Control of Radiation Pattern in UWB Antenna using an EBG Structure

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Abstract

This paper is devoted to a study on controlling radiation pattern in a UWB (Ultra Wide Band) antenna. The antenna is a U-shaped typical planer monopole type but it has a EBG (Electrical Band Gap) structure. This paper shows variation in radiation pattern with frequency and shows that the radiation pattern is kept almost same during the UWB band. As results, we can expect that this structure can avoid having the UWB pulse distorted by the frequency dependence.

1. INTRODUCTION

Since February 2002, UWB technology has been noticed as an attractive technology and many researchers have studied on devices, circuit ,antenna and etc. Antennas for UWB technology are also key devices and , at least, it should cover the UWB frequency from 3.1GHz to 10.6 GHz. In fact, many antennas covering the UWB band have been reported and recently have been supposed to be minimized for their applications [1][2]. At the same time, the UWB technology should be available for high-speed digital communication using UWB pulse signals that should not be distorted by the frequency dependence. For this purpose, antennas should avoid having frequency dependence in gain so that the antenna can have a good impulse response with minimum distortion in time domain[3].

Many papers have reported UWB antennas[1][2]. Some are compact UWB antennas and some have almost constant antenna gain in a certain azimuth with respect to frequency. However, it seems difficult to realize small size and constant gain at the same time. Apart from minimizing, some techniques to keep the gain constant should be required independently so that

As typical UWB antennas, various type of disk monopole antennas such as disk monopole, O-shaped , U-shaped and so on have been reported. In conventional U-shaped antenna, -10dB S_{11} is obtained during the UWB band from 3.1 to 10.6 GHz, however, the radiation pattern is changed as frequency increases. This results in variation of antenna gain at a fixed azimuth angle. This is due to the variation in current distribution with frequency. In the lower frequency, the current forms a sinusoid distribution of half wavelength. On the other, in higher frequency, several harmonic sinusoids of half-wavelength take place on the antenna causing additional nulls in the far-field radiation pattern. If the half wavelength sinusoid is kept one even in higher frequency, we can keep the pattern, i.e. directivity, constant.

As a technique to keep directivity constant, this paper presents a U-shaped UWB antenna with an EBG structure. Using the EBG structure, effective antenna length for frequency in the band gap can be limited so that limited sinusoid of current can exist on the antenna element. Mainly, the effect of the EBG structure on radiation pattern is discussed. The every data has been simulated by IE3D throughout this paper.

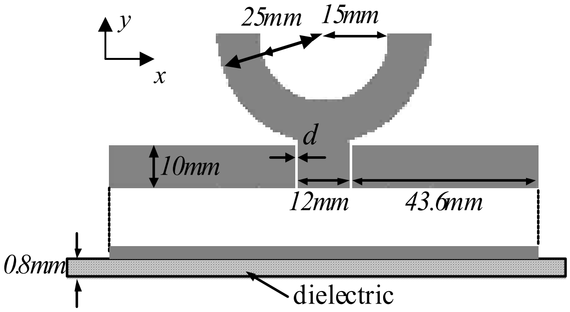


Fig. 1: U-shaped UWB antenna

2. U-SHAPED UWB ANTENNA

Figure 1 shows a typical U-shaped UWB antenna. The substrate is assumed as RT/Duroid 5880 (εr=2.2, tanδ=0.001) with thickness of 0.8 mm. The coordinate system is the same throughout this paper. This antenna is well matched with 50 Ω in the UWB band, as shown in fig. 2. Figure 3 shows current distributions at 3, 9, and

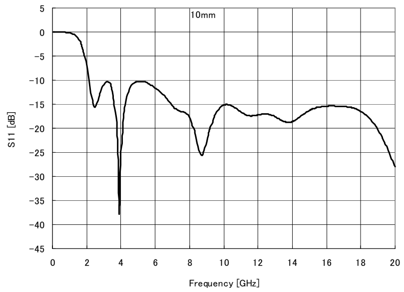
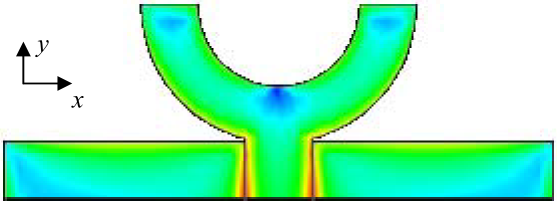
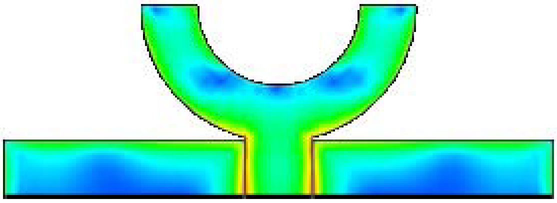


