AVF inversion of anelastic reflectivity: Practical issues concerning implementation

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ABSTRACT

A frequency by frequency method (AVF) of inverting for Q exists which requires as input an estimate of the local spectrum of the absorptive reflection coefficient. We have a calibrated fast S-transform (FST) which we have demonstrated provides a high fidelity estimate of the local spectra of seismic reflection events and is suitable as input for AVF inversion. In this paper we consider a prioritized set of issues a method like this face when applied in the field. We develop mehtodologies and recommendations to manage:
1. Nearby/difficult-to-isolate events;
2. Random/uncorrelated noise;
3. Source wavelet.

1. Nearby/difficult-to-isolate events

The more proximal two events are the greater the portion of their spectra will interfere. Hence, the spectrum of a target reflection will be contaminated by the spectra of nieghboring reflection events, the portion of the spectrum which will be interfered with is a function of how proximal the other event is. An event which is far away will only interfere with the target at very low frequencies but closer events will interfere at higher frequencies. It is unavoidable that, in the presence of nearby events, the only high fidelity estimate of the target reflection's spectrum we can obtain is at the high frequencies.

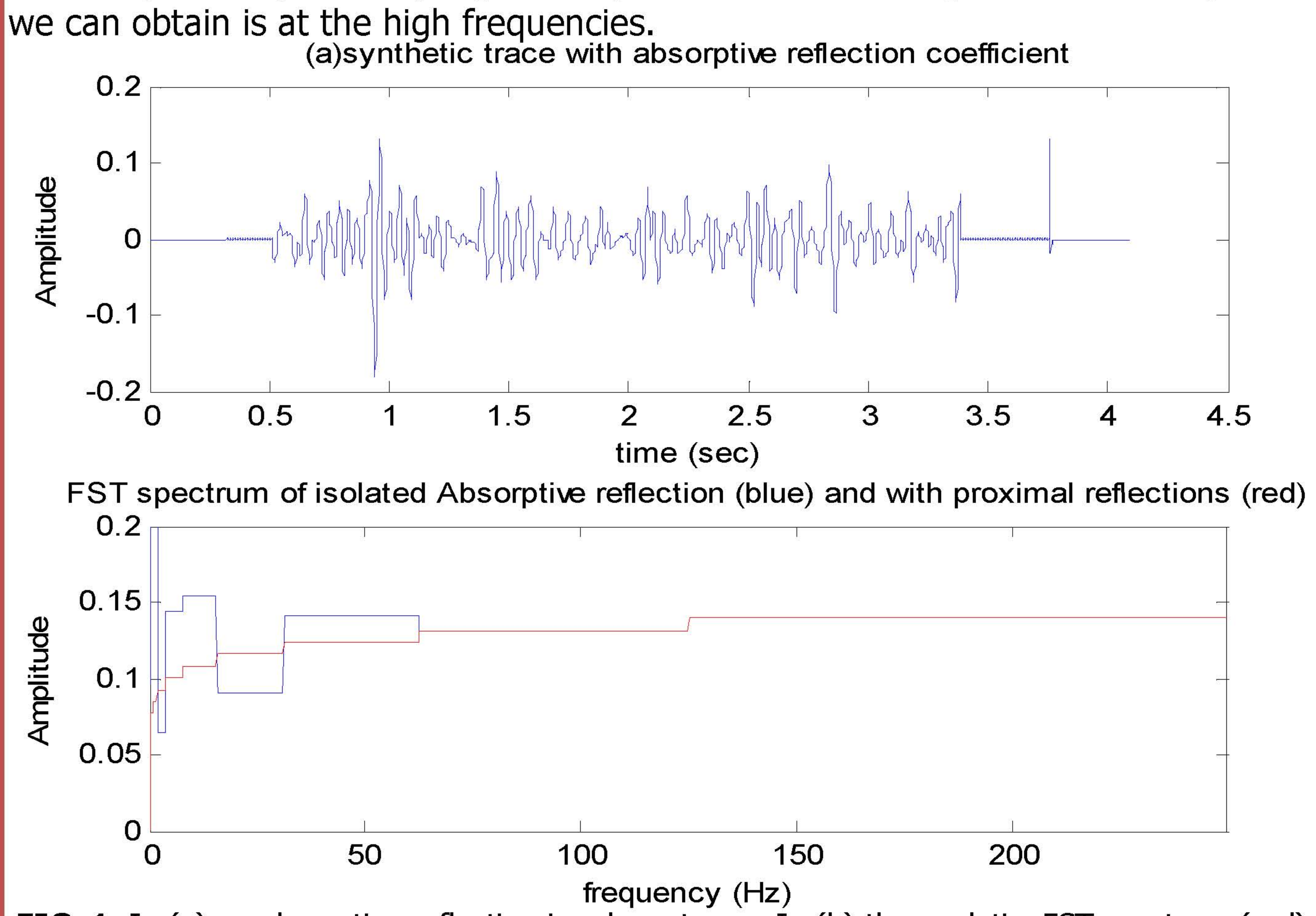

FIG. 1. In (a) an absorptive reflection in a busy trace. In (b) the analytic FST spectrum (red) of the absorptive reflection and the FST spectrum obtained from the trace in (a)

