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Measurement of Underwater Sound Source Levels from Ships

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Background

As one of important vehicles in present economy development, ship has many advantages which cannot be exceeded by other vehicles. Recently, with the integration of the world economy, transportation at sea is more and more busy. At the same time, problem of noise disturbance on board ship and underwater noise environment produced by ship gets more attention of international society. Therefore , in 2012, The DRAFT CODE ON NOISE LEVELS ON BOARD SHIPS has been adopted in MSC337 & MSC339 by MSC91 to provide international standards for protection against noise regulated by regulation [II-1/3-12] of the International Convention for the Safety of Life at Sea (SOLAS) .

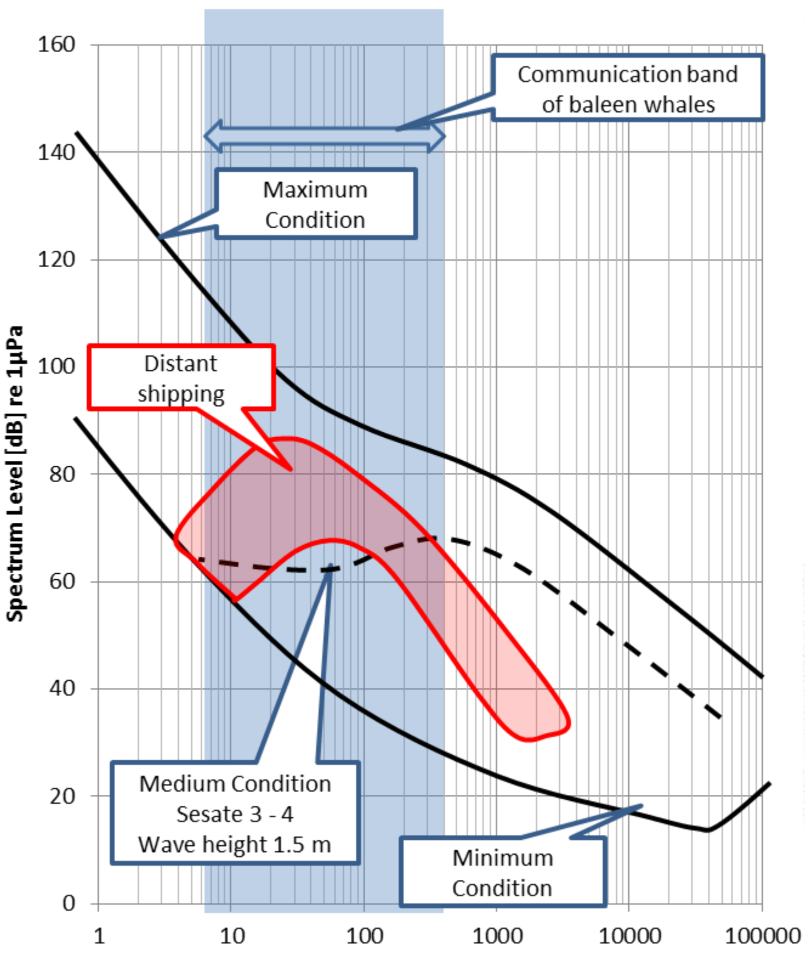
Background

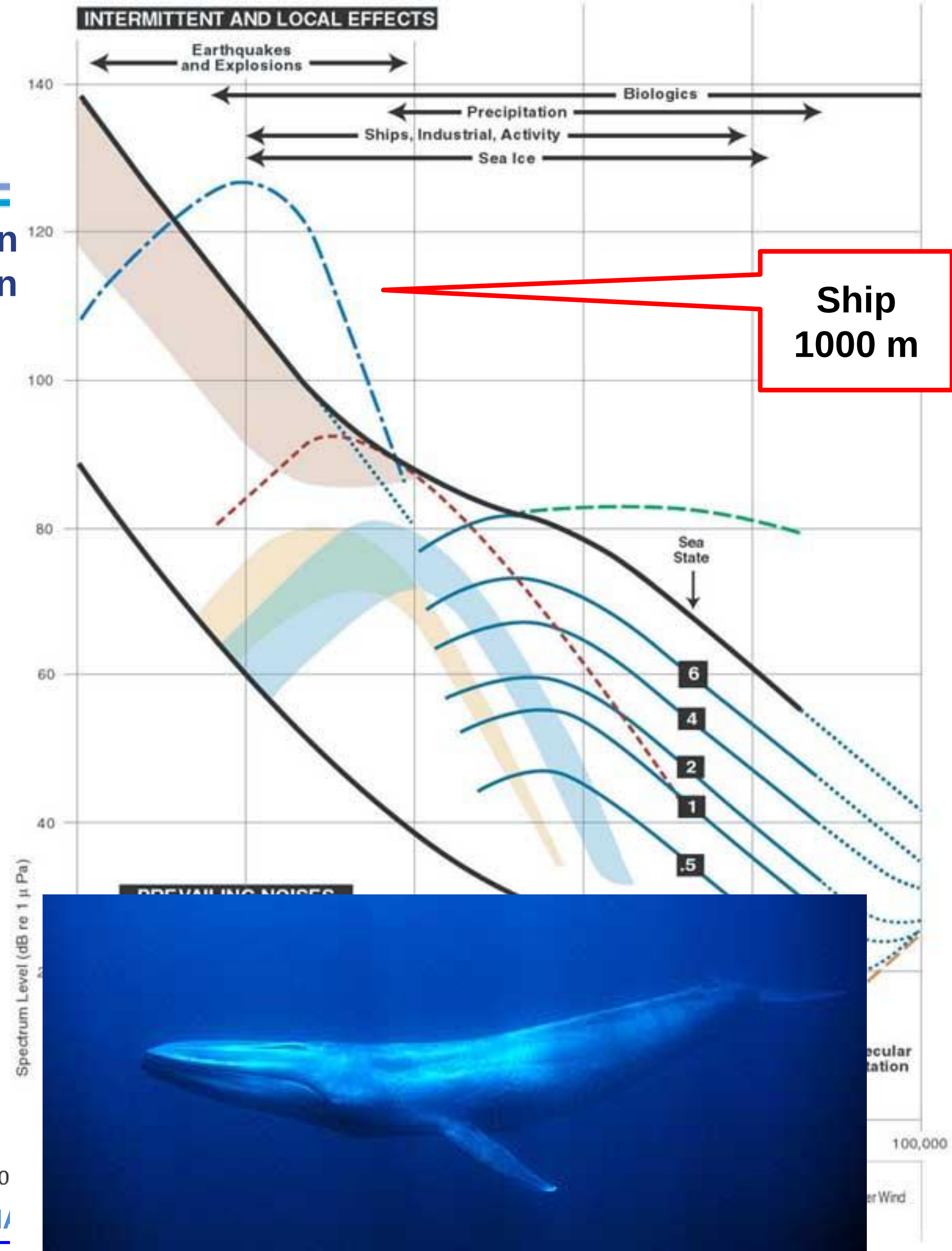
And Underwater radiated noise of merchant ships becomes a growing concern. Among others the International Maritime Organization (IMO) MEPC66 has approved the Outcome of DE 57 concerning provisions for the reduction of noise from commercial shipping and its adverse impacts on marine life.

