

# Sea Clutter Generation and Target Detection

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# Report Documentation Page

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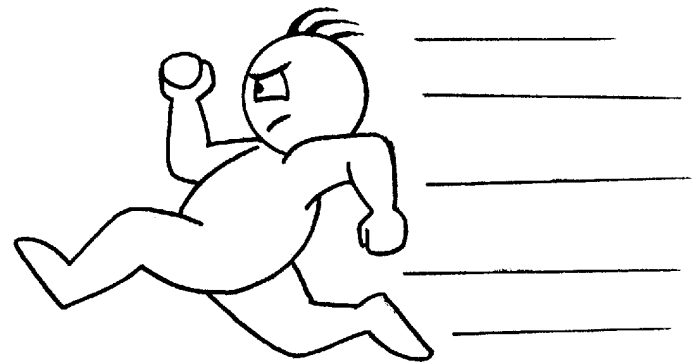
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# Purpose

- Propagation model for the electromagnetic field that accounts for the clutter and metallic objects in the sea

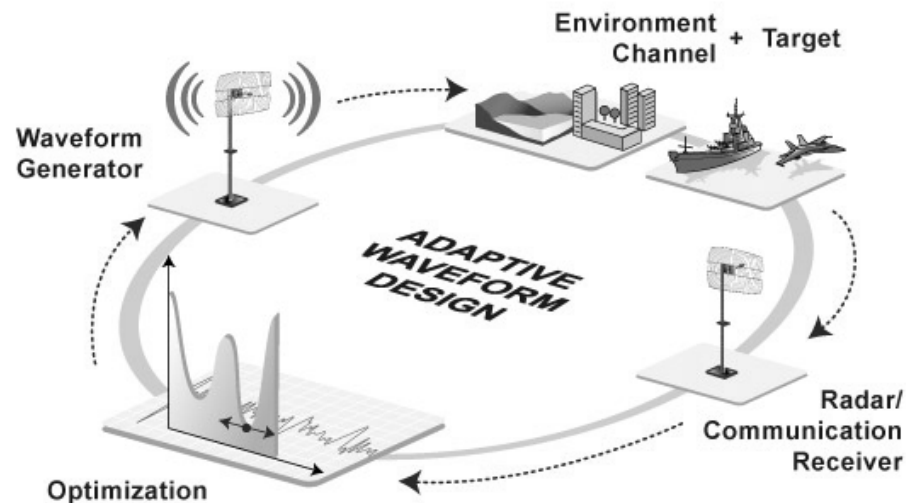


- Computationally fast



# Purpose

- The complete work will include EM propagation models and vector antennas
- Support from U.S. DoD/AFOSR MURI and NRL/DARPA



# Theoretical Background

- Stochastic models:
  - K-compound distribution
  - They take into account various aspects of the scattering process by sea waves

$$p(x) = \frac{2b}{\Gamma(\mathbf{n})} \left( \frac{bx}{2} \right)^{\mathbf{n}} K_{\mathbf{n}-1}(bx)$$

- Difficult to control the single physical quantities for wave generation



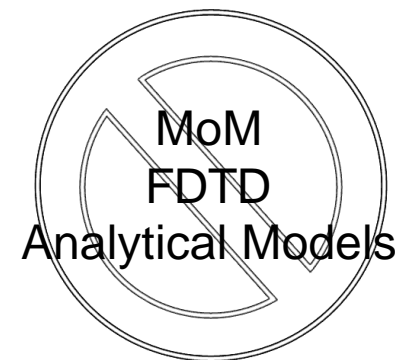
# Theoretical Background

- Fractal deterministic models of the sea surface contain better physical modeling
  - Sea surface as a summation of an arbitrarily large number of wave contributions
  - Based on hydrodynamic models
  - Based on observation of quantities:
    - Wave velocity and direction
    - Wind velocity and direction
    - Multi-scalar description
    - Movement of target and observer



