A UWB Band-Rejected Antenna Fed by Embedded Nonuniform Microstrip Line

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Abstract

An ultra-wide band (UWB) antenna with band rejection on the range of the wireless local area network (WLAN) is proposed. The antenna consists of a radiation element with broadband radiation and a nonuniform microstrip line which is designed by the inverse scattering theory for necessary band rejection. A fabricated antenna shows that the measurement agrees with the theory very well. The antenna radiates properly in the UWB range except the WLAN range.

Keywords: UWB antenna, Nonuniform transmission line, Inverse scattering theory, WLAN

1. Introduction

Recently, wireless communication technologies using ultra-wide band (UWB) have attracted much attention since the U.S. Federal Communications Commission (FCC) released the unlicensed use of UWB range from 3.1 to 10.6 GHz for commercial purposes. However, the UWB occupies a wide band and overlaps some existing wireless systems such as IEEE 802.11a standard for the wireless local area network (WLAN). For an antenna used for the UWB applications, it is desirable to confine strictly the radiation into the allocated range and suppress the operation over a range from 5 to 6 GHz to avoid interferences to the WLAN systems.

Some UWB antennas with band rejection have been reported but systematic approaches are lacked to satisfy arbitrary requests [1]–[4]. In this paper, a UWB antenna with band rejection is proposed. The antenna consists of a radiation element that supports radiation in a range from 2.5 to 11 GHz and a ground plane. The antenna is fed by a microstrip line embedded on the back of the ground plane. The microstrip line is designed to have nonuniform width along longitudinal direction by using the inverse scattering theory so as it has band rejections at 2 to 3.1 GHz and 5 to 6 GHz. A fabricated antenna shows that the measurement agrees with the theory very well. The antenna radiates properly in the UWB range except the WLAN range from 5 to 6 GHz.

2. Antenna Configuration

Figure 1 shows the configuration of the proposed antenna which consists of a radiation element and a ground plane. The element composed of a rectangle, a half ellipse and a square base covers fully the UWB range [5]. In order to realize necessary band rejection, the antenna is fed by a microstrip line which is constructed on the back of the ground plane as shown in Fig. 2. The width of the microstrip line varies continuously along longitudinal direction to form a nonuniform transmission line (NTL) which implements synthesized impedance. The NTL is embedded on the back of the ground plane to avoid the disturbance to the radiation and is rounded spirally to save the installation space.

3. Formulation of Nonuniform Transmission Line for Band Rejection

The NTL can be formulated by an equivalent circuit shown in Fig. 3, where L and C are inductance and capacitance per unit length, respectively, and z the longitudinal position. With a

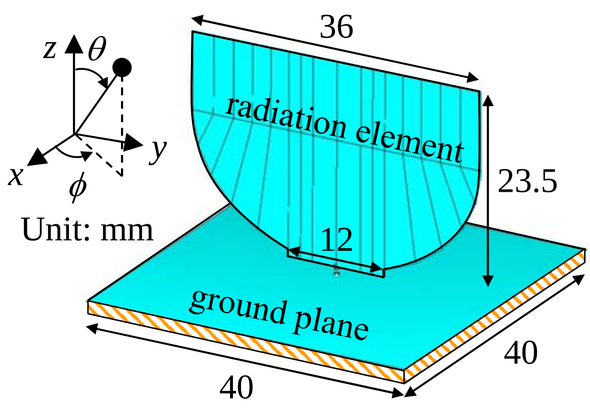

Figure 1: Configuration of antenna.

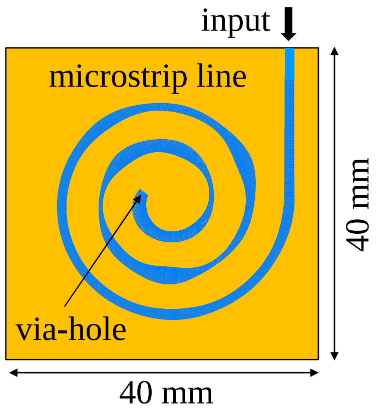

Figure 2: Microstrip line on back of ground plane.

time dependence of $\exp(-i\omega t)$ with an angular frequency ω, Telegrapher's equations for the circuit yield the following Zakharov-Shabat equations

$$\begin{cases} \dfrac{\partial \phi_1(x,\omega)}{\partial x} - i\omega\phi_1(x,\omega) = -q(x)\phi_2(x,\omega), \\ \dfrac{\partial \phi_2(x,\omega)}{\partial x} + i\omega\phi_2(x,\omega) = -q(x)\phi_1(x,\omega) \end{cases} \tag{1}$$

by introducing two variables as

$$\begin{cases} \phi_1(x,\omega) = \dfrac{v(x,\omega) + Z(x)i(x,\omega)}{2\sqrt{Z(x)}}, \\ \phi_2(x,\omega) = \dfrac{v(x,\omega) - Z(x)i(x,\omega)}{2\sqrt{Z(x)}} \end{cases} \quad \text{where} \quad \begin{cases} Z(x) = \sqrt{\dfrac{L(x)}{C(x)}}, \\ q(x) = \dfrac{1}{2}\dfrac{d\ln Z(x)}{dx}, \\ x(z) = \displaystyle\int_0^z \sqrt{L(s)C(s)}ds. \end{cases} \tag{2}$$

