On the Design of Fractal Patch Antenna and Backscattering Reduction

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Abstract—This paper presents the design of rectangular, fractal Microstrip patch antenna and their backscattering reduction. These antennas have been designed on $\varepsilon_r = 4.3$, h = 1.53 mm substrate with rectangular patch dimension 36.08 x 29.6 mm and its 2nd iterative fractal patch. The experimental resonant frequency of 2nd iterative fractal patch is observed 2.11 GHz in comparison to rectangular patch 2.42 GHz. This reveals the size reduction of patch antenna. The radiation pattern of fractal antenna is as similar to simple rectangular patch but cross polarization level is better in fractal patch. The gain loss of fractal antenna compared with rectangular antenna on resonant frequency is less than 1 dB. The investigation reveals that 2nd iterative fractal patch provides low RCS in comparison to other iteration and simple patch. Such type of antenna is useful for wireless communication in defence environment.

Index Term — Microstrip antenna, Resonant Frequency, Fractal Antenna, Miniaturization and Backscattering RCS

I. INTRODUCTION

Microstrip antennas are commonly used in a broad range of applications such as airborne, navigation and mobile etc. This is primarily due to their simplicity of fabrication, ease of production, low manufacturing cost, light in weight, conformal and easy to integrate with RF devices [1-2]. The antenna size with respect to the wavelength is the parameter that will have influence on the radiation characteristics. For efficient radiation, the size should be of the order of half a wavelength or larger. But as antenna size reduces, the bandwidth, gain, efficiency and polarization purity of antenna deteriorate. Several researchers [1-2] studied & suggested that incorporation of fractal geometry in conventional antenna has advantages compared with conventional antenna in size [3-5] reduction and multi-frequency performance. Such antennas can be mount on platform or target. Antennas on the platform are one of main contributions to total radar cross section. There are many microstrip antenna RCS reduction techniques, such as resistive loading [6] varactor - tuning [7], substrate – superstrate layer structure [8] and so on.

This paper presents the design of antenna for the size and its backscattering RCS reduction. The Fractal patch antennas have been designed, fabricated and tested. All results are validated by simulations and experiments. Such type of fractal patch antenna elements are useful to design very compact arrays for high gain and low RCS.

II. GEOMETRY OF FRACTAL ANTENNA

The combination of fractal geometry in microstrip configuration is named as microstrip fractal patch antenna. Microstrip fractal patch antenna can be miniaturized by adding indentations along the resonant length of the patch. The indentation is applied in the border length of rectangular microstrip patch antenna as shown in Fig. 1a to miniaturize the size. The indentations force the currents to meander along a long path length allowing the patch to be miniaturized for a given resonant frequency. The microstrip fractal patch shown in Fig. 1b, is generated with two iteration.

The simple rectangular patch, the starting structure is called the initiator. The initiator defines the general shape of the structure, its iteration order is zero. Next, add the indentations along the resonant length of simple rectangular patch in the first iteration and repeat the process at similar scale. The iterative process can be performed an infinite number of times. Therefore, the infinite iterative process should be truncated at a reasonable level because of fabrication constraints.

Figure 1a. Rectangular Patch antenna    Figure 1b. Fractal Patch antenna

III. SIMULATED AND EXPERIMENTAL RESULTS

A. Microstrip Fractal Antenna

The numerical FDTD technique [9] has been used for the simulation of rectangular and fractal patch antenna of 0th, 1st and 2nd order iteration patches. The simulated center frequency of simple rectangular patch antenna as shown in Fig. 1a has been observed at 2.48 GHz. The fractal antenna of 2nd iteration with coaxial feed has been simulated with shifted center frequency 2.14 GHz. The experimental center frequency of the 2nd order fractal patch has been observed 2.1116 GHz in comparison of rectangular patch resonant frequency 2.426 GHz with the
same feed position. This shows the size reduction of the patch antenna. The simulated and experimental results are shown in Fig. 2 and Fig. 3 respectively.

