Design of a Compact Reconfigurable RDRA

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***Abstract*— In this paper, a compact rectangular dielectric resonator antenna is proposed by using fractal geometries. The Minkowski fractal patch is used on DRA's top to reduce the resonant frequency of the antenna. Numerical results are computed and compared up to three iterations. The fractal iterations offer an additional 19% reduction in the resonant frequency compared to a full size metal top. Switches are proposed at suitable places to achieve frequency reconfigurability. A 43% reduction in the resonant frequency (3.312GHz) is shown when switches are in OFF state compared to a conventional RDRA (5.84GHz) without any increase in antenna size or volume.**

Keywords-compact; RDRA; frequency reconfigurable;switch; fractal: Minkowski

I. Introduction

In last few years an extensive research has been done on dielectric resonator antennas because of their many advantages over the other low gain antennas like microstrip patch antennas. They provide low conductor loss, small size, wide impedance bandwidth and high radiation efficiency. Rectangular dielectric resonator antenna offers more flexibility than other conventional shapes in design considerations. There are many feeding techniques available for DRA in literature [1]. Microstrip line is one of the simplest feeding techniques with an aperture in ground plane. In today's cost-conscious world size reduction and frequency agility are most desirable features in antennas. Many researchers have investigated different schemes to reduce the size of DRA. In [2], a lower frequency operation is achieved by using a better matched feed for a half cylindrical DRA. Some other techniques like zonal slot [3], differentially fed hollow RDRA [4] and asymmetrical T-shape DRA [5] are investigated. Hybrid structures also embedded with the main DRA element to achieve lower resonating mode or enhancing the bandwidth of the antenna [6-8]. The resonant frequency can also be greatly reduced by a full size metal patch loaded on DRA's top [9]. Frequency agility offers more flexibility to use an antenna at different frequencies by changing external bias. The need for physically small antennas with frequency agility creates new possibilities for DRAs. A few papers are published on frequency agile DRAs [10-12].

In this paper a novel method is introduced to reduce the resonant frequency of DRA. Initially resonant frequency of the antenna is decreased by covering the top of RDRA with a full size metallic patch and additional reduction is achieved by means of a fractal patch. Fractal geometries have been used to reduce the resonant frequency by increasing the electrical length [13-14]. Further it is also shown that the antenna is suitable for frequency agility. A Metal tab has been used as a switch in ON state while the OFF state is realized by removing the tab.

II. Antenna Design

The structure consists of an aperture coupled microstrip fed RDRA as shown in Fig. 1. The dimensions of the DRA are given by a=9mm, b=9mm, and d=5mm. Its dielectric constant is given by ε_r=15. The DRA is placed on ground plane of a 50Ω microstripline and is excited by an aperture of L_s=7mm and W_s=1.6mm. The aperture is etched on the ground plane of 25×30mm^2 on a substrate of ε_{rg}=3.2 and thickness (h_{sub}) 0.762mm. The center of RDRA is aligned with that of the aperture. The width of 50Ω microstripline is (W_m) 2mm and length is extended by S=12mm from the center.

A. Miniaturisation of Antenna

Initially a metal patch of same size as RDRA (9×9mm^2) is placed on its top; Fig. 2 shows the iterated fractal geometries of metal patch. A Minkowski fractal is used to reduce the size of the patch while increasing the electrical length which results into reduction of resonant frequency of the antenna.

