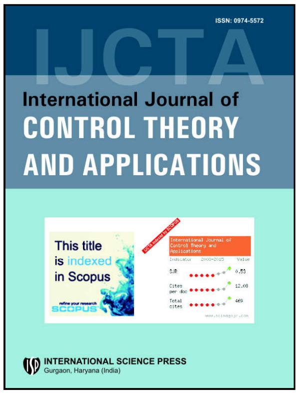

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On the Notch Band Characteristics of Koch Fractal Antenna for UWB Applications

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Abstract: In this paper, design and simulation of circular patch antenna for rejecting WiMAX and WLAN bands is presented. Fr4 epoxy with ε_r-4.4 is used as dielectric substrate. Designed patch antenna operates in 2 GHz-11 GHz band, covering both WiMAX (IEEE-802.16e) and UWB (3-10 GHz). By using the fractal properties and geometry, multiband behavior and notch band characteristics are achieved. Antenna is designed and simulated using HFSS V.15 3D electromagnetic simulation software. Antenna parameters such as Return Loss, VSWR, Radiation Patterns and field distributions were analyzed and plotted.

Keywords: Fractal, Koch Fractal, UWB, HFSS, WiMAX, WLAN

1. INTRODUCTION

As Federal Communication Commission (FCC) allocated a frequency band from 3.1-10 GHz for Commercial ultrawideband (UWB) applications [1-3], several compact antennas have been designed and the research on these UWB antennas is still going on. To avoid interference with the existing services in UWB range like WiMAX (IEEE 802.16e- 2.73-2.9 GHz), WLAN (5.1-5.8 GHz) conventional UWB systems uses band rejection filters. But it increases cost and complexity. UWB antennas have the unique advantage that it is possible to implement notch band characteristic on the antenna itself.

For UWB applications, Microstrip patch antennas are more preferable due to their low profile and ease of fabrication. Different shapes of microstrip antennas are available, in that rectangular and circular are more common. A circular monopole patch antenna can be designed by using the formulas given in [4]. Microstrip antennas have narrow bandwidths and less gain. UWB antennas should have wide bandwidth. Bandwidth can be increased by making slots on radiating patch or by reducing the ground plane. A trapezoidal shaped slot was made on radiating patch to increase the bandwidth [5].

To achieve notch band characteristics several techniques have been proposed. By adding stubs to the radiating patch or by using slots band notch characteristics can be achieved. Single notch band is achieved in

[6-7] by making slots on radiating patch. Dual notch band is achieved by using parasitic microstrip lines and T-shaped stub in [8].

In order to achieve dual notch band characteristics, a slot which provides multiple band rejections should be used. Fractal antennas are type of antennas which provides multiband characteristics [9-11]. By using different types of fractal slots dual notch bands can be achieved [12]. Sierpinski gasket shaped slot was made on patch for number of iterations to achieve dual notch bands in [13-15].

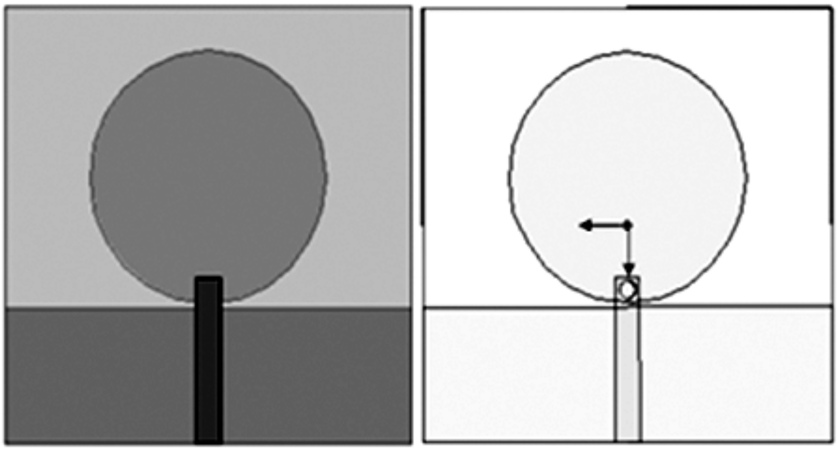
However, as number of iterations increases, design complexity also increases. So a fractal shaped slot should provide dual notch characteristics at the same time with less design complexity. In this work a circular monopole antenna with Koch fractal shaped slot of 1st iteration is used to achieve dual band notches at 2.8 GHz and 5.4 GHz. FR4 epoxy with ε_r-4.4 dielectric substrate is used to isolate patch and ground plane.

