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Non-Planer Parasitic of Semi-Fractal patch Antenna with Multi Ring Structure for Multi Band Applications

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Abstract

A new A new form of hybrid design of a microstrip-fed parasitic coupled ring fractal monopole antenna with semi ellipse ground plane is proposed for modern mobile devices having a wireless local area network (WLAN) module along with a World-wide Interoperability for Microwave Access (WiMAX) function. In comparison to the previous monopole structures, the miniaturized antenna dimension is only about 30 x 40 x 0.8 mm^3, which is smaller than the previous proposed design. By only increasing the fractal iterations, very good impedance characteristics are obtained. Throughout this letter, the improvement process of the impedance and radiation properties is completely presented and discussed.

Keywords: fractal antenna, multi band.

INTRODUCTION

Mandelbrot first introduced the fractal geometry in 1975 [1], in which each sub-section has the characteristics of the whole structure in a smaller scale. This is the basic property of self-similarity. Fractal geometries have been applied in various science and technologies, such as antennas and radiators. Generally, the utilization of fractal geometries in antennas tends to reduce their physical sizes and produce multiband response in their radiation characteristics. Since fractal structures have a repetitive geometry, they can generate long paths in a limited volume. Accordingly, we may refer to fractal geometries, such as the Koch, Minkowski, Hilbert and tree fractals [2], [5], which have been used for dipole and ring antennas. The property of self-similarity of fractal geometries is used to achieve multiband operations from fractal antennas and their space-filling property is used for the antenna miniaturization. [3], [4], [6]. Fractal geometries are used in radiating systems and even microwave devices to benefit from their interesting properties [6].

Since the generation of fractal configurations have an iterative procedure, then they can achieve long linear dimensions and high surface areas in a limited volume [5]. [oraisi]. To support the high mobility necessity for a wireless telecommunication device, a small and light antenna characteristic would be likely preferred.

Microstrip antenna is one of the most suitable candidates for this purpose. The development of antenna for wireless communication also requires an antenna with more than one operating frequency. This is due to many reasons mainly because there are various wireless communication systems and many telecommunication operators using various frequencies. Therefore one antenna that has multiband characteristic is certainly more efficient than having many antennas for each frequency band. One close example is the IEEE 802.16 standard, which allocates WiMAX frequency to operate at several frequencies. The frequency allocation for WiMAX used till now for each countries differ, they are 2.3 GHz, 2.5 GHz, 3.3 GHz, 3.5 GHz and 5.5 GHz. WiMAX technology also provide larger bandwidth compared to cellular phone application which can accommodate the data communication.

Several researches that have been published about triple band antennas are reported in [7-9]. In [7], a three multilayer structure is designed to achieve its triple band; this requires a more complex manufacturing procedures and also thicker dimension. The design [8] and [9] uses microstrip monopole antenna to achieve the triple band, however the gain of the antenna is rather low compared to usual microstrip patch antenna. is introduced using the novel multi ring fractals.

It is designed for operation in the following bands: Universal Mobile Telecommunications System (UMTS 1920-2170 MHz); Hiper-Lan2 (High Performance Radio Local Area Network Type2) in the band 2.12–2.32 GHz; industrial, scientific and medical (ISM 2.4-2.5 GHz); IEEE802.11b/g in the band from 2.4 to 2.484 GHz, which is one of the WLAN bands and IMT advanced system or fourth generation (4G) and WLAN/WiMAX (5.27-5.9 GHz). We investigate the miniaturization and multi-banding [6] properties of the semi-fractal microstrip patch antenna. A prototype sample of the proposed fractal antenna is fabricated and measured. The miniaturization, multi-banding of the proposed fractal antenna is verified by the simulation results and measurement data.

MATERIALS AND METHODS

Antenna design and configuration

Fig. 1 shows the geometry of the proposed small multi-band antenna, which consists of five multiple rings. The antenna uses FR4 substrate with a dimension of 30 x 40 x 0.8 mm^3, ε_r and a loss tangent of 0.02. The width W_f of the microstrip-fed line is fixed at 1.5 mm to achieve 50 characteristic impedance, and is connected to the multi-ring semi-fractal patch via a line of length L_f. a semi ellipse-shaped ground plane of width W_g and length L_g and a circular conductor of radius r_p = 13.8 mm are placed on the other side of the substrate. On the front surface of the substrate, a 2mm wide large ring with outer diameter D_1 = 24 mm and four 1mm wide multiple rings with outer diameters D_2 =12 mm are printed. The fractal patch has a distance of g = 3.4 mm to the ground plane having L_g = 9 mm and width W_g= 30 mm printed on the back surface of the substrate.

