

A WIDEBAND ELLIPTICAL BOWTIE IMPULSE ANTENNA

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Abstract—A wideband elliptical bowtie impulse antenna is proposed and investigated in this paper. Simulated results reveal that it can achieve an impedance bandwidth of 141% for $|S_{11}| \leq -10$ dB, a broadside gain of 2.4–5.3 dB, and stable radiation pattern over the whole operating band. The measured reflection coefficient is less than -10 dB over the frequency from 1.30 to 6.65 GHz, and it agrees well with the simulated results. The characteristics of frequency-domain such as radiation pattern, phase center and time-domain behaviors are discussed. The antenna electrical dimension is $0.31\lambda_0$, where λ_0 is the free-space wavelength at lower edge of the operating frequency band. Parameters are studied to optimize the antenna performance.

1. INTRODUCTION

In modern wireless communications, broadband antenna is a crucial component. Several types of broadband antennas, such as reflector antenna, log-periodic antenna, and helical antenna [1], are well researched. Since antenna size is a major constraint for portable wireless communication devices, these antennas have been optimized for minimum size. In many application cases, antennas with wide impedance bandwidth, low profile, and stable radiation pattern are required. Many attempts have been made to widen the bandwidth of these antennas. The operating frequency of the folded antenna is from 1.86 to 5.04 GHz, and the total dimension of the antenna is $1.38\lambda_0$ with $0.43\lambda_0$ of the antenna element [2]. A bow-tie antenna that can achieve an impedance bandwidth (BW) of 165% with electrical length of $0.83\lambda_0$ is reported in [3]. The low frequency band of the proposed antenna

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can reach 1.30 GHz, and the overall dimension is $0.74\lambda_0$. Thus, a large size reduction is achieved.

With regard to antennas radiating in the microwave range, the input signal is a very-short-duration pulse, typically in the picoseconds confines [4]. The frequency spectrums analysis of the Gaussian pulse shows that there is higher energy content in low frequency. Therefore, the antenna with wider bandwidth is demanded, especially in the low frequency. Furthermore, the characteristics of the frequency-domain have effect on the performance of the time-domain. However, in practical applications, not all broadband antennas can be used as pulse antenna. Dispersion, ringing and distortion of signal waveforms are likely to happen to some broadband antennas [5], as reported in [6, 7], a distortion of a short pulse radiated from log-periodic antennas and log conical spiral antennas. The stable phase center can ensure pulse fidelity. The distortion of the frequency-domain characteristics causes the distortion of the impulse response [8]. In this paper, we propose an ultra-wideband elliptical antenna, with wide bandwidth, stable phase center in the low frequency, and Omni-directional radiation characteristics.

2. ANTENNA DESIGN

The proposed antenna is fed by an SMA connector through a wideband balun. Fig. 1 shows the geometries of the proposed antenna and its design parameters. The antenna consists of a balun, two elliptical bowtie elements with trapezia, a metal ring and an SMA connector. Fig. 1(a) shows that the two elliptical bowtie elements with trapezia, a metal ring are fabricated on a substrate with dielectric constant $\epsilon_r = 3.5$, and the thickness of the substrate is 2 mm. There is a hole in

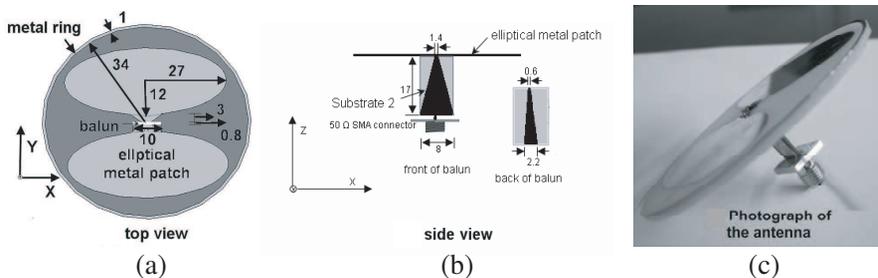


Figure 1. Geometries and photograph of the proposed antenna (unit: mm). (a) Top view of the proposed antenna. (b) Wideband balun and side view of the antenna and (c) Photograph of the fabricated antenna.

the center of the substrate which connects the antenna with the balun. Fig. 1(b) shows a conventional balun fabricated on substrate 2 with $\epsilon_r = 2.6$ and thickness of 0.8 mm. The balun is used to connect a 50Ω SMA connector to the elliptical bowtie antenna. The coupling value of the elliptical bowtie and metal ring can be tuned by changing the elliptical radius and width of the metal ring. The geometry parameters are optimized by CST Microwave Studio [9].

