Characterization of Multipath Acoustic Channels in Very Shallow Waters for Communications

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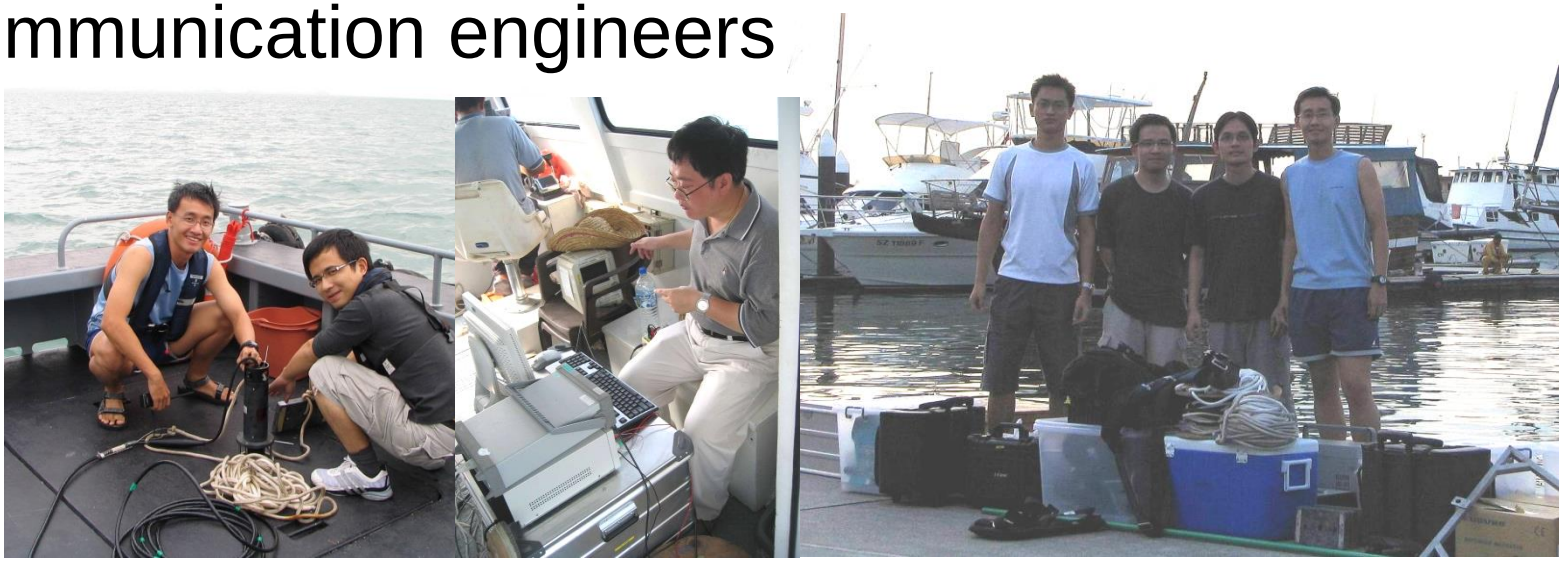
INTRODUCTION

- Typical COTS modems performed at 200-300bps @ BER ~ 10^{-7} to 10^{-6} for distances up to 2400m (Actual shallow water performance evaluated by DSO)
- July 2004 – assembled a team of acoustics and communication engineers

