

A Novel Multiband and Broadband Fractal Patch Antenna

J. J. Huang, F. Q. Shan, and J. Z. She
Tsinghua University, China

Abstract—a novel multiband and broadband fractal patch antenna is presented in this paper. The proposed antenna is compact, simple to design and fabricate. The impedance bandwidth of the proposed antenna could reach 18%, which has rarely been reported for single layer and single patch antennas. Multiband characteristics are also observed and analyzed. All results are proved by simulation and experiment.

1. Introduction

Microstrip patch antenna (MPA) has attracted wide interest due to its important characteristics, such as light weight, low profile and low cost, mechanically robust, simple to manufacture, easy to be integrated with RF devices, allow multi-frequency operation to be achieved, etc. However, its further use in specific systems is limited because of its relatively narrow bandwidth. The impedance bandwidth of a typical patch antenna may be just 1–2%. Much intensive researches have been done in recent years to develop bandwidth-enhancement techniques: using a thick air or foam substrate results in a maximum bandwidth of less than 10%; using stacked or co-planar parasitic patches [1] obtains a bandwidth of 10%–20%; using a gap-coupled probe feed [2] achieves a bandwidth of 16%; more recently, the addition of a U-shaped slot [3] and the use of an L-shaped probe have both been shown to provide bandwidth in excess of 30%. However, these techniques increase antenna volume, complicate the design and fabrication of the antennas.

Fractal geometries have recently been introduced in the design of antennas. It has been shown that fractal shaped antennas exhibit characteristics that are associated with the geometric properties of fractals. One property associated with fractal geometry that is used in the design of antennas is self-similarity. A fractal antenna can be designed to receive and transmit over a wide range of frequencies using the self-similarity properties associated with fractal geometry structures.

In this paper, a novel multi-band and broadband fractal patch antenna is designed, measured and analyzed. The impedance Antenna Structure bandwidth of the proposed antenna could reach 18%, which has rarely been reported for single-layer and single-patch antennas. As the scale R_a increases, multi-band characteristics are observed. All results are validated by simulations and experiments.

2. Antenna Structure

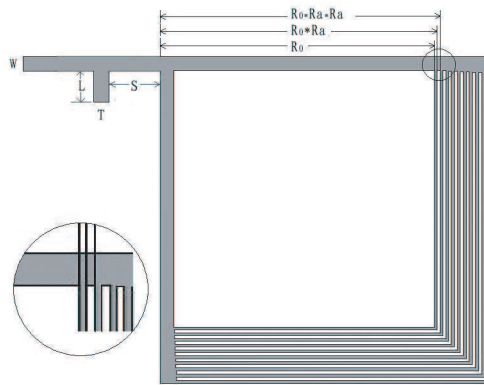


Figure 1: Geometry of the broadband and multi-band fractal microstrip antenna with a tuning stub.

Figure 1 shows the geometry of the fabricated antenna. The exact dimensions for the proposed antenna are also given in Figure 1. The patch is printed on a microwave substrate FR4 of the thickness $H = 1$ mm and the relative permittivity $\epsilon_r = 4.4$. The antenna is fed through a 50 ohm microstrip line of the width $W = 2$ mm. As the FR4 substrate is not suitable to be used at frequencies above 4 GHz, R_0 should not be too small. For the present design $R_0 = 40$ mm. The radiation elements are composed of ten similar orthogonal bars. Both the length and width of the orthogonal bar are magnified by the factor of $R_a * R_a$. Four antennas with different

Ra (1.01, 1.02, 1.03 and 1.05) are simulated, fabricated and measured. A tuning stub with the width T and the length L is added to the feed-line of the antenna of $Ra = 1.01$ to get a wider bandwidth of 18%.

3. Simulated and Measured Results

The proposed antenna is simulated using Ansoft HFSS 9.2 and measured with a HP8510C network analyzer. Figure 2 compares the simulated and measured return loss of the antenna of $Ra=1.01$. The measured impedance bandwidth of the un-tuned antenna is approximately 11% (2.996 GHz–3.321 GHz) while that of the tuned antenna is approximately 18% (3.03 GHz–3.65 GHz). In addition, the antenna has a resonant frequency around 0.9 GHz, which proves the electrically small characteristics of the antenna. Good agreement can be seen between the simulated and measured results.

