Time-Domain Signal Investigations of Notched VHDMA for UWB Communications

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***Abstract*—In this paper the signal transfer characteristics of VHDMA (Vertical Half Disc-Loaded Ultrawideband Monopole Antenna) and notched VHDMA in time-domain are investigated, analyzed, and optimized in terms of flat transfer function corresponding to elevation angle θ = 30˚, 60˚, and 90˚. A close relationship between signal distortion and signal fidelity are described. In addition, it is seen that the antenna optimization process results in an improvement of flatness of transfer function.**

***Keywords*-Ultrawideband (UWB), fidelity, notched characteristic**

I. INTRODUCTION

A considerable interest and effect are put into UWB technology since ultrawideband (3.1~10.6GHz, BW=7.5GHz) has been permitted to civilian works from military products. Hence, the UWB antenna and notched UWB antenna still have an attraction for many researchers[1]-[9]. Recently the time-domain performance analysis of UWB antenna is carried out by many researchers while the frequency-domain analysis is still important for antenna design[6]-[9]. Especially, since UWB communications transmit/receive the pulse signal without carrier frequency, the electrical performance of UWB transceiver is considerably dependent on the signal distortion. The distortion level of this signal is greatly related with the transfer function between input and output signals. In order to satisfy the linearity of transmitted signals, the flatness of the magnitude and the linear phase variation of transfer function are required.

In this paper, the signal distortion of VHDMA (Vertical Half Disc-Loaded Ultrawideband Monopole Antenna) for UWB communication is treated and the effects of flatness of transfer function on signal distortion through parametric studies will be focused on. Furthermore, two types of notched UWB antenna with rejection band (5.15~5.825 GHz, 675 MHz) are suggested and the transfer function of the notched UWB antenna with the best rejection level will be described.

II. TRANSFER FUNCTION CHARACTERISTICS OF VHDMA

Consider the VHDMA antenna composed of design parameters d = 6.25 mm, rp = 17 mm, rv = 17 mm, gh = 10 mm, and gl = 40mm as shown in Figure 1. In order to increase input impedance bandwidth and maintain total height of the antenna,

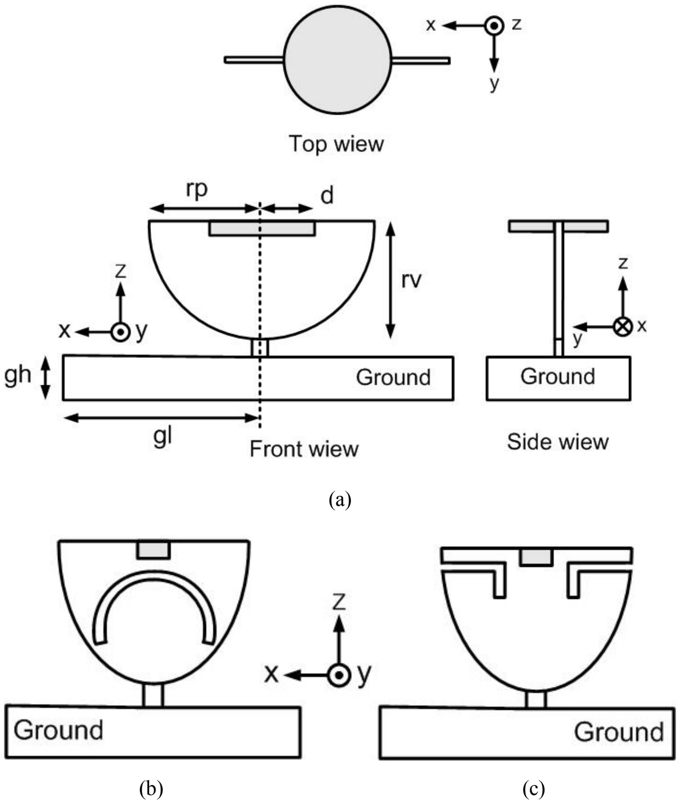
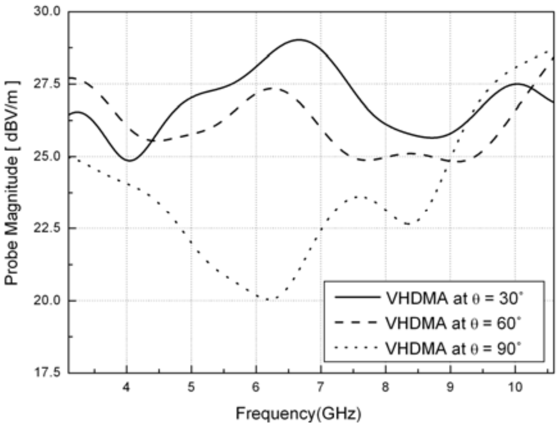