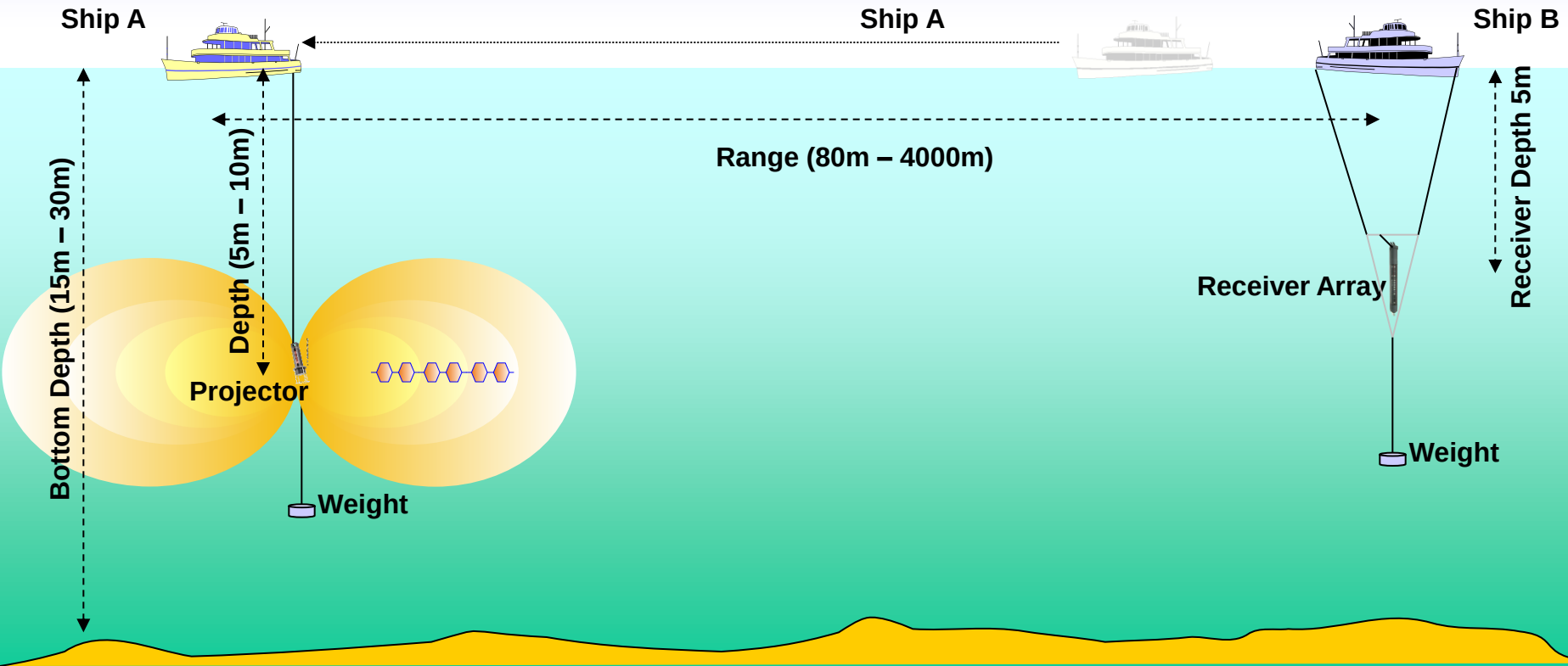


OBJECTIVES

- Study of local shallow waters through channel measurements and analysis
- Developed a versatile and reconfigurable underwater acoustic communications test bed
- Investigate and evaluate communications processing techniques
  - OFDM, DPSK
  - Turbo Product Codes

HARDWARE OVERVIEW

SEA TRIAL SETUP

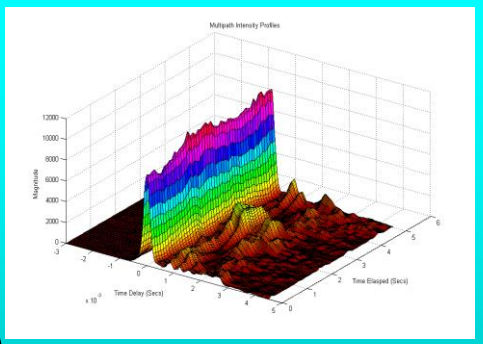


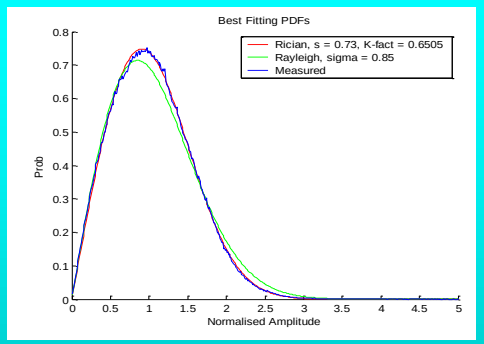
HARDWARE OVERVIEW

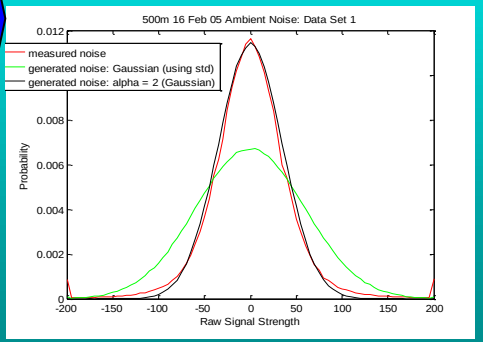
Projector

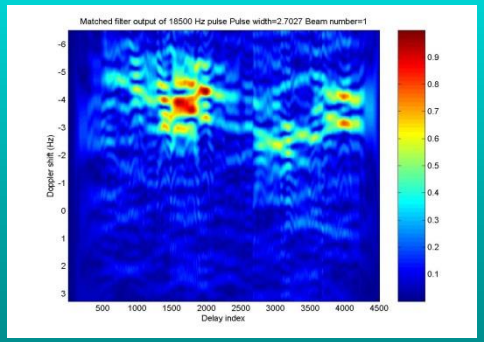
Frequency Band
10 kHz – 26 kHz

SHALLOW WATER CHANNEL









Sea trial analysis results to aid waveform and modem design / simulation / implementation

