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Miniaturized Ultra Wideband Microstrip Antenna Based on a Modified Koch Snowflake Geometry for Wireless Applications

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Abstract: This paper presents a compact micro-strip patch antenna for ultra wideband (UWB) applications using a Koch Snowflake fractal radiating antenna. The antenna supports two ultra widebands. For the lower band, a good impedance bandwidth of 6.55GHz has been achieved from 3.4892GHz to 10.0392GHz. While the upper band covers 5.4976GHz (from 10.9013GHz to 16.3989GHz). It is fed by a 50Ω micro-strip transmission line with an overall size of 30x27 mm. The simulation was performed by Computer Simulation Technology (CST) MICROWAVE STUDIO software, and compared with High Frequency Structural Simulator (HFSS) software. The results show that the proposed antenna has interesting characteristics for UWB applications.

Keywords: Ultra Wideband Antenna, Fractal Antenna, Koch Snowflake

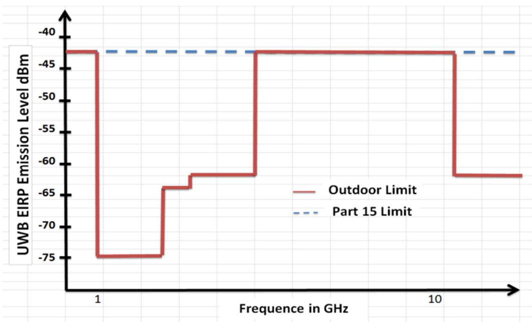
1. Introduction

Antenna became a part of electrical devices in wireless communication systems since 1888. The Ultra Wide Band (UWB) technology opens new doors for wireless communication systems. It plays a dominant role in communication systems since the antenna is a key component for wireless communication systems.

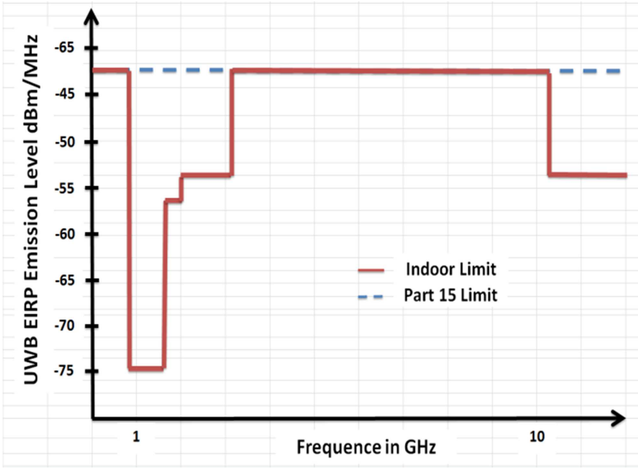
Since the Federal Communications Commission (FCC) allowed [3.1 – 10.6] GHz unlicensed band for UWB applications, many wideband antennas have been proposed [1], [2], [3] and [4]. This technology has become very popular in recent years and attracted more attention due to its advantages such as low consumption, high data rate transmission, immunity to multipath propagation and high degree of reliability, etc. The UWB has found widespread applications in communication systems [1], landmine detection [2], radar systems [3], and biomedical applications such as breast cancer detection [4], [5].

In the United States (US), the operating bandwidths for communications released by FCC reach up to 7 GHz but the FCC has limited the emission levels of UWB signals lower than -41.3dB within the bandwidth as shown in Fig. 1 [6].

In general, the antennas for UWB systems should have sufficiently broad operating bandwidth for impedance matching and high gain radiation in desired directions. The fractal antennas are preferred in UWB technology not only because they are small and light weight or for easy installation, but also because they have an extreme wideband [7], [8], [9]. The Snowflake-Koch is a fractal shape which was constructed by starting with an equilateral triangle. In the first iteration, a triangle with side's one-third unit long is added in the center of each side of the original triangle (Fig. 2-a).



