Interesting (?) Applications for Acomms

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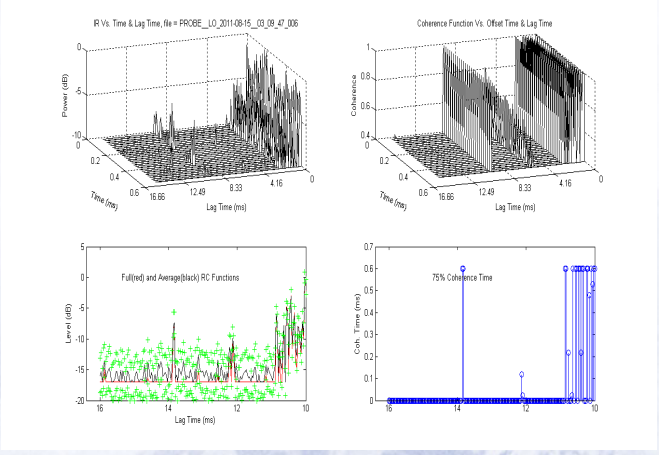
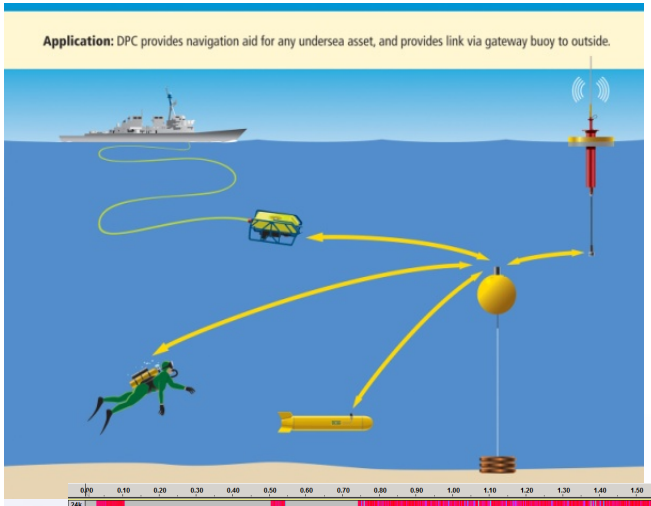
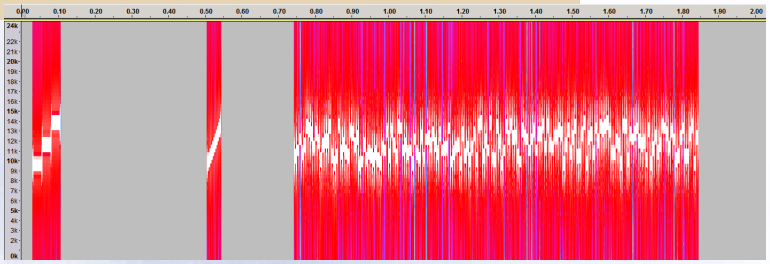
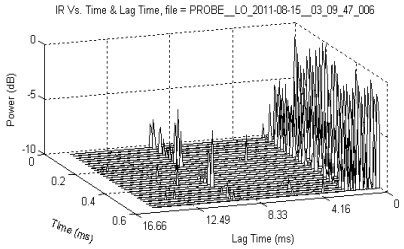


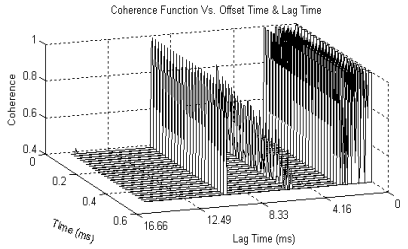
Rev 12/14/09

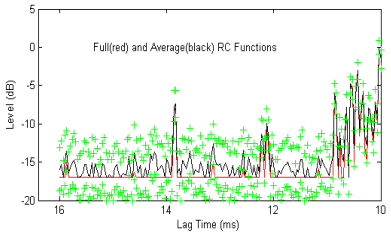
Outline

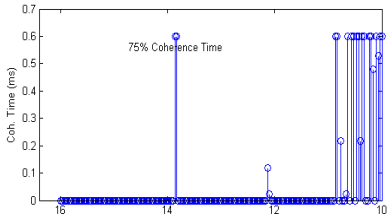

Application: DPC provides navigation aid for any undersea asset, and provides link via gateway buoy to outside.

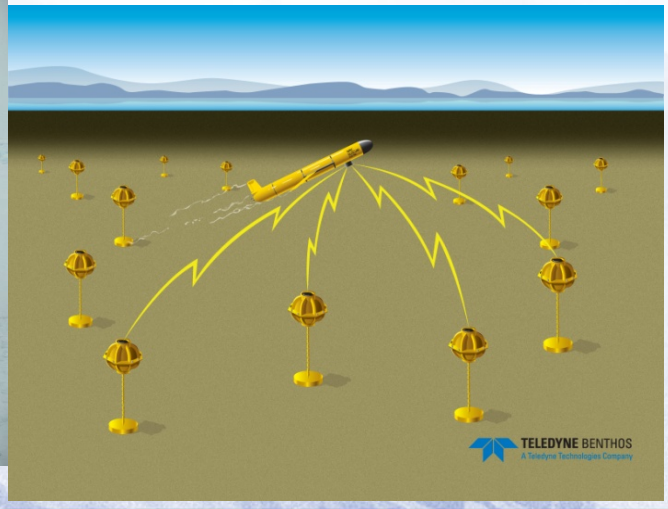



IR Vs. Time & Lag Time, file = PROBE__LO_2011-08-15__03_09_47_006
Power (dB)
Time (ms)
Lag Time (ms)


Coherence Function Vs. Offset Time & Lag Time
Coherence
Time (ms)
Lag Time (ms)


Full(red) and Average(black) RC Functions
Level (dB)
Lag Time (ms)

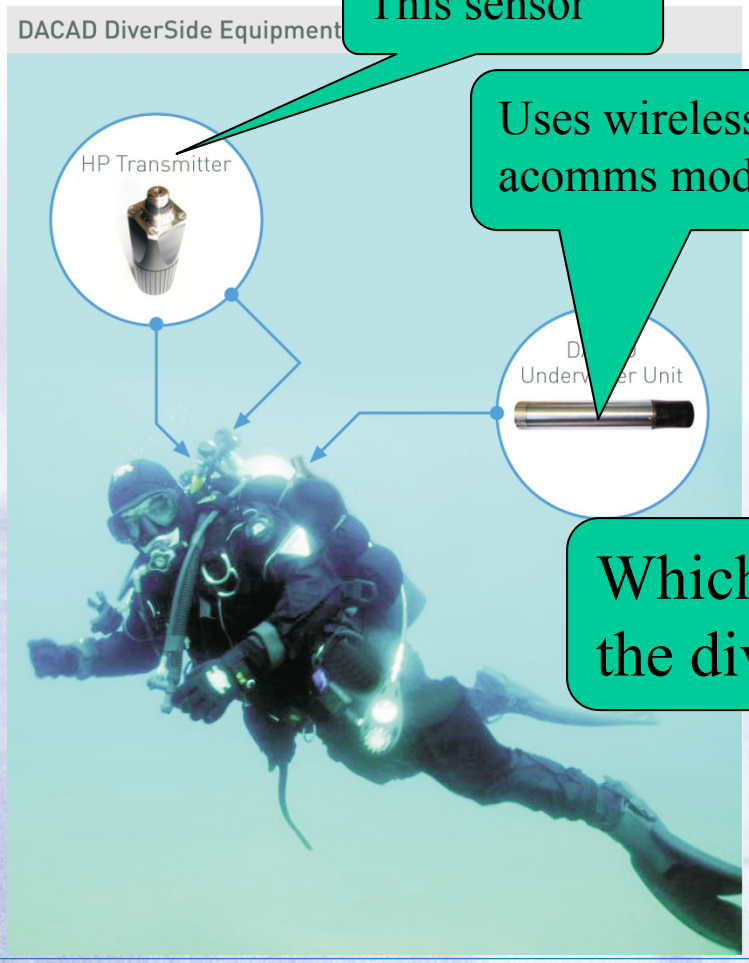

75% Coherence Time
Coh. Time (ms)


