# SUPERWIDE-BAND RADAR TARGET DISCRIMINATION USING THE E-PULSE METHOD

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**Abstract.** An aspect independent radar target discrimination method, using the natural frequencies of radar target, is introduced. The approach is based on the extinction-pulse (E-pulse) technique and, as the numerical simulation shows, it is relatively insensitive to random noise and to estimations of modal contents. This method allows effectively discriminate superwide-band radar targets down to the signal/noise ratio approximately 5 dB. The experimental verification of the discrimination concept using simplified aircraft models is presented.

## I. Introduction

A lot of superwide-band radar target discrimination methods use the late-time natural transient response of the conducting targets for the purpose of theirs identification. To contrast the traditional parametrical methods which are usually based on estimations of a finite quantity of object parameters (for example, Prony's method), this paper introduces one of the non-parametrical methods – the E-pulse technique [1].

The late-time part of the transient response of radar targets can be decomposed into a finite sum of damped sinusoids with the parameters determined by the target geometry and size. The E-impulse method applies the synthesizing of discriminate exiting signals (E-pulses), which in the case of a numerically convolution with a late-time transient response of the target causes the zero-mode response, thus the different targets can be discriminated.

This paper quantifies discrimination using E-pulses in a way that is suitable for use in automated discrimination scheme. Examples of the performance of this automated scheme using theoretical scattering data for aircraft models with varying amounts of additive noise are presented.

## II. The E-pulse Technique

It is well known that the impulse response of a conducting target to a band-limited transient excitation in the late time can be written as [2]:

$$y(t) = \sum_{i=1}^{M} a_i \, e^{\sigma_i t} \cos(\omega_i t + \varphi_i), \qquad t > T_l, \tag{1}$$

where $p_i = \sigma_i + j\omega_i$ is the aspect independent natural frequency of the $i$-th target mode, $a_i$ and $\varphi_i$ are the aspect and excitation dependent amplitude and phase of the $i$-th target mode, $T_l$ describes the beginning of the late-time period, and the number of modes in the response $M$ is determined by the finite frequency content of the waveform exciting the target.

The E-pulse technique consists of synthesizing discriminant signals finite duration, which can be written as:

$$e(t) = \sum_{n=0}^{N} e_n h(t - nT_h) = \sum_{n=0}^{N} e_n \delta(t - nT_h) * h(t), \qquad h(t) = \begin{cases} 1, & 0 \le t \le T_h \\ 0, & t < 0, t > T_h \end{cases} \tag{2}$$

where $\delta(t)$ is the delta function, $T_h$ is the duration of basic pulse, and $NT + T_h = T_e$ is the finite duration of the E-pulse. The structure of (2) is linear and uniquely determined by the parameters $e_n$ if $N$, $T_h$, and $h(t)$ for $0 \le t \le T_h$ are fixed. These parameters are chosen so that

$$c(t) = e(t) * y(t) = 0, \qquad t \ge T_e, \tag{3}$$

where "*" denotes convolution. The duration of elementary impulse in structure of E-pulse is inverse proportional to the highest resonance frequency in a spectrum of the radar target response $T_h = r\pi/\omega_i$, $r = 1, 2, \ldots$ The duration of the E-pulse corresponds to the low-frequency component of a spectrum of the response.

As a measure of the deviation from the expected value of zero late-time energy we were used the E-pulse discrimination number (EDR) [2]:

$$\text{Ш}=\int_{T_e}^{T_y} c(t)^2\,dt \bigg/ \int_{0}^{T_e} e(t)^2\,dt\,, \tag{4}$$

that is the late-time energy of $c(t)$, normalized by the E-pulse energy.

## III. Numerical Results

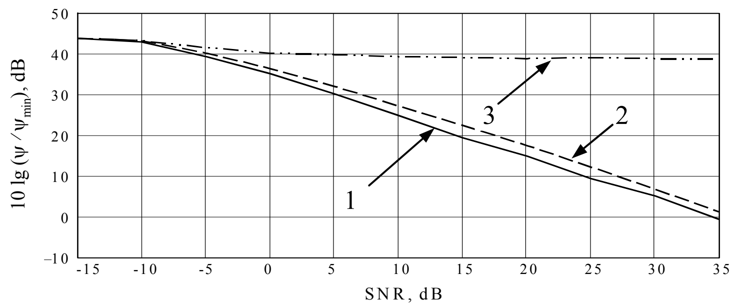
The research of E-pulse method is carried out on models of signals obtained in outcome of measurement responses, scattered by aircraft models [3]. These models consist of five damped sinusoids and Gaussian noise. The signal/noise ratio is estimated as

$$\mathrm{SNR} = 10\cdot\lg\left(\frac{\mathrm{M}\left(x(t)^2\right)}{\mathrm{M}\left(n(t)^2\right)}\right) \tag{5}$$

where M(•) denotes the mean value, $x(t)$ is the noise-free signal, $n(t)$ is the Gaussian band-limited noise.

The researches of the E-pulse method include the study of it effectiveness while the aspect of radar target was changed. It was modeling by changing of initial phases and amplitudes of harmonic components of signals. We have researched the sensitivity of E-pulse method to the level of Gaussian band-limited noise. Automated discrimination requires a measure of the amount of the late time of the target response for each E-pulse. Thus, we defined that the E-pulse discrimination number may be a measure of the deviation from the expected value of zero late-time energy.

To test the sensitivity of the E-pulse method to SNR and differences in target geometry, the E-pulse for the Boeing 707 response was used to discriminate the responses of the Boeing 707 and F-18 aircraft models. The responses were corrupted with varying amounts of noise with the SNR varying from –15 dB to 35 dB. EDR values for these cases were computed. Fig. 1 shows the results of these tests.




"1" – convolution of the Boeing 707 E-pulse with the Boeing 707 measured response;
"2" – convolution of the Boeing 707 E-pulse with the Boeing 707 measured response with random amplitudes and initial phases;
"3" – convolution of the Boeing 707 E-pulse with the F-18 measured response

Fig.1. EDR values computed for the Boeing 707 measured response.

Fig. 1 shows that in cases random initial phases and amplitudes of the observed signal the results of convolution of the E-pulse with the measured response are identical. It's confirms the statement about aspect-independence of E-pulse method.

## IV. Conclusions

This paper present an automated discrimination scheme based on the E-pulse method. The scheme can be readily applied in applications where many targets are considered and a computer is used to make the discrimination decisions. As results of experimental researches we obtained that the E-pulse method is practically aspect-independent technique of radar target discrimination and allows effectively identify radar targets down to the signal/noise ratio approximately 5 dB.

## References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