ACoRNE Hardware Status Report: Generation of Bipolar Acoustic Pulses in Water

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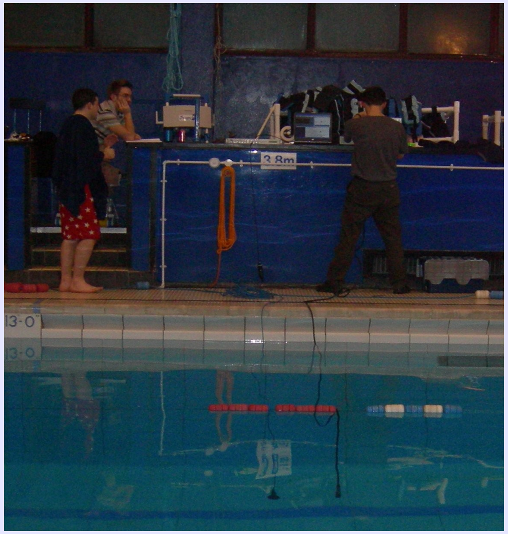
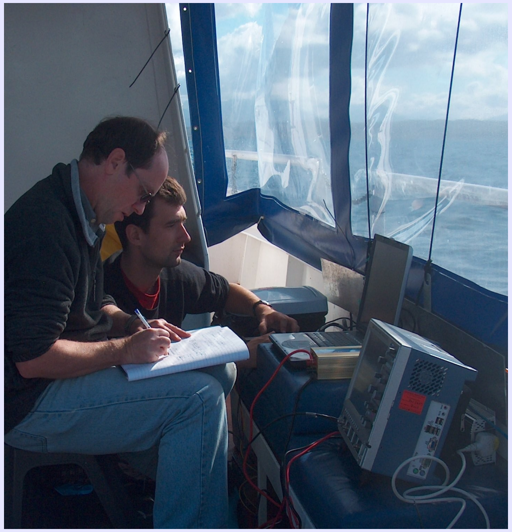
Outline

- Bipolar acoustic pulse generation – theory and practice
- Pool results
- Initial deployment
- Further work – possibilities

Introduction

- Have access to Rona hydrophone array
- To inject bipolar acoustic pulses in water – mimic neutrino shower generated signal
- Progression: lab tank – pool – open sea





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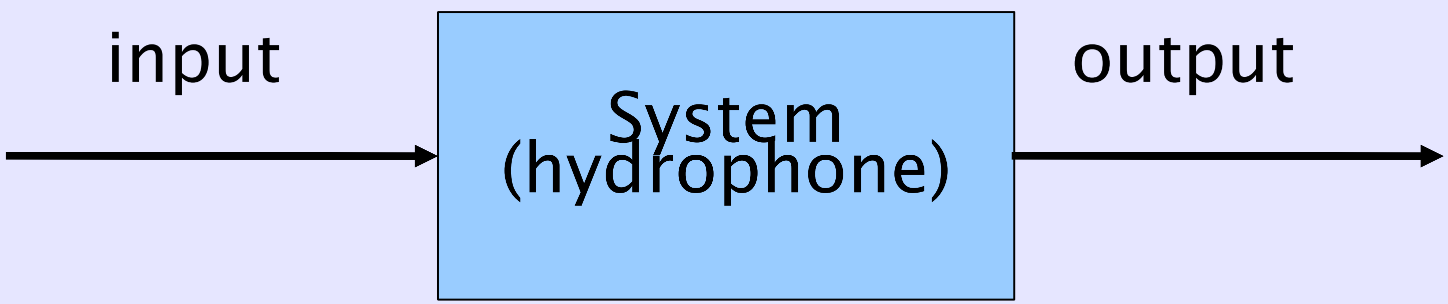
Introduction – signal generation

- Use signal processing techniques to deduce required hydrophone excitation signal that produces bipolar acoustic pulse



- Knowing system and its required output yields the required excitation pulse

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System modelling – convolution

- Convolution: a mathematical operator used to define an output (o/p) from any Linear Time Invariant (LTI) system in response to any input (i/p)

$$y(t) = x(t) * h(t)$$

y(t): o/p, x(t): i/p, *: convolution integral, h(t): impulse response

- Time domain is 'somewhat' complicated when considering more complex signals and systems
- Hence, calculate in frequency domain

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Modelling – Frequency domain

- An alternative method of describing LTI systems

$$Y(s) = X(s) \,.\, H(s)$$

- Resulting o/p converted to time domain using Inverse Fast Fourier Transform (IFFT)

$$y(t) = \mathrm{IFFT}(Y(s))$$

- Impulse response difficult to obtain, hence use step response

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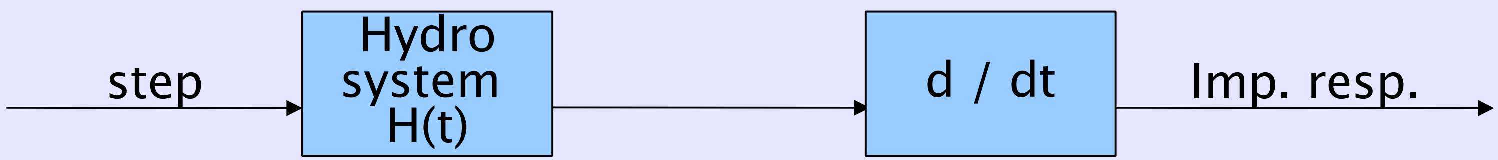
Modelling – Step response

- Impulse response difficult to get in practice
- Step response is time integral of impulse response and this can be exploited:



- Assuming that hydrophone is a LTI system:

- Deconvolution finds i/p for required o/p

System modelling – practice

- Practical implications:
  - Differentiating noise gives even noisier signals, hence require very clean input signal
  - Reflections in the tank produces incomplete step response
- Fit a transfer function (H(s)) to the step response in order to model the system

$$H(s) = Y(s) / X(s)$$

H(s): TF, Y(s): o/p Laplace tr., X(s): i/p Laplace tr.
H(s): also Laplace transform of impulse response h(t)

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From model to excitation pulse

- Differentiating Gaussian signal creates bipolar pulse (desired output)
- Deconvolution (in frequency domain) of this signal and modelled system function generates desired excitation pulse