Assuming that the transmission line only exists for $x \geq 0$ and the reflective spectrum of $\phi_2(0,\omega)/\phi_1(0,\omega)$ is given, the potential $q(x)$ can be solved by the inverse scattering theory [6]. Then the characteristic impedance is obtained by

$$Z(x) = Z(0)\exp\left[2\int_0^x q(s)ds\right], \tag{3}$$

which gives the width profile of the NTL necessary.

Figure 4 shows the realized reflective spectrum with a NTL by assigning two rejected bands at 2 to 3.1 GHz and 5 to 6 GHz. Figure 5 shows the designed characteristic impedance distribution for the NTL which has a length of three wavelengths at 2 GHz.

4. Experimental Results

To demonstrate the validity of the theory, a prototype antenna shown in Fig. 6 is fabricated and measured. The ground plane is made on a dielectric substrate with a thickness of 1.27 mm and a dielectric constant of 10.6. The spiral microstrip line on the back of the plane is designed to have a gap of 5 mm between adjacent lines.

Figure 7 compares the calculated and measured input characteristics for an antenna without the NTL filter. It is shown that there exists a good agreement between the calculation and measurement and the antenna covers the UWB range with a voltage standing wave ratio (VSWR) less than 2.

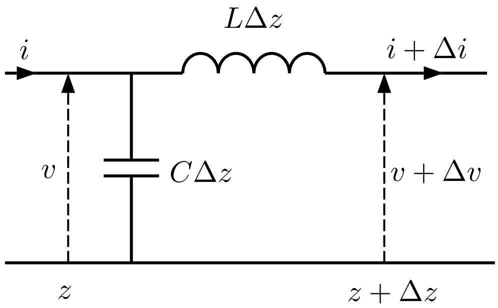

Figure 3: Equivalent circuit for NTL.

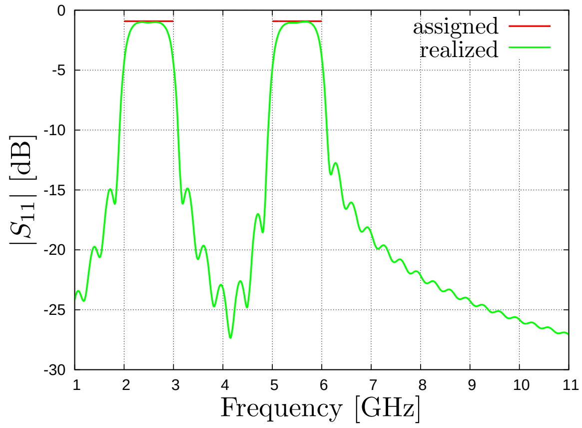

Figure 4: Assigned and realized reflective spectra for NTL.

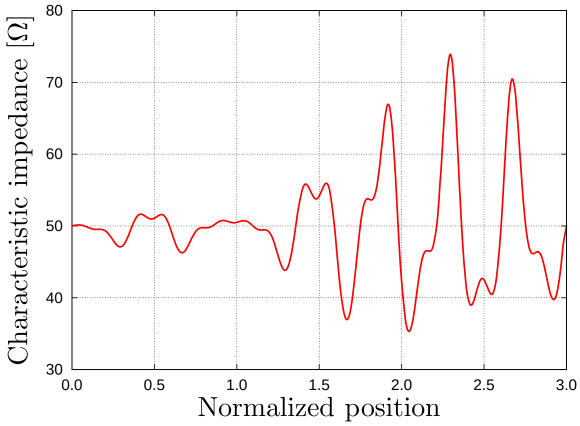

Figure 5: Characteristic impedance distribution.

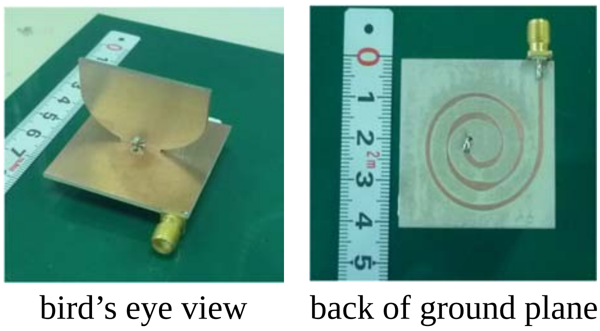

Figure 6: Fabricated prototype antenna.

