Uncertainty in Acoustic Mine Detection due to Environmental Variability

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Sponsored by the Naval Oceanographic Office

Purpose

- Determine the impact of bottom type and wind variations on bottom moored mine detection

- Determine the significance of transducer depth on bottom moored mine detection

Navy Relevance

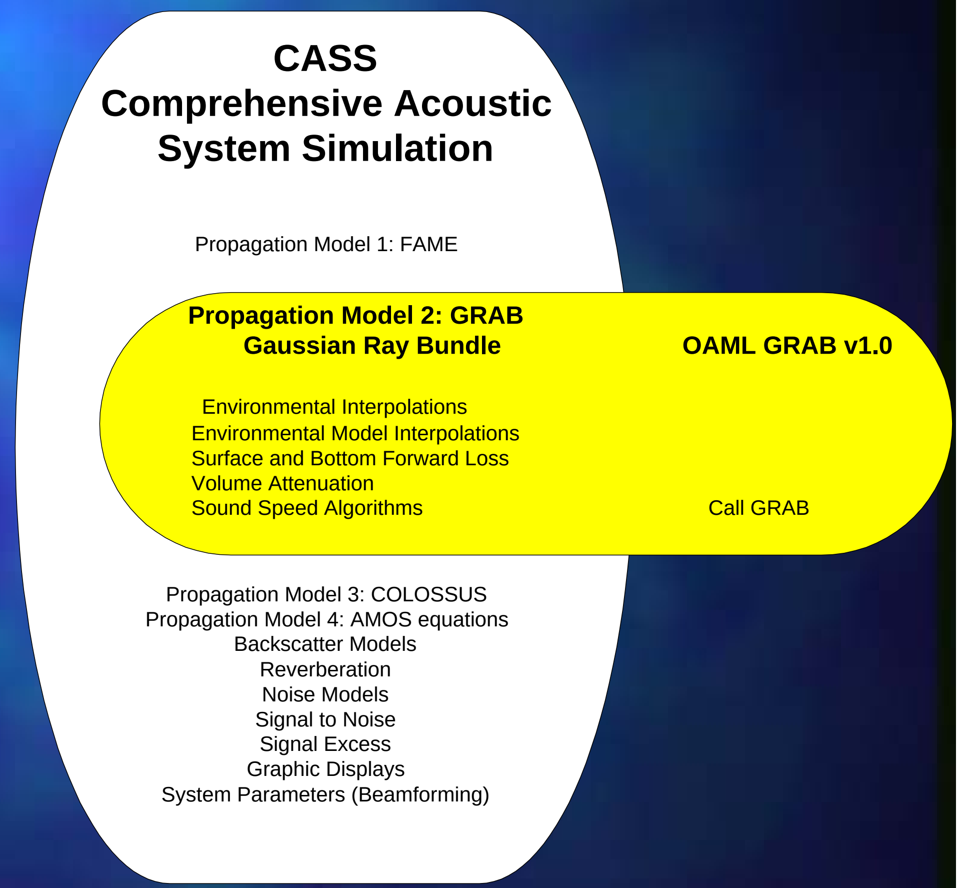
- Littoral engagement
- Mine warfare
- Diesel submarines
- Unmanned Undersea Vehicles (UUVs)

CASS/GRAB

- Comprehensive Acoustic Simulation System (CASS)
- Gaussian Ray Bundle (GRAB) Eigenray model
- Navy standard model for active and passive range dependent acoustic propagation, reverberation and signal excess
- Frequency range 600Hz to 100 kHz

CASS/GRAB Model Description

- The CASS model is the range dependent improvement of the Generic Sonar Model (GSM). CASS performs signal excess calculations.
- The GRAB model is a subset of the CASS model and its main function is to compute eigenrays and propagation loss as inputs in the CASS signal excess calculations.



Comprehensive Acoustic Simulation System/Guassian Ray Bundle (CASS/GRAB)

- In the GRAB model, the travel time, source angle, target angle, and phase of the ray bundles are equal to those values for the classic ray path.
- The main difference between the GRAB model and a classic ray path is that the amplitude of the Gaussian ray bundles is global, affecting all depths to some degree whereas classic ray path amplitudes are local. GRAB calculates amplitude globally by distributing the amplitudes according to the Gaussian equation

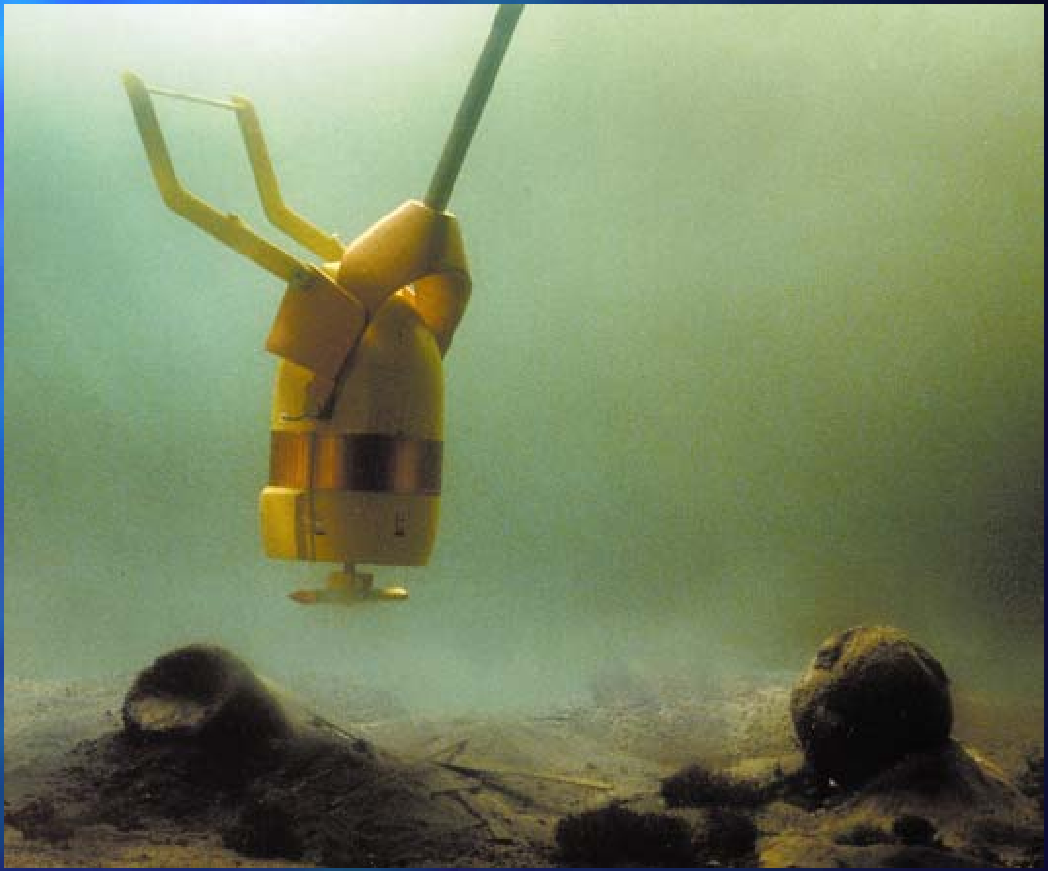
$$\Psi_{\nu} = \frac{\beta_{\nu,0}\Gamma_{\nu}^{2}}{\sqrt{2\pi}\,\sigma_{\nu}\, p_{r,\nu}\, r}\exp\left\{-0.5\left[(z - z_{\nu}) / \sigma_{\nu}\right]^{2}\right\}$$

Mine Hunting Sonar

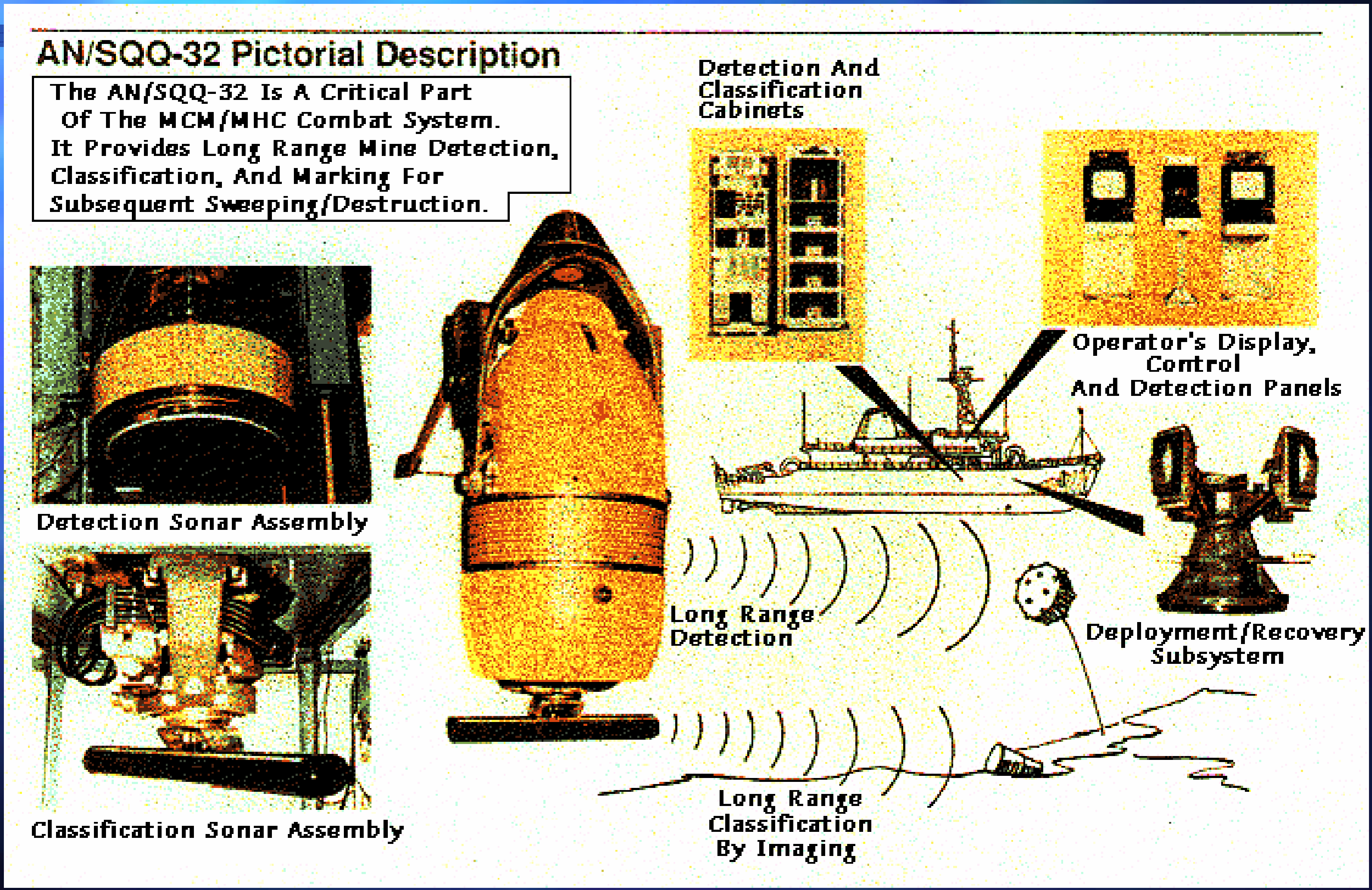
- Generic VHF forward looking
- CASS/GRAB input file for MIW with signal excess output
- Generic bottom moored mine

