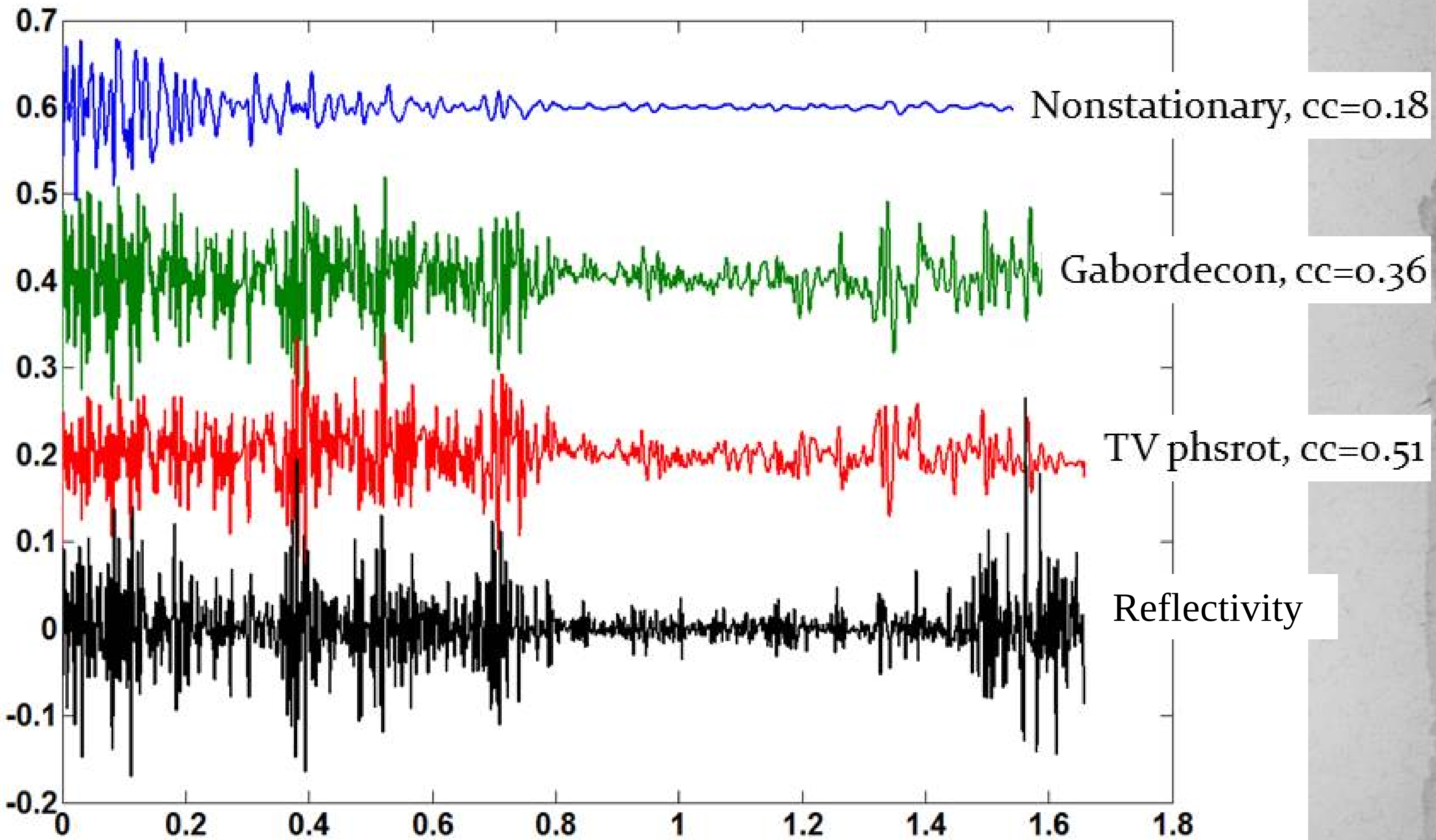
Analysis of well tying: The influence of attenuation and Gabor deconvolution

Tianci Cui and Gary F. Margrave

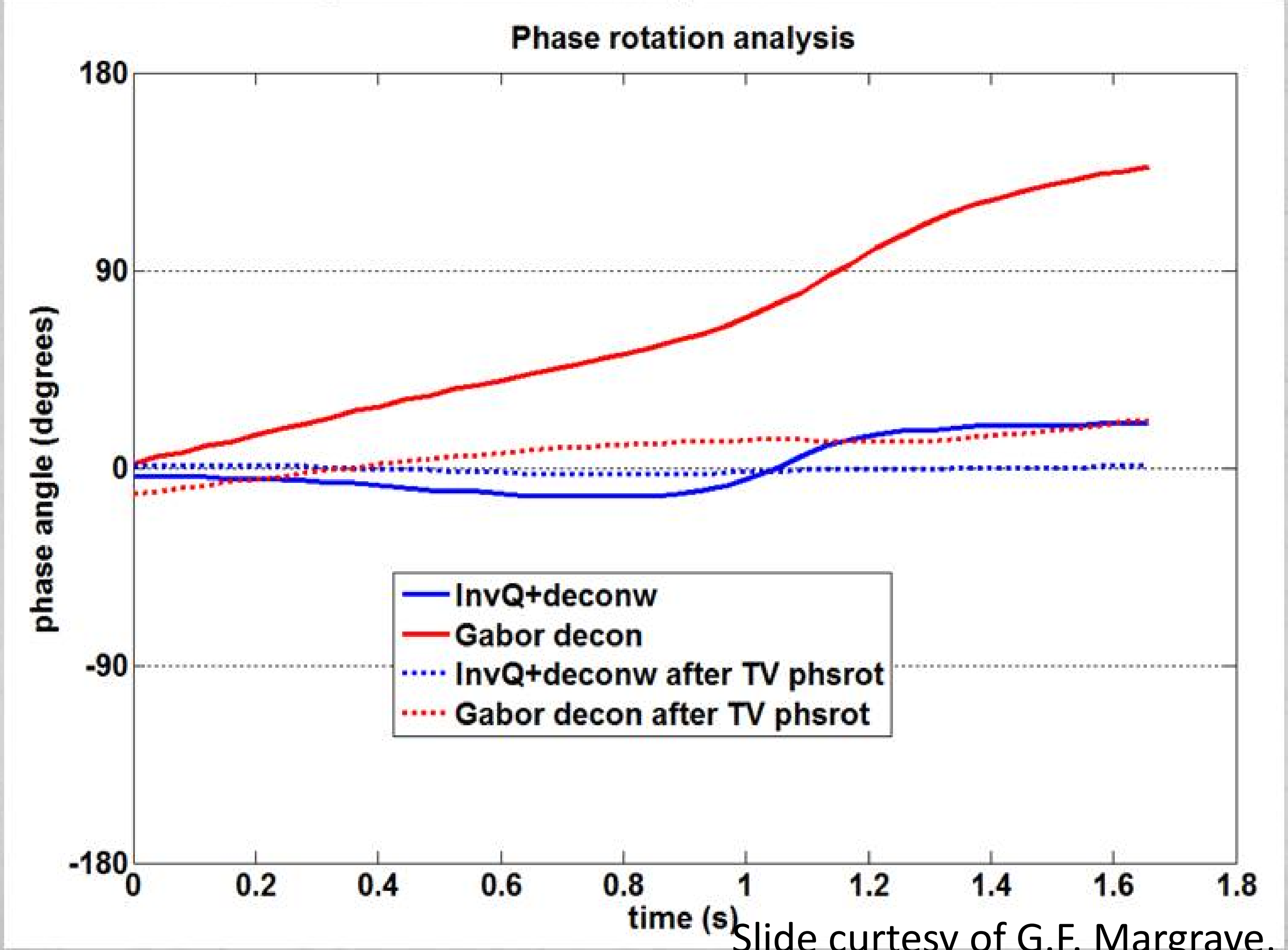
Gabor decon

avoiding the nonstationary catastrophe



Slide curtesy of G.F. Margrave, 2013

Phase rotation analysis
Inverse Q+deconw compared to Gabor decon



Slide curtesy of G.F. Margrave, 2013

Outline

- **Tie synthetic reflectivity to nonstationary trace model**

  Estimate the propagating wavelets

- **Tie well reflectivity to nonstationary trace model**

  Estimate the residual drift time

- **Conclusions and future work**

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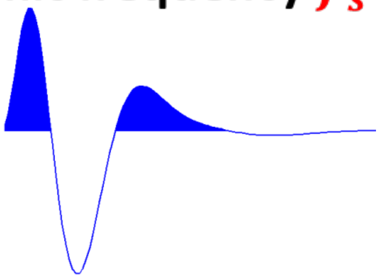
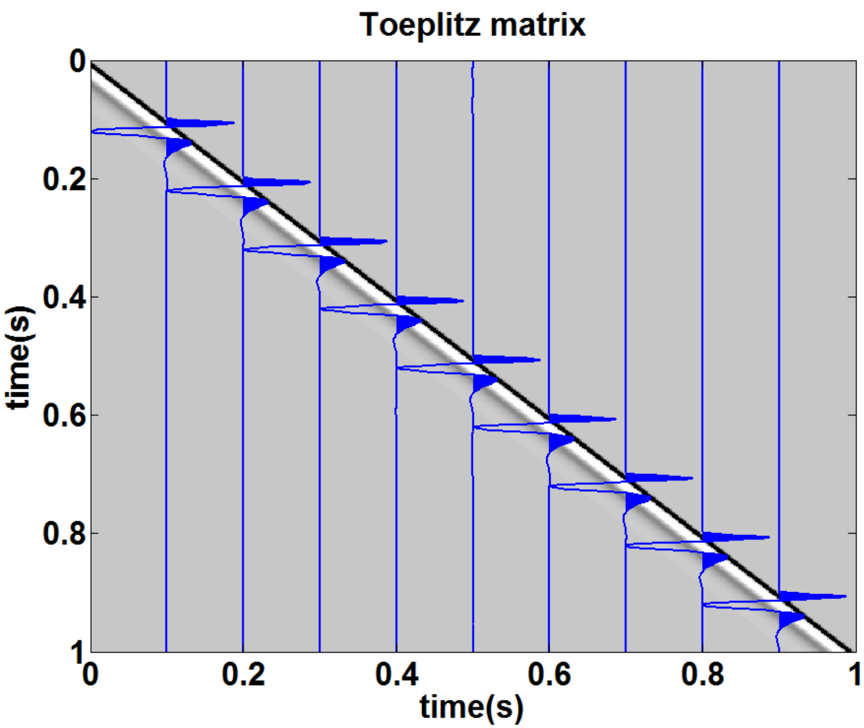
Stationary trace: s

min-phase source wavelet

seismic frequency f_s = 30 Hz





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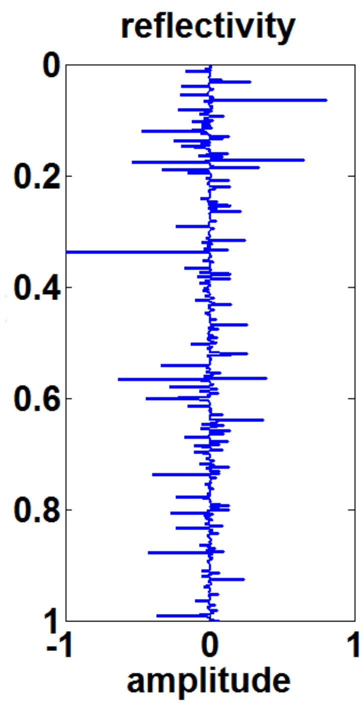

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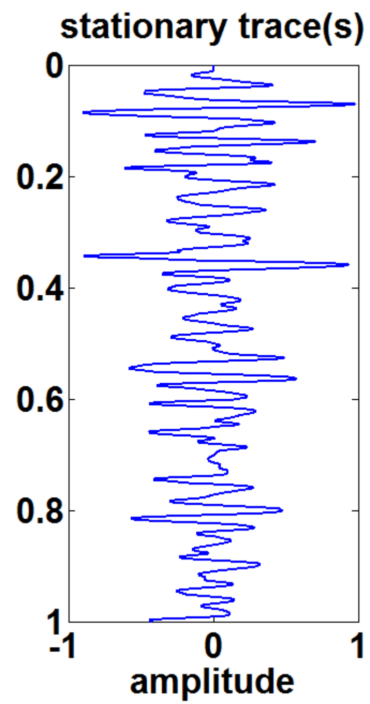
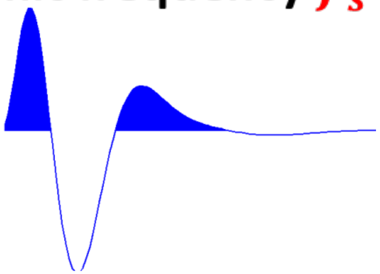


Nonstationary trace: sn

min-phase source wavelet

seismic frequency f_s = 30 Hz



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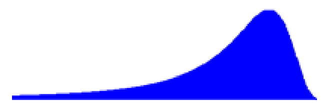


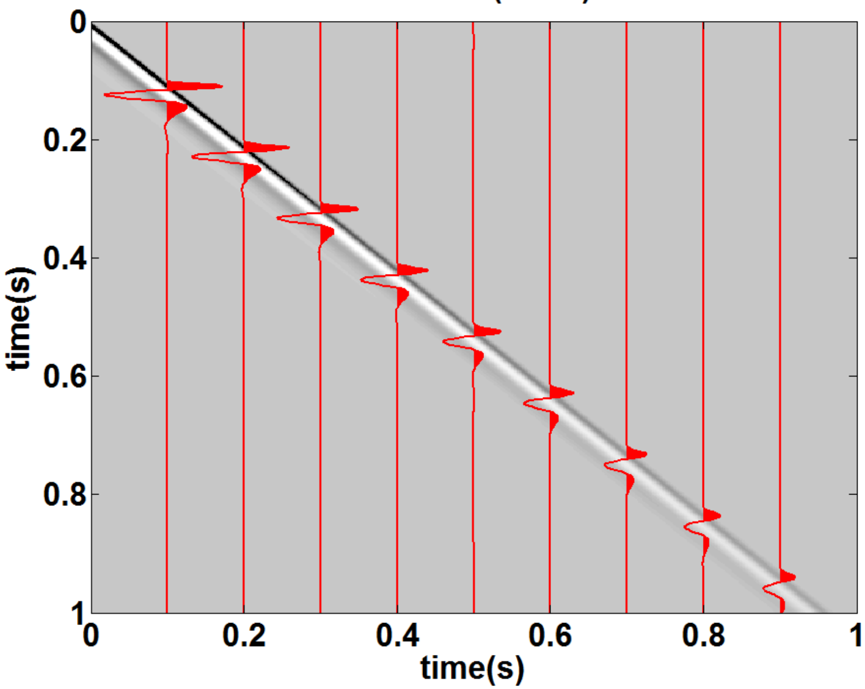
Constant-Q impulse response

Amplitude= $exp(-\frac{\pi f x}{V_0 Q})$

Phase= $-\frac{2\pi f x}{V_0}(1-\frac{1}{\pi Q} ln \frac{f_s}{f_0})$

Reference frequency f_0 and velocity V_0

f_0=12.5 kHz



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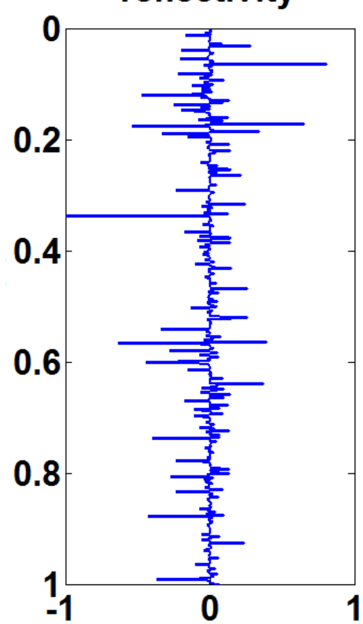

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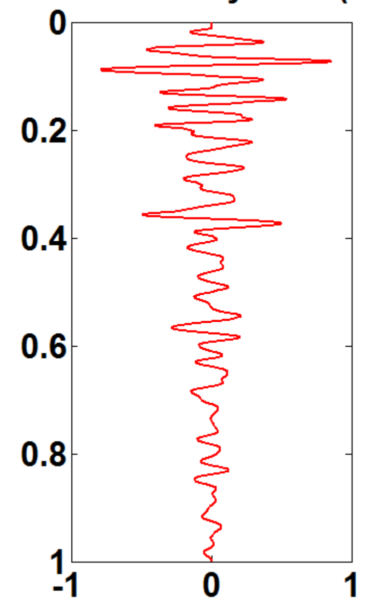
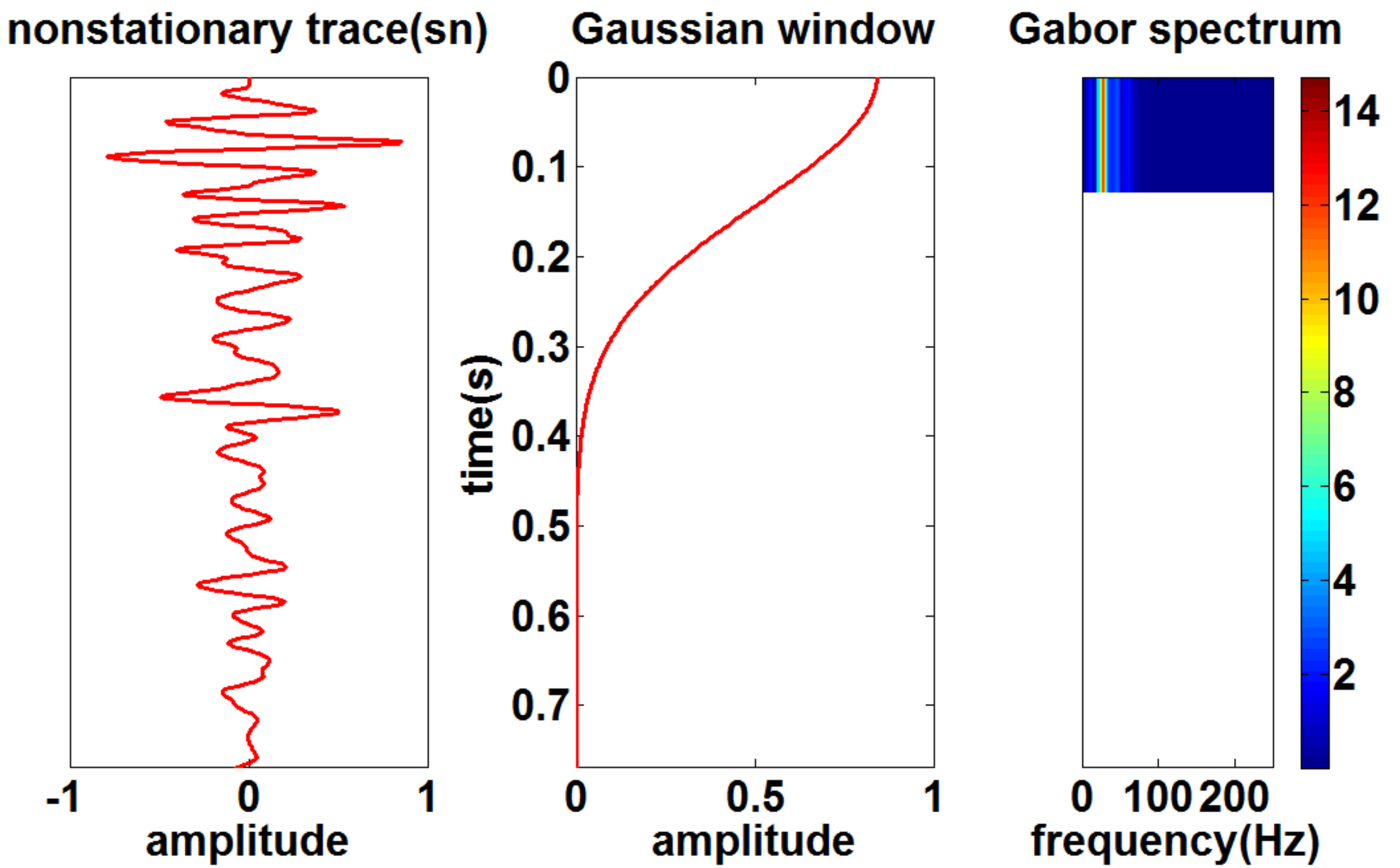