Fig. 2 depicts the configuration of the fabricated Non-Planer Parasitic of Semi-Fractal patch Antenna with Multi Ring Structure, which consists of five multiple rings.

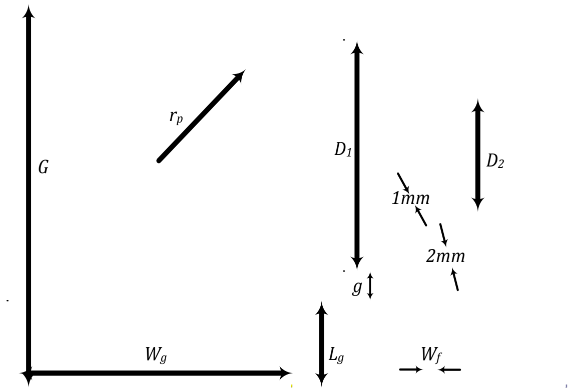

Figure 1. Geometry of the proposed multi-band antenna

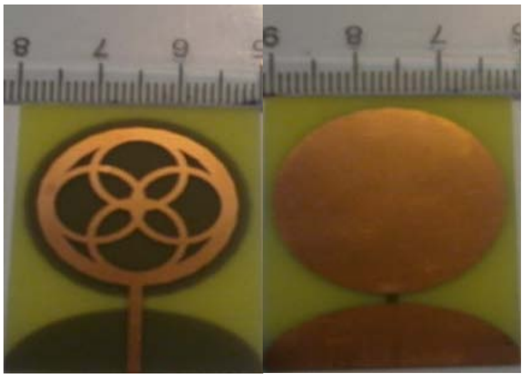

Figure 2. Photograph of the fabricated Semi-Fractal patch Antenna

RESULTS AND DISCUSSIONS

The proposed antenna structures are simulated using a High Frequency Structure Simulator (HFSS, ver. 11). During the simulation process, by adding various metal strips and blocks to the antenna structure, the effects of bad soldering and great SMA connector are considered.

At first, for clarifying the improvement process, four iterations of semi-fractal patch are defined as follows (Fig. 3): 1) the first iteration includes only one circular patch with D_1

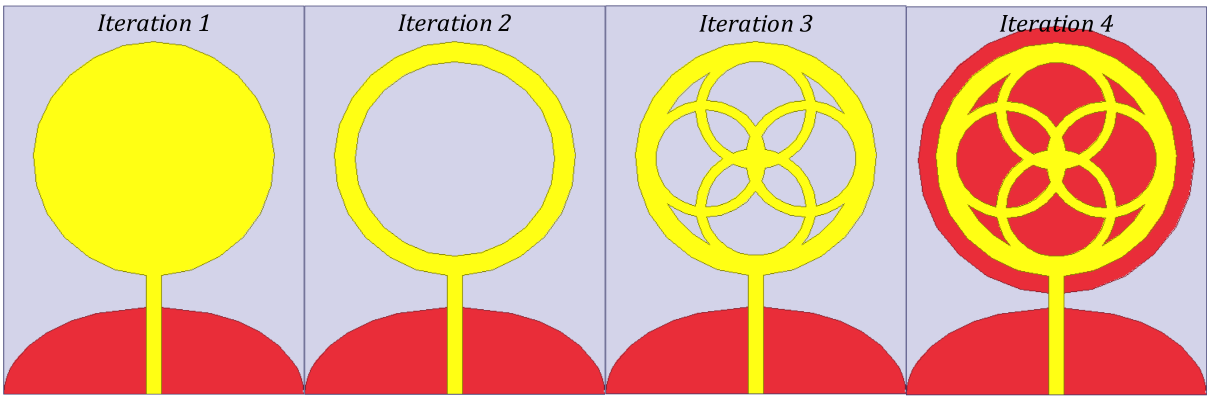

Figure 3. Four iterations of semi-fractal patch

outer diameter; 2) the second iteration contain a 2mm wide large ring with outer diameter D_1 =mm; 3) the third iteration has four 1mm wide multiple rings with outer diameters D_2 = 12 mm; and 4) the fourth iteration contains five rings with D_1 and D_2 outer diameters and a circular conductor of radius r_p are placed on the other side of the substrate , respectively. The simulated curves for four iterations of fractal are plotted in Fig. 4.

