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# Radar Emitter Signal Intra-Pulse Feature Extraction Based on Empirical Mode Decomposition

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**Abstract:**

Aiming at this problem that the analysis of instantaneous frequency for radar emitter signal(RES), based on empirical mode decomposition(EMD) the intra-pulse feature extraction method for RES is studied. Using empirical mode decomposition the normalized energy entropy (NeEn) feature is extracted. The experiment result displays that if the signal-to-noise ratio is greater than 12 dB, the feature shows only small fluctuations.



Keywords: radar emitter signal, intra-pulse feature, empirical mode decomposition (EMD).

## 1 Introduction

The radar emitter signal is a typical non-stationary signal, and the relatively straightforward analysis of non-stationary signals requires the use of localized fundamental quantities and basis functions. The instantaneous frequency(IF) is a concept that has been proposed very early, and it is a basic quantity with locality. The IF is defined under the concept of derivative of the phase for the resolved signal, but this definition often produces some erroneous results in actual signal analysis. Aiming at this problem, the feature extraction method of intra-pulse for RES based on EMD is studied.

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## 2 EMD **Analysis**

Empirical mode decomposition (EMD) refers to the gradual decomposition of different scale fluctuations or trends in a signal, which would generate data sequences in series under different feature scales. The sequence of data is called intrinsic mode function (IMF)[1]. The EMD method refers to decompose the signal into sets which contains several different IMFs. Different IMF represent different the signal frequency bands components. And also the frequency components in each frequency band could be different. The IMF is defined as a signal component that satisfies the following two conditions: (1) the extreme points number and zero crossings number differ by less than two; (2) the envelope mean value formed by local maxima and local minima could be 0. In the process of signal decomposition, it is difficult for the basic mode components to strictly satisfy the above two conditions. In order to ensure the convergence of the algorithm, and to ensure that the IMF component preserves sufficient amplitude and frequency modulation to reflect the physical reality, an appropriate decomposition termination condition needs to be defined. Huang [2] modeled the Cauchy convergence criterion and defined the standard deviation as the algorithm convergence criterion. Rilling [3] improved the standard deviation convergence criterion, and Zhu [4] concluded that in the EMD decomposition process, the screening process can be terminated as long as the number of extreme points and zero crossings of the waveform are equal. In addition, after a lot of experiments, if the difference between the obtained signal sequence and the IMF component obtained during the screening process is a monotonic function during the EMD decomposition process, the decomposition process can be terminated at this time.

In the EMD decomposition, the envelope averaging is performed by spline interpolation and then averaging on the upper and lower extreme points in the original data, respectively, when the spline is interpolated, unless the two ends of the data are It is the extreme point of the data, otherwise the extreme point at the endpoint cannot be determined, so direct interpolation will cause the upper and lower envelopes to be distorted at both ends of the signal, thus forming an endpoint problem of the EMD. For high-frequency components, because the extreme point time interval is small, the end effect is limited to a small range at both ends of the signal, but for low-frequency components, the end effect is propagated inside the signal due to the increase of the extreme point spacing, while each layer The error of decomposition will gradually increase, which seriously affects the quality of the later decomposition layer. Even in the case of serious accumulated error, the decomposed data may be meaningless.

It can be seen from the above analysis that weakening the end effect is a bottleneck problem that improves the accuracy of decomposition. In order to weaken the end effect, it is generally considered that for long data sequences, the EMF-decomposed IMF or the data at both ends of the decomposed spectrum can be discarded according to the extreme point to weaken the end effect. For short data sequences, the data sequence must be extended, and the extended signal is EMD decomposed to obtain higher analysis accuracy.

An effective solution is to use the mirror closure continuation method for endpoint extension [5]. The mirror closure continuation method maps the extended signal into a periodic ring signal according to the distribution characteristics of the signal, and there is no end point, thereby avoiding the end problem of the EMD.

