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Automated Ultrasound Data Acquisition and Analysis

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Mentors: Cristian Pantea, Blake Sturtevant

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Outline

- Background and Motivation
- Handyscope HS5 and Setup
- Waveform Generation
- Data Acquisition
- Data Analysis
- Results
- Applications

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Background and Motivation

- Ultrasound characterization
 - fast and noninvasive
- Waveform generators and oscilloscopes are large and heavy
 - lack mobility required for portable use in field experiments
- Different scenarios require different waveforms and parameters
 - flexible software with greater user control

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Background and Motivation

- Real-time data analysis
 - Saves time from manual data processing
 - Enables real-time monitoring and response
- Dynamic Systems
 - Quickly evolve over time
 - Can be studied using continuous fast ultrasound measurements

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Handyscope HS5 and Setup

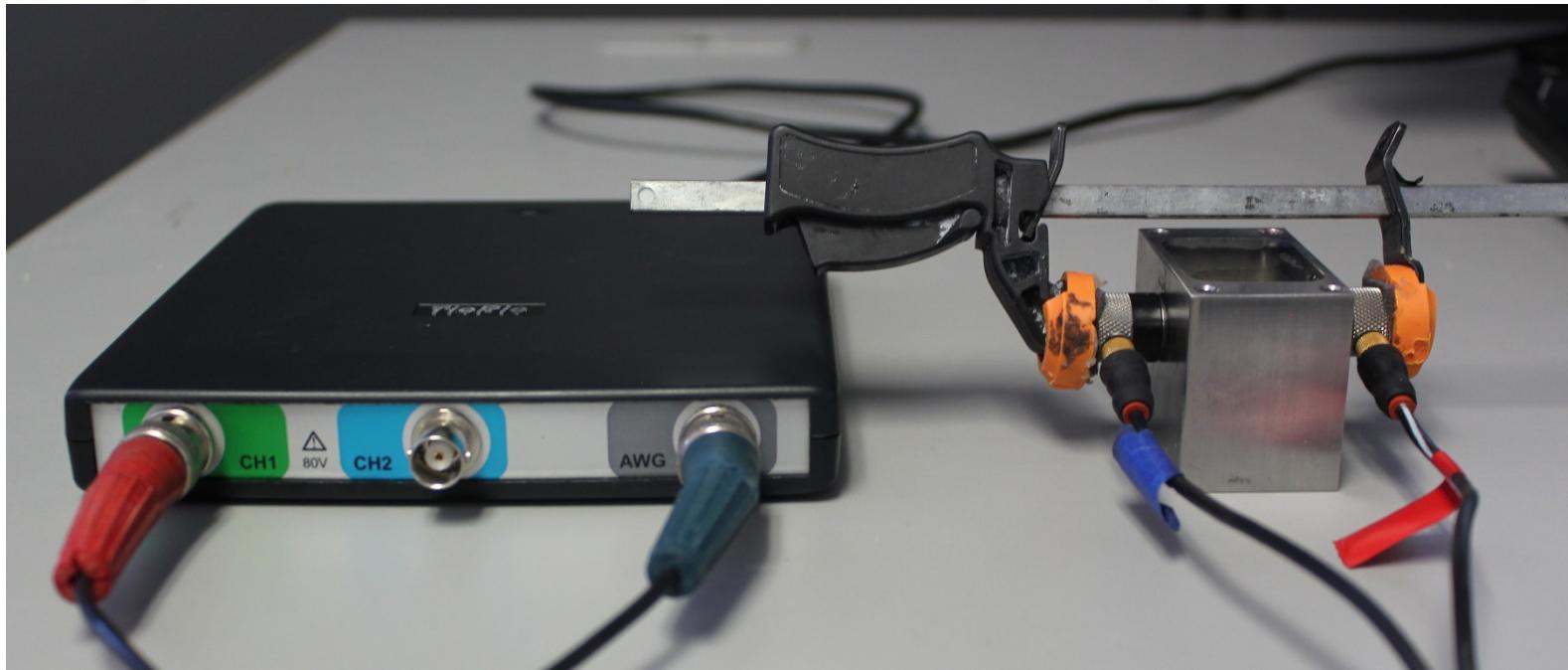


Figure 1: Blue tagged wire leads from AWG to transducer. Red tagged wire leads from receiver to Ch1.