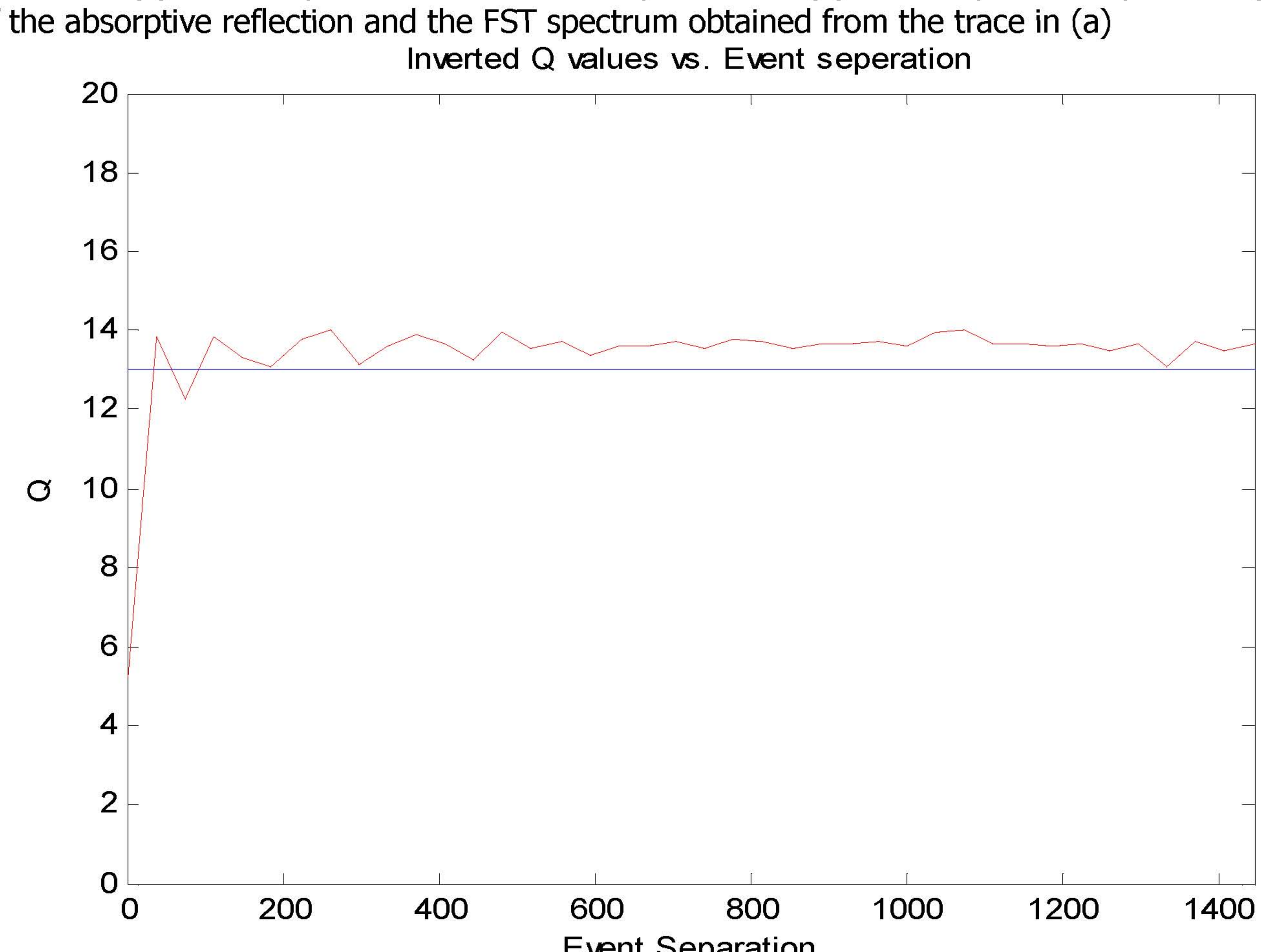

FIG. 2. AVF inversion accuracy as a function of the event separation. The blue line is the actual value of Q and the red line is the inversion result.

2. Random/uncorrelated noise

Because random noise is present in any seismic experiment, it is necessary to test the effectiveness of AVF inversion in the presence of noise if we hope to ever implement it on real seismic data. In order to perform this testing, synthetic seismic traces were generated with a single absorptive reflection coefficient. Then 3% percent random noise was added and the traces were input into the FST and an estimate of the absorptive reflections spectrum was extraced and used to invert for Q. The inversion results on these noisy traces were exremely poor. This is not surprising as the FST algorithm averages over short time windows at high frequencies, and so noise will have a significant contribution to the output of the FST at high frequencies. To combat the effect of noise, repeat experiments could be performed (i.e. acquire numerous traces) and then the traces stacked to attenuate the random noise. Figure 4 examples of how stacking improves the fidelity of the FST estimate of the spectrum of the reflection coefficient.

