# A Compact Dual-band Printed Dipole Antenna Based on Fractal Feature in ISM Band

Sarawuth Chaimool# and Prayoot Akkaraekthalin

Electrical Engineering, Faculty of Engineering, King Mongkut's University of Technology North Bangkok
1518 Pibulsongkram Rd, Bagsue, Bangkok, Thailand, E-mail: sarawuth@kmutnb.ac.th

## 1. Introduction

Wireless communication systems now operate in two or more frequency bands, requiring dual- or multi-band operation of narrowband antennas. In such cases, an antenna operates at two frequencies and can be used in several applications such as GSM-900, 1800, and IMT-2000. Dual-band antennas are not used only in mobile communications; in fact, they are widely used for dual industry, scientific and medical (ISM) band applications [1]. Various kinds of dual-band antennas have been found in the literatures, such as printed slot antennas [2], PIFA [3], the monopole [4], and others. Unlike dipole antenna, those antennas could not provide uniform omni-directional coverage, but they are suitable for low profile installation. As far as compact dipole antennas are concerned, it is mandatory to develop miniaturized radiators able to guarantee a good efficiency and reliability. In such a field, fractal antennas seem to be good candidates for achieving reduced dimensions keeping suitable radiation properties.

This paper proposes a new dual-band printed dipole antenna based on fractal feature whose radiation pattern in the horizontal plane is omni-directional in both the 433 MHz and 900 MHz ISM bands. This technique has been imposed on fractal space-filling dipole antenna that is FASS (space-Filling, self-Avoiding, Simply, and self-Similar) curve antenna. By properly choosing the dimension of a coupled slot on a dipole antenna, dualband and tunable impedance bandwidth characteristics for both 433 MHz and 900 MHz applications can be achieved. The proposed antenna satisfies the 10 dB return loss characteristics from 425 to 441 MHz (3.6%) for ISM-900 and 840 to 1200 MHz (20%) for ISM-900 applications, respectively.

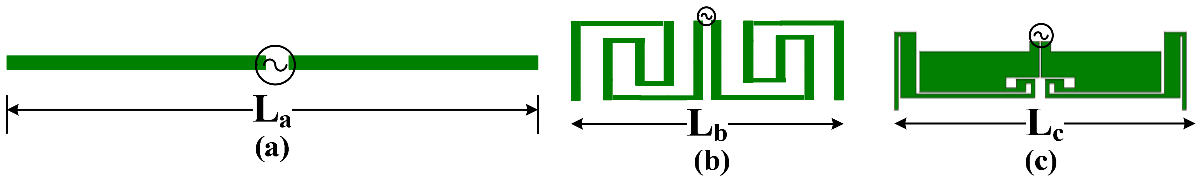
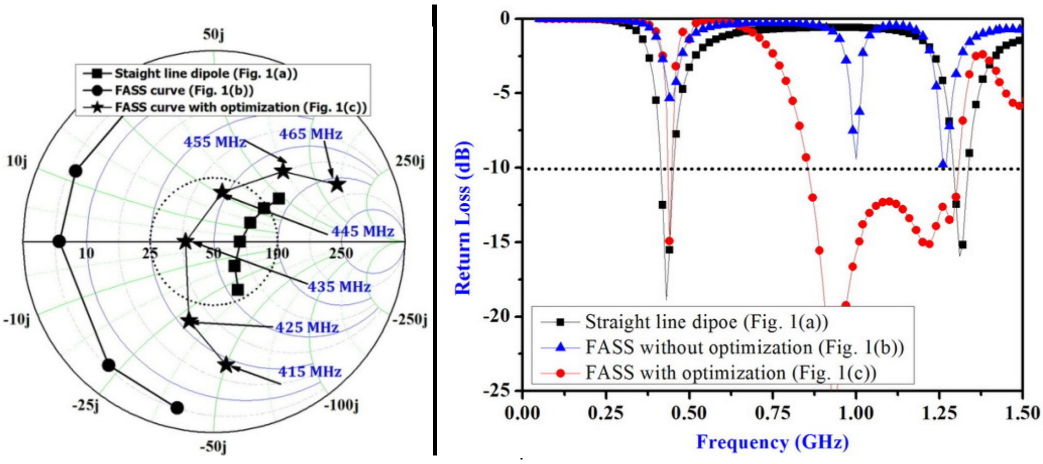



Fig. 1 Configurations of symmetrically fed dipole antennas (a) conventional half-wave dipole, (b) FASS curve dipole, and (c) FASS curve dipole plus a tuning treatment.