TELEDYNE BENTHOS

Keeping Track Of Divers

This is very dangerous work – the dive supervisor needs to know where all of his divers are – all of the time

Divers are visually searching, and listening for pingers placed on the containers



This sensor

Uses wireless RF to the acomms modem

While divers look for black box pingers

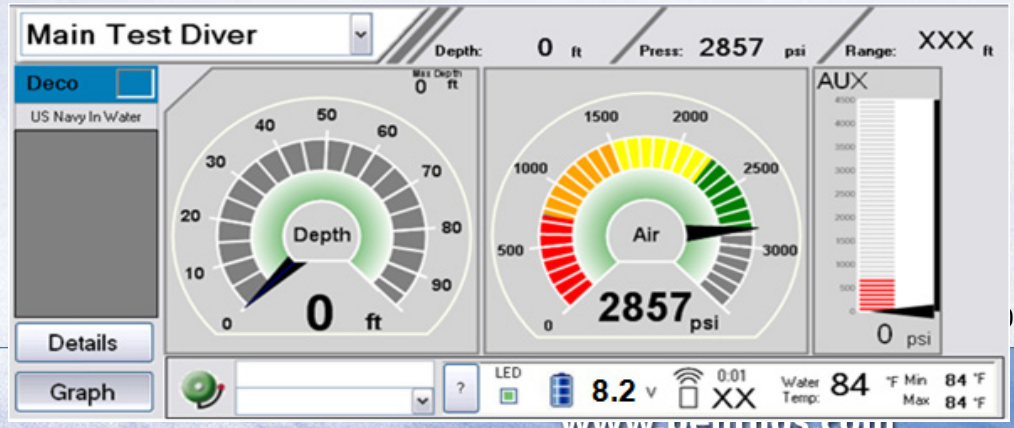
Which uses acomms to the dive supervisor

Who monitors status & location of all divers

Diver DACAD

Observing output of the DAT portion of DACAD

DACAD Screen Shot:
Test Dive 1
Dive Start: Initial Readings (Surface)



Integrated Acomms & Positioning

DAT Technology being used:

1. MBARI – DORADO UUV, DAT on vehicle, for autonomous guidance, control & docking. Recent experience is excellent performance (comms, range, bearing) from 2500 m to near docking in 40 m of water.
2. SAIC/ONR – large "mother UUV" with multiple smaller UUVs. DAT on (moving) mother. Used for autonomous acomms, command & control of small vehicles. Excellent performance (range, bearing,) to ~2-3 meters where another docking process is used.

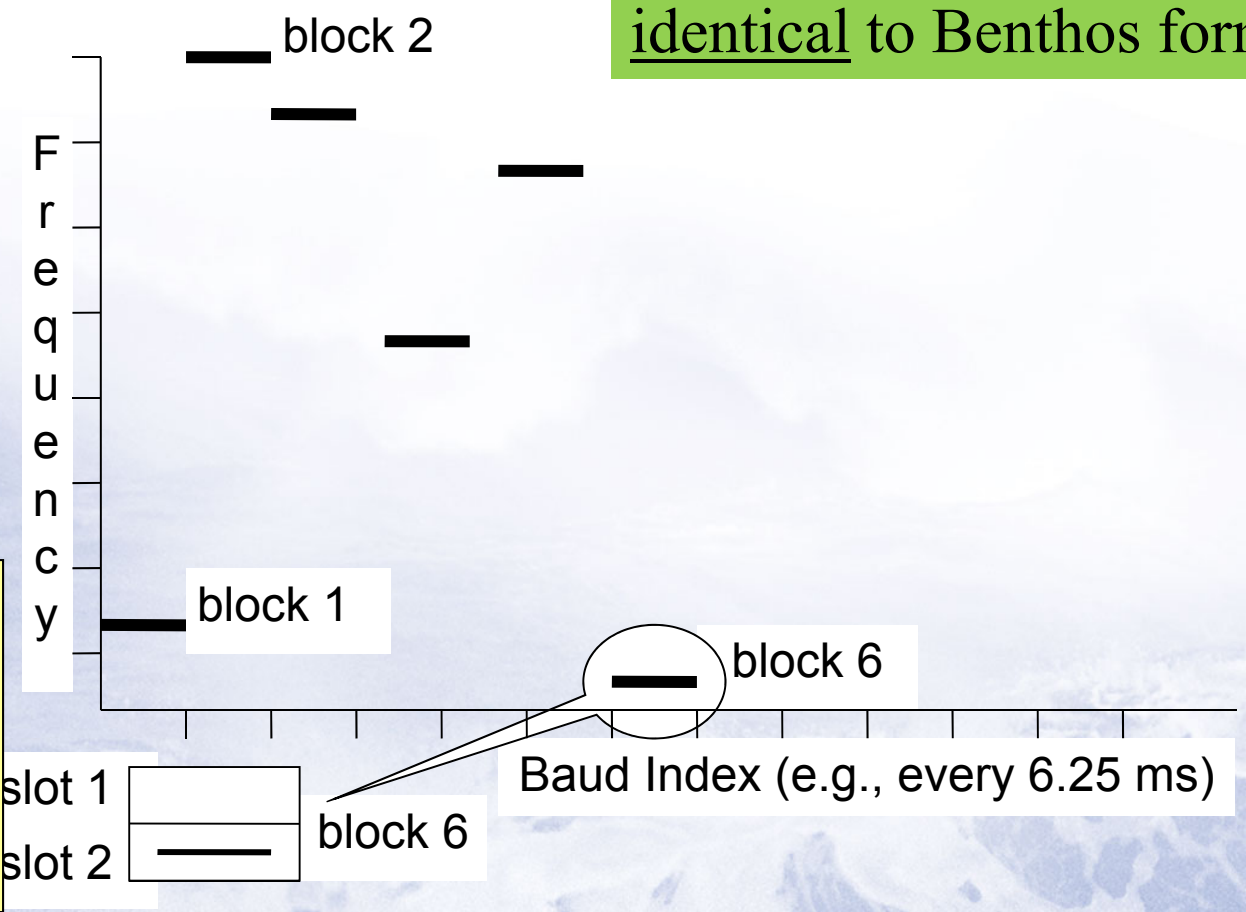
JANUS – At The NATO Undersea Research Centre

JANUS is a multi-national effort to establish a simple, robust STANDARD for underwater signaling

- For use as a beacon (think of an underwater lighthouse)
- IFF equivalent
- Comms with undersea sensors
- Open to all, design documentation available
  - Tells you precisely how to build the waveform, how to encode the data
  - Gives you a rudimentary (though complete) receiver design
- They welcome collaboration

