NAME_____

Passive Sonar Wrap-up Exercise

The two submarines described below are to engage in a sonar detection exercise off the coast of Kauai. Use the following data for all questions.
(Note: all numbers are made up and do not reflect reality.)

USS Memphis (Target)
SL of sub 180 dB in band from 100 Hz to 500 Hz
Main tonal in band = 400 Hz due to sound short of 400 Hz generator

USS Seawolf (Attacker)
Use hull array consisting of 50 hydrophones in groups of 4 spaced 30 m down the side of the sub (consider as continuous line array)
Bandwidth of sonar suite = 400 Hz from 100 to 500 Hz
Integration time of sonar suite = 20 ms
Want P(D) = 90%, P(FA) = 0.2% assume ideal sonar processor
NL_{self} = 81 dB in band from 100 Hz to 500 Hz

Environment
Sea State = 1
Shipping = light
transition range = 14 Kyds

1. What is the detection index required for detection of the Memphis by the Seawolf?

2. What would be the detection threshold for detecting the Memphis using passive sonar?

3. What are the angles for the nulls of the Seawolf's 30 m long hull array (only give from 0° to 90°)?

4. What is the Directivity Index for this 30 m long array at the frequency of the principle tonal?

5. What is the attenuation coefficient at the frequency of the principle tonal?

6. What is the Ambient Noise Level (Sea State and Shipping)?

7. What is the Total Noise Level?

8. If the Memphis were at 16,000 yds from the Seawolf, what would be the Transmission Loss (include attenuation)?

9. If the Memphis were at 16,000 yds from the Seawolf, what would be the signal-to-noise level?

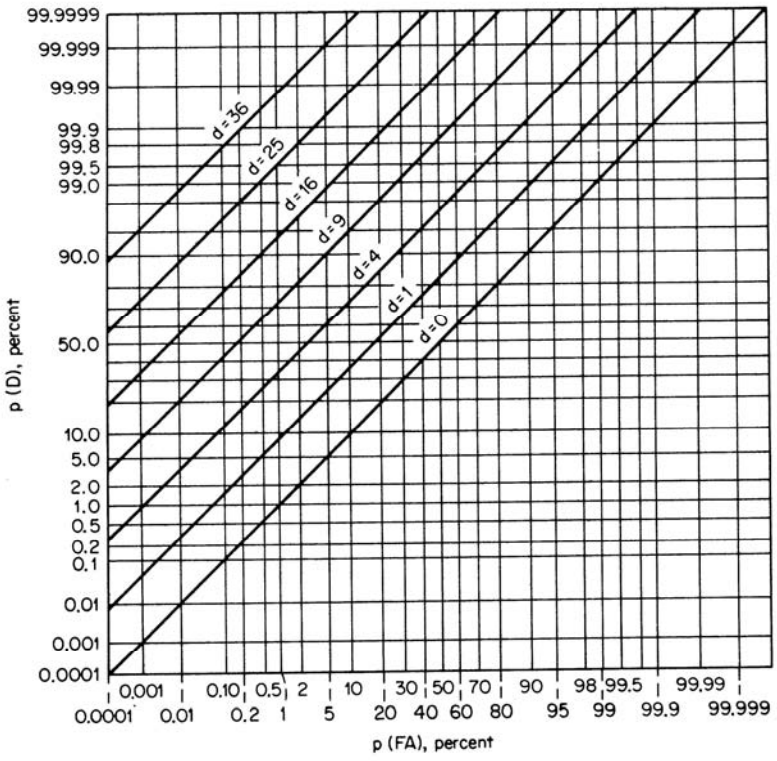
10. Is Memphis detectable? If so, what is the Signal Excess?