The International Towing Tank Conference (ITTC) has founded a working group to handle the issue. Standardization organizations (ANSI, ISO) work on measuring standards for ships at sea. But noise control of ship is a systemic engineering that covers all phases such as design, manufacture, operation and servicing. Up to the present, there is no concrete regulation on acoustic design of ship, and the ISO standards about acoustic inspection and test of ship are not so completed yet.

Background

Shipping noise masks the communication frequencies of sea animals like the baleen whales





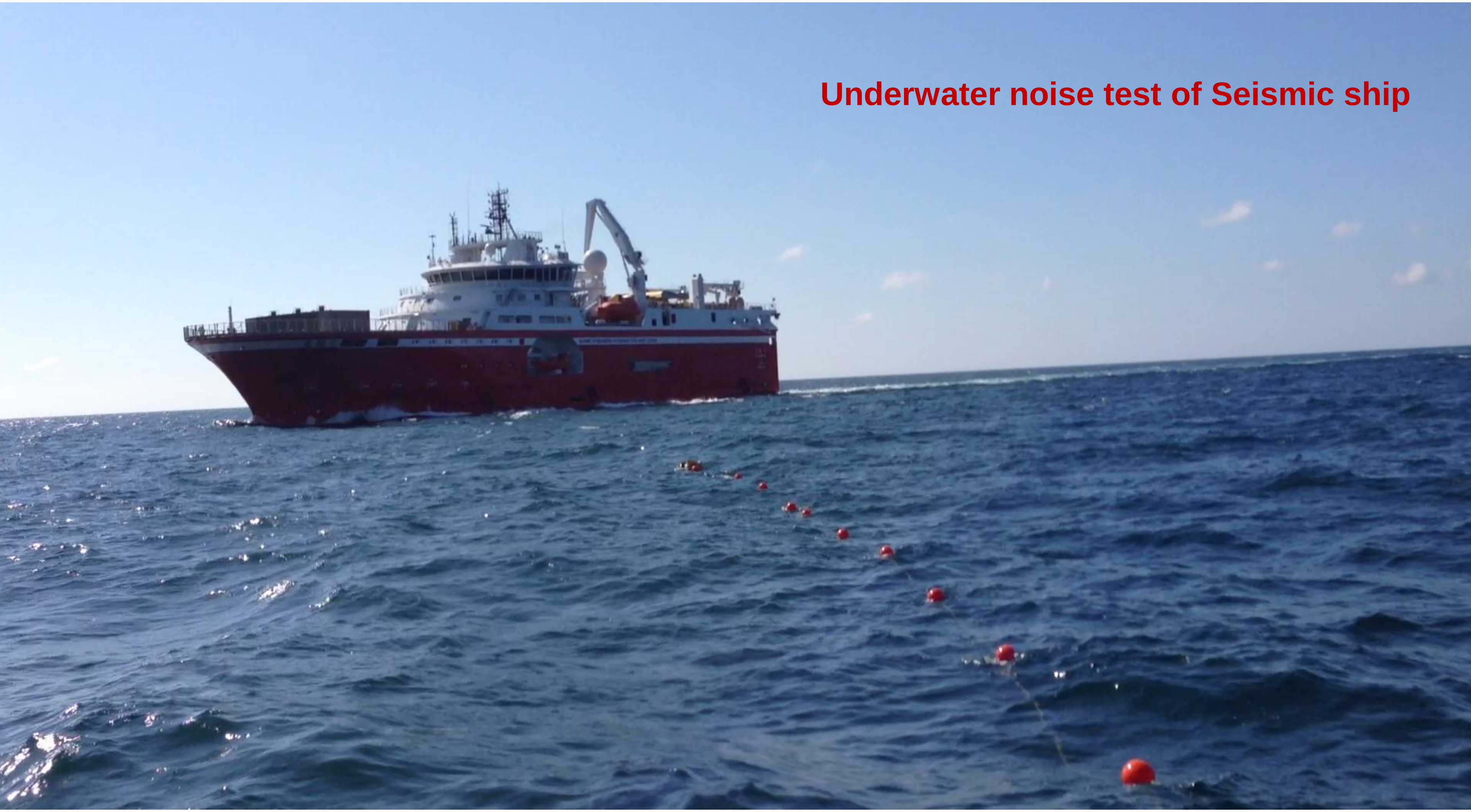
Rules on measurement of underwater noise from ships

Traditional rules on measurement of underwater noise from ships are made for naval use, but now new rules are made for merchant ships for the Safety of Life at Sea .

	USA (ANSI/ASA 12.64-2009)			IMO/ISO 17208-1(Draft)	IMO/ISO 17208-2(Draft)	DNV	China GJB4057-2000
Precision	Precise (A)	Engineer (B)	Normal (C)	Deep Water Precise	Deep & Sallow Water Engineer	Engineer	Engineer
Num. of Hydrophone	3	3	1	3	≥3	1	1
Hydrophone Depth	15° 30° 45°				1/3H, 2/3H and H	bottom	10-20m
Uncertainty	1.5dB	3dB	4dB	+/- 2dB	+/- 2dB	\	3dB
repeatability	1dB	2dB	3dB	2dB	2dB	\	3dB
Freq. Span	10Hz~50kHz	20Hz~25kHz	50Hz~10kHz	20Hz~20kHz	20Hz~20kHz	3.15-315Hz	10Hz~50kHz
Analyzer	1/3oct. NB	1/3oct. NB	1/3oct. NB	1/3oct. NB	1/3oct. NB	1/3oct. NB	1/3oct. NB
Water Depth	>300m or 3L	>150m或1.5L	>75m or 1L	>150m或1.5L	>30m	>30m	>30m
Meas. Distance	100m or 1L	100m or 1L	100m or 1L	100m or 1L	100m or 1L	1L-2L	50m~75m
Source Level Method	20lg(R)	20lg(R)	20lg(R)	20lg(R)	20lg(R)+Correct	18lg(R)	20lg(R)

1. ANSI/ASA S12.64-2009 part1: Quantities and Procedures for Description and Measurement of Underwater Sound from Ships –Part 1 General Requirements
2. ISO 17208-1, Underwater acoustics — Quantities and procedures for description and precision measurement of underwater sound from ships — Part 1: Requirements for deep water measurements used for comparison purposes
3. ISO 17208-2 , Underwater acoustics — Quantities and procedures for description and measurement of underwater noise from ships — Part 2: Determination of source levels
4. DNV rules for classification of ships newbuildings- special equipment and systems additional class- Part 6 Chapter 24:Silent Class Notation
5. GJB 4057-2000 Measurement method for noise of ships

