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A Study of a Leaf-Shaped Bowtie Slot Antenna for UWB Applications

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1. Introduction

Ultra-wideband (UWB) radio technology has recently attracted considerable attention for various applications, such as short-range high-speed communication, sensor networks, radar and location tracking. The Federal Communications Commission (FCC) announced its decision to allow the unlicensed use of the frequency band from 3.1GHz to 10.6 GHz for UWB radio systems in 2002. Since then, many research groups have reported various kinds of UWB antennas. In particular, planar-type UWB antennas have attracted significant research power in the past few years. For example, Schantz proposed various new designs such as magnetic slot antennas [1] and planar elliptical dipole antennas [2]. Chen et al. investigated the characteristics of a few types of square dipole antennas [3] and also proposed the bi-arm rolled monopole [4].

As a planar-type wideband antenna being useful for UWB radio systems, the authors have previously proposed a wideband dipole antenna being composed of leaf-shaped bowtie radiating elements [5]. In this paper, a leaf-shaped bowtie slot antenna, which is a complementary structure of the above-mentioned dipole antenna, is proposed and its characteristics are revealed by FDTD analysis and measurements. In the first place, the antenna having the operating frequency band from 7GHz to 10GHz (UWB high band in Japan) is designed, and its reflection coefficient is evaluated for the case when the feeding point is arranged in the centre portion of the antenna. Based on the evaluated results, a feeding circuit for the proposed antenna is designed. Antenna characteristics for the case with the feeding circuit are evaluated with FDTD analysis and measurements in order to confirm the effective performance of the proposed configuration.

2. Leaf-Shaped Bowtie Slot Antenna

The self-complementary antenna [6] has constant input impedance of about 180Ω independent of the frequency, and is useful for UWB applications. This characteristic is obtained only for the case when the antenna is composed of infinitely extended radiating elements. On the other hand, it is necessary to truncate the infinite structure for the practical use of the self-complementary antenna. As long as the self-complementarity is maintained around the feeding point of the radiating elements, various kinds of shape can be adopted for the truncated part of the radiating element of the self-complementary antenna. For this case, however, the operating frequency range of the antenna depends on the truncation shape of the radiating element. In this paper, a leaf-shaped radiating slot is employed as shown in Fig. 1. The radiating slot is cut on the ground plane of a dielectric substrate having a thickness of h and a relative permittivity of ε_r. The radiating slot is designed by rounding the corner of the square-shaped slot with the curvature radius of R_s and the central angle of α. The side length of the square shape is denoted by L_e. The geometrical parameters assumed in the following investigations are listed in Table 1. The dimensions of the radiating elements are optimised to achieve the operation over the frequency range from 7GHz to 10GHz, which corresponds to the UWB high band in Japan.

The reflection coefficient of the leaf-shaped bowtie slot antenna is evaluated by the FDTD analysis. In the analysis, it is assumed that the antenna is excited by a delta-gap voltage source arranged on the centre portion of the slot as shown in Fig. 1. Fig.2 shows the frequency response of the simulated reflection coefficient for the different reference impedances. It can be seen from the figure that the bandwidth of the antenna varies with the reference impedance, and that the widest bandwidth is obtained when the reference impedance is set to the value from around 140Ω to 160Ω.

3. Antenna characteristics for the case with the feeding circuit

In this section, evaluation of the antenna characteristics for the case with the feeding circuit is carried out by the FDTD analysis and measurements. The geometry of the leaf-shaped bowtie slot antenna with the feeding circuit is depicted in Fig. 3. In order to achieve 50Ω impedance matching, a linearly tapered microstrip line is employed, and its end is connected to the centre portion of the radiating slot with a conducting post having the diameter of d = 0.6mm. Based on the simulated results indicated in Fig. 2, the width of the output port of the tapered microstrip line is set to W_a = 0.3mm so that the characteristics impedance of the output port is equal to 140Ω. On the other hand, the width of the input port is chosen to be W_f = 2.4mm, with which the characteristic impedance of 50Ω is obtained. In the following investigations, the length of the feed line is set to 50mm.

