Ambient Noise

The background noise of the sea.

When trying to detect a target or contact out in the ocean, one of the most difficult parts is to "hear" the target through all the background noise. This is just like trying to hear a friend talk while standing in a crowd of people at a noisy rock concert. But out in the ocean, what are the sources of the background noise?

Major sources of background noise in deep water

Tides

A small contribution to ambient noise is the movement of water due to tides. This movement can create large changes in ambient pressure in the ocean. These changes will be most significant at very low frequencies (<100 Hz) but will decrease in strength with increasing depth. Overall though, tides contribute little to the ambient noise level.

Seismic

Another source of very low frequency noise is that due to the earth's seismic activity. The noise due to seismic activity is not significant though, above 10 Hz. As with tides, we will treat seismic sources as being insignificant in our calculations of ambient noise levels.

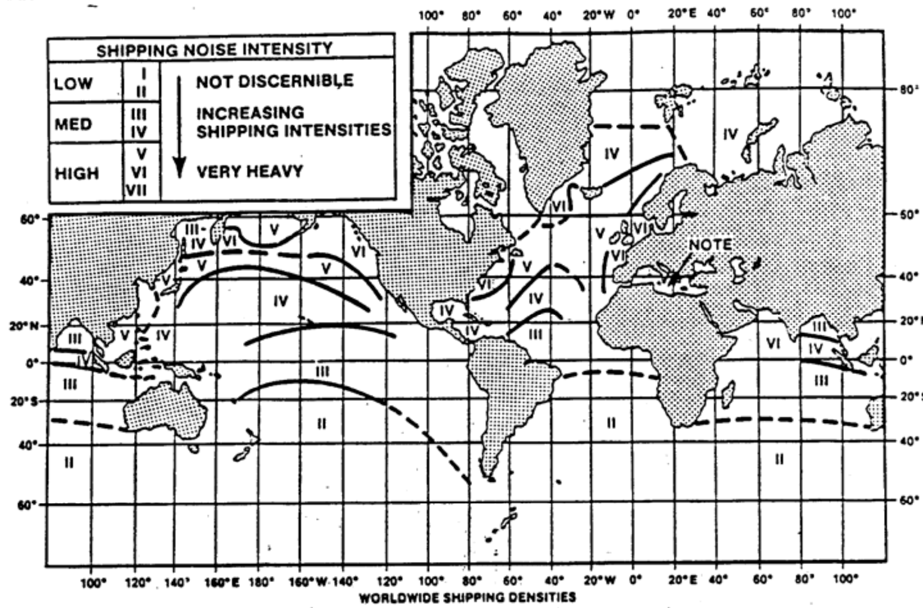
Turbulence

This can be a significant factor in ambient noise levels below 100 Hz but generally, we will not consider the affect of turbulence in our calculations.

Ship Traffic

In the North Atlantic, there can be more than 1000 ships underway at any one time. The noise from this shipping traffic can sometimes travel up to distances of 1000 miles or more. The frequency range where this man-made noise is most dominant is from 10 Hz to 1000 Hz. Noise levels depend on area operating in and "shipping density". Close proximity to shipping lanes and harbors increases noise levels. Shipping traffic is one of the two dominant factors we will use to determine ambient noise levels. The below chart shows how shipping density varies throughout the oceans of the world.

AMBIENT NOISE VALUE GUIDE



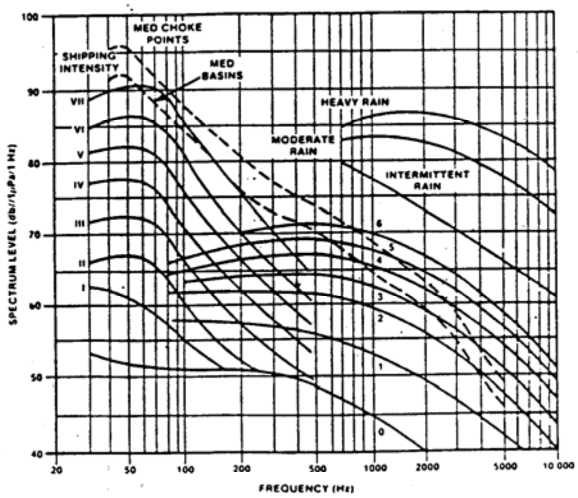
Note: For shipping intensity in the Mediterranean Sea, use Med choke points and Med basin data

Sea State

Sea State (or more importantly wind speed) is the dominant factor in calculating ambient noise levels above 500 Hz. The noise levels depend on sea state and wind speed. Less the 10 Hz, wind-generated turbulence induces pressure variations similar to acoustic pressure variations. Greater than 100 Hz, wind generated microbubbles in the shallow water layers burst and cause pressure changes.

