Radiated Noise of Research Vessels

Greening the Research Fleet Workshop
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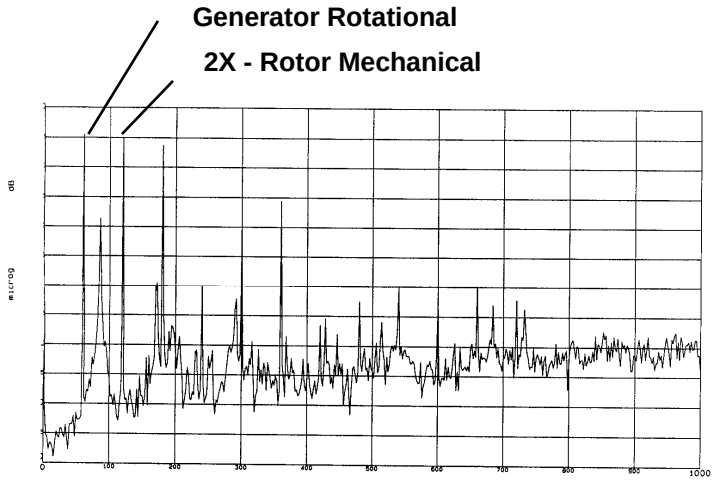
Ship Radiated Noise

- 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



Bearing Cap Vertical - 3600 RPM

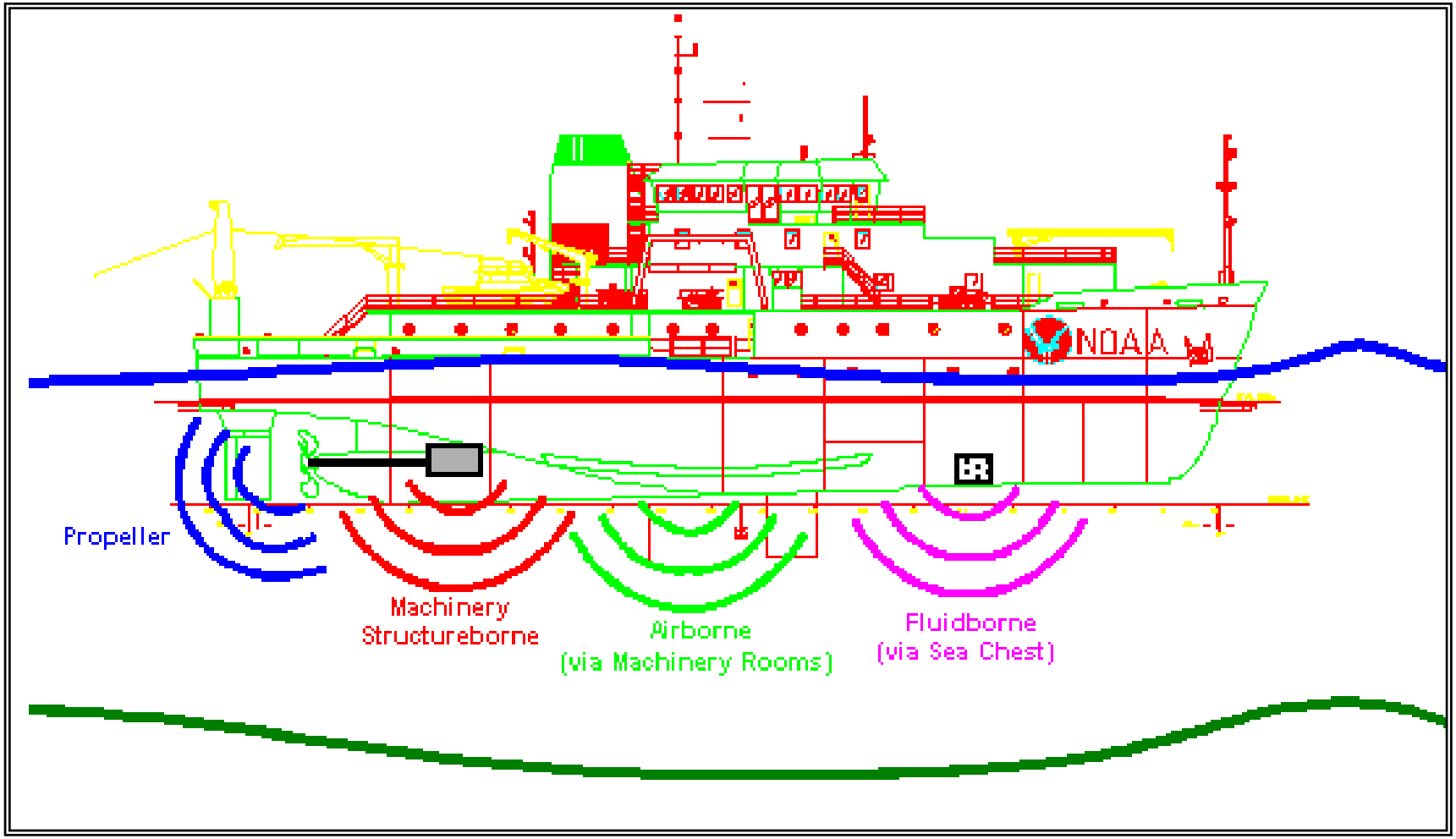
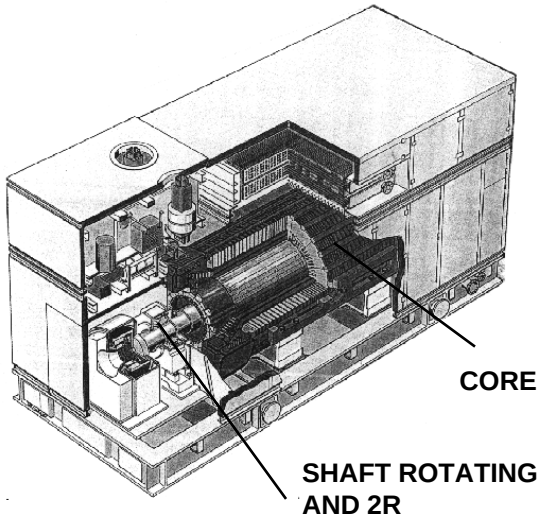