AN/SQQ-32 Mine Hunting Sonar System

- The CASS/GRAB Acoustic model input file used in this study simulates a VHF forward looking sonar, similar to the Acoustic Performance of the AN/SQQ-32.
- The AN/SQQ-32 is the key mine hunting component of the U.S. Navy's Mine Hunting and Countermeasure ships.



Detection Sonar and Classification Sonar Assembly



Input Parameters

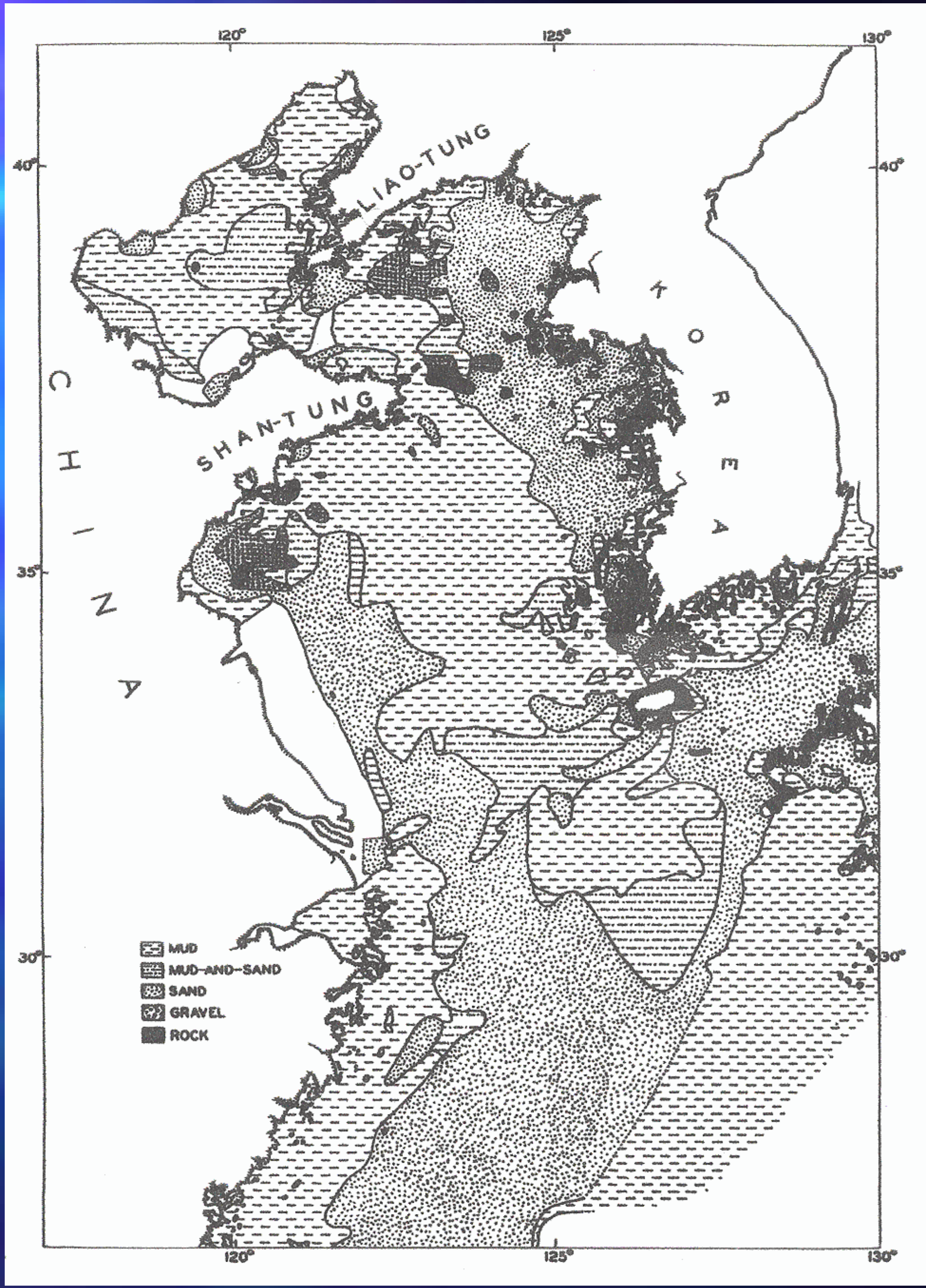
- Bottom depth
- Target depth
- Transducer depth
- Wind speed
- Bottom type grain size index
- Frequency min/max
- Self noise
- Source level
- Pulse length
- Target strength/depth
- Transmitter tilt angle
- Surface scattering /reflection model
- Bottom scattering /reflection model

Bottom Type Geoacoustic Properties

Bottom Composition	Grain Size	Long Name	Density	Sound Speed Ratio	Wave Number Ratio	Volume Parameter ***	Spectral Exponent ***	Spectral Parameter ***
BOULDER	-9.0	ROUGH ROCK	2.500	2.5000	0.01374	0.0020	3.25	0.206930
ROCK	-7.0	ROCK	2.500	2.5000	0.01374	0.0020	3.25	0.018620
	-3.0	COBBLE	2.500	1.8000	0.01374	0.0020	3.25	0.016000
GRAVEL	-3.0	GRAVEL	2.500	1.8000	0.01374	0.0020	3.25	0.016000
	-3.0	PEBBLE	2.500	1.8000	0.01374	0.0020	3.25	0.016000
	-1.0	SANDY GRAVEL	2.492	1.3370	0.01705	0.0020	3.25	0.012937
	-0.5	VERY COARSE SAND	2.401	1.3067	0.01667	0.0020	3.25	0.010573
	0.0	MUDDY SANDY GRAVEL	2.314	1.2778	0.01630	0.0020	3.25	0.008602
	0.5	COARSE SAND	2.231	1.2503	0.01638	0.0020	3.25	0.006957
	0.5	GRAVELLY SAND	2.231	1.2503	0.01638	0.0020	3.25	0.006957
	1.0	GRAVELLY MUDDY SAND	2.151	1.2241	0.01645	0.0020	3.25	0.005587
SAND	1.5	SAND	1.845	1.1782	0.01624	0.0020	3.25	0.004446
	1.5	MEDIUM SAND	1.845	1.1782	0.01624	0.0020	3.25	0.004446
	2.0	MUDDY GRAVEL	1.615	1.1396	0.01610	0.0020	3.25	0.003498
	2.5	FINE SAND	1.451	1.1073	0.01602	0.0020	3.25	0.002715
	2.5	SILTY SAND	1.451	1.1073	0.01602	0.0020	3.25	0.002715
	3.0	MUDDY SAND	1.339	1.0800	0.01728	0.0020	3.25	0.002070
	3.5	VERY FINE SAND	1.268	1.0568	0.01875	0.0020	3.25	0.001544
	4.0	CLAYEY SAND	1.224	1.0364	0.02019	0.0020	3.25	0.001119
	4.5	COARSE SILT	1.195	1.0179	0.02158	0.0020	3.25	0.000781
	5.0	SANDY SILT	1.169	0.9999	0.01261	0.0020	3.25	0.000518
	5.5	MEDIUM SILT	1.149	0.9885	0.00676	0.0010	3.25	0.000518
	5.5	SAND-SILT-CLAY	1.149	0.9885	0.00676	0.0010	3.25	0.000518
SILT	6.0	SILT	1.149	0.9873	0.00386	0.0010	3.25	0.000518
	6.0	SANDY MUD	1.149	0.9873	0.00386	0.0010	3.25	0.000518
	6.5	FINE SILT	1.148	0.9861	0.00306	0.0010	3.25	0.000518
	6.5	CLAYEY SILT	1.148	0.9861	0.00306	0.0010	3.25	0.000518
MUD	7.0	SANDY CLAY	1.147	0.9849	0.00242	0.0010	3.25	0.000518
	7.5	VERY FINE SILT	1.147	0.9837	0.00194	0.0010	3.25	0.000518
	8.0	SILTY CLAY	1.146	0.9824	0.00163	0.0010	3.25	0.000518
CLAY	9.0	CLAY	1.145	0.9800	0.00148	0.0010	3.25	0.000518
	10.0		1.145	0.9800	0.00148	0.0010	3.25	0.000518