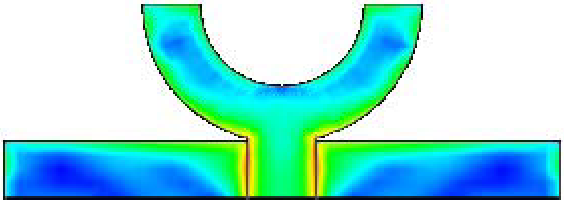
Fig. 2: S_{11} characteristics.



(a) 3 GHz

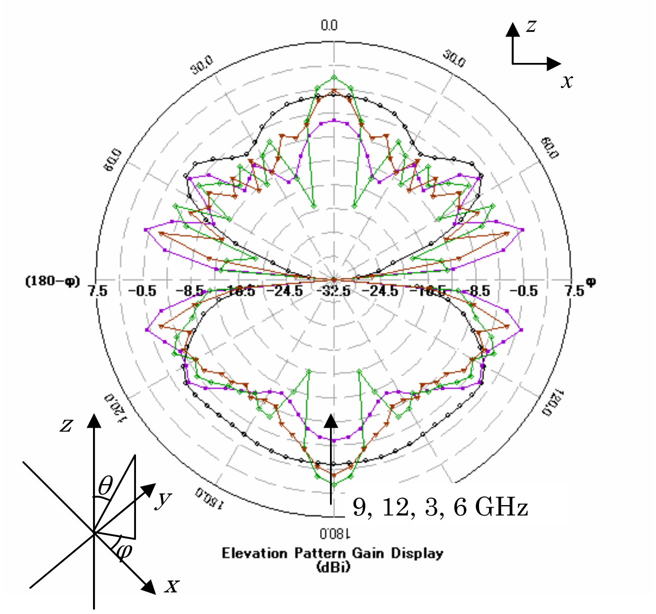


(b) 6 GHz

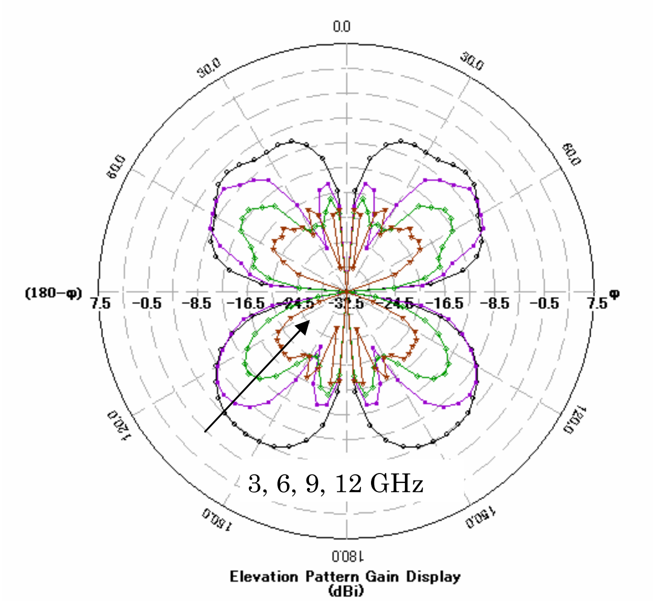


(c) 12 GHz

Fig. 2: Current distribution of the U-shaped UWB antenna



(a) E_{φ}



(b) E_{θ}

Fig. 3: Radiation pattern of the U-shaped UWB Antenna (φ= 0 degrees)

12 GHz. At 3 GHz, there is a sinusoidal distribution with almost half-wavelength in each arm of the U-shape. As the frequency increase, the number of sinusoids will increase, for example, there are 2 half-wavelength sinusoids at 6 GHz and there are 4 at 12 GHz in the figures.

Figure 3 shows the variation in radiation patterns with frequency of 3, 6, 9, 12 GHz. Large variation of more than 5 dB is shown at boresight (θ=0 degree) and other azimuth angles.