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Waveform Generation

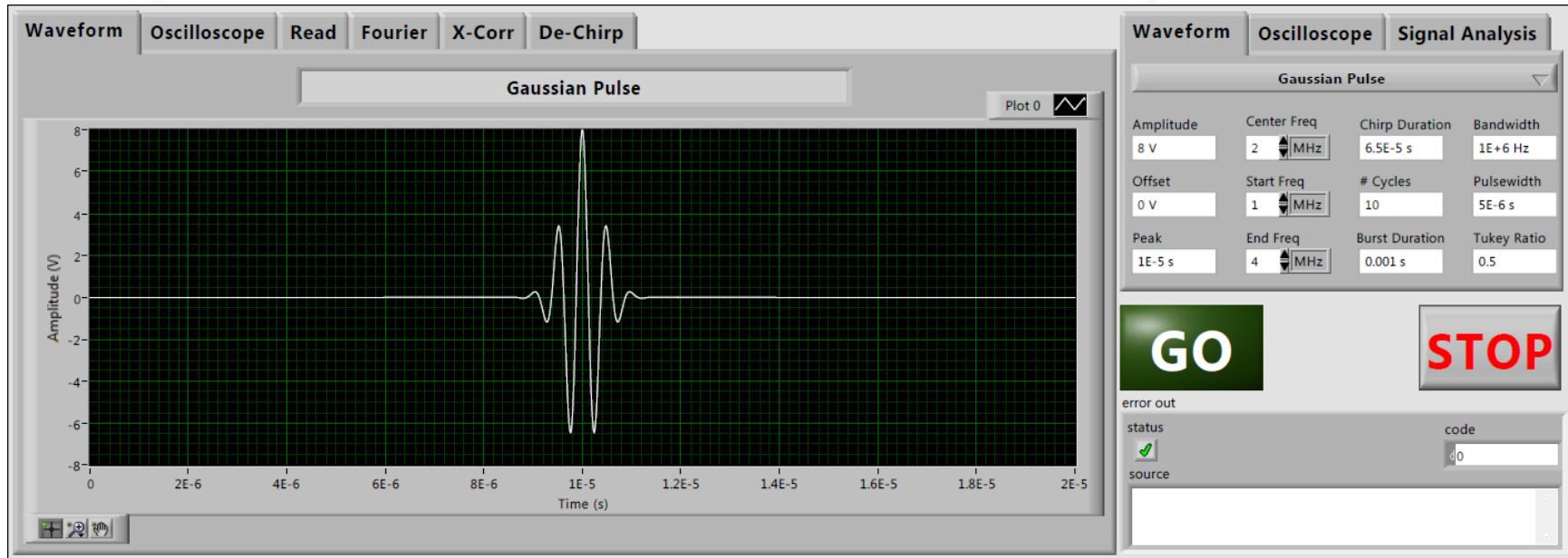


Figure 2: A Gaussian Pulse is one of the common waveforms used to characterize media

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Waveform Generation

- Arbitrary Waveform
 - any user defined shape
 - limited only by physical constraints
- New waveforms are easily added if needed

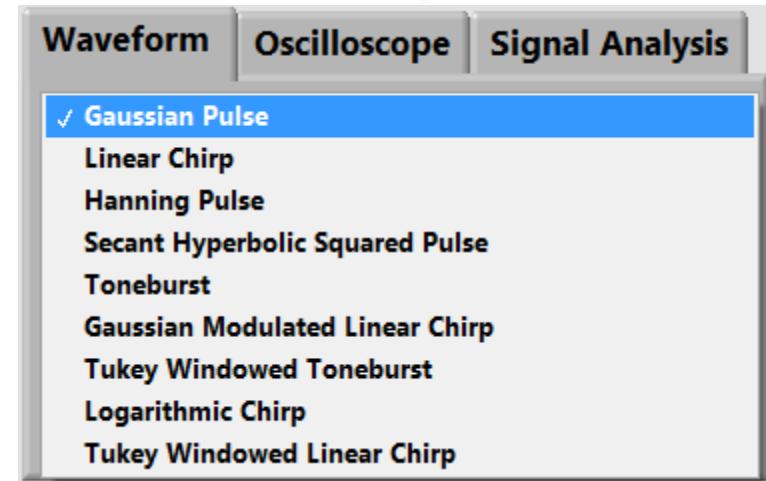


Figure 3: Currently, we have implemented 9 waveforms.

