Dual Use Multi-Frequency Radar For Current Shear Mapping and Ship Target Classification

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Objective:

- **Develop scheme for Classification / Identification of ships and small boats using Multi-Frequency HF radar**

- **Dual-Use Coast Guard application for mapping current shear and vector winds for SAR operations**

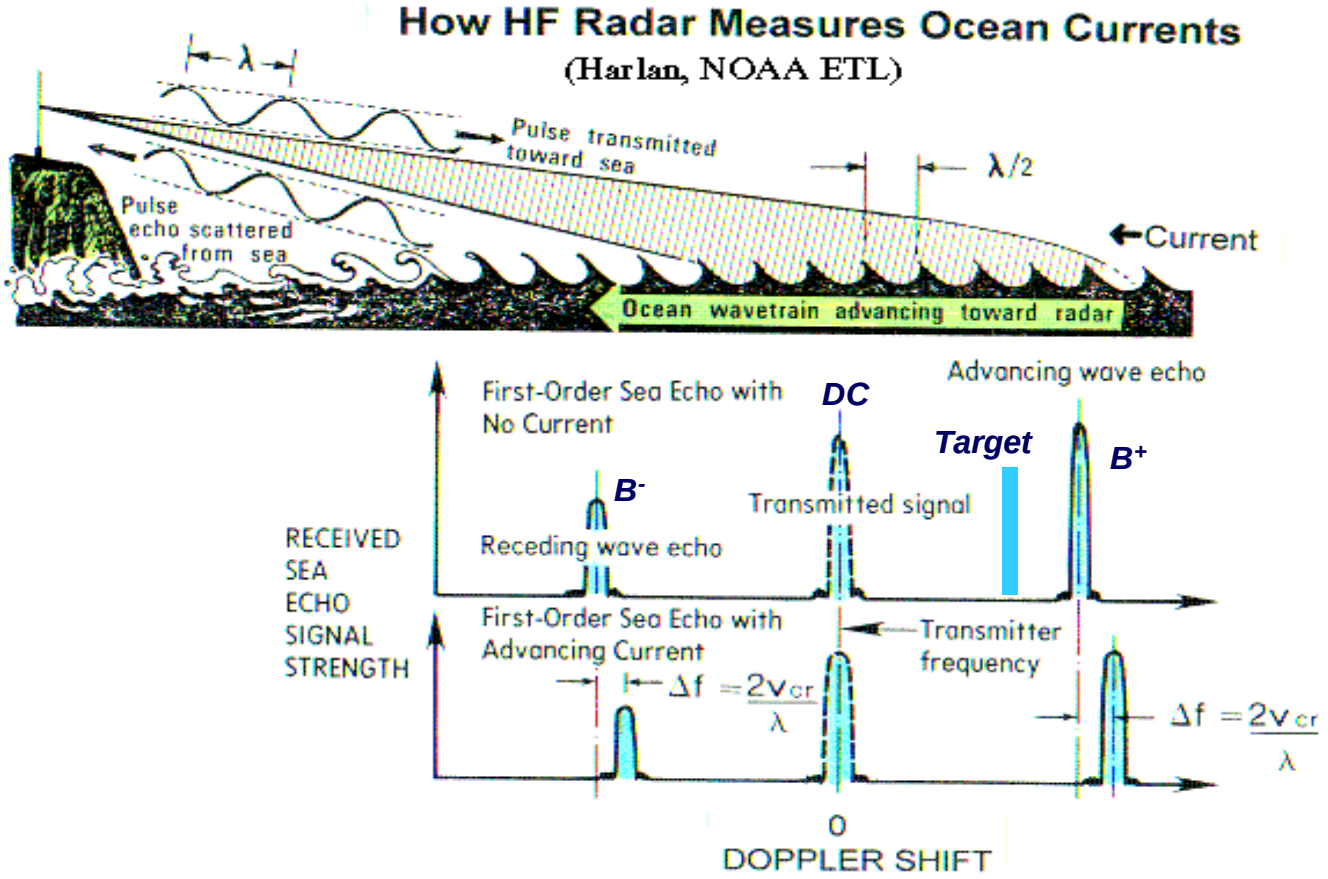
Approach:

- **Measure Radar Cross Section of Ships vs. Radar Frequency**
  - **Interleaved Pulse Frequency switching important**
  - **Subtle RCS changes with azimuthal bearing measured simultaneously while on a single course**
  - **Course repetition using single frequency operation is error fraught due to minor bearing changes while underway**