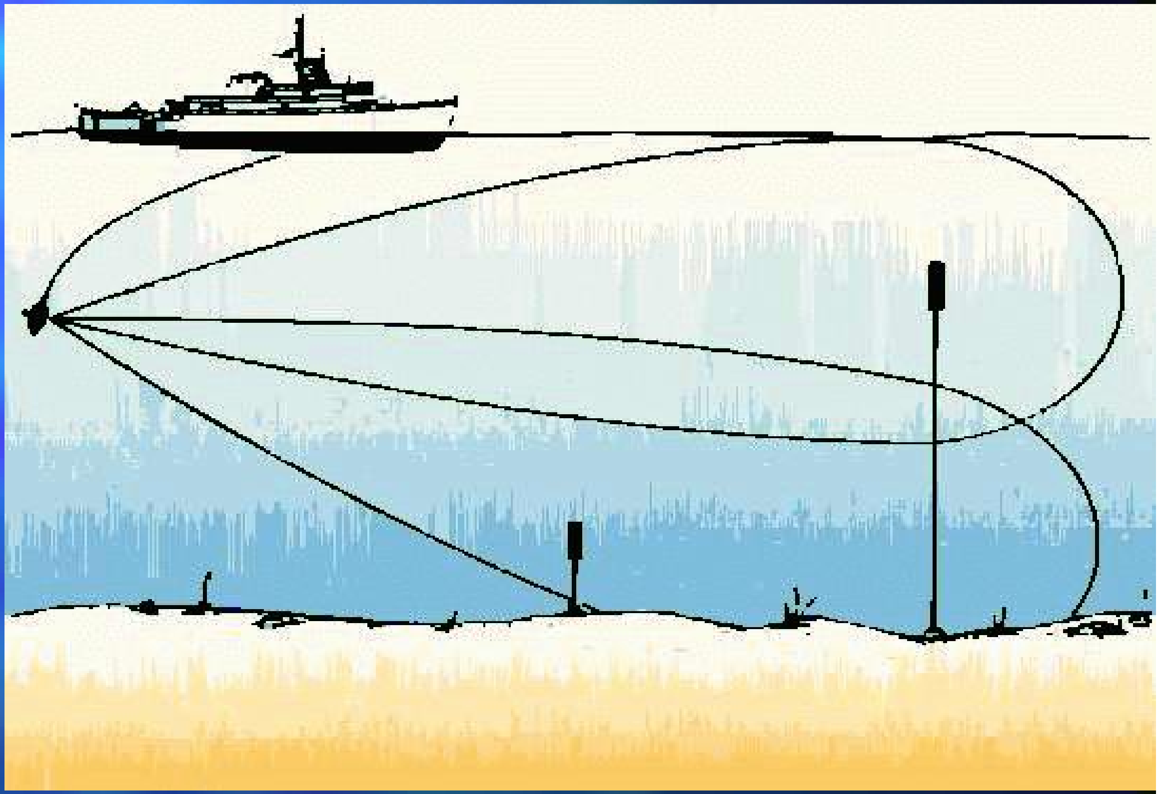
Yellow Sea Bottom Sediment Chart

- Bottom Sediment types can vary greatly over a small area
  1. Mud
  2. Sand
  3. Gravel
  4. Rock



AN/SQQ-32 Employment

- Variable depth high frequency sonar system
  - Sonar can be place at various positions in the water column to optimize the detection of either moored or bottom mines.



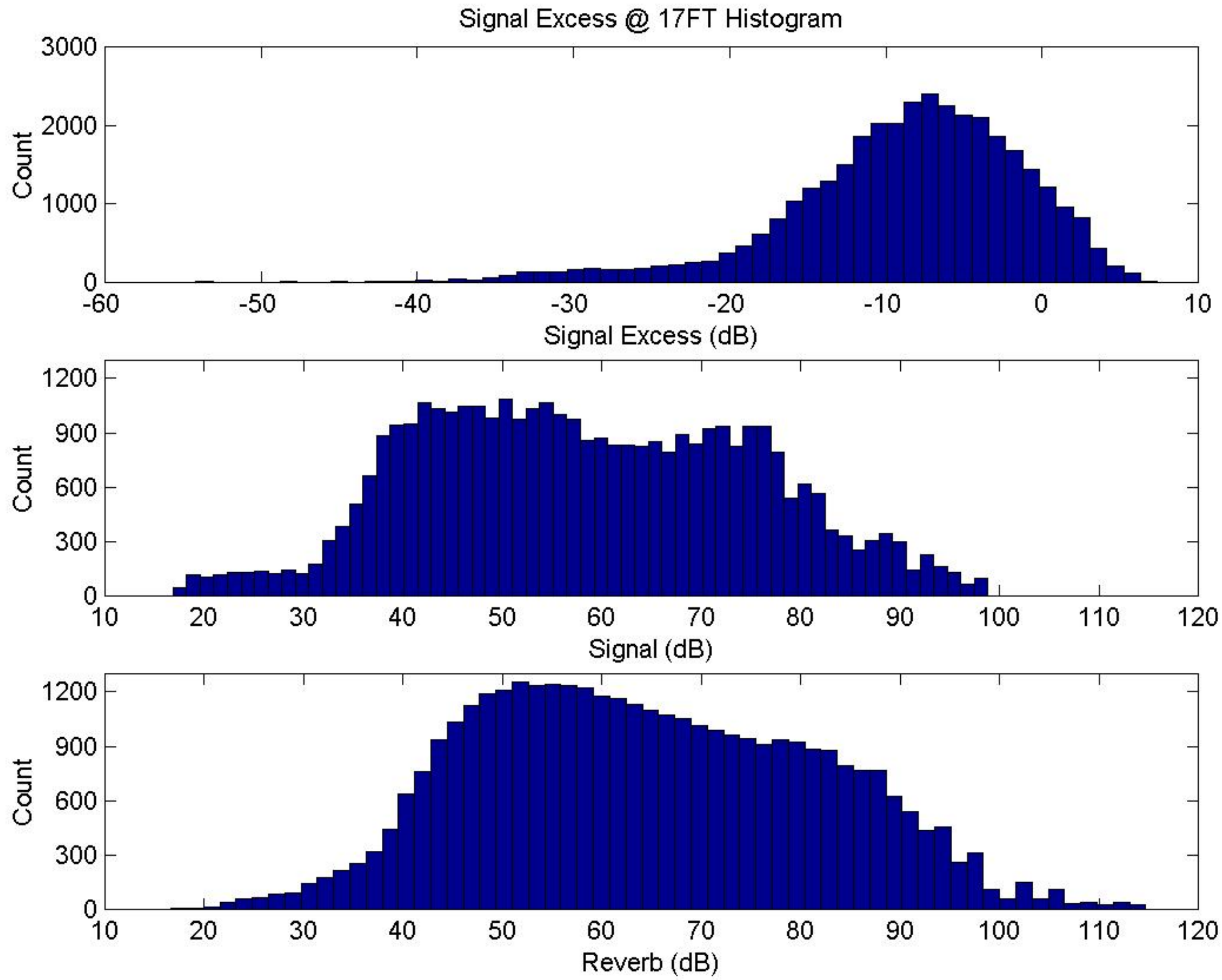
Two Depths of Transducer

- Shallow Transducer: 17 ft (5.18 m)
- Deep Transducer (25 m)
- Water depth: 30 m