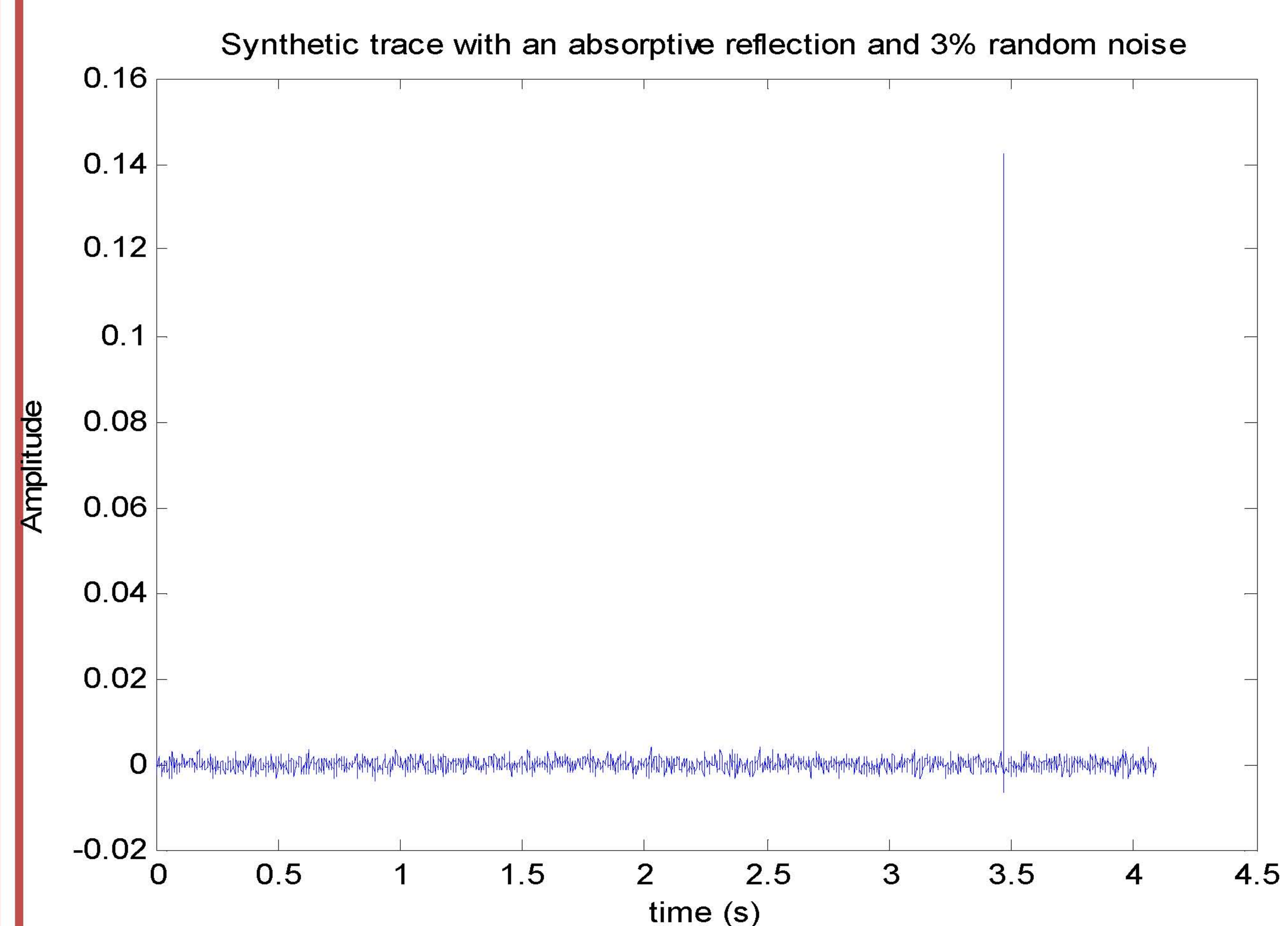

FIG. 3. A trace with a single absorptive reflection and 3% random noise. The results of inverting this trace as is are very poor. Stacking a number of traces greatly attenuates the noise and improves the inversion results

