

# **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**



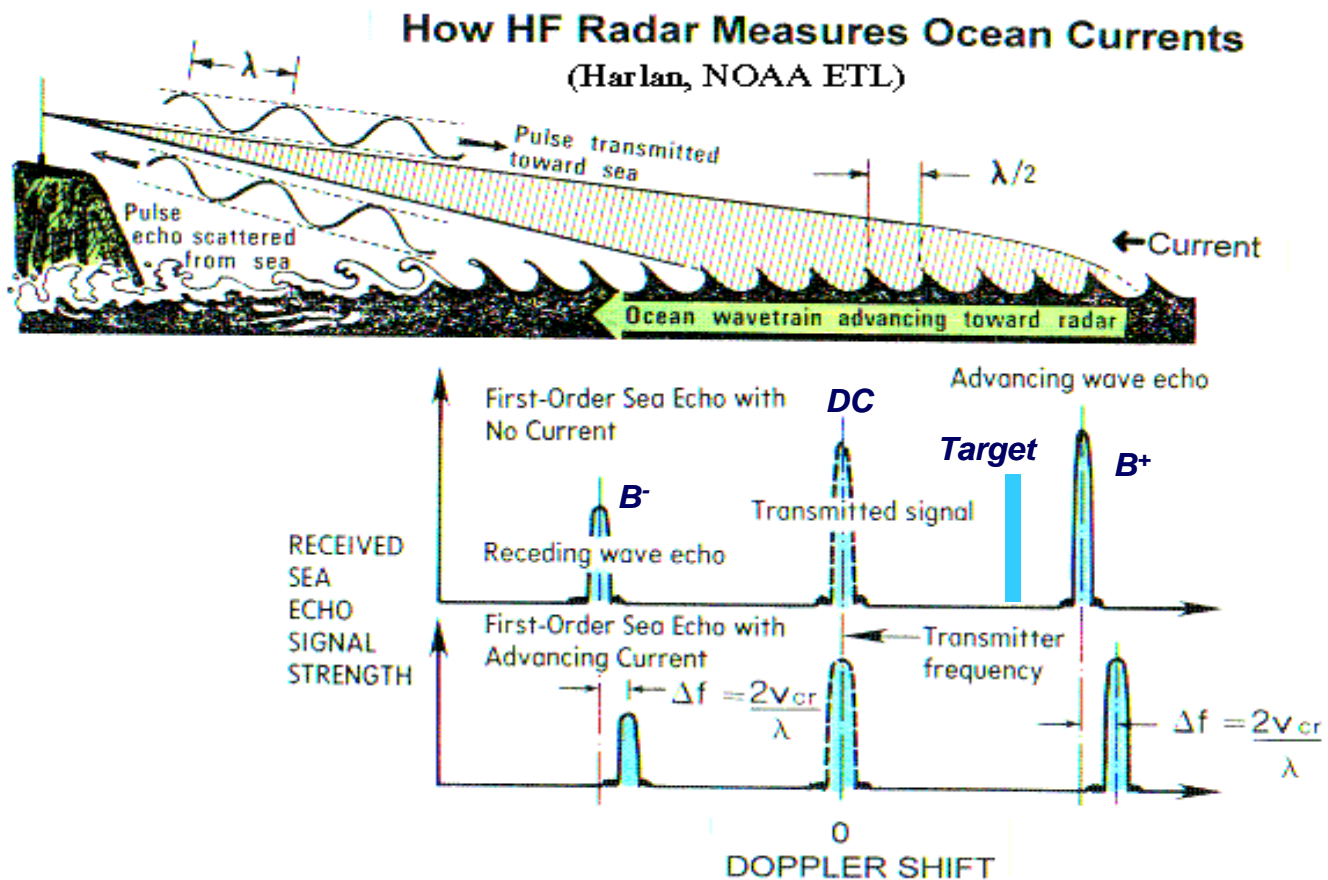
## ***Approach:***

- **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

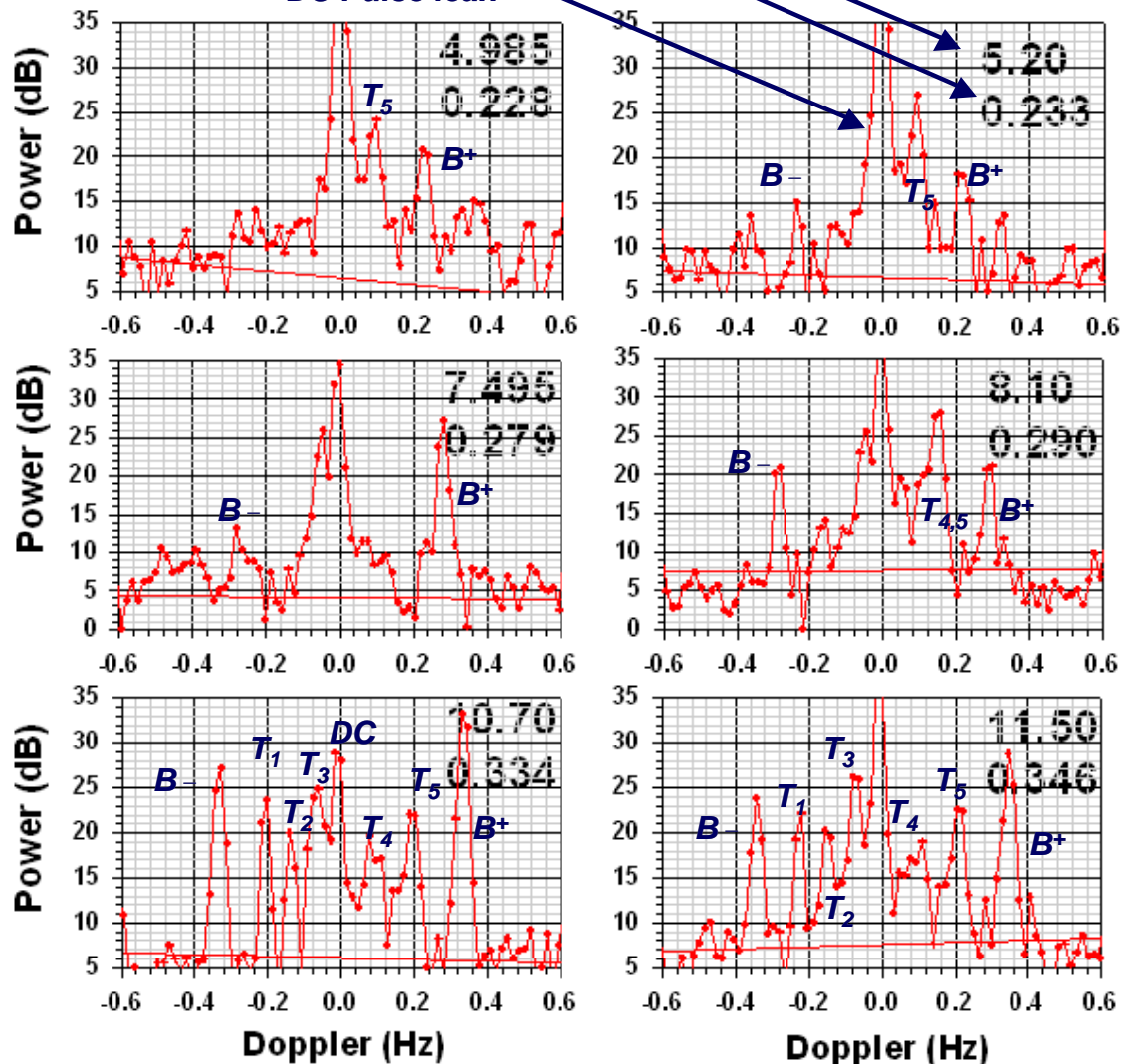


# Target Detection: (1) RCS Amplitude, (2) Radial Speed Measure

Doppler spectrum shows sea echo Bragg lines + Target echoes

- Radial Speed(kt)=1.94\*Doppler/(1/2)
- 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
- $V_T \sim F$
- $V_B \sim F^{1/2}$

