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THE EFFECT OF NORMAL CORRECTION ERRORS ON THE STACKING OF COMMON-DEPTH-POINT TRACES

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The analog processing of seismic stacking profiles consists of two basic steps: normal correction of single-coverage profiles and stacking.

When investigating stacking problems from different points of view, it is generally assumed that normal correction can be carried out accurately, i.e. the individual arrivals of the channels to be stacked can be brought into full phase-identity. Experiences gathered in areas with poor energy conditions and high noise-level, however, contradict this assumption. Therefore it will be tried to follow the effect of correction errors throughout the course of the stacking process.

Assuming the traces are normalized, the transfer function of stacking is

$$S(\omega)=\sum_{i=1}^{f} e^{j\omega\tau_i}, \tag{1}$$

where f is the coverage number, τ_i the time-shift between identical phase points of the reference and of the i-th trace.

If the correction itself is considered as free of error, τ will indicate, in an actual case, some fixed phase-shift on each channel. If, however, the correction is considered as burdened with error, this phase-shift may assume various values. Within a certain part of a section, where the signal-to-noise ratio can be regarded as constant, every possible value of error has a cetain probability of occurrence. Let us denote the possible values of the error by x, the corresponding probabilities by $p(x)$, and let us consider $M\{S(\omega)\}$ the expectable value of the transfer function for a given error-distribution. (The treatment of errors as random variables is reasonable due to the great number of single-coverage traces in the profile). In this case, in Relation (1), $(\tau+x)$, i.e. the error-burdened value of the phase-shift must be taken instead of τ, and the expected value of the transfer function will be

$$M\{S(\omega)\}=\int_{-\infty}^{\infty}\dots\int_{-\infty}^{\infty}\sum_{i=1}^{f} e^{j\omega(x_i+\tau_i)}p(x_1)\dots p(x_f)\,dx_1\dots dx_f=$$

$$=e^{j\omega\tau_1}\int_{-\infty}^{\infty}\dots\int_{-\infty}^{\infty} e^{j\omega x_1}p(x_1)\dots p(x_f)\,dx_1\dots dx_f+\dots$$

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$$\ldots + e^{j\omega\tau_f} \int_{-\infty}^{\infty} \ldots \int_{-\infty}^{\infty} e^{j\omega x_f} p(x_1) \ldots p(x_f)\, dx_1 \ldots dx_f =$$

$$= e^{j\omega\tau_1} \int_{-\infty}^{\infty} e^{j\omega x_1} p(x_1)\, dx_1 \int_{-\infty}^{\infty} p(x_2)\, dx_2 \ldots \int_{-\infty}^{\infty} p(x)\, dx_f + \ldots$$

$$\ldots + e^{j\omega\tau_f} \int_{-\infty}^{\infty} p(x_1)\, dx_1 \ldots \int_{-\infty}^{\infty} p(x_{f-1})\, dx_{f-1} \int_{-\infty}^{\infty} e^{j\omega x_1} p(x_f)\, dx =$$

$$= e^{j\omega\tau_1} \int_{-\infty}^{\infty} e^{j\omega x_1} p(x_1)\, dx_1 + \ldots + e^{j\omega\tau_f} \int_{-\infty}^{\infty} e^{j\omega x_f} p(x_f)\, dx_f$$

since

$$\int_{-\infty}^{\infty} p(x)\, dx = 1,$$

assuming that

$$p(x_1) = p(x_2) = \ldots p(x_f) = p(x)$$

$$M\{S(\omega)\} = \left(\sum_{i=1}^{f} e^{j\omega\tau_i} \right) \int_{-\infty}^{\infty} e^{j\omega x} p(x)\, dx.$$

The expected value of the transfer function is consequently the product of the error-free transfer function and of an integral expression depending on the error.

