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Broadband Printed Dipole Antenna Consisting of Self-Complementary Radiating Element and Tapered Microstrip Line

Michitaka Ameya[1], Manabu Yamamoto[1], Toshio Nojima[1] and Kiyohiko Itoh[2]

[1] Graduate School of Information Science and Technology, Hokkaido University
Kita 14, Nishi 9, Kita-ku, Sapporo, 060-0814, Japan
E-mail: yamamoto@ice.eng.hokudai.ac.jp

[2] Tomakomai National College of Technology
Nishikioka 443, Tomakomai, 059-1275, Japan

1. Introduction

Ultra-wideband (UWB) technologies are promising candidate for constructing high-speed wireless communication systems, and have attracted considerable attention in recent years. In UWB radio systems, information is transmitted by using narrow pulses that are generated and processed without the use of RF components, such as local oscillators or mixers. Thus, the transceiver hardware can be made very simple in comparison with conventional narrow-band radio systems. On the other hand, the UWB systems require extremely wide frequency spectra due to the use of short pulses.

The design of ultra-wideband antennas that are optimized for the pulse transmission and reception is one of the important tasks for the development of the UWB radio systems. Since the FCC approved the UWB in 2002 [1], various kinds of UWB antennas have been studied and reported by many research groups. However, most of these antennas are bulky and are not compatible with portable systems [2], [3]. From the viewpoint of ease of installation and low manufacturing cost, the employment of UWB antennas having a planar geometry can be the most prospective technology.

Taking these backgrounds into consideration, in this paper, we propose a planar-type broadband dipole antenna comprising of self-complementary radiating element [4], [5] and tapered microstrip line. Fundamental characteristics such as frequency response of reflection and radiation patterns are revealed by FDTD analysis and experiments. The reflection below –10dB and almost omni-directional radiation in the azimuth plane is obtained over the FCC approved UWB frequency band of 3.1 to 10.6GHz. Transmission characteristics of the antenna are also evaluated by experiments.

2. Antenna Structure

Fig. 1 shows the geometry of the proposed antenna, where dimensions are indicated in millimeters. Two radiating elements are arranged on upper and lower surfaces of a dielectric substrate. The radiating elements are excited with a tapered microstrip line having a length of 45mm. In order to achieve wideband characteristics, the radiating elements are designed by truncating infinite radiators of the ideal self-complementary antenna [5], as shown in Fig. 2. As long as the self-complementary condition is maintained around the feeding point of the antenna, various kinds of shapes can be adopted for the truncated part of the radiating element. In this paper, diamond-shaped elements are employed as shown in Fig. 1. The tapered microstrip line is adopted in order to the input impedance of the self-complementary antenna (= $60\pi\,\Omega$) to a 50 Ω feedline.

3. Numerical and Experimental Results

Fundamental characteristics of the proposed antenna having the dimensions shown in Fig. 1 are evaluated by the analysis and experiments. Numerical evaluation of the antenna performance is carried out by using the electromagnetic simulator SEMCAD based on the FDTD method [6].

The frequency response of the return loss is shown in Fig. 3, where solid and broken lines indicate

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measured and calculated results, respectively. Note that the reference impedance of 50 Ω is assumed in the evaluation. The calculated results coincide well with the measured one, from which the validity of the FDTD analysis can be confirmed. It is observed that wideband characteristics (the reflection of less than –10dB) are obtained over the frequency range from 3 to 12GHz, which includes the FCC approved UWB band (3.1 to 10.6GHz).

Radiation patterns measured in the azimuth plane (*xy*-plane) are shown in Fig. 4, where solid and broken lines represent co- and cross-polarization components, respectively. It can be seen that the proposed antenna exhibit almost omni-directional radiation in the azimuth plane over the frequency range from 3 to 9GHz.

Fig. 5 shows the current distributions on the antenna elements calculated at 3GHz, 6GHz and 9GHz. The peripheral length of the radiating element is approximately 90mm, which is nearly equal to a free space wavelength of 100mm at 3GHz. This fact implies that the antenna acts as a one-wavelength dipole antenna at 3GHz. As for 6 and 9GHz, the antenna can be seen as two- and three- wavelength dipole antennas, respectively. In general, the radiation pattern of two-wavelength dipole antenna exhibits the null in the broadside direction. In the proposed antenna, however, the null is not observed in the broadside direction. This is because the amplitude of the current around the tips of the radiating element is weak in comparison with that flowing on the center of the element.

A pair of antennas forming a transmitting and receiving system as shown in Fig. 6 was measured in order to investigate the transmission characteristics of the proposed antenna. As shown in the figure, they are arranged front-to-front or side-to-side with a separation of d = 30cm. Transmission characteristics between two antennas were measured by using vector network analyzer HP8510C.