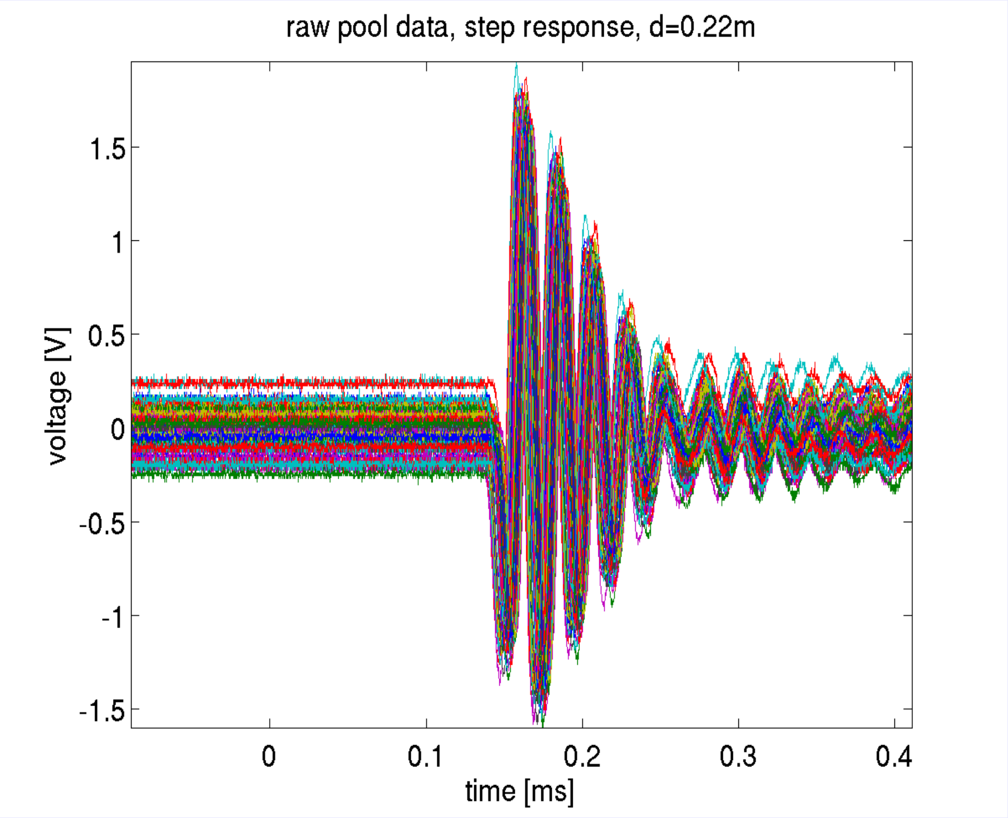
$$X(s) = Y(s) / H(s)$$

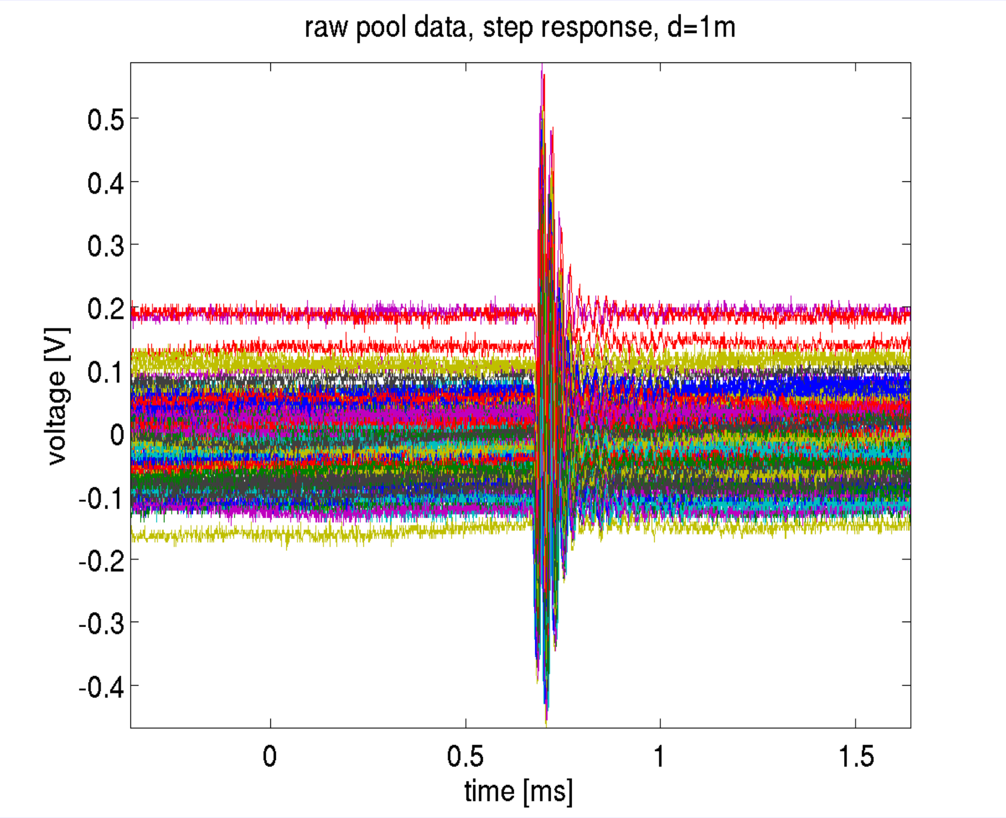
- Transform to time domain

$$x(t) = IFFT(X(s))$$

Pool – hydrophone modelling

