Study of Antenna Effect on UWB Pulse Shape in Transmission and Reception

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Abstract

This paper presents antenna effect on UWB pulse shape in transmission and reception. This study discusses different combination of transmitting and receiving antennas for pulse radiation and reception. Different Gaussian pulse excitations are considered and measured received pulses are compared with theoretical Gaussian pulses.

1. INTRODUCTION

Ultra-Wideband (UWB) technology started in 1960 as a time-domain study of electromagnetic wave propagation [1]. It finds application in low-probability radar and in data communications. The UWB antenna design and analysis require an extension of conventional antenna theory from steady state to transient conditions. Radiation of UWB short pulse is different from narrowband signal [2]. M. Kanda et al. [3] have showed that the transmitting transient response of an antenna is proportional to the time derivative of the receiving transient response of the same antenna. Therefore, the response of a UWB antenna in receiving and transmitting mode is different, integration and differentiation depending on mode of the antenna.

Most frequently used UWB antennas are monopoles, dipoles, ridge horns, TEM horns, vivaldi antennas, disc cone and bicones. The radiation characteristics of an antenna depend on the radiating aperture of the antenna. Unlike narrow band antennas, the transmitting and receiving characteristics (e.g. gain) of an antenna for UWB short pulse radiation are different. Many of the UWB applications need the prior knowledge of the receiving pulse shape and few applications demand for same transmitted and received pulse shapes.

Generally UWB antennas differentiate the input pulse in transmitting mode and receive the incident pulse as it is. Very few UWB antennas (e.g. biconical) transmit the input pulse as it is and integrate the received pulse in receiving mode. Few UWB applications need proper combination of transmitting and receiving antennas to receive the intended transmitted pulse without differentiation or integration. This study presents the transmitting and receiving pulse characteristics of different UWB antennas.

2. GENERATION OF DIFFERENT GAUSSIAN PULSES

Gaussian pulse and its derivatives are frequently used UWB pulses for various applications. Different Gaussian pulses have been generated by sending a step pulse through various differentiating circuits (high pass filters). To generate an approximate Gaussian pulse, a positive step of peak amplitude 10 V and a rise time 45 ps has been sent through a high pass filter circuit. By sending this Gaussian pulse through subsequent differentiators, first and second derivative Gaussian pulses have been generated.

A. Gaussian Pulse

Mathematical representation of the Gaussian pulse is

$$S(t) = \exp\left[-\left(t/\tau\right)^2\right]. \tag{1}$$

Fig. 1 compares the theoretical and generated Gaussian pulses for τ = 36 ps. It is very difficult to generate the Gaussian pulses without distortion. Generally short pulses are associated with ringing.

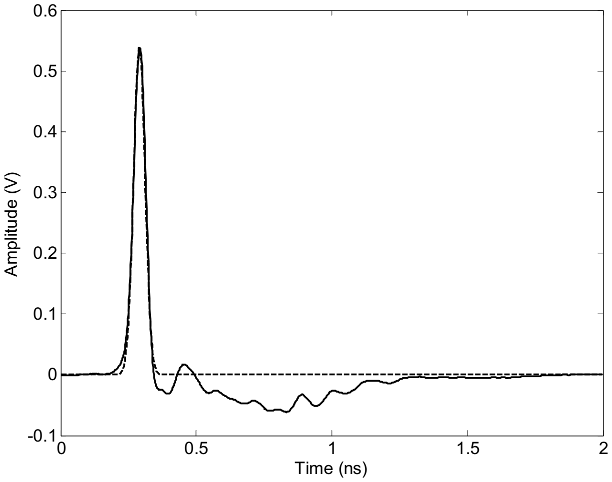

Fig. 1. Plot of theoretical (dash) and generated (line) Gaussian pulse.

B. First Derivative Gaussian Pulse

First derivative Gaussian pulse can be represented as

$$S(t) = -\left(2t/\tau^2\right)\exp\left[-\left(t/\tau\right)^2\right]. \qquad (2)$$

Fig. 2 compares the theoretical and measured first derivative Gaussian pulse for $\tau = 40$ ps.