## 2. Antenna design and Optimization

The design of the antenna has been formulated as an optimization problem fixing suitable constraints in terms of impedance matching at the input port in the operating frequency band and in term of size reduction compared to the length of a conventional planar half-wave dipole antenna. For designing the dipole antennas based on fractal geometrics, the straight line half-wave dipole and the first iteration FASS curves are developed as shown in Fig. 1. These configurations are in a single layer metallic structure without ground plane. All these antennas have been fabricated on an inexpensive FR-4 dielectric substrate with a dielectric constant of 4.4 a substrate thickness of 1.6 mm. Fig. 1(a) shows a base structure (non-fractal or iteration index n=0) of a planar straight line dipole fed by a symmetrical line. Initially, a center-fed straight line dipole antenna (shown in Fig. 1 (a)) was designed with a dipole length ($L_a$) of 280 mm and the suitable line width of 5.0 mm and also can excite the resonant frequency (435 MHz for calculate) of this antenna. Fig. 1(b) is the first level of FASS curve. This fractal antenna can be arranged in many geometrical configurations to satisfy user-defined geometrical constraints. Unfortunately, its input impedance is generally low and active or passive networks are needed to obtain a satisfactory impedance matching.




(a) (b)

Fig. 2 Simulated (a) input impedance on the Smith chart and (b) return losses for the antennas in Fig. 1 when $L_a$ = 280 mm, $L_b$ = 120 mm and $L_c$ = 153 mm.

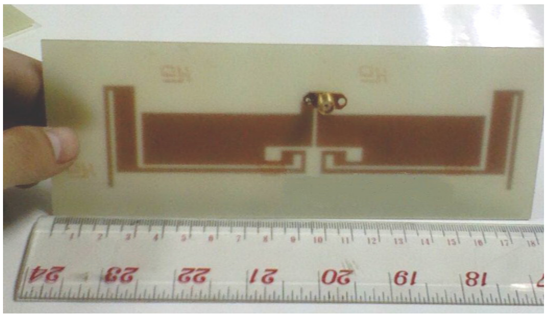
As an example, a linear fractal antenna has been designed [5] with a genetic algorithm based on procedure able to minimize simultaneous the antenna size and the positions of two lumped loads in order to match the input impedance. A simple measure of the performance of a broadcast antenna is its radiation resistance $R_{rad}$, which relates the radiation power P to the peak current $I_o$ that drives the antenna, according to P = 1/2 $I_o^2 R_{rad}$. A higher radiation resistance is better, in that more power is radiated compared to the power $I_o^2 R_{ohm}/2$ lost to heating the antenna due to the ordinary resistance $R_{ohm}$ of its conductor. Recall that the radiation resistance of a small center-fed linear dipole antenna of length a<< λ is $R_{rad} = 197(a/\lambda)^2$ Ω. The simulated input impedances of the antennas in Fig. 1 when $L_a$ = 280 mm, $L_b$ = 120 mm and $L_c$ = 153 mm, are shown in Fig. 2(a). For resonance frequency of 435 MHz, radiation resistance of FASS curve antenna calculated is 5.9 Ω, and the simulation shows input impedance is 5.3 Ω.

