complimentary QPS-SRR (Design C1 to Design C5). From the graph, it shows that the size of the complimentary QPS-SRR can effect the location of the second resonant frequency. For example, the resonant frequency of the 4.8 mm width x 4.8 mm length is effect to resonate at 3.008 GHz while it will shift to 3.888 GHz by using the 3.2 mm width x 3.2 mm length.

For the first resonant frequency, it shows that the QPS-SRR give the minimum effect to the location of the resonant frequency compare with the second resonant frequency. It also shows the 4.8 mm width x 4.8 mm length shows the combination of the bandwidth compare with the 3.2 mm width x 3.2 mm length. In this case, it shows the single bandwidth of the 4.8 mm width x 4.8 mm length is 1.218 GHz while the 3.2 mm width x 3.2 mm length have two bandwidth regions.

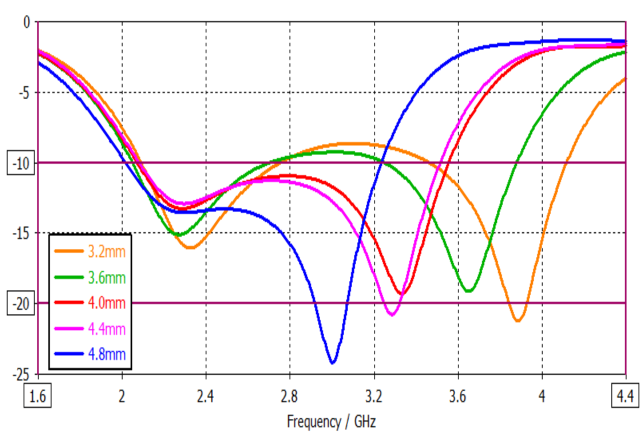


Figure 8 Return losses for Minkowski Island fractal antenna with 4-N complimentary QPS-SRR (Design C1 to Design C5)

Table 2 Frequency, return loss, and bandwidth for the Minkowksi Island fractal antenna with 4-N complimentary QPS-SRR (Design C1 to Design C3)

Minkowski Antenna	Resonant frequency (GHz)	Return loss (dB)	Bandwidth (GHz)
C1	2.332	- 16.028	2.091 – 2.754
	3.888	- 21.218	3.465 – 4.117
C2	2.272	- 15.101	2.049 – 2.704
	3.652	- 19.121	3.251 – 3.879
C3	2.292	- 13.254	2.072 – 3.555
	3.340	- 19.278	
C4	2.295	- 12.901	2.082 – 3.515
	3.292	- 20.743	
C5	2.312	- 13.526	2.017 – 3.235
	3.008	- 24.146	

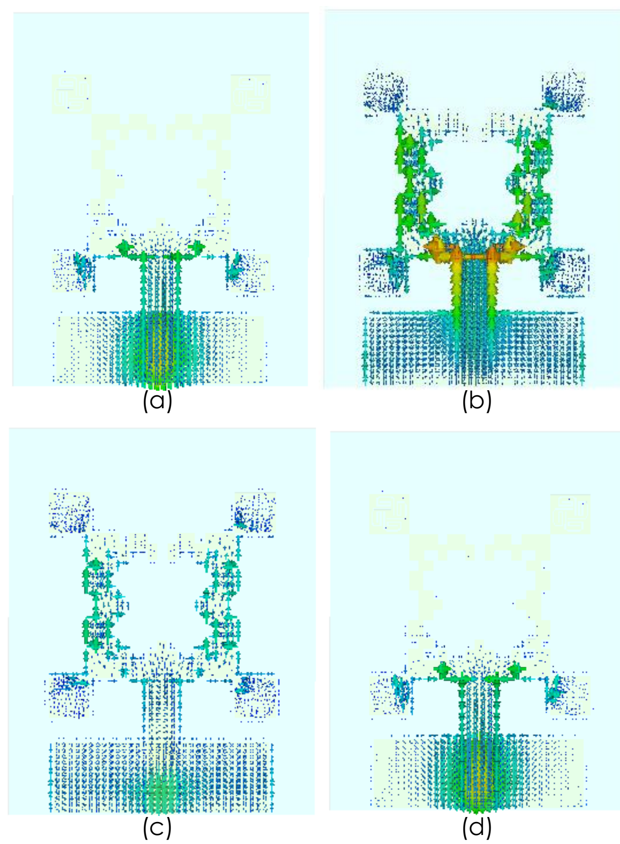


Figure 9 The surface current distribution of Minkowski Island fractal antenna with 4-N complimentary QPS-SRR (Design C3) at 2.4 GHz, (a) 0^0, (b) 90^0, (c) 135^0, (d)180^0,

