Bandwidth Characteristics and Downsizing Limitation of Power Function Shaped Bow-tie Antennas with Triangle Hats

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Abstract

This paper proposes the power function shaped bow-tie antennas for UWB system. The antennas are designed under the condition of finite dimension and improved by adding some triangle hats. By studying on the parameters of the proposed antennas, the bandwidth characteristics and downsizing limitation characteristics are clarified. The proposed antennas can achieve the highest relative bandwidth at 170%, and the lowest value of f_l/f_0 at 0.49, respectively.

Keywords : Bow-tie Antenna Bandwidth Characteristics Downsizing UWB

1. Introduction

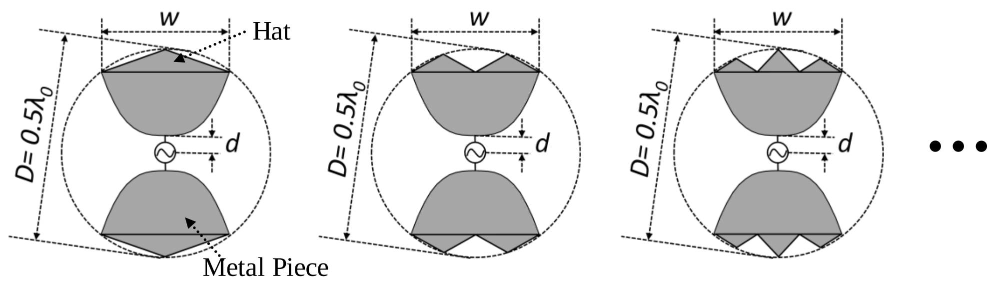
Wireless communication systems have grown up quickly and developed widely, especially the UWB (Ultra Wideband) and WiMAX (World Interoperability for Microwave Access) have become more and more popular in wireless communication systems. The UWB technology is a fast emerging technology with uniquely attractive features inviting major advances in wireless communication system, networking, radar, positioning systems and so on [1][2]. The UWB technology has been attracted much attention in recent years. In such a high-speed communication system, low-profile and wideband antennas are required [3]. Recently, some kinds of bow-tie antennas have been proved having UWB characteristics. Because of the simple-designed structures and the low cost of the bow-tie antennas, they have been applied for a practical use [4].

This paper describes the characteristics of relative bandwidth and downsizing limitation of power function shaped bow-tie antenna with triangle hats. Furthermore, the antenna is designed under the condition of finite dimension. In order to clarify the limitation of the relative bandwidth of power function shaped bow-tie antenna, the effects of antenna parameters are simulated. Antenna parameters include the shape of metal pieces, the distance between the feed point and the metal piece, and the triangle numbers of one hat. Finally, the relationship between the normalized lowest frequency and the relative bandwidth are compared.

2. Analysis Models and Evaluation

The analysis models of the power function shaped bow-tie antennas and antenna parameters are shown in Fig. 1 [5]. The antenna consists of two power function metal pieces and is improved by adding hats composed of several isosceles triangles. Antennas are limited in a finite area, actually the finite area is a circle with diameter (D) of $0.5\lambda_0$ (λ_0 is the wavelength of the design frequency f_0). The shape of the metal piece is determined by function $y = \left|ax^m/(w/2)^{(m-1)}\right| + d$ and $(w/2)^2 + \left((aw/2) + d\right)^2 = (D/2)^2$; here a serves as a simple scaling factor, m is called the power and the element width is w. Another parameter is the distance between the feed point and the metal piece (d). These isosceles triangles with equal bottom edge share the element width and their vertexes are fixed on the limited circle. Characteristics of the relative bandwidth and the normalized lowest frequency of the antennas are calculated by using the moment method (EEM-MOM).

The characteristics of the proposed bow-tie antenna are evaluated by the relative bandwidth (RBW) and the normalized lowest frequency (f_l/f_0) of the frequency band within 2.0 for VSWR (Voltage Standing Wave Ratio) [6].