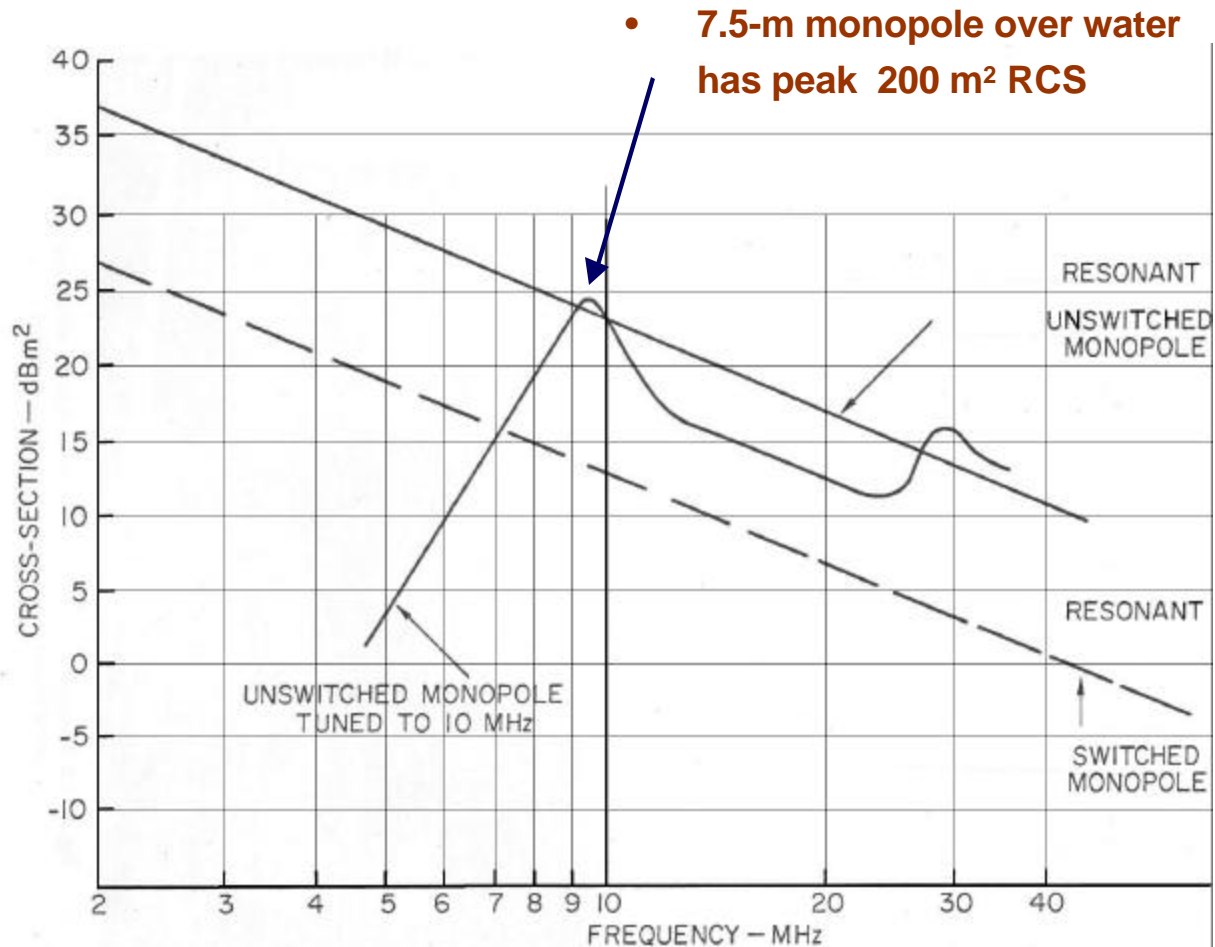
Radar Frequency (MHz)  
Zero-current Bragg Shift (Hz)  
DC Pulse leak



