# A Multiband CPW-Fed Slot Antenna with Fractal Slits in Rectangular Stub

<sup>#</sup> Tanan Hongnara<sup>1</sup>, Chatree Mahatthanajatuphat<sup>2</sup>, and Prayoot Akkaraekthalin<sup>3</sup> Department of Electrical Engineering, King Mongkut's University of Technology North Bangkok, 1518 Phibulsongkram Rd., Bangsue, Bangkok, Thailand 10800 <sup>1</sup> tanan.hongnara@hotmail.com,<sup>2</sup> cmp@kmutnb.ac.th, and <sup>3</sup> prayoot@kmutnb.ac.th

*Abstract* – A multiband cpw-fed slot antenna with fractal slit in rectangular stub is proposed. The conventional wideband slot antenna was modified by inserting the fractal silts in both side of the rectangular stub. The fractal silts can generate multi-notch frequency that affects to change the wideband performance antenna to the multiband performance antenna suitable for applications in wireless communication systems. In this paper, the fractal Hilbert slit with the 0 and  $1^{st}$  iterations has been employed. The comparisons between simulation and measured results are agree well, resulting from  $1^{st}$  iteration slit. The S<sub>11</sub> bandwidths of each band include 25.12%, 35.32%, and 17.18%. Additionally, the presented antenna can operate and cover the applications of DCS1800, WCDMA 2100, Worldwide Interoperability for Microwave Access (WiMAX), Wireless Local Area Network (WLAN IEEE 802.11a/n), and IMT advance system (4G mobile communication system).

Keywords: Multiband antenna Tuning stub Fractal silt.

## **1. Introduction**

Generally, the designing methods of multiband antennas have two main methods. First method, the multiband operation is generated by using multi-resonators to radiate electromagnetic wave at operating frequencies. In [1], each of three resonant frequencies of the antenna was occurred by each resonator that has different geometry. The CPW-fed monopole antenna in [2] uses the U-shape parasitic and defect inverted-L pair slits on ground plane to create multiband operation. Another method for design multiband antenna is modification or reconfiguration geometry in wideband antenna. The slots on the radiating patch and slit on ground plane was proposed in [3], causing to two notched frequency bands in conventional wideband antenna, as resulting in multiband operation. The technique to create notched frequency bands using the slot and slit inserted on the radiating patch to generate multiband operation was proposed in [4].

Usually, fractal geometry is used for designing the antenna to achieve the multiband, broadband and compact size [5]. In [6], the radiating line of monopole antenna is modified with Koch fractal geometry by increasing the electrical length of monopole to reduce the antenna size. The patch monopole with Minkowski fractal geometry was proposed in [7]. The fractal geometry generates suitably multiband operation for UMTS, WLAN, and WiMAX. Also, the applying fractal geometry on ground plane of slot antenna in [8] has affected to increase bandwidth of antenna.

This paper proposes a multiband CPW-fed slot antenna with fractal slit in rectangular stub. The multiband operation of the slot antenna is obtained by modifying conventional wideband slot antenna. For notched frequency of wideband slot antenna usually uses a stub or slit to create one notched frequency [9, 10]. However, this research uses fractal geometry to create slit for occurring multi-notched frequency in wideband operation, resulting in multiband antenna. The proposed antenna covers in the application bands of DCS1800 (1710-1880 MHz), WCDMA 2100 (1710-2155 MHz), WiMAX (3.3-3.8 GHz), IMT advanced system or 4<sup>th</sup> Generation mobile communication system (3.4-4.2 GHz), and WLAN IEEE802.11a/n (5.725-5.825 GHz). The effective parameters of the proposed antenna will be investigated by simulation that uses the full wave method of moment (MOM) software package, IE3D program. The prototype antenna with optimum values of the antenna parameters is fabricated and experimented. Additionally, the proposed paper is as follows. In section 2, the method of antenna configuration will be explained, while the simulated and measured results will be discussed in sections 3 and 4.

