Self-Noise

Self-noise is the noise that own ship produces and is detected by own ships sonar system, contributing to the overall noise interfering with the detection of other vessels. Some of the sources of self-noise are:

Propeller Noise - Rotating propellers generate spectral lines in VLF band, f = 0.1-10 Hz. These frequencies depend on rotation speed of propeller and its geometry. Cavitation induced creates broadband noise at higher frequencies. Cavitation depends on:

1. Rotation speed of propeller
2. Type of propeller (fixed or variable pitch)
3. Depth of propeller (deep depths inhibit cavitation)

Flow Noise – Turbulence generated by flow of water over ship's hull. Depends on ship speed, shape and placement of transducer.

Machinery Noise – Ships have numerous noisy machines - engines, reduction gears, generators and hydraulic machinery. This machinery causes vibrations in the hull by solid transmission through internal structures or through the air. These vibrations are then passed on to the water. Machinery noise is independent of ship's speed, therefore it is the major component of self noise at low speeds and is masked at high speeds by flow noise. Both primary frequencies and harmonics are transmitted.

Submarine Transient Noise - Acoustic stealth can be degraded by transmission of short transient noises (from few milliseconds to several seconds). These transients are caused by opening torpedo tube doors, control surface movement, and starting/stopping machinery. These are very characteristic of submarines and can help classify them as such.

Activity Noise – Civilian ship activities can be very noisy (drilling, trawling, seismic surveys, etc).

Ship Radiated Noise Model – Self noise represents continuous broadband noise spectrum whose level increases with ship speed. The maximum level is typically around 100 Hz and generally decreases by 6 dB per octave above a few hundred hertz. In VLF band, narrowband components (spectral lines) exceed broadband noise. The combination of spectral lines and broadband forms a ship's "acoustic signature" and can be used to classify a ship passively.

The ship's self noise can be modeled by two components:

1. RNL_{1K} at f = 1 kHz, from which we can derive the level at other frequencies.

$$RNL(f) = RNL_{1K} - 20\log\left(\frac{f}{1000}\right)$$

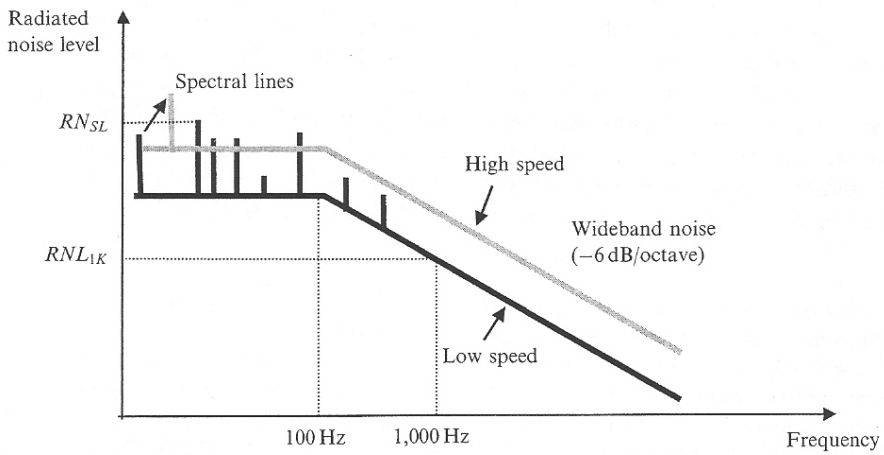


Figure 4.4. Generic spectrum of ship-radiated noise.

2. Radiated noise of the spectral lines RNL_{SL} - these lines are generally described by their maximum level.

Considerable time and money has been spent to improve acoustic performance on submarines and other naval vessels since WWII. In the below table from Lurton, we see how the RNL has decreased for French submarines since WWII (modern US submarines lower RNLs than those presented here.)