The rest of the paper is organized as follows. Geometric modelling of circular patch antenna is explained in section II. Simulation results are presented in section III. Conclusion was given in section IV.

2. PROPOSED ANTENNA DESIGN

2.1. Design of circular patch antenna

A circular patch antenna can be designed by using the design equations mentioned in [4]. In this paper, a circular monopole antenna with a radius of 14.5mm is designed using back feeding. Fr4 epoxy (50 mm X 50 mm) with relative permittivity-4.4 and thickness-1.6mm is used as dielectric substrate. Feed line is coupled to the radiating patch through via of diameter 1mm as shown in Figure 1(b). In order to achieve UWB characteristics ground plane length is varied, and for ground plane length Lg=15.5mm, designed circular patch antenna radiates in 2-11 GHz frequency range.



(a) (b)

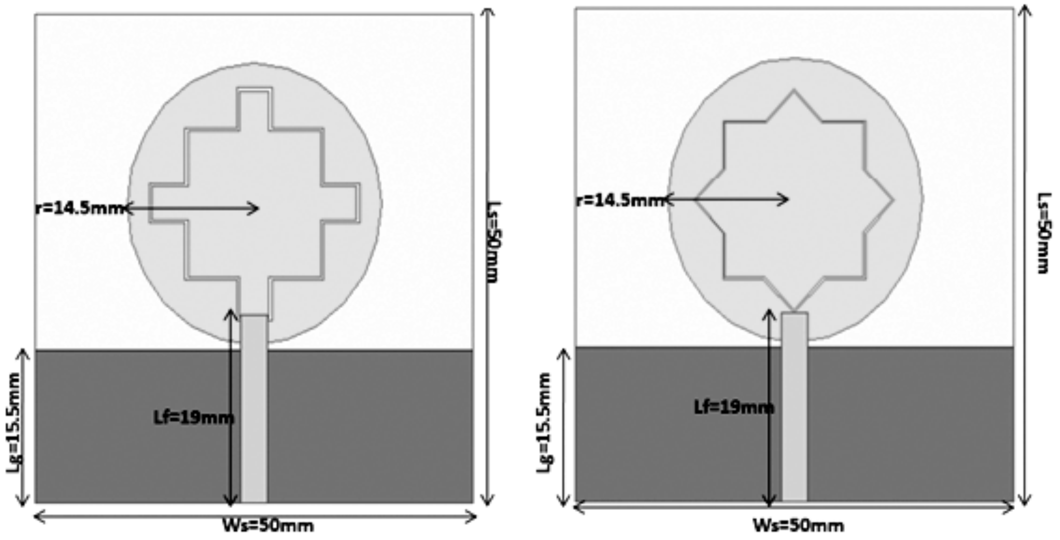
Figure 1: (a) Front View (b) Back View of a Circular Monopole Patch Antenna

As the frequency bands of WiMAX and WLAN lay in this range it is necessary to reject these bands to avoid interference. A square shaped slot was made on the circular patch as shown in Figure 2 (a) and with this slot single notch is achieved. By using the fractal properties such as self similarity the shape of slot was modified according to the shape of Koch Fractal. Koch fractal can be designed by using [9]. With this structure as shown in Figure 2 (b) dual notch characteristics are achieved.

Table 1 shows the calculated dimensions for circular monopole antenna with FR4 substrate.

