Journal of Instrumentation

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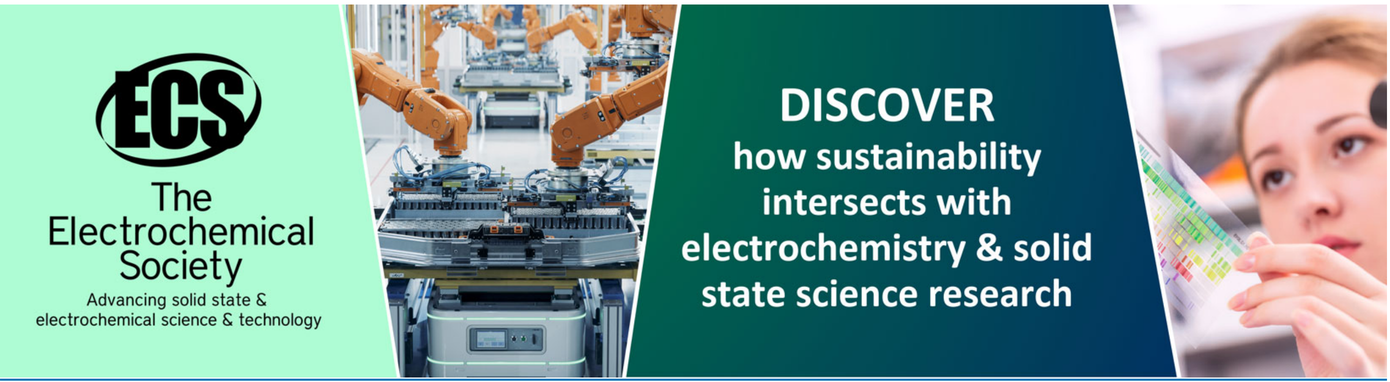
To cite this article: T. Sedghi 2018 *JINST* **13** P09021



Published by IOP Publishing for Sissa Medialab

Received: *September 1, 2018*
Accepted: *September 13, 2018*
Published: *September 24, 2018*

Compact fractal antenna for WiMAX 1.4 GHz and IEEE 802.11a using double branch line

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Abstract: This paper describes a novel configuration of a CPW-fed fractal antenna that exhibits dual-band performances of WiMAX 1.4 GHz and WLAN bands. The proposed fractal antenna consists of unit-cell based duble branch line attached to fractal patch as the main radiator, and a pair of mirror rectangular-shaped notch on the ground plane. Dual-band operations can be obtained by adjusting dimensions and length of fractal branch lines of patch, simultaneously. The fractal antenna is of a compact size with dimensions $17 \times 17\,\text{mm}^2$. The impedance bandwidth with S11 < -10 dB is about 2.3 GHz (1.1–2.2 GHz) for WiMAX 1.4GHz band and for WLAN-band 2.9 GHz (4.8–7 GHz). The measured peak gains are about 2.9dBi at WiMAX and 3dBi at WLAN-band. The fractal antenna has desirable S11 level, omni-directional radiation pattern and gain characteristics over the aforementioned bands. The proposed antenna is an excellent choice for multi-band wireless communication systems and mobile device.

Keywords: Antennas; Microwave Antennas

2018 JINST 13 P09021

https://doi.org/10.1088/1748-0221/13/09/P09021

Contents

1 Introduction

There is a tremendous increase in the applications that use the high data rate communications and wireless local area network (WLAN) technology, which has resulted in wireless devices expected to function under different multi-band environments. A particularly challenging issue for these applications is the design and development of multi-band antenna modules which are simple structure, compact size, low cost, and omnidirectional radiation pattern across the all operating bands [1–6]. In the design of a monopole antenna, the shape of the antenna patch, the ground plane, and the geometry of the ground plane slots are of great importance for access to multiband operations. These antenna modules are expected to provide effective broadband matching, an acceptable gain, and consistent radiation patterns throughout the designated frequency bands [7, 8]. Several designs in the literature concerning the monopole antenna with multiband characteristics and large size or even compact size have been reported in recent years for exciting broad impedance bandwidths, dual or multi frequency mode and agreeable radiation characteristics. However, printed antennas with broadband and multi-band functionality can be operated at multiple frequency bands. Those designs use different types of slots, slits, and parasitic elements in the radiator, the ground plane or even in the feeder to achieve the required band-operating characteristics [4–12]. The drawback of these antennas includes the increase of antenna size and complexity to realize the required operating frequency bands [8–12].