Radiated Noise at 4 kts

	RNL_{SL}	RNL_{1K}
WWII Deisel Sub (Electric)	140	120
Modern Diesel Sub (Electric)	100	80
Modern Diesel Sub	140	120
Modern SSN	110	90
Modern SSBN	120	100

Above 10-20 kts, flow noise becomes the dominant factor and significantly increases with speed (@1.5-2 dB/KT)

Thermal Noise – In electronic circuits, resistors create some electric noise due to electronic agitation. Nyquist formula describes the voltage created:

$$u = \sqrt{4KRT\Delta f}$$
$$K - \text{Boltzmann constant}$$
$$\text{T - °K}$$

For ideal hydrophone, we need only consider resistivity, therefore:

$$R_r = \frac{\pi\rho c}{\lambda^2} S_H^2 \qquad \text{S}_\text{H} \text{ - hydrophone sensitivity}$$

This creates electronic noise voltage:

$$u = \sqrt{4\pi k\rho cT}\,\frac{S_H}{\lambda} \qquad \text{AND} \qquad p_a = \frac{\sqrt{4\pi k\rho cT}}{\lambda}$$
$$\Rightarrow NIS_{therm} \approx -75 + 20\log f - 10\log\eta$$
$$\eta \text{ - transducer efficiency}$$

Noise Measurement

There is no way to calculate the self-noise of a platform however it can be measured for a given platform. Very difficult to assess the self-noise level of transducer, since it is a combination of several components:

1. Acoustic noise radiated in the water by the platform and received by the transducer through the water.
2. Mechanical vibrations passed on to the transducer.
3. Electronic noise radiated by other high-power electrical devices if inadequately shielded.

Most modern sonars have self-monitoring capabilities to measure real-time self noise levels. For this course, it will normally be given for students in a problem.

How self-noise is taken into account in our evaluation of the sonar equations is that self-noise is a second component of the overall noise level. The total noise level of sources that interferes with detection of other vessels is the combination of the ambient noise (that we determined in the previous section) and the self-noise. In other words:

$$NL_{tot} = NL_{ambient} \oplus NL_{self}$$

Additionally, this self-noise level is the combination of the broadband and tonal noise. This must be added to the self-noise as shown below:

$$NL_{self} = NL_{BB} \oplus NL_{tonal}\left(\oplus\, NL_{tonal2} \oplus NL_{tonal3} \oplus \ldots\right)$$

$$\text{where } \text{NL}_\text{BB} = \text{ISL}_\text{BB} + 10\log\Delta\text{f}$$

Problems:

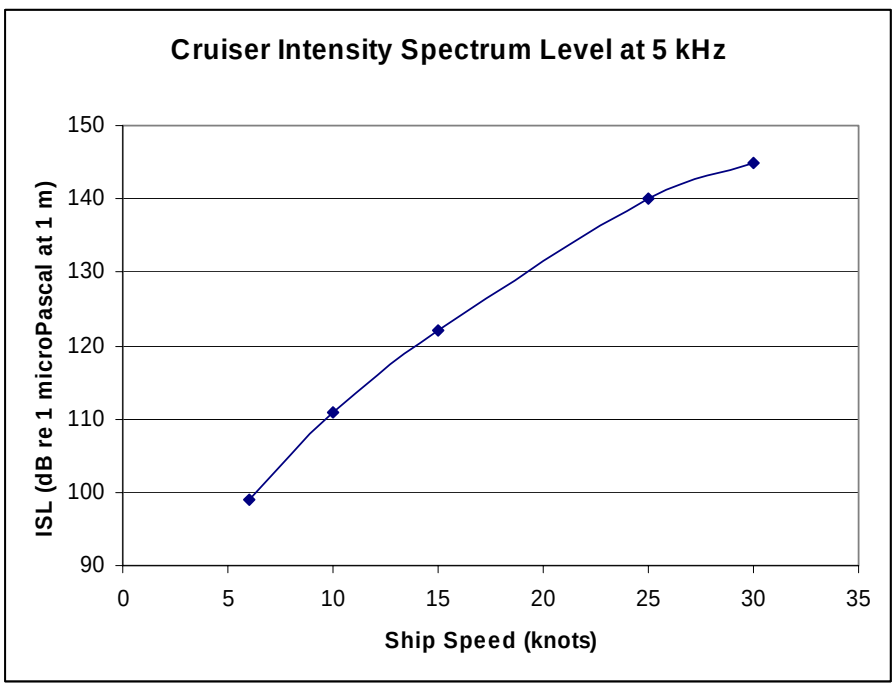
1. Determine the isotropic ambient noise level for a lightly traveled shipping lane. Assume that winds are moderate at 12 knots, the sea state is equal to 3 and the receiver is set to look in the 100 Hz ≤ f ≤ 500 Hz range.

2. Using the conditions from problem 1 above, and given the following table of data:

   a. Plot the total ISL as a function of frequency from 100 Hz to 500 Hz.
   b. Compute the total noise level.