(a)



(b)

Figure 1. *The spectra released by FCC for commercial communications in US: (a) for outdoor communication systems, (b) for Indoor communication systems.*

In the second iteration, a triangle with side's one-ninth unit long is added in the center of each side of the first iteration (Fig. 2-b). Successive iterations continue this process indefinitely.

Figure 2. *The Koch Snowflake antenna: a) First iteration, b) Second iteration.*

In this paper, a high gain microstrip patch antenna based on a modified Koch Snowflake geometry has been presented. The antenna has been created by introducing techniques that broadens the bandwidth. To increase the bandwidth of the patch antenna, there are two methods.

The first one is coupling several resonances between them. The equation (1) shows that when h increases, the bandwidth also increases.

$$BW = 3.77.\frac{\varepsilon_{r-1}}{{\varepsilon_r}^2}.\frac{L.h}{\lambda.w} \quad (1)$$

The second method which is used in this paper is to reduce the quality factor (Q) of a resonance (equation 2). To do so, we can add an inductive (stubs), a capacitive element (slots) or both of them. Also, by adding a lossy element or it can be achieved by a progressive evolution of the impedance between the feed-line and the radiating element.

$$BW = \frac{f_{res}}{Q} \quad (2)$$

With f_{res} the resonant frequency

2. Antenna Design

The geometry of the Koch patch antenna is based on the first iteration Koch Snowflake (Fig. 2-a). This antenna has been designed using a 1.6mm thick FR4 substrate with a relative dielectric $\varepsilon_r = 4.4$, which has a global dimensions of $30\times27\ mm^2$ ($W_{sub} \times L_{sub}$). The dimensions of our proposed antenna according to the Fig. 4 are shown in the table 1. W_f and L_f are the width and length of the feed-line. W_f is calculated using the equations (3), (4) [12], for $_r = 4.4$, h = 1.6mm, and $Z_0 = 50\Omega$.

$$eff = \frac{r+1}{2} + \frac{r-1}{2}.\frac{1}{\sqrt{1+12\frac{h}{w}}} \quad (3)$$

$$Z_0 = \frac{120\pi}{\sqrt{\varepsilon_{eff}}*\left[\frac{w}{h}+1.393+0.667\ln\left(\frac{w}{h}+1.444\right)\right]} \quad (4)$$

Table 1. *Optimized antenna parameters.*

Dimensions	W_{sub}	L_{sub}	L_f	W_f	L_1
Value (mm)	30	27	11.6	3	2.7
Dimensions	L_g	W_s	L_s	B	W
Value (mm)	11	1.2	1	18	3.59

Fig. 3 depicts the steps used to develop the antenna, by introducing techniques that broadens the bandwidth mentioned in the first section, namely:

1. Create a Fractal Koch Snowflake antenna (first iteration) fed by a micro-strip line with a total ground plane (Ant. 0)
2. Add a rectangular element between fed-line and radiation element (progressive evolution of the impedance between the feed-line and the radiating element) (Ant. 1).
3. Embed a slot element (Ant. 2).
4. Remove a top triangle of the fractal antenna (Ant. 3).