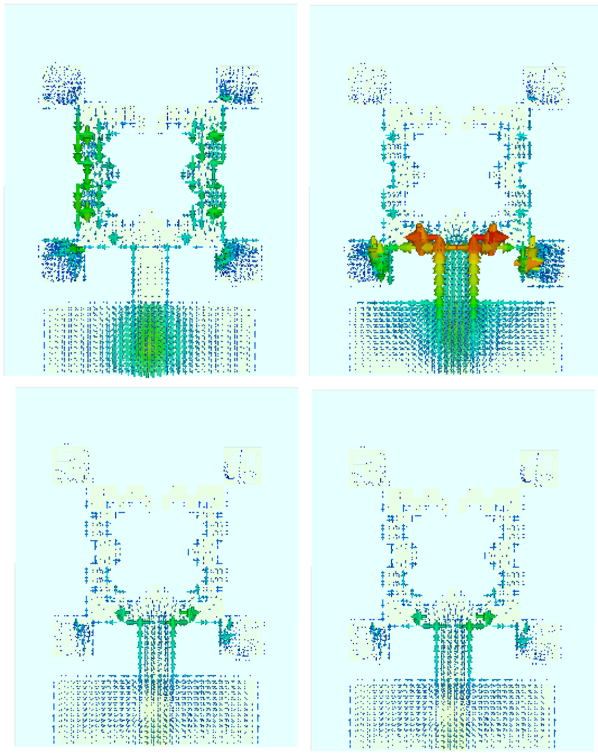


Figure 10 The surface current distribution of Minkowksi Island fractal antenna with 4-N complimentary QPS-SRR (Design C3) at 3.5 GHz, (a) 0^0, (b) 90^0, (c) 135^0, (d)180^0,

Figure 9 represents the surface current distribution of Minkowksi Island fractal antenna with 4-N complimentary QPS-SRR structure (Design C) at 2.4 GHz. Figure 10 represent the surface current distribution of Minkowksi Island fractal antenna with 4-N complimentary QPS-SRR (Design C3) at 3.5 GHz.

Figure 11 shows a comparison of radiation for the of Minkowksi Island fractal antenna with 4-N complimentary QPS-SRR (Design C3). Two different phase considered in this work, firstly at phase = 0^0 while another at phase = 90^0. At 2.4 GHz, it shows that the eye drop shaped for Phi = 0^0 and eight-like shaped for Phi = 90^0. At 3.5 GHz, it shows that the peanut-like shaped for Phi = 0^0 and eight-like shaped for Phi = 90^0.

For the future work, this antenna had the potential to combined in the full communication system with several design of RF filter, switch or amplifier [12-13].

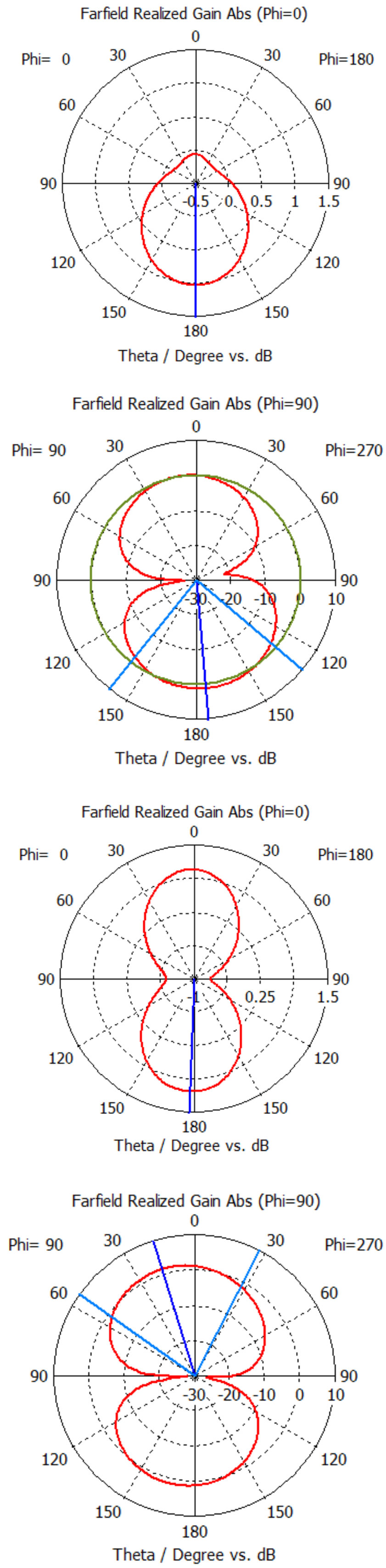


Figure 11 Comparison of 2D radiation pattern for microstrip patch antenna with different locations of quadruple P-spiral split ring resonators, (a) at phase = 0^0, (b) phase = 90^0.

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. This structure can create another resonant frequency at several points. By change the dimension of 4-N QPS-SRR, it can effect to control the wanted second resonant frequency.

Acknowledgement

The authors would like to thank Universiti Teknikal Malaysia Melaka (UTeM) and the MyBrain15 program from the Government of Malaysia for sponsoring this study. The authors would also like to thank UTeM for sponsoring this work under the TRGS/1/2014/FKEKK/02/1 grant. The authors would like to thank UTeM for their support in obtaining the information and material in the development of our work and we also want to thank the anonymous referees whose comments led to an improved presentation of our work.

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