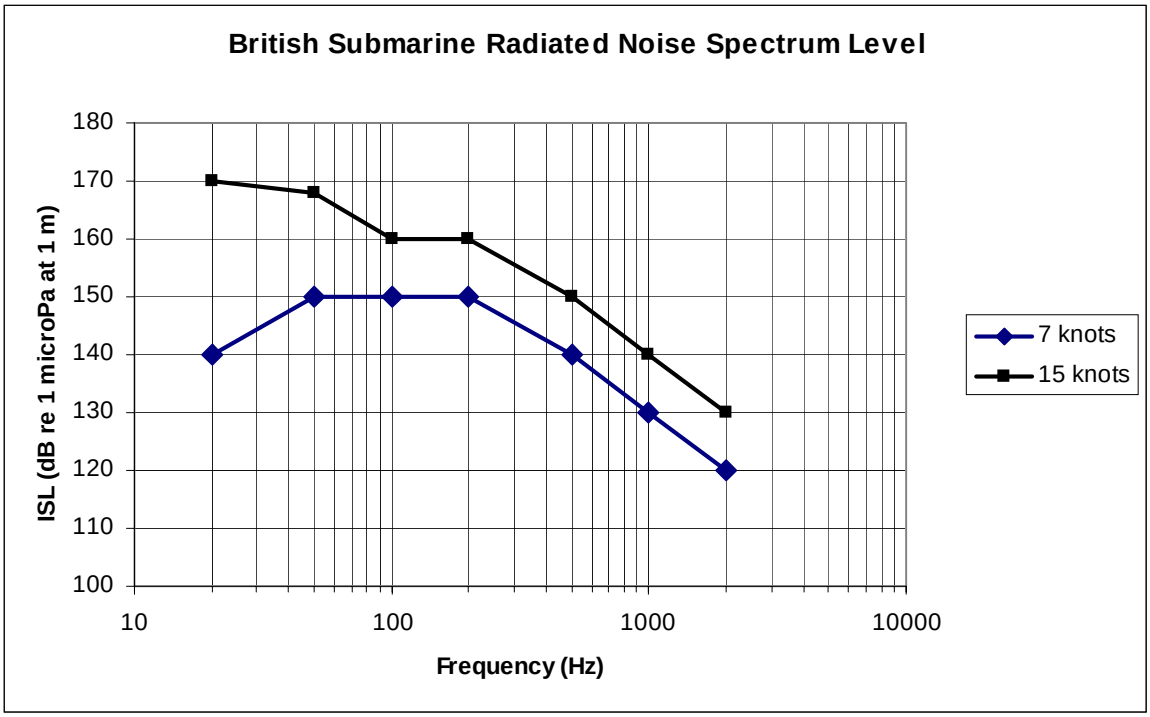
BL_{shrimp}	76 dB
$ISL_{engine\ at\ 400\ Hz}$	124 dB
$BL_{generators}$	99 dB
$BL_{propellers}$	89 dB
BL_{pumps}	92 dB
BL_{whales}	44 dB
$BL_{hull\ flow\ noise}$	80 dB
BL_{rain}	78 dB
$BL_{crew\ noise}$	82 dB

3. a) Using the figure below, compute the increase in radiated noise spectrum level when the cruiser's speed is doubled from 6 knots. Also compute the increase when the speed is increased by a factor of 5 from 6 knots.



b) If $ISL = 10\log k^n + A$, where k is the speed in knots, and n and A are constants. Use the figure above to solve for n and A.

4. a) Using the figure below, estimate the radiated noise level of the British sub traveling on the surface a 7 knots and in a band ranging from 50 to 200 Hz.



b) Estimate the radiated noise level of the sub traveling at 15 knots in a band from 50 to 200 Hz.

Self Noise

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- Mechanical vibrations passed on to the transducer.
- Electronic noise radiated by other high-power electrical devices if inadequately shielded.

Propeller Noise

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Ship Radiated Noise Model

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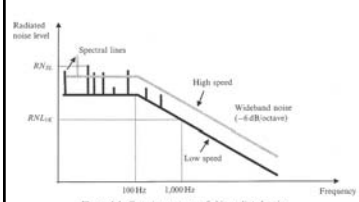

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Total Noise

$$NL_{tot} = NL_{ambient} \oplus NL_{self}$$

$$NL_{ambient} = NL_{ship} \oplus NL_{SS}$$

$$NL_{self} = NL_{BB} \oplus NL_{tonal} \left(\oplus NL_{tonal2} \oplus NL_{tonal3} \oplus ... \right)$$

$$NL_{BB} = ISL_{BB} + 10 \log \Delta f$$