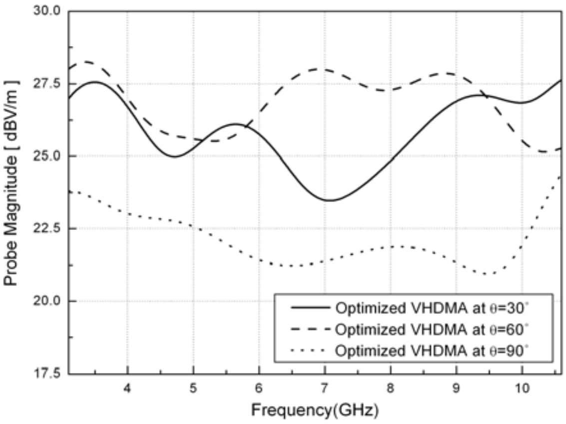
Figure 1. Antenna geometry (a) VHDMA (b) notched VHDMA with half ring slot (c) notched VHDMA with double slits

vertically loaded planar type of half-circular radiator is employed and horizontally small circular disc is loaded on the top-edged line[1].

The system transfer functions at radiation angle θ = 30˚, 60˚, and 90˚ are evaluated at 300 mm away from the center point of feeding structure using probe. It is emphasized for optimization that the magnitude of the transfer function should be flat over the interested frequency bands and phase variation of the transfer function should be linearized. The optimization process has been carried out over the UWB band in terms of input impedance bandwidth by changing design parameters, d, rp, gh, and gl. As an optimized result, optimized antenna



(a)



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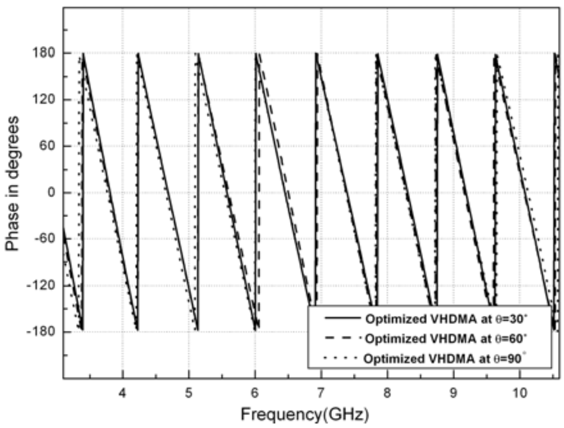


(c)

Figure 2. (a) The magnitude of transfer function of VHDMA without optimization according to receiving angle (b) The magnitude of transfer function of the optimized VHDMA according to receiving angle (c) The phase variation of transfer function of the optimized VHDMA according to receiving angle

corresponding to three radiation angles have been obtained and listed in Table I. Figure 2(a) and (b) show the flatness of the transfer function of VHDMA with/without optimization process. In addition to that, Figure 2(c) describes the phase linearity characteristics of the optimized VHDMA. It is recognized from Figure 2 that the optimized structure results in

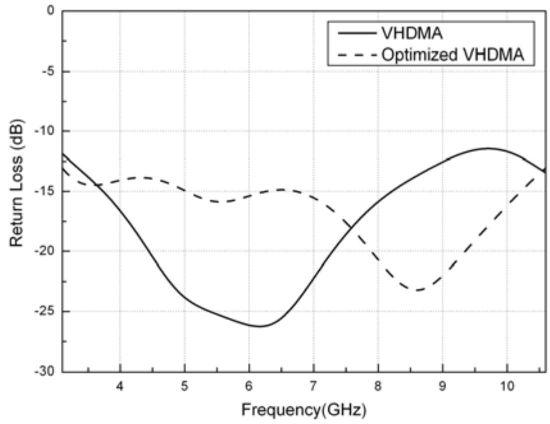


Figure 3. The return losses of VHDMA and optimized VHDMA

TABLE I. DEVIATION OF AMPLITUDE OF TRANSFER FUNCTION

	θ = 30˚	*θ = 60˚*	*θ = 90˚*
VHDMA	4.16 dBV/m	3.61 dBV/m	8.67 dBV/m
Optimized VHDMA	4.16 dBV/m	3.13 dBV/m	3.45 dBV/m

TABLE II. FIDELITY OF OPTIMIZED VHDMA

	Fidelity		
	θ = 30˚	*θ = 60˚*	*θ = 90˚*
VHDMA	0.961	0.917	0.847
Optimized VHDMA	0.904	0.959	0.894

the small fluctuation in magnitude of the transfer function and good phase linearity.

