What's in this section?

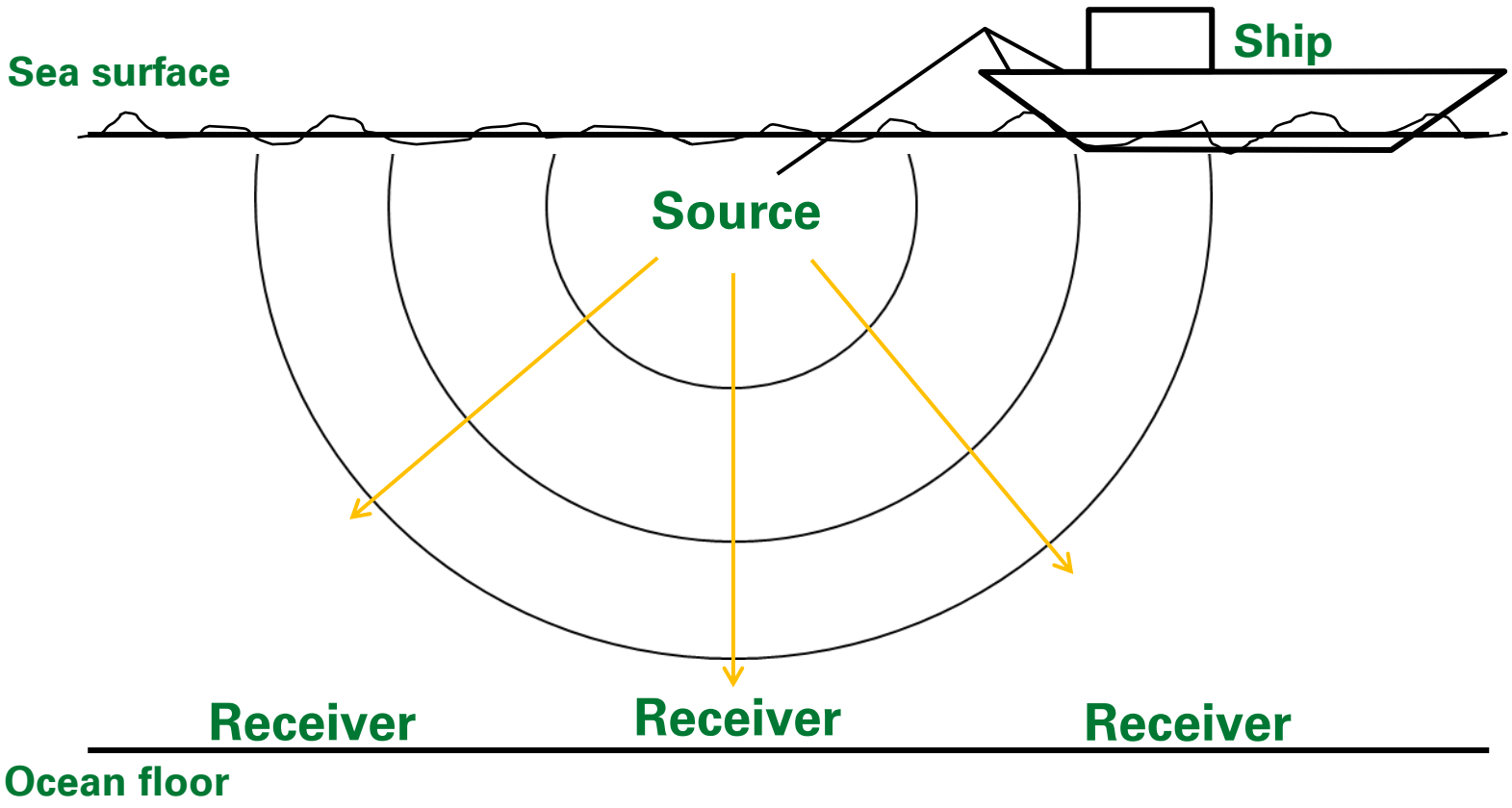
- **Looking at the properties of airguns as sources**
  slides 13-21
- **Real-life complications**
  slides 22-24
- **How to process airgun data back to a source signature**
  slides 25-33

- **The math behind the SEG dB standard**
  Supplementary material; can be skipped.
  slides 34-46

Part 1: Examining Sources

Theory: How it's supposed to work….

Acquisition at sea using airgun sources into ocean-bottom nodes



Acquisition at sea into streamers



Reproduced from Dragoset, 2005, TLE

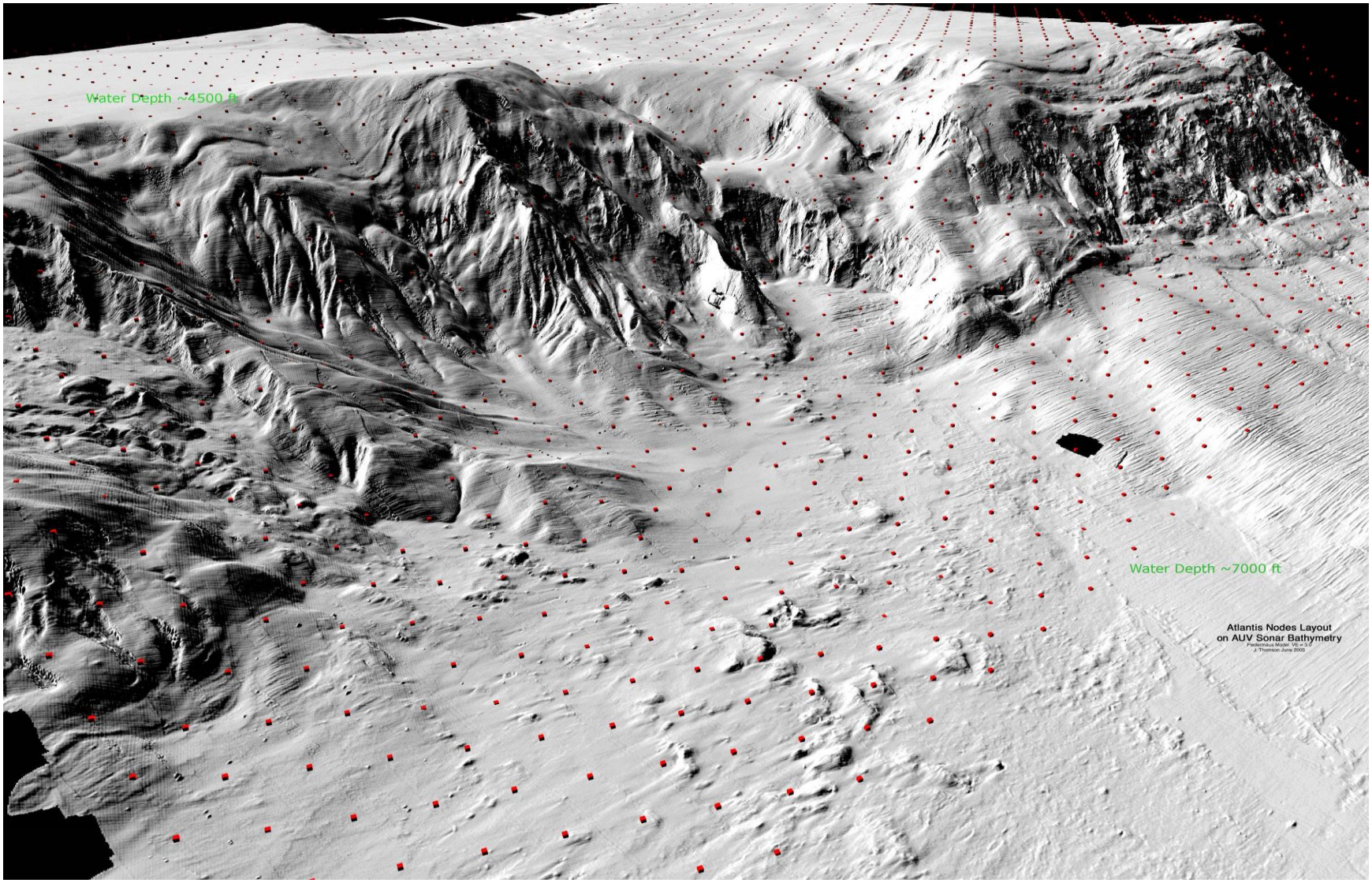
What is an airgun?