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Data Acquisition

- User controls sampling frequency and sample size
- Averaging to reduce random noise
- Data saved in a binary format
 - Memory efficient
- Saving speed (for shown setup):
 - No averaging: 0.447 ms/file
 - 10 wvfms: 3.71 ms/file
 - 100 wvfms: 37.6 ms/file.

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Data Acquisition

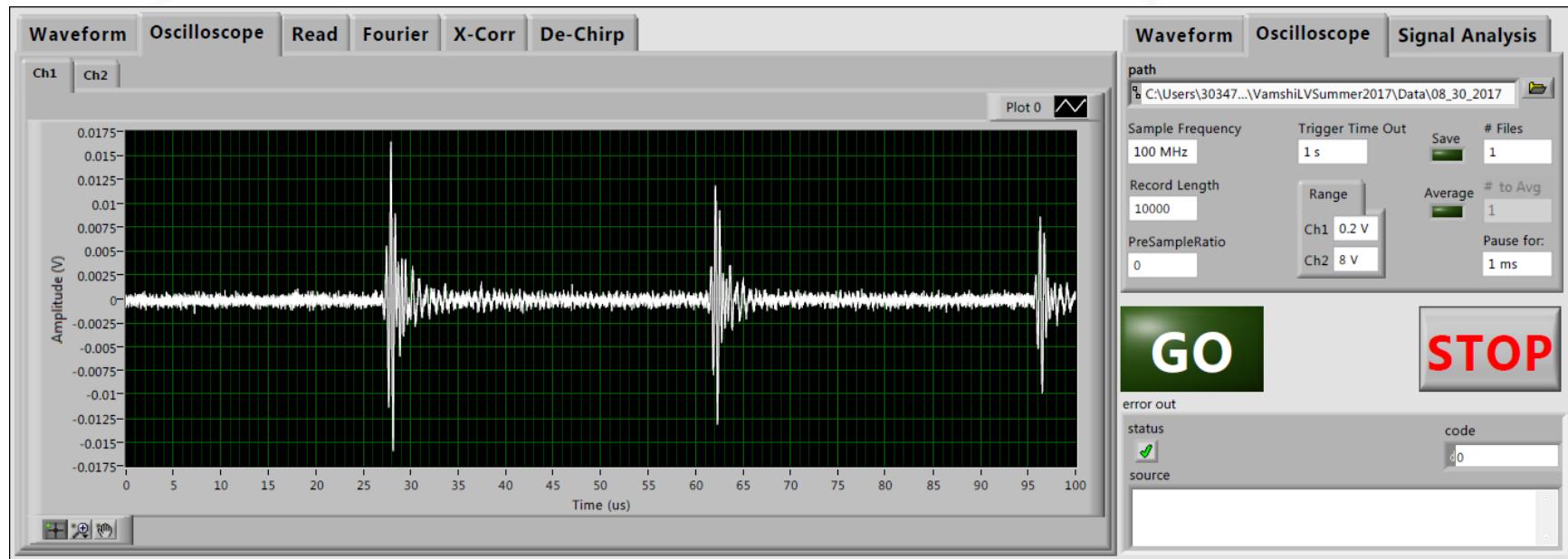


Figure 4: An oscilloscope Channel 1 measurement sampled at 100 MHz for 100 s shows the initial arrival followed by two reflections.