- Hydrophone step response is recorded at various distances





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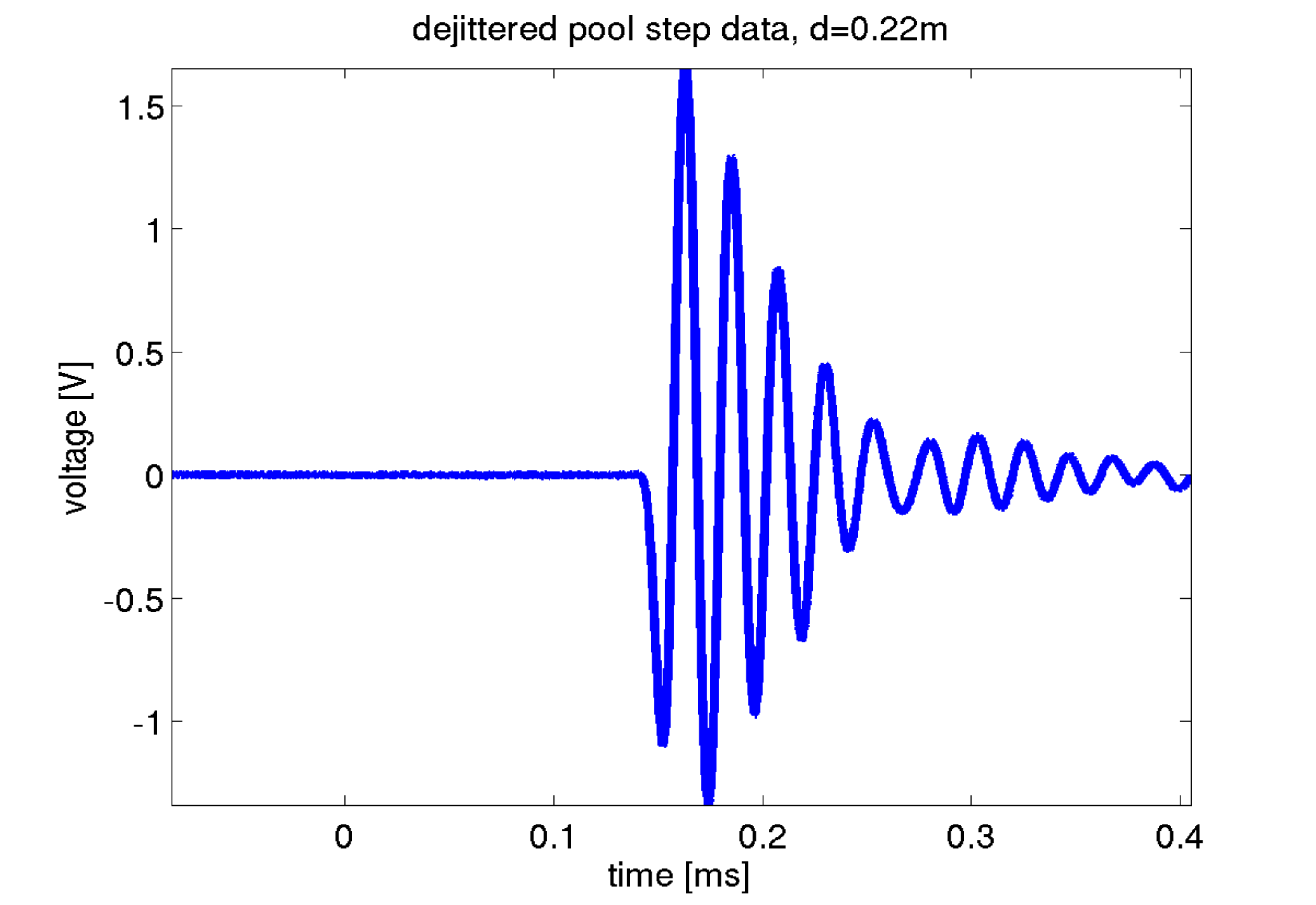
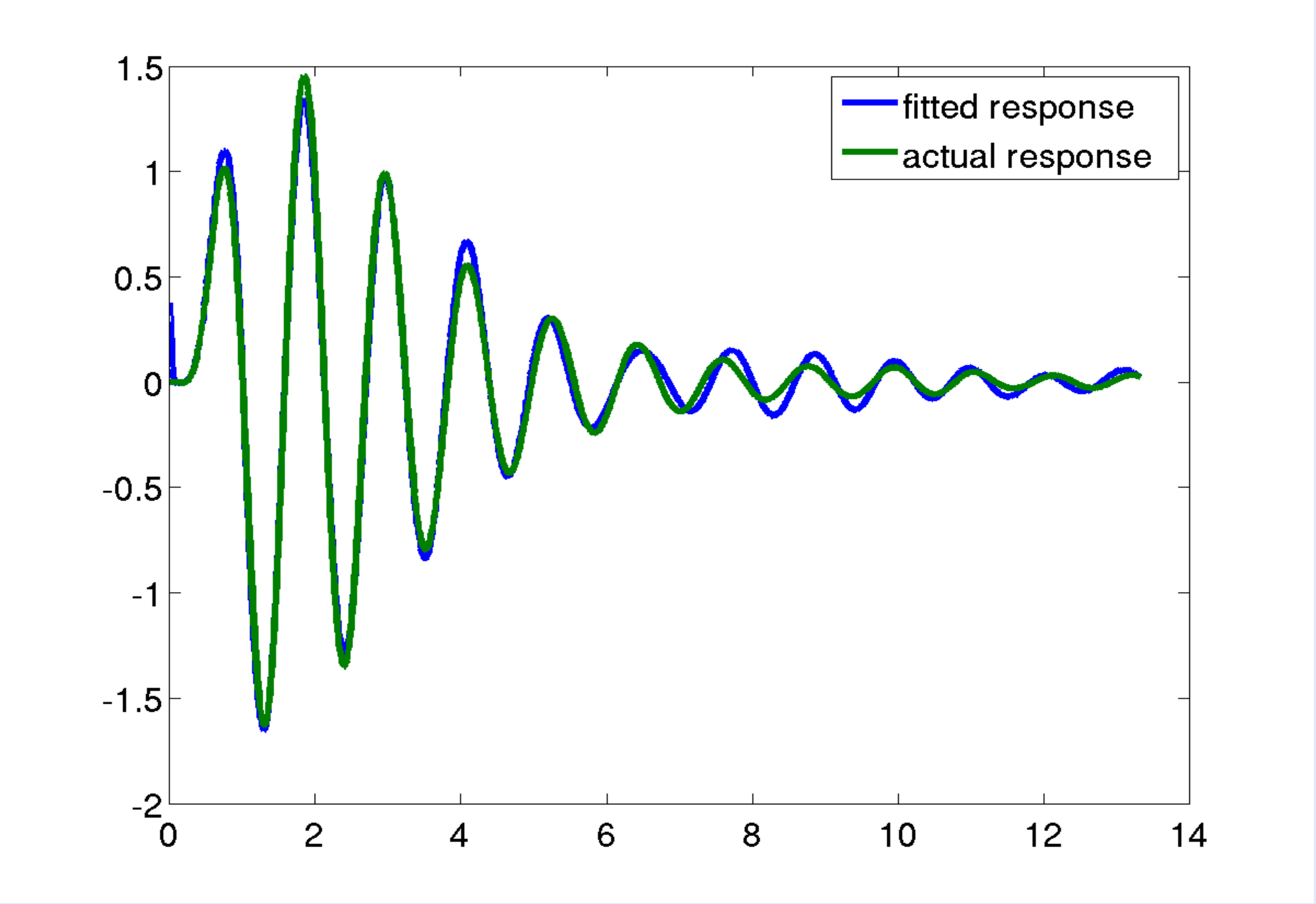
Data dejittering