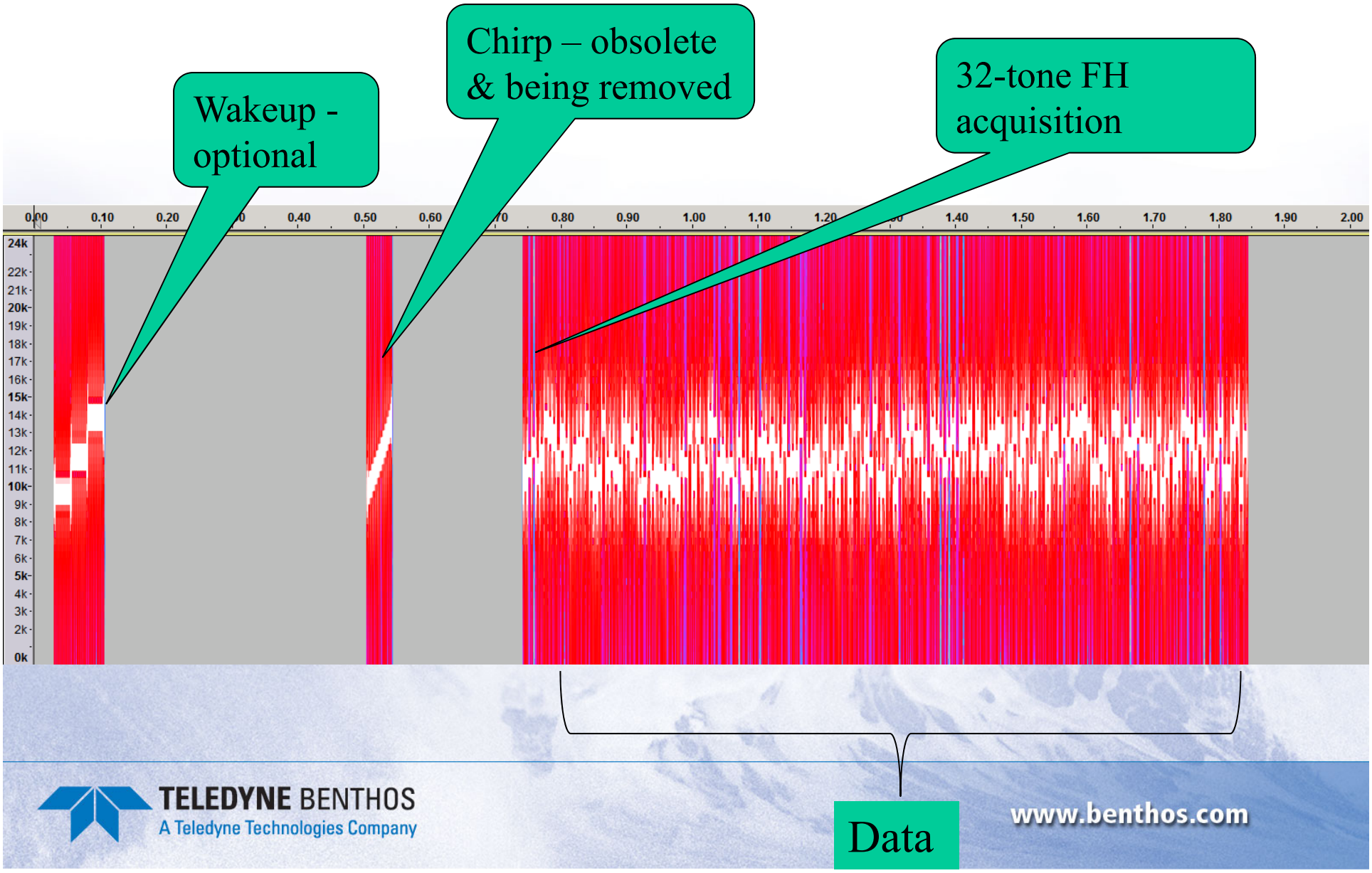
Frequency Hopping Binary Frequency Shift Keying (BFSK)