Front-end Receiver

Nested Hydrophone Array

Signal Conditioning Boards

HARDWARE OVERVIEW

PC with PCI NI DAQ, PCI Nallatech FPGA Board (Transmitter/Receiver)

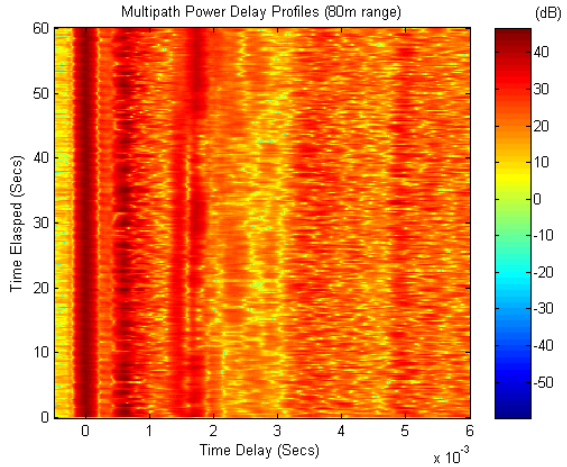
National Instruments Multi-function DAQ Card

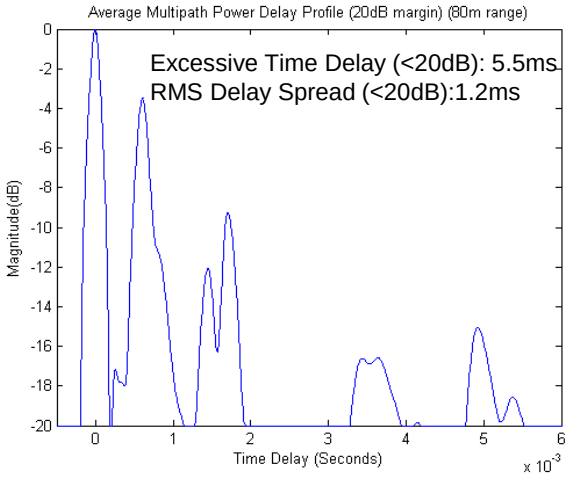
Nallatech FPGA Board

Communication Algorithms Test Bed

CHANNEL MEASUREMENTS

80metres



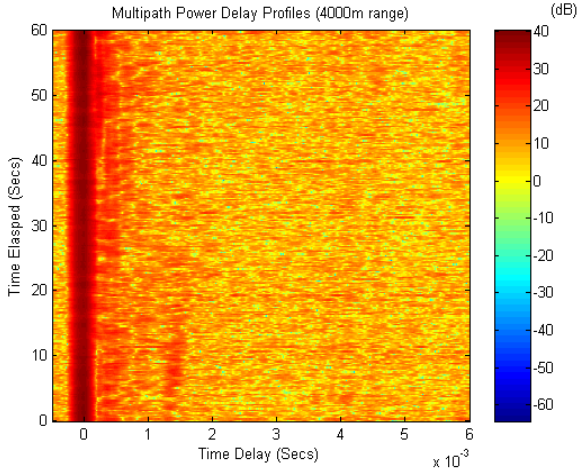


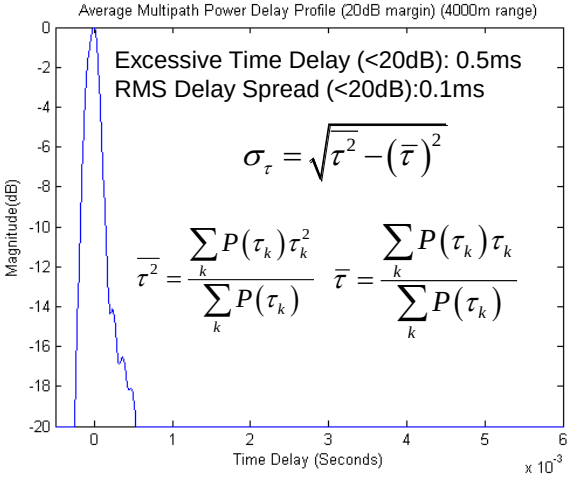
MULTIPATH DELAY

Range (m)	T_m (ms) Excessive Time Delay	σ_τ(ms) RMS Time Delay	Approx Coherence Bandwidth (Hz)
80	5.5	1.2	167
130	7	1.9	105
600	3	0.85	235
1030	3.5	0.85	235
1510	2.5	0.38	526
1740	1.3	0.13	1538
2740	0.5	0.10	2000
4000	0.5	0.10	2000