It is possible to decrease the reactance and increase the $R_{rad}$ of the antenna by changing the shape of its conductors without increasing the overall size of the antenna. To avoid lumped loads, this paper considers optimization of fractal antennas. To fit these constraints, the parameters to be optimized are the fractal geometry and the width of each fractal segment. According to the guidelines reported [6] and [7], the optimization method defines a sequence of trial configurations. Anyway, fractals do not promise to have best result for antenna, usually an optimization or tuning step is also necessary to make antenna better. Furthermore, in order to avoid the generation of impractical solutions (due to their intricate and convoluted shapes) some physical constraints have been defined on the antenna parameters and a penalty has been imposed on those configurations that while not unfeasible would be difficult to realize (e.g., higher fractal orders or large ratio between width and length of the fractal segment). The process of designing the antenna was complex and fine-tuning of this antenna was carried through trial and error. Starting from this basic radiating element, several variations of the initial geometry have been numerically and experimentally analyzed to allow the best performances with maximum compactness. At the end of the optimization process, the FASS curve fractal antenna has been obtained as shown in Fig. 1(c). It will be demonstrates here that fractal antenna can be designed to have a reduced size and low reflection properties by changing width of some segments.

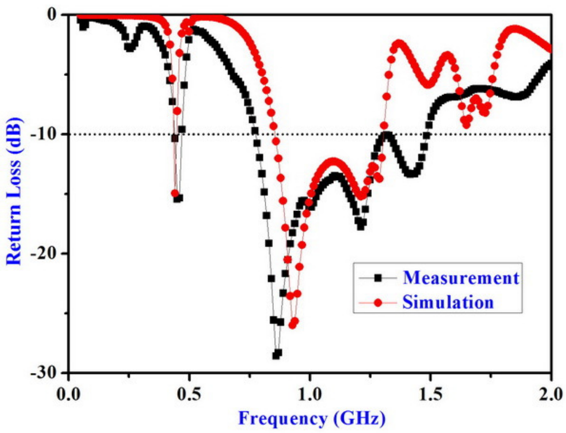
In addition, it is well known that one may be able to broaden the bandwidth of a single band dipole antenna by increasing the diameter of the dipole arms. However, to increase width of some arm dipole segments the bandwidth at 435 MHz is not widened, but to change the input impedance values in the 900 MHz band is wide good impedance matching. Fig. 2(b) shows the simulated return losses of these three antennas. From these results, the resonant points have been little influenced by the different antennas, but a good impedance matching only straight line dipole (Fig. 1(a)) and FASS curve with optimization (Fig. 1(c)) antennas. Moreover, by changing the shape of its widths of dipole arms, two operating bands can be obtained.

## 3. Experimental Results

The antenna prototypes have been built by using a photolithographic printing circuit technology following the geometric guidelines of the optimized geometry shown in Fig. 4(a). For the return loss measurement, the antenna prototype (Fig. 4(a)) has been equipped with a SMA connector. The input impedance characteristic of this antenna has been measured using a network analyzer (Agilent8719ES). The measured and simulated return losses of the FASS curve dipole antenna with optimization is shown in Fig. 4(b). We can see a good agreement of the simulation and measurement results.



(a)




(b)

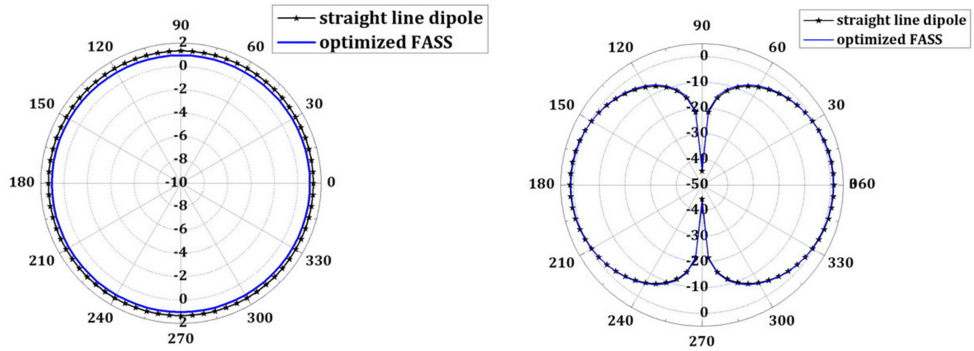
Fig. 4 (a) Photograph of an optimized FASS curve dipole and (b) measured and simulated return losses.

