Generating low-frequencies: a study on prediction filters and their use for impedance inversion

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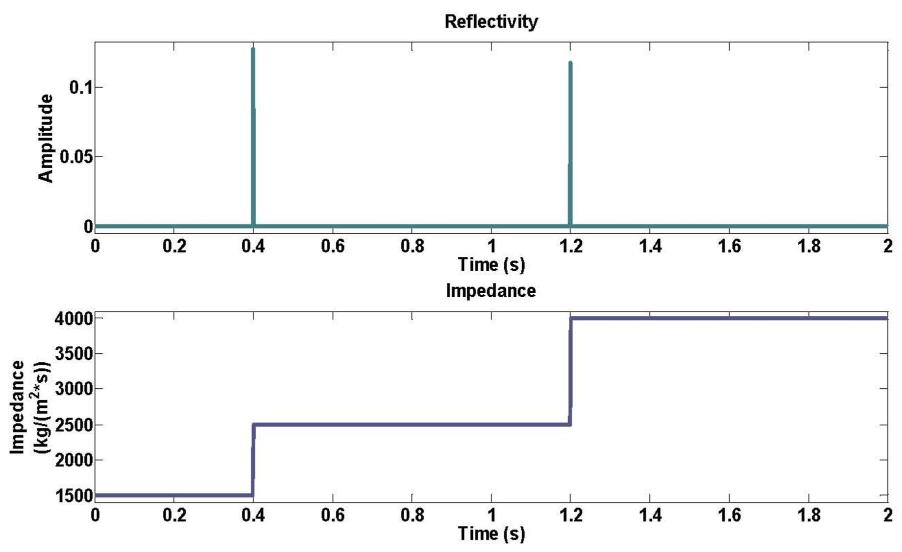
WHY WE NEED LOW-FREQUENCIES

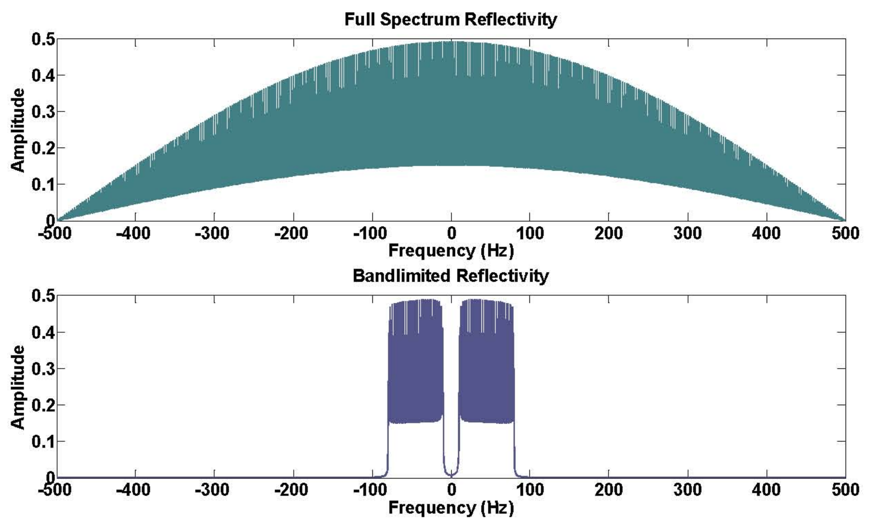


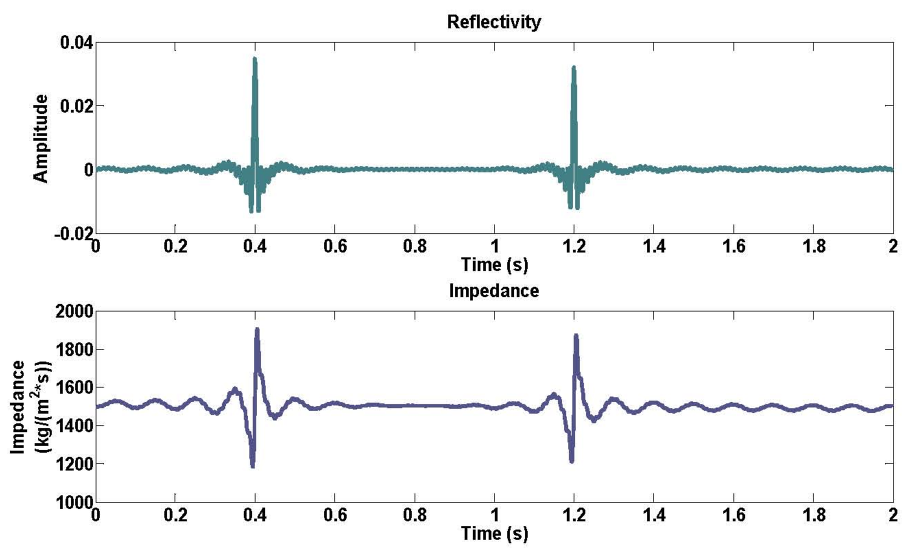
Reflectivity has a full bandwidth so when it is used to solve for impedance using the recursion formula,

