Non-stationary deconvolution and imaging of 2D tissue sensing adaptive radar data

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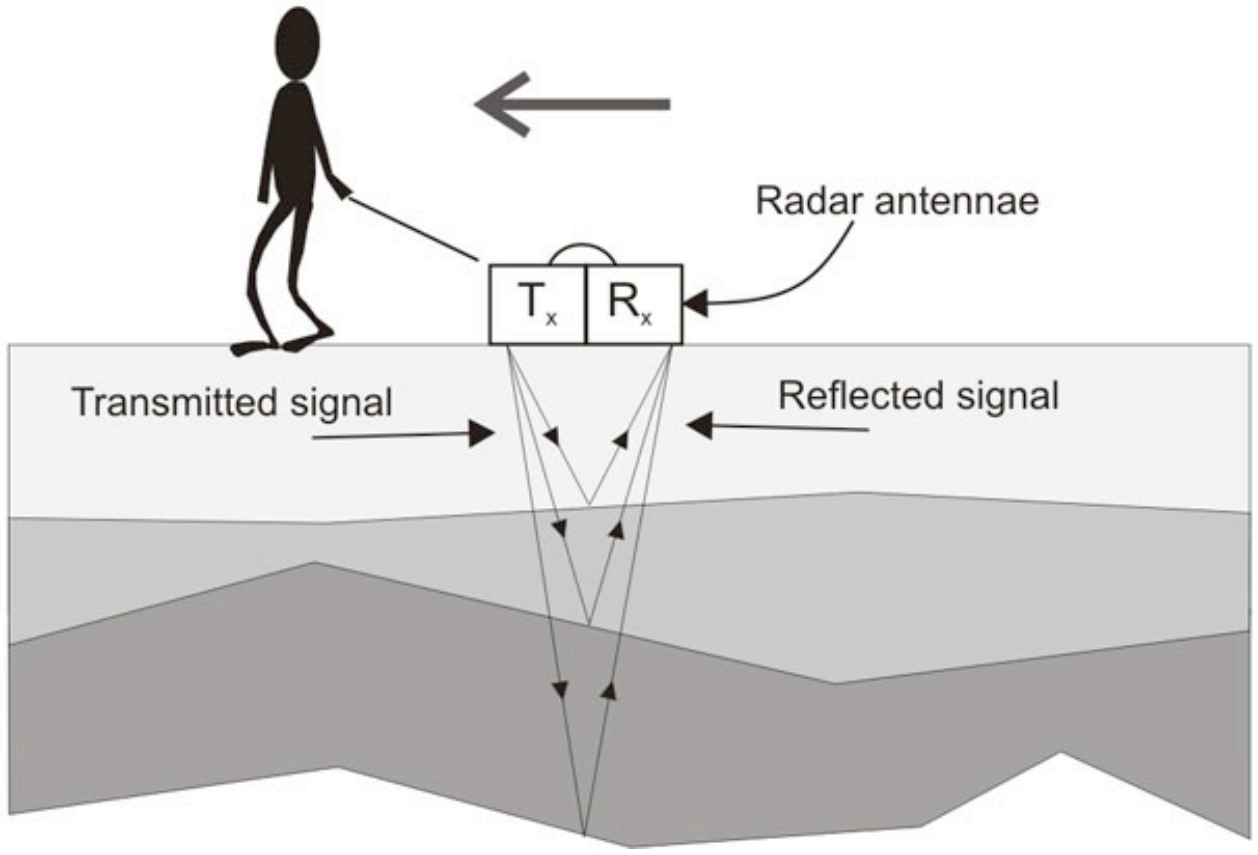
CREWES

Outline

- Introduction
- Tissue sensing adaptive radar (TSAR) data
- Motivation - application to georadar data
- Simulated TSAR data
- Preliminary results
- Further work

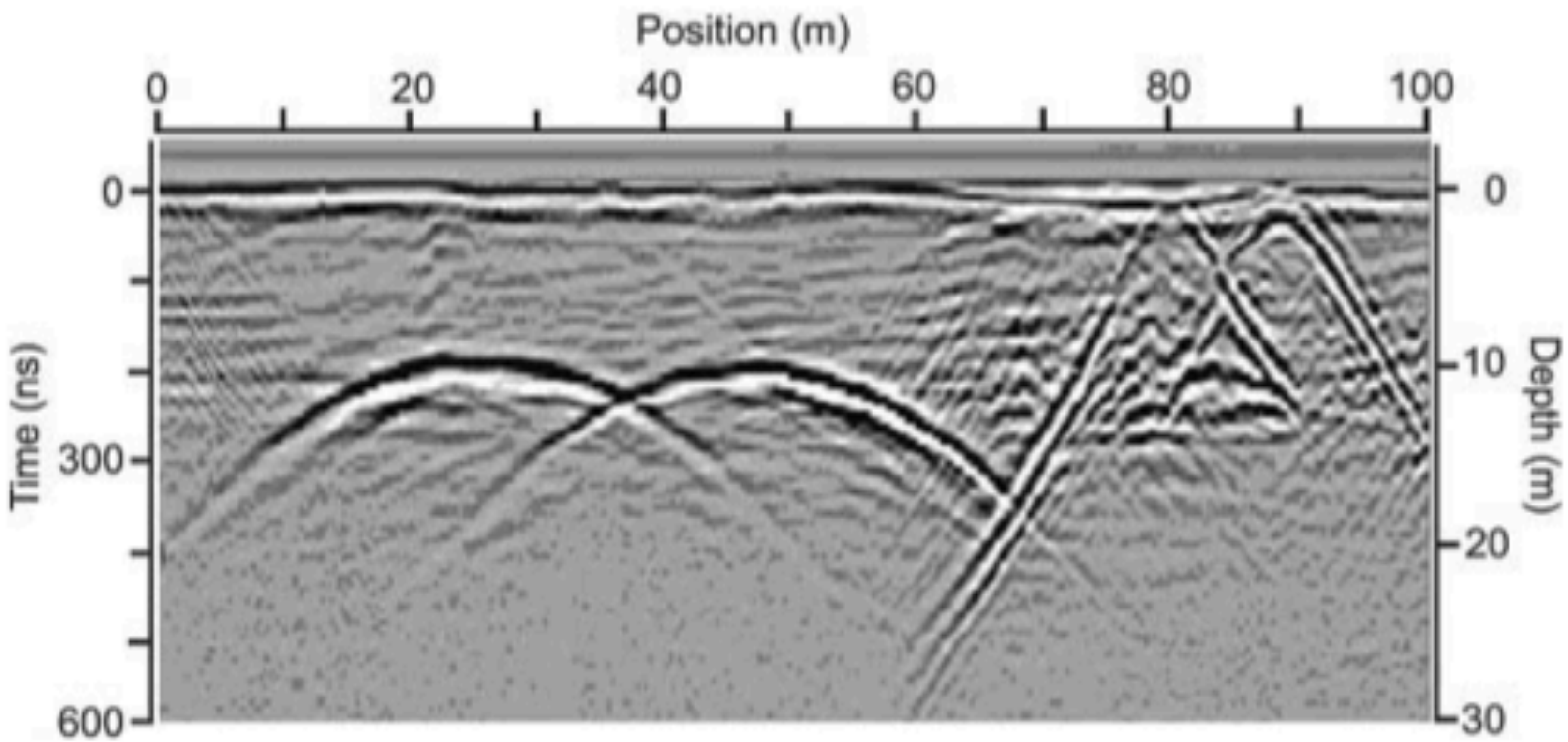
Radar Reflection

- Active source
- EM waves
- Reflections caused by changes in dielectric constant (relative permittivity) between different media
- Analogous to seismic reflection experiment
- Different scale (*t*, *f*, *x*, and *z*)



$$RC = \frac{\sqrt{\varepsilon_{r2}} - \sqrt{\varepsilon_{r1}}}{\sqrt{\varepsilon_{r2}} + \sqrt{\varepsilon_{r1}}}$$