Fig. 5 shows the radiation patterns produced by the FASS curve antenna compared with a straight line half-wave dipole. The radiation patterns for this fractal antenna has negligible cross-polarization components (i.e. <-50 dB) and is nearly identical to the radiation pattern of the half-wave dipole antenna. The maximum gains at 435 MHz are 1.23 and 0.96 dBi of straight line half-wave dipole and FASS curve, respectively. Fig. 6 shows the comparison of the 3D radiation patterns between the infinite and finite dielectric substrates. They agree very well except at the θ = 90 degree. This notch is created by surface waves due to the infinite extended substrates and it can not be eliminated with the infinite substrate model.

## 4. Conclusion

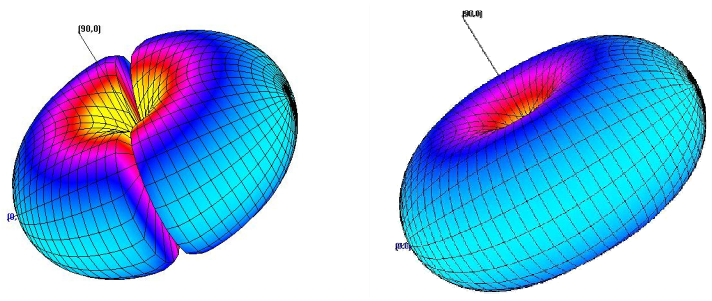
This paper presents the design of miniaturized dipole fractal antenna for two ISM bands. The proposed antenna is observed to pose band behavior similar to the conventional straight line dipole antenna.

However, the size of proposed fractal antenna has been reduced around 42% compared with the conventional dipole. The antenna explores good radiation characteristics including two available bands with 10 dB return loss bandwidths of about 15 MHz centered at 435 MHz band and of about 40% ranging from 845 to 1220 MHz, a stable radiation pattern, and average gains of greater than 1.2 and 2.5 dBi, respectively, over the two operating bands.




(a) (b)

Fig. 6 Radiation patterns of dipole antennas with various fractal antennas (a) H-plane and (b) E-plane.



(a) (b)

Fig. 6 Comparison in the 3D radiation pattern between the (a) infinite and (b) finite dielectric substrates.

# References

[1] S. Chaimool, P. Akkaekthalin, and V. Vivek, "Dual-band CPW-fed slot antennas using loading metallic strips and a widened tuning stub," *IEICE Trans. Electron*., vol. E88-C, no. 12, pp. 2258-2265, Dec. 2005.

[2] X.- C. Lin and C. -C. Yu, "A dual-band CPW-fed inductive slot-monopole hybrid antenna," *IEEE Trans. Antennas Propagat.,* vol. 56, no. 1, pp. 282-285, Jan. 2008.

[3] Y.-S. Wang, M.- C. Lee, and S.- J. Chung, "Two PIFA-related miniaturized dual-band antennas," *IEEE Trans. Antennas Propagat.,* vol. 55, no. 3, pp. 805 - 811, Mar. 2007.

[4] C.-Y. Pan, T.-S. Horng, W.S. Chen, C.-H. Huang, "Dual Wideband Printed Monopole Antenna for WLAN/WiMAX Applications," *IEEE Antennas and Wirel. Propagat. Letts,* vol. 6, pp. 149-151, 2007.

[5] D. H. Werner, P. L. Werner, and K. H. Church, "Genetically engineered multiband fractal antennas," *Electron. Lett.,* vol. 37, no. 19, pp. 1150-1151, Sep. 2001.

[6] R. Azaro, G. Boato, M. Donelli, G. Franceschini, A. Martini, and A. Massa, "Design of miniaturized ISM-band fractal antenna", *Electron. Lett.,* vol. 41, no. 14, pp. 785-786, July 2005.

[7] R. Azaro, G. Boato, M. Donelli, A. Massa, and E. Zeni, "Design of a prefractal monopolar antenna for 3.4-3.6 GHz Wi-Max band portable devices," *IEEE Antennas and Wirel. propagat. Lett.,* vol. 5, no. 1, pp. 116-119, Dec 2006.