The main goal of the optimized process is to accomplish the improvement of fidelity of transferred signal and the compactness of UWB antenna. As a result of parametric study using d, rp, gh, and gl shown in Figure 1(a), the return losses according to d = 1.5 mm, rp = 12 mm, gh = 2 mm, and gl = 38 mm have been obtained in Figure 3 by considering the variation of the magnitude and phase of transfer function. The variation of the magnitude of transfer function according to elevation angles are listed in Table I when the optimized parameters are used. It is seen from Table I that the flatness of transfer function of optimized VHDMA has been achieved with the reduction of 0.48 dB and 5.22 dB at θ = 60˚ and θ = 90˚, respectively.

As a key performance in UWB communications, the fidelity describing the amount of transferred signal distortion should be specified. Especially the magnitude of fidelity is dependent on the cross-correlation between transmitted and received signals and normalized to the product of energy of two signals, resulting in the range from 0 to 1[10]. Fidelity equal to 1 represents no signal distortion through material propagation so that the received signal can be perfectly received in ideal situation. Table II depicts that the fidelities of the optimized VHDMA at elevation angles (θ = 60˚ and 90˚) have been improved with a little performance degradation at θ = 30˚.

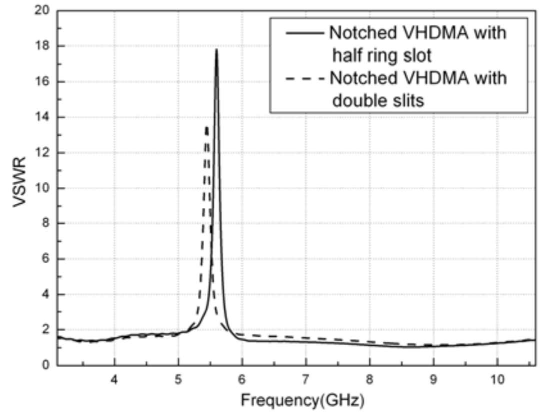
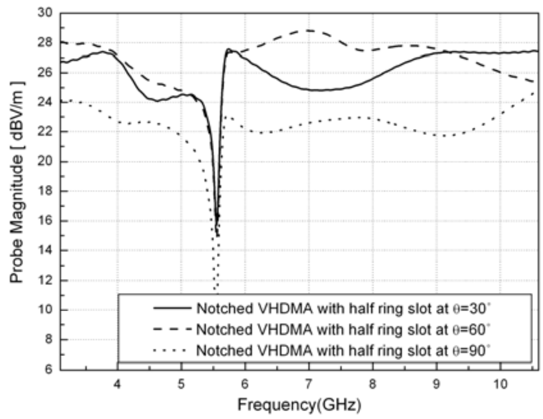
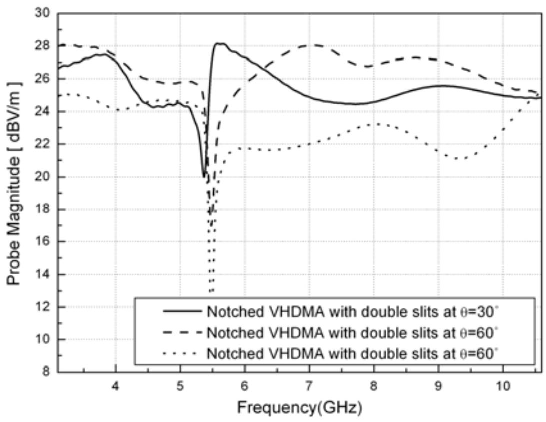


Figure 4. VSWRs of notched VHDMA



(a)

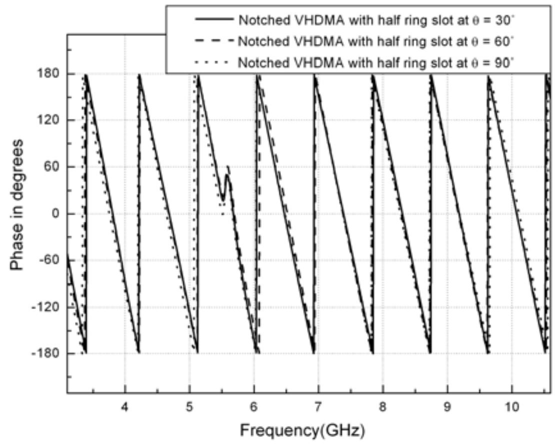


(b)