Georadar Example

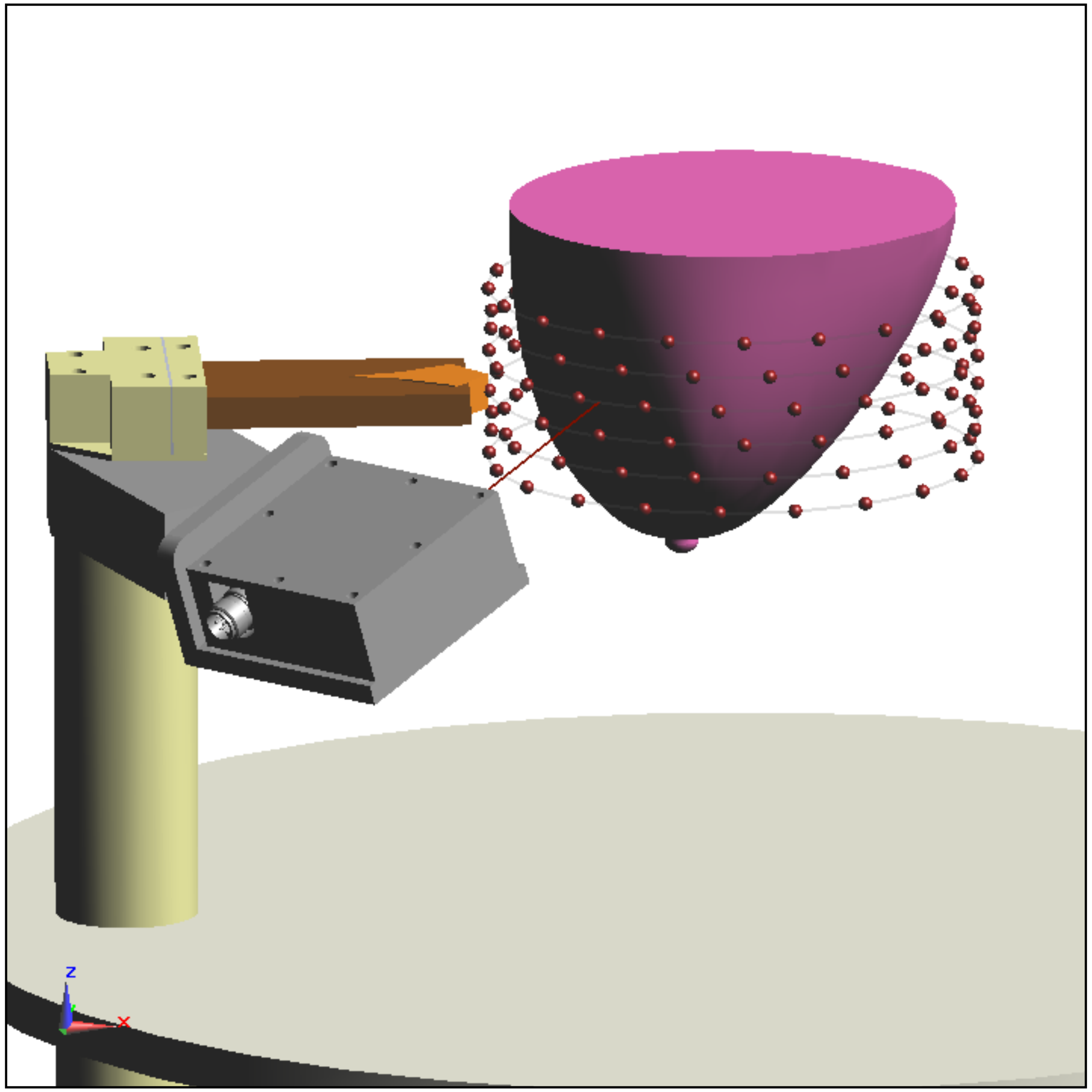


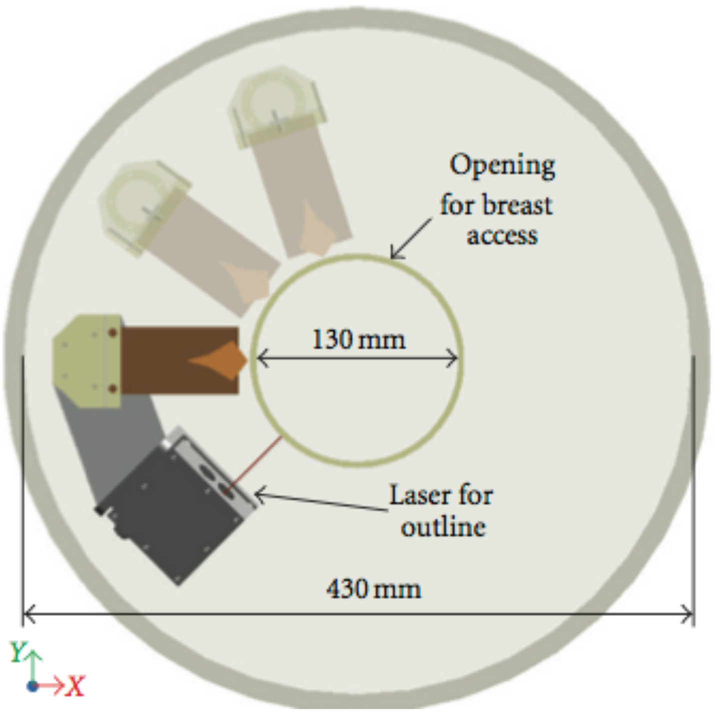
50 MHz georadar data over road tunnels. (Jol 2009)

Tissue Sensing Adaptive Radar (TSAR)

- Prototype breast imaging technique developed by Dr. Elise Fear and her group in Electrical Engineering at the University of Calgary
- Method uses lower-power signal relative to other medical imaging methods
- TSAR is designed as a patient-friendly technology, as it does not involve breast compression
- Technique is based on imaging mono-static radar reflections
- Reflections result from change in electromagnetic properties between healthy and cancerous tissue
- Similar to georadar

Tissue Sensing Adaptive Radar (TSAR)

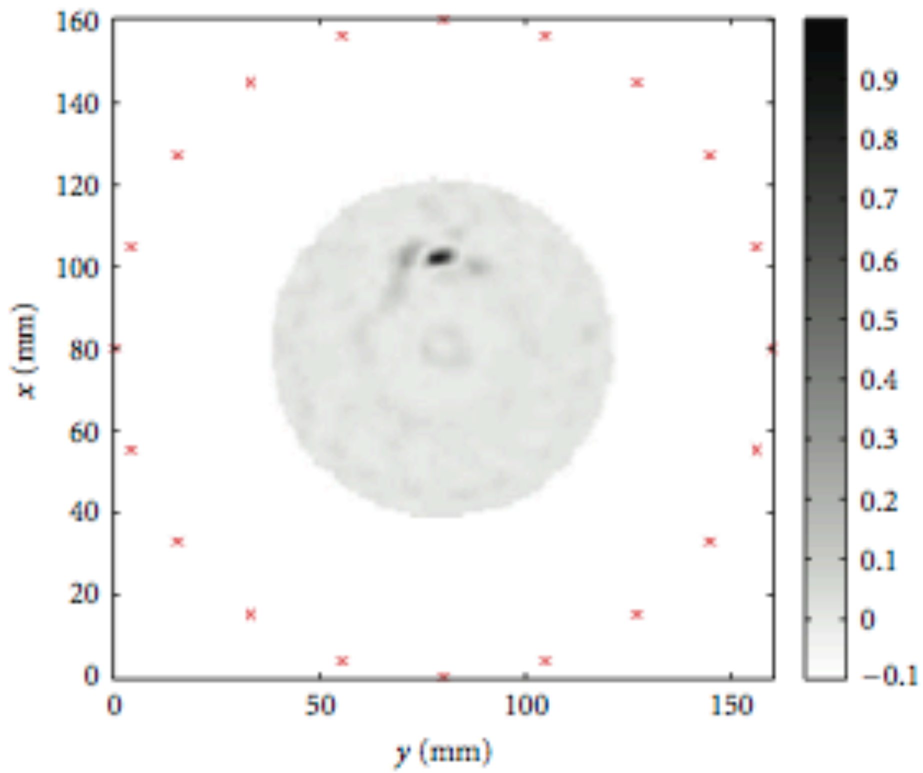


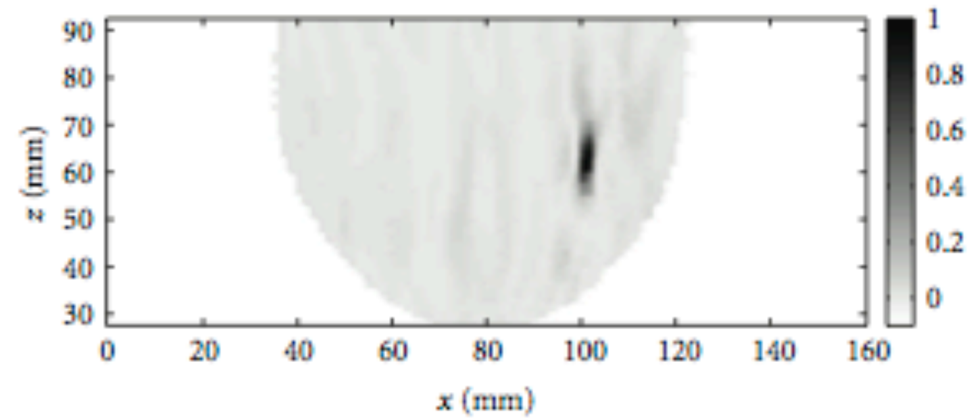


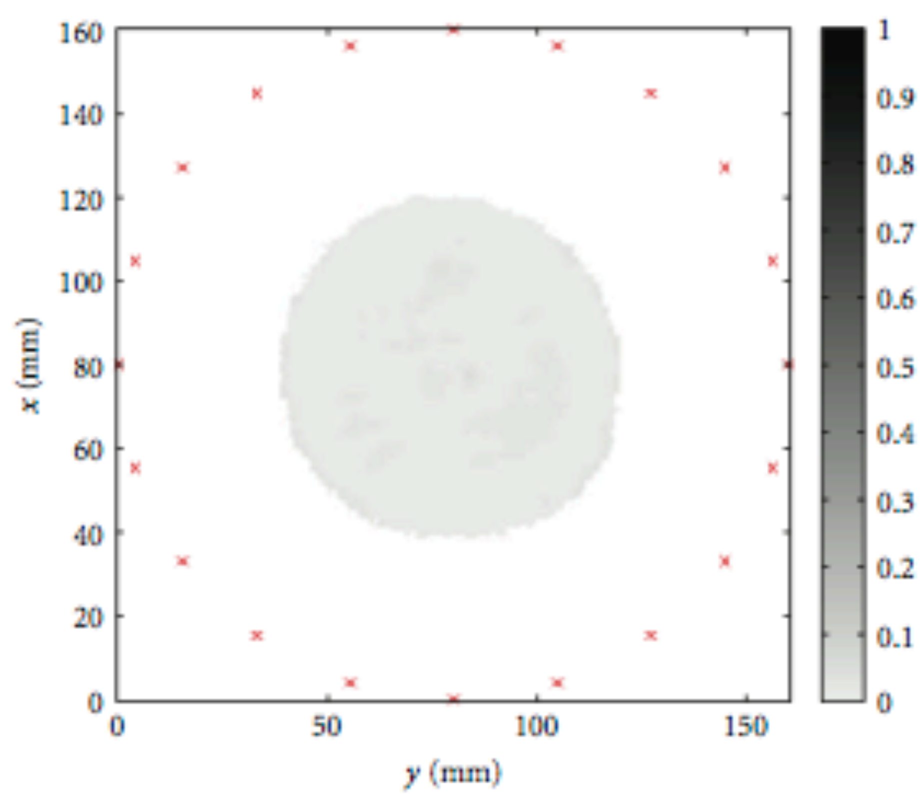
Various illustration of TSAR apparatus. (Bourqui et al. 2012)

