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Analysis of Radar Emitter Signal Sorting and Recognition Model Structure

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Abstract:

Aiming at the problem that there are some defects and shortcomings of traditional radar emitter signal sorting model structure, the structure of radar signal sorting model based on intra-pulse characteristic parameters is analyzed. Although the model is more complete than the early recognition model, there are still some shortcomings in the face of the increasingly complex electromagnetic environment and the emergence of complex radar signal sources. This article has studied this.

Keywords: radar emitter signal sorting, intra-pulse feature, inter-pulse feature.

1 Introduction

The purpose of radar emitter signal sorting is to separate the randomly interleaved signal streams using the inter-pulse and intra-pulse parameters of the signal, and use these parameters to perform the following functions [1]: (1) identify the enemy in the operational environment; (2) determine its deployment location and direction; (3) provide early warning to friendly forces based on its threats; (4) provide reconnaissance personnel with information on enemy radar technical parameters, radar systems and tactical operational characteristics.

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With the rapid development of modern military industry and electronic technology, the wide application of various electronic information devices has made the electromagnetic environment of electronic warfare increasingly complex. The generated electromagnetic signals are densely interleaved and the working parameters are seriously overlapped, resulting in degradation of signal sorting and recognition performance. It adversely affects the overall operational efficiency of the radar against the reconnaissance system. This paper introduces the model structure of radar signal sorting and identification, and points out its problems, providing ideas for future research.

2 Analysis of Traditional Sorting Model Structure

The traditional radar emitter signal sorting model structure (shown in figure 1) is mainly based on the five basic parameters of TOA, RF, PA, PW and DOA [2,3].

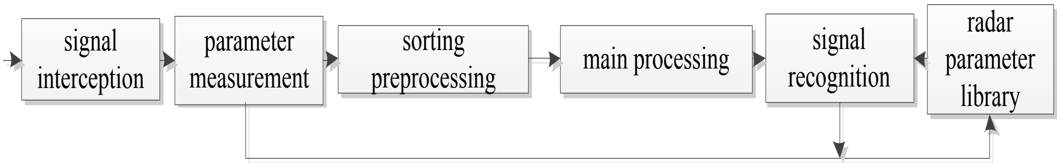

Figure 1 Radiation source sorting traditional model structure

In figure 1, the role of the parameter measurement section is to obtain various parameters of the radar source signal, such as TOA, RF, PA, PW, DOA [4~7], preparing for the sorting and identification of the pulse train; the pre-processing part mainly completes the pulse stream dilution to obtain the known radar sub-flow and the unknown radar sub-flow. The main processing part of the radar signal mainly uses single parameters (such as TOA), or sorts by different parameters (such as using the spatial domain DOA firstly, then using the frequency domain parameter RF, and finally using the time domain parameters PW and TOA to complete the entire sorting) or use multiple parameters (such as using RF, PRI, PW to directly form a feature vector) for sorting. The radar radiation source parameter library is mainly used to store the characteristic parameter values of a plurality of known radar radiation sources for the identification method to call, and store the characteristic parameter values obtained by other methods for identifying the radiation source signals.

2.1. complicated waveform design

When the signal density in the electromagnetic environment is not very large and the conventional parameters are relatively stable, the sorting model of figure 1 is more effective. That is, the sorting method is only suitable for the conventional radar signal parameters when the parameters are basically constant under certain conditions. In the modern electromagnetic environment, the waveform design of radar is becoming more and more complicated. Traditional radar signals such as fixed-frequency, jagged, and jitter are more and rarer in modern radar design, and agile, random re-frequency and other complexities are more and more complicated. Specifically, in order to improve the anti-reconnaissance performance, some radars modulate the inter-pulse parameters of the signal, that is, the pulse signal adopts a complex change mode in the time and frequency domain. Take the AN/SPS-73(V) as an example, a sea-based search and navigation radar equipped by the US Navy, when the radar is operating in the 1st band, the repetition frequency varies from 600 to 2200 Hz. In addition, in order to improve the low interception and anti-interference performance of the radar signal, the intra-pulse modulation waveform and modulation parameters used in the radar signal tend to be diversified, and one radar can transmit a plurality of intra-pulse modulated signals, such as chirp, phase encoding, etc. Some radar even uses composite modulated signals[8].

2.2. complicated work mode

The re-frequency pattern has become a hot spot in current radar design, and these features have caused the battlefield electromagnetic environment to deteriorate rapidly. Taking the modern phased array radar as an example, it has the function of random scanning of the antenna beam, which can realize random search and edge tracking search, so its pulse parameters are also randomly variable. The carrier frequency varies with the beam pointing, and the pulse repetition period PRI and the pulse width PW vary with the detection distance. In addition, in order to complete the missions of target detection, target tracking, guidance, etc., the integrated complex radar uses multiple functions in one, has different working modes, and quickly switches between different working modes. Different working modes usually correspond to different types of signals. For example, the AN/SPY-1 multi-function radar developed by Lockheed Martin of the United States can transmit four pulse widths (51μs, 25.4μs, 12.7μs, 6.4μs) and two bandwidths (10MHz, 40MHz) radiation source signal. When sorting such radiation source signals, it is easy to sort signals belonging to different working modes of the same radiation source into multiple radiation source signals, resulting in a "batch increase" phenomenon. In addition, the application of multi-sensor radar has brought great difficulties to signal sorting. For example, multi-input multiple-output (MIMO) radar is with excellent anti-stealth, high-resolution, low-interception and damage-resistance performance. The signals transmitted by different channels of MIMO radar overlap in space-time-frequency domain, lacking a priori information and the number of antennas. Under the underdetermined condition of the number of source signals, it is difficult for the prior art to effectively separate the mutually overlapping signals and accurately extract the feature parameters, thereby failing to ensure the effectiveness of the signal deinterleaving process[8].