Courtesy CGG



BP photo

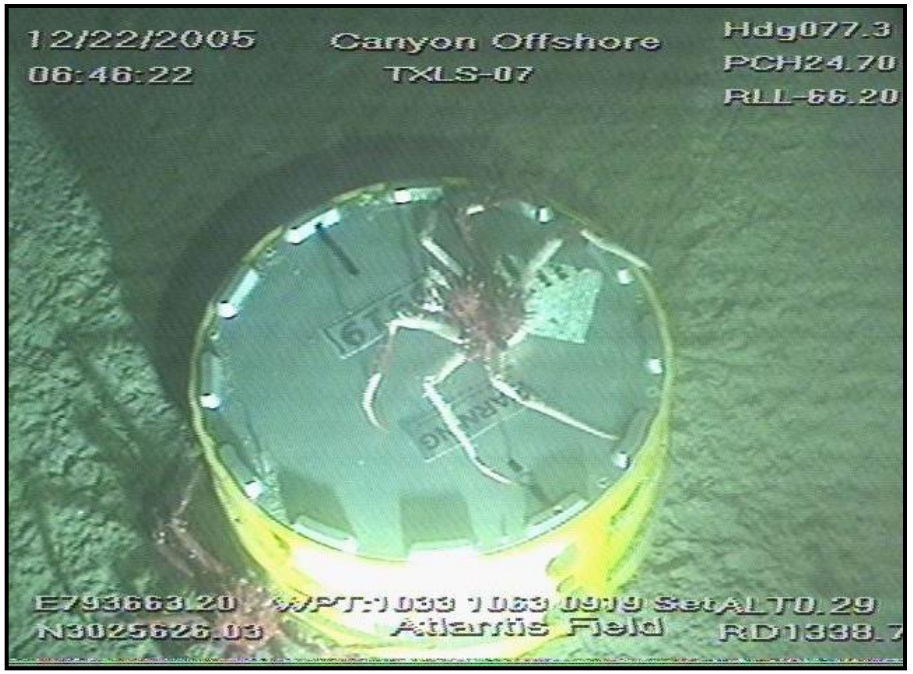
Atlantis ocean-bottom node array



Atlantis 2006

What an ocean-bottom node (OBN) looks like

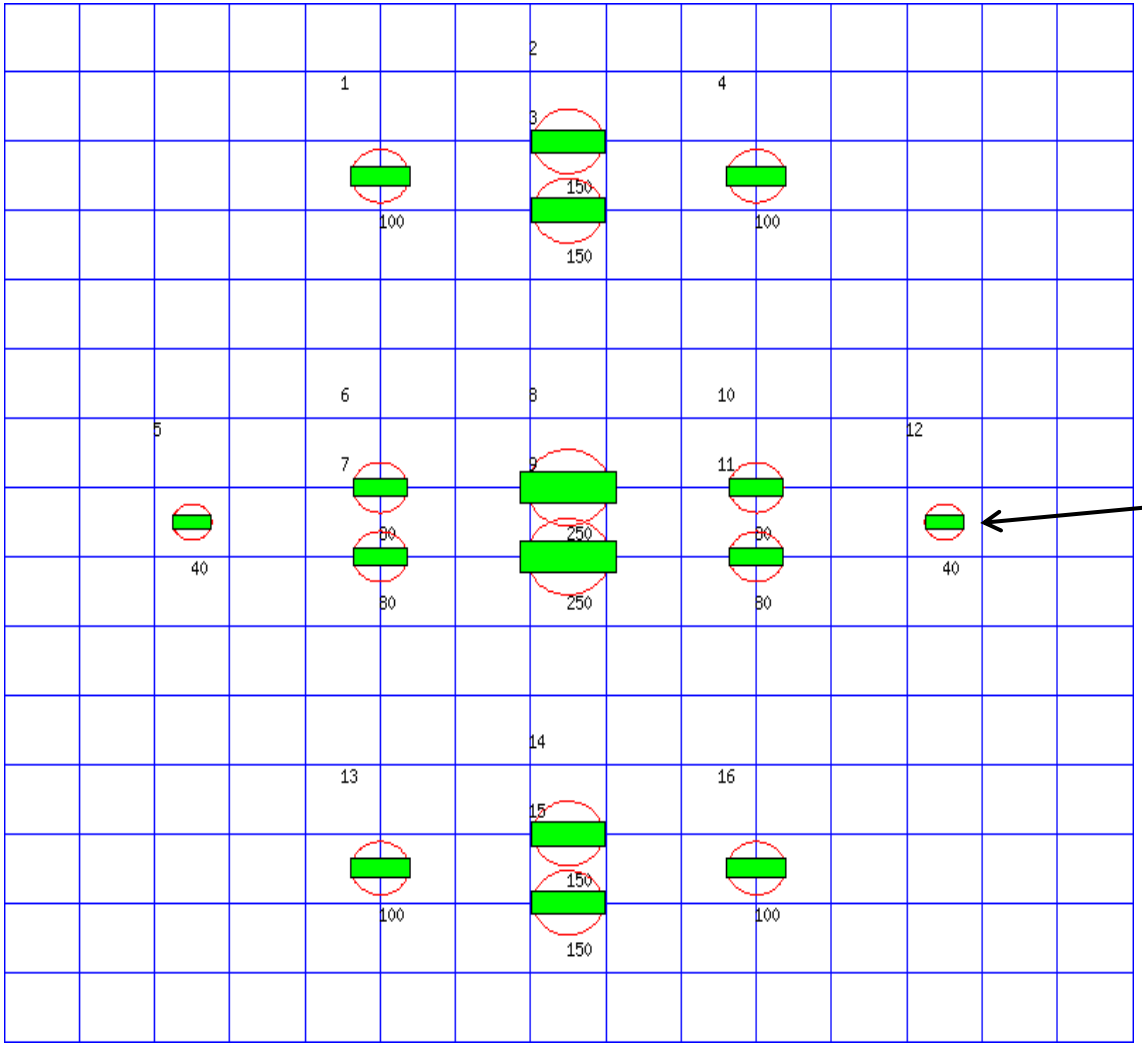




OBN

Courtesy Fairfield, Atlantis 2006

Airgun array design



1 meter grid



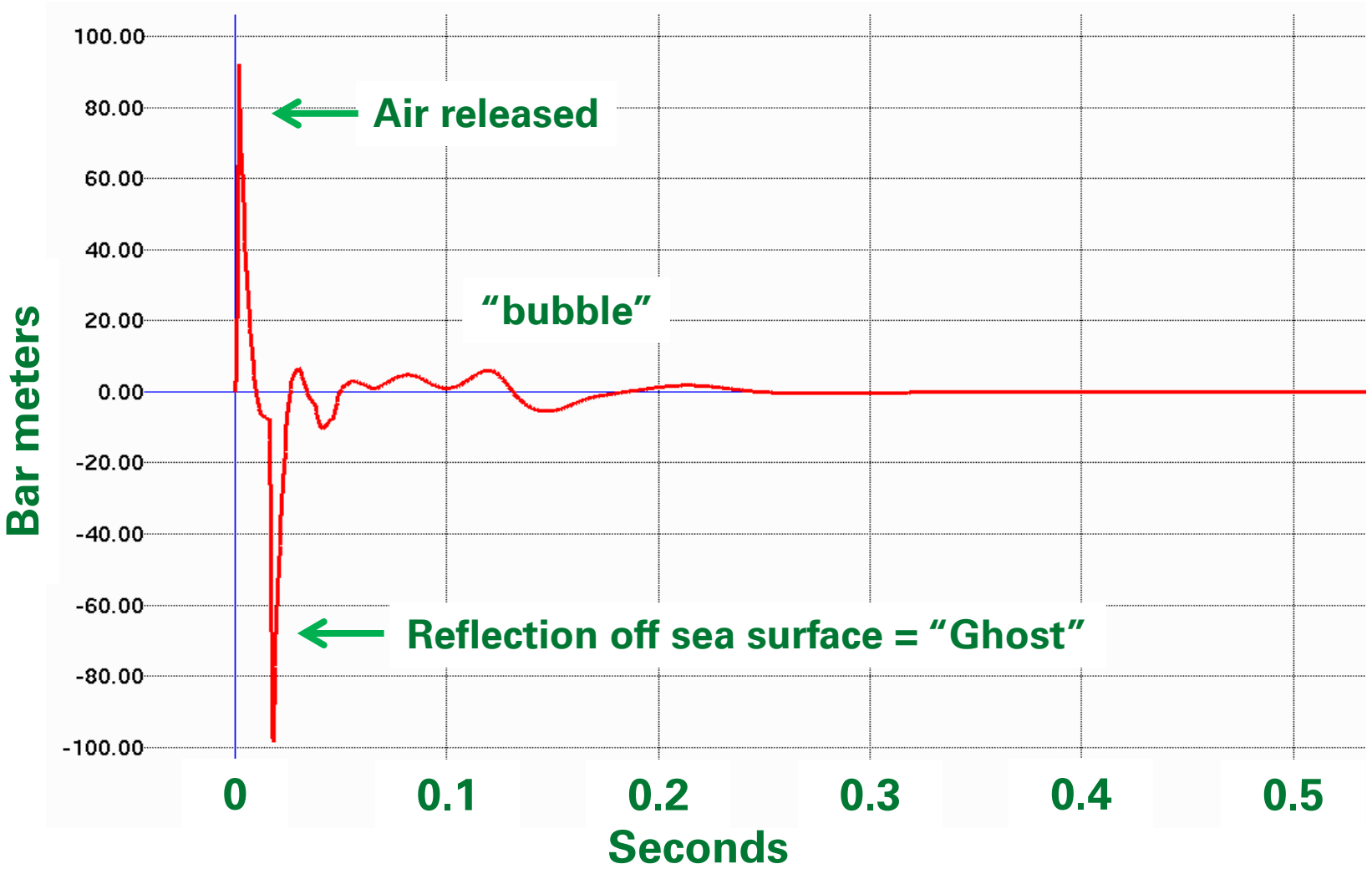
One airgun

Each green box represents an airgun. Size shows the volume of that airgun.

Airgun photo courtesy Sercel.

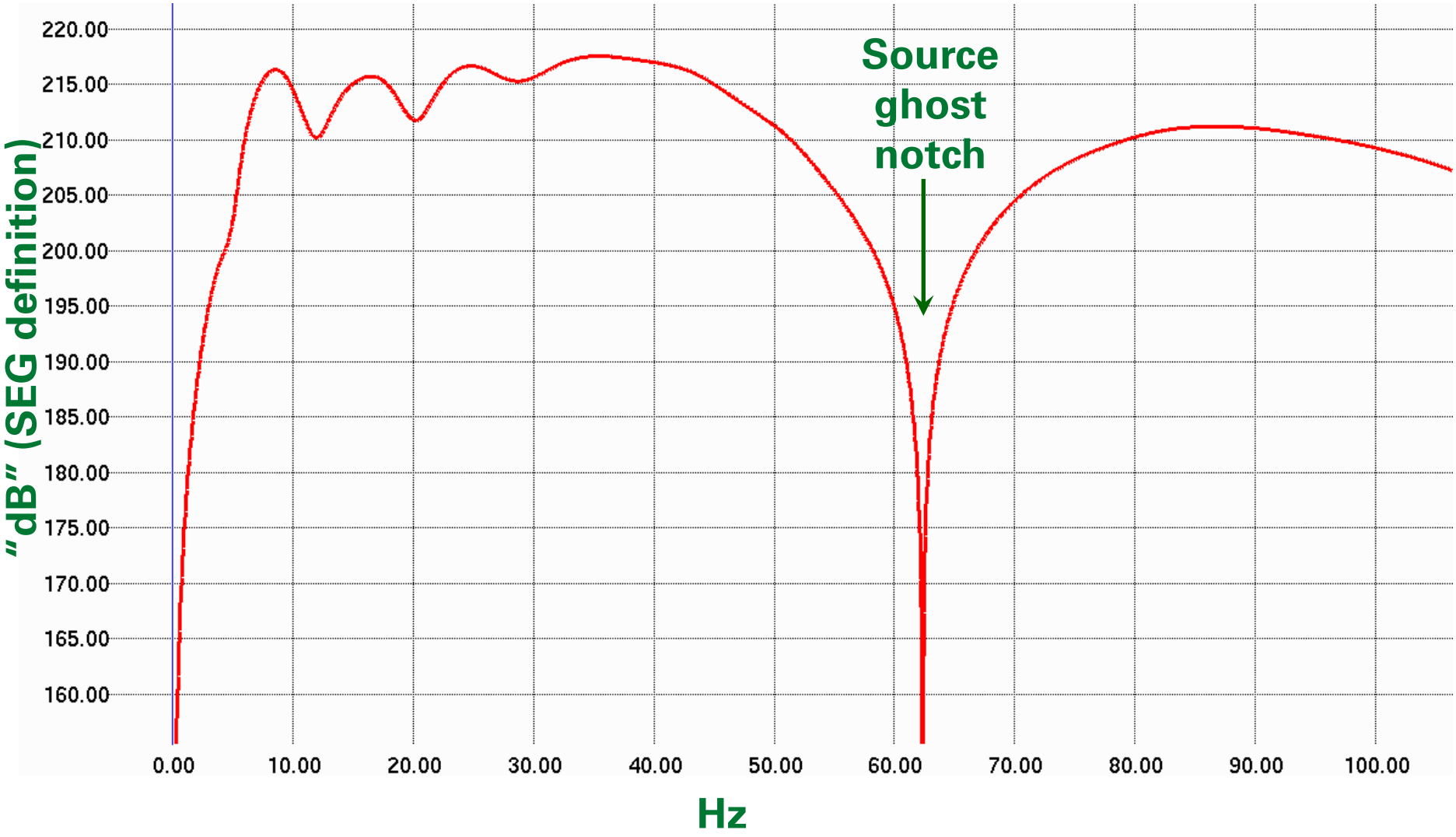
Airgun array design courtesy Fairfield

The modeled signature of that airgun array



Modeled signature calculated by "Gundalf"

