“Airguns: what we know and what we don’t know”

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Version 1.1: 04/Mar/2007

An underlying theme

Airguns are a lot simpler to understand than the acoustic response and resulting behaviour of marine life.

Notes

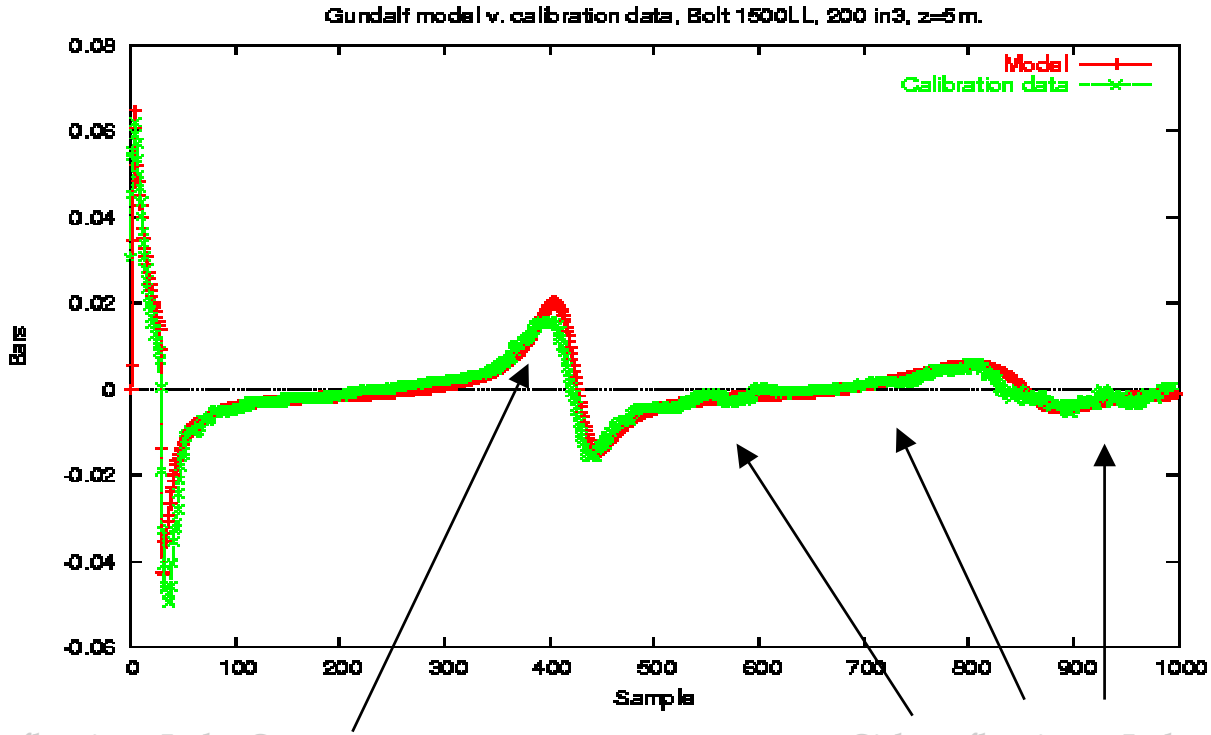
- **Airguns**
  - What we know
  - What we don’t know
- **Mitigation in seismic airgun surveys**

Airguns – what we know

- **Basics**
  - Very reliable
  - Repeatable
  - Nearly all seismic data acquired by them and they are typically excellent in the exploration seismic band (5-100Hz).
  - Modelling quality in time-domain is excellent.

