Operative Recognition of Standard Signals in the Presence of Interference with Unknown Characteristics

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Abstract. The purpose of this work is to develop new methods for the operative recognition of standard signals in the presence of interference with unknown characteristics. To solve this problem, the disproportion functions are used.
With the exception of the method based on the use of current spectra, the proposed methods do not require observation of the analyzed signal over a certain period of time. For a given set of standard signals, recognition is performed by the current values of the analyzed signal and its derivatives. The problem is solved for several cases.
The cases are considered when additive or multiplicative interference appears and disappears at random times. The solution of the problem is given when the standard signals can be pulses of different types. An option is also considered when the interference with an unknown spectral characteristic is superimposed on the standard signal at some obviously unknown frequencies. In addition, the case is considered when additive interference takes constant values at random times. In all cases, the standard signal is a part of the analyzed signal with some constant, previously unknown scale factor. The proposed methods make it possible to recognize a fragment of the standard signal if it is in the analyzed signal at the current time.

Keywords: signal recognition, disproportion functions, integral disproportion function, additive interference, multiplicative interference, standard function, pulses, signal fragment, spectrum, harmonic.

1 Introduction

There is a wide class of tasks for which solution it is necessary to recognize the standard signals. Such problems arise in technical diagnostics and in solving other technical and technological problems. For example, in flaw detection, it is necessary to recognize the oscillograms characteristic of defects of a certain type [1].

There is a problem of recognition of acoustic pulse signals against the background of technogenic noise is described [2].

When radio signals are retransmitted in automatic mode, they are scanned in order to identify one of the pre-defined sound images [3]. If they are detected, commands are generated to change the mode of operation of the repeater.

The waveform recognition is also used in asynchronous address communication systems (AACC). Each channel (subscriber) is assigned a certain waveform, which is the hallmark of this subscriber [4].

If an analysed signal is a sum of standard signal and of the interference, it is usually unknown with what coefficient the standard signal is included in the analyzed one. It's a serious obstacle to recognize the standard signal. In addition, often the decision-making system imposes restrictions on the time required for recognition. Therefore, the development of recognition methods that would be operational and invariant with respect to the scale factors is an important task.

This paper describes methods for recognizing standard signals in the presence of random interference with unknown characteristics. The cases when additive or multiplicative interference appears and disappears at random time are considered.

A variant is considered when the interference with an unknown spectral characteristic is superimposed on the standard signal at some obviously unknown frequencies.

It is also considered the case when the standard signals can be different types of pulses.

In addition, the problem is solved for the conditions when the additive interference at random times takes constant values, with the result that its first and second derivatives are equal to zero. All the standard functions are continuous, smooth. In all the cases considered, the standard signal is included in the analyzed one with some constant, previously unknown scale factor.

2 Formal Problem Statement

Below is the mathematical formulation of the problem. There are the finite set of standard signals that are described by the functions $f_i(t)$, where $t \in [0;T_i]$, $i = 1, 2, ..M$.

These functions are smooth, continuous, having first derivatives.

In the presence of additive interference, the analyzed signal is described by the expression:

$$y(t) = kf_i(t + \tau_i) + \eta(t) , \tag{1}$$

where $f_i(t)$ is the i-th standard function; $\tau_i \in [0;T_i]$ is the time shift between the signal and the i-th standard; $\eta(t)$ is an additive interference, which is known only that it can disappear and appear at random points in time; k is a coefficient whose value is unknown.

The expression for the signal with multiplicative interference is

$$y(t) = kf_i(t + \tau_i)\eta(t) . \tag{2}$$

It is necessary to determine by the current values of the signal and its first derivative, which of the standard functions is present at a given time in the analyzed signal.

3 Literature Review

There are many different ways to recognize signals. In [1] a neuron is proposed that can find a signal in the presence of interference. A deterministic neural network based on this neuron is proposed.

However, this network needs a certain number of samples of the processed signal. In addition, for each neuron, it is necessary to experimentally select the so-called coefficient of generalization.

In [2], the problem of recognizing acoustic pulsed signals against a background of technogenic noise is solved using samples of seismoacoustic pulses and pulses of industrial noise, as well as from sound recordings during coal mining.

A non-classical approach for solving the signal recognition task, which occurs during automated radio monitoring, is described in [5]. It is proposed to use the decision rule for selection and recognition of specified signals in the presence of unknown signals, which is based on the signal description, operating in the frequency channel, by a probability model in the form of orthogonal expansions.

The operative recognition of fragments and complexes of signals and the allocation of video data objects by means of object systems of wireless networks is developed in [6]. In this case, so-called essential counts are used. Among them, with the help of information parameters, the significant weighty counts are selected. They are a basis for the operative processing of data.

