Target Discrimination based on E-pulse for Similar Sticklike Targets

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Abstract. - In this paper, we will show the results for target discrimination of similar sticklike targets using E-pulse technique. The complex natural resonance (CNR) frequencies can be used for radar target recognition. By SEM (singularity expansion method), the late-time measured response of a conducting radar target can be represented as a sum of natural resonance modes. An extinction-pulse (E-pulse) waveform is a finite duration waveform which extinguishes a pre-specified portion of the target's late-time response. The simulation results show that the extracted resonance frequencies from the sticklike targets are well separated in the s-domain and the E-pulse technique can efficiently discriminate similar stick-like targets .

Keywords: complex natural resonance frequency, late-time response, target discrimination

1 Introduction

It is well known that the late-time transient response of radar targets can be represented as follows [1]:

$$r(t)=\sum_{n=1}^{N} a_n e^{\sigma_n t}\cos(\hat{\omega}_n t+\phi_n),\quad T_L<t<T_F \qquad (1)$$

where $s_n=\hat{\sigma}_n+j\hat{\omega}_n$ is the nth mode natural frequency, $\hat{a}_n$ and $\hat{\phi}_n$ are the amplitude and phase of nth mode, T_L and T_F represents the beginning and end time of the late-time period and N is the number of modes in the late-time response. For a discrimination of radar target based on natural resonances, the accurate estimation of natural frequencies (s_n) from a measured response is very important. There have been many methods for this purpose, such as Prony's method [2], the pencil-of-functions (POF) method [3] and the E-pulse (Extinction-pulse) technique [4].

A good resonance frequency extraction method requires to be computationally efficient, automatically operated, insensitive to random noise, and to the estimation of model order (number of modes). Prony's method meets the first and second requirements and E-pulse technique meets the third requirements.

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Rothwell and Chen proposed a E-pulse/least square technique for natural resonance extraction which meets all three requirements [5]. Therefore, we use the hybrid E-pulse/least square technique for the natural resonance extraction in this paper.

The E-pulse technique is a radar target discrimination scheme which utilizes the natural resonance mode of conducting scatterers. It is also a transient finite duration waveform which eliminates the contribution of a certain number of the natural resonances of the target. Since the target's resonance frequencies are aspect independent, the E-pulse will eliminate the desired natural response of the late-time scattered filed regardless of the target orientation.

In this work, we will extract the natural resonance frequencies from the scattered responses of the similar stick-like targets. Then, the E-pulse synthesized using the extracted resonances is applied to the target discrimination of three similar sticklike targets.

2 Target Discrimination Using E-pulse Technique

An E-pulse $e(t)$ is a real-valued waveform of finite extent T_e that upon convolution with $r(t)$ eliminates a preselected component of the exponential series. Therefore, the entire series can be eliminated, resulting in [5]

$$c(t) = e(t)*r(t) = \int_0^{T_e} e(\tau)r(t-\tau)d\tau = 0, \quad T_L + T_e < t < T_F \tag{2}$$

The overall process for E-pulse based target discrimination is shown in Fig. 1. The first step for the discrimination technique is a generation of E-pulses which are unique for each target and stored in a database. Then, an impulse-like waveform is transmitted and the received transient response $r(t)$ is convolved with all the E-pulses stored in the database during the discrimination process. The convolved output $c(t)$ is investigated for zero (or near zero) in the late-time region. The unknown target is then classified consistent with the target whose E-pulse gave the zero signal in the convolved output $c(t)$. Therefore, we can discriminate a certain target against the other targets whose E-pulses are generated and stored in the database.

