Application of internal multiple prediction: from synthetic to lab to land data

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ABSTRACT

Multiple reflections represent a serious problem in the field of seismic processing. Multiple events can be mistaken for primary reflections, and may distort primary events and obscure the task of interpretation. In this work we will focus in the prediction of internal multiples and we will illustrate how the inverse scattering internal multiple algorithm introduced by Weglein and Araujo in 1994, is capable to attenuate internal multiples without any a priori information about the medium through which the waves propagate. One of the advantages of this method over other is its ability to suppress multiples that interfere with primaries without attenuating the primaries themselves. I consider the version of the algorithm for 1D normal incidence case.

In this work we promote a stepped approach to predicting multiples in a given field data set: first, by carrying out synthetic/numerical examples; second by carrying out tests on laboratory physical modeling data; and finally by testing prediction of a field data set suspected to be strongly contaminated with internal multiples.

INTRODUCTION

For the exploration of oil and gas reservoirs, multiples can be one of the main issues in applying the seismic method. The inverse scattering series internal multiple (Araujo et al., 1994) attenuation method is capable of attenuating internal multiples without any a priori information about the medium through which the waves propagate, i.e., is a data-driven process. Furthermore, the primaries reflections remain untouched. The output of the algorithm is a data set that contains the predicted multiples.
and not equal to z'_2 and similarly for z'_3. This parameter is related to the width of the wavelet, and could be estimated knowing the source wavelet or an approximation.

The main objective of this work is to apply1D version of the inverse scattering series internal multiple attenuation algorithm on 2D land field data. In order to accomplish this goal, we first implemented the algorithm in 1D synthetic data (Hernandez, and Innanen, 2012) and then in 2D marine common offset physical model data (Hernandez, Innanen, and Wong, 2012). Finally, using these two previous experiences we applied in 2D land field data from Northeast of British Columbia, Canada.

SYNTHETIC ANALYSIS OF INTERNAL MULTIPLE PREDICTION

In this section we examine using synthetic data the relationship between the parameter epsilon in the algorithm and aspects of the data, such as wavelet, and resolution of the data. The goal is to complete these experiments with a strong intuition for optimal estimation of epsilon in order to move to physical model data and field data. By knowing or controlling the source wavelet the estimation of the value of this parameter is straightforward. In more complex data, where the source wavelet is uncertain the autocorrelation can be applied to have a sense between what values the parameter epsilon (є) varies. In the next three examples examine the sensitive of the algorithm to the parameter epsilon, with the expectation that an underestimation or overestimation of epsilon (є) would lead us to a wrong prediction.

Sensitivity to Epsilon

Since the parameter epsilon is related to width of the source wavelet we made a series of tests varying the central frequency of the source wavelet in order to evaluate how sensitive the algorithm is to the parameter epsilon (є). Figure 1, shows high frequency input data. Three different values of epsilon were tested: 8, 15, and 60 samples points. The algorithm is capable of predict internal multiples using any a value of epsilon as long as is equal or higher than the width of the source wavelet, as we shown in Figure 1.

Figure 2, shows a medium frequency experiment. In the output predictions we can notice how a wrong estimation of the parameter epsilon (є) can lead us to a wrong prediction, for an underestimation of epsilon (smaller than width of the source wavelet) can damaged the output significantly, affecting the primaries and/or creating artifacts or wrong events. On the other hand, an extreme overestimation of the parameter epsilon would not damage the output prediction but neither shows any events, because the algorithm is not capable to identify the events.

We generated a low frequency seismic synthetic data, Figure 3. This experiment revealed data a wrong estimation, especially an underestimation of the value of epsilon would damage considerably the output prediction.

Wavelet removal

In this experiment we remove the source wavelet and tested three differents values of the parameter epsilon. All of the output predictions are correct. The importance of the parameter epsilon lies in the fact that events are not delta functions, they have an intrinsic form, the width of the wavelet. Without the parameter epsilon the algorithm could take one side of the wavelet as a single event and the other side as other events that satisfy a lower-higher-lower pseudo depth condition and construct an internal multiple, but that would be wrong because they are all part of the same event.

