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CONSIDERATION OF MUTUAL COUPLING IN A MICROSTRIP PATCH ARRAY USING FRACTAL ELEMENTS

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Abstract—In this paper we investigate the effect of replacing the ordinary rectangular microstrip patches in a linear antenna array with fractal patch elements. It is shown that using fractal patches substantially decreases the Mutual Coupling between elements. The effects of fractal type, spacing between elements, feed point location and number of parasitic elements on array performance has been studied.

1. INTRODUCTION

It is well known that array antennas in various forms increase the efficiency, and improve the performance of radiating system in communication networks and other applications [1–3]. One of the important parameters is the mutual coupling between elements, which may have notable effect on driven elements current distribution, thus causing drastic changes on radiation pattern and other antenna characteristics such as SLL and so on. Mutual coupling, as long as, the spacing between elements in large compared to wavelength can be ignored, otherwise, it must be kept within tolerable level, somehow, ways to accomplish this are discussed in [4, 5].

Of particular interest, are microstrip patch antenna arrays, which due to their interesting properties such as being compact, conformal, and light weight have found vast applications. In this paper, we consider a linear microstrip patch array in which the conventional rectangular patches have been replaced with patches generated by fractal geometries. Simulation results have shown reduction of mutual coupling between the patch elements as compared to array with rectangular patches by considerable margin. We have, also investigated the effect of feed point displacement, as well as, size of fractal patches, and spacing between them, as well as, the number of parasitic elements on array performances.

2. FRACTAL PATCHES ARRAY

Fractal meaning broken or fractured derived from Latin word "fractus" dates back to 19th century as a branch of classical mathematics. Fractals are geometrical shapes that are self similar, and can generate almost any complex structure in nature, through iterating of certain simple geometries. Fig. 1 shows examples proposed by Sierpinski (1916), and Koch (1904).

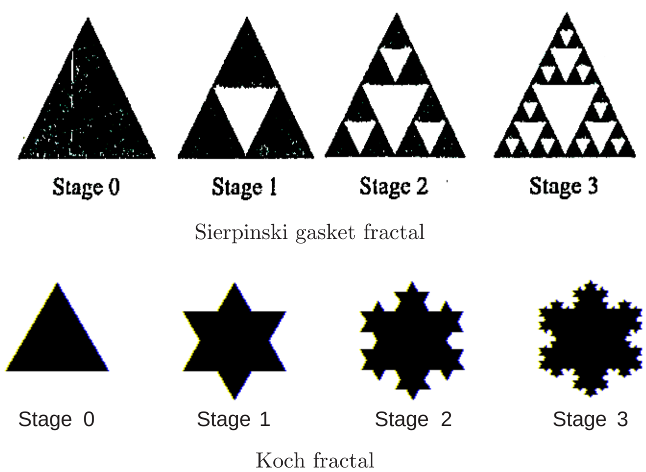


Figure 1. Two kinds of fractals.

Based on their interesting properties, fractals have found vast application in various disciplines of sciences. One of this application is in antenna theory, where thanks to their filling property, may be used to miniaturize antenna structures and make efficient radiating structures in GHz band [6, 7].

In this paper we consider a fractal array with 10 elements. Each element is generated by three iterations using Koch fractal. The fractal patch element and array is shown in Fig. 2 and Fig. 3. Each patch is 20 mm wide and 23 mm long. The distance between the centers of elements is considered to be 0.38λ (24 mm) at the center frequency of 4.75 GHz. Substrate is duriod with $\varepsilon_r = 2.33$ and thickness of 3.175 mm. For comparison basis, we have chosen an array of rectangular patches with the same number of elements discussed in ref. [8].

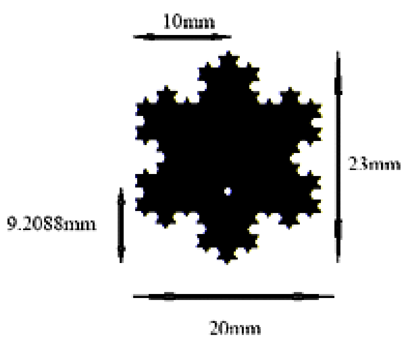


Figure 2. Typical one element in proposed fractal patch array with feed point.