Table 1
Dimensions of Proposed Antenna

Material	*Length (mm)*	*Width (mm)*
Substrate	Ls - 50	Ws - 50
Ground plane	Lg – 15.5	Wg - 50
Feed Line	Lf - 19	Wf - 3



(a) **(b)**

Figure 2: (a) Using Square Shaped slot (b) Using Koch Fractal 1st iteration

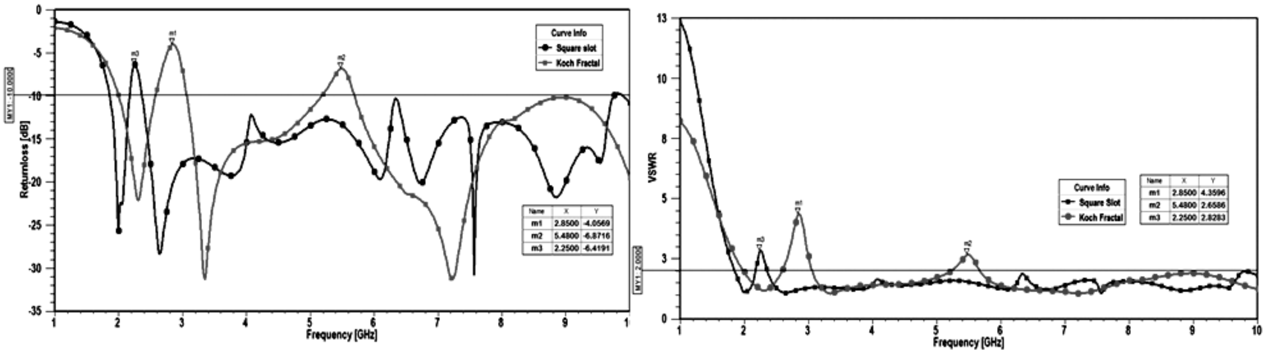
3. SIMULATION RESULTS

3.1. Return Loss

Antenna design and simulation was carried out in HFSS V.15. Return Loss is an important parameter of Antenna which gives the loss of signal power due to discontinuities or mismatch in transmission lines. Circular monopole patch antenna shown in Figure 1 operates in Ultra Wide Band (UWB) frequency range covering frequencies from 2-11 GHz. By making a square shaped slot on the radiating patch, single notch obtained at 2.24 GHz frequency. By using the Koch fractal geometry dual notch band characteristics are achieved. The final design shown in Figure 2(b) gives dual notch bands with centre frequencies 2.8 GHz and 5.4 GHz. The return loss plots for square shaped slot patch and Koch fractal slot patch are shown in Figure 3(a). Return loss of -10dB is taken as reference value by considering that 90% of signal power is transmitted and only a 10% power is reflected back due to discontinuities in transmission line.

3.2. VSWR

Voltage Standing Wave Ratio (VSWR) is a measure of impedance matching. It gives a numerical value that describes the matching between transmission line and radiating patch. Ideally VSWR value is 1. But it is impossible to achieve VSWR-1 practiaclly. So a VSWR <2 will be considered as reference value. The simulated VSWR plots for 2 designs are shown in Figure 3(b). Circular monopole antenna with square shaped slot has a VSWR value <2 for the entire range 2-11 GHz except at 2.24 GHz. It has VSWR-4.3 at that particular frequency. Antenna with Koch fractal slot has VSWR <2 for 2-11 GHz except at two frequencies 2.8 GHz and 5.48 GHz i.e. both Wi-Fi and WLAN bands are being rejected by this antenna.