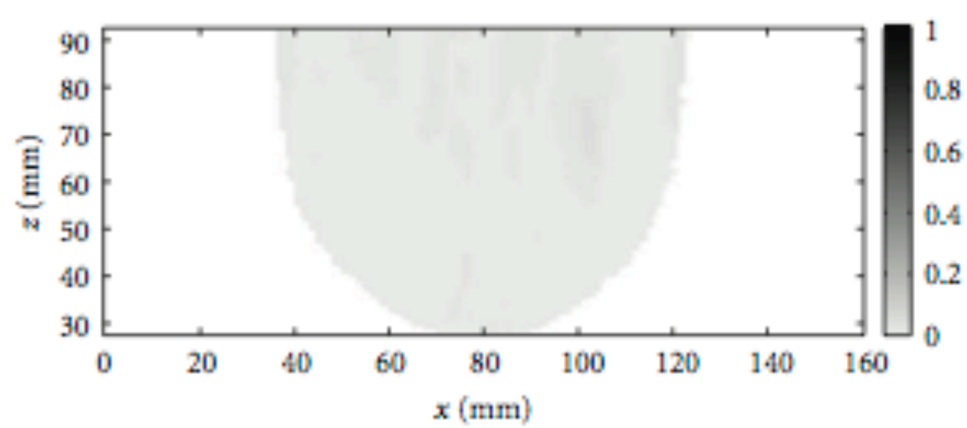
Tissue Sensing Adaptive Radar (TSAR)

Example TSAR Images





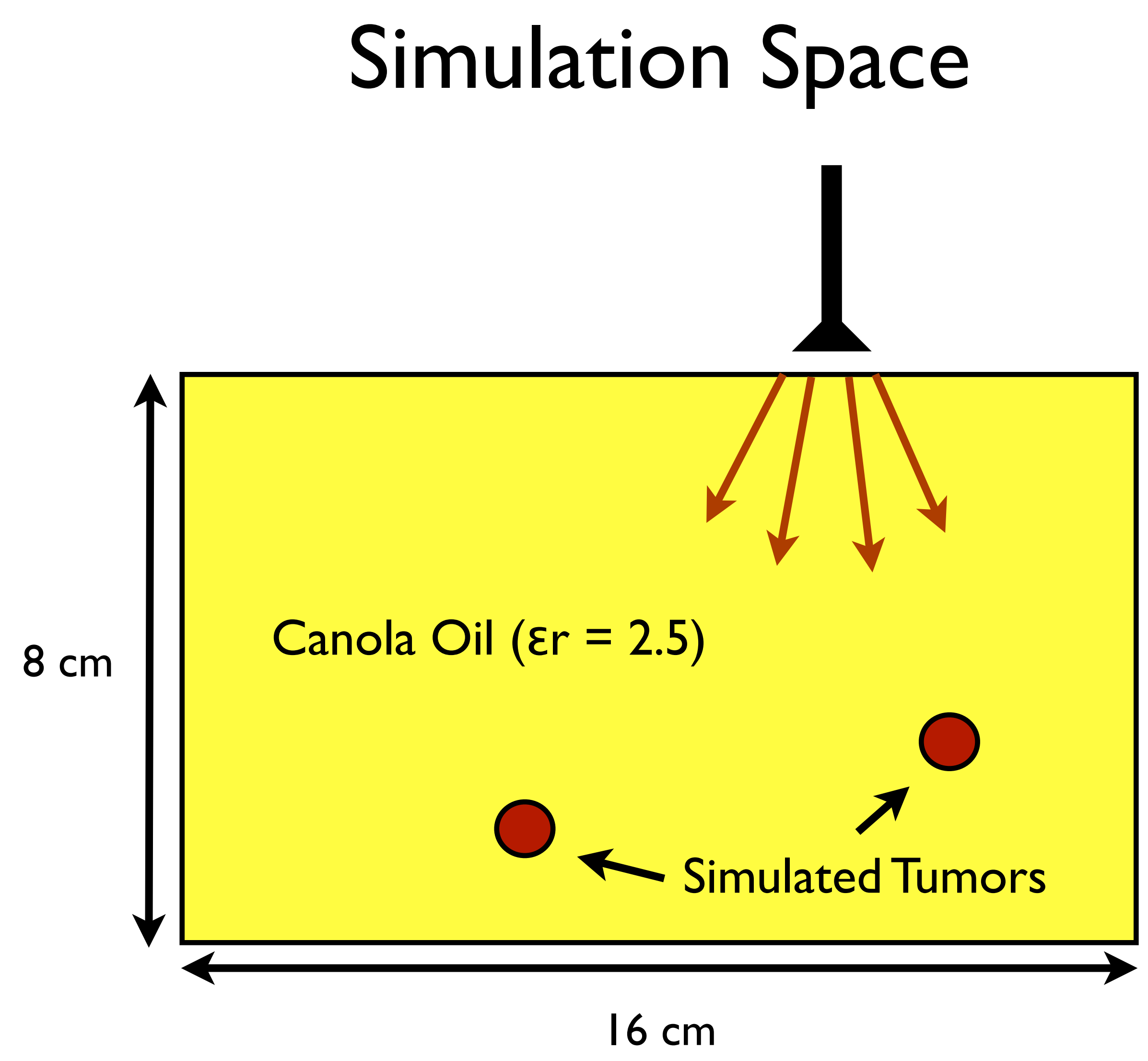




Measured data from hemispherical model. (Bourqui et al. 2012)

Simulated TSAR Data

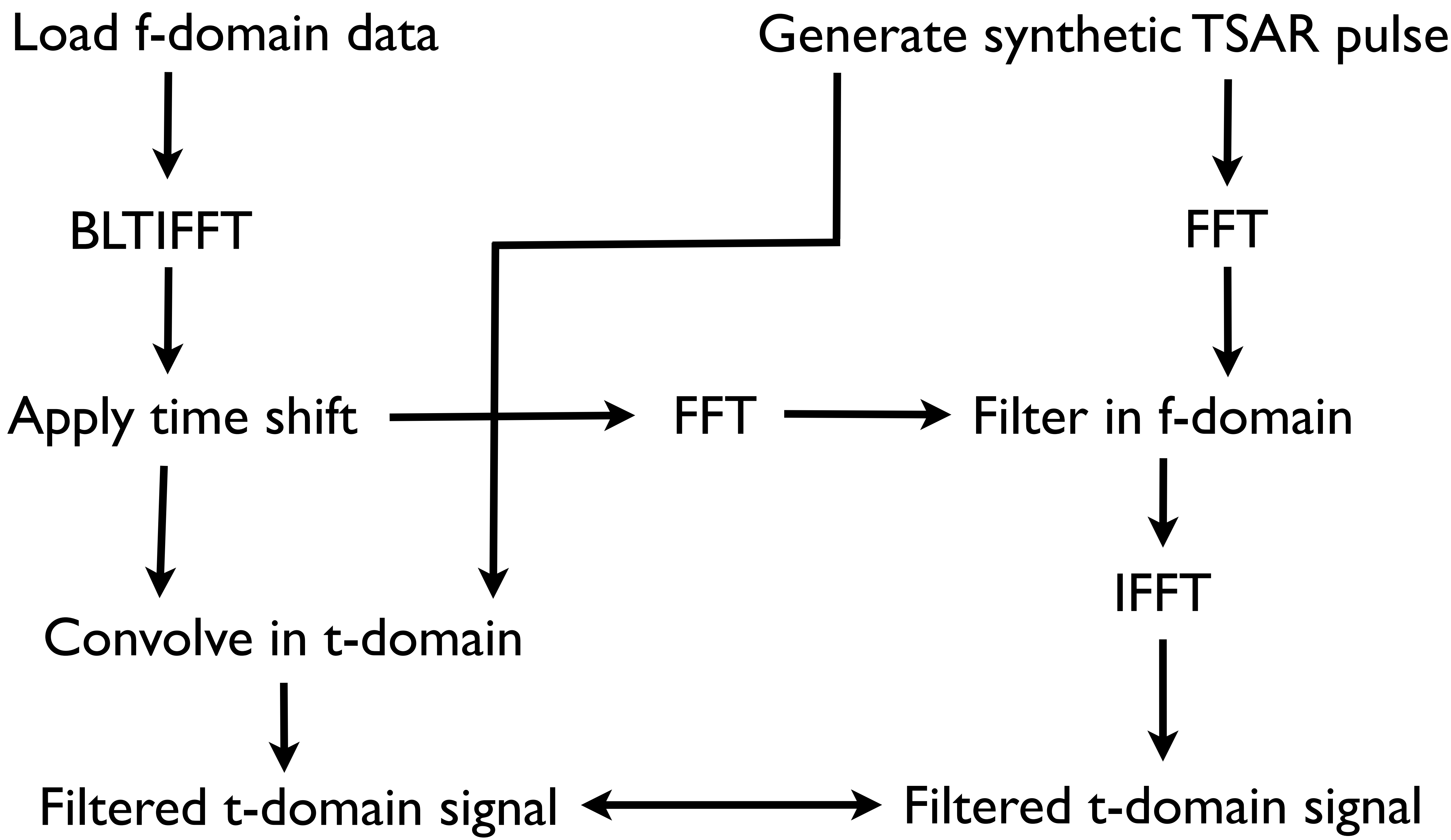
- Homogeneous canola oil with imbedded imaging targets (tumors)
- Number and location of targets not known
- Data recorded in the frequency domain
- Frequency range from 0 Hz to 14.99 GHz



