RADIO ENGINEERING

METHOD OF REDUCING THE INHERENT NOISE LEVEL
IN PARAMETRIC RECEIVERS

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UDC 534.222

The results of experimental investigations of methods of reducing the inherent noise level in parametric receivers used in hydroacoustic systems are considered. The noise immunity of the antenna is ensured by using a method which involves preliminary filtering of the low-frequency signal before the processing channel.

In parametric receiving antennas, as in linear hydroacoustic systems, designed to detect signals, the input data is processed in stages [1].

In the first stage the receiving antenna operates as a spatial filter, while in the second stage the signal is subjected to quasioptimal filtering in both the time and frequency domains.

One of the most effective ways of improving the quality of spatial processing of signals is to use parametric receiving antenna arrays. These consists of several pairs of pumping and receiving radiators, oriented in one direction. When using such antenna arrays it becomes possible to carry out electronic scanning of the directional characteristics of the antenna by delaying the signal from the elementary parametric receivers.

The next procedure for separating the signal on a background of interference is time processing. It should be noted that for a parametric receiving antenna, unlike linear antennas, there is a specific form of disturbing action due to the effect of the high-frequency pumping signal on the receiving element of the antenna. Then the interference situation in the field of the antenna (the acoustic-wave interaction region) has specific features. The overall interference is determined not only by the level of the noise field of the medium within the passband of the receiving channel of the antenna, but also by the intensity of the sidebands of the pumping signal, which occur as a result of their nonlinear interaction with low-frequency signal within the passband of the receiving channel.

Since the receiving elements of the parametric receiving antennas are in the field of two waves — the high-frequency pumping signal of frequency $\omega_p$ and the useful low-frequency signal of frequency $\Omega$, the signals formed in the receiving channel due to the nonlinearity of its parameters have parasitic combination components which are intense interference in the antenna.

We will consider one possible method of reducing the level of inherent interference (parasitic combination components) in the channels of parametric receiving antennas.

To illustrate the basic principles of the method we will approximate the amplitude–frequency response of the receiving channel of the parametric receiving antenna by the following power series [2]:

$$v = \rho_x \gamma_1 + \rho_x^2 \gamma_1^2 + \ldots$$  \hspace{1cm} (1)

where $v$ is the response of the receiving channel, and $\rho_x, \gamma_1$ is the sound pressure and sensitivity of the channel for the linear, quadratic and other terms ($i = 1, 2, 3, \ldots$).

The overall sound pressure acting on the receiving channel of the parametric receiving antenna can be represented in the form

$$\rho_x = \rho_c \exp(-jQt) + \rho_p \exp(-j\omega_p t).$$  \hspace{1cm} (2)
where $p_c$ and $p_p$ are the sound pressure of the signal wave and the pumping wave, and $\Omega$ and $\omega_p$ are the corresponding frequencies.

Substituting (2) into (1) and confining ourselves to the parabolic approximation of the first expression, it can be shown that the response of the receiving channel of the antenna will contain components at frequencies $\omega_p \pm \Omega$.

The components of the sideband signals which occur due to the nonlinearity of the antenna processing channel correspond to the components of the sidebands of acoustic origin. However, the directivity of signal reception will be determined mainly by the wave dimensions of the receiving element of the antenna $l$ and the wavelength of the low-frequency signal $\lambda_c$. Since the situation when $l \ll \lambda_c$ is of the greatest practical interest, the side components of electric origin carry no information on the direction of the source and represent interference ("parasitic" modulation).

We will consider the problem of the ratio of the sideband levels in the spectra of the modulated pumping signals when waves interact in an aqueous volume, and also the intermodulation distortions of the waves in the receiving channel of the antenna.

We know [3], that the amplitude of the sidebands when there is acoustic interaction of the waves are 140-170 dB below the level of the carrier. At the same time, it has been established experimentally that the parasitic modulation index in the signal-processing apparatus within the dynamic range of the amplifiers can amount to 1-3%. Hence, the components of the combination frequencies, which determine the directivity of the antenna, will mask the inherent interference of the antenna considerably, due to the intermodulation distortions in the electronic apparatus. This form of interfering action is specific to parametric receiving antennas and makes the greatest contribution to the overall interference level.

To combat "parasitic" modulation, methods are used at the present time which eliminate any signal of frequency $\Omega$ which is incident on the input of the receiving element. This is achieved by connecting a high-pass filter to the input of the electronic signal processing unit [3]. This method enables the action of signals in the electronic apparatus to be reduced to a minimum, but does not eliminate interaction in the electroacoustic transducer of the antenna because of the nonlinear properties of the piezoelectric ceramic.