Estimation of passive acoustic threat detection distances in estuarine environments

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Introduction

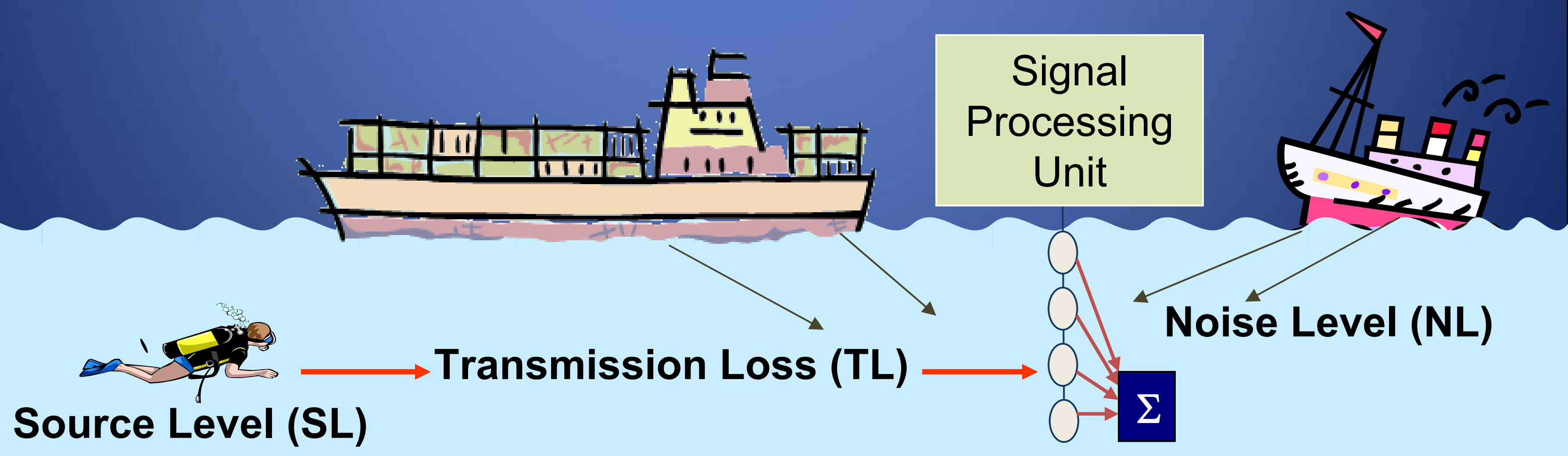
- The Hudson estuary has complex sound propagation conditions because of its shallow depth (≈ 15 meters) and high temporal and spatial variability.
- Ships, barges, and smaller boats generate significant amounts of noise which greatly impact the range of acoustic detection.
- Using data that results in the positive detection of a diver at a predetermined distance, we want to show how variations in the acoustic parameters influence the range of detection.