Fig. 4 shows the simulated frequency response of the reflection coefficient at the input port of the tapered microstrip line for the case when the output port is terminate with a load resistance of 140Ω. The reflection is less than –20dB over the frequency range from 7GHz to 10GHz. This result implies that the tapered microstrip line having the above-mentioned geometrical parameters can be used as an impedance transformer from a 50Ω input port to a 140Ω output port.

The frequency responses of the simulated and measured reflection coefficients are shown in Fig. 5. As can be seen from the figure, the measured and calculated results are in good agreement. As for the measured result, the reflection is less than –10dB over the frequency range from 6.2GHz to 9.5GHz. This bandwidth is slightly narrower than that for the simulated one (from 6.0GHz to 10.3GHz). Slight discrepancy between the measured and simulated results may be due to the effect of the reflection at the SMA connector that is not incorporated in the simulation.

The actual gain observed in the z direction as a function of the frequency is plotted in Fig. 6. As appeared in the figure, the simulated result coincides well with measurements. The actual gain is ranging from 3dBi to 5dBi over the frequency band from 7GHz to 10GHz. The co-polarization patterns in the H-plane (yz-plane) and E-plane (xz-plane) are shown in Fig. 7 and Fig. 8, respectively. As can be seen from the figures, simulated and measured results are in good agreement. It can be confirmed from these figure that the maximum radiation intensity is obtained in the direction normal to the substrate surface. The ripple observed in the E-plane patterns may be attributed to the effect of the diffraction at the edges of the substrate and ground plane.

4. Conclusions

An UWB antenna consisting of a leaf-shaped bowtie slot and a linearly tapered microstrip line is proposed, and its characteristics are investigated by FDTD analysis and measurements. In the first place, the leaf-shaped bowtie slot having the operating frequency band from 7GHz to 10GHz is designed, and its reflection coefficient is evaluated for the case when the feeding point is arranged in the centre portion of the antenna. From the simulated results, it is confirmed that the widest bandwidth is obtained when the characteristic impedance for the feeding port is set to the value from 140Ω to 160Ω. Based on this result, a feeding circuit for the leaf-shaped bowtie slot is designed. For the case when the leaf-shaped bowtie slot is fed by the designed feeding circuit, the simulated reflection coefficient is observed to be less than –10dB over the frequency range from 6.0GHz to 10.3GHz, and the actual gain ranging from 3dBi to 5dBi over the frequency band from 7GHz to 10GHz is obtained.

Acknowledgments

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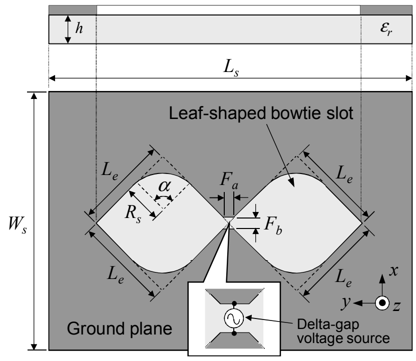

Figure 1: Leaf-shaped bowtie slot antenna.

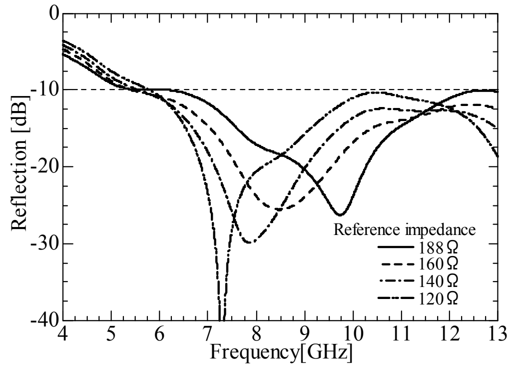

Figure 2: Simulated reflection coefficients.

Table 1: Geometrical parameters of the antenna.