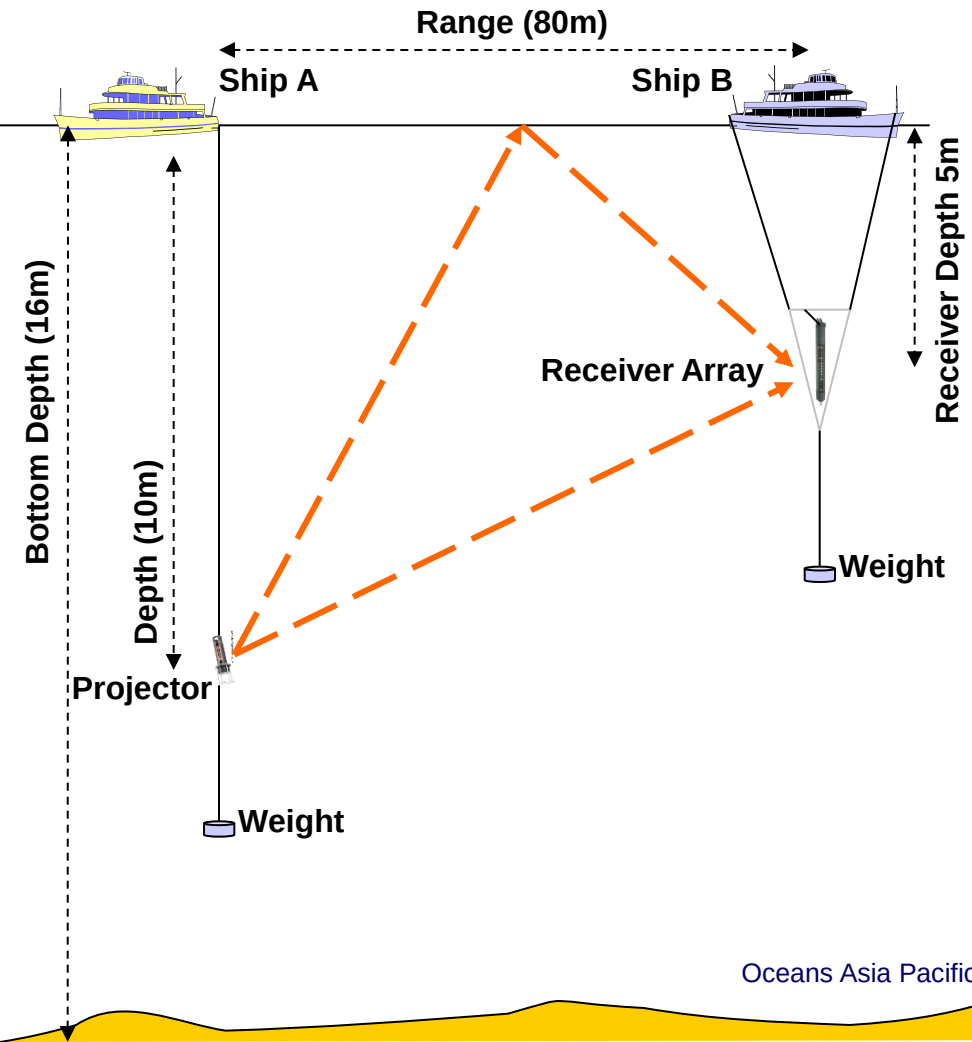
$$B_c = \frac{1}{5\sigma_\tau}$$

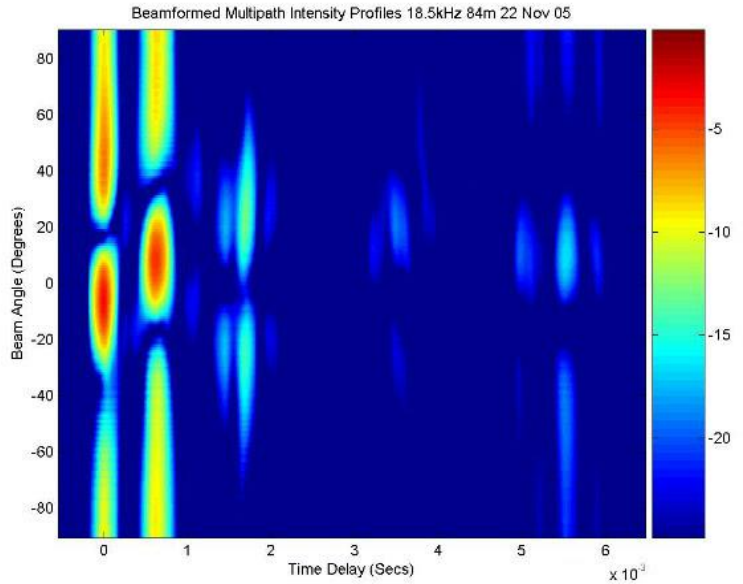
4000metres

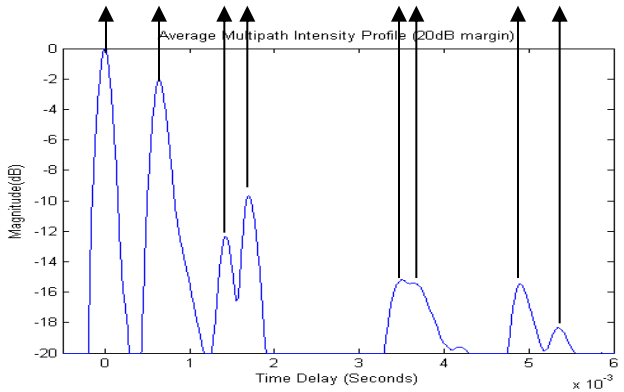




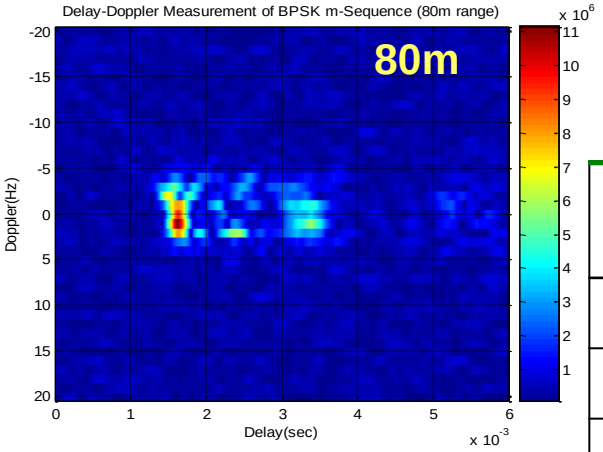
CHANNEL MEASUREMENTS

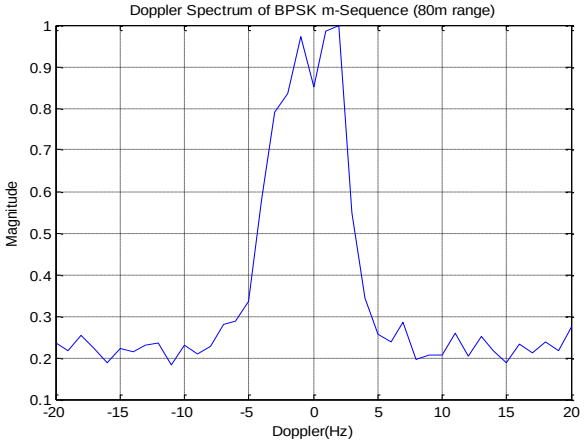






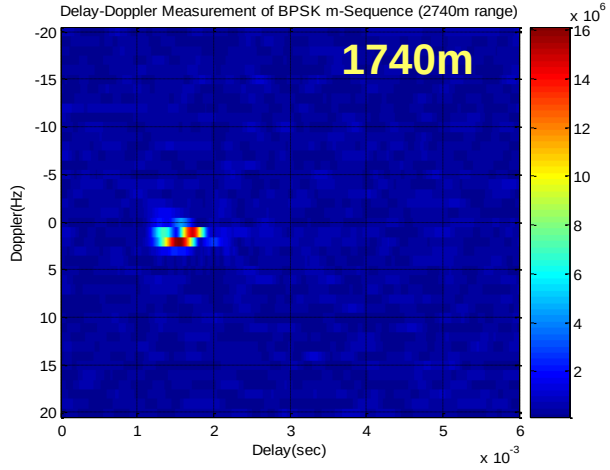
CHANNEL MEASUREMENTS