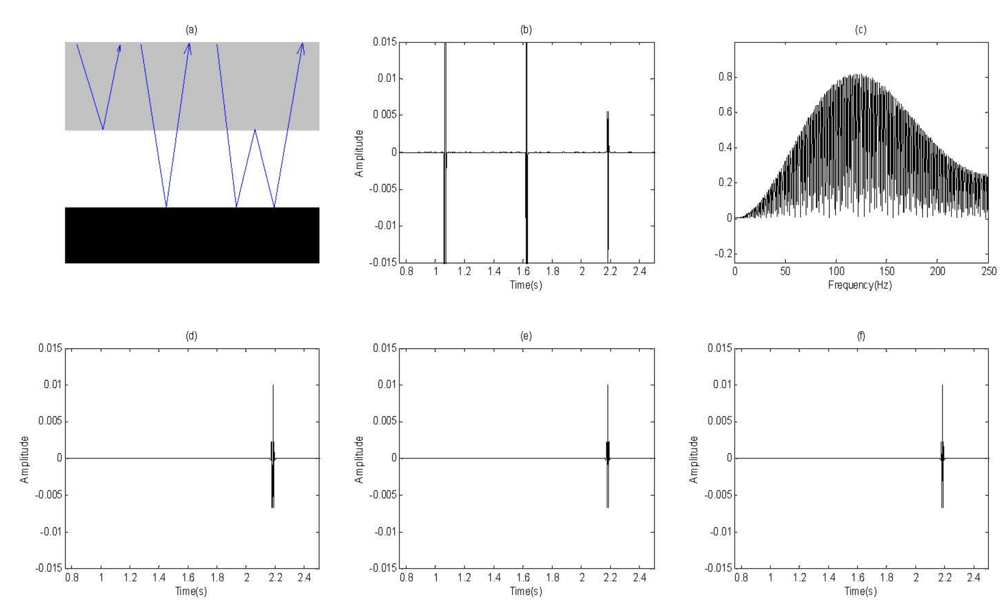

Figure 1: High Frequency experiment: (a) Sketch of the input model. (b) Synthetic medium frequency (120Hz) input data, two reflectors and one internal multiple. (c) Amplitude Spectrum of the synthetic data. (d) Output prediction using a value of epsilon optimum for low frequency 15 Hz (60 samples points). (e) Output prediction using a value of epsilon optimum for high frequency 80Hz (15 samples points). (f) Output prediction using a value of epsilon optimum for high frequency 120Hz (8 samples points).