W_s [mm]	L_s [mm]	h [mm]	L_e [mm]	R_s [mm]	α [deg]	F_a [mm]	F_b [mm]	ε_r
100	100	0.762	12	7.1	90	1.0	1.0	2.17

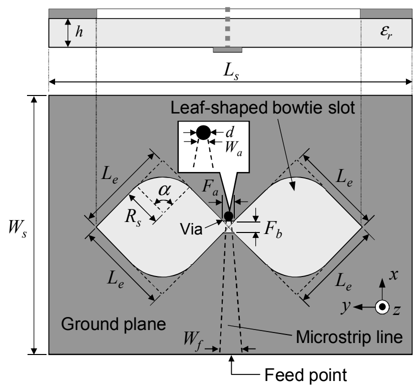

Figure 3: Antenna configuration with feeding circuit.

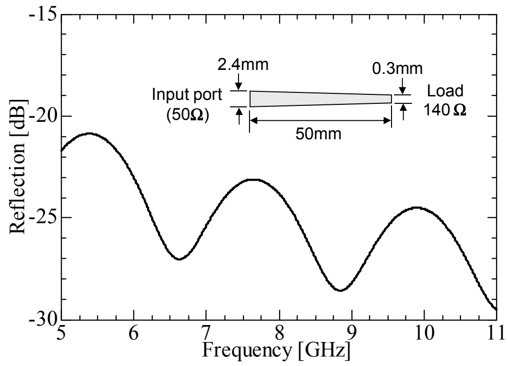

Figure 4: Characteristic of feeding circuit.

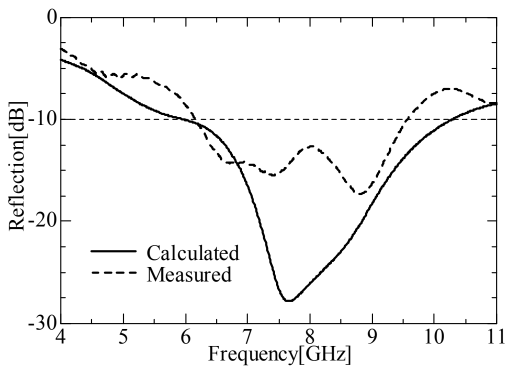

Figure 5: Reflection coefficient for the case with the feeding circuit.

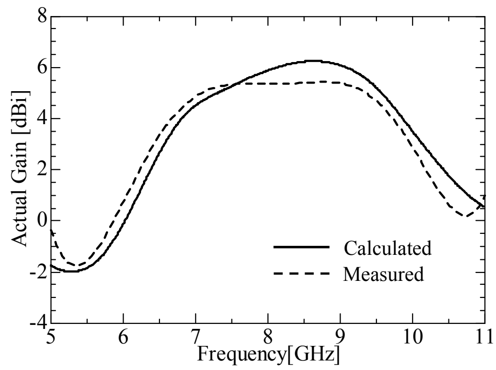

Figure 6: Actual gain versus frequency for the case with the feeding circuit.