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Data Acquisition

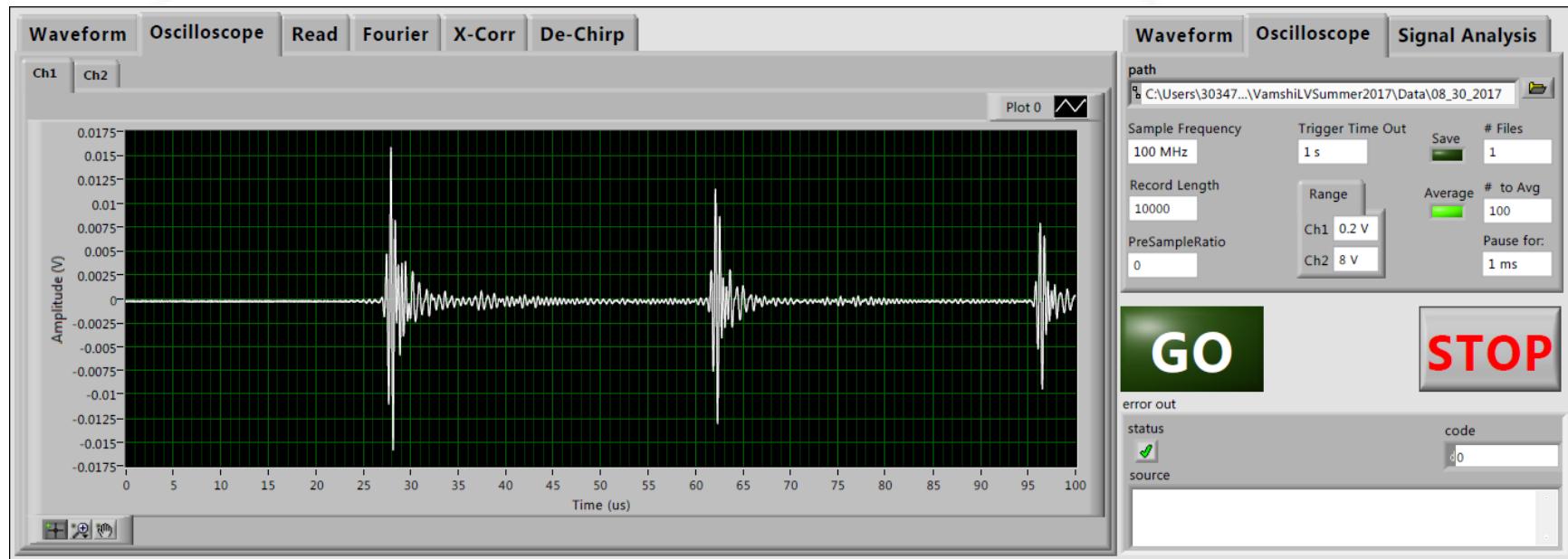


Figure 5: Averaging over 100 waveforms noticeably reduces random noise, producing a clearer signal.

