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An Improved Feature Extraction Algorithm of Radiation Source Based On Multiple Fractal Theory

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Abstract

Multiple fractal dimensions can be used to depict the geometry characteristic of the radiation source signals from different dimensions, thus it can be used to extract the features of different radiation source signals. In this paper, it proposes an improved feature extraction algorithm of radiation source signals based on the multiple fractal theory, it improves the solution method of traditional multiple fractal dimension which accumulated the q dimensions characteristics. Meantime, it increases the regularity and gathered degrees of the characteristics of radiation source signals, and under the condition that the basic computational complexity of algorithm is not changed. Simulation results show that, for the classification of different radiation source signals, the improved algorithm has better property and classification rate.

Keywords: *Multiple Fractal Dimensions; Geometry Characteristic; Signal Feature; Signal Classification*

1. Introduction

Radar echoes usually contains a lot of information related to the target feature and a variety of stray echoes, therefore, it has been a hot topic that how to extract the characteristics of radar intra-pulse signal in the low SNR environments which in order to identify the radar signals. For the feature of the radar intra-pulse signals' characteristics, the theory of signal complexity characteristics, entropy theory and fractal theory get the more extensive application. References [1] used the signals' complexity feature box dimension and index entropy double complexity characteristics to identify the communication signals achieved a better result. References [2] improved the traditional box dimension, although it increases a certain amount of calculation, the recognition effect have been significantly improved. References [3-4] applied the multiracial spectrum characteristics to the identification of the radar signals' intra-pulse modulation characteristics. References [5] provided the method calculating discrete signals' multiracial spectrum characteristics and annotated the meaning of multiple fractal dimension spectrum.

In the dense emitter signal environment, the in-pulse characteristic extracting of radar emitter signal is both important to radar radiation recognition and an important means of sorting all types of radar signals quickly. It not only finished the recognition of properties and systems of radar emitter but also individual identification. The in-pulse characteristic of radar emitter signal is mainly showing as different kinds of modulation. The features of different modulation methods are also reflected at

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frequency, the phase and the amplitude. However, the waveform of in-pulse signal contains the geometrical and shape information of three parameters. The fractals are composed of some similar parts with the whole. It has the fine-structure and self-similarity with the statistical meaning. The fractal dimension can be measured the complexity and irregularity of signal waveform. So the radar emitter signal could be considered as a time series, it can be used the fractal dimension to describe. Then this method is feasible.

From the point of view of the measure, fractal dimension [6] which usually used to represent the degree of irregularity fractal sets expanded the dimension from integer to fraction and broke through the boundary that general topological dimension is integer. Thus it has been a wide range of application in various fields. The paper improved multiple fractal dimension characteristics after comparing with the traditional multiple fractal dimension characteristics. The simulation results showed that compared with the traditional algorithm, it decreased amount of calculation and far more stable than traditional multiple fractal dimension algorithm and had better application value.

2. Multiracial Theory

The fractal theory is an active branch in the study of nonlinear science. Its object of study mainly describes the nature and nonlinear system objects which are not smooth and irregular. It has broad application prospects in physics, geology, material science and engineering technology. With the rapid expanding of electronics and computer technology, the basic idea and principle of the fractal theory has made great progress in the fields of pattern recognition[6], natural image simulation [7], communication signal processing[8], art manufacture[9] and so on. The fractal theory is one of the most influential and charisma basic concepts of modern science. The mathematical basis of it is fractal geometry; the fractal geometry is the most effective tools at exploring complexity.

Specifically, the fractal theory is a serious of sets which formed by some complex points in simply space. The sets have special nature and characteristics. They must be the compact subsets with the space, and have the following typical performances:

(1) The fractional sets have the detail ratio in arbitrary little scale.
(2) The fractional sets cannot be measured by the traditional geometrical description. It is not the trajectory of some points which certain same conditions, or the solution of some simple equation.
(3) The fractional sets have some self similar shapes which could be the approximate self-similarity or statistic self-similarity.
(4) For general purposes, the fractal dimension (which defines the dimension on Falconer) is strict bigger than topological dimension.
(5) In most intriguing cases, the fractional sets are defined by a very simple method. It could be produced by transforming iteration

For different fractal theories, some of them can't hold all of nature above, some of them might only have most of them. But this does not affect we called the set as fractal. It should point out that the fractal in nature and most of applied science is approximation. When the scale reduced to about molecular size, the fractal theory is disappear. The strictly fractal theory only exist in the theoretical study.

2.1. Traditional Multi-fractal Dimension Algorithm

The fractal dimension is an important parameter in fractal theory. It has many definitions and computing methods, such as Hausdorff dimension [6], box dimension, information dimension, similarity dimension, correlation dimension, generalized fractal dimension and so on.