3. RESULTS

To verify the design, the antenna prototype with the optimized dimension is fabricated. In this paper, the time-domain and frequency-domain characteristics of the antenna are discussed. The results demonstrate its good performance.

The return loss is measured by an Agilent E5071C ENA network analyzer. The simulated bandwidth of the antenna ranges from 1.32 to 7.81 GHz. The measured bandwidth ranges from 1.30 to 6.65 GHz, and it is much wider than that of the folded antennas [10]. The measured and simulated reflection coefficients agree well with each other as shown in Fig. 2. The reflection coefficient of simulation is a bit wider than the measured value. There are two main causes for the discrepancy: The fabrication errors and the roughness solder between the balun and elliptical metal patch. Fig. 3 shows the simulated radiation patterns in the E plane (y - z plane) and H plane (x - z plane) and the far-field radiation patterns of the antenna at 1.5, 3, 4.5, 6 GHz. It is observed from Fig. 3 that the antenna's main beam is fixed in the operating band, and side lobe appears when the frequency exceeds 4.5 GHz. The gain of the designed antenna is quite stable in the beam direction, and the maximum gain is 5.3 dB at 6.5 GHz.

The received signals and peak value of the antenna are discussed to investigate time-domain performance of the antenna [11–13]. The time-domain characteristics of the antenna are calculated by placing virtual probes at a distance of 1000 mm from the feeding point of the antenna [14]. As illustrated in Fig. 5, the received signal is similar to the input signal. The amplitude varies with incident angle, and the received wave signals arise from ringing. The ringing effect is mainly caused by reflection of the metal ring.

In some literature, with regard to the pulse antenna, the radiation pattern is based on the radiation energy [15]. The instantaneous value of radiation pulses is an important indicator to describe the antenna. Therefore, the maximum peak value of the radiation waveform can describe radiation pattern of the impulse antenna. In the E plane, the maximum peak value of the waveform is monitored by the virtual

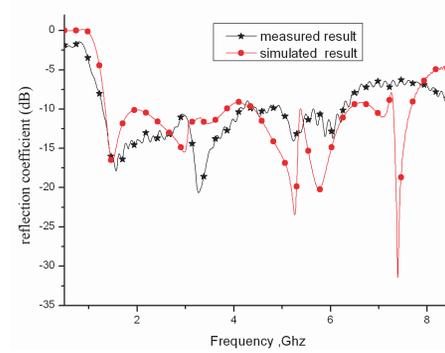


Figure 2. Measured and simulated return loss.

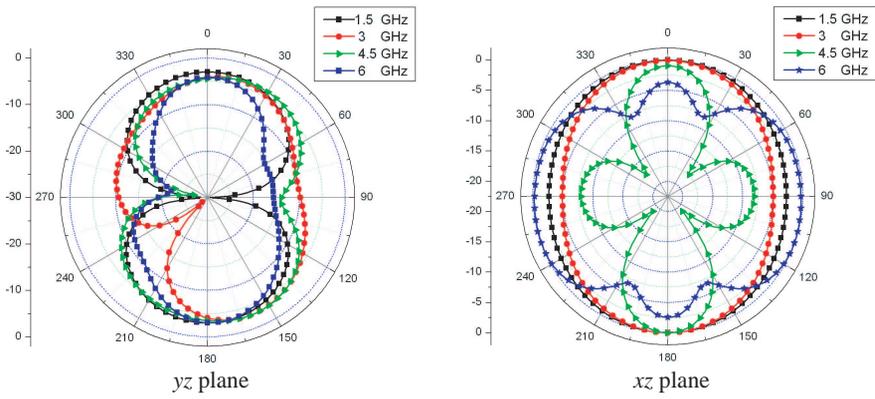


Figure 3. Simulated radiation patterns of the proposed antenna.