- **Identify HF RCS Spectral peaks and nulls as ship classifiers**
  - **Based on work conducted in ‘70’s at NRL**

Doppler spectrum analysis provides individual target echoes at different radial velocities:

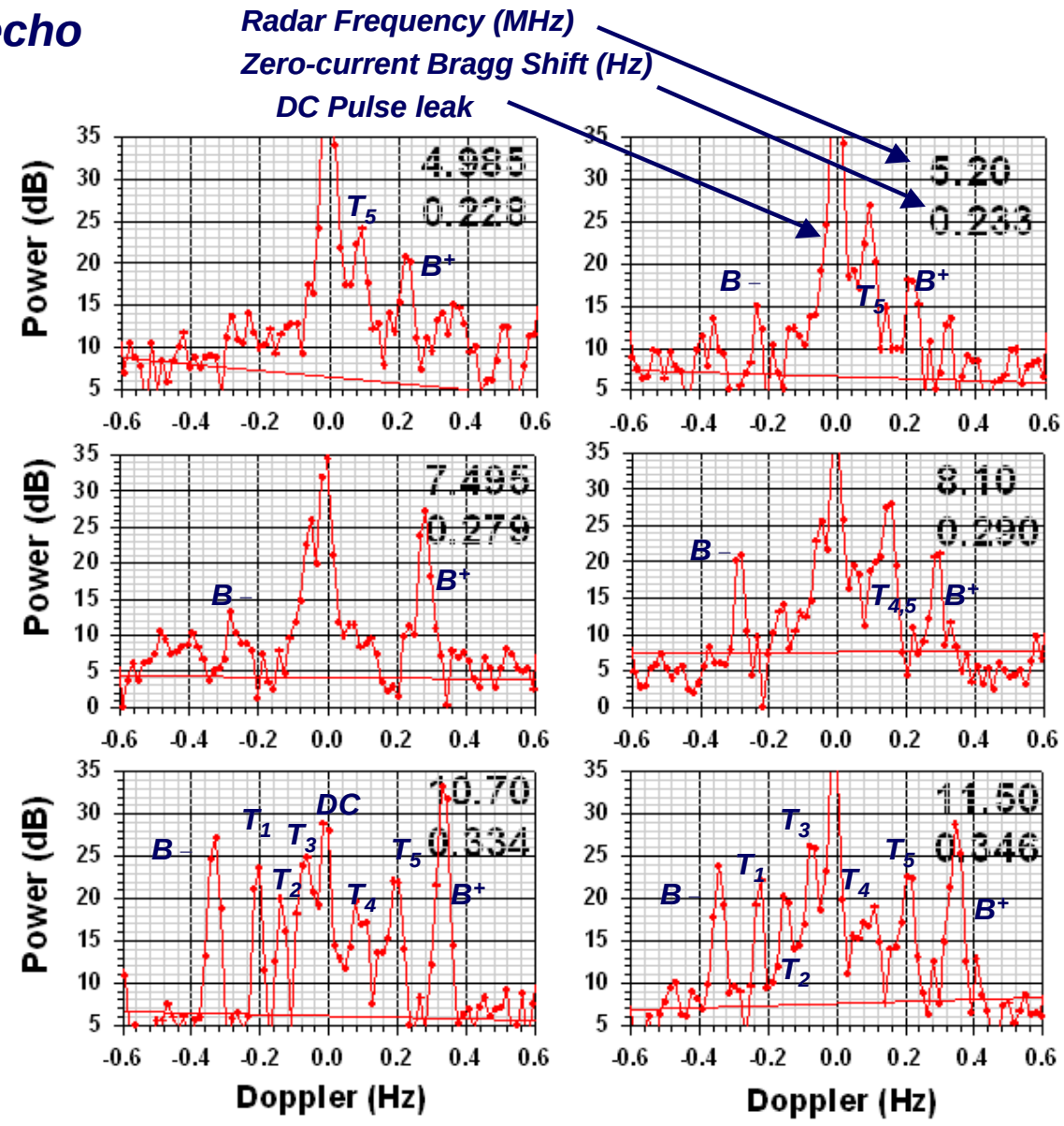
- **Ship's Radar Cross Section ~ Received Power in Doppler filter**
- **Ship's speed ~ to radial velocity**
- **Sort targets from Bragg lines either side of zero Doppler**



