International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Impact Factor (2012): 3.358

# Planar Monopole Rectangular Antenna With Fractal Stub For Dual Band Applications

**Amrita Mardikar[1], Ravi Mohan[1], Mahima Arrawatia[2], Girish Kumar[2]**

[1]Electronics and Communication Engineering Department
SRIT Engineering College, Jabalpur, India

[2]Electrical Engineering Department, IIT Bombay
Powai, Mumbai, India

**Abstract:** ***In this paper, a low cost dual band planar monopole rectangular antenna with fractal stub is presented. Rectangular antenna with fractal stub is designed and fabricated on 1.6mm thick FR4 substrate. The bandwidth of the antenna is from (0.80-0.96) and (1.74-2.92) GHz for return loss < -10dB. This antenna covers CDMA, GSM900, GSM1800, 3G, 4G and Wi-Fi bands. An acceptable radiation pattern is obtained at all these bands. The maximum gain of the designed antenna is 2.7dBi.***

**Keywords:** Planar monopole antenna, Dualband antenna, fractal stub, radiation pattern

## 1. Introduction

Fractal antennas are multiband structures with compact size [1-3]. Various broadband antennas using fractals have been also reported in [4-5]. Various broadband monopole antenna designs have been reported in [6] but the radiation pattern degrades at the higher frequencies. CPW fed slot antenna with fractal stub is reported in [7] which shows the multiband behavior with uniform radiation pattern. A CPW fed wheel shaped antenna with broadband bandwidth is reported in [8] but the radiation pattern is not uniform at higher frequencies.

In [9] a dual band miniaturized monopole antenna designed for UWB wireless applications with fractal geometry is reported but the radiation pattern degrades at higher frequency. Micro strip line fed modified Sierpinski fractal monopole antenna for dual-band application is reported in [10] but pattern stability is not achieved. A multiband fractal ring antenna with capacitive coupling feed technique has been reported in [11]. In this configuration also the pattern degrades as the frequency increases.

In this paper, a dual band antenna is designed which can cover the application areas like cell phones, wi-fi, laptops, etc. The proposed antenna finds its application in portable devices. A dual band planar monopole rectangular antenna with fractal stub is designed and fabricated.

## 2. Antenna Design

A planar rectangular monopole antenna is designed to obtain dual bandwidth. The planar rectangular antenna (zero iteration) is shown in Fig.1 (a). Coaxial feed technique is used to feed the antenna. Radiating patch is on one side and ground plane is on the other side of the substrate. For simulation, IE3D [12] software based on method of moments is used. The antenna is designed on FR4 substrate (h = 1.6mm, dielectric constant ($\varepsilon_r$) = 4.4 and tan $\delta$ = 0.02). The length of the radiating patch (L) = 90mm and width of the radiating patch (W) = 37mm. The dimensions of the ground plane of the zero iteration rectangular antenna are: ($W_g$ x $L_g$) = (39 mm x 48 mm). The feed line of the coaxial feed technique has a width ($W_f$) of 3mm and length ($L_f$) of 5mm. The simulated $S_{11}$ of zero iteration is shown in Fig.1 (b). Bandwidth of the dual band antenna is between (0.80-1.00) GHz and (1.72-2.71) GHz.

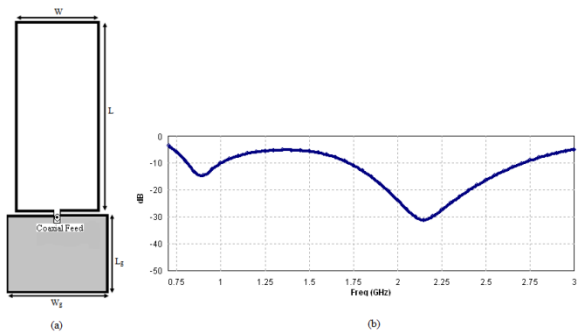


**Figure 1: (a)** Planar monopole rectangular antenna (zero iteration) and its **(b)** Simulated $S_{11}$

The simulated radiation pattern at 880MHz and 2.1GHz is shown in Fig.2 (a) and (b), respectively. At 880MHz, in H plane, the pattern is nearly omni directional and variation is less than 2dB. In E plane, the HPBW is nearly 90˚. The cross polar level is less than -40 dB in both E and H planes.