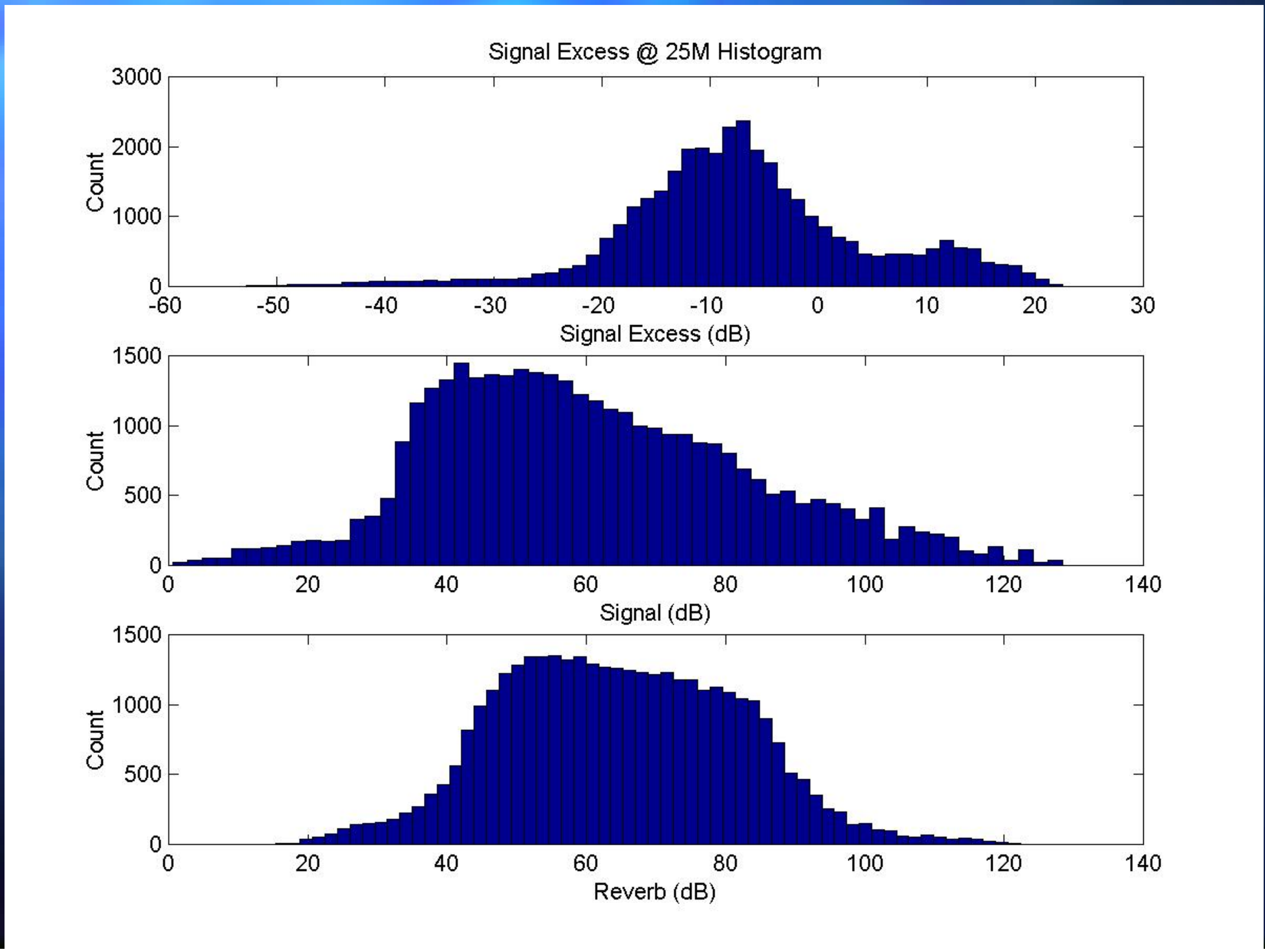
Uncertainty

- Tilt angles + 4^0 to – 12^0
- Wind 5 – 25 knots
- Coarse sand to silt bottoms

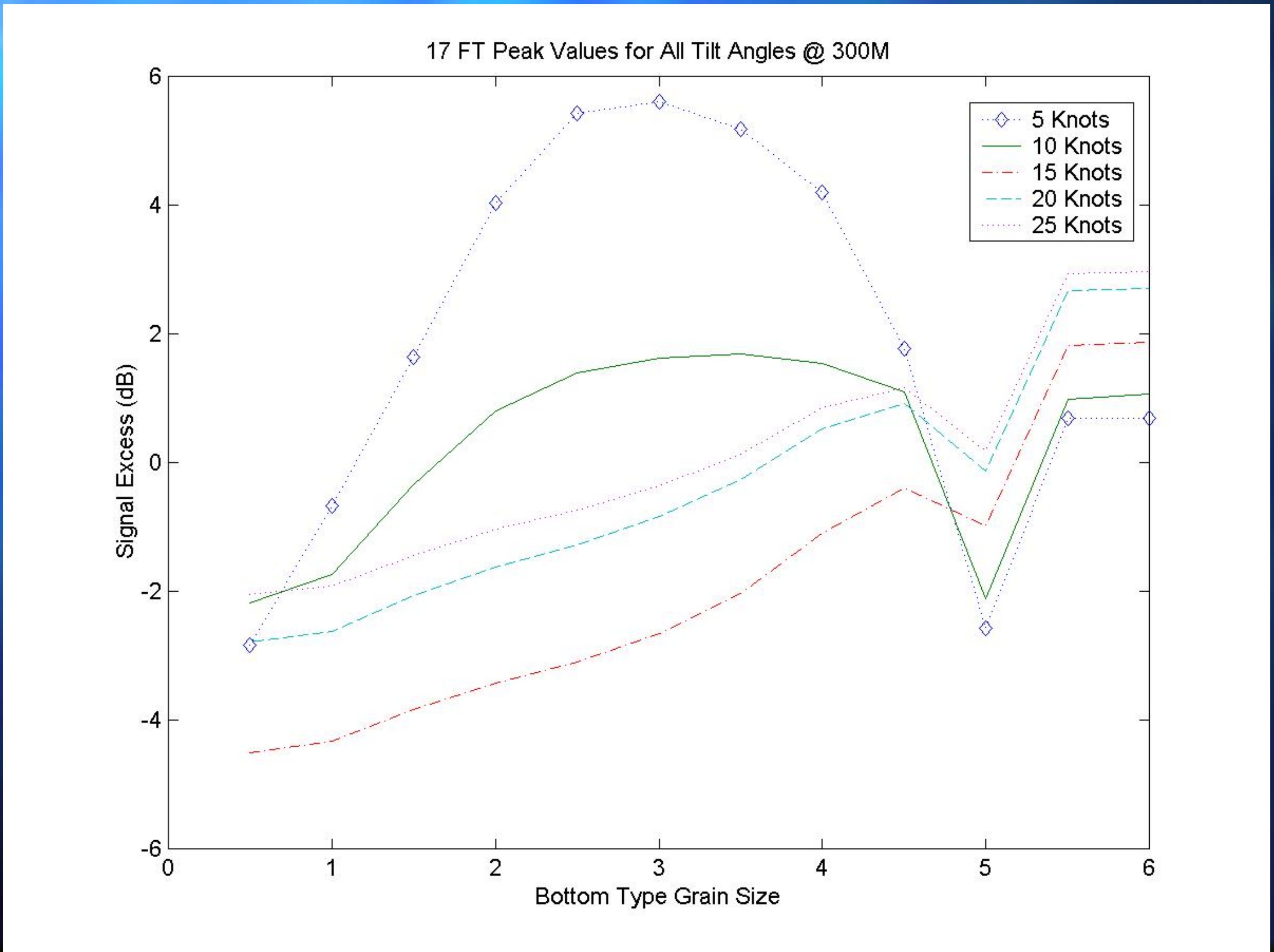
Shallow Transducer



Deep Transducer



Acoustic Uncertainty Due to Wind and Bottom Type Uncertainty for Shallow Transducer (Range = 300 m)