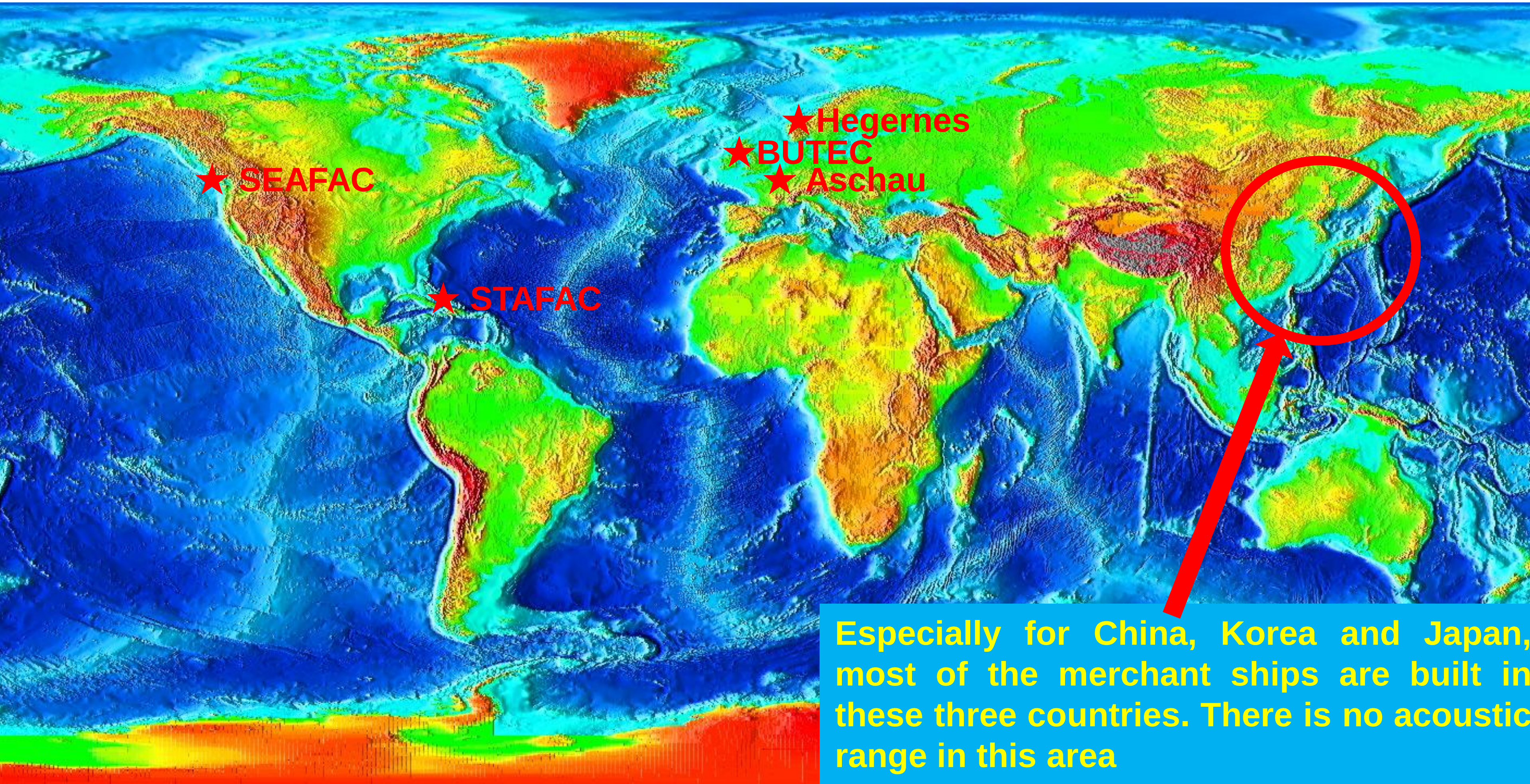
Needs on measurement of underwater noise from ships



Underwater noise test of Seismic ship

Reason for ISO 17208-2

1, ISO 17208-1 is an precision method for deep water measurement, it bring a lot of difficulties for countries with wide continental shelf which is usually called shallow water (water depth less than 150m) .

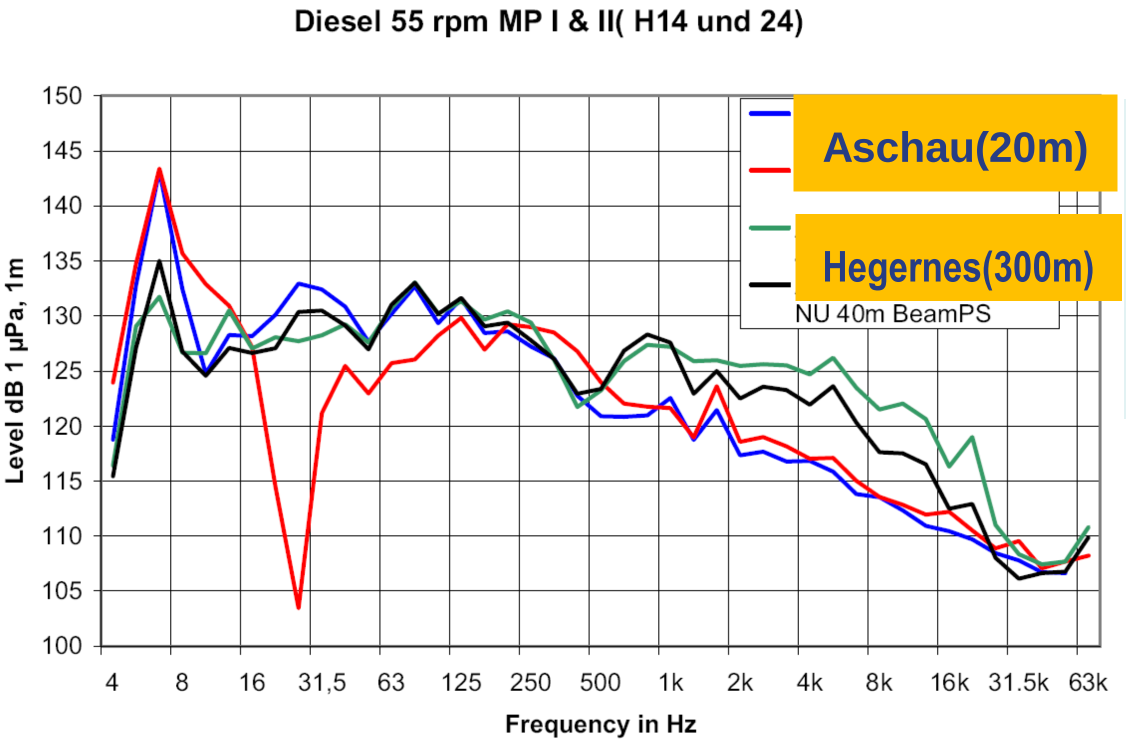


Especially for China, Korea and Japan, most of the merchant ships are built in these three countries. There is no acoustic range in this area

Reason for ISO 17208-2

2, The underwater sound pressure levels are affected by the presence of the free surface and the bottom, such quantities are considered "affected source levels," herein referred to as source levels.