*Calibration example: Bolt 8500 APG**

- 200 cu.in gun, Lake Seneca data (green), Model in red



Water bottom reflection, Lake Seneca

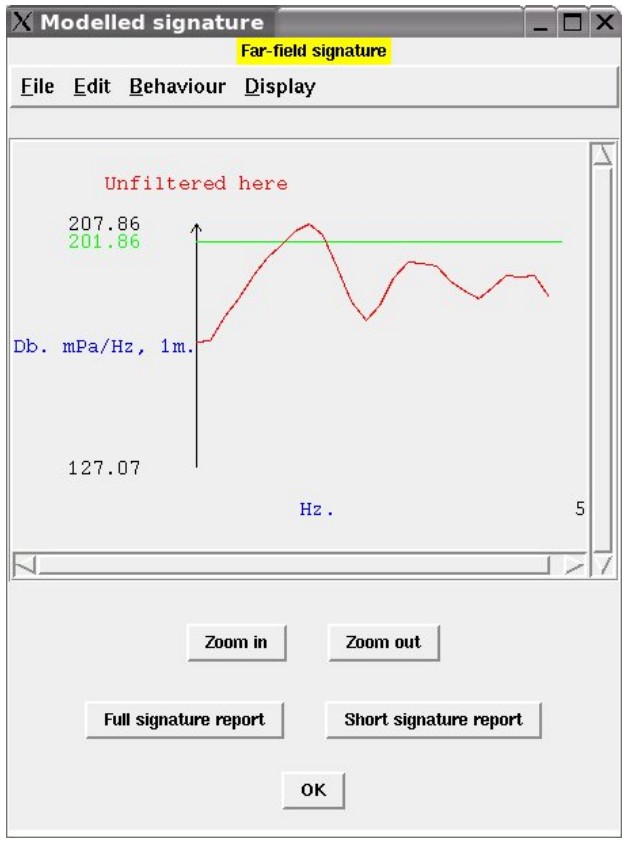
Side reflections, Lake Seneca

Airguns – what we know

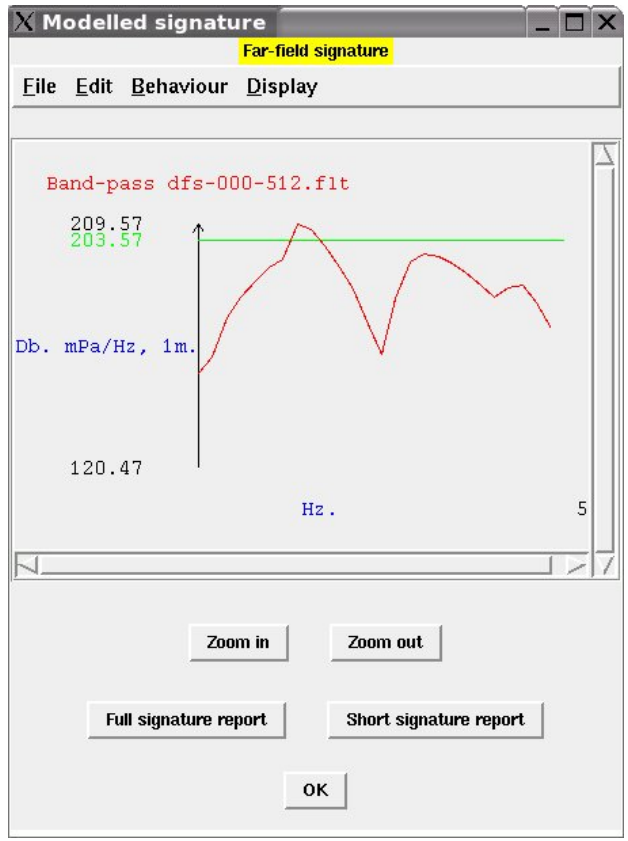
- **Quality of measurements so far**
  - Low frequencies
    - Reasonable quantity of good measurements for single guns and clusters deployed between 2m and 30m for volumes 0.3 – 7 litres (10-500 cu.in.) at normal operating pressure of 2000 psi (138 bar, 13.8 MPa) for 5-500Hz, (sometimes 1kHz).
    - Measurement quality around 10% on critical parameters due to hydrophone calibration, wavy sea surface, analog -> digital filter inaccuracies and other uncertainties but in general pretty good.
  - High frequencies
    - Only 1 dataset, (IFRC 2003), 5 – 25,000 Hz.

