Fundamentals of Underwater Sound

Outline for DOSITS webinar, 2 June 2020

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Goal: Understanding fundamentals of underwater sound including the role of sound levels and spectrograms in ocean acoustics

- Sound waves are variations in pressure
  - Equilibrium/background pressure depends on location
  - Sound waves are fluctuations in pressure about the equilibrium pressure
  - Sound waves are detected by acoustic receivers
  - Sound waves are generated by acoustic sources

- Sound levels are in decibels (dB), which is a logarithmic scale
  - Sound pressure waves are measured in Pascals (Pa)
  - Level = 20 * $\log_{10}$ (abs(pressure)/(reference pressure))
    - Air-borne sounds: reference pressure = 20 microPa (20×10^{-6} Pa)
    - Water-borne sounds: reference pressure = 1 microPa (1×10^{-6} Pa)
    - Levels in water are 26 dB higher than in air due to the difference in reference pressures

- Pressure waveforms show how the sound amplitude changes with time

- Spectrum shows the frequency content of a sound

  - Explore how complex waves are built from adding harmonic partials using the Fourier: Making Waves interactive simulation from Phet (University of Colorado Boulder). https://phet.colorado.edu/en/simulation/legacy/fourier
    - This interactive simulation is written in JAVA. Download/run on a computer with JAVA

- Spectrograms show how the frequency content of the sound changes in time

- Different acoustic sources have distinct signatures
  - Signatures are easier to discern in spectrograms

- The received sound depends on the ocean environment (temperature and depth of water and seabed)

- The received sound contains background noise
  - Noise is often easier to discern in spectrograms

- Summary
  - Sounds can be viewed either as pressure waves or as spectrograms

- Signatures of acoustic sources and background noise are easier to identify on spectrograms
- Sounds in the ocean depend not only on the acoustic source but also on the ocean environment
- Sound levels in the ocean have a different reference pressure than that used for in-air sound levels

Additional information on the DOSITS website:

Science of Sound > What is sound?
(https://dosits.org/science/sound/what-is-sound/)

Science of Sound > How do you characterize sound?
(https://dosits.org/science/sound/characterize-sounds/)

Science of Sound > How is sound viewed and analyzed?
(https://dosits.org/science/measurement/how-are-sounds-viewed-and-analyzed/)

Science of Sound > What units are used to measure sound?
(https://dosits.org/science/measurement/what-units-are-used-to-measure-sound/)

Science of Sound > What are common underwater sounds?
(http://www.dosits.org/science/soundsinthesea/commonsounds/)

Science of Sound > How does sound in air different from sound in water?
(https://dosits.org/science/sounds-in-the-sea/how-does-sound-in-air-differ-from-sound-in-water/)

Advanced Topic > Introduction to Decibels
(https://dosits.org/science/advanced-topics/introduction-to-decibels/)

Advanced Topic > Introduction to Phase
(https://dosits.org/science/advanced-topics/phase/)

Advanced Topic > Ocean Noise Variability and Noise Budgets
(http://www.dosits.org/science/advancedtopics/noisebudget/)

In preparation for the webinar or to review the material, you can also download apps that allow you to look at sound levels, pressure waveforms, and spectrograms of the sounds around you.

Sound Levels:

- For a smartphone or other device that runs apps: In the app store, search on "Sound Level Meter." Some possible free apps (as of Sept 2017):
    - NIOSH SLM (for iOS, free)
    - Decibel Meter (for iOS, free)
    - Decibel 10th (for iOS, free)
    - Spectrum Analyzer (for iOS, free - has sound level meter and spectrum analyzer)
    - dB by Faber Acoustical (for iOs, $0.99)
    - dB Volume Meter for (for iOs, $0.99)
    - Sound Meter (for Android, free)
    - Sound Decibel Detector (for Android, free)
- For a computer: Search on "Sound Level Meter free software." Some possible free software (as of Sept 2016):
    - "Decibel Meter" is available for different versions of Windows OS
    - "LAMA" has a free trial period for Mac OSx

Oscilloscope: View sound pressure waveforms (how the sound wave changes with time)

- For a smartphone or other device that runs apps, here are some suggested apps:
    - Sonic Tools (for iOS, free)
    - Oscilloscope (for Android, free)

Spectrum Analyzer: View the frequency content of the sound (as a single line)

- For a smartphone or other device that runs apps: In the app store, search on "Spectrogram." Some possible free apps (as of Sept 2016):
    - SpectrumView (for iOS and Android, free) - This also has spectrogram.
    - Spectrum Analyzer (for iOS, free)
    - Sonic Tools (for iOS, free)
    - Specscope (for Android, free)
    - Advanced Spectrum Analyzer Pro (for Android, free)
- For a computer: Some possible free software (as of Sept 2016):
    - Spectrum Lab free download for Windows Spectrum Lab http://www.qsl.net/dl4yhf/spectra1.html - This also has spectrogram for LA II.7.
    - Windows Media Player can show time waveforms, spectra
    - Visual Analyzer (http://www.sillanumsoft.org/) for Windows
    - Audacity Free download for both Windows and Macs
        - You can record a sound, zoom in to see the waveform. Select Analyze, plot spectrum to see the frequency spectrum.

- AudioXplorer for Macs. This shows waveforms and spectra and spectrogram (for LA II.7). http://www.arizona-software.ch/audioxplorer/download.html

Spectrogram: View the frequency spectrum (in colors) as a function of time.

- For a smartphone or other device that runs apps: In the app store, search on "Spectrogram." Some possible free apps (as of Sept 2016):
  - SpectrumView (for iOS and Android, free)
  - Simple Spectrogram (for Android, free)
  - Spectral Audio Analyzer (for Android, free)
- For a computer: Search on "Spectrogram free software." Some possible free software (as of Sept 2016):
  - Windows
    - Spectrum Lab http://www.qsl.net/dl4yhf/spectra1.html
    - Visual Analyzer http://www.sillanumsoft.org/
  - Mac
    - Sonic Visulaizer http://sonic-visualiser.en.softonic.com/mac
  - Both Mac and Windows
    - Spec - Acoustic Spectrum Analyzer http://spek.cc/

Explanation: A spectrogram shows the frequency spectrum as it changes with time. Imagine looking at a spectrum (from the spectrum analyzer) at an instant in time and assigning a color to the peaks based on their heights. The colored spectrum becomes a single line on the spectrogram corresponding to that instant in time. Instead of looking at single instances at one time in a rapidly varying spectrum on a spectrum analyzer, sound is often studied with a spectrogram because it shows how the frequency content changes with time.