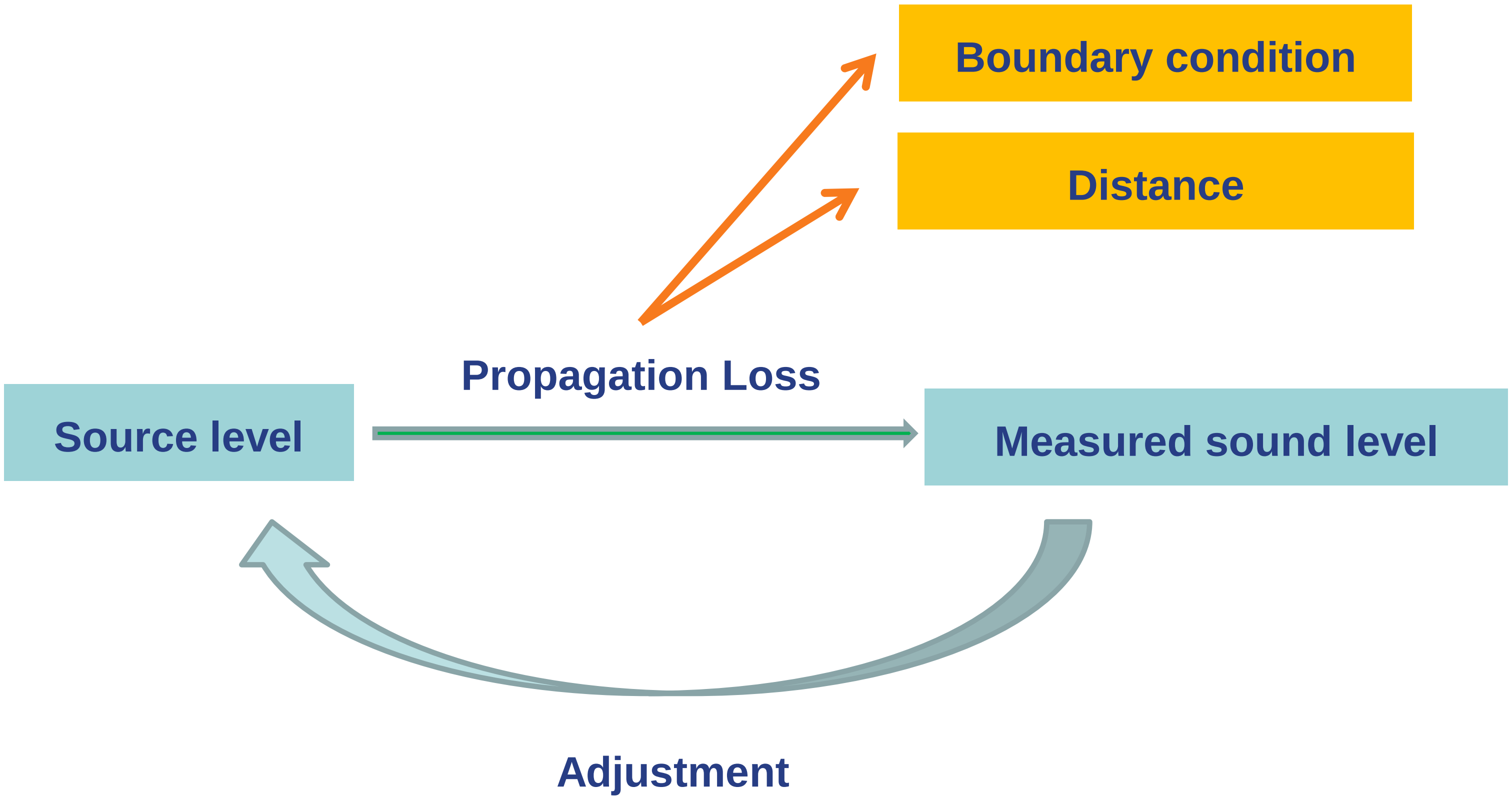
Affected source levels measured in deep water and affected source levels measured in shallow water could not be compared. Only the "real" source level could be compared.



Ship noise measured in Aschau (shallow water 20m) and Hegernes (deep water 300m) shows considerable deviations.

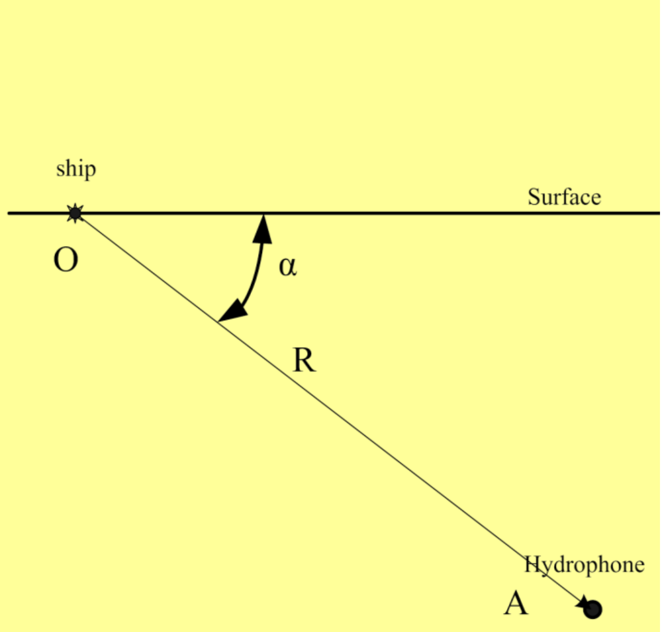
Anton Homm and Stefan Schäl, Radiated underwater noise levels of two research vessels, evaluated at different acoustic ranges in deep and shallow water, Proceedings of Meetings on Acoustics, Vol. 17, 070062 (2012)

How to get the “real” source level



Monopole Source

The sea is looked as frees pace, monopole source level is adjusted using spread factor 20lg(R)



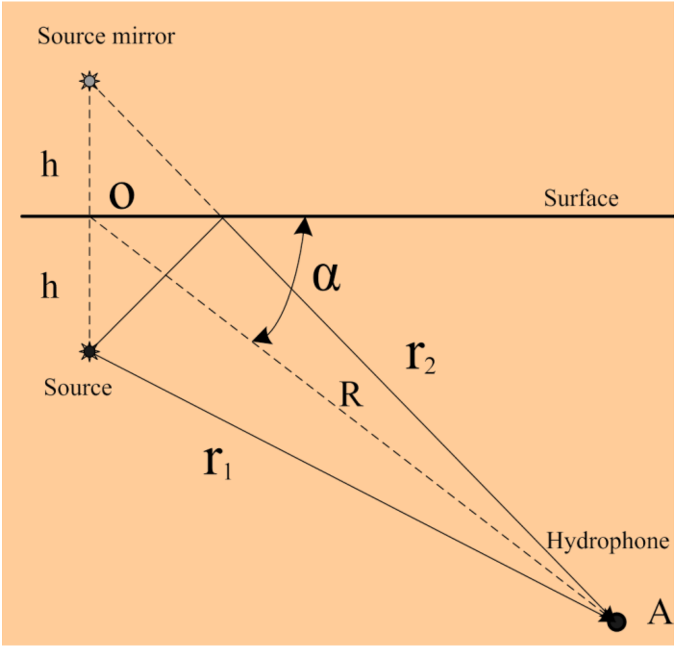
$$L_s = L_p + PL = L_p + 20\log_{10}\left(\frac{d_{total}}{d_{ref}}\right)$$ **[dB re 1μPa²]**

L_s	**Source level**
L_p	**Measured sound level in far field**
PL	**Propagation loss**
d_{total}	**Distance from Hydrophone to acoustic center of ship**
$d_{ref} = 1m$	**Normalized distance**