# Contributions

- Geometry: 2D fractal model
- Electromagnetics: ray-launching
- Large scale problem ( $> 5000\lambda$ )



- Ray-tracing: good compromise between accuracy of the solution and computation time



# Contributions

- Better low-grazing incidence description
  - Cylindrical wave-front for radiated power
  - Multiple reflection
  - Scattering factors
  - Shadowing



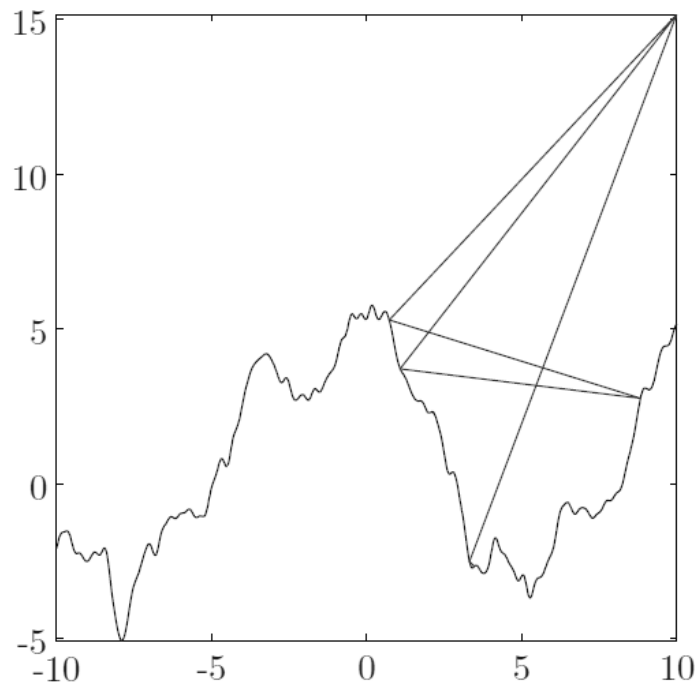
# Model

- Better control over the generation of the environment geometry
  - Wind speed and direction
  - Sea wave direction and height
  - Phase shift among different contributions
  - Evolution in time
  - Position and possible movement of an observer
- Based on hydrodynamics models