A problem of acceleration of objects detection process on the images is solved in [7]. A multiscale scanning is used. For the solution of this task, it is offered to use preliminary processing of candidates with using integrated characteristics. This processing is realized as the first stage of the classifiers cascade of the mixed type.

The artificial neural networks are used widely to solve the recognition problem [8,9].

The Wavelet analysis is also used to recognize signals [10]. However, its use also requires observations of the analyzed signal over a certain period of time.

In practice, the decision-making system often requires operative detection of signs that a fragment of one of a given set of standard signals is present in the signal being processed. To do this, it's necessary to filter the interference. However, this can be done only if certain information about the interference is known, for example, the spectral characteristic. In practice, obtaining such information can be an independent task.

The widely used correlation methods can show a close correlation for similar in shape, but different standard signals, which prevents their recognition.

There are several methods for solving a problem that satisfies the conditions set. All of them are based on using the disproportion functions, proposed in [11].

For the case when the analyzed signal is described by expression (1) or (2), the first order derivative disproportion function is used for numerical functions that are parametrically defined [12]. The first-order derivative disproportion function of $y(t)$ with respect to standard function $f_j(t+\tau_j)$ is defined as follows:

$$@d^{(1)}_{f_j(t+\tau_j)}y(t)=\frac{y(t)}{f_j(t+\tau_j)}-\frac{y'(t)}{f'_j(t+\tau_j)}=\frac{kf_i(t+\tau_i)+\eta(t)}{f_j(t+\tau_j)}-\frac{kf'_i(t+\tau_i)+\eta'(t)}{f'_j(t+\tau_j)}. \\ =k\,@d^{(1)}_{f_j(t+\tau_j)}f_i(t+\tau_i)+@d^{(1)}_{f_j(t+\tau_j)}\eta(t) \tag{3}$$

The symbol "@" is selected to denote the operation of computing the disproportion. The left-hand side of (3) is read "at *d* one $y(t)$ with respect to $f_j(t+\tau_j)$ ".

4 Method of recognition of a continuous standard signal when impulse interference appears and disappears at random times

In this case, it is necessary to calculate the disproportion (3) for each of a given set of standards $f_j(t+\tau_j)$ while gradually increasing the shift τ_j from zero to T_j.

For the case, when $j=i$, the disproportion (3) has the form:

$$@d^{(1)}_{f_i(t+\tau_i)}y(t)=\frac{\eta(t)}{f_i(t+\tau_i)}-\frac{\eta'}{f_i'}=@d^{(1)}_{f_i(t+\tau_i)}\eta(t). \tag{4}$$

Obviously, with the disappearance of interference when $\eta(t)=0$, $\eta'(t)=0$, as well as with a properly selected time shift $\tau_j \in [0;T_i]$, the disproportion (4) is zero. Thus, the zero of disproportion (3) indicates that at the moment of time t the interference disappeared, and the standard function $f_i(t)$ presents in the analyzed signal with shift by τ_i. For other standard functions, the disproportion (3) will not be zero for any shifts in time. An exception may be the case when several standards have matching fragments.

When the analyzed signal is described by expression (2), the disproportion (3) $y(t)$ with respect to $f_i(t+\tau_i)$ is:

$$@d^{(1)}{}_{f_i(t+\tau_i)}y(t)=-k\eta'(t)\frac{f_i(t+\tau_i)}{f_i'(t+\tau_i)}. \tag{5}$$

At the moment when the derivative of interference $\eta'(t)=0$, the disproportion (5) becomes equal to zero. That is, in this case, operative recognition of the standard signal occurs even in the presence of multiplicative interference.

5 The method of recognition of pulsed standard signals with the appearance and disappearance of impulse interference at random times

In [12], the case is considered when pulsed standard signals are recognized: rectangular, trapezoidal, etc., for which the first derivative does not always exist or a significant time interval it's equal to zero. As a result, the method discussed above cannot be applied since the disproportion (3) cannot always be calculated. For these conditions, it is proposed to use the first-order integral disproportion for the functions defined parametrically [14]. In this case, the derivatives are not used. This disproportion of the analyzed signal $y(t)$ with respect to the standard $f_i(t+\tau_i)$ is:

$$@I^{(1)} f_i(t+\tau_i) y(t) = \frac{\int_{t-h}^{t} y(t)dt}{\int_{t-h}^{t} f_i(t+\tau_i)dt} - \frac{y(t)}{f_i(t+\tau_i)} \tag{6}$$

where h is the preset time interval. In the discrete representation of signals, this is a time quantization step.

At the time when the interference disappears, a fragment of the standard signal is automatically recognized.

If in general, we denote any standard function by $x(t)$, then it is represented by an array of samples $x_0, x_1, \ldots x_q, \ldots . x_N$. The corresponding array $y_0, y_1, \ldots y_q, \ldots . y_N$ is the analyzed signal.