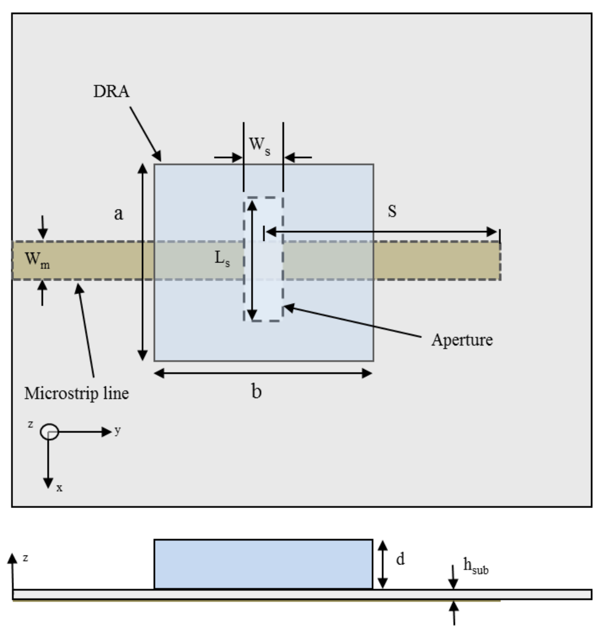


Figure 1. Geometry of an aperture coupled DRA

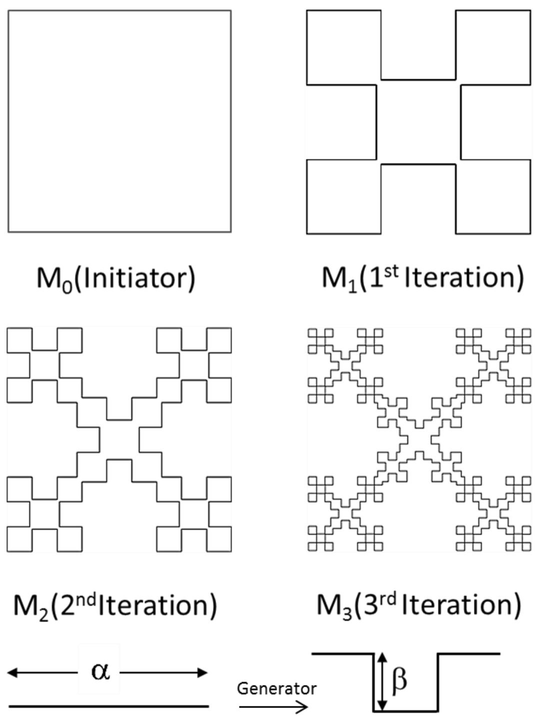


Figure 2. The Minkowski fractal and iterated structures

The starting geometry of fractal, called the zeroth iteration is a Euclidean square (M_0). When structure is iterated, each of the straight segments of the fractal geometry, called α, is replaced with the generator, which is shown at the bottom of Fig. 2. The iteration depth β is smaller than α/3. The iteration factor is $\rho=\beta\times(\alpha/3)^{-1}$ ($0<\rho<1$). The iterated fractal geometries are called M_n, where n is order of iteration. In this work ρ is 0.9 and iterations are done up to 3rd order.

B. *Frequency Reconfigurable Antenna*

Afterward reducing the resonant frequency of the dielectric resonator antenna, in attempt of attaining frequency reconfigurability, four suitable places are identified for employing the switches. Fig. 3 shows positions of the switches. In this work an ideal switch is used in place of a diode switch hence biasing is not taken into account but proper biasing circuit will be required in case of a diode switch. A metal tab of 0.3×0.54 mm^2 is used as a switch which is present when switch is in ON state however the tab is missing when switch is in OFF state. For connectivity between the switch and the patch two lines are added to the circuit on the both sides of each switch (shown in blue color), Fig. 3.

III. Numerical Results & Discussion

Fig. 4 compares the simulated return loss characteristics for the conventional RDRA loaded with and without a full size metal patch. It can be seen that a full size metal patch pulls down the resonant frequency of the antenna. The conventional RDRA resonates at 5.84GHz when fed through an aperture. When a full size metal patch is placed on the DRA's top the resonant frequency (f_r) becomes 4.72GHz.

