NTNU
Norwegian University of
Science and Technology

High frequency signals from airguns

Daniel Barker, Martin Landrø and Audun Sødal

Department for Petroleum Engineering and Applied Geophysics

Background

The use of air guns as seismic sources has been an issue of several debates regarding possible damage done to fish and marine mammals.

Especially interesting is the high-frequency content of the signals.

Questions:

- What is the cause of the high-frequency content?
- Can anything be done to reduce it?

Possible causes

- Solenoid (known)
- Cavitations
- Mechanical - piston
- Mechanical - rig

Solenoid signal

This is a signal appearing before the main pulse, which is believed to be caused by the action of the solenoid and shuttle mechanism triggering within the gun when firing.

Cavitations

Cavitations are vapour bubbles of a flowing liquid in a region where the pressure of the liquid falls below its vapor pressure.
When cavities collapse, they send out a high-frequency signal.
Rayleigh (Rayleigh (1917)) calculated that the collapse time of a cavitation is approximately

$$\tau = 0.91468 R_0 \sqrt{\frac{\rho}{P}}.$$

For reference: A cavity with radius 1 mm at 12 m depth, will collapse in about 0.062 ms.

Mechanical

The sudden stop motion of the piston inside the air gun could cause a high frequency signal.

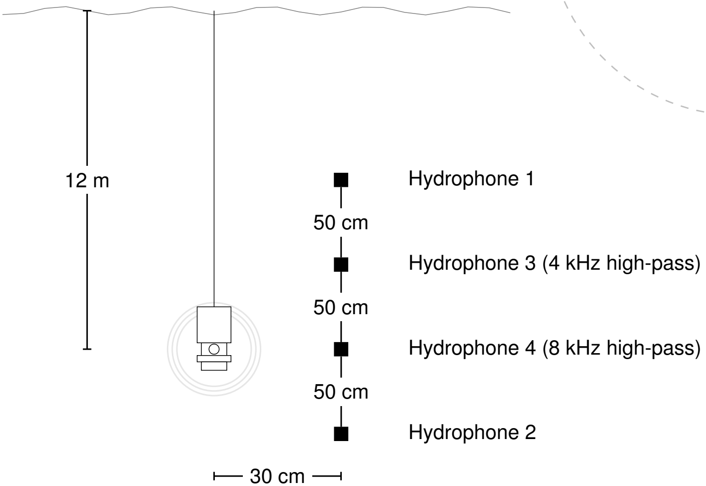
In the event of a signal created by this we would expect a strong spike followed by weaker “ringing” oscillations (Richards et al. (1979)). The estimated time until the start of this signal could be estimated in a similar way as by Landrø et al. (1993).

Modelling implies that the increasing the volume decreases the port-opening time slightly.

Objective

Try to shed some light on the problem by looking at the high-frequency content of airguns for differing sizes (5 and 10 cu.in.).

Experimental setup



Sample recording

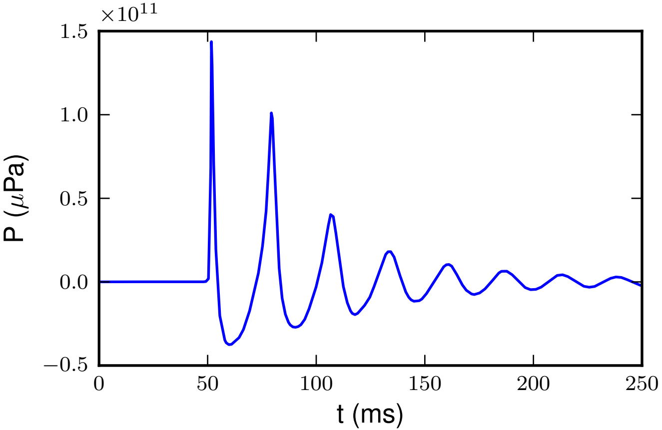


Figure: 10 cu.in. shot, hydrophone 2 (normalised to 1 m)

Sample recording

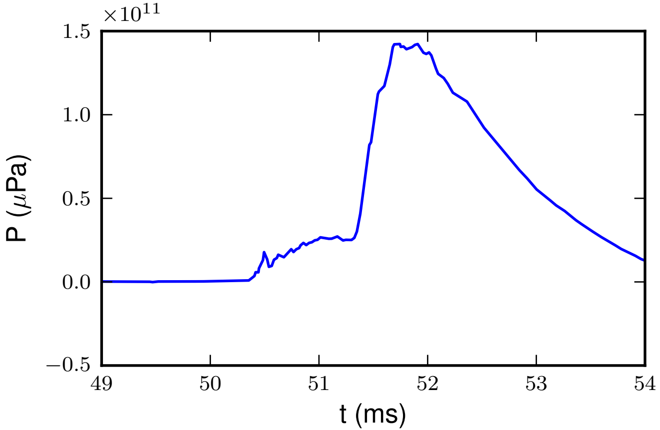


Figure: 10 cu.in. shot, hydrophone 2 (normalised to 1 m)

