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雷达信号调制方式识别与参数估计算法研究

Study on Algorithms of Radar Signal Identification and
Parameters Estimation

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摘要

在现代军事电子侦察与电子对抗作战中,通过对截获到的雷达信号进行调制方式识别与参数估计,以识别的结果和具体参数值为依据,按照某种规则和算法及查询信号特征数据库,判断出发射该信号的敌方雷达平台的用途或类型,为我方制定作战预案提供参考,做到先发制敌,取得战场的主动权。

近年来出现的很多雷达信号调制方式识别算法中,神经网络理论与脉内分析算法应用较为广泛,但它们各自都有自己的不足,单一的方法无法满足日益复杂调制方式信号的识别与参数估计需要。本文将神经网络理论与脉内分析相结合应用于雷达信号的调制方式识别和参数估计中,重点围绕如何利用神经网络的自学习能力提升针对参数畸变、干扰严重的脉冲串的信号调制方式识别正确率,解决脉内分析方法中存在的一些不足与缺陷。本文的主要工作和一些贡献有:

(1) 介绍了实信号的复数表示形式,推导出了经典信噪比估计算法的完整过程公式,并引入克拉美-罗不等式,给出性能比较的理论最值。另外,还介绍了两种重要的信号处理过程中相关技术——曲线拟合和平滑滤波,给出了几种窗函数的简单介绍,在此基础上作了一些仿真并分析了平滑滤波对信号处理过程中的性能、精度等的提高效果。

(2) 针对目前信号到达时间估计方法的不足,提出了一种基于准匹配滤波的信号到达时间估计算法。该方法先利用相关检测,对信号的前沿和后沿进行粗估计,估计出信号粗脉宽和调频斜率,依此构造出本地参考信号。接着,对接收信号进行准匹配滤波,从而实现线性调频信号到达时间的精估计。计算机仿真表明,本方法在较低信噪比条件下可实现对信号到达时间的精确估计。

(3) 介绍了神经网络的基本理论与模型,总结了 6 种不同调制方式的雷达信号模型,并仿真分析了这些信号的时相、时频特征。接着,提出了一种基于 BP 神经网络与脉内分析相结合的信号调制方式识别与参数估计算法。本方法克服了单一方法各自的不足与缺陷,一定程度上提高了信号调制方式识别的准确率和参数估计的精度。MATLAB 仿真验证了本方法的正确性。

关键词: 调制方式识别; 到达时间估计; 神经网络; 脉内分析。

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Abstract

Fighting in modern military electronic reconnaissance and electronic countermeasure, through to the identification and parameter estimation of the intercepted radar signal source, and on the basis of the results and specific parameter values, according to certain rules and algorithm and querying the emitter characteristics database, we can determine the purpose or type of radar signal from which enemy platform. After that, the reference for we make operational plans is provided, so we can do a start system and obtain the initiative of the battlefield.

In recent years, in the emergence of a lot of radar signal identification algorithm, neural network theory and intra-pulse analysis algorithm have been widely applied, but they each have their own shortages. And a single method can't meet the increasingly complex modulation mode signal source identification and parameter estimation. In this paper, the combining the neural network theory and intra-pulse analysis is applied to radar signal identification and parameter estimation. And the emphasis is how to use the self-learning ability of neural network to ascend with the serious distortion parameters, disturbance pulse string of radar signal identification accuracy, solve some of the deficiencies and defects in analysis method. In this paper, the main work and some contributions are:

(1) First, it introduces the real signal of plural representation and deduces the classic complete process formula of SNR estimation algorithm, and introduces in Cramer-Rao inequality by which the most theoretical value of performance comparison is given. Then, it also introduces two important related technology in the process of signal processing, that is curve fitting and smoothing filtering. What's more, the simple introduction of several kinds of window function is given. At last, based on that some simulation and analysis are made to show the enhancement effect of performance and precision by smoothing filtering in the processing of signal processing.

(2) The problem of estimating time of arrival (TOA) of linear frequency modulation (LFM) signal is considered, under the condition of unknown parameters of

signal. The coarse estimation of the front and rear of the signal by correlational detection is used at first. Consequently, the coarse width of the pulse and the slope of frequency modulation are estimated. According this, the local reference signal is constructed. And then the received signal is made quasi-matched filtering. After that the accurate estimation of the TOA is realized. The MATLAB simulations results indicate that, the TOA of signal can accurately be estimated with lower signal noise ratio (SNR) by the proposed method of this paper.

(3) This paper introduces 6 kinds of different modulation modes of the radar signal, and the simulation analysis of the time-phase and time-frequency characteristics of these signals is made. Then, on the basis of the mature theory of neural network, this paper proposes a based on BP neural network combined with intra-pulse analysis of radar signal identification and parameter estimation algorithm. Comparing with the traditional single method, this method overcomes their shortcomings and defects in a single method. To some extent, it improves the accuracy of signal identification and the precision of parameter estimation. The correctness of this method is verified by MATLAB simulation.

Key words: Signal Identification; TOA Estimation; Neural Network; Intra-pulse Analysis.

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