Hausdorff dimension is a basic fractal dimension in the fractal theory. But in practical application, it is very difficult to compute directly. So box dimension is used in describing geometric dimensions information of fractal signal. The information dimension is used in describing distribution information of fractal signal in on dimensional plane. The fractal algorithm which has the best feature extraction results is the feature extraction algorithm based on the multi fractal dimension.

Multiple fractal dimensions can describe the features of the objects in various ways. The method to define the traditional multiple fractal dimension is as follows:

The research object divided into N micro-regions, suppose the length of the "i" region is ε_i, and then the probability density function of this region P_i can be describe by the scaling exponent α_i:

$$P_i = \varepsilon_i^{\alpha_i},\ i = 1, 2, \cdots, N_i \tag{1}$$

Non-integer α_i was generally called singularity exponent, its value was related to the region. Defined the function $X_q(\varepsilon)$ which was the probability weighted summation of all regions: $X_q(\varepsilon) = \sum_{i=1}^{N} P_i^q$.

From this, the further definition of the generalized fractal dimension " D_q "was:

$$D_q = \frac{1}{q-1} \lim_{\varepsilon \to 0} \frac{\ln X_q(\varepsilon)}{\ln \varepsilon} = \frac{1}{q-1} \lim_{\varepsilon \to 0} \frac{\ln\left(\sum_{i=1}^{N} P_i^q\right)}{\ln \varepsilon} \tag{2}$$

Different q showed different property of probability characteristic area, by means of weighted summation processing; we divided a signal into numerous regions with different singular degree. Thus we could know the refined structure of internal signals step by step.

2.2. Improved Multi-fractal Dimension Algorithm

Based on the instruction of traditional feature extraction algorithm based on the multi fractal dimension, the paper improved the multi-fractal dimension algorithm. In the evaluation process of D_q, we cancel the summation of probability in different regions and calculate the multiracial characteristics of signals which in different levels directly.

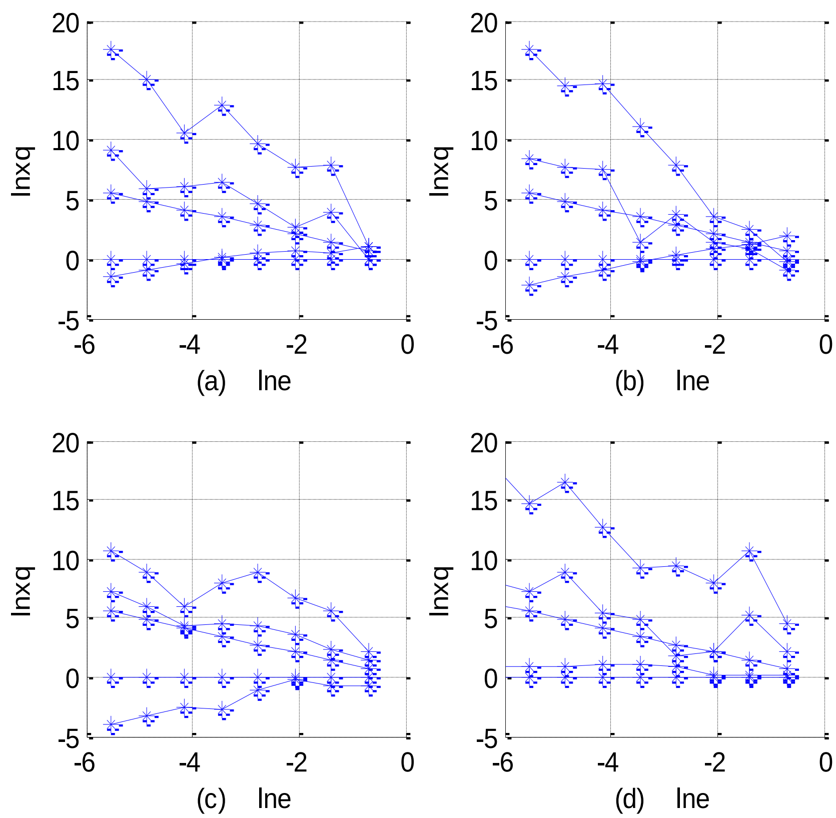
Defined the function $X'_q(\varepsilon)$: $X'_q(\varepsilon) = P_i^q$ .And the improved multiple fractal dimension D'_q is :

$$D'_q = \frac{1}{q-1} \lim_{\varepsilon \to 0} \frac{\ln X'_q(\varepsilon)}{\ln \varepsilon} = \frac{1}{q-1} \lim_{\varepsilon \to 0} \frac{\ln\left(P_i^q\right)}{\ln \varepsilon} \tag{3}$$

D'_q is the value of improved multiple fractal dimension at present. D'_q and D_q both could describe the signals characteristics in different levels, the result of D'_q showed the signals' distribution characteristics in each level. It reduced a addition summation and had a better feature extraction effect compared with traditional method.