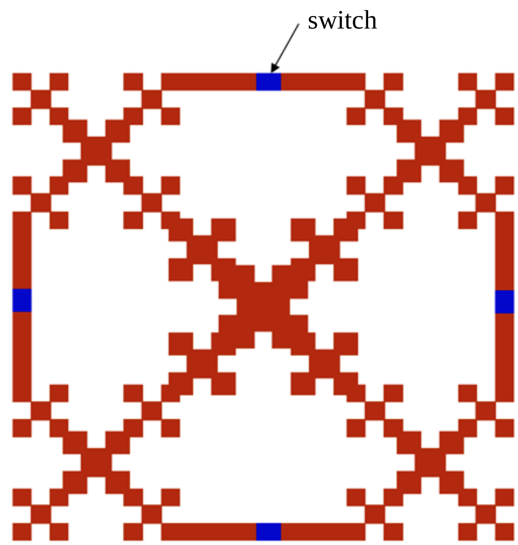


Figure 3. Switches positioned on DRA's top

This patch reduces the resonant frequency (f_r) by 19%. A further reduction in f_r is achieved using fractal geometries. Fig. 5 displays the effect of fractal iterations on the return loss variation of the antenna. After three iterations the resonant frequency (f_r) is reduced to 3.608GHz with a good return loss value of -43.6dB while that (f_r) was 4.72GHz for a full size metal patch. In this way an additional reduction of 19% or a total of 38% reduction in resonant frequency is achieved.

In Fig. 6 reconfigurable characteristics of the proposed antenna are shown. Here simulations are done only for two states, when all switches are in ON state or in OFF state; though there also may be other combinations as four switches are used in the structure. Table 1 comprises the antenna characteristics for the two states of the switches. When switches are in OFF state the antenna resonates at (f_{off}) 3.312GHz while for 3rd iterated antenna it was 3.608GHz this slight shift in frequency is accounted for the additional length due to the added lines.

