Using Corrective Filters to Improve the Accuracy of Seismic Data

Naila Allakhverdiyeva

Azerbaijan State Oil Academy, Baku, Azerbaijan

nailaallakhverdiyeva@yahoo.com

Abstract— **In paper the question of increase of accuracy of seismic data processing by use of low-frequency and band-pass filters is considered. Thus the purpose of a filtration is decomposition of noisy seismic signal. For management of process of decomposition the operational information on spectral structure of signals is used.**

Keywords— *seismic data; noisy signal; low-pass filter; band-pass filter; decomposition of signal; cutoff frequency*

I. INTRODUCTION

The majority of natural processes including results of seismic exploration are nonlinear and non-stationary. For processing and the analysis of such processes it is necessary to know internal structure of signals.

Received during the field works seismograms contain a considerable share of undesirable waves-noises and stirring fluctuations, and useful waves are inconvenient for interpretation. Therefore primary seismograms should be processed with use of the most modern computer equipment. One of the most widespread methods of processing of noise data is correcting filtration.

II. APPLYING LOW-PASS FILTERS

Let's set mathematical model of a noisy fn signal with local non-stationary signals $f1n \div f4n$ which in the sum form useful $f0n$ information (fig.1(a)). The capacity of noise is commensurable with capacity of local signals.
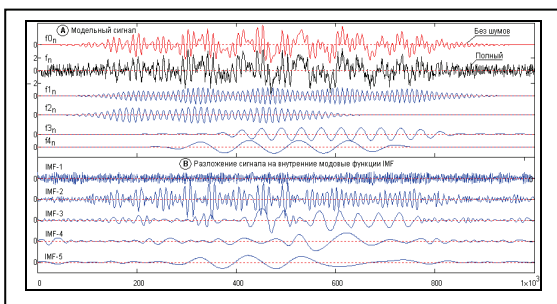

Figure 1. Mathematical model of a noisy signal

Local signals represents radio impulses with carrier frequencies $\omega1 \div \omega4$, two first of which is peak modulated. White noise of constant capacity is distributed on all frequency range of a signal. The module of signal spectrum is given on fig. 2. For spectrum calculation was used Fast Fourier Transform (FFT).
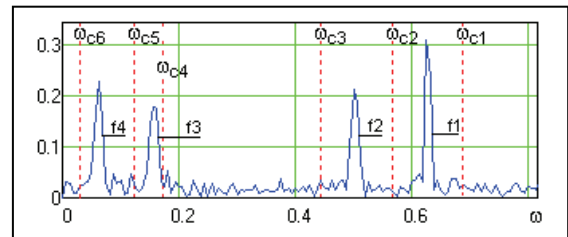

Figure 2. Noisy signal spectrum

When a signal is not noisy and in a range of a signal all frequency components are well allocated, there is no need for decomposition. Division of signal into components can be executed by band-pass filters. However in the presence of noise in signal's spectrum it is possible surely to identify only the main carrier frequencies, but all non-stationary components of signal and lateral modulating frequencies are masked by noise.

Results of decomposition are influenced also by the signal/noise ratio. Noise causes "crushing" and distortion even the monotone frequency IMF functions (fig.1(b)).

Division of signals in various IMF (inner majority function) can be executed with use of operational information about spectrum of signal and spectrums of allocated IMF [1].

Taking into account following of levels of IMF from high frequencies to low, on the first level in IMF-1 high-frequency noises of a signal outside of high frequencies of useful information are separate. On the second level in IMF-2 in the model of a signal accepted by us it is necessary to separate $f1$ signal. For this purpose by means of low-frequency filter with boundary cutoff frequency of ω_{c2} below radio impulse $f1$ frequencies we will filter all frequencies of a signal in an interval $0 \div \omega_{c2}$ and we use result as the initial $m1(k)$ function (fig.2). Similarly, on the next stage the following IMF $f2$ radio impulse can be eliminated and etc [2].

On a modeling signal the assessment of signals division quality can be carried out calculation of factor of mutual correlation (ρ) between information functions and their IMF images.

Noises is not belong to type oscillatory processes, but satisfy to definitions of the IMF functions. At distribution of noise spectrum on all frequency range of a signal, frequency components of noise are distributed on all IMF functions. The

example of elimination of a noise signal on IMF levels is given in the main frequency range on fig.3.
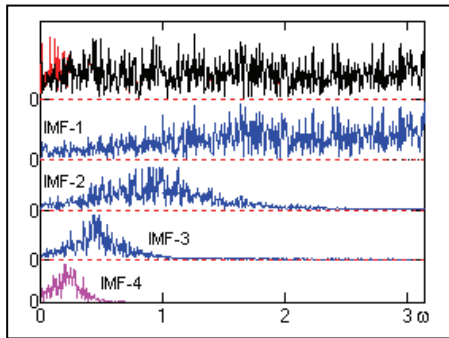

Figure 3.   Noise signal in IMF functions spectrum

If in signal spectrum is well expressed the highest frequency ω_{max} of information component, a direct way of signal cleaning is cutting of high-frequency noise from a signal spectrum from this ω_{c1} border (fig.2) to Nyquist frequency ω_N with transfer to a time domain as the first IMF-1 function.