Figure courtesy of Noise Control Engineering

Machinery Sources

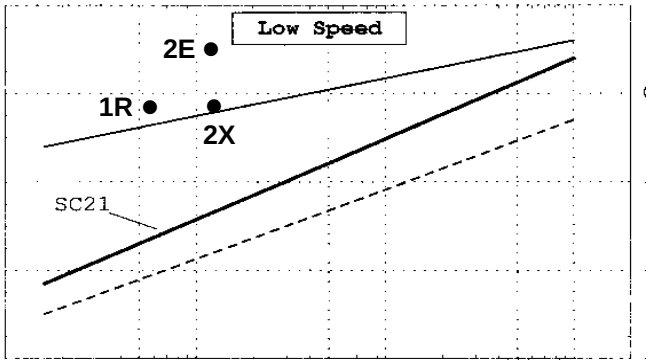
25 MW Alstom Generator



Measurements taken 30 Sept 1998

CORE MAGNETOSTRICTION 2E

SHAFT ROTATING 1R AND 2R

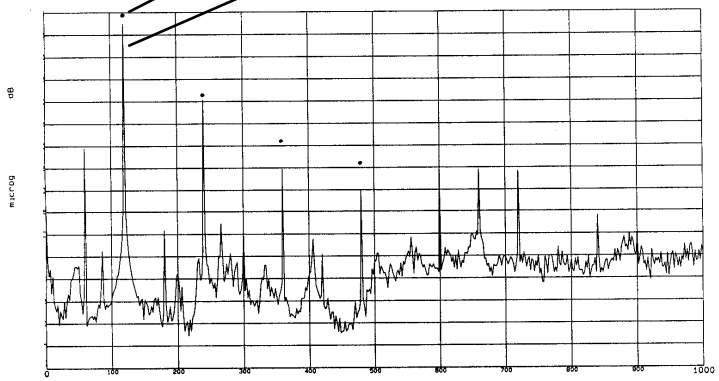


Frequency, Hz

5 to 15 Knots Low Speed Limits

2E - Full load

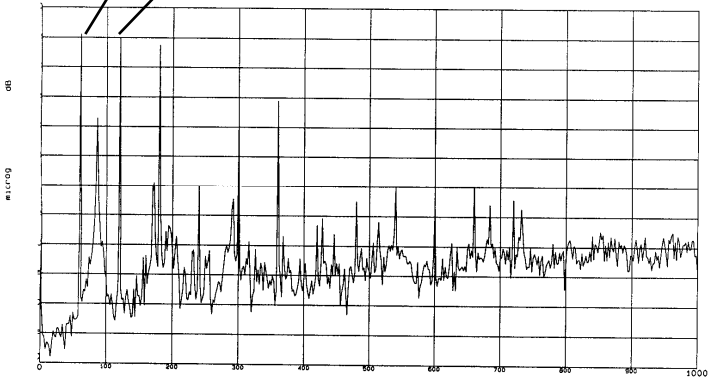
2E - No load with excitation



Stator Core Radial

Generator Rotational

2X - Rotor Mechanical



Bearing Cap Vertical - 3600 RPM

Paths for Machinery Noise

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

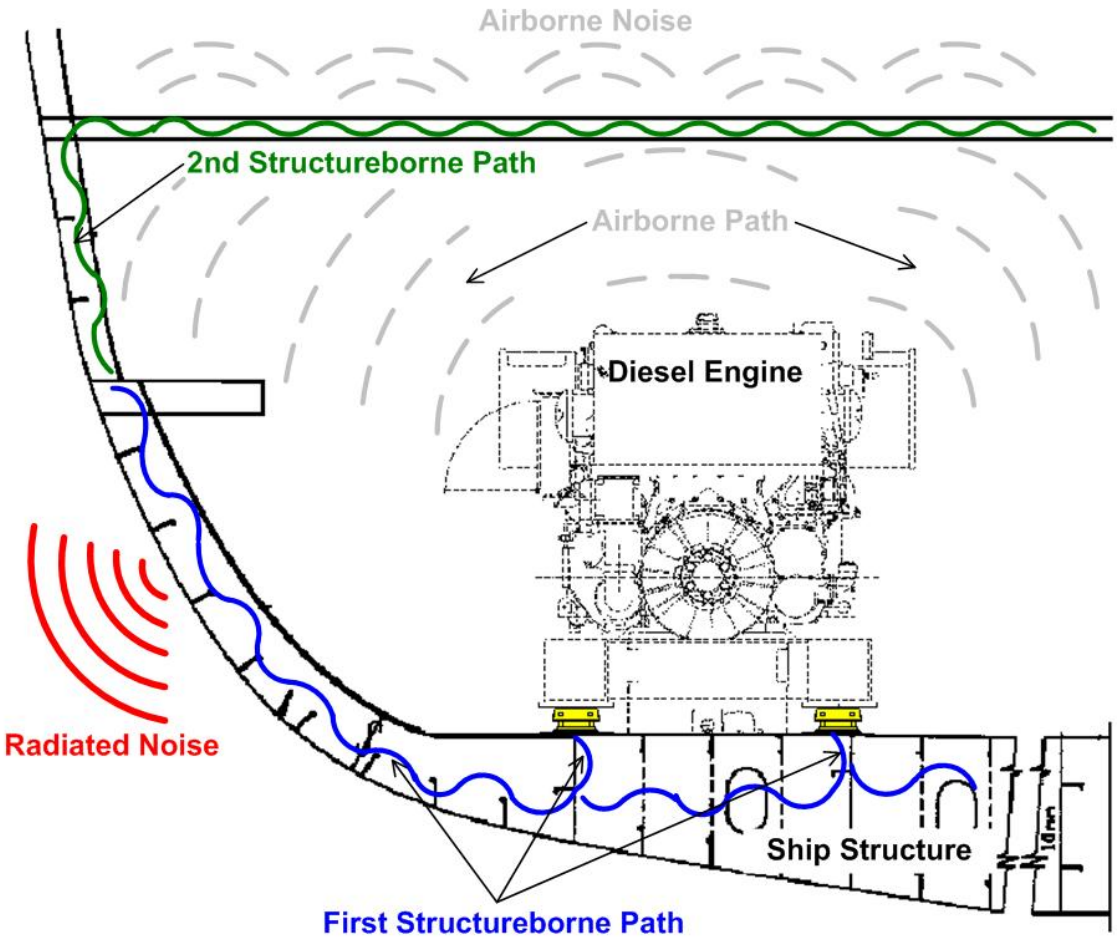