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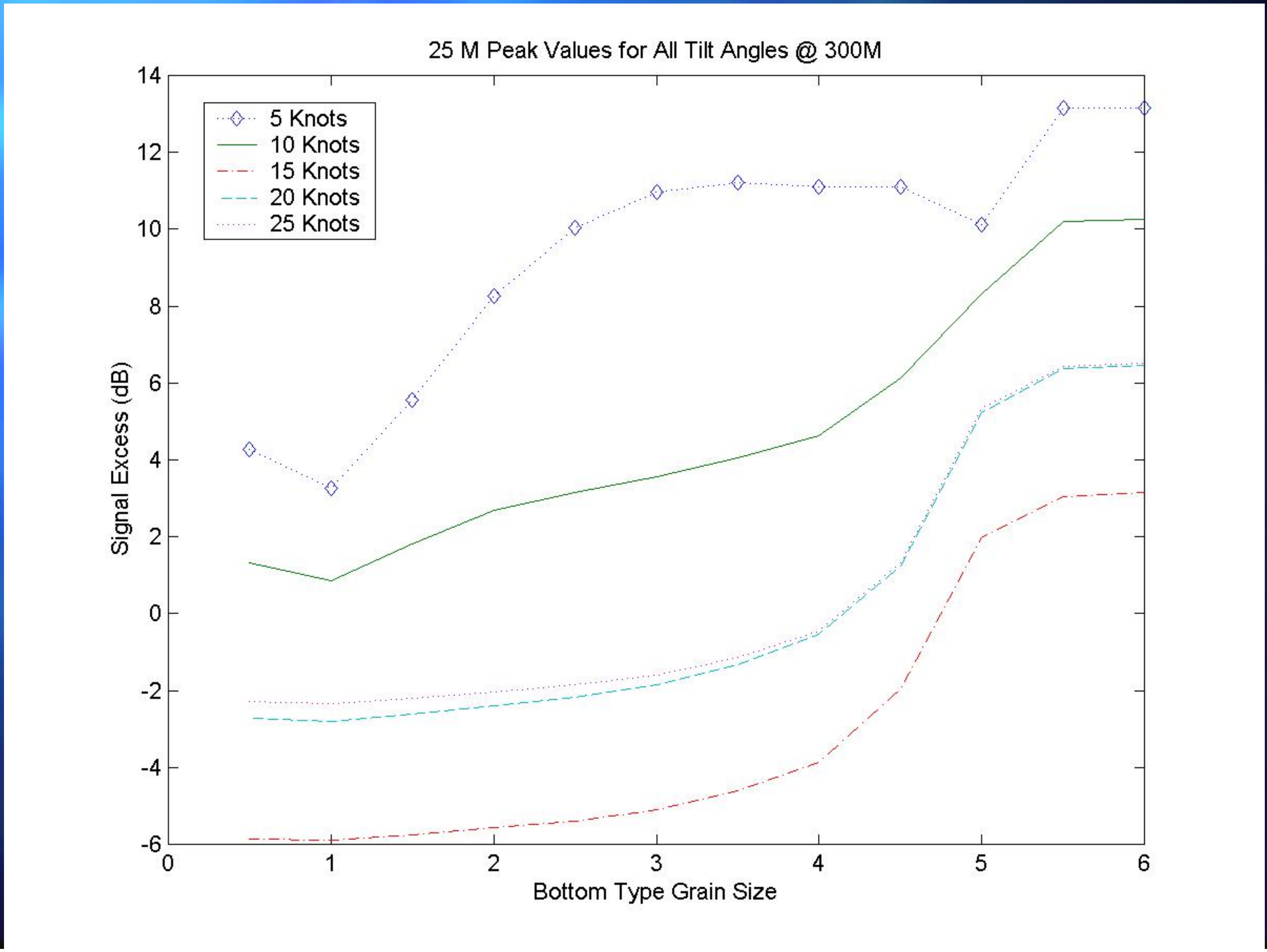
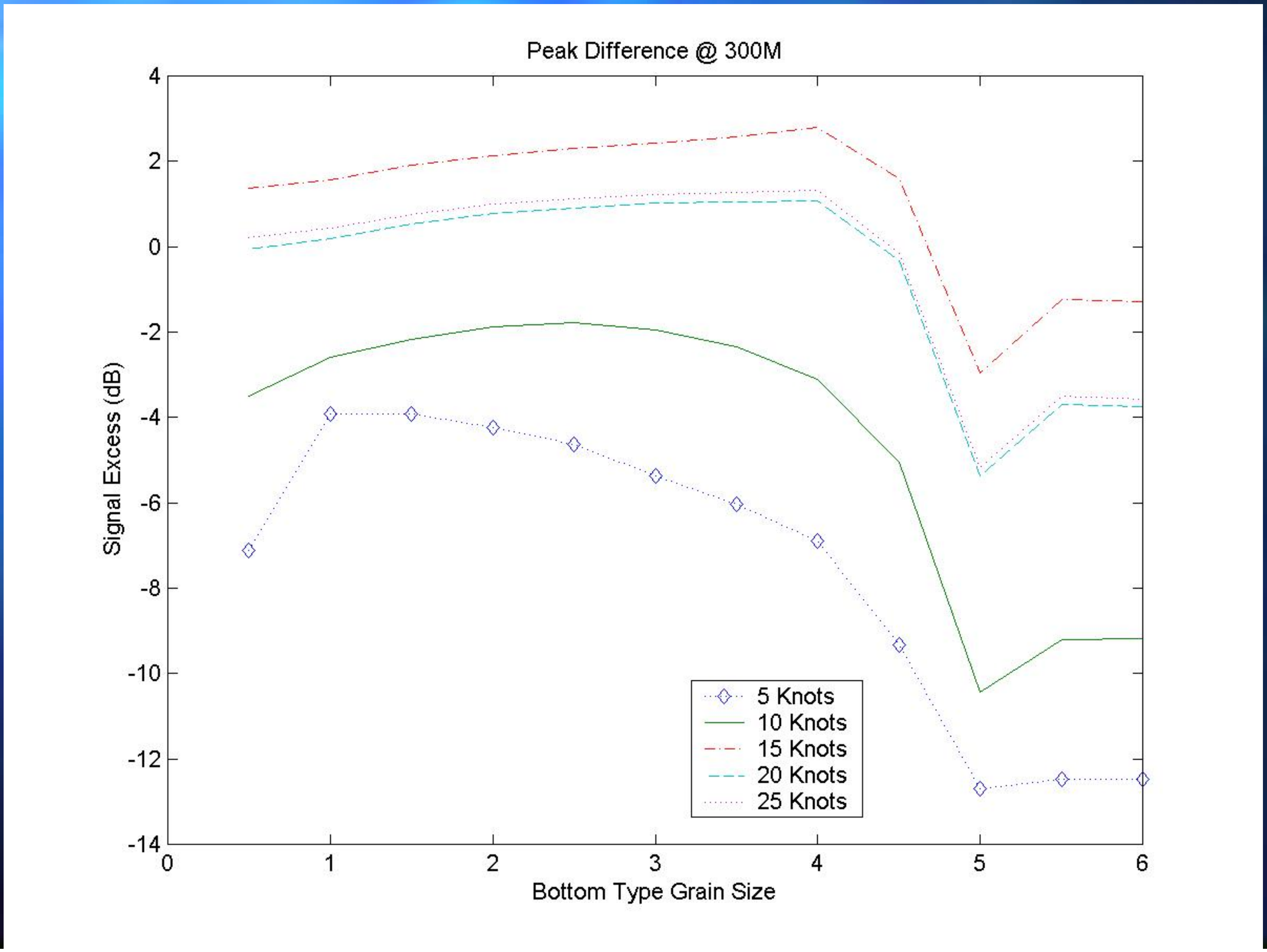
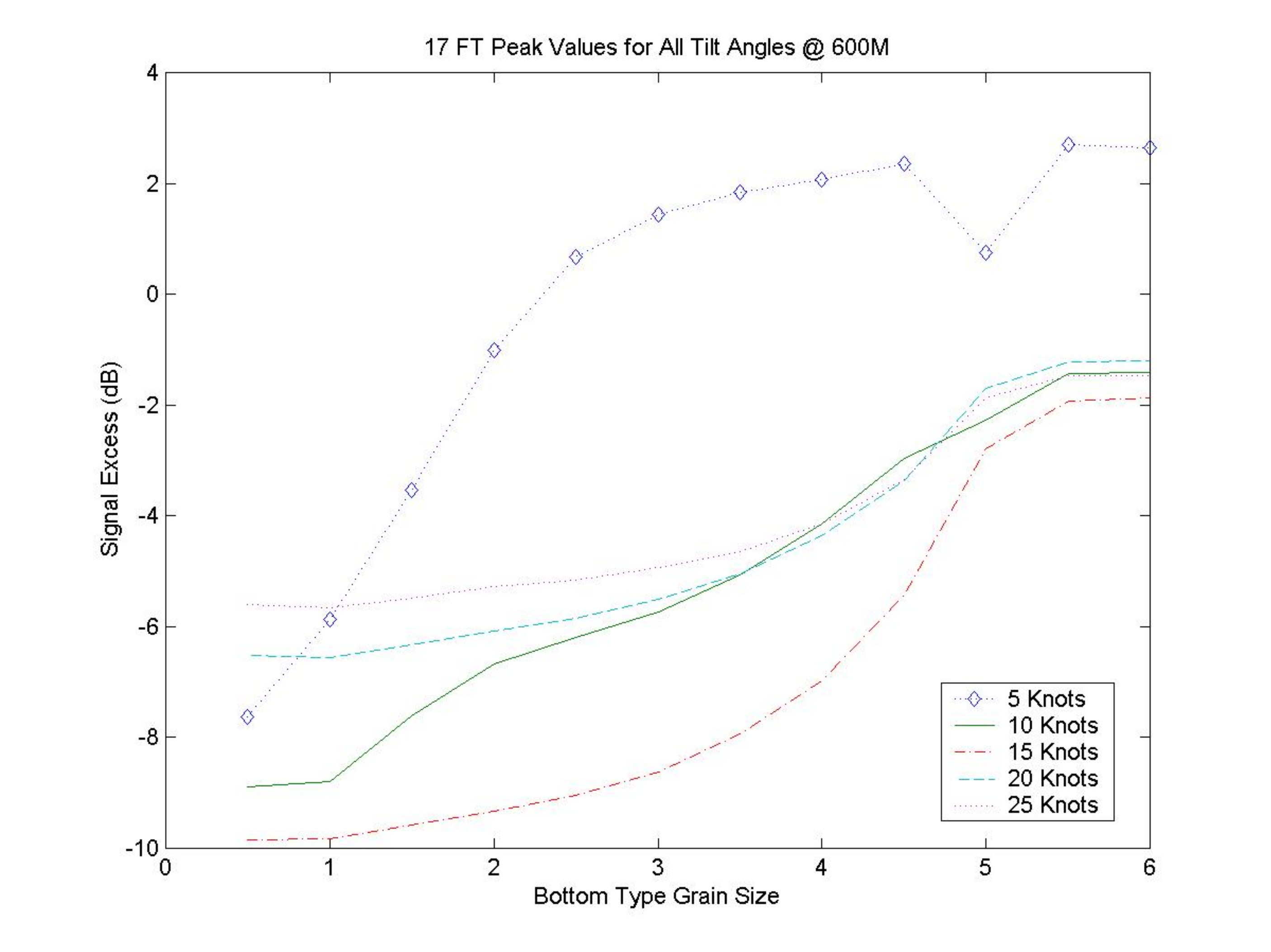


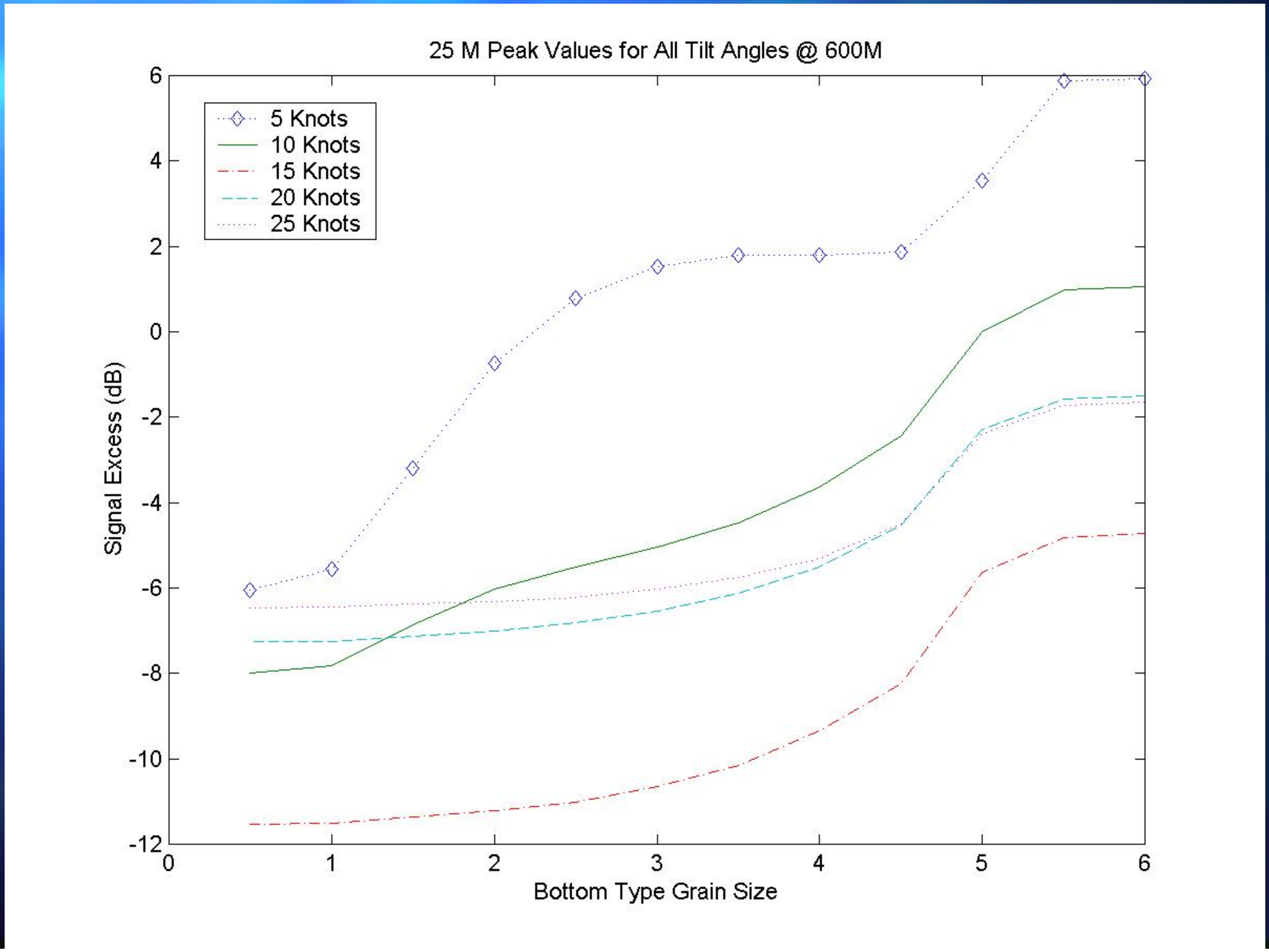
Difference Between Deep and Shallow Transducers (Range = 300 m)