- Signals combined into a common waveform



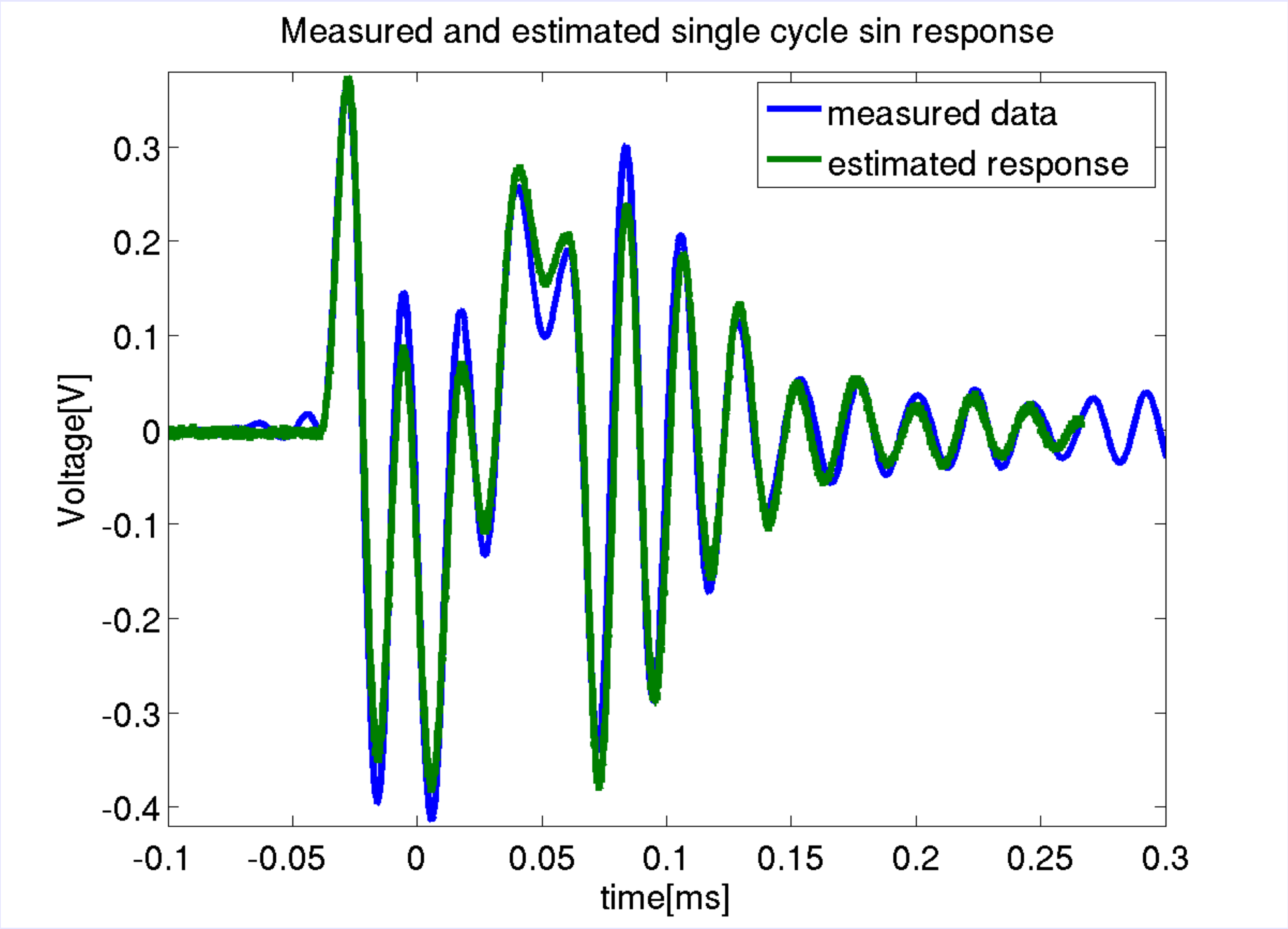
Hydrophone data fitting

- 5th order TF used to model hydrophone

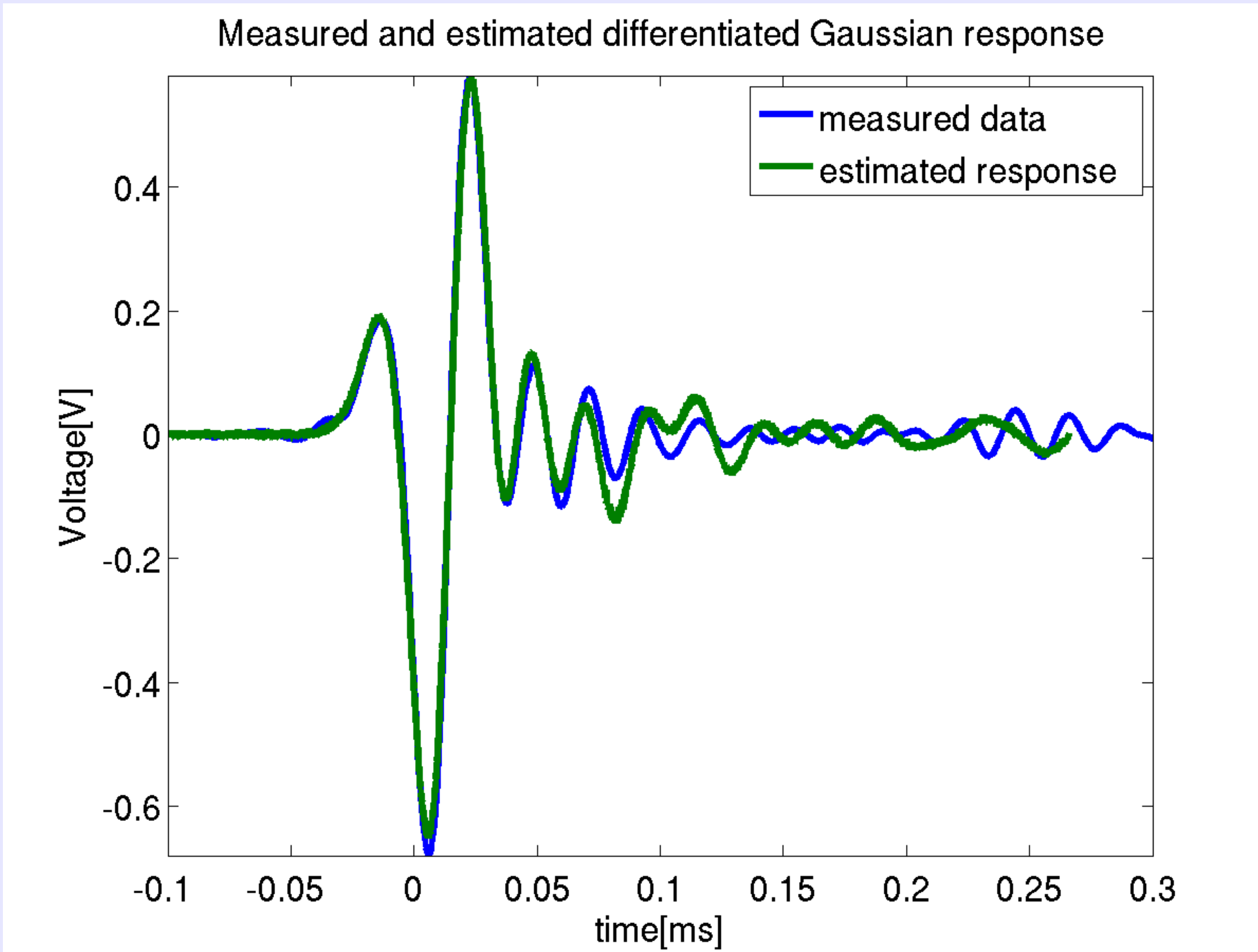


Estimated sinusoidal response