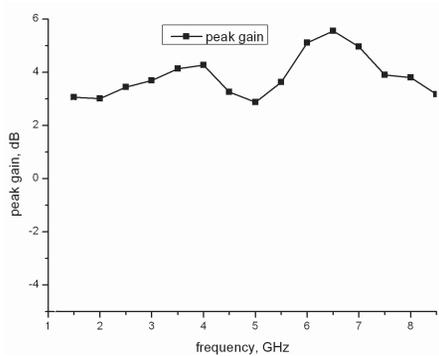


Figure 4. Simulated gain of the proposed antenna.

probes which are located in the far field. Fig. 6 presents the normalized peak-peak voltage value radiation patterns (the absolute value of the maximum peak subtracts the minimum peak value of the pulse) of the proposed antenna. From Fig. 6, it is concluded that the p-p voltage radiation pattern is also in the main beam.

In this paragraph, comparison is made between the time-domain and frequency-domain characteristics of the antenna. In Fig. 3, the radiation patterns of the antenna arise from side lobes while frequencies above 4.5 GHz in the E plane. The frequency-domain distortion has effect on the time-domain. In Fig. 5, the received pulses contain in a long tail and ringing wave. The phase centers of E and H planes with

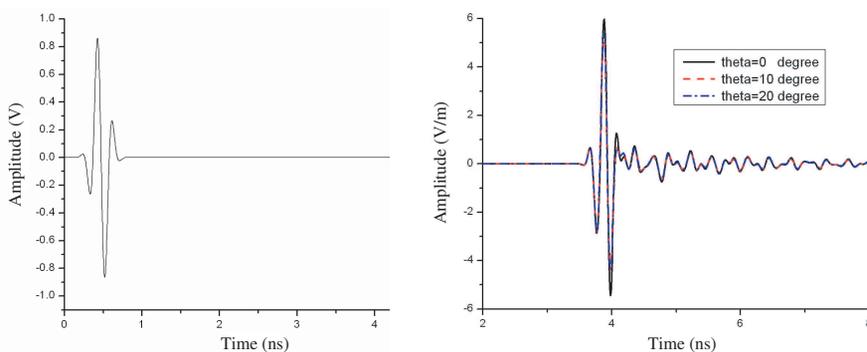


Figure 5. Time-domain characteristic of the proposed antenna. (a) Input signal, (b) received signal.

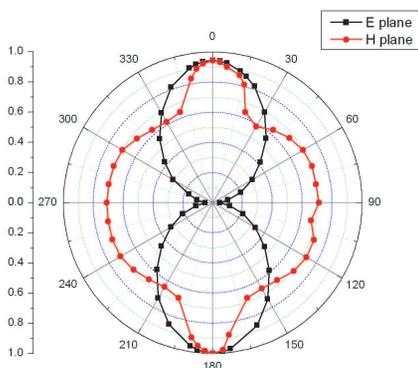


Figure 6. Simulated radiation patterns defined by the p-p voltage value of the proposed antenna.

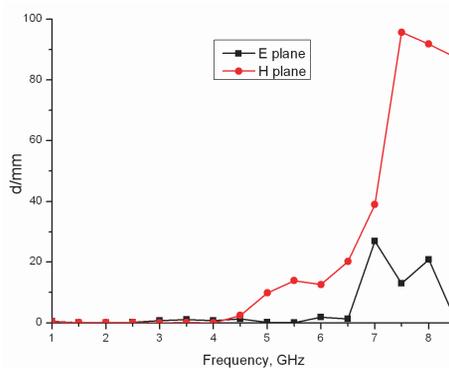


Figure 7. The comparison of phase center between the E and H plane with 30° beam-width.

30° beam-width are presented in Fig. 7. These results indicate that the phase center of the antenna is unstable in the high frequency. It is found that the phase center of E plane varies from 0.1 mm to 26 mm, and the phase center of H plane fluctuates in high frequency band. But the phase centers of E and H planes are stable in low frequency. Thus, the phase center of the antenna is unstable in the high frequency. It is concluded that the antenna is a good candidate for impulse antenna applications, especially when it operates in the low frequency band (1.30–5.0 GHz).

4. CONCLUSION

A wideband elliptical bowtie antenna is presented in this paper. This design demonstrates a bandwidth of 141% and stable phase center in the low frequencies. The characteristics of the frequency- and time-domains of the antenna are discussed. The phase centers of E , H planes are compared. The antenna has excellent performance such as large impedance bandwidth, stable phase center and good time-domain characteristics, which can be used for wireless devices, proximity fuse, and UWB system.

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