SAR Contributions to Ship Detection and Characterization

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Outline

- Ship Detection
  - Robustness, Timeliness, Development Costs, K-distribution
- Detection Threshold
- Wakes from Surface Ships and Internal Wave Wakes
- Space-Based AIS Performance

Ship Detection

- Clutter Statistics
  - Remove the ship from a clutter cell
    - Cut out the ship
    - Handle statistically
- Estimate Clutter Parameters
  - Choose a statistic
    - Moments (simple)
    - Logarithms

Threshold Calculation

- Density by steepest descents
  - J.K.E. Tunaley, “K-Distribution Algorithm”, Sept. 2010 (www.london-research-and-development.com/K-Distribution Algorithm.Version2.pdf)
  - Avoid Bessel functions
- Distribution/Threshold
  - Suggest using expansion with polynomial correction in shape parameter and number of looks

Probability Density Comparison

THRESHOLDS OF DETECTION

		$L = 1$		$L = 4$	
PFA	ν	Accurate	Approx.	Accurate	Approx.
10^{-9}	0.5	214.7	214.8	91.59	91.62
10^{-9}	5.0	47.49	47.50	18.796	18.800
10^{-9}	50.0	24.24	24.24	8.841	8.842
10^{-6}	0.5	95.43	95.55	46.40	46.43
10^{-6}	5.0	25.69	25.70	11.263	11.267
10^{-6}	50.0	15.337	15.338	6.128	6.128

Parameter Estimation

- Fisher information
  - J.K.E. Tunaley, “Ship Detection”, December 2010, (www.london-research-and-development.com/Ship Detection.Version3.pdf)
- Mean can be estimated reasonably accurately
- In spiky clutter shape parameter tends to require 10,000 resolution cells using moments

Detection Thresholds

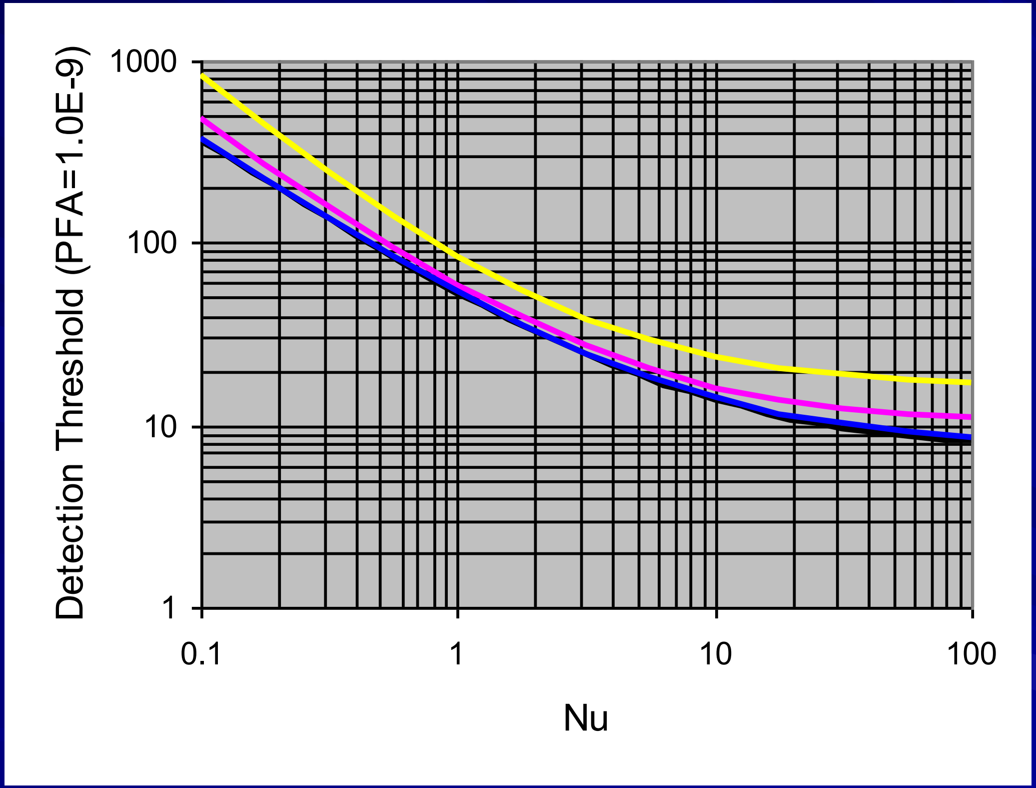
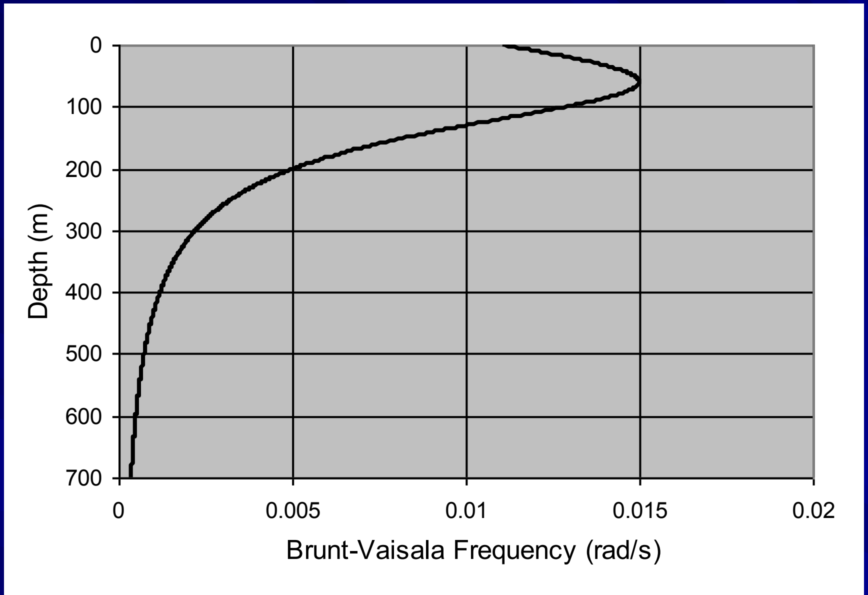


