Design of the Tree-Shaped UWB Antenna Using Fractal Concept

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***Abstract* —In this paper, we have proposed a novel tree-shaped ultra-wideband antenna for UWB applications. We have used the partial ground plane technique and the fractal concept to achieve an ultra-wideband impedance matching. It is found that as the number of iteration increases, the lower-edge of the impedance bandwidth is moved to the low frequency and the level of the impedance matching over the operating frequency band(3.1~4.8 GHz) is improved. Prototypes of the proposed antennas have been successfully implemented and good radiation characteristics in the operating frequency bands have been achieved. The effect of the angle between upper and lower trapezoids on the return loss was also studied.**

***Index Terms* — UWB antenna, MB-OFDM, DS-CDMA, fractal antenna, partial ground plane, tree-shaped**

I. INTRODUCTION

UWB technology has attracted much attention for use in short-range high-speed wireless communication applications. UWB has allocated 7.5GHz of spectrum for unlicensed use by the FCC in February 2002 for communication applications in the 3.1 to 10.6 GHz frequency band. There are two main approaches as a solution for the IEEE 802.15.3a standard: MB-OFDM (Multi-Band Orthogonal Frequency Division Multiplexing) and DS-CDMA (Direct-Sequence Code Division Multiple Access). The DS-DCMA approach uses three spectral modes of operation, low band (3.1 to 5.15 GHz), high band (5.825 to 10.6 GHz), and multi-band (low band plus high band). MB-OFDM approach divides its full band 3.1 to 10.6 GHz into 14 sub-bands with each bandwidth of 528 MHz. Each sub-band consists of 128 tones and is modulated with OFDM. The MB-OFDM approach uses lower three bands (3.1 to 4.8 GHz) as a mandatory mode [1]. In this paper, we will focus on the UWB antenna design in the MB-OFDM system over 3.1~4.8 GHz. The UWB antenna for use in portable systems requires an omni-directional radiation pattern, ultra-wideband, small size, flat gain and linear phase, and low-cost.

In fractal electrodynamics, fractal geometry is used to investigate a new class of radiation, propagation, and scattering problems. One of the promising researches is antenna theory and design using the fractal concept [2]. Recently, various UWB fractal antennas have been developed for UWB applications [3]-[6]. In [3], Crown-Sierpinski microstrip antenna is proposed to reduce the size of a Crown square fractal. The frequency notched ultra-wideband microstrip slot antenna with a fractal tuning stub is proposed to achieve frequency notched function [4]-[5]. Ding et al [6] have proposed a new UWB fractal antenna by adopting the fractal concept on the CPW-fed circular UWB antenna.

In this paper, we present the promising fractal tree-shaped antennas for the UWB applications in the MB-OFDM system over 3.1~4.8 GHz. To achieve ultra-wideband operation with omni-directional radiation patterns, we have used the partial ground plane technique [7] and the fractal concept. Prototypes of the proposed antennas have been successfully implemented and good radiation characteristics in the operating frequency bands have been achieved. The effect of the angle between upper and lower trapezoids on the return loss was also studied. The performance of the proposed antenna is characterized with Ansoft's High Frequency Structure Simulator (HFSS) [8].

II. ANTENNA DESIGN AND SIMULATED/MEASURED RESULTS

Three antenna structures of the rectangular tree-shaped UWB antenna are shown in Figure 1: the original structure (K0), the first order iteration (K1), and the second order iteration (K2). Figure 1(d) is the bottom view of the above antennas. Another antenna structure of the trapezoidal tree-shaped UWB antenna is shown in Figure 2.

The above proposed antennas are etched on the partial ground plane of a FR-4 substrate (thickness h = 0.8 mm and relative permittivity ε_r = 4.4) and the substrate has the dimensions of $L_{sub}\times W_{sub}$. The dimension of the partial ground plane is $L_g\times W_{sub}$. The antenna is excited using 50 • microstrip feed line. The distance between the partial ground plane and the first patch ($L_{p1}\times W_{p1}$) is G. In Figure 2, the angles between upper and lower trapezoids are $_1$, $_2$, and $_3$, respectively. Figure 3 shows the photograph of the fabricated antennas. The design parameters for Figure 2 are W_{sub} = 20 mm, L_{sub} = 30 mm, W_{p1} = 16 mm, L_{p1} = 8 mm, W_{p2} = 12 mm, L_{p2} = 6 mm, W_{p3} = 8 mm, L_{p3} = 4 mm, G = 2.5 mm, L_g = 7 mm, $_1$ = 60°, $_2$ = 64°, and $_3$ = 68° based on the extensive simulation using HFSS. In the case of $_1$ = $_2$ = $_3$ = 90°, the trapezoidal tree-shaped antenna of Figure 2 corresponds to the rectangular tree-shaped antenna of Figure 1.