In this paper, a CPW-Fed fractal dual-band antenna is presented to cover the following operational bands: 1.4 GHz WiMAX band (1.390–1.435 GHz) and 5GHz-WLAN (5.15–5.825 GHz). In this proposed fractal antenna, the main target is to present compact structures of fractal patch and unit-cells with a step-by-step fractal design procedure to access dual-band operations. By adjusting the length of uni-cell based fractal branch lines attached to patch, resonance frequencies created can be finely controlled. The impedance matching of the antenna is further enhanced by using a pair of mirror rectangular-shaped notches on the CPW-ground plane. The ultimate fractal antenna provides appropriate gain and suitable omni-directional radiation pattern over the both bands

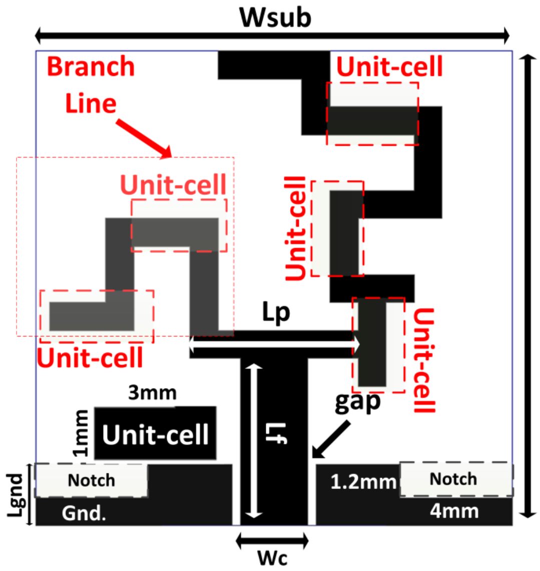

Figure 1. Configuration of the proposed dual-band fractal antenna with double branch line made of definite number of unit cells.

2 Antenna design

Figure 1 shows the geometry of the proposed fractal antenna with $W_{sub} \times L_{sub}$ dimensions. The fractal antenna includes the two uintcell based main radiators in the form of two branch lines, rectangular-shaped strip and the truncated CPW ground plane. The proposed fractal antenna, with compact dimensions is constructed with a substrate made of FR4, with the thickness 1mm and the relative dielectric constant 4.4 and loss tangent 0.024. The antenna is fed by a 50Ω truncated CPW.

The optimized dimensions are 17 mm × 17 mm for the substrate. For the impedance matching, the distance between the fractal patch and truncated CPW is indicated with a gap, which dictates its performance and determine the resonance frequencies. The optimum gap between the fractal patch and the truncated CPW ground is selected 3.7 mm. To modify the performance of the fractal antenna for creating two bands at the WiMAX and WLAN, two branch lines are etched in the manner depicted in figure 2. By inserting each of branch line at the patch and proper tuning the lengths of the unitcells, two dual-band operations can be achieved. The ultimate antena is desined in three steps as following:

Step1: notched CPW ground plane (truncated CPW) and definite number of unit cells for generating Band 2.

Step2: ordinary ground plane and definite number of unitcell for generating Band 1.

Step3: truncated ground plane with notches and the combinational of steps 1 & 2 for creating final Dual-band fractal Antenna.

