Simulation and Test of Tunable Organ Pipe for Ocean Acoustic Tomography

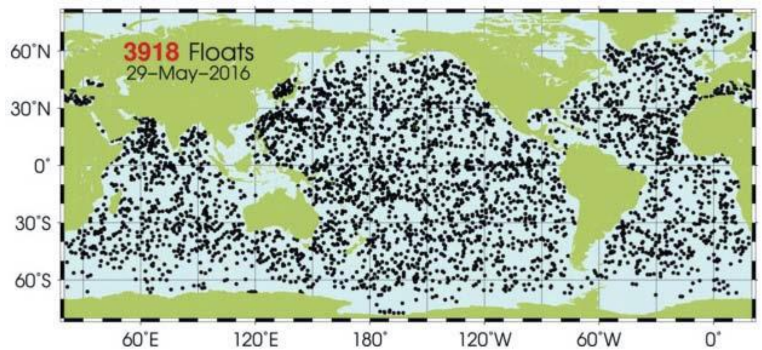
COMSOL CONFERENCE 2016 BOSTON

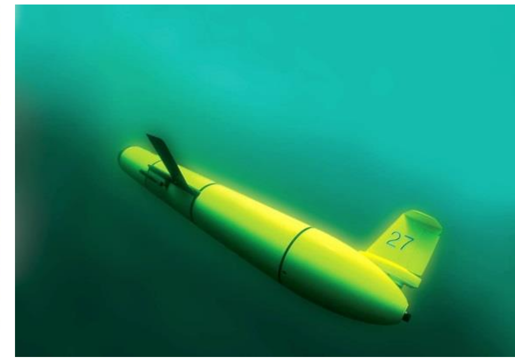
Andrey K Morozov
Teledyne Marine 49 Edgerton Drive, North Falmouth, MA 02556 USA

Presentation plan

- Background. Deep-water tunable sound sources for long-range acoustic navigation and ocean acoustic tomography. 15 years of operating history.
- COMSOL simulation of octave frequency band sound source.
- New variant of tuning mechanism and sea test of a sound source.
- Comparison of COMSOL simulations and experimental data.