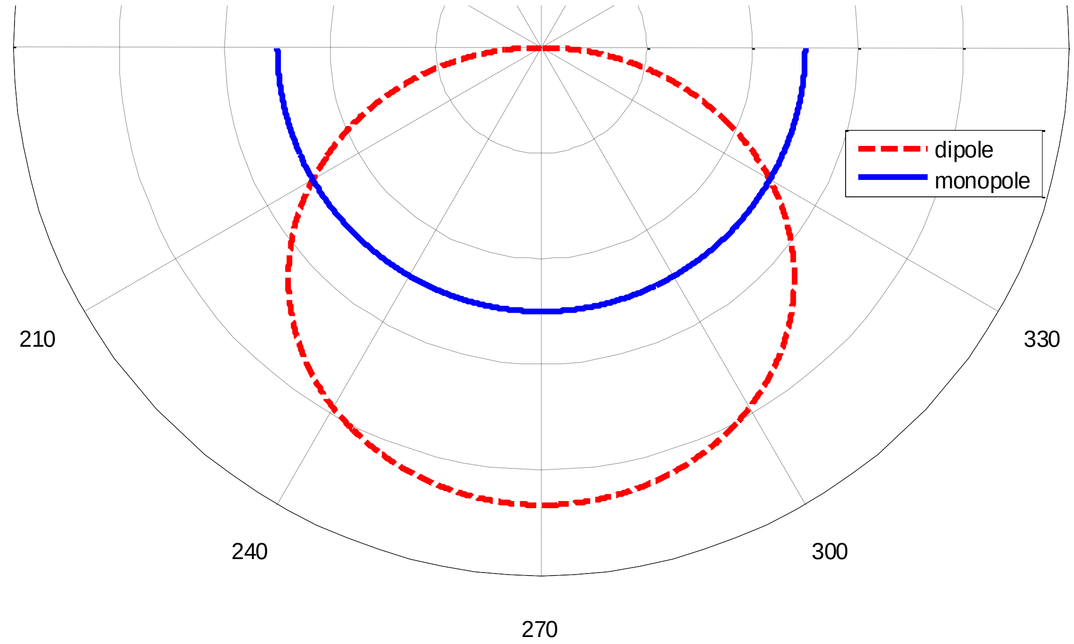
"Affected source levels" are referred to source levels using the adjustment method of "monopole source level"

Dipole Source

For measurement in deep water, the presence of bottom could be negligible, but the presence of surface must be considered, the reflection of surface often referred to as Lloyd's Mirror effect, thus the surface ship could be looked as a dipole source.



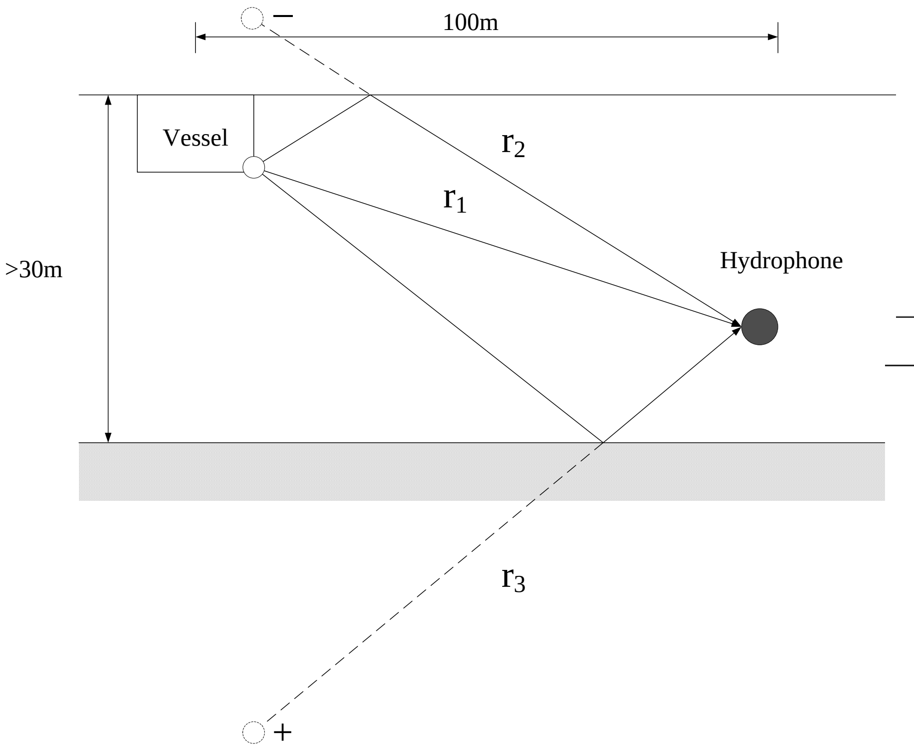
Lloyd's Mirror Effect

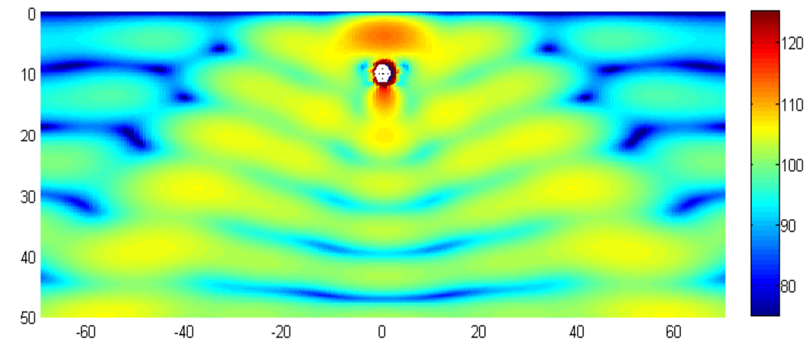


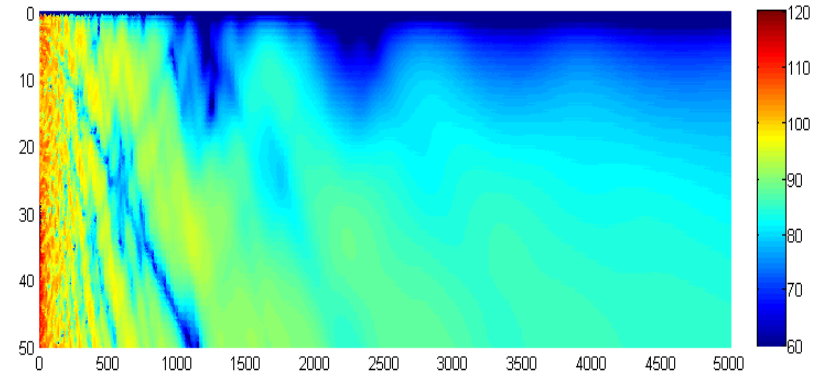
Directivity of sources

Source in waveguide with absorptive bottom

For shallow water, noise source propagation in a waveguide with the reflection of surface and bottom, two mirrors are used to analyze the propagation