Airguns – model quality low frequencies

Measurement in calibration facility

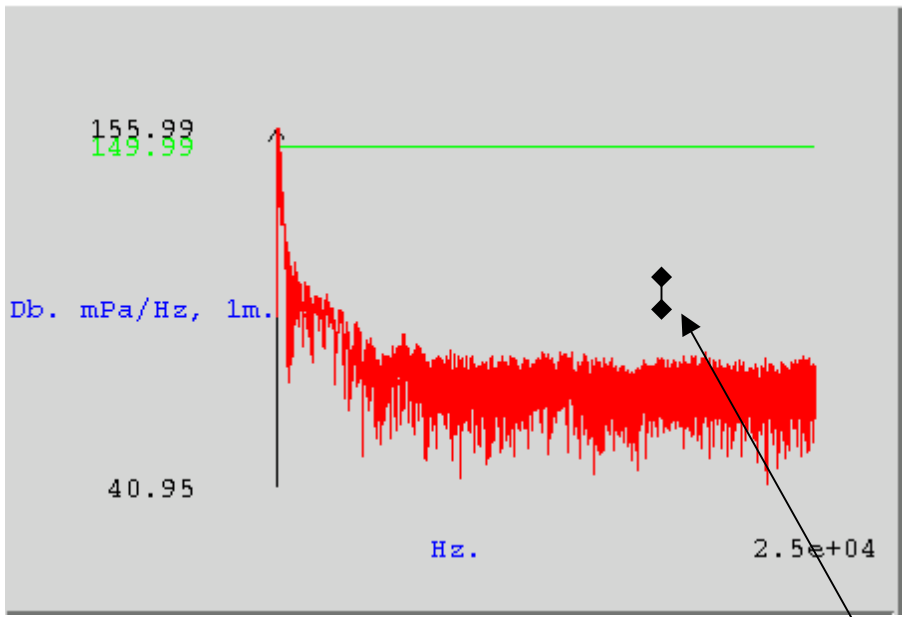


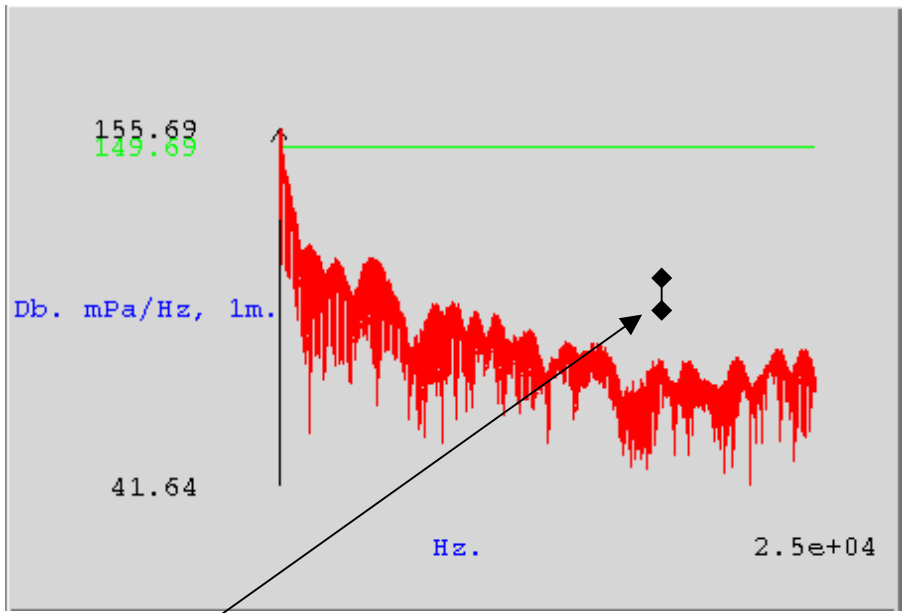
Model



Airguns – model quality high frequencies

Comparison against IFRC data





Data: hydrophone at 739m

Model: 4^0 offset, gun jitter 0.0005ms

18kHz Depth Transponder

Environmental concerns: High-frequency calibration

Comparison against IFRC data, (Fontana 2004)