## Model Ship RCS: Bulk Echo + $\lambda/4$ monopoles (vertical structures)

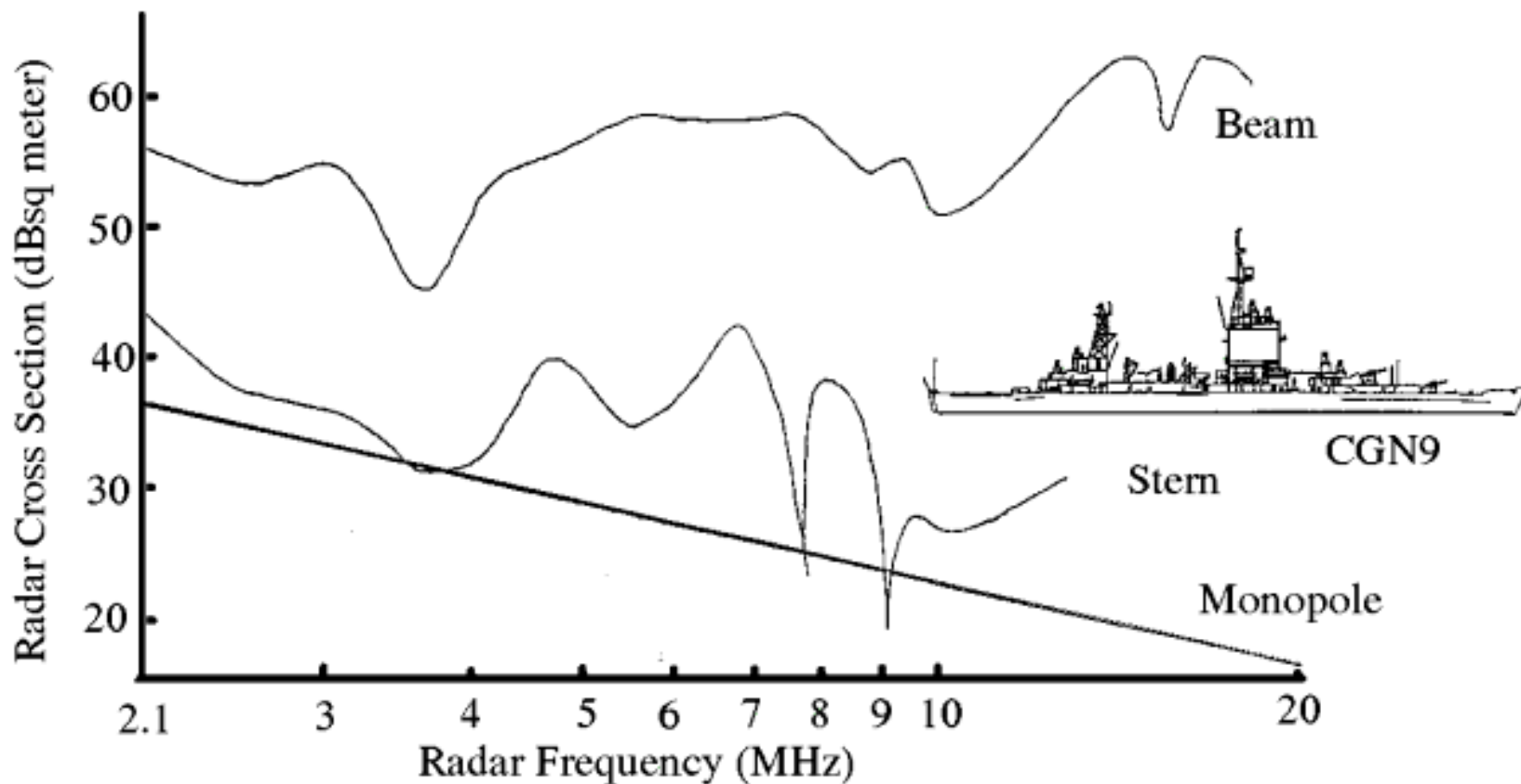
### Monopole RCS frequency dependence:

- 10-MHz  $\lambda/4$  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  $\lambda/4$  peaks also appear
- Low Frequency decline as  $f^{-7}$
- Use as a RCS Calibration tool