The corresponding spectrum for that signature

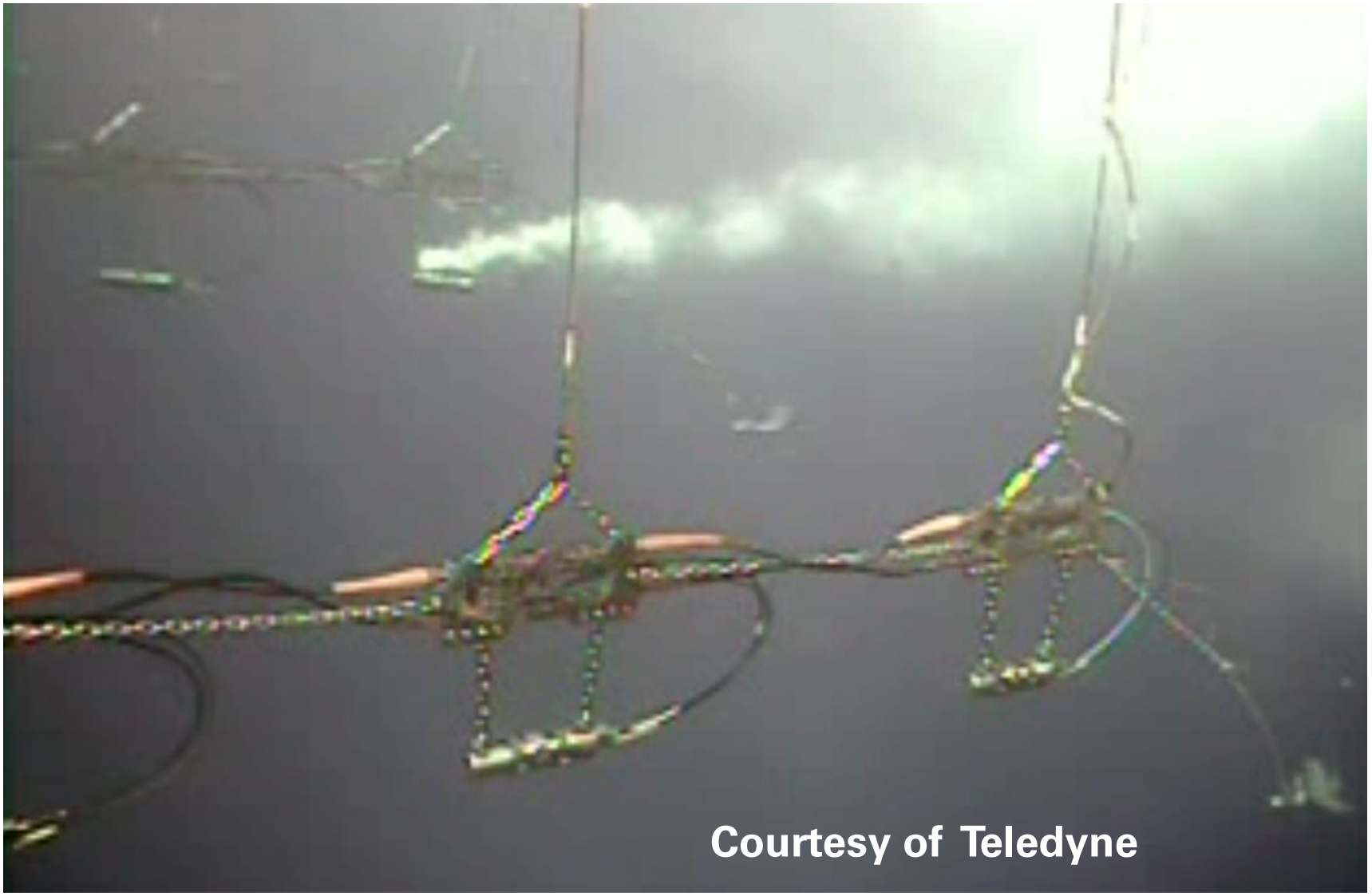


Reality: What actually happens!

Are airguns perfectly repeatable?

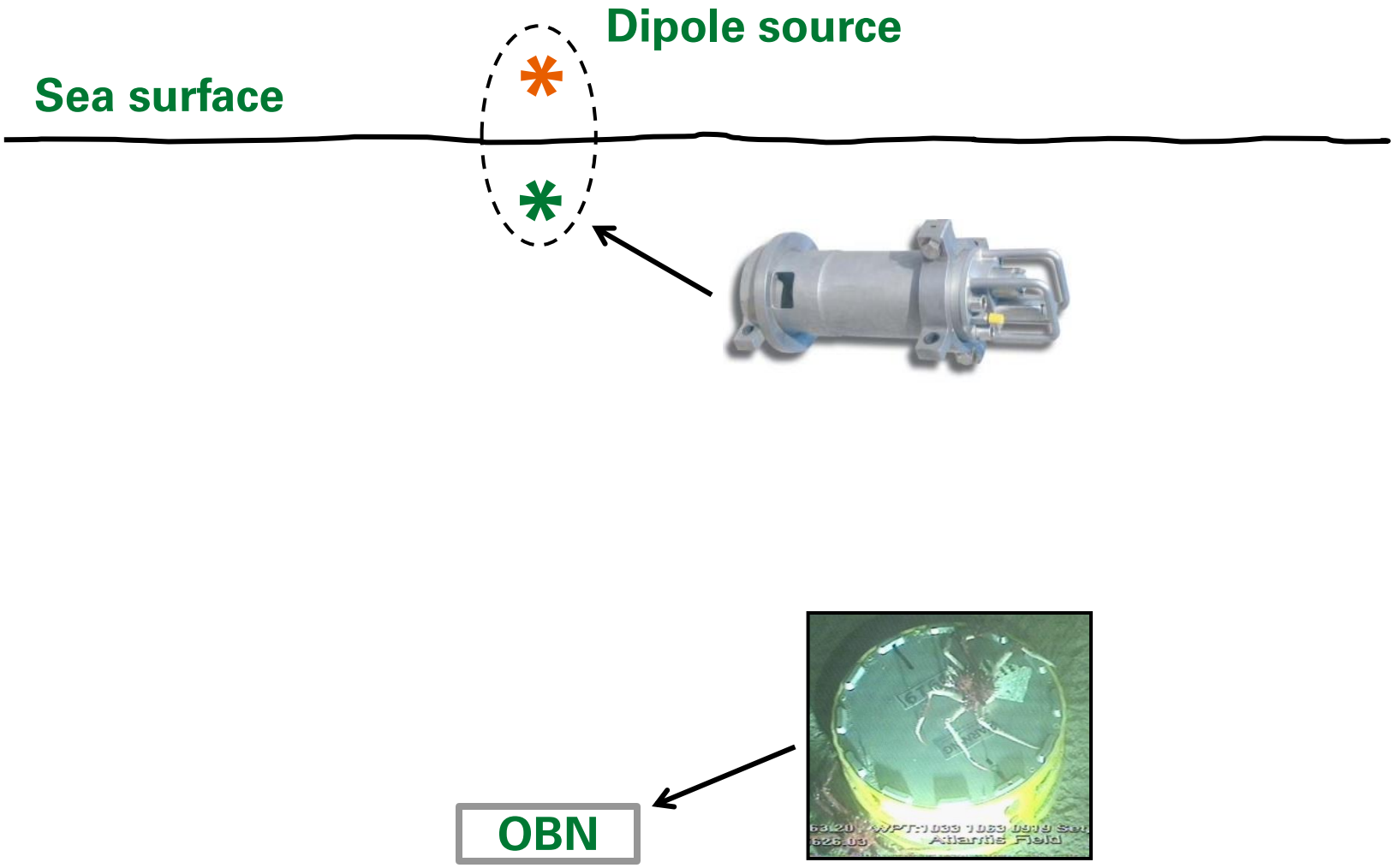


A real (imperfect) airgun array



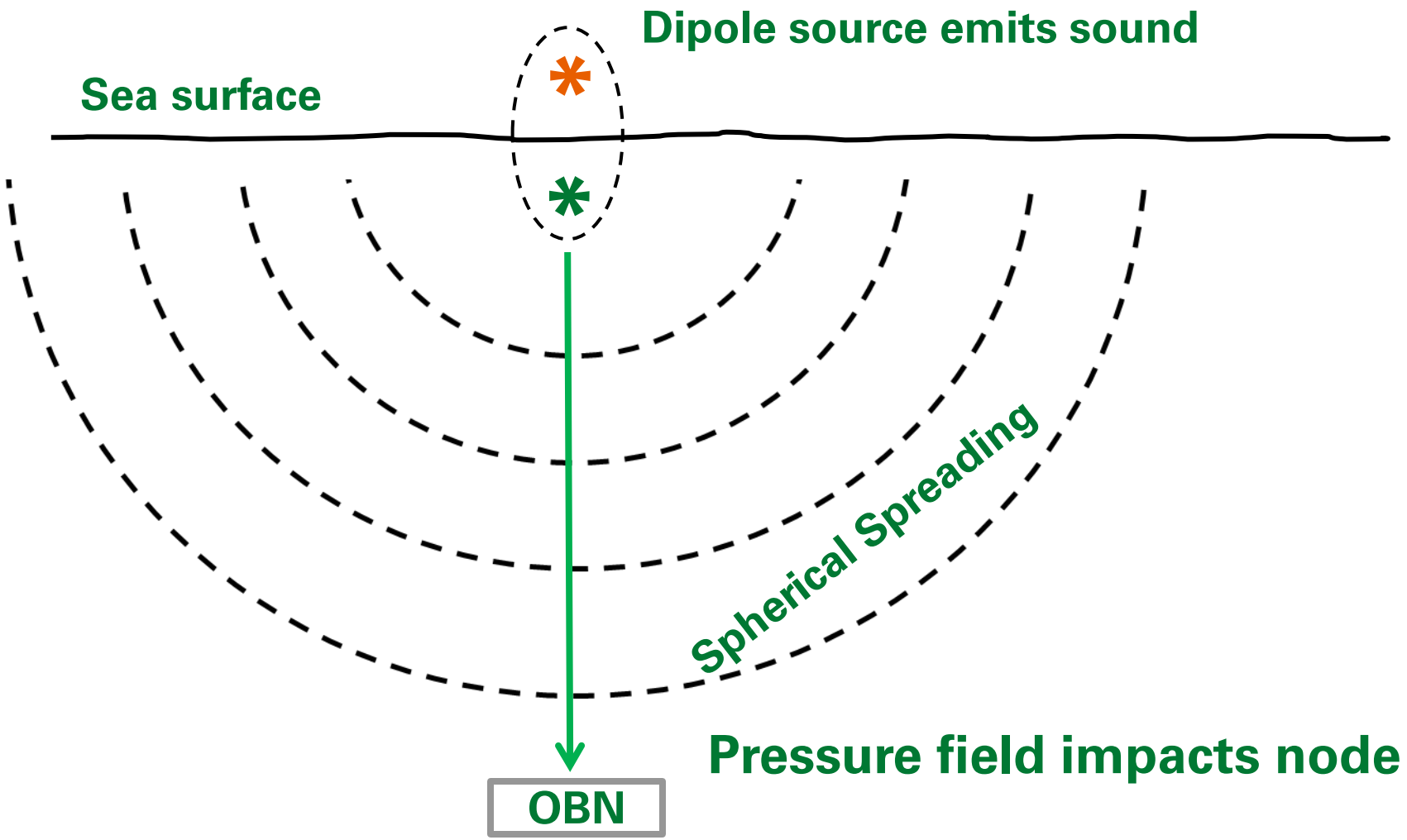
We can use the *data* to see what *actually* happens

Closing the loop from source to receiver: What happens when you record seismic data

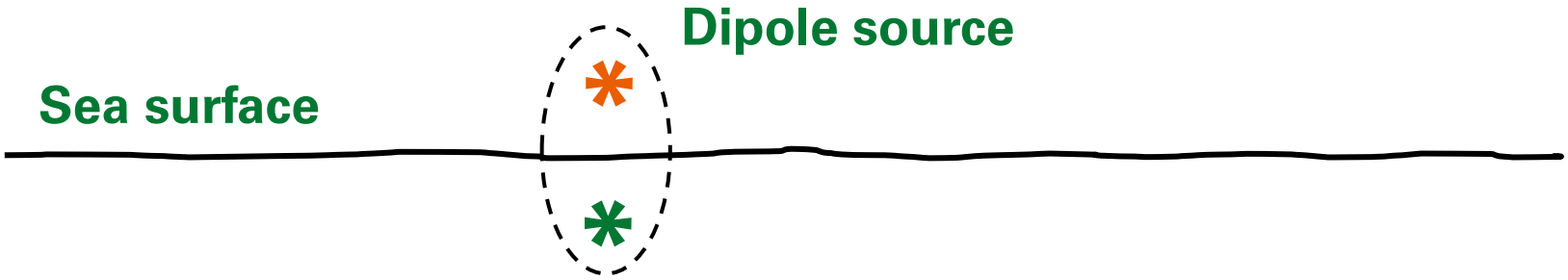


Courtesy Fairfield and Sercel

Closing the loop from source to receiver: What happens when you record seismic data



… and the part everyone forgets about!