Target Detection: (1)RCS Amplitude, (2)Radial Speed Measure

Doppler spectrum shows sea echo Bragg lines + Target echoes

- Radial Speed(kt)=1.94*Doppler/(ι/2)
- 5 targets seen at high frequencies
  - 2 approach (T_4, T_5)
  - 3 Recede (T_1, T_2, T_3)
- RCS~Power, changes with frequency
  - *Use as Target Classifier*
- *Target can overlap Bragg line*
  - *Loss of target track results*
  - Mitigated by multiple Radar frequencies
    - $V_T \sim F$
    - $V_B \sim F^{1/2}$

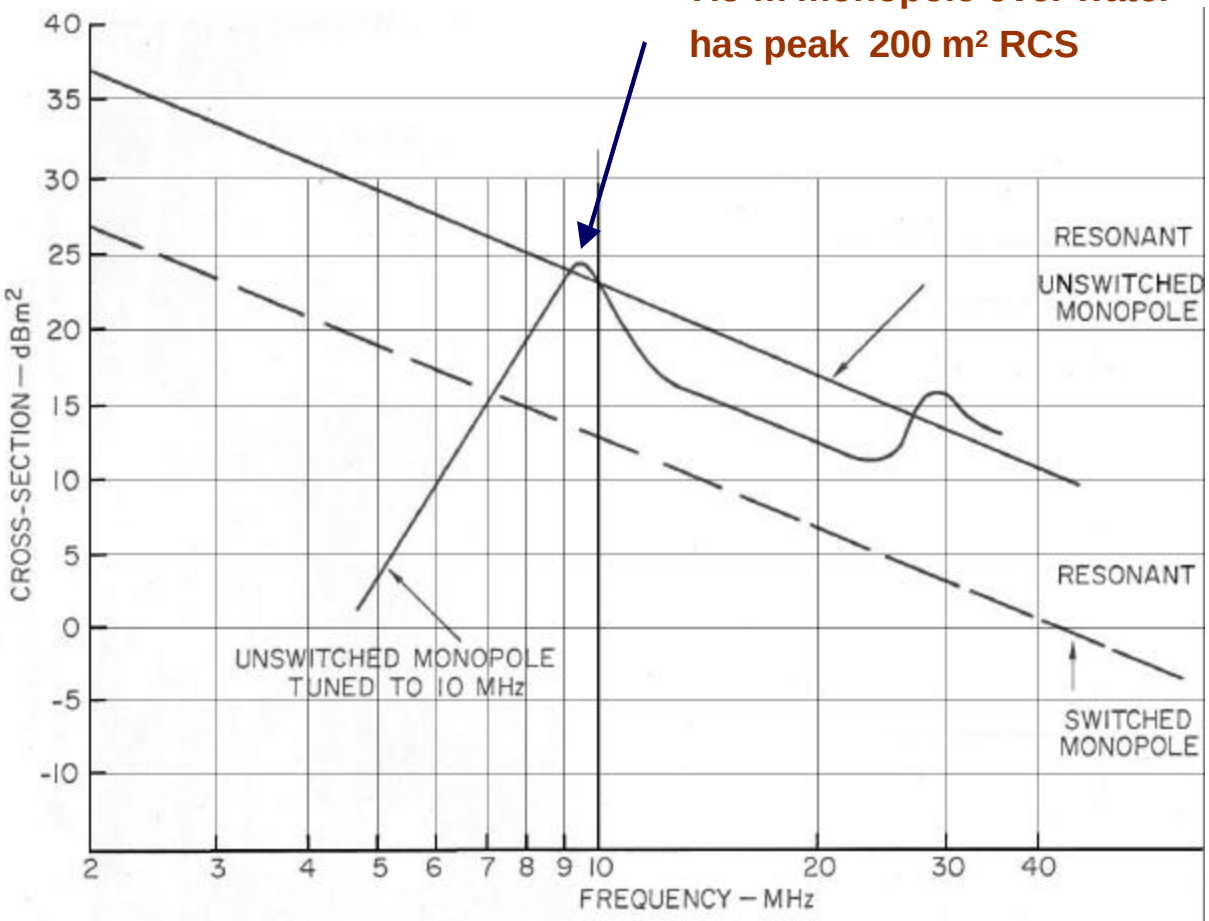


Model Ship RCS: Bulk Echo + λ/4 monopoles (vertical structures)

Monopole RCS frequency dependence:

