A nonparametric algorithm for detecting useful nonstationary signals on the background of stationary noise is described. The algorithm properties were investigated with the aid of test signals describing monopole and dipole sources.

The problem of detecting signals emitted by moving source on the background surrounding space noise is discussed. The signal is assumed to be a noise signal with a level essentially lower than the level of space noise [1, 2]. The signal is received by a single receiver. Since the assumed conditions are close to reality, the solution of this problem may be of practical interest.

Signal processing consists in passing the received input signal through square-law detector and through a low-pass filter. The source is assumed to move linearly and uniformly with a velocity \( v \), \( h \) being the minimum distance from the trajectory of source motion to the receiver and \( L \), the distance of the source from point \( M \) at the instant emission began (see Fig. 1).

The signal applied to the receiver can be represented by the sum of the useful source noise \( s \) and background space noise \( \eta \)

\[ y(t) = s(t) F(t) + \eta(t) \]

where \( F(t) \) is a function describing the attenuation of the useful signal as a result of propagation in space taking into account the directivity pattern of the source, and normalized so that \( \max\{F(t)\} = 1 \), and \( t \) and \( T \) are signal emission and reception times respectively.

The relation between the useful signal and space noise strength at the receiver input is described by the parameter

\[ q = 10 \log \left( \frac{\sigma_0^2}{\sigma^2} \right) \]

where \( \sigma_0^2 \) and \( \sigma^2 \) is the variance of useful noise and space noise respectively. The times \( t \) and \( T \) are related by

\[ t = \frac{T - \beta t_2 - \sqrt{t_1^2 \left(1 - \beta^2\right) + (t_2 - \beta T)^2}}{1 - \beta^2} \]

In (1) \( t_1 = h/c \), \( t_2 = L/c \), and \( \beta = v/c \), where \( c \) is speed of sound in the medium.

The object begins to move at the time \( t = 0 \) when it is at a distance \( L \) from point \( M \). The signal from the object arrives at the receiver input at the time \( T_0 = \sqrt{\tau_1^2 + \tau_2^2} \). The received signal is rectified by the detector and filtered by the low-pass filter. The mathematical expectation of the processed signal is

\[
\langle y^2 \rangle = \sigma_0^2 + \sigma^2,
\]

where \( \sigma_0 \) is defined for the instant the useful signal peak is at the receiver input. The average noise signals \( s \) and \( \eta \) in (2) are assumed to be equal to zero and not cross-correlated.

The problem consists in finding by measurement the useful noise variance \( \sigma_0^2 \) and the times when the useful signal is maximum.

The various signal processing methods can be divided into parametric and nonparametric. The former assume a priori knowledge of the form of the function \( F(t) \) and operate, as a rule, by searching for parameters describing the function \( F(t) \) that minimize a certain functional. Since in practice this form is not known, the nonparametric approach is more suitable. Here we describe a nonparametric algorithm of processing the received signal that makes it possible to extract the desired function \( F(t) \) from noise.

The received signal is measured at time instants \( T_n \) differing from each other by a fixed value \( \Delta T \) so that after the object passes by the receiver we get a sequence (\( N \) readings in all) of measurements \( y_n, n \in [0, N - 1] \). The signal is processed by applying to it elementary operations consisting of piecewise linear interpolation of the received signal by the method of least squares.

The obtained sequence of measured values is divided into windows of length \( 2(K + 1) \), where \( K \) is an integer beginning with a certain \( y_m \). Inside the window the measured values are indexed by the letter \( i \) so that at the center of the window \( i = 0, i \in [-K + 1, K + 1] \) (see Fig. 2). The windows are indexed by \( k, k \in [1, P + 1] \), \( P + 1 \) windows in all. In the final result, \( y_i \) is described by three numbers \( (m, k, i) \) related to \( j \) by

\[
j = m + i + (2K - 1)(K + 1)
\]

At the window boundaries are specified the values \( f_k^m \) defined below and inside the windows the measured values are approximated by the linear function

\[
f_k^m(i) = \alpha_k^m i + \beta_k^m
\]

The coefficients \( \alpha_k^m \) and \( \beta_k^m \) can be found from the boundary values \( f_k^m(-k - 1), f_k^m(K + 1) \) and the function \( f_k^m(i) \) has the form