Fig. 8. Detection thresholds for PFA = 10^{-9}, L = 4 and N = 100 (—), N = 1000 (—), N = 10,000 (—) and $N = \infty$ (—).

Ship Image Information

- Position
- Length (may be poor estimate)
  - Heavy ship motion in high sea states
- Velocity (from wake displacement)
  - Ocean going ships usually create visible wake
    - D.M. Roy and J.K.E. Tunaley, "Visibility of the Turbulent Wake", March 2010 (www.london-research-and-development.com/Visibility of Turbulent Wakes.Ver2a.pdf)
  - Wake characteristics depend on propulsion system; screw number and sense of rotation

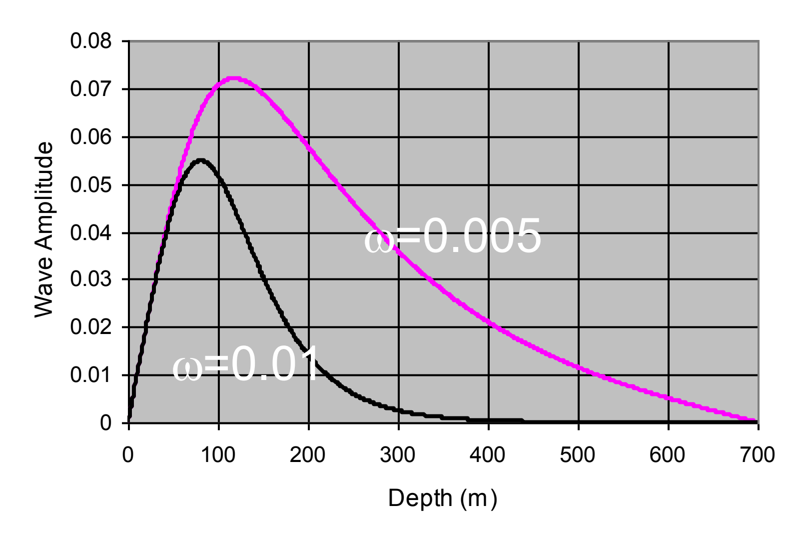
Internal Wave Wake

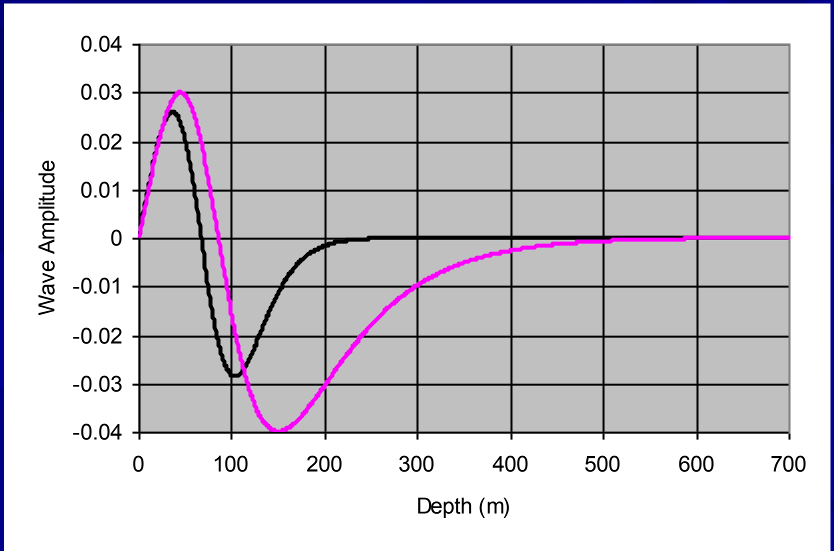


Typical Brunt-Vaisala Vertical Profile.

