NORMABLE METROLOGICAL CHARACTERISTICS OF GROUPS OF SEISMIC DETECTORS

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An analysis is made of metrological characteristics of seismic detectors categorized in different groups. A discussion is presented of aspects of calculating the characteristics of a group from the parameters of individual detectors while using different methods to compare these parameters.

The method of reflected waves is widely used in modern seismic prospecting. Prospecting is made more efficient by using groups of seismic detectors connected in parallel, in series, or in a combination scheme.

Seismic detectors may be joined into groups either in the field or during production at the factory. In either case, it is necessary to evaluate the quality of the group as a single product. Such evaluation in turn requires an adequate set of representative parameters. This problem has yet to be fully resolved and remains an important issue.

The advantages of grouping seismic detectors includes strengthening of the useful signal achieved as a result of the directionality of the detectors' sensitivity, frequency filtration and averaging of discontinuities connected with the arrangement of the detectors, and relative attenuation of random noise. Signal strength depends on the distance between the detectors in the given group, the number and arrangement of the detectors, the length of the wave being recorded, and the characteristics of the detectors joined to form the group (conversion factor, damping factor, natural frequency, etc.)

The foremost consideration is that the group of detectors is replacing a single detector, i.e., is the group equivalent of the latter and must be characterized by the same parameters. Important parameters in addition to those already mentioned include the coefficient of nonlinear distortion, output resistance, and displacement and frequency ranges. The tolerances for each parameter must also be taken into account. The parameters already mentioned characterize the static, dynamic, impedance, and service properties of the detector group; the tolerances for the parameters determine the limit of the main conversion error of the group, the scatter of the conversion factor, the maximum deviations of the amplitude—frequency characteristic (AFC) and phase—frequency characteristic (PFC) from their nominal values, and the degree to which they differ within the nominal frequency range. The characteristics just noted are also important characteristics for the method of reflected waves.

The natural frequencies and damping factors of a group composed of individual seismic detectors will obviously be the same as the nominal values of these parameters for a given detector within the group. Similarly, the tolerances for these parameters will be equal to the tolerances for the single detector, i.e., \( \omega_{gr} = \omega_0; \beta_{gr} = \beta; \delta\omega_{gr} = \delta\omega_0; \delta\beta_{gr} = \delta\beta \). The situation in regard to the value of the equivalent conversion factor of the group and its tolerance is not quite as clear.

The conversion factor of a seismic detector — as that of a group of detectors — is determined by the ratio of the voltage at its output to the velocity of the vibrations acting on the detector (group):

\[
K_{gr} = \frac{U_{gr}}{v},
\]

where \( K_{gr} \) is the conversion factor of the group of detectors; \( U_{gr} \) is the voltage at the output of the group; \( v \) is the velocity of the vibrations acting on the group.

The output voltage depends on the method used to connect the detectors to form the group (series, parallel, combination).
With series connection of the detectors, it is obvious that

\[
U_{gr} = \sum_{i=1}^{n} U_i = nU_d.
\]

Then

\[
K_{gr} = \frac{nU_d}{U_{gr}} = nK_d,
\]

where \( n \) is the number of detectors in the group; \( U_d \) is the voltage at the output of a typical detector; \( U_i \) is the voltage at the output of the \( i \)-th detector; \( K_d \) is the conversion factor of a typical detector.

With allowance for the tolerances for the output voltage and conversion factor of the detectors, we have

\[
\begin{align*}
U_{gr} &\pm \Delta U_{gr} = n(U_d \pm \Delta U_d) ; \\
K_{gr} &\pm \Delta K_{gr} = n(K_d \pm \Delta K_d) ; \\
\Delta U_{gr} &\pm n\Delta U_d ; \\
\Delta K_{gr} &n\Delta K_d.
\end{align*}
\]

or

\[
\begin{align*}
\delta U_{gr} &= \frac{\Delta U_{gr}}{U_{gr}} = \delta U_d ; \\
\delta K_{gr} &= \frac{\Delta K_{gr}}{K_{gr}} = \delta K.
\end{align*}
\]

Thus, for a group of detectors connected in series, the nominal value of the conversion factor of the group will be equal to the sum of the conversion factors of the individual detectors, the absolute value of the deviations of the group conversion factor from the nominal value will be equal to the sum of the absolute deviations of the conversion factors of the individual detectors, and the relative value of the deviations of the group conversion factor will be equal to the relative value of the deviations of the conversion factors of the individual detectors from the nominal value.

For parallel connection of seismic detectors into a group, the output voltage, conversion factor, and the tolerance for the factor will be equal to the output voltage, conversion factor, and tolerance for a single detector of the given type.

For a combination wiring scheme, the output voltage, conversion factor, and tolerance will be equal to the analogous parameters of the group with a series connection.

To increase the conversion factor of a detector group or strengthen the useful signal at its output, it is necessary to match the impedance of the output resistance of the group to the input resistance of a compatible amplifier. It is also necessary to know the voltage limits at the output of the group in order to ensure normal functioning of the amplifier. In light of this, the output resistance and voltage of the group should be included among its basic characteristics. In examining this question, it becomes obvious that the output resistance of \( n \) identical seismic detectors joined into a group by a series connection will increase by a factor of \( n \). Output resistance will also increase by the factor \( n \) (relative to the output resistance of a single detector) for a parallel connection. For a combination scheme, the output resistance of the group can be determined from the formula

\[
Z_{gr} = \frac{n}{m} Z_d.
\]

where \( Z_{gr} \) is the output resistance of the group; \( n \) is the number of series-connected detectors; \( m \) is the number of parallel circuits with series-connected detectors; \( Z_d \) is the output resistance of a typical detector within the group.

As was shown above, the no-load output voltage for the combination scheme is equal to the sum of the output voltages of the unloaded series-connected detectors:

\[
U_{gr,n} = nU_d.
\]

Then, with allowance for (1), we can use the input resistance to write the following expression for the output voltage of a loaded group of detectors:

\[
U_{gr,l} = U_{gr,n} \frac{Z_{in}}{Z_{in} + Z_{gr}} = nU_d \frac{Z_{in}}{Z_{in} + (n/m)Z_d}.
\]