Design of CPW-Fed Dodecagon Monopole Antenna for Ultra-Wideband Applications with Hilbert Curve Fractal

C. Muthu Ramya and R. Boopathi Rani

Abstract This paper deals with the design of CPW-fed Dodecagon Monopole antenna for Ultra-wideband applications that exhibits the bandwidth ranges from 2.97 to 15.58 GHz which corresponds to the fractional bandwidth of 135.96%. By introducing a second-order Hilbert curve slot in the patch nearby feed line, the rejection of band occurred around 3.5 GHz, to eliminate the Worldwide interoperability for Microwave Access (WiMAX) band was achieved. The peak antenna gain of 3.2 dBi is detected. The proposed antenna was designed on FR-4 substrate with a dimension of 40×40 mm^2.

Keywords Dodecagon monopole · Hilbert fractal · Ultra-wideband · CPW feed · Bandwidth enhancement · Fractal antenna · Band notch

1 Introduction

The Ultra-wideband antenna (UWB) is mostly preferred for High speed and short range communications to meet the requirements of recent technological advancements in mobile communication. The UWB antenna with band rejections is desirable to mitigate the problem of interference with the conventional wireless communication systems. It is possible to obtain band notch characteristics by using any one of the techniques such as fractal structure [1], Slots [2], Parasitic stub [3], Electromagnetic Band Gap structures [4]. In this paper, the band notch characteristics were created by inserting a Hilbert curve slot in the Dodecagonal monopole radiating patch.

By incorporating a Hilbert curve slot, the miniaturization as well as the frequency rejection characteristics is obtained. The third iteration order Hilbert curve is used to make the antenna compact and the band notch creation [5]. An antenna that uses Hilbert like curve for multiple band operation was proposed [6]. A hexagonal boundary Sierpinski carpet fractal antenna by modifying hexagonal monopole

C. Muthu Ramya (✉) · R. Boopathi Rani
National Institute of Technology Puducherry, Karaikal, India

R. Boopathi Rani
e-mail: rbrani@nitpy.ac.in

A. Sivasubramanian et al. (eds.), *Futuristic Communication and Network Technologies*, Lecture Notes in Electrical Engineering 792,
https://doi.org/10.1007/978-981-16-4625-6_73

antenna for UWB application was proposed in [7]. By introducing a 'Y' like slot, the antenna can reject the band from 5.15 to 5.825 GHz.

Designing an antenna to serve for the modern-day wireless communication necessitates broadband, multiband and high gain which is being the biggest challenge today. The incorporation of fractal is one of the techniques utilized to satisfy such needs. In this proposed work a dodecagon monopole has been presented in which a Hilbert fractal was introduced to get the band rejection characteristics. This monopole antenna produced the wideband resonance from 2.97 to 15.58 GHz. A Hilbert curve slot is etched from the patch to create a notch band around 3.5 GHz through which the disturbances from WiMAX communication system will be eliminated.

This paper is arranged as follows: Sects. 2 and 3 present the antenna design and simulated results and discussions respectively. Section 4 reports the conclusion about the work.

2 Antenna Design

A dodecagon monopole has been proposed for UWB antenna. The dodecagon-shaped patch radiator is shown in Fig. 1. There are research papers proposed hexagonal or octagonal patch for bandwidth enhancement [8, 9]. In line with that, it is aimed to find the dodecagon as radiating element. Hence the construction starts with a dodecagonal of radius 10 mm. The CPW feed of width 3.2 mm provides a good amount of impedance matching over a wide frequency range also offers a less dispersion at higher frequencies [10].

Fig. 1 Basic dodecagonal shape patch

The expression given in Balanis [11] is utilized to calculate the dimension of the proposed patch antenna since the circular shape patch and the dodecagonal shape patch are closely related to each other. The mathematical expression for resonant frequency corresponding to a circular radiating patch is as follows:

$$F_r = \frac{X_{\mathrm{nm}} C}{2\pi a_e \sqrt{\varepsilon_r}} \quad (1)$$

where the value of $'X'_{\mathrm{nm}} = 1.8412$ for TM_{11} mode. 'C' is free space light velocity, $'\varepsilon'_r$ is the dielectric constant of the substrate, and $'a'_e$ is the effective radius of circular patch. The $'a'_e$ in terms of physical radius is given as,

$$a_e = a\sqrt{\left[1 + \frac{2h}{\pi a \varepsilon_r}\left(\ln \frac{\pi a}{2h} + 1.7726\right)\right]} \quad (2)$$

where 'a' is the physical radius of the same patch, the thickness of the substrate is represented as 'h'. The resonant frequency of the proposed dodecagonal patch is calculated by equating the area of circular patch with that of the dodecagon patch.

$$\pi (a_e)^2 = 11.196 r^2 \quad (3)$$

where the side length of dodecagon patch is denoted as 'r'.