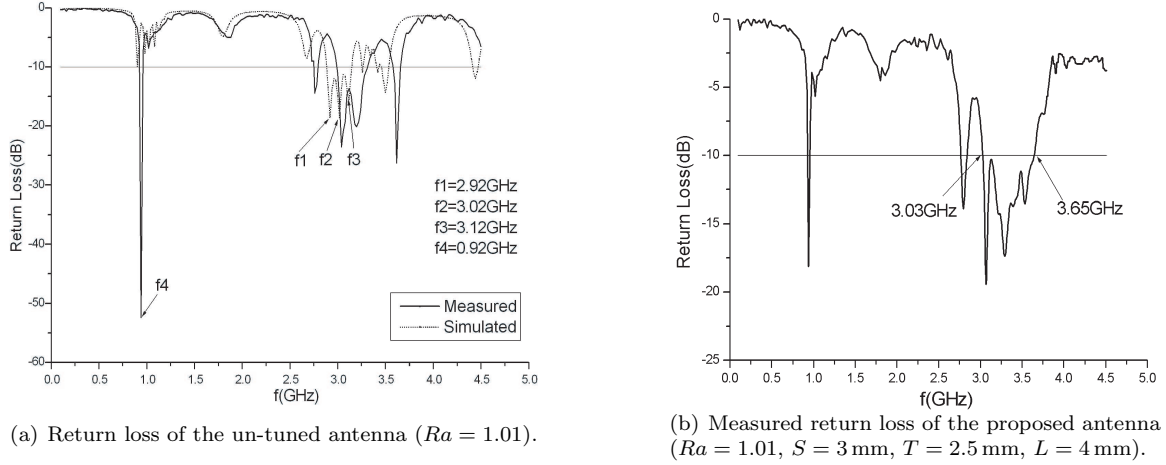


Figure 2: Return loss of tuned and untuned antenna.

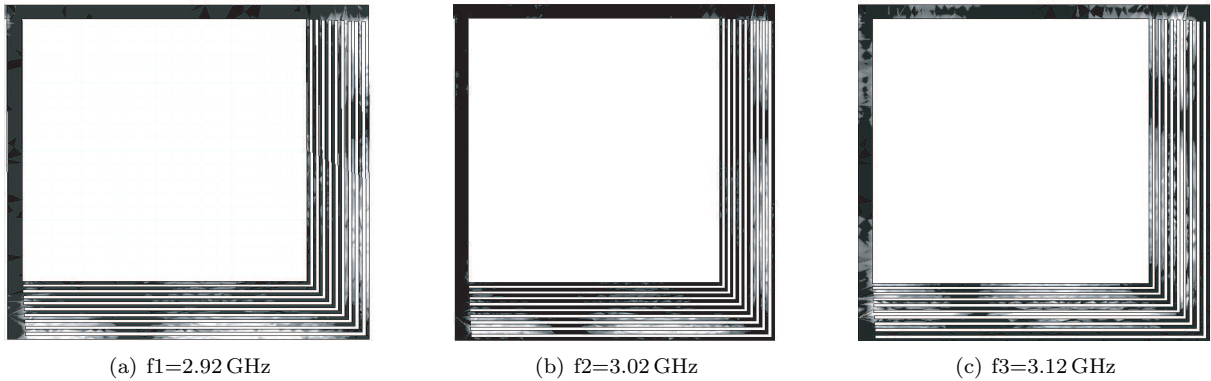
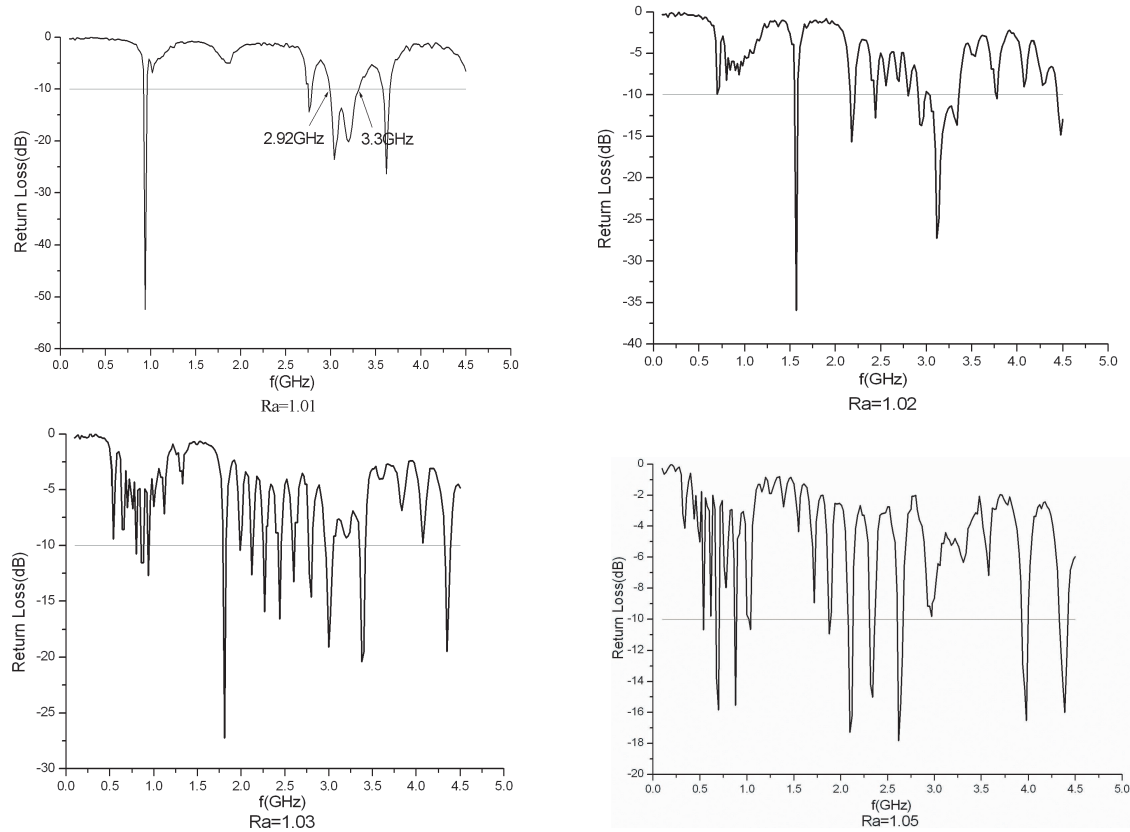