Acoustic Uncertainty Due to Wind and Bottom Uncertainty for Shallow Transducer (Range = 600 m)



Acoustic Uncertainty Due to Wind and Bottom Uncertaint for Deep Transducer (Range = 600 m)



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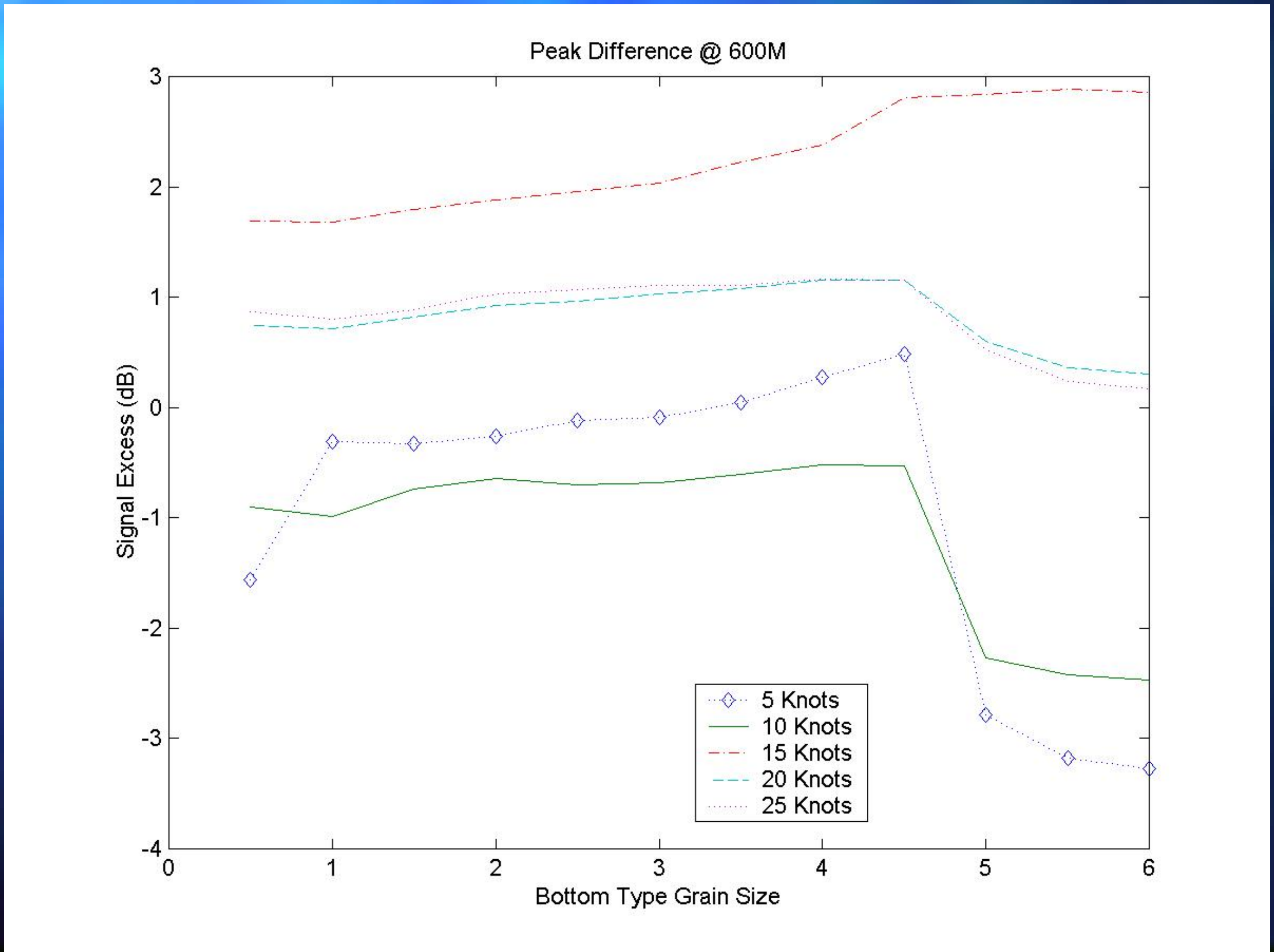
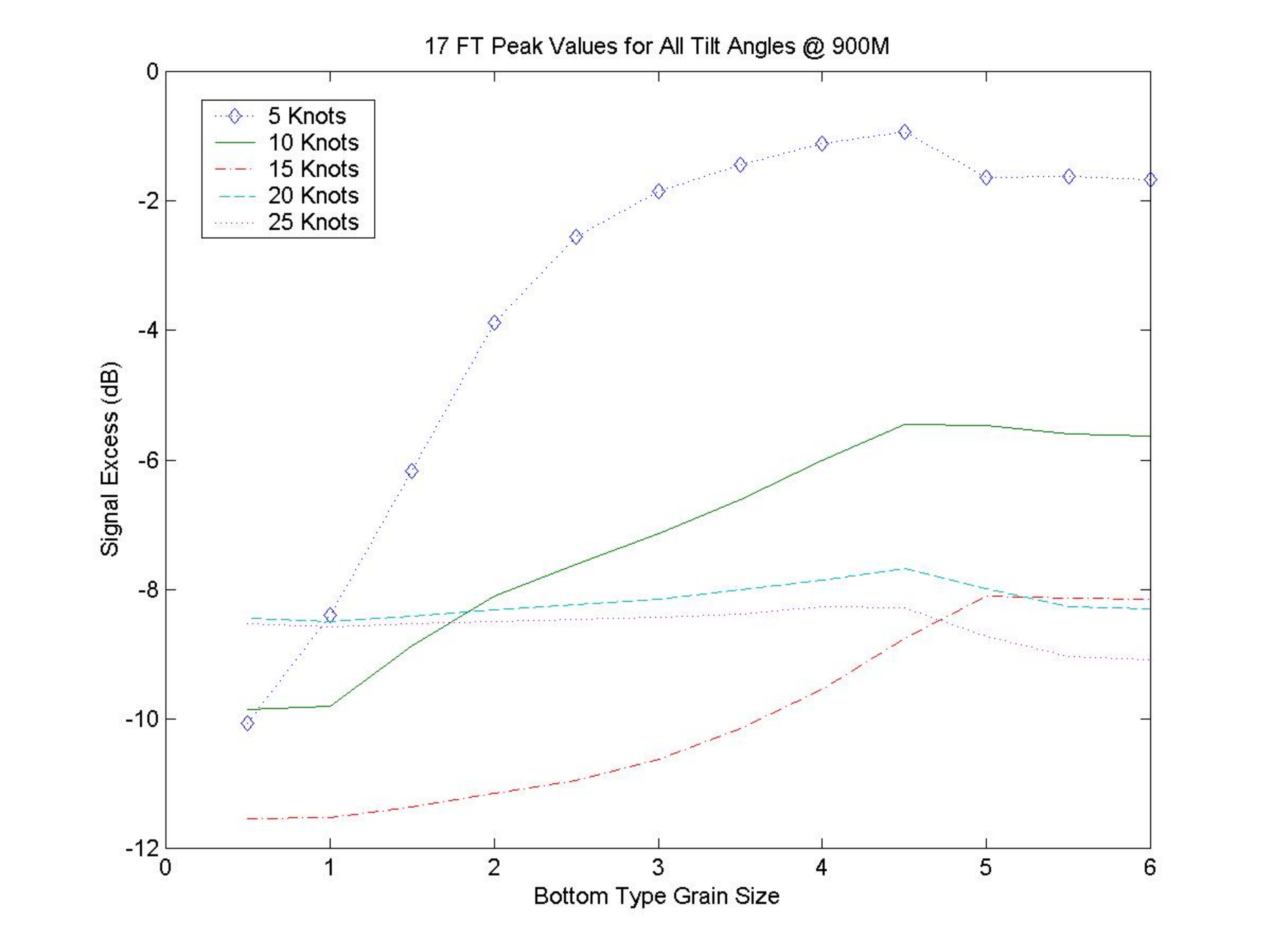
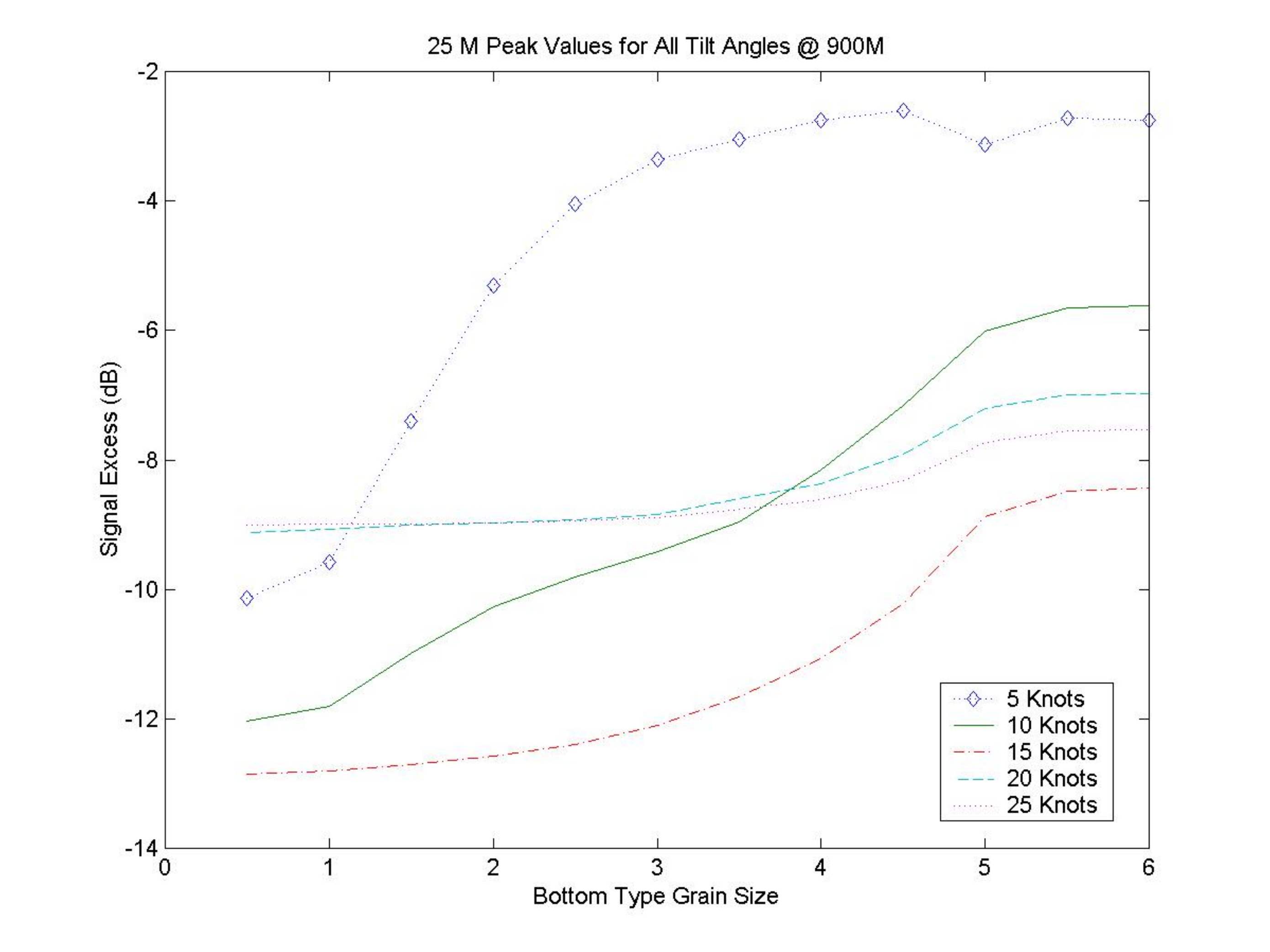