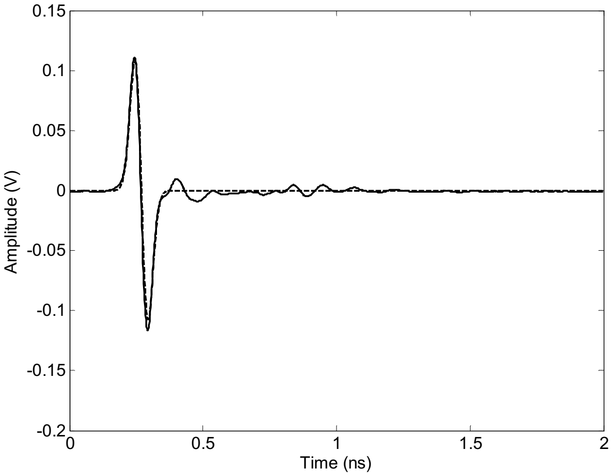

Fig. 2. Plot of theoretical (dash) and generated (line) first derivative Gaussian pulse.

C. Second Derivative Gaussian Pulse

Second derivative Gaussian pulse can be represented as

$$S(t) = 2/\tau^2\left(2t/\tau^2 - 1\right)\exp\left[-\left(t/\tau\right)^2\right]. \qquad (2)$$

Theoretical and measured second derivative Gaussian pulse is compared in fig. 3 for $\tau = 45$ ps.

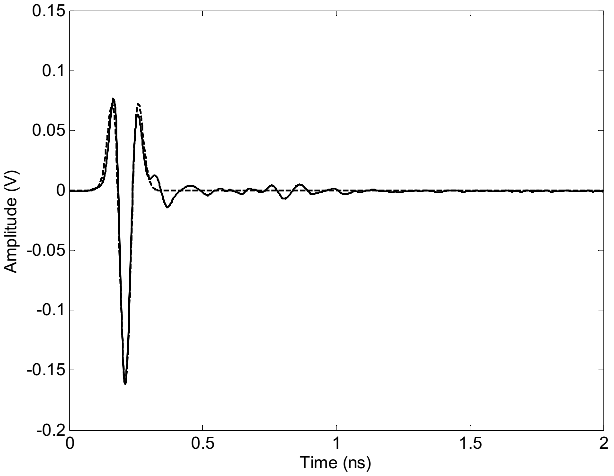

Fig. 3. Plot of theoretical (dash) and generated (line) second derivative Gaussian pulse.

3. Antenna Effect on Pulse Radiation and Reception

A. Case I

Here we show a case study of received pulse for the case of TEM-horn as a transmitting antenna and ridged-horn as a receiving antenna. Fig. 4, fig. 5 and fig. 6 show the received pulse for Gaussian pulse, first derivative Gaussian pulse and second derivative Gaussian pulse excitations respectively. The received pulses are the derivative of their respective input pulses.

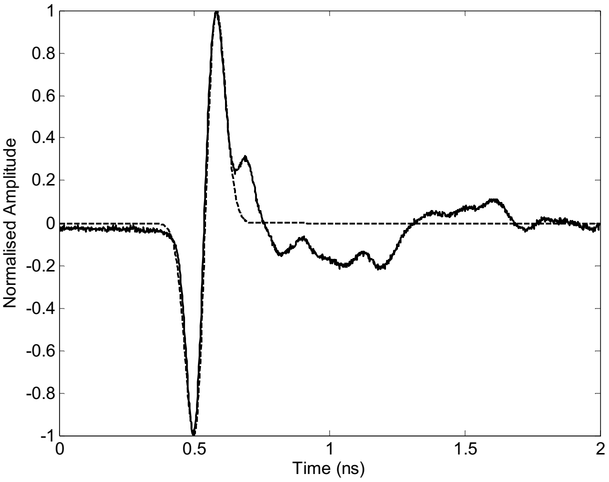

Fig. 4. Received pulse for the case of TEM-horn as transmitting antenna and ridged-horn as receiving antenna for Gaussian pulse (line) excitation compared with first derivative Gaussian pulse (dash)