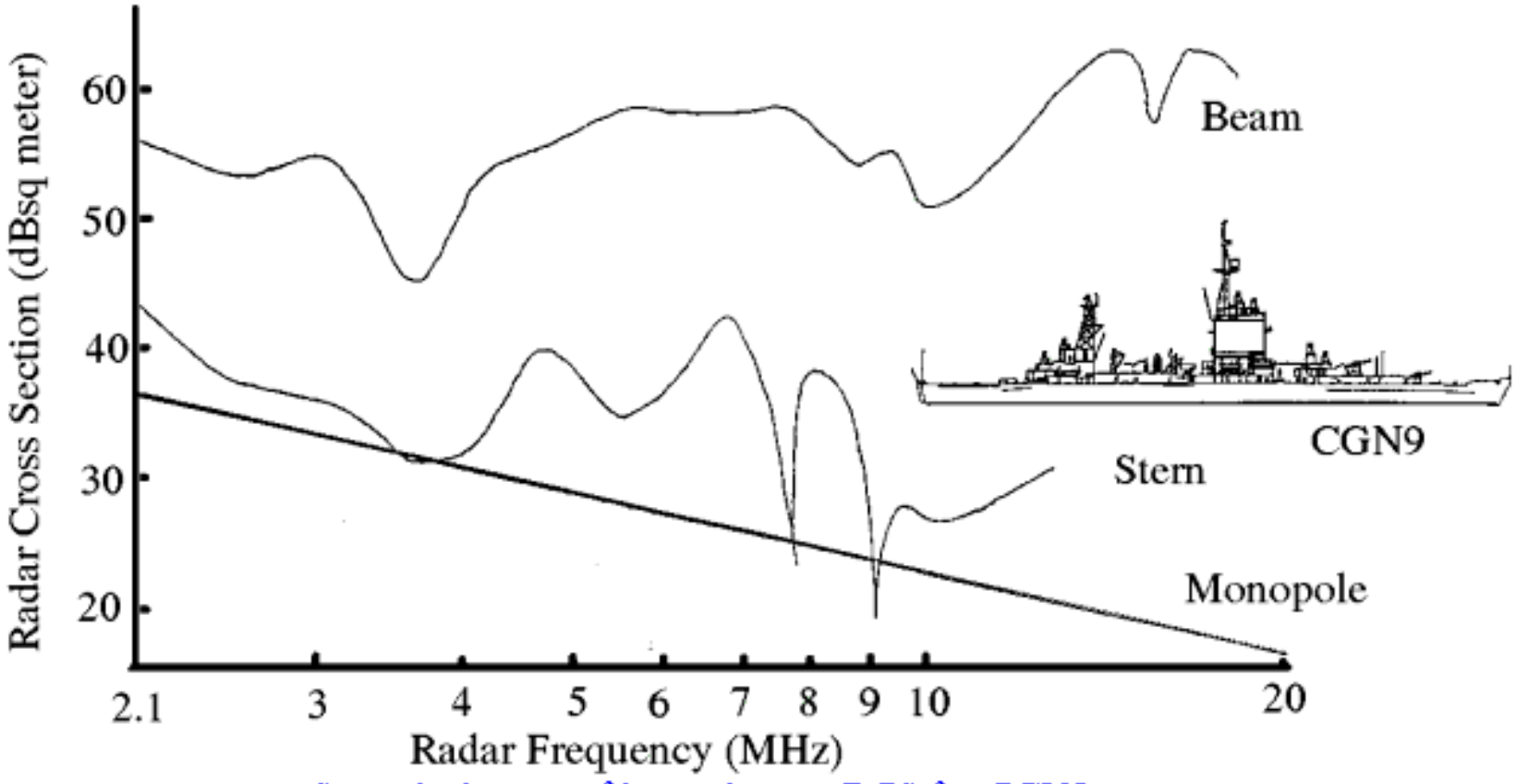
- **10-MHz λ/4 monopole is 7.5 m high**
- **Ocean Ground Plane produces image of induced currents, thus a dipole RCS**
- **10 Mhz resonant peaks at ~9.4 MHz as shown below**
- **Odd λ/4 peaks also appear**
- **Low Frequency decline as λ^7**
- **Use as a RCS Calibration tool**

- **7.5-m monopole over water has peak 200 m² RCS**



Large ship RCS is dominated by bulk RCS source beam-on then by monopoles, with interference nulls when observed bow/stern-on