## 3 Normalized Energy Entropy Feature Extraction

For the radar radiation source signal, the signal energy distribution in different frequency bands changes with the modulation mode. Therefore, the type of the radiation source signal can be judged by calculating the normalized energy entropy of the IMF component of different radiation source signals. Let the obtained pulse data sequence be directly resampled in step 4 of the signal preprocessing to be s(t), then the process of decomposing s(t) by EMD is as follows:

Step 1 Let i=1, j=1;

Step 2 connects the local maximum value and the minimum value sequence of the signal s(t) with a cubic spline function to form an upper and lower envelope of the signal;

Step 3 Calculate the mean value mij(t) of the upper and lower envelopes, and record hij(t)=s(t)-mij(t);

Step 4 If hij(t) satisfies the IMF condition, go to step 5, otherwise replace s(t) with hij(t), and let j=j+1, go to step 2;

Step 5 Let ci(t) be the i-th IMF component obtained by EMD decomposition, then we have ci(t)=hij(t); let ri(t)= s(t)-ci(t), if ri(t) Is a monotonic function, the decomposition process would be terminated, then ri(t) is called the trend residual, otherwise replace s(t) with ri(t), and let i=i+1, go to step 2;

It can be seen from the above steps that the original signal s(t) is decomposed into the sum of k IMF components and trend residuals by EMD, namely:

$$s(t) = \sum_{i=1}^{k} c_i(t) + r_k(t) \quad (1)$$

Where $k$ is the total number of decompositions.

After obtaining the IMF component of the pulse data sequence $s(t)$, the normalized energy entropy of the IMF component of the signal can be obtained by equation (2):

$$P_e = -\sum_{i=1}^{k} p_i \ln p_i \quad (2)$$

In equation (2),

$$p_i = \frac{\sqrt{\sum_{j=1}^{N} |c_i(j)|^2}}{\sum_{i=1}^{k} \sqrt{\sum_{j=1}^{N} |c_i(j)|^2}} \quad (3)$$

Where $p_i$ represents the normalized IMF energy and $N$ represents the length of the signal sequence $s(t)$. Obviously $\sum p_i=1$, $i=1,2,\ldots k$, the number of decompositions $k$ is related to the complexity of the signal, and is determined adaptively by the decomposition algorithm. According to the theory of entropy, if the energy distribution of each IMF component of the radiation source signal is uniform, the normalized energy entropy is the largest; if the energy is concentrated at a few IMF components, the normalized energy entropy is small.

The experiment is performed by selecting a signal as shown in the following equation to illustrate the anti-noise performance.

$$f(t) = 3\sin(30\pi t) + \sin(150\pi t) + 5\cos(21.6\pi t) \quad (4)$$

The sampling frequency is 1000Hz, taken $t \in (0,1]$ as the time.

Figure 1 shows the NeEn as a function of signal-to-noise ratio as a function of the test signal represented by equation (4).

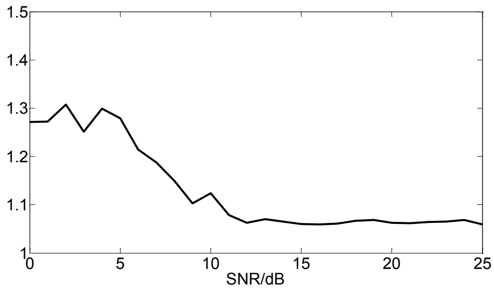


Figure 1 Variation of normalized energy entropy with signal-to-noise ratio

As can be seen from figure 1, as the signal-to-noise ratio increases, the NeEn feature gradually becomes stable, especially when the signal-to-noise ratio is greater than 12 dB, the feature shows only small fluctuations, indicating that the normalized energy entropy (NeEn) feature has certain anti-noise ability.

## 4 Conclusion

In this paper, the method of extracting the intra-pulse features of radar radiation source signals is studied. If the IF is defined as the phase derivative for the resolved signal, some erroneous results are often produced in the actual signal analysis. Hilbert-Huang Transform (HHT), which is based on the time-frequency analysis of Empirical Mode Decomposition (EMD), decomposes arbitrary signals into intrinsic mode function (IMF), that is, empirical mode decomposition, which gives a reasonable definition, physical meaning and method of instantaneous frequency, and establishes a new time-frequency analysis method system based on the instantaneous frequency to characterize the signal alternating, and the new function based on IMF. The paper studies the intra-pulse feature extraction method based on empirical mode decomposition radar signal.

## 5 Acknowledgments

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