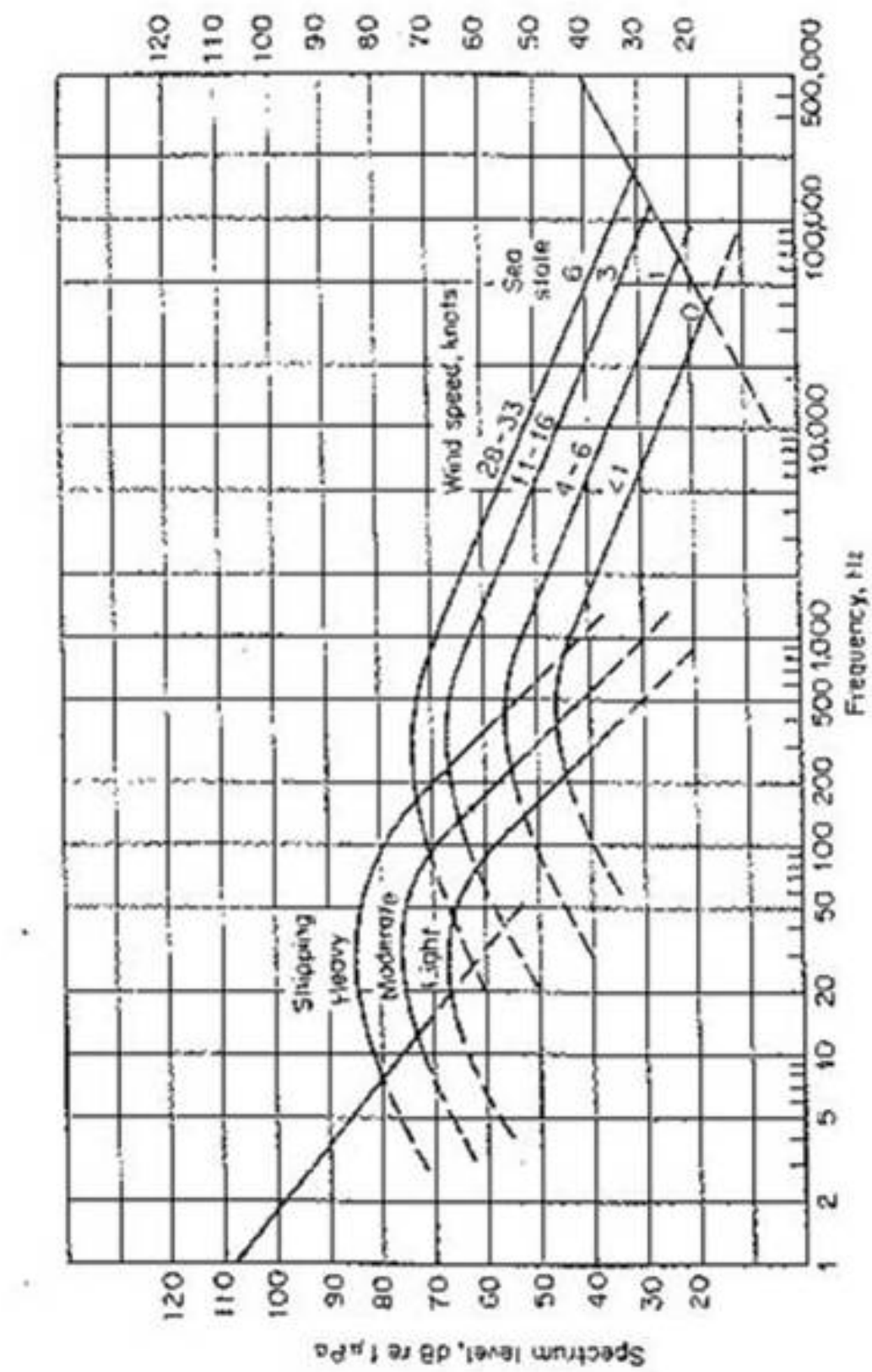
11. What is the max detection range of the Memphis by the Seawolf (this time you can ignore attenuation)?