We assume that they are obtained with the same quantization step. The defined integrals in (6) are approximately calculated by the trapezium formula. Then the integral disproportion (6) of the function $y(t)$ with respect to $x(t)$ is:

$$@I_x^1 y = \frac{y_{q-1} + y_q}{x_{q-1} + x_q} - \frac{y_q}{x_q} \tag{7}$$

To illustrate the operation of the proposed algorithm, a signal was simulated, which is the sum of a rectangular pulse multiplied by a scale factor and of some random interference. The waveform of the signal is shown in fig. 1. On intervals from 18 to 38 and from 218 to 238, the fragments of rectangle pulse are visible because the interference disappears in this time. But the automatic detection of these fragments is possible only due to the calculation of the disproportion (7). The disproportion function (7), that is appropriate for the analyzed signal is shown in the fig.2.

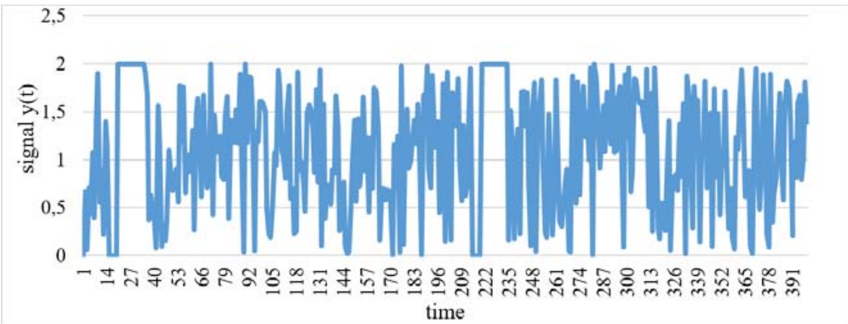


Fig. 1. Rectangular impulse with additive interference

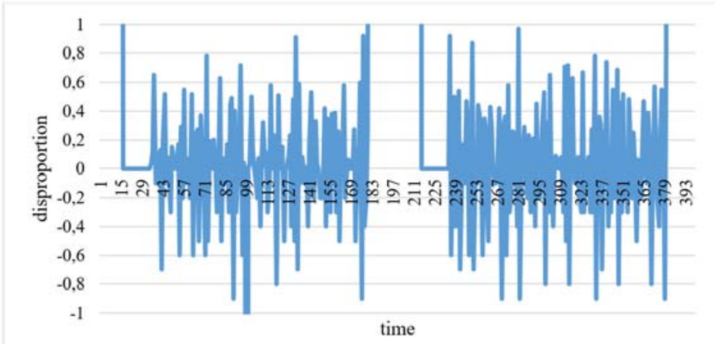


Fig. 2. The disproportion of a rectangular pulse with presence addition interference with respect to a rectangular standard one.

As can be seen from the fig.2, for points where the interference is not superimposed on the standard signal, the disproportion (7) is equal to zero, despite the presence of an unknown scale factor. Therefore, we can conclude that the analyzed signal contains a rectangular pulse.

6 Signal recognition with partial overlapping of its spectrum by the interference spectrum

The case is considered when the interference with an unknown spectral characteristic is superimposed on a standard signal at unknown frequencies. Let the set of spectra of the standard periodic signals be given. The analyzed signal is the sum of an unknown standard signal from a given set with an unknown coefficient and of random interference. The interference is an unknown periodic signal with an unknown spectrum. It is only known that the interference spectrum is partially intersected with the spectra of the standard signals at unknown frequencies. It is necessary to develop a method of recognition of the standard signal in the analyzed one by the current values of the spectrum of the analyzed signal at the current time.

In this case, the mathematical formulation of the problem can also be represented by the expression (1). However, as the standard functions, the spectra $s_i(\omega)$ of these signals are used, where ω is the frequency, $i = 1, 2, ..., n$. Each of the functions by the condition is periodic with a period $T_{i,}, i = 1, 2, ..., n$.

In fact, the ordinates of the spectrum for discrete frequencies are known.

The spectrum $s_y(\omega, t)$ of the analyzed signal $y(t)$ (1) is calculated on the current interval $[t - T_i]$.

It is necessary to execute the operational recognition of a fragment spectrum of the standard signal, that is included in the analyzed one.

Let there are M harmonics of analyzed signal, that belong to standard signal only. The interference spectrum is equal to zero on these frequencies. In general, if the standard signal is a part of the analyzed one, it can be expected that there will be harmonics m such that $m \in M$. Then the obtained amplitudes of the harmonics will differ from the amplitude of the harmonics of the standard function by the scale factor c, the value of which is unknown.

$$A_{yi}(\omega,t) = cA_i(\omega) , \tag{8}$$

here, $A_i(\omega)$ is the amplitude of the i -th standard signal for the harmonic m , $A_{yi}(\omega,t)$ is the corresponding amplitude of the analyzed signal at the time instant t.