Measured amplitudes of the transmission coefficient $|S_{21}|$ are shown in Fig. 7. In the figure, the free-space loss factor L calculated by the Friis's transmission equation is also indicated with a broken line. Over the frequency range from 3 to 10GHz, it can be observed that $|S_{21}|$ has almost the same values as those of the free-space loss factor.

Fig. 8 shows the group delay measured for the case of front-to-front and side-to-side. In the case of front-to-front, the group delay is within the range of 0.9 to 1.9nS over the frequency of 3 to 10GHz. On the other hand, the group delay is within the range of 1.1 to 1.7nS over the frequency of 3 to 12GHz as for the case of side-to-side. Since the two antennas are used in the measurement, the group delay of the single antenna can be estimated as a half value of above-mentioned results.

4. Conclusions

In this paper, a planar-type antenna having ultra-wideband characteristics has been proposed. The antenna is composed of self-complementary radiating elements and a tapered microstrip line printed on a dielectric substrate. Fundamental characteristics of the proposed antenna were evaluated by FDTD analysis and measurements. The reflection below –10dB and almost omni-directional radiation in the azimuth plane was obtained over the FCC approved UWB frequency band of 3.1 to 10.6GHz. Transmission characteristics of the antenna were also revealed by experiments.

Acknowledgement

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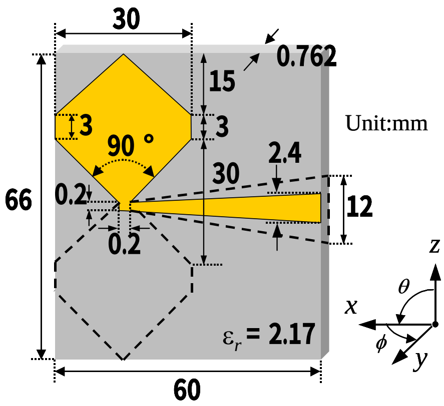


Fig. 1 Geometry of antenna

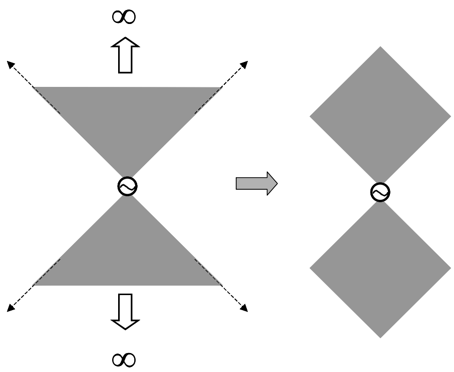


Fig. 2 Self-complementary structure

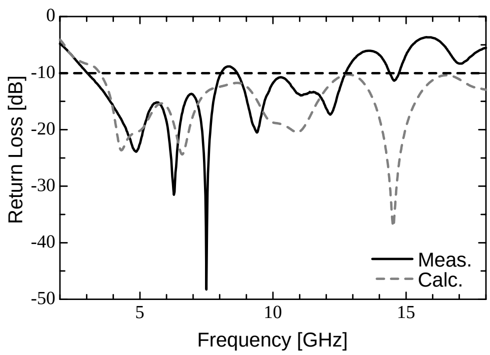


Fig. 3 Measured and calculated return loss

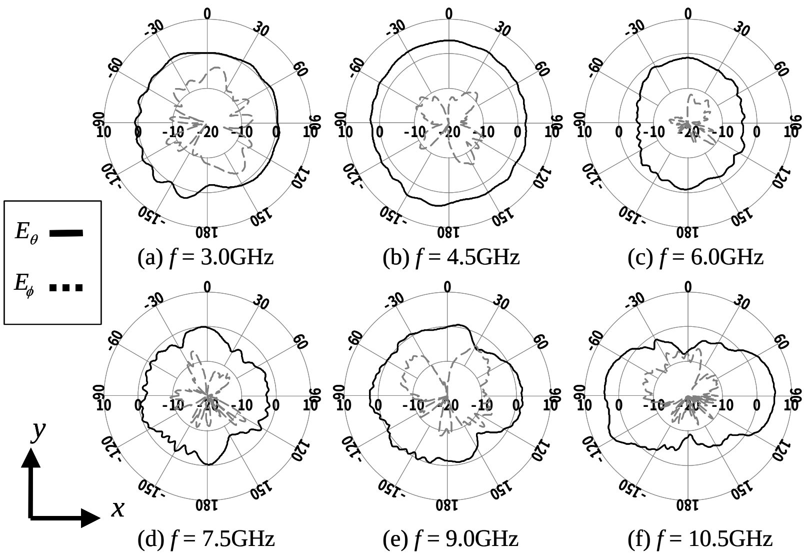
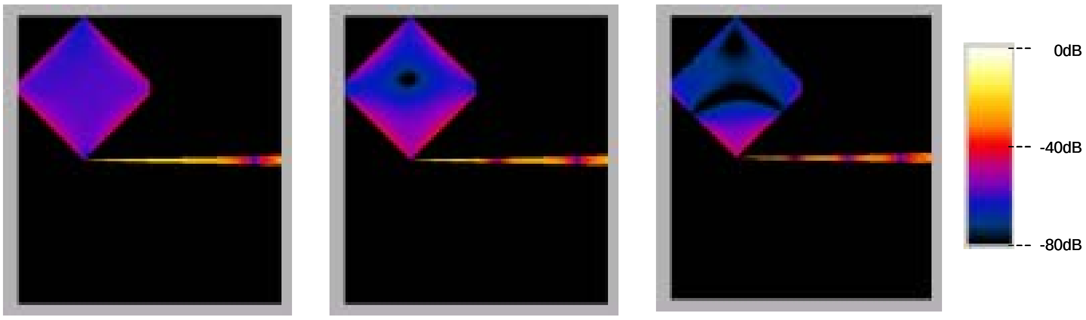


