алгоритма – ПИФ работает в 8…12 раз быстрее ранее используемого алгоритма ФОП.

Заключение

По результатом исследования, было выявлено, что алгоритм прямой инверсии Фурье дает наилучшее качество реконструкции среди рассматриваемых аналитических методов. Поэтому, он был выбран и реализован для исполнения на графических процессорах. Результаты тестирования скорости реконструкции показали, что, он в 8…12 раз быстрее своего ближайшего соперника – алгоритма фильтрованного обратного проецирования, который должен быть заменен. В ходе дальнейшей работы метод прямой инверсии Фурье должен быть внедрен в рабочий процесс системы UFO и программы PyHST.

Литература

1. Weber M. et al. UFO2–Ultra fast X-ray imaging of scientific processes with on-line assessment and data-driven process control.

2. Mersereau R. M. Direct Fourier transform techniques in 3-D image reconstruction //Computers in biology and medicine. – 1976. – T. 6. – №. 4. – C. 247-IN4.

3. Matej S., Bajla I. A high-speed reconstruction from projections using direct Fourier method with optimized parameters-an experimental analysis //Medical Imaging, IEEE Transactions on. – 1990. – T. 9. – № 4. – C. 421-429.

4. Shepp L.A., Logan B.F. Reconstructing interior head tissue from x-ray transmissions // Nuclear Science, IEEE Transactions on. – 1974. – T. 21. – № 1. – C. 228-236.

5. Nadernejad E., Hassanpour H. A comparison and analysis of different PDE-based approaches for image enhancement //Proc. Int. Conf. on Signal Processing and Communication Systems ICSPCS. – 2007.

THE ALGORITHM FOR PREDICTING RESERVOIR PROPERTIES OF ROCKS BASING ON THE INFORMATION PROPERTIES OF THE MUTUAL PHASE SPECTRUM OF REFLECTED SEISMIC WAVES

S.N. Sidorenko, V.P. Ivanchenkov, R.V. Deniko
Tomsk Polytechnic University
Lenina Avenue, 30, 634050, Tomsk, Russia
E-mail: sofyasn@mail.ru

Nowadays, a number of methods for predicting the geological section have been created. There are software systems for processing and interpretation of seismic data, which widely use dynamic parameters of waves bound with the amplitude and the energy of reflections. The phase characteristics of reflections are used to a lesser extent [1].

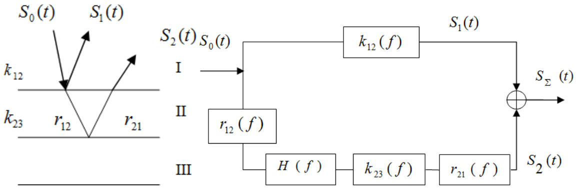
Thus, there is an increased relevance for searching new ways to analyze seismic records in order to extend the number of informative parameters. Among such parameters there is the mutual phase spectrum (MPS) of reflected waves.

The law of signal phase spectrum change contains information allowing the most reliable detection of signals against intense noise and assessment of their kinematic parameters. The MPS of reflections carries information about acoustic properties, heterogeneity of absorption and dispersion of geological environments [2].

The purpose of this work is the description of algorithm for predicting properties of geological section basing on the MPS of reflected waves. To achieve this goal the following objectives should be accomplished:

1. In order to isolate the information properties of MPS of reflected seismic waves a model of layered absorbing media should be considered.
2. The algorithm for predicting geological section properties basing on the MPS of reflected waves should be described.

Let’s consider the model of layered absorbing formations. The construction of such a model with horizontal interfacial boundaries represents the whole thing in the form of a linear system, which introduces some changes in the oscillation [3]. The example of a simple model of a plane-parallel layered absorbing formation (Fig. 1a) shows the essence of the approach (fig. 1b).



a b

Fig. 1. The model of plane-parallel layered absorbing formation: $S_0(t)$ – the initial seismic signal, $S_1(t)$, $S_2(t)$ – signals reflected from top and bottom of the observed formation II, $k_{12}(f)$ and $k_{23}(f)$ – the reflection coefficients from top and bottom of layer II, $r_{12}(f)$ and $r_{21}(f)$ – the refraction coefficients on the top of layer II, $H(f)$ – frequency characteristic of the absorbing layer

The spectra of the waves reflected from the top and bottom of the layer II:

$$S_1(f)=k_{12}(f)\cdot S_0(f)=|S_1(f)|e^{j\phi_1(f)}, \qquad (1)$$

where $\phi_1(f)=\phi_{k_{12}}(f)+\phi_0(f)$ defines the phase spectrum of the reflected wave $S_1(f)$, which depends on the argument of the reflection coefficient $\varphi_k(f)$, and the initial phase of the incident wave $\varphi_0(f)$.

$$S_2(f)=S_0(f)r_{12}(f)H(f)k_{23}(f)r_{21}(f)= \\ =|S_2(f)|e^{j\varphi_2(f)}, \qquad (2)$$

where $\phi_2(f)=\phi_{r_{12}}(f)+\phi_{H_S}(f)+\phi_{k_{23}}(f)+\phi_{r_{21}}(f)+\phi_0(f)$ defines the phase spectrum of the reflected wave $S_2(f)$, $S_1(f)$, which depends on the arguments of the coefficients refraction $\varphi_r(f)$ and reflection $\varphi_k(f)$, as well as the phase-frequency characteristics of the system $\varphi_H(f)$, and the initial phase of the incident wave $\varphi_0(f)$.