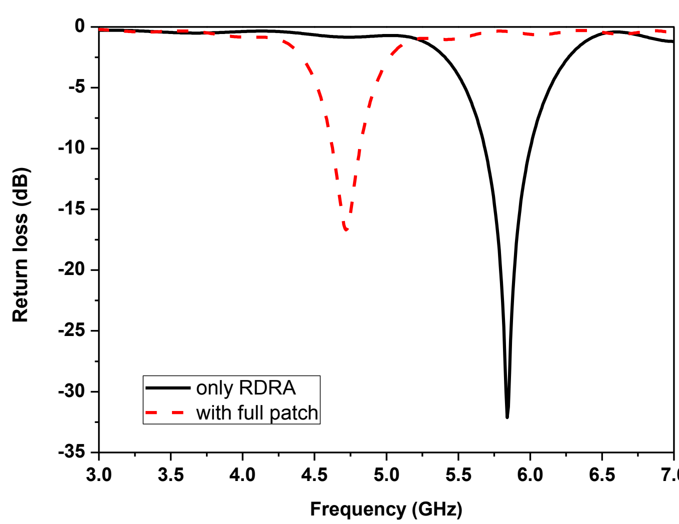


Figure 4. Return loss characteristics for RDRA with and without metal top

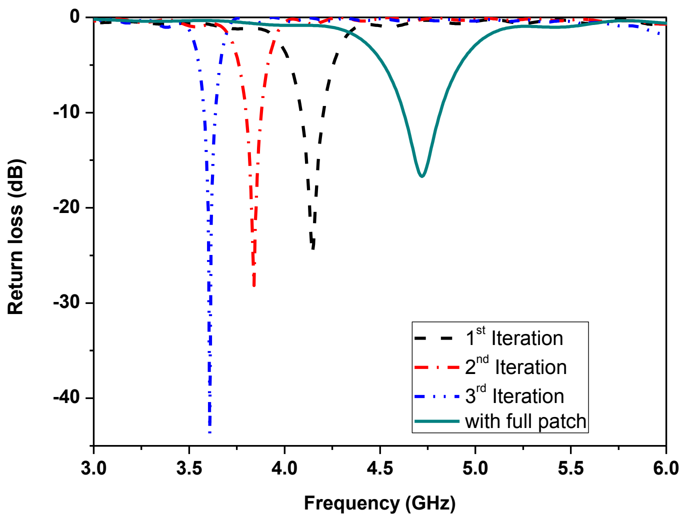


Figure 5. Effect of fractal iterations on the antenna

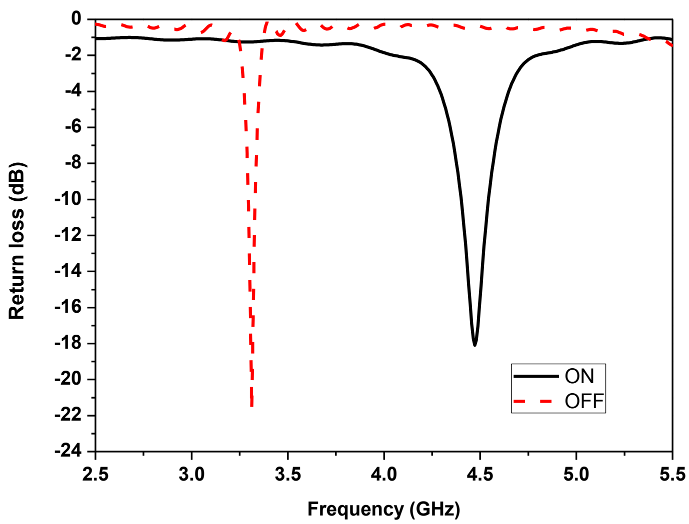
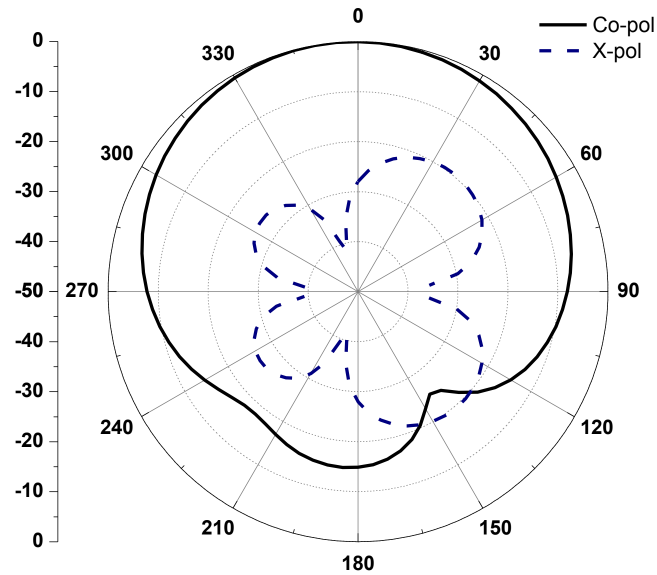
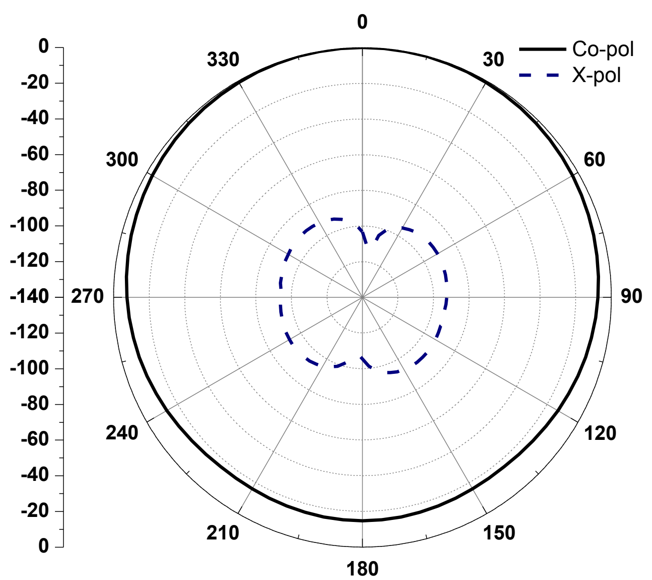