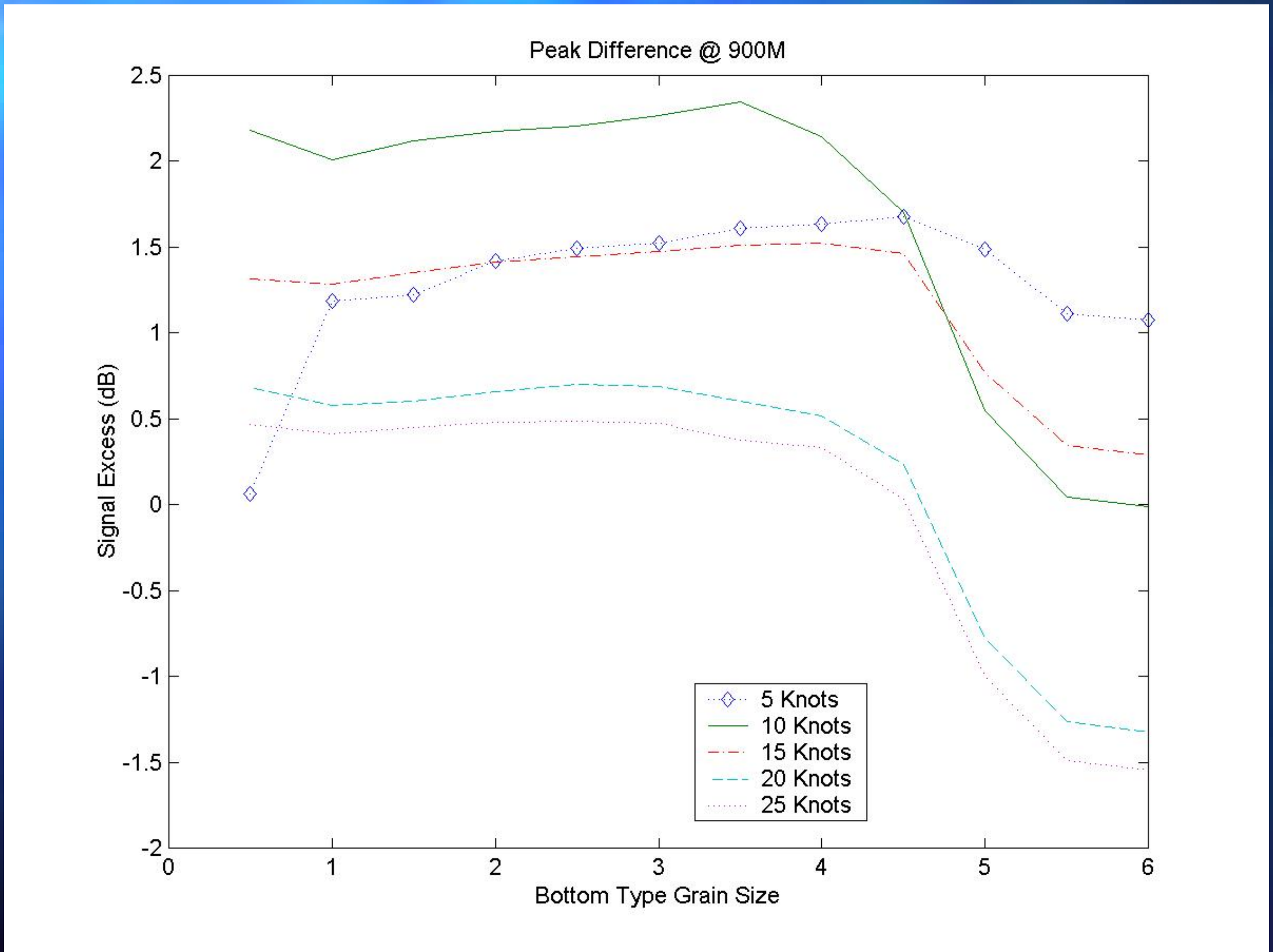
Acoustic Uncertainty Due to Wind and Bottom Uncertainty for Shallow Transducer (Range = 900 m)



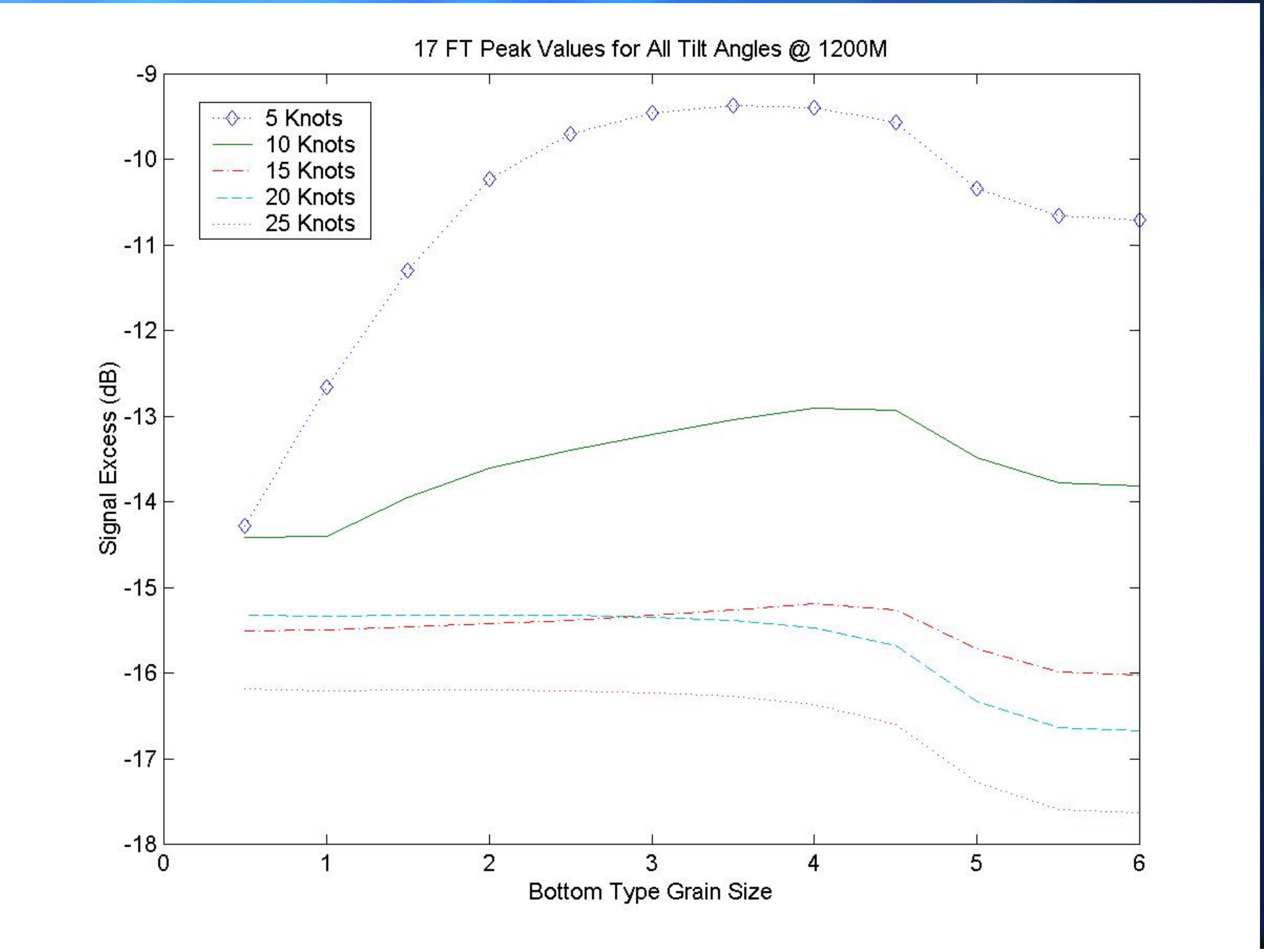
Acoustic Uncertainty Due to Wind and Bottom Uncertainty for Shallow Transducer (Range = 900 m)