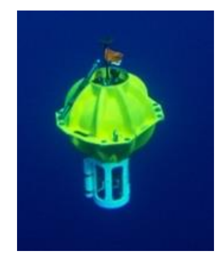
Teledyne Marine TWR





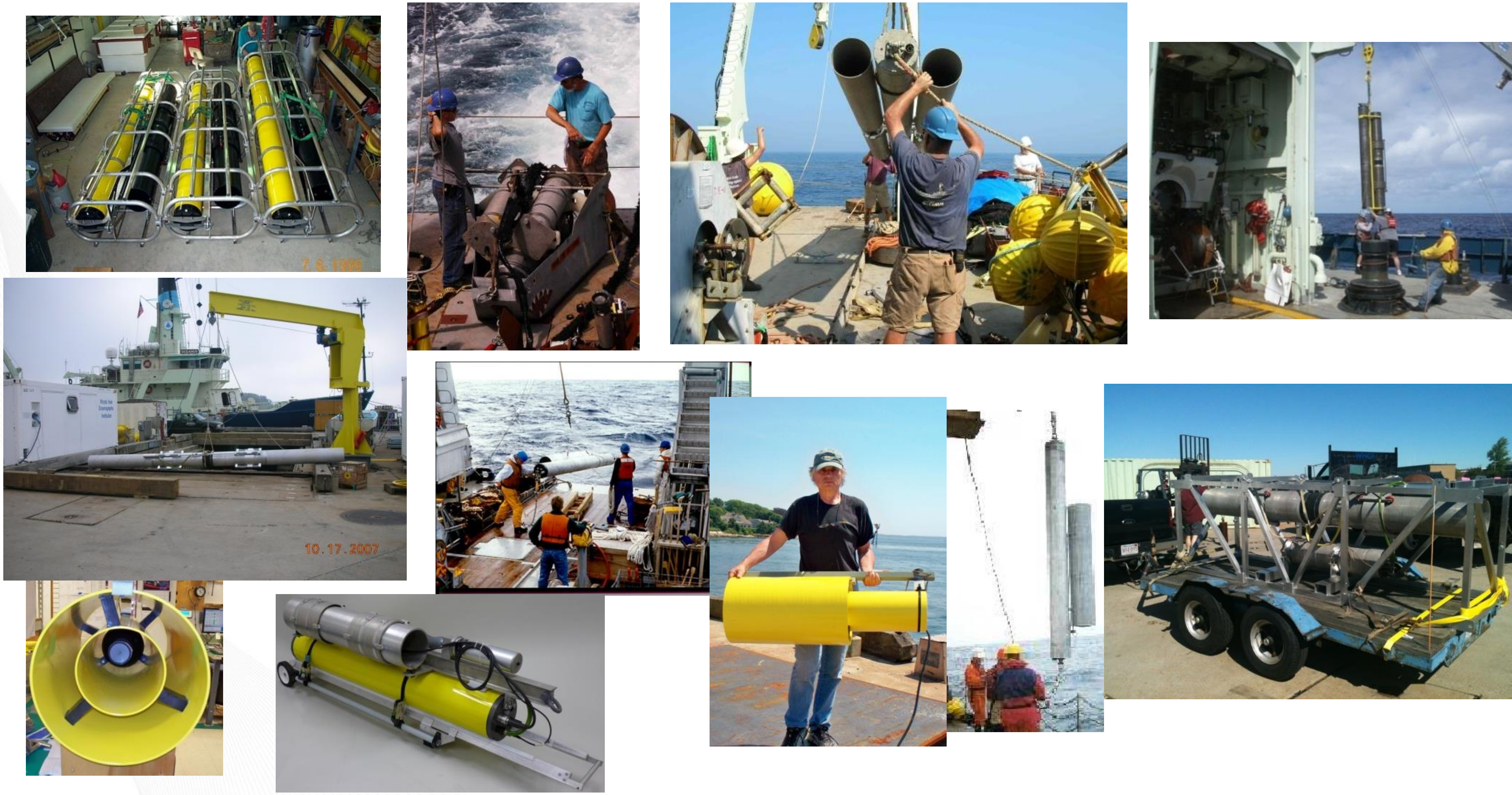
Long Endurance Worldwide Remote Sensing

- Low Frequency Sound Sources for Navigation and Tomography
- APEX Profiling floats, 2000m and 6000m depth operation
- Slocum Autonomous Underwater Gliders



Teledyne Webb Research has a core focus and commitment to providing tools that better enable our understanding of the world's oceans.

Teledyne Low Frequency Sound Sources for Long-Range Underwater Navigation Communications and Tomography



Frequency Swept Tuneable Organ Pipe

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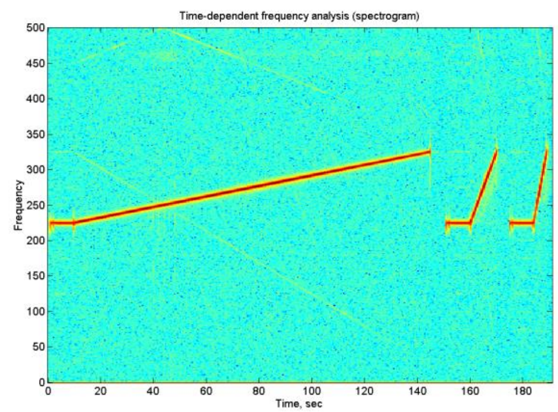
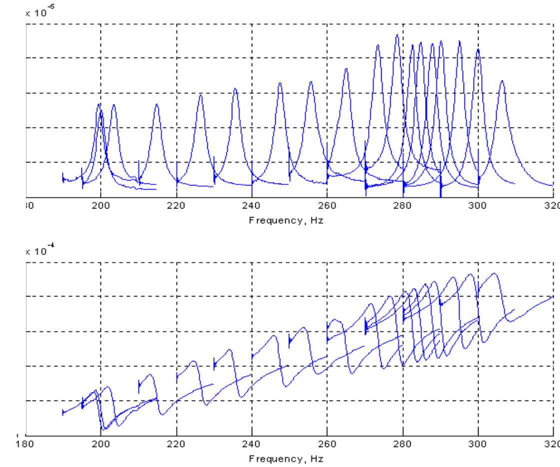
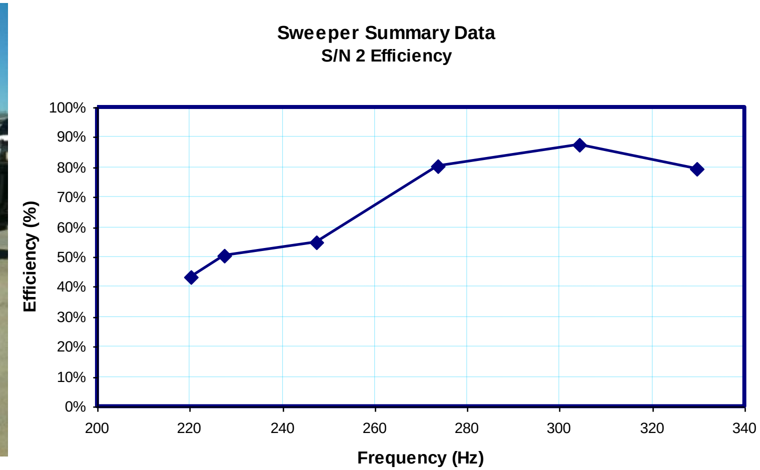
Advantages

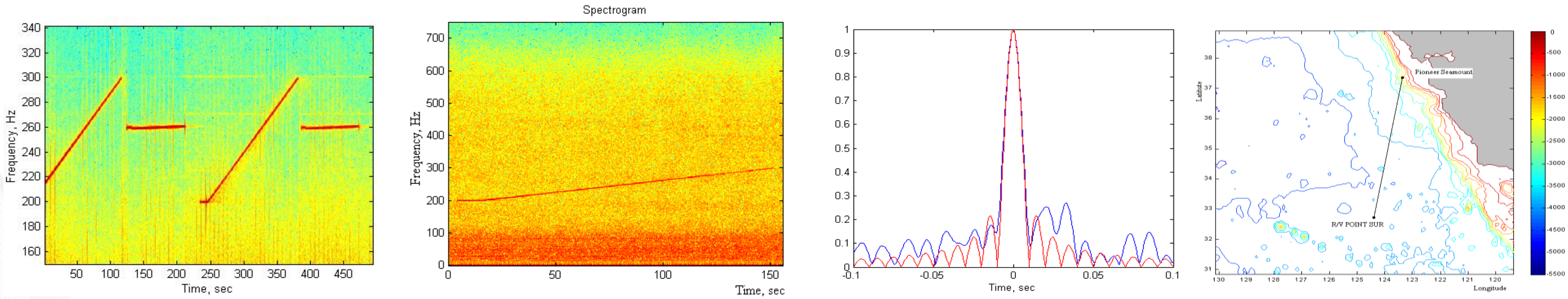
- Very high efficiency > 60 %
- Clean harmonics content
- Large frequency band
- Reliable tested technology
- Unlimited depth