Wenz Curves

For ASW operators to predict the ambient noise levels for a given condition and frequency band, we have the Wenz Curves. Wenz Curves are plots of the average ambient noise spectra for different levels of shipping traffic, and sea state conditions (or wind speeds). Below is a complex example given in the Naval Warfare Publication. At the end of this handout are the simplified Wenz curves you will use for all homework, quizzes and exams.



SEA STATE	WIND SPEED (kts)
6	28-47
5	22-27
4	17-21
3	11-16
2	7-10
1	4-6
0	1-3

NOTE: ADD 2 dB TO SHIPPING NOISE LEVELS FROM JANUARY THROUGH MARCH AND SUBTRACT 2 dB FROM SHIPPING NOISE LEVELS FROM JULY THROUGH SEPTEMBER.

AMBIENT NOISE LEVEL VERSUS FREQUENCY

10-100 Hz – Noise levels depend heavily on shipping density and industrial activities. Levels are typically in range of 60-90 dB with very little frequency dependence.

100-1000 Hz – Noise in this band is dominated by shipping (decreasing intensity with frequency increases). A significant contribution is also from sea surface agitation. Urick (1986) developed a model for predicting this shipping noise:

$$NL_{SHIPPING} = NL_{100} - 20\log\left(\frac{f}{100}\right)$$

Where NL_{100} is 60-90 dB based on shipping density

1-100 kHz – Sea surface agitiation is now the dominant factor, unless marine mammals or rain is present. Knudsen (1948) presented a model to predict this contribution:

$$NL_{SURF} = \begin{cases} NL_{1K} & \text{IF f} < 1000\text{ Hz} \\ NL_{1K} - 17\log\left(\frac{f}{1000}\right) & \text{IF f} > 1000\text{ Hz} \end{cases}$$

NL_{1K} is in the below table, and is based on sea state.

A new model has been developed by APL (1994), it is more accurate but is more complex.

Beaufort Force	Sea State	Windspeed Knots	NL 1K dB	Description	Sea Condition
0	0	0	44.5	Calm	Sea like a mirror
1	0.5	1 - 3	50	Light Air	Ripples but without foam crests
2	1	4 - 6	55	Light Breeze	Small wavelets. Crests do not break
3	2	7 - 10	61.5	Gentle Breeze	Large wavelets. Perhaps scattered white horses
4	3	11 - 16	64.5	Moderate Breeze	Small waves. Fairly frequent white horses.
5	4	17 - 21	66.5	Fresh Breeze	Moderate waves, many white horses
6	5 - 6	22 - 27	68.5 - 70	Strong Breeze	Large waves begin to form; white foam crests, probably spray
7	7	28 - 33		Near Gale	Sea heaps up and white foam blown in streaks along the direction of the wind
8	8	34 - 40		Gale	Moderately high waves, crests begin to break into spindrift
9	9	41 - 47		Strong Gale	High waves. Dense foam along the direction of the wind. Crests of waves begin to roll over. Spray may affect visibility
10	9	48 - 55		Storm	Very high waves with long overhanging crests. The surface of the sea takes a white appearance. The tumbling of the sea becomes heavy and shock like. Visibility affected
11	9	56 - 63		Violent Storm	Exceptionally high waves. The sea is completely covered with long white patches of foam lying in the direction of the wind. Visibility affected
12	9	64+		Hurricane	The air is filled with foam and spray. Sea completely white with driving spray. Visibility very seriously affected.

>100 kHz – Noise is dominated by electronic thermal noise (we will discuss causes later)
$NL_{TH} = -75 + 20\log f$

The total ambient noise level is derived by calculating the level sum of the contributing noise factors given by the following equation:

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

The appropriate level of shipping is selected based on location. The “heavy shipping” curves should be used when in or near the shipping lanes in the North Atlantic. The “light-shipping” curves should be used for more southerly, remote areas of the ocean.

The regions below 10 Hz and above 200 kHz are dominated by other factors that are quantified by the solid lines.

General Rules –

1. NL generally decreases with frequency increasing
2. NL decreases at great depths since most noise sources are at the surface.
3. Ambient noise is greater in shallow water (noise is trapped between sea floor and the ocean surface).