According to the condition, the frequencies $m = 1, 2, ..., q$, for which the interference spectrum does not overlap with the spectrum of the i -th standard function are unknown. Therefore, the value of the coefficient c from equation (8) cannot be found. Also, the presence of interference does not make it possible to determine this coefficient, with the help of the normalization of the analyzed signal spectrum with respect to the spectrum of the standard one, since it is not known which fragment of the standard spectrum is included into the spectrum of the analyzed signal.

Thus, for recognition, it is necessary to detect the presence of a proportional relationship between fragments of the amplitude spectra of the standard and analyzed signals although the coefficient of proportionality c is unknown.

Therefore, to detect a proportional relationship between the amplitudes of the current spectra of the signal $y(t)$ and the standard $f_j(t)$, the first order derivative disproportion function is used for the functions specified parametrically [11].

At the current time, the disproportion (3) is calculated for the amplitude spectra of the signals $y(t)$ and $f_j(t)$. These characteristics are functions of frequency ω: $A_{yi}(\omega,t)$ and $A_i(\omega)$, that is, the parameter in both cases is frequency.

The spectrum of the analyzed signal includes the harmonics of both the standard and the interference. At the same time, the spectrum of the analyzed signal may be wider than the spectrum of the standard one. Therefore, in order to carry out recognition for each harmonic of the analyzed signal in this case, it is preferable to calculate the disproportion of the amplitude spectrum of the standard signal with respect to the spectrum of the analyzed signal.

Accordingly, the disproportion for them is

$$@d^{(1)}_{A_{yi(\omega,t)}} A_i(\omega) = \frac{A_i(\omega)}{A_{yi}(\omega,t)} - \frac{dA_i / d\omega}{dA_{yi} / d\omega} \tag{9}$$

If the recognition of i-th standard occurs, its decomposition into a Fourier series occurs on the current interval of length T_i . The frequency changes discretely. Therefore, disproportion (9) is calculated for discrete values of the frequency $k\omega_i$, where k is the harmonic number, $k > 0$. Since discrete spectra are used, it is proposed to calculate the integral disproportion (7).

For the problem under consideration, this disproportion has the form:

$$@\, I^{(1)}_{A_{yi(\omega,t)}} A_i = \frac{A_i[(k-1)\omega] + A_i[k\omega]}{A_{yi}[(k-1)\omega_i t] + A_i[k\omega_i t]} - \frac{A_i[d\omega_i]}{A_{yi}[k\omega_i t]} \tag{10}$$

The disproportion (10) equals to zero for proportional harmonics of both spectra.
Example.
Let a set of standard functions consists of two functions $f_1(t)$ and $f_2(t)$.

$$f_1(t) = \cos(t) - 0.5\cos(2t) + 1.2\sin(3t) + 2.2\cos(4t) + 2\cos(5t+1) + \\ +4.3\cos(6t) - 3\sin(7t) + 1.1\cos(8t) - 1.5\sin(9t) \tag{11}$$

$$f_2(t) = -1.6\sin(t) + \cos(2t) - 2.7\cos(3t) + 3\sin(4t) - 1.7\cos(5t) - \\ -0.3\sin(6t) + 0.8\cos(8t) + 1.6\cos(10t) \tag{12}$$

The interference is

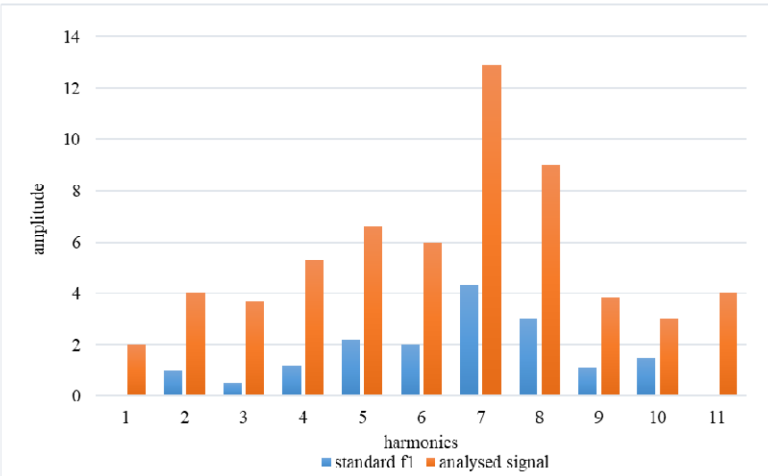
$$\eta(t) = 1 + \cos(t) + 3.2\sin(2t-3) - 1.7\sin(3t+3) - \cos(8t-2) + \\ +2.8\cos(9t+4) - 2\cos(10t) \tag{13}$$

The choice of $f_1(t)$ and $f_2(t)$ was due to the need to model such standard signals so that the interference partially crosses both standards at some frequencies.