Figure courtesy of Noise Control Engineering

Sea Connected Systems – Fluid-coupled paths

Pump generated fluidborne **acoustic energy travels via piping systems.**

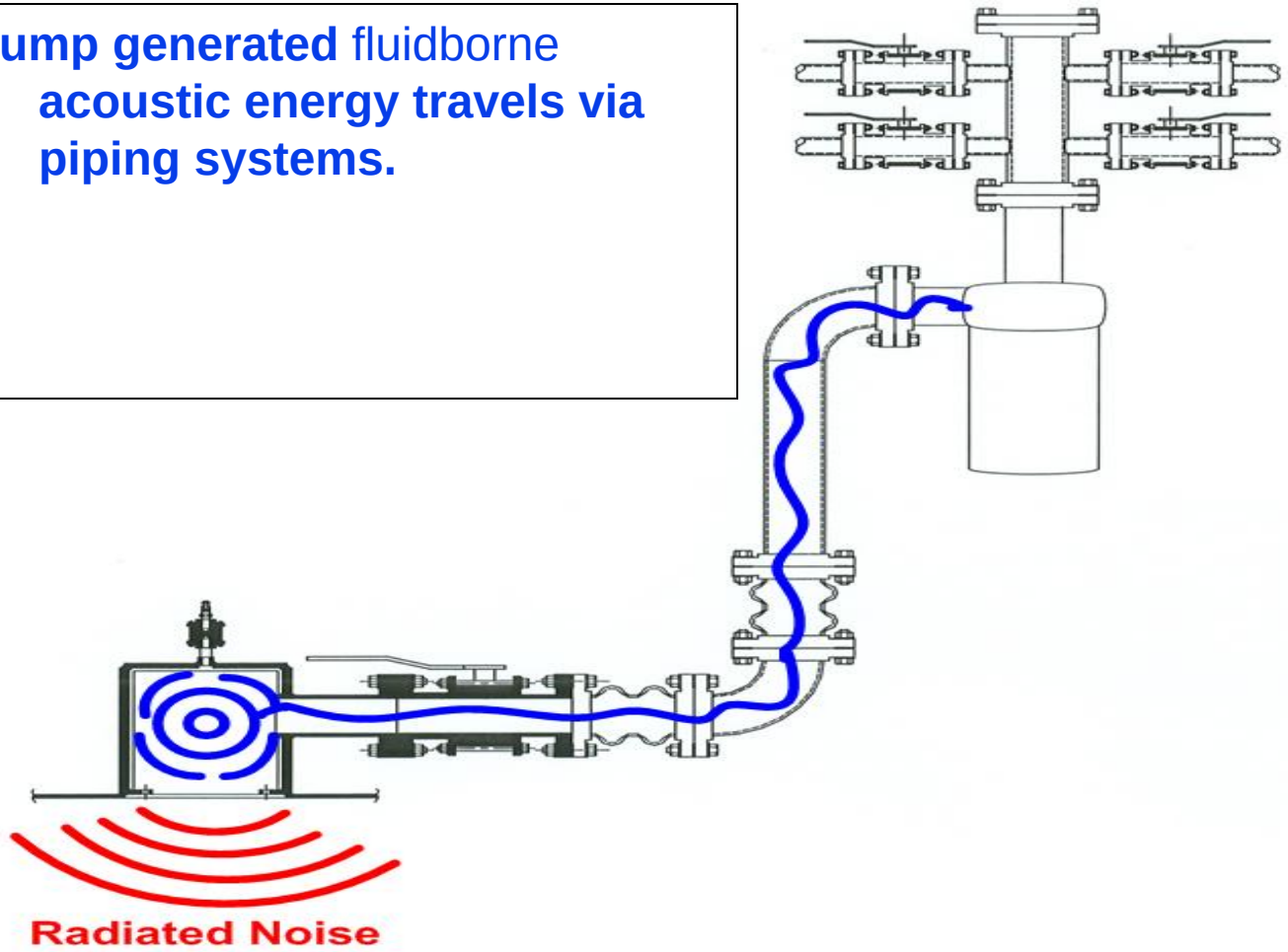


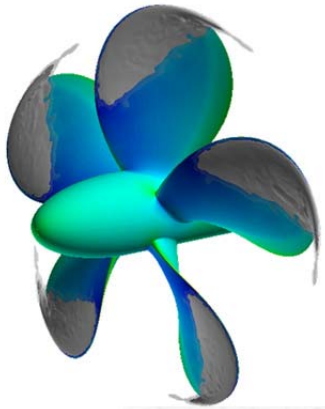
Figure courtesy of Noise Control Engineering

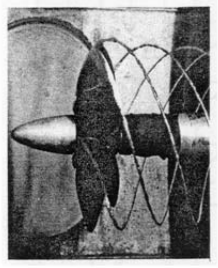
Propeller Noise

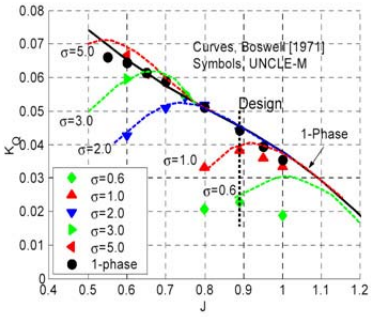
- **Cavitation typical dominates broadband ship signature**

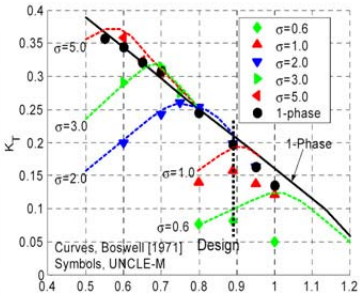
Mitigation:

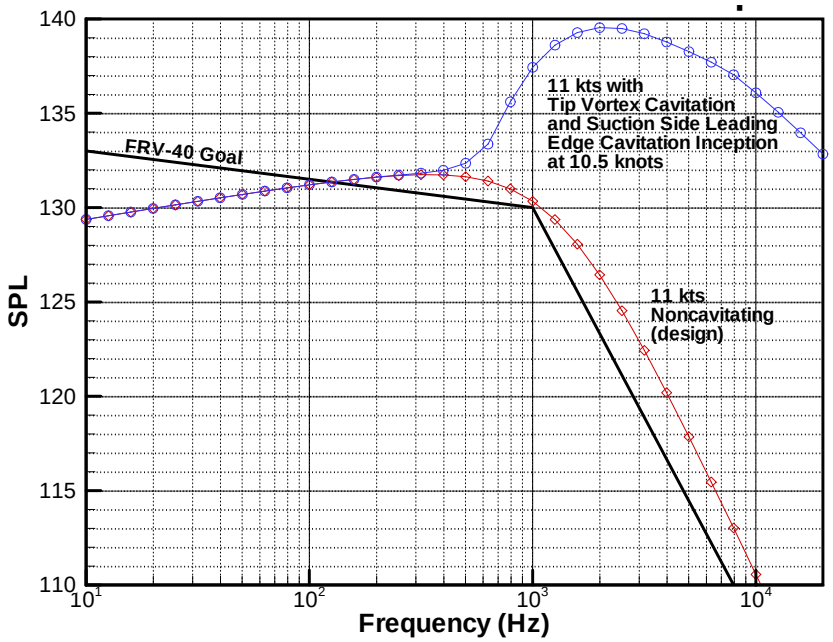
  - **Design prop for maximum cavitation inception speed**
  - **Restrict noise-sensitive**