For comparison purposes qualities of cleaning modeling signal from noise at known frequency borders of a local signal *f1* (including modulating frequencies) we will execute signal selection in the range of $\omega_{c2} \div \omega_{c1}$ by means of pass-band filtration (PF) and the decomposition method (in IMF-2) and we will calculate the VDA parameter (vectors divergence angle) between the allocated signals and the f1 function. Results of operation are given on fig.4. Quality of noise cleaning of both methods is almost equally.
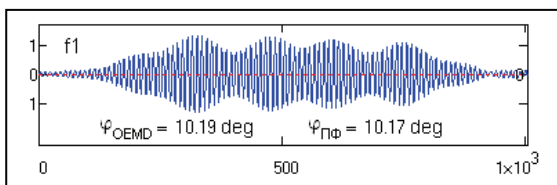

Figure 4.   Comparison pass-band filtration and decomposition method

But peak, frequency or phase changes of information frequencies are equivalent to their modulation and emergence in the main peaks of carrier frequencies of lateral frequencies which cannot be allocated in spectrum, and their cutoff will lead to partial loss of information.

Let's consider one more parameter which is directly influencing on process of decomposition. It is width of a passing zone of the filter.

With reference to high-pass filters for noise selection the width of passing zone is a negative factor. At passing zone widening to the left from ω_{c1} in cut noise will be include and excluded from the analysis modulating frequencies of a signal *f1* (fig.2). When we use decomposition nature of influence of passing zone changes on opposite. At passing zone expansion to the right from ω_{c1} the part of noise from passing zone starts to remain in the range of *f1* signal and the VDA parameter

starts to increase, but all modulating frequencies in f1 signal remain. This factor starts to play a positive role if the width of a lateral band of *f1* signal is a priori unknown and at installation of cutoff frequency ω_{c1} of low-pass filter the mistake can be allowed.

At setup of cutoff frequency of low-pass filter of decomposition within modulating frequencies of an allocated signal, the VDA parameter increases in relation to possible minimum. But at increasing of passing zone the VDA parameter starts to decrease (losses of lateral frequencies) and reaches a certain minimum (at complete inclusion of lateral frequencies in structure of selected signal), near to absolute minimum then starts over again to increase at the expense of inclusion in structure of a signal of the increasing share of noise frequencies. For complete inclusion of all lateral frequencies in structure of selected signal value of passing zone should be such that the factor of transfer of low-pass filter on limit of lateral frequencies wasn't lower than 0.707. Wide zones of minimal VDA on dependence on width of passing zones do decomposition process steady against errors of installation of borders and width of passing zones.

From here the simple logic of installation of low-pass filters of decomposition for cleaning of noise is follow. The cutoff frequency of filter is established directly after peak of the maximum frequency of cleared noisy signal which is usually well fixed on signal spectrum or is known according to aprioristic data. The width of passing zone is established according to aprioristic data or on expected peak of non-stationary signal.

On fig.5 spectrums modules of the 4th consistently eliminated functions (ω_{c1}=0.65 rad, passing zone is 0.075 rad, the IMF-1c and 1d functions are given in the increased scale), and also a spectrum of the sum of these functions in comparison to noisy *f1* signal spectrum are shown. It is possible to see that in the IMF functions there are low-frequency components in an interval $0 \div \omega_{c1}$. These components don't display any noise frequencies in a signal, and are formed by an interference of the allocated high-frequency noise. It allows to null spectrum values in an interval $0 \div \omega_{c1}$ that gives additional reduction of VDA between IMF-2 and f1 for $3 \div 5\%$.
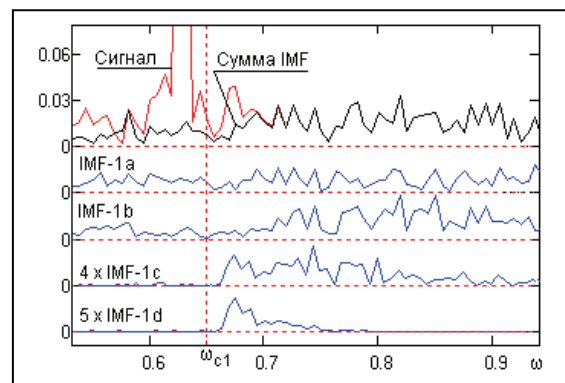

Figure 5.   Spectrums of selected components

When cleaning of noise decomposition has possibility of separate setup of cutoff frequencies and width of passing zones at selection of functions in IMF-1 that allows increasing controllability process of signals cleaning.

III. CONCLUSION

The stated technique is free as from physical essence of processed data, and statistics of distribution of noise signals and destabilizing fluctuations, and can be used effectively for cleaning from noise practically all seismic data.

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