Figure 6. Frequency shifting due to proposed switches



(a) E-plane



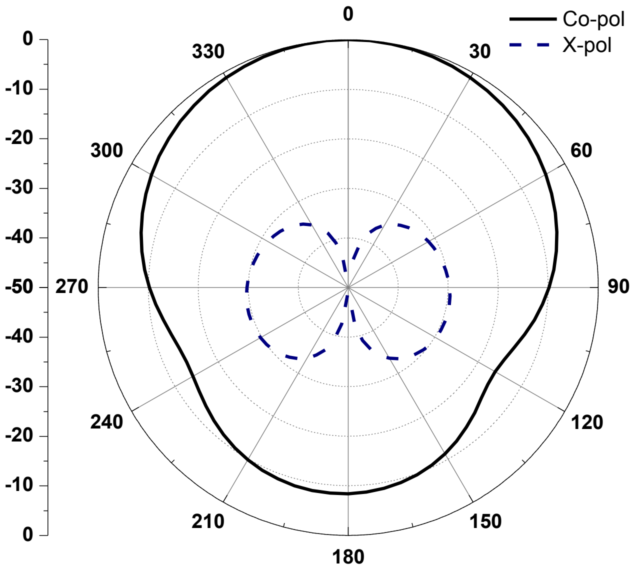
(b) H-plane

Figure 7. Simulated radiation patterns of the proposed reconfigurable antenna when switches are in ON state, f_r=4.472GHz.

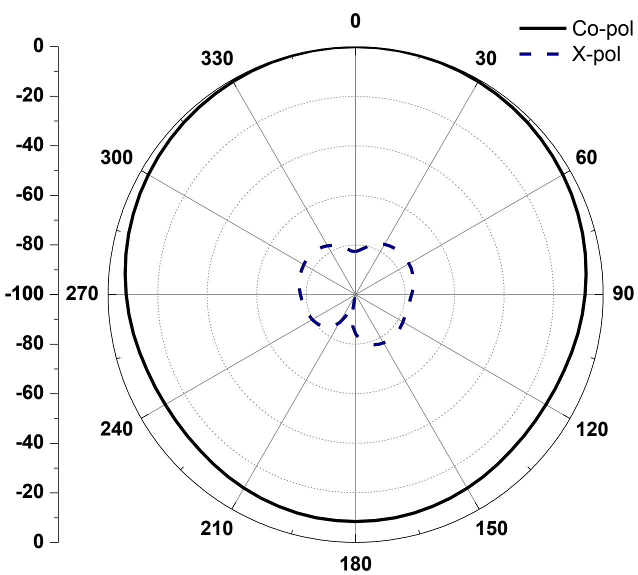
TABLE I. KEY PARAMETERS OF THE PROPOSED ANTENNAS

Key Parameter	**Conventional RDRA**	**Switches 'ON'**	**Switches 'OFF'**
Resonant frequency (GHz)	5.84	4.472	3.312
Impedance bandwidth (MHz)	308	124	35
Gain (dBi)	4.69	5	3.6
Directivity (dBi)	5.6	5.64	5.65
HPBW (degree)	115.1	105.3	97.7

When switches are ON, they behave as short circuits and provide a higher resonant frequency (f_{on}) of 4.472GHz. Fig. 7 shows the normalised E-plane and H-plane radiation patterns when all switches are in ON state. The cross polarization level (shown by dashed line) is 30dB down in the main lobe direction in E-plane and in H-plane this level is much lower than its coplanar field component.