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Data Analysis: Frequency

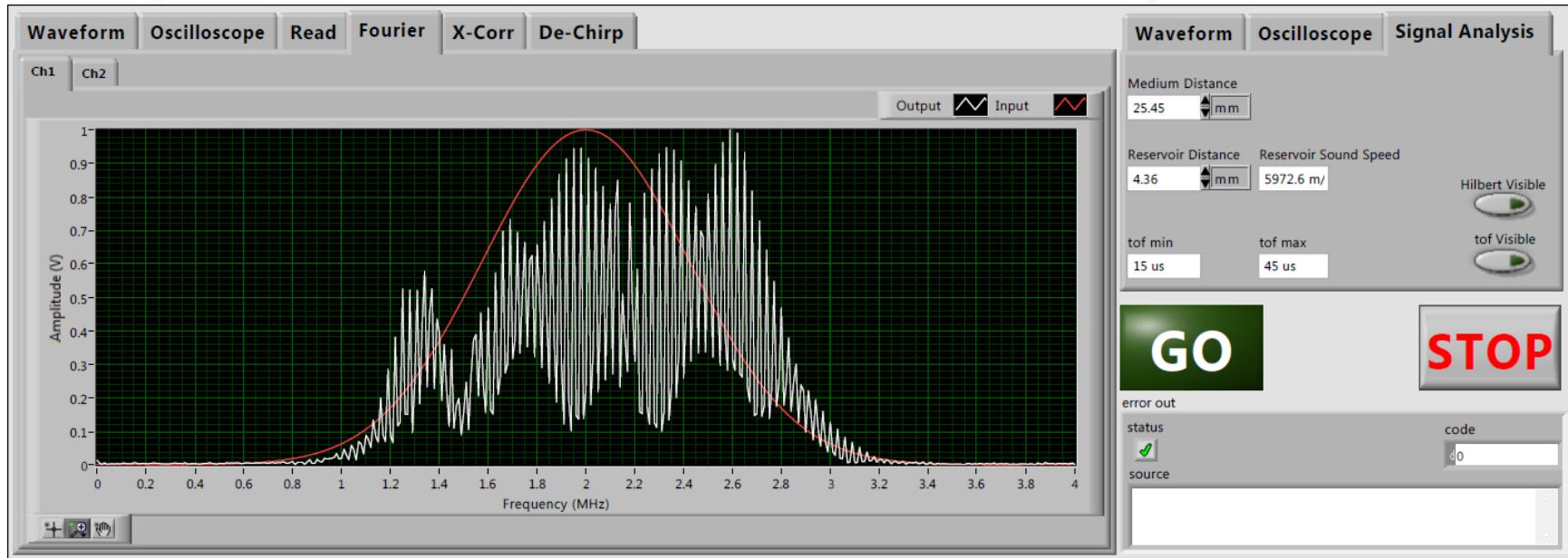


Figure 6: The frequency domain of the input is displayed in red while that of Ch1 is displayed in white.

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Data Analysis: Cross-Correlation



Figure 7: Cross-Correlation graph with time of flight window and Hilbert envelope, displaying the calculated sound speed as 1482.24 m/s. The medium is room-temperature water.

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Data Analysis: De-Chirp

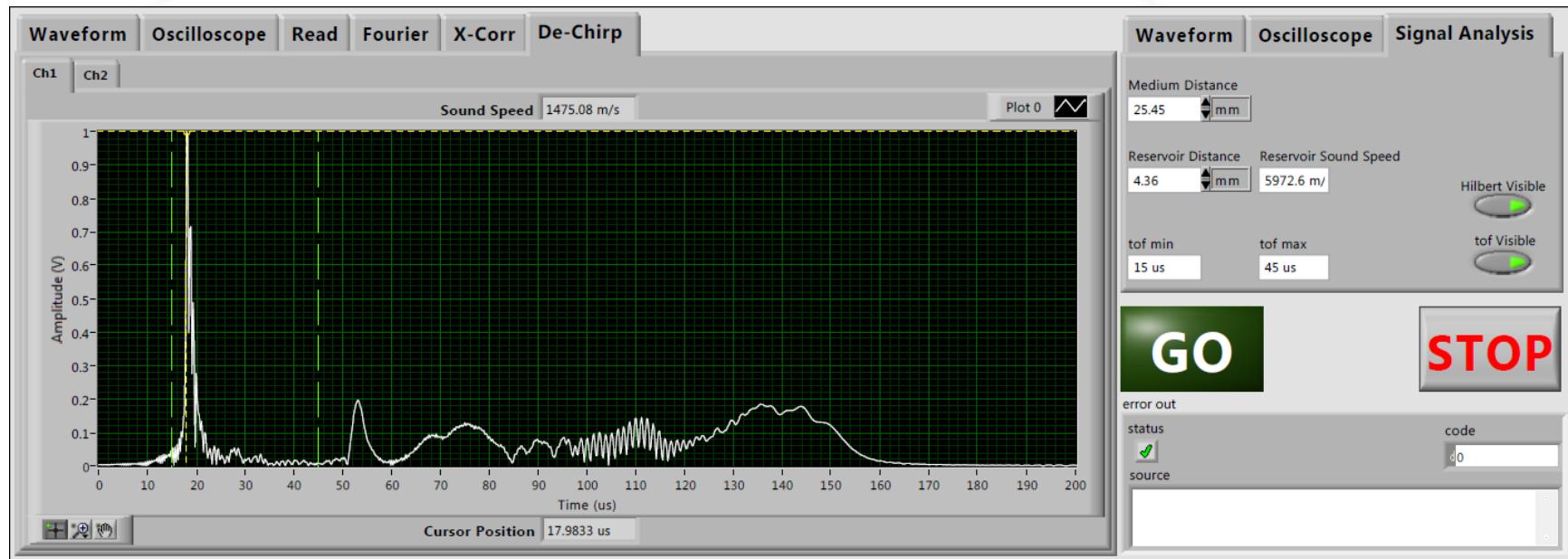


Figure 8: De-Chirp of a Linear Chirp. The Cross-Correlation method (not depicted) finds 1477.93 m/s while the De-Chirp gives 1475.08 m/s, showing the two methods are relatively consistent.