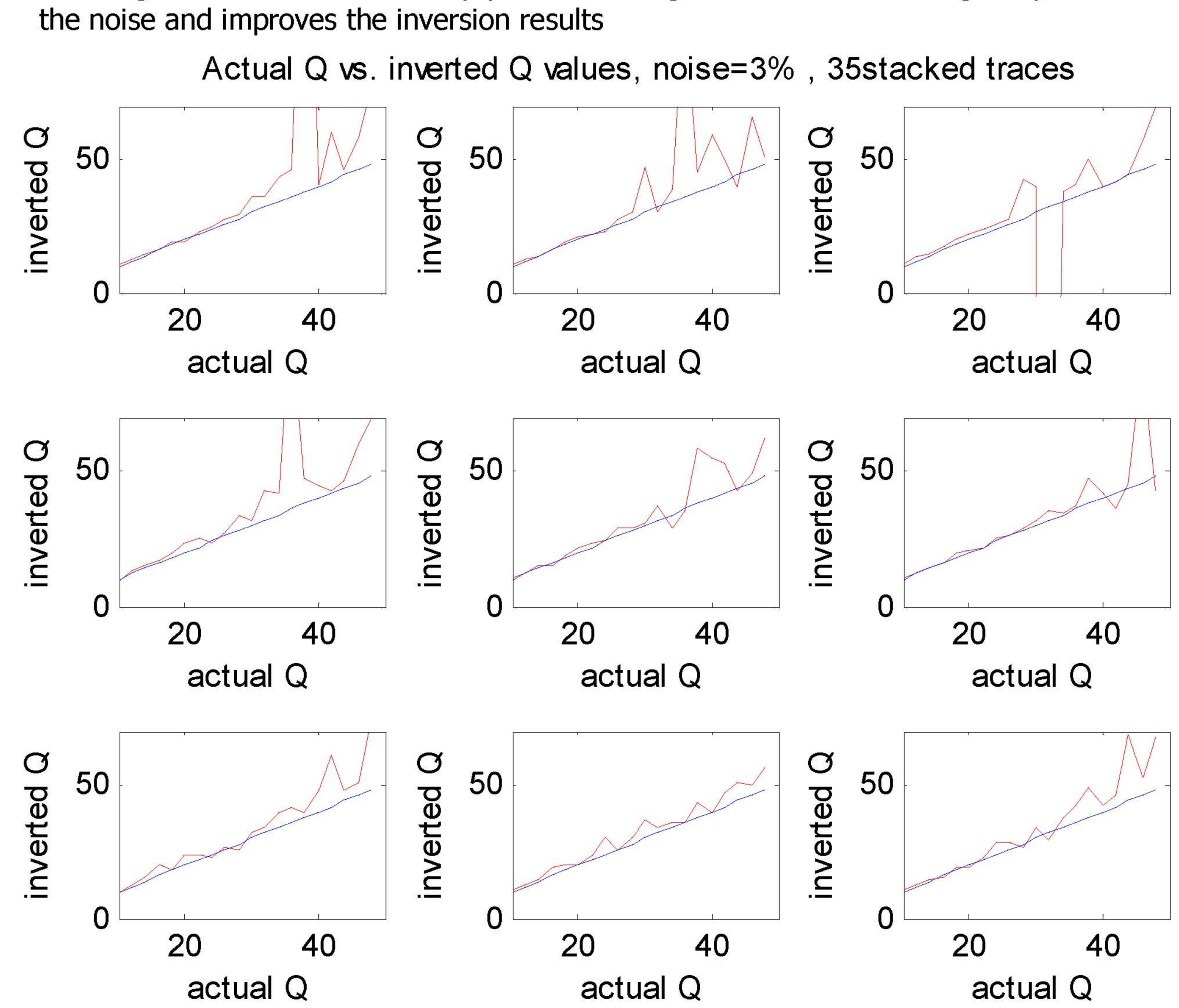

FIG. 4. Inversion results after performing stacking to attenuate noise. The blue curve is the actual Q value and the red curve is the result of inversion. The procedure was repeated nine times for statistical significance.

3. Source wavelet

The source wavelet imposes a footprint onto the spectrum of the reflection which needs to be removed in order to implement AVF inversion. To remove the effect of the embedded wavelet we can perform deconvolution of the seismic trace. To test how effective AVF inversion may be on deconvolved traces a number of synthetic traces were generated with a single absorptive reflection convolved with a minimum phase wavelet. The traces were then deconvolved using the weiner deconvolution codes from the CREWES toolbox. Next the deconvolved trace was input into the FST to obtain an estimate of the absorptive reflection coefficient and the spectrum was used to invert for Q. Figure 5 shows a trace with an absorptive reflection embedded in a busy trace convolved with a wavelet and random noise added. Stacking is performed to attenuate the noise and then deconvolved. Figure 6 shows the analytic FST spectrum of the absorptive reflection in blue and the red curve in Figure 6 shows the FST spectrum of the absorptive reflection obtained from the trace in Figure 5. Notice that the spectrum of the absorptive reflection is a fairly reasonable estimate of the true spectrum at high frequencies.