An important factor used for the prediction of reservoir rock properties is the absorption. In absorbent environments there is velocity dispersion. Absorbing and dispersive properties of layered media can be measured by the MPS of a wave.

Assuming that the processes $S_1(t)$ and $S_2(t)$ are deterministic, then the mutual spectral density is:

$Q_{12}(f)=[S_1^*(f)\cdot S_2(f)]=|Q_{12}(f)|\cdot e^{j\varphi_{12}(f)}$, where $S_1(f)$ and $S_2(f)$ complex spectra of the reflected waves $S_1(t)$ and $S_2(t)$, $|Q_{12}(f)|$ – mutual energy spectrum, $\varphi_{12}(f)=\varphi_2(f)-\varphi_1(f)$ – MPS. (3)

Substituting the values of (1) and (2), it is possible to obtain:

$$Q_{12}(f)=|S_0(f)|^2\cdot k_{12}^*(f)\cdot k_{23}(f)\cdot H(f)\cdot r_{12}(f)\cdot r_{21}(f) \qquad (4)$$

$$\phi_{12}(f)=\phi_{k_{23}}(f)-\phi_{k_{12}}(f)+\phi_H(f)+\phi_{r_{12}}(f)+ \\ +\phi_{r_{21}}(f), \qquad (5)$$

where $\varphi_{k_{12}}(f)$, $\varphi_{k_{23}}(f)$ – phase shifts introduced by the reflection of waves from the top and bottom of layers; $\varphi_{r_{12}}(f)$, $\varphi_{r_{21}}(f)$ – phase shifts associated with the refraction of the waves, which are directly linked to the petrophysical parameters of the environment.

From the expressions (4) and (5) it is possible to deduce that the absorbing and dispersive properties of the environment II appear in the MPS of a wave. It should also be noted that distortion doesn't affect the evaluation of absorption and dispersion of the observed formation, calculated through the MPS of waves. Therefore, the spectral characteristics of the mutual reflection of the observed formation provide more reliable and stable estimates.

To assess the information content of MPS the following parameters can be introduced [1]:

1. Mean value of MPS $\bar{\phi}_{12}(f)=\frac{1}{n}\sum_{i=1}^{n}\phi_{12}(f_i)$.

2. The central point of the 2nd order for the MPS $\sigma_\phi^2=\frac{\sum_{i=1}^{n}(\phi_{12}(f_i)-\bar{\phi}_{12}(f))^2}{n-1}$.

3. The average value of the phase delay $\bar{\tau}_\phi=\sum_{i=1}^{n}\tau_\phi(f_i)$, where $\tau_\phi(f_i)=\frac{\phi_{12}(f_i)}{2\pi f_i}$ – mutual phase delay at the i-th frequency.

4. The central point of the 2nd order for mutual phase delay $\sigma_\tau^2=\frac{\sum_{i=1}^{n}(\tau_\phi(f_i)-\bar{\tau}_\phi))^2}{n-1}$.

Thus, the parameters (1-4) may be used as informative while studying reservoir rock properties using the MPS of reflected waves.

In accordance with the considered properties the MPS of waves, an algorithm for predicting the reservoir rock properties has been developed [1]. The flowchart of the algorithm is shown in Fig.2.

It shows the following:

1. Seismic section is read from the file.

2. The waves which reflect from the top and bottom of observed formation are identified, and their temporary position is determined using the algorithm of phase-frequency tracking (PFT).

3. The assessment of MPS is carried out with the help of PFT algorithm quality function.

4. The results of PFT are used in building axes, called object-oriented sections.

5. In accordance with certain predetermined axes and reflecting boundaries, the analysis windows are installed.

6. The complex spectra of waves are determined $S_1(t)$, $S_2(t)$:

$$S_1(t)\xrightarrow{F}S_1(t)e^{j\varphi_1(f)}=A_1(f)+jB_1(f)$$
$$S_2(t)\xrightarrow{F}S_2(t)e^{j\varphi_2(f)}=A_2(f)+jB_2(f),$$

where F – the operator of the direct Fourier transform.

The phase spectrum of a signal $S_1(t)$:

$$\varphi_1(f)=\mathrm{arctg}\frac{B_1(f)}{A_1(f)}+2\pi m \qquad (6)$$

$$A_1(f)=\int_{-\frac{T}{2}}^{\frac{T}{2}}S_i(t)\cos(2\pi ft)dt$$

$$B_1(f)=\int_{-\frac{T}{2}}^{\frac{T}{2}}S_i(t)\sin(2\pi ft)dt,$$

where T – the size of the analysis window.