$$\frac{d^2Q}{dz^2} + k^2\left(\frac{N^2}{\omega^2} - 1\right)Q = 0$$

Zeroth and First Modes

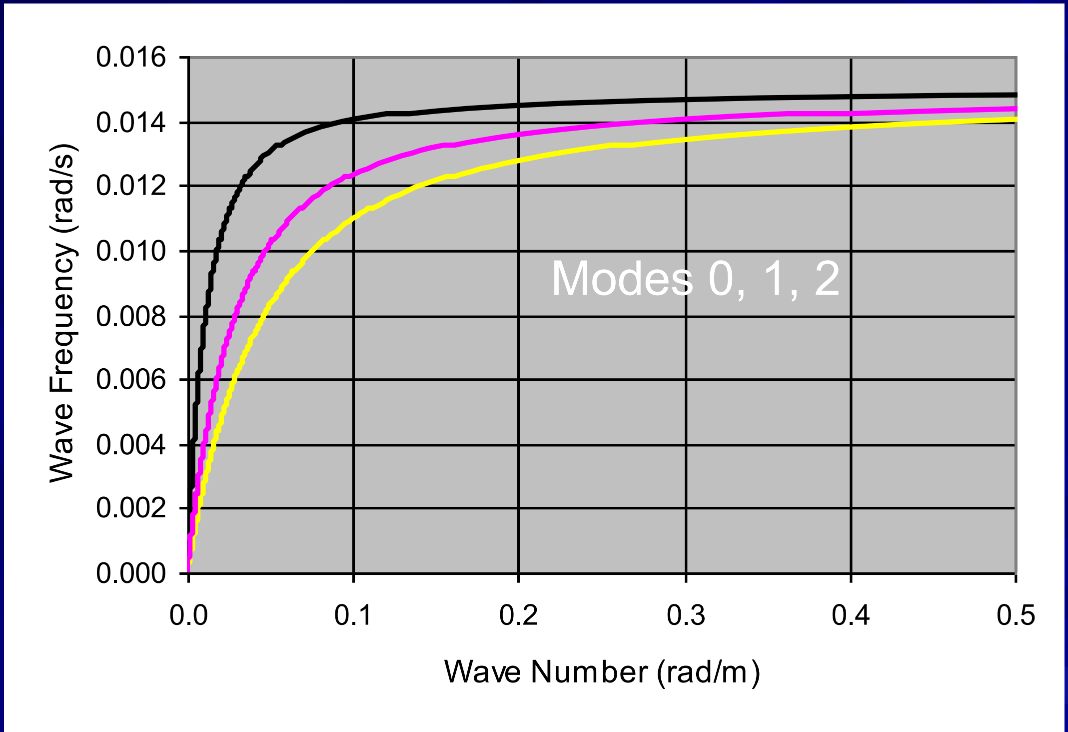




Sinuous Modes

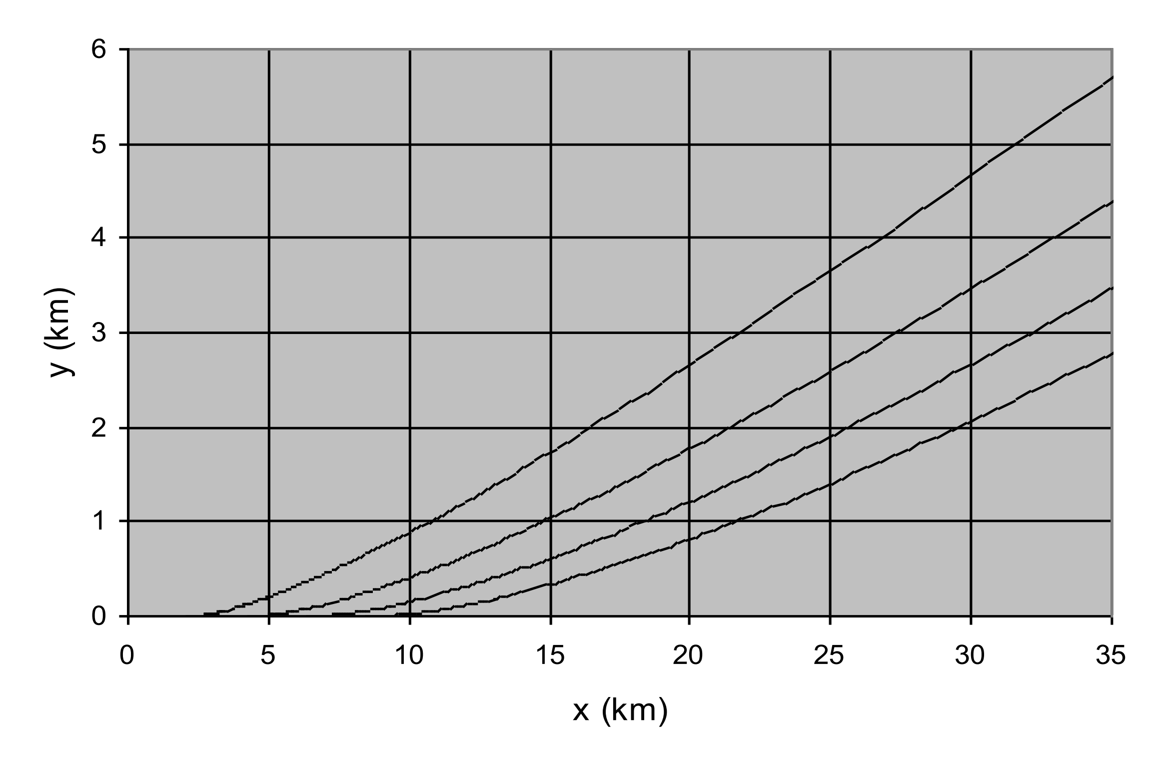
Varicose Modes

Frequency-Wave Number



Determines phase and group velocities

Crest Pattern



Zeroth mode crest pattern for a source moving horizontally at 5 m/s in the above profile.

