Application of Half Impulse Radiating Antenna (HIRA) for Discrimination of Canonical Scatterers

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Abstract

Radiation of base band impulse like signal has open up many research area in the field of high resolution UWB radars. Reflector based impulse radiating antennas (IRAs) are commonly designed for 200Ω input impedance. The half impulse radiating antenna(HIRA) designed with half reflector, ground plane and two feed arms has input impedance of 100Ω needs an impedance adaptor to connect to standard single ended 50Ω voltage source. A new 50Ω HIRA is designed and developed and used to measure transient response of various canonical scatterers. The resonance based E-pulse method is used to discriminate various scatterers. Auto-regressive (AR) based E-pulse method is used for the automated target discrimination.

Keywords: *IRA,HIRA, SEM, E-Pulse, AR.*

I. Introduction

Time domain response obtained from different scatters can be used for target discrimination using singularity expansion method (SEM). Advent of antennas capable of radiating baseband fast pulse signal has open up the area of research related to target discrimination using time domain response of scatterers. The reflector based impulse radiating antenna popularly known as IRAs are know for their UWB and pulse fidelity properties[1-3].The commonly used IRAs have 200Ω input impedance, needs 50Ω-200Ω balun to connect to 50Ω standard instrumentations[1-3]. The new half impulse radiating antenna design offers 50Ω input impedance and can be readily connected to standard single ended source[12].The time domain measurement setup using this HIRA is used to collect transient response of various scatterers for discrimination process. The natural frequency based UWB radar target discrimination schemes using time domain analysis have generated considerable interest in the past. The most frequently used technique, called E-pulse scheme [4] can be realized in time domain, which uses the impulse response of target without converting to frequency domain. The time-domain scattered field response of a conducting target is composed of an early time forced period followed by a late time period [4]. The late time response contains free oscillations defined by the natural frequencies of the target [5].

Discrimination is accomplished by the convolution of E-pulse with the late-time scattered field response of the target. For an anticipated target the convolved response will have an interpreted portion of the expected natural mode spectrum else it will result in an unexpected convolved response [4]. The natural frequency of the target is known a priori or can be estimated by measurements. This is the intermediate step in the generation of E-pulse by the conventional method, which is in the frequency domain and is very sensitive to the noise in the measurements. The information about starting of late time needs target dimension and distance from the antenna, which defeats its wide application for real time applications. Auto-regressive (AR) based approach [5] used in this paper to discriminate realistic scatters based on their time domain response obtained using FDTD simulation as well as measurement. AR method iteratively find the starting of late time from target time domain response without knowledge of target dimension, hence it offers very good alternative to E-pulse technique for automating the target discrimination process.

Section II of this paper presents design and analysis of HIRA. The AR based E-pulse method is discussed in Section III. Target discrimination process and discrimination of various target is presented in Section IV. Conclusion is presented in Section V.

II. HIRA DESIGN AND ANALYSIS

The time domain target response of different scatterers is collected directly in time domain using reflector-based impulse radiating antenna. The conventional Impulse Radiating Antennas had been designed for 200 Ω input impedance wherein the conical plate transmission line feed used is of 400 Ω characteristic impedance. Typically, in an IRA,two 400 Ω conical plate lines are connected in parallel at the feed point to get 200Ω input impedance. The reason for choosing a 400 Ω line is to get a smaller cone angle for the transmission line thereby reducing the aperture blockage and, in turn, achieving a better antenna gain. The input impedance of this antenna is reduced to 100 Ω by using half reflector, ground plane and two feed arms known as half impulse radiating antenna (HIRA) shown in Fig. 1.The conventional HIRA as shown in Fig.1. needs an 50Ω to 100Ω impedance adaptor for connecting it with standard 50Ω waveform generators. The new HIRA is designed (Fig.2) with asymptotic conical dipole (ACD) feed [12] to get nearly 50Ω input impedance without any compromise in gain and time domain performance.