The relation obtained becomes still simple, if only the case of primary reflexion is considered, where

$$\tau_i = 0.$$

For the primary reflexion,

$$M\{S(\omega)\} = f \int_{-\infty}^{\infty} e^{j\omega x} p(x)\, dx.$$

By means of the expected value of the transfer function, the expected signal energy loss as related to the case of error-free correction can be estimated. Denoting the expected loss by

$$\alpha = \frac{\int_{-\infty}^{\infty} [M\{S(\omega)\} A(\omega)]^2\, d\omega}{\int_{-\infty}^{\infty} [S(\omega) A(\omega)]^2\, d\omega}.$$

For a primary reflexion:

$$\alpha = \frac{\int\limits_{-\infty}^{\infty} \left[\left\{ f \int\limits_{-\infty}^{\infty} e^{j\omega x} p(x)\, dx \right\} A(\omega) \right]^2 d\omega}{\int\limits_{-\infty}^{\infty} [fA(\omega)]^2 d\omega} \tag{2}$$

where $A(\omega)$ is the spectrum of the arrival.

Since constant f can be eliminated from the integrals by division, the expected signal-energy loss does not depend on the number of coverage but only on the error distribution and on the spectrum of the arrival. In what follows, the error distribution will be estimated from actual field material, and the expected energy loss will be given with respect to this distribution, as a function of error scattering for some possible spectra.

Before passing to the actual calculations, a few words are in order regarding multiples. The transfer function for primaries is constant, therefore the expected effect of the error depends, in case of identical input signals, on the scattering of the error alone. Its calculation and representation is, therefore, comparatively simple. The situation is much more complicated for the case of multiple arrivals. Here, the error-free value of the transfer function depends on the RMO series of the stacked trace (Bodoky, 1970). This tansfer function is distorted by the error, and the expected effect upon a multiple is a function of f variables (f–*1 RMO* values, and the scattering of the error). For threefold stacking this was investigated in detail by P. Halász, 1970.

The distribution of correction errors

If one has to treat the correction errors also in practice, the question arises at once: what is to be considered as correction error and how can it be estimated from the actual field records?

In the present investigation the time data of an uncurved good horizon, read out from all coverages, were corrected with static corrections computed and improved in field work with routine methods, dynamic correction prescribed (for analog processing) and compared with the theoretical, statically and dynamically corrected time-distance curves, i.e. with straight lines. The deviations were accepted as correction errors. The investigations were performed on six samples, each including 200–300 traces, from the Nyir region stacking profile of 1969.

The frequency histograms of the correction errors of these samples are shown in Figs. 1–6.

As to the distribution of correction errors it was as reasonable null hypothesis to assume that they obey a normal distribution, since they are presumably results of several smaller, independently acting factors. This is also corroborated by the frequency histograms. In order to avoid sampling errors, the sampled data were put together in seven intervals, each of 3 msec length, and a test of fitting was carried out on them by the χ^2 test (Vince, 1968).

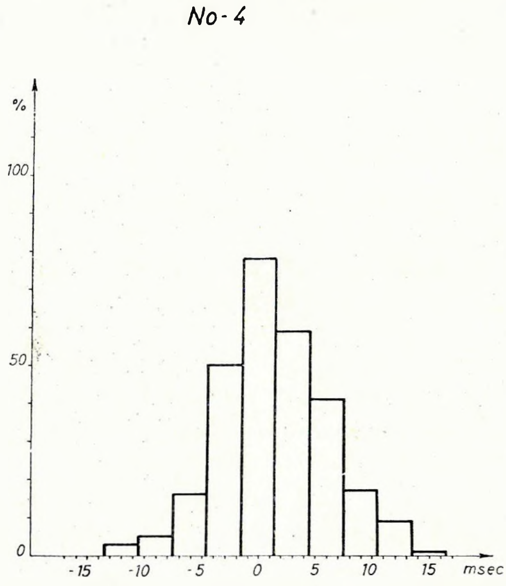

Fig. 1 Frequency histogram of the normal-correction errors, sample taken from the No-4 profile

1. ábra. A normál korrekció hibáinak gyakorisági hisztogramja a No-4 vonalból vett mintánál

Рис. 1. Гистограмма повторяемости погрешностей динамических поправок для выборки записей, полученных по профилю No-4