Contents

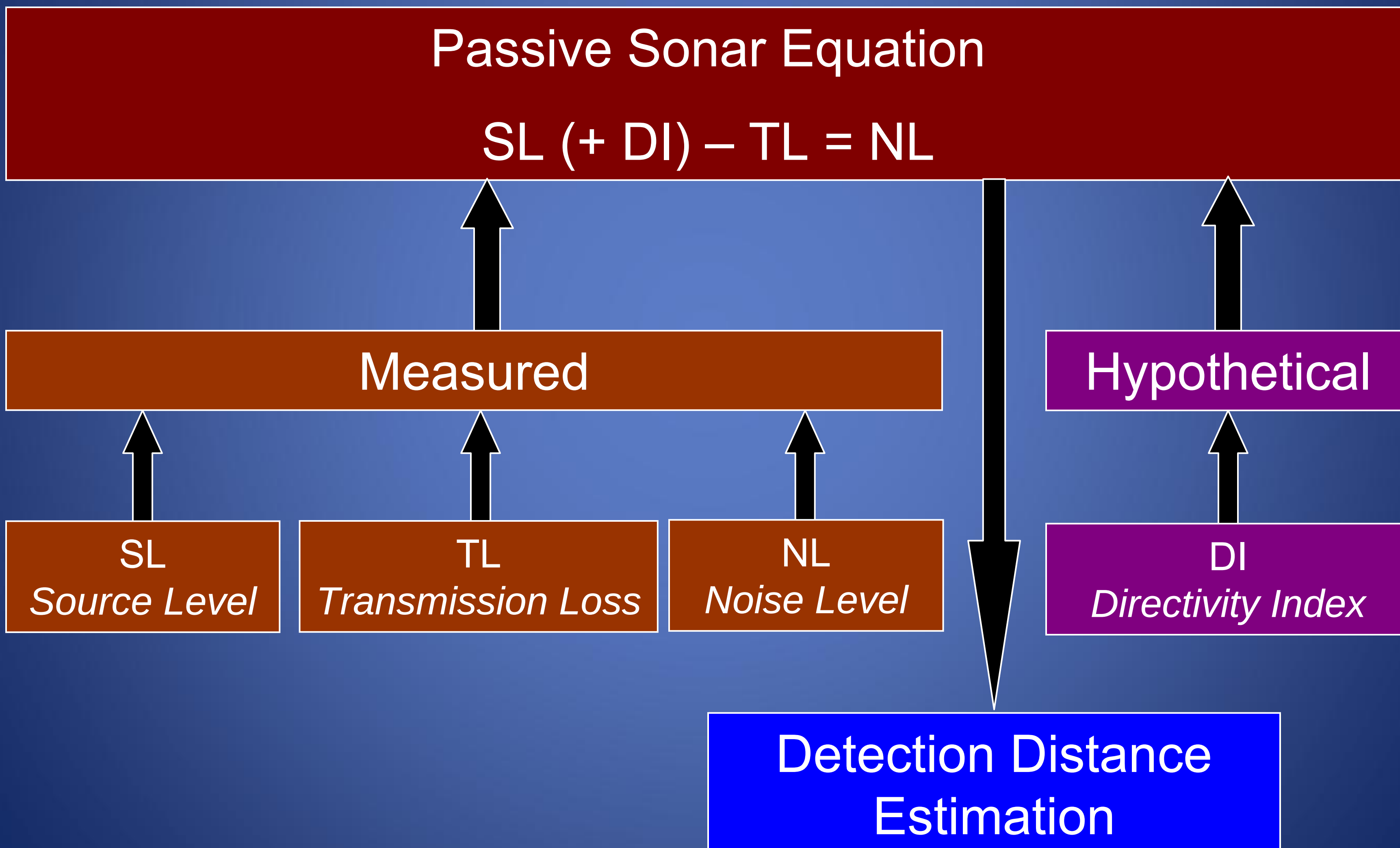
- Passive sonar equation and overview of acoustic parameters
- Source level
- Noise level
- Transmission loss
- Putting the pieces together – estimating the variation in detection distance under different conditions

Acoustic Parameters

- **Source Level** – Sound produced from the diver's gear recalculated to 1 meter.
- **Transmission Loss** – Attenuation of sound over a distance.
- **Noise Level** – Ambient noise.
- **Directivity Index** – Increase in signal-to-noise ratio from the use of an array of hydrophones.



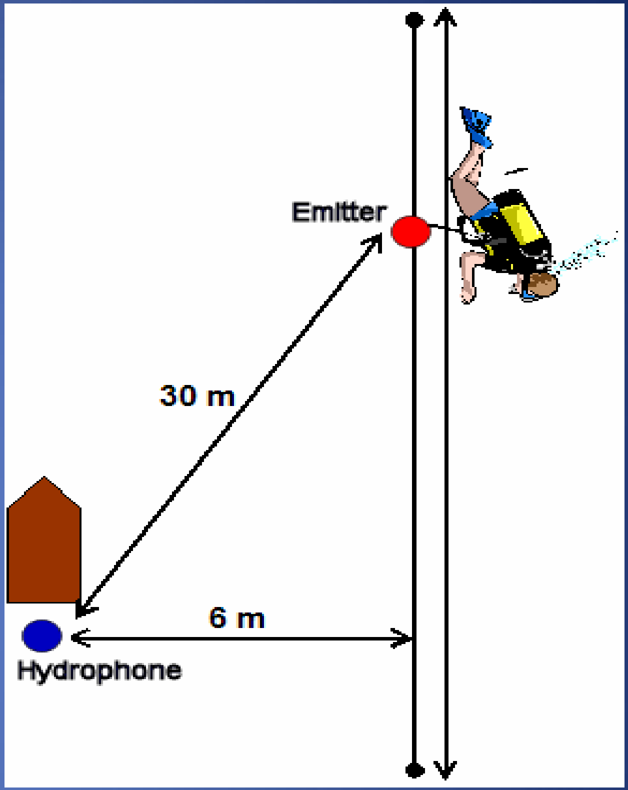
Methodology



Source Level

- A calibrated emitter (Reson TC4034-1) providing a known source level was placed 30 meters from the hydrophone, and the signal, swept from 1 – 100 kHz, was recorded.
- The diver was equipped with GPS.
- Measurements of SL were taken along the 200 meter path of the diver.
- After taking all measurements, the SL for the diver at 30 meters was compared to the data for the emitter, allowing us to compute the equivalent SL of the diver at 1 meter.