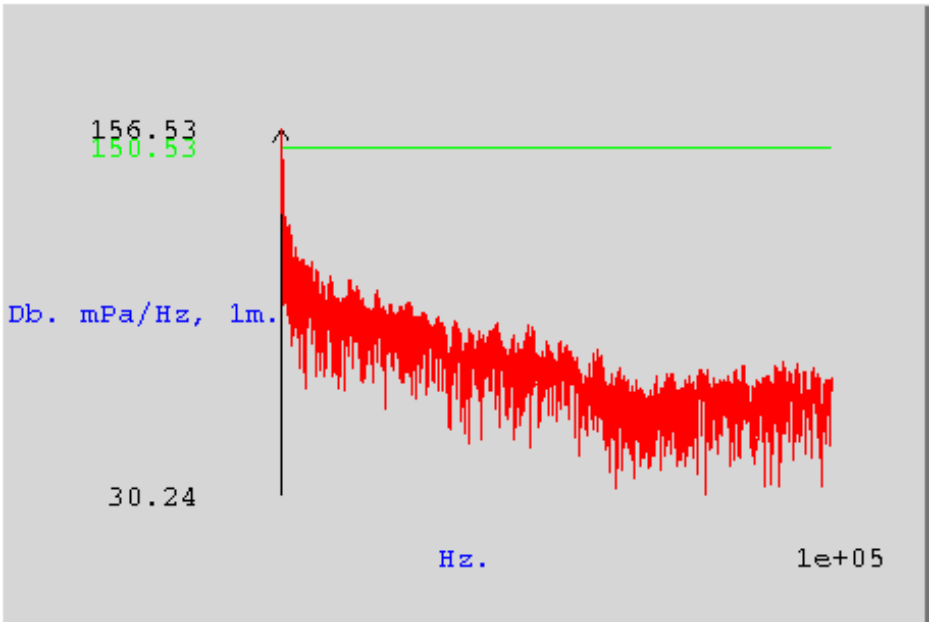
Source	Amplitude spectral value at 18kHz. db ref 1mPa/Hz at 1m.
Depth transponder	**95.57**
Measured 3590 cu.in array	**74.0 +/- 3.0**
Modelled 3590 cu.in array	**76.7 +/- 3.0**

Airguns – what we don't know

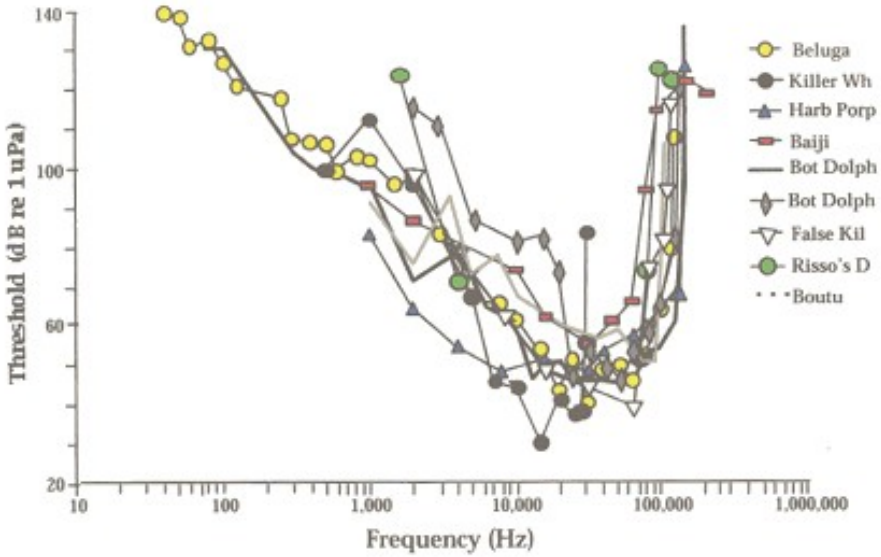
- **Spectral behaviour**
  - Detailed behaviour with direction in range 1kHz – 25kHz.
  - Anything above 25kHz.
- **Details of absorption at sea surface**

Environmental concerns: Implementation

Modelling out to 100kHz.



Audiogram data



Surface Reflection

The shot effect in practice. The bubble of the far airgun can clearly be seen under the water unattached to the disturbance at the surface.

Airguns – source characterisation and modelling

- **Modelling pretty good in seismic band, probably reasonable up to 25kHz and unknown above.**
- **Early investigations of anelastic response at sea surface suggest that energy loss can be as much as 46% over model prediction for typical shallow deployments**

  http://www.leshatton.org/Documents/anelastic.pdf

Notes

- **Airguns**
- **Mitigation in seismic airgun surveys**
  - Directivity
  - Overshooting

Mitigation

- **Directivity**
  - Energy still goes somewhere, nothing is lost.
- **Overshooting**
  - It is my personal belief that seismic arrays may sometimes be over-powered for the acoustic illumination they have to provide. This needs quantifying.

To mitigate properly however, we have to understand how marine life responds to sound. This appears to be much more poorly understood.

Acknowledgements

- The IFRC for kindly giving permission to use their high frequency dataset
- Bolt for the airgun signature data
- The models were run with Gundalf v. 5.1i