Radiated Noise of Research Vessels

Greening the Research Fleet Workshop
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Ship Radiated Noise

- **What makes noise?**
  - Propulsion
  - Machinery
  - Hydrodynamic sources, transient sources and transducers

- **How can you build and operate a quiet ship?**
  - Propulsor and hull design
  - Noise control technologies
  - Operational awareness

- **Why care?**
  - Environmental Impact
  - Shipboard Habitability
  - ICES
  - Impact on Shipboard Mission Systems (self-noise)

- **How to measure it?**
  - Acoustic ranges, portable systems
  - Shallow water measurements
Radiated Noise Sources

- **Sources**
  - Propulsor Noise
  - Motor and Aux Machinery Noise
  - Sea connected systems (pumps)
  - Transient sources
    - *incl. active acoustic transponders*
  - Hydrodynamic sources

- **Paths**
  - Direct acoustic propagation
  - Shaft line propagation
  - Sound/structure interaction
  - Diffracted paths
  - Tanks
Machinery Sources

25 MW Alstom Generator

Measurements taken 30 Sept 1998

CORE MAGNETOSTRICTION 2E
SHAFT ROTATING 1R AND 2R

2E - Full load
2E - No load with excitation

Stator Core Radial

Frequency, Hz
5 to 15 Knots
Low Speed Limits

2E - Low Speed
1R 2X

Generator Rotational
2X - Rotor Mechanical

Bearing Cap Vertical - 3600 RPM

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Paths for Machinery Noise

- **Airborne**
- **First Structureborne**
- **Secondary Structureborne**
- **U/W Radiated Noise**

Figure courtesy of Noise Control Engineering
Pump generated fluidborne acoustic energy travels via piping systems.
Propeller Noise

- Cavitation typical dominates broadband ship signature

Mitigation:
- Design prop for maximum cavitation inception speed
- Restrict noise-sensitive
Non-propulsion flow-related noise

Hull and appendage cavitation
- Rudders, Struts
- Fairings, Bilge Keels

Mitigation: good hydrodynamic design

Bow wave transients
- Acoustic source
- Bubble sweepdown
Sonar Self-Noise Sources

- **Hull-mounted sonars**
  - Bow-area flow noise
  - Bow wave transient
  - Flow-induced structural excitation

- **Installation details**
  - Window material and attachment mechanism
  - Fairings

- **Propagation of external ship sources into sonar**
  - Machinery / prop noise via hull grazing path
  - Bottom reflected path

\[
SNR = [SL - 2TL + 20\log(H_T H_R + TS)] - \{NR + (NL_0 - DI_R)\}
\]
Impact - Environmental Noise

- Studies ongoing to assess impact of anthropogenic noise on marine mammals
  - general shipping noise
  - Local radiated noise
  - Science mission sources

<table>
<thead>
<tr>
<th>Sound Source</th>
<th>SPL dB re 1μPa (1m)</th>
<th>Ping Energy dB re 1μPa s</th>
<th>Ping Duration</th>
<th>Duty Cycle (%)</th>
<th>Peak Frequency (Hz)</th>
<th>Band Width (Hz)</th>
<th>Directionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underwater Nuclear Device (30 kilo-ton)</td>
<td>328</td>
<td>338</td>
<td>10 s</td>
<td>Intermittant</td>
<td>Low</td>
<td>Broad</td>
<td>Omni</td>
</tr>
<tr>
<td>Ship Shock Trial (10,000 lb TNT)</td>
<td>299</td>
<td>299</td>
<td>1 s</td>
<td>Intermittant</td>
<td>Low</td>
<td>Broad</td>
<td>Omni</td>
</tr>
<tr>
<td>Military Sonar (SURTASS/LFA)</td>
<td>235</td>
<td>243</td>
<td>6 – 100 s</td>
<td>10</td>
<td>250</td>
<td>30</td>
<td>Horizontal</td>
</tr>
<tr>
<td>Research Sonar (AFOC Source)</td>
<td>195</td>
<td></td>
<td>20 minutes</td>
<td>8</td>
<td>75</td>
<td>37.5</td>
<td>Omni</td>
</tr>
<tr>
<td>Acoustic Harassment Device</td>
<td>185</td>
<td></td>
<td>0.5 – 2 s</td>
<td>50</td>
<td>10,000</td>
<td>600</td>
<td>Omni</td>
</tr>
<tr>
<td>Multibeam (Echosounder Hull-mounted)</td>
<td>235</td>
<td>218</td>
<td>20 ms</td>
<td>0.4</td>
<td>12,000</td>
<td>Narrow</td>
<td>Vertical</td>
</tr>
<tr>
<td>Research Sonar (RAFOS float)</td>
<td>195</td>
<td>120 s</td>
<td>small</td>
<td>250</td>
<td>100</td>
<td>Omni</td>
<td></td>
</tr>
<tr>
<td>Fishing Vessel 12 m long (7 knots)</td>
<td>150</td>
<td>CW</td>
<td>100</td>
<td>300</td>
<td>250-1000</td>
<td>Omni</td>
<td></td>
</tr>
</tbody>
</table>