The Gabor transform



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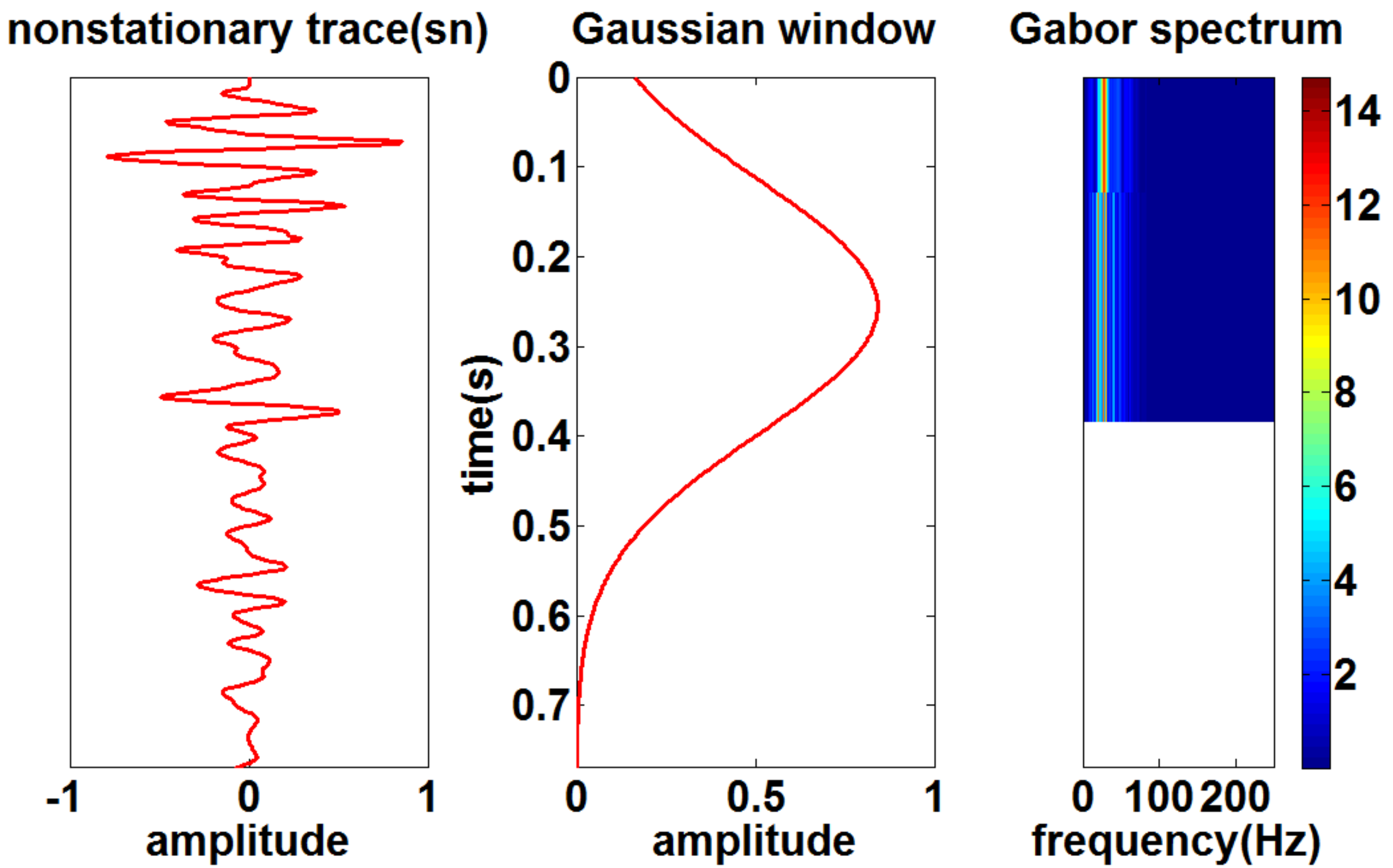

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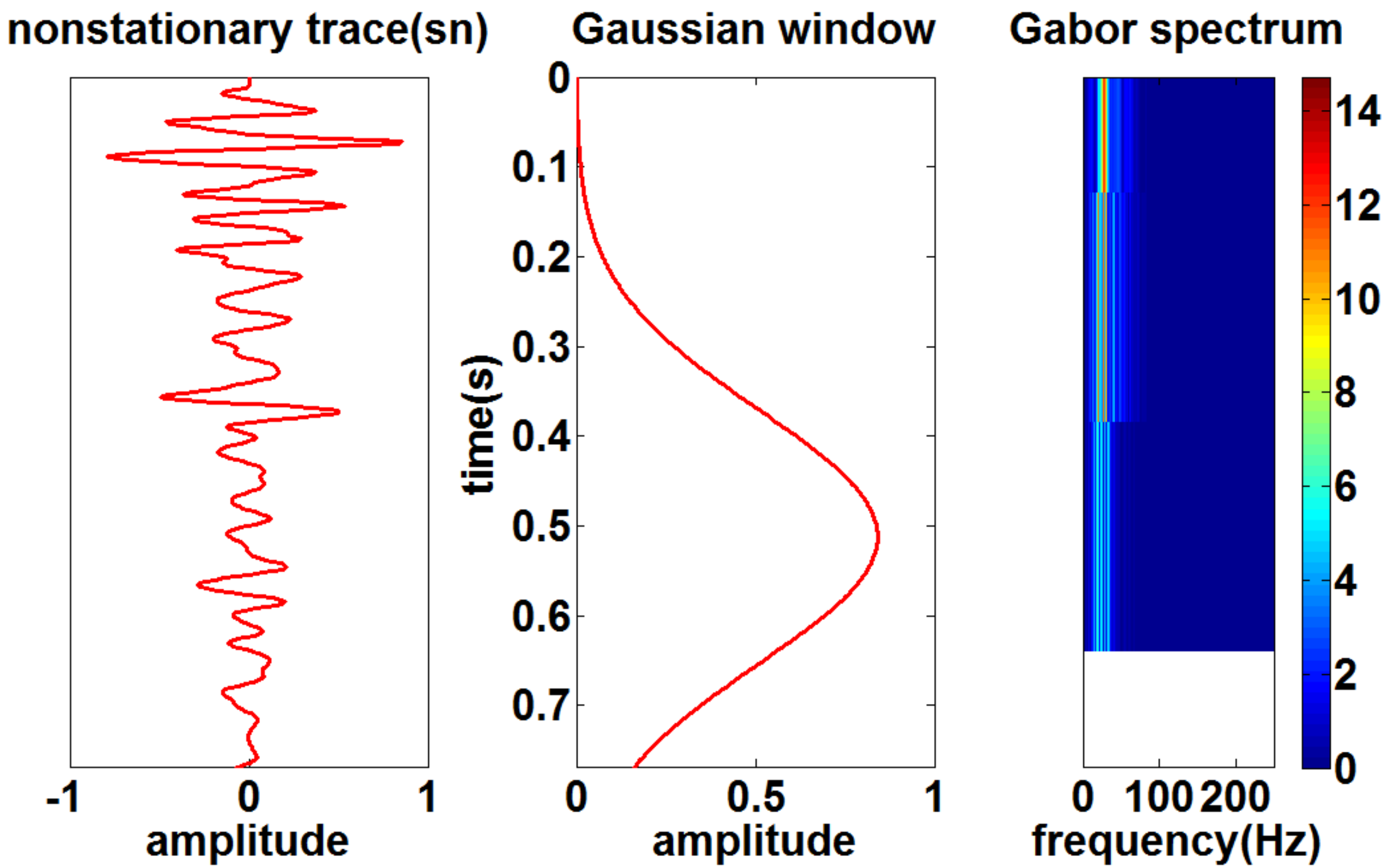

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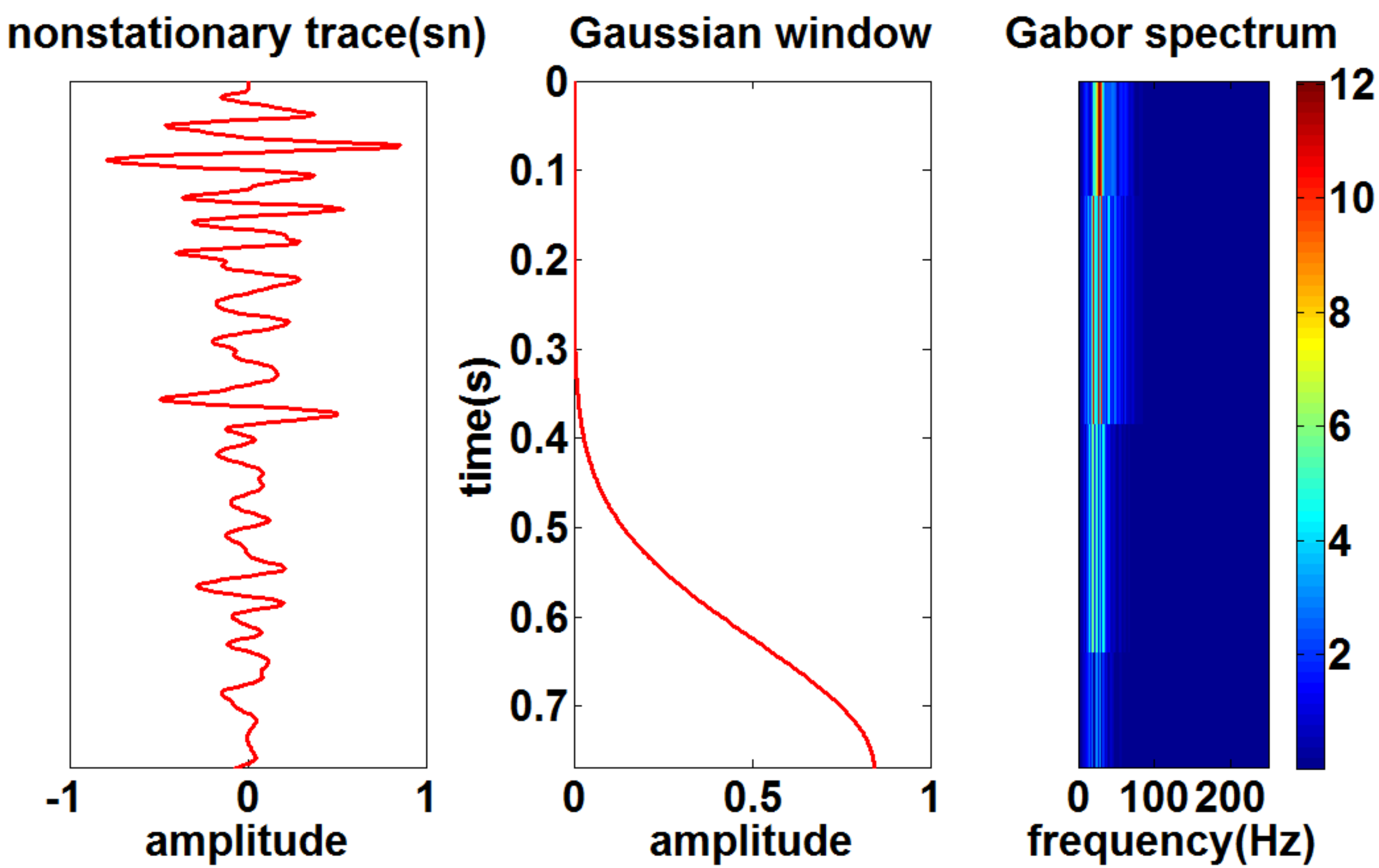
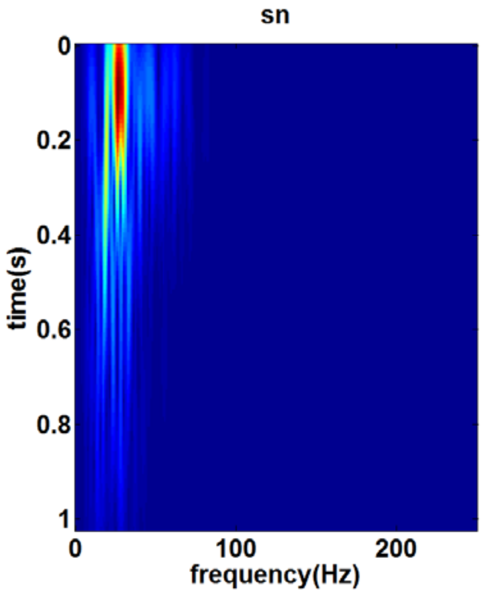
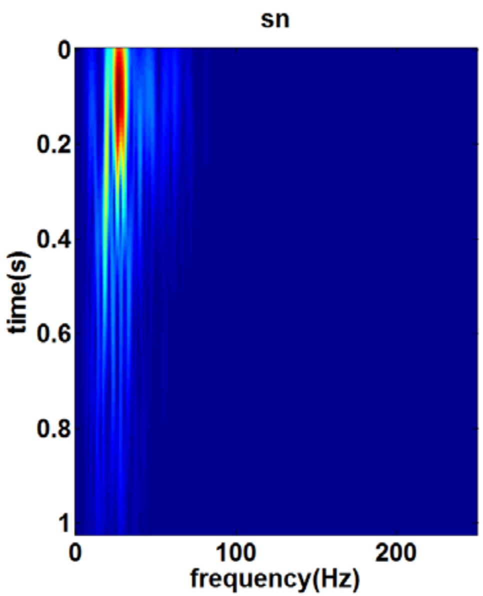


Nonstationary trace factorization

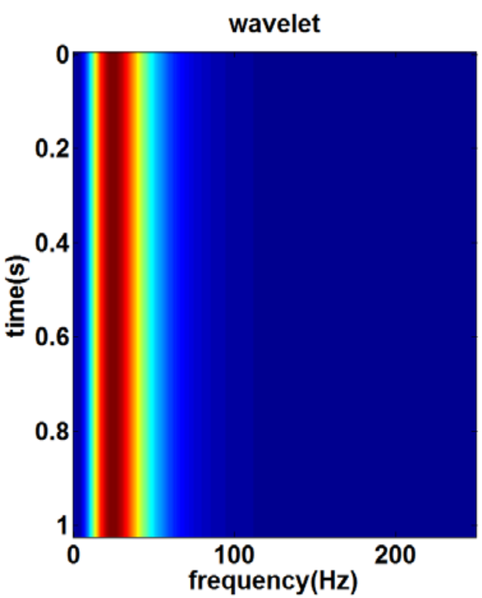


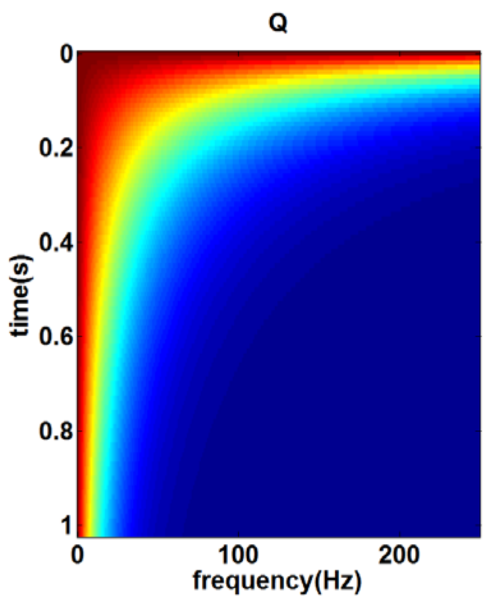
Nonstationary trace factorization

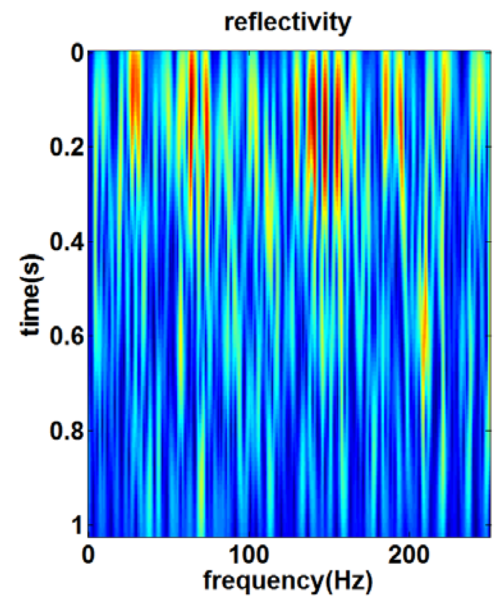


$$\widehat{sn}_g(t,f) \approx \hat{w}(f)\, exp\left(-\frac{\pi f t}{Q}\right) \hat{r}_g(t,f)$$

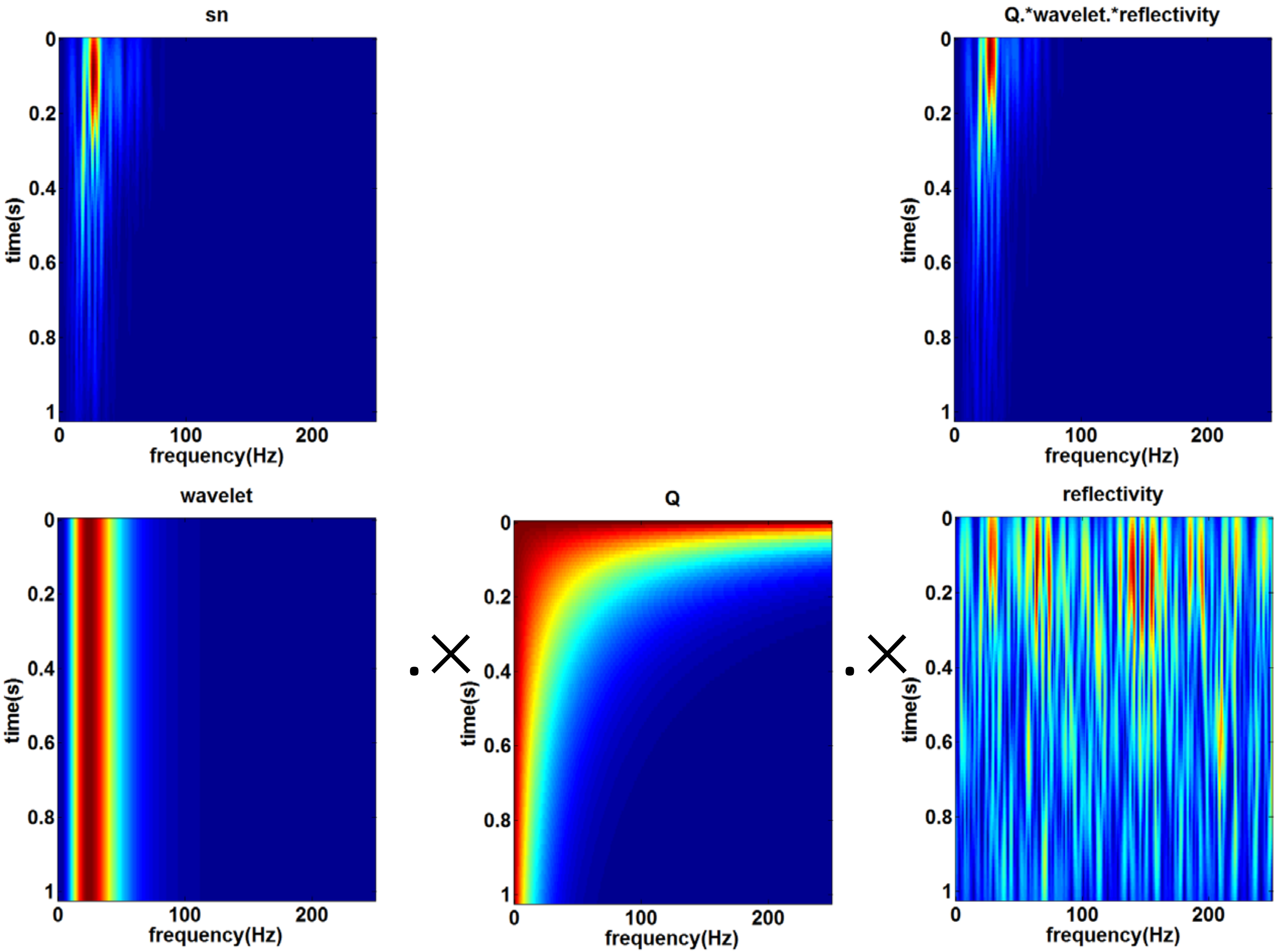
(Margrave, Lamoureux and Henley, 2011)