Similar to WHOI Micromodem, identical to Benthos form



Block 6, expanded, shows a CW tone in slot 2, indicating transmission of a 1 bit

Frequency vs. Time (spectrogram) of a JANUS Signal

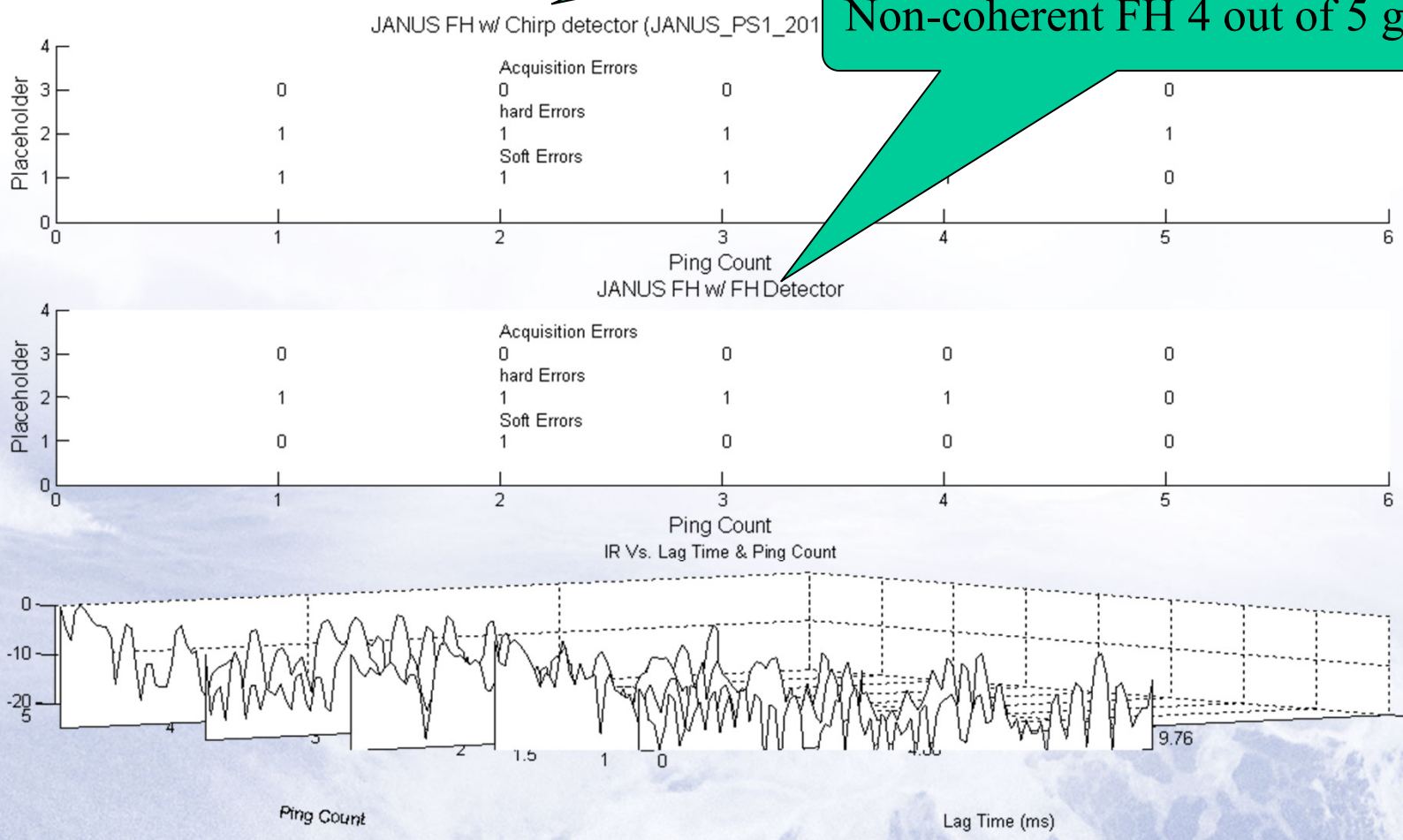


Acquisition

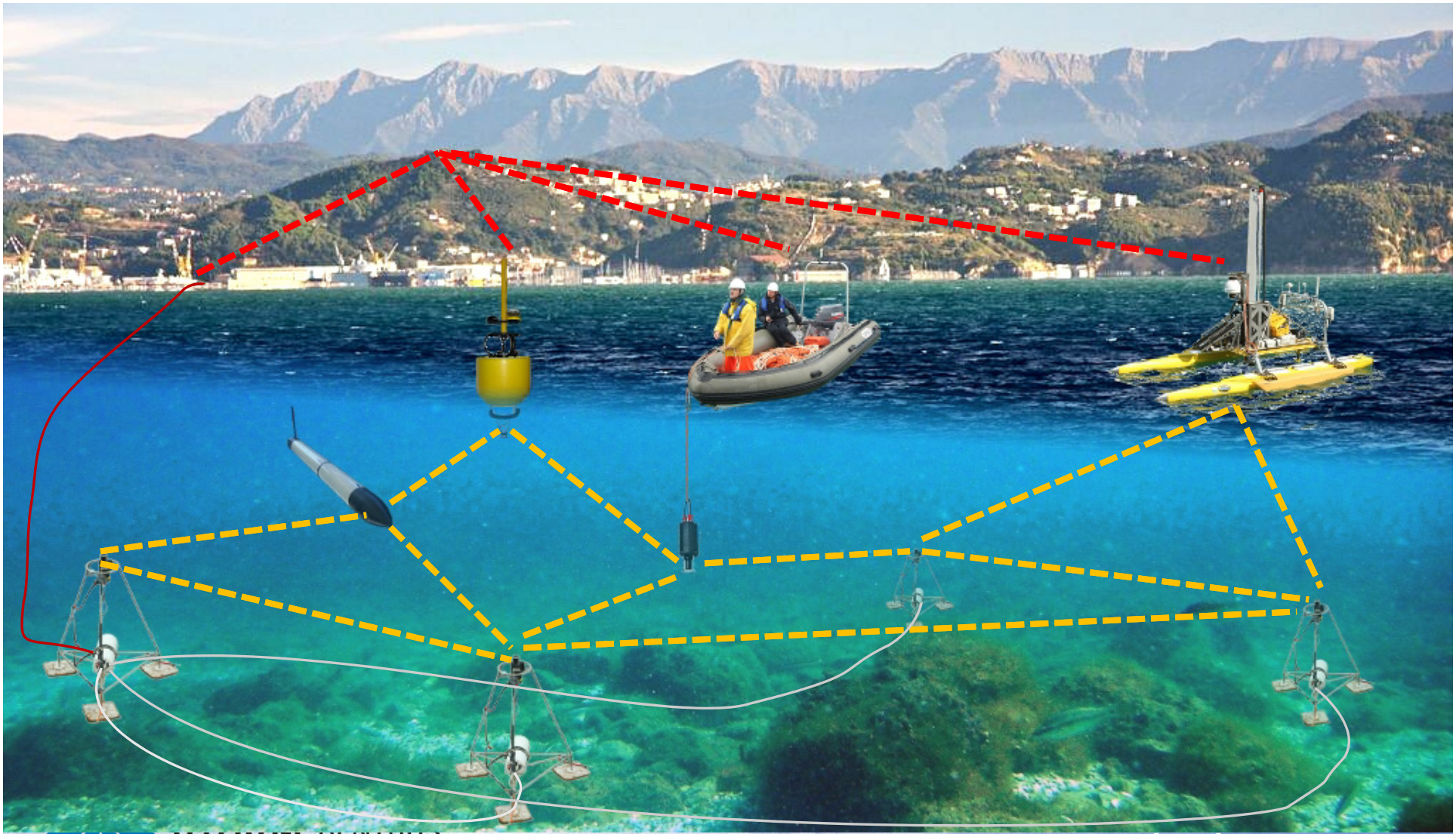
- This is the most difficult part of acomms
- You can put a wideband signal (e.g., a chirp) in front (but this is being removed from JANUS)
- There are several methods for FH Signals
  - Semi-Coherent Replica Correlator – rarely works well
  - Non-Coherent Energy summation
- A Challenge!
  - Design an efficient, robust non-coherent acquisition process for 32 randomly-placed tonals
  - Design theoretically defensible and practical detection algorithm – when does the signal arrive?