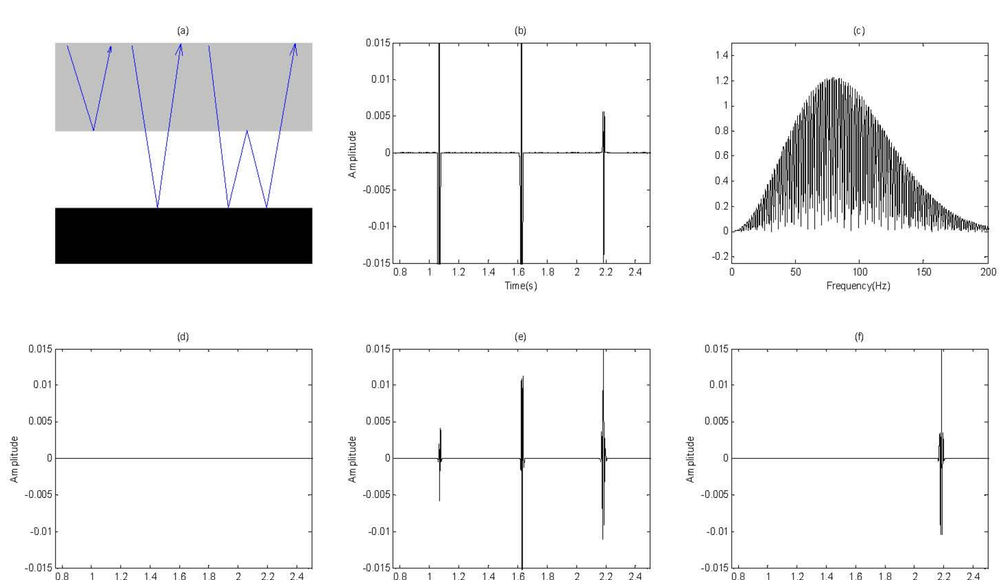

Figure 2: Medium Frequency experiment: (a) Sketch of the input model. (b) Synthetic high frequency (80Hz) input data, two reflectors and one internal multiple. (c) Amplitude Spectrum of the synthetic data. (d) Output prediction using a large value of epsilon, overestimation. (e) Output prediction using a small value of epsilon, underestimation. (f) Output prediction using a value of epsilon optimum for medium frequency 80Hz (15 samples points).

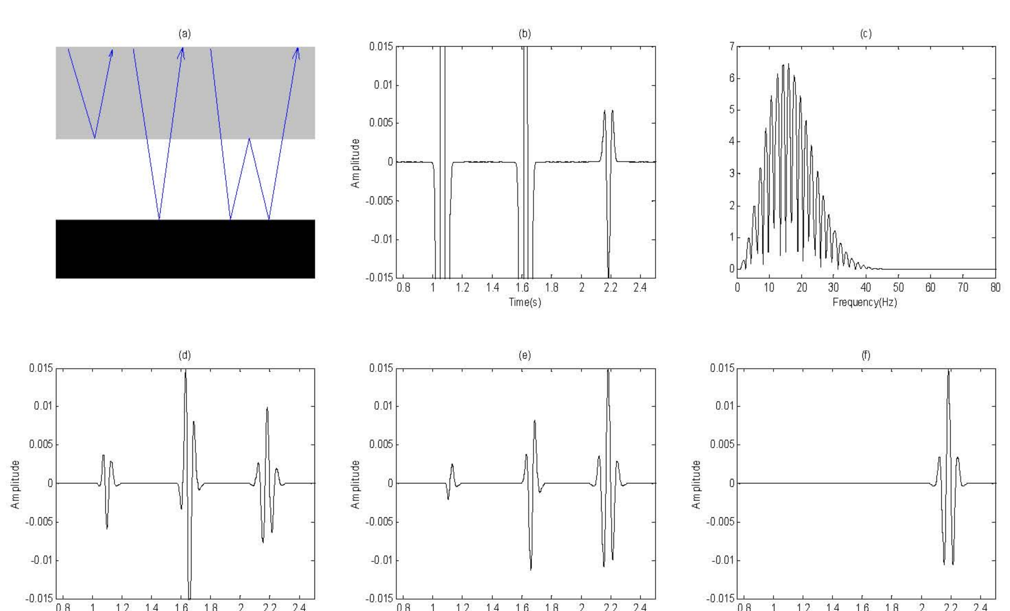

Figure 3: Low Frequency data (15Hz) experiment. a) Sketch of the input model. (b) Synthetic low frequency (15Hz) input data, two reflectors and one internal multiple. (c) Amplitude Spectrum of the synthetic data. (d) Output prediction using a value of epsilon optimum for high frequency. (e) Output prediction using a value of epsilon optimum for medium frequency 80Hz. (f) Output prediction using a value of epsilon optimum for low frequency 15Hz (60 samples points).