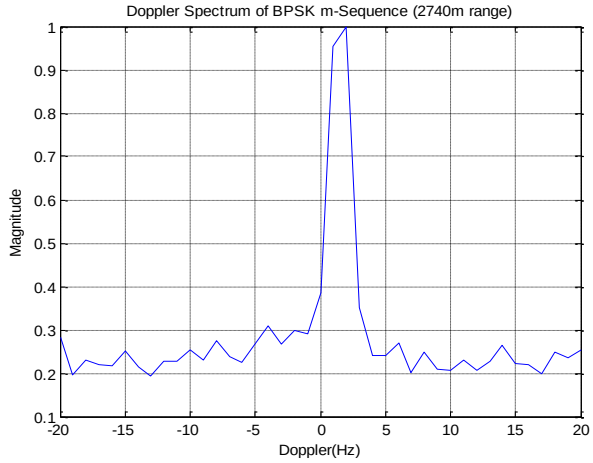




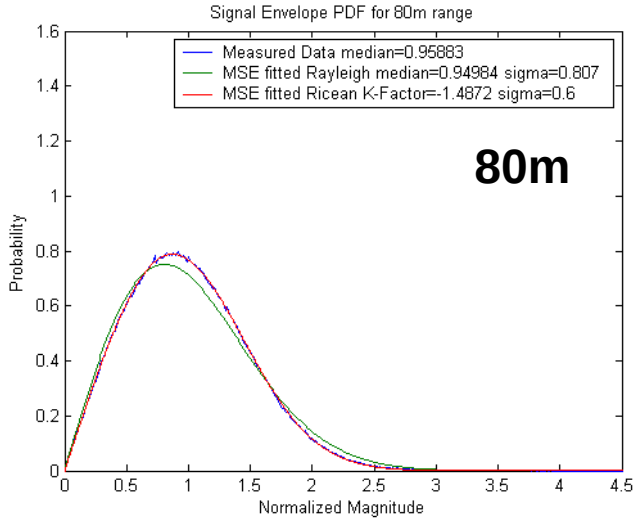
DOPPLER SPREAD / SHIFT

Range (m)	Doppler Spread $2f_d$(Hz)	Doppler Shift (Hz)	Coherence Time (sec)
80	9	-1,+2	1/9
130	8	-1	1/8
600	4	-2	¼
1030	3	0	1/3
1510	2	-1	½
1740	2	+1	½
2740	3	+2	1/3
4000*	4	0, +3	¼



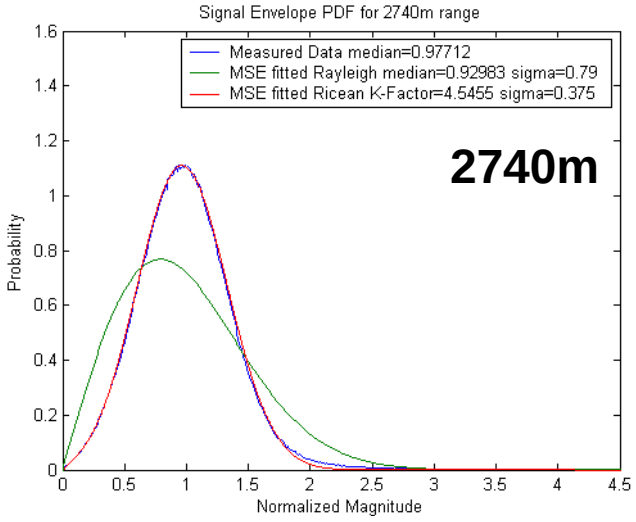


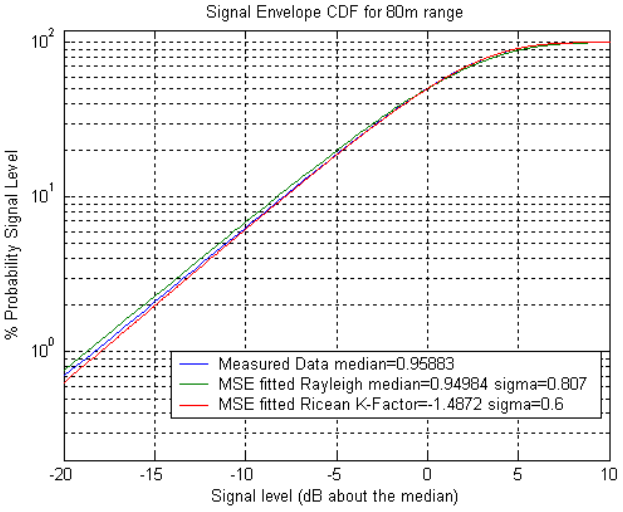