The proposed antenna was constructed and studied. The return loss (S_{11}) of the proposed antenna was measured using an Agilent Vector Network Analyzer (85107B) in an anechoic chamber and shown in Figure 4. Figure 4 also shows the simulated results for comparison and indicates a reasonable agreement between them. The impedance bandwidths of the proposed antenna for $|S_{11}|$ < -10 dB are 75.5 % (2.8 ~ 6.2 GHz) and 81.3 % (2.7 ~ 6.4 GHz), respectively. Figure 5 shows the

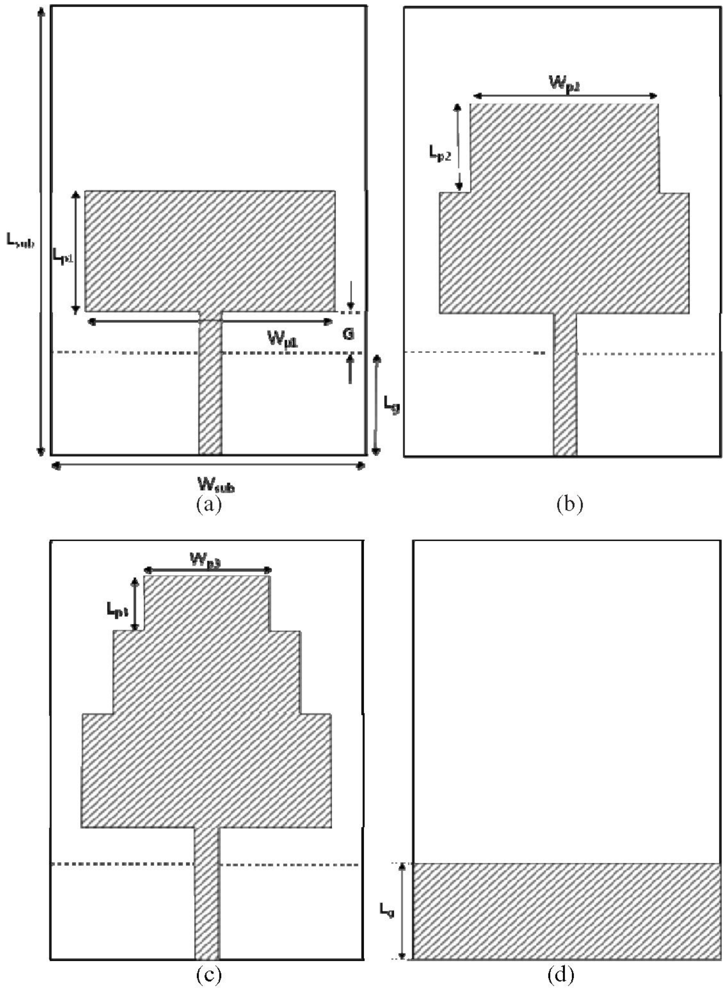

Fig. 1. Geometry of the rectangular tree-shaped antenna: (a) the original structure (K0) (b) the first order iteration (K1) (c) the second order iteration (K2) (d) the bottom view

