Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 201 (2017) 296–301

Procedia Engineering

www.elsevier.com/locate/procedia

3rd International Conference "Information Technology and Nanotechnology", ITNT-2017, 25-27 April 2017, Samara, Russia

Detection of radio pulses in unfiltered signals received by spatially distributed receivers

A. Tashlinskii[a,*], M. Tsaryov[a]

[a] *Ulyanovsk State Technical University, Severnyi Venets str., 32, Ulyanovsk 432027, Russia*

Abstract

Two recursive algorithms for detection of radio pulses in unfiltered signals received by spatially distributed sensors, such as antenna array elements, are proposed. The algorithms are based on the stochastic gradient ascent algorithm estimating the parameters of mutual mismatch between signals received by spatially distributed sensors. Stabilization of the estimates of signals' time alignment is chosen as one of the detection criteria. Another criterion is based on the analysis of the correlation coefficient between the aligned signals. Signal alignment is performed recurrently in real time. It is shown that if correlation coefficient is chosen as the objective function showing the alignment quality we need to estimate only time shift between the received signals. Experiments show the efficiency and the high probability of correct detection of the proposed algorithms. In order to increase detection reliability the algorithms can easily be combined.

Peer-review under responsibility of the scientific committee of the 3rd International Conference "Information Technology and Nanotechnology".

Keywords: radar; detection; estimation; radio pulse; filtering; spatially distributed receivers; time-lag; time shift

1. Introduction

One of the main problems in electronic warfare is radio pulses detection in real time. Theoretical aspects of this problem are intensively researched usually based on the principles of non-parametric statistics [1,2]. The most effective practical results in solving non-stationary problems in radar systems derived from semi-heuristic methods which use robust approximation of actual distributions [2,3]. Other widely used methods of overcoming a priori uncertainty are Robinson method [4] and empirical Bayesian approach [5] which consists in estimating a priori unknown data on the basis of a posteriori results. For many practical problems Robinson method is quite effective, but not for all of them. Nonlinear robust filtering method [2,6] based on the quasi-parametric detection of non-stationary signals in noisy input is positioned as a new approach in this area. This method allows organizing operation of radar systems both in conditions of priori statistical uncertainty and in conditions of strong noise. In this case, even if we know the distribution of the noise, likelihood functions turn into multimodal distributions of an unknown class.

* Corresponding author. Tel.: +7-842-277-8102 ; fax: +7-842-277-8407.
E-mail address: tag@ulstu.ru

1877-7058
Peer-review under responsibility of the scientific committee of the 3rd International Conference "Information Technology and Nanotechnology".
10.1016/j.proeng.2017.09.637

Methods for syntheses of new algorithms usually use principles of robust statistics theory and Markov processes. When using such approaches, the problem of detection is formulated as a problem of testing composite statistical hypotheses regarding the distribution of the observed sample, which requires a sufficient amount computations.

Another group of methods that solve the problem of signal detection are those operating in the frequency domain [7]. In case of additive noise, usually there are several narrow-band radio signals in a wide frequency band. In these conditions, there is no priori information about the number of signals, their carrier frequencies, modulation and its parameters. In the observed sample each element depends in a complicated way on the spectral parameters of all present signals. This fact complicates the process of detection and estimation of signal parameters.

At first glance, the transformation into the frequency domain solves the problem. Here the dependence of probability characteristics of spectral coefficients on the signal parameters is more local, since narrowband signals are well separated in frequency domain [8]. When constructing spectrogram of a process observed in time, it is divided into equal segments, within which it can be considered stationary. There are many methods for assessing spectrograms (methods of Welch, Daniell, Bartlett [9]). These methods use window functions that can be of various shapes (Chebyshev, Parzen, Gaussian, etc.). However, despite the efficiency of FFT, the computational complexity of frequency-domain methods remains relatively high.

In [10,11] the algorithm solving the problem based on co-processing of time-difference and phase-difference characteristic of signals obtained from two spatially distributed receivers is proposed. The detection problem is solved as follows. Each of the receivers via narrowband bandpass filters covering predetermined operating range forms the signal set of different frequency ranges. The detection consists in searching for predetermined threshold value crossing in any of the frequency bands. However, this approach has an obvious draw-back: a large number of false positive detections at relatively low signal-to-noise ratio (SNR).

Note that any filtering leads to the loss of some useful information about the original signal, which increases the error of estimating the parameters of the signal. Therefore, development of algorithms for detection and estimation of signal parameters based on the use of unfiltered samples is important. One of the limiting factors in the development of such algorithms is a requirement of computational efficiency.

Further we propose a recursive algorithm for detection of radio pulses in real time based on the joint processing of unfiltered signals from spatially distributed receivers, e.g. elements of an antenna array. The first algorithm is based on sliding window analysis of changes in probabilistic properties of time shift estimates in the process of convergence. The second one on the correlation coefficient (CC) between the signals from different receivers in the sliding window.

2. Algorithm based on alignment parameters' convergence

To find the time shift between unfiltered signals from different receivers in real time, one can use the stochastic gradient algorithm [12] for estimating the parameters of mutual mismatch between two signals (signal alignment). In addition to the time shift, the signals from different antenna array elements have different intensities and parameters of their alignment include the time shift and the gain factor, making signals equal with respect to the level. In this problem, we are only interested in time shift. Therefore, it is reasonable to use the CC as an objective function. Since the linear change of signal level does not change the CC, the number of alignment parameters is reduced to one [13].

Optimal parameters of radio pulses' alignment are priori unknown. However, the achievement by the parameters' estimates the vicinity of the optimal values can be indirectly determined by considering the sequence of estimates as a random process and analyzing the change in the probability properties of estimates in the process of convergence. Some of these criteria proposed in [14]. They are based on the fact that the behavior of estimates changes significantly when they are reaching the vicinity of the optimal values. When aligning in time two uncorrelated signals, estimates of the time shift vary around zero with a relatively large variance, and the estimates do not converge to any particular value. This situation is typical in case of absence of useful signal from a source at the inputs of antenna array elements. If the *useful signal* received, as time shift estimate converge, i.e. its value stabilize and does not vary a lot. This stabilization of the time-alignment parameter estimates can be used for solving the signal detection problem. Good results are achieved when the trend of estimates is used as a convergence criterion. Fig. 1 shows that before reaching the stabilization, there are regions with uptrends and downtrends (fig. 1(a)), and after the stabilization (fig. 1(b)) trend disappears. Here $\hat{h}$ is the approximation of shift, n is the iteration number.

Time shift parameter $\hat{h}$ in proposed algorithm is approximated in the sliding window by a linear function $s_t = \gamma_t k + c_t$ (straight line), where: $k = \overline{t, t+w}$; w is window width; t is discrete time (hereinafter is expected that $n = t$). If the