$y = \left|ax^m/(w/2)^{(m-1)}\right| + d$

(a) Triangle no. of a hat=1 (b) Triangle no. of a hat=2 (c) Triangle no. of a hat =3 …

Figure 1: Analysis models of power function shaped bow-tie antennas

For an antenna, the frequency bandwidth is from f_l (the lowest frequency) to f_h (the highest frequency) on condition of VSWR≤ 2.0. Furthermore, f_h, f_l and the relative bandwidth (RBW) of the frequency band are related to each other as shown in the following equation (1). For a UWB system, the frequency bandwidth is covered from 3.1GHz to 10.6 GHz and the relative bandwidth is at least 110%. The normalized lowest frequency is evaluated by f_l/f_0 in equation (2), C is the speed of the light. The normalized lowest frequency for an antenna can be evaluated by f_l/f_0 because the size of the antenna is determined by the normalized lowest frequency. When the ratio of the normalized lowest frequency is less than 1, that means the antenna is downsized.

$$\mathrm{RBW} = \frac{(f_\mathrm{h}-f_\mathrm{l})}{(f_\mathrm{h}+f_\mathrm{l})/2} \times 100\% \quad (1)$$

$$f_0 = \frac{\mathrm{C}}{\lambda_0} = \frac{\mathrm{C}}{2D} \quad (2)$$

3. Bandwidth Characteristics

The effects of antenna parameters on the bandwidth characteristics are simulated. Antenna parameters include the shape of metal pieces, the distance between the feed point and the metal piece, and the triangle numbers of one hat.

3.1 Effects of the Shape of the Metal Piece

The effects of the shape of the metal piece on the bandwidth characteristics are studied. Here, the power function shaped bow-tie antenna has one triangle of one hat on each metal piece, the distance between the feed point and the metal piece *d* is $0.004\lambda_0$ and the characteristic impedance is 75Ω. As mentioned in Sec. 2, the shape of the metal piece is determined by equation $y = \left|ax^m/(w/2)^{(m-1)}\right| + d$.When parameters *m* and *a* change, the shapes of the metal piece are different. Figure 2 shows the relationship between antenna parameters *m*, *a* and the relative bandwidth.

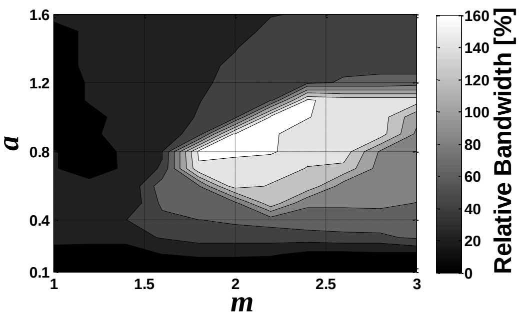


Figure 2: Relationship between antenna parameter *m*, *a* and the relative bandwidth

Figure 2 indicates that when using different parameter *m* and *a*, the antennas show different bandwidth characteristics. It can be seen that the relative bandwidth of the antennas in the bright area can achieve over 110%. The antennas in the bright areas are suit for the UWB system. The best area is the white area where parameter *m* is around 1.8 to 2.2 and parameter *a* is around 0.7 to 1.0.

3.2 **Effects of the Distance between the Feed Point and the Metal Piece**

The influences of the distance between the feed point and the metal piece on bandwidth characteristics are examined. Figure 3 shows the relationship between the antenna parameter *d* and the relative bandwidth. Here, the power function shaped bow-tie antenna has one triangle of one hat on each metal piece, antenna parameters *m* and *a* are 2 and 0.8 respectively, the characteristic impedance is 75Ω. The distance between the feed point and the metal piece *d* is variable.

It is shown in Fig. 3 that the distance between the feed point and the metal piece *d* affects much on the relative bandwidth of the antenna. Although *d* changes little, the antenna could show completely different bandwidth characteristics. When *d* is around $0.003\lambda_0$ to $0.007\lambda_0$, wide bandwidth characteristics are achieved. Furthermore, when *d* is $0.004\lambda_0$ the antenna can reach the highest relative bandwidth of 165%, which is wide enough for a UWB system.

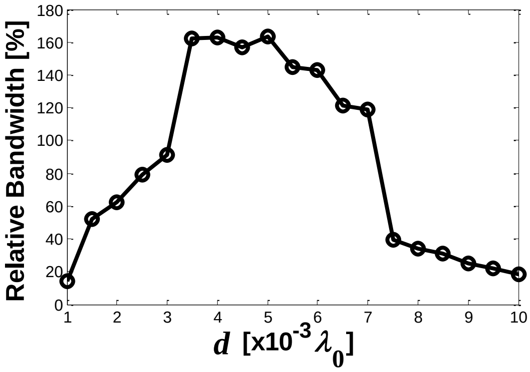


Figure 3: Relationship between antenna parameter *d* and the relative bandwidth

3.3 **Effects of the Triangle Numbers of One Hat**

The effects of the triangle numbers of one hat on bandwidth characteristics are researched. The relationship between triangle numbers of one hat and the relative bandwidth is shown in Fig. 4. Here, antenna parameters *m* and *a* are 2 and 0.8, the distance between the feed point and the metal piece *d* is $0.004\lambda_0$ and the characteristic impedance is 75Ω, respectively. The number of triangles in one hat is changed from 0 to 10.