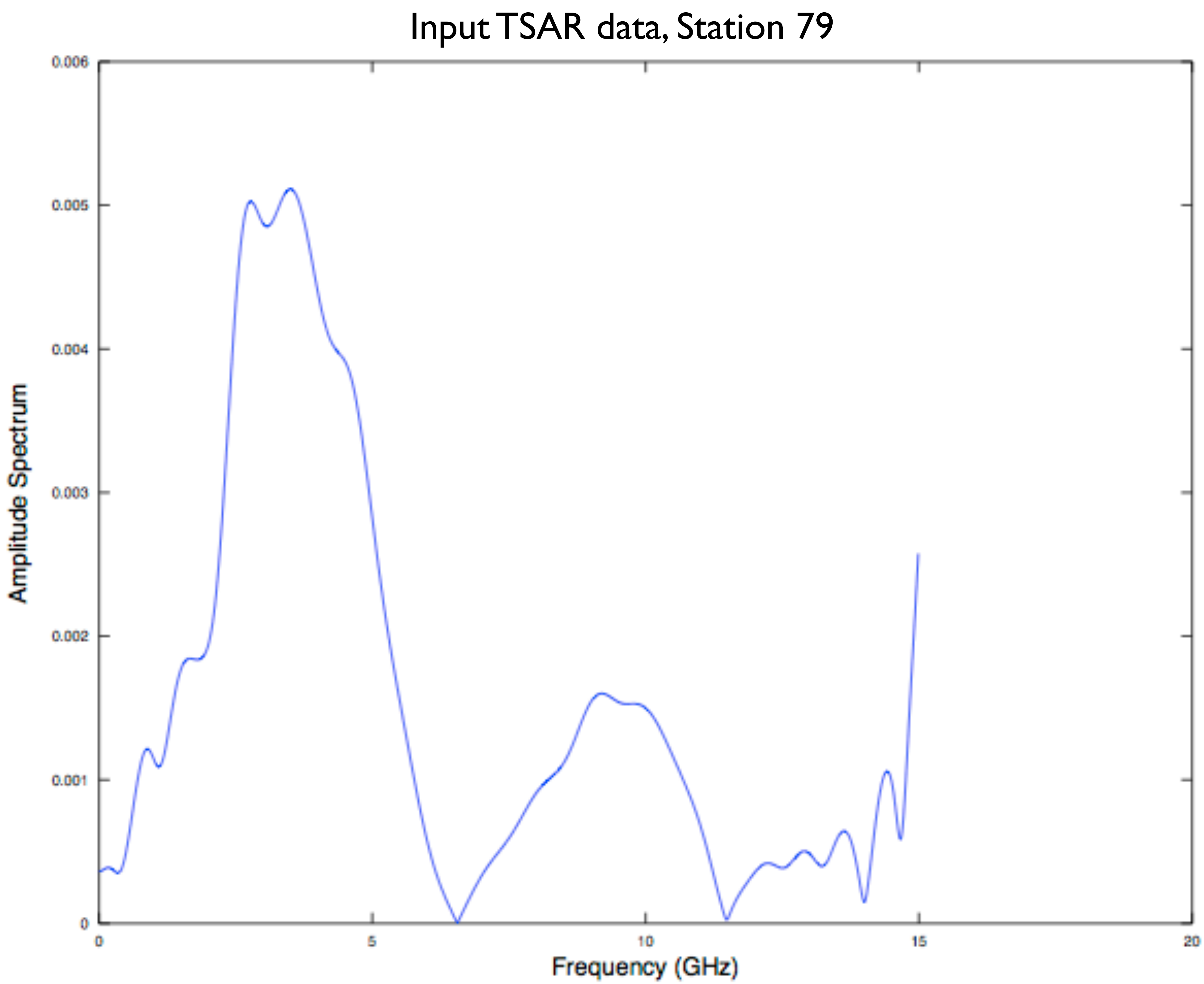
Motivation

- Frequency-domain radar data has advantages over field georadar data
- Compare wavelet-shaping filtering with non-stationary deconvolution as preconditioning for imaging
- Improve upon non-stationary deconvolution workflow for radar data
- Properly image diffraction points
- Semi-automation of diffraction imaging for velocity analysis
- Apply methods for TSAR data to field georadar data

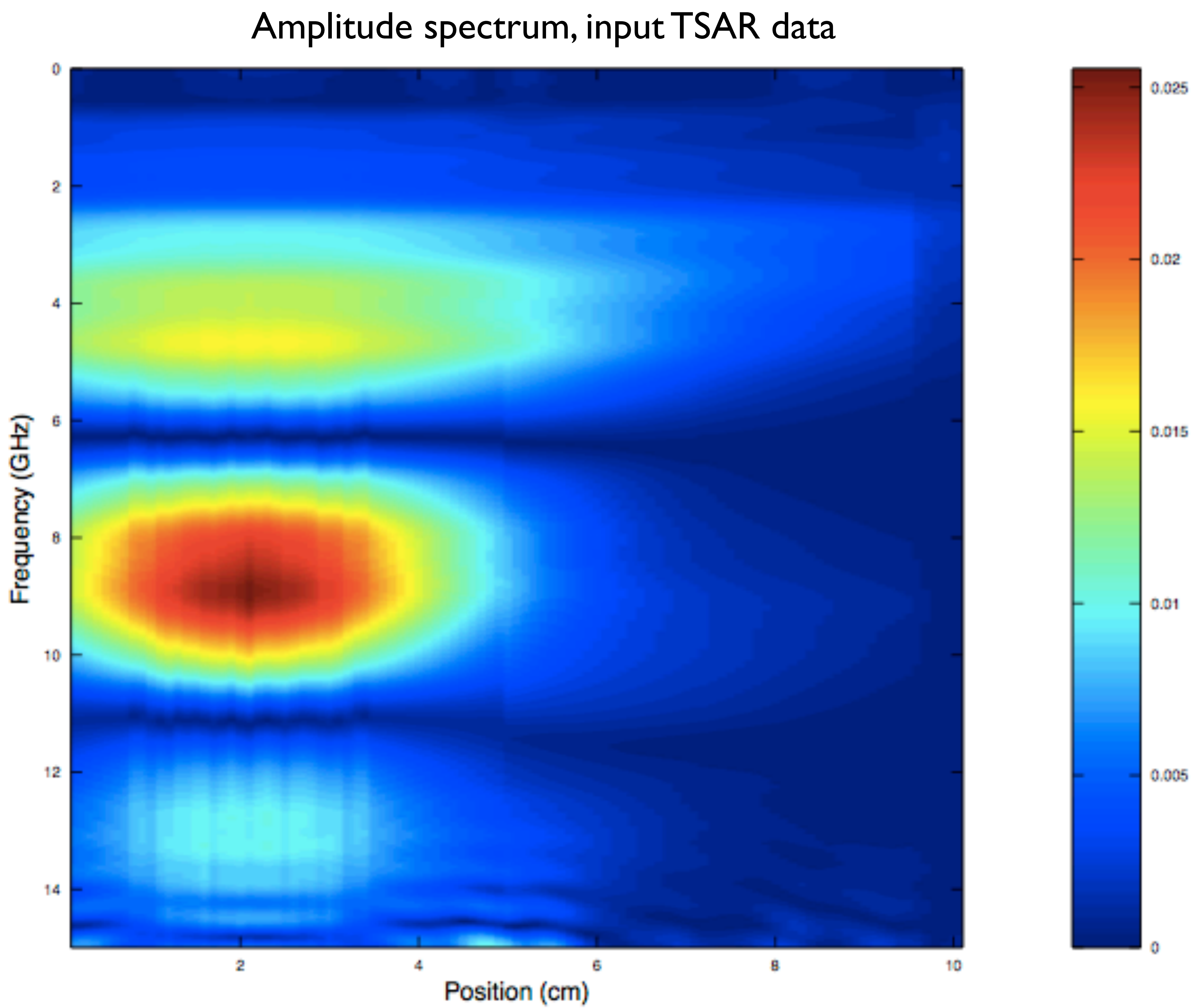
Workflow


Load f-domain data
Generate synthetic TSAR pulse
BLTIFFT
FFT
Apply time shift
FFT
Filter in f-domain
IFFT
Convolve in t-domain
Filtered t-domain signal
Filtered t-domain signal