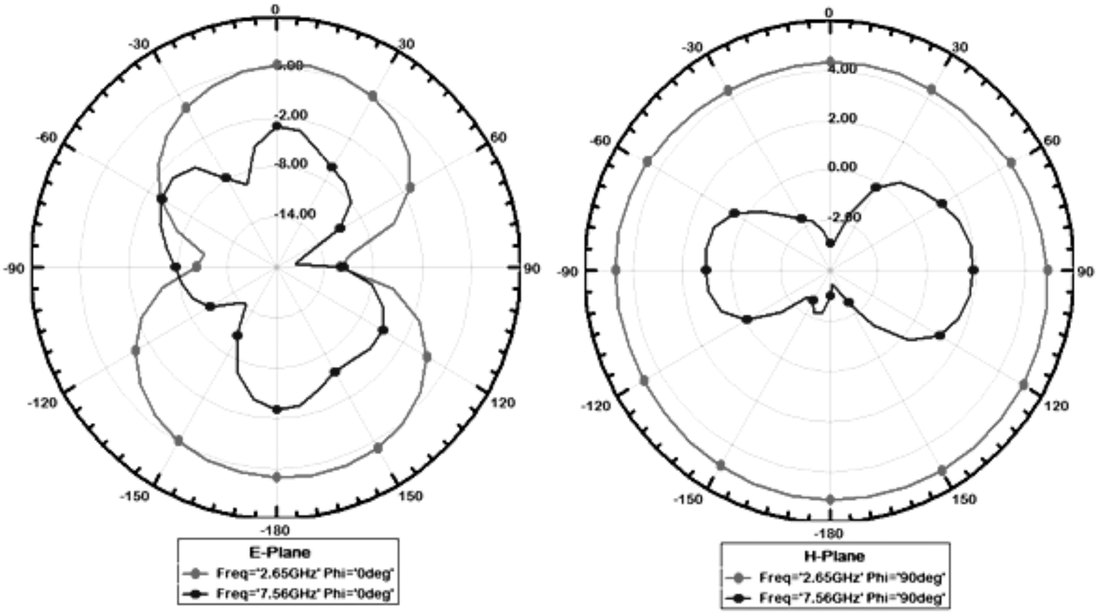
(a) **(b)**

Figure 3: (a) Return Loss plot (b) VSWR plot for both square shaped and Koch fractal slots

3.3. Radiation Patterns

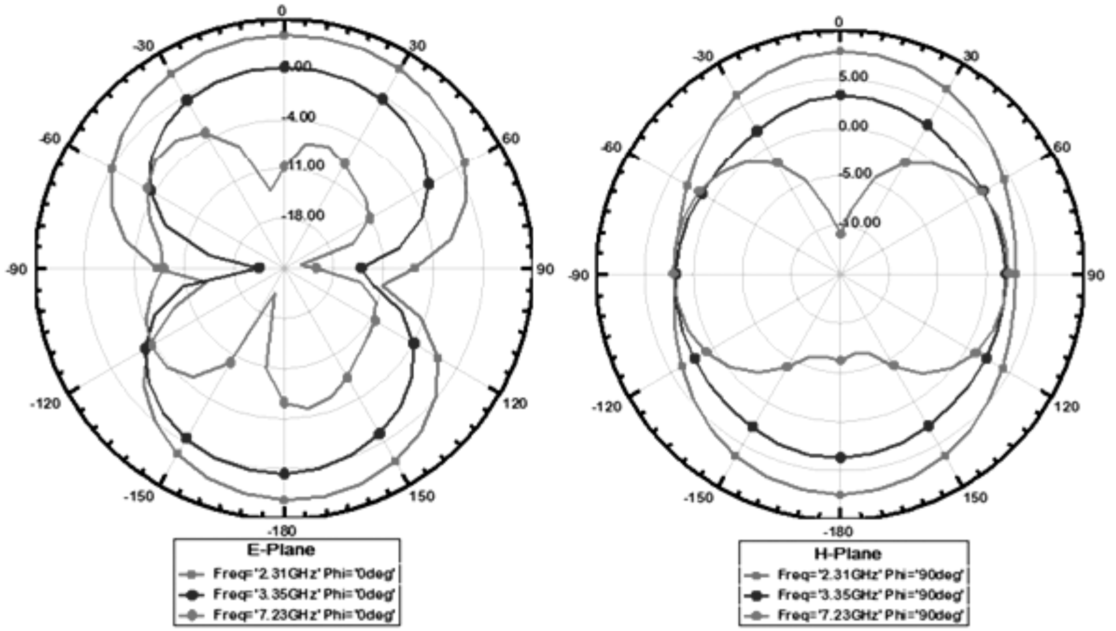
Radiation patterns for both square shaped slot and Koch fractal slot are shown in Figures 4 and 5. Figure 4(a) and (b) shows the two dimensional radiation patterns of circular monopole patch antenna with square shaped slot in both E-plane and H-plane. The antenna operates in 2-11 GHz band giving a notch band at 2.24 GHz centre frequency. Radiation Patterns were plotted for two resonant frequencies 2.65 GHz and 7.65 GHz in 2-11 GHz range. From the plots it is clear that antenna is radiating Omni-directionally. In one plane, antenna is radiating power equally and in another plane it produces a dumbell shaped pattern. We can observe the Omni-directional pattern more clearly for 2.65 GHz frequency in both planes from Figure 4(a) and (b). (red colored-line).