CHANNEL MEASUREMENTS

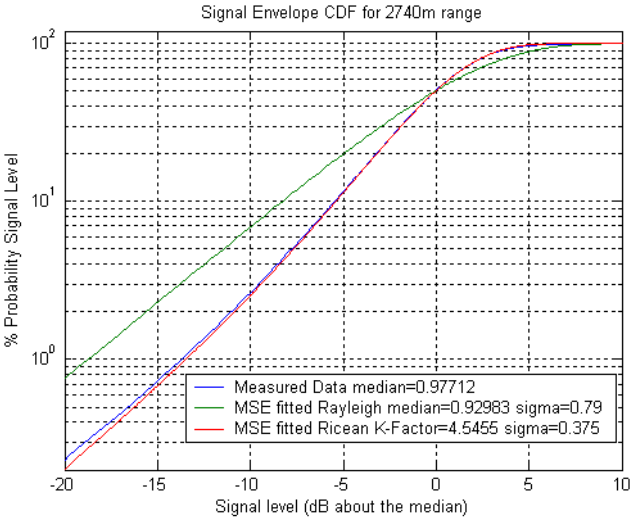


SIGNAL ENVELOPE FADING

Range (m)	MSE Fitted Rayleigh Sigma	MSE Fitted Ricean K-Factor (dB)	Approx Fit
80	0.807	-1.487	Rayleigh
130	0.803	-4.167	Rayleigh
600	0.815	2.757	Ricean
1030	0.802	-6.787	Rayleigh
1510	0.807	2.192	Ricean
1740	0.802	6.253	Ricean
2740	0.790	4.545	Ricean
4000*	0.885	-32.571	Rayleigh

