Passive Acoustic Classification
Traditional Practice

- Traditional emphasis has utilized horizontal line array’s azimuthal selectivity to extract cues from observed geometric and spectral dynamics.

\[ BTR \quad \text{Lofargram} \]

- Requires detailed understanding of target signature and some awareness of operational tactics.

- No explicit mechanism is incorporated for the estimation of target depth.
Passive Acoustic Classification
Environment Specific Approaches

**Matched Field Processing**

- Emerging technique which combines known or assumed environmental parameters with a propagation model to explicitly estimate range/depth
- Complements BTR and lofargram by trading bearing selectivity for depth

**Ambiguity Surface**

- Requires relatively accurate estimate of environmental parameters
- Computational expense may limit tactical application for near term
Modal Scintillation Classifier
Definition

- Complex pressure field proportional to time-varying mode excitations

\[ p(z,t) = \alpha \sum_{m=1}^{M} \psi_m(z_s(t)) \psi_m(z) \frac{e^{jk_rm r_s}}{\sqrt{k_rm r_s}} \]

- Estimate the time-varying modal excitation via pseudoinverse mode filter

\[ \hat{\alpha}(t) = \psi^+ p(t) \quad \text{where} \quad \psi^+ = (\psi^H \psi)^{-1} \psi^H \]

- Calculate modal scintillation index over several cycles of depth modulation

\[ SI = \frac{\text{Var}\{|\hat{\alpha}_m|\}}{\text{E}\{|\hat{\alpha}_m|\}} \quad m = 1, 2, \ldots, M \]
Mode Scintillation Classifier

Processing Flow Diagram

- **Surface Indicator**
  - **Time**
  - **Frequency**

- **Sub Indicator**
  - **Time**
  - **Frequency**

• SFC/SUB interest images obtained by thresholding minimum scintillation index observed over all modes
  - Surface source exhibits HIGH-VALUED scintillation index across ALL modes simultaneously
  - Submerged source exhibits LOW-VALUED scintillation index for AT LEAST ONE mode
SWellEX-96 Experiment Overview
Array Geometry

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Mode Scintillation Classifier
Modal Decomposition

\[ p(z,t) = \alpha \sum_{m=1}^{M} \Psi_m(z_s(t)) \Psi_m(z) \frac{e^{ik_m r_s}}{\sqrt{k_m r_s}} \]

- **Depth (m)**
- **Sound Speed (m/s)**
- **Vertical Line Array**
- **Surface**
- **Submerged**
SWellEX-96 Preliminary Results

• Measured PDF separation in SWellEX-96 consistent with shallow water KRAKEN predictions

RMS Depth Fluctuation of 1–2 m Is Consistent with Low to Moderate Sea State

SUB Class PDF Separates Toward Low-Valued SI

SFC Class PDF Separates Toward High-Valued SI
SWellEX-96 Results

Thresholded "Scintillation Grams" Using Measured SSP

- Independent thresholds are applied to "scintillation grams" to render SFC and SUB decisions
SWellEX-96 Results
Thresholded "Scintillation Grams" Assuming Isovelocity Profile

- Emphasis on mode shape rather than fine structure (i.e. phase) enhances tolerance to imperfect environmental model assumptions
For surface source, weak mode excitation combined with large vertical derivative maps depth modulation into energetic mode amplitude scintillation for all waveguide modes.

For source at depth there exists at least one waveguide mode for which strong excitation is accompanied by small vertical derivative, mapping to near zero-valued scintillation.