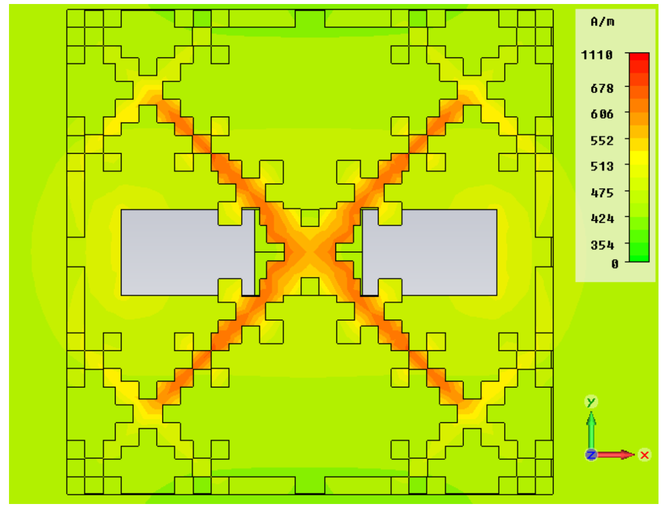
(a) E-plane



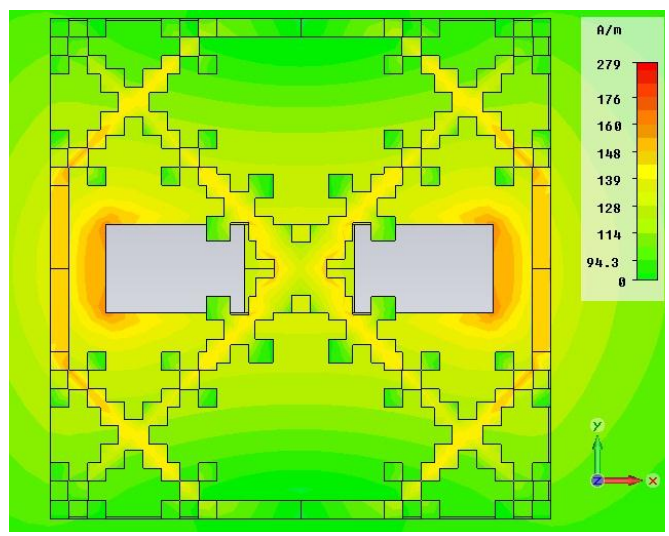
(b) H-plane

Figure 8. Simulated radiation patterns of the proposed reconfigurable antenna when switches are in OFF state, f_r=3.312GHz.

The surface current distribution, on the top layer of the proposed reconfigurable antenna, is also investigated for better understanding. In Fig. 9 current densities (top view) are shown for both the states of the switches. In OFF state, Fig. 9(a), the current is concentrated in centre and the diagonal branches of the fractal geometry as an open switch will not pass the current further, with a maximum value of 1.1x103 Amp/m, whereas in ON state the switch allows the current to flow through the linear branches as well as shown in Fig. 9(b). The simulated realized gain characteristics are shown in Fig. 10 for both the states of the switches.



(a)



(b)

Figure 9. Simulated surface current distribution of the proposed reconfigurable antenna when switches are in (a) OFF state and (b) ON state.

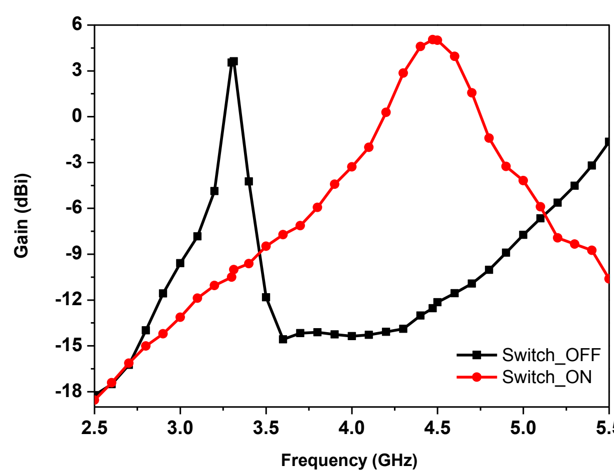


Figure 10. Simulated gain of the proposed reconfigurable antenna

IV. CONCLUSIONS

It has been shown that an additional reduction in resonant frequency of a DRA loaded with a full size metal patch can be achieved using fractal geometries. Fractal geometries are loaded on a DRA for the first time to reduce the resonant frequency of the DRA. A total reduction of 38% in the resonant frequency of a DRA is shown due to a fractal patch loading. Further the antenna is proposed with frequency reconfigurability between f_{on} and f_{off}. Frequency agility is achieved with four ideal switches (metal tab) without affecting other radiation characteristics. The f_{off} is 43% lower than the resonant frequency of the conventional RDRA. The antenna offers a moderate gain of 3.6dBi and 5dBi at 3.312GHz and 4.472GHz respectively.

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