#### 2. Antenna Design

The proposed slot antenna is designed and fabricated on an inexpensive FR4 substrate with thickness of h = 0.8 mm and relative permittivity of 4.2. The geometry of proposed multiband slot antenna is depicted in Fig. 1(a). Typically, a conventional wideband slot antenna consists of the rectangular stub with dimension of 10x25 mm ( $L_{Bx}W_A$ ). It is fed by 50  $\Omega$  CPW-fed line with strip width and distance gap of 7.2 mm ( $W_t$ ) and 0.48 mm, respectively. In order to create a multiband slot antenna with fractal slit on rectangular stub, the Hilbert fractal model [5] is used to create a pair slits at the both side in horizontal axis on the rectangular stub as shown the 0 iteration and the 1<sup>st</sup> iteration Hilbert slit line in Fig.1(b). Therefore, the return loss of antenna with 0 and 1<sup>st</sup> iteration fractal slit and without slit in the rectangular stub is illustrated in Fig. 2(a). It has been found that there is not notched frequency in the antenna without slit, while the antenna with 0 and 1<sup>st</sup> iteration fractal slit have 2 and 3 notched frequencies, respectively. In order to adjust the notched frequency, the effective parameter of  $L_1$ ,  $L_2$ , and S will be observed. The alternating notched frequency in the next section and the optimal parameters of the proposed antenna are following: W = 48 mm, L = 50 mm,  $W_{S1} = 39.8$  mm,  $W_{SL} = 9.9$  mm,  $L_{SL} = 9$  mm,  $L_{S1} = 20.6$  mm,  $W_{S2} = 7.42$  mm,  $L_{S2} = 7.72$  mm,  $W_{S3} = 15.84$  mm ,  $L_{S3} = 19.28$  mm.  $W_I = 2.2$  mm,  $W_2 = 3.2$  mm, and  $L_3 = 7.3$  mm.

#### 3. Simulation and experiment

This section discusses the investigation on the effective parameters  $L_1$ ,  $L_2$ , and S respectively, as shown in Fig. 2. As the increasing parameter of  $L_1$  depicted in Fig 2(c), it has affected to all notched frequencies shifted to the higher frequency, resulting from the decreasing the electrical length in the slit. Moreover, the return loss level in the first band is enhanced due to the improving coupling effect between the fractal slits in the rectangular stub. Also, the result of varying parameter  $L_2$  is examined and investigated in Fig.2(d). It is obviously found that the 2<sup>nd</sup> and  $3^{rd}$  notch frequencies are shifted to higher frequency as the parameter  $L_2$  is abated due to the reducing electrical length of slit. However in Fig. 2(e), the decreasing parameter S has affected to the all notched frequencies, which the all notched frequency shifted to lower frequency resulting from the extending electric coupling in the gap of fractal slits. Therefore, the optimal values of parameters  $L_1 = 5$  mm,  $L_2 = 11$  mm, and S = 0.1 mm are decided for covering the operating frequency bands of 1.7 - 2.34 GHz, 3.27 - 4.34 GHz, and 5.42 - 6.3 GHz for the applications of DCS 1800 (1710 - 1880 MHz), WCDMA 2100 (1710 - 2155 MHz), WiMAX (3.3 - 3.8 GHz), IMT advanced system or 4th generation (4G) mobile communication system (3.4 - 4.2 GHz), and WLAN IEEE802.11 a/n (5.725 – 8.825 GHz). Then, the optimal values of parameters are used to manufacture the antenna by milling machine. The photograph of prototype antenna is depicted in Fig. 1(c). The simulation and measured return losses of the antenna are illustrated in Fig. 2(b). It is obviously seen that the different between simulation and measured return losses of antenna occurs because of the manufacture and the effect of an SMA connector to feed the antenna. As shown in the results, it has been found that the proposed antenna can respond to the operations of DCS 1800, WiMAX, IMT advanced system or 4th generation (4G) mobile communication system, and WLAN IEEE 802.11 a/n. In addition, the measured X-Z plane and Y-Z plane radiation patterns are displayed in Fig. 3. It is clearly noticed that the X-Z and Y-Z plane patterns at all operating frequencies are almost the bi-directional radiation patterns with occurring the peak gain at approximately 0 and 180 degrees. However, the cross polarization in X-Z plane patterns are expanding as increasing frequency due to the higher order mode of the operating frequency in the slot antenna. Moreover, the average gains of measured results are above 2 dBi at each operating frequency band, as summarized in table 1.