What happens in the node:

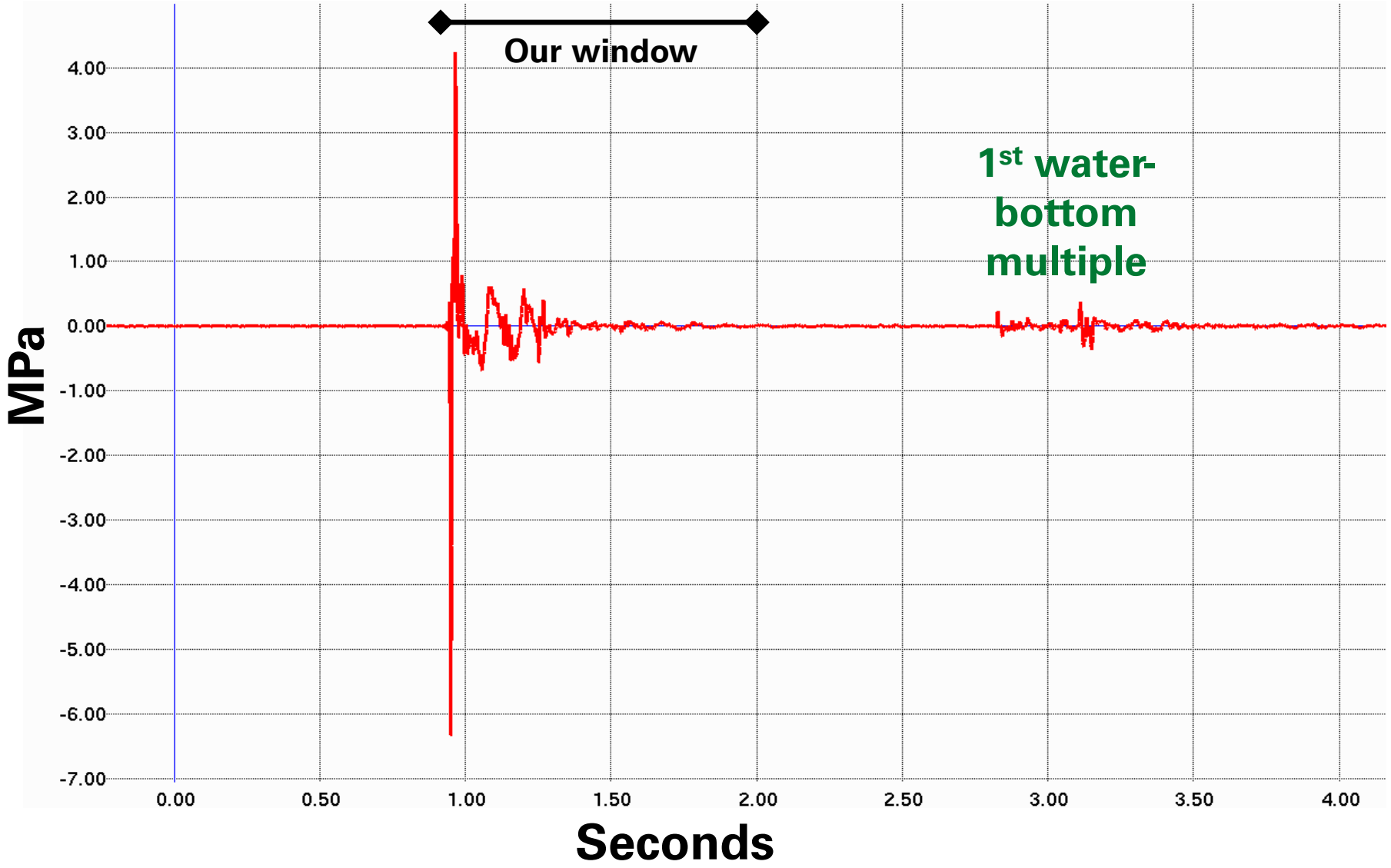
- **Convolves signal with device impulse response**
- **Transducer converts pressure to volts**
- **Digitizes the volts to create a data trace**
- **Applies digital recording filters (low-cut, antialias)**
- **Subsamples to requested sample rate**

→ Output data trace



OBN

Airgun array at 12 meters – near-offset trace



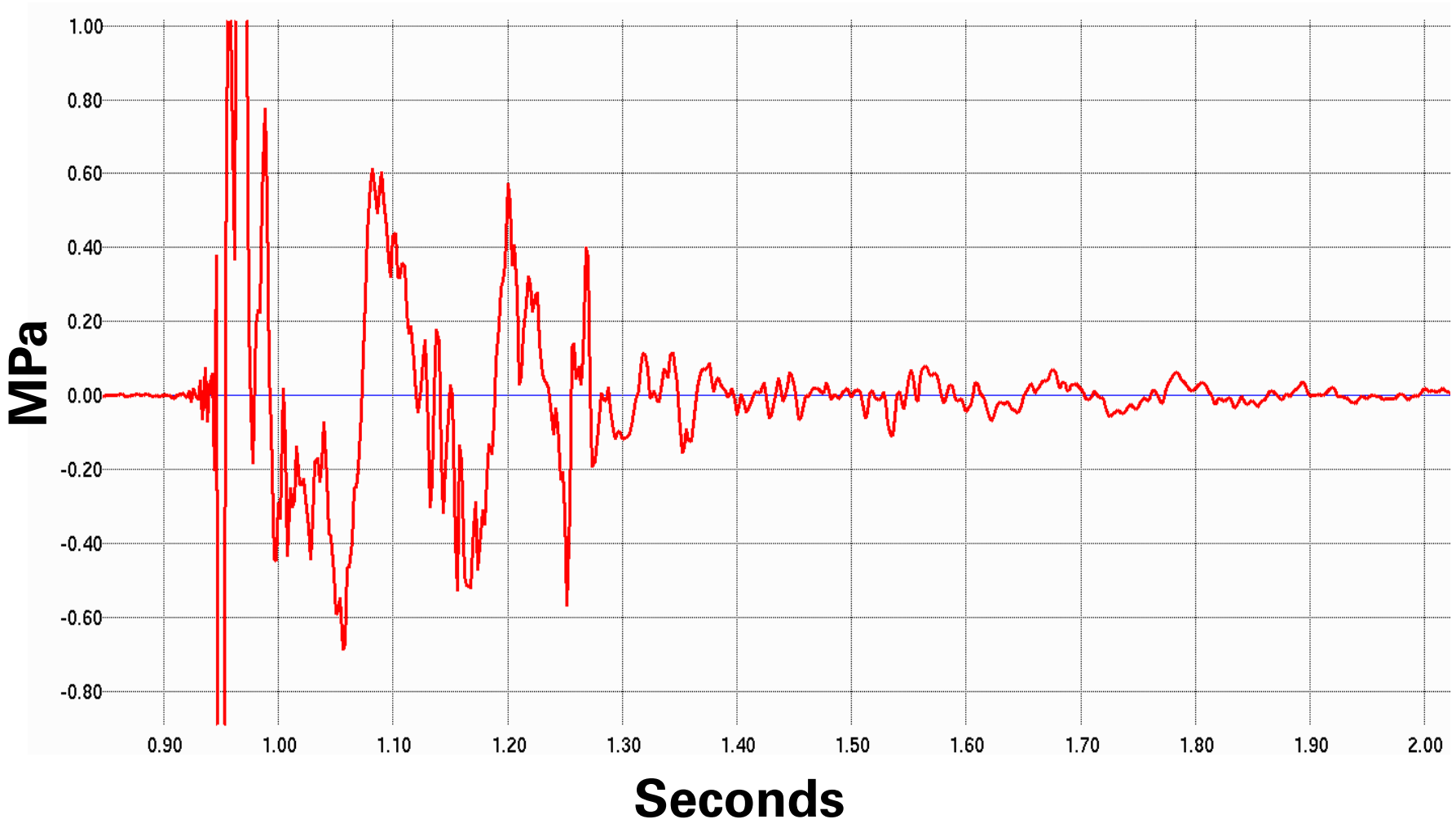
From the data back to a source spectrum

Start from a near-offset data trace…

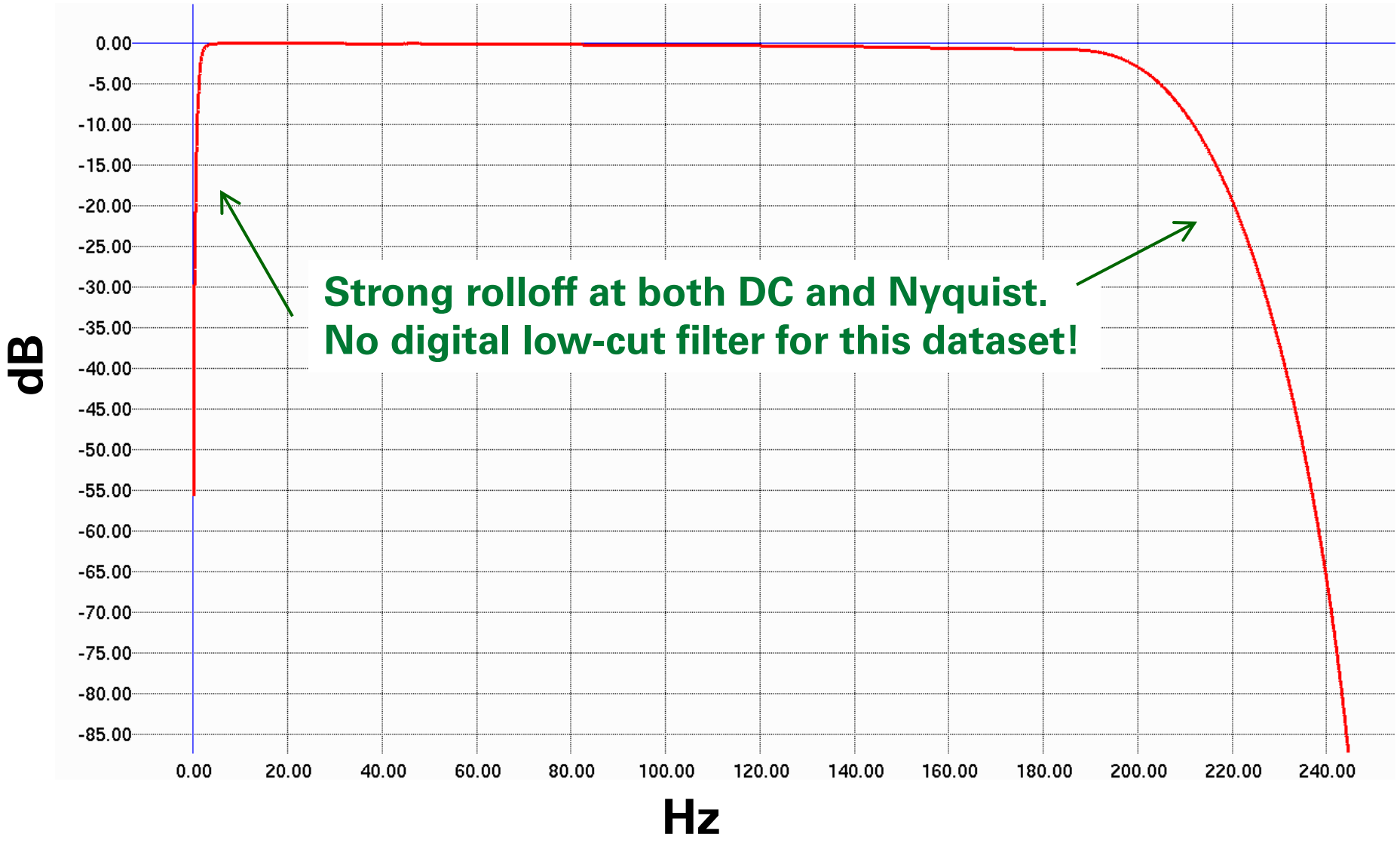


1. Window out the desired time interval.
2. Scale the data to nominal microPascals.
3. Fourier transform the scaled data (preserving energy!) to an amplitude spectrum. (*)
4. Correct amplitudes for spherical spreading back to a reference distance of 1 meter.
5. Divide by spectrum of node impulse response.
6. and by spectrum of any digital recording filter.
7. Units of result: dB re (microPascals/Hz)^2 @1m.

