A study on half-shaped printed monopole antenna with short stub for UWB system

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Abstract: In this paper, the authors propose a small printed monopole antenna corresponding to the frequency band of UWB (Ultra-wideband) system that use a frequency of 3.1 GHz to 10.6 GHz. This antenna has a structure in which a bell-shaped UWB monopole antenna formed on a dielectric substrate (FR-4) has a half shape and a short stub is attached to the antenna. The size of the antenna is $30 \times 12 \times 1.6 \text{ mm}^3$. The antenna is designed to be smaller than the conventional one proposed by the author, and can operate in the frequency band of the UWB system. From the simulation result, it is shown that good characteristics can be obtained to UWB application for high speed wireless communication.

Keywords: UWB, small antenna, short stub, impedance matching

Classification: Antennas and Propagation

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1 Introduction

The Ultra Wideband (UWB) system is widely studied as a system that enables high-speed wireless communication by performing communication using a wide frequency band [1]. In 2002, The Federal Communication Commission (FCC) has approved the spectrum within the frequency 3.1 GHz to 10.6 GHz for ultra-wideband systems, and the design of an antenna covering those frequency band is required [2]. The antenna is required to have a small size, and it is desirable that the antenna have non-directional radiation characteristics assuming communication with devices in various directions [3]. Impedance matching technology used to improve antenna characteristics has been reported as a miniaturization technology for ultra-wideband antennas [4, 5]. A bell-shaped planar monopole antenna attached with a short stub has been proposed [6]. This antenna improves the impedance matching in the lower band by attaching a short stub and is an antenna with a wide band characteristic that satisfies the band of the ultra-wideband system. The size is $28 \times 20 \times 1.6 \text{ mm}^3$. In this paper, we focus on the symmetrical structure of the previously proposed ultra-wideband antenna, and propose a half-shaped UWB monopole antenna with the antenna cut in half. By adjusting the parameters of the short stub and the ground conductor, the characteristics satisfying the frequency band of the ultra-wideband system are shown. In order to achieve impedance matching, the antenna is shaped by cutting off the microstrip line, and short stubs is useful for impedance matching in the low frequency band of the ultra-wideband system.

2 Antenna design

Fig. 1 shows the half-shaped printed monopole antenna with short stub for the UWB system. This antenna is formed on a dielectric substrate (FR-4: $\epsilon_r = 4.4$, $\tan \delta = 0.02$) with a length $L = 30 \text{ mm}$, a width $W = 13 \text{ mm}$, and a thickness $t = 1.6 \text{ mm}$. The antenna is fed by microstrip transmission line to the monopole on a dielectric substrate, and the short stub is connected to the ground plane of the microstrip transmission line from the central lower part of the monopole through holes. The monopole and the ground conductor are half-shaped compared to the previously proposed antenna. The characteristic impedance is 50Ω . In general, the equivalent circuit of the UWB monopole antenna can be considered as a series of multiple resonant circuits [7]. The short stub operates as a parallel impedance to the UWB monopole antenna, and the antenna's input impedance can be matched by properly adjusting the short stub's parallel impedance. This antenna structure provides broadband operation. The dimensions of the proposed antenna are length (L) = 30.0 mm, width (W) = 13.0 mm, length of microstrip line (L_L) = 10.0 mm, width of microstrip line (W_L) = 2.0 mm, width of antenna (W_A) = 12.0 mm, length of ground (L_G) = 10.5 mm, width of ground (W_G) = 12.0 mm, length of short stub

Fig. 1. Antenna configuration

(L_S) = 2.5 mm, width of short stub (W_S) = 0.5 mm, and diameter of through hole (D_H) = 0.5 mm.

3 Simulation results

The antenna is analyzed using the electromagnetic field simulator Keysight EMPro. The antenna parameters are calculated using the same values as the reference values shown in chapter 1. Fig. 2 shows the calculation results of the characteristics of the antenna. In this figure, (a) shows the smith chart when the length of short stub is changed from 1.5 mm to 3.0 mm at 0.5 mm intervals, (b) shows the result when the width of short stub is changed from 0.3 mm to 0.9 mm at 0.2 mm intervals. And, (c) and (d) show comparison of s-parameters with short stub and without short stub in VSWR and smith chart. Calculation results with short stubs are indicated by blue solid lines, and calculation results without short stubs are indicated by red dotted lines. From Fig. 2(a), it is obtained that when the length of the short stub is increased, the capacitance component of the input impedance tends to increase. From Fig. 2(b), it is obtained that when the width of the short stub is increased, the inductance component of the input impedance tends to increased. The input impedance can be adjusted by changing the length of short stub (L_S) and the width

Fig. 2. Simulation result of proposed antenna

Fig. 3. Radiation pattern (x-y plane)

of short stub (W_s). It can be solved the problem that when the antenna is designed small, the frequency band shifts to a high frequency and impedance matching in the low frequency is degraded. The proposed antenna's short stub is adjusted to

$L_S = 2.5$ mm and $W_S = 0.5$ mm for impedance matching. From the calculation results of VSWR, the proposed antenna showed good results that is the VSWR is 2 or less over the entire desired band of the ultra-wideband system. This result shows that even in the case of the half shape, almost the same characteristics as the conventional antenna could be obtained. The simulation result of radiation pattern is shown in Fig. 3. The radiation pattern in the x-y plane is shown. The calculation frequencies are 3.5 GHz, 5.0 GHz, 6.5 GHz, 8.0 GHz, 9.0 GHz and 10.0 GHz. From the calculation results, radiation in the cut direction at high frequencies is slightly degraded, however it can be confirmed that almost non-directional radiation patterns are obtained at each frequency. It can be confirmed that good results were obtained as an antenna for UWB high speed wireless communication applications.

4 Conclusion

A half-shaped printed monopole antenna corresponding to the desired frequency band of the UWB system is proposed, and the calculation results of the antenna characteristics are presented. By adjusting the length and width of the short stub, the input impedance of the antenna can be obtained a good value throughout the UWB system, and even if the antenna is designed to be small, a wideband characteristic that satisfies the desired frequency band of the UWB system is realized. It was also confirmed that nearly all of the omnidirectional radiation characteristics were obtained. The proposed antenna achieves miniturization with an antenna configuration that is 30% size reduction of the conventional antenna, and achieves wideband characteristics that operate in the UWB frequency band.

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