Design of a Leaf-Shaped Bowtie Slot Antenna Electromagnetically Fed by a Microstrip Line

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***Abstract* - This paper presents a design of a wideband printed antenna being useful for ultra-wideband applications. In the designed antenna that operates over the frequency band of 7-10 GHz, a leaf-shaped bowtie slot antenna (LSBSA) is employed as a radiating element, and electromagnetic coupling feed based on a microstrip line is adopted for the excitation of the radiating element. In order to demonstrate the effective performance of the presented configuration, characteristics of the designed LSBSA are evaluated by the finite-difference time domain (FDTD) analysis. Over the above-mentioned frequency band, the simulated reflection coefficient is observed to be less than -10 dB, and the maximum actual gain of 7.5 dBi is obtained. Measured results are also presented in order to validate the simulated results.**

***Index Terms* — printed antenna, wideband antenna, UWB, slot antenna, electromagnetic coupling feed.**

I. Introduction

Since the allocation of the UWB bands by the FCC [1], various types of UWB antennas have been proposed by many research groups. In particular, planar-type UWB antennas have attracted significant research power for decades [2],[3]. As a planar-type wideband antenna which is useful for UWB radio systems, the authors have previously proposed a wideband dipole antenna which is composed of leaf-shaped bowtie radiating elements [3].

This paper presents a design of a printed antenna being useful for UWB applications. In the designed antenna that operates over the frequency band of 7–10 GHz, a leaf-shaped bowtie slot antenna (LSBSA), which is a complementary structure of the above-mentioned dipole antenna, is employed as a radiating element having wideband characteristics. For the excitation of the radiating element, electromagnetic coupling feed based on a microstrip line is adopted in the designed antenna.

In order to demonstrate the effective performance of the presented configuration, characteristics of the designed LSBSA are evaluated by the finite-difference time domain (FDTD) analysis. Over the above-mentioned frequency band, the simulated reflection coefficient is observed to be less than −10 dB, and the maximum actual gain of 7.5 dBi is obtained. In addition to the simulated results, measured reflection coefficient and actual gain for the prototype antenna are also presented in order to confirm the validity of the simulated results obtained by the FDTD analysis.

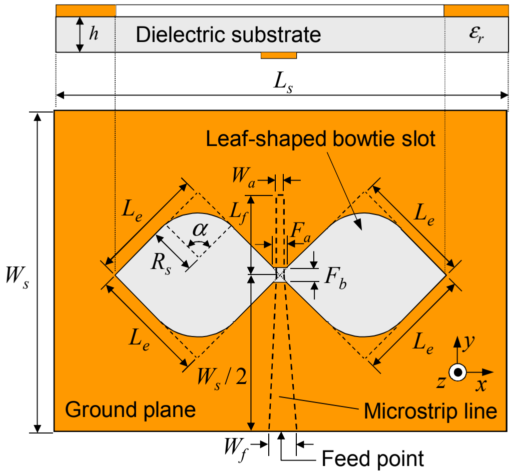


Fig. 1. Structure of the designed antenna.

TABLE I
STRUCTURAL PARAMETERS OF THE DESIGNED ANTENNA.

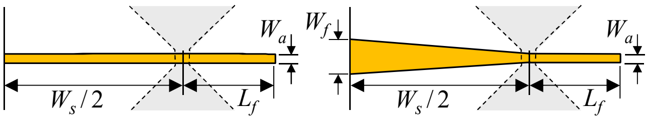
W_s [mm]	L_s [mm]	h [mm]	L_e [mm]	R_s [mm]	ε_r
30	60	0.762	13	8.0	2.17

F_a [mm]	F_b [mm]	L_f [mm]	W_f [mm]	W_a [mm]	α [deg.]
1.0	1.0	7.0	2.4	0.4	90

II. Antenna Structure

A self-complementary antenna has an input impedance of $60\pi = 188\ \Omega$, which is independent of the frequency [4]. This performance is realized only for the case where the antenna is composed of infinitely extended radiating elements. However, it is necessary to truncate the infinitely extended structure for the practical use. 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 truncation of the radiating elements of the self-complementary antenna. For this case, the operating frequency range of the antenna depends on the truncation shape of the radiating elements.

In this paper, a leaf-shaped slot antenna, which can be classified into the self-complementary antenna with finite element size, is employed as a radiating element of the designed antenna. The structure of the designed antenna is shown in Figure 1. The radiating slot is cut on a 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



(a) Microstrip line with uniform width (b) Tapered microstrip line

Fig. 2. Configuration of the microstrip line.