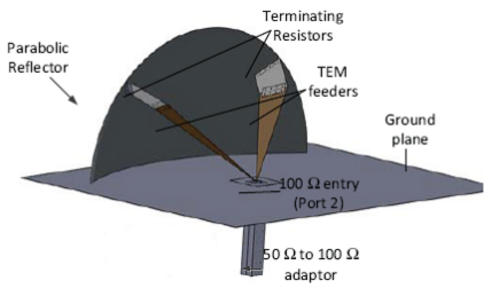

Figure 1: CONVENTIONAL HIRA

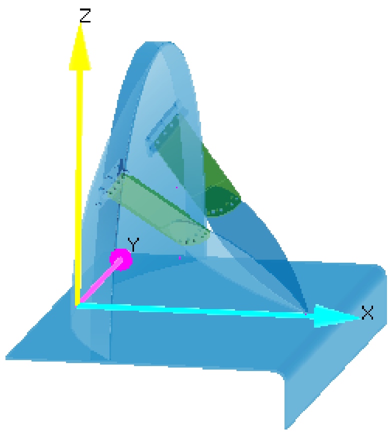

Figure 2: NEW HIRA

The new HIRA was analyzed using finite difference time domain (FDTD) method. A gaussian pulse of 50ps full width half maximum (FWHM), 50ps rise time and 0.56 volts peak amplitude as shown in Fig.3 is used as excitation for simulation. An absorbing boundary condition with seven perfectly matched layers (PML) is used for this simulation. The calculated far zone electric field at the bore sight of the antenna is first time derivative of the excitation signal is shown in Fig.4.It also consists of prepulse of duration 1.2ns and post pulse as expected from these antennas.

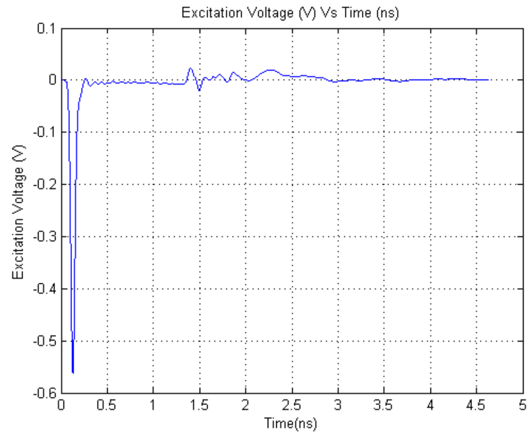

Figure 3:Solid model of Hybrid Bow tie Antenna

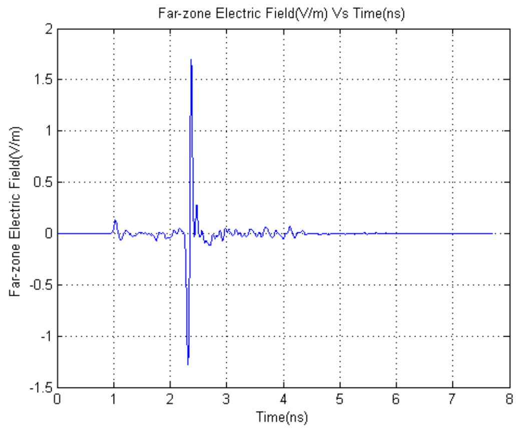

Figure 4 : FAR ZONE ELECTRIC FIELD (V/M) VS TIME (NS)

III. AUTO-REGRESSIVE (AR) METHOD

Auto-regressive (AR) filter approach to generate E-pulse is helps in estimating beginning of late-time without the knowledge of dimensions of the various targets. It does not require the calculation of natural frequencies as an intermediate step and is comparatively less sensitive to noise [2]. The late-time scattered response of a target can be re-written as:

$$c(t) = e(t) * r(t) = 0 \quad , \; t > T_L = T_l + T_e \qquad (1)$$

where, Te is the duration of e(t) and r(t) is the response of target from any aspect angle.

To achieve target discrimination, the response from unknown target is convolved with each of the E-pulses in a database. The convolution, which is closest to zero, identifies the target. The convolution in discredited form can be written as:

$$r_k + e_1 r_{k-1} + e_2 r_{k-2} + \cdots + e_n r_{k-n} = 0 \quad , \quad \sum_{i=0}^{n} e_i . r_{k-i} = 0 \qquad (2)$$

The above equation can be multiplied with r_k to get n linear equations. Thus we assume the model of target response in the form (2). On combining the n linear equations, we get the auto-regressive(AR)equation [5],

$$y_k + e_1 y_{k-1} + e_2 y_{k-2} + \cdots + e_n y_{k-n} = 0$$

$$\sum_{i=0}^{n} e_i . y_{k-i} = 0 \qquad (3)$$

where, $e_0=1$

This is equivalent to a convolution sum and is equal to zero. Therefore the vector [e_n e_n …………… 1] represents the discretized E-pulse. By solving the auto-regressive (AR) equation using the the Yule-Walker algorithm [8], the AR coefficients will directly give the E-pulse. In summary, AR parameters are estimated successively for each response by starting from the end of the response and adding more and more data points to the data set being analyzed. The estimated AR parameters are compared to each other when a change between two successive sets is observed the beginning of the late time part is identified.