For better understanding the effect of the branch lines, figure 3 shows currents on branch lines of the proposed final fractal antenna at 1.5GHz & 5.5GHz. It is obvious from figure 3(a) that for first band (WiMAX) the current vector on right branch line is stronger than the left one. Beside that it is clear from figure 3(b) that for second band (WLAN) the current vector on left branch line is stronger than the right one. Measured results of the realized fractal antenna with the difference structures

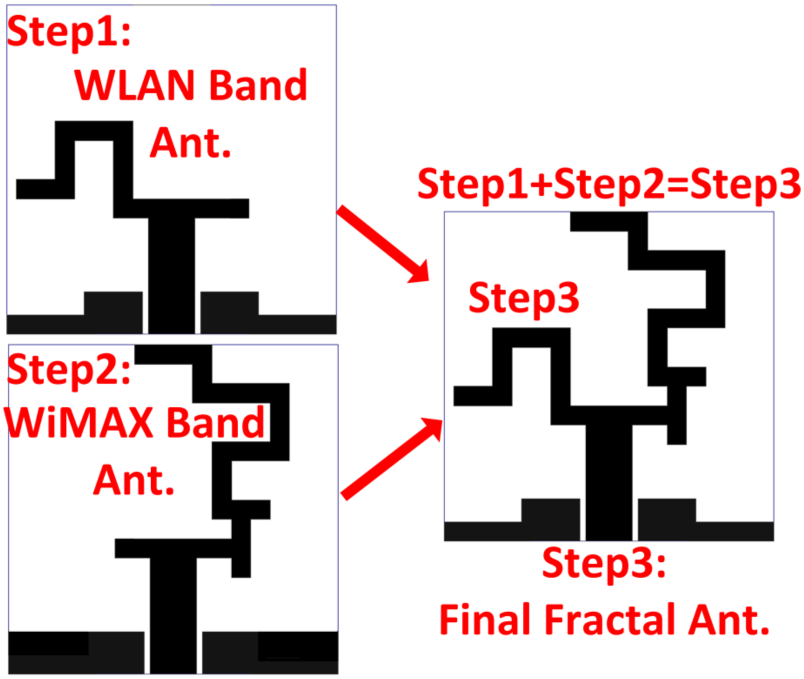

Figure 2. Geometry of the proposed final fractal antenna.

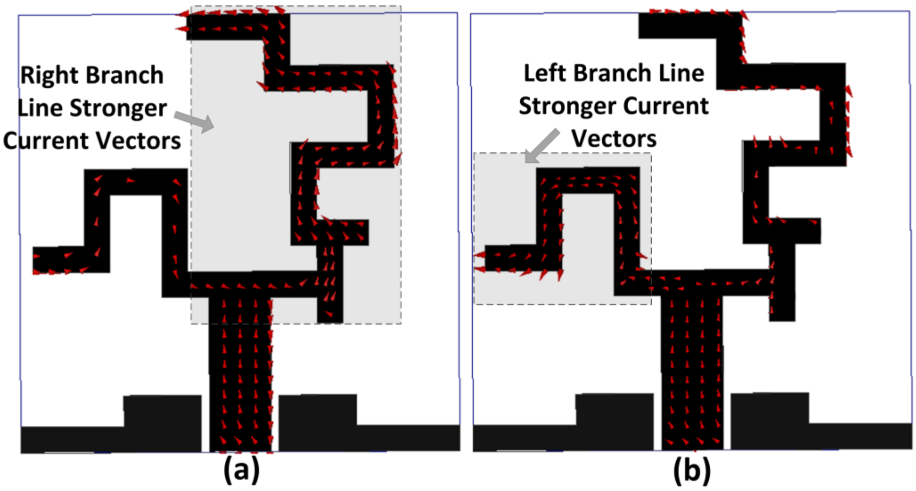

Figure 3. Currents on branch lines of the proposed final fractal antenna. (a)Right Branch Line at 1.5GHz (b) Left Branch Line at 5.5GH.

are presented. The impedance matching of the fractal antenna is further enhanced by inserting of unitcell based double branch line patch whose optimum dimensions were determined through a parametric study. In addition, for enhancing the matching of the band 1 upper frequencies, a pair of mirror rectangular-shaped notches is located on the CPW ground plane. The optimization of the structure is obtained using the Ansys simulator (HFSS). The optimal parameters of the constructed antenna are as follows: W_{sub} = 17 mm, L_{sub} = 17mm, Wc = 2.4 mm, gap = 0.7 mm, Lgnd = 2.2 mm. The other optimized dimensions of the antenna are indicated in figure 1.