In the discrete form of the Fourier transform:

$$A_1(f_k)=A_k=\sum_{-\frac{n}{2}}^{\frac{n}{2}}S_i\cos(2\pi kf_i\Delta t)$$

$$B_1(f_k)=B_k=\sum_{-\frac{n}{2}}^{\frac{n}{2}}S_i\sin(2\pi kf_i\Delta t),$$

where $n=\frac{T}{\Delta t}$ – number of reports in the analysis window, k,i – number of samples of the discrete frequency step and time, $\Delta f,\Delta t$ – discretization intervals in frequency and time.

$A_2(f_k)$ and $B_2(f_k)$ for the second signal are defined in the similar way.

Then (6) can be rewritten as $\varphi_k = \operatorname{arctg}\frac{A_k}{B_k}$.

7. MPS $\varphi_{12}(f)$ is determined using the expression (3).

8. The predictive parameters are calculated basing on the obtained values $\varphi_{12}(f)$, They are later used for conclusions about reservoir properties of the observed formation.

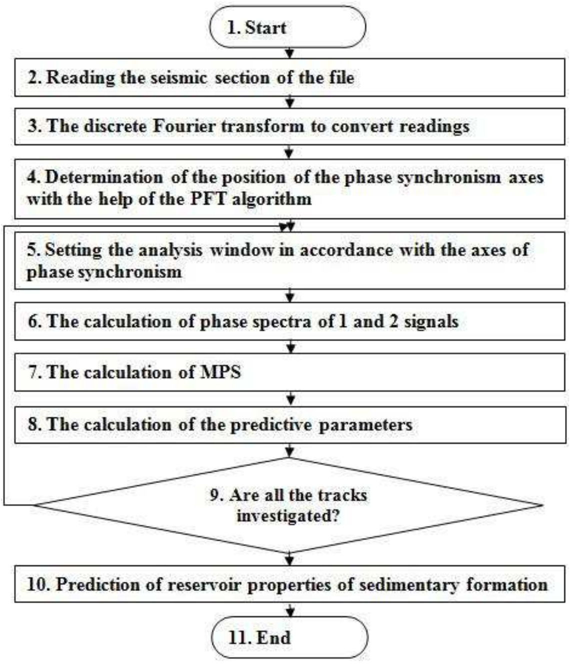


Fig. 2. The flowchart for the prediction of reservoir properties of sedimentary formation

Currently, the proposed algorithm is implemented on a computer and the research of its effectiveness is carried out on the model of layered absorbing environments.

References

1. Иванченков В.П., Вылегжанин О.Н., Орлов О.В. и др. Фазочастотный анализ сейсмических сигналов и его применение в задачах прогноза геологического разреза// Инновационные методы и технологии нефтегазопоисковых. – Томск: ЦНТИ. –2000. –с. 62–74.

2. Авербух А.Г., Трапезникова Н.А. Отражения и преломления плоских волн при нормальном падении на границы// Физика земли. –1972. –№9.

3. Птецов С.Н. Анализ волновых полей для прогнозирования геологического разреза. – М.: Недра, 1989. –135с.

ПОСТРОЕНИЕ И АНАЛИЗ ФАЗОВЫХ ПОРТРЕТОВ ДИФФУЗИОННОЙ ПЛАЗМЫ ТЕРМОЭМИССИОННОГО ДИОДА

Тарасова Л.П., Зимин В.П.
Томский политехнический университет
634050, Россия, г. Томск, пр–т Ленина, 30
E-mail: Tarasova.luda31@mail.ru

Введение

Диффузионный режим термоэмиссионного преобразователя энергии характеризуется сравнительно малыми плотностями токов J и сравнительно небольшим отклонением параметров плазмы от термодинамического равновесия. Это обусловлено малыми ионными плотностями тока за счет поверхностной ионизации и, соответственно, малой компенсацией пространственного заряда в межэлектродном зазоре. На вольтамперной характеристике термоэмиссионного преобразователя энергии (ВАХ ТЭП) в недокомпенсированном режиме, когда химический потенциал плазмы больше работы выхода эмиттера $\mu_E > F_E$, появляется участок насыщения тока (квазинасыщения) (рис. 1, точка А). Последнее название определяется тем, что этот ток может быть заметно меньше тока эмиссии с эмиттера $J \ll J_{Ee}$ [1].

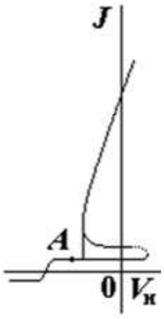


Рис. 1. Схематическое изображение ВАХ ТЭП и распределения параметров плазмы (точка А – диффузионный режим)

ВАХ является интегральной характеристикой конфигураций параметров плазмы и поэтому правильность моделей диффузионного режима необходимо подтверждать сравнением с эксперимен-