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Method of filtration of vibroseismic signals

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The method of filtration of monochromatic vibroseismic signals is offered. The proposed method is based on the application of the operation resulting in the compression of a frequency characteristic of the passband filter with the centre of compression assigned to a basic signal. The coefficient of compression of the frequency characteristic can reach several thousands and more.

Seismic vibrators of comparatively low power, but operating for a long time, are used for the Earth's vibrational sounding in contrast to explosive methods. Therefore, in deep seismic sounding the useful vibrational signal is much lower than the level of microseismic noise. In this connection, the identification of a weak vibrational signal against the microseismic noise, i.e., obtaining the data about the amplitude and the phase of a wave field, is one of the main tasks of the Earth's vibrational sounding.

This paper is devoted to the identification of a method of a monochromatic signal with the accumulation time of up to several hours and, maybe, even tens of hours. It should be noted that the accumulation time of the passband filter is the reciprocal value of the effective bandwidth of the passband filter. The present method is referred to synchronous filtration, because the frequency tuning is given by the reference signal.

The advantage of this method is that it can be implemented by the analogue means and enables one to create the field instrumentation – reliable and rather simple, having small weight, small size and low electric energy consumption – for making observations of the fields generated by the vibroseismic sources.

The principles of such a filtration are described in [1, 2].

It is known that the output signal of any linear filter is determined both by the input signal and by the initial state of the filter at any time. The essence of the proposed method is that the accumulation procedure takes place not for the input signal (as in conventional filtration methods), but for the state of the passband filter by the short-term connection of all capacitors of an active passband RC-filter to the block of storage capacitors with a frequency within the filter passband.

It is shown that the above-mentioned operation performs the compression of the frequency characteristics of the passband filter with the compression centre equal to the frequency of the reference signal.

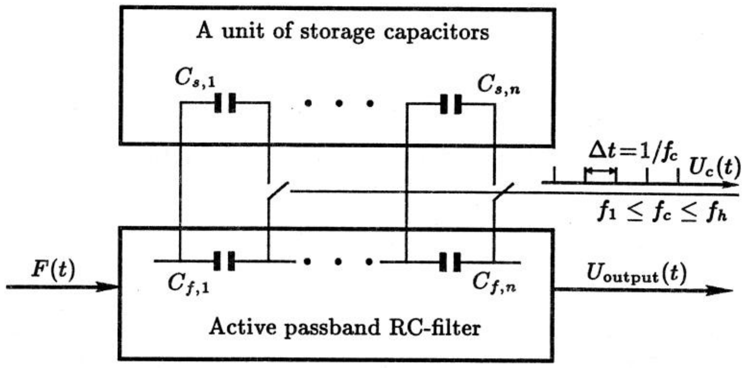

Figure 1. The block-functional scheme of the passband filter with accumulation of state

The block diagram of the filter is shown in Figure 1.

Let us define a transfer function of the active passband RC-filter. Its transfer function will be the following:

$$K(s) = \frac{K_0 \gamma s}{s^2 + \gamma s + \omega_n^2},$$

where s is the Laplace variable, γ is the passband, ω_n is the resonant frequency, $\omega_0 = \sqrt{\omega_n^2 - \gamma^2/4}$ is the free-running frequency, K_0 is the amplification factor of the passband filter at the resonant frequency.

Based on the solution obtained, the transfer function of the synchronous filter is written down as follows:

$$\tilde{K}(s) = \frac{K_0 \frac{\gamma}{k} s}{s^2 + \frac{\gamma}{k} s + \left(\frac{\omega_0 - \omega_c}{k} + \omega_c\right)^2 + \frac{\gamma^2}{4k^2}}, \qquad k = \frac{C_{s,i}}{C_{f,i}} + 1.$$

Though the formula defining the transfer function is rather complicated, it is not difficult to understand it. In the process of accumulation of state, there is compression of the frequency characteristic of the passband RC-filter with respect to the frequency of synchronization ω_c. The coefficient of compression of the frequency characteristic k can reach several thousands and more. With such a coefficient, the effective bandwidth of the filter becomes so narrow that the signal-to-noise ratio increases by a factor of 30–100 and more, and the accumulation time of the filter in the range of 1–10 Hz reaches about several hours and more.

This circumstance is confirmed by the following three graphs shown in Figure 2: the frequency characteristics of the passband filter with accumulation of state for three cases are presented, which are in full agreement with the carried out experiments.