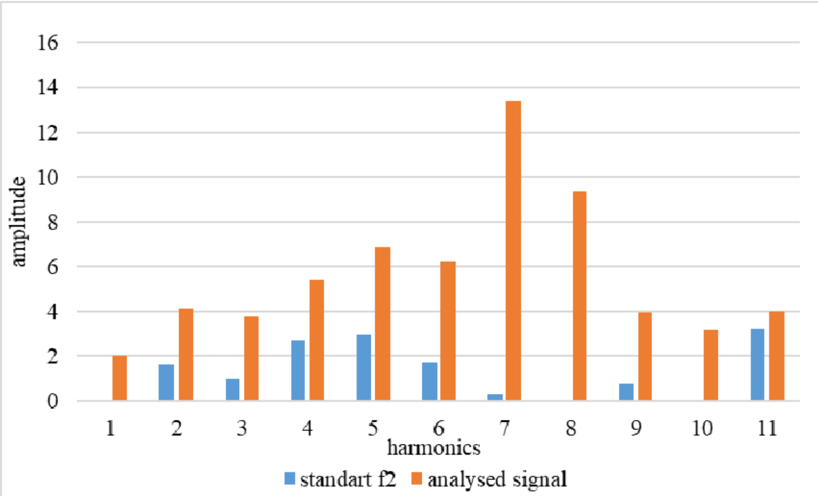
The analyzed signal (14) presents the first standard with a scale factor of $k = 3.12$.

$$y(t) = 3.12\, f_1(t) + \eta(t) \tag{14}$$

The fig. 3 shows the graphs of the amplitude spectra of both standards against the background of the spectrum of the analyzed signal. It is obvious, that it's difficult to identify the relationship between the spectra of standard and analyzed signals visually.



a)



b)

Fig. 3. Graphs of the spectra for the first time reference of the time of the first (a) and second (b) standards against the background of the signal under study

For the solving task, the values of disproportion (10) are calculated for the amplitude spectra of the standards $f_1(t)$, $f_2(t)$ with respect to the spectrum of the analyzed signal $y(t)$. The results are shown in fig. 4 and fig. 5.

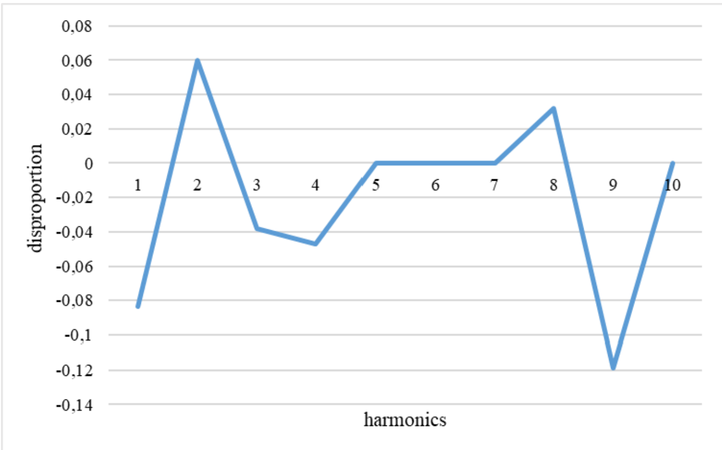


Fig. 4. Graph of the disproportion of the first standard $f_1(t)$ with respect to the signal under study

An analysis of fig. 4 and fig. 5 shows that for the first standard, the disproportion is zero at harmonics 5, 6 and 7. At the same time, for the second standard, it turned out to be non-zero for all harmonics. This suggests that it is the first standard is a part of the signal under study.

Fig. 5. Graph of the disproportion of the second standard $f_2(t)$ *i*-th respect to the signal under study

It is advisable to compare the proposed method of recognition of the standard signal with the correlation one. To do this, it is necessary to determine the presence or absence of a correlation between the harmonics of the analyzed and standard signals. To improve the accuracy, 21 harmonics of every standard spectrum were used to calculate the pair correlation coefficient. The critical (tabular) value is $r = 0.423$ at a significance level of $p = 0.05$ [16, 17].

For this example, the following pair correlation coefficients were obtained: between the first standard and the signal under study $r_1 = 0.837$; between the second standard and the signal under study $r_2 = -0.447$. The absolute values of both coefficients exceed the critical value. It means that there is a correlation between the spectra of the signal under study and both standards. Although the coefficient of pair correlation for the second standard signal is less than for the first one, however, this does not give grounds for asserting that the namely first standard is included in the analyzed signal.