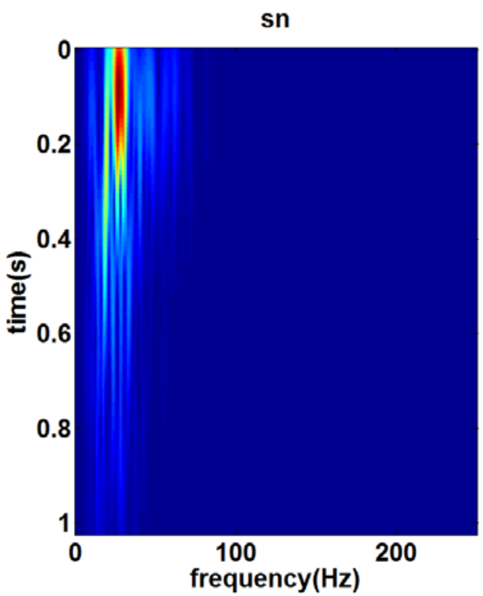


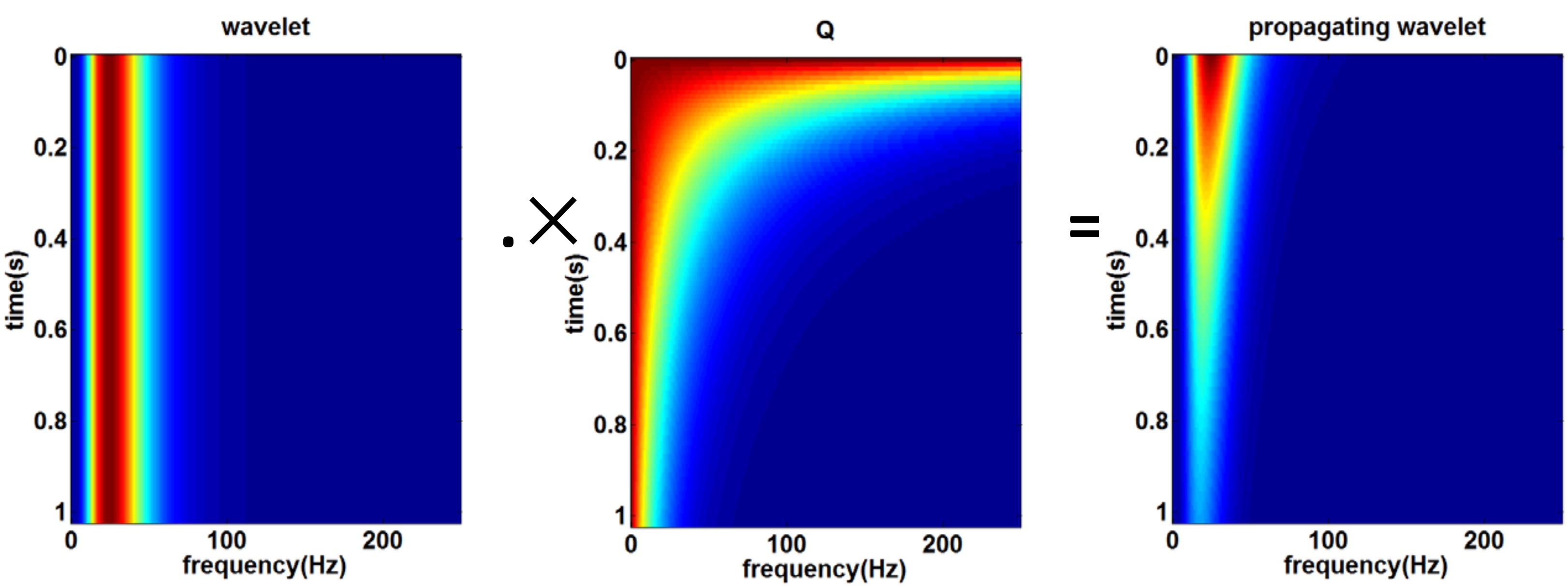


Nonstationary trace factorization

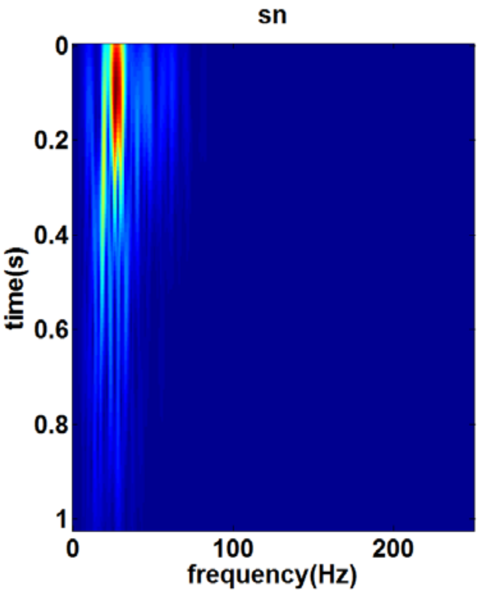


Nonstationary trace factorization





Gabor deconvolution



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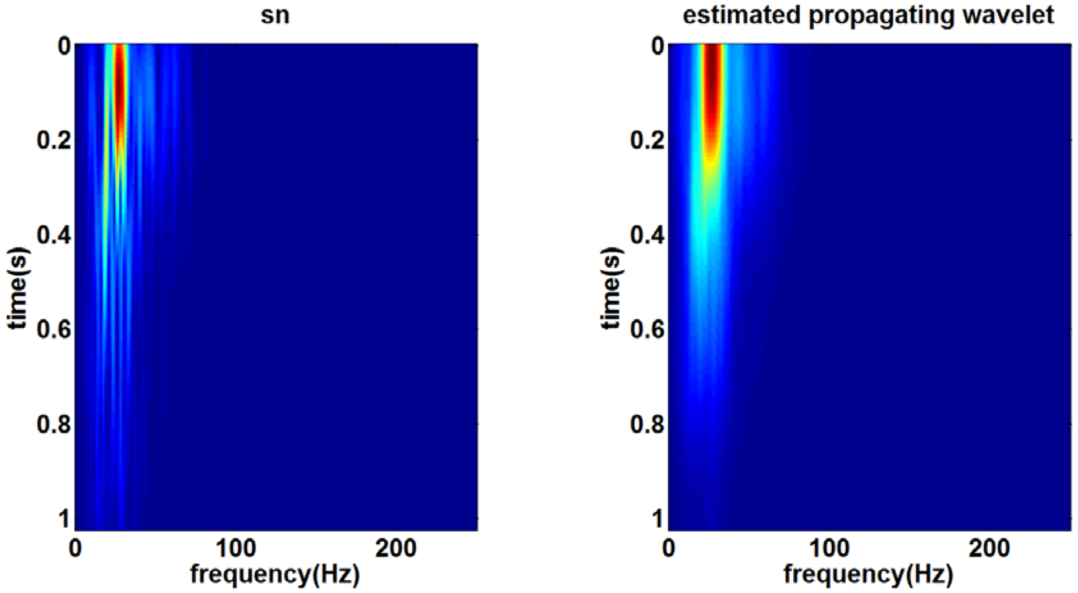

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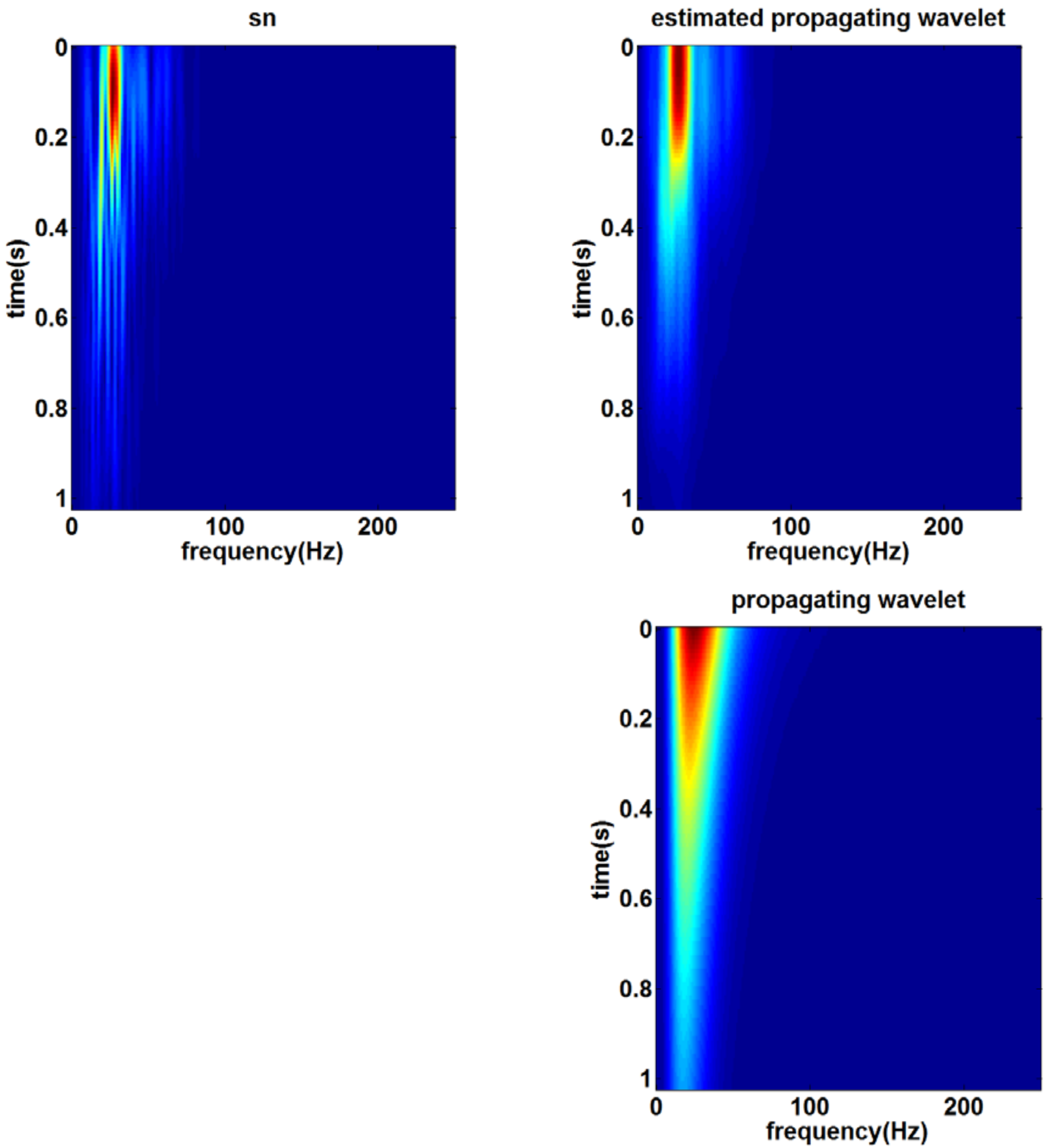

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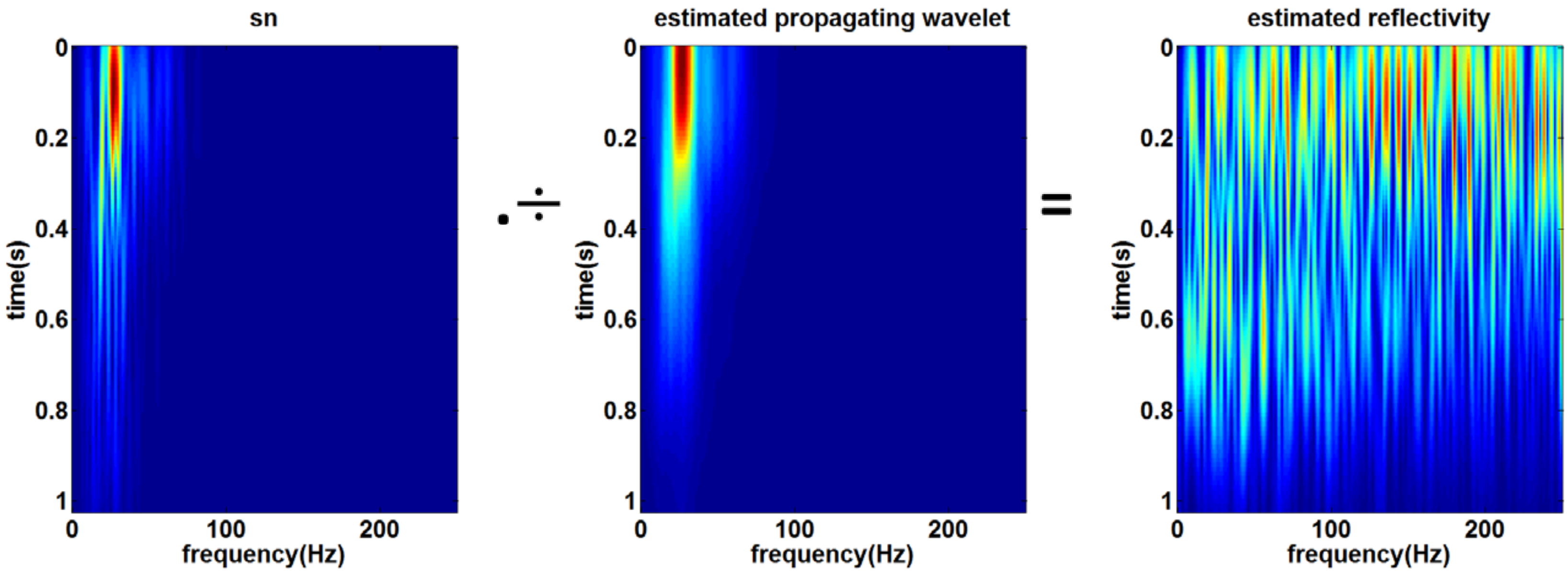

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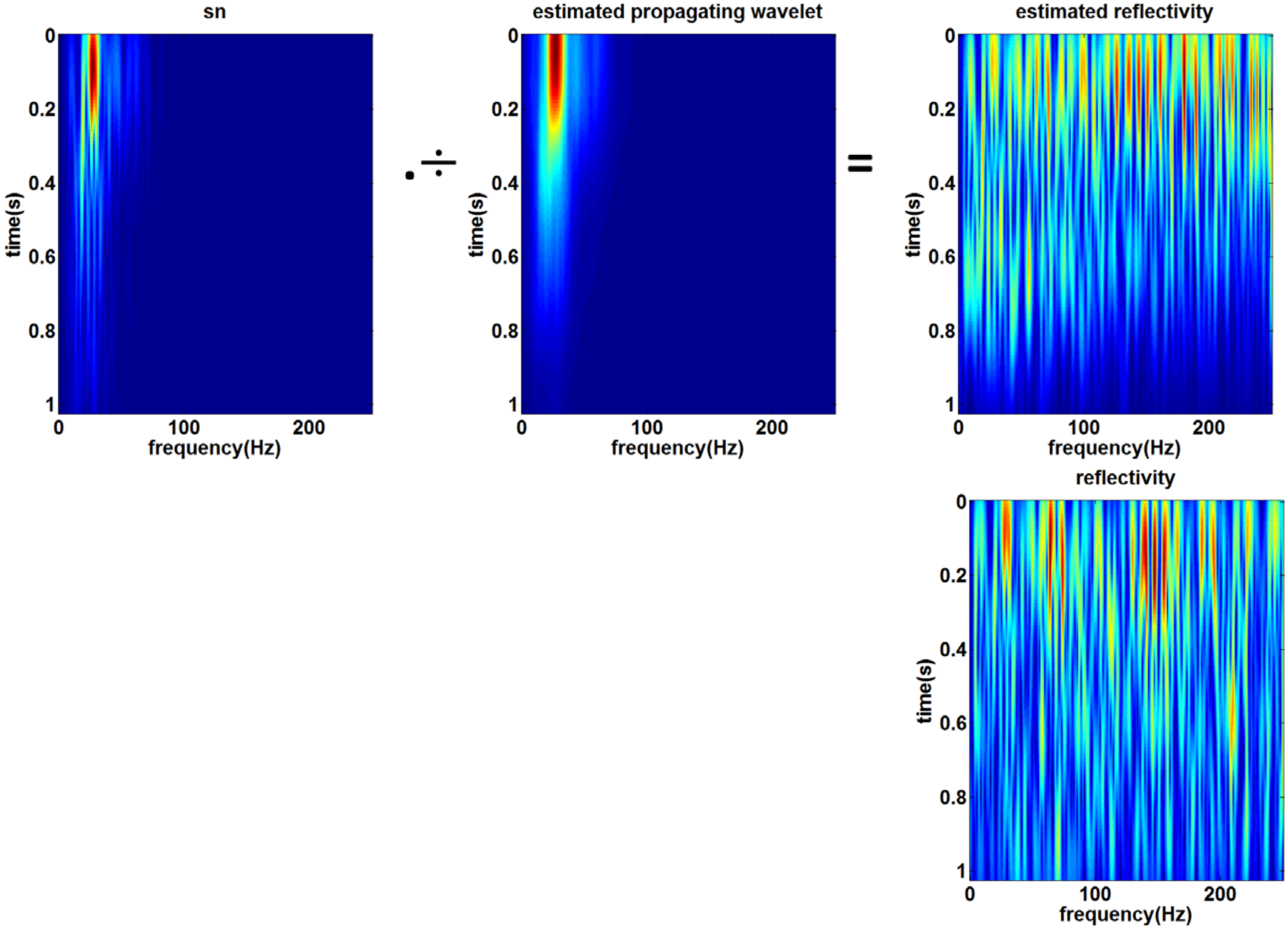
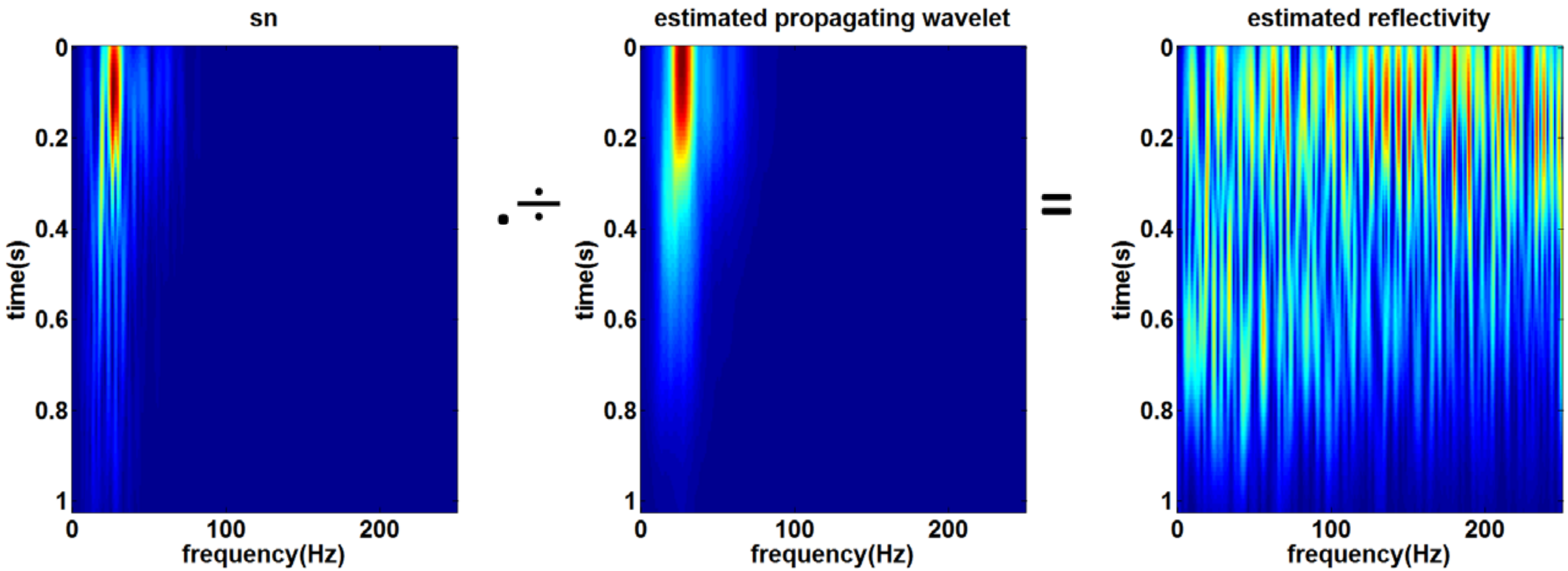
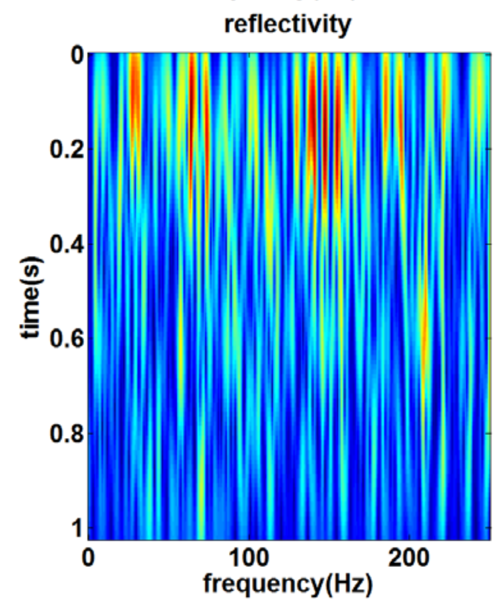