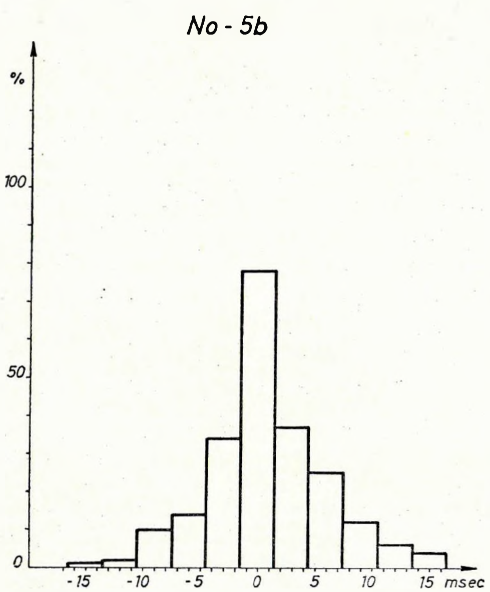

Fig. 2 Frequency histogram of the normal-correction errors, sample taken from the No-5b profile

2. ábra. A normál korrekció hibáinak gyakorisági hisztogramja a No-5b vonalból vett mintánál

Рис. 2. Гистограмма повторяемости погрешностей динамических поправок для выборки записей, полученных по профилю No-5б

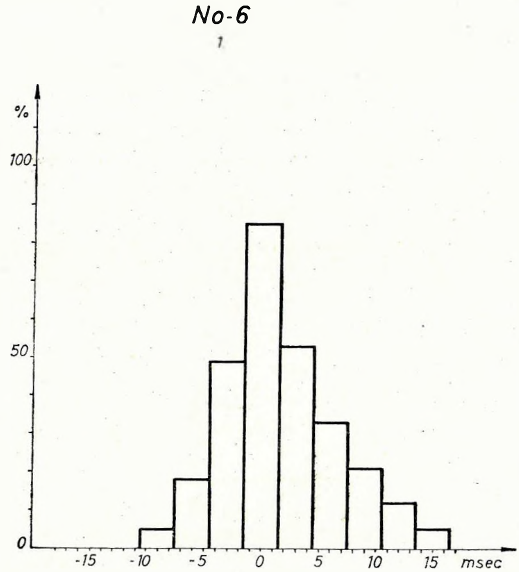

Fig. 3 Frequency histogram of the normal-correction errors, sample taken from the No-6 profile (first sample)

3. ábra. A normál korrekció hibáinak gyakorisági hisztogramja a No-6 vonalból vett első mintánál

Рис. 3. Гистограмма повторяемости погрешностей динамических поправок для первой выборки записей, полученных по профилю No-6

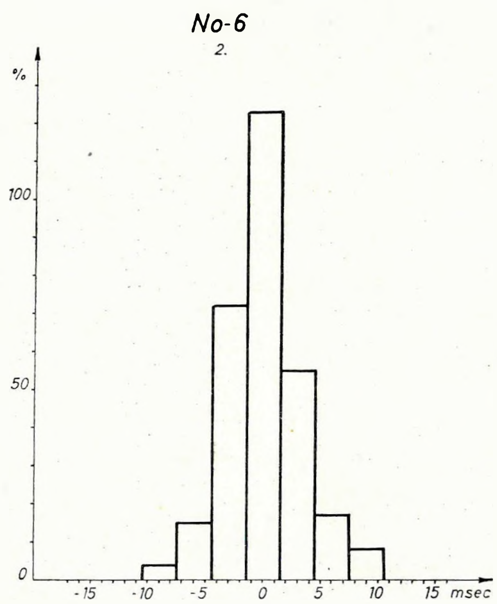

Fig. 4 Frequency histogram of the normal-correction errors, sample taken from the No-6 profile (second sample)

4. ábra. A normál korrekció hibáinak gyakorisági hisztogramja a No-6 vonalból vett második mintánál

Рис. 4. Гистограмма повторяемости погрешностей динамических поправок для второй выборки записей, полученных по профилю No-6