7 Statement of the problem for the case when the standard functions are smooth, but the interference takes constant values

In the mentioned works, the case is not considered when the standard signal is continuous and is described by a smooth function, but the interference is of a pulsed nature. Specifically, the interference may be a sequence of rectangular or trapezoidal pulses with arbitrary parameters. There may be other impulse interferences, for example, the sinusoid with cut vertices due to passing through non-linear devices with amplitude limits. In all these cases, the interference can take constant values at random times.

Thus, a constant value of the interference and a time-varying one of the standard signals arrive at the input of the discriminator at random times. The analyzed signal is described by expression (1), but now the first and second derivatives of the interference η (t) become zero at random times.

In this case, it is proposed to investigate the first derivative of the analyzed signal (1)

$$y'(t) = kf_i'(t+\tau_i) + \eta'(t); \qquad (15)$$

Instead of (3), it is necessary to calculate the current values of the first-order derivative disproportion of the function $y'(t)$ with respect to $f_j(t+\tau_j)$

For the case when $j = i$, this disproportion is:

$$\begin{aligned} zyf(t) &= @d_{f_i'(t+\tau_i)} y'(t) = \left(\frac{kf_i'(t+\tau_i)+\eta'(t)}{f_i'(t+\tau_i)} + \frac{kf_i''(t+\tau_i)+\eta''(t)}{f_i''(t+\tau_i)}\right) = \\ &= \frac{\eta'(t)}{f_i'(t+\tau_i} - \frac{\eta''(t)}{f_i''(t+\tau_i)} = @d^1_{f_i'(t+\tau_i)} \eta'(t) \end{aligned} \qquad (16)$$

Obviously, if the interference disappears or its value is constant, $\eta'(t) = \eta''(t) = 0$. So, if the time shift is selected properly in this case, the disproportion (16) is equal to zero. In practice, the disproportion (16) also may be close to zero, if a denominator modulo tends to infinity. Therefore, it is also required to calculate the coefficient

$$k_i(t) = \frac{y'(t)}{f_i' \ (t+\tau_i)} \qquad (17)$$

If coefficient (17) is not equal to zero and it doesn't tend to infinity, and disproportion (16) is equal to zero, this indicates that the interference has a constant (including zero) value at time t, and a fragment of the standard function $f_i(t)$ is included to the analyzed signal. It may be if the time shift τ_i is selected properly.

For the other standard functions, these two conditions will not be fulfilled at the same time for any shifts of time. As in the previous cases, the exception may be the case when several standards have matching fragments.

Now consider an example, when the analyzed signal $y(t)$ is defined as follow:

$$y(t) = kf(t) + \eta(t), \qquad (18)$$

where $k = 3$;

$$f(t) = \exp(-0.1t)\cos(t)\,. \qquad (19)$$

Here, for simplicity, the shift $\tau = 0$ is assumed.

The interference $\eta(t)$ is a sine wave with cut vertices.

The disproportion $zyf(t)$ (16) for $y(t)$ (18) with respect to $f(t)$ (19) at $\tau = 0$ is showed in fig.6.

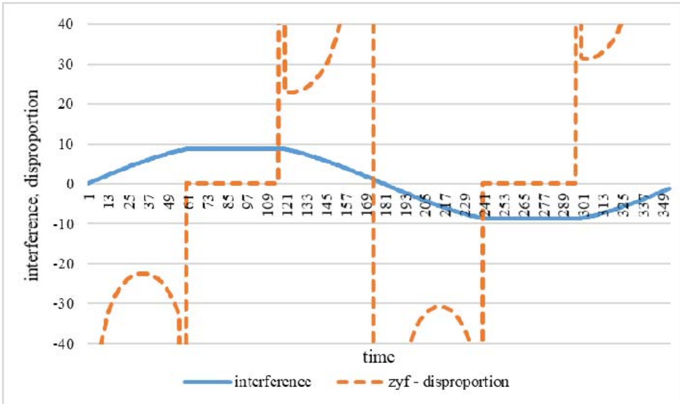


Fig. 6. Dependence of the disproportion $zyf(t)$ on the interference $\eta(t)$

From fig. 6 it can be seen that the disproportion $zyf(t)$ (16) equal to zero in the intervals, where the interference has constant values. The coefficient (17) is equal to three. Thus, fragments of the standard signal $f(t)$ are recognized at these intervals.

Let's consider another example when the standard function $f_3(t)$ is defined as

$$f_3(t) = \exp(\sin(t)) + \sin(t + 0.1). \tag{20}$$

This standard signal isn't a part of the analyzed one.

The disproportion $zyf_3(t)$ (16) for $y(t)$ (18) with respect to $f_3(t)$ (20) at $\tau = 0$ is shown in fig.7.

