Minkowski Fractal Antenna Design with DMS-SRR and DGS-SRR Structure for WLAN Application

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Abstract— Nowadays, the high gain and compact antennas are the most common issue that commonly considered by many researchers in the telecommunication area, especially in antenna design. There are many types of microstrip patch antenna had been researching to cater this problem. This paper is focused on the combination of defected microstrip structure of split ring resonators (DMS-SRR) and defected ground structure of split ring resonators (DGS-SRR) on the ground plane. The proposed DMS-SRR structure effect to wider the bandwidth and also increase the gain of the Minkowski fractal patch antenna. The other technique used in this design is a double layer substrate of FR-4 to improve the gain of the antenna. This double layer effect to increase the Minkowski fractal antenna gain to 3.827 dB, but it shifted the resonant frequency to 2.634 GHz. The DGS-SRR structure used to shift back the resonant frequency to 2.4 GHz region. Other parameters that had been considered in this work are return loss, radiation pattern and surface current. The first work is started by designing a normal Minkowski patch antenna. Then, three units of DMS-SRR had been added to the front side of the Minkowski fractal antenna. After that, a pair of DGS-SRR had been added to the ground plane of the antenna. The resonant frequency of this antenna is 2.4 GHz used for wireless LAN (WLAN) application. The proposed antenna capability to improve the antenna gain from 2.445 GHz to 3.650 GHz while the bandwidth is improving from from 69.00 MHz (2.368 GHz to 2.437 GHz) to 129.90 MHz (2.407 GHz to 2.537 GHz).

1. INTRODUCTION

In the recent day, the high gain and miniaturize patch antennas are the most common issue that had been focusing by many researchers in the telecommunication sector. There are many techniques can matter this problem such as using array patch, slots, dielectric resonator, metamaterial and fractal geometry structure in their design. In 1968, Veselago had been introduced the combination of the conducting wire and split ring resonator structure into his design [1]. This theory had been applied by Pendry work in 1999 [2] and Smith work in 2000 [3]. In literature, the metamaterial is the artificial material that had been implemented to miniaturize the patch antenna size by reducing the resonant frequency. Split ring resonator (SRR) [4, 5] is an example of a left handed material (LHM) in a metamaterial structure group beside photonic band gap (PBG) [6], electronic band gap (EBG) [7] and artificial magnetic conductor (AMC) [8]. There are many works that apply the defected microstrip structure (DMS) [9, 10] , defected ground structure (DGS) [11, 12] and defected stripline structure (DSS) [13, 14] on their work.

The term of fractal was originally introduced by Mandelbrot [15]. Fractals are generally composed of multiple copies of the similarity structure with different scale and size. Minkowski design is one of the popular fractal that had been used. The other examples of fractal geometry that use in antenna design are Koch, Sierpinski, Hilbert. This fractal design such as Minkowski can provide a multiband effect and also significantly can miniaturize the patch antenna design by reducing the resonant frequency [16]. The Minkowski design is based on a square, rectangular or triangular generator structure [17].

2. ANTENNA DESIGN

The complementary structure of defected microstrip structure SRR (DMS-SRR) had been attached at the upper part of the FR-4 substrate. It consists a combination of two main parts — straight line part and spiral part. The location of this complimentary DMS-SRR is at the center of the modified Minkowski patch antenna, based on this paper [18]. Figure 1(a) shows the single unit and the DMS-SRR structure. The dimensions of the DMS-SRR are SRR width, $W_{s1} = 1.13$ mm, SRR length, $L_{s1} = 1.78$ mm while SRR gap, $G_s = 0.16$ mm. Figure 1(b) and Table 1 shows the first