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

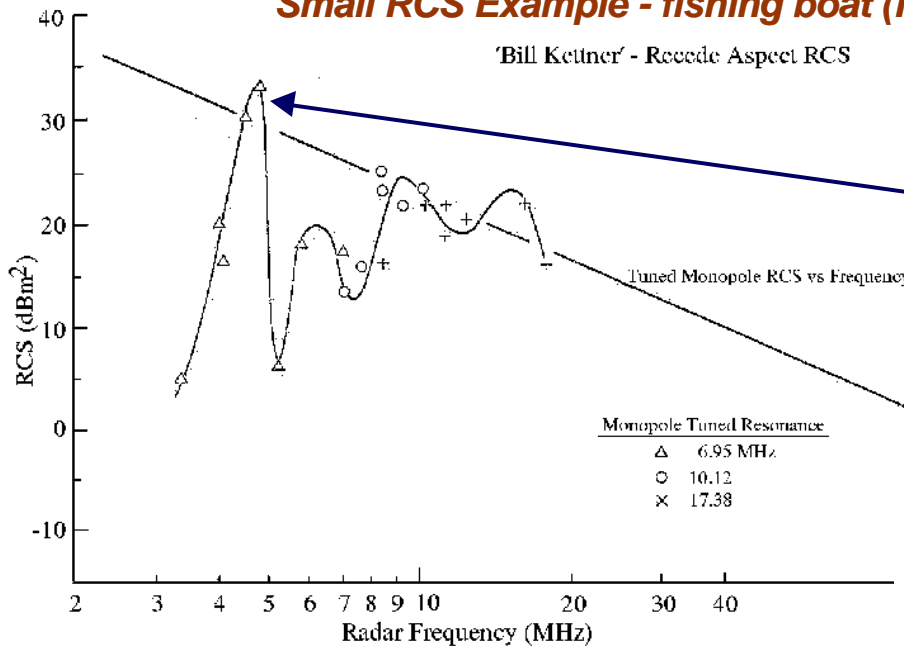


Smoothed curve of beam & stern RCS for CGN9  
(Headrick & Rachuba, NRL/MR/5309-98-8173)