At 2.1 GHz, in E plane, the pattern is shifted from the broadside by more than $37^0$ and has a cross polar level of around -30dB. The variation in H plane is approximately 10dB and cross polar level is less than -40dB.

In the first level iteration, to reduce the tilt present in the pattern at higher frequency, fractal cut is added to the two sides of the planar monopole rectangular patch (zeroth iteration). First level iteration of the proposed antenna design is shown in Fig.3 (a). In this iteration, a small fractal cut of length $L_1$ = 13mm is added to the zeroth iteration. The simulated $S_{11}$ of first iteration is shown in Fig.3 (b).


Licensed Under Creative Commons Attribution CC BY

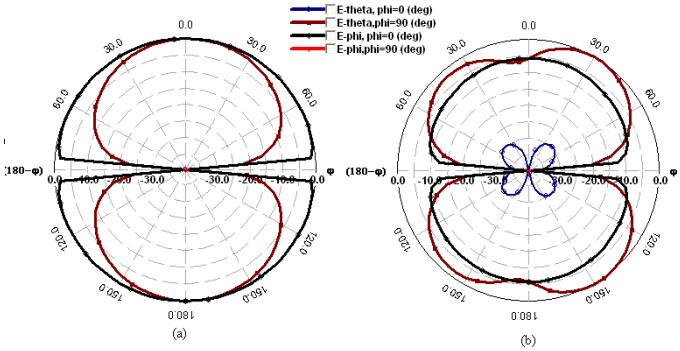


**Figure 2:** Simulated Radiation pattern of zeroth iteration at (a) 880MHz and (b) 2.1GHz

Simulated bandwidth of the first iteration for return loss < -10 dB is from (0.78-0.95) and (1.76-2.68) GHz. The simulated radiation patterns of the first iteration at 880MHz and 2.1 GHz are shown in Fig.4 (a) and (b), respectively. Radiation pattern is omni directional at lower band and also the cross polar level is <-40dB in E plane as well as in H plane.

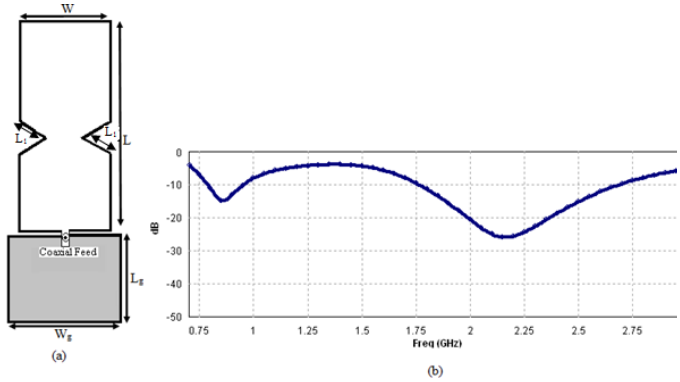


**Figure 3: (a)** First iteration of fractal antenna and its **(b)** Simulated $S_{11}$

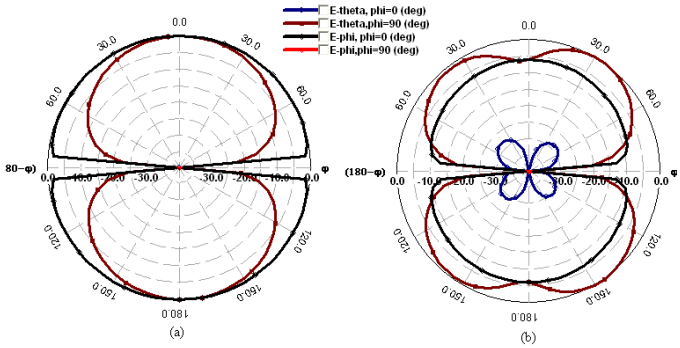


**Figure 4:** Simulated Radiation pattern of first iteration at **(a)** 880MHz and **(b)** 2.1 GHz

The E plane pattern at 2.1GHz has a tilt of 35°, which is slightly less than that of original rectangular monopole. The cross polar level is almost -30 dB in E plane. The variation in H plane is 10dB.