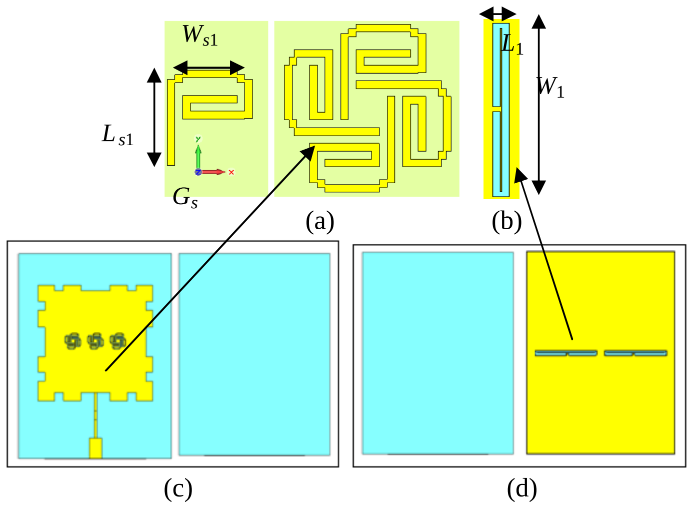


Figure 1: (a) DMS-SRR structure. (b) DGS-SRR structure. (c) 3-N DMS-SRR Minkowski antenna (first layer). (d) 3-N DMS-SRR Minkowski antenna with DGS-SRR structure on the ground (second layer).

layer of proposed antenna that contain Minkowski patch antenna with feedline. The dimension of this antenna is patch width, W_p and patch length, $L_p = 28.866$ mm, feedline width, $W_f = 2.81$ mm and feedline length, $L_f = 14.5$ mm. Figure 1(c) shows the second layer of antenna that contain a defected ground structure SRR (DGS-SRR). Figure 1(d) represents the DGS-SRR with dimension of 14 mm width, $W_1 \times 1.9$ mm length, L_1.

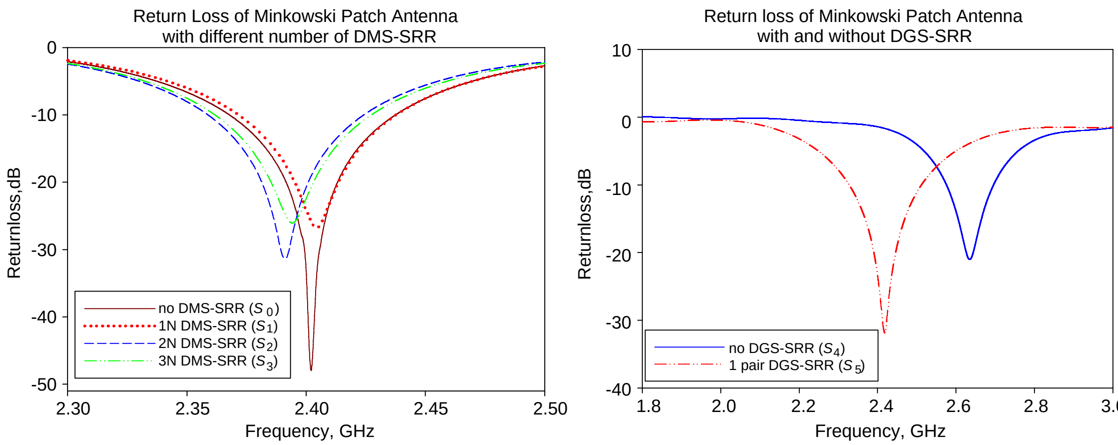
There are five stages of development of the proposed antenna, the initial stage (S_0) is a single layer of the Minkowski antenna without any SRR structure. The first stage (S_1), second stage (S_2) and third stage (S_3) is the addition of 1-N DMS-SRR, 2-N DMS-SRR and 3-N DMS-SRR. All three design is single layer with ground plane at the back. The fourth stage (S_4) is the double layer 3-N DMS-SRR antenna with ground plane while the fifth stage (S_5) is the double layer 3-N DMS-SRR with a pair DGS-SRR at the ground plane.