![Figure 2. Simulated Results Rect. and Fractal Patch](image1)

![Figure 3. Experimental Result Rect. and Fractal Patch](image2)

Figure 2. Simulated Results Rect. and Fractal Patch

Figure 3. Experimental Result Rect. and Fractal Patch

![Figure 4. Radiation Pattern of Fractal Patch Antenna at f = 2.14 GHz](image3)

![Figure 5. Radiation Pattern of Fractal Patch Antenna in multilayered with air gap.](image4)

Radiation pattern of 2nd iterative fractal patch antenna at resonant frequency has been shown in Fig. 4. The radiation pattern of rectangular and fractal antenna were found similar. The cross polarization level of fractal antenna is better than simple rectangular patch. Thus, the fractal patch antenna can be used to replace a normal rectangular patch with its similar characteristic of radiation and smaller patch size. The gain of fractal patch antenna is around 5.2 dB against simple patch 6 dB. The bandwidth of simple rectangular and fractal patch has been observed experimentally around 5.1 % and 3.82 % respectively.

![Figure 6. Backscattering RCS of Fractal Patch with respect to iteration](image5)

Figure 4. Radiation Pattern of Fractal Patch Antenna at f = 2.14 GHz

C. Backscattering RCS of Fractal Antenna

First, a comparison of results calculated by [9] and published result [10] has been verified for rectangular flat plate of dimension 101.6 mm x 101.6 mm at 9.23 GHz. Then, the monostatic backscattering RCS of Microstrip Fractal patch has been investigated with respect to iteration as shown in Fig. 6 for er1 = 2.2 and h = 1.53mm. The rectangular patch of 0th iteration backscattering power is -16.0 dB, -15.68 dB for 1st iteration, -16.92 dB for 2nd iteration and -15.4 dB for 3rd iteration. The 2nd iterative fractal antenna provides low backscattering. The RCS of this 2nd iterative Microstrip Fractal antenna has also been calculated for various substrate thickness using [9] as shown in Fig. 7. It is clear as the substrate thickness increases the RCS reduces to -24.2 dB for 6.5mm thickness beyond this thickness RCS increases.

![Iterative Plot of RCS values](image6)

Figure 6. Backscattering RCS of Fractal Patch Antenna in multilayered with air gap.

B. Multilayered Microstrip Fractal Antenna

The two fractal patches with 2nd iteration in stack printed on same thickness substrate has also been simulated with the same feed position as fractal patch. The fractal patches on multilayer in stack with air-gap of 0.8mm have been designed to improve the impedance bandwidth. The air-gap improves the bandwidth but cross polarization increases with the air-gap height in comparison to fractal patch as shown in Fig. 5. The bandwidth can further be improved by optimizing the feed position along with air-gap and substrate thickness. The proximity electromagnetic coupled 2nd iterative fractal patch antenna has also been designed. In this bandwidth improves but the size of total antenna becomes large by 44.74 % of fractal patch because of feed length 37 mm which reaches to the center of fractal patch.
reduction.

Figure 7. Backscattering RCS with respect to various thickness of substrate for $\varepsilon_r = 2.2$ at Frequency 2.42 GHz

Figure 8. Backscattering RCS reduction vs frequency for various substrate thickness at 2.42 GHz

Figure 9. Bistatic Backscattering RCS Reduction versus frequency at 60 deg.

Fig. 9, shows the bistatic backscattering RCS reduction at angle $60^\circ$ versus frequency for $\varepsilon_r = 2.2$ and optimum thickness. The RCS reduction for vertical and horizontal polarization is considerable good in wide frequency range. This backscattering study of antenna is also useful for wireless communication in military environment.

IV. CONCLUSION

Microstrip Fractal patch antennas based on fractal geometry has been studied. It has been found that this structure with proper indentation in the border length offers considerable miniaturization compare to conventional rectangular patch antenna. As the iteration order increases, the resonant frequency decreases more to lower side and indicates more size reduction. Such properties of the patches make it possible to apply fractal antennas to those applications needing reduced size of antennas. The radiation pattern of fractal patch antenna is similar to conventional patch. The cross polarization is better for fractal patch antenna but increases with the air-gap height between the fractal patch in stack. It is concluded that 2nd iterative fractal patch gives low RCS. The gain loss of fractal antenna compared to conventional rectangular patch antenna is less than 1dB, which is acceptable for antenna RCS reduction. Such types of antennas are useful to design compact arrays for high gain and low RCS mobile communication in defence environment.

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REFERENCES

[9] Simulation was performed using the package Concerto 6.5, developed by vector Fields Limited, England 2006.