$$I_{j+1} = I_j \frac{1+r_j}{1-r_j} = I_0 \prod_{k=1}^{j} \frac{1+r_k}{1-r_k}$$

(Oldenburg et al., 1983) we get the true Impedance that created the reflectivity.

When a wavelet is convolved with the reflectivity it becomes bandlimited. We are missing the high frequencies but more importantly we are missing the low frequencies. The low frequencies are what give the impedance its trend.





This time when the impedance is calculated from the bandlimited reflectivity, the impedance curve has no trend to it and only shows the location of the changes not the magnitude of them. This illustrates the importance of the Low-frequencies.

PREDICTION FILTERS

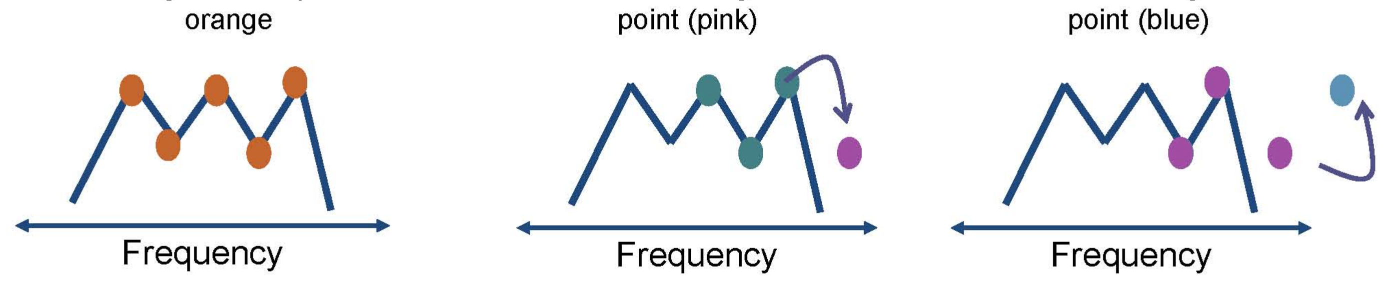
Prediction filters are one method that can be used to recover the low-frequencies in a bandlimited trace. Two different types of prediction filters will be described below.

One-Lag Prediction Filter

Create a filter "a" that has a length of 3 using the data points in orange

Convolve the data points in teal with the filter "a" to get the next point (pink)

Convolve the data points in pink with the filter "a" to get the next point (blue)



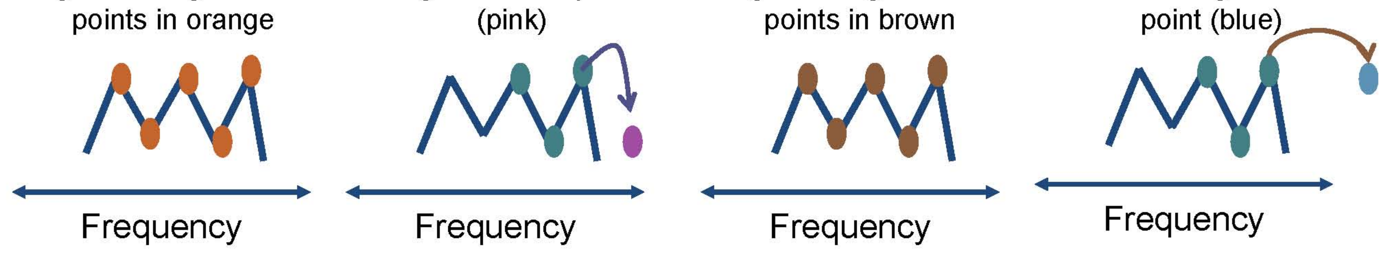
Multi-Lag Prediction Filter

Create a filter "a1" that has a length of 3 and a lag of 1 using the data points in orange

Convolve the data points in teal with the filter "a1" to get the next point (pink)

Create a filter "a2" that has a length of 3 and a lag of2using the data points in brown