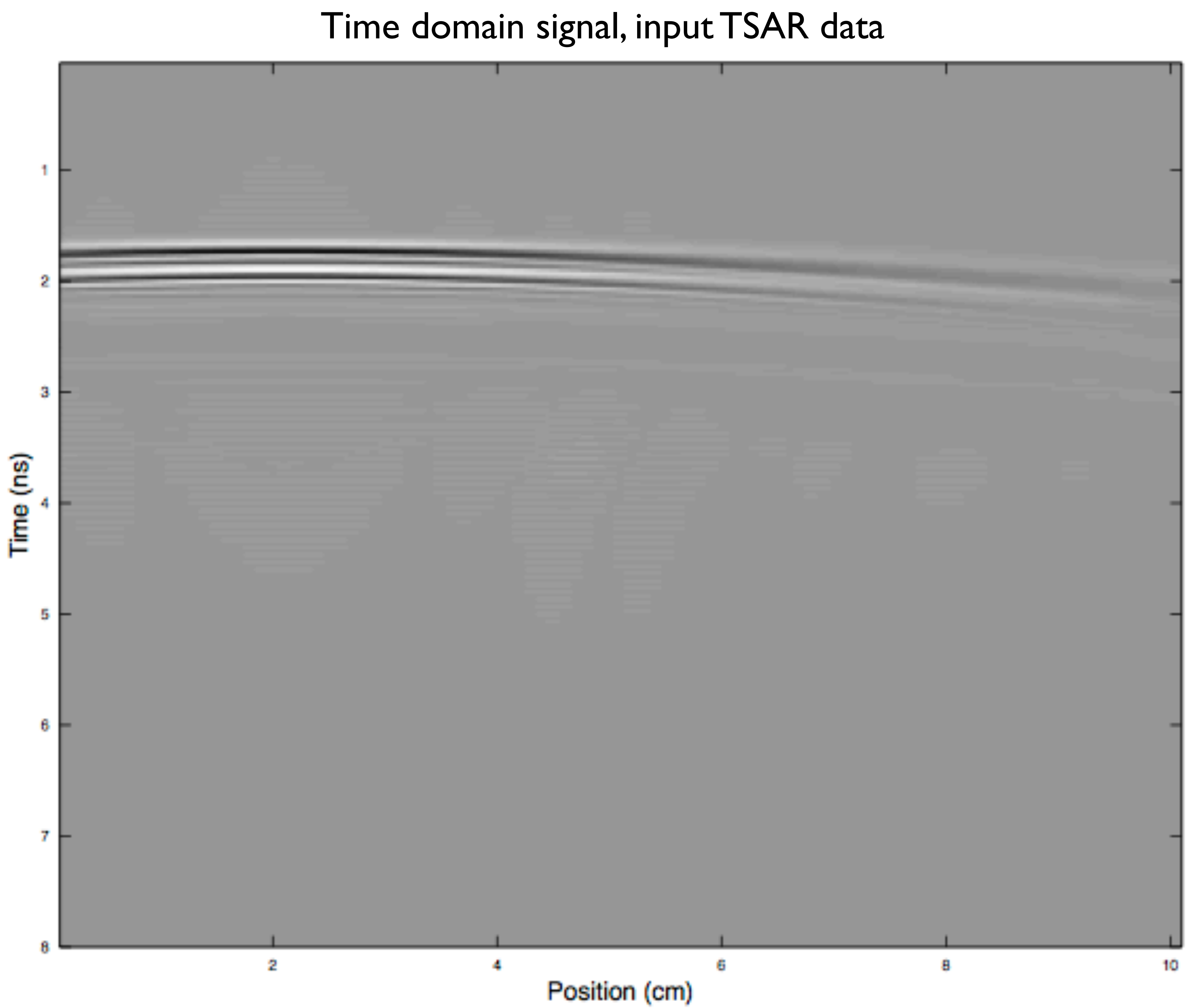
Input TSAR Data



Input TSAR Data

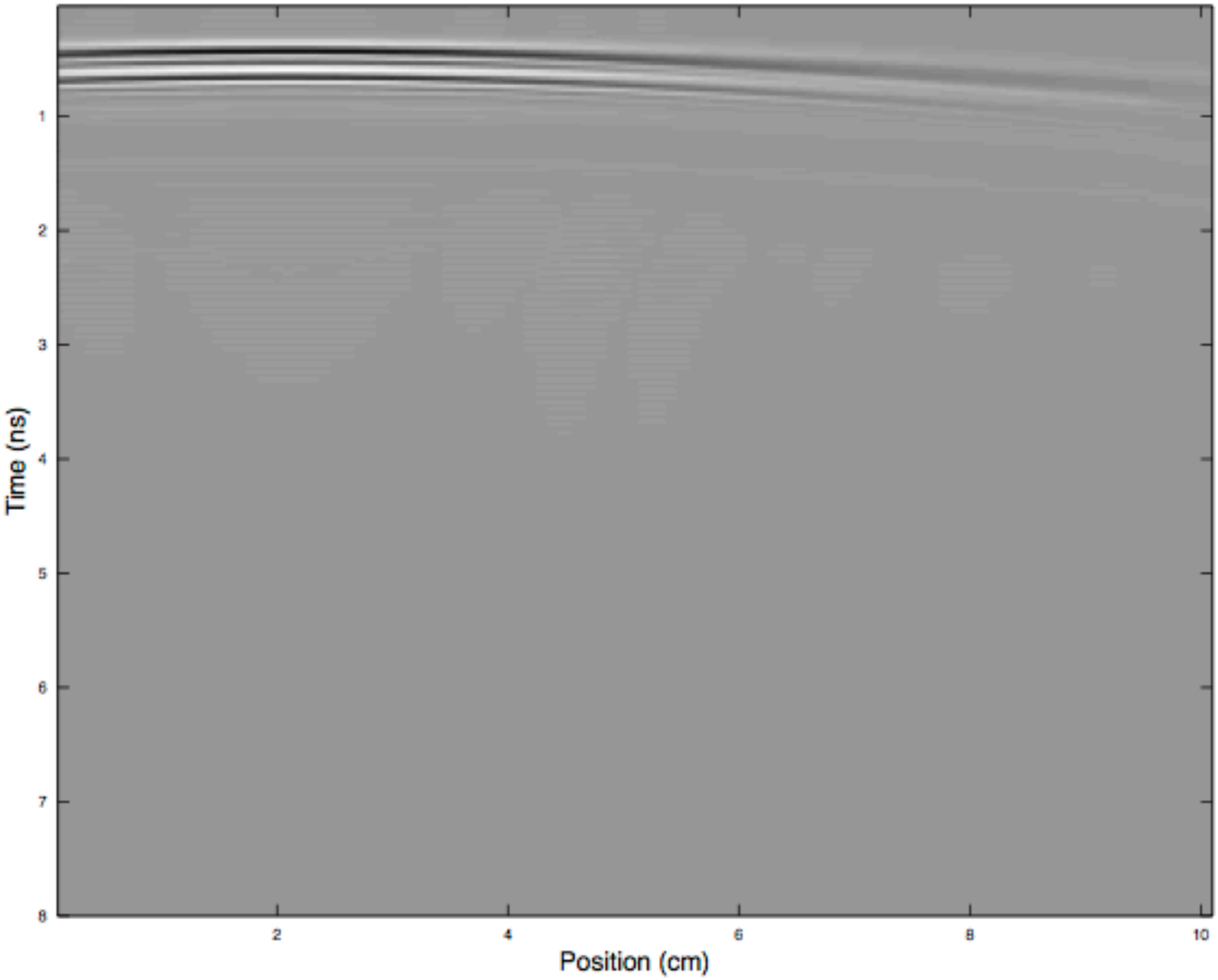


Input TSAR Data

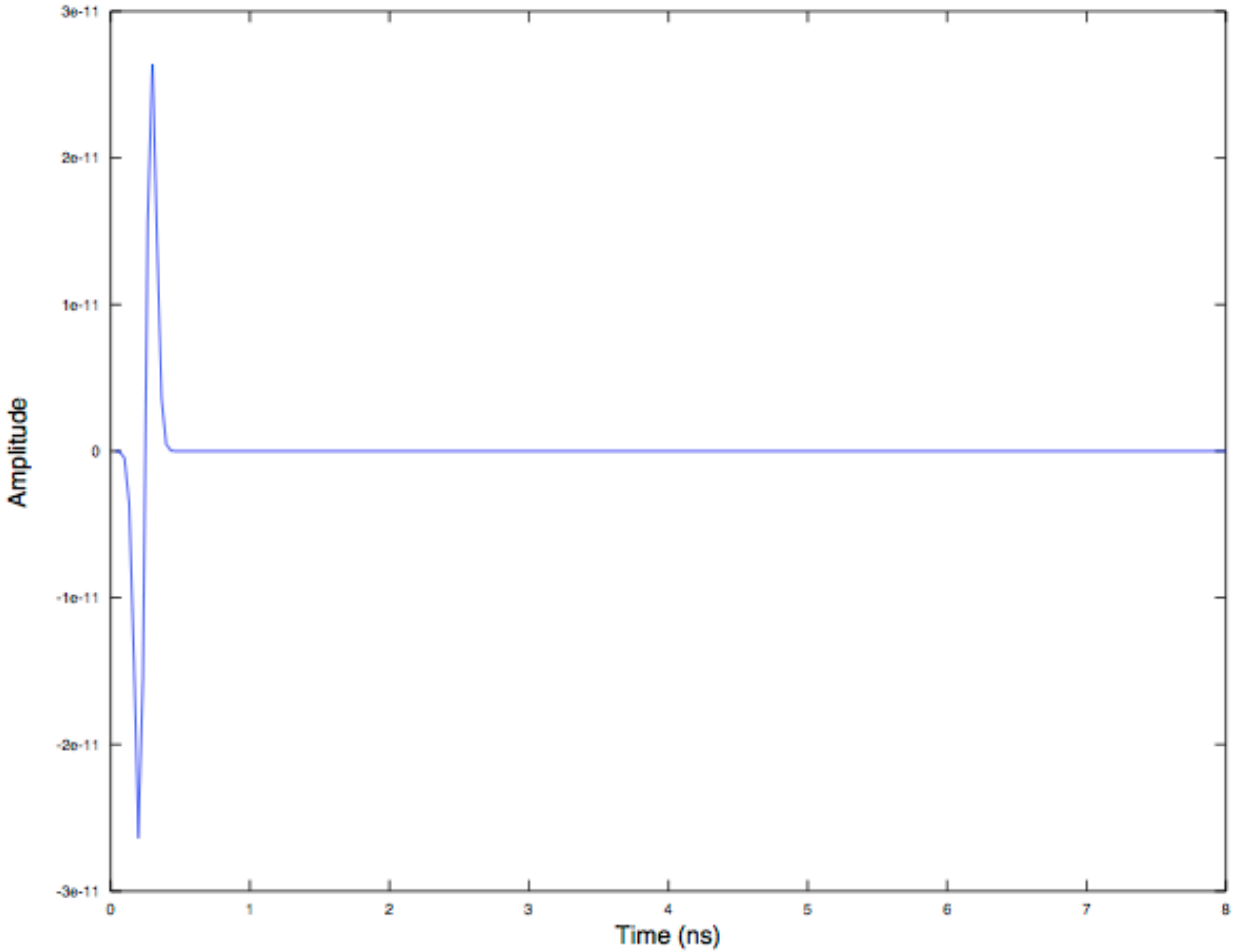


Input TSAR Data

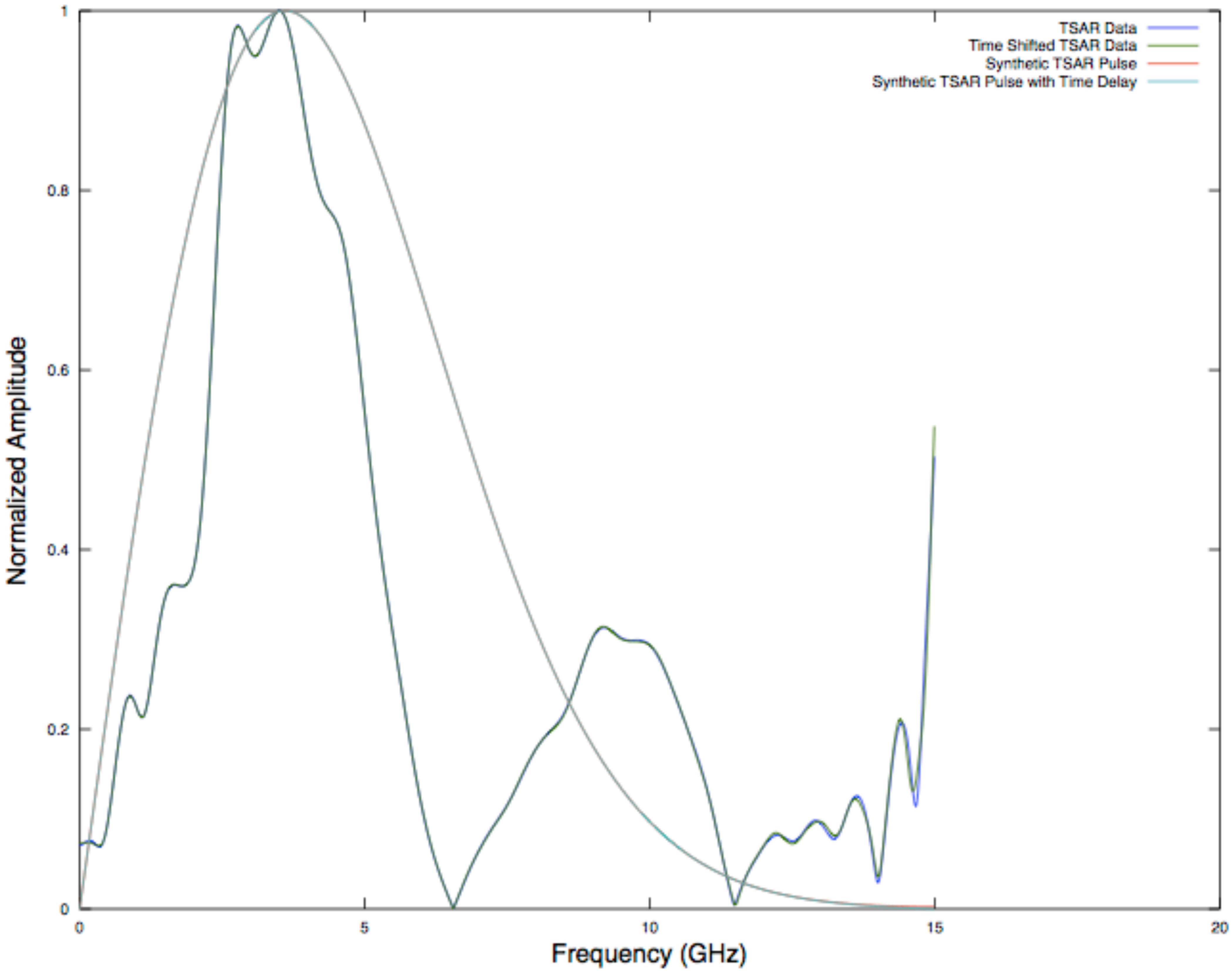
Shifted time domain signal, input TSAR data