Chirp – all demodulation failed

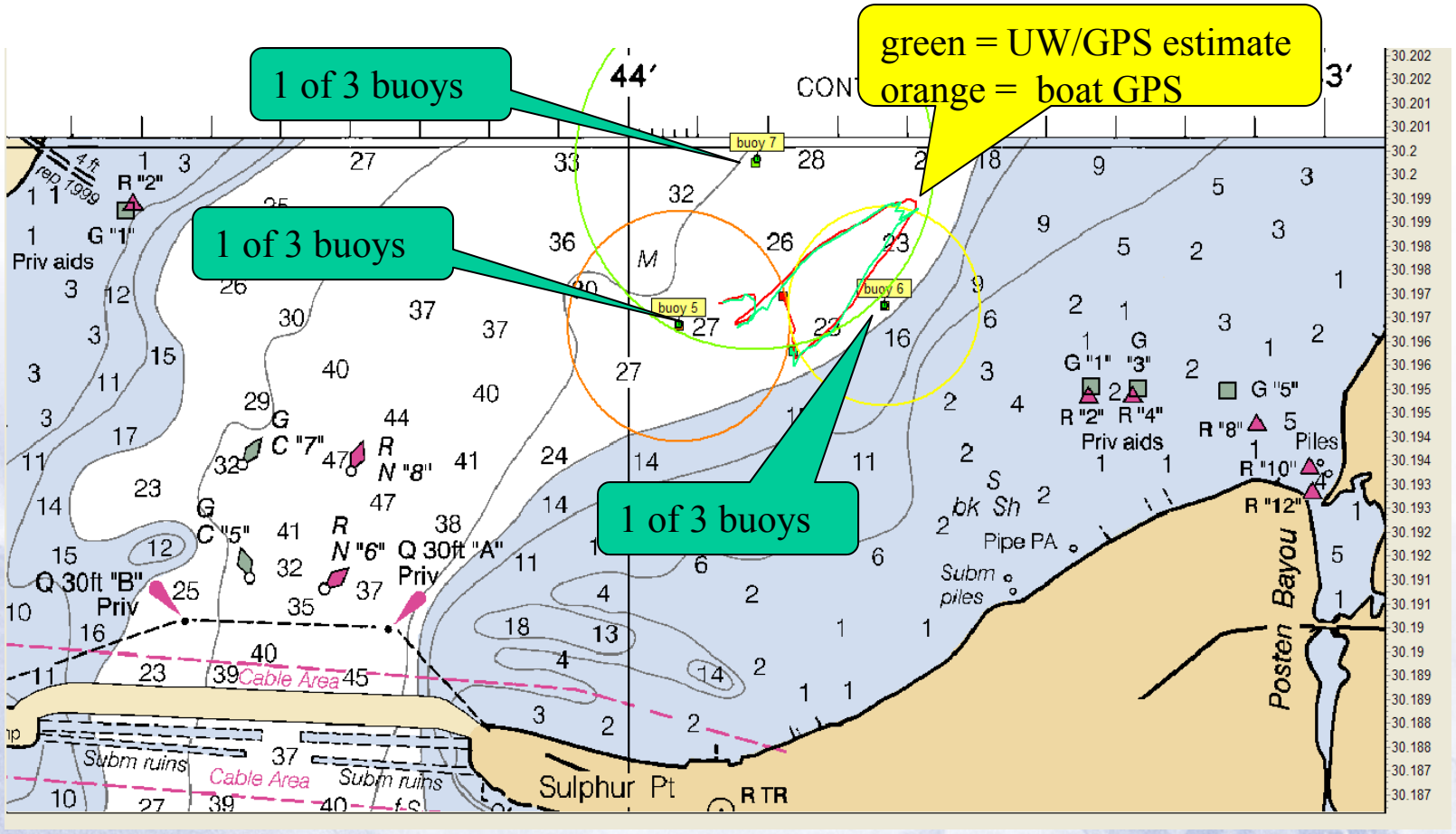
Non-coherent FH 4 out of 5 good



NURC Testbed, La Spezia Italy. Data available on-line



UW/GPS Example
10 m water, 400 m buoy-to-buoy range

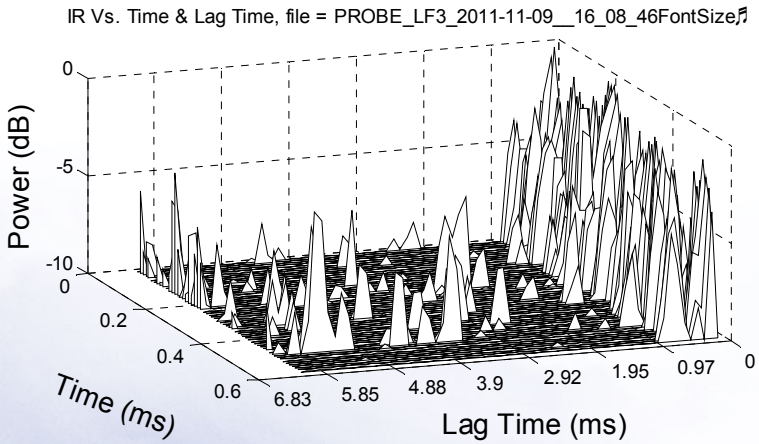


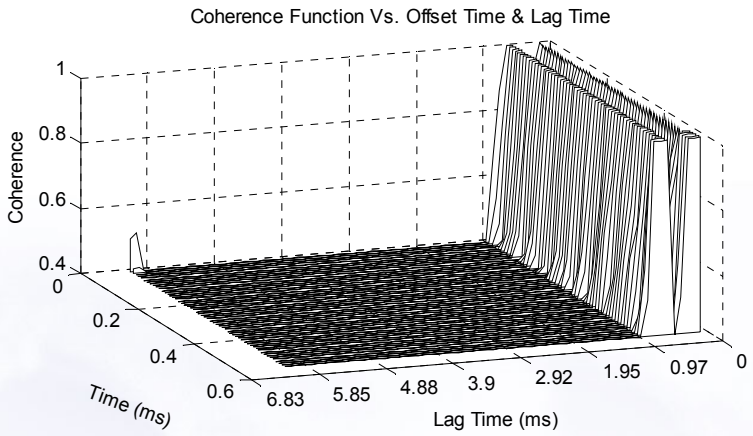
Performance within satellite GPS error

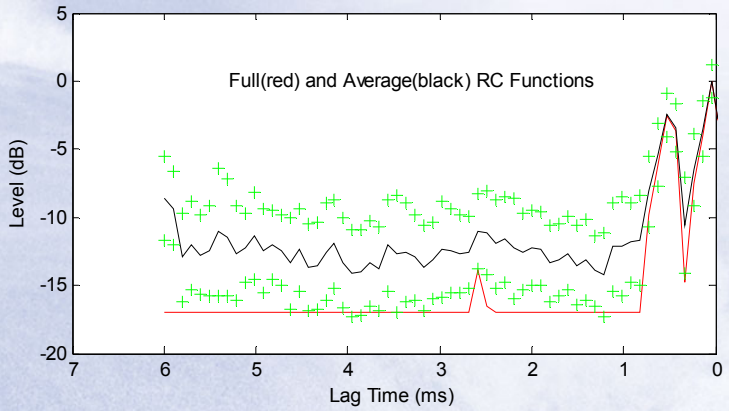
Academic Project (?)

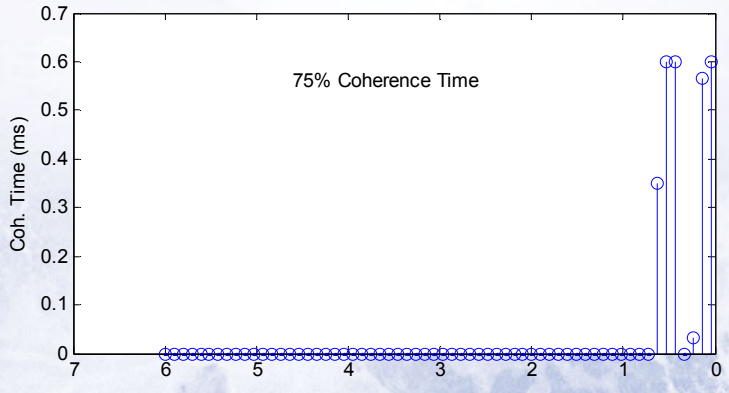
- The FH-based signaling scheme is the most basic scheme that will work well underwater, but making it work well and efficiently isn't easy.
- The WHOI MicroModem operates in a fairly similar way
- NATO NURC is preparing an open standard (STANAG) based exactly on this FH system I have presented
- This would be (?) appropriate for a graduate-level development
  - Acquisition components
  - Statistical detection theory – how do you know when it arrives?
  - Error correction coding, interleaving, CRCs, FFT-based demodulation, Galois theory, fast correlation processing…..
  - Multi-access unsynchronized networks
- FYI, NURC is looking for partners