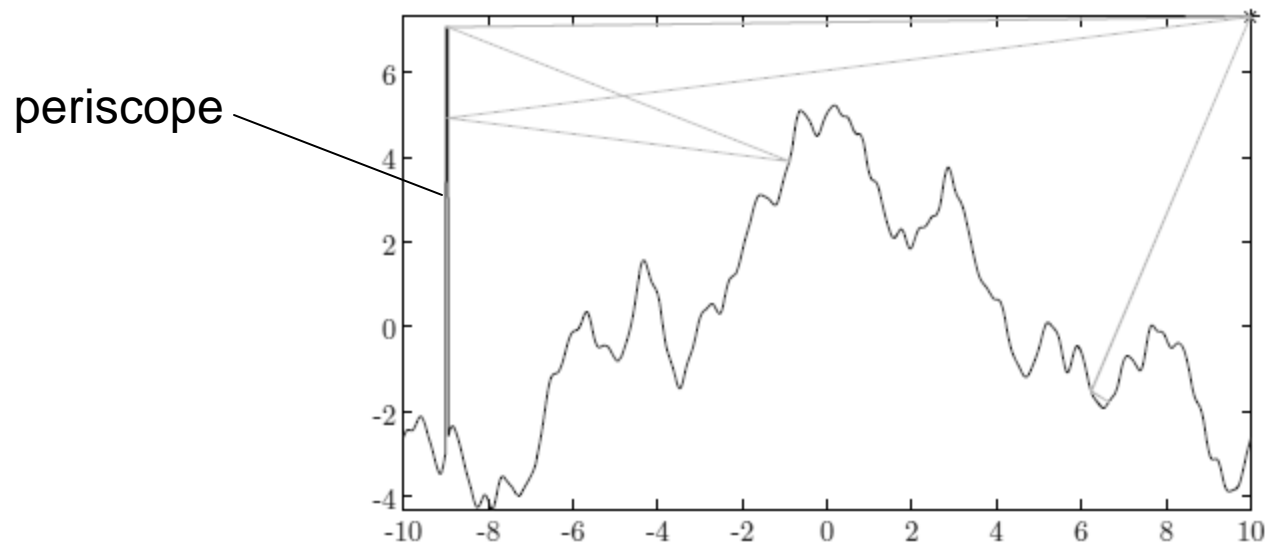
# Assumptions

- Sea modeled as a lossy dielectric
- Multiple reflections over the sea surface



# Assumptions

- Periscope: rectangular thin perfect conductor
- Reflections over the periscope walls and diffraction at the periscope edges



# Assumptions

- We do not consider:
  - Transmission in the sea
  - Double diffractions on the periscope edges
  - Curved-element diffraction:
    - Sea water modeled as a dielectric
    - No whispering-gallery modes
    - High Losses



# Validation in a Simple Case

- Very hard to acquire measured data
- IPIX: sampling rate too coarse for our model
- Military data not accessible
- Simple validation with FDTD method
  - Reduced surface
  - $30\lambda \times 30\lambda$

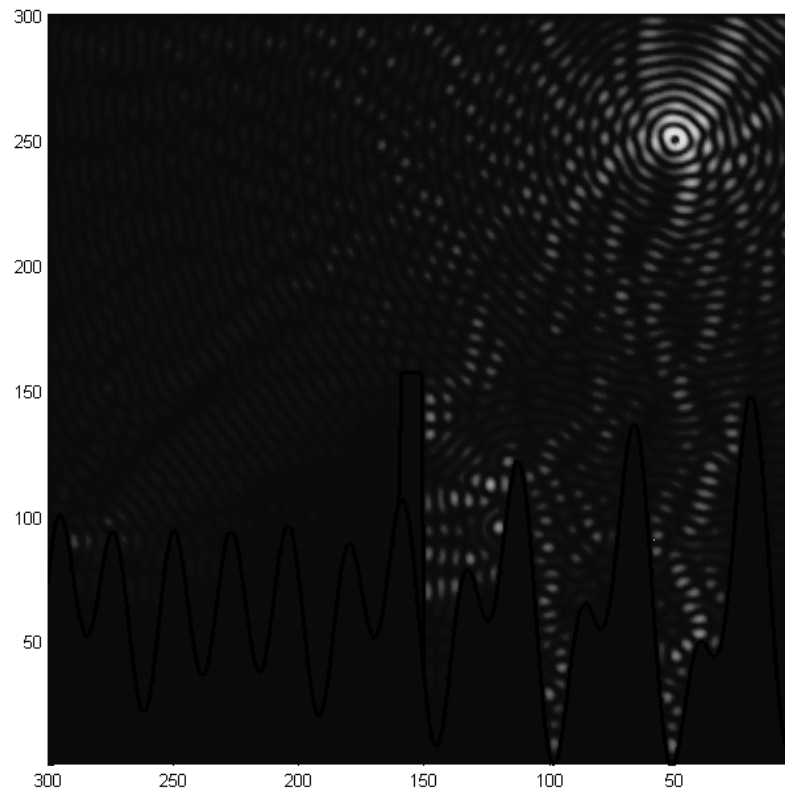


# Validation in a Simple Case

- Differences:
  - Absence of curved-element diffraction
  - Double-diffraction
  - Instantaneous ray propagation vs. FDTD propagation
- FDTD Fourier Transform in test points is max  $\pm 1.5$  dB compared to ray tracing



# Validation in a Simple Case



# Simulations

- TM and TE polarizations
- 2 different sea states, calm and high
- Different periscope heights that match the significant height of the waves
- Roughly 1750 different time instants
- 11 realizations of the sea evolving in time for each case
- Constant radar height when referred to the sea
- Fixed and floating periscope