The second iteration is shown in Fig.5 (a). In this iteration to improve the radiation pattern at higher band, three sides of the rectangular patch are cut with the fractal stub. The length of the patch (L) = 90mm, width (W) = 37mm, length of fractal stub cut $L_1$ = 13mm. The length of the feed ($L_f$) = 5mm and width ($W_f$) = 3mm. The size of the ground plane is $L_g$ x $W_g$ = 48mm x 39mm. The gap between the radiating patch and ground plane is 0.5mm.

The simulated $S_{11}$ of the second iteration is shown in Fig.5 (b). Bandwidth for $S_{11}$ < – 10 dB is from (0.79-0.95) and (1.77-2.69) GHz. The simulated radiation patterns of the second iteration at 880MHz and 2.1 GHz are shown in Fig. 6(a) and (b) respectively. At 880MHz, the pattern is good. The cross polar level is less than -40dB in both E and H planes. The radiation pattern at 2.1 GHz is shifted by $34^0$ in E plane and variation in H-plane is 10 dB. The cross polar level is -30dB in E plane and -40dB in H plane.

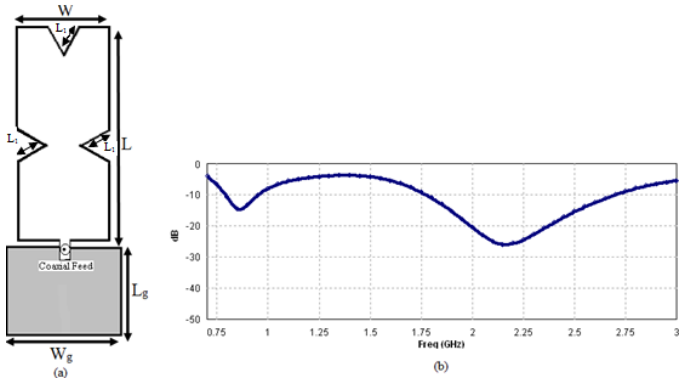


**Figure 5: (a)** Second iteration of fractal antenna and its **(b)** Simulated $S_{11}$

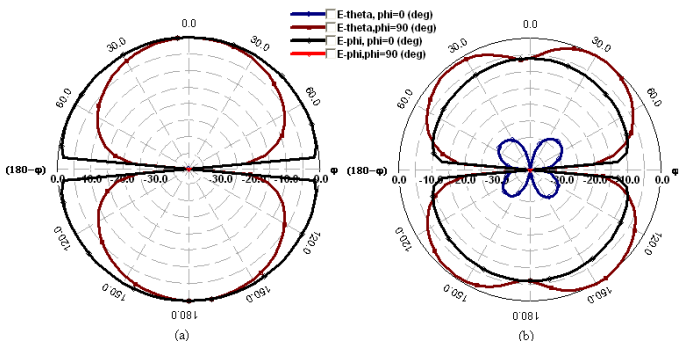


**Figure 6:** Simulated Radiation pattern of the second iteration of fractal antenna at **(a)** 880MHz and **(b)** 2.1 GHz

In the second iteration, the pattern is improved from the previous iterations but still tilt is present at the higher frequency. The fabricated dual band fractal antenna is shown in Fig.7. The antenna is fabricated on FR-4 substrate with dielectric constant 4.4 and loss tangent value 0.02. Radiating patch is on one side and ground plane is on other side of the substrate. Coaxial feed technique is used to feed the antenna. Dimensions of proposed antenna are: length of the rectangular patch (L)=90mm, width of the rectangular patch (W)=37mm, length of the ground plane ($L_g$)=48mm, width of the ground plane ($W_g$) =39mm, length of the feed line ($L_f$) =5mm, and width of the feed line is ($W_g$) =3mm.