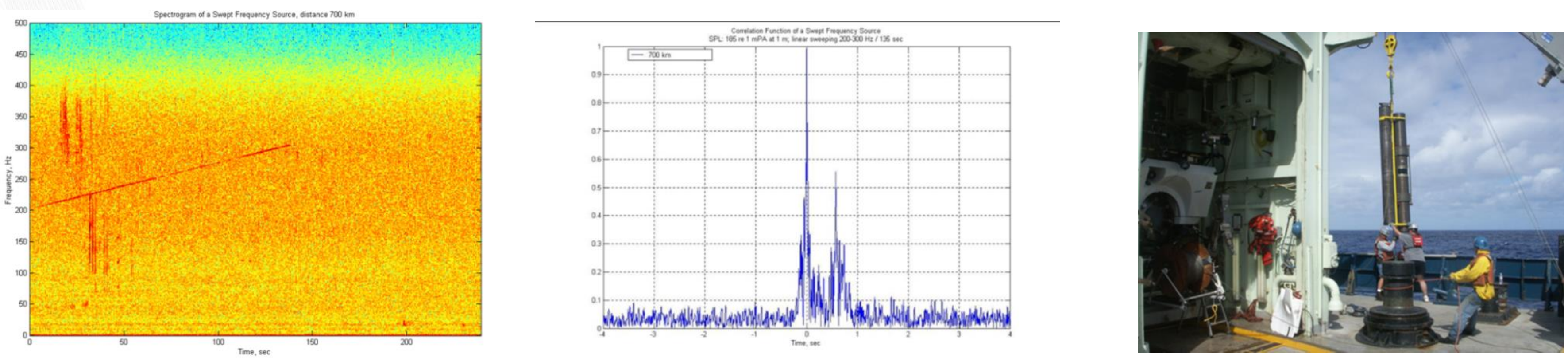




Operating History. First Test RV "Point Sur" 11.9.2001

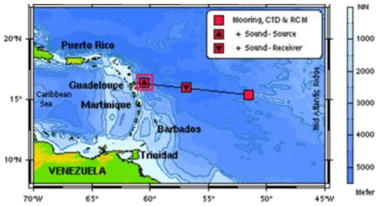


Spectrogram and correlation function at the Pioneer Seamount Receiver. The red curve is a perfect theoretical correlation; the blue curve is the experimental correlation.

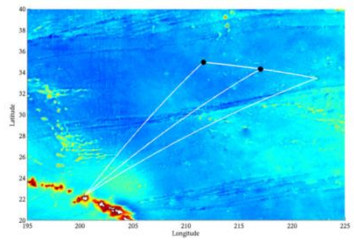


200-300 Hz sweep signal was transmitted from Hoke Seamount. Spectrogram and correlation function at San Nicolas receiving station (one can see whales sound at the spectrogram).

15 Years of Operating History

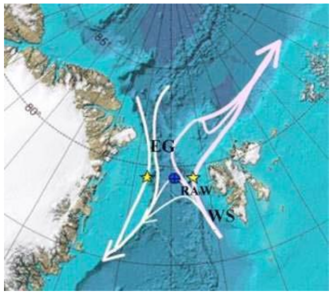


Meridional Overturning Variability Experiment (MOVE), International program CLIVAR. Acoustic tomography of the North Atlantic cold deep water April 2004 –April 2005

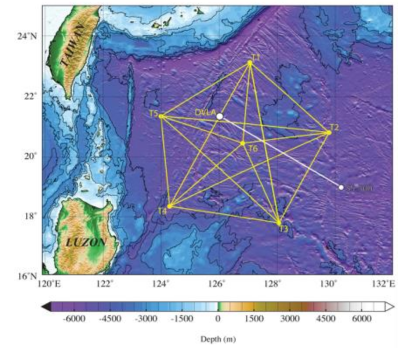


NPAL04 Long-Range Propagation Experiment: SPICE04 Pacific Ocean May 2004 –May 2005

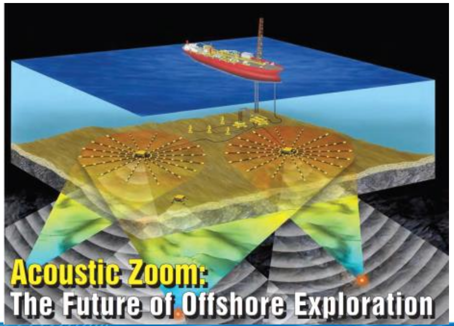
The Fram Strait Acoustic Tomography: 2008 DAMOCLES , 2010-2012 ACOBAR. Three sources worked for two years in the Fram Strait, experiment is continued