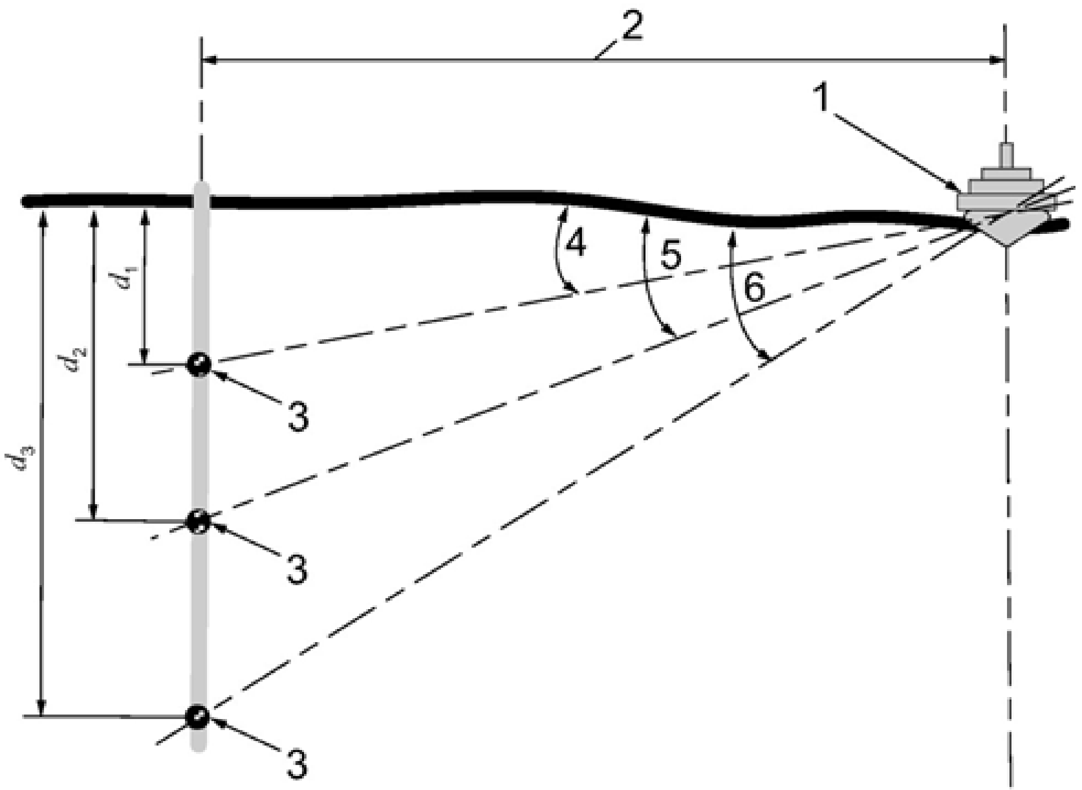


Propagation loss of varies sources

Monopole source	Dipole source	Source in waveguide
$p = \frac{\|A\|}{R} e^{j(\omega t - kr)}$	$p = \left(\frac{e^{jkr_1}}{r_1} - \frac{e^{jkr_2}}{r_2} \right) \|A\| e^{j(\omega t)}$	$p = \left(\frac{e^{jkr_1}}{r_1} - \frac{e^{jkr_2}}{r_2} + \frac{R_a e^{jkr_3}}{r_3} \right) \|A\| e^{j(\omega t}$
$PL = 20\log_{10}\left(\frac{d_{total}}{d_{ref}} \right)$	$PL = 20\log_{10}\left\| \frac{e^{-jkr_1}}{r_1} - \frac{e^{-jkr_2}}{r_2} \right\|$	$PL = 20\log_{10}\left\| \frac{e^{-jkr_1}}{r_1} - \frac{e^{-jkr_2}}{r_2} + \frac{R_a e^{-jkr_3}}{r_3} \right\|$
$L_s = L_p - 20\log_{10}\frac{1}{r}$	$L_s = L_p - 20\log_{10}\left\| \frac{e^{-jkr_1}}{r_1} - \frac{e^{-jkr_2}}{r_2} \right\|$	$L_s = L_p - 20\log_{10}\left\| \frac{e^{-jkr_1}}{r_1} - \frac{e^{-jkr_2}}{r_2} + \frac{R_a e^{-jkr_3}}{r_3} \right\|$

Hydrophone geometry for ISO 17208-1

For deep water, $d1=d_{CPA}\tan(15°)$, $d2=d_{CPA}\tan(30°)$, $d3=d_{CPA}\tan(45°)$;



d_{CPA} = 100 m or one overall ship length, whichever is the greater.

1 vessel under test

2 distance, *d*CPA, at closest point of approach

3 hydrophone

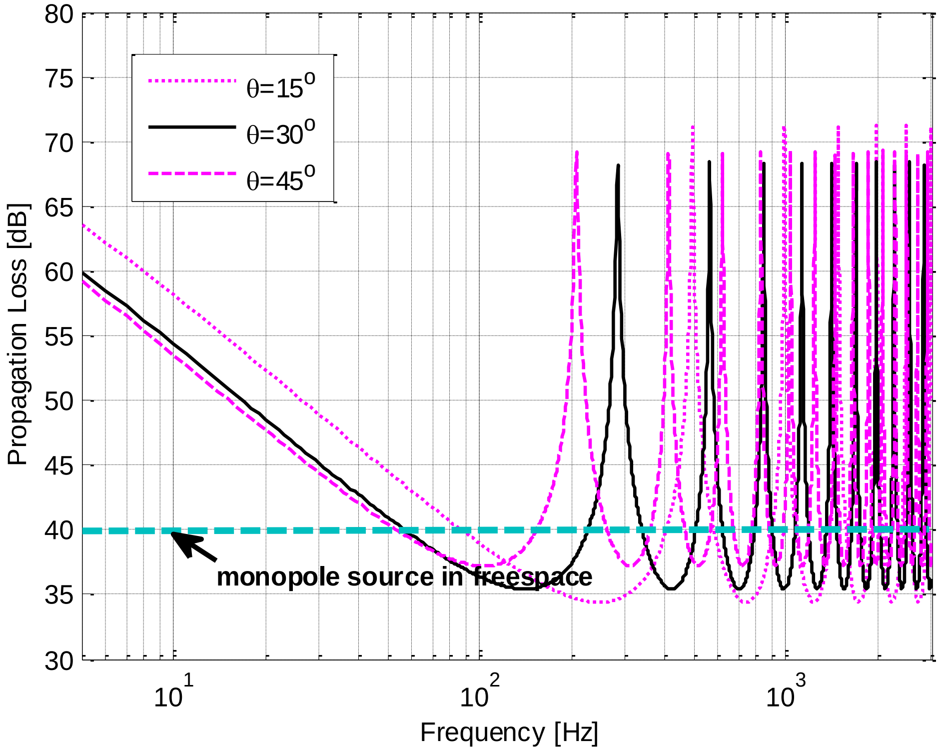
4 slant angle between surface and shallowest hydrophone

5 slant angle between surface and middle hydrophone

Hydrophone output for deep water

For deep water, noise source in half space radiates as dipole source, the propagation loss spectrum has a great of peaks.