Licensed Under Creative Commons Attribution CC BY

**Figure 7:** Fabricated dual band antenna with fractal stub

Measured $S_{11}$ graph for the antenna is shown in Fig.8. Measured bandwidth for $S_{11}$ < -10 dB is from (0.81-0.89) and (1.93-2.69) GHz. Theoretical and measured results are slightly different because of the fabrication error. The simulated gain plot of the antenna is shown in Fig .9. The maximum gain of the antenna is 2.7dBi. The measured radiation patterns at 880MHz and 2.1GHz are shown in Fig 10. The measured and simulated radiation patterns are in agreement. To improve the radiation pattern further and also to improve the bandwidth range to cover GSM900, GSM1800 and 3G bands, some more simulations have been done. The effects of following parameters are studied.

**Figure 8:** $S_{11}$ of the fabricated dual band fractal antenna

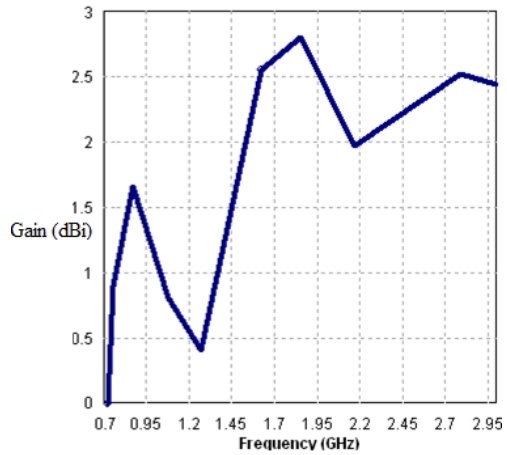


**Figure 9:** Gain Vs frequency plot of the simulated second iteration of fractal antenna with fractal stub

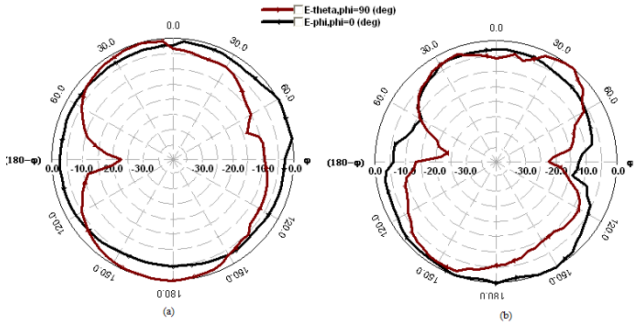


**Figure 10:** Measured radiation pattern of the fabricated antenna with fractal stub at (a) 880 MHz and (b) 2.1 GHz

- Dimensions of the radiating patch
- Dimensions of the notch
- Position of the notch

A) Change in the dimensions of the radiating patch

In this configuration, the width of the patch is reduced by 4mm and the feed point is shifted downwards by 1.5mm. All other dimensions are same as the earlier. Antenna with reduction in patch width is shown in Fig. 11 (a) and simulated $S_{11}$ is shown in Fig.11 (b). Simulated bandwidth for $S_{11}$ < -10dB is from (0.81-0.98) GHz and (1.71-2.88) GHz.

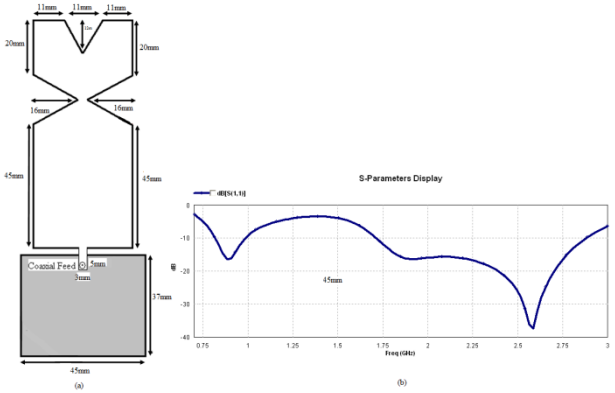


**Figure 11: (a)** Reduced width of fractal antenna and its **(b)** Simulated $S_{11}$

Simulated radiation patterns at 900MHz and 2.1 GHz for reduced width of the patch are shown in Fig.12 (a) and (b), respectively. At 900 MHz, the pattern is good and cross polar level is less than -40dB in both the planes. At 2.1 GHz, the co-polar pattern has improved in both the planes and the cross polar level is < -28dB in both the planes.