Miscellaneous Questions

12. If P(D) = 75% and P(FA) = 1%, what is the probability that you will miss a detection of an actual contact?

13. Is a passive sonar system a correlator detector or an energy detector?




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

Passive Sonar Wrap Up Exercise

And Exam Review

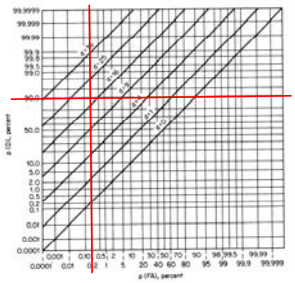
Data

- The two submarines described below are to engage in a sonar detection exercise off the coast of Kauai. Use the following data for all questions.
- (Note: all numbers are made up and do not reflect reality.)
- **USS Memphis (Target)**
  - SL of sub 180 dB in band from 100 Hz to 500 Hz
  - Main tonal in band = 400 Hz due to sound short of 400 Hz generator
- **USS Seawolf (Attacker)**
  - Use hull array consisting of 50 hydrophones in groups of 4 spaced **30 m** down the side of the sub (consider as continuous line array)
  - Bandwidth of sonar suite = 400 Hz from 100 to 500 Hz
  - Integration time of sonar suite = 20 ms
  - Want P(D) = 90%, P(FA) = 0.2% assume ideal sonar processor
  - NLself = 81 dB in band from 100 Hz to 500 Hz
- **Environment**
  - Sea State = 1
  - Shipping = light
  - transition range = 14 Kyds

Part 1

- What is the detection index required for detection of the Memphis by the Seawolf?

  p(D)=90%
  p(FA)=0.2%



$$d \approx 18$$

Part 2

- What would be the detection threshold for detecting the Memphis using passive sonar?

  –Bandwidth of sonar suite = 400 Hz from 100 to 500 Hz
  –Integration time of sonar suite = 20 ms

$$DT = 5\log\left(\frac{d}{T\Delta f}\right) = 5\log\left(\frac{18}{20x10^{-3}s\ 400Hz}\right) = 1.8dB$$

Part 3

- What are the angles for the nulls of the Seawolf's 30 m long hull array (only give from 0° to 90°)?

$$\sin\theta = m\frac{\lambda}{L}$$

$$\lambda = \frac{c}{f} = \frac{1500\frac{m}{s}}{400Hz} = 3.75m$$

	2-element array	continuous line array	circular piston
defining parameters	element separation distance – d	array length – L	array diameter - D
beam pattern function b(θ) =	$\cos^2\left(\frac{\pi d}{\lambda}\sin\theta\right)$	$\left(\frac{\sin\left[\frac{\pi L}{\lambda}\sin\theta\right]}{\frac{\pi L}{\lambda}\sin\theta}\right)^2$	$\left[\frac{2J_1\left(\frac{\pi D}{\lambda}\sin\theta\right)}{\frac{\pi D}{\lambda}\sin\theta}\right]^2$
directivity index DI	$10\log\left[\frac{2}{1+\left(\frac{\sin\left[2\pi d/\lambda\right]}{2\pi d/\lambda}\right)}\right]$	$10\log\frac{2L}{\lambda}$ for $L >> \lambda$	$10\log\left(\frac{\pi D}{\lambda}\right)^2$ for $D >> \lambda$
null angles b(θ) = 0 θ_{null}	$\sin\theta = (m)\frac{\lambda}{2d}$ m = 1, 3, 5, ...	$\sin\theta = (m)\frac{\lambda}{L}$ m = 1, 2, 3, ...	$\sin\theta = (z)\frac{\lambda}{D}$ z = 1.22, 2.23, 3.24, 4.24, ... roots of $J_1\left(\frac{\pi D}{\lambda}\sin\theta\right) = 0$
side lobes b(θ)=1 θ_{max}	$\sin\theta = m\frac{\lambda}{d}$ m = 0, 1, 2, 3....	$\tan\left(\frac{\pi L\sin\theta}{\lambda}\right) = \left(\frac{\pi L\sin\theta}{\lambda}\right)$ $\sin\theta = y\left(\frac{\lambda}{L}\right)$ where y = 1.43, 2.46, 3.47, 4.48, ...	$\sin\theta_{hp} = 0.51\frac{\lambda}{D}$
half power angles b(θ)=0.5 θ_{hp} $\theta_{BW}=2\theta_{hp}$ (only for beam about array axis)	$\sin\theta_{hp} = \frac{n\lambda}{4d}$ n = 1, 3, 5, 7,...	$\sin\theta_{hp} = 0.442\frac{\lambda}{L}$	$\sin\theta = w\frac{\lambda}{D}$ where w = 1.64, 2.68, 3.70, ...

