Comparing Stacking Velocities

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SUMMARY

This paper is written to compare the accuracy of two-way traveltimes and stacking velocity calculations for horizontally stratified, vertically heterogeneous, acoustic layered media. The two-way traveltimes and stacking velocities are calculated for a given model using the Dix formula (Dix, 1955) and the modified Root-Mean-Square formula introduced by Fokkema and Van den Berg (1989). As a reference the Cagniard - De Hoop technique for primary reflections is used, providing exact arrival times for a given layer model and geometry. In this paper absolute differences between the reference times provided by Cagniard - De Hoop and the arrival times calculated by Dix and modified RMS are compared. Test results indicate that the stacking velocity and the two-way traveltime (zero-offset) calculations by the modified RMS formula yield more accurate results.

INTRODUCTION

In the seismic industry people try to extract as much information as possible from seismic traveltimes and amplitudes. Wavefront curvature in the space-time domain relates seismic data to parameters of the subsurface (Shah, 1973). Traveltimes of primary reflections can provide us with valuable information about the curvature of the reflection wavefronts and therefore about velocities of single or stacks of layers. This paper tries to give some insight into the accuracy of procedures which provide us with RMS stacking velocities. The procedures introduced by Dix in 1955 and those introduced by Fokkema and Van den Berg in 1989 are discussed.

Fokkema and Van den Berg (1988, 1989), Fokkema, Vercrujssse and Van den Berg (1989) and De Oliveira and Fokkema (1990) have shown that the modified RMS velocity (Fokkema and Van den Berg, 1989) can be successfully used in seismic inversion procedures on Common Midpoint gathers. Neves and Weglein (1990) showed that a smoothly varying reference velocity profile, such as the modified RMS velocity, can yield significant improvements in the agreement between a sonic log and a migration-inversion of real marine data.

Fokkema and Van den Berg (1989) defined the modified RMS velocity for layer n as

$$c_n^{RMS} = \sqrt{c_n c_n^*} \quad (1)$$

with

$$c_n^* = \frac{\sum_{m=0}^n c_m h_m}{\sum_{m=0}^n c_m^{-1} h_m} \quad (2)$$

and

$$c_n^* = \frac{\sum_{m=0}^n h_m}{\sum_{m=0}^n c_m^{-2} h_m} \quad (3)$$

where h_m and c_m denote the thickness and interval velocity of layer m respectively. Note that equation (2) is the definition of the RMS velocity introduced by Dix (1955), although here it is formulated in terms of layer thicknesses.

TESTING PROCEDURE

The model we used for the tests is a nine-layer model as shown in Table 1, used by Fokkema and Van den Berg (1989) and Fokkema, Vercrujssse and Van den Berg (1989). The testing procedure is outlined in Figure 1 as a flow chart. The Cagniard - De Hoop technique for primary reflections is used as a reference for our tests. This technique provides us the exact arrival times for a stack of homogeneous fluid layers given a certain geometry. From the model RMS velocities are calculated using equation (1) and equation (2), modified RMS velocity and Dix RMS velocity respectively. The two-way traveltimes (zero-offset) are calculated replacing a stack of layers, with corresponding interval velocities, by a single layer with corresponding RMS velocity. For these (zero-offset) two-way traveltimes and RMS velocities the reflection hyperbolas are calculated for a given geometry using the Normal Moveout equation

$$T^2(x) = T^2(0) + \frac{x^2}{(c_n^{RMS})^2} \quad (4)$$

For small offsets x over a horizontally layered (one-dimensional) subsurface, equation (4) provides a satisfactory fit to the traveltime data of our model (Dix, 1955). As a last step a comparison of the

absolute differences for all layers and all offsets is made with respect to the reference traveltimes provided by the Cagniard - De Hoop technique. The results are shown in Figure 2. The results of the water layer are trivial and therefore omitted in Figure 2.

CONCLUSIONS

We observe that the zero-offset two-way traveltime calculations performed by the modified RMS formulas are more accurate than those performed by the Dix formula. It is also shown that the absolute difference in timing of all the reflectors at zero-offset is negligible if we use the modified RMS velocity formula and compare it to the exact two-way traveltime at zero-offset.

The Dix timing of the reflectors is less accurate and therefore the decreasing absolute difference with increasing offset is of no significance because the initial timing of the zero-offset trace is inaccurate. It can be shown that if the correct timing for each layer at zero-offset is available, Dix's formula can best be used to invert interval velocities from stacking velocities. So, hyperbolic trajectories calculated with Dix's stacking velocity definition, using correct zero-offset times as an input, will approximate real reflection trajectories slightly better than in the case where we calculate them with the modified RMS velocity definition. If, on the other hand, there are less accurate zero-offset traveltimes available then the hyperbolic trajectories calculated with the modified RMS velocity definition will approximate the real reflection trajectory in space-time domain best.

REFERENCES

De Oliveira, A. S., and Fokkema, J. T., 1990, Application of the modified RMS inversion technique on real CMP marine data including directivity effects, Expanded Abstracts, 60th SEG Meeting, San Francisco, CA, U.S.A., 1165 - 1169.

Dix, C. H., 1955, Seismic velocities from surface measurements, *Geophysics* 20, 68 - 86.

Fokkema, J. T., and Van den Berg, P. M., 1989, Seismic inversion by a RMS Born approximation in the space-time domain, *Geophysical Prospecting* 37, 53 - 72.

Fokkema, J. T., Vercrujssse, P. A., and Van den Berg, P. M., 1989, Seismic inversion by RMS stacking on CMP gathers, Expanded Abstracts, 59th SEG Meeting, Dallas, TX, U.S.A., 992 - 995.

Neves, F. A., and Weglein, A. B., 1990, Should we use a discontinuous or smooth reference velocity in seismic migration-inversion?, Expanded Abstracts, 60th SEG Meeting, San Francisco, CA, U.S.A., 1245 - 1248.

Shah, P. M., 1973, Use of wavefront curvature to relate seismic data with subsurface parameters, *Geophysics* 38, 812 - 825.

Depth (m)	Interval velocity (m/s)
70.0	1500.0
120.0	1600.0
175.0	1700.0
215.0	1800.0
250.0	1700.0
300.0	1600.0
380.0	1900.0
455.0	2000.0
Halfspace	2200.0

Table 1. Nine-layer model.

Calculation of arrival times for the nine-layer model (Table 1, Fokkema and Van den Berg, 1989) using the Cagniard - De Hoop technique for primaries

Calculation of stacking velocities and two-way traveltimes (zero-offset) using the Dix formulas

Calculation of stacking velocities and two-way traveltimes (zero-offset) using the modified RMS formulas

Calculation of the reflection hyperbolas for all layers using the Dix two-way traveltimes and stacking velocities

Calculation of the reflection hyperbolas for all layers using the modified RMS two-way traveltimes and stacking velocities

Calculation of the absolute difference in arrival times (Figure 2, Cagniard - Dix (solid line); Cagniard - RMS (dashed line)) for all layers and all offsets

Figure 1. Flow chart of the testing procedure used.