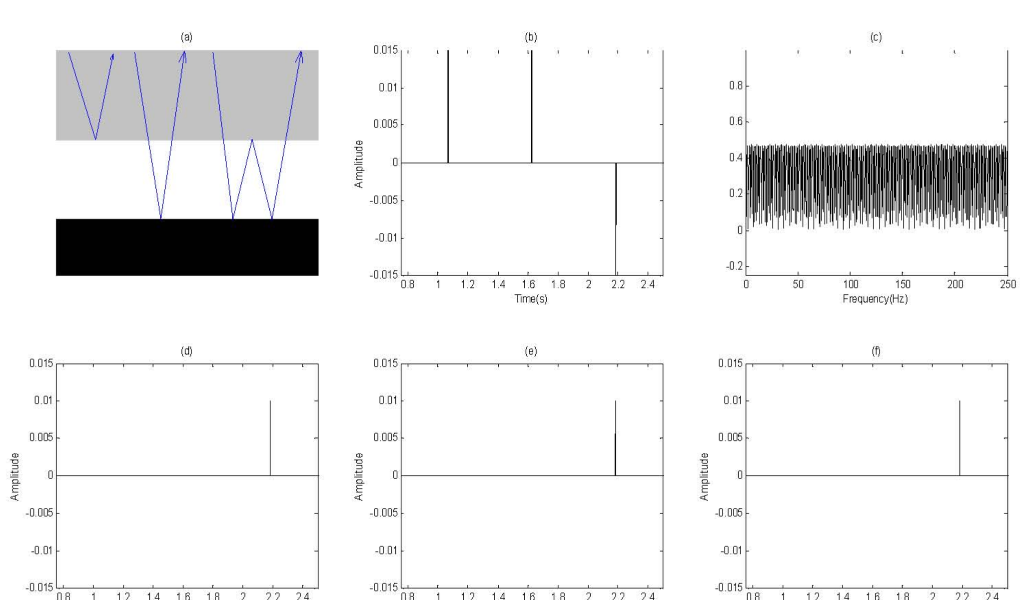

Figure 4: Removal of the wavelet of the input data. (a) Sketch of the model. (b) Synthetic input data, two primary reflections and one internal multiple. (c) Amplitude Spectrum. (d) Output prediction using a value of epsilon equal to 8 samples. (e) Output prediction using a epsilon of 15 samples points. (f) Output prediction using a value of epsilon of 60 samples points.

APPLICATION ON PHYSICAL MODELLING DATA

We conducted a 2D common-offset seismic survey over the model shown in Figure 5, with 401 traces at a spacing of 10m (field scale). The source and the receiver were slightly immersed in the water. The frequencies emitted varying between 5 to 100Hz (field scaled) . The model used in this study consisted of a PVC slab, Plexiglass, smaller Aluminum slab, Plexiglass immerse in Water, Figure 7 shows sketch of this model and its physical characteristics. The scaling used for distance in the model was 1:10000, therefore, 1cm long by 2.5cm deep model represented 100m in horizontal distance and 250m in depth.

Estimation of epsilon

Autocorrelation is a very useful mathematical tool for finding repeating patterns, such as the existence of a periodic signal which has been buried under noise, and/or identifying the missing fundamental frequency in a signal implied by its harmonic frequencies. Autocorrelation is frequently used in seismic processing to designing the deconvolution operator. In this work, the autocorrelation is used to estimate the source wavelet in subsequently a value of parameter epsilon (є). Figure 6 shows the autocorrelation of input data.

Results

We applied our 1D multiple attenuation algorithm on physical model data and the results are quite satisfactory. Setting at epsilon (є) value of 50 (sample points) we predicted internal multiples reflections at 1.4, 1.9, 2.3, 2.6 and 2.7 seconds as we expected according to the model. The ray path of the main first order internal multiples are shown in Figure 11. The form of the wavelet is affecting the output prediction. Notice that in Figure 7 the strongest internal multiples is IM3 (1.83s) due to the high contrast of impedance between the aluminum layer and water, is very strong in the input data and output prediction. Moreover, the output prediction presents reverberations or ringing effect. A certain amount of seismic energy is not been transmitted from one layer to the next through the water and aluminium layers. It remains trapped within of these layers producing additional arrivals on the section at each rebound.

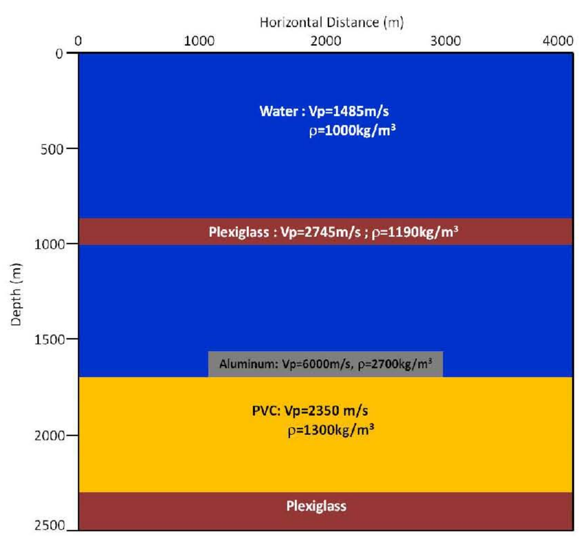

Figure 5. Schematic diagram of the model used.