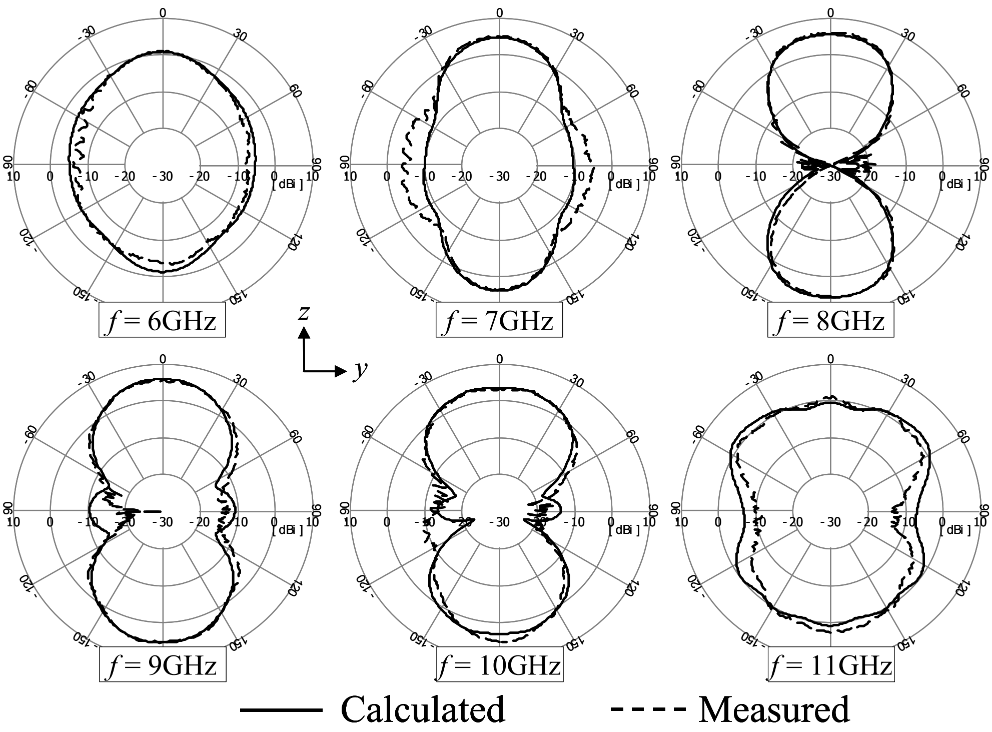

Figure 7: Radiation patterns in *yz*-plane (H-plane).

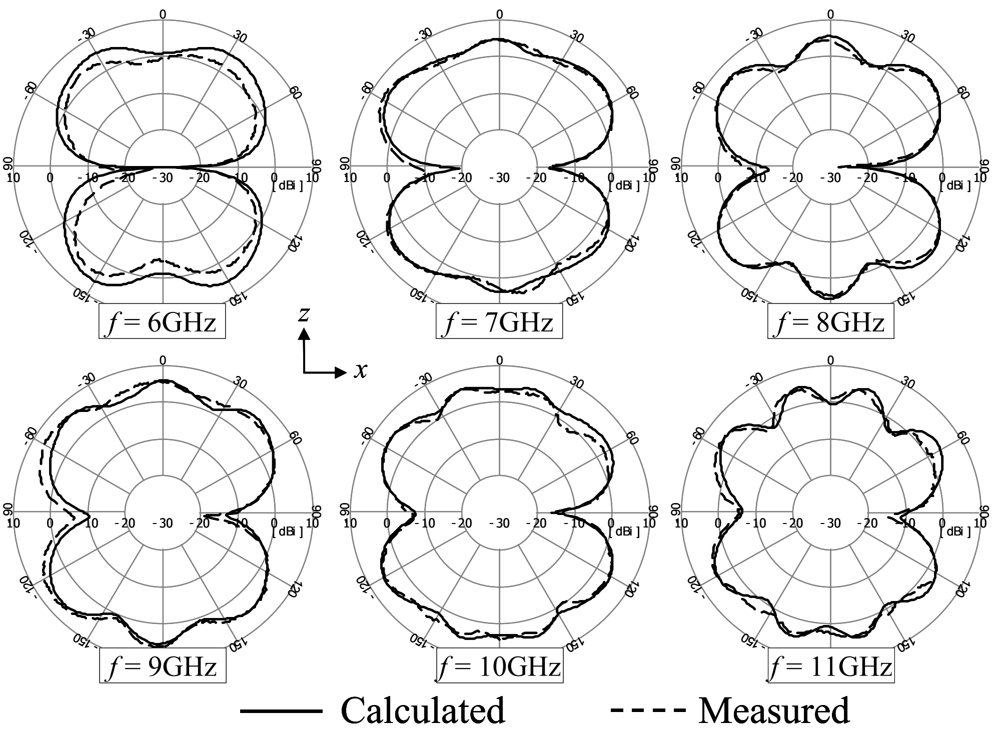

Figure 8: Radiation patterns in *xz*-plane (E-plane).