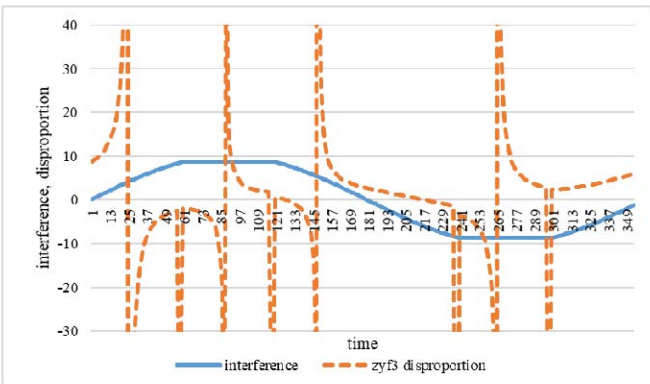


Fig. 7. The dependence of the disproportion $zyf_3(t)$ on the interference $\eta(t)$

In this example, fig.7 shows that the disproportion (16) $zyf_3(t)$ differs from zero on intervals where the interference is constant. In some cases, its values approach zero as a derivative of the standard function tends to infinity. In this case, the coefficient (17) tends to zero. All these circumstances indicate the absence of a fragment of the standard signal $f_3(t)$ in analyzed signal $y(t)$ for the current value of t.

Figures 8, 9 show the graphs of disproportions $zyf(t)$ and $zyf_3(t)$ for another interference. In this case, the interference is a sequence of rectangular pulses with pauses between them. In fact, in this example, the case when the interference disappears is also considered.

The standard and analyzed signals are previous.

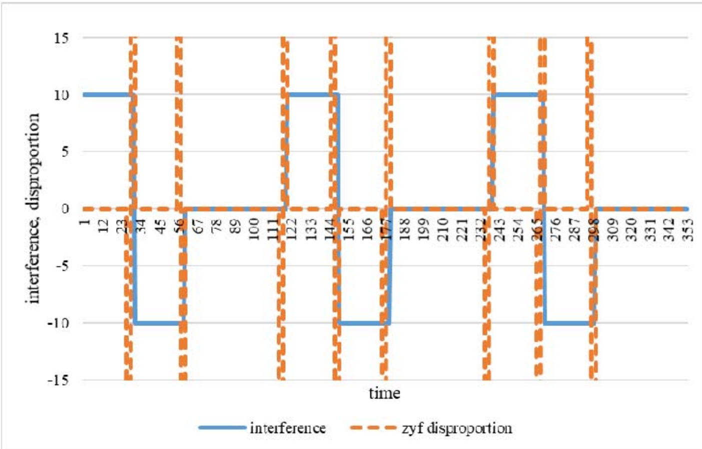


Fig. 8. The dependence of the disproportion $zyf(t)$ on the interference $\eta(t)$

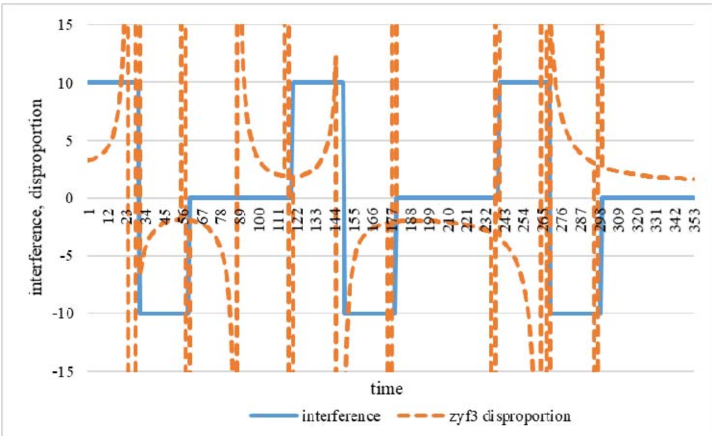


Fig. 9. The dependence of the disproportion $zyf_3(t)$ on the interference $\eta(t)$

As can be seen in fig. 8, with the exception of transients, the disproportion $zyf(t)$ is zero for almost the entire interval of change of t. In this case, the coefficient (17) is equal to three and constant. This indicates recognition of a fragment of the signal $f(t)$ at time t.

Unlike the previous case, the fig. 9 shows that the disproportion $zyf_3(t)$ differs from zero. The standard signal $f_3(t)$ does not present in the analyzed signal $y(t)$ at the time t.

8 Analysis of the methods considered

1. The advantage of the proposed methods is the recognition of a fragment of one of a given set of standard signals by the instantaneous values of the analyzed signal and its derivatives. The methods are invariant with respect to the coefficient before the standard signal.

In the case of using an analog computing device, recognition is performed instantly at the current time. For digital devices, several measurements are required to obtain derivatives by numerical methods. In particular, when computer modeling in this work, the derivatives were calculated using three points.