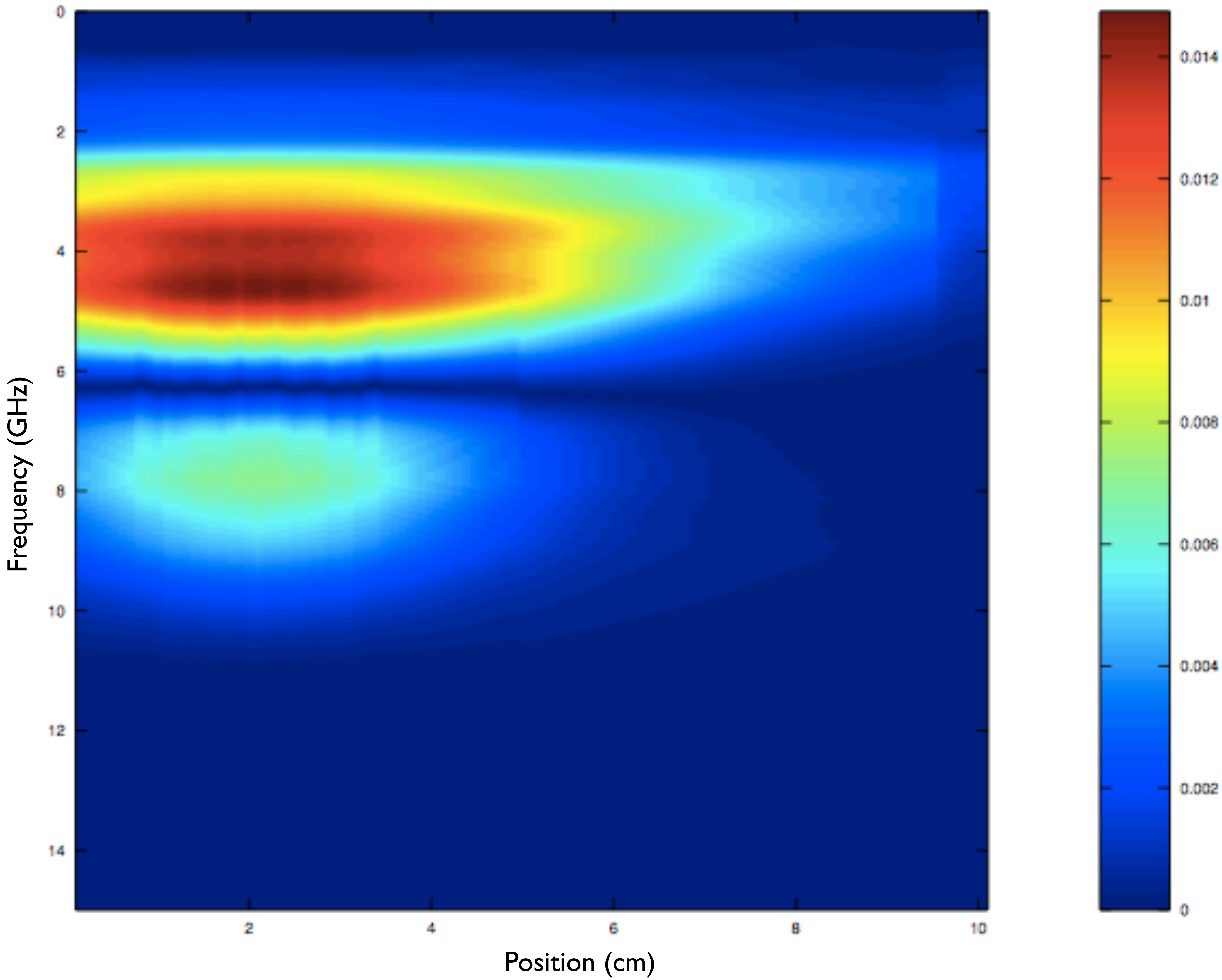
Synthetic TSAR Pulse



Comparison of Amplitude Spectra

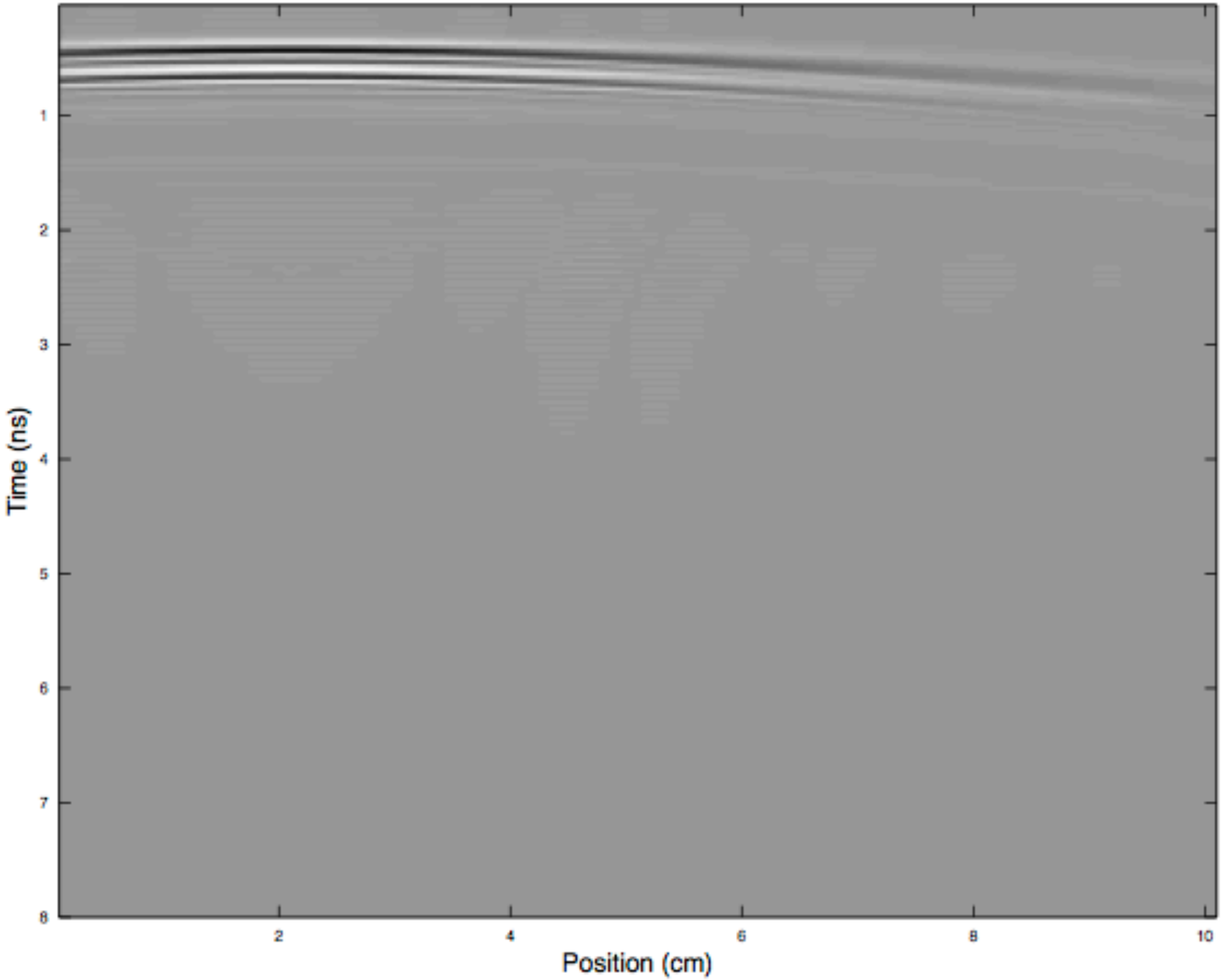


Filtered Amplitude Spectrum



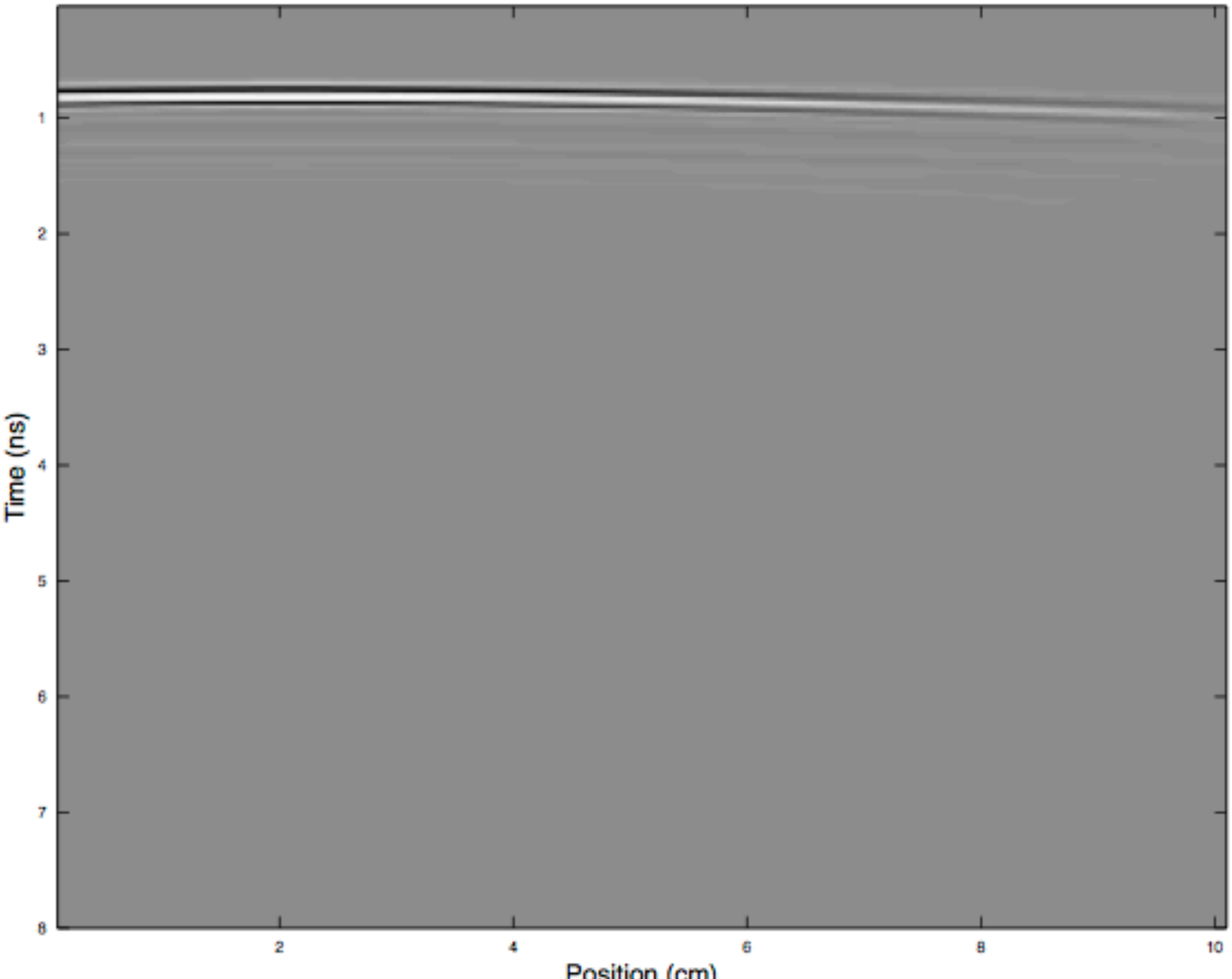
Phase Issues

Shifted time domain signal, input TSAR data



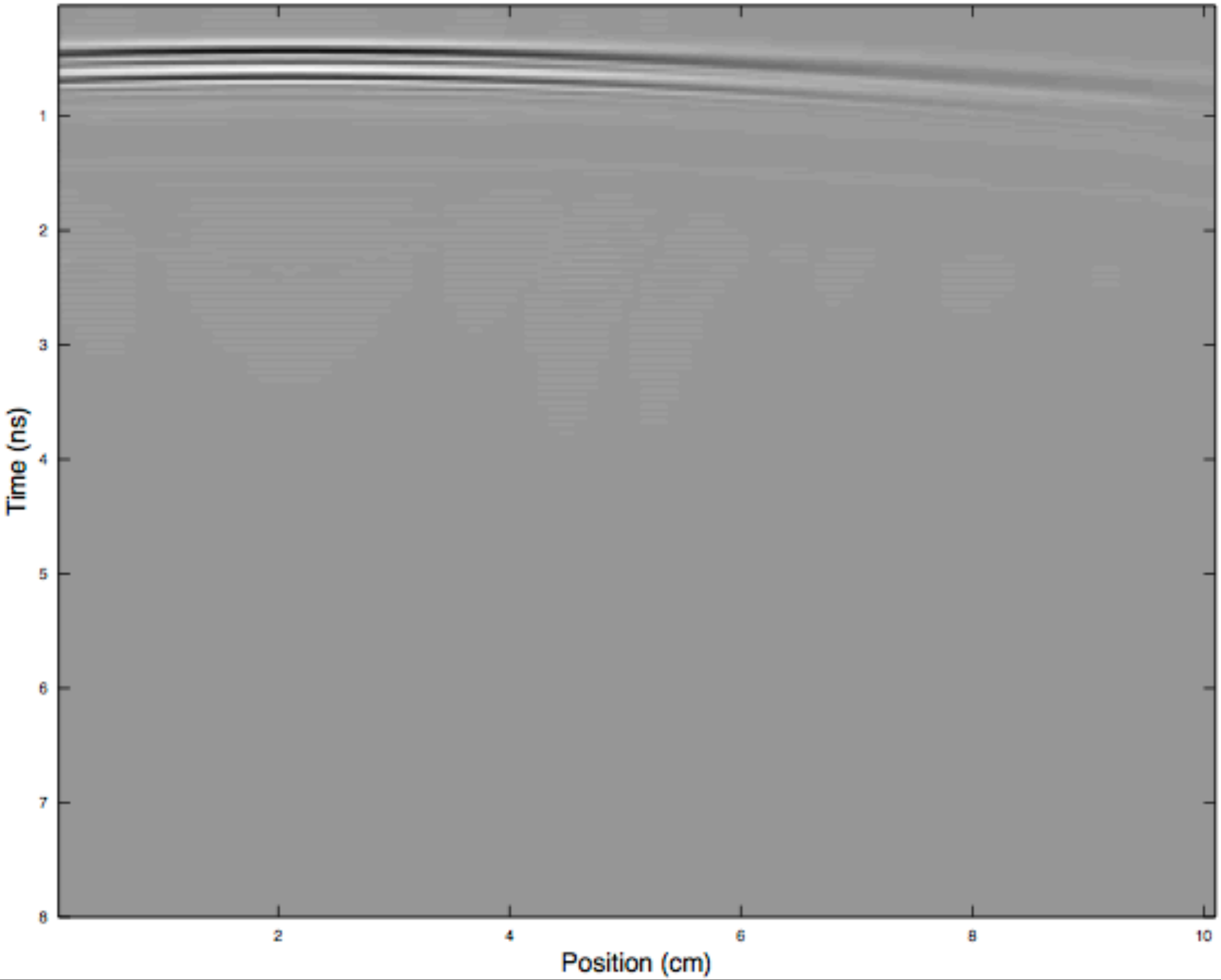
Phase Issues

Filtered time domain signal, input TSAR data



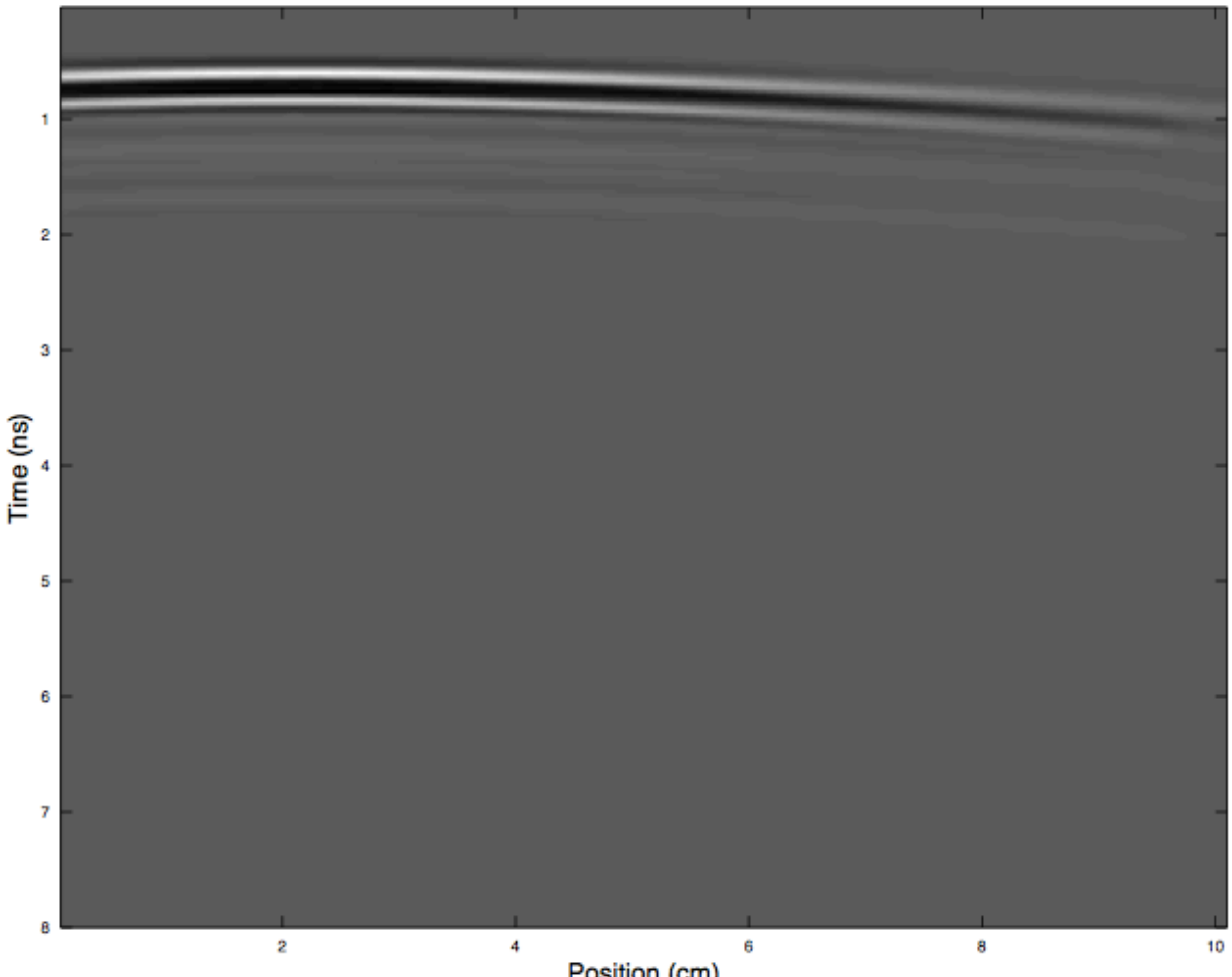