- Technique verification



Estimated differentiated Gaussian



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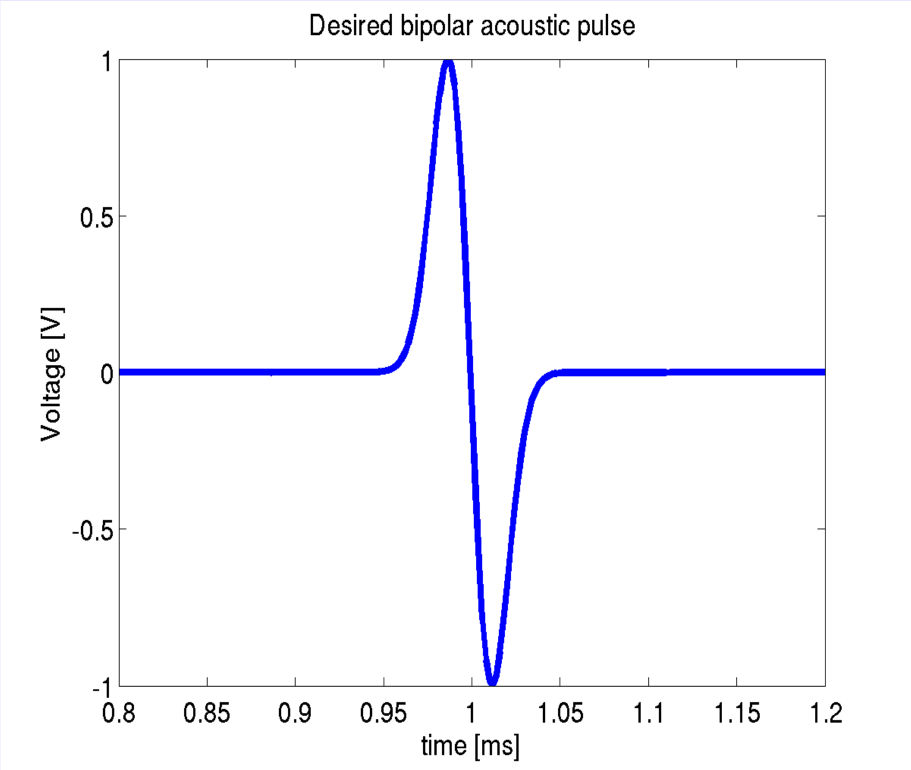
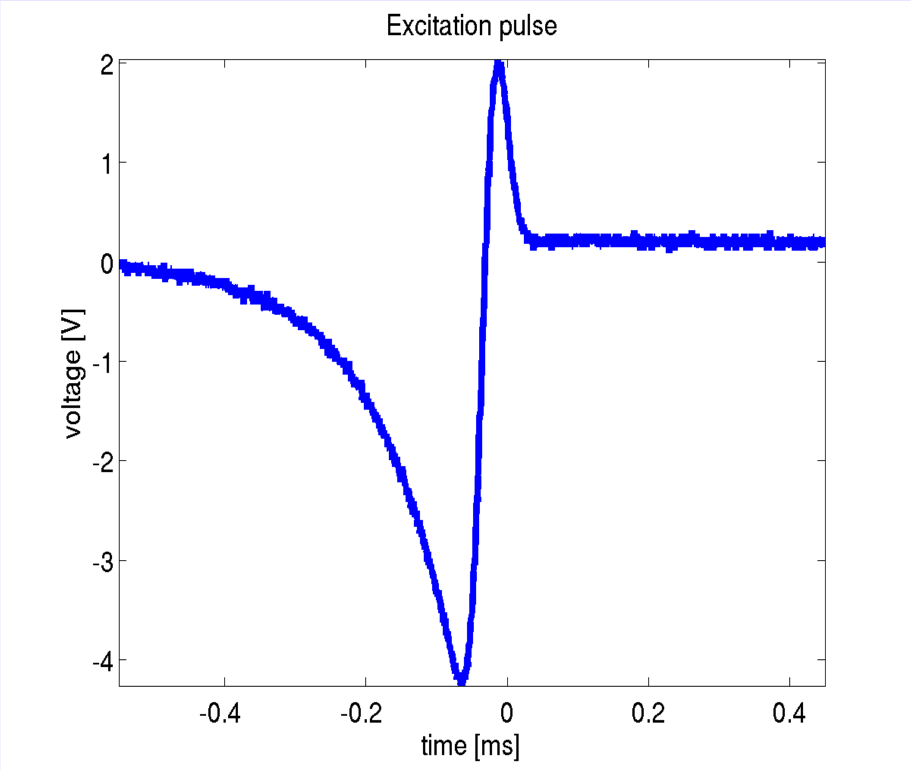
Excitation signal