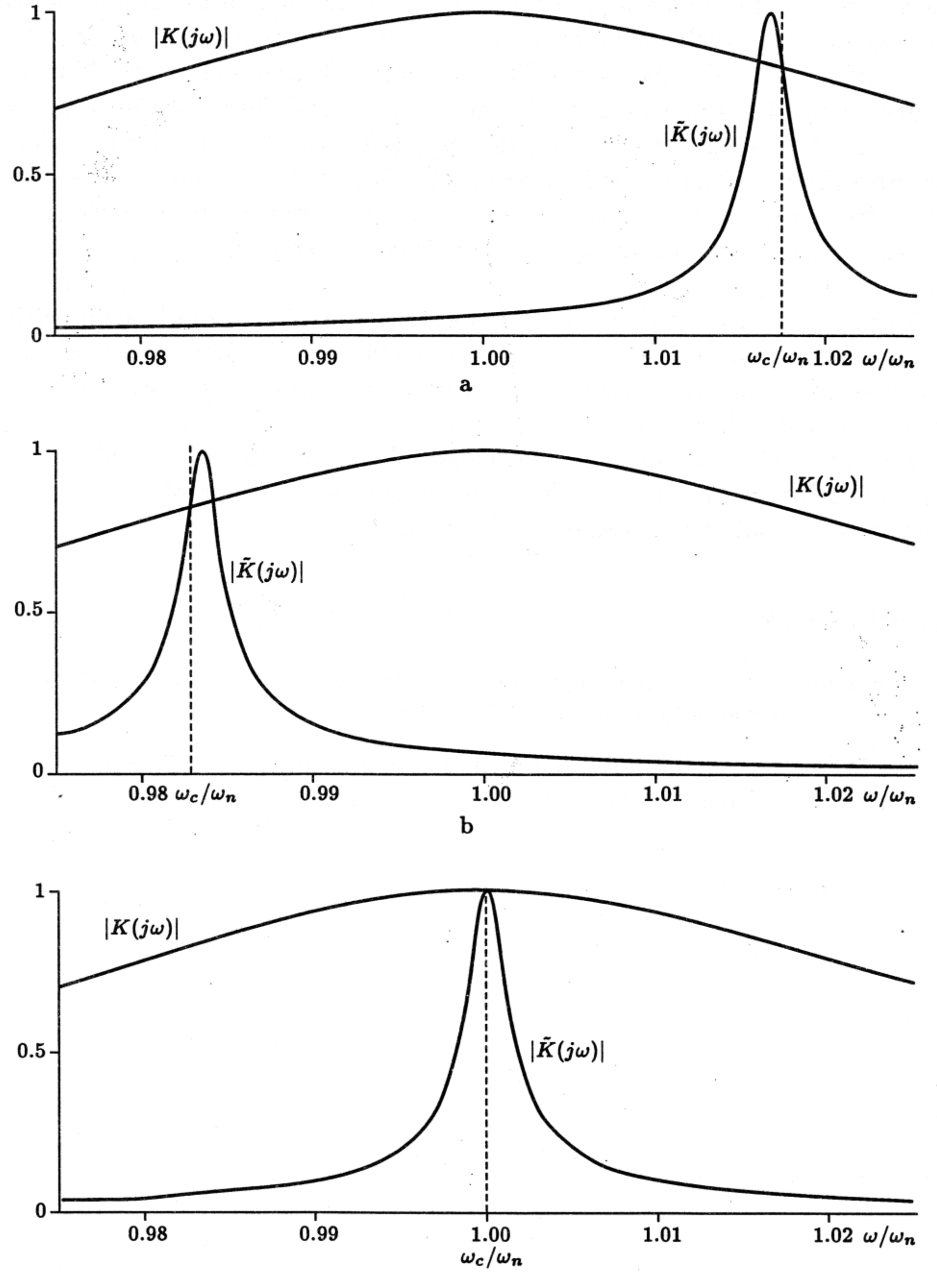

Figure 2. The change of a frequency characteristic of the passband filter with accumulation of a state for the cases: a) at $\omega_c > \omega_n$, b) at $\omega_c < \omega_n$, and c) at $\omega_c = \omega_n$

It should be noted that the process of compression of the frequency characteristics of the passband filter with the centre of compression equal to the frequency of synchronization ω_c in the process of accumulation of state is also peculiar to the passband filters of orders higher than two. This is confirmed by the well-known fact that the passband filter of any order is decomposed to a number of independent passband filters of second order. For these filters, with accumulation of state, there is a common compression of the frequency characteristics with a common centre of compression ω_c, and as consequence, the compression of the frequency characteristic with the same centre ω_c.

To conclude, it is possible to advocate, that the method of filtration with accumulation of state is a new promising technique. It enables optimizing any times of accumulation (theoretically without limitations), the absolutely stable frequency characteristic being given.

The quality of the obtained experimental data testifies to a high sensitivity of the offered method of filtration with full suppression of penetration of the basic signal to the seismometric channel.

References

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