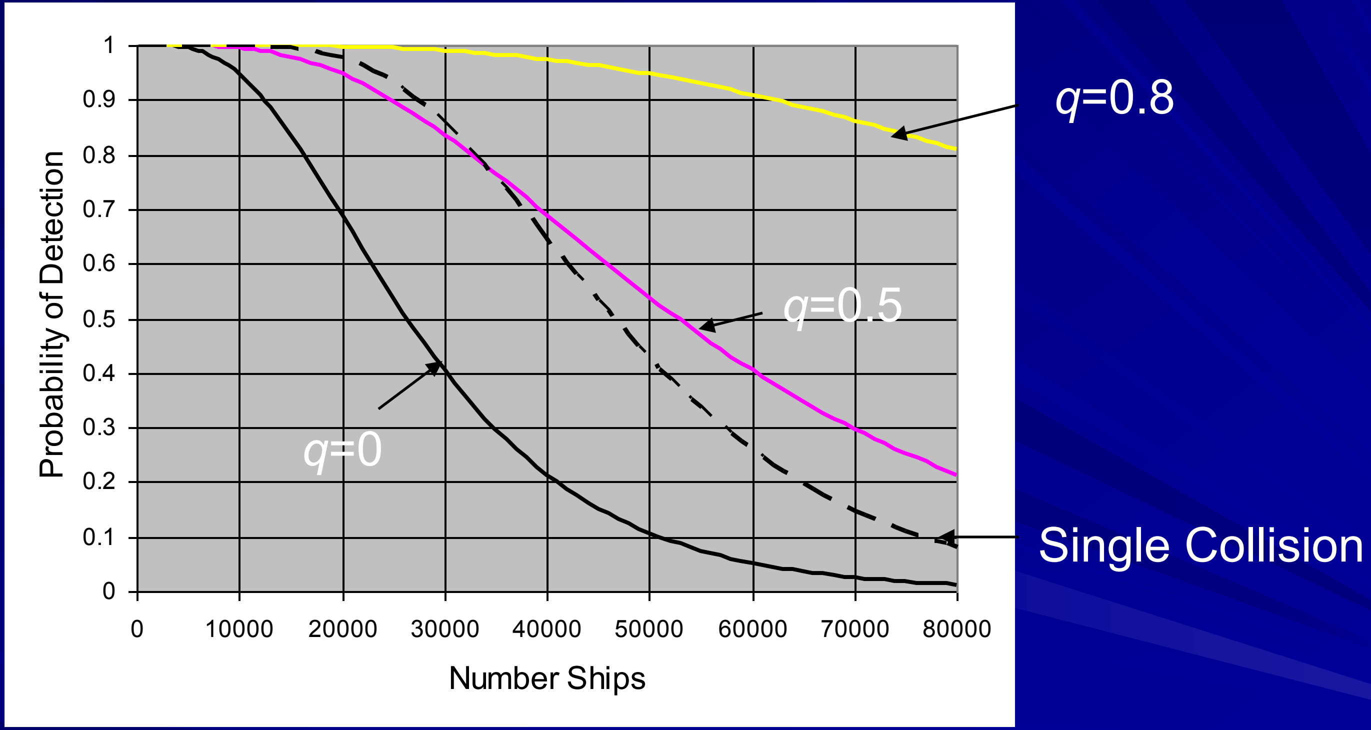
Internal Wave Wake Conclusions

- From Crest Pattern
  - Ship velocity from angle of wake (if strength of layer known)
  - Maximum B-V frequency
- From Amplitudes (Tentative)
  - Layer thickness/Position of vessel in layer
  - Vessel size