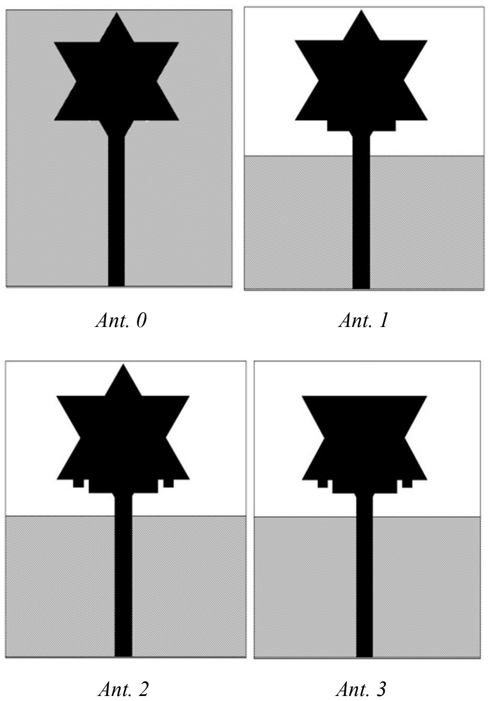


Figure 3. *Steps required in the implementation of the proposed antenna.*

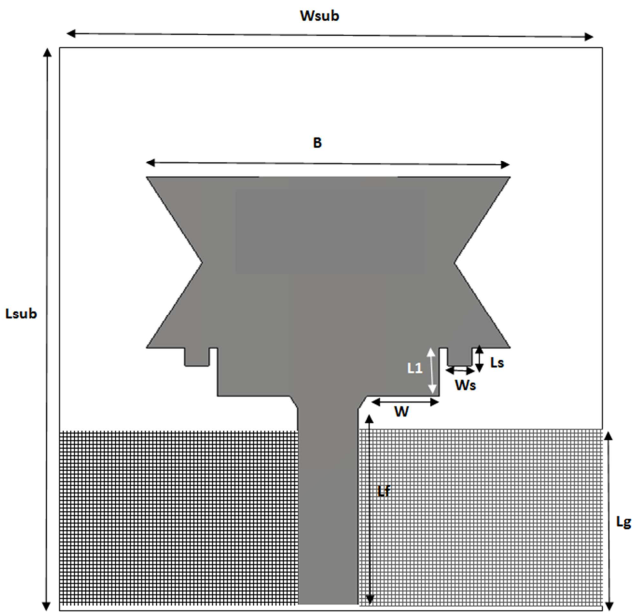


Figure 4. *Geometry and dimensions of the proposed antenna.*

3. Results and Discussion

The antenna design simulation is done using the time domain analysis tools from Computer Simulation Technology (CST) Microwave Studio which provides wide range of time domain signal that are used in UWB system. The numerical analysis of the software tools are based on the Finite Difference Time Domain (FDTD) [13]. For comparison purpose, High Frequency Structural Simulator (HFSS) in frequency domain since the numerical analysis is based on the Finite Element Method (FEM) [14] is performed.

Fig. 5 illustrates the simulated results of the return loss for the proposed antenna with the optimized parameters as listed in table 1. We note that at 10dB, the antenna supports two ultra widebands. In the first band, a good impedance bandwidth of 6.55GHz is covered (3.4892 to 10.0392GHz), while the second band covers 5.4976GHz (from 10.9013 to 16.3989 GHz).

