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SHAPING THE ACOUSTIC IMAGES OF OBJECTS

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An acoustic signal propagating from some source, is picked up by a totality of microphones located at a distance less than the wavelength of the most high-frequency component of the signal. We analyze the spectrum of the signal received by each microphone, and estimate its parameters as compared to signals from other microphones. Then we obtain the solution of an equation system in the form of geometric coordinates of the signal sources and of their spectral composition, which are used for shaping the acoustic image of the signal source.

A large class of objects is characterized with radiation of signals in the audio range from several hertz to several kilohertz. Such objects can be studied in considerable detail, although sometimes we have no direct access to the signal sources for their thorough investigation.

Of interest is the issue of (a) determination of geometric coordinates and spectral composition of signal sources and (b) using this information for shaping the acoustic image of the object. Analysis of this image will make possible to assess the state and to determine the deviation of parameters of the object under investigation from their normal values. The study and analysis of the acoustic image is especially useful in medical examinations, for example, of human viscera (heart, lungs etc.), since in this case we do not subject the living organism to any additional outer radiation [1].

Consider an object under investigation as a totality of point sources of signals $s_k(t)$, where k is the ordered number of signal source ($1 \le k \le K$) located in the point with its geometric coordinates x_k, y_k, z_k. While propagating from the radiation center in all directions, these signals are picked up by an ($N \times M$)-dimensional set of receivers (microphones).

The received signals are delayed in time and modified in amplitude replicas of the initial signals, and in the reception point they are described by the expression $p_{i,j}^{k}(t) = A_{i,j}^{k} s_k(t - \Delta t_{i,j}^{k})$, where i, j is the ordinal number of a microphone in the two-dimensional set ($0 \le i \le N-1$, $0 \le j \le M-1$); $\Delta t_{i,j}^{k}$ is the time delay of signal propagation from the kth point source to the i, jth microphone; $A_{i,j}^{k}$ is the weight factor characterizing amplitude attenuation when the signal is propagating from the point source to the microphone; and $p_{i,j}^{k}(t)$ is the signal received by the i, jth microphone from the kth source. The microphones are located in the points with coordinates id on the abscissa, and jd on the ordinate, where d is stepwise distance between two neighboring microphones. When investigating the acoustic signals of the heart and lungs, the set of microphones is put on the body surface, at a distance of several centimeters from the object under investigation, i.e., the distance from the signal source to the reception point is less than the wavelength of the most high-frequency component of the signal. Hence, this coefficient may be thought of as unity for all point receivers with a minimum of error. All the microphones are assumed to be excited only by direct signals, and not a single signal received is a reflection from some obstacle. Then, if denoting the superposition of signals received by each microphone from all the point sources as $p_{i,j}^{k}(t)$, we may write that

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