#### 4. Conclusion

The slot antenna with rectangular stub modified by Hilbert fractal slit line for the multiband wireless communication application is presented. It is clearly noticed that the notched frequency of the presented antenna can be alternated by effective parameters of  $L_1$ ,  $L_2$ , and S. Furthermore the

antenna radiation patterns are bi-directional patterns at all of operating frequencies, which can cover the applications of DCS 1800, WCDMA 2100, WLAN IEEE 802.11 a/n, WiMAX, and IMT advanced system or 4<sup>th</sup> generation (4G) mobile communication system.

### References

- [1]C. Mahatthanajatuphat, N. Wongsin, and P. Akkaraekthalin, "A multiband monopole antenna with modified fractal loop parasitic," International Symposium on Antenna and Propagation, pp.57-74, November 2010.
- [2] Z.-Y. Liu, Y.-Z Yin, S-F. Zheng, W. Hu, and L.-H Wen, "A compact CPW-fed monopole antenna with a U-shaped strip and apair of L-slits ground for WLAN and WIMAX application," Progress In Electromagnetics Research Letters, Vol. 16, pp 11-19, 2010.
- [3] Deepti Das Krishna, M. Gopikrishna, and C.K. Aanandan, "A CPW-fed triple band monopole antenna for WiMAX/WLAN applications," Proceeding of the 38th European Microwave Conference, pages 897-900. 2008
- [4] Wang-Sang Lee, Dong-Zo Kim, Ki-Jin Kim, and Jong-Won Yu, "Wideband planar monopole antennas with dual band-notched characteristics," IEEE Transactions on Microwave Theory and Techniques, Vol 54, NO 6, June 2006.
- [5] Douglas H. Werner and Suman Ganguly, "An overview of fractal antenna engineering research," IEEE Antenns and Propagation Magazine, Vol 45, NO 1, pp. 30-57, February 2003.
- [6] C. Puente, J. Romeu, R. Pous, J. Ramis, and A Hijazo, "Small but long Koch fractal monopole," Electronics Letter, Vol.34, NO. 1, pp. 9-10, 18<sup>th</sup> January 1998.
- [7] C. Mahatthanajatuphat, S. Saleekaw, and P. Akkaraekthalin, "A rhombic patch monopole antenna with modified mikowski fractal geometry for UMTS, WLAN, and mobile WIMAX application," Progress In Electromagnetics Research, vol. 89, pp.57-74, 2009.
- [8] D.D. Krishna, M. Gopikrishna, C.K. Annandan, P. Mohanan, and K. Vasudenan, "Compact wideband Koch fractal printed slot antenna," IET Microw. Antennas Propag., Vol. 3, Iss 5, pp. 782 – 789, 2009.
- [9] Natarajamani. S and S K Behera& S K Patra, "Compact slot antenna for UWB application and band-notch designs," International Conference on Computational Intelligence and Communication Systems, pp. 11-15, November 2010.
- [10] Mohammad Mehdi Samadi Taheri, Hamid Reza Hassani, and Sajad Mohammad Ali Nezhad, "UWB printed slot antenna with Bluetooth and dual notch bands," IEEE Antennas and Wireless Propagation Letter, Vol 10, pp. 254-258, 2011.



Figure 1: The geometry of the proposed antenna (a) overall geometry (b) rectangular stub with Hilbert fractal slits and (c) prototype of proposed antenna.



Figure 2: Measured and simulated return loss results from antenna design and investigation.



Figure 3: Measured radiation patterns of the proposed antenna. (a) 1.8 GHz, (b) 2.1GHz, (c) 3.5GHz, (d) 3.8GHz, and (e) 5.8 GHz.

T 1 1 1 N 1	· ·	1	· · · · ·		C
I able I · Measured	gaine of	nronosed	antenna toi	· onerating	rtreamency
1 abic 1. Micasulcu	gams or	proposed	antenna 101	operating	, moquene y
	0	1 1		1 6	, , ,

Antenna gains at operating frequencies (dBi)							
1.8 GHz	2.1 GHz	3.5 GHz	3.8 GHz	5.8 GHz			
2.12	2.7	3.7	3.6	1.6			