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Non-propulsion flow-related noise

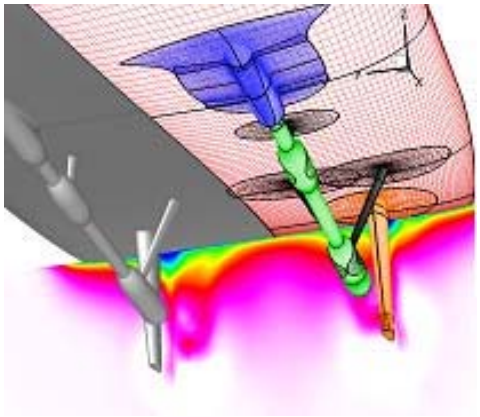
Hull and appendage cavitation

- Rudders, Struts
- Fairings, Bilge Keels

Bow wave transients

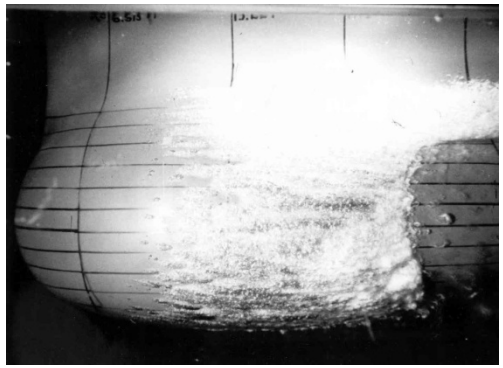
- Acoustic source
- Bubble sweepdown

Mitigation: good hydrodynamic design



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



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

Source Level; Transmit/Receive Directivity; Receive Reverb; Ambient + Self-Noise; Transmission (Propagation) Loss; Target Strength; Directivity Index