The Philippine Sea Ocean Acoustic Tomography.
PhilSea09 - Pilot test in the Philippine Sea during April-May 2009
PhilSea10. The 2010–2011 NPAL Philippine Sea deep-water acoustic propagation experiment

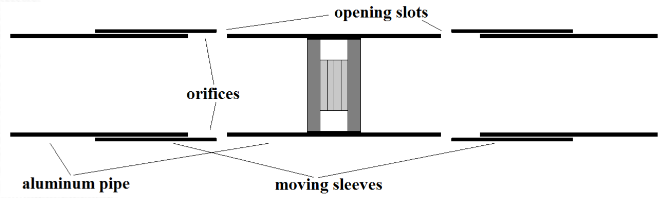


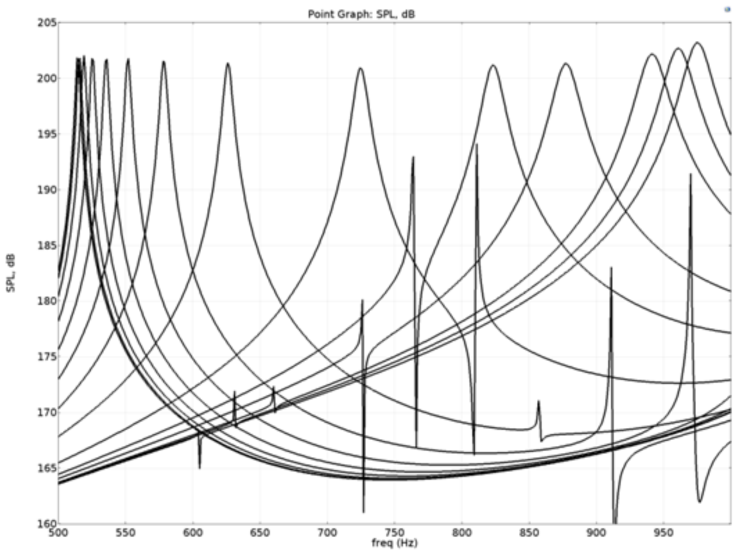
High resolution seismic source for near bottom deployment



Tunable Organ Pipe with the Octave Frequency Band

Experiments and simulation of the first prototype show the problem in the middle of frequency band. The COMSOL simulation helped to fix that problem