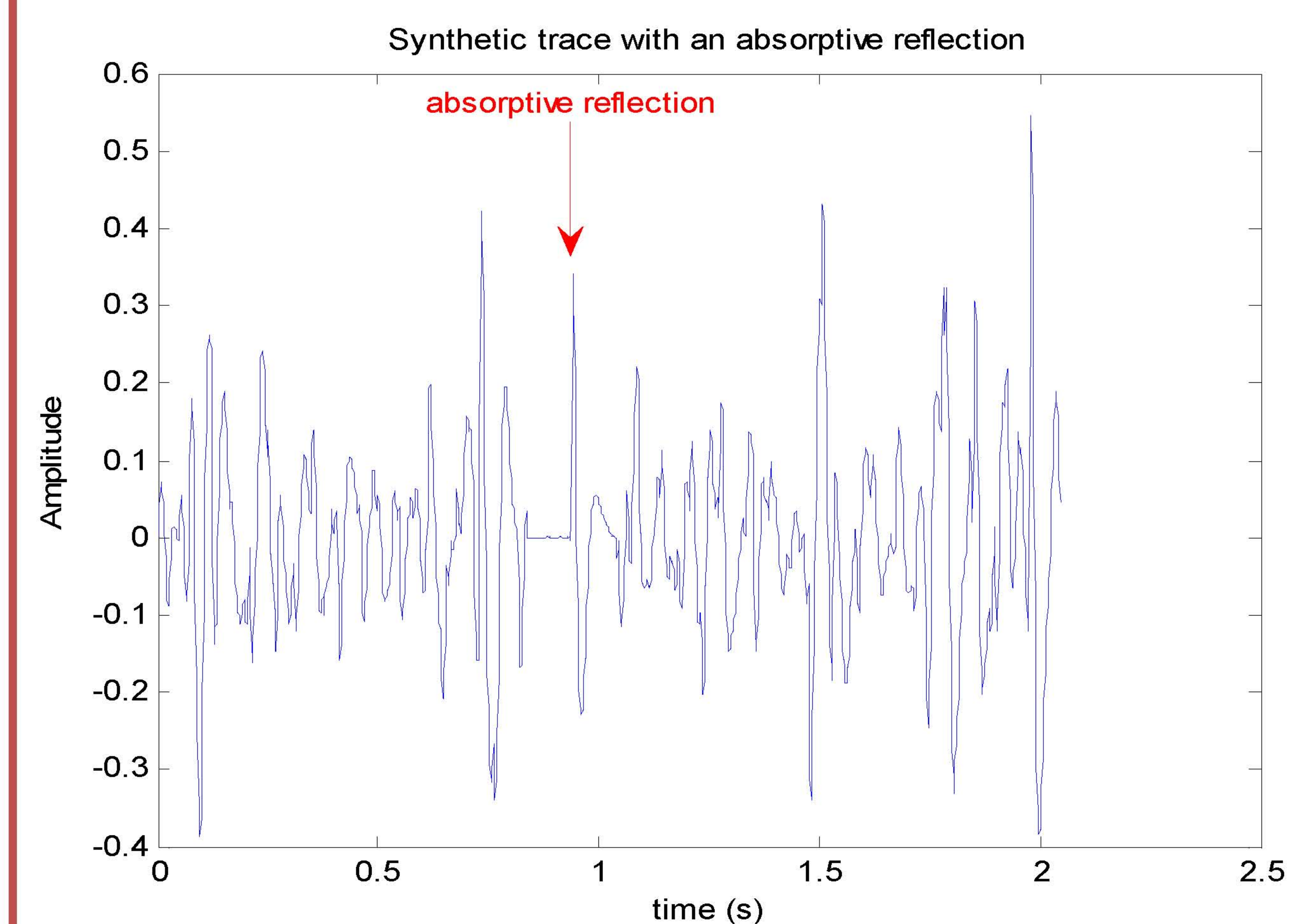

FIG 5. A random reflectivity, with an absorptive reflection coefficient, random noise and convolved with a wavelet.