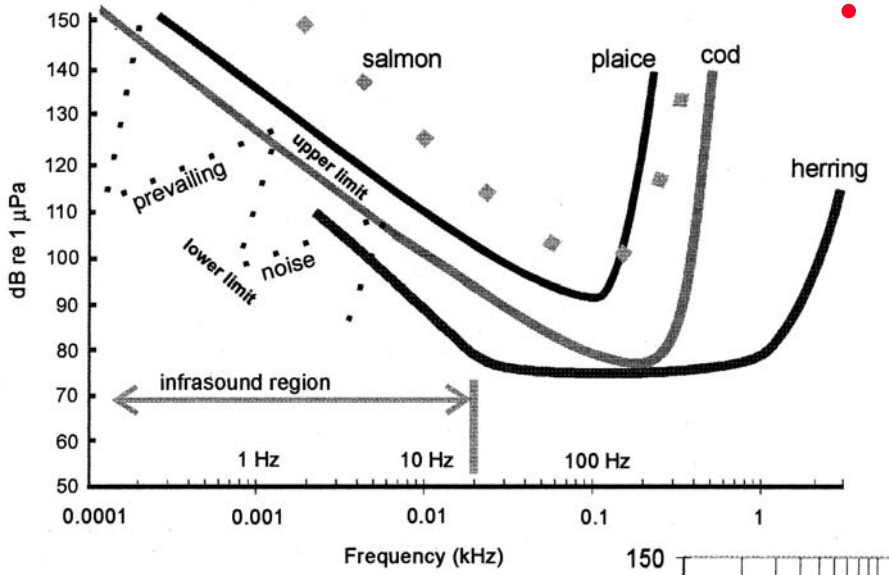
Impact - Environmental Noise

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

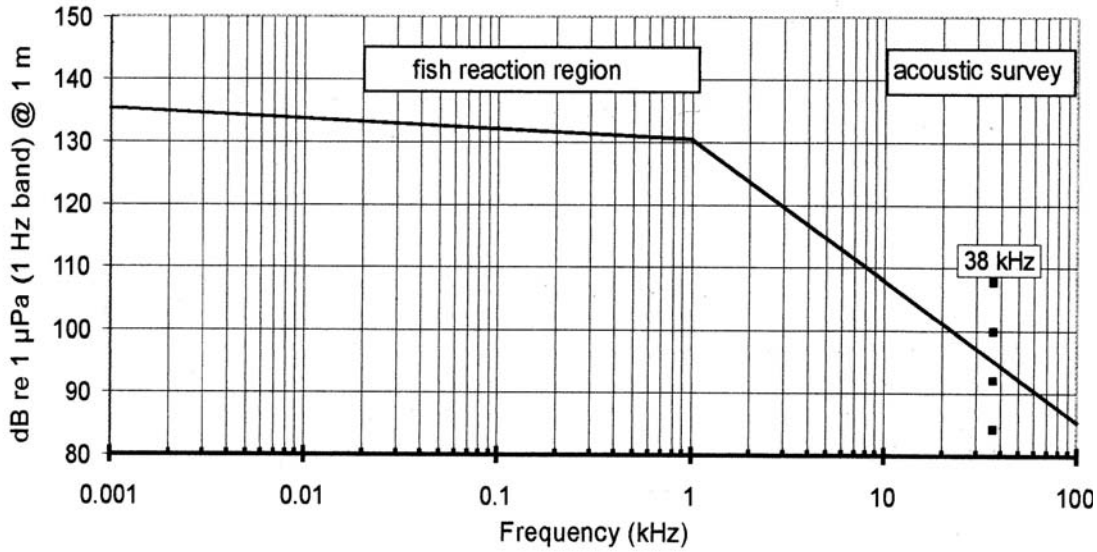
Sound Source	SPL dBre 1µPa @1m	Ping Energy (dB re $1\mu Pa^2*s$)	Ping Duration	Duty Cycle (%)	Peak Frequency (Hz)	Band Width (Hz)	Direct-ionality
Underwater Nuclear Device (30 kilo-ton)	328	338	10 s	Inter-mittant	Low	Broad	Omni
Ship Shock Trial (10,000 lb TNT)	299	299	1 s	Inter-mittent	Low	Broad	Omni
Military Sonar (SURTASS/LFA)	235	243	6 – 100 s	10	250	30	Horizontal
Research Sonar (ATOC Source)	195		20 minutes	8	75	37.5	Omni
Acoustic Harrassment Device	185	185	0.5 - 2 s	50	10,000	600	Omni
Multibeam (Echosounder Hull-mounted)	235	218	20 ms	0.4	12,000	Narrow	Vertical
Research Sonar (RAFOS float)	195		120 s	small	250	100	Omni
Fishing Vessel 12 m long (7 knots)	150		CW	100	300	250-1000	Omni