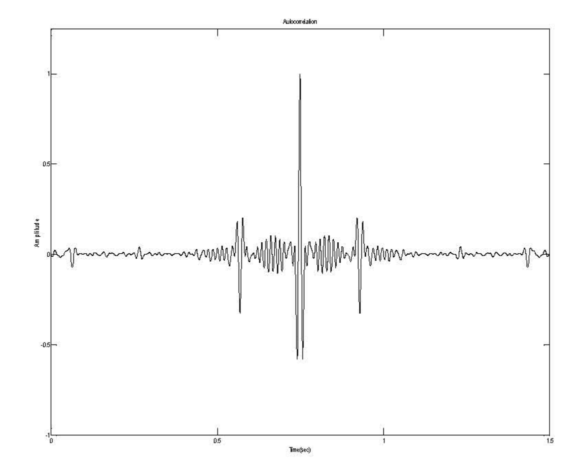

Figure 6. Autocorrelation of the data to estimate the value of epsilon.

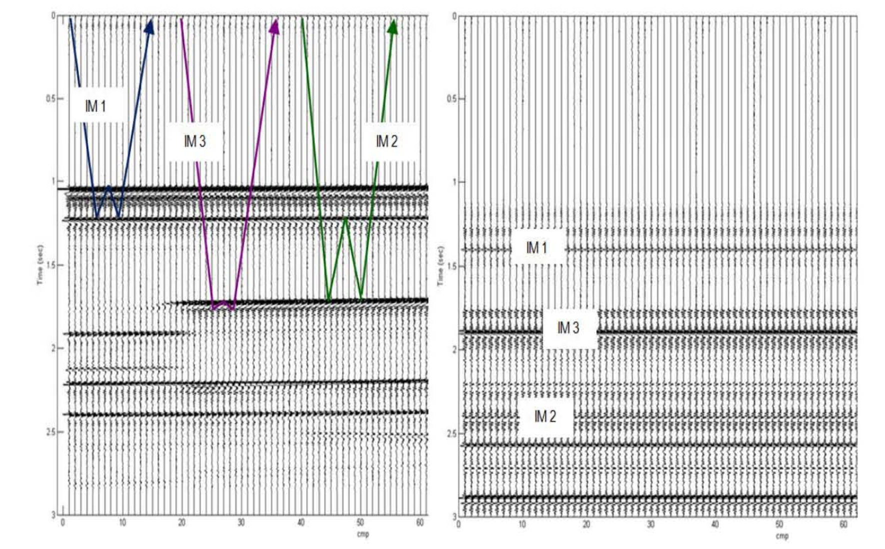

Figure 7. Comparison between input data (left side) and output prediction (right side).