# Simulations

- The periscope is a tough object to detect
  - Thin object, easier to detect when tall
- The radar is usually located on a much higher location than the top of the periscope
  - No direct reflections are seen from the periscope
- Diffraction from the edges gives a small increment to the total measured field



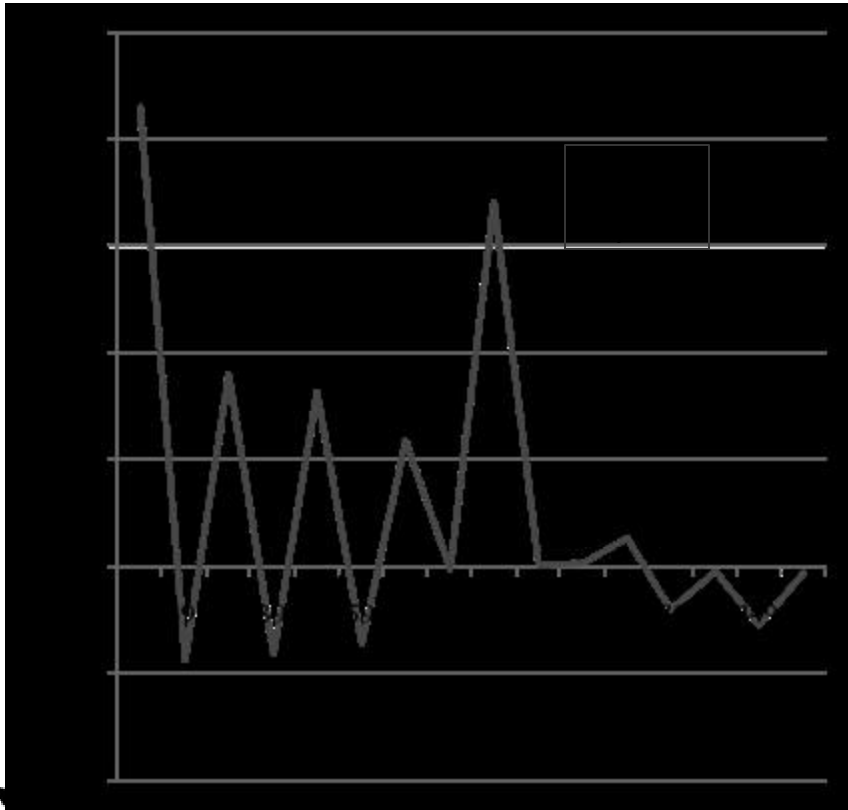
# State

- Standard deviation of wave height: 0.3m
- Height of the periscope: 3m
- Thickness of the periscope: 5cm
- Radar height: 20m
- The sea is at a relatively low state and the periscope oscillates on the sea surface
- The periscope is visible at short distances when the presence of the periscope is undisturbed by the sea
- At larger distances, the periscope is mostly invisible to the radar