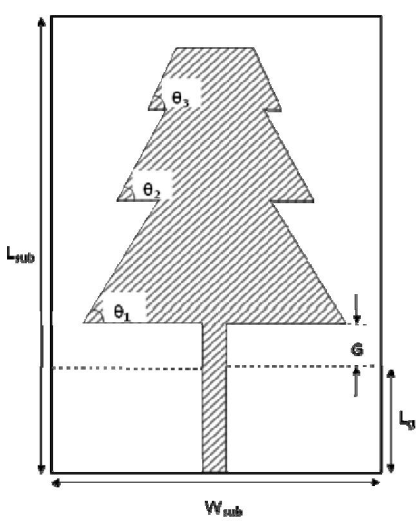

Fig. 2. Geometry of the trapezoidal tree-shaped antenna

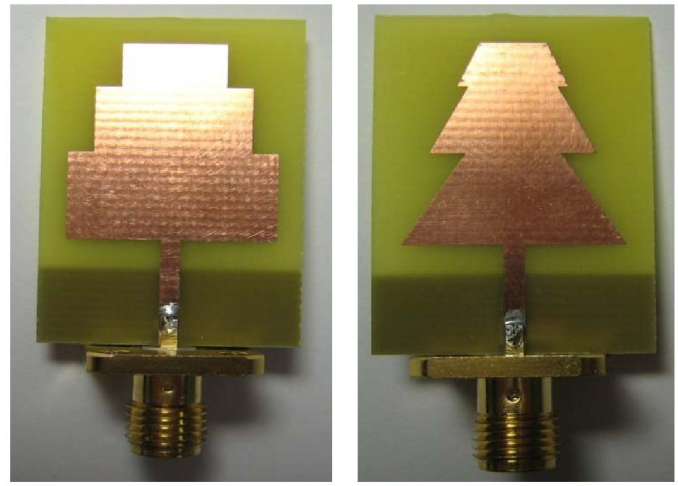

Fig. 3. Photograph of the fabricated antennas

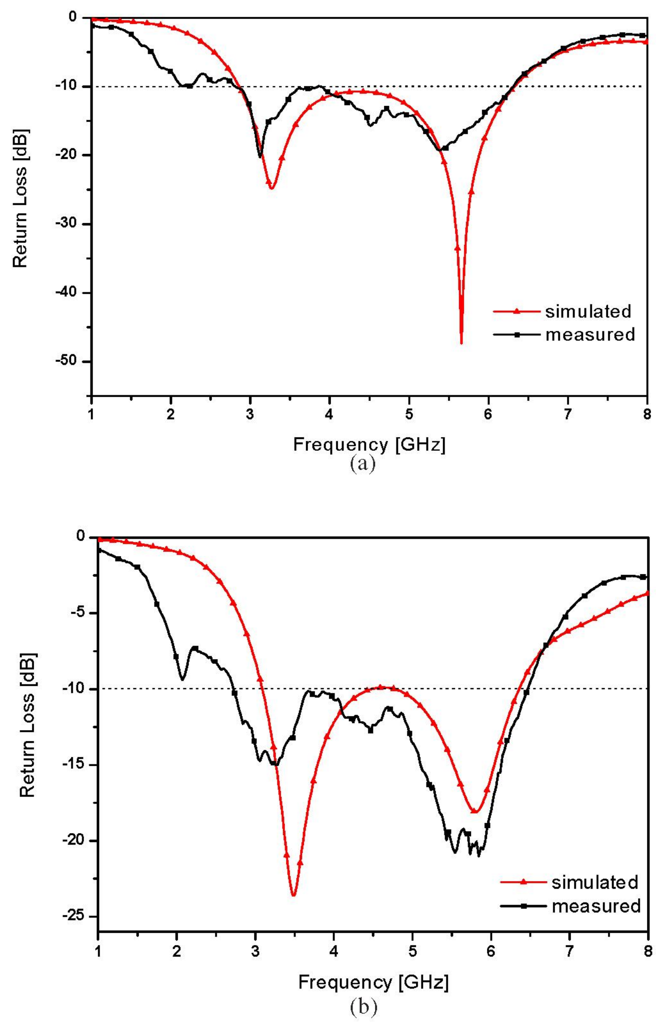

Fig. 4. Simulated and measured results of |S11| versus frequency: (a) rectangular tree-shaped antenna (b) trapezoidal tree-shaped antenna