3 Simulation and measurement result

In this section the impedance bandwidth of the truncated CPW printed fractal antenna construction and its numerical and experimental return loss was tested by using an Agilent 8722ES Vector Network Analyzer (VNA) In this proposed fractal antenna, the different length of branch lines based on unitcell patterns attached to the patch are indicated in figure 2. The effect of each branch line of the fractal antenna is investigated in the figures 3 & 4 for achieving dual functionality. In the proposed fractal antenna by using unitcell rectangular-shaped forms on the branch line strip in the manner indicated in figure 2, the first band can be obtained. In addition by inserting another branch line design on the radiator in the manner indicated in figure 2, the second band centered at 5.5GHz as shown in figure 4 is achieved. It can be observed that by using structure of figure 2 and choosing a suitable size for the strips, improves the performance significantly, especially at around 1.8 GHz & 5.8 GHz. The prototype of the CPW-printed fractal antenna was tested in microwave and antenna research center of Islamic Azad University, Urmia branch. The simulated and measured S_{11} characteristic of the proposed fractal antenna is depicted in figure 5. This figure shows there is generally good correlation between the measurement and simulation results. The deviation in the correlation is pronounced at the resonances which are attributed to the interface with the SMA connector. Figure 6 clearly highlights the measured maximum antenna gains from 1 to 2 GHz and 5 to 7 GHz for both bands. In this figure, antenna gain is increased from about 2 to 3.8 dBi for WLAN (5.15–5.825 GHz) band, whereas the upper band of WiMAX band has demonstrated a gain variation between 2–3.8 dBi. Figure 7 shows the measured radiation pattern for frequency of WiMAX at 1.5 GHz and also WLAN operating band at 5.5 in H-plane and E-plane. The figure is approximately exhibits an omnidirectional radiation pattern in H-plane and a dipole-like radiation pattern in the E-plane. Figure 8 illustrates the radiation efficiency of the proposed fractal antenna. It is obvious that the radiation efficiency of antenna is more than 85% for both bands. Table 1 shows the performance and Comparison of the proposed fractal Antenna with Other published works. It is obvious that the proposed fractal antenna is a good choice for dual-band WiMAX & WLAN systems.

Table 1. Performance Comparison of The Proposed fractal Antenna With Other published works.

	Fractal Design	Duall band property	WiMAX	WLAN	Impedance BW Band1 [GHz]	Impedance BW Band2 [GHz]	Size [dBi]
ref. [6]	×	✓	×	✓	4.8–6.5	7.5–12.5	15×15
ref. [8]	×	✓	×	✓	5–6	7.6–12.8	15×15
Proposed Antenna	✓	✓	✓	✓	1.1–2.2	4.8–7	17×17

4 Conclusion

In this letter, a compact and novel truncated coplanar waveguide fed (CPW-Fed) fractal antenna with dual-band applications is proposed which has a fractal and effective radiating patch for wireless

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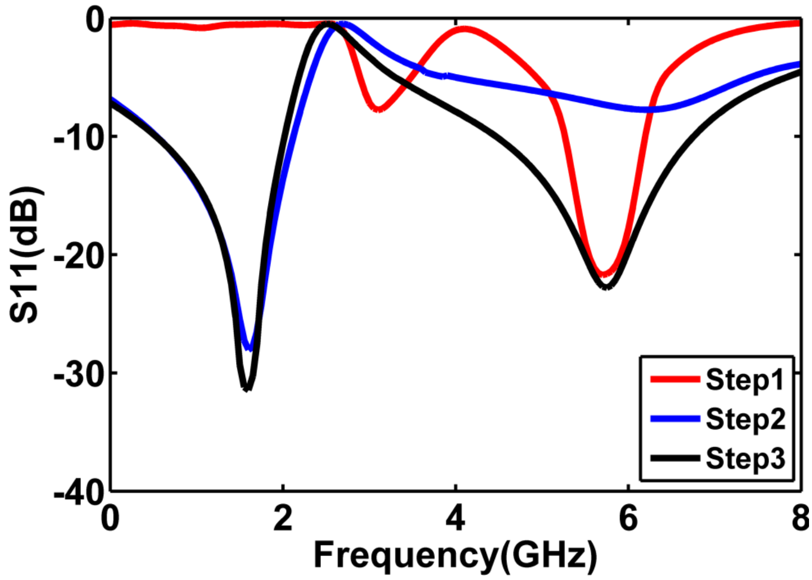

Figure 4. Simulated return loss for final Fractal antenna design steps as shown in figure 2.

