Impulsive Low-Frequency Active Sonar Detection Statistics with Environmental Uncertainty

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BBN Technologies

Capturing Uncertainty DRI: Final Review

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15 June 2004

Overview

- *Objective*: Characterize environmentally induced variability of impulsive LF active sonar detection statistics in well-behaved continental shelf environments
- *Analysis focus*: Area Characterization Test (ACT) sequence

Test	Location	Depth	Sediment
ACT I	28°23N85°18W (W Fl Shelf)	180m	Sand-Silt-Clay
ACT III	33°50N128°10E(Korea Str)	95m	Silty-Sand

- *Sonar parameters*:
  - Frequency band; 50-500 Hz
  - Sources: Broadband explosive sources
  - Receiving arrays: 100 m bottomed HLA (6λ @ 100,200,400 Hz)

Signal-to-Interference Ratio (SIR) Variability

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- Data recorded
  - Target echoes (reflector & signal repeater target)
  - Source-target TL; target-receiver TL(each event ACT I)
  - Background levels at HLA
- Variability scales observed
  - Short term (ping-to-ping fluctuations)
    - Temporal scale ~100s
  - Large scale uncertainty and/or variability
    - Temporal scale ~10^3-10^4s
    - Spatial scale 10-100 km
- Analysis results
  - TL and reverb intensity fluctuations(short term): saturated Gaussian statistics
  - Large scale SIR variation: 2-3 dB (ACT I & III)

Detection Statistics

- Sonar processing

- Output is estimate of prewhitened SIR
  - Interference: x^2 with N DOF, where N = 2WT » 1
  - Signal: amplitude modulated noise burst
  - SIR: random scaling γ (mean(γ) = 1, stdev(γ) = measured)
- Detection model with uncertainty
  - Measure of SIR large scale spread:

    Coeff of Variation(γ) = stdev(γ)/mean(γ)
  - Output pdf obtained as Gram-Charlier series about pdf conditioned on mean(SIR)
- Effect of 2-3 dB SIR uncertainty: No effect at PD~0.5; 1-2 dB additional SIR required at PD~0.7-0.8

Sonar Equation Analysis

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Key: M = Major
m = minor
0 = none
– = unmeas.

Variable	Uncertainty Contribution	Determination
Energy Source Level	0	Measured
Target Strength	m	Model
TL via target	M	Measured
Array Signal Gain	m	Measured
Bottom SS	M	Measured
TL via bottom	M	Measured
Ambient Noise Level	–	Measured
System Parameters	0	Measured/Model
Array Noise Gain	m	Measured

Remaining Effort

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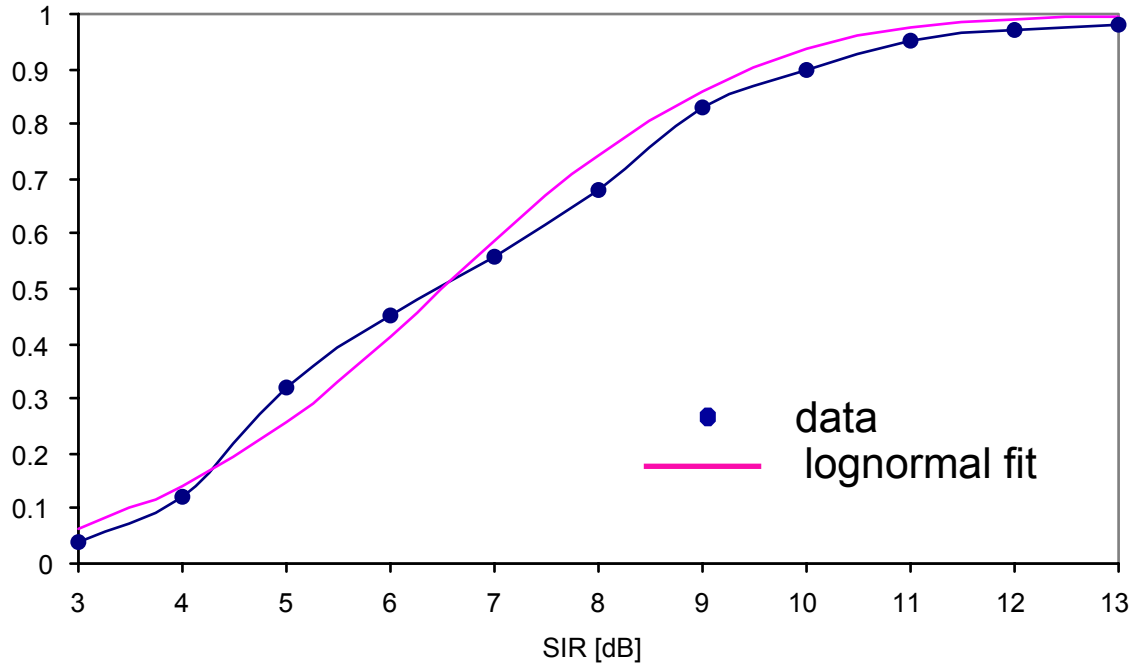
- Determine correlation of target path TL with bottom path TL
- Include effect of ABW estimation error in description of detection statistics
- Extend modeling of effect of uncertainty on detection statistics to larger spread of SIR
  - Current model limited to SIR std dev ≤ 3-4 dB
  - Will require more detailed description of uncertainty than SIR std dev
- Complete detection range estimation methodology using reverberation decay time