Airgun array at 12 meters – near-offset trace

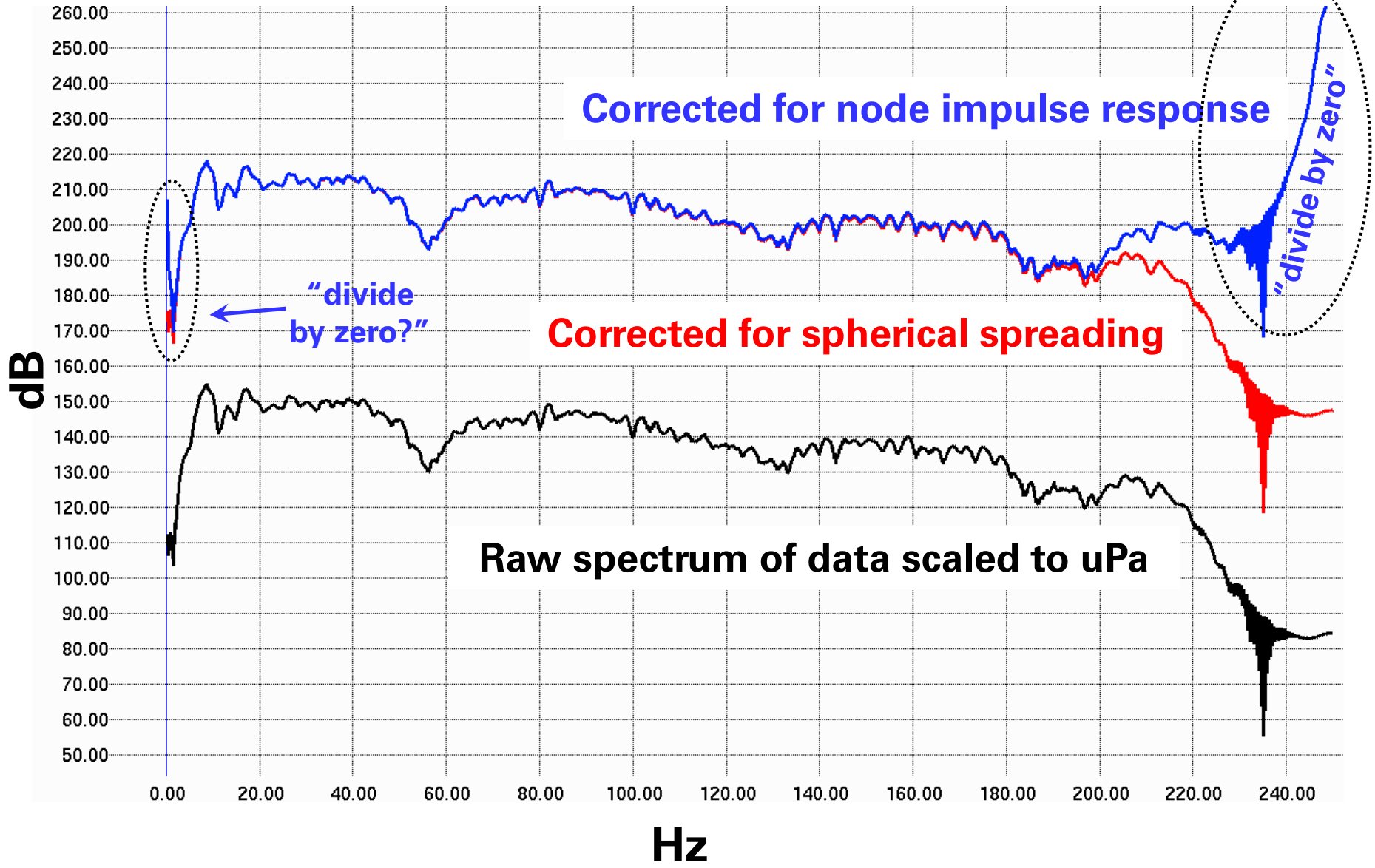


Spectrum of node impulse response: analog low-cut filter + antialias filter



Courtesy Seabed Geosolutions

Measured spectrum for an Airgun array at 12 m

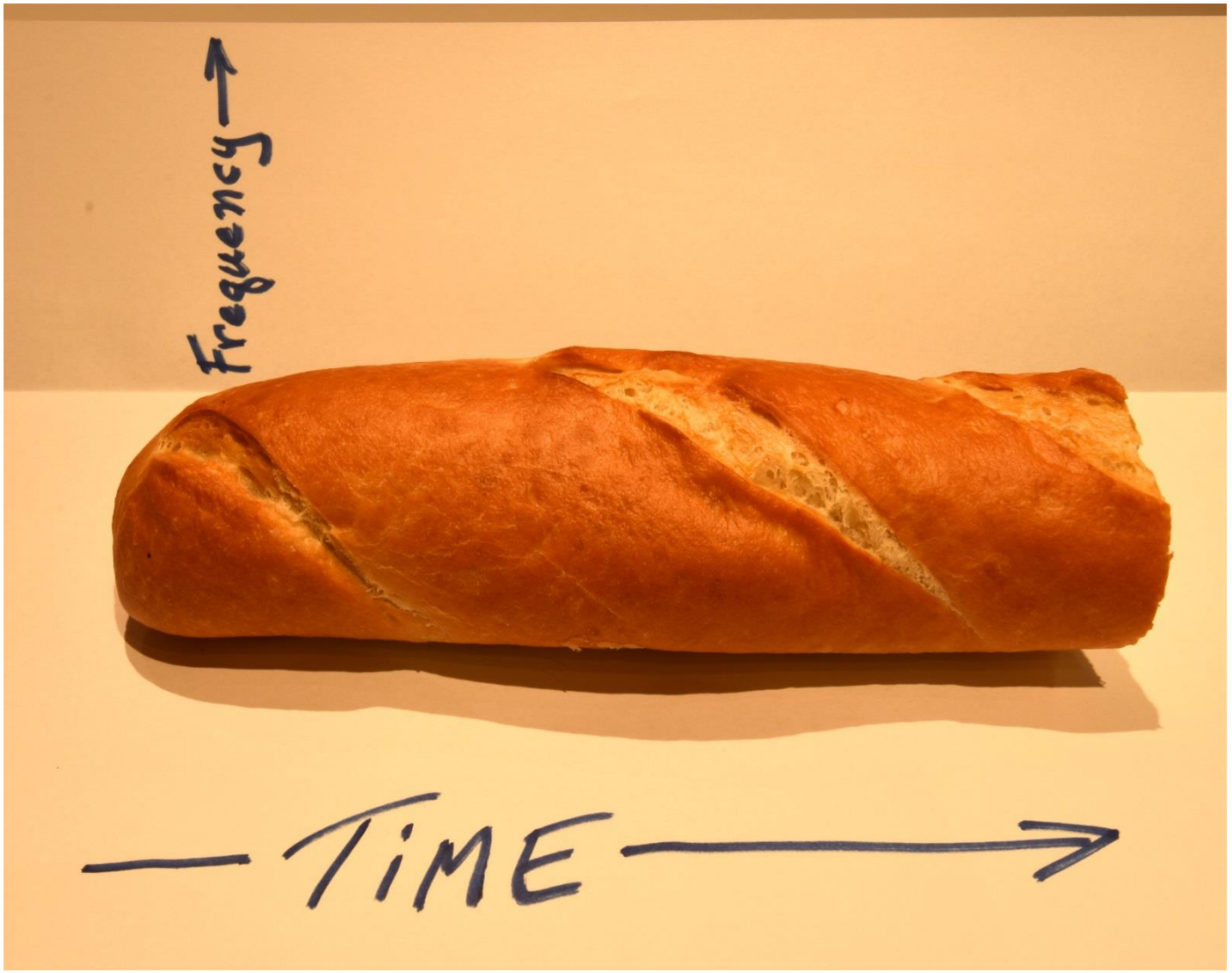


The math behind the SEG standard

The philosophy and math behind the SEG dB standard for sources.

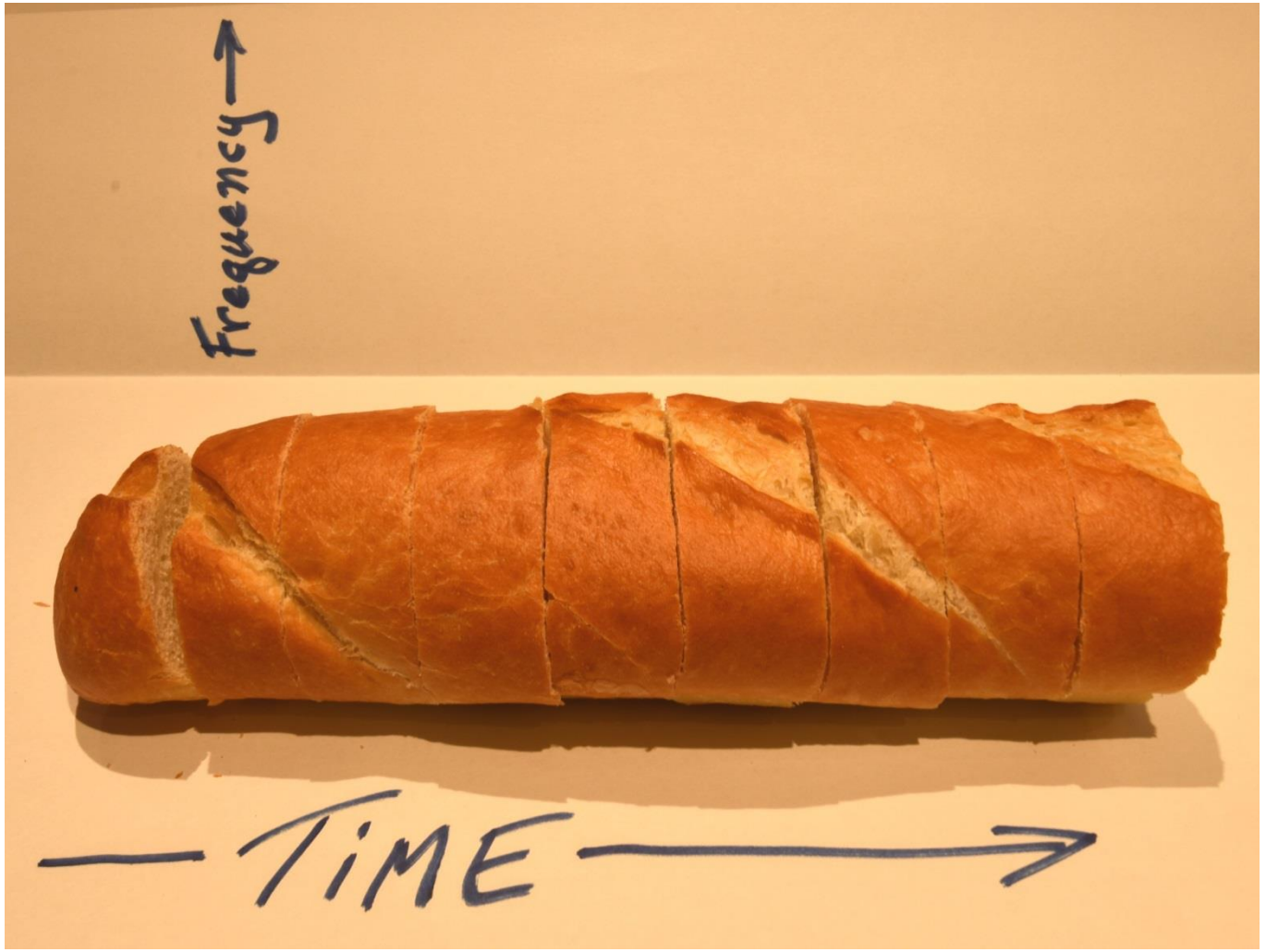
Where does the SEG unit for source amplitude:
"dB re (microPascals / Hz)^2 @1m"
come from?