Example

For a sonar receiver set with a band width of 100 Hz, centered around 200 Hz, what is the ambient noise level? (Shipping is heavy, sea state is 3.)

To calculate the upper and lower frequency of the band:

$$f_c = \sqrt{f_1 f_2}$$
$$200Hz = \sqrt{f_1\left(f_1 + 100Hz\right)}$$
$$\Rightarrow f_1 = 156Hz$$
$$f_2 = 256Hz$$

From the Wenz Curves (end of handout):

$ISL_{ave\ shipping} = 69$ dB $\qquad$ $ISL_{ave\ sea\ state} = 67$ dB

Thus:

$$NL_{tot} = NL_{ship} \oplus NL_{SS}$$
$$NL_{tot} = \left(ISL_{aveship} + 10\log\Delta f\right) \oplus \left(ISL_{aveSS} + 10\log\Delta f\right)$$
$$NL_{tot} = 89dB \oplus 87dB$$
$$NL_{tot} = 91dB$$

Transient Noise

Just for passing interest, there are numerous other sources of noise in the oceans. Many of these sources are transitory in nature though which makes them hard to quantify. They may only affect detectability of contacts for short periods of time. These sources may include but are certainly not limited to:

- Human industrial sources ashore – particularly in coastal areas
- Biological factors including
  - snapping shrimp – mostly in warm, shallow coastal areas
    - generate intense broadband noise, f = 1-10 kHz, SL =60-90 dB
  - whales, dolphins, etc – echolocation and communication
    - f = 12 Hz - @2-5 kHz for “whale songs”, SL up to 188 dB
    - Echolocation – 50-200 kHz – similar to active sonar, SL up to 180-200 dB

- Weather – rain
    - Rain drops impacting sea surface and implosion of air bubbles caused by rain, f = 1-100 kHz, max SL @ 20 kHz, SL can be up to 30 dB above sea surface noise

Problems

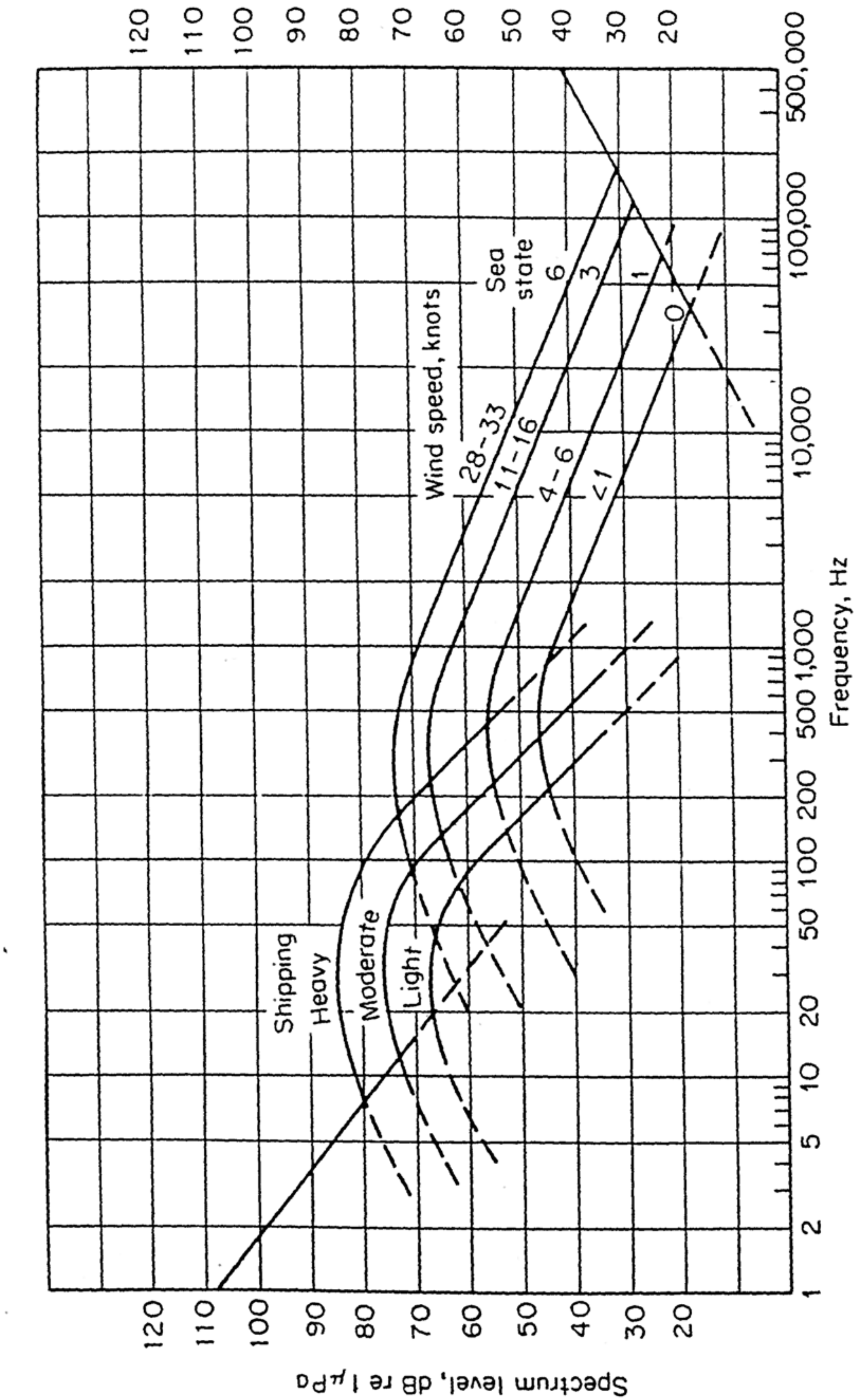
1. What is the principal cause of ambient noise at frequencies
    a. 1 to 20 Hz
    b. 20 to 500 Hz
    c. 500 to 50,000 Hz
    d. above 50,000 Hz