Gabor deconvolution

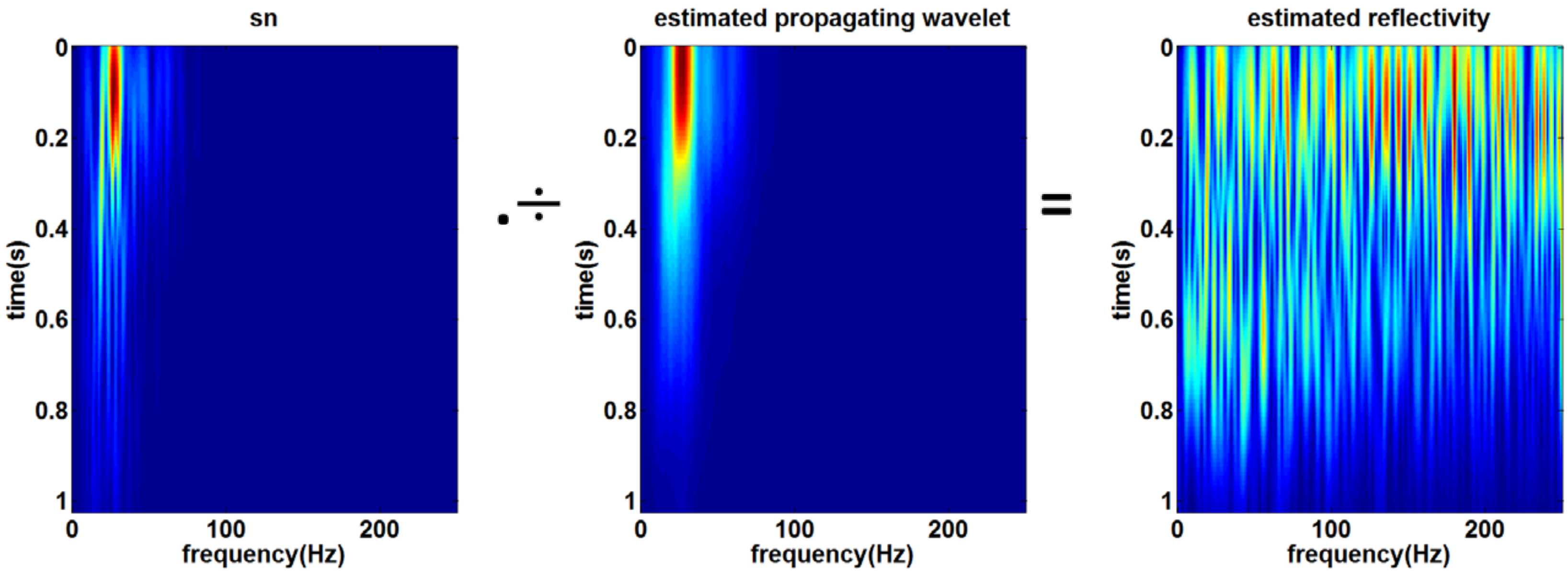


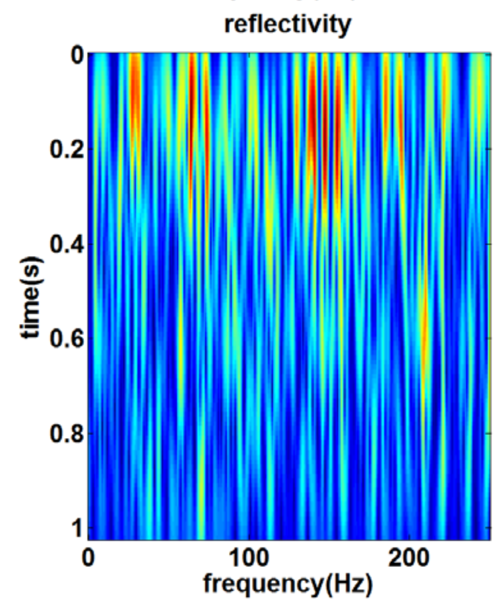


Amplitude and phase spectra of the propagating wavelet

$$\emptyset(f) = -\frac{1}{\pi}\int_{-\infty}^{\infty} \frac{\ln A(\tilde{f})}{f-\tilde{f}}\,\mathrm{d}\tilde{f}$$

Gabor deconvolution

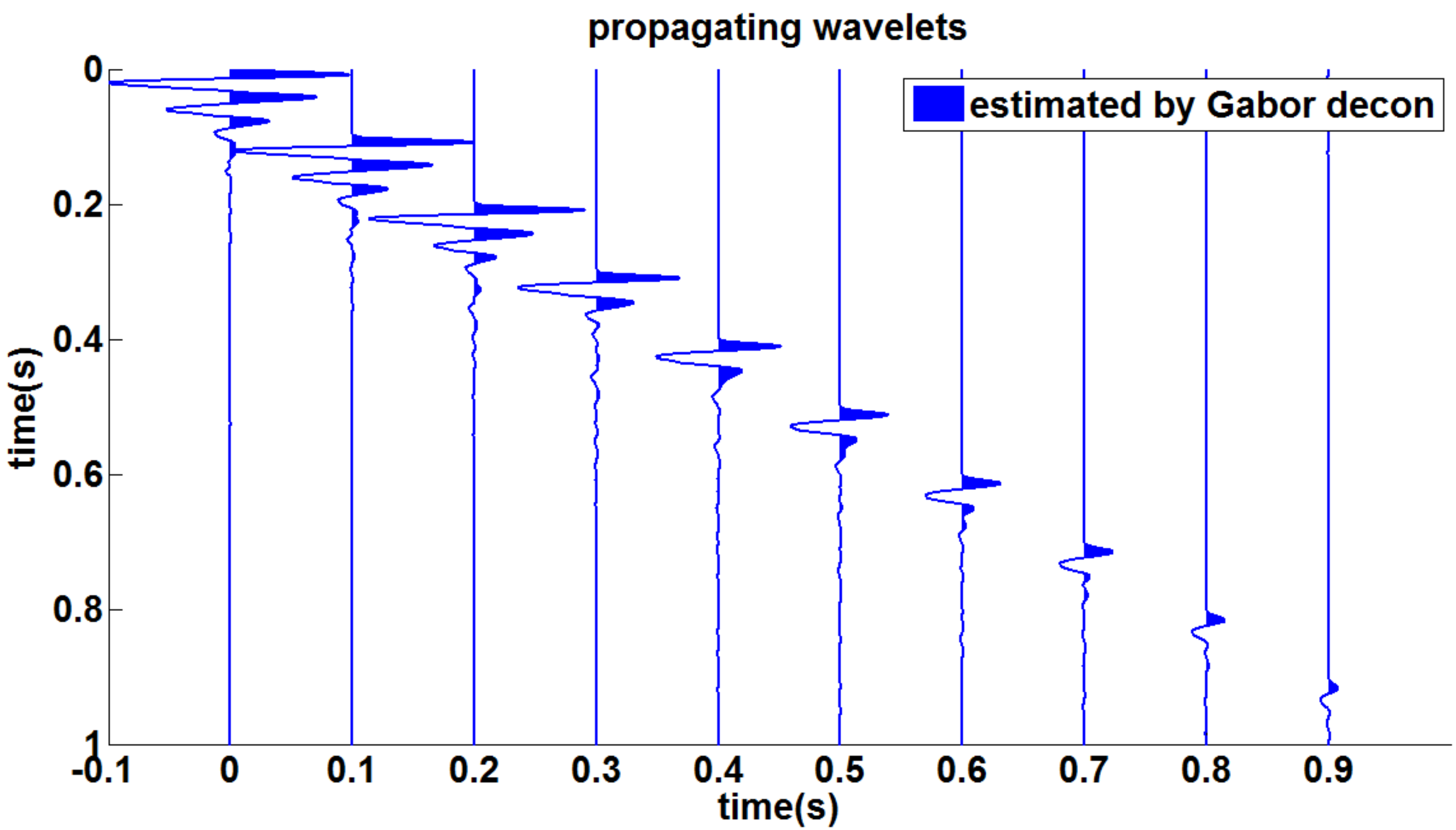




Amplitude and phase spectra of the propagating wavelet

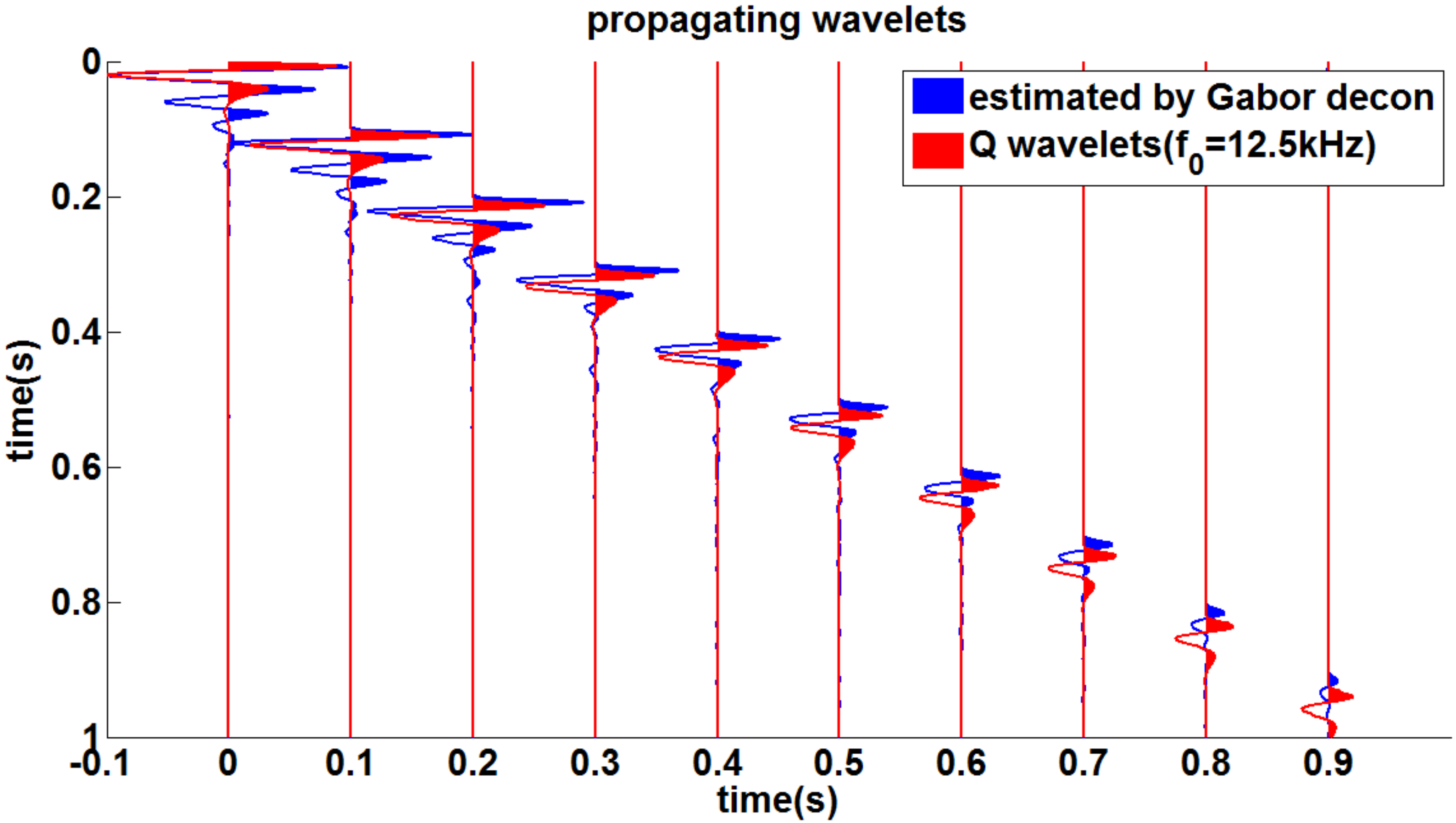
$$\emptyset(f) = -\frac{1}{\pi}\int_{-f_{NYQ}}^{f_{NYQ}} \frac{lnA(\tilde{f})}{f-\tilde{f}}\,\mathrm{d}\tilde{f}$$

Propagating wavelet estimation



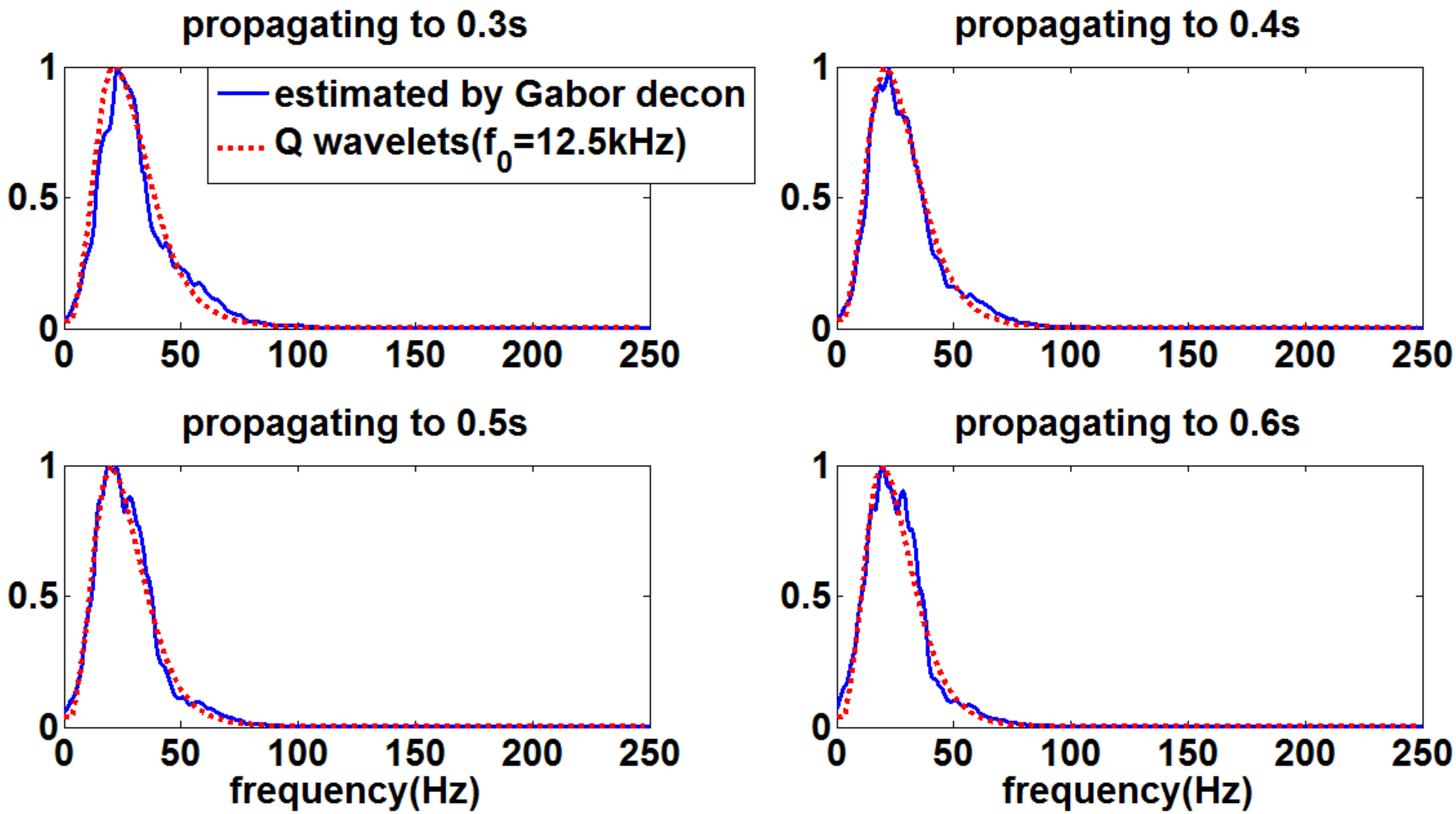
Propagating wavelet estimation

Estimated wavelets are too early



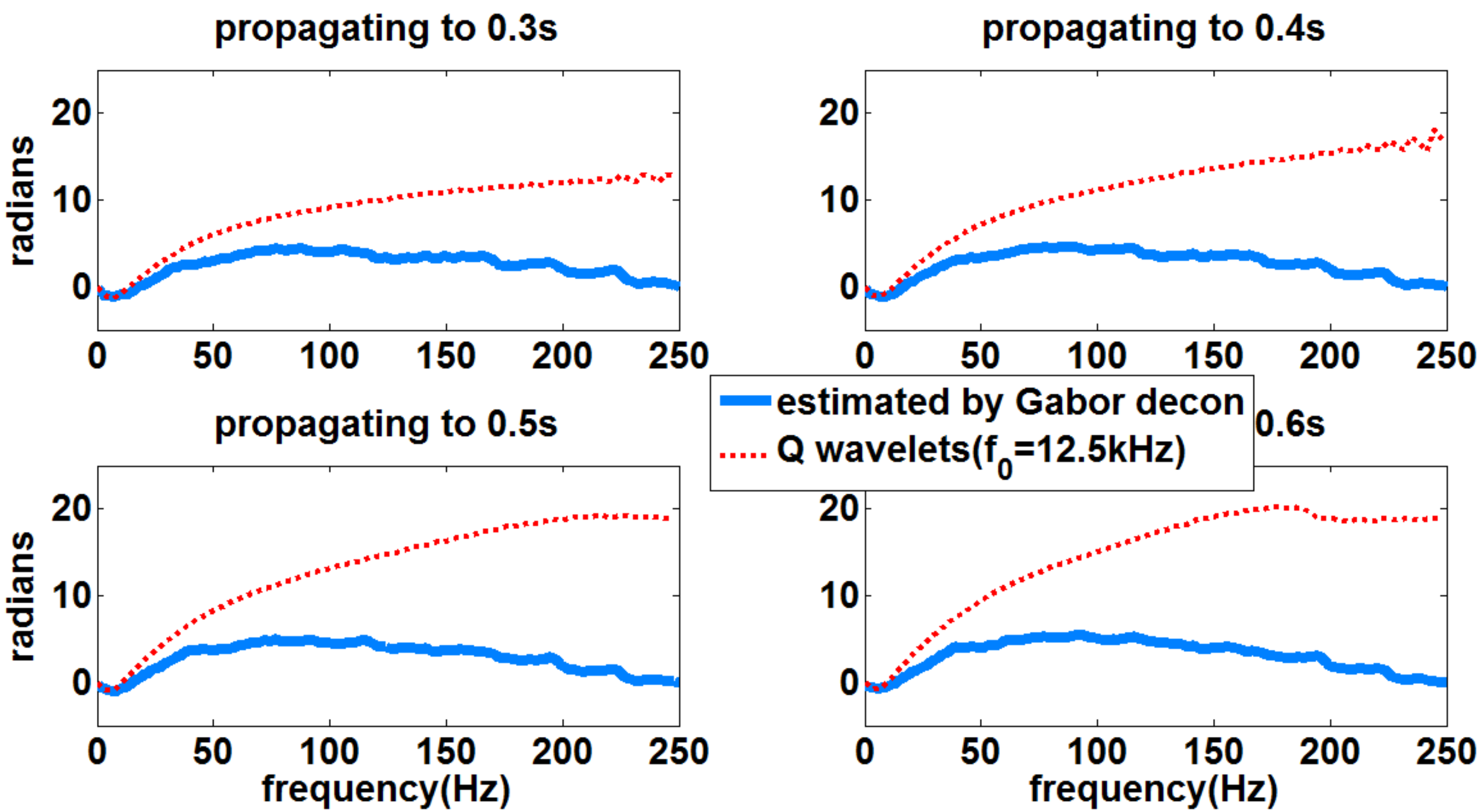
Amplitude spectra (normalized)