3. Simulation Results and Analysis

On the basis of the multiple fractal dimensions, in the SNR for 10dB conditions, we got the numerical value of 4 different types of radar signals: chirp signal, stepped frequency signal, frequency shift keying signal and phase shift keying signal and drew multiple fractal dimension graph. Figure 1 and Figure 2 showed the simulation results.

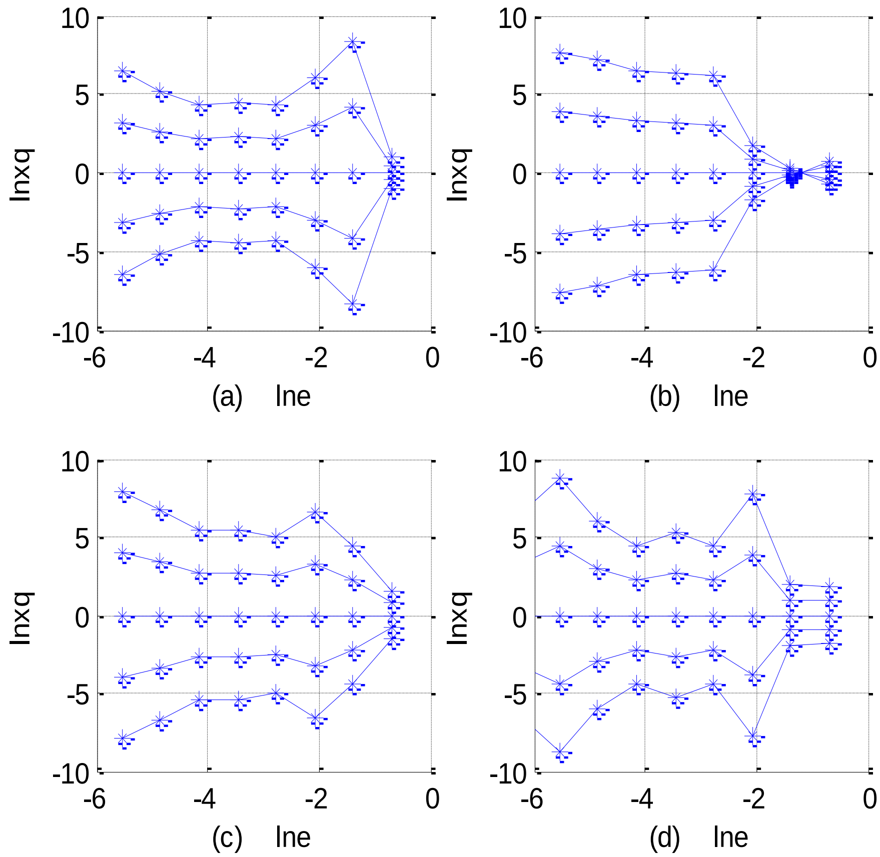


(a) Chirp Signal (b) Stepped Frequency Signal (c) Frequency Shift Signal (d) Phase Shift Signal

Figure 1. Four Kinds of Radar Signal' Traditional Multiple Fractal Dimension Graph

Abscissa $\ln e$ represent $\ln\varepsilon$ in the formula (2), ordinate $\ln xq$ represent $\ln X_q(\varepsilon)$ in the formula $X_q(\varepsilon)=\sum_{i=1}^{N} P_i^q$.

From the simulation results, we can see that multi fractal dimension of different classes of radar signals is different. But each fractal dimension of every signal lack regularity, and individual signal, multi fractal dimension characteristics with different fractal dimension is aliasing. This causes a lot of trouble with subsequent data processing. So it puts forward the improved multiple fractal algorithm. The simulation is shown in Figure 2.



(a) Chirp Signal (b) Stepped Frequency Signal (c) Frequency Shift Signal (d) Phase Shift Signal

Figure 2. Four Kinds of Radar Signal' Traditional Multiple Fractal Dimension Graph

From the simulation results in Figure 2, with improved multiple fractal algorithm, the improved multi fractal dimension of different signals is different. Compared with the traditional algorithm, it has more regularity and easily to be searched. Each dimension feature is not overlap, and extract feature is more conducive to data processing. These benefits provide a good data basis for classifier design.

From the simulation results of Figure 1 and Figure 2 we knew that 4 kinds of radar signal's improved the multi-fractal dimension were more regular than the traditional one and the calculated amount remain unchanged. In the SNR for 10 db conditions, it could classify and distinguish different signals better.

4. Conclusion

The paper proposed an improved algorithm of multiple fractal dimensions. The algorithm cancels the summation of characteristic parameter in different levels compared with the traditional one. In the premise of simplified algorithm, the radar signal's multiple fractal dimensions we extract had better stability and lay a better foundation for the rest of the classifier recognition work.

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