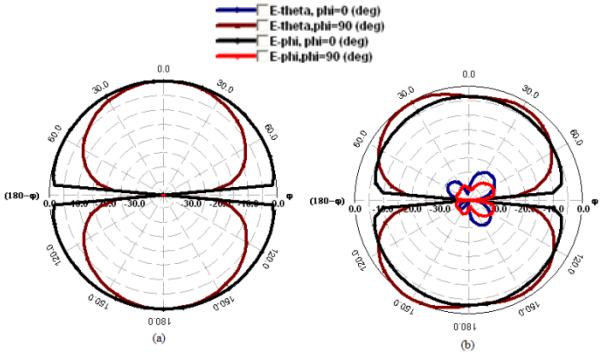


**Figure 12:** Simulated Radiation pattern of the reduced width of fractal antenna at **(a)** 900MHz and **(b)** 2.1 GHz


Licensed Under Creative Commons Attribution CC BY

B) Change in the dimensions of the notch

To improve the radiation pattern further with required bandwidth, dimensions of the notch is changed as compared with the original dimensions.

a) Upper single notch dimensions increases

Dimensions of the single upper notch of the rectangular patch are increased by 4mm in depth as well as in width, which is shown in Fig.13 (a). Simulated $S_{11}$ of this patch is shown in Fig.13 (b). Simulated bandwidth for $S_{11}$ < -10dB $_{is}$ from (0.81-0.98) GHz and (1.71-2.83) GHz. There is a mirror change in the pattern at 900 MHZ as well as 2.1 GHz.

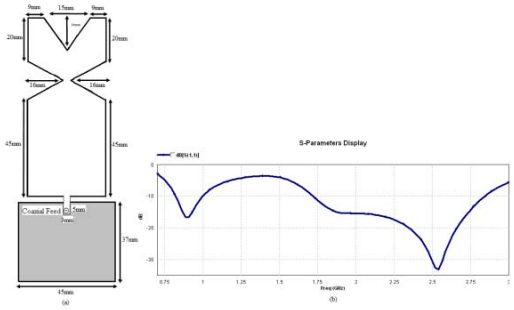


**Figure 13: (a)** Upper notch width increased fractal antenna and its **(b)** Simulated $S_{11}$

b) Two side notch dimensions increases

In this sub-section, the dimensions of the two side notches of the rectangular patch are increased by 6mm in width, which is shown in Fig.14 (a). Simulated $S_{11}$ of this antenna is shown in Fig.14 (b).

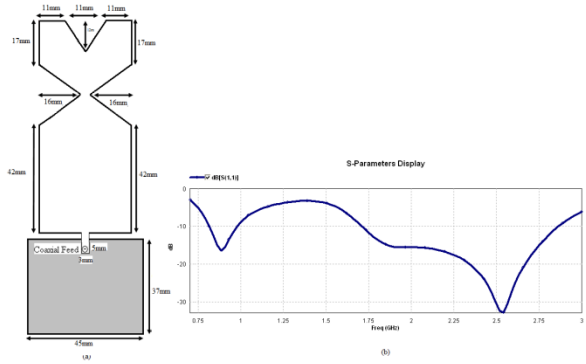


**Figure 14: (a)** Side notch increased fractal antenna and its **(b)** Simulated $S_{11}$

Simulated bandwidth for $S_{11}$ <-10dB is from (0.81-0.98) GHz and (1.71-2.85) GHz. Simulated radiation patterns at 900MHz and 2.1 GHz are shown in Fig.15 (a) and (b), respectively. At 900 MHz, the pattern is similar to the previous cases. At 2.1 GHz, pattern is slightly changed.