2. Using the Wenz curves, determine the isotropic ambient noise level for an area with heavy shipping. Assume that wind speeds are 14 knots and we are interested in the noise level at exactly 200 Hz (use a 1 Hz bandwidth).

3. The SONAR receiver onboard ship operates in a frequency range from 50 Hz $< f <$ 1000 Hz. Using the Wenz curves, determine the isotropic ambient noise level in the operating band of the receiver. Assume that winds are light as 4-6 knots and shipping traffic is moderate. (Note: You will have to determine an average ISL from the Wenz curves and calculate the appropriate band levels.)

4. List three intermittent sources of ambient noise.

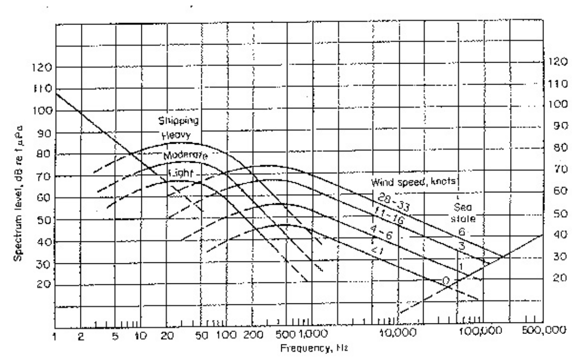
5. Using the wenz curves for average deep water ambient noise, estimate the band level noise for heavy shipping and sea state 6 for the following conditions:
    a. Noise received in a band between 20 and 50 Hz.
    b. Noise received in a band between 2000 and 5000 Hz.

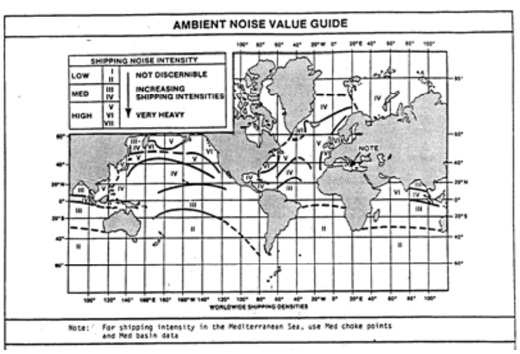

Spectrum level, dB re 1 μPa
Frequency, Hz
Wind speed, knots
Sea state
Shipping
Heavy
Moderate
Light
28–33
11–16
4–6
<1
6
3
1
0
120
110
100
90
80
70
60
50
40
30
20
1
2
5
10
20
50
100
200
500
1,000
10,000
100,000
500,000