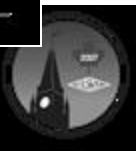
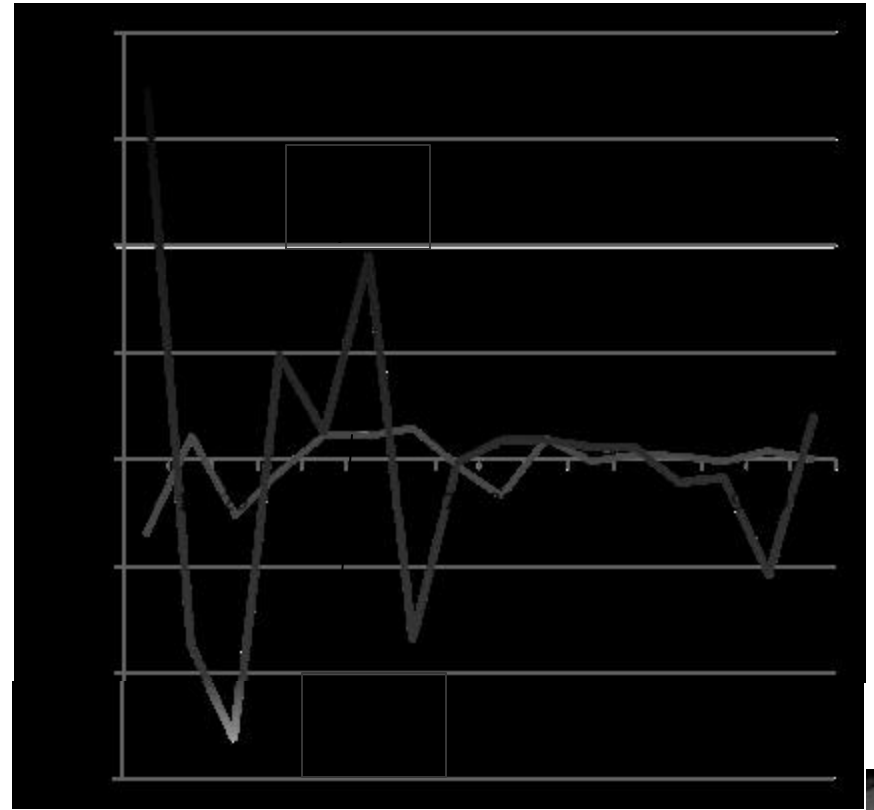


# State

**TE (H) pol.**



**TM (V) pol.**



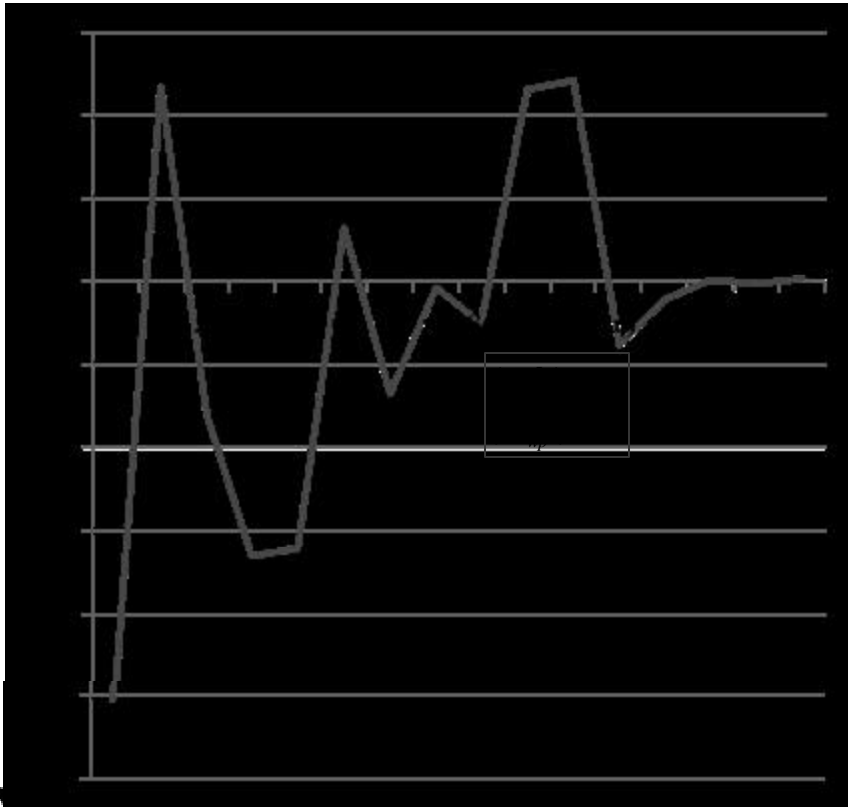
# State

- Standard deviation of wave height: 3m
- Height of the periscope: 10m
- Thickness of the periscope: 5cm
- Radar height: 20m
- The sea state is very high and the periscope oscillates on the sea surface
- Counter-intuitively, oscillations in field ratios are very high
  - The periscope has a direct effect on the return signal

