Nonparametric Signal Detection Algorithm Using Permutation Statistics of Signal Partial Likelihood Ratios

Rustem B. Sinitsyn [#1], Zhanna M. Bokal [#], Lilia V. Kolchenko [#]

[#] *Electronics Department, National Aviation University*
Prospect Komarova 1, Kiev, 03058, Ukraine

[1] comandor@i.com.ua

***Abstract*— This paper presents a new approach to design radar signal detection algorithms that are applicable when a priori information is limited. The problem is formulated as testing the hypothesis of the kind of a density function. A new method that uses nonparametric statistics of partial likelihood ratios and allows adopting a permutation test in a practical algorithm is suggested and researched. The results can be used for signal detection and processing in different radar systems.**

I. Introduction

Methods of a nonparametric statistics are among the most important methods of overcoming a priori uncertainty in the tasks of detecting radar signals, and these methods are often used in combination with the adaptive approach. Nonparametric criteria of checking statistical hypotheses are based on the application of principles of invariance and similarity [1].

It is known that a similar criteria have a stable probability of the first kind error (probability of a false alarm for radar signal detection) and have high power, comparable to the power of parametric algorithms of signal detection [2]. Particularly the permutation tests, which use all possible permutations of the samples, have the property of similarity. In theory, they provide good results [3].

Among other similar criteria are rather popular rank tests, which are attractive, because of their simplicity. In addition, they have the property of invariance to the group of all monotonous transformations [4]. Rank tests also use the permutations of tested statistic; however only some permutations of the samples are used, which ultimately weakens significantly the quality of signal detection in many cases. Permutation tests are more powerful in comparison to rank tests. Though rank tests can be classified as a kind of permutation tests, rank tests use a limited number of permutations, and this is the reason for their comparatively low power.

Thus, the principal disadvantage of true permutation tests is the difficulty of their practical use because of a great amount of calculation connected with the fact that they are based on the use of all permutations of the initial samples. In most cases they are unrealizable and cannot be applied for practical needs in radar systems because of huge number of permutations for real sample numbers. In many cases simpler rank tests are not capable of providing the desirable quality of detection [2].

The purpose of this paper is to develop and research a new nonparametric algorithm based on a functional transform [5] using the smoothed estimate of the empirical distribution function of partial likelihood ratios, which have some useful properties of a full permutation test.

II. General Problem Definition

We can divide the signal space observed by the radar into two areas. In one area, as supposed, there is a useful signal, in the other there is interference: noise or clutter. Signal detection is achieved by using a difference of a multivariate probability density in observed areas. Thus, the task of detection is reduced to checking the hypothesis H_0 about the equality of probability density functions and the alternative hypothesis H_1 :

$$H_0 : f_S(\mathbf{x}) = f_N(\mathbf{x}) \tag{1}$$

$$H_1 : f_S(\mathbf{x}) \neq f_N(\mathbf{x}), \tag{2}$$

where $f_S(\mathbf{x})$ is a probability density function of a signal in the area where we are trying to find a target, $f_N(\mathbf{x})$ is a probability density function of a received signal in the area where there is no target.

Let us assume that from the samples received from signal and noise (or clutter) areas, it is possible to generate a mixed vector

$$\mathbf{x} = \{x_1, x_2, \ldots, x_m, \ldots, x_n\}, \tag{3}$$

where $x_1, x_2, \ldots, x_m$ are samples received from the noise or clutter area, and $x_{m+1}, \ldots, x_n$ are samples received from the signal area. Sample element x_i can be not only a scalar one-dimensional variable but also have a form of a multidimensional vector. We will suppose that the signal and noise (or clutter) samples are statistically independent.

Then the task of testing the hypothesis can be reduced to checking the hypothesis about the form of the density function of the mixed vector

$$H_0 :\ f_0(\mathbf{x}) = \prod_{i=1}^{n} f_N(\mathbf{x}) \tag{4}$$

$$H_1 :.\ f_1(\mathbf{x}) = \prod_{i=1}^{m} f_N(x_i) \prod_{i=m+1}^{n} f_S(x_i).$$