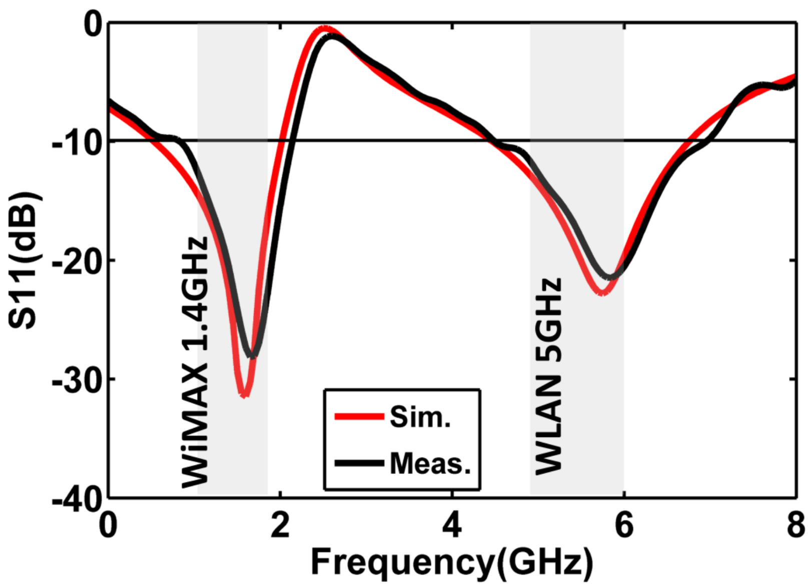

Figure 5. Measured and simulated S_{11} of the proposed fractal antenna.

communication systems and mobile devices. The main features of the proposed antenna are the compact dimensions of unit-cell based fractal radiator and band-operating characteristics. By using rectangular-Shaped unit-cells that are obtained with fractal geometry and without modifying the ground plane the new structure is proposed for dual-bad functionality. Also, desired resonances for each band can be achieved by increasing branch of fractal element of patch, simultaneously. The proposed antenna has a small size of 17 mm ×17 mm × 1 mm, and measured to cover the bandwidth for WiMAX 1.4 GHz and 5.2 GHz (5150–5350 MHz) and 5.8 GHz (5725– 5825 MHz) bands for IEEE 802.11a. The ultimate fractal antenna provides suitable omni-directional radiation

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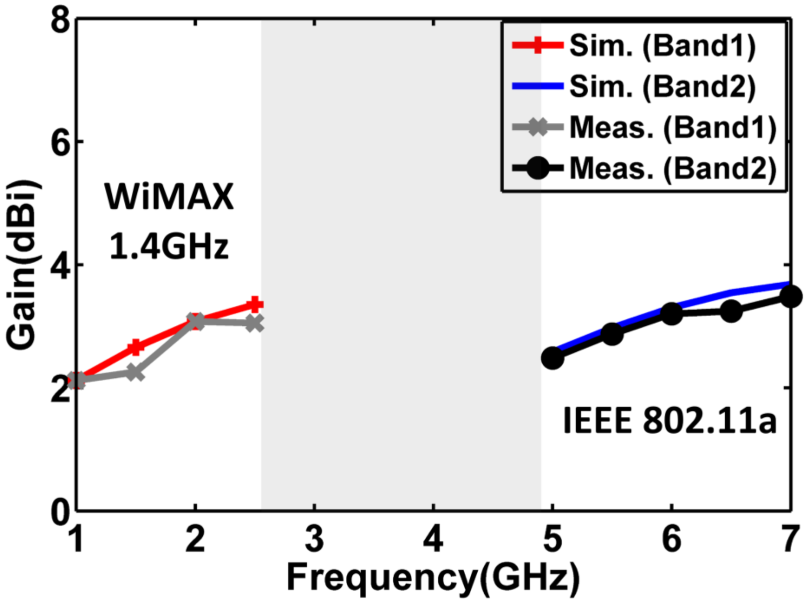

Figure 6. Measured and simulated fractal antenna gain for the proposed antenna with dual-band operation.