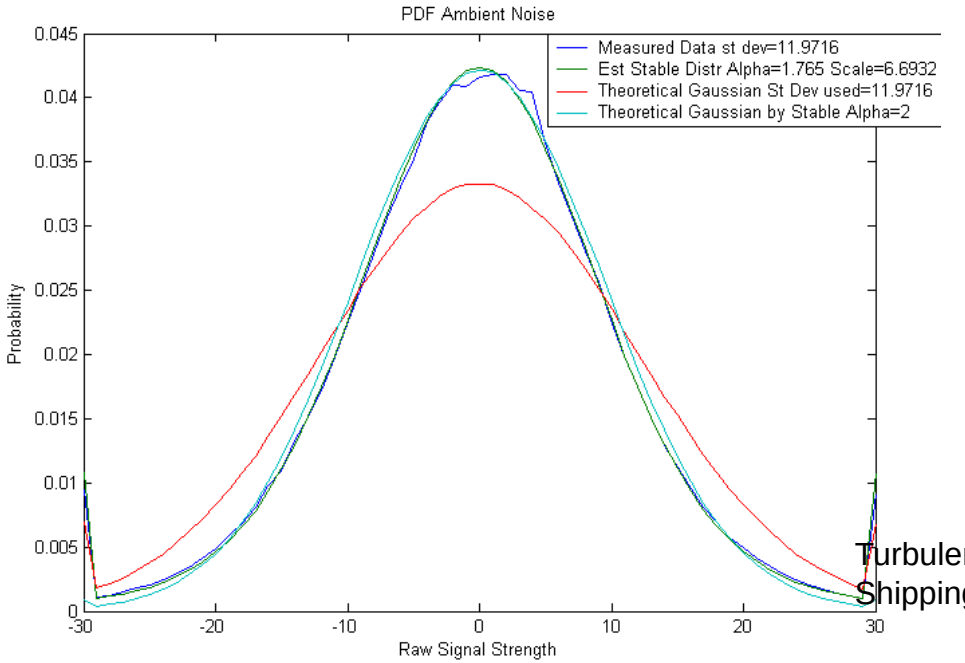


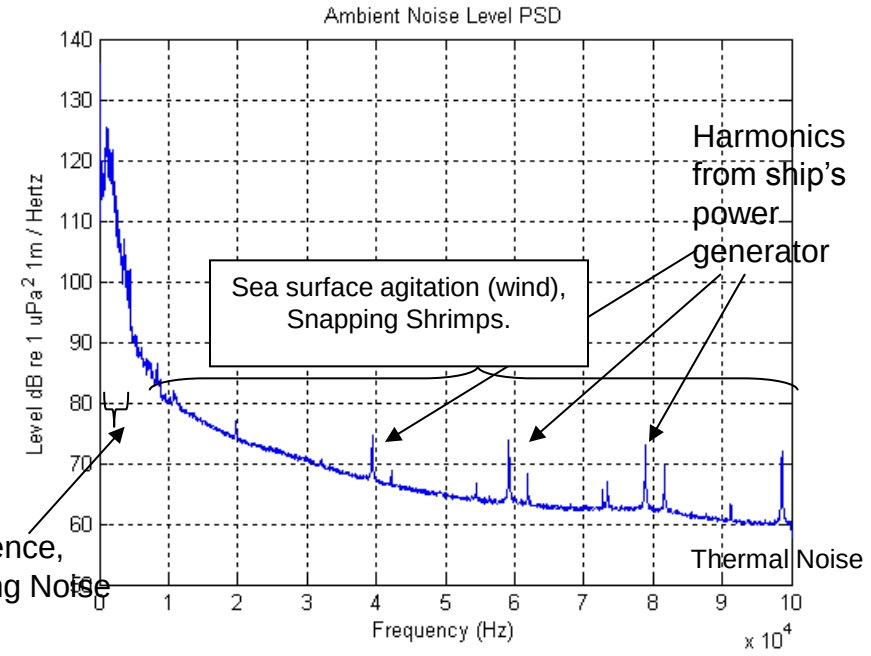




CHANNEL MEASUREMENTS

AMBIENT NOISE



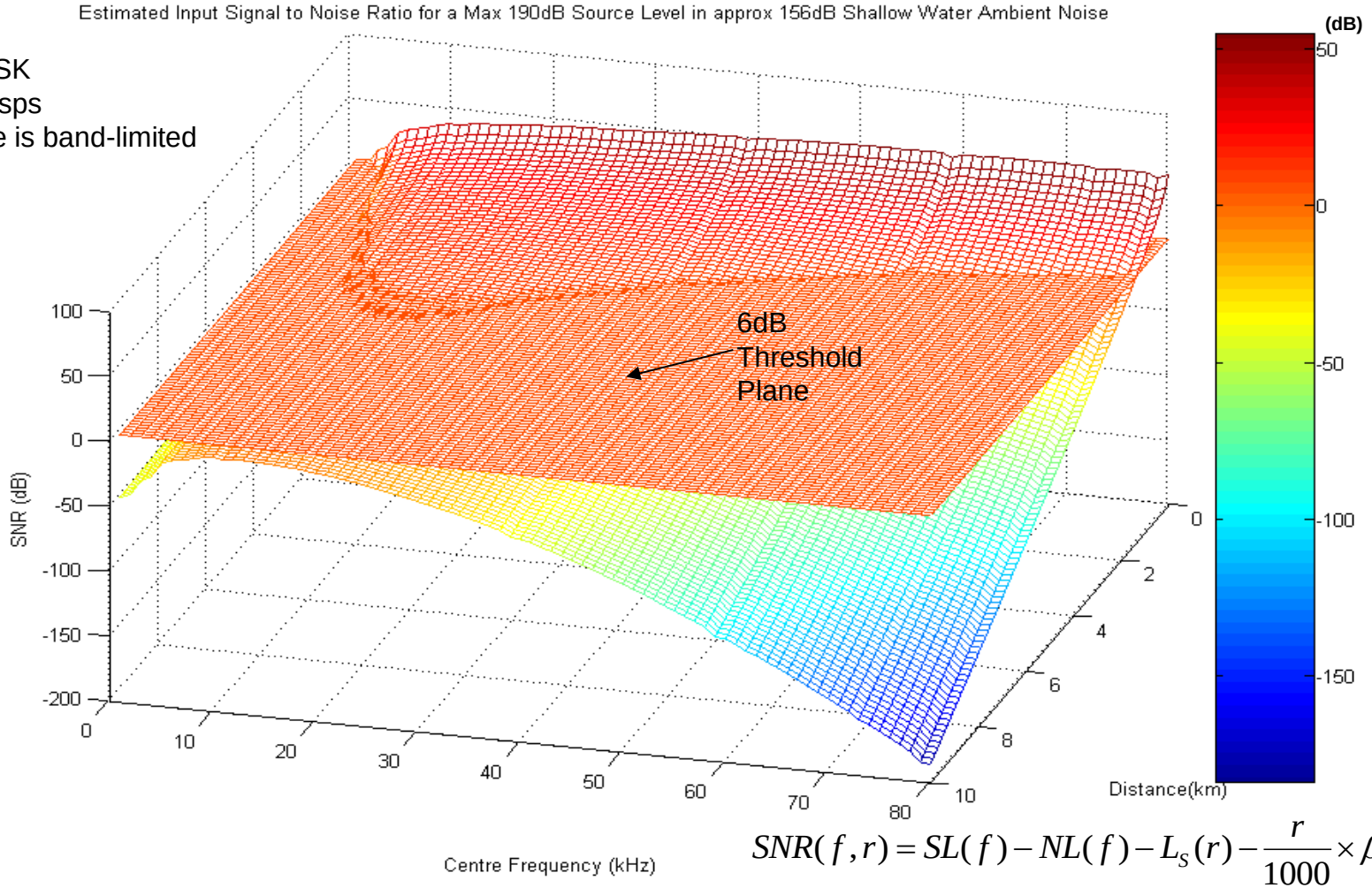


Noise Level (up to 100kHz):156dB re 1µPa 1m
Spectrum Noise Level(up to 100kHz): 106dB re 1µPa 1m

Noise Level (In Band 10-26kHz): 118dB re 1µPa 1m
Spectrum Noise Level (in Band 10-26kHz): 76dB re 1µPa 1m

LINK BUDGET

DBPSK
1000sps
Noise is band-limited



$$SNR(f,r) = SL(f) - NL(f) - L_S(r) - \frac{r}{1000} \times \beta_{dB/km}(f)$$

Conclusion

- Developed a versatile and reconfigurable underwater acoustic communication test bed
- Accumulated at-sea data for communication channel characterizations and communication signals
- Presented delay, Doppler, fading and ambient noise analysis of the channel.
- Observations:
  - delay and Doppler effects are less at longer distances
  - LOS component is more likely at the longer distances
  - Ambient noise is non-Gaussian with a heavy tailed distribution and a highly impulsive behavior
- Communication system designers should take note of the channel characteristics at longer distances (>1500m up to 4000m) to transmit at higher data rates. On the other hand, it would be a serious challenge to design a modem for shorter distances that can achieve the same level of performance that was possible at longer distances
- Change of mindset from “increasing ranges, decreasing bitrate” to “increasing ranges, increasing bitrate”. (range<3km)

THAT'S ALL FOLKS!

- Questions and Answers?
- Have a pleasant day ahead!