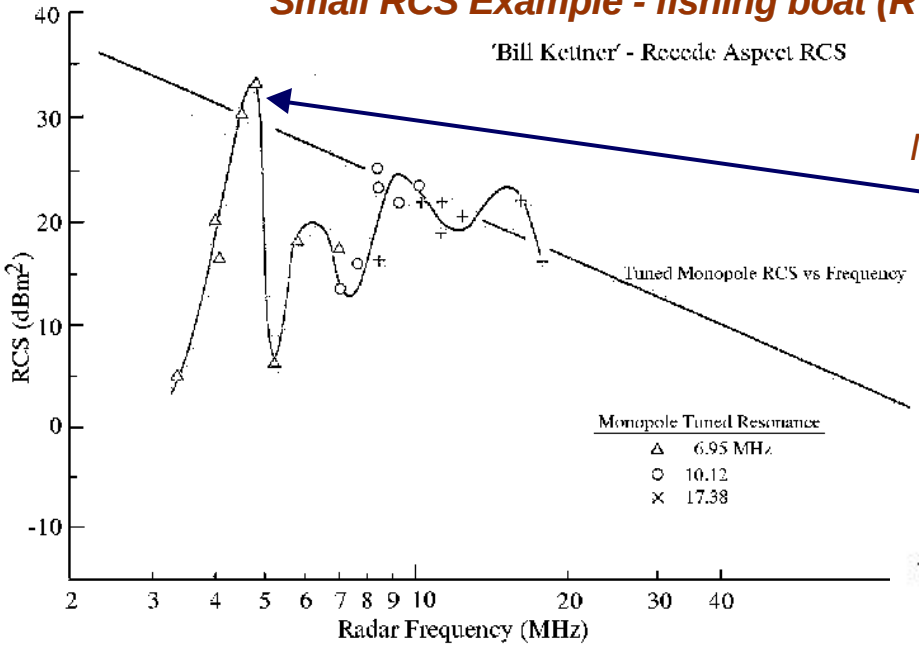
Stern/Bow Vs Beam-aspect RCS ratio is 20 dB or more



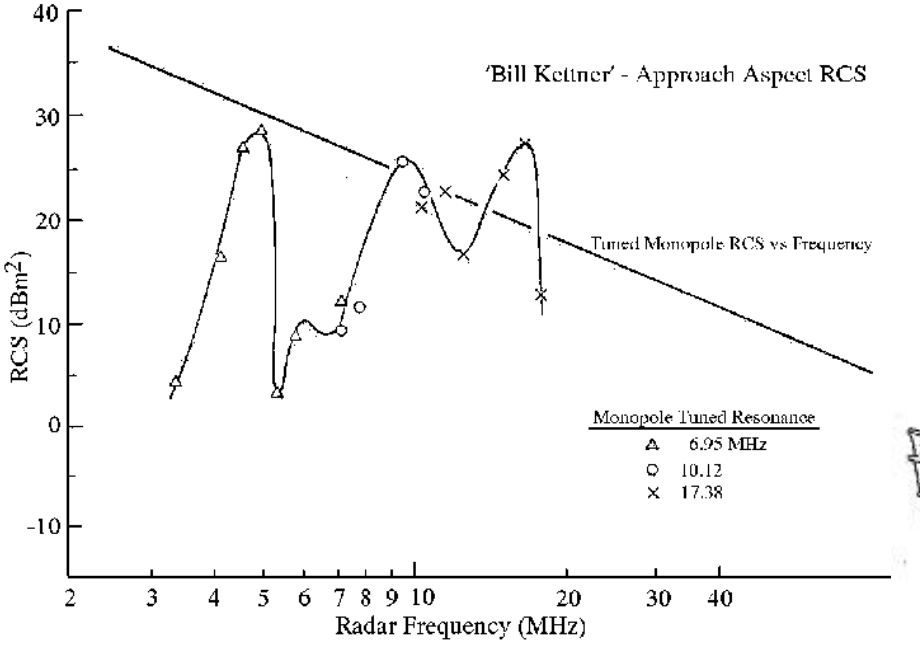
Smoothed curve of beam & stern RCS for CGN9
(Headrick & Rachuba, NRL/MR/5309-98-8173)