Estimated amplitude spectra are accurate



Phase spectra (unwrapped)

Estimated phase spectra are inaccurate



Why phase estimation is inaccurate

Propagating wavelet

$$\phi(f) = -\frac{1}{\pi}\int_{-f_{NYQ}}^{f_{NYQ}} \frac{lnA(\tilde{f})}{f-\tilde{f}}\,\mathrm{d}\tilde{f}$$

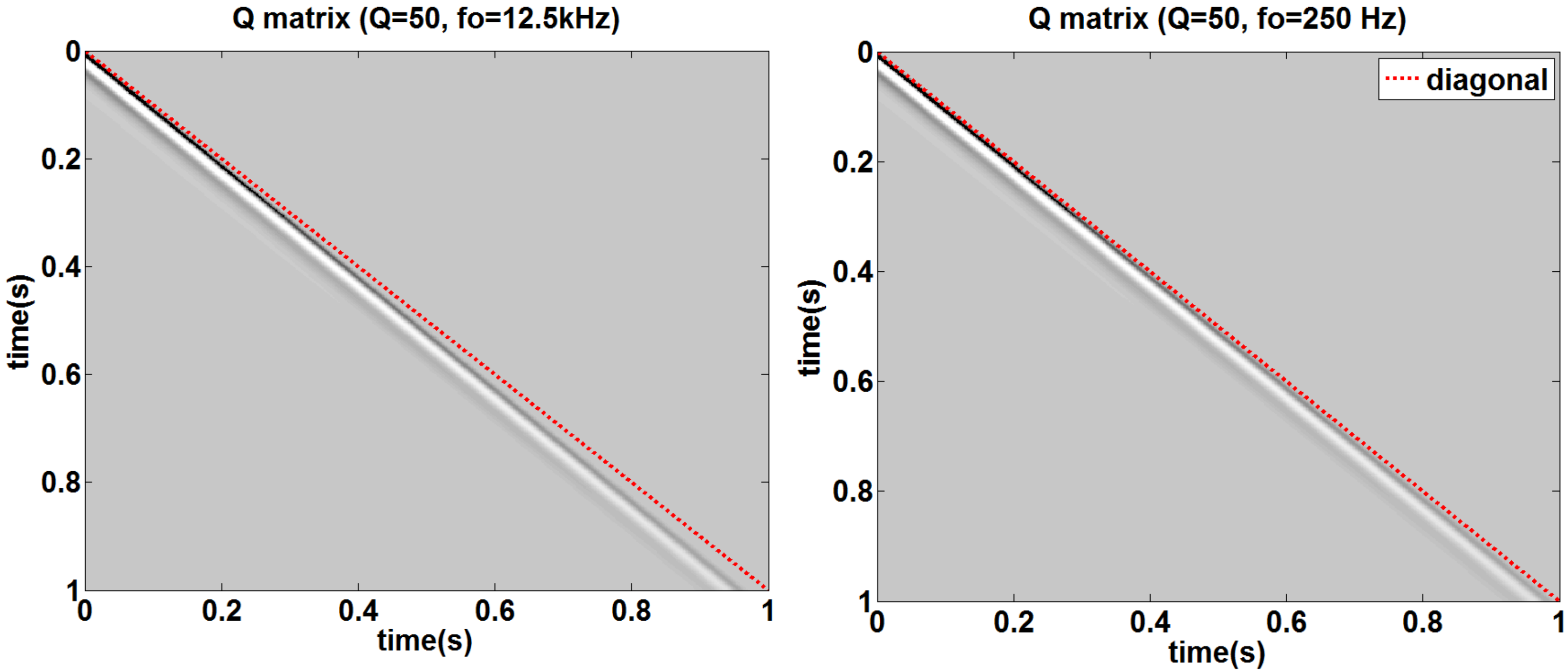
Remodel the constant-Q impulse response with respect to the Nyquist frequency

Constant-Q impulse response

Phase= $-\frac{2\pi f x}{V_0}\left(1-\frac{1}{\pi Q}ln\frac{f_s}{f_0}\right)$ $f_0 = 250$ Hz

Remodel Q wavelets W.R.T. f_{NYQ}

Q wavelets are less delayed



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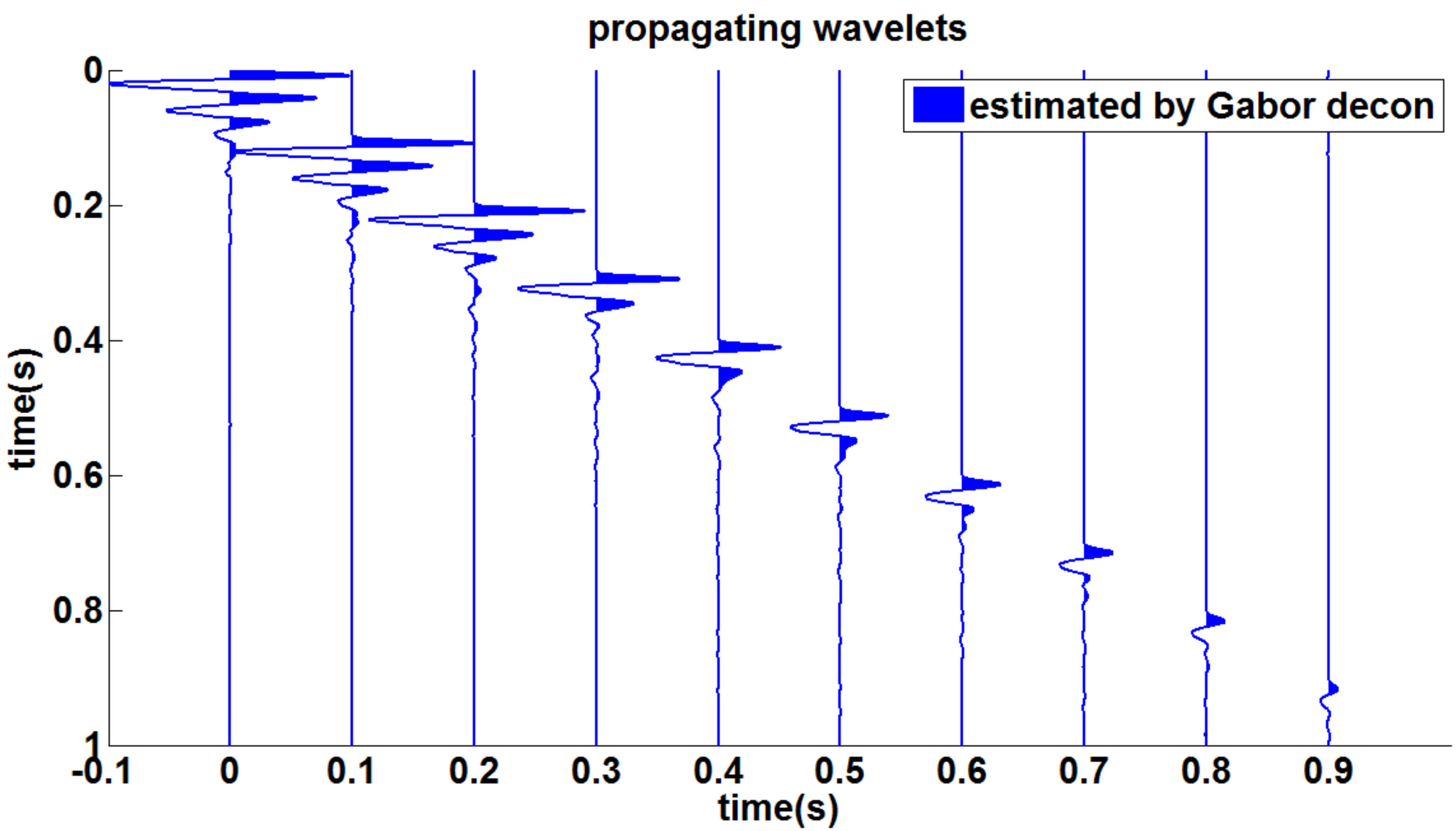
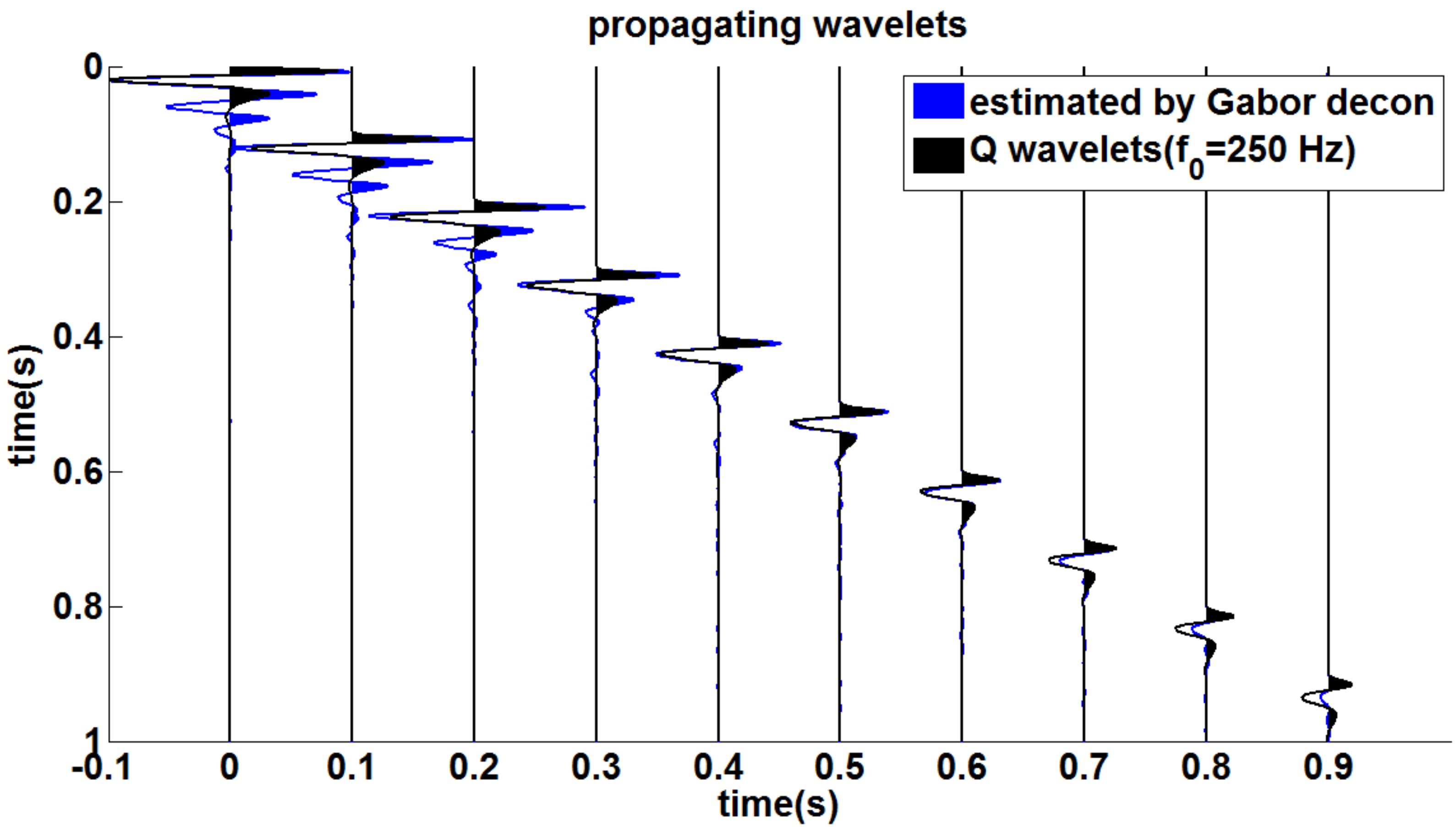
Propagating wavelet estimation



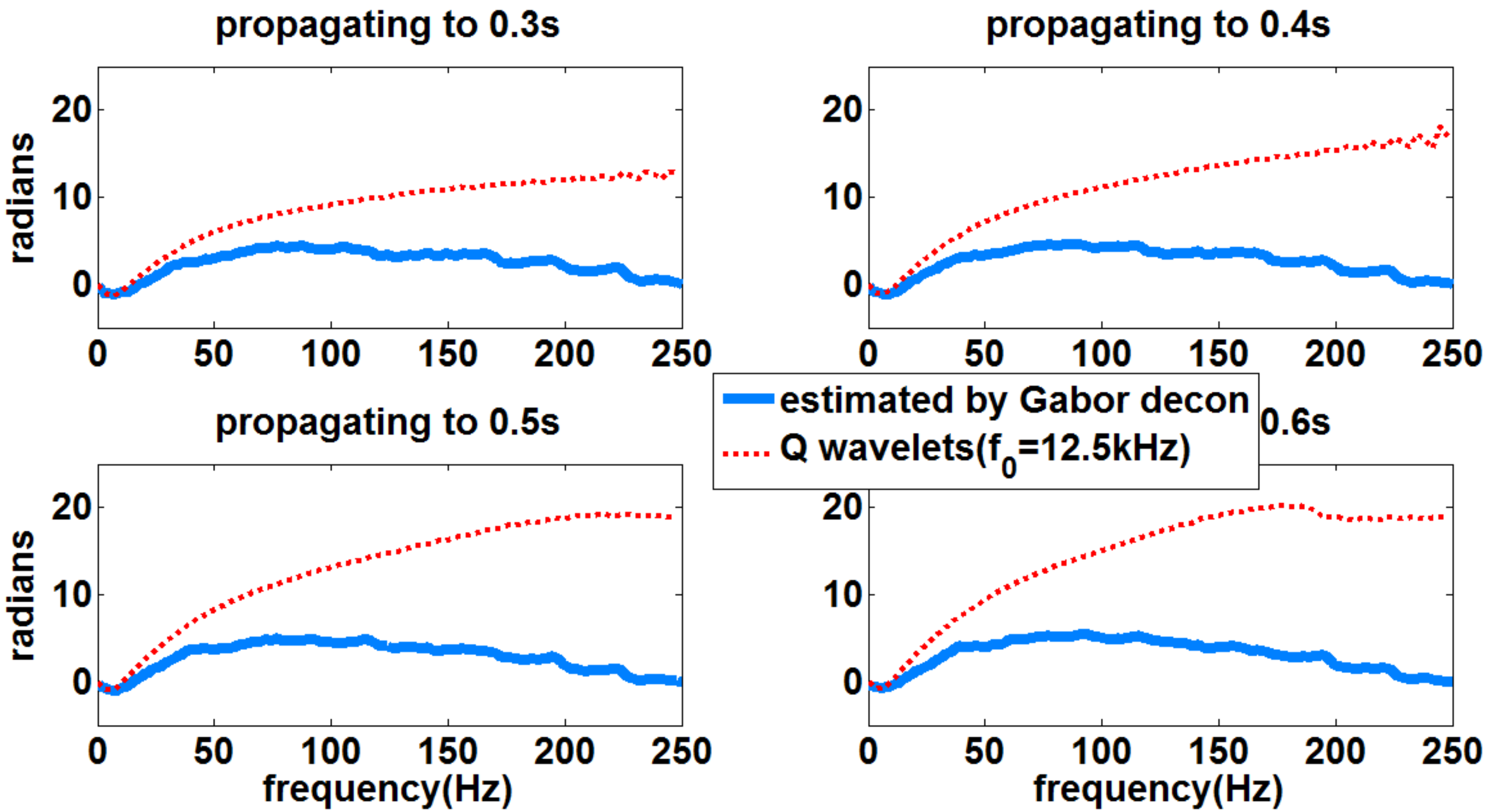
Remodel Q wavelets W.R.T. f_{NYQ}

Timing is consistent



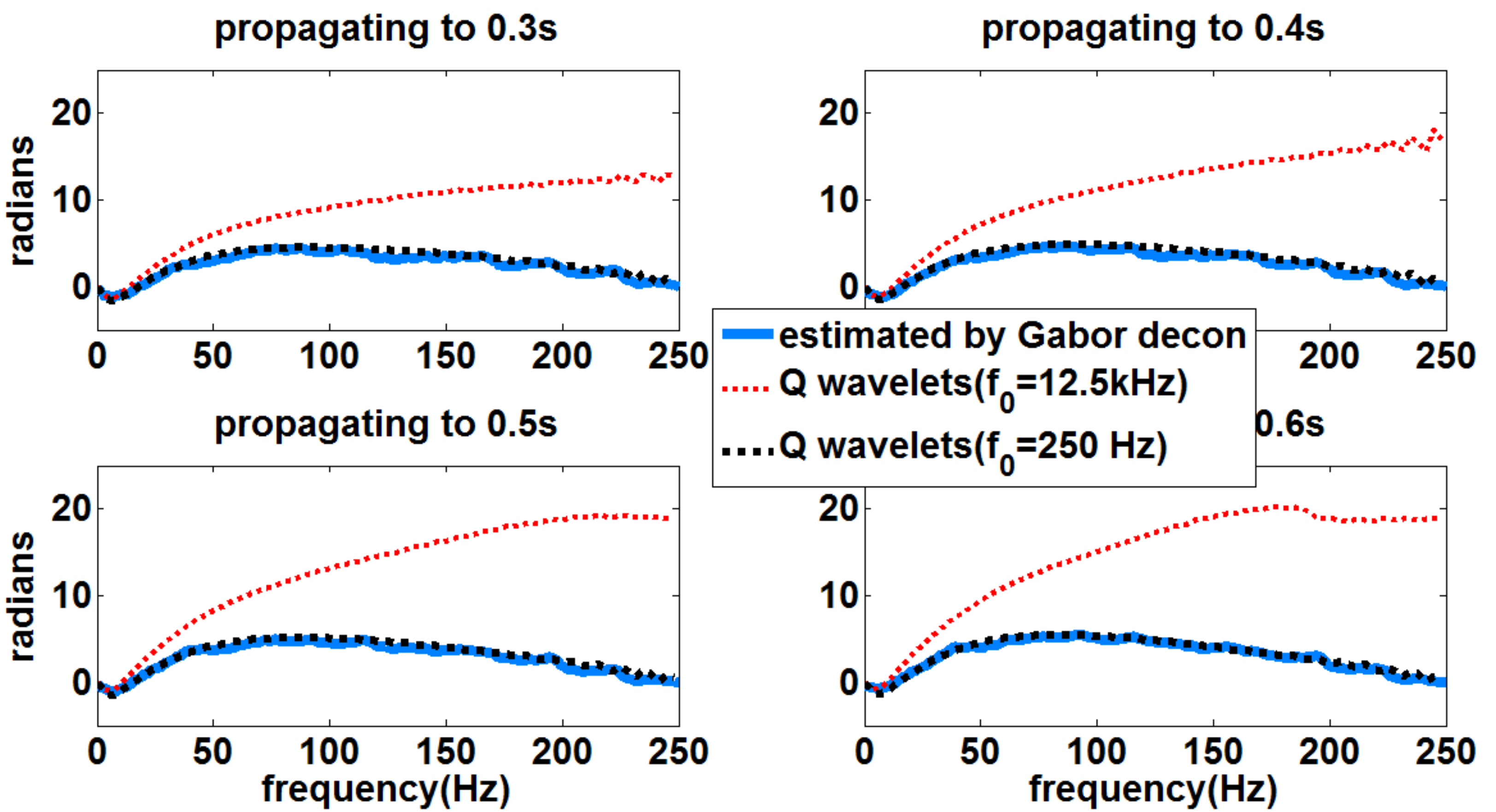
Phase spectra (unwrapped)