Sample recording

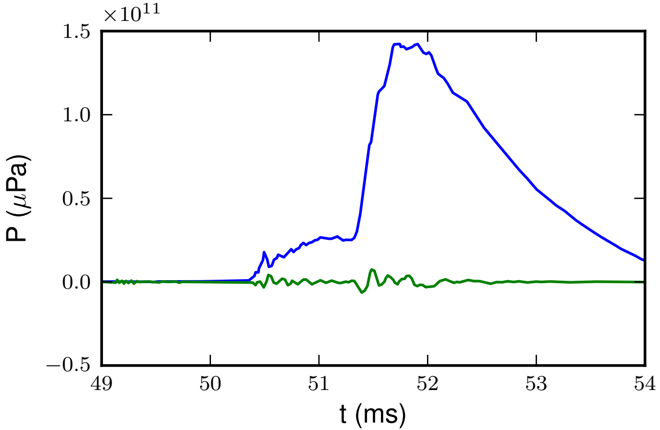


Figure: 10 cu.in., hydrophone 2 and 3 (normalised to 1 m)

Sample recording

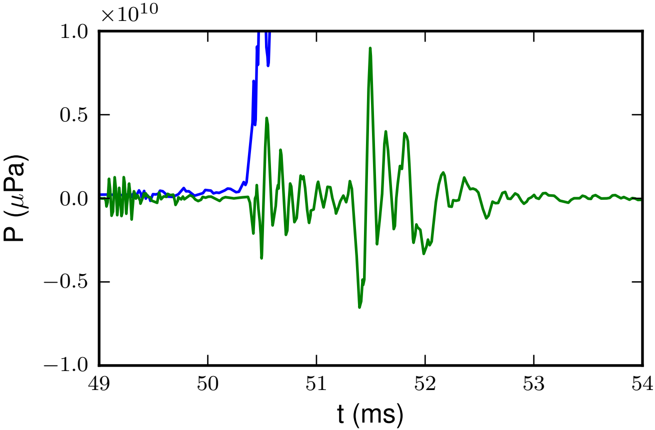


Figure: 10 cu.in. shot, hydrophone 2 and 3 (normalised to 1 m)

Sample recording

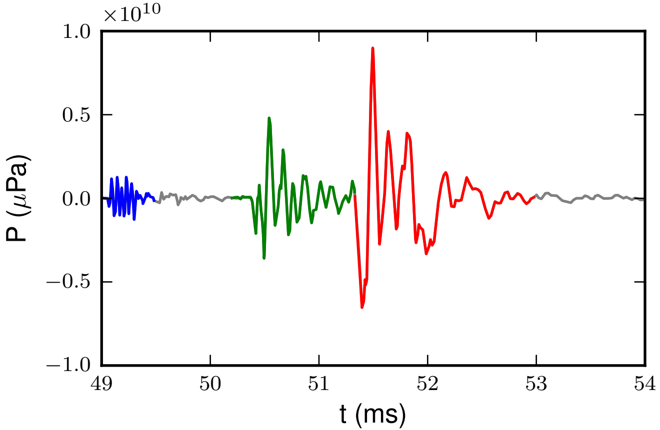
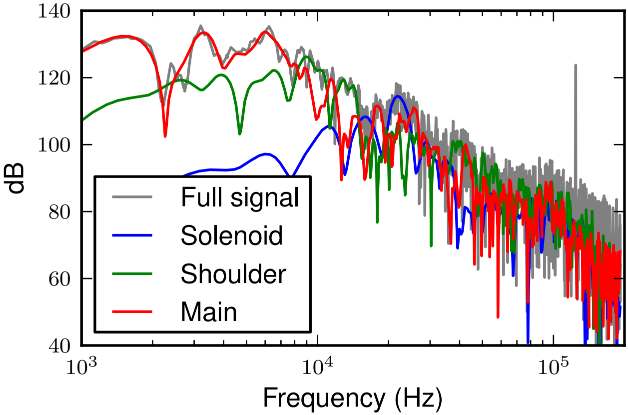


Figure: 10 cu.in. shot, hydrophone 3

Frequency spectrum



Frequency spectrum

The solenoid signal seems to be responsible for a peak at around 22 kHz.
The lower high-frequencies seem to originate from the main signal.