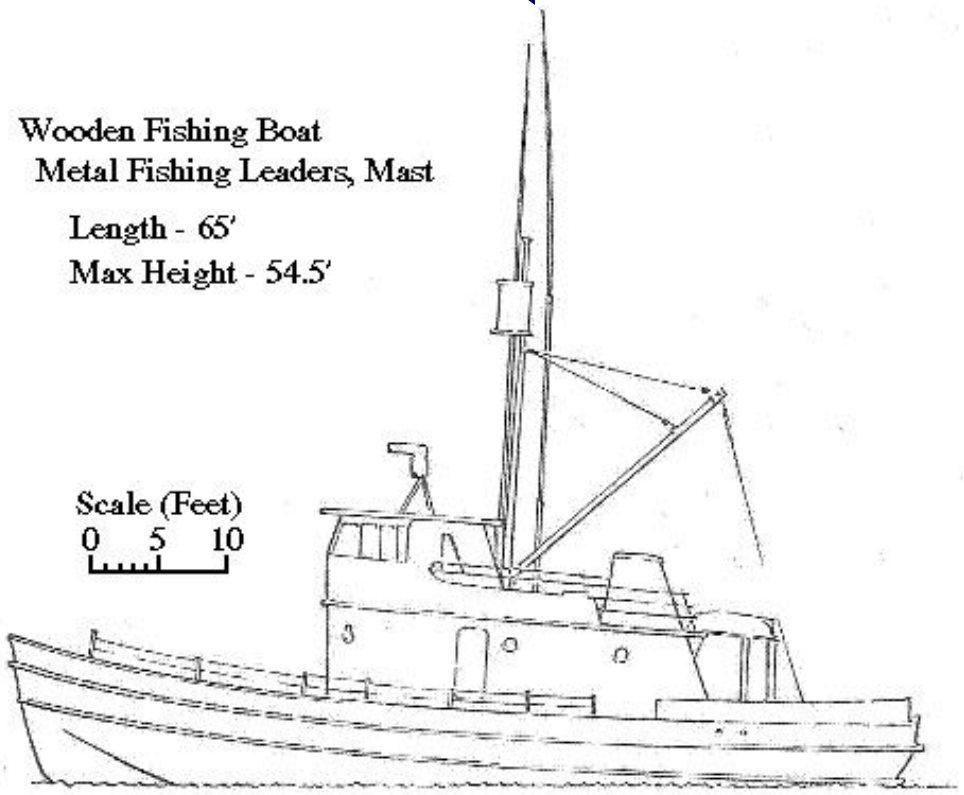
Ship Classification

Small RCS Example - fishing boat (RW Bogle, DB Trizna, NRL Report 3322, July 1976)



