

# THE SYSTEM OF AUTOMATIC DETECTION OF PENETRATION THROUGH THE PROTECTED PERIMETER BASED ON FIBER OPTIC SENSORS AND NEURAL NETWORK

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The article discusses the principle of constructing the software part of the alarm system's signal processing unit, which will solve the problem of detecting penetration through the protected perimeter by means of a signal coming from a sensitive optical fiber located on a mesh fence. The study is conducted through consideration of such problems as the decomposition of the signal received from a sensitive fiber-optic sensor into components and its further processing, first for training the neural network, and then for analyzing its state. A large part of the work is occupied by consideration of a solution that allows to form an algorithm for building a digital signal processing unit using a neural network and also to reduce the number of false alarms caused by interference and external influence on the security system.

*Keywords: neural network, sensitive optical fiber, security system, signal processing unit.*

## Introduction

At present, due to the growth of the scale of criminal and terrorist threats, measures are being taken to strengthen the protection of important and especially important sites. These measures are ultimately aimed at tightening the requirements for perimeter security systems, which are designed to ensure the security of the protected facility. The systems, as a rule, are located along the perimeter of the protected facility and provide the “early” alarm signal generation necessary for the timely and effective response of the security forces to the invasion [1].

## 1. Description of modules

The installation scheme for perimetral security alarms on the basis of fiber is shown in Fig. 1.

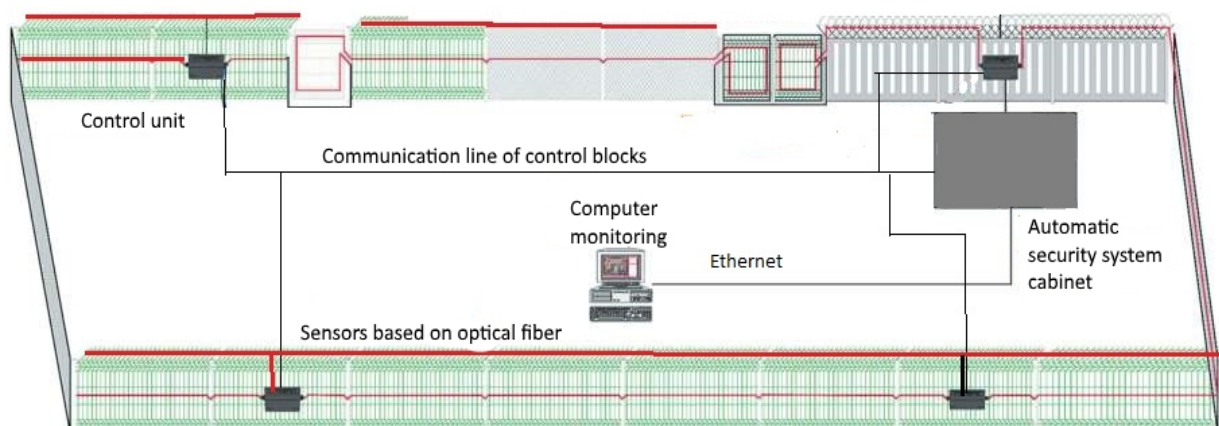


Fig. 1. Scheme of perimeter security alarm installation

Here on the mesh fence there is an optical fiber responsible for monitoring the snacking of the fence. On the top of the fence there is a parallel optical fiber line responsible for controlling climbing through the fence.

## Краткие сообщения

Consider an algorithm for detecting an intruder, which includes the registration of data and their processing with the generation of an alarm in the event of an intruder entering the protected area.

The signal from the sensor goes to the signal processing unit. The processing of the original signal in the general case consists of several stages. A typical scheme of the signal processing unit using a neural network analyzer is shown in Fig. 2. The scheme, as a rule, includes a signal adaptive filter, a digital signal processor (DSP), and a neural network analyzer is a decision block (intrusion and its type).