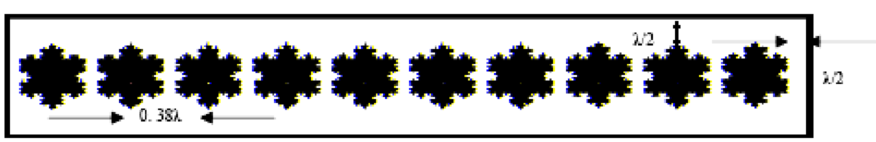
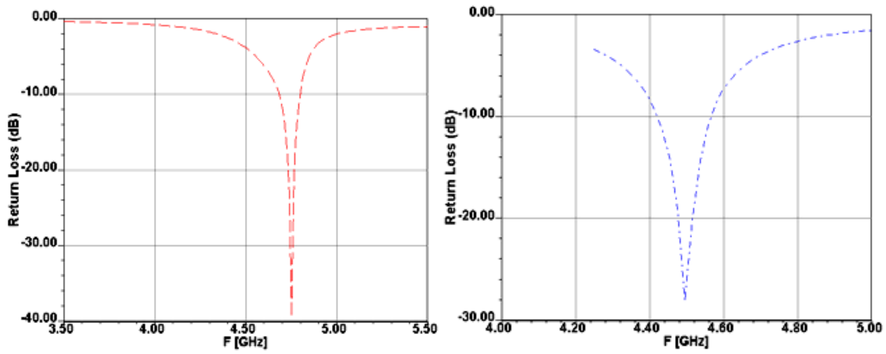


Figure 3. The structure of proposed fractal patch array.

3. SIMULATION RESULTS AND DISCUSSION

We have assumed that all patch elements are fed uniformly, that is, their exciting currents have the same amplitude and phase. Proposed array was analyzed by Ansoft Designer 1.1 based on Moment method. In Fig. 4(a) we have shown the return loss at the input of each patch for the case where two end elements are assumed to be parasitic. The result for array with conventional rectangular patch is also shown for



(a) (b)

Figure 4. (a) Return loss of the proposed fractal patch array as a function of frequency. (b) Return loss of the conventional rectangular patch array as a function of frequency.

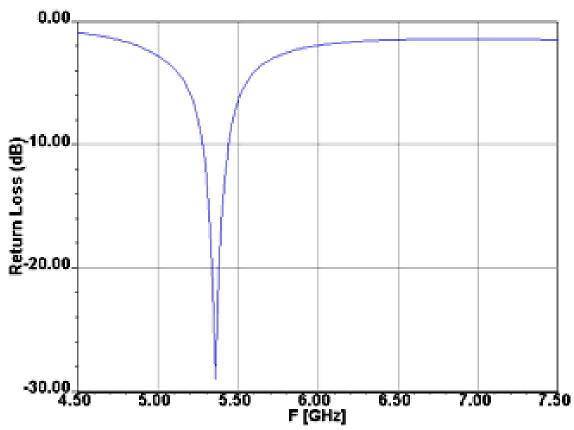


Figure 5. The effect of size reduction on resonance frequency and return loss of the array.

comparison in Fig. 4(b). It is noted that the proposed array has much less return loss as compared to the conventional array.

In Fig. 5 the effect of reduction in the size of the patches is demonstrated. For patches of the size $20\,\text{mm} \times 17.1\,\text{mm}$, we can see that, the resonance frequency increases, as expected, and becomes $5.35\,\text{GHz}$, the return loss in this case increase to $-28.5\,\text{dB}$.