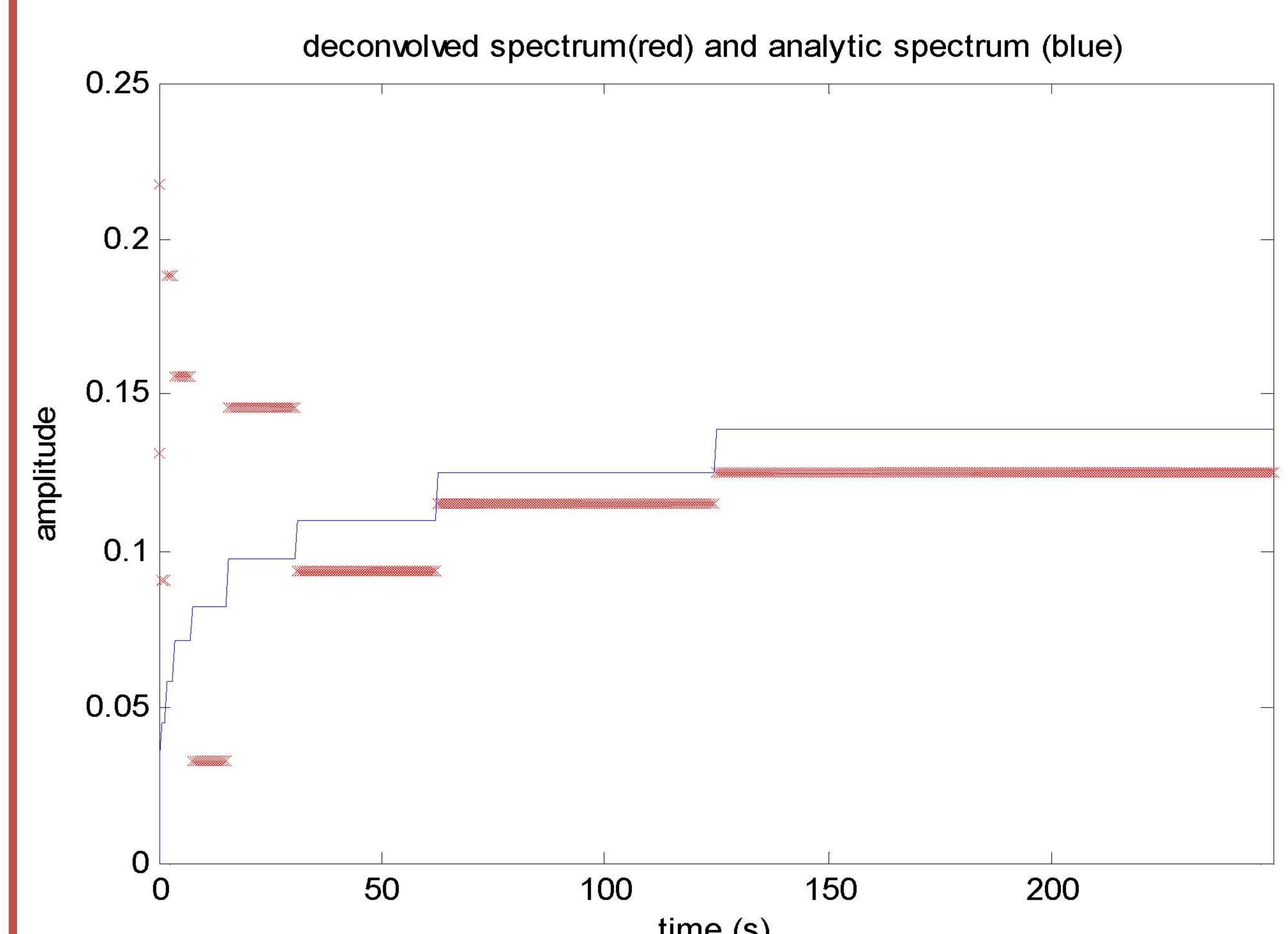

FIG 5 In (a) the spectrum of the direct arrival, In (b) the spectrum of the primary reflection from the top of the Milk River formation. In (c) the estimate of the reflection coefficient with Q-compensation (red) and without (blue).