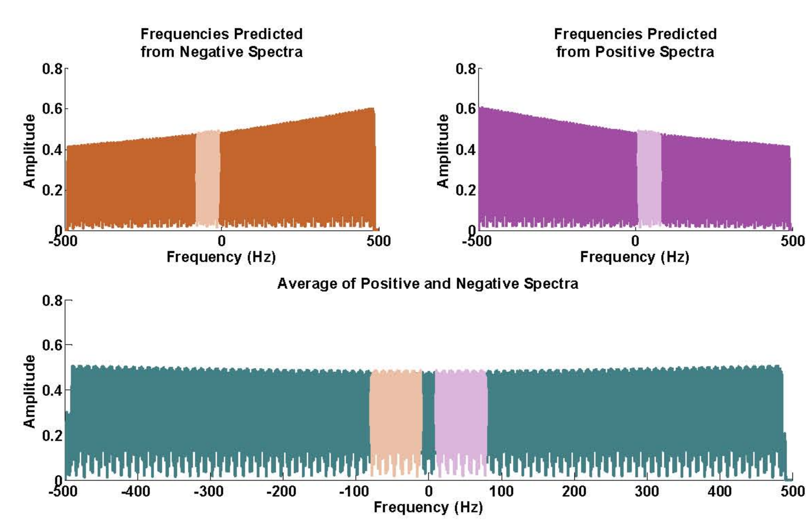
Convolve the data points in teal with the filter "a2" to get the next point (blue)



ABSTRACT

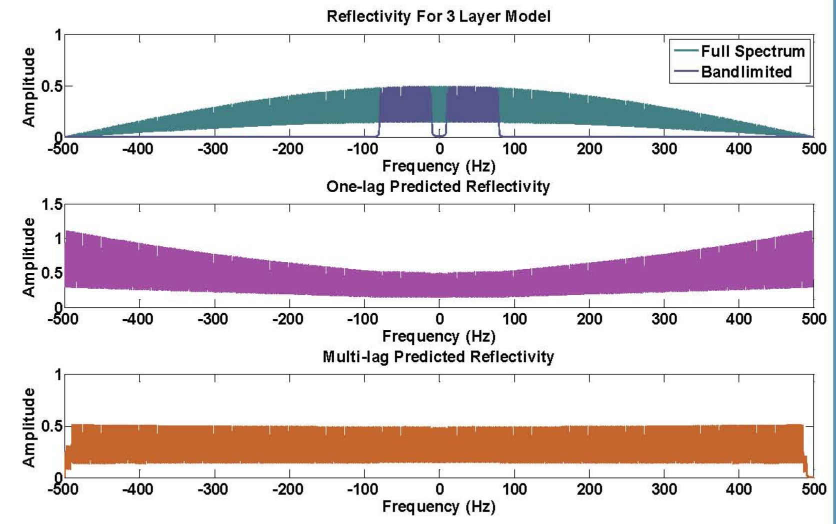
Accurate bandlimited acoustic impedance inversion is impaired by the missing low-frequencies in recorded data. There are several methods for restoring these missing frequencies - they can be recorded in the field, estimated by model inversion, borrowed from well logs or predicted using the available frequencies in the spectra. Two methods of prediction filters were explored in solving for the missing frequencies. The first method is the one-lag prediction method which predicts the needed samples using one prediction filter. The second method uses multiple lags to predict the needed samples and creates a new prediction filter for each sample. These methods were tested with a simple 3-layer model and a more complicated 12-layer model where it was evident that the method was sensitive to four main parameters. The prediction methods need a reliable band of frequencies to create the filters and predict the new samples that must be flat and larger than the low-frequency gap. The length of the filter was studied and we found that the length needed to be longer than the amount of layers in the model. The third sensitivity was the effect of noise in the signal, where low signal to noise affected the character of the inversion. The fourth sensitivity was the number of layers that the method could accommodate. On a realistic synthetic example using a synthetic trace created from well logs and deconvolved both the prediction methods failed when compared with the BLIMP method. This was partially due to the natural roll-off of low frequencies when there are a large amount of layers in the model and the complication of the frequency spectrum. This study has not conclusively determined which prediction method is preferable but the one-lag method is faster and has fewer errors when compared with the multi-lag method.