There is a certain amount of energy in one source activation…



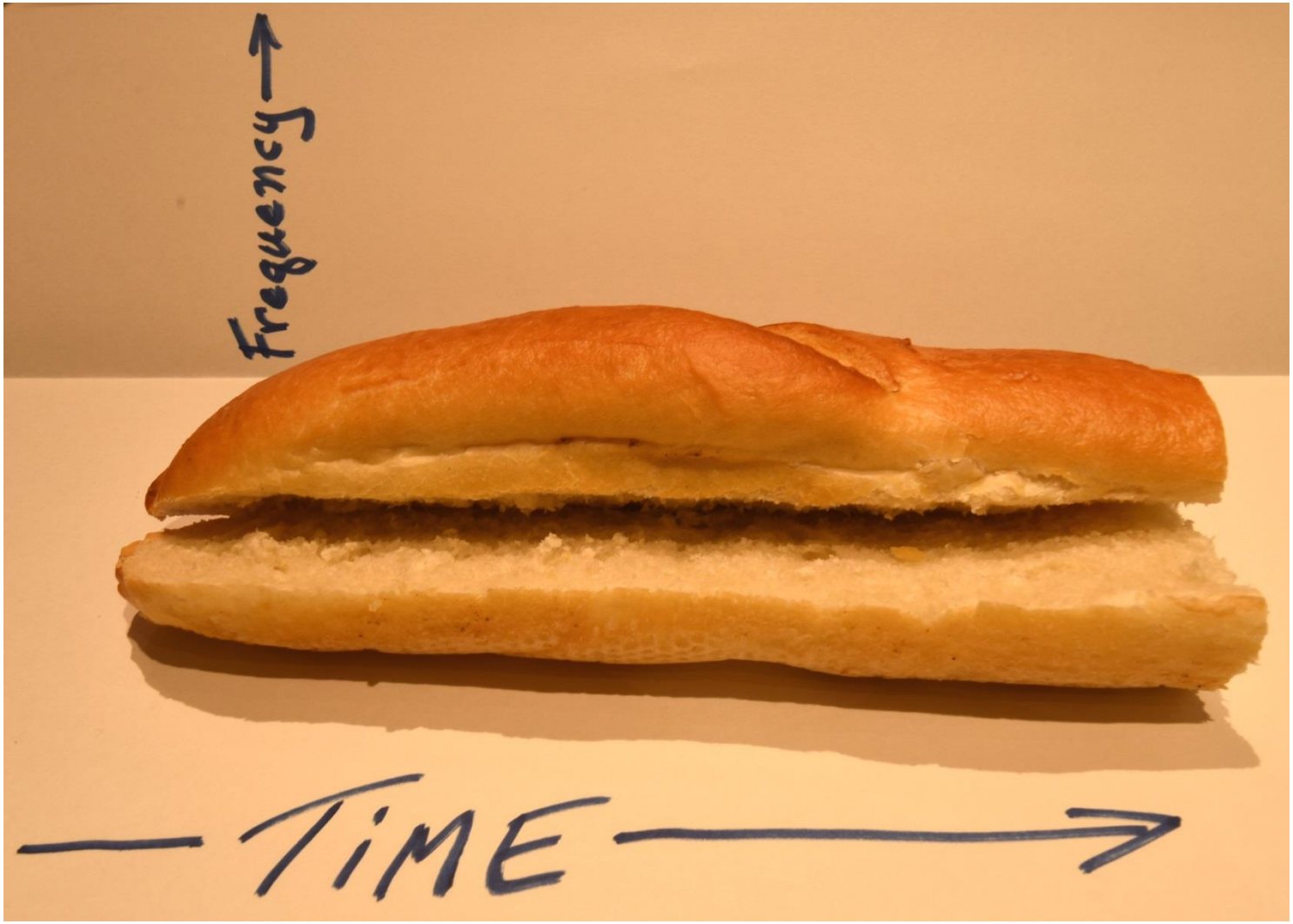
My own photo

Which can be sliced by time…



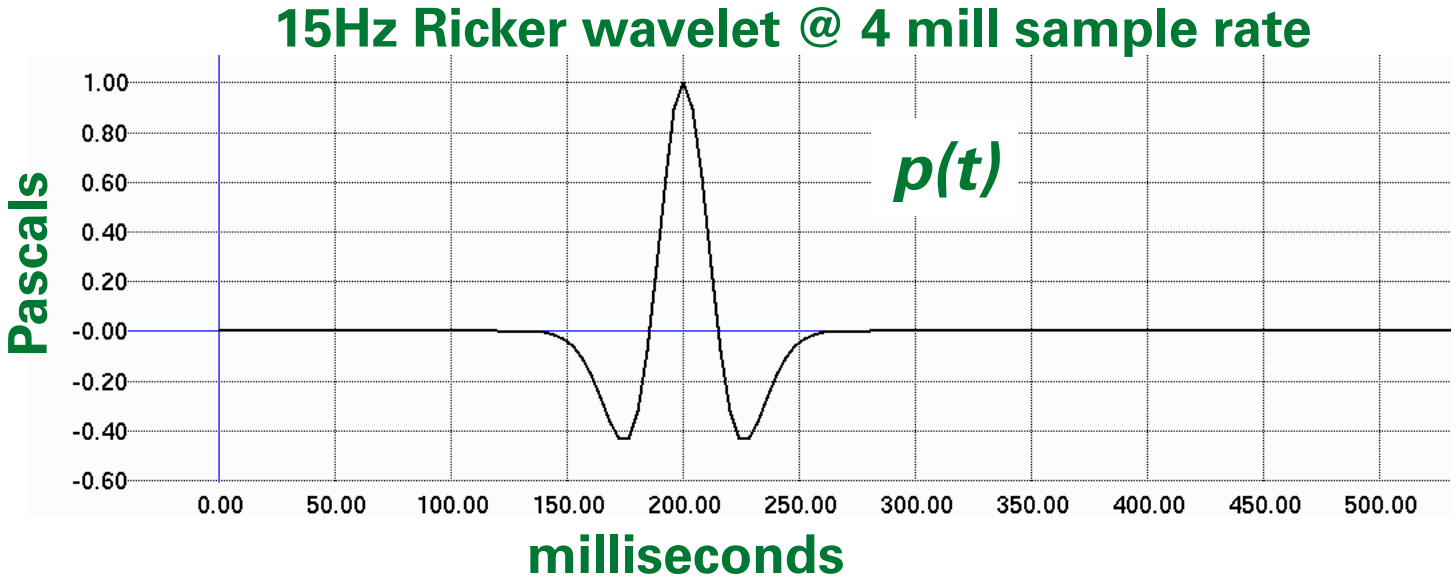
My own photo

Or can be sliced by frequency.
Same amount of bread either way!