ZERO OFFSET INTERNAL MULTIPLE PREDICTION ON FIELD DATA

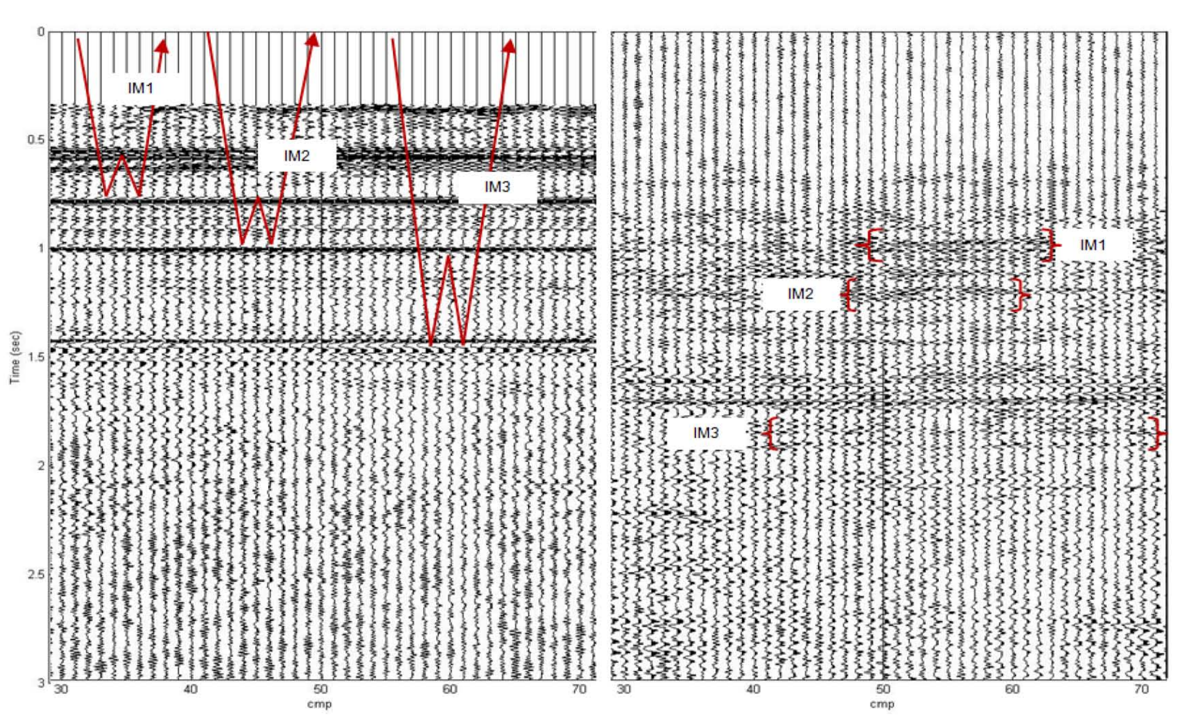

Figure 8. Comparison between input data (left side) and output prediction (right side), field data.

In this section we will present the results of the application of the algorithm on land field data. The data sets were donated by Nexen Inc., and belong to the northeastern of British Columbia (NEBC). The experience and knowledge acquired with the application of the algorithm on synthetic data and then physical modeling data allowed us to finally apply the internal multiple attenuation algorithm on field data. The 2D seismic data is high quality, presents strong reflections, low noise, and some internal multiples.

Since we are running a 1D version of the algorithm, the input data has been stacked, and muted in order to be as free as possible of noise, because the algorithm is very sensitive to noise. The value of epsilon (є) used was 20 sample points.

In the output field data prediction we identified an internal multiple due to the high impedance contrast between Banff and the receiver/source medium that arrives around 1.0s, coinciding with the Jean Marie reflector, Figure 8. Moreover, there is a strong internal multiples arriving around 1.6s, this is a short-path multiple, its amplitude is large due to high contrast of impedance between Jean Marie and Otter Park. This high contrast of impedance between those interfaces is also generating a strong long-path multiple arriving at 1.83s.

CONCLUSIONS AND FUTURE WORK

Based on the synthetic experiments we can conclude that the output prediction depends strongly in the parameter epsilon. For smaller epsilon values, the algorithm affects the primaries. Therefore, an underestimation of epsilon could damage significantly important information present in the data. An overestimation of the value of epsilon would not damage the data, but the output will not show any internal multiples or other seismic events. The components of the wavelet do not affect the prediction of internal multiples using this technique as long as the parameter epsilon is well estimated.

We recommend a autocorrelation of the input data to estimate the size of the parameter epsilon. We applied the algorithm in three differents types of seismic data; synthetic data, physical lab data, and field data and obtained substantial results . Using this technique the analyst can verify if an interbed multiple is interfering with a primary and affecting the amplitude of it. This is very important result because an erroneous value of the amplitude can be very harmful mistake in the application of specialized characterization techniques such as AVO. This output prediction section can be considered a map of the places where the internal multiples can be found.

For future work we recommend the application of adaptive subtraction method to remove the predicted internal multiples from the input data by estimating shaping filters, minimizing the difference or misfit between the input data and the output prediction using least-squares. Moreover, we recommend the application of the algorithm on geological complex seismic data, and developing of a 2D version of the algorithm.

ACKNOWLEDGEMENTS

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