Estimated phase spectra are inaccurate



Remodel Q wavelets W.R.T. f_{NYQ}

Estimated phase spectra are consistent with Q wavelets (f_0=f_{NYQ})



Outline

- **Tie synthetic reflectivity to nonstationary trace model**

  Estimate the nonstationary wavelets

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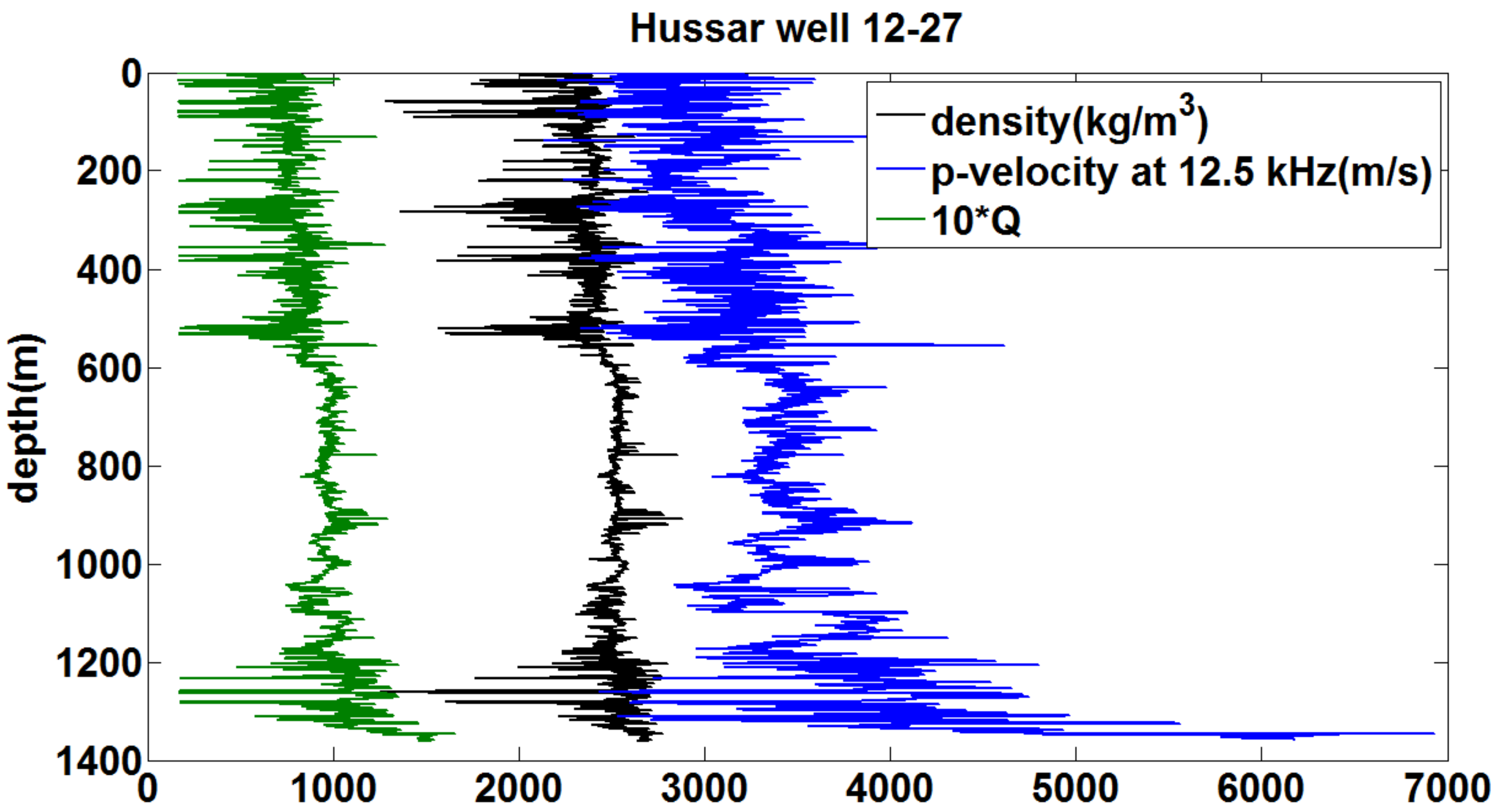
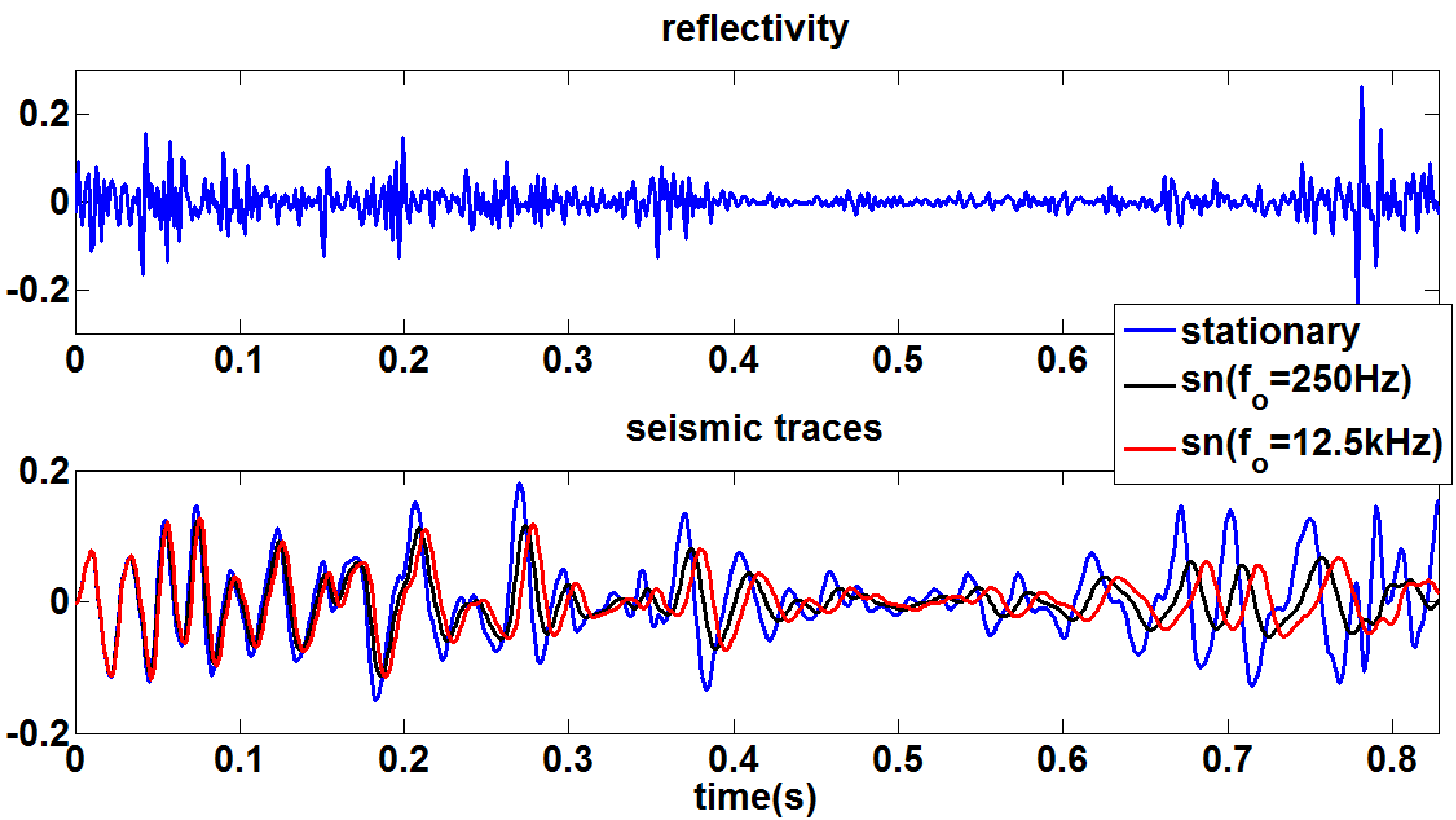
  Estimate the residual drift time

- **Conclusions and future work**

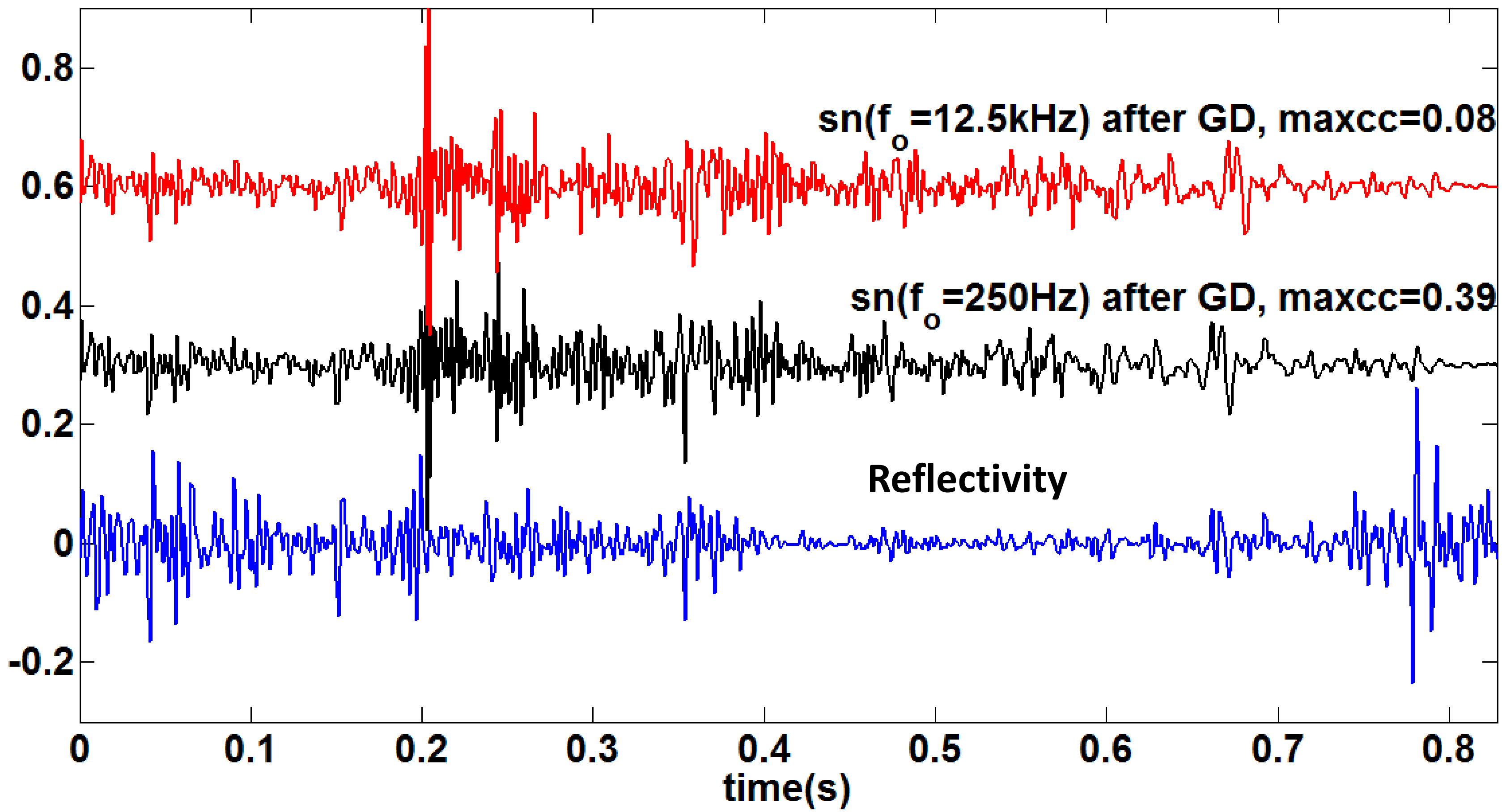
Well logs and hypothetical Q



Reflectivity and seismic traces



Traces after Gabor decon V.S. reflectivity



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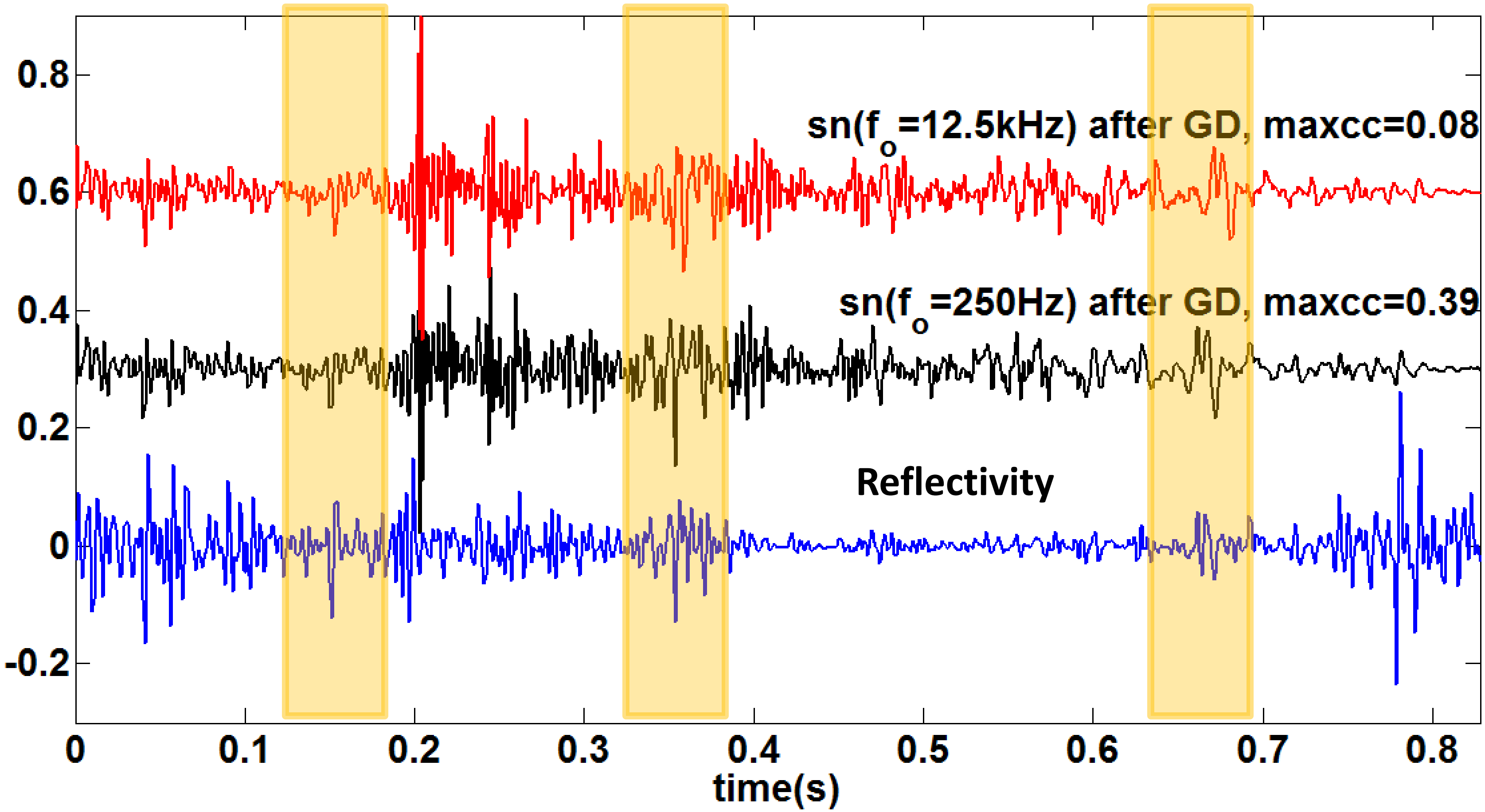
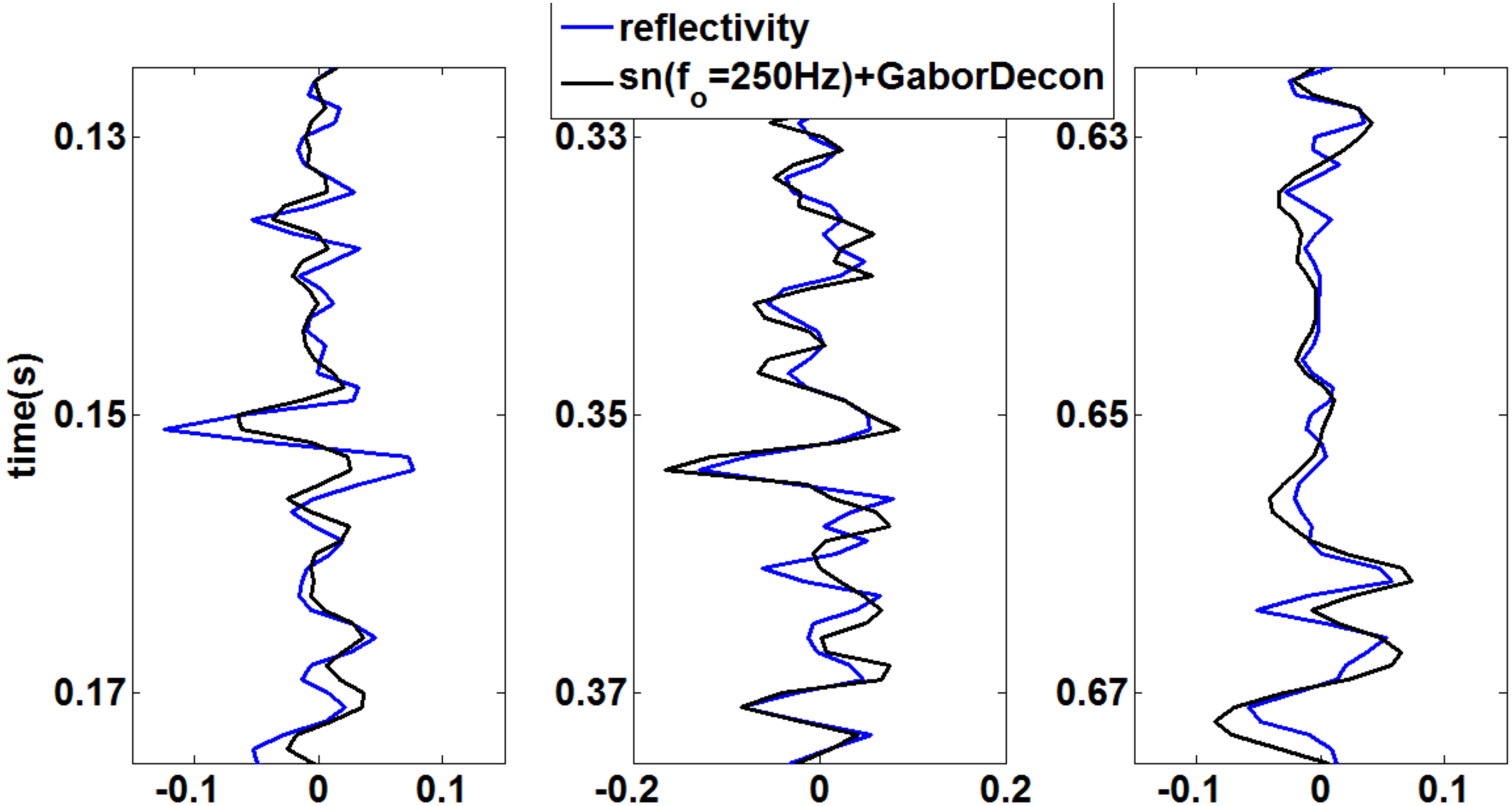