Test field for measuring SL



Reson TC4034-1 sensitivity

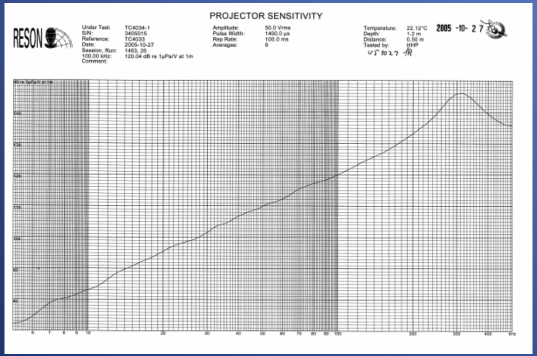
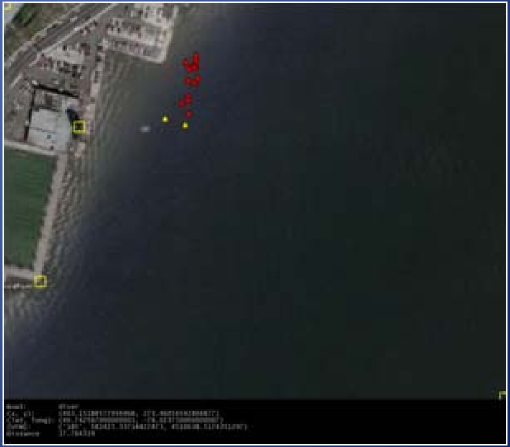
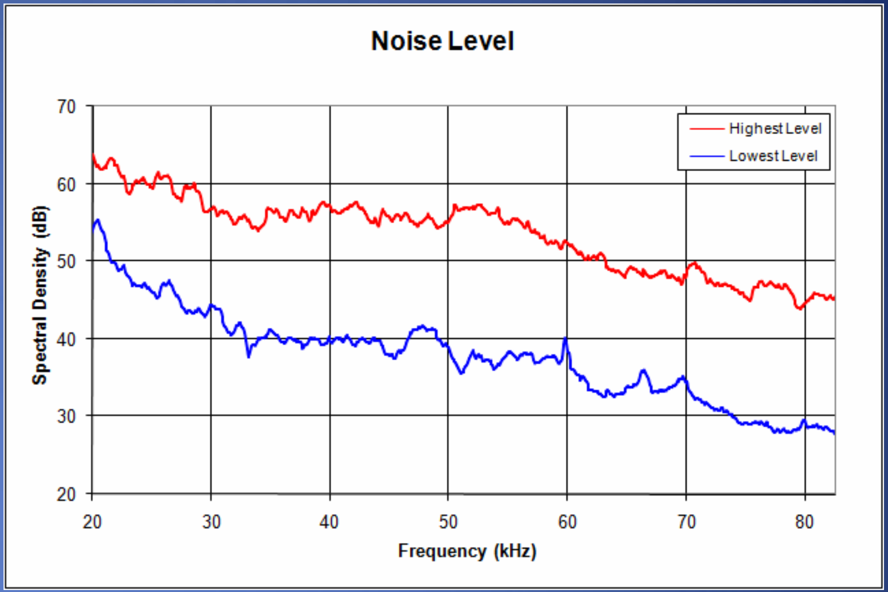


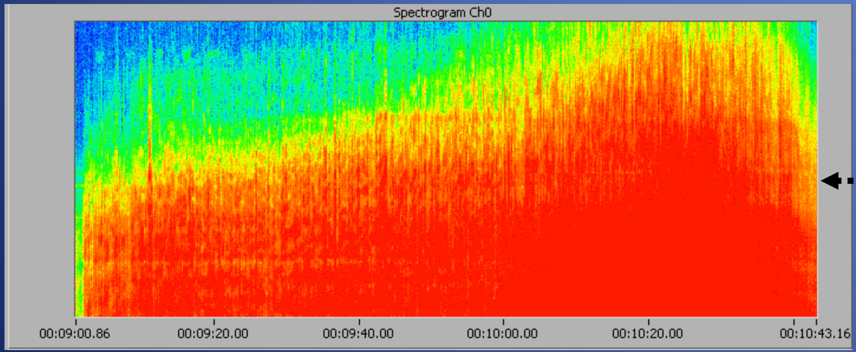
Image of GPS tracking the movement of the diver



Noise Level

- Water traffic is largely responsible for the noise in the Hudson River.
- Even sounds generated from pile drivers and other heavy machinery on construction sites in Hoboken can contribute to the noise level.