The NTL filter is designed to reject two bands: one is from 2 to 3.1 GHz to ensure the antenna to radiate from 3.1 GHz, another is from 5 to 6 GHz to avoid radiation to the WLAN band. The NTL has a length of 168 mm rounded spirally which corresponds to three wavelengths at 2 GHz. Figure 8 compares the calculated and measured input characteristics for the individual filter by replacing the radiation element of the antenna with a matched load. It is shown that the filter actually has two rejected bands as designed. Ripples occurs in the measurement due to the imperfect terminations.

Figure 9 compares the calculated and measured input characteristics for the antenna with the NTL filter. It is shown that the measurement agrees with the calculation very well and the antenna covers the UWB range with a VSWR less than 2.5 except the WLAN band.

Figure 10 compares the measured radiation efficiency for the antennas with and without the filter. It is shown that there is significant difference on radiation between the two antennas for the assigned rejected bands but there is not outside the bands.

5. Conclusion

We have proposed a UWB band-rejected antenna by embedded a spiral nonuniform microstrip line on the back of its ground plane. A fabricated antenna is successfully designed and works well in the FCC's allocated UWB range except the WLAN band.

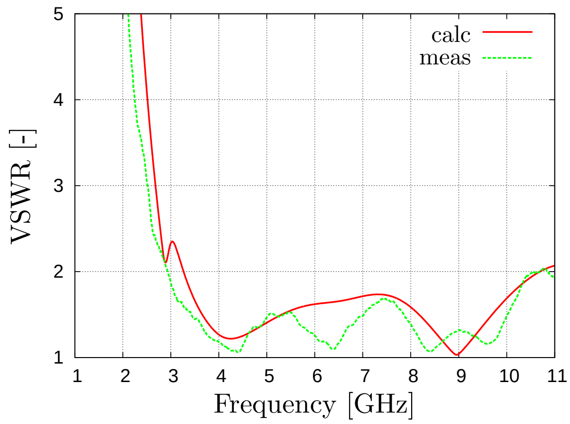

Figure 7: Input characteristics of antenna without filter.

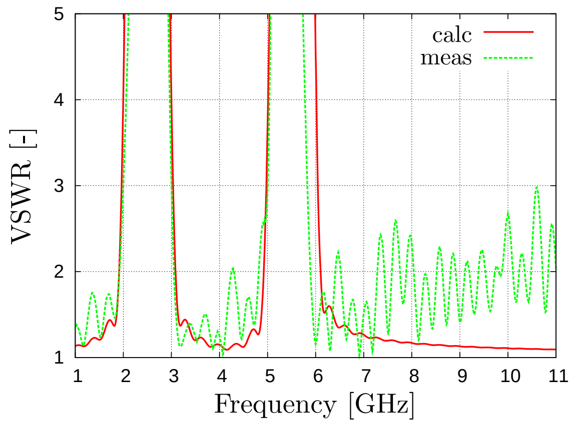

Figure 8: Input characteristics of individual filter.

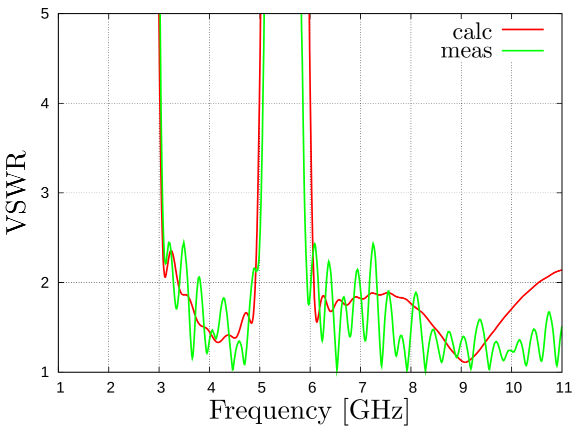

Figure 9: Input characteristics of antenna with filter.

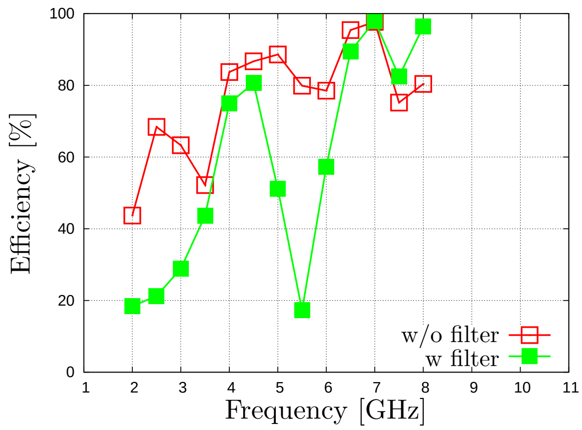

Figure 10: Radiation efficiency for antennas with and without filter.

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