Fig. 6 demonstrates the effect of changing distance between patches. If the distance between patches is increased to 0.475λ, the

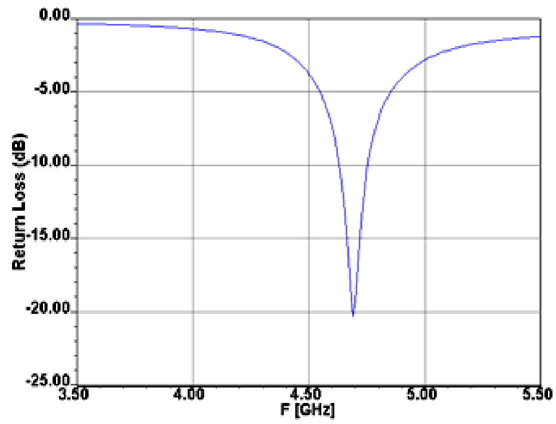


Figure 6. The effect of distance between patches in array.

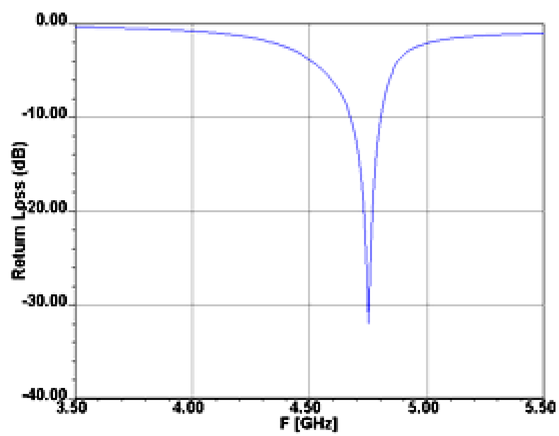


Figure 7. Return loss for the case of 10 driver elements.

return loss increases by about 9 dB, the change in resonance frequency, however, is negligible.

So far we have assumed that the two end patches are parasitic, now we consider the case where all 10 elements are excited (active), the result for return loss is shown in Fig. 7, it is seen that the return loss in this case increases by 8 dB, we noted, however, that increasing the number of parasitic patches causes a sharp increase in return loss, thus, worsen, the array performance, the result of this case has been shown in Fig. 8.

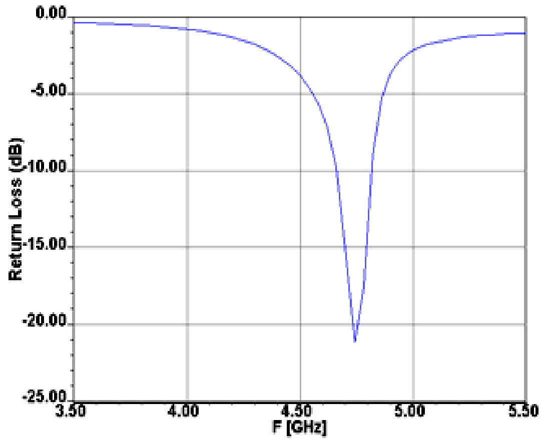


Figure 8. Return loss for the case of 4 parasitic elements.

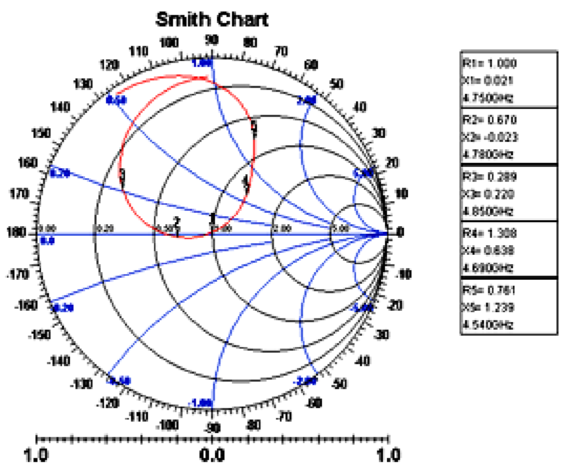


Figure 9. Input impedance of proposed fractal patch array at various frequencies.

The input impedance for one driven patch at various frequencies and radiation patterns for both E and H planes of proposed array are shown in Figures 9 and 10.