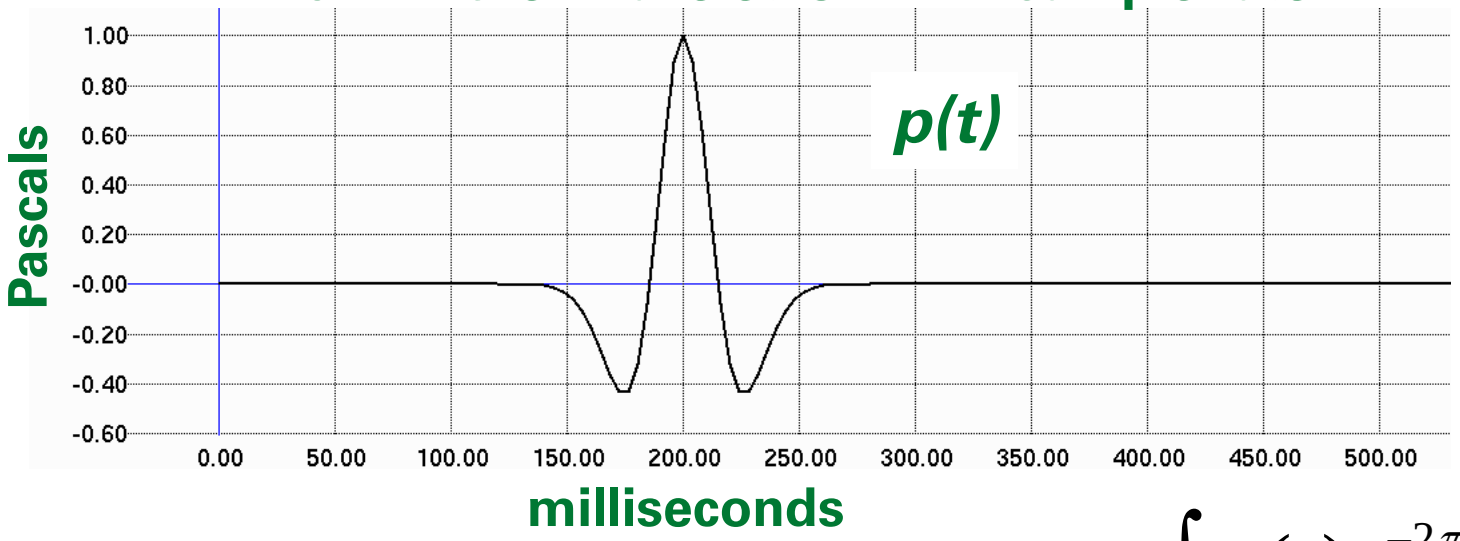
My own photo

Amplitude spectrum



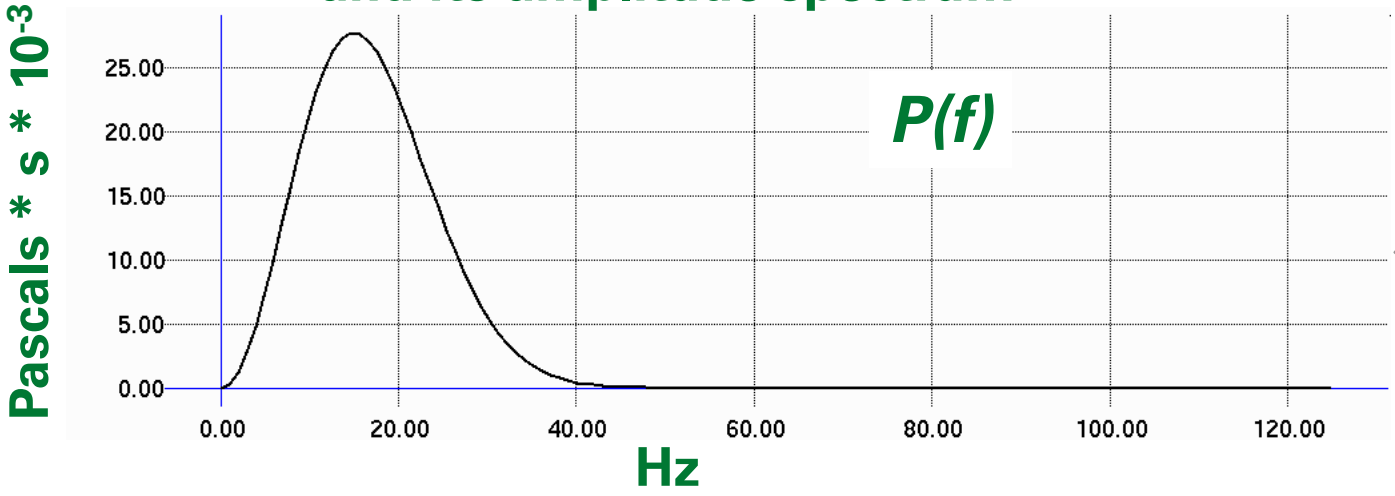
Amplitude spectrum

15Hz Ricker wavelet @ 4 mill sample rate

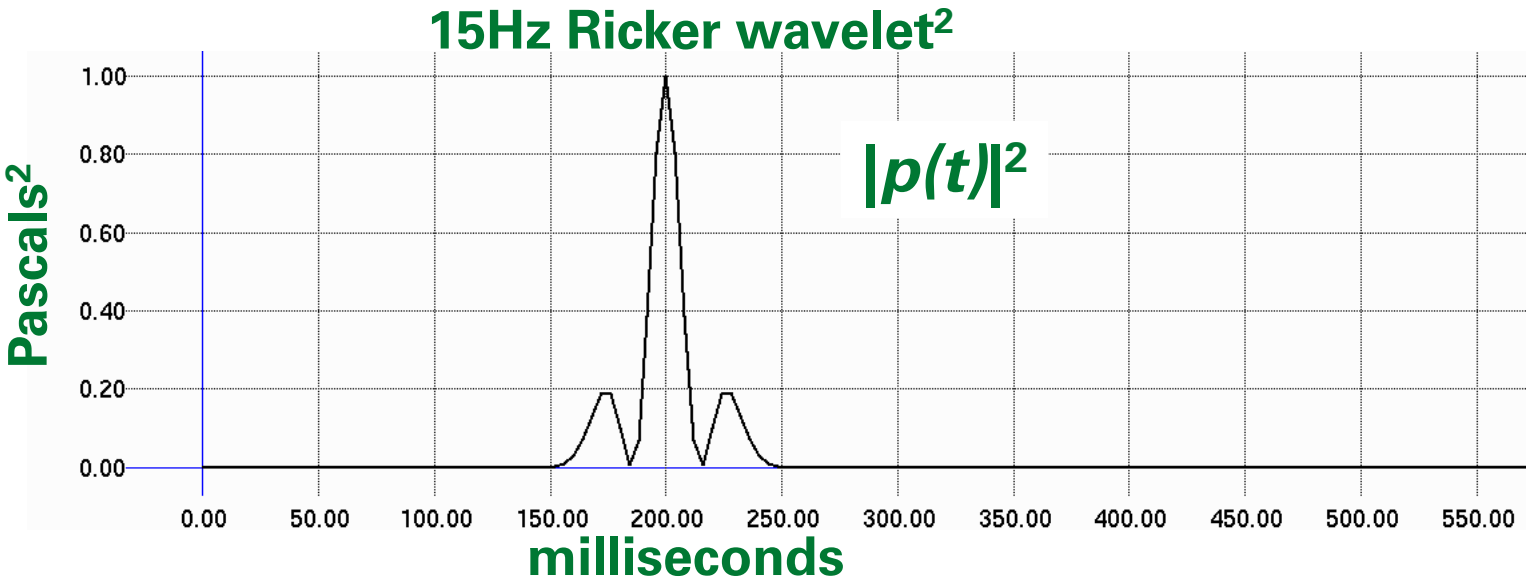


$$\int p(t)e^{-2\pi i\, ft}dt = P(f)$$

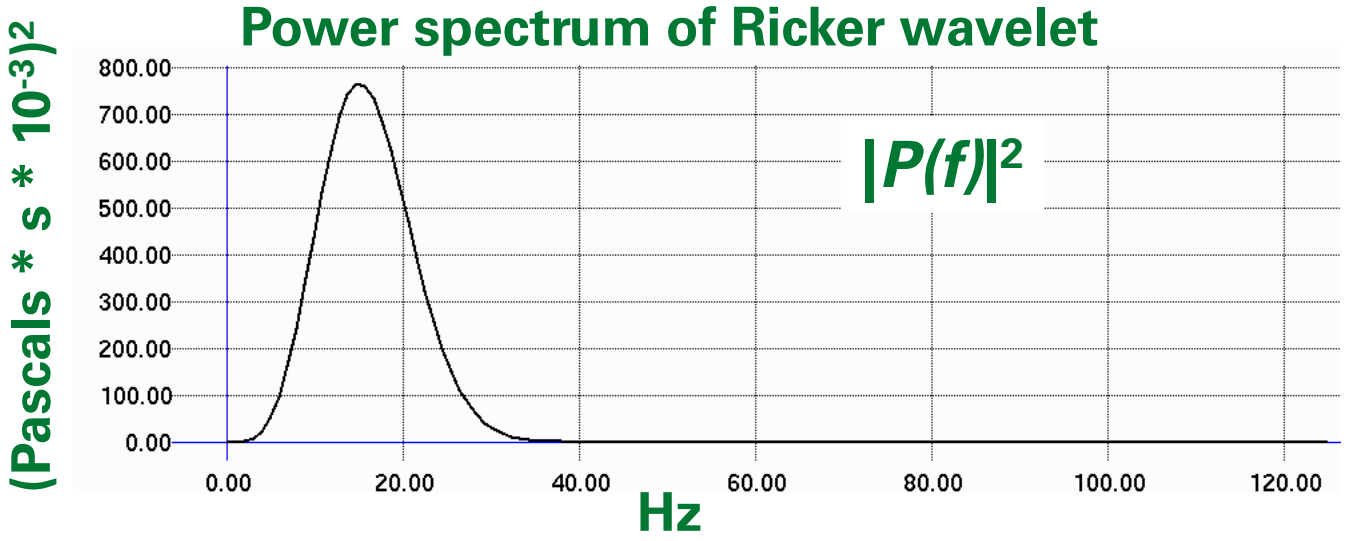
and its amplitude spectrum



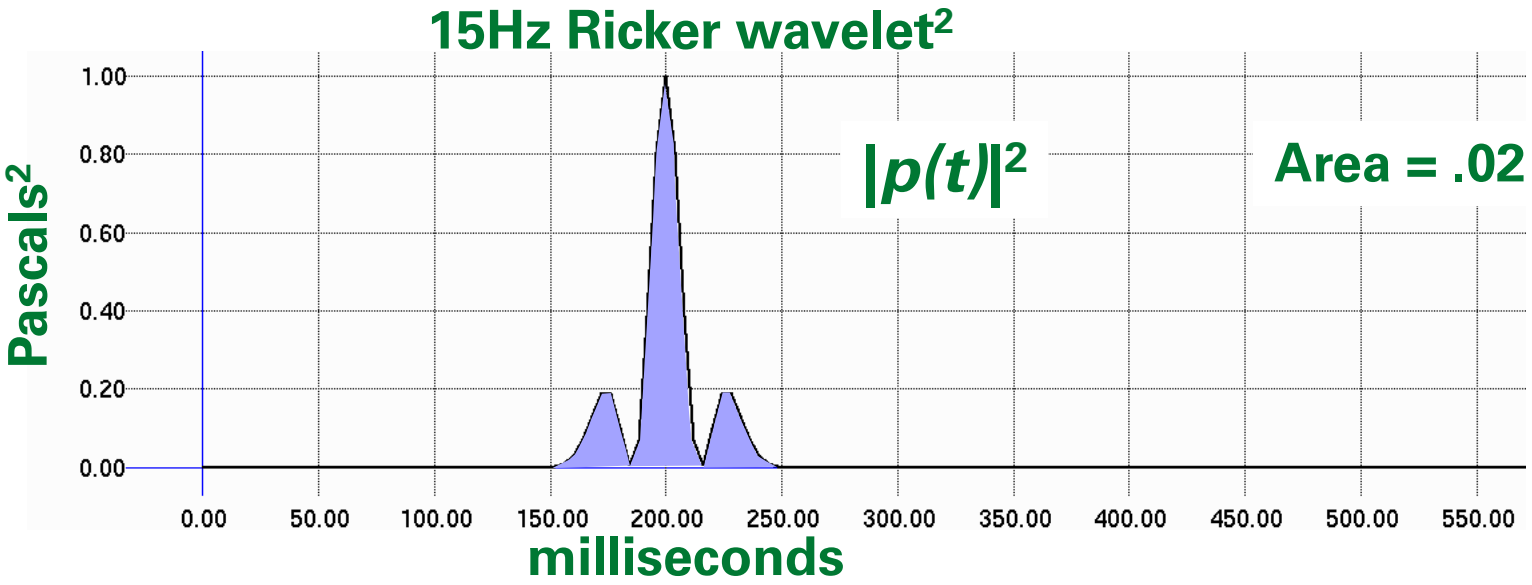
Power spectrum

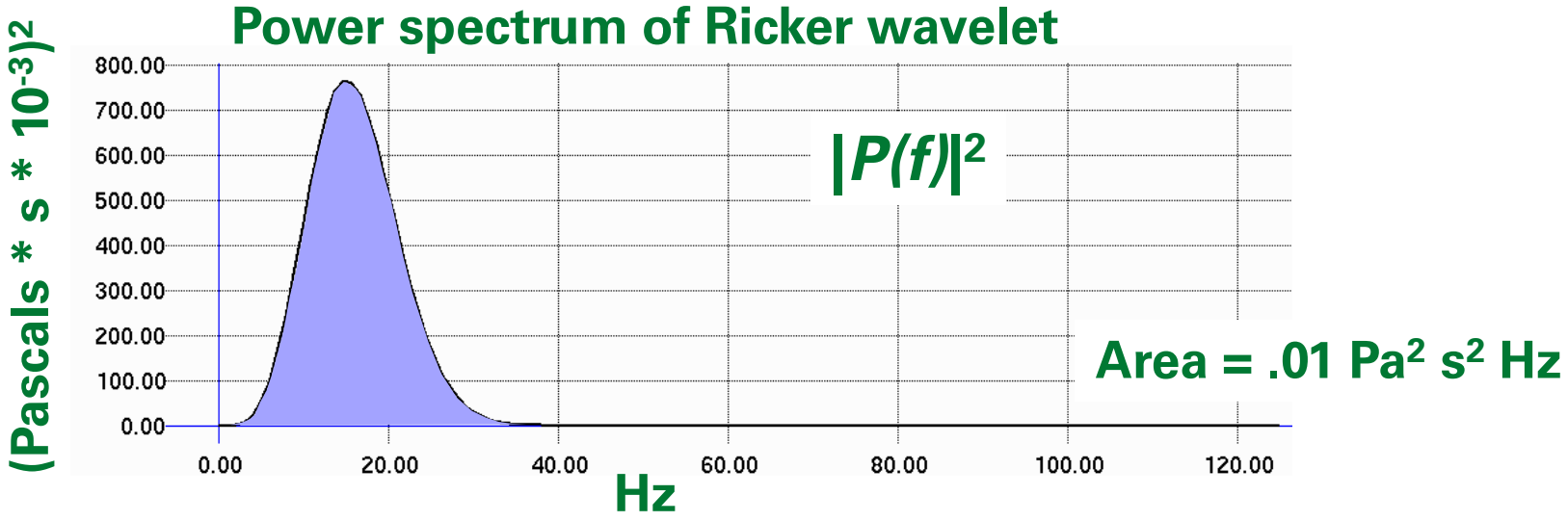


Square them!