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**

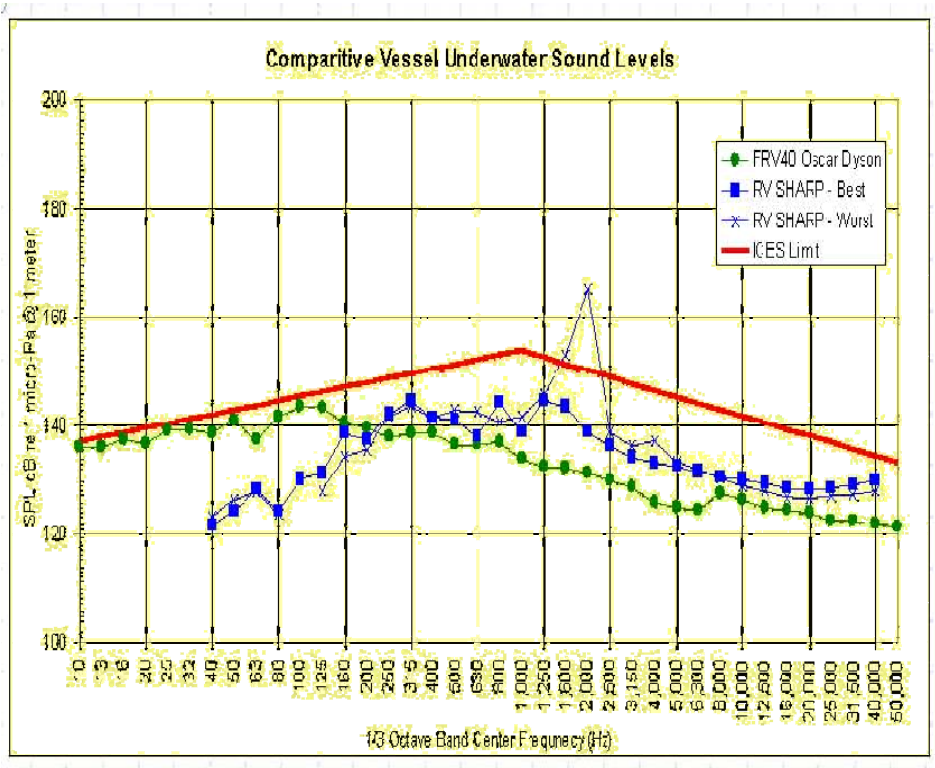


From Mitson, "UNDERWATER NOISE OF RESEARCH VESSELS, 1995

Radiated Noise Measurement

Objective: *Quantify* ship radiadted noise to…

- **Demonstrate compliance**
  - noise criteria, design goals, contractual requirements
- **Asses 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 dB re 1 µPa @ 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

Example Radiated Noise Data

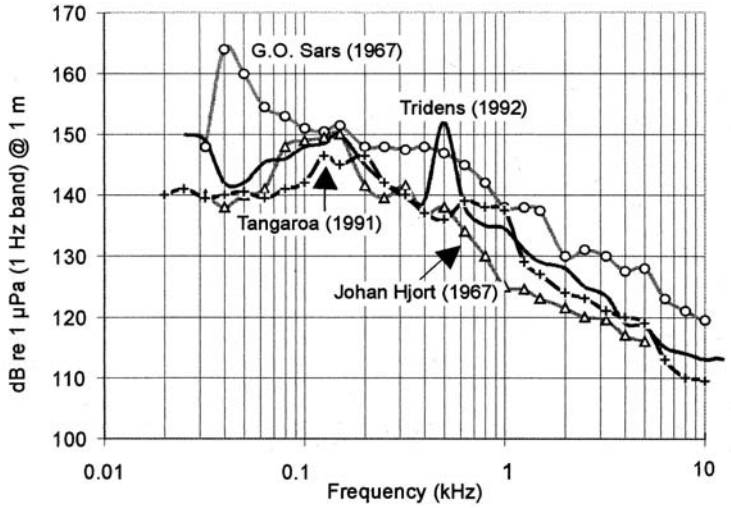


Figure 13. Comparison of noise levels between two vessels built in the 1960's and two built in the 1990's, all free-running at 11 knots.