Figure 5(a) and (b) shows the 2-D radiation plots for the circular patch antenna with Koch fractal slot in both azimuthal and elevation planes. This antenna operates in 2-11 GHz range giving dual notches at center frequencies 2.8 GHz and 5.4 GHz respectively. Radiation patterns were plotted for 3 resonant frequencies in the range 2-11 GHz. This antenna radites Omin-directionally for the selected three resonances.



(a) **(b)**

Figure 4: (a) 2.65GHz and 7.65 GHz E-Plane (b) 2.65GHz and 7.65 GHz H-Plane

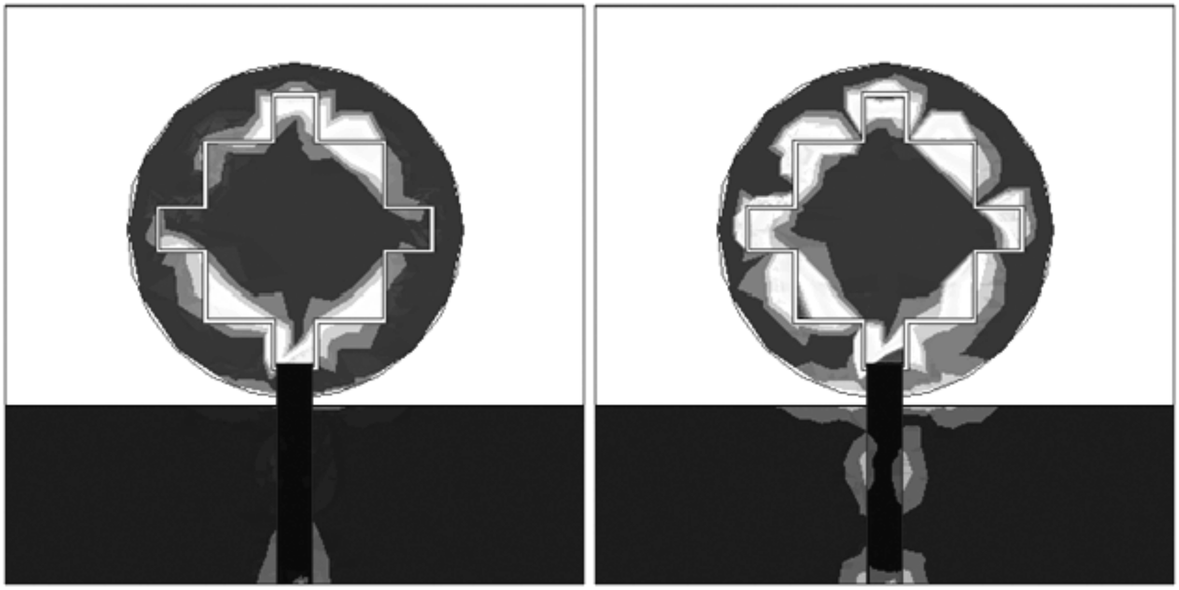


(a) **(b)**

Figure 5: (a) 2.31, 3.35, 7.23 GHz E-Plane (b) 2.31, 3.35, 7.23 GHz H-Plane

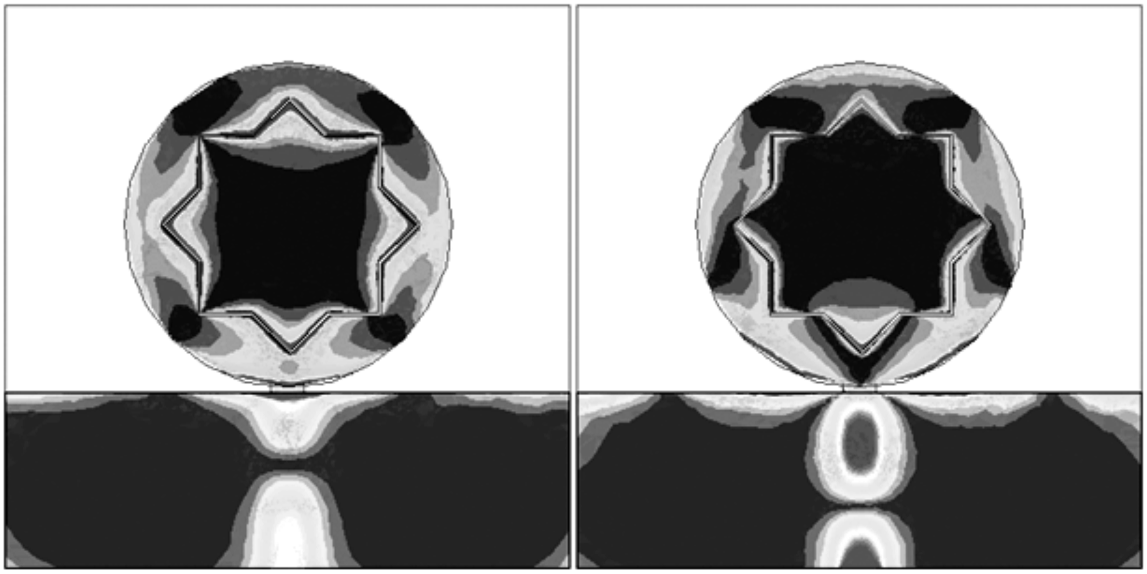
3.4. Field Distributions

Figure 6 and 7 shows the electric field distributions of circular patch antenna with square shaped slot and Koch fractal slot for one resonant frequency and notch frequency. From Figure 6(a) and (b) we can observe that maximum electric field exists at the sqaure shaped slot for resonant frequency 7.65 GHz. But field is moderate at the slot for notch band with center frequency 2.24 GHz. From these two it is clear that the square shaped slot



(a) **(b)**

Figure 6: (a) For notch band at 2.24 GHz (b) Resonant frequency at 7.65 GHz



(a) (b)

Figure 7: (a) For notch band at 5.48 GHz (b) Resonant frequency at 7.23 GHz

is responsible for maximum radiation. So by modifying the slot shape we can achieve our required dual notch characteristics. As fractal antennas provides multi band characteristics, by using one type of fractal geometry dual notch bands are achieved in this paper.

From Figure 7(a) and (b), we can observe that maximum current flows through the koch fractal slot in the notch band. But for the resonant frequency 7.23 GHz the field distributes at edges of the patch and slot.

4. CONCLUSION

A circular patch antenna with reduced ground plane and back feed is designed to provide wide bandwidth and the antenna is covering entire UWB range from 3.1-10 GHz. To avoid interference with the existing services like multipoint distribution service (MMDS) WiMAX (fr-2.8 GHz) communication applications and WLAN (fr-5.5 GHz) whose frequencies lies in the range of 2.73-2.95 GHz and 5.1-5.8 GHz respectively, a Koch fractal geometry has been used. The final antenna design provides a wide bandwidth from 2-11 GHz rejecting the frequencies 2.8 GHz and 5.4 GHz. The return loss, and VSWR values are below -10dB and <2 for the entire range from 2-11 GHz except at frequencies 2.8 GHz and 5.4 GHz there by making the antenna works well for UWB applications.

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