The pile driver obliterated all other signals in the water!

Transmission Loss

TL was measured in the acoustic path between an emitter/hydrophone pair and by using noise from ships. More details to follow in the next presentation entitled *Acoustic noise produced by ship traffic in the Hudson River estuary*.

Transmission loss

= cylindrical spreading loss + linear attenuation

= $A + 10 \times \log_{10}(r) + \alpha r$, as indicated by empirical testing. Values typically seen in the Hudson River are:

$A = -15$ dB

$\alpha = 0.03$ dB/m

Estimating the Detection Distance

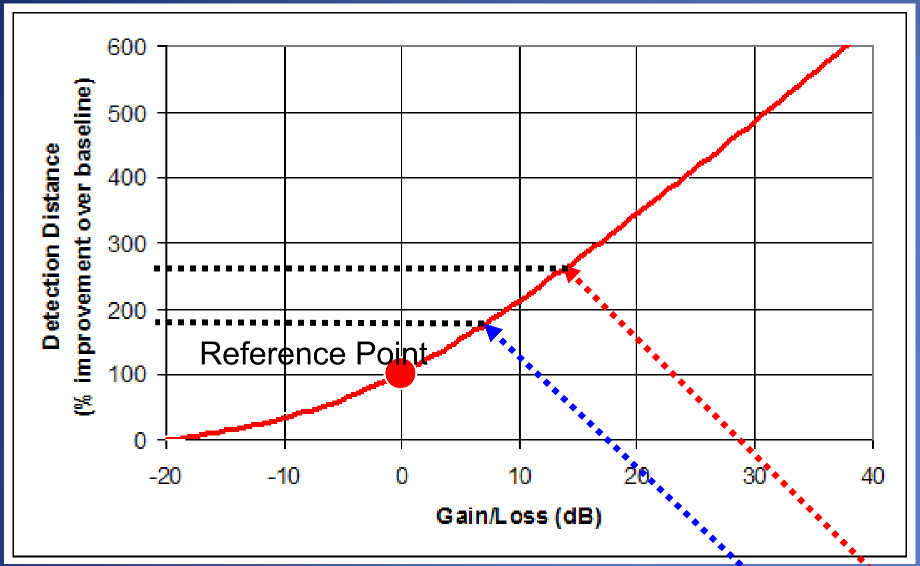
- We use the results of a positive diver detection at some distance r_0 as the baseline:

  $SL - TL_{r_0} - NL + DI = 0$
- The transmission loss will be modeled as previously described: $A + 10 \times \log_{10}(r) + \alpha r$
- So, for some distance r, the sonar equation will be:

  $SL - (A + 10 \times \log_{10}(r) + \alpha r) - NL + DI = 0$
- We can let gain be expressed as: $G = DI + \Delta SL - \Delta NL$
- Now the detection distance r can be calculated by subtracting the equation for r_0 from the equation for r:

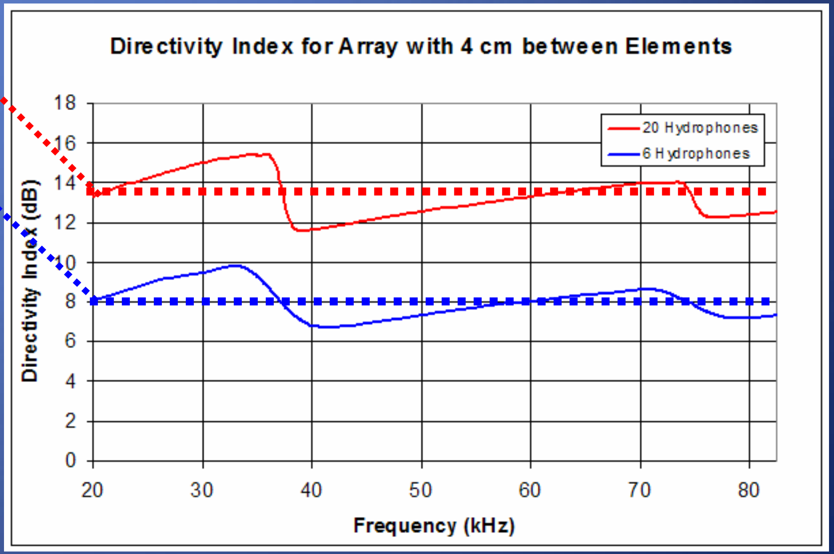
$$\mathbf{10 \times \log_{10}(r/r_0) + \alpha(r - r_0) = G}$$