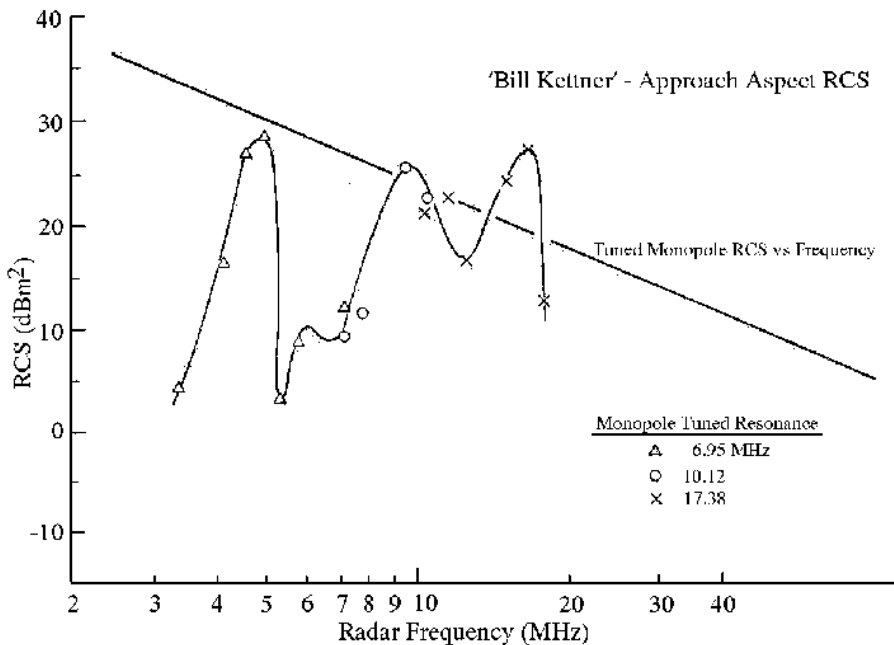


# Ship Classification

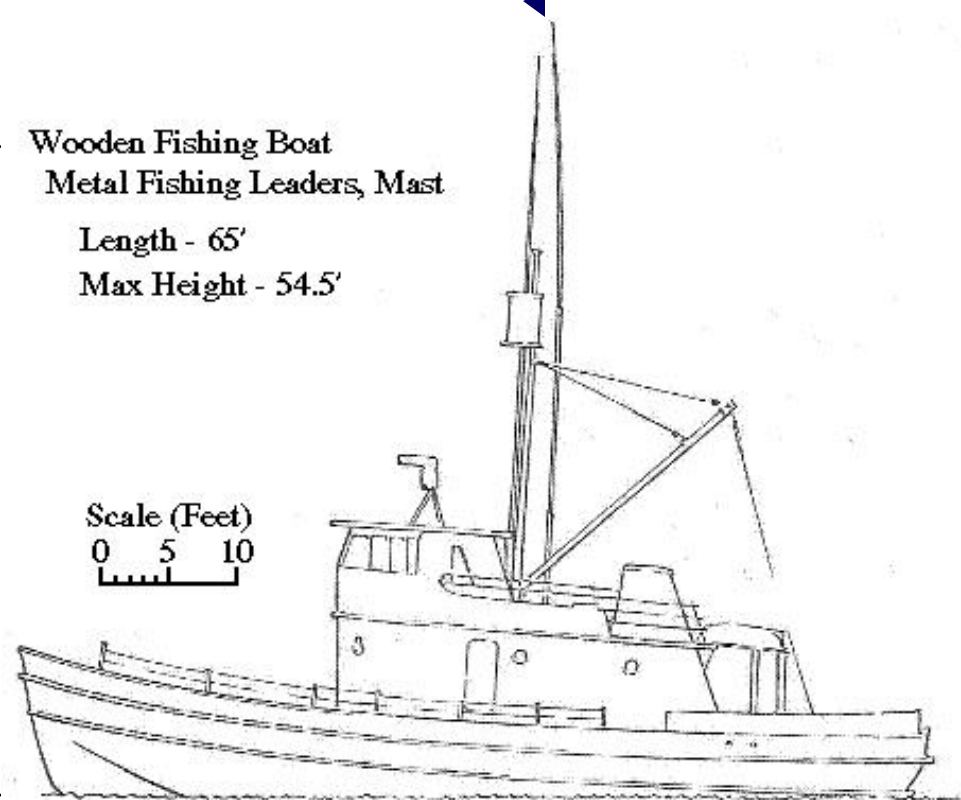
## Small RCS Example - fishing boat (RW Bogle, DB Trizna, NRL Report 3322, July 1976)



Metal Mast = 54.5 ft = 16.6 m  
 $\Rightarrow \lambda/4$  @ 4.5 MHz



Wooden Fishing Boat  
 Metal Fishing Leaders, Mast  
 Length - 65'  
 Max Height - 54.5'