To keep the radiation pattern constant, the number of the sinusoid of current should be limited to one in each arm of the U-shape. In next section , this paper will report some trials to reduce this variation using EBG structure.

3. U-SHAPED UWB ANTENNA USING EBG STRUCTURE

Figure 4 shows the U-shaped UWB antenna with EBG structure. EBG has a stop band frequency according to their structure. Using this characteristics, the current on the antenna element can be stopped to flow at a certain place. This probably means that this structure works as a parallel RC resonator that is installed in series to the antenna element.

Figure 5 shows variation in current distribution as a function of frequency. From the fig. 5(d), we can find that the current is cut off at a certain place resulting in no existence at the tip of each U-shape arm. However, fig.5(a) - (c), the effect of the EBG on the current seems to be small.

Considering the above results, the effect of the EBG on the radiation pattern should be discussed. The radiation patterns at 3, 6, 9, 12 GHz are shown in fig. 6.

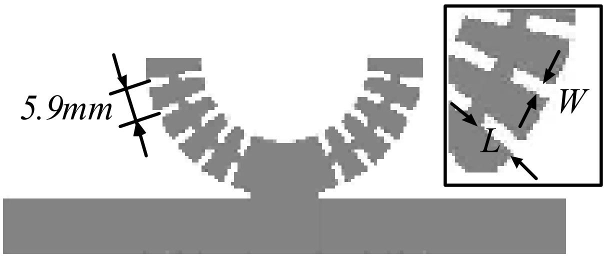
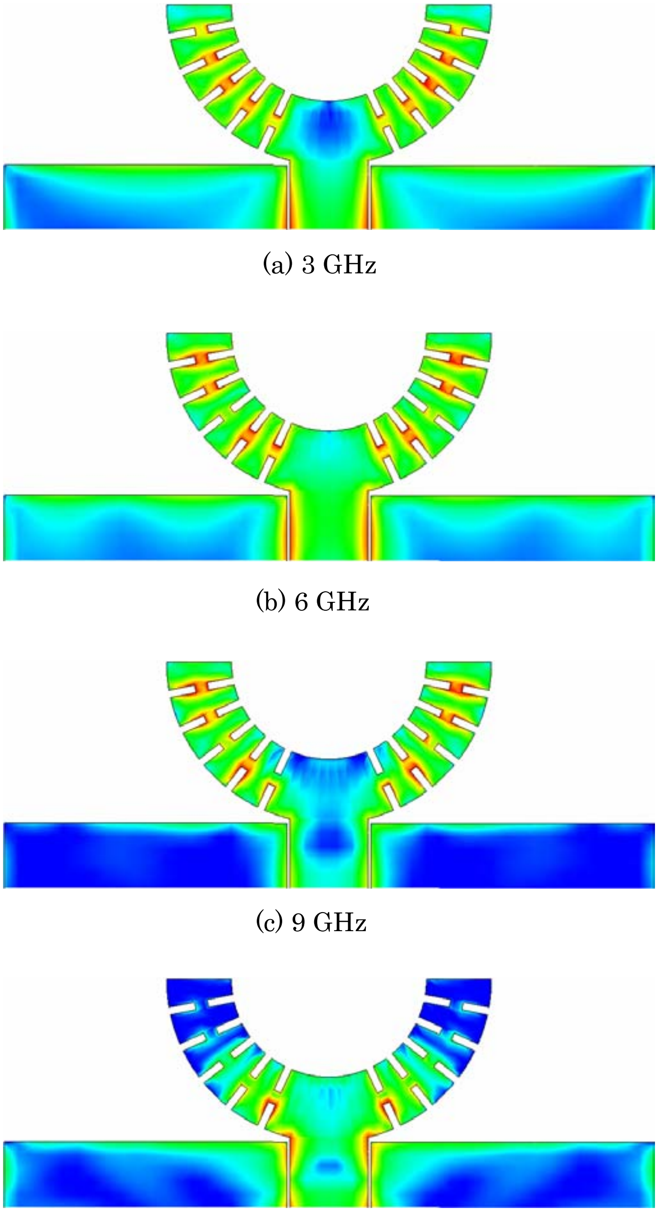


Fig. 4: U-shaped UWB antenna with EBG structure. (W=12 mm , L = 4 mm)