The Angles

$$\theta = \sin^{-1}\left(m\frac{\lambda}{L}\right) = \sin^{-1}\left(m\frac{3.75m}{30m}\right) = \sin^{-1}(0.125m)$$

$\theta_1 = \sin^{-1}(0.125(1)) = 7.2^o$ $\quad \theta_5 = \sin^{-1}(0.125(5)) = 38.7^o$

$\theta_2 = \sin^{-1}(0.125(2)) = 14.5^o$ $\quad \theta_6 = \sin^{-1}(0.125(6)) = 48.6^o$

$\theta_3 = \sin^{-1}(0.125(3)) = 22.0^o$ $\quad \theta_7 = \sin^{-1}(0.125(7)) = 61.0^o$

$\theta_4 = \sin^{-1}(0.125(4)) = 30.0^o$ $\quad \theta_8 = \sin^{-1}(0.125(8)) = 90.0^o$

Part 4

- What is the Directivity Index for this 30 m long array at the frequency of the principle tonal?

$$DI = 10\log\left(\frac{2L}{\lambda}\right) = 10\log\left(\frac{2x30m}{3.75m}\right) = 12dB$$

Part 5

- What is the attenuation coefficient at the frequency of the principle tonal?

$$\alpha = \left(0.003 + \frac{0.1f^2}{1+f^2} + \frac{40f^2}{4100+f^2} + 2.75\times10^{-4}f^2\right) \ dB/kyd$$

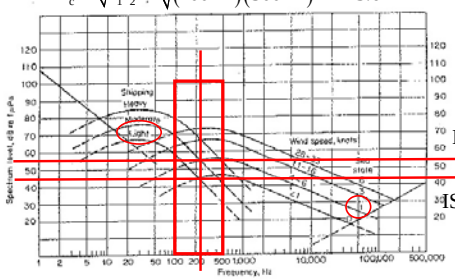
f in kHz

$$\alpha = \left(0.003 + \frac{0.1(0.4)^2}{1+(0.4)^2} + \frac{40(0.4)^2}{4100+(0.4)^2} + 2.75\times10^{-4}(0.4)^2\right) = 0.0184 \ dB/kyd$$

Part 6

- What is the Ambient Noise Level (Sea State and Shipping)?

$$f_c = \sqrt{f_1 f_2} = \sqrt{(100Hz)(500Hz)} = 223.6Hz$$



$ISL_{ss} = 55dB$

$ISL_{ship} = 44dB$

Ambient Noise Band Levels

$$NL_{ss} = ISL_{ss} + 10\log(\Delta f) = 55dB + 10\log(400Hz) = 81dB$$

$$NL_{ship} = ISL_{ship} + 10\log(\Delta f) = 44dB + 10\log(400Hz) = 70dB$$

$$NL_{Amb} = NL_{ss} \oplus NL_{ship} = 81dB \oplus 70dB = 81dB$$

Part 7

- What is the Total Noise Level?

$$NL = NL_{Amb} \oplus NL_{Self}$$

$$NL = 81db \oplus 81dB = 84dB$$

Part 8

- If the Memphis were at 16,000 yds from the Seawolf, what would be the Transmission Loss (include attenuation)?

transition range = r_o = 14 Kyds

$$TL = 20\log r_0 + 10\log\frac{r}{r_0} + \alpha\left(r\times 10^{-3}\right)$$

$$TL = 20\log(14000) + 10\log\frac{16000}{14000} + \alpha\left(16000\times 10^{-3}\right) = 83.7\text{dB}$$

Part 9

- If the Memphis were at 16,000 yds from the Seawolf, what would be the signal-to-noise level?

$$L_{S/N} = (SL - TL) - (NL - DI)$$

$$L_{S/N} = (180\text{dB} - 83.7\text{dB}) - (84\text{dB} - 12\text{dB})$$

$$L_{S/N} = 96.3\text{dB} - 72\text{dB} = 24.3\text{dB}$$

Part 10

- Is Memphis detectable? If so, what is the Signal Excess?