Fig. 4 Radiation patterns measured in xy-plane



(a) f = 3.0GHz (b) f = 6.0GHz (c) f = 9.0GHz

Fig. 5 Current distribution on antenna and feedline

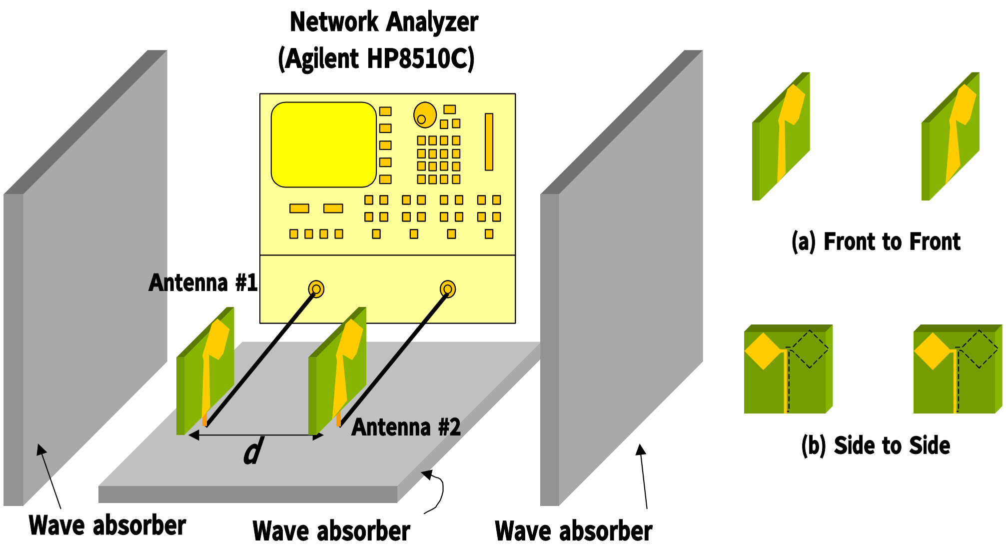


Fig. 6 Measurement of transmission characteristics

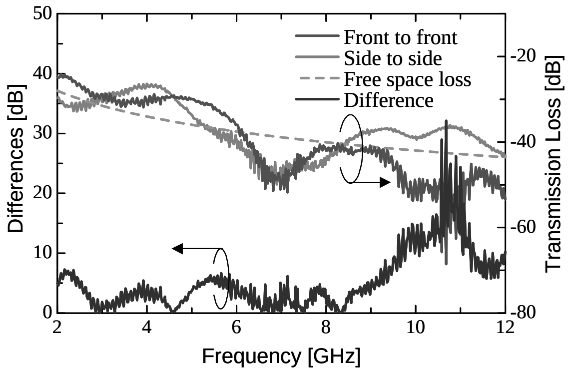


Fig. 7 Measured transmission loss

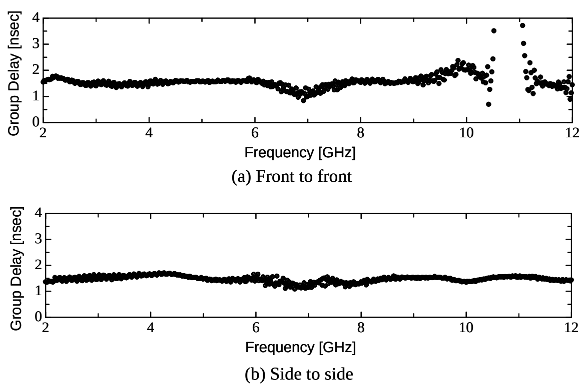


Fig. 8 Measured group delay