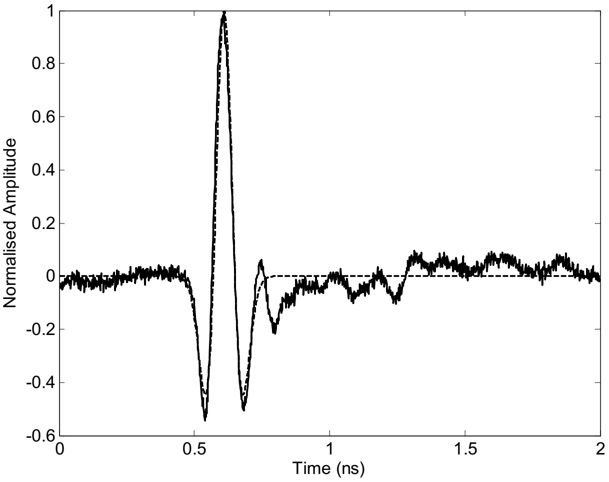

Fig. 5. Received pulse for the case of TEM-horn as transmitting antenna and ridged-horn as receiving antenna for first derivative Gaussian pulse excitation (line) compared with second derivative Gaussian pulse (dash)

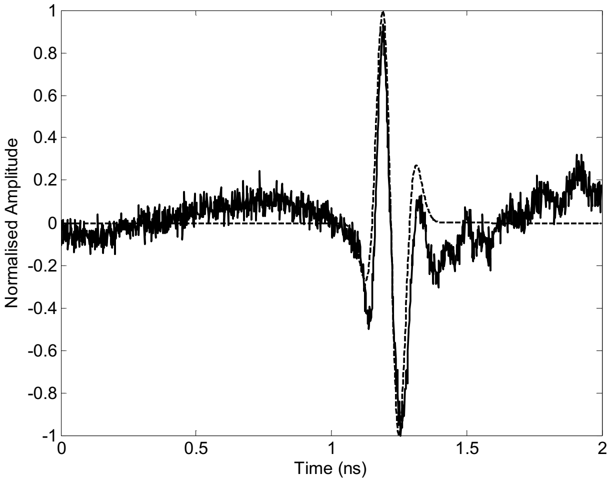

Fig. 6. Received pulse for the case of TEM-horn as transmitting antenna and ridged-horn as receiving antenna for second derivative Gaussian pulse excitation (line) compared with third derivative Gaussian pulse (dash)

B. Case II

Here we present a particular combination of transmitting and receiving antennas to receive the transmitted pulse as it is (no differentiation or integration). Fig. 7 shows the received pulse, received by a bi-conical antenna for first derivative Gaussian pulse excitation of ridged-horn transmitting antenna. Fig. 8 shows the received pulse by a ridged-horn antenna for the case of first derivative Gaussian pulse excitation of bi-conical transmitting antenna. In both cases, the received pulse is first derivative Gaussian pulse with some distortion. Therefore, this combination of antennas provides the received pulse similar to the input pulse.

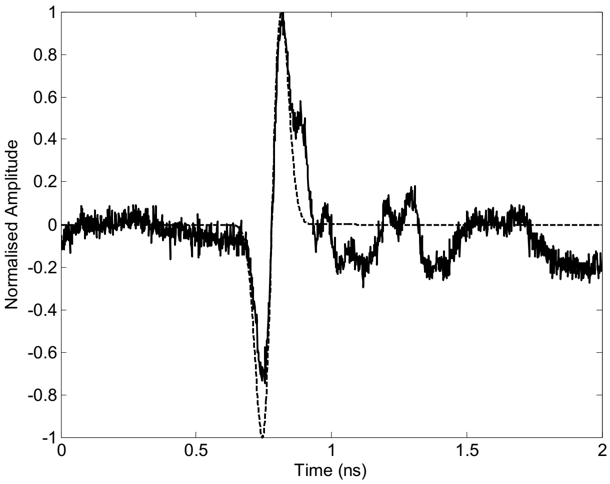

Fig. 7. Received pulse for the case of ridged-horn as transmitting antenna and biconical antenna as receiving antenna for first derivative Gaussian pulse excitation (line) compared with first derivative Gaussian pulse (dash)