2. The proposed methods require large computational resources in the case of a large number of standard signals, as well as if it is necessary to select a phase shift. However, it should be noted that the methods are easily implemented using the parallelization of calculations. Indeed, it is possible to solve the problem in parallel for each of the entire specified set of standard signals and, in turn, for each of them to do this for several shift values.

3. The proposed methods allow detecting the standard signal both at individual points in time and on segments of a certain length. Therefore, the final decision on which signal is present at the moment should be made by the decision-making system, for which these methods allow to obtain initial information. In some cases, you can use information about how often the disproportion function is zero for a particular signal, and in others, how long it takes.

4. In the presence of interference, the proposed methods work only under certain conditions. In some cases, recognition is performed only in cases where interference appears and disappears. In another case, it is required that the interference take constant values.

9 Conclusions

The proposed methods allow you to automatically recognize a fragment of one of the standard signals that is a part of the analyzed at the current time. Only current data are used. All methods have invariance with respect to amplitudes of the standard and analyzed signals.

The integral disproportions make it possible to work with signals for which the calculation of the first derivative is impossible.

Separately, it should be noted the possibility of fast recognition of standard signals in case of interference in the form of a sequence of rectangular pulses that appear and disappear at random times. In this case, recognition is possible almost constantly, regardless of the amplitude of the interference and the level of the standard signal. The effectiveness of the proposed methods is verified as a result of computer simulation.

References

1. Barhatov, V.A.: Obnaruzhenie signalov i ih klassifikacija s pomow'ju raspoznavanija obrazov. Defectoscopiya, vol.4, pp.14–27 (2006)
2. Deglina, JU.B.: Nejrosetevoj algoritm raspoznavanija signalov akusticheskoj jemissii. SHtuchnij intelekt, vol.4, pp. 731–734 (2006)
3. Spravochnaja sistema po moduljam Digispot II. URL: http//redmine.digispot.ru/.../digispot.ru/projects/digispot/wiki/WikiStart
4. Venediktov, M. D., Markov, V. V., Eydus, G. S.: Asinhronnyie adresnyie sistemyi svyazi. Svyaz, M.(1968)
5. Bezruk V.M., Ivanenko S.A.: Selection and recognition of the specified radio signals in the SW band. J. Information and Telecommunication Sciences, vol. 9, number 2, pp.21–25 (2018)
6. Shevchuk B. M., Zadiraka V.K., Fraier S.V., Luts V.K.: Operatyvne rozpiznavannia frahmentiv i kompleksiv syhnaliv ta vydilennia obiektiv videodanykh zasobamy obiektnykh system bezprovidnykh merezh.J. Iskusstvennyiy intellekt, vol.3. pp.275–283 (2013)
7. Muryigin K.V.: Obnaruzhenie avtomobilnyih nomernyih znakov s ispolzovaniem predvaritelnoy obrabotki kandidatov. J. Iskusstvennyiy intellekt, vol.3. pp.193-199 (2013)
8. Artifical Neural Networks: Concepts and Theory, IEEE Computer Society Press, 1992
9. Osovskij, S.: Nejronnye seti dlja obrabotki informacii. Finansy i statistika, M.(2004)
10. Lazorenko, O.V., Lazorenko, S.V., CHernogor, L.F.: Primenenie vejvlet-analiza k zadache obnaruzhenija sverhshirokopolosnyh signalov na fone pomeh. Radiofizika i radioastronomija, vol.1, t. 7, pp. 46–63 (2002)
11. Avramenko, V.V.: Harakteristiki neproporcional'nostey i ih primeneniya pri reshenii zadach diagnostiki. Vestnik SumGU, vol. 16, pp.12–20 (2000)
12. Avramenko, V.V., Slepushko, N.JU.: Raspoznavanie jetalonnyh signalov pri nepolnoj informacii o harakteristikah pomeh. Visnik SumDu, vol.4, pp. 13–18 (2009)
13. Avramenko, V.V., Konopljanchenko, A.E., Prohnenko, JU.I.: Raspoznavanie jetalonnyh signalov pri pojavlenii i ischeznovenii pomehi v sluchajnye momenty vremeni. ScienceRise , vol.3/2(20), pp. 38–42 (2016)
14. Karpenko, A.P.: Integral'nye harakteristiki neproporcional'nosti chislovyh funkcij i ih primenenie v diagnostike. Vestnik SumGU, vol. 16, pp. 20–25(2000)
15. Avramenko,V.V., Prohnenko, Yu.I.: Raspoznavanie signala pri chastichnom perekryitii ego spektra pomehoy. Visnik SumDu, vol.3, pp. 135–140 (2011)
16. Pustyilnik, E.I.: Statisticheskie metodyi analiza i obrabotki nablyudeniy. Nauka, M.(1966)
17. Stanton, A Glantz: Primer of Biostatistics, McGraw-Hill Education, New York(2011)