The radius and side length of the dodecagon patch are 10 mm and 5.176 mm respectively, and by using the Eqs. (1)–(3), the resonant frequency obtained is 4.28 GHz.

The German mathematician David Hilbert introduced an algorithm for Hilbert curve in 1891, [12]. The Hilbert curve is built with the iterative steps as shown in Fig. 2. Each step is built with four duplicates of the previous structure. The total length S of whole line portions is given as (4) [5],

$$S = \left(2^{2n} - 1\right)d = \left(2^{2n} + 1\right)L \quad (4)$$

$$d = \frac{L}{\left(2^{2n} - 1\right)} \quad (5)$$

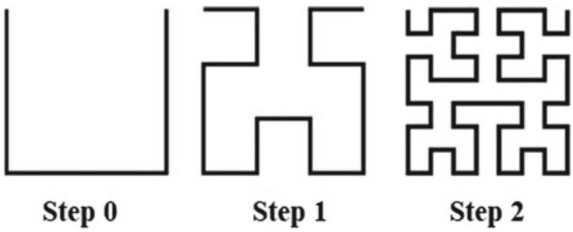


Fig. 2 Building process of Hilbert curve [5]

Here, the Hilbert curve's side dimension is denoted as 'L', the line segment's length is 'd' and the iteration order as 'n'. Hilbert curve of second order given in step 1 was utilized as a band notch segment in this proposed antenna by etching it from the main radiating patch.

The proposed antenna shown in Fig. 4a was designed on FR4 material of 1.6 mm height with dimensions of 40×40 mm^2, which has relative dielectric constant and loss tangent are 4.4 and 0.02 respectively. The space between the dodecagon and the ground is 1.25 mm. The width of each ground plane is 17.11 mm. The suitable width of the Hilbert curve in the proposed antenna is 0.52 mm.

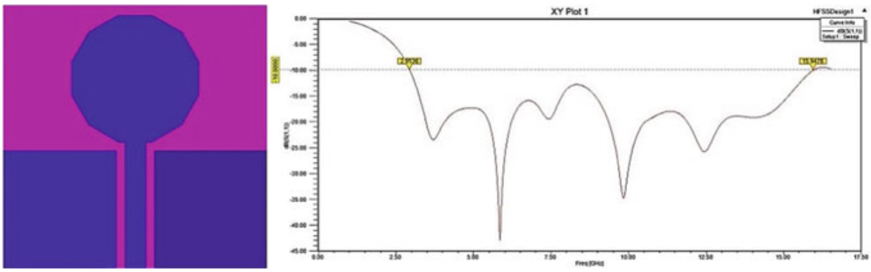
3 Results and Discussions

The design and analysis of the proposed antenna is carried out by using commercial electromagnetic simulator ANSYS HFSS. It uses Finite Element Method to analyze antenna. Figure 3 shows the dodecagon-shaped monopole antenna and its return loss output. It produces the bandwidth ranges from 2.95 GHz to 15.95 GHz which corresponds to the fractional bandwidth of 137.57%.

Figure 4a and b shows the proposed antenna consists of second-order Hilbert curve slot on the dodecagonal patch and its return loss results respectively.

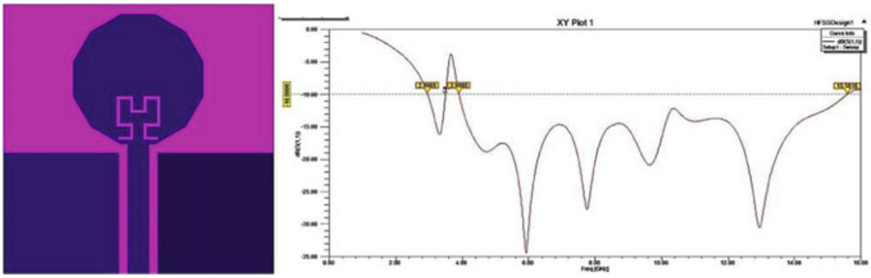
Figure 5a and b shows the E plane and H plane radiation patterns of the final antenna at 4.28 GHz and 4.78 GHz frequencies.