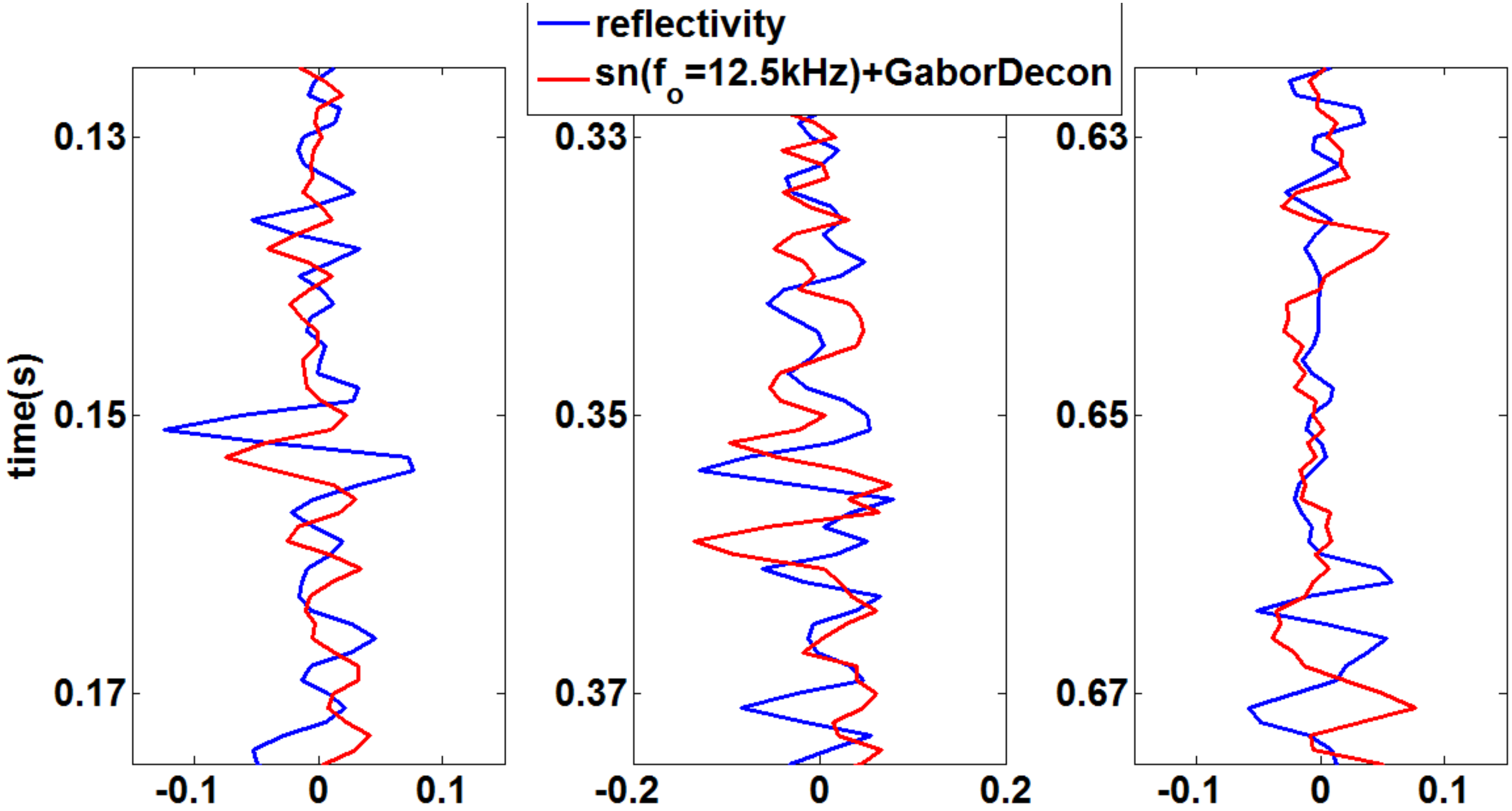
sn(f_0=f_{NYQ}) after Gabor decon V.S. reflectivity

Events are tied with reflectivity

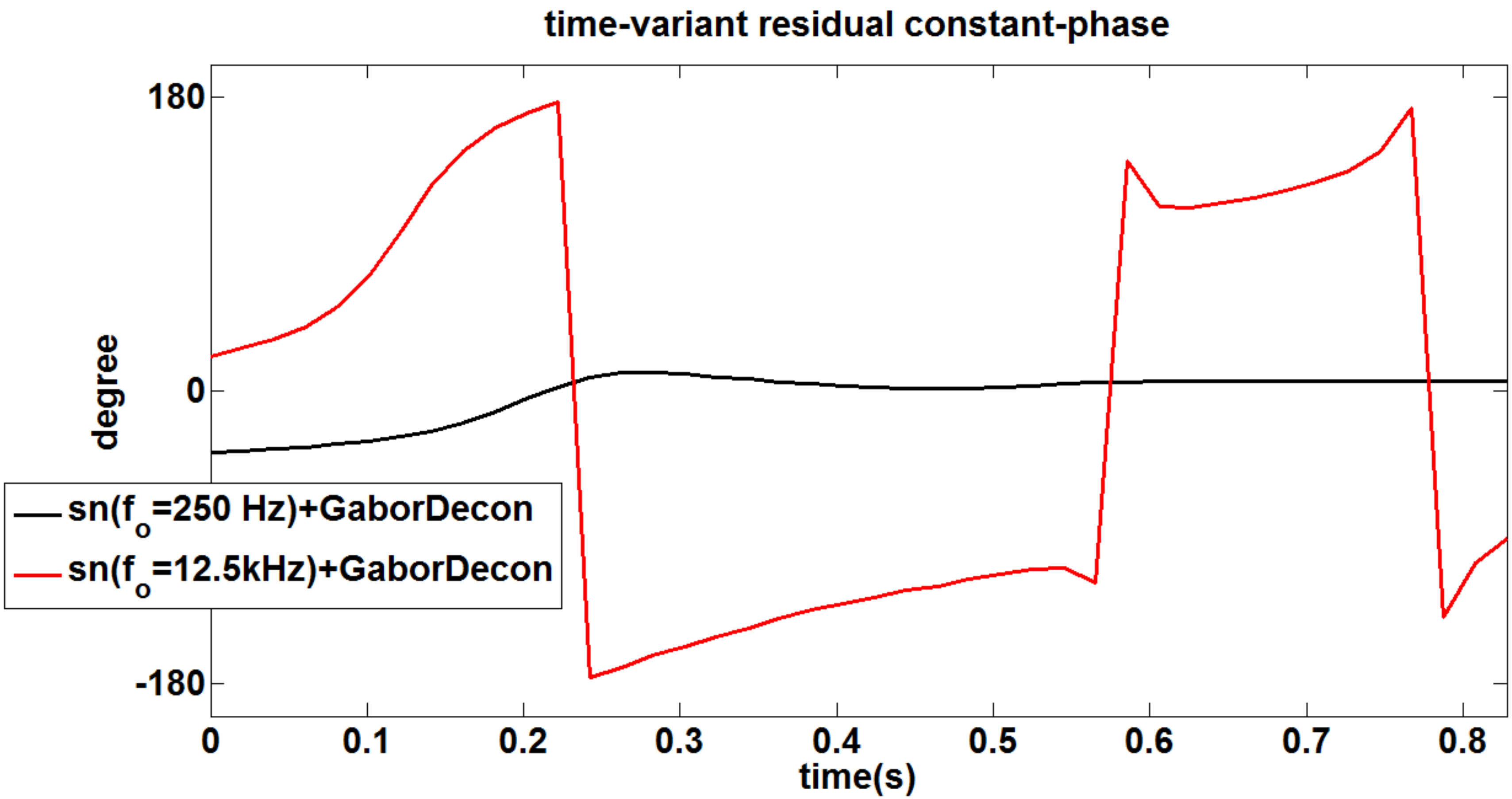


sn(f_0=f_W) after Gabor decon V.S. reflectivity

Events are not tied

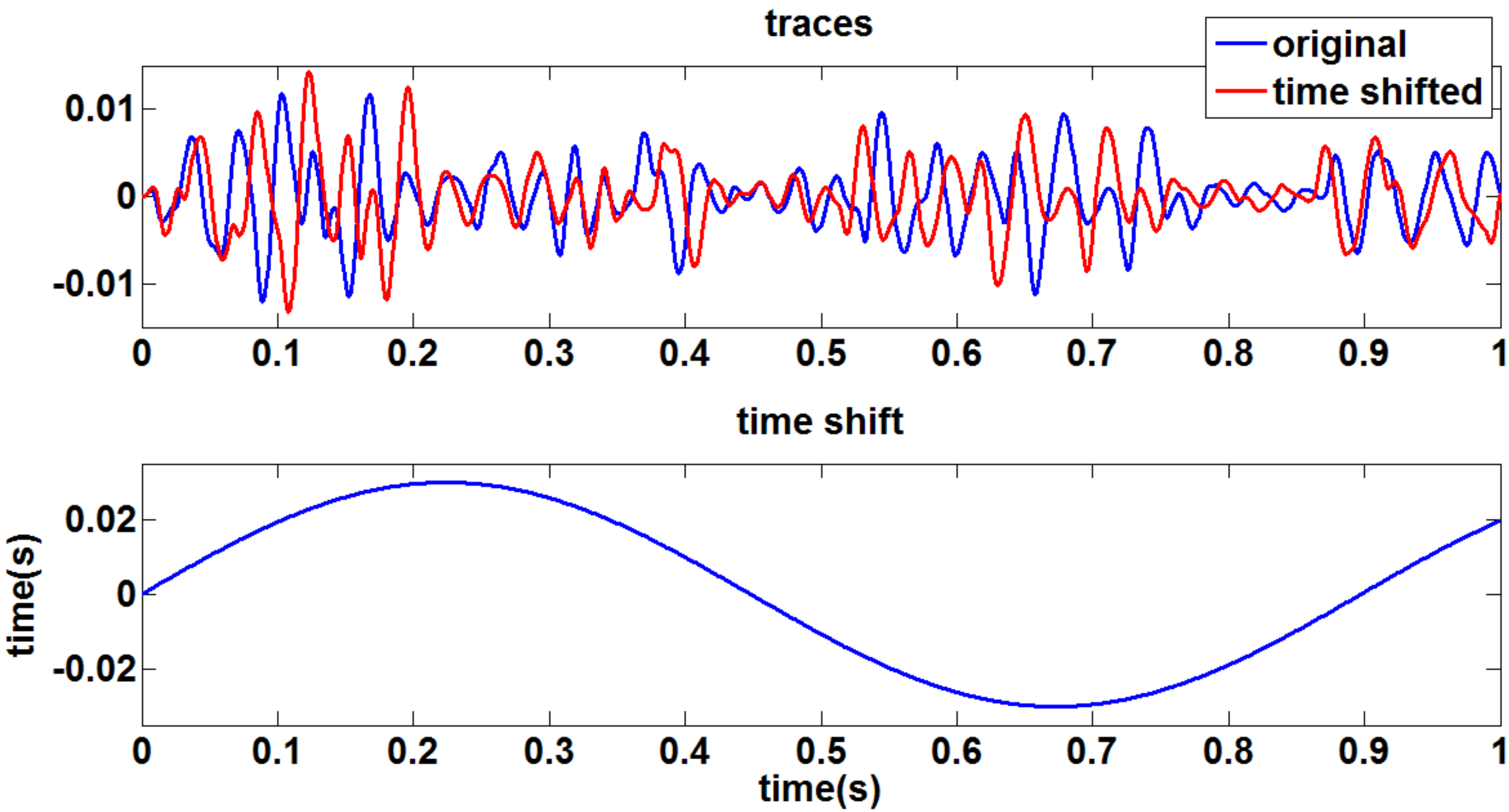


Traces after Gabor decon V.S. reflectivity



Residual drift time estimation

Dynamic time warping



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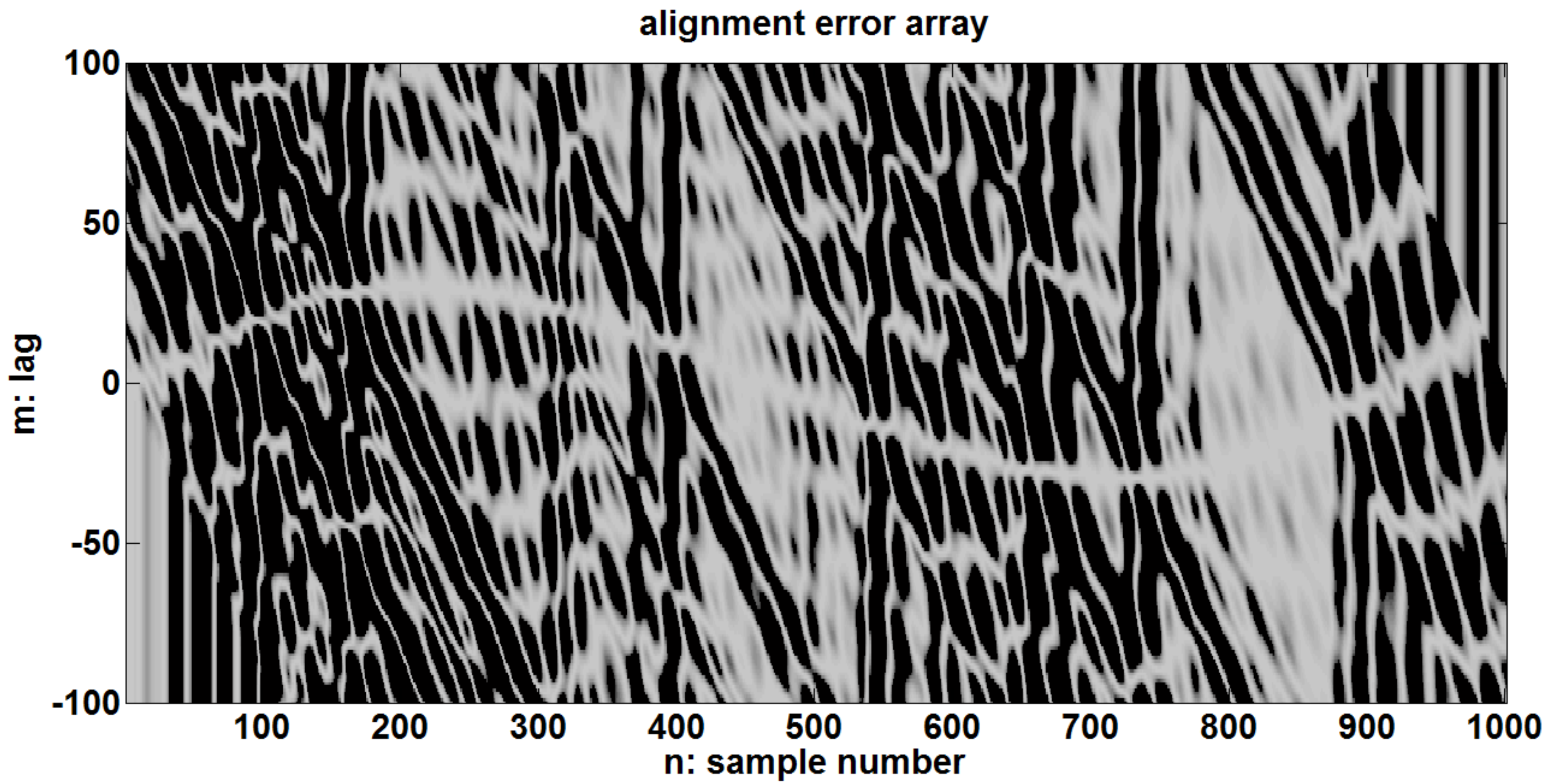
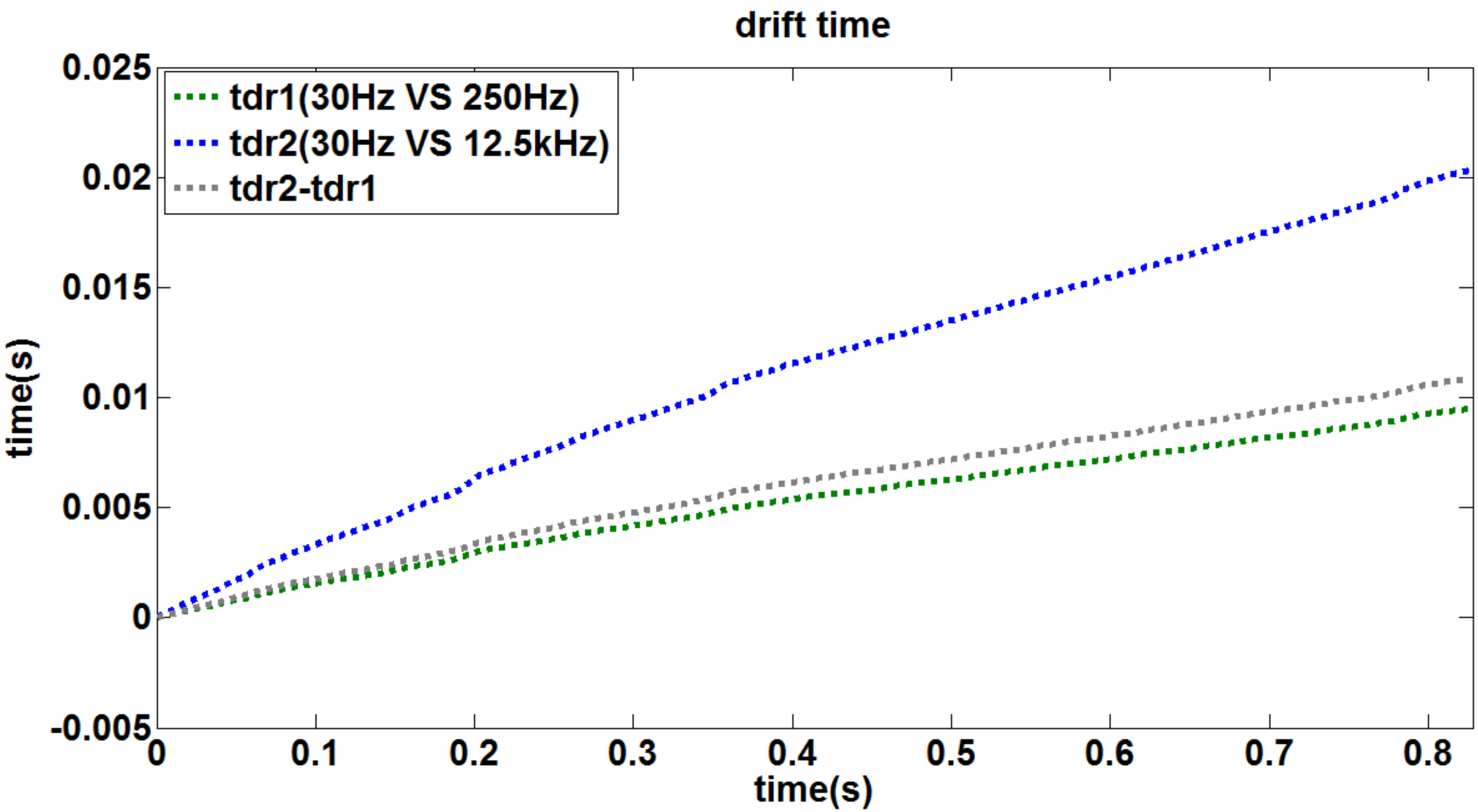