Metal Mast = 54.5 ft = 16.6 m
=λ/4 @ 4.5 MHz

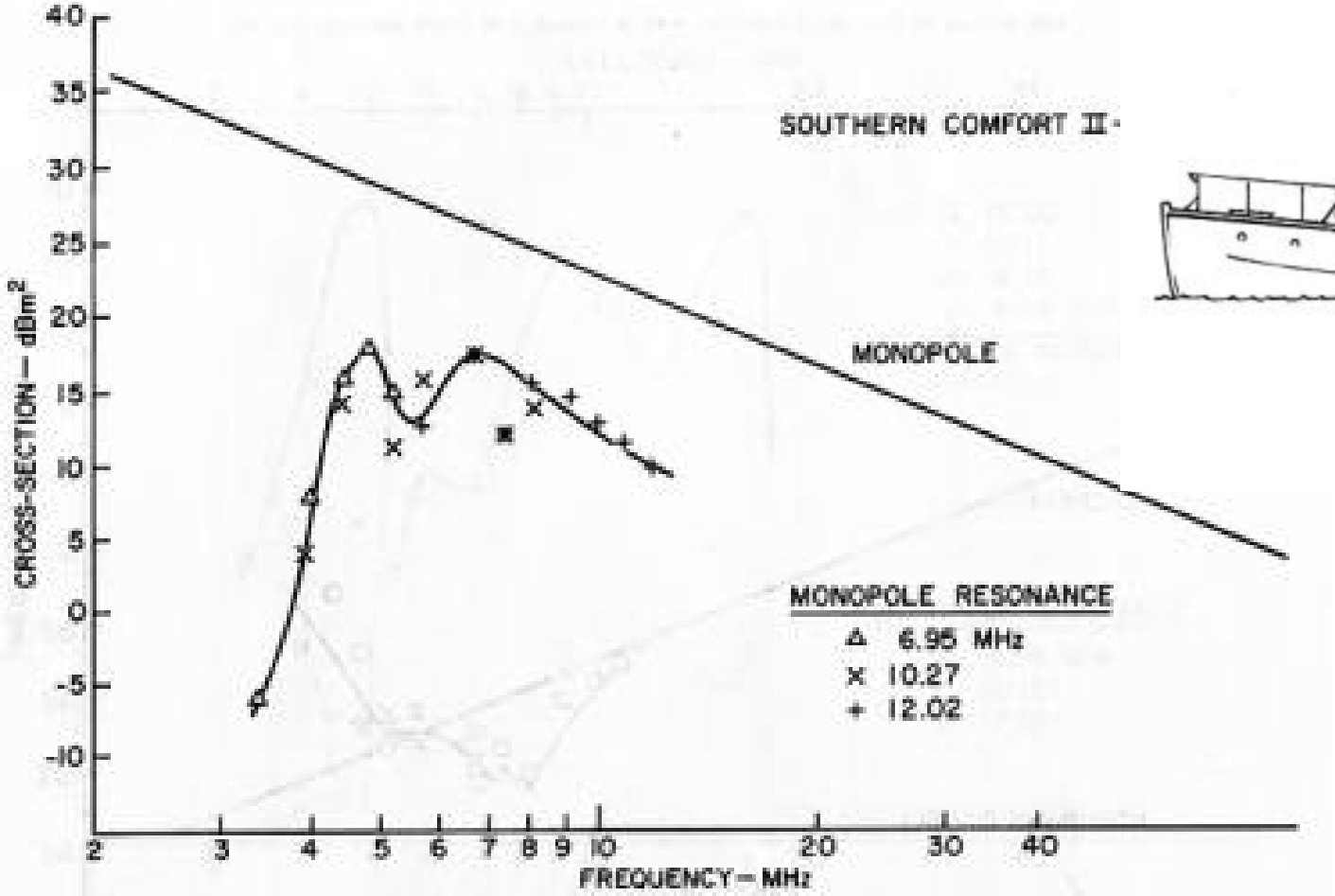


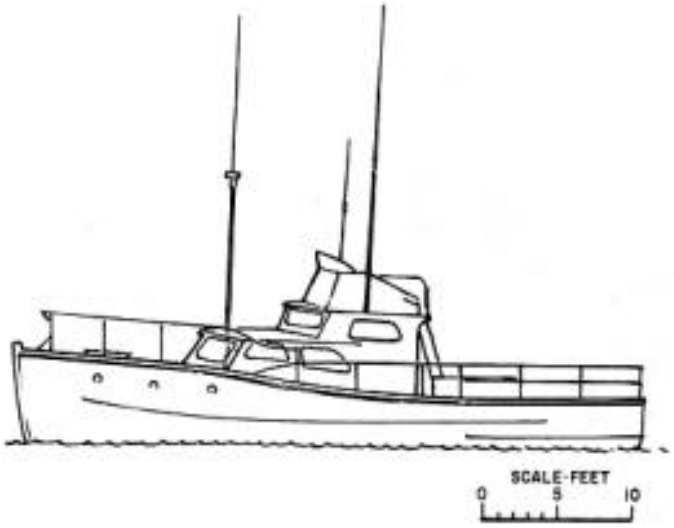


2nd Small RCS Example

Southern Comfort II Pleasure Boat

with possible monopole resonances, but smaller RCS than monopole

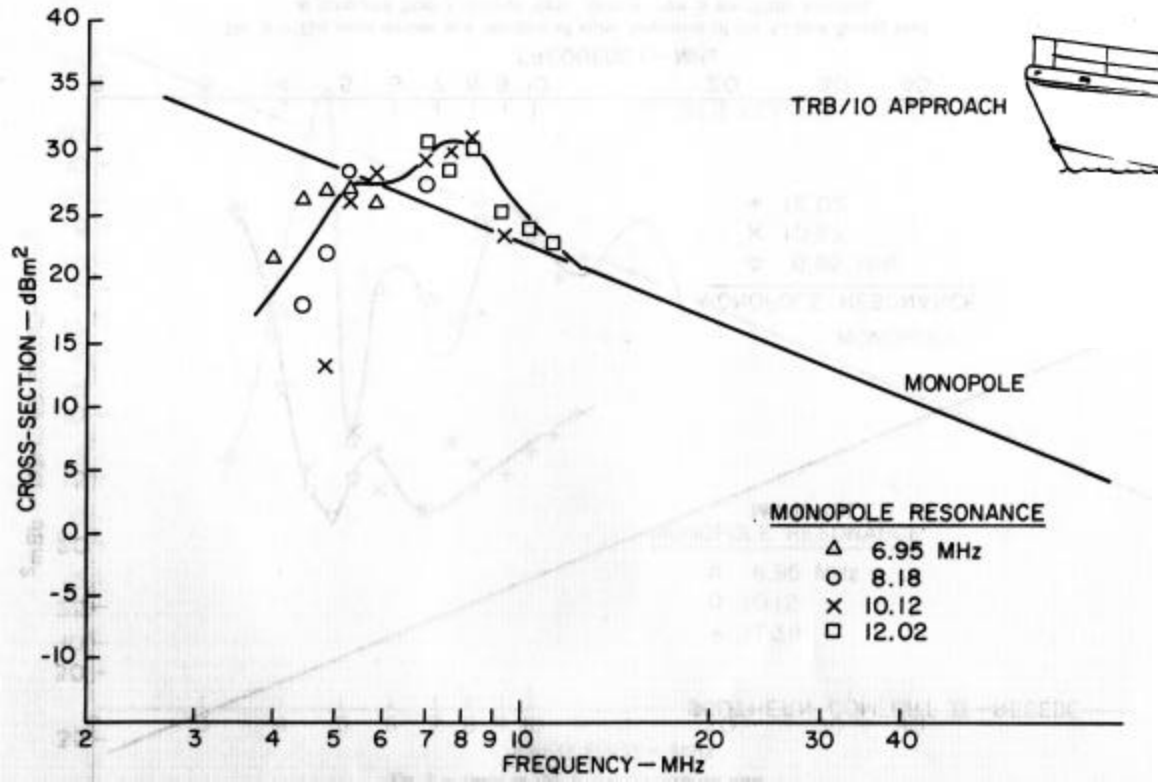


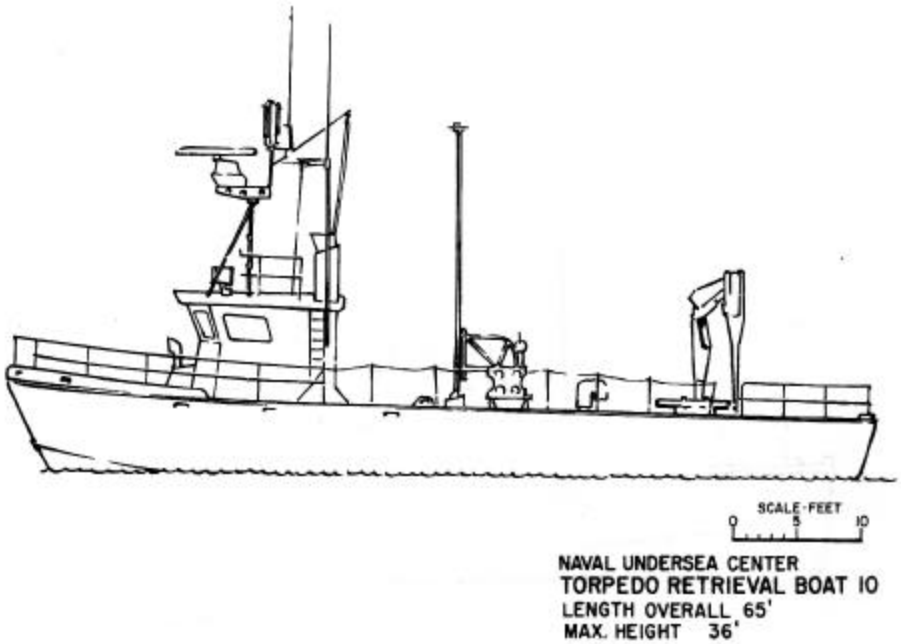


3rd Small RCS Example

Navy Torpedo Retrieval Boat (TRB)

Several monopole resonances





In Summary:

- **Boats demonstrate quite different Monostatic RCS Peak and Null characteristics**
  - **Maximum observed RCS indicative of Ship size**
  - **Peaks indicative of presence of vertical mast-like structures**
  - **Deep Nulls indicative of two or more masts, gives deep null when spacing is $\lambda/4$ x Odd Integer**
  - **Can be used as ship classification tool**
- **Added information content is available using Bistatic illumination - 2nd dimension**
  - **Combined with Monostatic results allows rapid classification**
- **Multiple Frequencies allow detection and tracking when Target Doppler shift = Bragg shift**
  - **Target and Bragg lines merge**
  - ***Can be counter-detection method* against single-frequency radar, if ship is aware of HF illumination and illuminating radar frequency**

Plan:

- **Monostatic / Bistatic tests proposed for building HF Classification library**
- **Large range of ship types at mouth of Chesapeake Bay**
- **Test range for dedicated small boats**
- **Several bistatic combinations available for transmit sites**
- **All controlled from single master site, processing done there**
- **Demo for operational prototype, develop tracking capability**