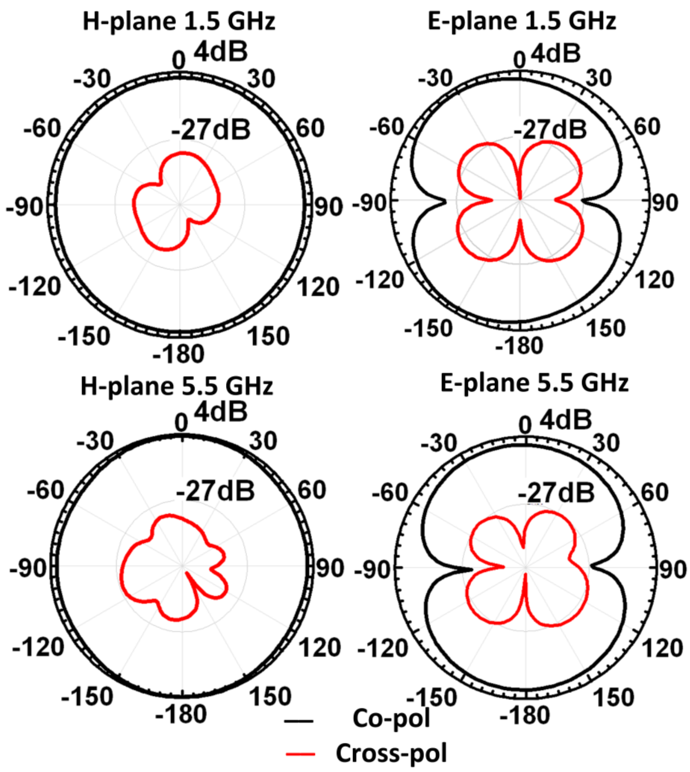

Figure 7. The radiation pattern of the proposed fractal antenna.

pattern and appropriate gain over the operating bands. The effect of the ground plane notch on the optimization of the S11 is discussed in detail.

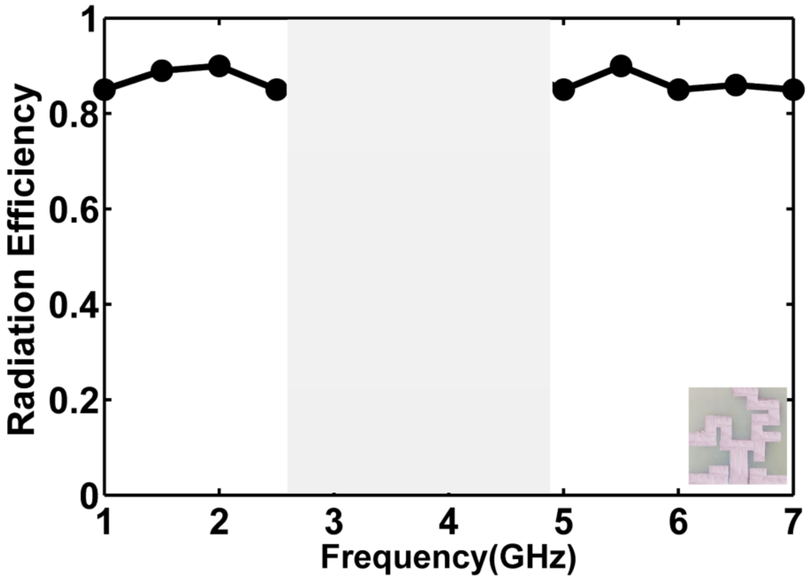

Figure 8. The radiation efficiency of the proposed fractal antenna.

Acknowledgments

This research is the consequence of a project agreed with research committee at Urmia Branch, Islamic Azad University. Authors would like to appreciate, Urmia branch, Islamic Azad University, Urmia, Iran for its supports. The author would like to appreciate the microwave and antenna research center of Islamic Azad University, Urmia branch members for measuring the structure and fantastic ideas. The authors would like to thank Prof. Bal S. Virdee for his valuable discussions and suggestions.

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