But propagation loss spectrum of monopole source in free space is a constant



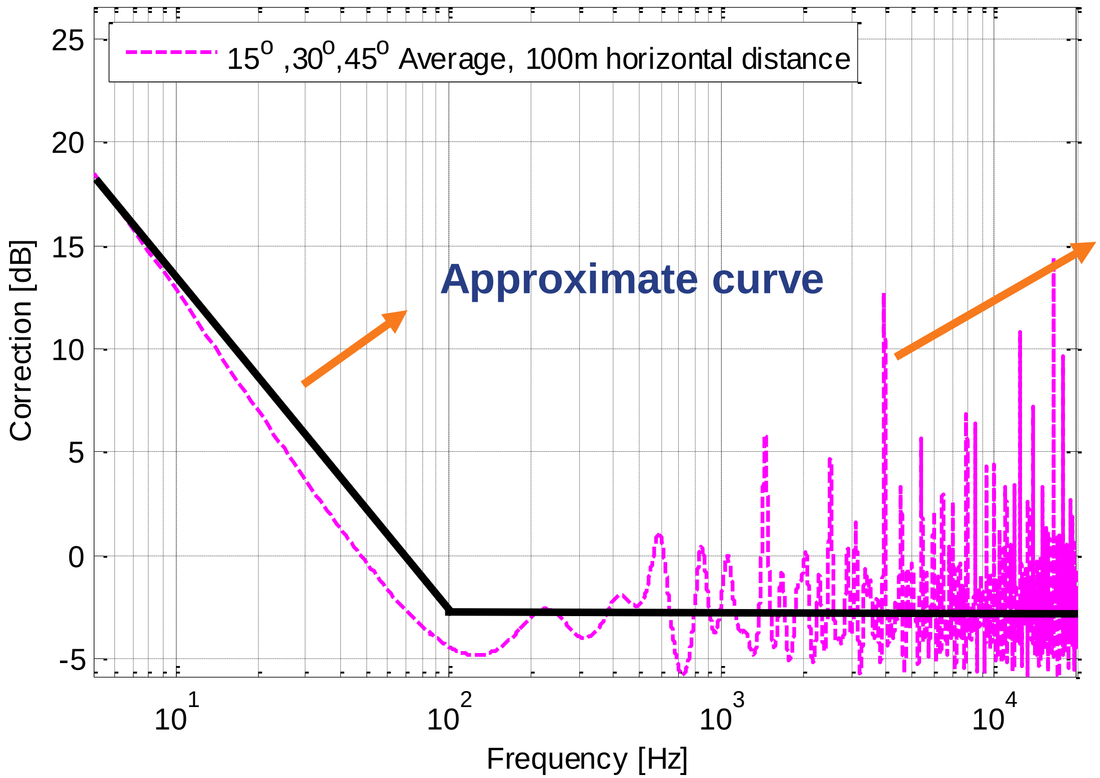
To get the monopole source level for comparing, correction factor is defined as the difference between monopole source level and measured source level

$$Cr = L_{monopole} - L_s$$

Correction factor for deep water

Correction factor for 3 hydrophone method in ISO 17208-1 could be approximately given as following function for engineering using.

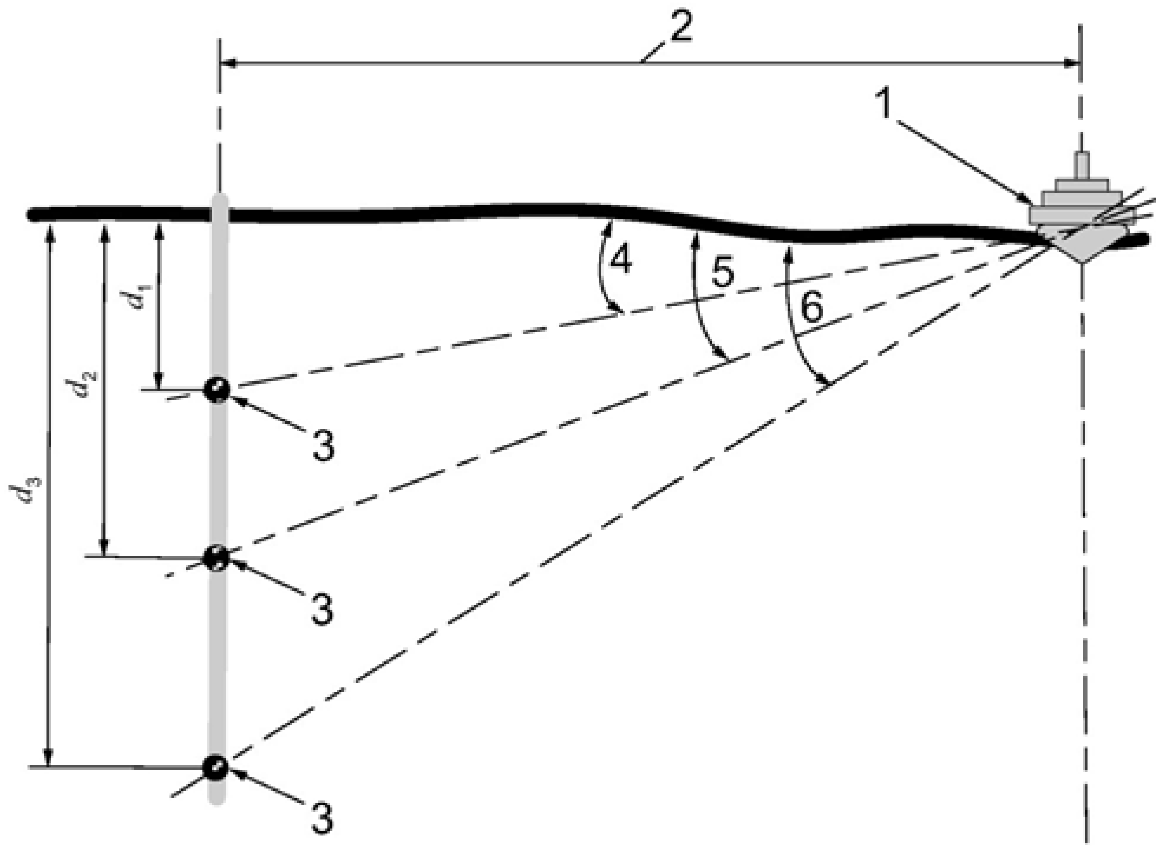
$$Cr_{dipole} = \begin{cases} -16*\log10(f)+29dB & f < 100Hz \\ -3dB & f \geq 100Hz \end{cases}$$



Peaks reduce with the number of hydrophone increasing

Hydrophone geometry for ISO 17208-2

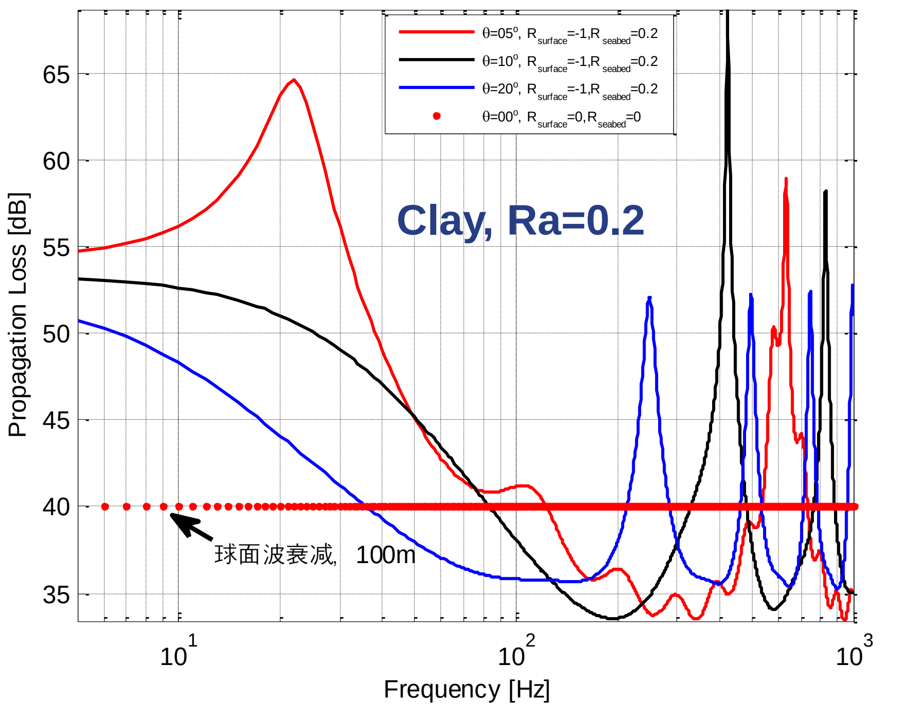
ISO 17208-2: For shallow water, at least 3 hydrophones should be used, d1=1/3H, d2=2/3H, d3=H-2m; H is water depth;