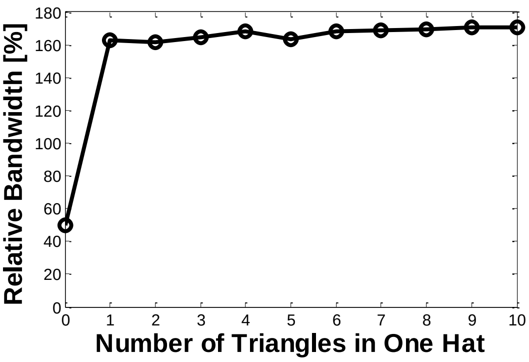


Figure 4: Relationship between triangle numbers of one hat and the relative bandwidth

Figure 4 indicates that the power function shaped bow-tie antennas with triangle hats have much better relative bandwidth characteristics than those antennas without hats. The bow-tie antennas with triangle hats can reach ultra-wide bandwidth characteristics. In addition, the relative bandwidth increases flatly when the triangle number increases. The triangle numbers of one hat make little effect on relative bandwidth.

4. Downsizing Limitation Characteristics

The relationship between the normalized lowest frequency and the relative bandwidth are studied. Simulation results are shown in Fig. 5. Here, the power function shaped bow-tie antenna has ten triangles of one hat on each metal piece, antenna parameter *m* is 2, the distance between the feed point and the metal piece *d* and antenna parameter *a* are variable, the characteristic impedance is 75Ω.

To design a UWB antenna, the relative bandwidth is the higher the better and the normalized lowest frequency is the lower the better. In fact, it is very difficult to obtain these two aspects at the same time. It can be seen in Fig. 5 that majority bow-tie antennas can be downsized, but only several antennas get wide bandwidth and be downsized at the same time. When the distance between the feed point and the metal piece *d* is $0.004\lambda_0$, parameter *a* equals 0.8, as shown in Fig.6 (a), the bow-tie antenna can achieve the highest relative bandwidth at 170% (VSWR≤ 2.0), and its lowest frequency can be downsized to $0.75f_0$ at the same time. When *d* is $0.003\lambda_0$, *a* equals 0.7, as shown in Fig.6 (b), the antenna can achieve the lowest value of f_l/f_0 at 0.49. However, the small-sized antenna only has a relative bandwidth of 17.8%. Although the shapes of the two antennas in Fig. 6 are similar, they perform completely different characteristics.

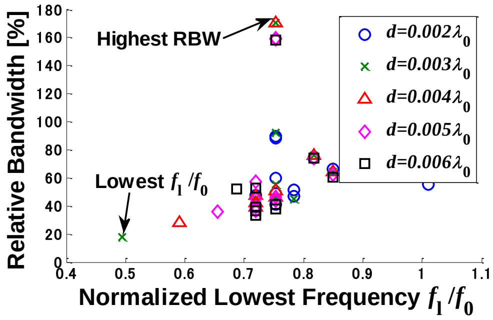
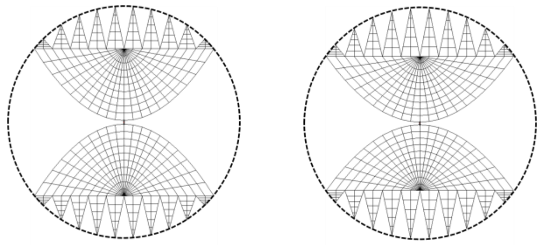


Figure 5: Relationship between the normalized lowest frequency and the relative bandwidth



(a) With highest RBW (b) With lowest f_l/f_0

Figure 6: Best shapes of the proposed antennas

5. Conclusion

In this paper, the wideband characteristics and the downsizing limitation of power function shaped bow-tie antennas with triangle hats were described. To clarify these characteristics and limitations, the effects of antenna parameters on the bandwidth characteristics were studied. Also the relationship between the normalized lowest frequency and the relative bandwidth were compared.

According to the simulation results above, when the antenna parameter *m* was around 1.8 to 2.2, *a* was around 0.7 to 1.0 and the distance between the feed point and the metal piece *d* was around $0.003\lambda_0$ to $0.007\lambda_0$, the antennas had UWB characteristics. The distance between the feed point and the metal piece *d* played the most important role on the wide bandwidth characteristics. On the other hand, the triangle numbers of one hat made little effect on relative bandwidth. When *d* was $0.004\lambda_0$, one of the proposed antennas with ten triangles in one hat got the best characteristics, which had the relative bandwidth and the lowest frequency of 170% and $0.75f_0$ at the same time.

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