Channel Characterization

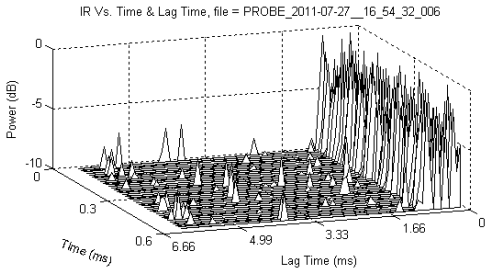


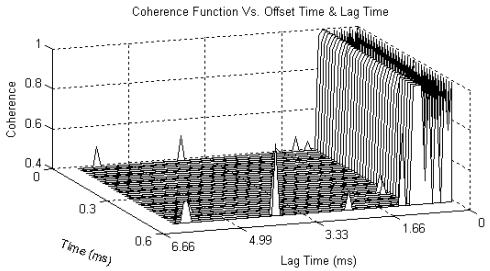




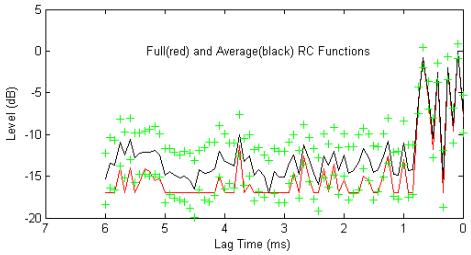


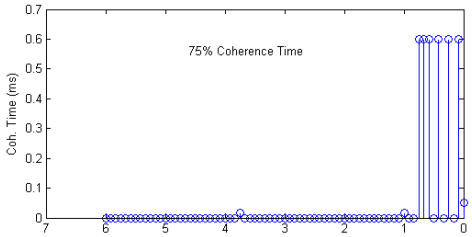
Channel Characterization



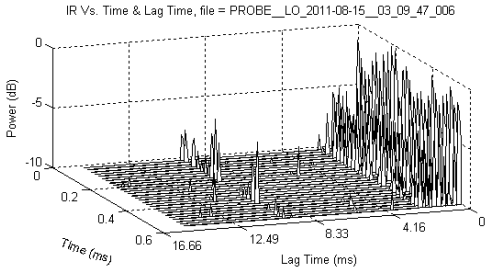


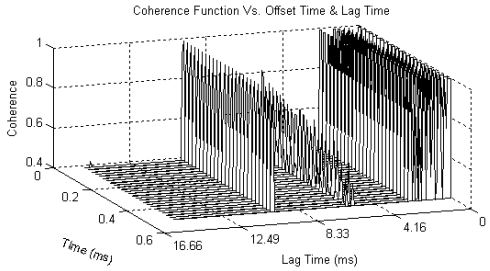
A benign moment in the bay

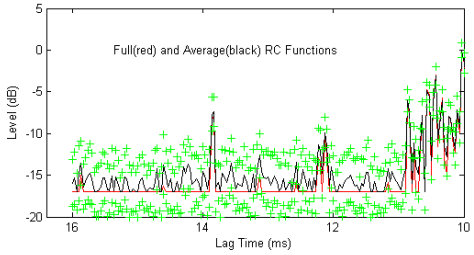


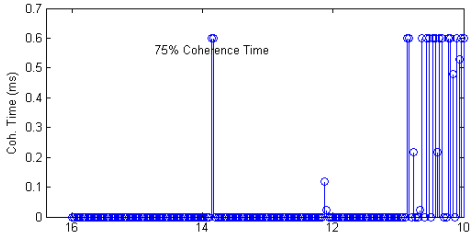


Some extra multipath momentarily present

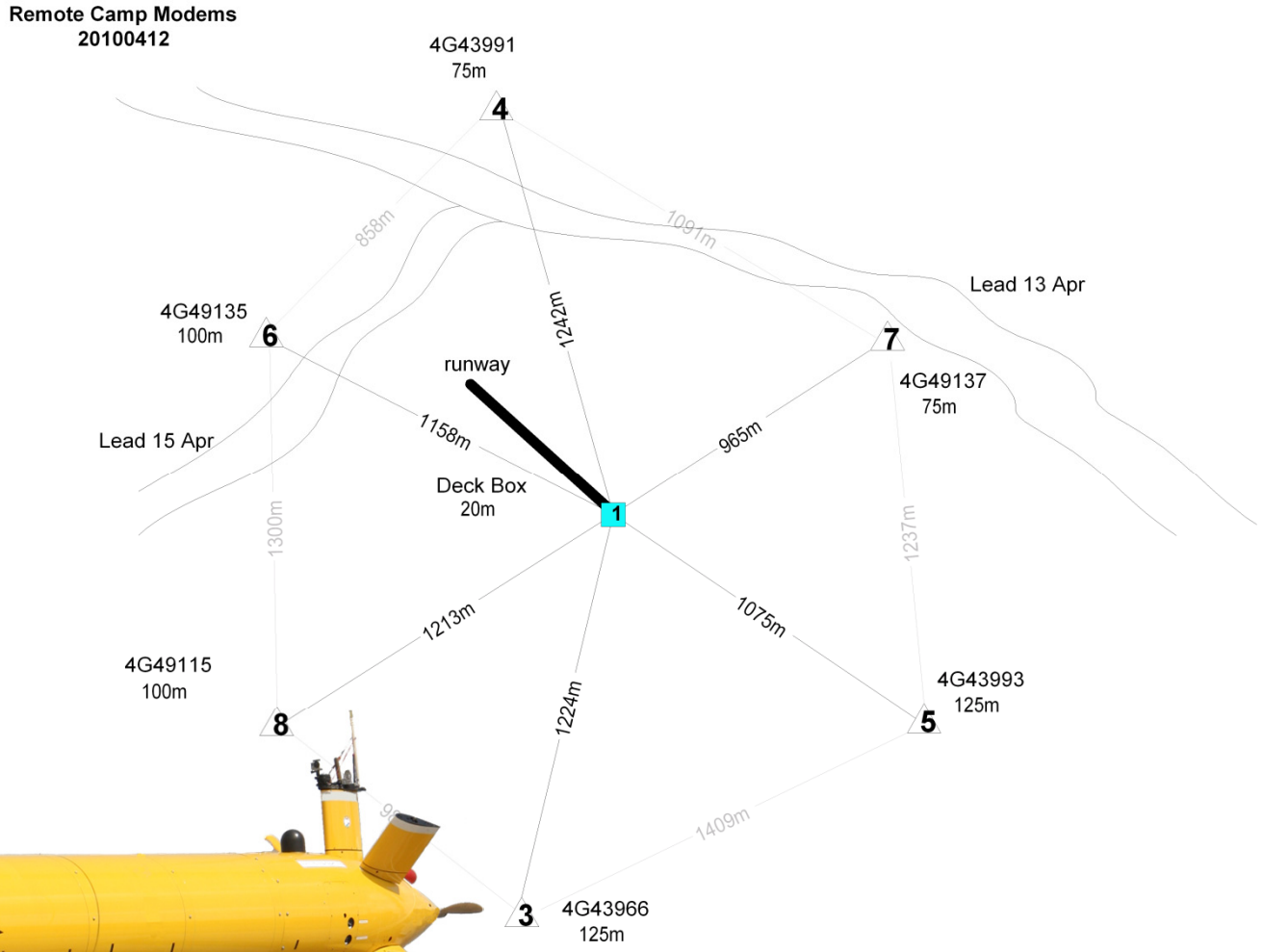








Under Ice Navigation and ACOMMS
DRDC Canada

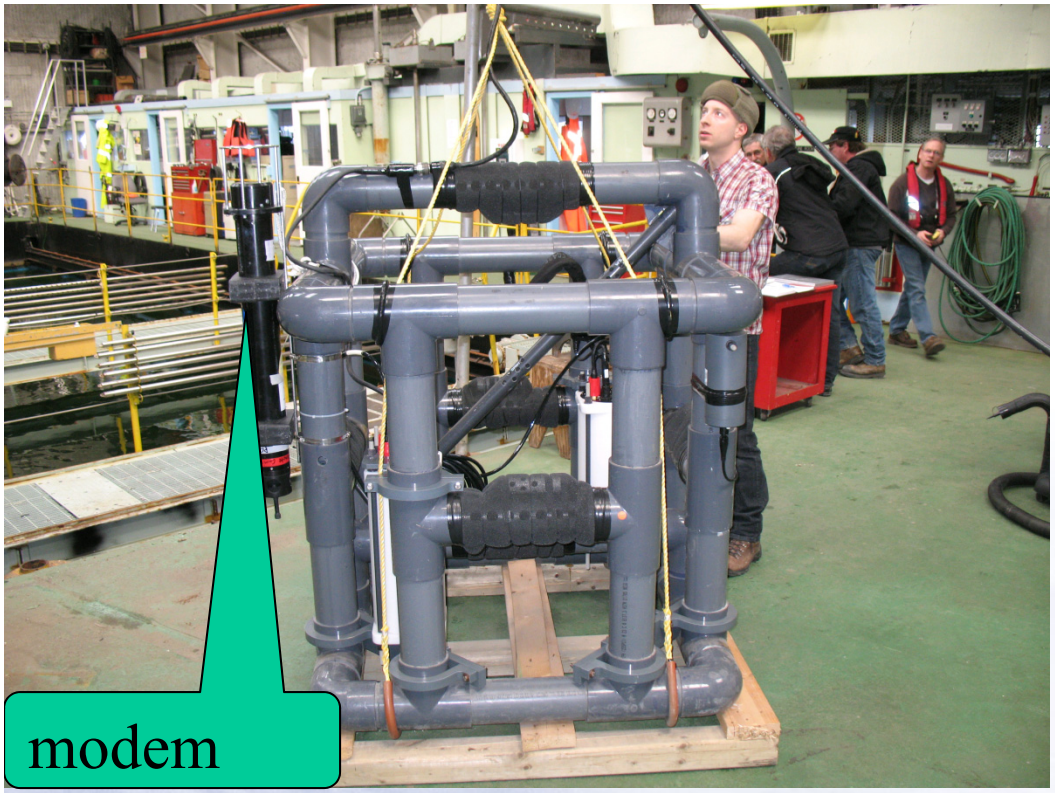


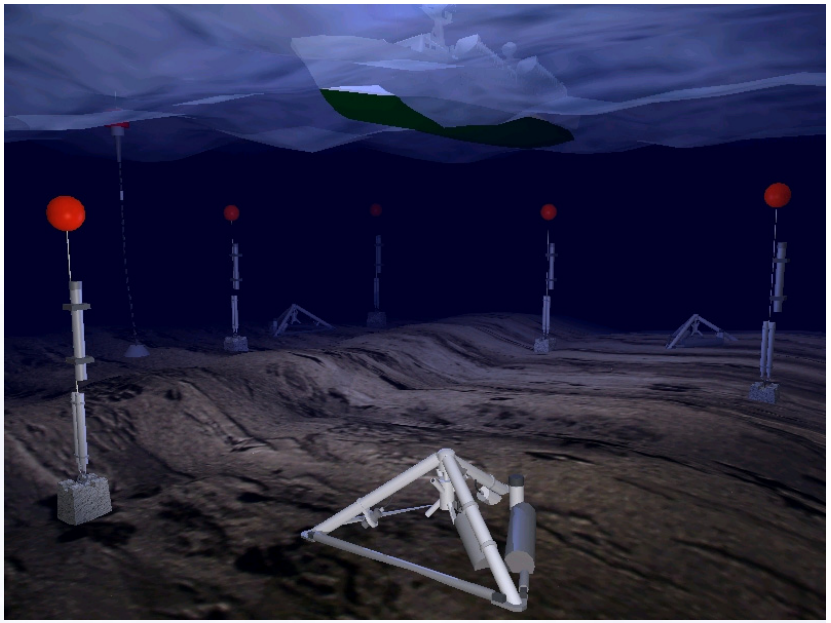
Modems, top & bottom

TELEDYNE BENTHOS
A Teledyne Technologies Company

www.benthos.com

Under Ice Navigation & Acomms





Just an update (unofficial but reliable) on the modem use up in the arctic on the AUV for command and control. Modem on AUV was at 3600 meters depth and surface modem was between 10 meters and 450 meters. "Very good telemetry was obtained out to a distance of approximately 15km" at which time the modem was turned off as per mission specification.