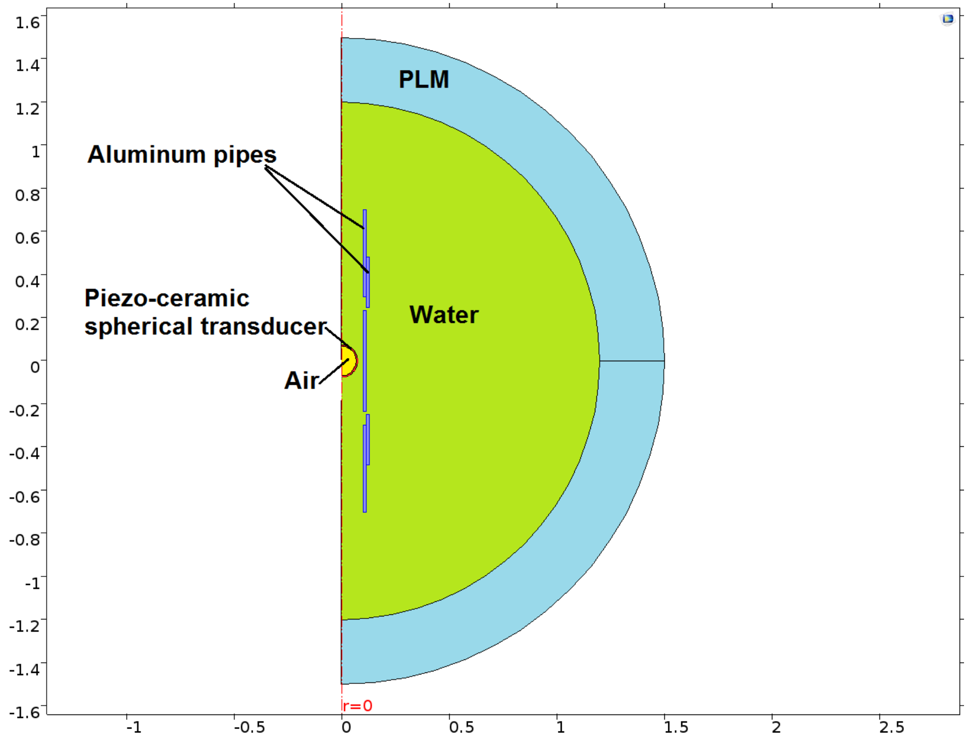




Frequency response for different sleeve positions

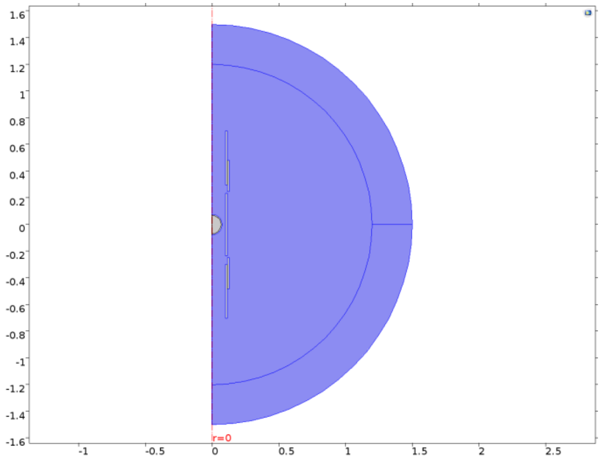
COMSOL simulation

Model: Acoustic Piezoelectric Interaction, Frequency Domain

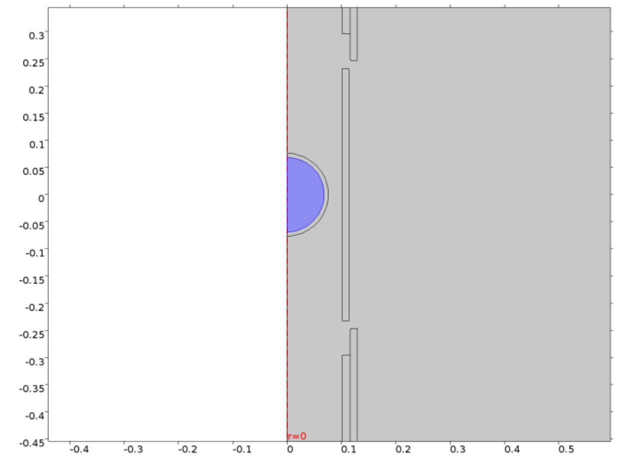


Aluminum pipes are shown in blue, water in green, piezo-ceramic spherical transducer in the center in red, and air inside the sphere in yellow. The sound source was surrounded by a Perfectly Matched Layer sphere with a spherical wave propagation condition. The Acoustic Structure Boundaries are the surfaces of the spherical transducer and the aluminum pipes. The Electric Potential boundary condition, 1000 V, was initiated on the external surface of the pieze-ceramic sphere.

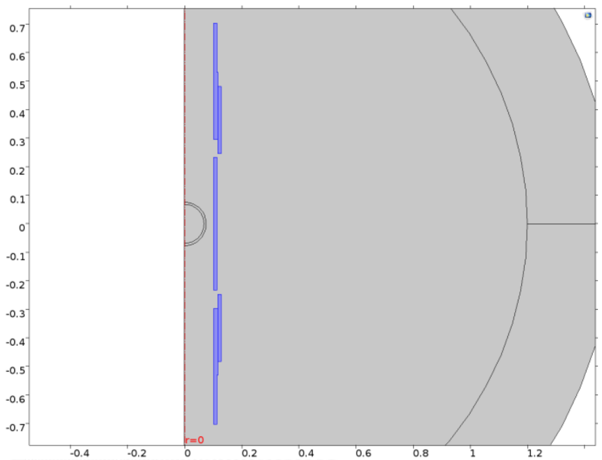
Materials:
Water, Air, Aluminum, Piezo-ceramics