Using an Array of Hydrophones



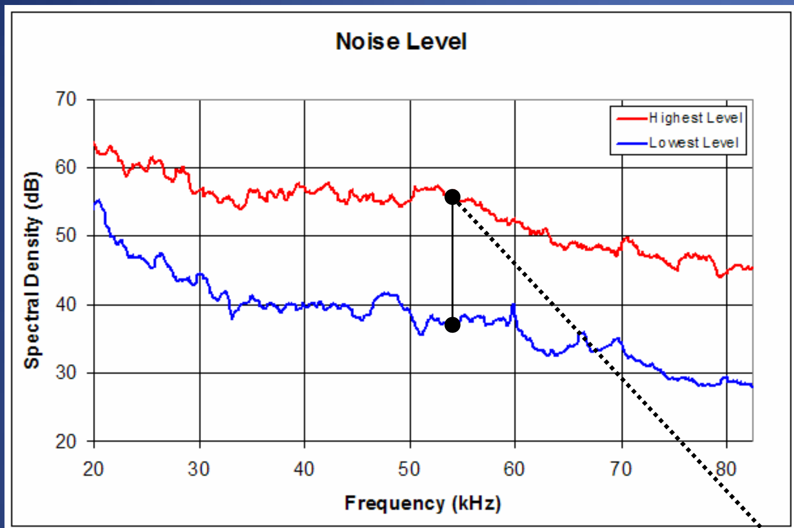
Keeping the other parameters constant, using an array of 6 hydrophones will increase the average gain by 8 dB, resulting in a detection distance 180% greater than the baseline distance.

Using an array of 20 hydrophones will increase the average gain by about 13 – 14 dB, resulting in a detection distance 260% greater than the baseline distance!



From Urick, *Principles of Underwater Sound*

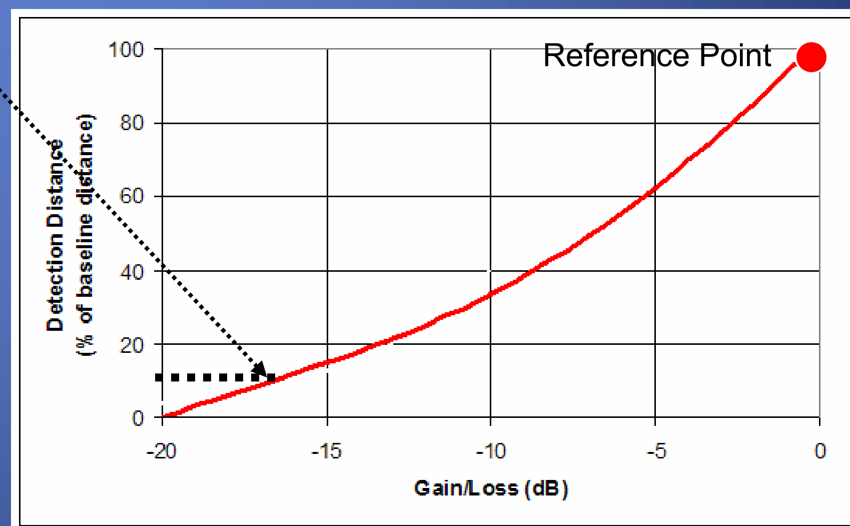
Influence of Noise on Detection Distance



Keeping the other parameters constant, a higher noise level of about 17 dB reduces the overall gain by the same level, resulting in a detection distance of about only 12% of the baseline distance.

More details about noise in the next presentation…

Thus, we can calculate the noise level at which a diver can no longer be detected for some designated distance.



Conclusion

- The Maritime Secure Laboratory (MSL) at Stevens Institute of Technology measured the main parameters defining the detection distance of a threat: source level of a scuba diver, transmission loss of acoustic signals, and ambient noise.
- We presented our approach to this problem and demonstrated how to use the measured parameters to estimate the detection distance under various conditions.

Acknowledgment

This work was supported by ONR project No. N00014-05-1-0632: Navy Force Protection Technology Assessment Project.

Thank You

Are there any questions?

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