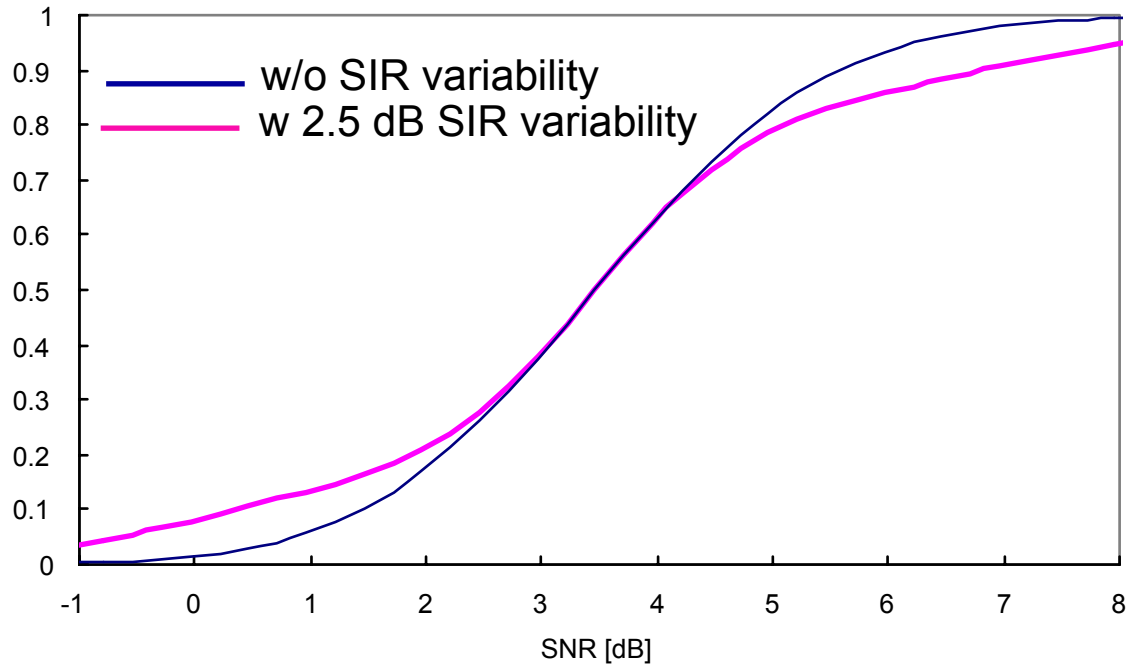
Backups

ACT III SIR Variability

151 echoes
5 km ≤ range ≤ 20 km

mean(SIR) = 6.5 dB
stdev(SIR) = 2.3 dB



Effect of SIR Variability on Detection

PFA = 10^{-6}
N = 2WT = 50