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From the simulation results in Fig. 4, it is observed that the impedance bandwidth increases as the fractal iterations are improved, thus we have maximum impedance bandwidth for the fourth iterated antenna at WiMAX frequencies.

The parameter (L_g), based on the parametric analysis of the fourth iteration of the proposed fractal antenna, are optimized to achieve the maximum impedance bandwidth and good impedance matching. The simulated S_{11} curves for the fourth iteration of fractals with different values of L_g are plotted in Fig. 5. The small changes in the length of the gap between the ground plane and the fractal patch (g) has a great effect on the impedance matching of the fourth iteration of the fractal antenna.Comparison of the simulated and measured results shows a reasonable agreement at all frequencies.This may be due to small parametric differences present in the FR4 substrate between the practical embodiment and the simulated models.

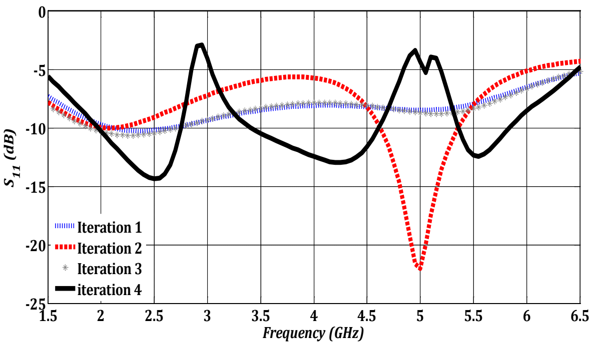

Figure 4. The simulated curves for four iterations of fractal

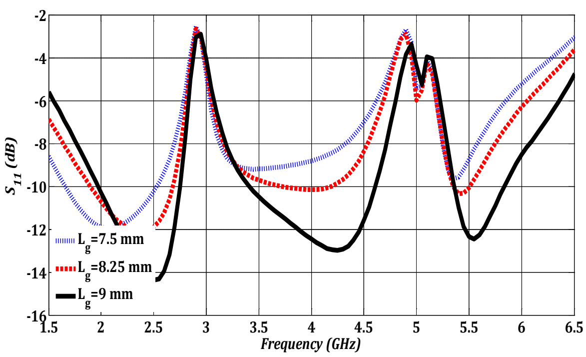

Figure 5. The simulated S_{11} curves for the fourth iteration of fractals with different values of L_g