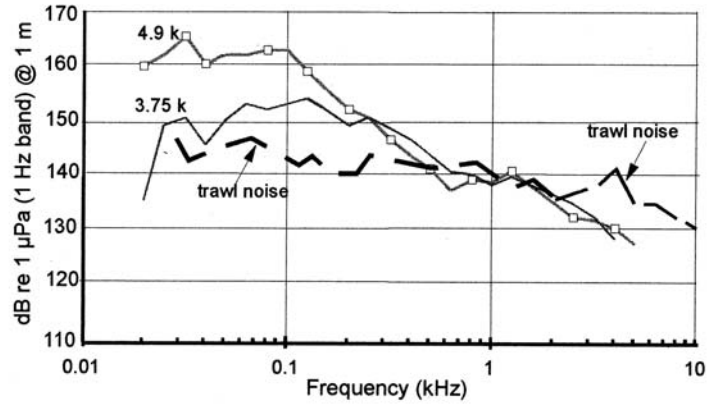
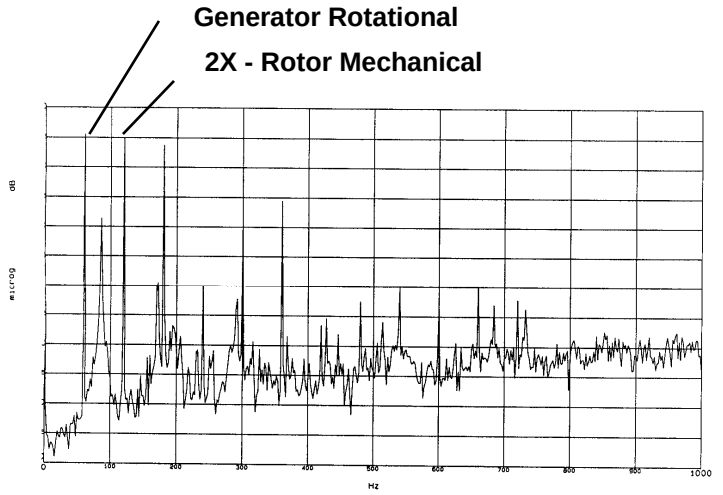
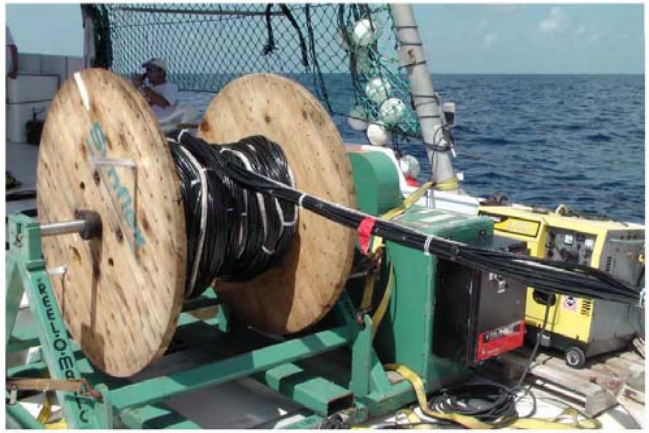


Figure 14. "Explorer" towing a bottom trawl at two speeds. Note that the trawl noise is less than the vessel noise below 500 Hz.