Phase Issues

Shifted time domain signal, input TSAR data

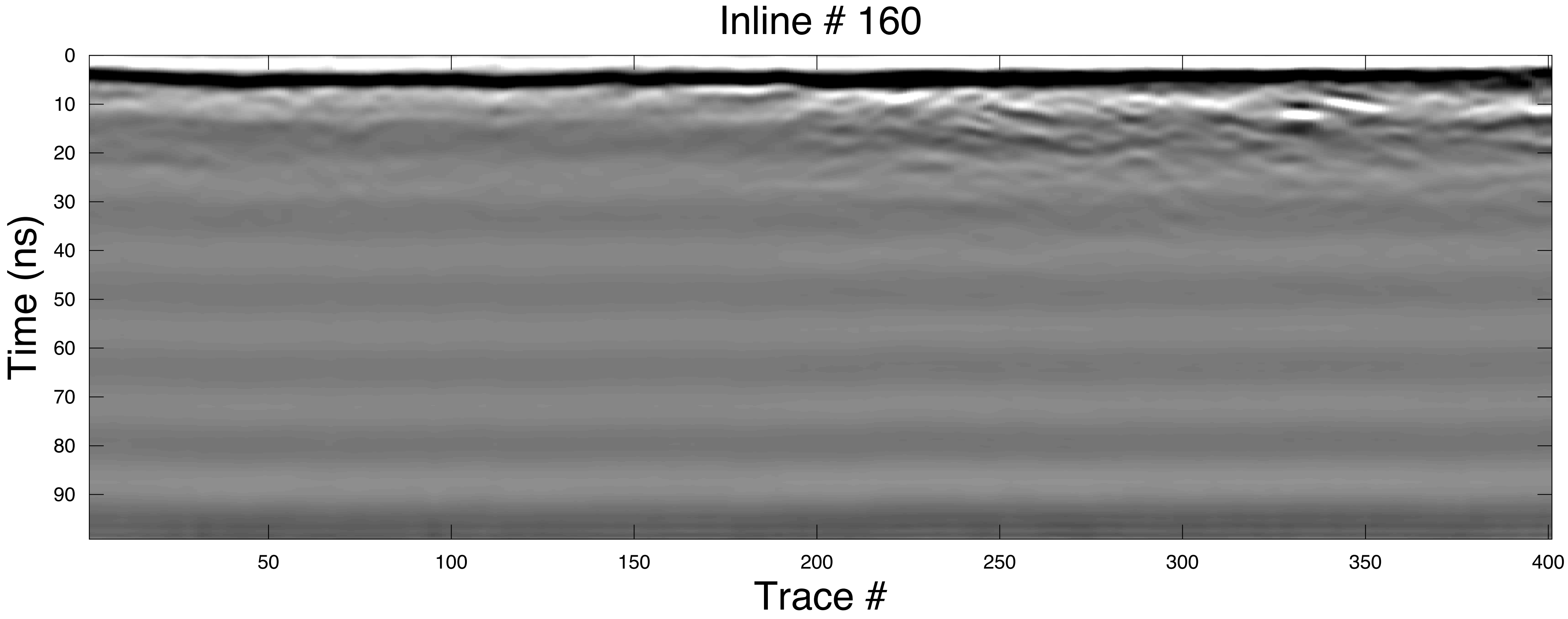


Phase Issues

Time domain signal convolved with TSAR pulse



Non-Stationary Deconvolution



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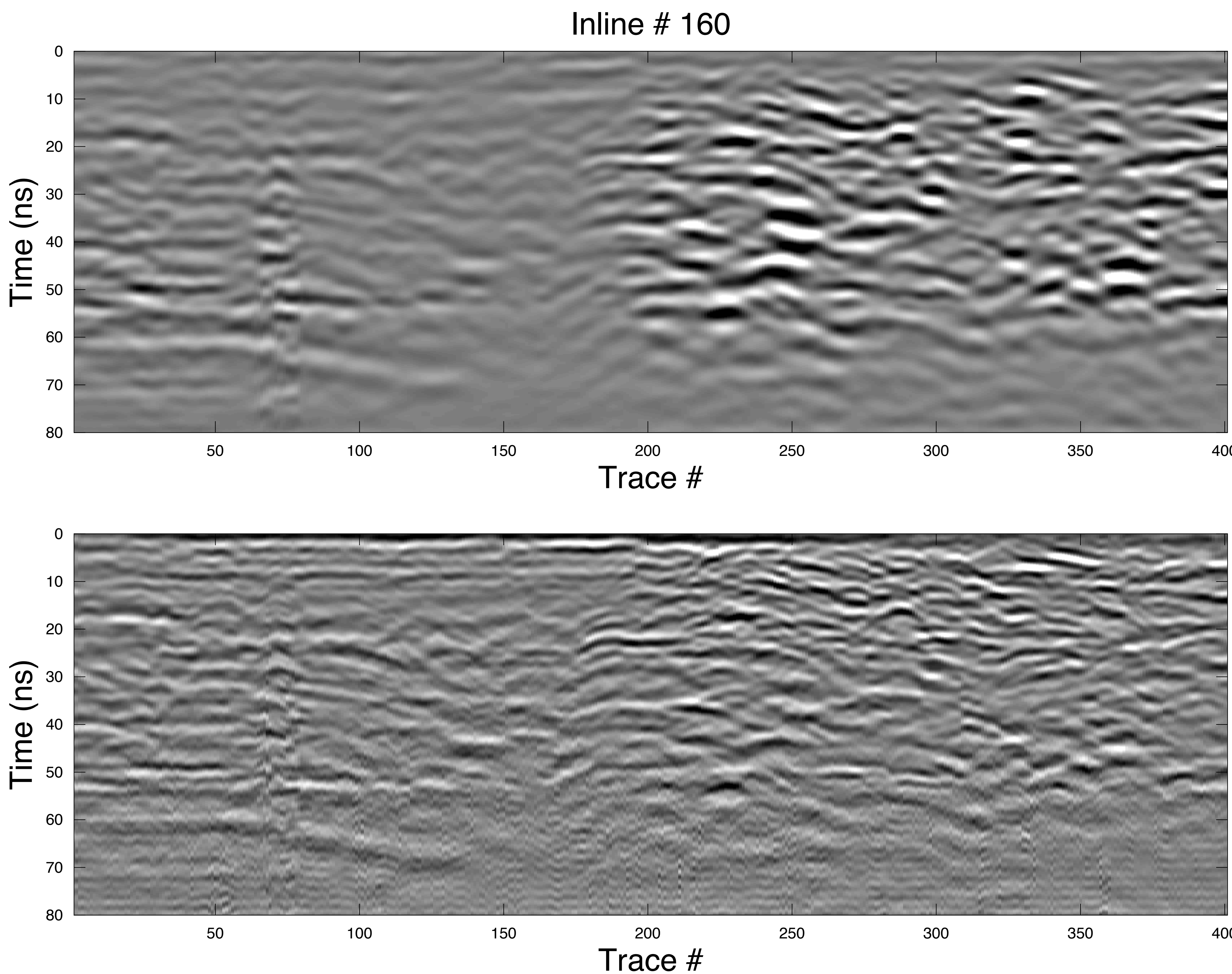

Conclusions

- Careful conversion of raw data to time domain is crucial
- First-pass wavelet shaping introduces an apparent phase-shift, must be dealt with carefully
- Non-stationary deconvolution is likely better at preconditioning data for imaging than wavelet shaping

Ongoing / Future Research

- Nonstationary deconvolution workflow
- Imaging (zero offset and pre-stack)
- Semi-automation of diffraction imaging for velocity analysis
- Apply methods to field georadar data

Acknowledgments

- Dr. Rob Ferguson
- Jérémie Bourqui
- Dr. Elise Fear
- CREWES