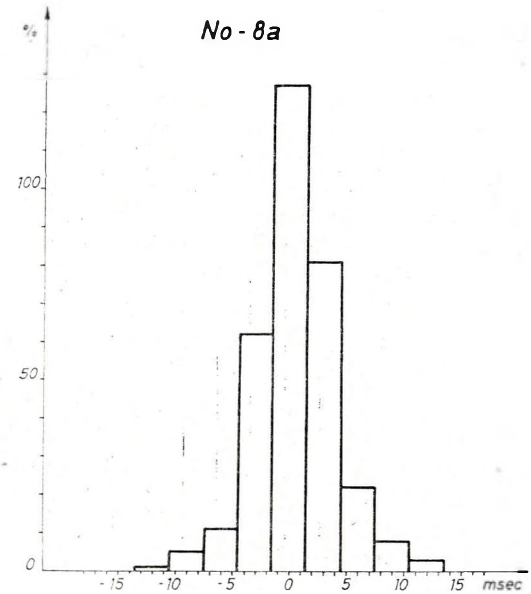

Fig. 5 Frequency histogram of the normal-correction errors, sample taken from the No-8a profile

5. ábra. A normál korrekció hibáinak gyakorisági hisztogramja a No-8a vonalból vett mintánál

Рис. 5. Гистограмма повторяемости погрешностей динамических поправок для выборки записей, полученных по профилю No-8a

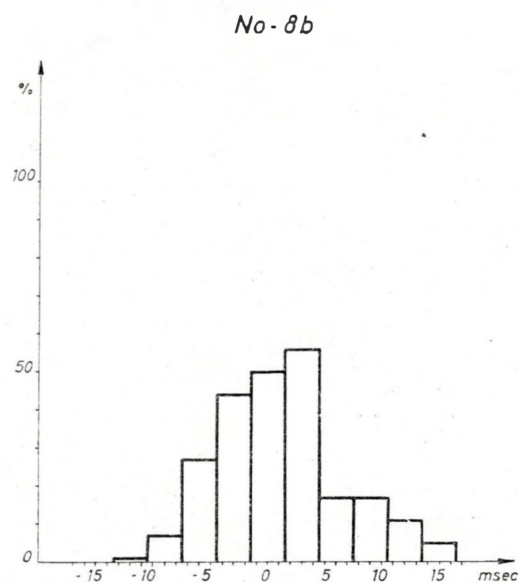

Fig. 6 Frequency histogram of the normal-correction errors, sample taken from the No-8b profile

6. ábra. A normál korrekció hibáinak gyakorisági hisztogramja a No-8b vonalból vett mintánál

Рис. 6. Гистограмма повторяемости погрешностей динамических поправок для выборки записей, полученных по профилю No-8б

The results of the computations are shown in a tabular form:

Sample	No-4	No-5b	No-6/I	No-6/II	No-8a	No-8b
N	283	228	281	293	319	237
$M(x)$	1,19	0,83	1,68	0,04	0,53	1,22
σ	4,87	5,04	4,81	3,25	3,32	5,75
χ_4^2	3,94	13,78	5,68	10,06	8,42	11,87

where N = number of traces investigated
$M(x)$ = expected value of the error, msec
σ = SD of the error
χ_4^2 = test result

The expected value and the standard deviation were estimated from the data; thus the number degrees of freedom of the test was $7-1-2=4$. For sake of comparison, the critical values of the χ_4^2-test with a degree of freedom of 4 are presented:

Probability in percents	Critical values for the application of the test
90,0	7,78
95,0	9,49
97,5	11,1
99,0	13,3
99,5	14,9
99,9	18,0
99,95	20,0

On the basis of the test, the initial hypothesis was accepted. (If the dynamical correction is erroneous, then the normal error distribution will surely not hold, the symmetry of the histogram will disappear. The analysis of correction errors provides a possible way also for checking the velocity function applied).

The expected signal-energy loss

Accepting error distribution as a normal one, the expected signal-energy loss was determined as a function of the standard deviation. The calculation was carried out for Ricker-wavelet spectra of 30, 40, 50, resp. 60 cps peak frequencies (Ricker, 1953).

The results of the calculation are shown in Figs. 7–10.

The purpose of multifold recording is generally a double one. Multiple reflexions can be filtered, and the signal-to-noise ratio improved, considering random noises alone.