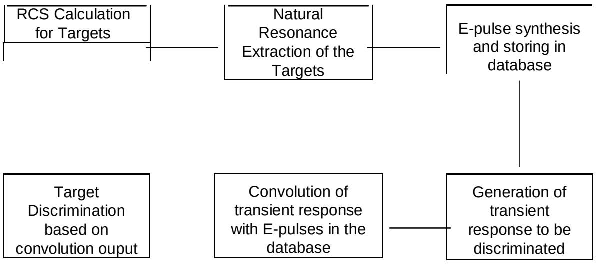

Fig. 1. Process for E-pulse based target discrimination

In the previous research [6], this E-pulse based target discrimination has been used in classifying a full-scale model of MiG-29 against another with missiles attached below the wings. In this paper, we apply this method to the sticklike targets which have a very similar size and geometry for a fuselage and wings.

3 Simulation results

3.1 RCS Calculation

We used three different sticklike targets to analyze the radar target discrimination performance of the E-pulse technique. Fig. 2 shows the sticklike target geometries used in the simulations. Targets A and C have the same length, but different wing angles. The wings of target A and C are 0.75 m in length, and the forward and aft sections of the fuselage are 0.5 and 1.0 m, respectively. Target B has two arms of 0.75 m and a third arm of 0.8 m.

To obtain the RCS, we used the method of moments (MoM) option in the FEKO simulation tool. FEKO simulation tool is EM simulation tool, and is based on a 3D grid. The frequency range was chosen as 7.8125 MHz to 1 GHz, with 128 samplings and with HH polarization. The nose of wire targets is placed at the position (0,0,0), and the wire targets are placed in the x-y plane. The azimuth angle region is form 0° to 90° using a 1° step.

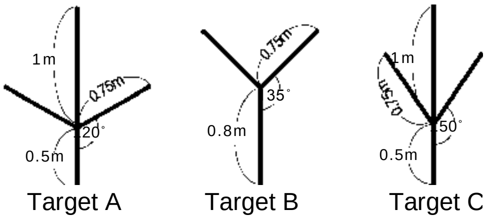

Fig. 2. Sticklike target used in the simulation.

3.2 Natural Resonance Extraction and Target Discrimination

In this section, we first extract the natural resonance frequencies from the RCS data shown in section 3.1. Fig. 3 shows the extracted CNR frequencies using E-pulse technique at the SNR of 30 dB. The CNR frequencies for each targets are well separated in σ_n vs. ω_n domain. This means that the extracted CNR frequencies can be a good feature vector for the radar target discrimination.

Theoretically, it is known that the CNR frequencies are aspect independent. However, the CNR frequencies extracted at different aspect angles for same target are slightly different in Fig. 3.

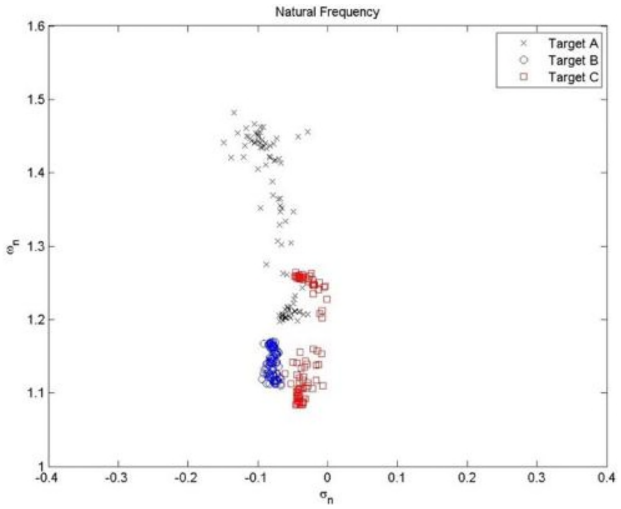

Fig. 3. **Extracted CNR frequencies using E-pulse method. SNR=30 dB.**

The next step for target discrimination is the E-pulse synthesis. Fig. 4 shows the generated E-pulse for the target C at the $1_e = 0.5$ [nsec]. This E-pulse is generated for each target and stored in the database.