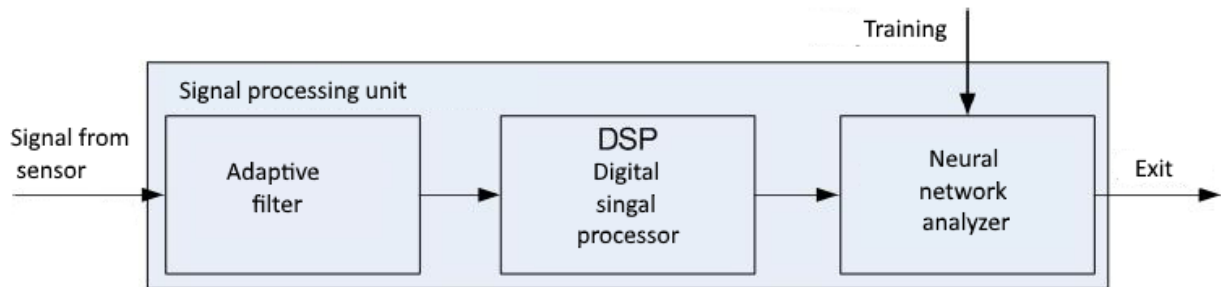


Fig. 2. Scheme of the signal processing unit

Seismic signals and vibrational processes can be described by a universal model: the process is a combination of narrowband components additively mixed with broadband noise. The parameters of the components completely characterize the process. To isolate the narrow-band signal components, the first stage involves the method of extreme filtering. It includes the allocation of signal extremes, the division into alternating components by an extreme filter, the calculation of the parameters of these components (for example, the mean frequency and dispersion in a sliding window), the application of the procedure to the residues formed when the next alternating component is removed.

The components and (or) their parameters allow us to judge the process, to obtain estimates of spectral characteristics, to isolate free and forced oscillations, to form diagnostic features, to substantially simplify the parametric analysis and to reduce its laboriousness, applying it not directly to the signal but to the selected components.

Given the time constraints for the allocation of informative components and decision-making, preference is given to a faster-acting method of extreme filtering.

### 2. Decomposition of the signal

The alternating component can be distinguished by centering relative to the moving average. The simplest method is in which only the extreme values  $x_{ei+1}$  are used, where  $i = 1, 2, \dots, m$ . Smoothing is performed by the operator of the form

$$x_{ci} = 0,25x_{ei-1} + 0,5x_{ei} + 0,25x_{ei+1}, \quad (1)$$

which corresponds to the transmission of data through a digital low-pass filter.

The first, high-frequency component is determined from relation:

$$x_{pi} = x_{ei} - x_{ci}. \quad (2)$$

The component can be extracted directly from the extremes as follows:

$$x_{pi} = -0,25x_{ei-1} + 0,5x_{ei} - 0,25x_{ei+1}. \quad (3)$$

Further transformations of the form (1), (3) are repeated over the component  $x_{pi}$ .

Then the parameters for all the components  $p$  (amplitudes  $A_i$ , frequencies  $f_i = \frac{n_i}{2\Delta t N} = \frac{n_i}{2T}$ ,  $i = \overline{1, n}$ ), which allow the formation of primary diagnostic features.

Fig. 3 shows the signal at the output of the vibration sensor, and in Fig. 4 – the marked alternating components represented by their extremes for one of the analyzed areas.