- Desired acoustic pulse and the estimated hydrophone driving electrical signal





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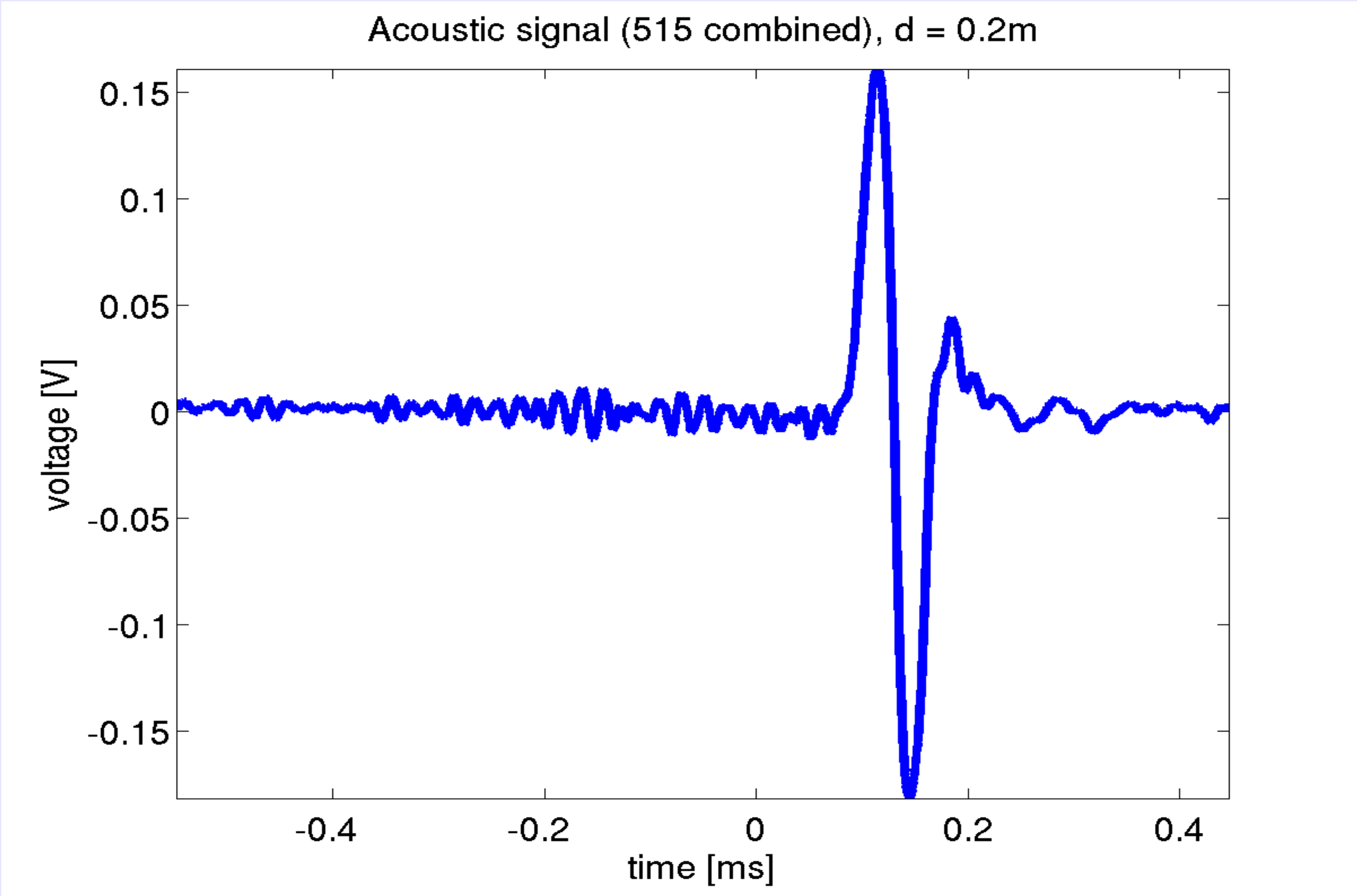
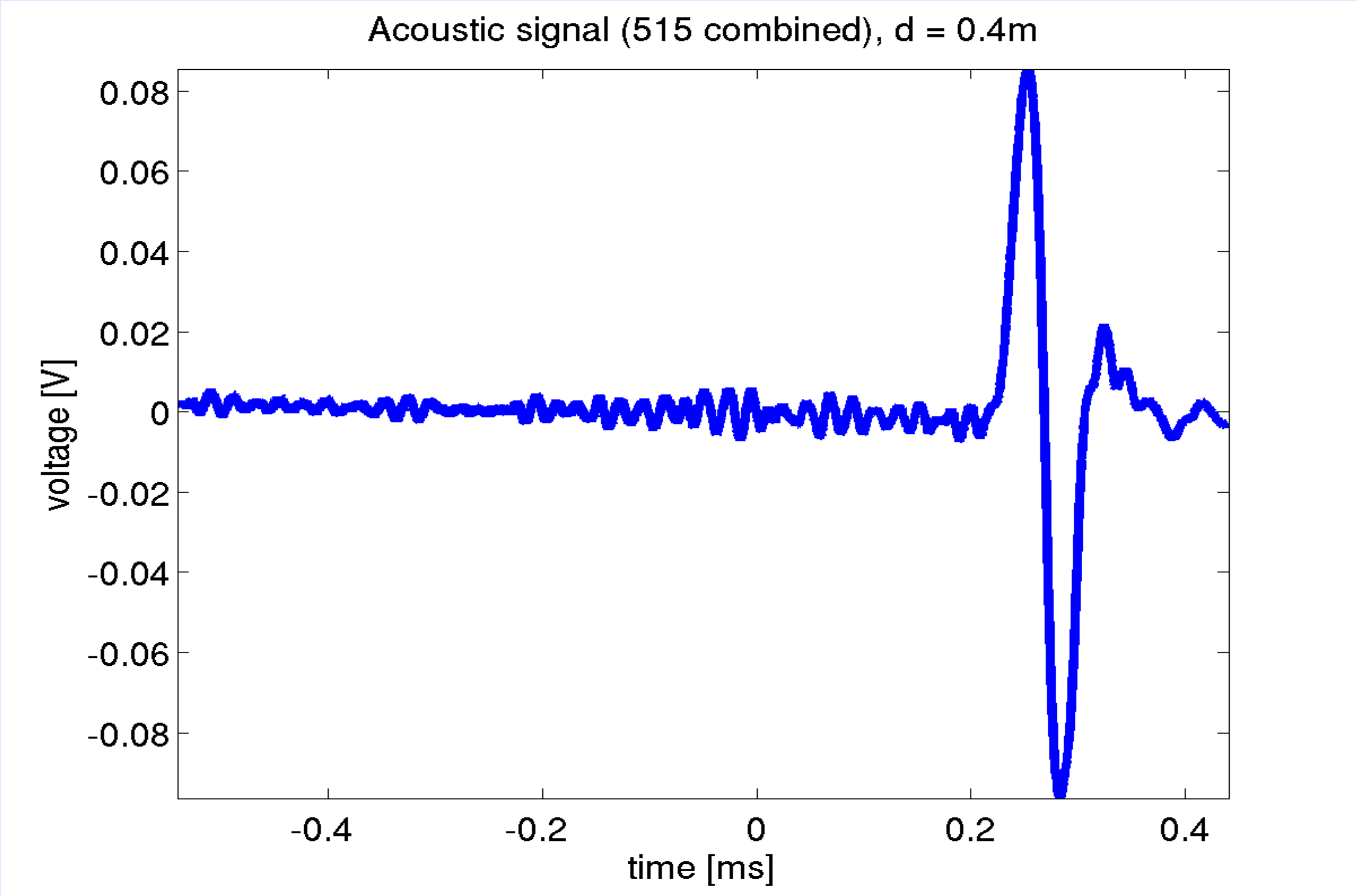
Pool results