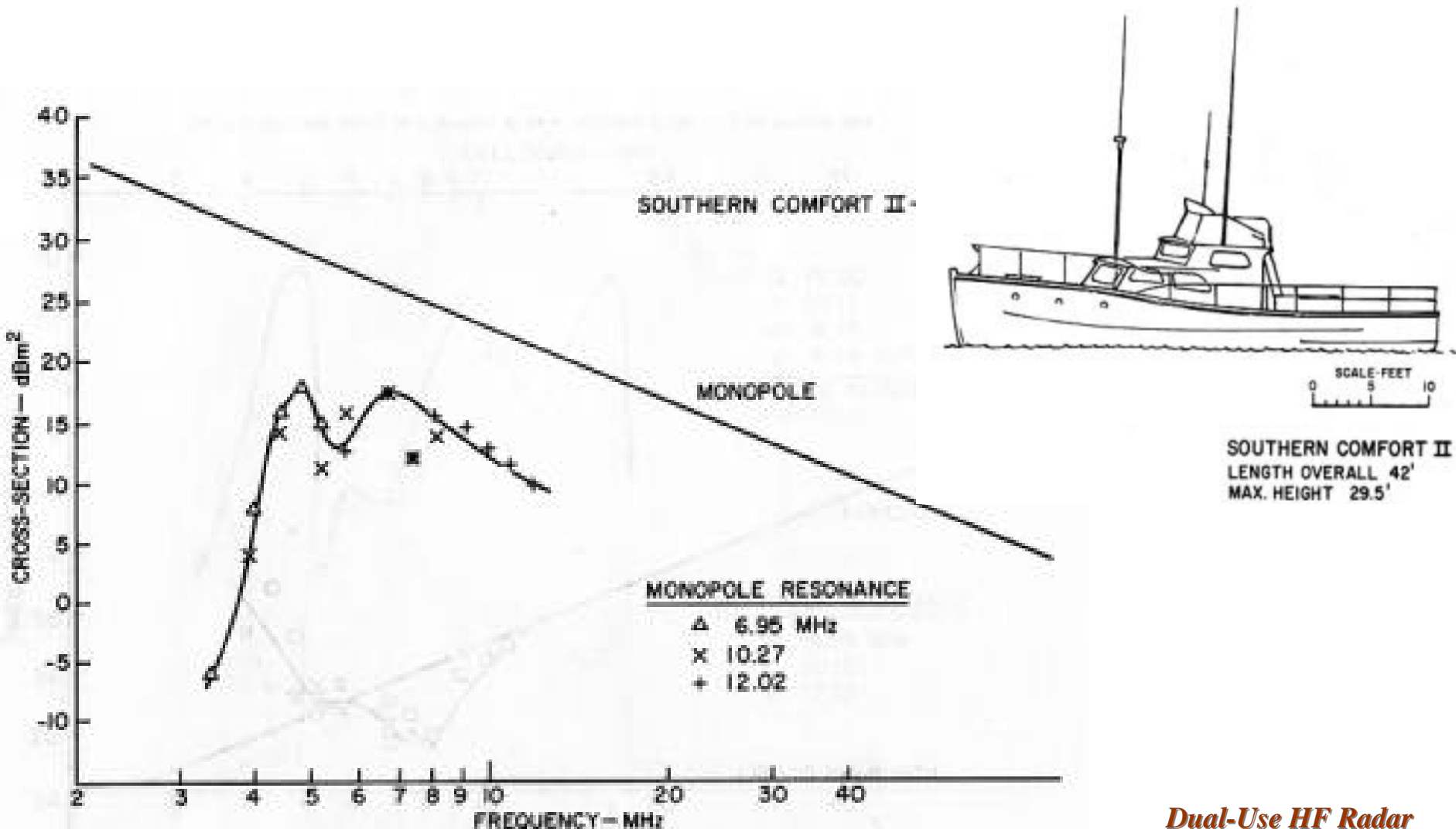


Dual-Use HF Radar

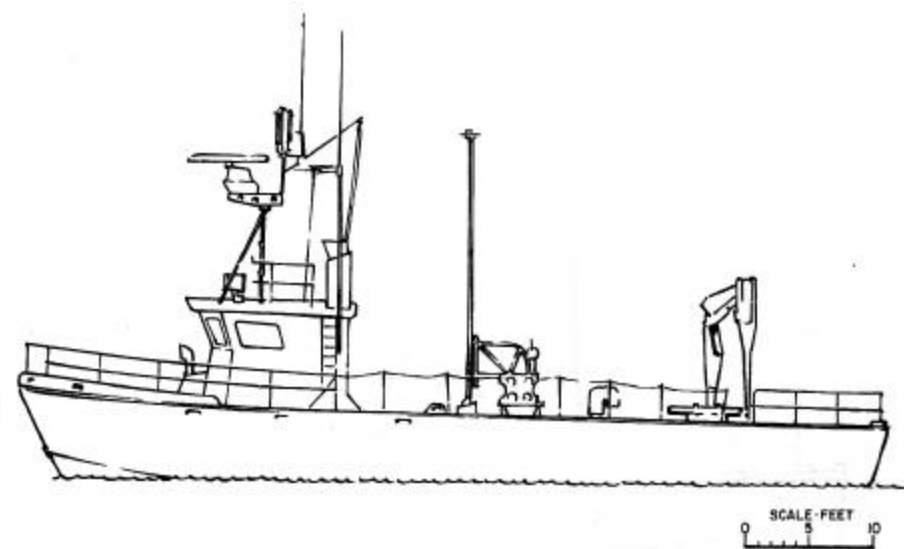
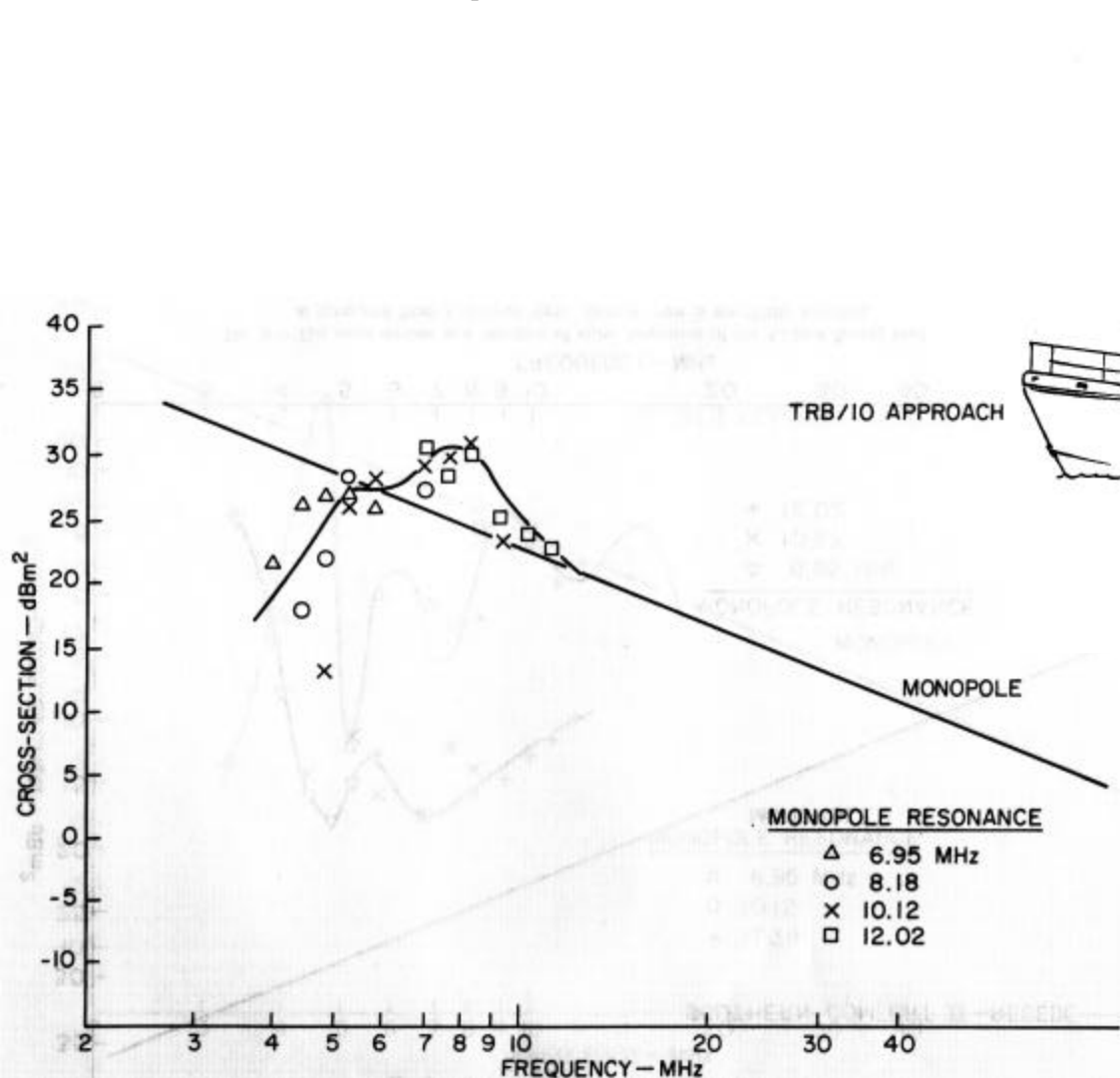
**2nd Small RCS Example**

**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  $1/4 \times \text{Odd Integer}$**
  - **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