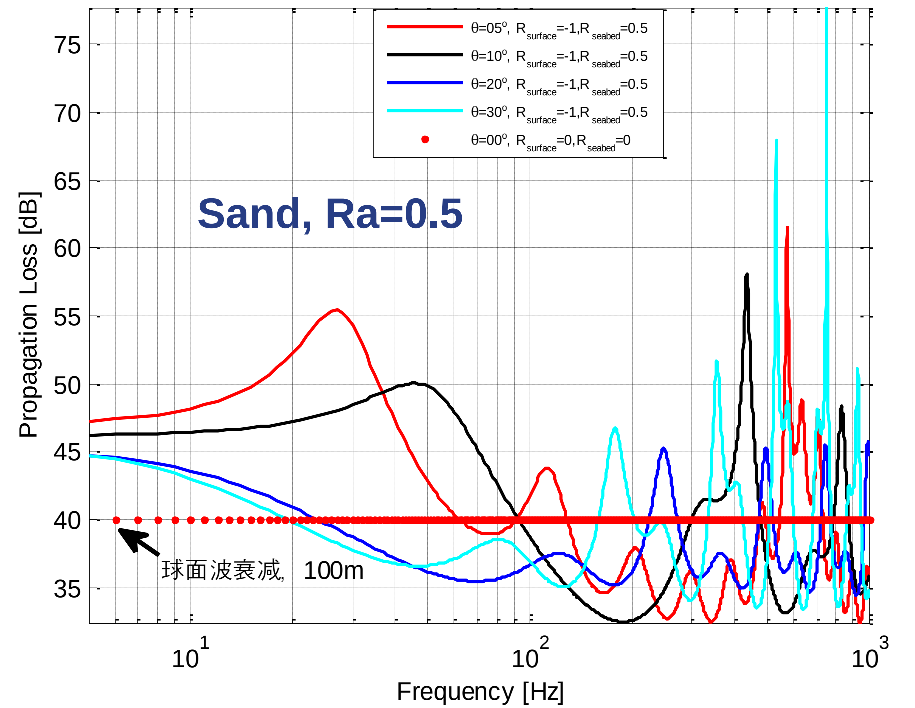
Hydrophone output for shallow water

The hydrophone output depends on the reflection of bottom, sand and silt bottoms have different propagation loss.

Depth of seabed=50m, Depth of Source =5m, Receiver horizontal distance=100m



Depth of seabed=50m, Depth of Source =5m, Receiver horizontal distance=100m



Propagation loss (water depth = 50m)

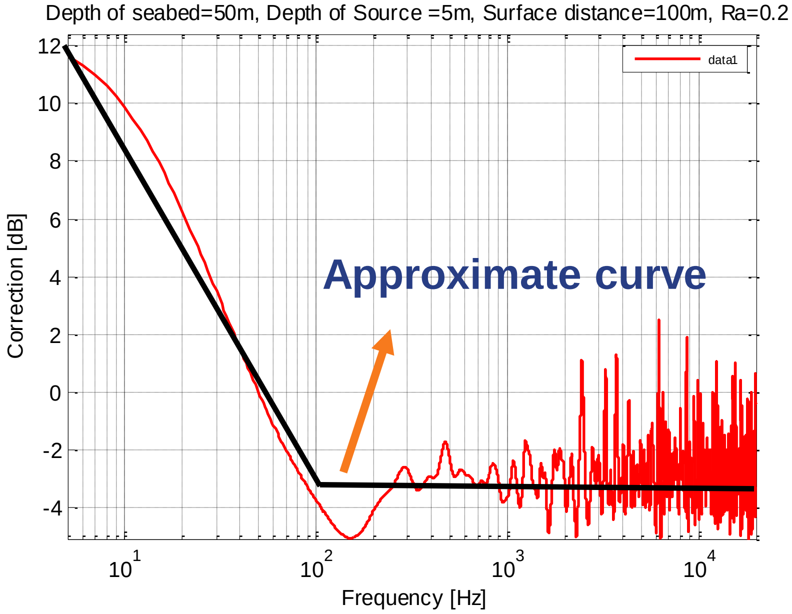
Edwin Hamilton, Reflection coefficients and bottom losses at normal incidence computed from pacific sediment properties, Geophysics 35(6),1970

Correction factor for shallow water

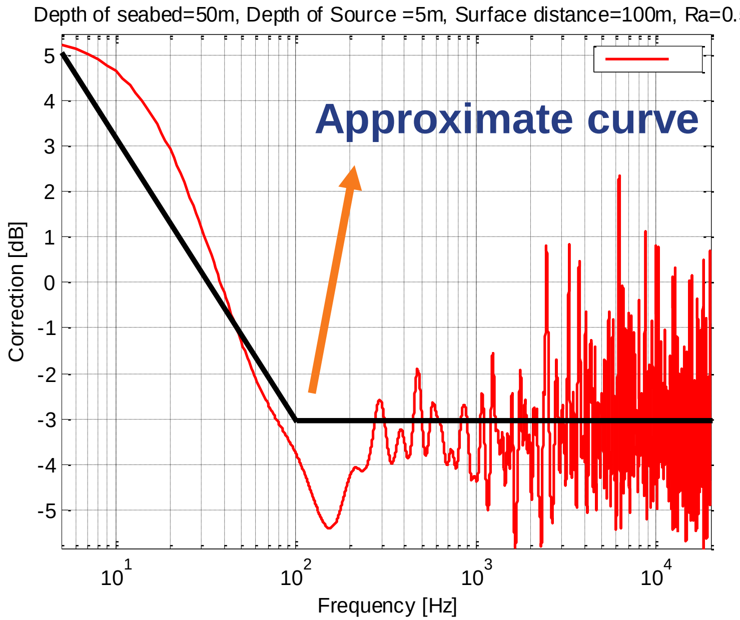
Correction factor for 3 hydrophone method in ISO 17208-2 could be approximately given as following function for engineering using. The correction factor varies with bottom reflections.

$$Cr = \begin{cases} -11*\log10(f)+19dB & f < 100Hz \\ -3dB & f \geq 100Hz \end{cases}$$

$$Cr = \begin{cases} -6*\log10(f)+9dB & f < 100Hz \\ -3dB & f \geq 100Hz \end{cases}$$



Clay, Ra=0.2



Sand, Ra=0.5

Correction curve (water depth = 50m)

What we can do next?

1. More test data to support ISO 17208-2;
2. More than 3 hydrophones could be used in the noise measurement;
3. Setup fixed acoustic range to measure ship noise;
4. …

Reference

1. GJB 4057-2000 Measurement method for noise of ships
2. ANSI/ASA S12.64-2009 part1: Quantities and Procedures for Description and Measurement of Underwater Sound from Ships –Part 1 General Requirements
3. [draft] ISO 17208-1， Underwater acoustics — Quantities and procedures for description and precision measurement of underwater sound from ships — Part 1: Requirements for deep water measurements used for comparison purposes
4. [draft] ISO 17208-2 , Underwater acoustics — Quantities and procedures for description and measurement of underwater noise from ships — Part 2: Determination of source levels
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