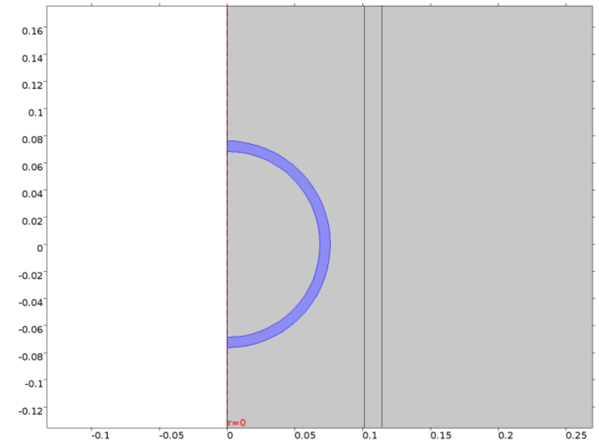
Water, liquid



Air

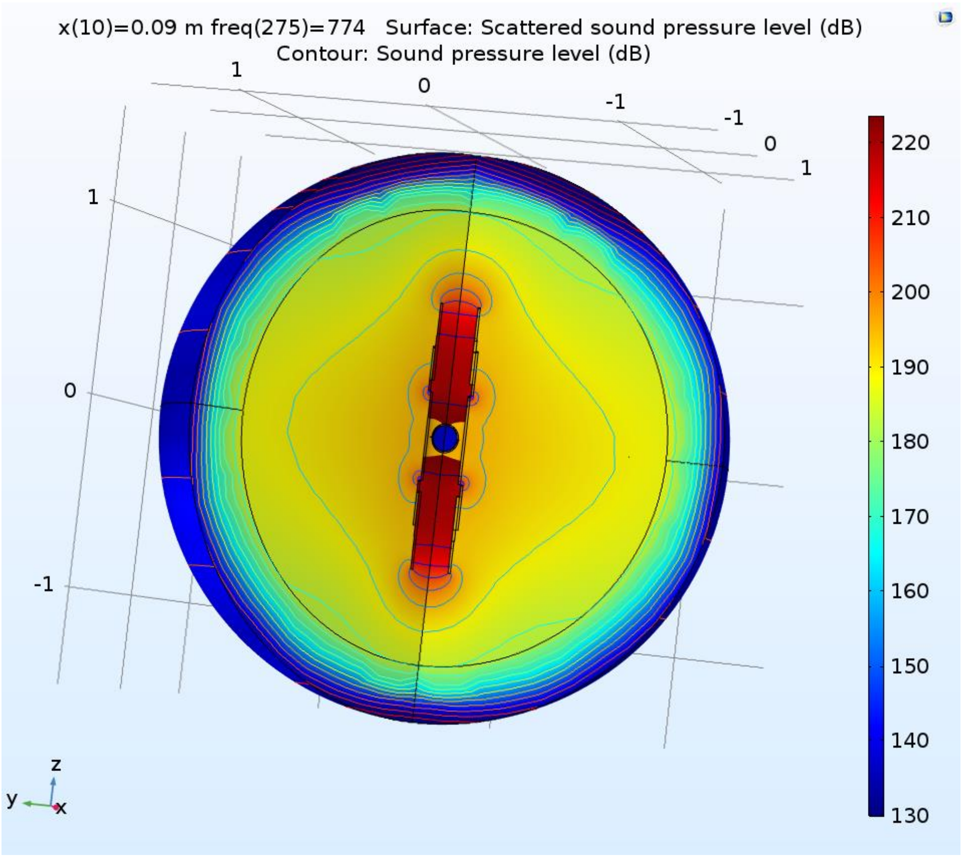


Aluminum 6063-T83



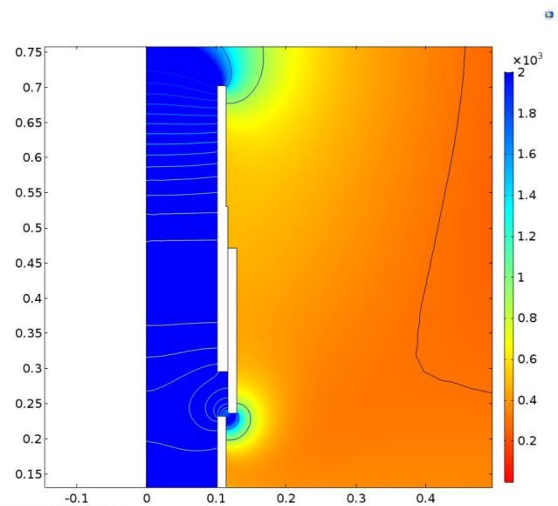
Lead Zirconate Titanate (PZT-4)

