slots and the crossed dog-bone slot should also be controlled in terms of rotational symmetry in the future.

VI. Conclusion

A rectangular-to-radial waveguide transformer through a crossed dog-bone slot was proposed as a feeder of a CA-RLSA. The transformer was analyzed and designed by using the MoM with numerical eigenmode basis functions. Crossed dog-bone slots have the potential to obtain amplitude ripple below 1.0 dB in the ϕ direction because of the wide beam width of dog-bone slots.

By using the crossed dog-bone slot, the measured amplitude ripple in the ϕ direction are 0.8 dB, which is 1.4 dB lower than that of crossed straight slot in the 5.8 GHz band.

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Planar Binomial Curved Monopole Antennas for Ultrawideband Communication

Ching-Wei Ling, Wen-Hsin Lo, Ran-Hong Yan, and Shyh-Jong Chung

***Abstract*—The curve of a planar antenna edge is an important parameter which affects the antenna performances. In this study, we propose a new edge curve, characterized by the binomial function, for designing ultrawideband antenna. The effect on the impedance bandwidth through the change with the different order of the binomial function and the gap width between the antenna and ground plane has been investigated and analyzed. The measurement result shows a good agreement with the simulation. Besides, the radiation patterns are omnidirectional in the H plane across the operating bandwidths.**

***Index Terms*—Binomial functions, monopole antennas, planar antennas, ultrawideband (UWB).**

I. Introduction

THE antenna is a key component of ultrawideband (UWB) systems. According to the regulations released by Federal Communications Commission (FCC), the UWB systems for indoor communications have been allocated to the frequency band of 3.1 to 10.6 GHz [1] for the merits of high transmission rate, high capacity, and low power consumption. Therefore, more and more researchers invest in developing UWB antennas which satisfy the regulations.

The wideband planar monopole antenna is one of UWB antennas that have attracted a lot of attention because it is simple in geometry, easy for manufacture and integration, low-cost, and exhibits a good impedance matching in addition to have stable radiation patterns over the bandwidths. There are many related studies to the type of antenna having been available in the open literature and most researches focus on the planar design antenna such as half-disc [2], [3], circular [4], rectangular [5], elliptical [6], hexagonal [7], and others [8], [9], which provide the possible shapes of antennas suitable for UWB application. But there are only little references concerned to the edge curve affecting the antenna characteristics.

In this study, we present a new method to construct the edge curve of the antenna and analyze parametric effects on the impedance bandwidth. Formulating the curves of the antenna edge by a binomial function, the impedance bandwidths of the proposed antenna can significantly be improved if the parameters of the binomial function are properly selected. The proposed antenna has the properties of compact size, easy fabrication, and omnidirectional radiation pattern in the H plane.

II. Antenna Configuration

Fig. 1 illustrates the geometry of the investigated antenna. This antenna is printed on a FR4 microwave substrate with the thickness of 0.8 mm and the dielectric constant of 4.4. The areas of the monopole

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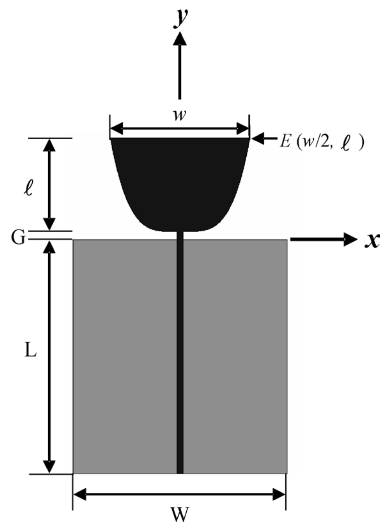

Fig. 1. Geometry of the planar binomial curved monopole antenna.

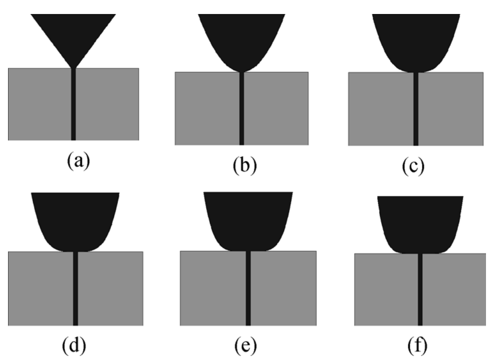

Fig. 2. Antenna forms for $G = 0$ mm with different order N. (a) $N = 1$, (b) $N = 2$, (c) $N = 3$, (d) $N = 4$, (e) $N = 5$, (f) $N = 6$.