(a) 3 GHz

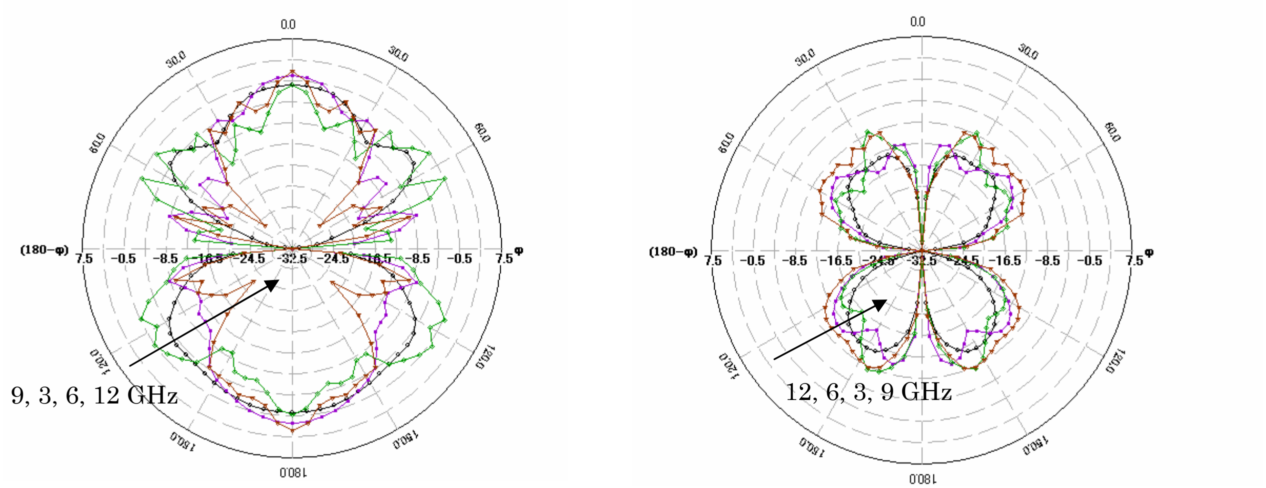
(b) 6 GHz

(c) 9 GHz

(d) 12 GHz

Fig. 5: Current distribution on the EBG antenna

According to the figures, variation of radiation pattern got smaller than that in fig. 3. In the boresight direction (θ=0 degree), the variation in gain is less than 3dB showing the effect of the EBG structure on the directivity.
In fig. 5, as far as we see the current distribution, the



(a) E_φ (b) E_θ

Fig. 6: Radiation pattern of the UWB antenna with EBG structure.(φ=0 degrees)

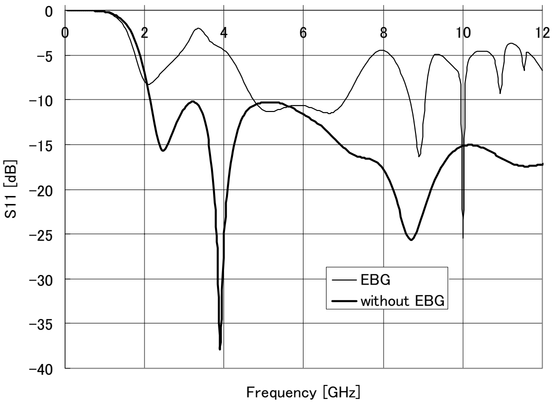


Fig. 7: Input impedance of the EBG antenna

effect of the EBG structure was unclear except that at 12 GHz, however, the variation of radiation pattern is obviously reduced. Especially, the gain in the boresight direction at 6GHz is increased by 5 dB, and those at 9 and 12 GHz are decreased by 2 and 3 dB, respectively. As a result, the variation in gain at the boresight direction less than 3dB is obtained .We can see the effect of the EBG structure.

The variation in gain is also due to the input matching. The S11 characteristics of the EBG antenna is not matched enough with 50 Ω at this moment as shown in fig. 7. This is an important problem to be solved.

4. CONCLUSION

This paper has presented an effect of EBG structure on the radiation pattern of a U-shaped UWB antenna. As for conventional U-shaped antenna, the gain in the boresight direction was changed by more than 3dB with respect to the frequency, however for the antenna with EBG structure, the variation of the gain has been reduced to 3 dB and less. This effect can contribute to avoid distorting the signal pulse. The input characteristics as to the EBG antenna should be improved in near future.

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