Simulation of Tunable Organ Pipe

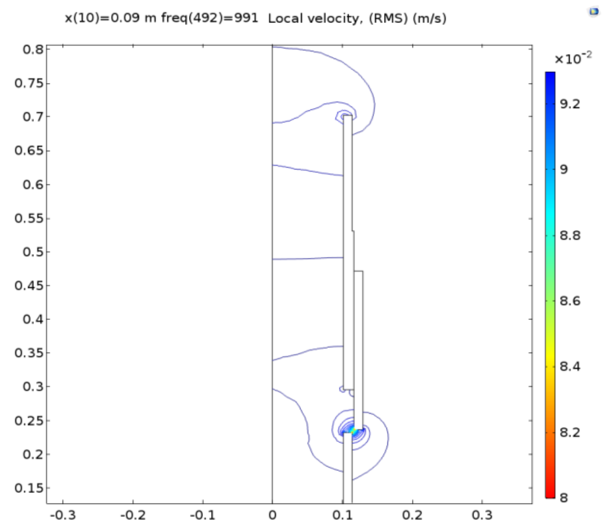


The FEA simulation

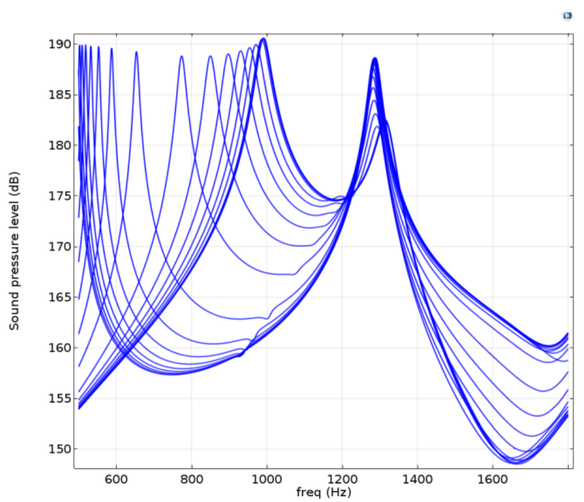
Optimal Frequency Tuning Mechanism



Corrected frequency tuning mechanism

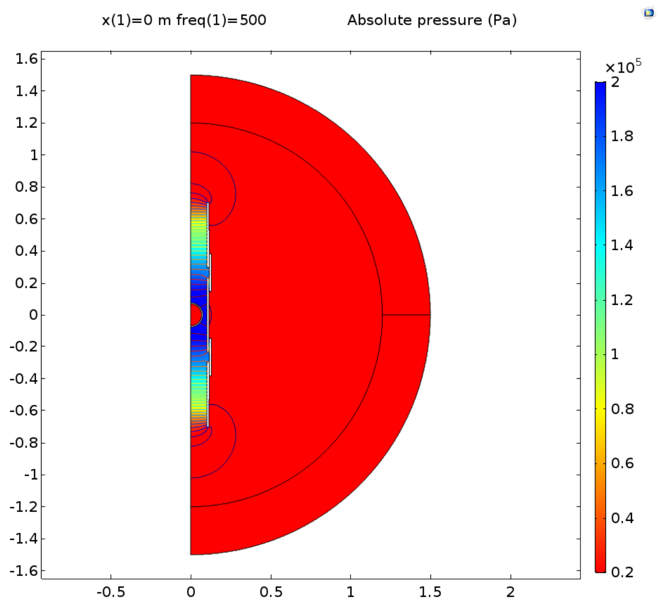


Particle velocity in the opening tuning mechanism.