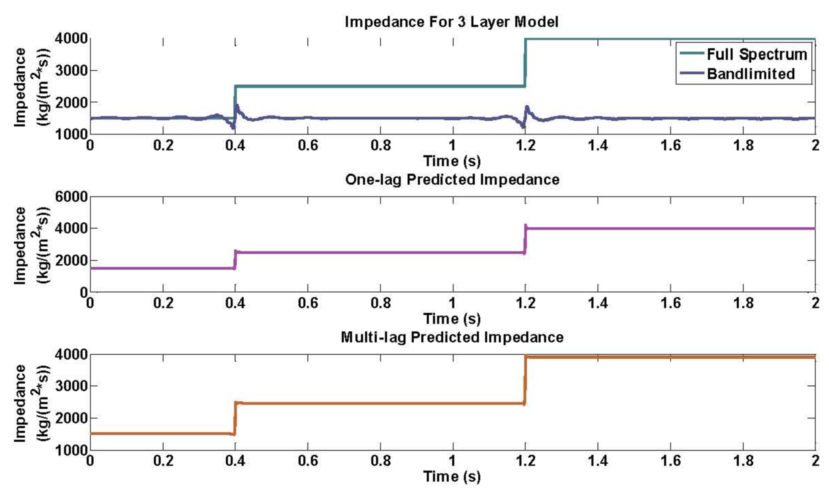
METHOD



A band of frequencies is selected that has a flat spectrum. The prediction filters take this band of positive frequencies indicated in pink and predict frequency samples in the forward and backward direction. This is repeated with he negative band of frequencies. These results are then averaged to create the predicted spectrum indicated by teal in the figure to the left.

The one-lag (pink) and multi-lag (orange) prediction filter methods are both able to approximate the reflectivity frequency spectrum of a three layer model. Even though the high frequencies are not estimated correctly, the low-frequencies are estimated properly which is essential to create the correct trend of the impedance curve.

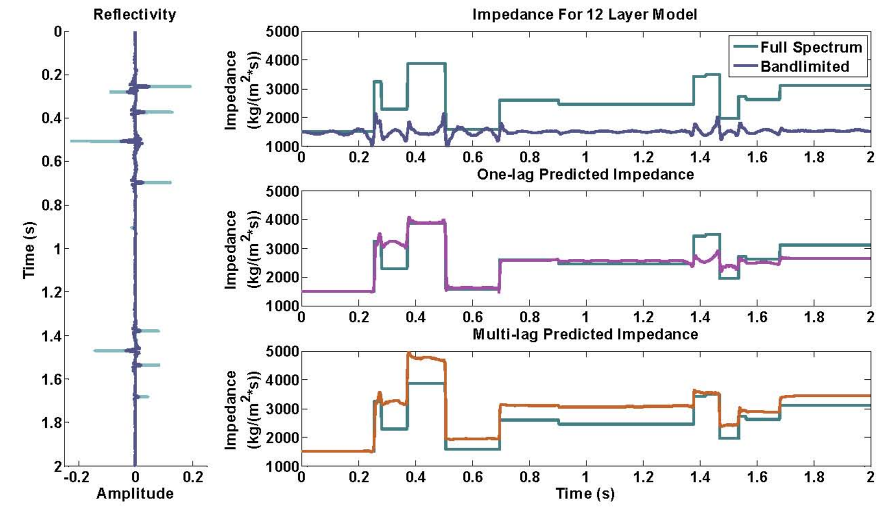


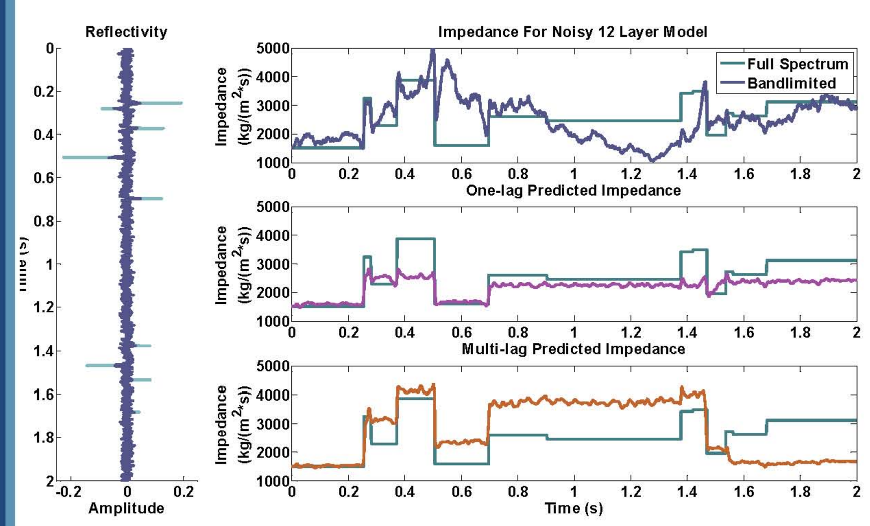


When the inverse Fourier transform is applied to the predicted frequency spectrum, we get the full band reflectivity in time. The recursion formula can then be used to invert for impedance, which the results are seen for the 3 layer model. Both methods were within 2% of the model impedance.