- Measured bipolar acoustic pulse

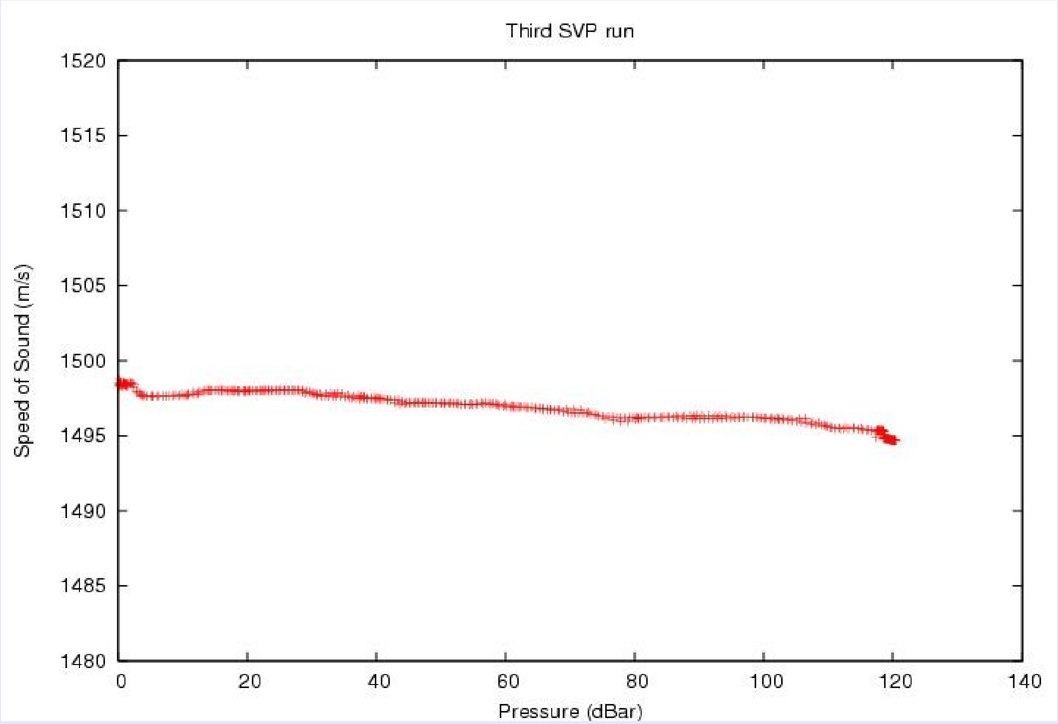


Pool results (...cont)



Rona – deployment

- Bipolar acoustic pulses introduced 20m below the surface
- Expecting data analysis results
- Sound Velocity Profile (SVP) measurements