Why is the shoulder there

It seems logical that the shoulder part of the signal comes from the buildup of the air bubble after the gun has fired, but before the bubble has evolved to being “spherical”.

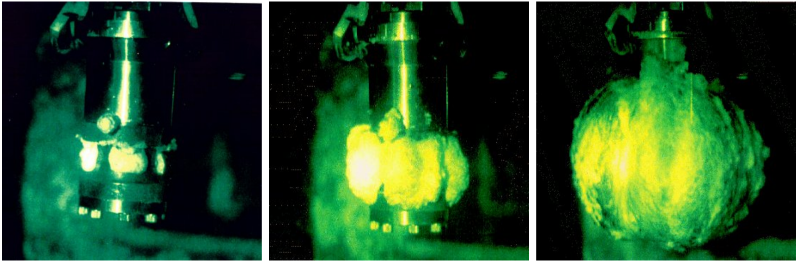


Figure: From Langhammer (1994)

Effects of volume

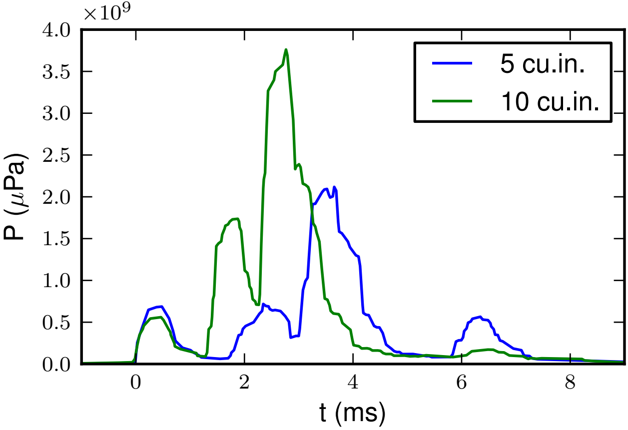


Figure: RMS values of signal, calculated with a window width of 0.5 ms

The 6 ms anomaly

An anomaly is observed at about 6 ms after the solenoid signal for the 5 cu.in. shots. While traces of this can be seen for 10 cu.in. shots, it is much weaker there.

- Why is it weaker?
- Why is it happening at that specific time?

More data is needed to determine the cause/importance of this effect.

Cavitation or mechanical noise?

A cavitational origin of the high-frequency sounds could be explained as following.

— As the gun is fired, movement of the piston creates a fast flow of water away from the gun, as it makes room for the piston and air, creating the signals appearing at the same time as the shoulder.

— As the seperate bubbles (from each port) are merged, the water between them is moved away, creating the stronger parts of the high-frequent signal.

Modelling of cavitations indicate that an appropriate size would be less than 1 mm. This seems plausible (Landrø et al. (1993)).

Cavitation or mechanical noise?

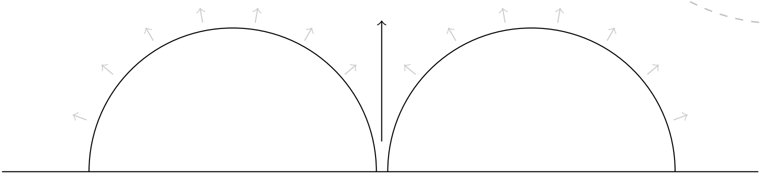


Figure: High-velocity flow created by the merging of seperate bubbles

Cavitation or mechanical noise?

A mechanical origin of the high-frequency sounds could be explained by the impact of stopping the piston.
The greater signal is not explained by this, indicating that the piston does not seem to be responsible for the high-frequent noise in this case.

Possible consequences

In the case of cavitations we would expect:

- APG-guns to create a weaker signal, due to nicer geometry.
- Possibly a high-frequent signal from clusters when the bubbles merge.

Reduction?

If the cause of the high-frequent signal is the creation of cavitation during the bubbles first expansion phase, the most effective way of reducing it would probably be a change of the geometry of the gun.

Acknowledgements

— PGS

References I

Landrø, M., Zaalberg-Metselaar, G., Owren, B., and Vaage, S. [1993] Modeling of water-gun signatures. *Geophysics*, **58**(1), 101–109.

Langhammer, J. [1994] Experimental studies of energy loss mechanisms in airgun bubble dynamics.

Rayleigh, O. [1917] On the pressure developed in a liquid during the collapse of a spherical cavity. *Philosophical Magazine*, **34**, 94–98.

Richards, E., Westcott, M., and Jeyapalan, R. [1979] On the prediction of impact noise, i: Acceleration noise. *Journal of Sound and Vibration*, **62**(4), 547 – 575.