Space-Based AIS Performance

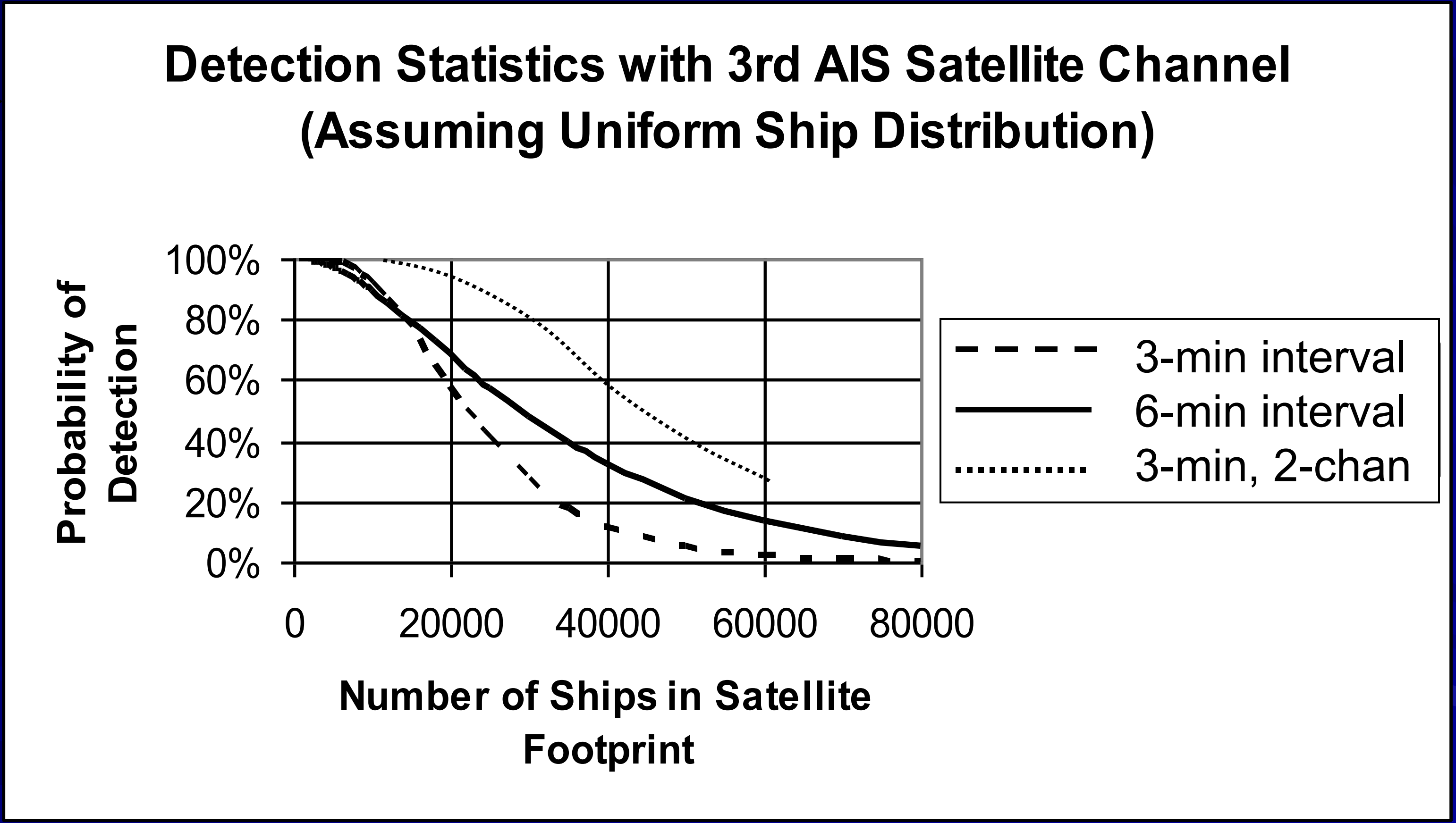
- Problems
  - Signal Collisions and Range Overlap
  - Message 27 solution with AIS channels 3 & 4 (ITU-R M.2169)
- FFI Theoretical Model
  - Based on signal corruption with one or more signal collisions
- Extension to multiple collisions
  - (www.london-research-and-development.com/Space-Based-AIS-Performance.pdf)