Table from Hildebrand, “Sources of Anthropogenic Sound in the Marine Environment”
ICES Criteria for Fisheries RV’s

- Impact of research vessel noise on fish surveys
  - Based on estimates of “fish hearing” for various species
  - Impact to both acoustic and catch surveys

From Mitson, “UNDERWATER NOISE OF RESEARCH VESSELS, 1995
Radiated Noise Measurement

Objective: **Quantify** ship radiated noise to...

- **Demonstrate compliance**
  - noise criteria, design goals, contractual requirements

- **Assess Environmental Impact**

- **Identify unique characteristics** *(radiated noise *signature*)
  - impact on internal sensors and systems
  - Interference in multi-static experiments
  - detection, classification and localization in naval applications

- **Acoustic signature monitoring**
  - Establish baseline for condition – based maintenance, problem identification, diagnostics
Definitions

• **Radiated Noise**
  - vessel noise that is transmitted into the water and can be detected by off-board receivers
    • Typically reported as One Third octave (OTO) Band
    • Narrowband (1 Hz) data used to characterize machinery tonals

• **Radiated Noise Source Level**
  - Equivalent simple source (omnidirectional monopole) level
    \[ SL \text{ dB re } 1\,\mu \text{Pa @ 1m} \]
    • Back-propagated to 1m assuming spherical spreading from a *far field, free-field* measurement

• **Platform Noise**
  - Ship noise that can be detected by acoustic or vibration sensors
    • Not necessarily detectable as radiated noise

• **Sonar Self-Noise**
  - Received acoustic levels in the output of onboard system receiving band(s) due to self-generated platform noise sources
Figure 13. Comparison of noise levels between two vessels built in the 1960’s and two built in the 1990’s, all free-running at 11 knots.

Figure 14. "Explorer" towing a bottom trawl at two speeds. Note that the trawl noise is less than the vessel noise below 500 Hz.
Acquisition System Considerations

- **Sensors**
  - Sensitivity, directivity, dynamic range

- **Signal conditioning**
  - High Pass, Low Pass, anti-aliasing
  - Gain
  - Grounding / isolation

- **Acquisition**
  - Sampling rate / bandwidth
  - Throughput
  - Data storage

- **Tracking**
  - Accurate position vs time

- **Environmental Data**
  - CTD / SVP
  - Bathymetry
  - Sea conditions
  - Wind
Deep Water Fixed Range Measurements

- Resource intense
  - Logistics
  - Instrumentation
  - Personnel
  - Assets

- Moving Source + Moving Receiver
  - Location, location, location…
  - RANGE = Source Level
  - Tracking
Ship-based Measurements

- Resource intense
  - Logistics
  - Instrumentation
  - Personnel
  - Assets
- Moving Source + Moving Receiver
  - Location, location, location…
  - RANGE = Source Level
  - Tracking
Measurement Considerations

- **Lloyd’s mirror**

- **Array motion**
  - Position uncertainty
  - Low frequency noise floor

- **CPA**
  - Defining “far field”

- **Acquisition window**

- **Test Vessel Aspect**
- Simple source representation coupled with simplified propagation assumptions do not capture sound field variability for real sources in shallow water.