Major Sources of Noise

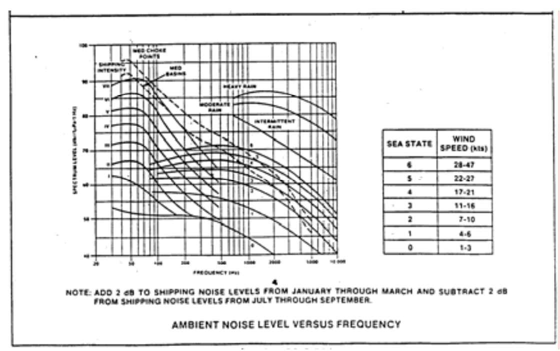
- Sea State – Dominant factor above 500 Hz
- Ship Traffic – Dominant factor 10 to 1000 Hz
- Minor Sources
  - Tides
  - Turbulance
  - Seismic
- Transients

Wentz Curves





NWP Wenz Curves

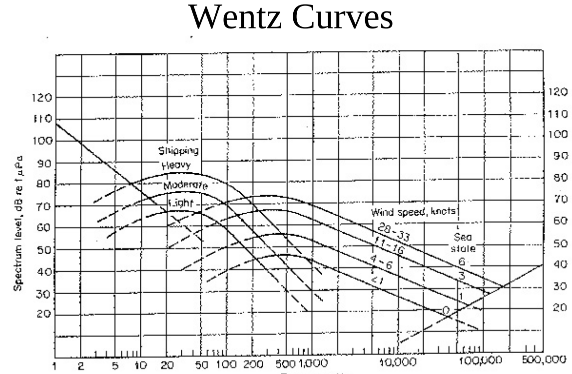


100-1000 Hz

- NL_{100} is 60-90 dB depending on shipping. Below 100 Hz NL is the same.
- Above 100 Hz, the noise decreases with frequency

$$NL_{SHIPPING} = NL_{100} - 20\log\left(\frac{f}{100}\right)$$

Wentz Curves



1-100 kHz

$$NL_{SURF} = \begin{cases} NL_{1K} & \text{IF f } < 1000 \text{ Hz} \\ NL_{1K} - 17\log\left(\frac{f}{1000}\right) & \text{IF f } > 1000 \text{ Hz} \end{cases}$$

NL falls at 17 dB per decade above 1000 Hz

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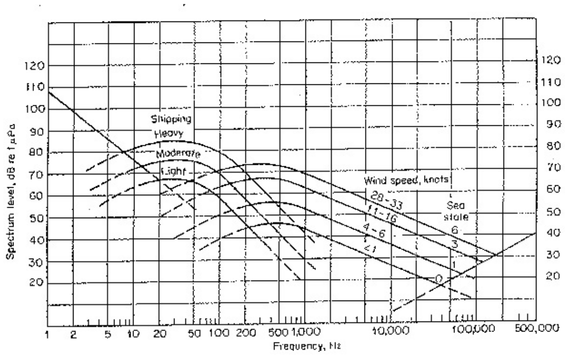
Wentz Curves



Above 50 kHz

- Thermal Agitation of water molecules
- Thermal noise in electronics
- 6 dB per octave increase in noise

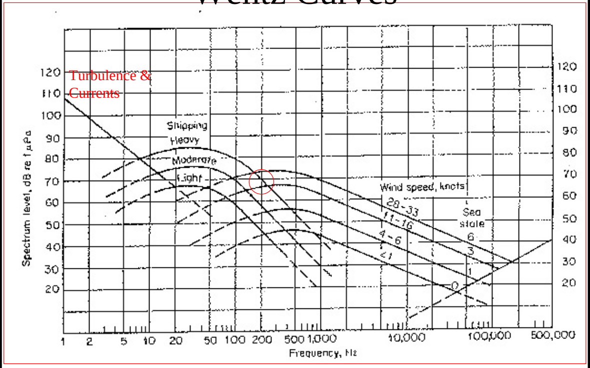
Total Noise

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

Example

- For a sonar receiver set with a width of 100 Hz, centered around 200 Hz,
- Shipping is heavy,
- Sea state is 3,
- What is the ambient noise level?

Wentz Curves



Transients

- Human industrial activity
- Biological Activity
  - Snapping Shrimp 1-10 kHz, SL = 60-90 dB
  - Whales, dolphins
    - Whale songs 2 – 5 kHz, SL = 188 dB
    - Echolocation 50 – 200 kHz, SL = 180 – 200 dB
- Weather – Rain
  - 1 – 100 kHz, SL(20 kHz) is 30 dB above sea state noise

General Noise Rules

- NL generally decreases with frequency increasing
- NL decreases at great depths since most noise sources are at the surface.
- Ambient noise is greater in shallow water (noise is trapped between sea floor and the ocean surface).

$$f_c = \sqrt{f_1 f_2}$$
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