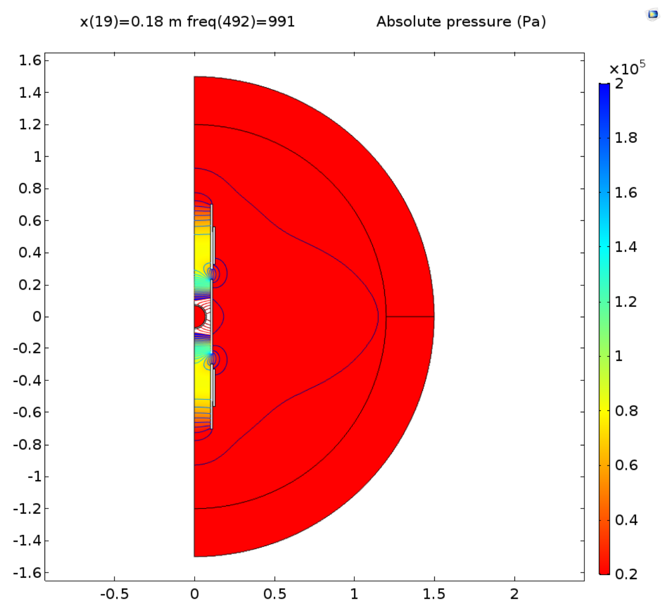


Frequency response for different sleeve positions

Radiation at the Lower and Upper Frequency Band

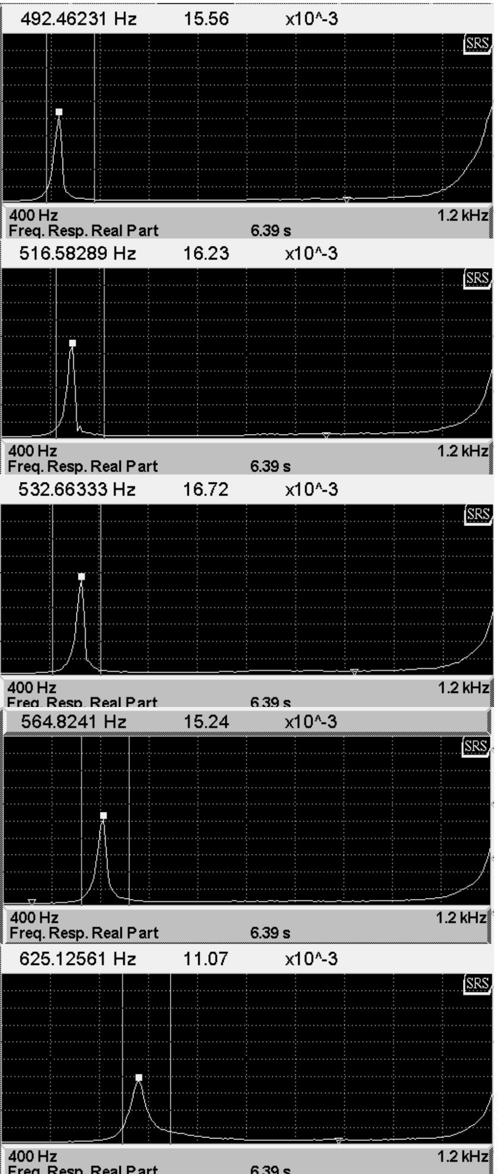


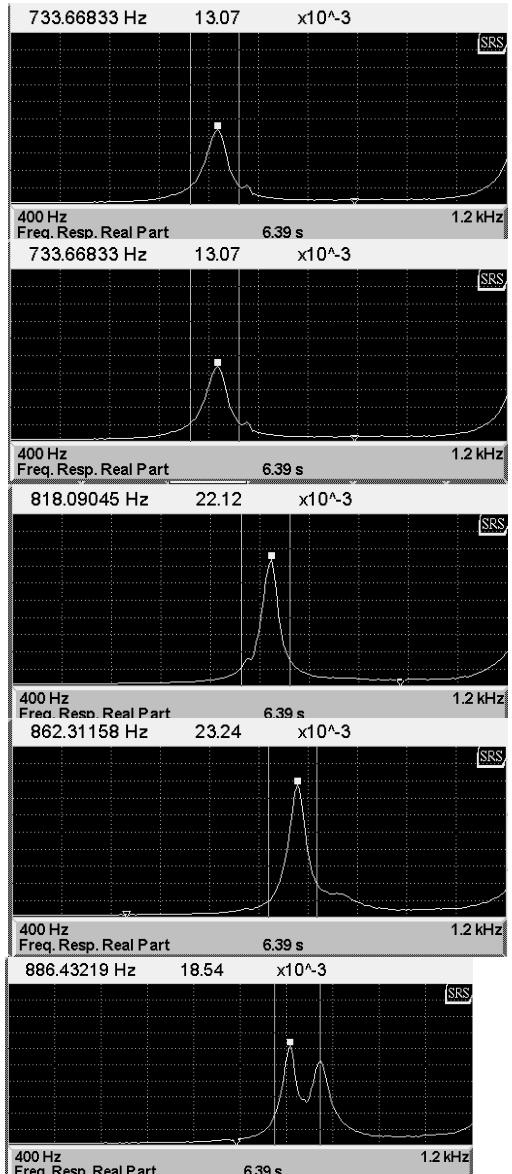
Absolute sound pressure at 500 Hz.

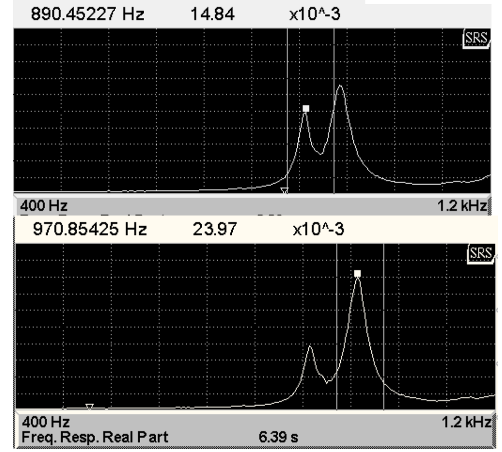


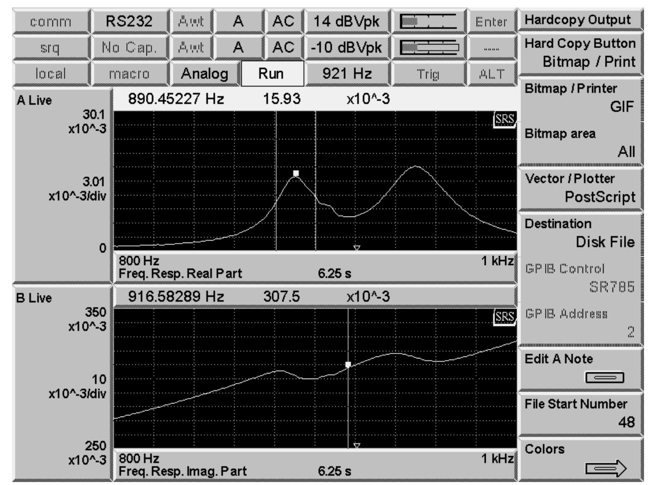
Absolute sound pressure at 1000 Hz

Radiated power vs tuning sleeve position









Dual-resonant 100Hz bandwidth frequency response at the end of high-frequency band

Comparison between simulation and Woods Hole Oceanographic Institution Test

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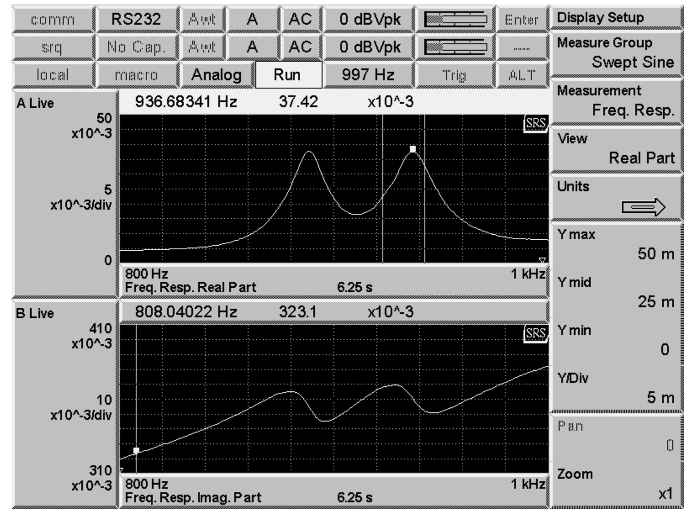

Experiment and simulation are in a very good agreement in the frequency estimation and frequency range prediction. The problem with false vibrations in the middle of the range has been solved by a new design of the tuning mechanism. The COMSOL simulation didn't predict and explain a dual resonance broadband frequency response at the higher end of a frequency band.

CONCLUSION

- A 15 year history of operating swept frequency Teledyne TWR sound sources has shown that it exhibits a high reliability, high efficiency, high radiated power, and unlimited operational depth.
- The new variant of the octave frequency band tunable organ pipe needed new improved design of the tuning mechanism.
- Application of the COMSOL finite element analysis allowed find the innovative design of the tuning mechanism.
- The parameters of the sound source prototype were reasonably close to the COMSOL simulations.
- The COMSOL simulation in 2D axisymmetric approach didn't predict and explain a dual resonance broadband frequency response at the higher end of a frequency band. Full 3D simulation is necessary.