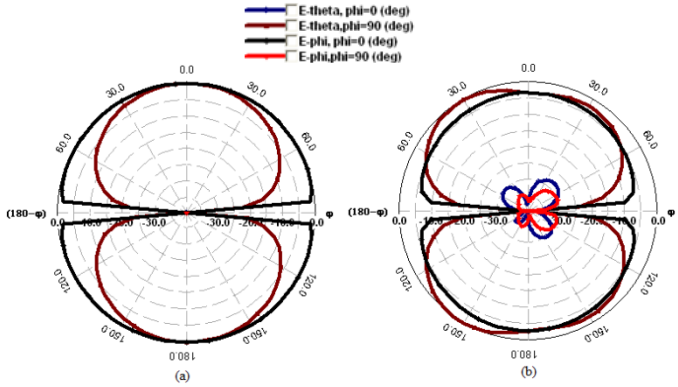


**Figure 15:** Simulated Radiation pattern of the side notch increased fractal antenna at **(a)** 900MHz and **(b)** 2.1 GHz

C) Change in the position of the notch

In this sub-section, the position of two side notches of the rectangular patch is moved by 5mm along the length of the rectangular patch.

a) Two side notches shifted in upward direction

Rectangular patch with two side notches shifted in upward direction with respect to its original position is shown in Fig.16 (a) and its simulated $S_{11}$ is shown in Fig.16 (b). Simulated bandwidth for $S_{11}$ < -10dB is from (0.82-0.99) GHz and (1.67-2.73) GHz. At 900 MHz, the pattern is similar to the previous cases and there is minor change in the pattern at 2.1 GHz.

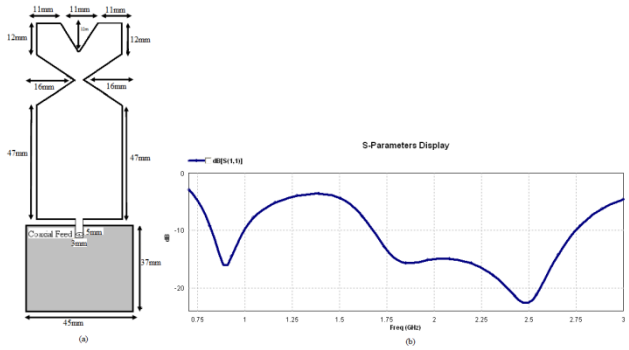


**Figure 16: (a)** Side notch moved upward fractal antenna and its **(b)** Simulated $S_{11}$

b) Two side notches shifted in downward direction

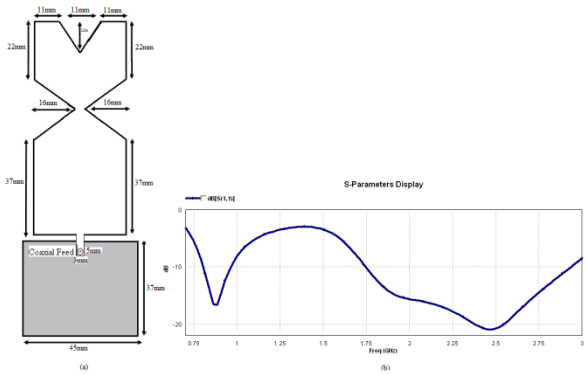


**Figure 17: (a)** Side notch moved downward fractal antenna and its **(b)** Simulated $S_{11}$


Licensed Under Creative Commons Attribution CC BY

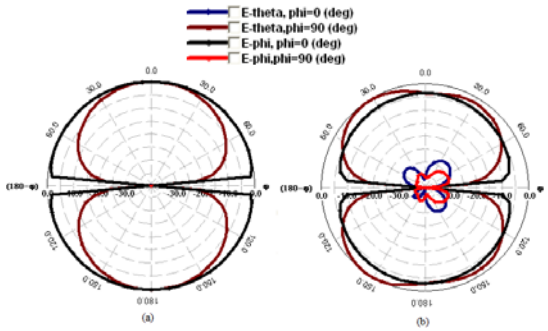


**Figure 18:** Simulated Radiation pattern of the side notches moved downward fractal antenna at **(a)** 900MHz **(b)** 2.1 GHz