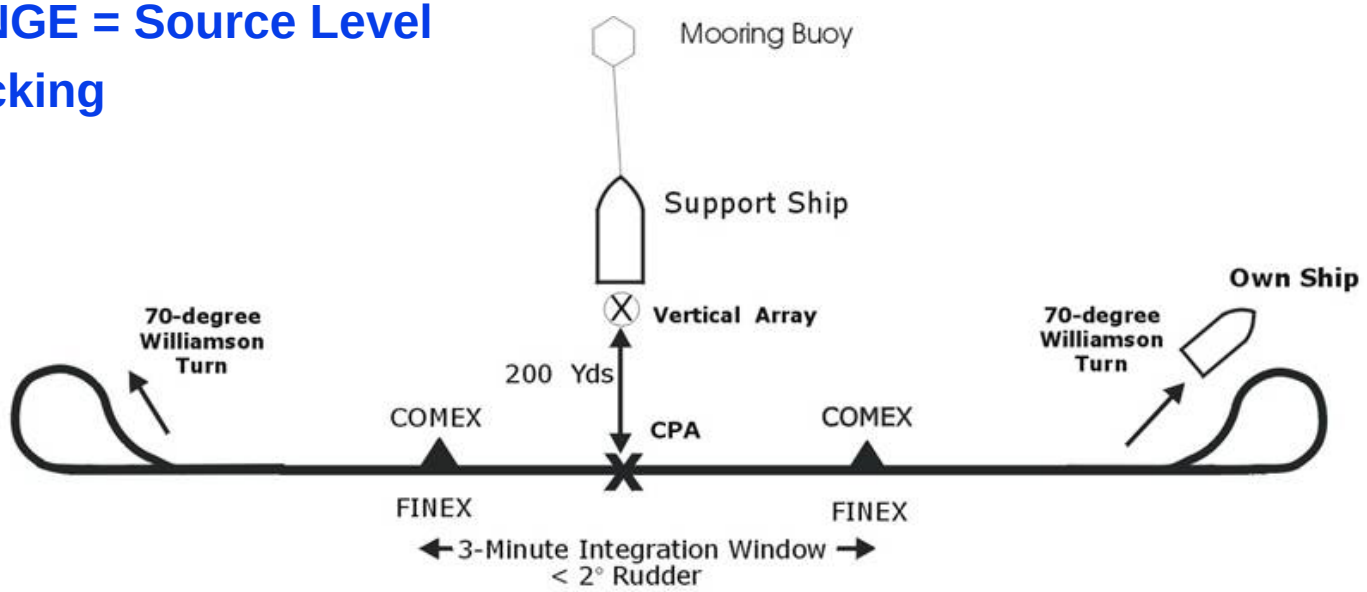
Acquisition System Considerations

- **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



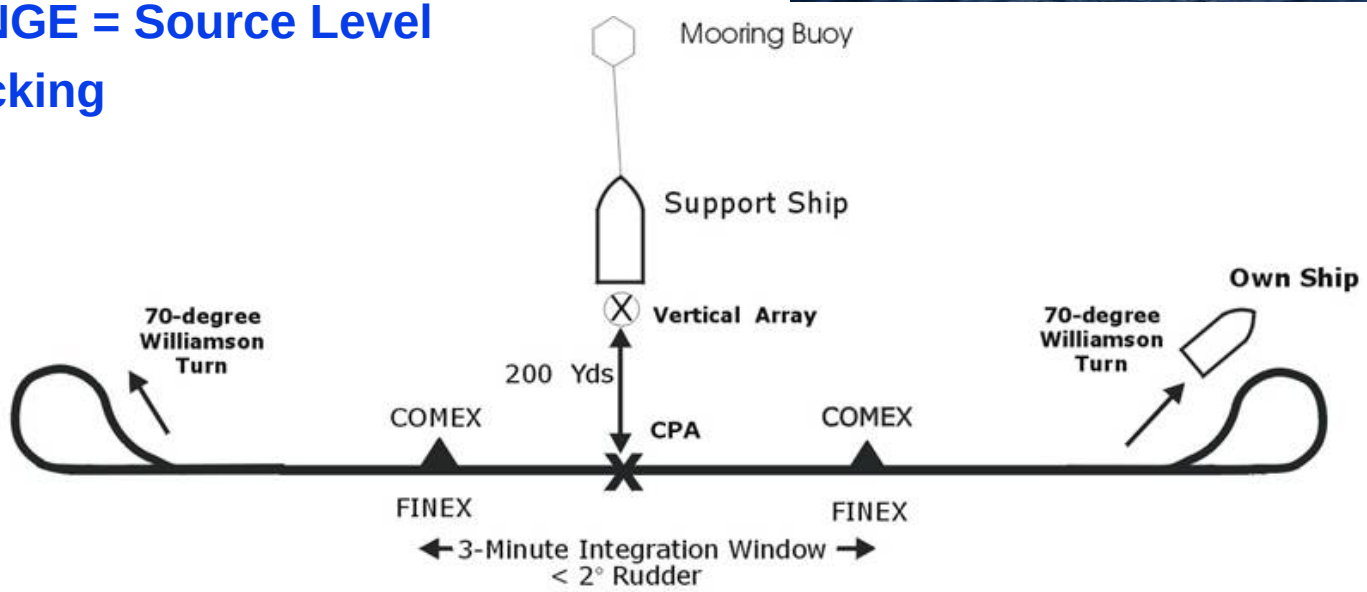
Deep Water Fixed Range Measurements

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



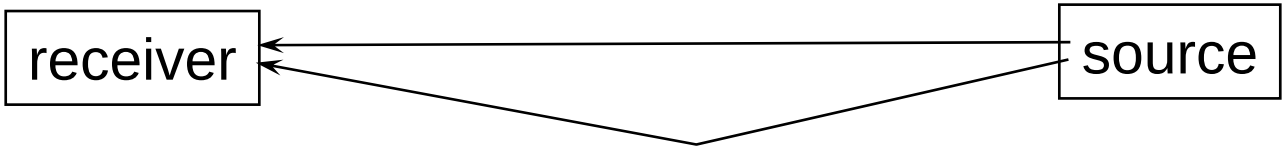
Ship-based Measurements

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

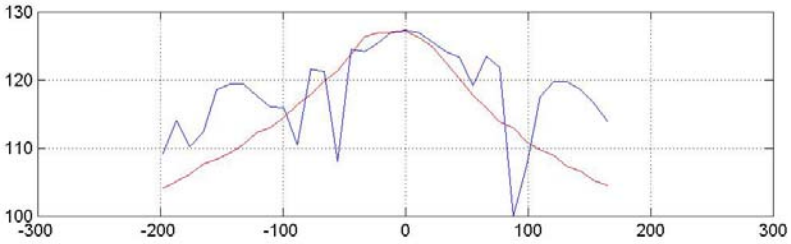


Measurement Considerations

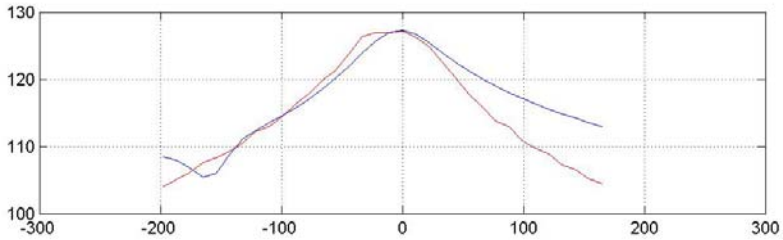
- **Lloyd's mirror**



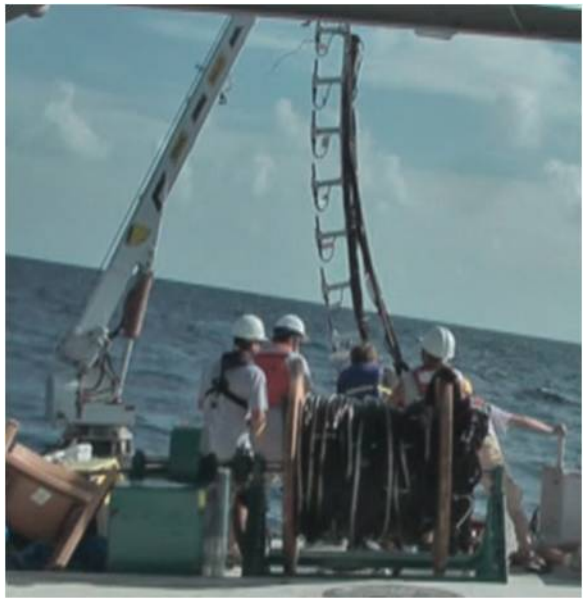
With Surface Reflected Path (Lloyd Mirror)



Without Surface Reflected Path



- **Array motion**
  - **Position uncertainty**
  - **Low frequency noise floor**
- **CPA**
  - **Defining "far field"**
- **Acquisition window**
- **Test Vessel Aspect**



Shallow Water Measurements

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