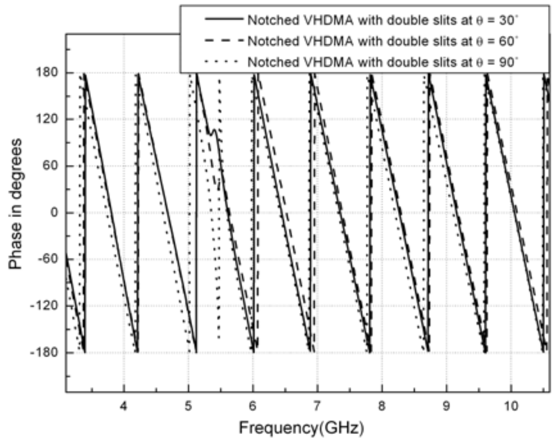
Figure 5. Received electric field strength of (a) notched VHDMA with half ring slot (b) notched VHDMA with double slits

III. TRNASFER FUNCTION CHARACTERISTICS OF NOTCHED VHDMA

The transmitted/received power in UWB communications must be considered to protect the interference phenomena with other communication systems. In this paper, two notched VHDMA with band rejection characteristics in a specific frequency are proposed in Figure 1(b) and (c) to protect the interference with WLAN (5.15~5.825 GHz, BW = 675 MHz) and compared with each other. The widths of half ring slot and double slits are assumed to be 0.5 mm for simulation. The slot is composed of radius 6.9 mm and symmetric structure to the z-axis with rotation angle 220˚. The distance between slot and feeding point determines the bandwidth of band rejection characteristics whereas the notch frequency is under the control of the radius and rotation angle of half ring slot. In addition, in case of slits, the rejection frequency is controlled by the distance between the horizontal and vertical length of slits and feeding point while the bandwidth is dependent on the slit width. From Figure 4 showing VSWR of notched VHDMA, it is observed that in two cases of notched VHDMA with slot and slits, the rejection bands amount to 5.19~5.8 GHz occupying



(a)



(b)

Figure 6. Phase non-linearity characteristics at rejection band (a) Notched VHDMA with half ring slot (b) Notched VHDMA with double slits

TABLE III. FIDELITY OF NOTCHED VHDMA

	Fidelity		
	$\theta = 30^\circ$	$\theta = 60^\circ$	$\theta = 90^\circ$
Notched VHDMA with half ring slot	0.916	0.946	0.908
Notched VHDMA with double slits	0.932	0.940	0.854

BW = 610 MHz and 5.16~5.75 GHz occupying BW = 590 MHz, respectively. In a similar way to section II, signal transfer characteristics of two notched VHDMA are investigated. Figure 5(a) and (b) describe the deviation from flatness of magnitude of transfer function at three elevation angles in two notched VHDMA. As expected, the magnitude of transfer function within rejection band reduces considerably and the detected power at probing port is very small. In phase-linearity point of view, it is seen from Figure 6 that phase non-linearity characteristics occur at rejection band, resulting in group delay and signal distortion. Finally, Table III represents the fidelity of notched VHDMA according to three elevation angles. In a notched VHDMA using half ring slot, fidelities at three angles are more than 0.9, giving a good signal transfer characteristics while in a notched VHDMA using double slits, fidelities are mostly more than 0.9 except at $\theta = 90^{\circ}$. The reason of good fidelities is thought that the variation of transfer function is within 4 dB except at rejection band.

IV. CONCLUSION

The signal transfer characteristics of VHDMA with/without band rejection in UWB communications are investigated by employing the magnitude and phase characteristics of transfer function and fidelity. By carrying out parametric studies to transfer the input signal without distortion as well as considering the return loss, the flatness of the magnitude of transfer function, and phase linearity, it is seen that the fidelity of the proposed antenna has been improved and a reduction of signal distortion has been accomplished. Furthermore, notched VHDMA employing slot and slits on radiator to protect the interference with WLAN has been proposed and studied. As a result, it is observed that notched and optimized VHDMA gives a good fidelity characteristic and sharp rejection performance.

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