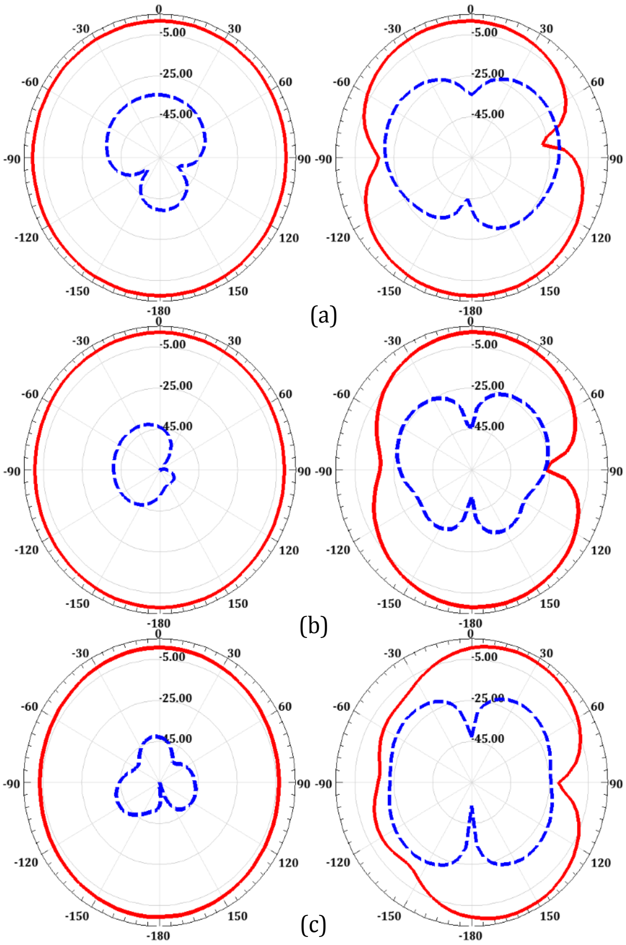

Figure 6. Measured radiation pattern at (a) 2.4 GHz (b) 4.2 GHz (c) 5.5 GHz

It is also possible that the dielectric constant and dissipation factor has some variation with frequency.The E- and H-planes radiation pattern at 2.4, 4.2 and 5.5 GHz for the antenna is shown in Figs. 6a - c, respectively. During measurements, care was taken to place a sheet of absorber material underneath the connector of antenna. Thus, almost no surface waves are excited in the measurement process from the connector. The simulated and measured results show good agreement. The gain and radiation patterns were measured using the ETS 3115 system. Some errors in the measured bandwidth, radiation pattern and antenna peak gain can be expected owing to the feed cable placed in the near-field of the antenna. The co-and cross-polarized components of the field are different in the x–z (H-plane) and y–z (E-plane) plane. In the H-plane, the co-polarized component is E_φ, and the cross-polarized component is Eθ. In the E-plane, it is contrary. In the H-plane, the radiation pattern is Omni-directional at lower frequencies and is nearly Omni-directional at higher frequencies. In the E-plane, the radiation pattern is nearly bidirectional as for a traditional slot antenna.Fig. 7 shows the simulated and measured frequency response of the S_{11} for the antenna. The Return Loss was measured using an Agilent 8722ES network analyzer. The measured impedance bandwidth (S_{11} < -10 dB) is about 3.73 GHz, starting from 1.9 to 5.9 GHz, including the bands of Universal Mobile Telecommunications System (UMTS 1920-2170 MHz); Hiper-Lan2 (High Performance Radio Local Area Network Type2) in the band 2.12–2.32 GHz; industrial,, scientific and medical (ISM 2.4-2.5 GHz); IEEE802.11b/g in the band from 2.4 to 2.484 GHz, which is one of the WLAN bands and IMT advanced system or fourth generation (4G) and WLAN/WiMAX (5.27-5.9 GHz). Fig. 7 shows the measured peak gain for the proposed antenna at (1.9-2.7GHz), (3.4-4.7GHz) and (5.27-5.9GHz). The measured peak gain with frequency among all φ and all θ is selected for the proposed antenna. The average gain for the triple-band antenna is about 2.5 dBi.

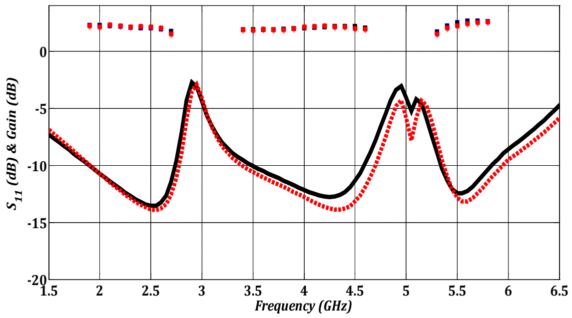

Figure 7. Compare between Simulated (black curve) and Measured (red curve) of proposed semi fractal antenna

CONCLUSION

A triple band microstrip patch antenna for the Multi-Band application has been designed, simulated, fabricated and tested. Both simulation and experiment shows similar results. The proposed antenna exhibits three bands, covering the 2.4 GHz (1.9-2.7GHz), 4.2 GHz (3.4-4.7 GHz) and 5.5 GHz (5.27-5.90 GHz) as well as good radiation properties. Therefore this antenna is suitable for WiMAX application or other wireless applications that works in these frequencies.

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