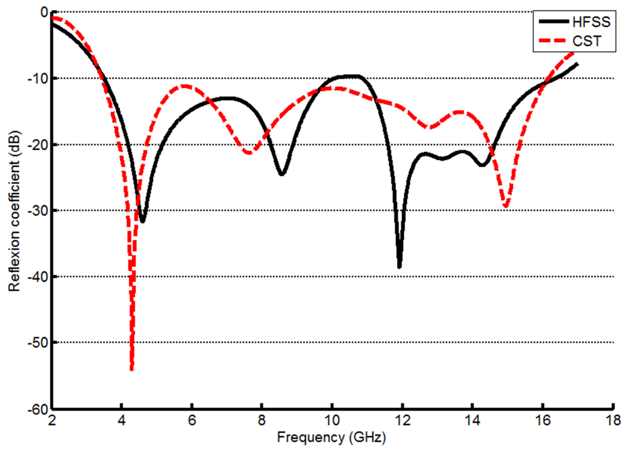


Figure 5. *Simulated reflexion coefficient for the proposed antenna.*

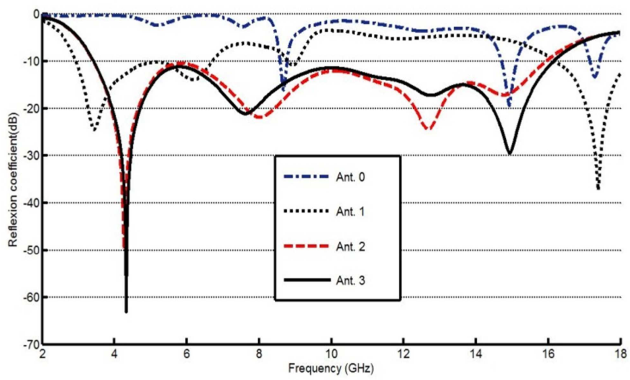
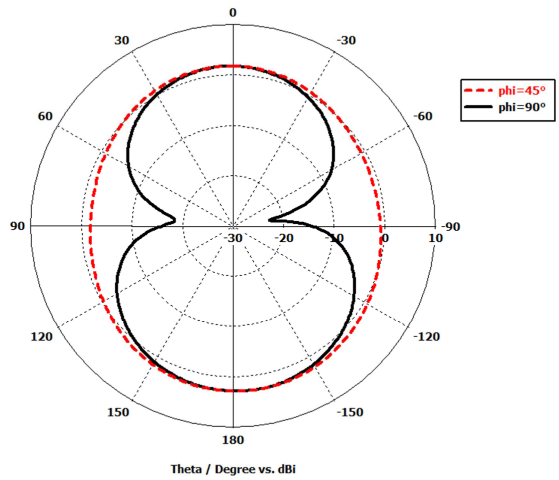
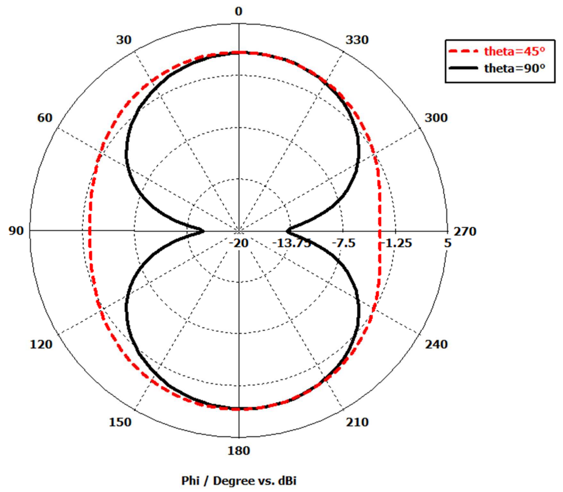


Figure 6. *Simulated reflexion coefficient for Ant. 0, Ant. 1, Ant. 2, and Ant. 3.*

Parametric study of each element added to the original antenna (Ant. 0) is presented in Fig. 6. As shown in this figure, the addition of the rectangle element which allows an adaptation of the impedance between radiation element and feed-line, the partial ground plane and slots in rectangle element allows increasing the bandwidth.

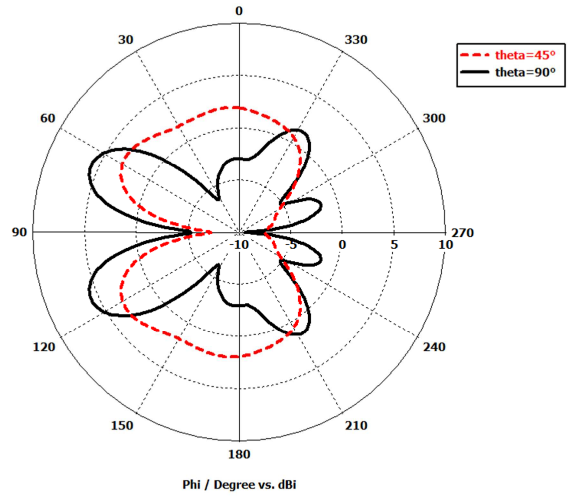


(a)



(b)