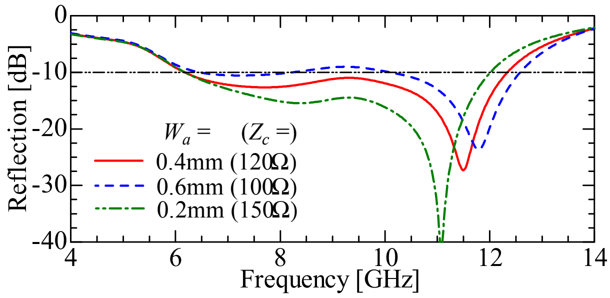


Fig. 3. Simulated reflection coefficients with the uniform width feedline.

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 radiating slot is centered on the dielectric substrate whose length and width are denoted as L_s and W_s, respectively.

A strip conductor of a microstrip line is placed on the bottom side of the dielectric substrate. The electromagnetic fields propagating along the microstrip line excites the radiating slot. The strip conductor is terminated in an open-circuited stub beyond the center portion of the radiating slot. The length L_f of the open-circuited stub is chosen to be approximately a quarter-wavelength at the center frequency of the design frequency band in order to realize the efficient excitation of the radiating slot.

The structural parameters of the antenna assumed in the following investigations are listed in Table 1. The dimensions of the radiating slot are optimized to achieve the operation over the frequency range from 7GHz to 10GHz, which corresponds to the UWB high band in Japan. The length of the stub is fixed to approximately a quarter-wavelength at 8.5 GHz, which corresponds to a center frequency of the above-mentioned frequency band.

III. Simulated and Measured Results

In the first place, the frequency response of the reflection coefficient is evaluated by the FDTD analysis for the case where the microstrip line has uniform width of W_a as shown in Fig. 2(a). Fig. 3 shows the simulated reflection coefficients for W_a = 0.2 mm, 0.4 mm and 0.6 mm. Characteristic impedances of the microstrip line for these widths are 150Ω, 120Ω and 100Ω, respectively. These values are used as reference impedances for the evaluation of the reflection coefficients presented in Fig. 3. It can be seen from Fig.3 that the bandwidth of the antenna varies with the width of the microstrip line, and that the widest bandwidth is obtained when the width of the line is chosen to be W_a=0.2mm.

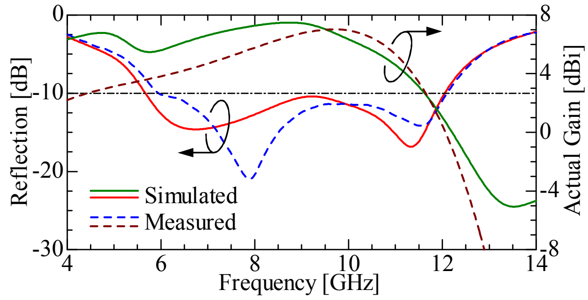


Fig. 4. Reflection coefficients and actual gain observed in main beam direction.

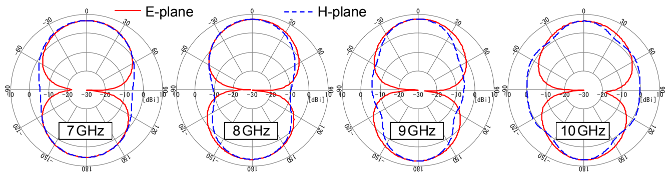


Fig. 5. Simulated radiation patterns (co-polarization) in E- and H-planes.

In the designed antenna, a linearly tapered microstrip line is employed in order to achieve 50Ω impedance matching as shown in Fig. 2(b). Based on the results shown in Fig. 3, the width W_a is chosen to be 0.4mm. 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.

Simulated and measured reflection coefficients for the case with the tapered microstrip line are shown in Fig. 4. 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 6.0GHz to 12GHz.

The actual gain observed in the main beam (+z-) direction as a function of the frequency is also plotted in Fig. 5. As appeared in the figure, the simulated result coincides well with the measurements. It is seen that the maximum gain of about 7.5dBi is obtained around 9.5GHz.

The simulated radiation patterns (co-polarization) in the E-plane (yz-plane) and H-plane (zx-plane) are shown in Fig. 5. The antenna radiates equally on both sides of the substrate at each frequencies. The maximum radiation is observed in the directions normal to the substrate. As for the E-plane patterns, there is a null in the directions in the plane of the substrate.

IV. Conclusion

A design of a leaf-shaped bowtie slot antenna using electromagnetic coupling feed based on a microstrip line is presented, and its characteristics are evaluated by the FDTD analysis and measurements.

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