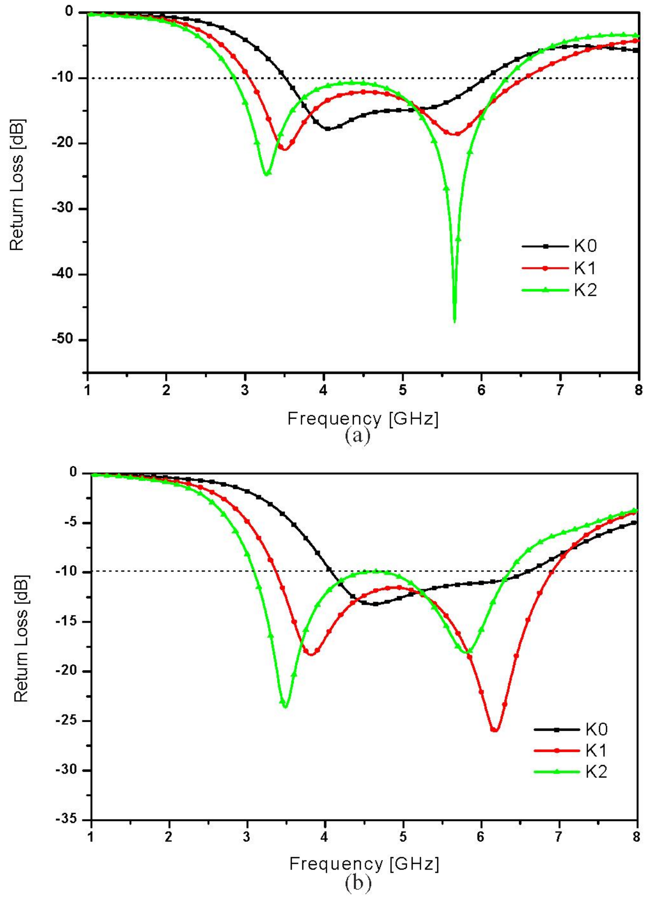

Fig. 5. Simulated results of |S11| versus frequency as a function of the iteration: (a) rectangular tree-shaped antenna (b) trapezoidal tree-shaped antenna

simulated results of |S11| versus frequency as a function of the iteration for the proposed antennas. As shown in the figure, as the number of iteration increases, the lower-edge of the impedance bandwidth is moved to the low frequency and the level of the impedance matching over the operating frequency band (3.1~4.8 GHz) is improved.

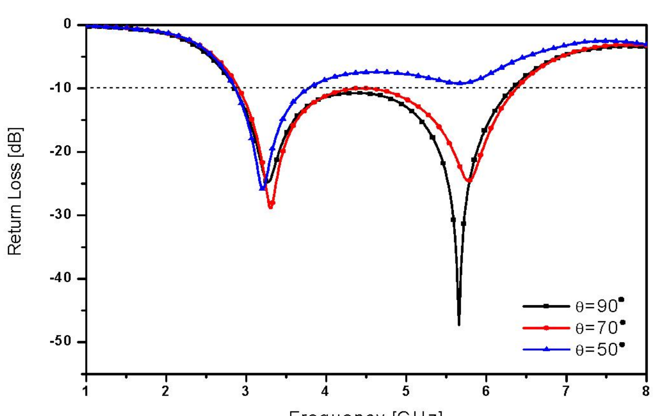

Fig. 6. Simulated results of |S11| versus frequency for the angle between upper and lower trapezoids (= 1 = 2 = 3)

Figure 6 shows the simulated results of |S11| versus frequency for the angle between upper and lower trapezoids. As the increases, the return loss decreases and thus leading a good impedance matching.