12 LAYER MODEL RESULTS

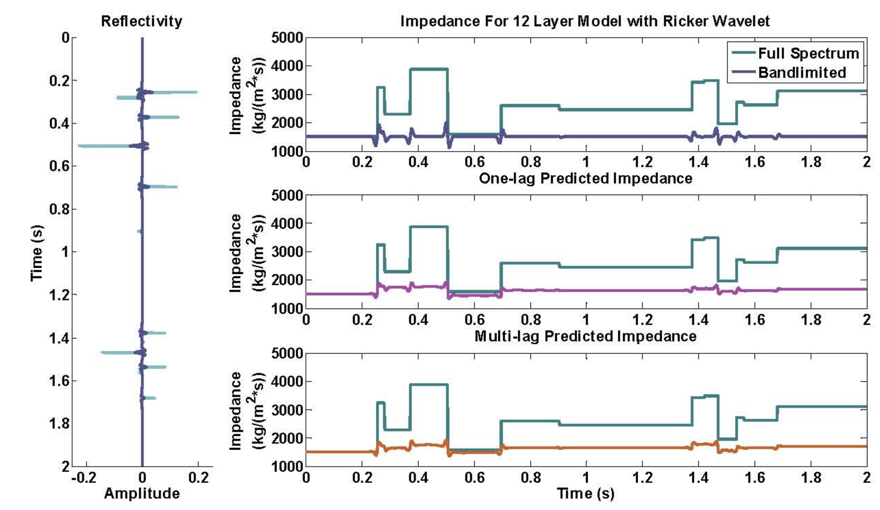
A twelve layer model was also tested and the results to the right were obtained. These results show that the one-lag method is more accurate for lower times and the multi-lag method is more accurate for higher times. This indicates that the multi lag method is better at predicting the very low-frequencies.





Noise was added to the twelve layer model and the results to the left were obtained. From these results it may seem that the multi-lag performs better on a noisy case but vigorous testing has showed that the inversion is sensitive to the amount of noise that is present. High signal to noise ratios produce the best results

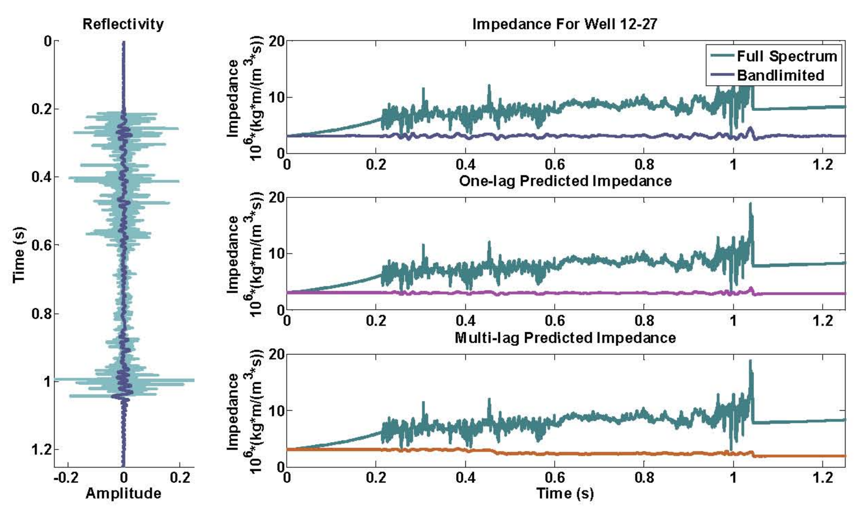
A Ricker wavelet was also applied to the twelve layer model. The Ricker wavelet has a curved spectrum and thus the prediction filters are unable to reproduce the inversions accurately. Curved spectra is the one of the largest problems for the prediction filter methods



REFERENCES

Oldenburg, D. W., Scheuer, T., and Levy, S., 1983, Recovery of the acoustic impedance from reflection seismograms: Geophysics, Vol. 48, No. 10.

WELL LOG RESULTS



Prediction filter frequency recovery methods were found to be ineffective on well data. The figure to the left uses a prediction filter length of 25 as longer lengths produce unstable results.

When Prediction filter frequency recovery methods are used with well logs the algorithm can become unstable when choosing the prediction filter length. This length should be greater or equal to the number of layers in the model. For well log models the number of layers tends to be larger than the amount of samples in the chosen band. The length of the prediction filter is another of the very sensitive properties in the prediction filter frequency recovery methods.

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