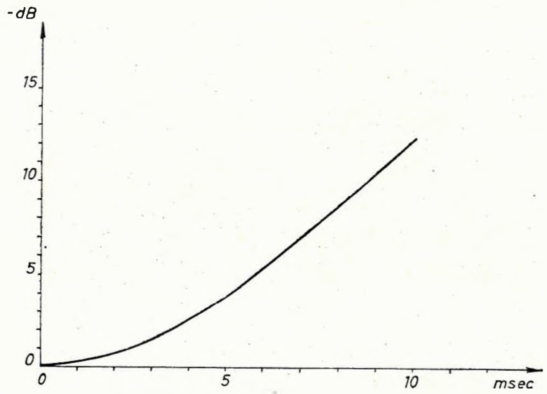

Fig. 7 Signal energy loss in stacking as function of the standard deviation of correction error, for input signals of 30 cps peak frequency

7. ábra. Az összegzésnél beálló jel energia veszteség a normál korrekció hiba szórásának függvényében 30 Hz csúcsfrekvenciájú bemenő jelnél

Рис. 7. Потеря энергии сигнала, намечающаяся при суммировании, в зависимости от разброса погрешностей динамических поправок при частоте входного сигнала 30 гц

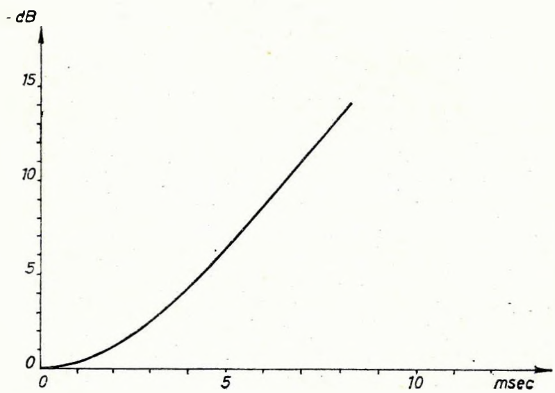

Fig. 8 Signal energy loss in stacking as function of the standard deviation of correction error, for input signal of 40 cps peak frequency

8. ábra. Az összegzésnél beálló jel energia veszteség a normál korrekció hiba szórásának függvényében 40 Hz csúcsfrekvenciájú bemenő jelnél

Рис. 8. Потеря энергии сигнала, намечающаяся при суммировании, в зависимости от разброса погрешностей динамических поправок при частоте входного сигнала 40 гц

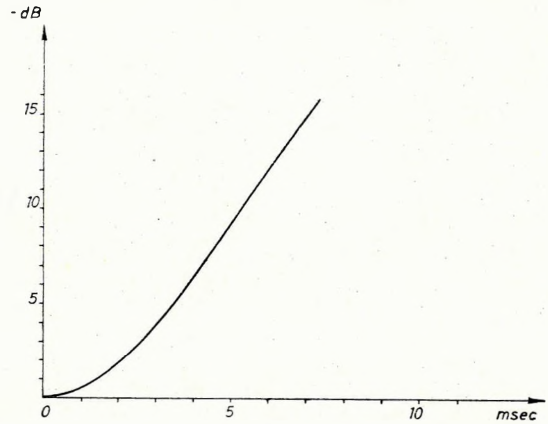

Fig. 9 Signal energy loss in stacking as function of the standard deviation of correction error, for input signals of 50 cps peak frequency

9. ábra. Az összegzésnél beálló jel energia veszteség a normál korrekció hiba szórásának függvényében 50 Hz csúcsfrekvenciájú bemenő jelnél

Рис. 9. Потеря энергии сигнала, намечающаяся при суммировании, в зависимости от разброса погрешностей динамических поправок при частоте входного сигнала 50 гц

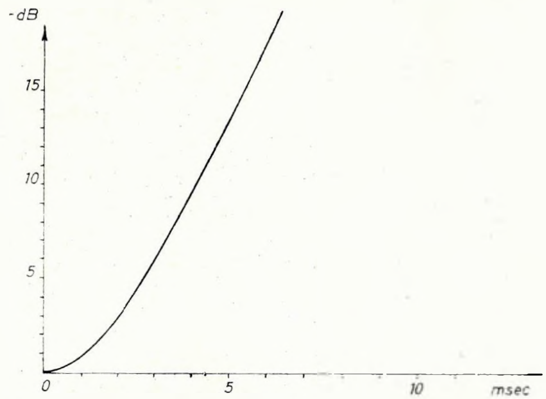

Fig. 10 Signal energy loss in stacking as function of the standard deviation of correction error, for input signals of 60 cps peak frequency