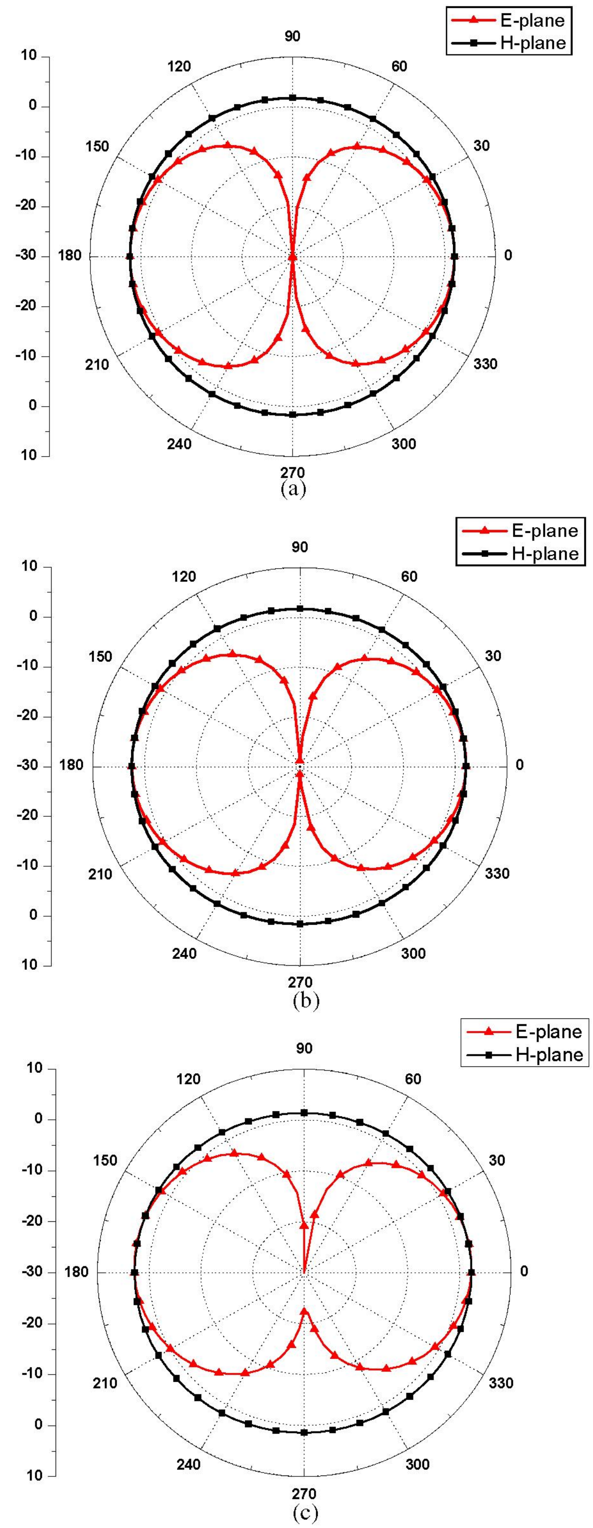

Fig. 7. Simulated radiation patterns for the rectangular tree-shaped antenna at (a) 3 GHz (b) 4 GHz (c) 5 GHz

Figure 7 shows the simulated radiation patterns at 3, 4, and 5 GHz for the rectangular tree-shaped antenna. The obtained radiation patterns are very close to those of the conventional dipole antenna and the shape of the patterns are almost unchanged over the operating frequency band, which is a good feature for the UWB antenna. Within the operating frequency bands, the simulated antenna gain for the rectangular tree-shaped antenna is 2 to 2.7 dBi and presented in Figure 8.

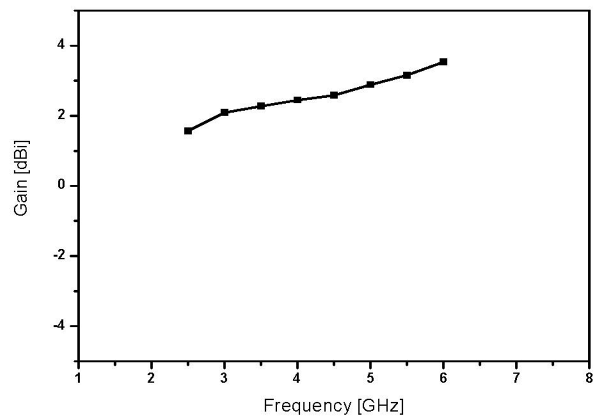

Fig. 8. Simulated antenna gain for the rectangular tree-shaped antenna

III. Conclusion

A novel tree-shaped ultra-wideband antenna using a partial ground plane technique and a fractal concept has been proposed for UWB system. By adjusting the angles (1, 2, 3) and the distance G, the proposed antenna can be achieved a wide operating bandwidth with good impedance matching. Good radiation characteristics of dipole-like pattern and gain (2-2.7 dBi) were obtained over the frequency band and thus indicating that the proposed antenna is a good candidate for UWB applications

Acknowledgement

This work was supported by the Korea Research Foundation Grant funded by the Korean Government (MOEHRD) (KRF-2006-331-D00428) and the second stage of BK21.

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