Existing and Soon-to-be Acomms schemes

- Present Capabilities (5 kHz band, 11.5, 18, 25 kHz center frequencies)
  - Multi-channel, MFSK: 140, 300, 600, 800, 1200 bps
  - MPSK: 2560, 5120, 10K bps
- Coming Capabilities (6 months)
  - JANUS 80 bps
  - Differential OFDM (binary, quadrature) : 950, 1850, 3700 bps

- Some Examples of D-OFDM Performance

THE TEST FACILITY IS DOWN

However, D-OFDM shows real promise. At 11.5 kHz center frequency, 5 kHz bandwidth, it tolerates 0.25 kt uncompensated range rate.

We automatically correct to within 0.5 kt
But D-OFDM offers excellent methods for tracking and removal of residual compression/dilation.

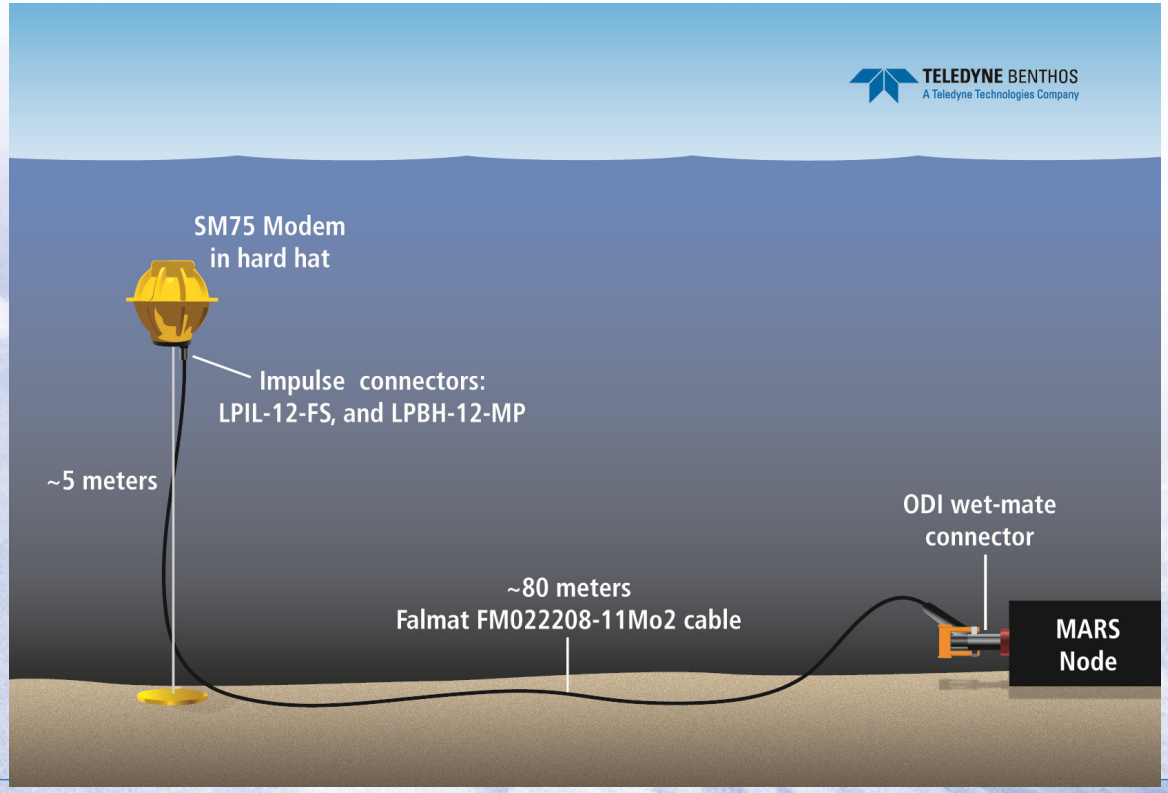
Requires higher SNR than fully coherent OFDM, but no extraneous tracking symbols required. Receiver design is MUCH easier.

Recommend repetition coding for severe multipath

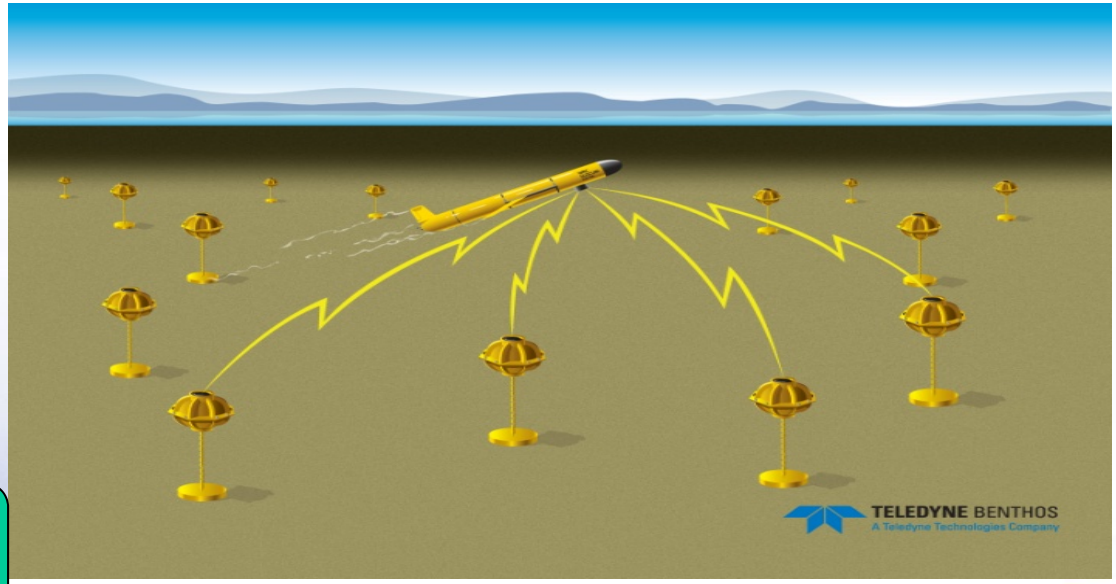
Ocean Observatories

We are participating in Ocean Observatories in 3 ways

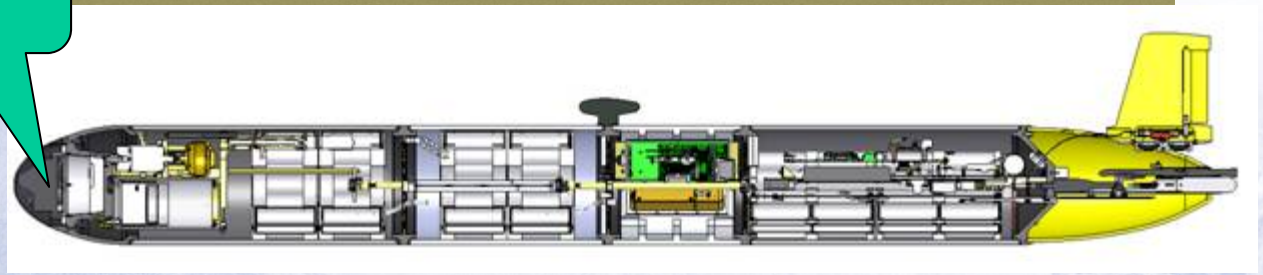
1. Permanent modem installations
2. Gliders as data trucks
3. Bio-energy harvesting