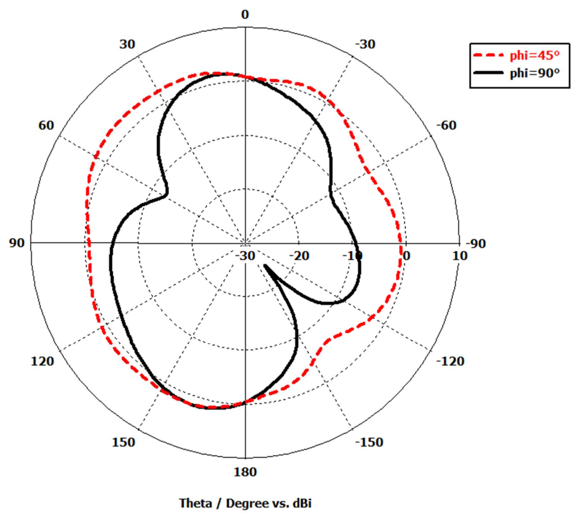
Figure 7. *Radiation patterns of the proposed UWB antenna (a): E-plane ,(b): H-plane @ 3.6 GHz.*



(b)

Figure 8. *Radiation patterns of the proposed UWB antenna (a): E-plane ,(b): H-plane @ 12.2 GHz.*

Antenna radiation pattern gives the radiation properties on an antenna as a function of space coordinate. For linearly polarized antenna, performance is often described in terms of the E-plane (xy-plane) and H-plane (yz-plane) patterns [11]. Fig. 7 shows the two simulated dimensional E and H planes at 3.6 GHz then Fig. 8 presents the E-plane and H-plane at 12.2 GHz.



(a)

We can see that the antenna has nearly good omnidirectional radiation patterns at all frequencies in the E and H-planes. This pattern is suitable for applications in most wireless communication equipment. Excepted, the antenna exhibits directional orientation in H-plane at 12.2GHz.

The simulation group delay and Gain of the proposed antenna is shown in Fig. 9. Group delay is an important parameter in the design of the UWB antenna since it gives the distortion of the transmitted pulses in the UWB communications. For good pulse transmission, the group delay should be almost constant in the UWB [10].

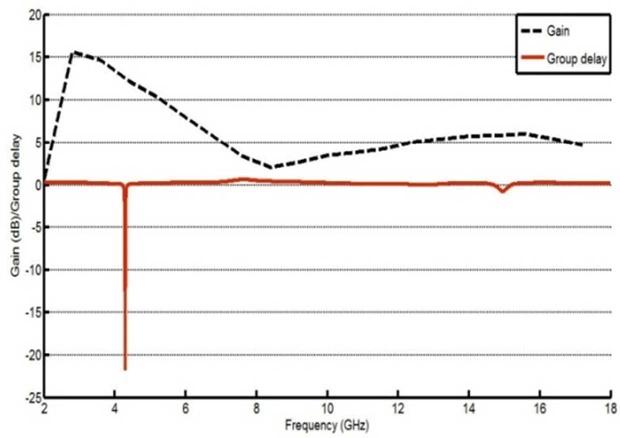


Figure 9. *Group delay and Gain for the proposed antenna.*

As it can be seen, the variation of the group delay for the proposed antenna is almost constant for the entire UWB, except for a sharp change in the first band at 4.3GHz. This confirms that the proposed UWB antenna is suitable for UWB communications.

Gain of over 2dBi over the whole frequency band has been obtained. The value of gain is greater than 5dBi in the frequency range of 3GHz- 7GHz and 12.4Ghz-16GHz which is sufficient for use in most UWB applications such as in

Ground Penetrating Radars (GPR) and in Breast Cancer detection [3], [5].

4. Conclusion & Future Work

In this paper, a simple and compact UWB antenna, based on the Koch Snowflake geometry is proposed. The antenna supports two ultra widebands, the first band (3GHz -9.43GHz) a good impedance bandwidth of 6.43GHz has been achieved. While the second band covers 5GHz from 10.9GHz to 16GHz. The simulated results of the proposed antenna, using the CST Microwave Studio and HFSS tools, present a constant group delay and an omnidirectional radiation patterns. These results make this antenna a good candidate for UWB applications and systems such as WiMAX II [3.4-3.6] GHz, IEEE 802.11y [3.65-3.7] GHz and WLAN [5.15-5.35] GHz.

To complete this work, the realization of the proposed antenna should be done to compare the measured and simulated results. This work will be also completed by associating the proposed antenna in an antenna array to improve the gain.

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