Mutual coupling between elements of proposed patch array and conventional rectangular patch array are shown in Figures 11 and 12 respectively. It is to be noted that the mutual coupling between patches in array with fractal patches has decreased by about at least 20 dB.

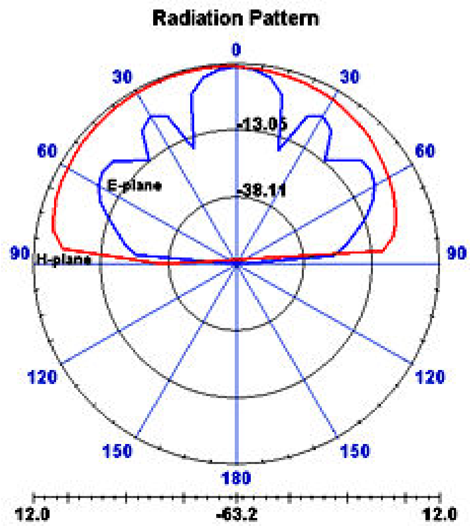


Figure 10. Radiation pattern of proposed fractal patch array in E and H planes.

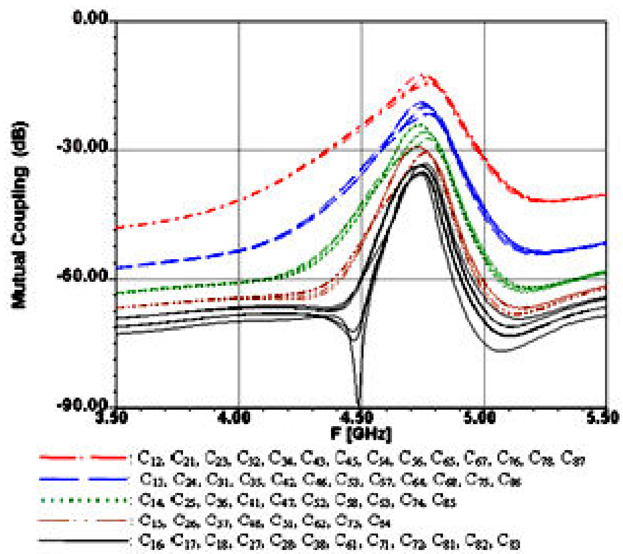


Figure 11. Mutual Coupling of proposed fractal patch array.

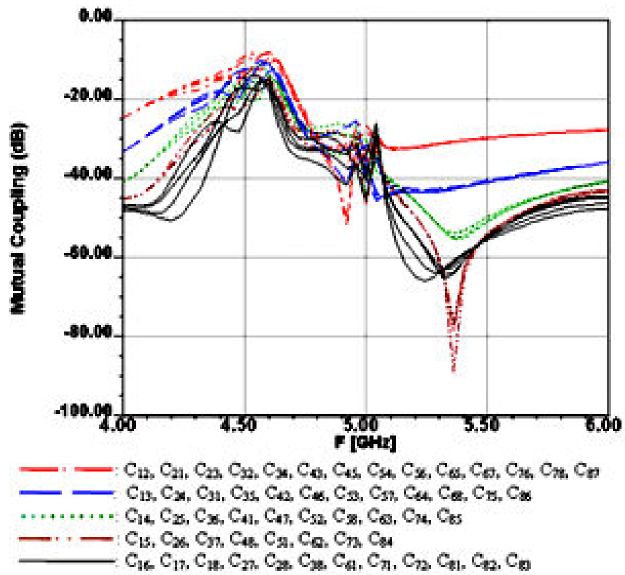


Figure 12. Mutual Coupling of conventional rectangular patch array.

4. CONCLUSION

In this paper we proposed a new microstrip patch antenna array with fractal patches instead of conventional rectangular patches. Simulation results show that using fractal patches enhances the performance of the array. We noted that the mutual coupling between elements decreases substantially, and input return loss decreases compared to rectangular patch array.

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