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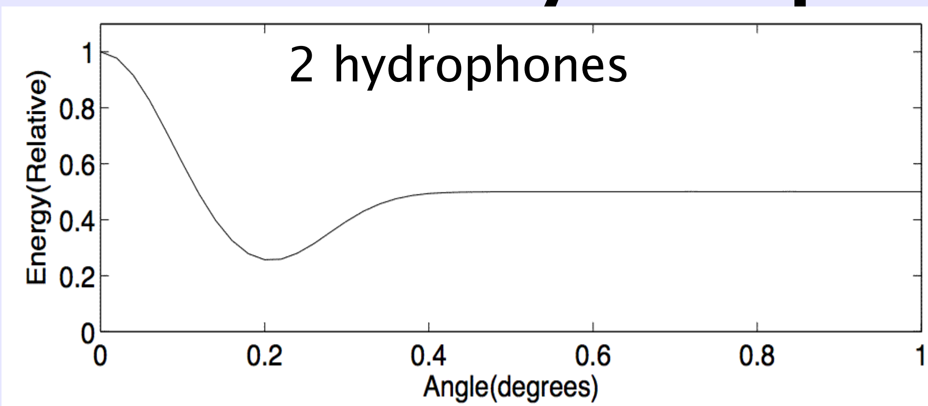
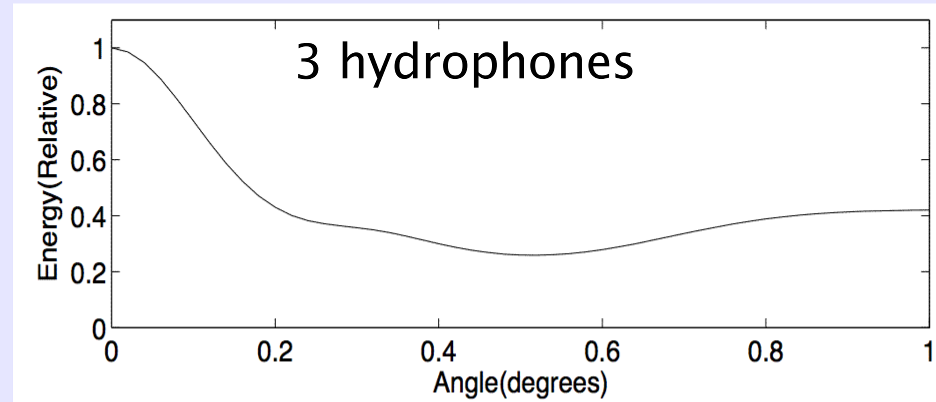
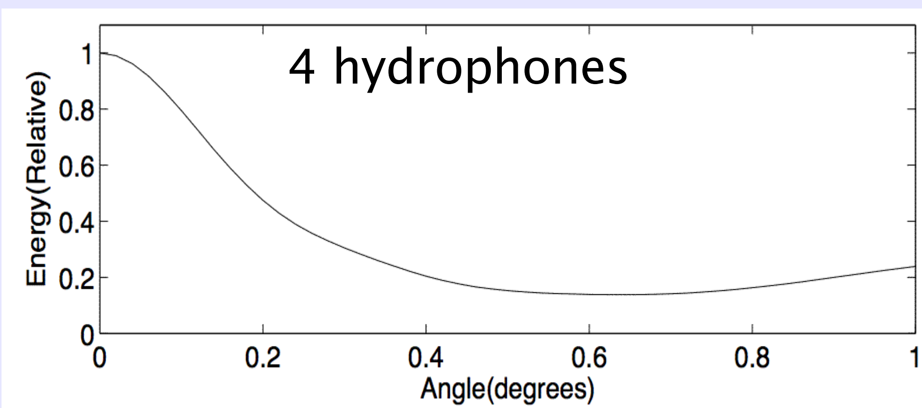
Future work

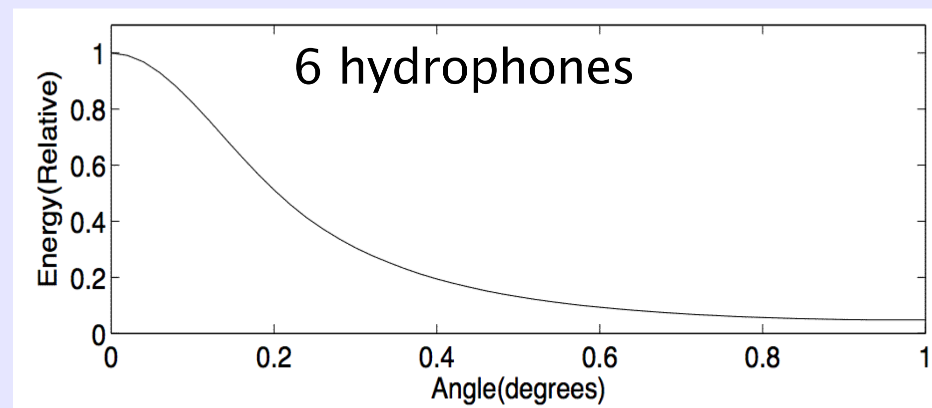
- Repeat Rona deployment at different sea state and over different hydrophones
- All previous work done using an omnidirectional hydrophone
- An array development using 6 – 10 hydrophones
- Line array – acoustic pancake?
  - Fully autonomous for great depths
  - Surface deployment => PA, easy DAQ

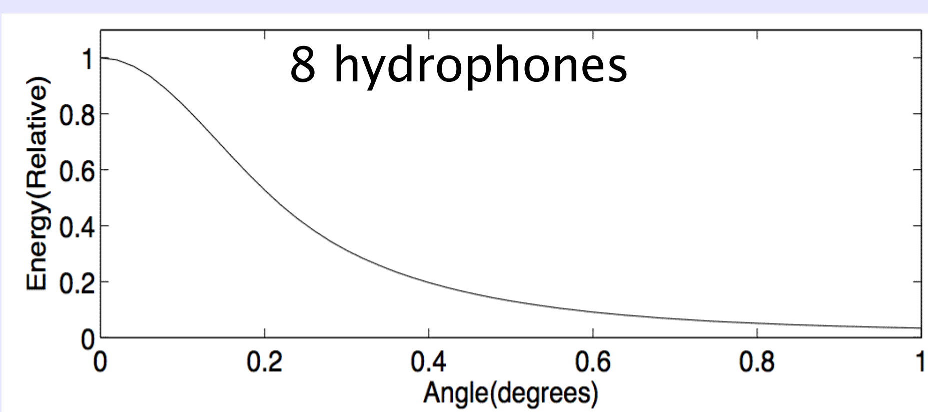
Hydrophone count

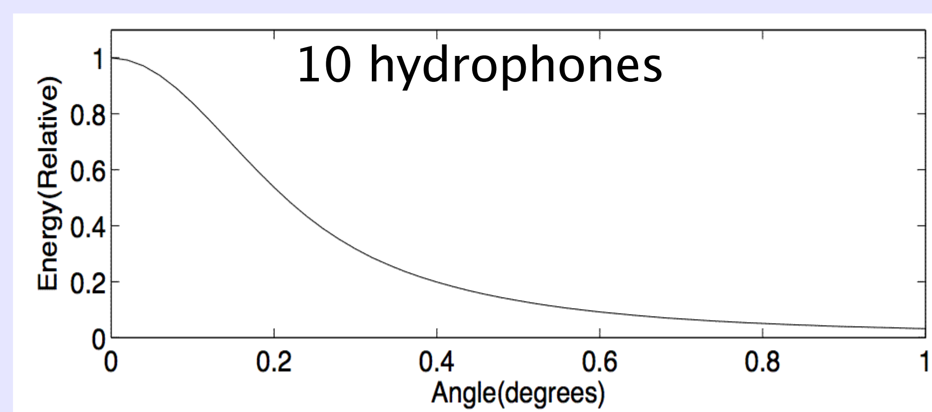












Conclusions

- Successfully modelled hydrophone
- The bipolar acoustic pulses generated in the pool
- Awaiting for the analysis of the Rona data
- Looking into developing an array

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Thank you

Questions ?

http://pppa.group.shef.ac.uk/acorne.php