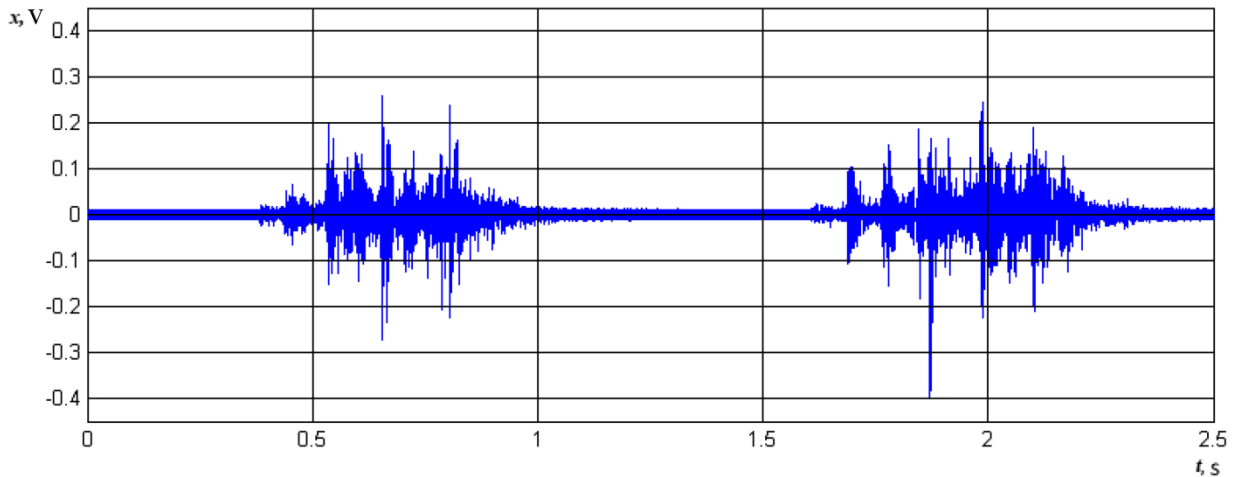


Fig. 3. Signal from the sensor

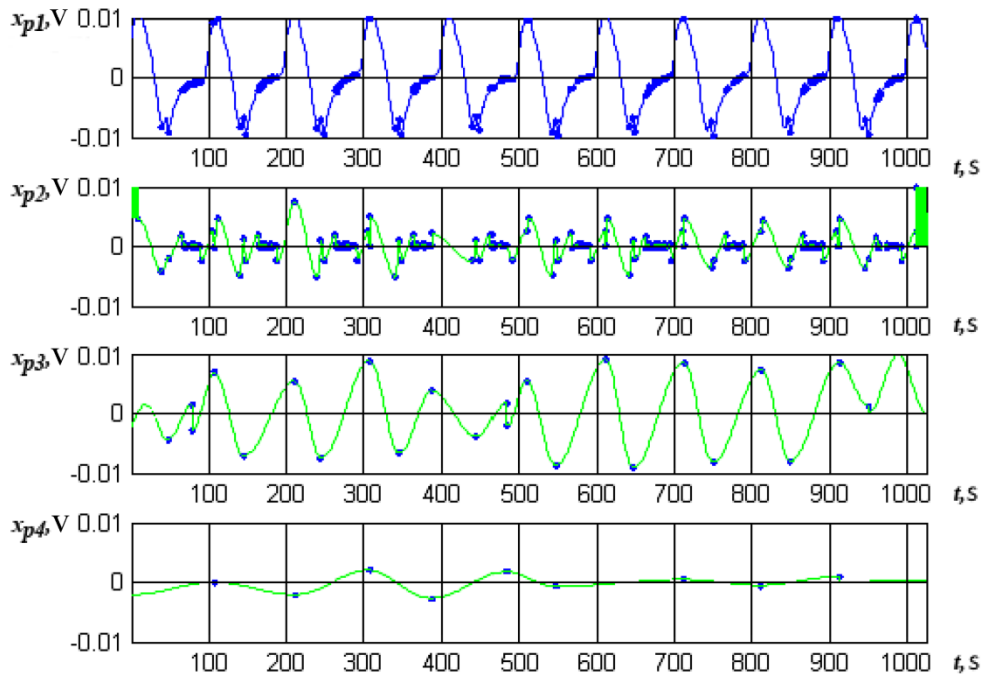


Fig. 4. Variable components of one of the analysis areas

In the transition from seismic noise to the signal generated during the intrusion into the zone of responsibility, the frequency of the components and their amplitude (and, correspondingly, the power) varies significantly. This is illustrated in Fig. 5, where the upper graph shows the signal, and on the second and third – the frequencies and amplitudes  $A_i$  of the selected components in the sliding window, tied to the beginning of the analysis interval. Here  $i = 1 \dots p$ , and  $p$  is the number of allocated components. It can be seen that, when detected, there is a decrease in frequency (high-frequency noise is masked by a more powerful signal) and an increase in amplitude.

It is known that signal extrema carry information about the highest-frequency narrow-band component. If we remove (filter out) this part from the signal, we get a smoothed curve, the extremums of which carry information about the next narrowband component. The procedure can be performed until a sequence with alternating extremums is obtained-the lowest-frequency narrow-band component. Thus, an adaptive filtering algorithm is possible.

To separate signals created by the violator from noise and interference, the third and final part of the processing in the Signal Processing Unit performs data analysis based on the principle of the neu-

ral network. The use of a neural network provides high reliability of detection at a low level of false positives.