Figure 3: Surface current distribution at $f1$, $f2$ and $f3$.

From Figure 2(a), one can see that three frequencies $f1$, $f2$ and $f3$ which are close to each other result in a wide bandwidth. Figure 3 shows the simulated surface current density of the three frequencies. When working frequency increases, the area surface current mainly distributed on moves from outer bars to inner bars. Because the dimension of the bars vary slowly by the factor of $Ra * Ra = 1.02$, the antenna has several resonant frequencies close enough to each other to form a wide bandwidth. One can see that $f1$, $f2$ and $f3$ increase by the factor of 1.03, which agrees with the geometry of the structure.

Four antennas of $Ra = 1.01$, 1.02, 1.03 and 1.05 are fabricated and measured to study the influence of the parameter Ra on the antenna's characteristics. Figure 4 shows each return loss of the antennas. Figure 4 also shows that when Ra increases, the antenna change from a broadband antenna ($Ra = 1.01$ and 1.02) into a multi-band antenna ($Ra = 1.03$ and 1.05). As Ra becomes larger, the dimensions of the bars and the working region vary faster, the resonant frequencies is not close enough to each other to form a wide bandwidth.

Figure 4: Return loss of four antennas with different R_a .

The radiation characteristics are also studied. Typical results of the tuned antenna at 3.30 GHz are shown in Figure 5.

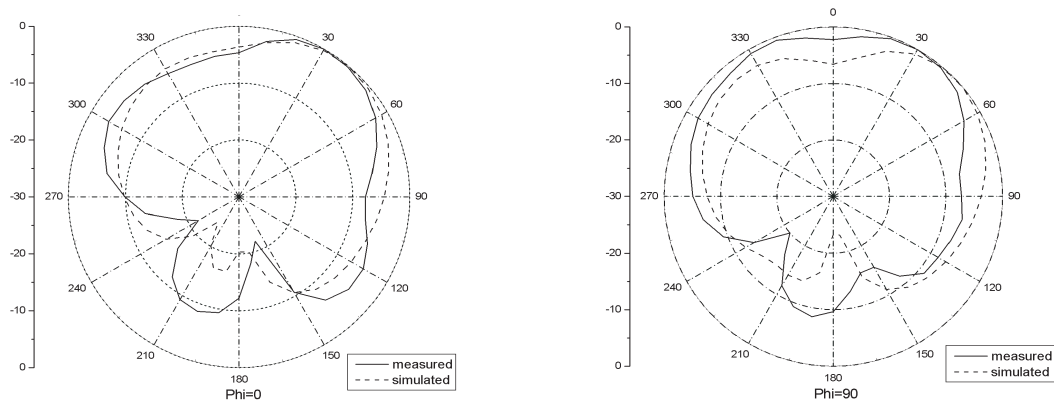


Figure 5: Radiation pattern at 3.3 GHz of the tuned antenna.

4. Conclusion

A novel fractal microstrip antenna with multi-band and broadband characteristics has been successfully demonstrated. The obtained impedance bandwidth of the antenna ($R_a = 1.01$) can be 18% around 3.3 GHz. As R_a increases, Multi-band characteristics of the proposed antennas are also observed. The antenna is compact, simple to design and easy to fabricate.

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