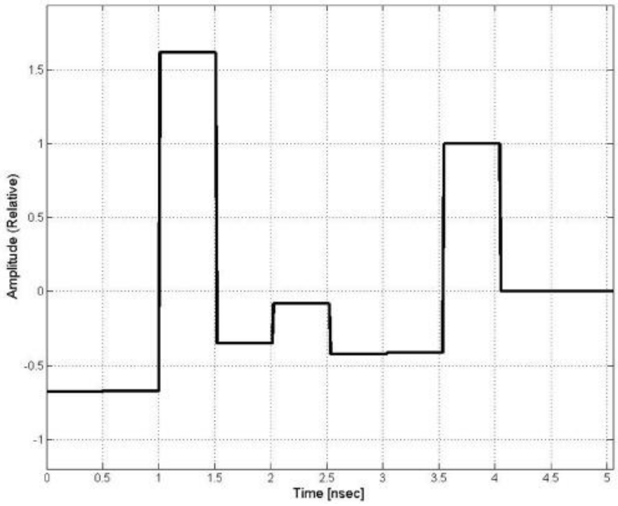

Fig. 4. **E-pulse for Target C.**

Then, the transient response to be discriminated is generated. Fig. 5 shows the transient response for target C at the aspect angle of 0°. This transient response has both an early-

time response and late-time response. The late-time response starts approximately at T_L =10 [nsec].

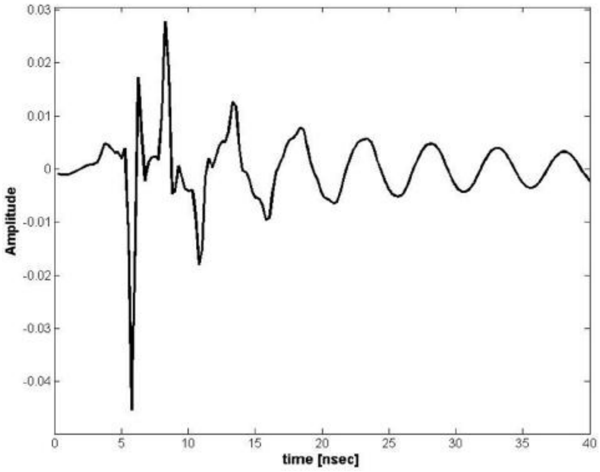

Fig. 5. **The transient response for target C at the aspect angle for 0°.**

The final step for target discrimination is the convolution of transient response with E-pulses in the database. Fig. 6 shows the convolution output of transient response of target C with E-pulses of three targets.

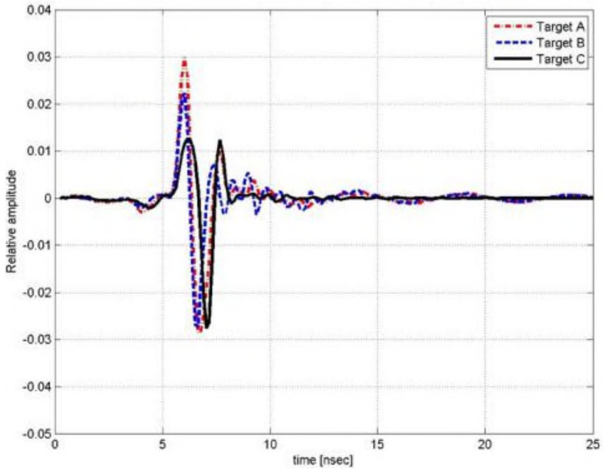

Fig. 6. **Convolution output of transient response of target C with E-pulses of three targets.**

The convolution output in the late-time is found to be nearly zero for the target C. This

means that the target C is discriminated against the other targets successfully.

4 Conclusions

In this study, we investigated the target discrimination for the similar sticklike targets using E-pulse technique. It is shown that the extracted CNR frequencies for each targets at all aspect angles are well separated in the s-domain. It is also shown that the target discrimination of certain target against other targets is possible using the convolution of E-pulse with transient response. Especially, it is proven that targets A and C which have the same length and different wing angles are also discriminated successfully.

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