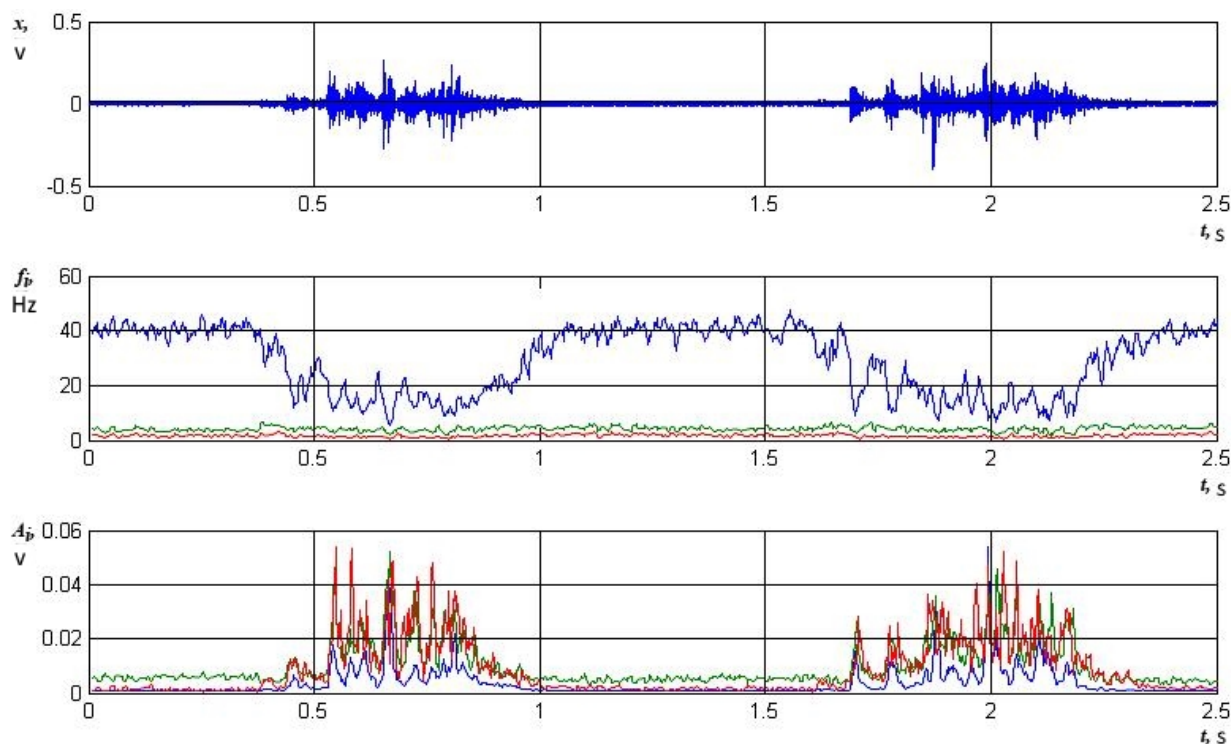


Fig. 5. The signal  $x$  and the parameters of the components:  $f_i, A_i, i = 1 \dots p$

### 3. Training of neural network

For the neural network to work, it is required to preteach it. The algorithm for learning a neural network is that the output of the last layer of neurons is compared with the sample of training, and from the difference between the desired and the actual, it is concluded what the neurons of the last layer should be to the previous one. Then a similar operation is performed with the neurons of the penultimate layer. As a result, on the neural network, from the output to the input, a table is made for changing the connection weights. The training of the system is reduced to the work of the algorithm for selecting the weight coefficients, which operates without the direct participation of the operator.

Training involves recording the initial signals from sensors installed on the perimeter. The training of the security system is performed as part of the overall configuration of the system – by adding to the database images of signals that are the result of noise factors and characteristic responses of a particular fence.

So, in Fig. 6, training is provided using a radial-basis network with zero error. The first graph is the desired network output (detection); the second graph is the amplitude of the signal in the vibration protection system; the third schedule is a fixed violation of the perimeter of the protected object. This network was trained on the signal “mesh web”. Testing on another kind of impact (“climbing through the fence”) showed the correct operation of the detector.

To create, train, and test the network, the Anfisedit editor of the Media environment was used. Network structure: four inputs, one output, number of membership functions – 5 per input, type of the psigmf accessory function. At the input of the network, the parameters of the high-frequency component are given – the mean, minimum, maximum frequencies, and the amplitude-normalized amplitude range in the 3-second observation interval.

For the data “car driving, group run, car driving”, Fig. 6 shows the detection of transport. The output of the network is  $-1$ .