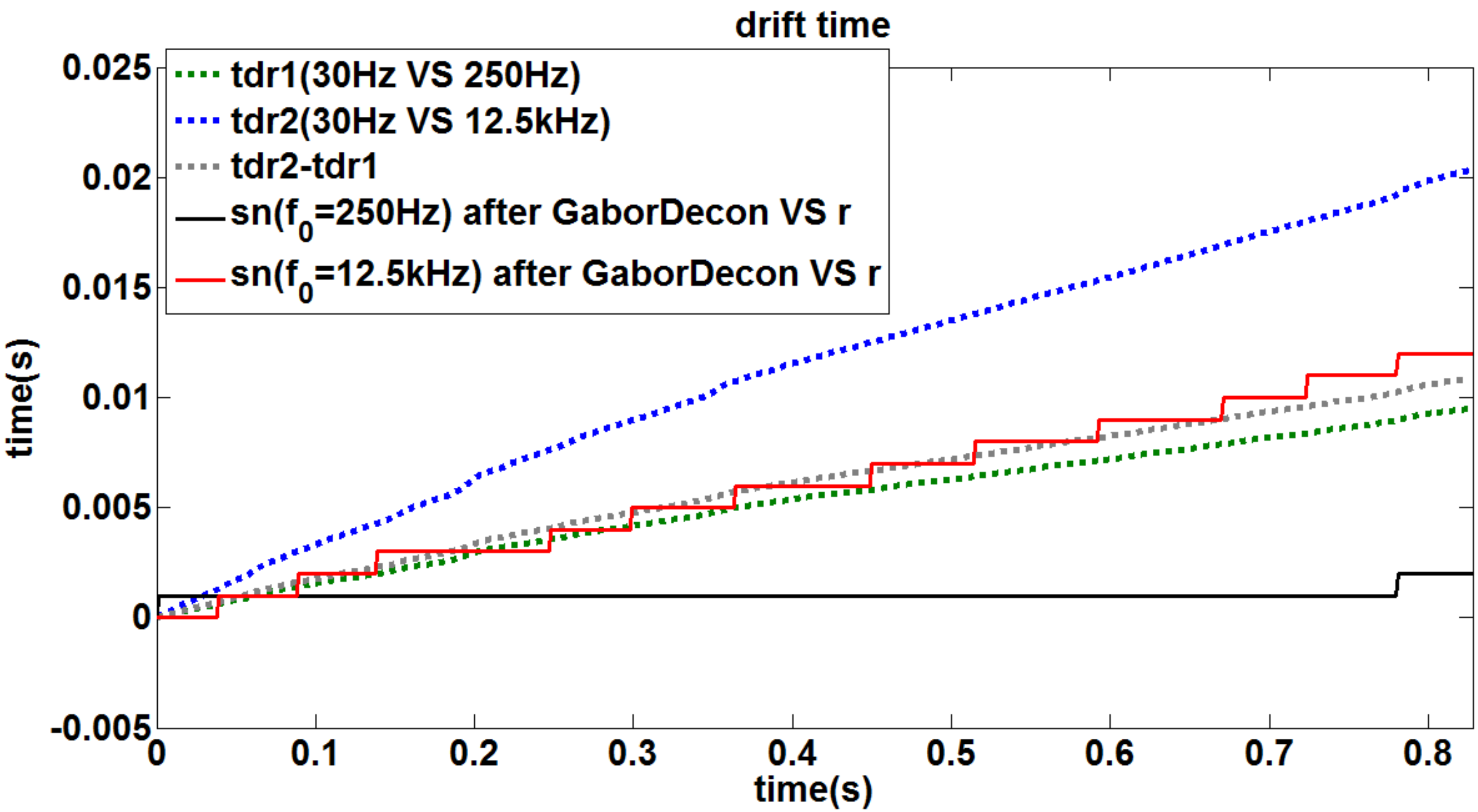
Residual drift time estimation

Theoretical drift time

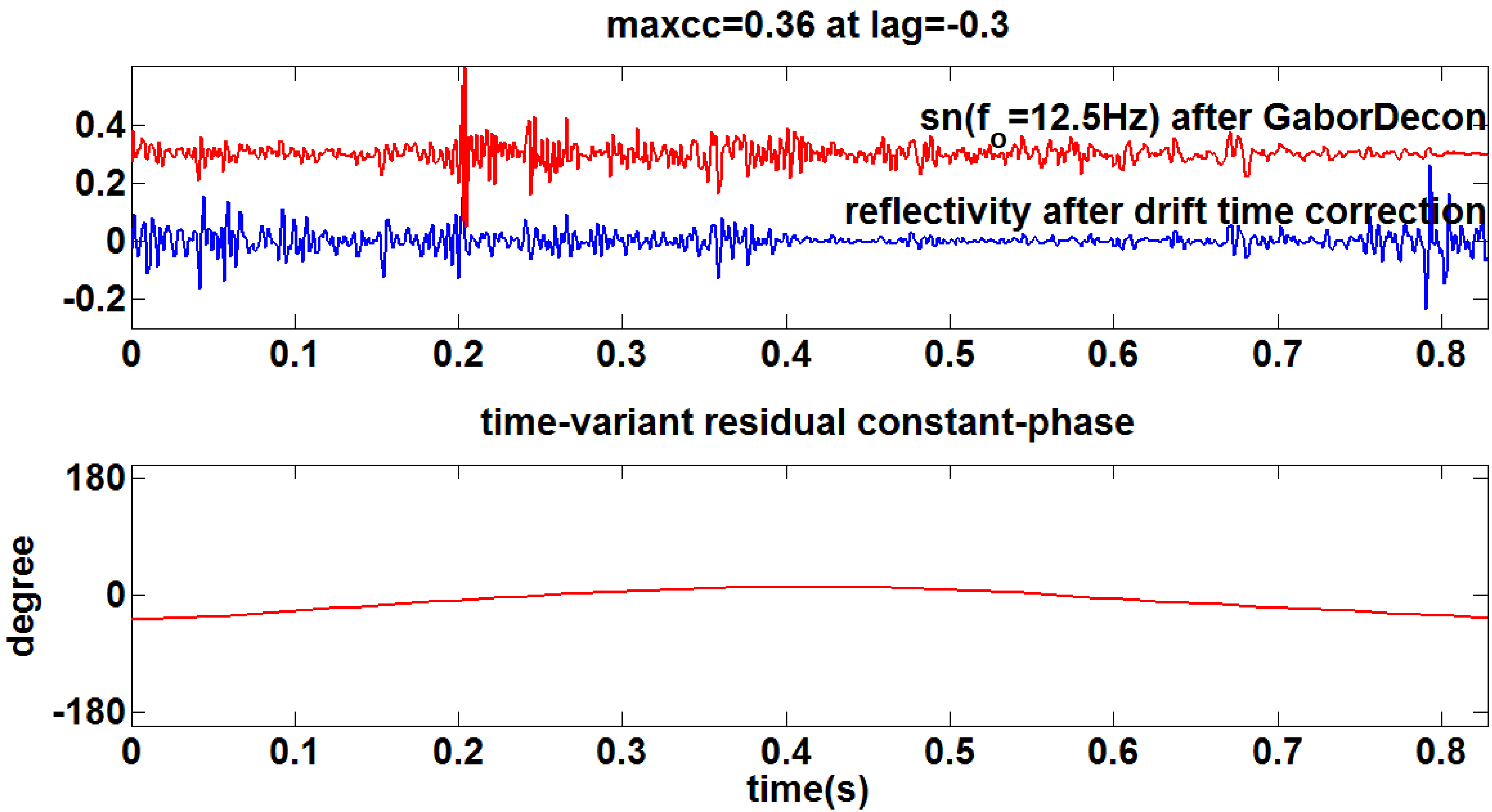


Residual drift time estimation

sn(f_0=f_w) residual drift time is the difference



Drift time correction



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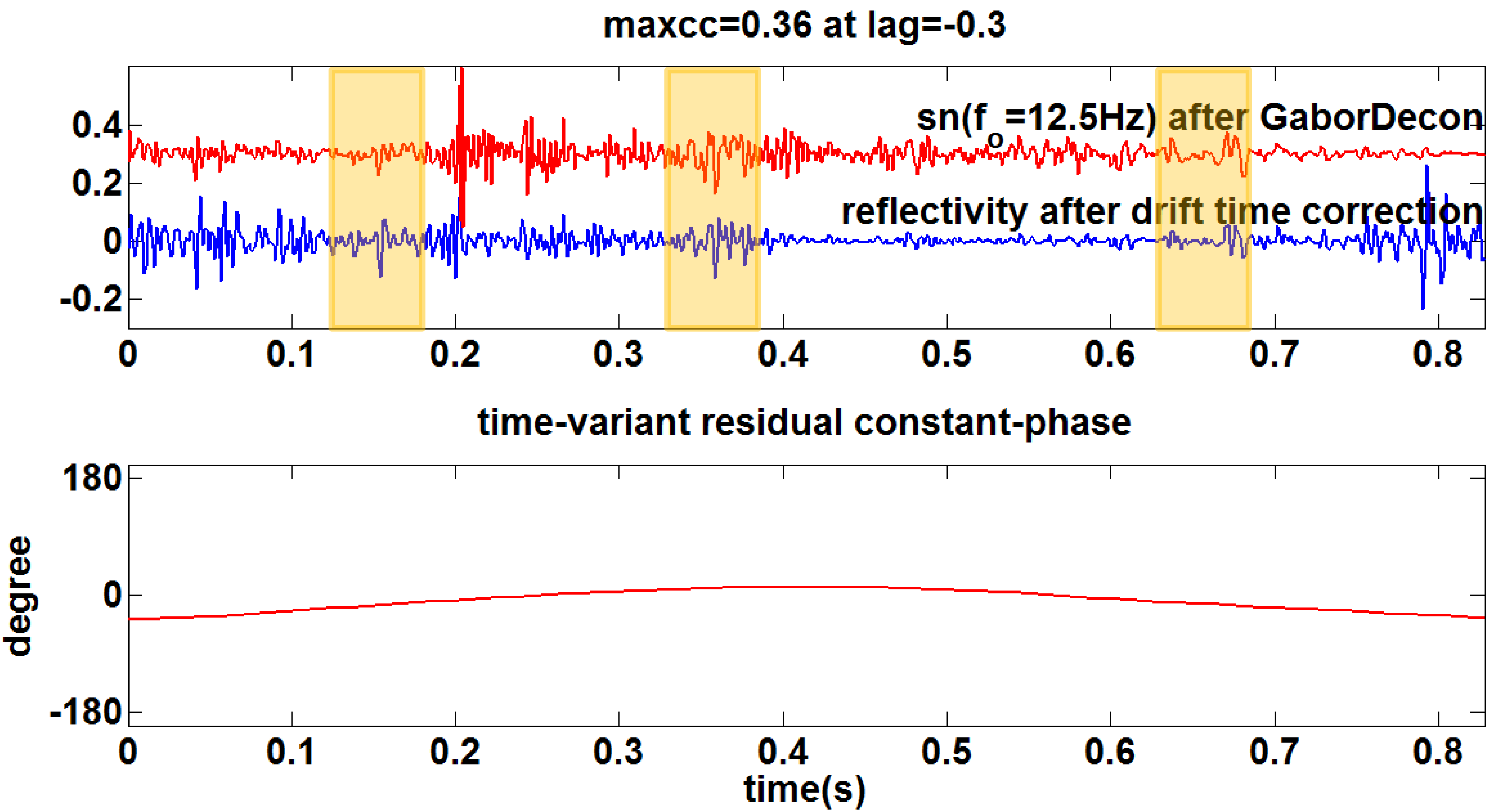
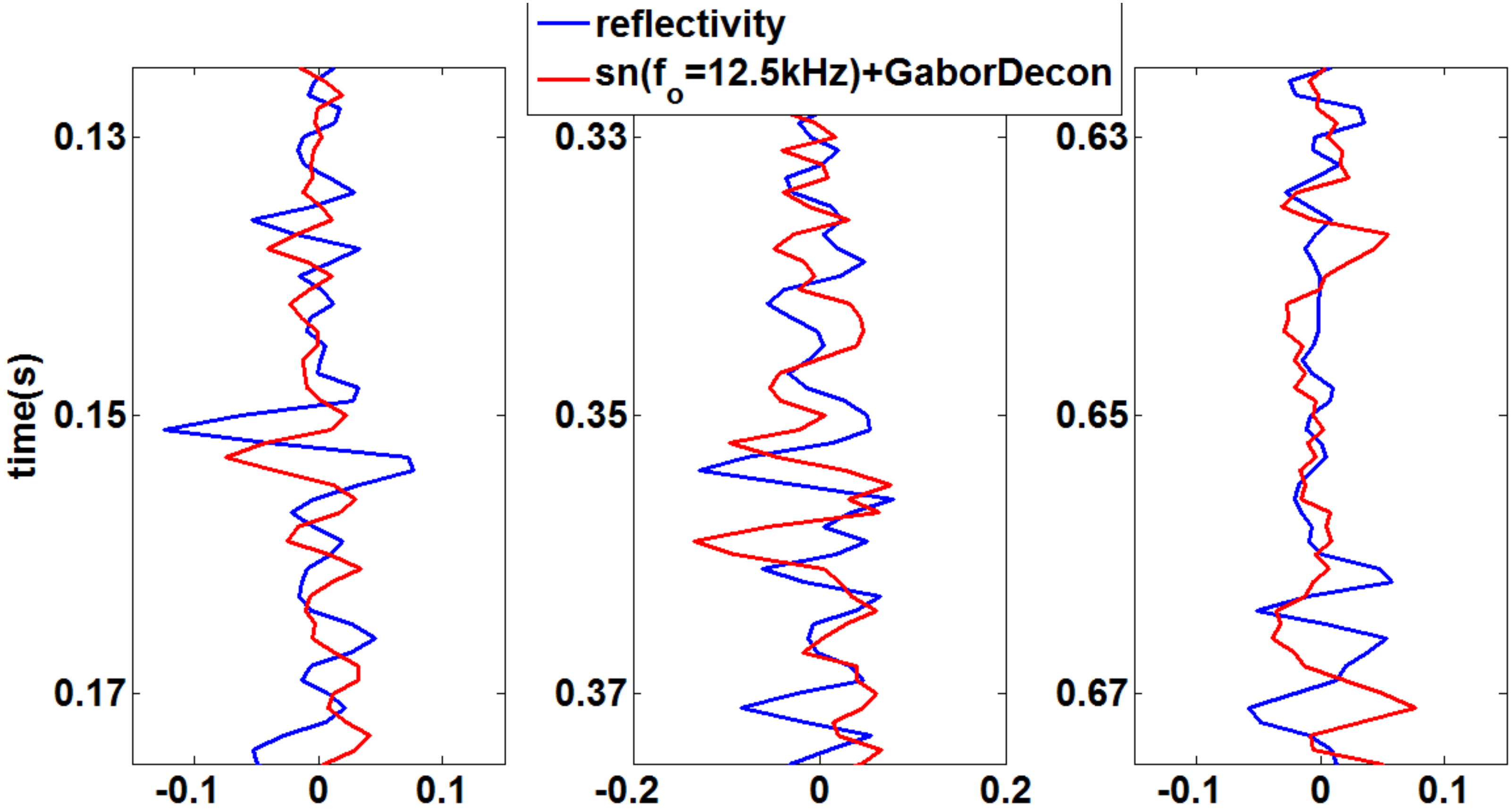


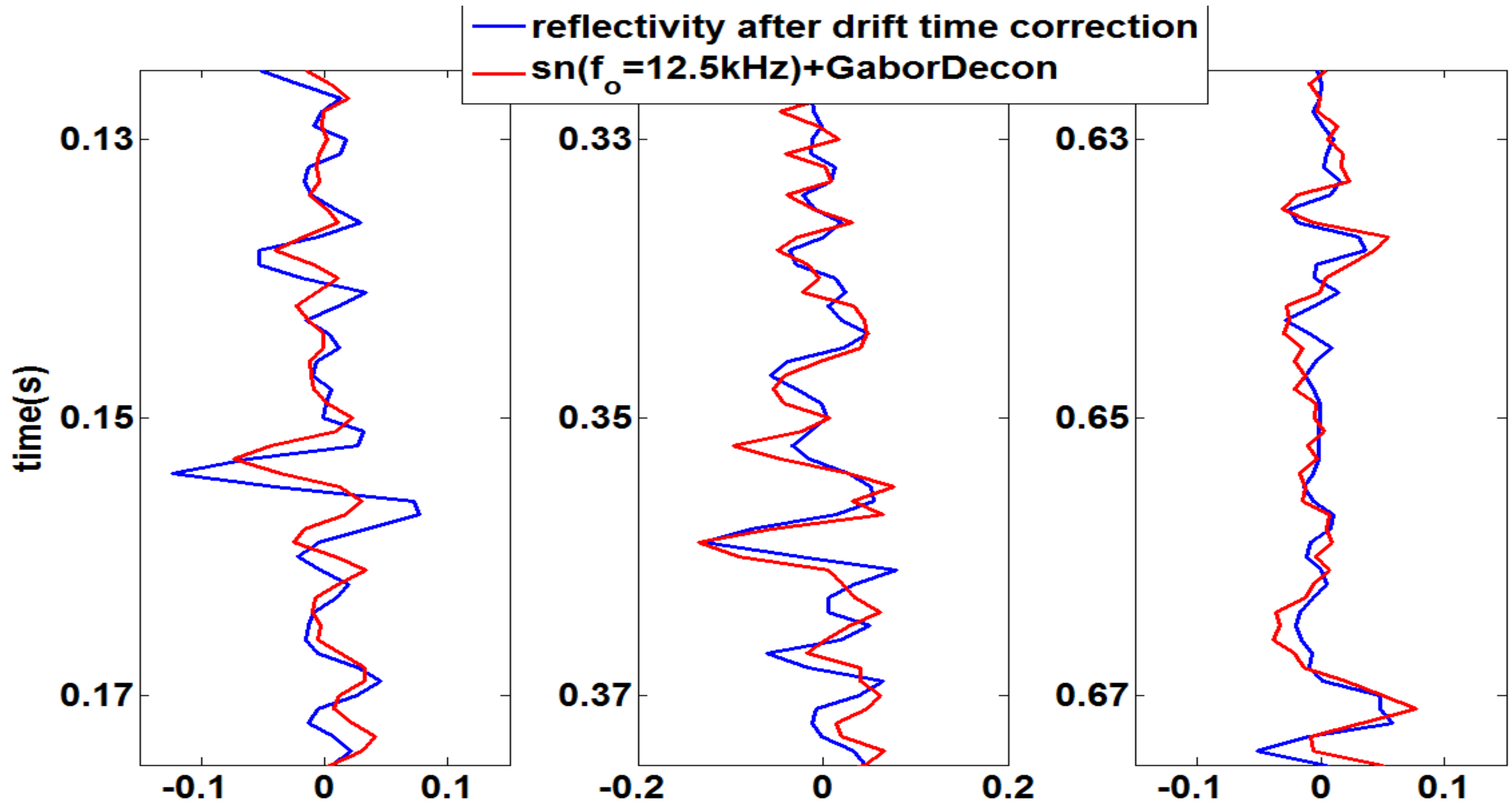
Before drift time correction

Events are not tied



After drift time correction

Events are tied



Conclusions

- **Gabor deconvolution accurately estimates the amplitude spectra of the propagating wavelets due to the constant-Q attenuation.**

- **Gabor deconvolution calculates the phase spectra of the propagating wavelets by the Hilbert transform, which integrates within the seismic frequency band and corrects the drift time to the Nyquist frequency only.**

Future work

- **Include noise in the seismic trace model.**
- **Test nonstationary wavelet estimation and drift time estimation on the field VSP dataset.**
- **Improve Gabor deconvolution by correcting the phase error.**

Acknowledgements

- CREWES sponsors
- NSERC: grant CRDPJ 379744-08
- CREWES staff and students

THANK YOU !