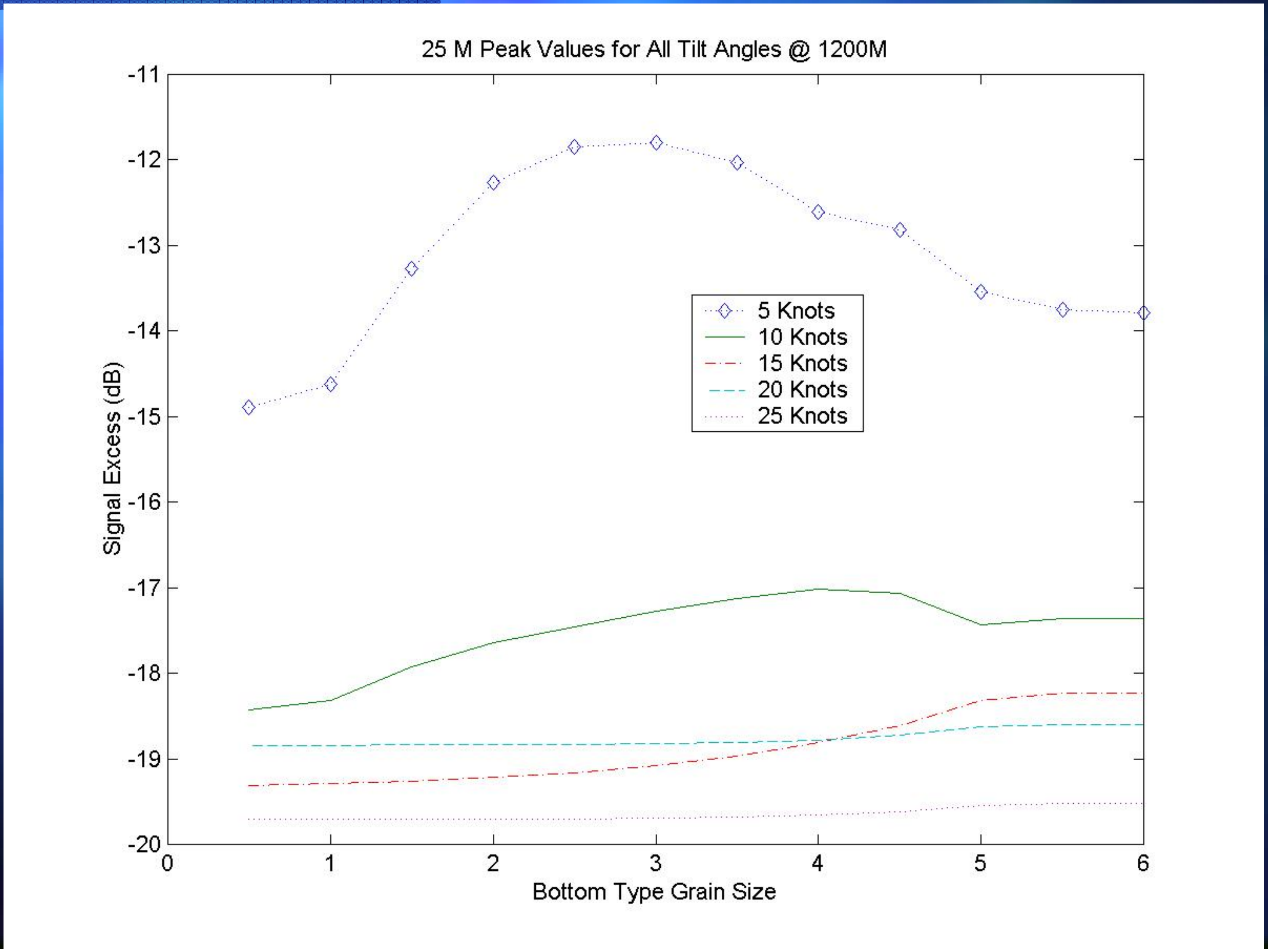
Difference Between Deep and Shallow Transducers (Range = 900 m)



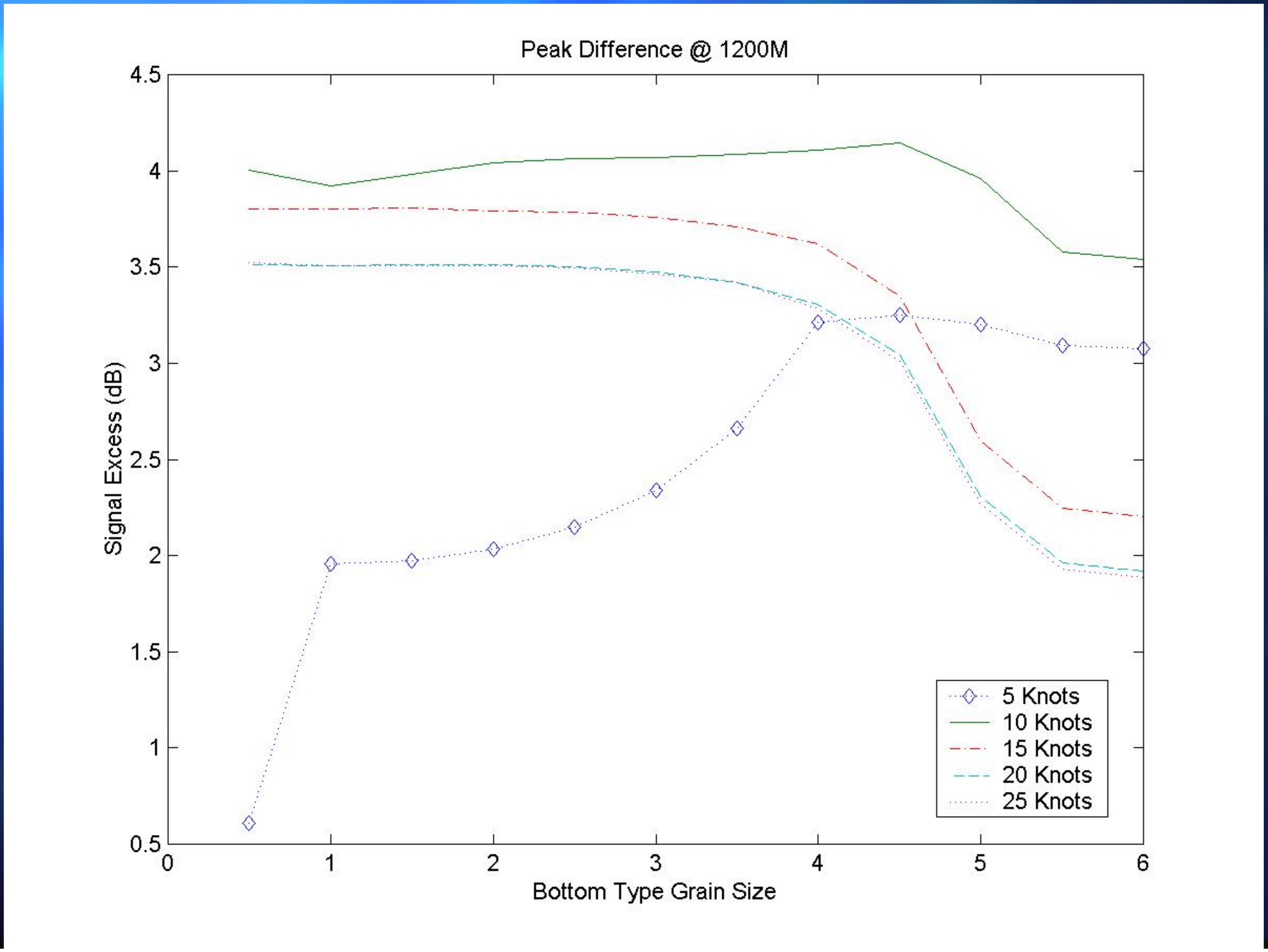
Acoustic Uncertainty Due to Wind and Bottom Uncertainty for Shallow Transducer (Range = 1200 m)



Acoustic Uncertainty Due to Wind and Bottom Uncertainty for Deep Transducer (Range = 1200 m)



Difference Between Deep and Shallow Transducers (Range = 1200 m)



Conclusions

- Bottom type and wind variability are important for sandy silt detections
- Acoustic uncertainty due to bottom type and wind data variability is on the order of a few decibels
- Deep transducers provide higher signal excess for most detectable cases

Recommendations

- Sensor improvements of a few decibels are significant for detection
- Employment of sensors deeper aids bottom moored mine detection