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Results

- Lubbers and Graff (1998) simplified temperature-dependent water sound-speed equation for temperatures of 15-35 C is:

$$c_w = 1404.3 + 4.7T - 0.04T^2$$

- Water measured at 21.3C using a thermocouple. Lubbers and Graff's equation predicts the sound-speed to be about 1486.26 m/s.

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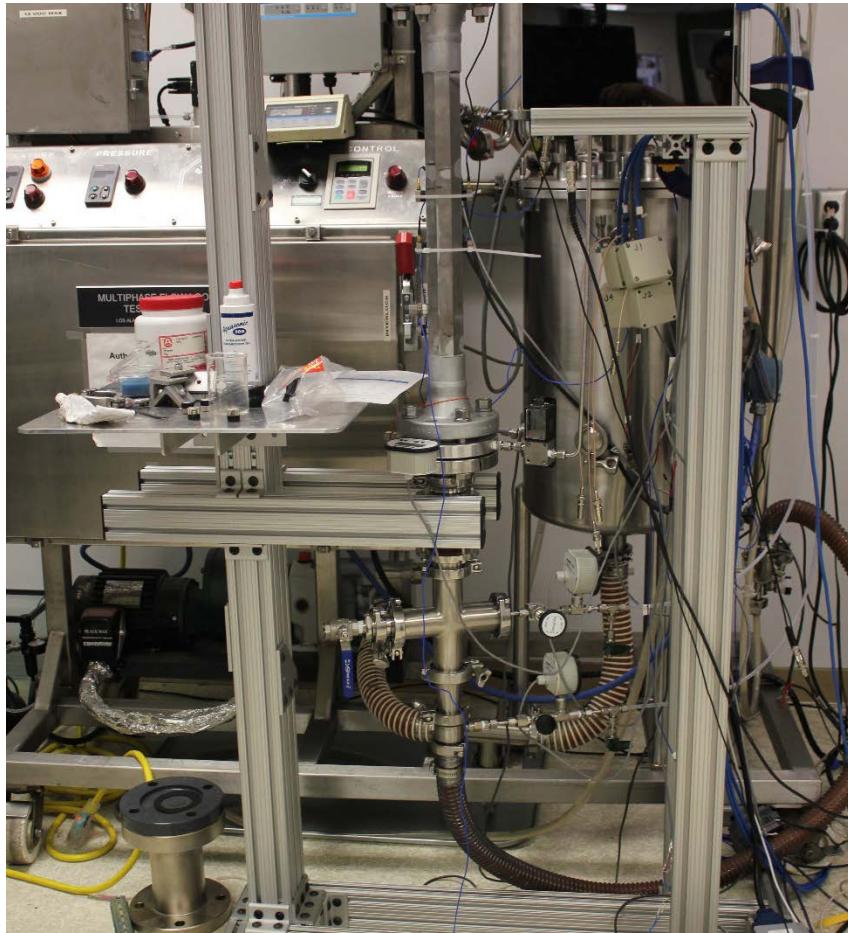
Results

- Gaussian Pulse
 - 1482.24 m/s
 - within 0.27% of the predicted value
- Linear Chirp
 - 1477.93 m/s and 1475.08 m/s
 - 0.56% and 0.75% of the predicted value, respectively.
- Measurements are precise and relatively accurate

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Applications



- Dynamic System: Flow Loop (left) to study of oil flow with gas bubbles or particles
- Determine deuterium concentration of heavy water using speed of sound measurements

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 - Vamshi Chillara
 - Eric Davis

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References

- J. Lubbers & R. Graaff (1998). A simple and accurate formula for the sound velocity in water, Ultrasound Med. Biol. Vol 24, No 7, pp 1065-1068.

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