Moreover, the illumination time of the antenna beam for each target also varies with the search and tracking states, so that the pulse parameters do not have a repeating change rule. The above factors cause the failure of the sorting model shown in figure 1.

At the same time, the model structure fully embodies the idea of sorting as a recognition service. The sorting result directly affects the accuracy of the identification. There are shortcomings such as sorting and recognition, irreversible information interaction, inflexible information interaction, and further improvement of anti-noise performance.

3 Signal Sorting and Identification Model Structure Using Intra-pulse Features

Based on the above reasons, some scholars have proposed a method for signal sorting identification using intra-pulse features [9]. The basic principle is shown in figure 2.

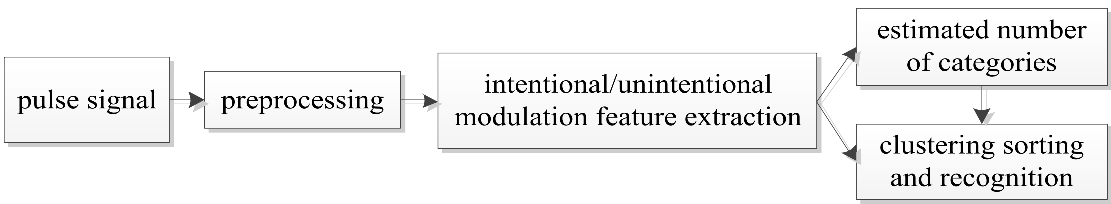

Figure 2 Radar signal sorting model based on intra-pulse characteristic parameters

It can be seen from the figure that the method mainly studies three aspects of intentional and unintentional modulation feature extraction, classification number estimation and clustering and sorting identification of radar radiation source signals. The authors believe that the number of classifications is estimated to be provided by unsupervised clustering and sorting. The necessary prior information helps to evaluate the rationality and effectiveness of the sorting results. Compared with the traditional sorting model, the sorting model shown in figure 2 is mainly reflected in feature extraction, classification number estimation and clustering method. Feature extraction refers to the extraction of characteristic parameters different from the conventional five parameters that can characterize the signal characteristics by linear or non-linear transformation of the radiation source signal. The estimation of the number of classifications refers to estimating the number of radiation sources by certain criteria (such as the minimum description length criterion, etc.), and then performing clustering and sorting of signals by using an effective clustering algorithm.

Although the model is more complete than the early recognition model, there are still some shortcomings in the face of the increasingly complex electromagnetic environment and the emergence of complex radar signal sources, mainly reflects in:

(1) There may be mis-selection or abnormal pulse in the same type of radiation source signal after sorting. The model does not deal with this kind of abnormality, so the accuracy of the parameters used to identify the radiation source is not high, and even the signal is caused. Missing police and false alarms.

(2) As an unconventional parameter, the unintentional modulation feature is an intrinsic feature attached to the signal by the radar using a certain modulator. This feature is often reflected in the nuances of similar signals, so to capture these feature information. A larger sampling bandwidth must be used. For example, most unintentional frequency modulation occurs at the leading and trailing edges of the pulse oscillator signal, which indicates that a high sampling rate is required to capture these characteristic information. Therefore, the in-pulse unintentional modulation feature is not a conventional de-interlacing or recognition tool.

(3) The estimation algorithm of the number of classifications serves the clustering algorithm, but it also directly affects the accuracy and timeliness of clustering.

Throughout the current research status of radar signal sorting, and the structure of this sorting model, it is not difficult to see that there is still a lack of complete signal sorting feature set in the field of signal sorting, and most of the existing methods only from the feature parameter dimension (mainly including inter-pulse feature dimension and intra-pulse feature dimension)[8]. Obtaining feature information for signal sorting has been unable to adapt to complex system radar signals. In-depth analysis of the working characteristics of radars in complex systems and the essential characteristics of signals, exploring and mining new features of radar signals from complex systems from multiple information dimensions, and researching new methods and new model structures for radar signal sorting in complex systems is currently the field of radar countermeasures Lieutenant research work to be carried out.

4 Conclusion

In this paper, the structure of traditional radar signal sorting model and the model structure based on intra-pulse characteristics for signal sorting and identification are analyzed, and it could be confirmed that there are insufficient degrees are obtained. If it is considered to combine the inter-pulse parameters with the intra-pulse features to form a feature vector for sorting, the method reduces or partially reduces the overlap caused by the simple use of inter-pulse or intra-pulse features by combining inter-pulse parameters and intra-pulse parameters. Then it could get better results.

5 Acknowledgments

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