Multiple Collision Model

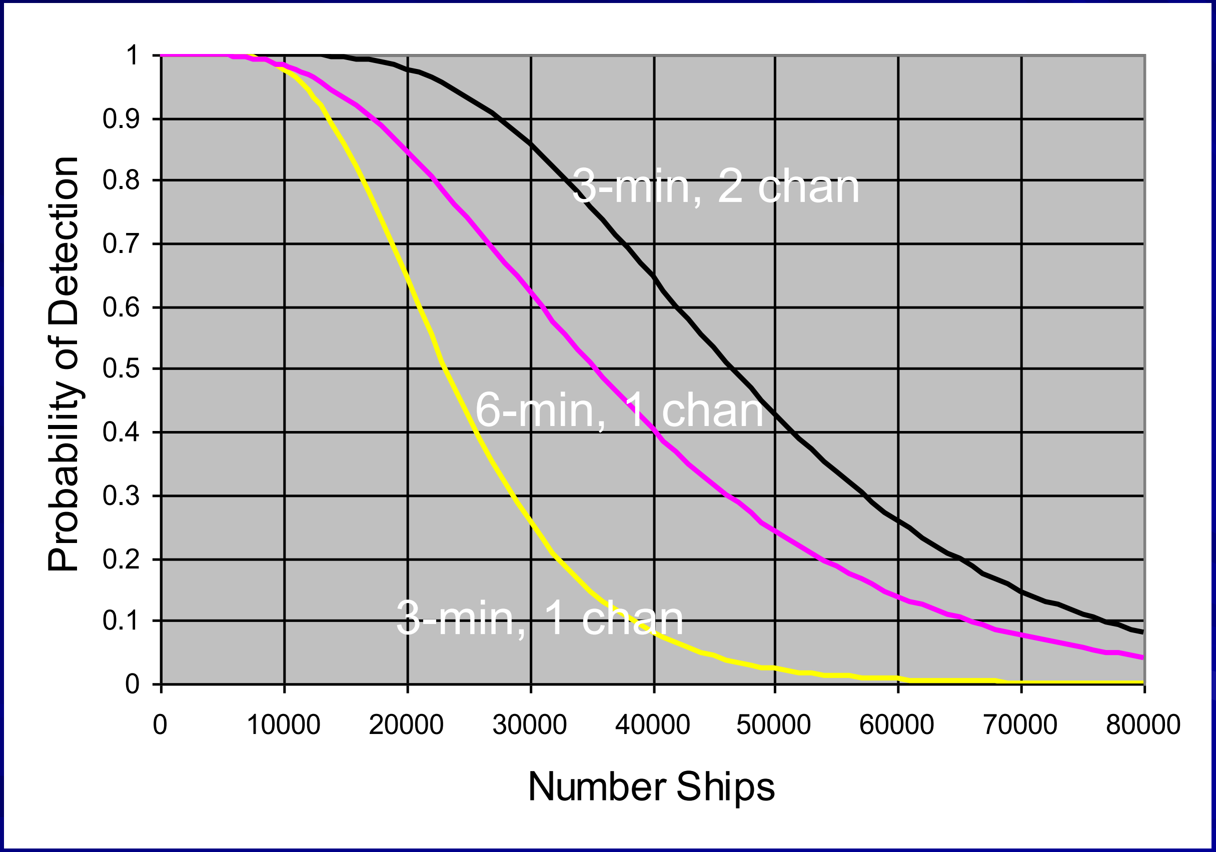


q is the probability that a collision can be tolerated

ITU-R.M2169


Detection Statistics with 3rd AIS Satellite Channel
(Assuming Uniform Ship Distribution)
Probability of Detection
100%
80%
60%
40%
20%
0%
0
20000
40000
60000
80000
Number of Ships in Satellite Footprint
3-min interval
6-min interval
3-min, 2-chan

Theoretical Performance



Space-Based AIS Conclusions

- Model 1 is based on the receiving system resolving a fixed number of collisions
- Model 2 is based on the system resolving an average number of collisions
- Model 1 more or less consistent with simulations in ITU-R M.2169

END

Thank You All!