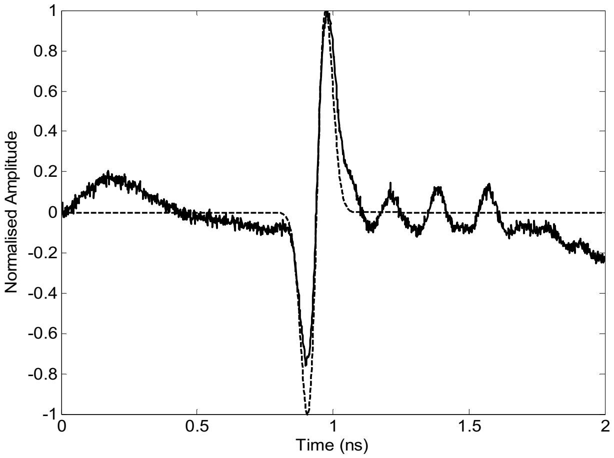

Fig. 8. Received pulse for the case of biconical antenna as transmitting antenna and ridged-horn as receiving antenna for first derivative Gaussian pulse excitation (line) compared with first derivative Gaussian pulse (dash)

C. Case III

Here we show the received pulse, as shown in fig.9, received by a bi-conical antenna for second derivative Gaussian excitation of a bi-conical transmitting antenna. The received pulse is an integral of the excited pulse.

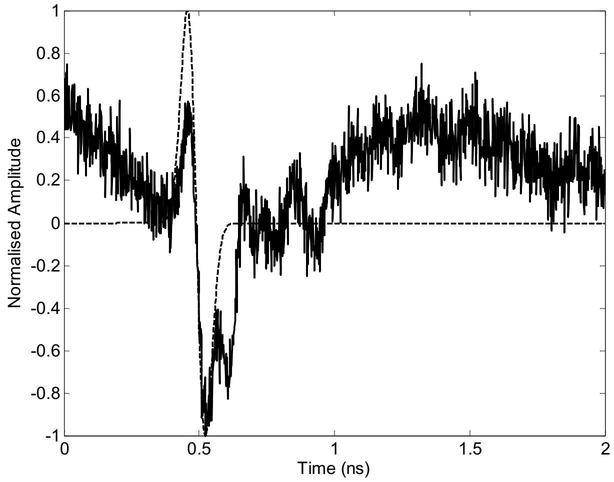

Fig. 9. Received pulse for the case of biconical antenna as transmitting antenna and biconical antenna as receiving antenna for second derivative Gaussian pulse excitation (line) compared with first derivative Gaussian pulse (dash)

The relation between input and received pulse for various transmitting and receiving antennas has been shown in table-I.

TABLE I
THE RELATIONSHIP BETWEEN INPUT AND RECEIVED PULSE FOR VARIOUS TRANSMITTED AND RECEIVED ANTENNAS

Transmitting Antennas	Receiving Antennas				
	RDH	VVD	TEM	DSC	BCN
RDH	diff.	diff.	diff.	diff.	same
VVD	diff.	diff.	diff.	diff.	same
TEM	diff.	diff.	diff.	diff.	same
DSC	diff.	diff.	diff.	diff.	same
BCN	same	same	same	same	int.

Legend:
RDH = Ridged-Horn antenna
VVD = Vivaldi antenna
TEM = TEM-Horn antenna
DSC = Disc-Cone antenna
BCN = Biconical antenna

diff. = received signal is the differentiation of input signal
same = received signal is the same as input signal
int. = received signal is the integration of input signal

4. CONCLUSION

This study and measurements show the antenna effect on pulse while in transmission and reception. A combination of transmitting and receiving antenna has been shown for receiving the pulse without differentiation or integration of the input pulse. The relationship between input and received pulse for various transmitted and received antennas has been studied.

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