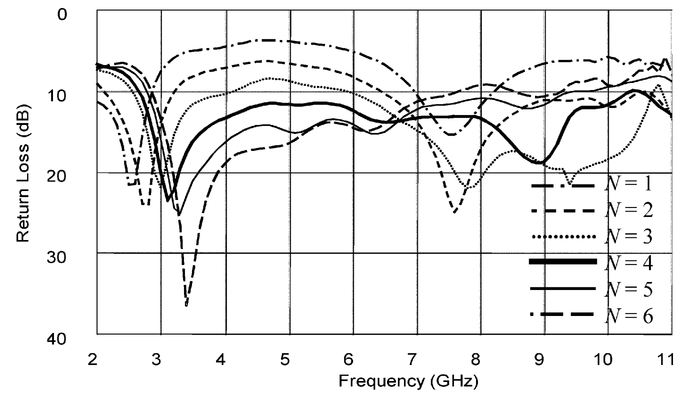

Fig. 3. Simulated return losses for proposed antenna with different order N, $w = 30$ mm, $\ell = 20$ mm, $W = 46$ mm, $L = 50$ mm, and $G = 0.45$ mm.

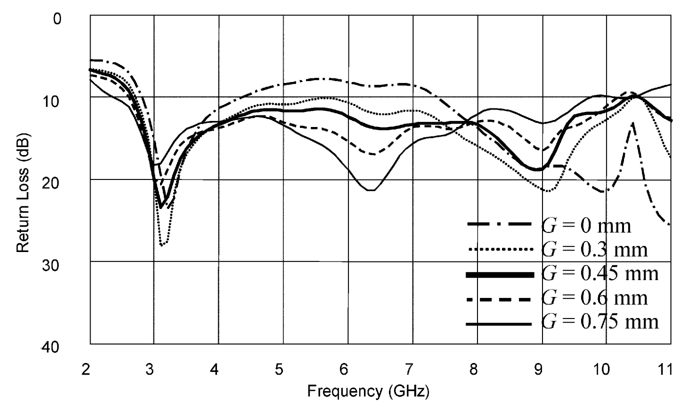

Fig. 4. Simulated return losses for proposed antenna with different gap width G, $w = 30$ mm, $\ell = 20$ mm, $W = 46$ mm, $L = 50$ mm, and $N = 4$.

antenna and the ground plane are denoted as $w \times \ell$ and $W \times L$, respectively. A 50 Ω microstrip feed line of 1.5 mm width is etched on the same side of the monopole. The gap width between the monopole antenna and the ground plane is G. Hence, the whole substrate size of the antenna is $W \times (\ell + G + L)$.

The curve of a planar antenna edge is an important parameter which affects the antenna characteristics. The parametric effects on the impedance bandwidth of the proposed antenna are analyzed by utilizing a binomial function. The function includes parameters of the length ℓ and width w of the antenna, the gap width G between the antenna and the ground plane, and the order N of the binomial function, which is expressed as follows:

$$y = f(x) = G + \ell \left(\frac{x}{\frac{w}{2}} \right)^N, \ 0 \le x \le \frac{w}{2} \tag{1}$$

where (x, y) is the coordinate of the curved boundary. In this study, the vertex point $E(w/2, \ell)$ is fixed, with $w = 30$ mm and $\ell = 20$ mm. By selecting the different order N and the gap width G, we can obtain the half shape of the antenna and then mirror along with y axis to obtain the whole antenna configuration.

The antenna shape is like a triangle with $N = 1$ as shown in Fig. 2(a). When N approaches infinite, the shape of the antenna looks like a rectangle. Fig. 2 shows the antenna configurations for $G = 0$ mm with different order N from 1 to 6.

III. Parametric Analysis

In this section, the effects with respect to parameters N and G of the binomial function on impedance bandwidth are discussed. The simulation results shown below are tackled by using the commercial 3-D full-wave electromagnetic (EM) simulation software package, Ansoft High Frequency Structure Simulator (HFSS) [10].

Fig. 3 shows the simulated return losses of the proposed antenna for $G = 0.45$ mm with different binomial order N. The relationship between the order N and return loss is not obvious, but by selecting the order N properly, it can be observed that the proposed antenna can cover the frequency band 2.65–10.4 GHz for the case of $N = 4$.

Furthermore, it should also be noted that the gap width G between the antenna and the ground plane has important effect on the impedance bandwidth of the proposed antenna as shown in Fig. 4. When $N = 4$, the impedance bandwidth of the proposed design can further be improved by selecting G. The bandwidth increases if $G > 0.3$ mm. In particular, the widest 10 dB return-loss bandwidth, from 2.7 GHz to more than 11 GHz, occurs when $G = 0.45$ mm and $N = 4$.