$$L_{S/N} = 24.3\text{dB} \quad > \quad DT = 1.8\text{dB}$$

$$SE = L_{S/N} - DT = 24.3\text{dB} - 1.8\text{dB} = 22.5\text{dB}$$

Part 11

- What is the max detection range of the Memphis by the Seawolf (this time you can ignore attenuation)?

$$L_{S/N} = DT = (SL - TL) - (NL - DI)$$

$$TL = (SL - DT) - (NL - DI) = (180\text{dB} - 1.8\text{dB}) - (72\text{dB}) = 106.2\text{dB}$$

$$TL = 20\log r_0 + 10\log\frac{r}{r_0} = 106.2\text{dB}$$

$$TL = 20\log 14000 + 10\log\frac{r}{14000} = 106.2\text{dB}$$

$$r = 2980\text{kyds}$$

NAME_____

Passive Sonar Homework

Attacking Platform Data
A passive continuous line array sonar 40 m long receives signals in a one half octave bandwidth centered on a frequency of 400 Hz.
The Integration time of the sonar suite = 2.0 s.
Want P(D) = 50%, P(FA) = 0.1% assume ideal sonar processor
$ISL_{self\ noise}$ = 52 dB

Target Data
ISL_{target} = 120 dB

All spectrum levels are constant in the range of frequencies in the sonar's receiver bandwidth.

Environment
Wind Speed = 5 knots
Shipping = moderate to heavy (split the difference)
transition range = 5000 yds

1. What are the upper and lower frequencies in the half octave band and what is the band width?

2. What is the detection index required for detection of the target?

3. What would be the detection threshold for detecting the target using passive sonar?

4. What are the first three angles for the side lobes of the sonar's 40 m long linear array (only give from 0° to 90°)?

5. What is the Directivity Index for this 40 m long array at the center frequency?

6. What is the attenuation coefficient at the center frequency?

7. What is the Ambient Noise Level (Sea State and Shipping) in the half octave band?

8. What is the Self Noise Level in the half octave band?

9. What is the Total Noise Level in the half octave band?

10. What is the Source Level, SL, of the target in the half octave band?

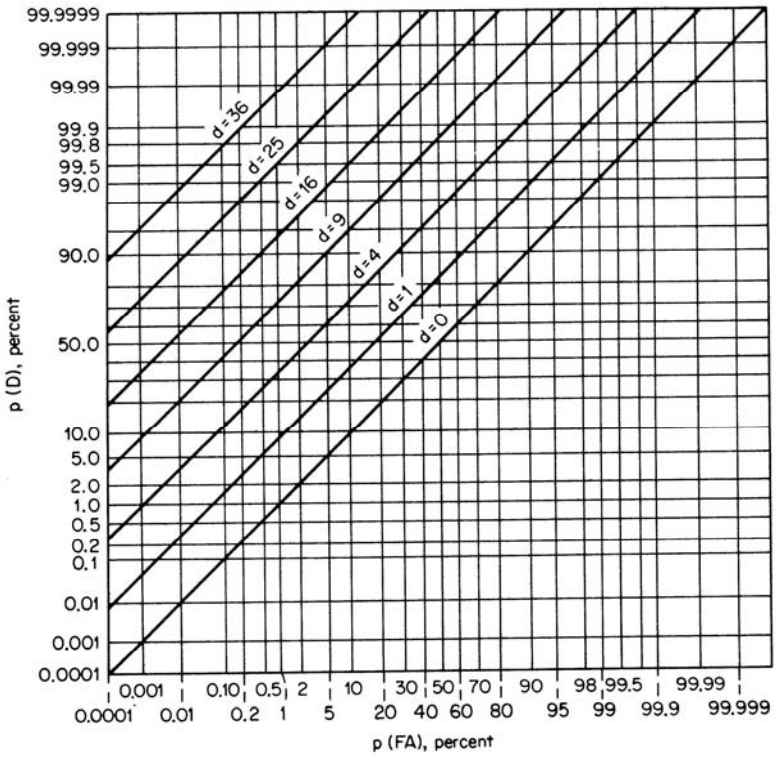
11. If the target is at 10000 yds, what would be the Transmission Loss (include attenuation)?