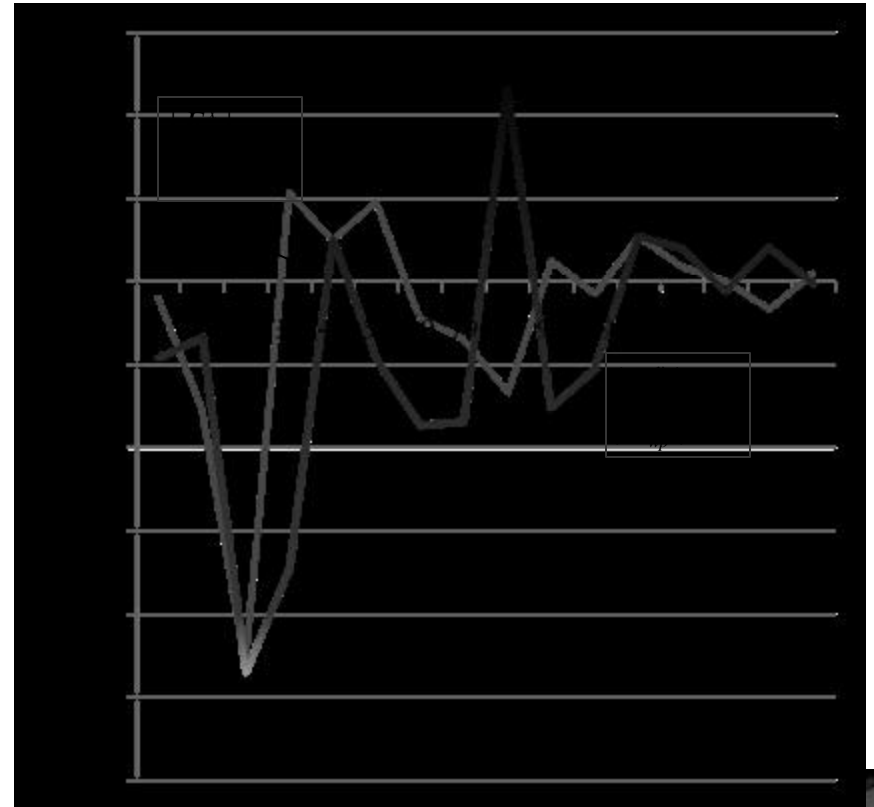


# State

**TE (H) Pol.**



**TM (V) Pol.**



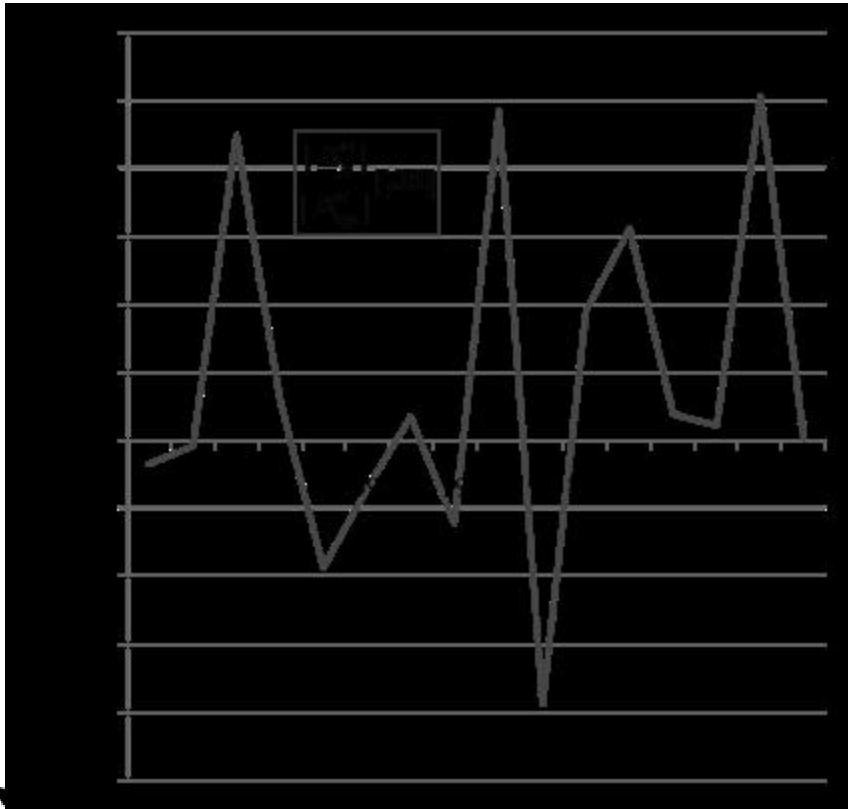
# State

- Standard deviation of wave height: 3m
- Height of the periscope: ~10m
- Thickness of the periscope: 5cm
- Radar height: 20m
- The sea level is very high and the periscope DOES NOT oscillate on the sea surface

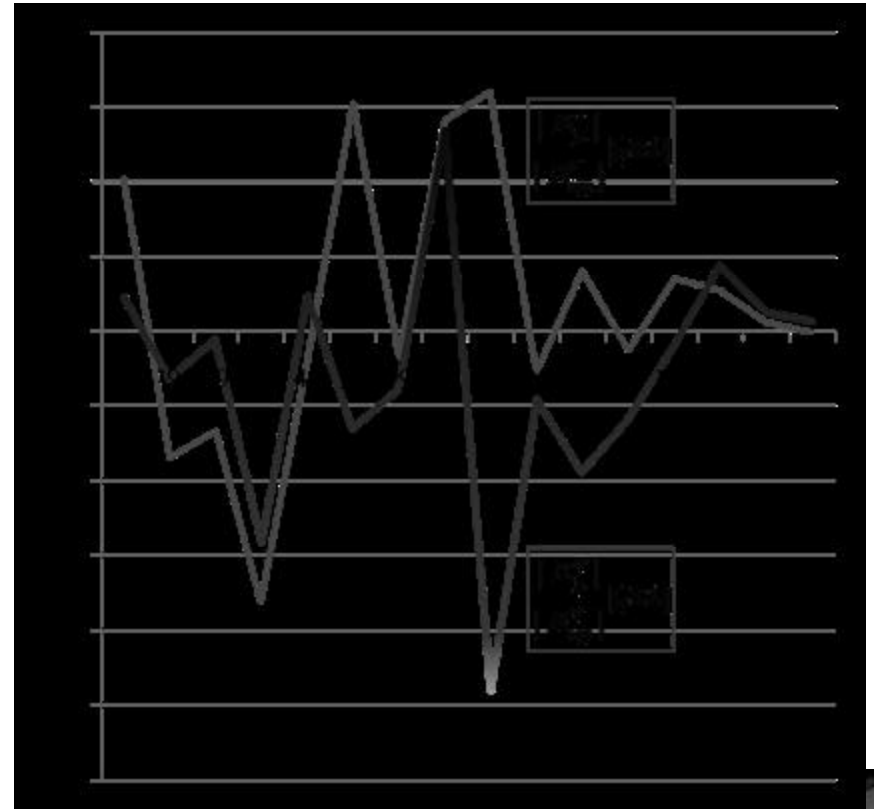


# State

**TE (H) Pol.**



**TM (V) Pol.**



# Challenges in our Results

- Low sea state: the periscope is visible only at short distance
  - Only a few rays bounce back to the radar source
  - The sea is seen as a plate by the radar
- High sea state: the periscope is high
  - A significant amount of rays is bounced back
  - Large deviations in the measured fields



# Future Development

- 3D fractal and ray-tracing model
- Run more simulations at higher distances and different sea states to determine the effect of the sea clutter
- Try to include diffraction by the sea
- Obtain measurement data (?)



Thank you!

Questions?