The simulated current distributions for the proposed antenna at the frequencies 3, 5, and 8 GHz are shown in Fig. 5. At 3 GHz, the current is mainly distributed over the monopole and the upper edge of ground plane, which is similar to the current of a printed resonant monopole. At 8 GHz, the current is mainly distributed around the gap between the monopole and the ground, therefore, its behavior acts like a slot antenna. By comparing with Fig. 4, it is clear that, the effect of the high-

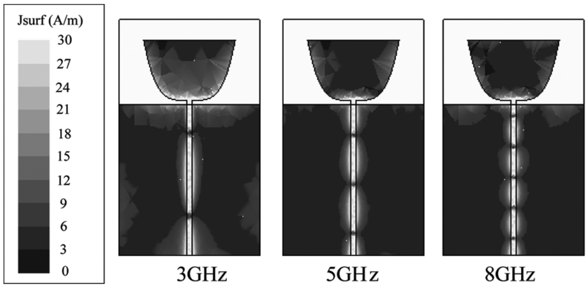

Fig. 5. Simulated current distributions for the proposed antenna with $w = 30$ mm, $\ell = 20$ mm, $W = 46$ mm, $L = 50$ mm, $G = 0.45$ mm, and $N = 4$.

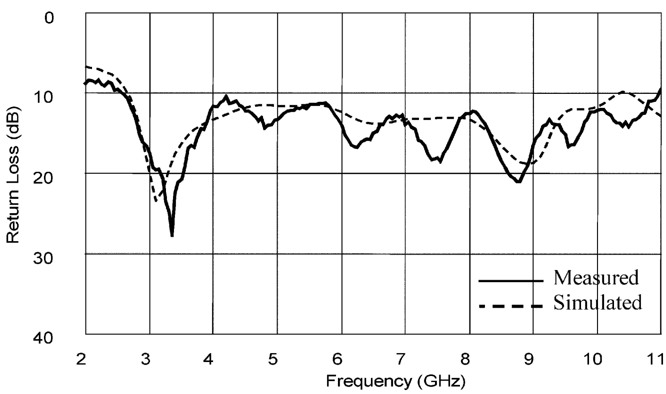

Fig. 6. Measured and simulated return losses for proposed antenna with $w = 30$ mm, $\ell = 20$ mm, $W = 46$ mm, $L = 50$ mm, $G = 0.45$ mm, and $N = 4$.

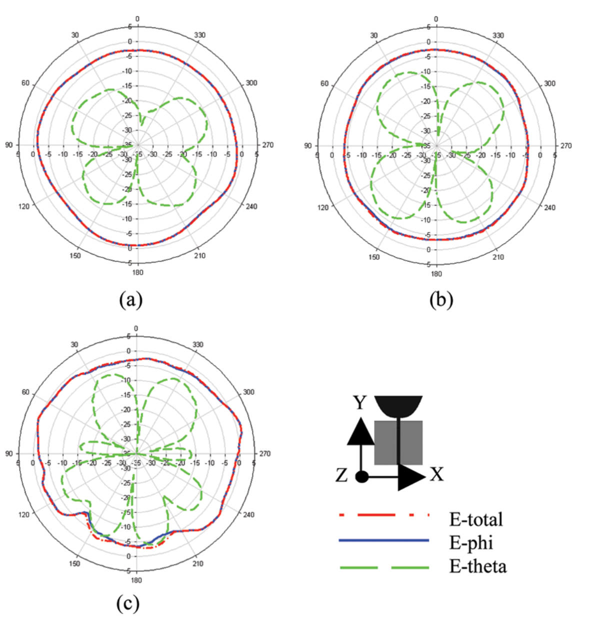

Fig. 7. Measured x-z plane radiation patterns at (a) 3.1 GHz, (b) 5.0 GHz and (c) 8.0 GHz for the proposed antenna with $w = 30$ mm, $\ell = 20$ mm, $W = 46$ mm, $L = 50$ mm, $G = 0.45$ mm, and $N = 4$.

frequency performance through the change with different gap width G is more remarkable than that of the low-frequency.

IV. Experiment Results

Fig. 6 shows the measured return loss of the proposed antenna for $N = 4$ and $G = 0.45$ mm. The simulation results are also shown for comparison. A good agreement between the measurement and the simulation results is obtained. The measured impedance bandwidth, determined by a 10 dB return loss, is from 2.59 to 10.97 GHz.

The measured radiation patterns of the proposed antenna at the frequencies 3.1, 5.0, and 8.0 GHz in x-z plane are shown in Fig. 7(a)–(c), respectively. The radiation pattern is omnidirectional and quite stable over the whole frequency band. The measured peak (average) gains for the frequencies of 3.1, 5.0, and 8.0 GHz are, respectively, −0.88 dBi (−3.65 dBi), −2.36 dBi (−4.51 dBi), and 1.54 dBi (−2.1 dBi).

V. Conclusion

The planar binomial curved monopole antenna has been proposed and investigated. The antenna has a simple structure and can be designed by utilizing only few parameters. The experiment results show that the impedance bandwidth of the proposed antenna can significantly be improved by selecting the suitable binomial order N and the gap width G. Also show that a wide impedance bandwidth has been obtained, which makes the proposed antenna suitable for UWB (3.1–10.6 GHz) applications. A stable omnidirectional radiation pattern was also obtained for the whole impedance bandwidth.

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