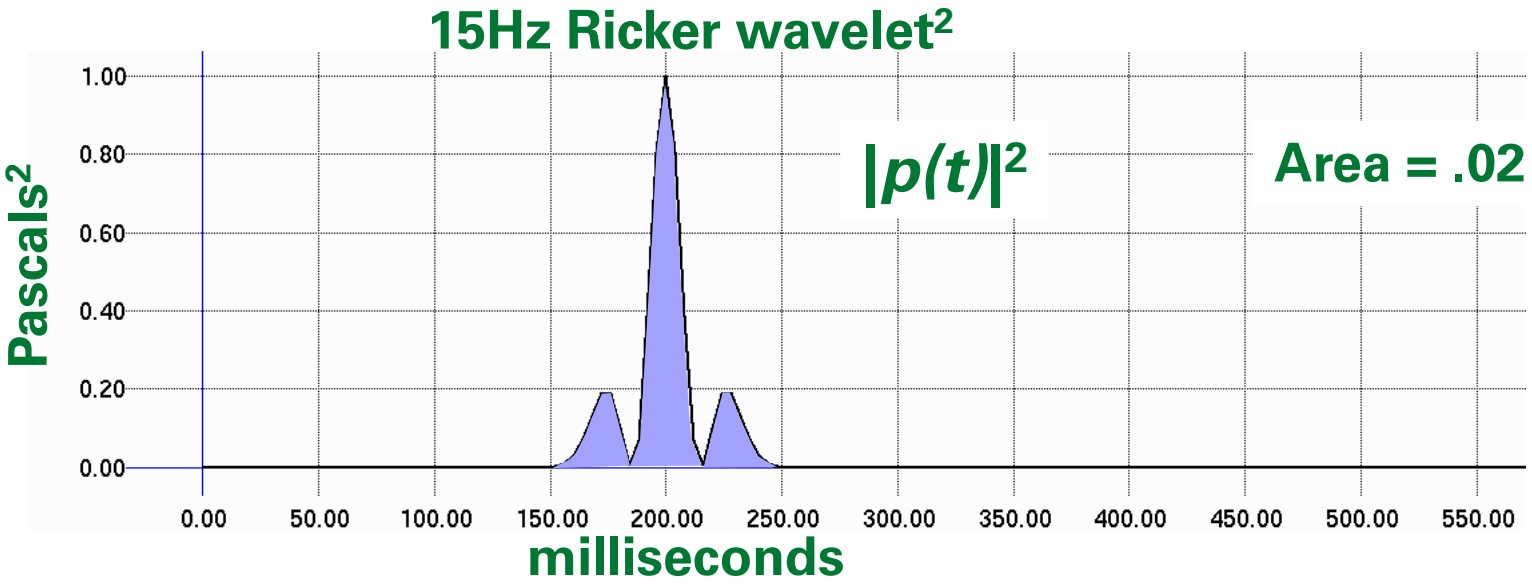


Power spectrum

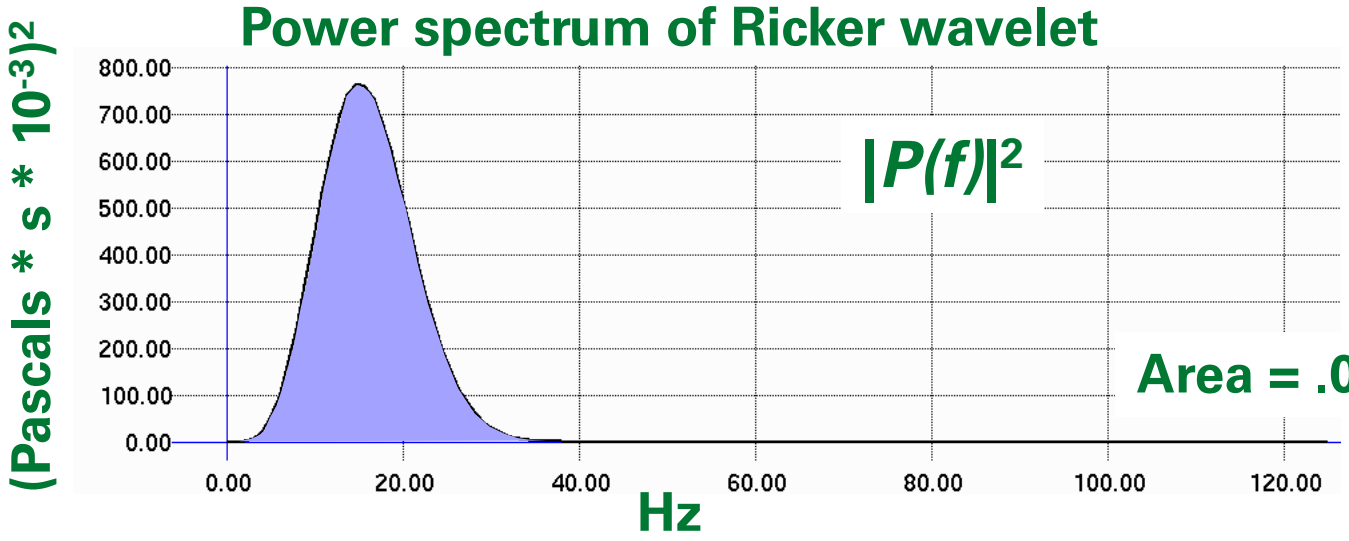




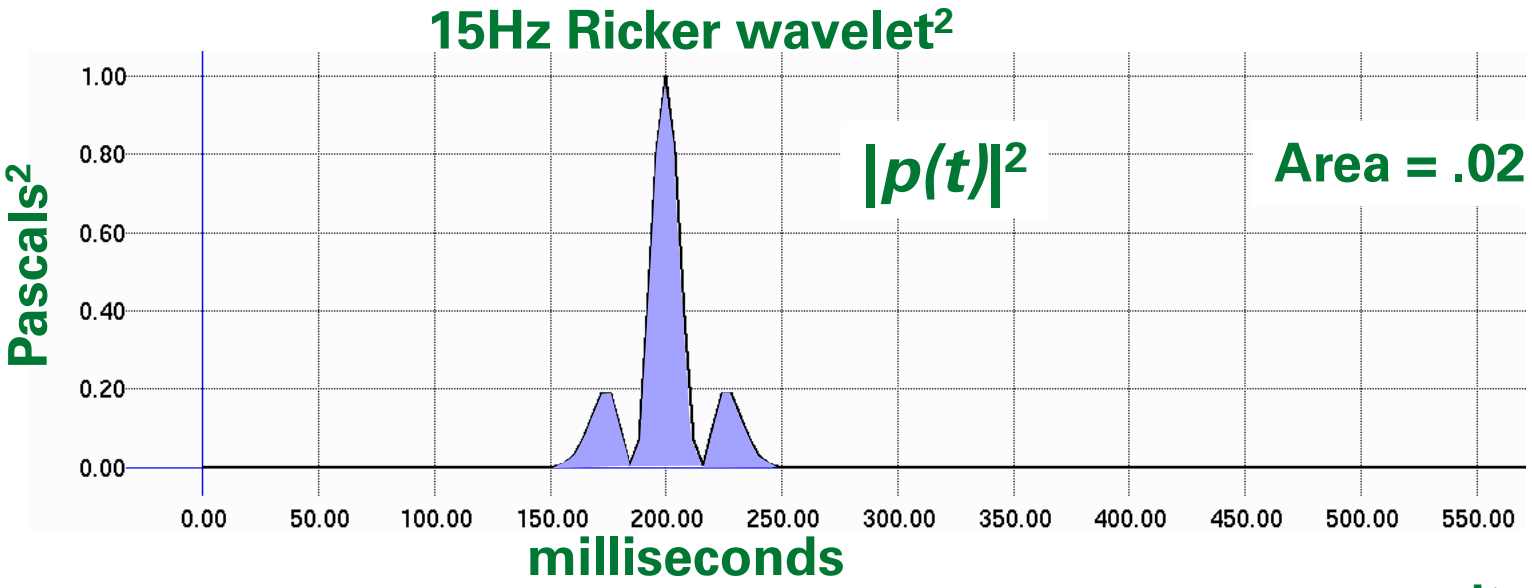
Power spectrum

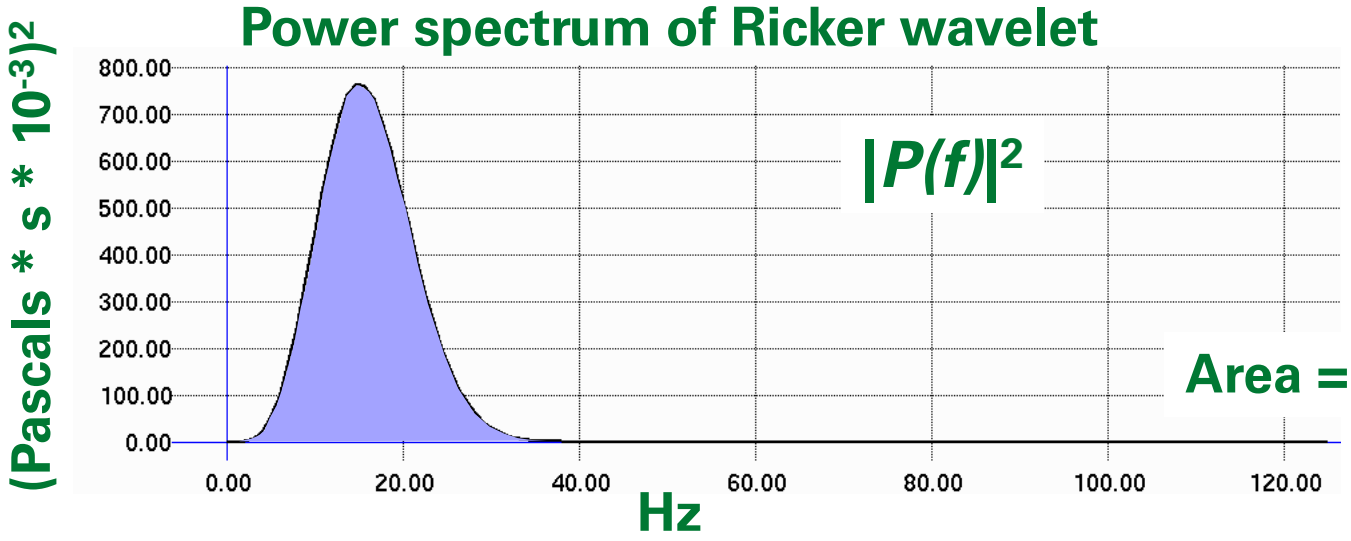


Parseval says these two areas should be equal ?



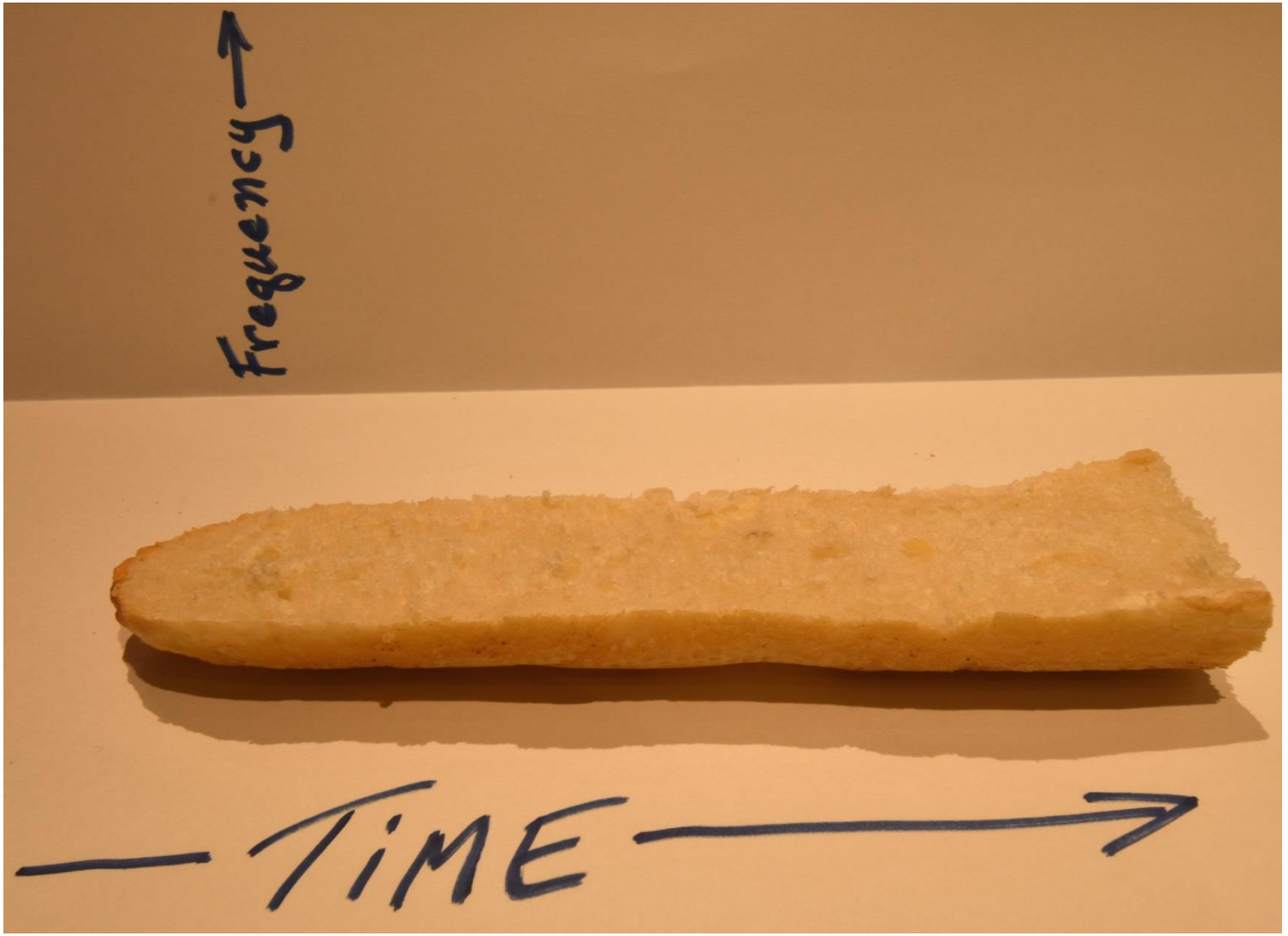
Power spectrum





It does work.
Note Hz = s^{-1}
and
Must include the negative frequencies!

The SEG forgot to count the negative frequencies!



My own photo

Continuous signals require a different dB standard

- **The SEG definition isn't the right one for continuous background noise, which doesn't really have any particular start or end, but just goes and goes and goes…**



← Time →

My own photo

Acoustician's vs SEG's definition of "dB"

- Instead of energy, we use **energy per time = power**.
- There is also no well defined "shot-receiver distance", so we measure *local ambient acoustic power at the node*.
- Dividing by time (seconds) changes the units.
  So instead of:
  dB re (microPascals / Hz)^2 @1m (SEG), we get:
  dB re $(\boldsymbol{microPascals}/\sqrt{\boldsymbol{Hz}})^{\boldsymbol{2}}$ (Acoustician's).
- The acousticians didn't forget to include the negative frequencies in their standard!