The return loss results plot states that the proposed dodecagon monopole antenna with Hilbert curve fractal slot can be used for UWB applications. The radiation pattern expresses the radiation characteristic of the antenna is suitable for the proposed application. The peak antenna gain detected is 3.2 dBi.



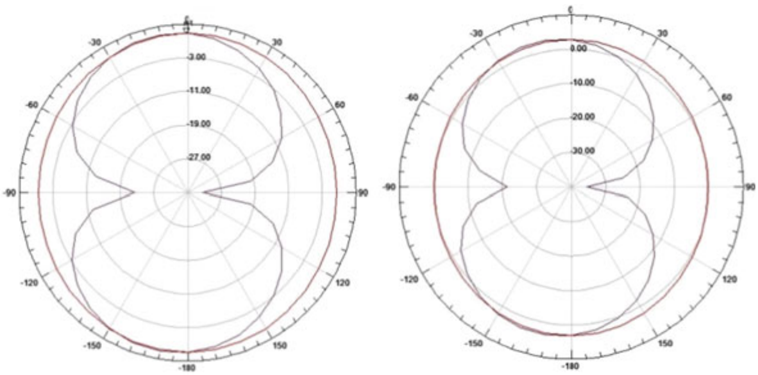
(a) (b)

Fig. 3 **a** Dodecagonal shaped monopole, **b** return loss characteristics



(a) (b)

Fig. 4 **a** Proposed antenna, **b** return loss results of proposed antenna



(a) (b)

Fig. 5 **a** Radiation pattern at 4.28 GHz, **b** radiation pattern at 4.78 GHz

4 Conclusion

This paper proposes and analyzes a dodecagonal monopole antenna with CPW feed for Ultra-wideband communications. The antenna operates in the frequency range of 2.97–15.58 GHz for S_{11} better than -10 dB. The notch band is created around 3.5 GHz by means of incorporating the Hilbert curve slot on the radiating patch. The return loss and gain are determined to analyze the performance of the given antenna. This antenna performs well for UWB communication and X-band satellite communication systems.

References

1. Banerjee J, Gorai A, Ghatak R (2020) Design and analysis of a compact UWB MIMO antenna incorporating fractal inspired isolation improvement and band rejection structures. AEU Int J Electron Commun 153274
2. Boopathi Rani R, Pandey SK (2016) A parasitic hexagonal patch antenna surrounded by same shaped slot for WLAN, UWB applications with notch at vanet frequency band. Microw Opt Technol Lett 58(12):2996–3000
3. Ojaroudi Parchin N, Basherlou HJ, Abd-Alhameed RA (2020) UWB microstrip-fed slot antenna with improved bandwidth and dual notched bands using protruded parasitic strips. Prog Electromagn Res 101:261–273
4. Sanmugasundaram R, Natarajan S, Rajkumar R (2020) Ultrawideband notch antenna with EBG structures for WiMAX and satellite application. Prog Electromagn Res 91:25–32
5. Kim DO, Kim CY, Park JK, Jo NI (2011) Compact band notched ultra-wideband antenna using the Hilbert-curve slot. Microw Opt Technol Lett 53(11):2642–2648
6. Kaka AO, Toycan M, Bashiry V, Walker SD (2012) Modified Hilbert fractal geometry, multi-service, miniaturized patch antenna for UWB wireless communication. COMPEL Int J Comput Math Electr Electron Eng
7. Ghatak R, Karmakar A, Poddar DR (2013) Hexagonal boundary Sierpinski carpet fractal shaped compact ultrawideband antenna with band rejection functionality. AEU-Int J Electron Commun 67(3):250–255
8. Sawant KK, Kumar CS (2015) CPW fed hexagonal micro strip fractal antenna for UWB wireless communications. AEU-Int J Electron Commun 69(1):31–38
9. Singhal S, Singh P, Kumar Singh A (2016) Asymmetrically CPW-fed octagonal Sierpinski UWB fractal antenna. Microw Opt Technol Lett 58(7):1738–1745
10. Kumar R, Malathi P, Sawant K (2011) On the design of wheel-shaped fractal antenna. Microw Opt Technol Lett 53(1):155–158
11. Balanis CA (2016) Antenna theory: analysis and design. Wiley
12. Sagan H (2012) Space-filling curves. Springer Science & Business Media