Data Truck with the Teledyne Webb Slocum Glider

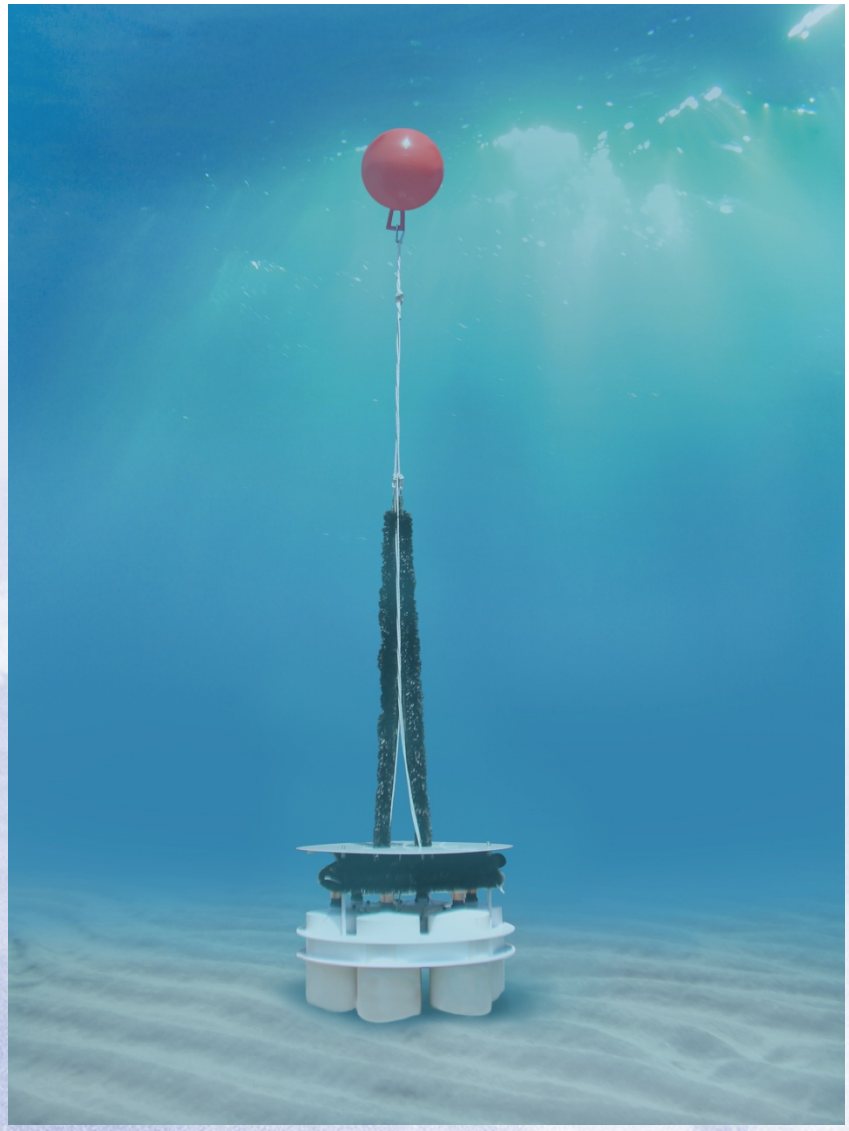


Modem



US Navy has purchased ~ 200 gliders, 25 with modems

Benthic Microbial Fuel Cell (BMFC)



Actual photo, superimposed on an aqueous background

Working with Oregon State University, Harvard, and ONR, we have (just) deployed two BMFCs, each with integrated modem & Power Management Platform (PMP) – at the MARS Observatory

Powers an optode, a temperature sensor & a modem

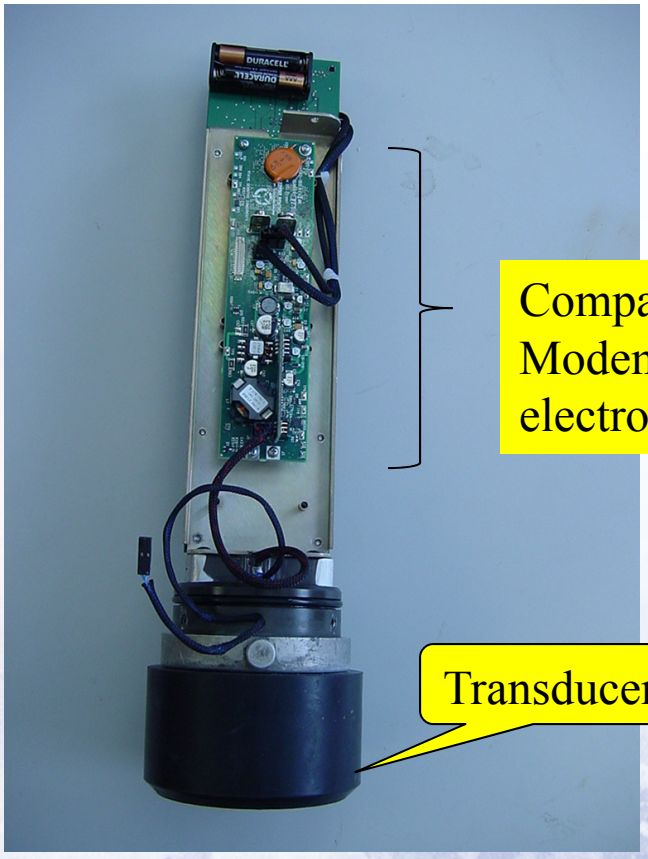
Power management and integration with undersea systems

…”significant power fluctuations appear to be a common feature of all chambered BMFC deployments regardless of where they are deployed. Regardless of the underlying cause, variable power generation affects the requirement for power management devices in that they must be able to store fluctuating levels of power for subsequent use in powering a sensor with steady or variable demands.”

[Girguis, Nielsen, & Reimers, “Fundamentals of Benthic Microbial Fuel Cells: theory, development and application”]

Front and back photos of modem/power management board

Power Management Board



Conclusions

- Robust Acomms
- Careful thought reveals (?) that most underwater applications can make do with lower data rate links.
- The channel often (frequently) will not support high rate, coherent comms, or the dsp infrastructure is too complex, or too energy consuming.
- Our customers generally want physically small, battery-powered, energy-efficient acomms. They will sacrifice data rate for robustness.
- Navigation Aids: Acomms *per se* isn't too interesting anymore – it is becoming commonplace.
- A wideband modem provides the waveforms and dsp infrastructure required for robust, flexible and high precision navigation aids – while still providing real-time communications.
- Arbitrary Waveform Transmission & Data Recording
- Channel characterization: tools available for understanding time-varying scattering function with each and every transmission