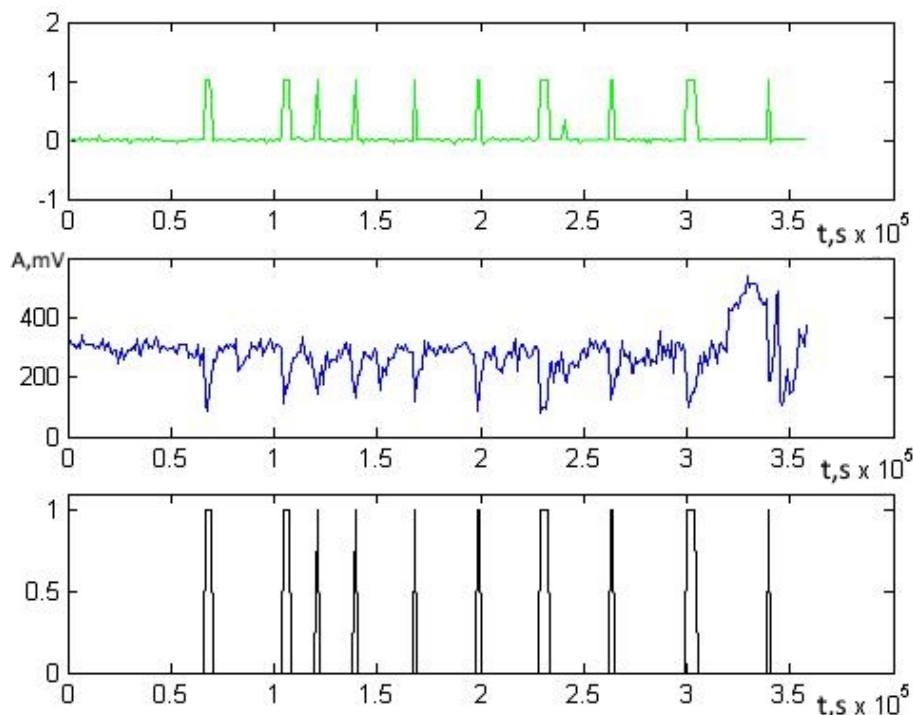


Fig. 6. The operation of a radial-basis network with zero error

### Conclusion

In security alarm systems, a neural network is a computer system, the algorithm for solving problems in which is presented in the form of a network of threshold elements with dynamically tunable coefficients and tuning algorithms independent of the size of the network of threshold elements and their input space. The introduction of neural network structures into the algorithms of the signal processing unit allows to approach the development of security systems with artificial intelligence, to increase the noise immunity of the perimeter security system as a whole. Increases as the average time to false alarm, and the likelihood of detection with subsequent classification of the type of intruder. The security system with artificial intelligence performs the task of detection and recognition automatically, taking into account all the characteristics of the original signal when analyzing. The processing process is much faster and gives a more reliable result. The use of intelligent perimeter security systems does not require operator intervention to analyze alarms and determine signs of a real intrusion or false alarm. As a result, the system itself makes a decision – this signal is a signal of real alarm or interference.

Formation of a system of signs – parameters of alternating components, extracted from the observed signal by an extreme filter, allows solving the problem of detection and classification with the help of neural networks.

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## СИСТЕМА АВТОМАТИЧЕСКОГО РАСПОЗНАВАНИЯ ПРОНИКНОВЕНИЯ ЧЕРЕЗ ОХРАНЯЕМЫЙ ПЕРИМЕТР НА ОСНОВЕ ОПТОВОЛОКОННЫХ ДАТЧИКОВ И НЕЙРОННОЙ СЕТИ

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Рассматривается принцип построения программной части блока обработки сигнала охранной системы, который позволит решить задачу обнаружения проникновения через охраняемый периметр при помощи сигнала, поступающего с чувствительного оптоволоконного датчика, расположенного на сетчатом заборе. Исследование ведется через рассмотрение таких проблем, как разложение сигнала, полученного с чувствительного оптоволоконного датчика, на составляющие и дальнейшая его обработка сначала для обучения нейронной сети, а потом для анализа ее состояния. Большое место в работе занимает рассмотрение решения, которое позволит сформировать алгоритм построения блока цифровой обработки сигналов с использованием нейронной сети, а также уменьшить с ее помощью количество ложных срабатываний охранной системы, вызванных помехами и внешним воздействием на охранную систему.

*Ключевые слова: нейронная сеть, чувствительное оптическое волокно, система безопасности, блок обработки сигналов.*

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