IV. TARGET DISCRIMINATION PROCESS

The time domain measurement setup was made using newly developed HIRA as shown in Fig.5. The scattered time domain response of some of the realistic items readily available in laboratory like a horn antenna, a CPU, Cylinder and a monopole was used as targets obtained from time domain measurement. Once the time domain response is obtained, the late time scattered field response of the unknown target is convolved with each of the E-Pulse waveform e_i in the E-pulse library. The convolved outputs

$$c_i(t) = e_i(t) * r_{target}(t) , 1 \le i \le I \qquad (4)$$

Where, *I* is the number of models stored in the library, are observed and the one, which is nearest to zero in the late time, the object corresponding to the E-Pulse is considered to be the anticipated target. E-Pulse discrimination number (EDN) provides a measure of this (nearest to zero convolved output). EDN, defined as the ratio of energy level of the convolution in the late time to that of the E-Pulse, is introduced to quantify the convolution result. The target is identified as the one associated with the smallest EDN value [10].

$$EDN = \frac{\int_{T_L}^{T_L+W} c^2(t)dt}{\int_{T_L}^{T_L+W} e^2(t)dt} \qquad (5)$$

The choice of window duration W depends on the duration of target response. The numerator of EDN corresponds to energy level of convolution integral and the denominator is the energy level of E-pulse. Since the energy level of E-pulse directly affects the energy level of convolution, normalizing the convolution according to E-pulse convolution makes it a measure for E-pulse performance. Maximum the AR filter order, more the difference in EDN and better the EDR. Practically, EDN factor for an unspecified target and its corresponding E-pulse function is calculated and is taken as reference.

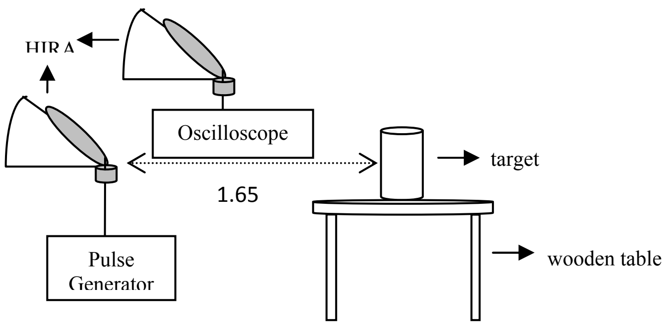

Figure 5: Time Domain Measurement Setup

The EDN is calculated from the convolved response of incoming target response with the E-pulse of various scatters stored in the library. The EDN values for the various scatterers are shown in the table1.1.The table shows that the EDN value for the expected target is minimum, hence discrimination is done.

Table 1.1: EDN (dB) of various Scatterers

Object	Cylinder	CPU	Horn	Monopole
Cylinder	-27.0977	-25.9701	-24.8967	-25.6153
CPU	-24.8638	-27.3233	-25.1189	-25.029
Horn antenna	-26.4248	-26.5023	-28.1641	-26.7866
Monopole	-26.467	-26.457	-26.5598	-27.9635

V. CONCLUSION

The newly developed HIRA can be readily used to get directly the time domain response of various scatterers.AR method does not need a priori knowledge of the dimension of targets for getting start of late. It generates the E-pulse directly without the extraction of natural poles and with a lesser number of assumptions as compared to the traditional approach.AR method is applied to discriminate realistic targets from their time domain response obtained from time domain measurement.

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Dhiraj Kumar Singh was born in Dhanbad, India, in 1977.He received the B.E degree in electronics and communication engineering from the Magadh University in 2001 and M.Tech degree in Microwave engineering from Banaras Hindu University (BHU) in 2003. He joined EMI-EMC group of Electronics & Radar Development establishment in 2003. His research mainly devoted to EMC problems in Radar systems, Ultra wideband antennas and time domain characteristics of antennas.