10. ábra. Az összegzésnél beálló jel energia veszteség a normál korrekció hiba szórásának függvényében 60 Hz csúcsfrekcenciájú bemenő jelnél

Рис. 10. Потеря энергии сигнала, намечающаяся при суммировании, в зависимости от разброса погрешностей динамических поправок при частоте входного сигнала 60 гц

In noisy areas under poor energy conditions, where even the recording of primary reflexions meets difficulties, the improvement of the signal-to-random noise ratio is of decisive significance. It appears from the calculations that in such areas the signal-to-noise ratio improvement which could be expected from multiple coverage may be lost even in cases of relatively small correction errors, especially in case of high frequency arrivals. Namely

$$\frac{\text{signal}}{\text{noise}} \longrightarrow f\text{-fold stacking} \longrightarrow \frac{f}{\sqrt{f}}\,\frac{\text{signal}}{\text{noise}} = \sqrt{f}\,\frac{\text{signal}}{\text{noise}},$$

where f is the number of traces stacked. In three-fold stacking, the expected improvement is 4,8 dB, in six-fold stacking, 7,8 dB, in twelve-fold stacking, 10,8 dB.

Consequently, the advantages of CDP methods can be exploited only if a sufficienty accurate correction, involving not greater error scattering than 1–2 msec is applied. The precondition of the determination of a correction of such a high degree of accuracy is, on the other hand, a good signal-to-noise ratio of single coverages. This can be improved by diminishing the size of spread parameters,—offset, seismometer spacing. The optimum performance of multiple filtering, however, is bound to certain definite sizes of the parameters (Bodoky, 1970).

Consequently, if necessary in the interest of proper signal-to-noise ratio, the optimum multiple filtering effect of CDP systems must be sacrificed.

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BODOKY TAMÁS—SZEIDOVITZ GYŐZŐNÉ

A NORMÁLKORREKCIÓ HIBÁINAK HATÁSA A KÖZÖS MÉLYSÉGPONTOS CSATORNÁK ÖSSZEGEZÉSÉNÉL

A tanulmány a közös mélységpontos csatornák összegezését korrekciós hiba jelenlétében vizsgálja és az összegezés átviteli függvényét erre az esetre vezeti le. A korrekciós hiba eloszlását konkrét mérési anyagon vizsgálja, és a vizsgálat eredményeképpen normál eloszlásnak fogadja el a hibaeloszlást. Különböző csúcsfrekvenciájú beérkezésekhez a korrekciós hibák okozta jel-energia veszteséget a hiba szórásának függvényében számítja ki. Az eredményekből látható, hogy az összegzés érzékenysége a korrekciós hibákkal szemben nő az összegezett jelek növekvő csúcsfrekvenciájával. A számítások megmutatják a korrekciós hibák szórásának még megengedhető legnagyobb értékét az egyes jelspektrumok esetében.

Т. БОДОКИ—Ж. СЕЙДОВИЦ

О ВЛИЯНИИ ПОГРЕШНОСТЕЙ ДИНАМИЧЕСКИХ ПОПРАВОК НА СУММИРОВАНИЕ ЗАПИСЕЙ ОГТ

В работе рассматривается задача суммирования записей ОГТ при наличии погрешностей в поправках и приводится характеристика суммирования для этого случая. Распределение погрешностей поправок анализируется на фактических материалах. В результате проведенного анализа распределение погрешностей принимается нормальным. Потеря энергии сигналов, вызванная погрешностями поправок вычисляется для волн с различной частотой, в зависимости от разброса погрешностей. Результаты показывают, что чувствительность суммирования к погрешностям поправок увеличивается с повышением частоты сигналов. Вычислениями определяются максимальные допустимые величины разброса погрешностей поправок для различных спектров сигналов.