3. RESULT

Figure 2(a) and Table 1 compare the return loss of Minkowski patch antenna (S_0) and the DMS-SRR Minkowski patch antenna design (S_1, S_2, and S_3) in CST Microwave Studio simulation software. The resonant frequency, f_r for this normal Minkowski antenna is 2.402 GHz with −47.990 dB of return loss performance. The bandwidth of this antenna is 69.0 MHz in the frequency range between lower frequency limit, f_L and higher frequency limit, f_H. The value of $f_L = 2.368$ GHz while the $f_H = 2.437$ GHz. The return loss of the DMS-SRR Minkowski antenna had been worst the return loss value to −26.761 dB, −31.106 dB and −26.072 dB respectively. This DMS-SRR structure had been functioning to shifting the frequency into the lower frequency tan the normal Minkowski antenna. It shows that, the addition of 2-N DMS-SRR structure can be shifted to the resonant frequency from 2.402 GHz to 2.392 GHz. This is can be a potential technique to reduce the size

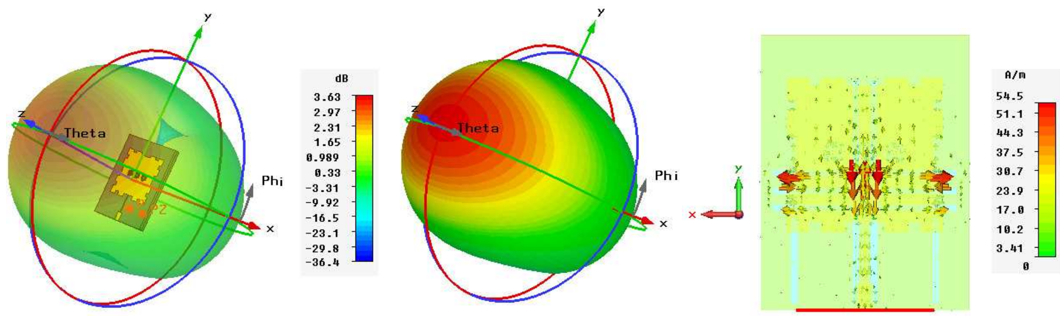
Table 1: Minkowski patch performance with different number of QPS-SRR.

Antenna Design	**Resonant frequency (GHz)**	**Return loss (dB)**	**Bandwidth (MHz)**	**Gain (dB)**
Normal Minkowski	2.402	−47.990	69 (2.368–2.437)	2.445
1-N DMS-SRR	2.404	−26.761	66 (2.372–2.438)	2.573
2-N DMS-SRR	2.392	−31.106	65 (2.359–2.424)	2.536
3-N DMS-SRR	2.394	−26.072	65 (2.362–2.427)	2.540
3-N DMS-SRR (double layer, without DGS-SRR)	2.634	−21.013	120.3 (2.575–2.695)	3.827
3-N DMS-SRR (double layer, with DGS-SRR)	2.410	−23.695	129.90 (2.407–2.537)	3.650



(a) (b)

Figure 2: (a) Return loss of Minkowski patch antenna with different number of QPS-SRR. (b) Return loss of Minkowski patch antenna with different number of SF-SRR at the ground plane.



(a) (b)

Figure 3: (a) The gain performance of the 3-N DMS-SRR Minkowsi patch antenna with a pairs DGS-SRR at the ground. (b) The surface current flow of the 3-N DMS-SRR Minkowsi patch antenna with a pairs DGS-SRR.

of the antenna. It also can improve the gain performance from 2.445 dB for normal Minkowski antenna to 2.573 dB.

In Figure 2(b), the fourth stage and fifth stages of the antenna had been compared its return loss performance. This double layer technique potentially to improve significantly the gain of the antenna from 2.445 GHz to 3.827 GHz. The problem a is the resonant frequency had been shifted from 2.402 GHz to 2.634 GHz. So, it had settled up by adding the DGS-SRR at the ground plane. It shows that the frequency had been shifted back to the 2.410 GHz by adding of DGS-SRR structures.

Figure 3 shows the performance gain of the 3-N DMS-SRR Minkowsi patch antenna with a pairs DGS-SRR at the ground while Figure 9 shows the surface current flow of the 3-N DMS-SRR Minkowsi patch antenna with 6 pairs DGS-SRR.

4. CONCLUSION

From the simulated results, it shows that the split ring resonator can be functioned to increase the gain and miniaturized the size of the Minkowski patch antenna. A different number of the DMS-SRR and DGS-SRR also can affect the resonant frequency, gain, return loss and bandwidth of the Minkowski antenna performances.

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