In this sub-section, the two side notches are shifted downward by 5mm along the length of the rectangular patch with respect to its original position. Rectangular patch with notch shifted in downward direction is shown in Fig.19 (a) and its simulated $S_{11}$ is shown in Fig.17 (b). Simulated bandwidth for $S_{11}$ <-10dB is from (0.80-0.96) GHz and (1.74-2.92) GHz. Simulated radiation patterns at 900MHz and 2.1 GHz are shown in Fig.18 (a) and (b) respectively. At 900 MHz, the pattern is similar to the previous cases and there is minor change in the pattern at 2.1 GHz.

## 3. Conclusion

In this paper, a dual band planar monopole rectangular antenna with fractal stub is designed and fabricated. Parametric studies have been carried out to study the effect of various parameters on the bandwidth and radiation patterns at the two bands. The final antenna has bandwidth from (0.80-0.96) and (1.74-2.92) GHz. This dual band antenna covers the application areas of CDMA, GSM900, GSM1800, 3G, 4G and Wi-Fi bands with acceptable radiation pattern. Further improvement can be done in the radiation pattern at higher band.

## References

[1] Ghatak, R.; Mishra, R.K.; Poddar, D.R., "Perturbed Sierpinski Carpet Antenna With CPW Feed for IEEE 802.11 a/b WLAN Application," IEEE Antennas and Wireless Propagation Letters,vol.7, pp.742-744, 2008
[2] Choukiker, Y.K.; Behera, S.K., "CPW-Fed compact multiband Sierpinski triangle antenna," Annual IEEE INDICON, 2010 , pp.1-3, 17-19 Dec., 2010
[3] Dau-Chyrh C.;et.al, "CPW-Fed Circular Fractal Slot Antenna Design for Dual-Band Applications," IEEE Transactions on Antennas and Propagation, vol.56, no.12, pp.3630-3636, Dec. 2008
[4] Jeemon, B.K.; Shambavi, K.; Alex, Z.C., "A multi-fractal antenna for WLAN and WiMAX application," IEEE Conference on Information & Communication Technologies (ICT), 2013, pp.953-956, 11-12 April 2013
[5] Min D.,; et.al, "Design of a CPW-fed Ultra Wideband Crown Circular Fractal Antenna," IEEE Antennas and Propagation Society International Symposium 2006, pp.2049-2052, 9-14 July 2006
[6] Kumar G and Ray K. P., Broadband Microstrip Antenna, Artech House, USA 2003.
[7] H.Tanan, C. Mahatthanajatuphae, A. Prayoot , "Study of CPW-Fed Slot Antennas with Fractal Stubs," The 8th Electrical Engineering/ Electronics, Computer, Telecommunications and Information Technology (ECTI)Association of Thailand - Conference 2011
[8] K. Raj, M. P, S.K, "On The Design Of Wheel-Shaped Fractal Antenna," Microwave And Optical Technology Letters / Vol. 53, No. 1 January 2011
[9] A. Kaka, M. Toycan, V. Bashiry, H. Ademgil and S. D. Walker, "A Fractal Geometry, Multi-band, Miniaturized Monopole Antenna Design for UWB Wireless Applications," 978-1-4577-0048-4/11/$26.00 ©2011 IEEE
[10] C.Yogesh, B.S.K, "Microstrip Line-Fed Modified Sierpinki Fractal Monopole Antenna for Dual-Wideband Applications," 978-1-4244-7770-8/10/$26.00 © 2010 IEEE
[11] W. Norakamon, S. Thanakarn, "A Multiband Fractal Ring Antenna Fed by Capacitive Coupling," The 8th Electrical Engineeringl Electronics, Computer,Telecommunications and Information Technology (ECTI) Association of Thailand - Conference 2011
[12] IE3D Software from Mentor Graphics


Licensed Under Creative Commons Attribution CC BY