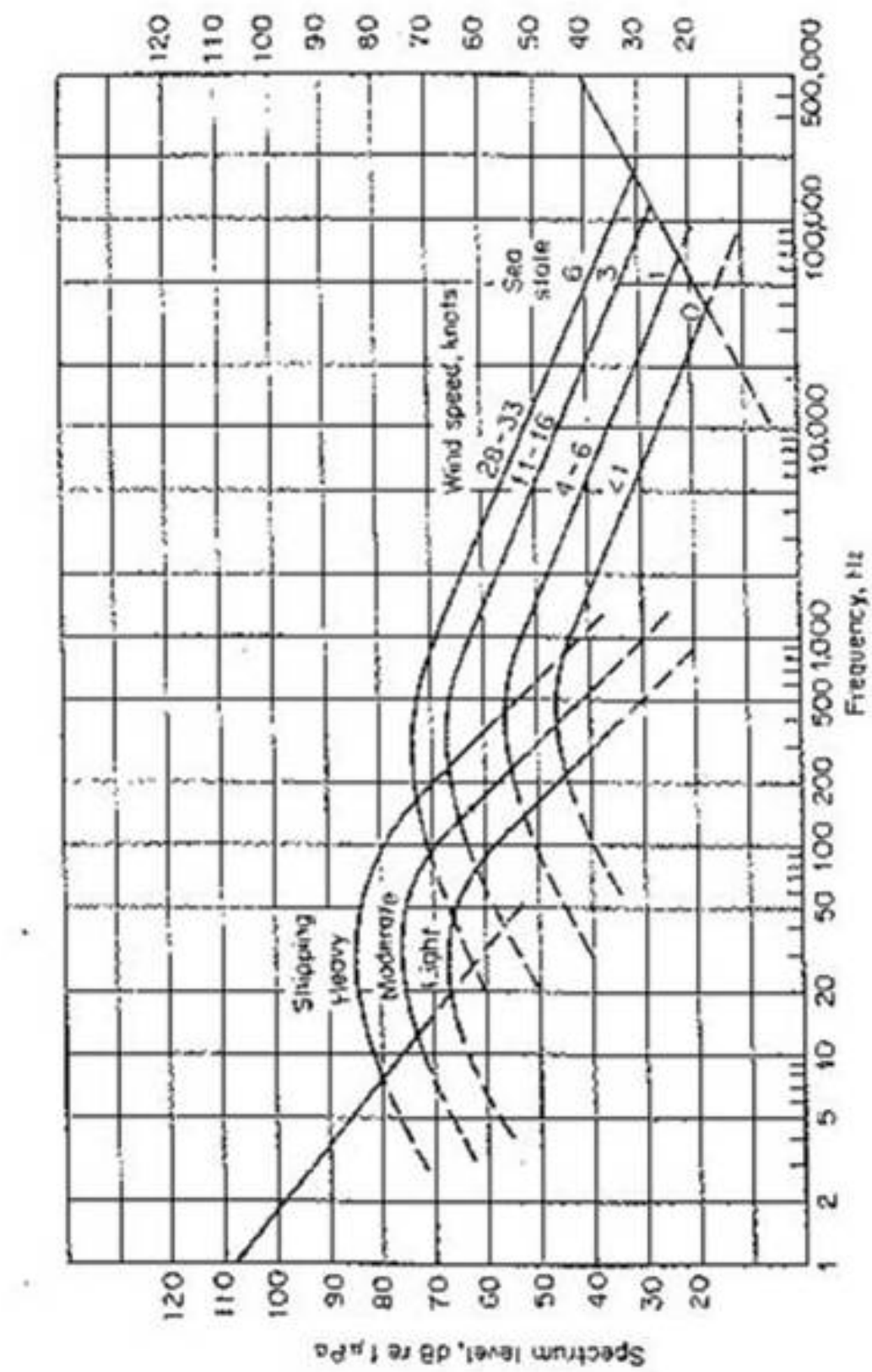
12. If the target is at 10,000 yds, what would be the signal-to-noise level?

13. Is the target detectable? If so, what is the Signal Excess?

14. What is the Figure of Merit (this time you can ignore attenuation)?

15. What is the max detection range of the target (this time you can ignore attenuation)?

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