Are Acoustic Communications the Right Answer?

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Background

- BS in Electrical and Computer Engineering, Cornell university 2002
- MS in Electrical and Computer Engineering, Johns Hopkins 2005
- Hardware Engineer, JHUAPL 2002-2005
- PhD Candidate, MIT/WHOI Joint Program

Motivation

- Starting Research
  - Had not examined issue before
- Good for proposals
  - Can’t do anything without money
- Interested in Results

Acoustic Communications

- De facto standard
  - Appropriate size, power, and scale
  - Question not formally studied

- Large Knowledge Base
  - Acoustics channel well studied
  - DoD funding

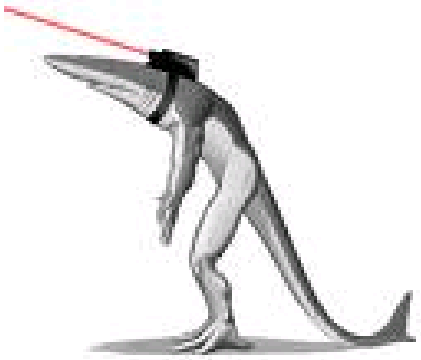
Alternatives – Radio Frequency (RF)

- Pros
  - Same as terrestrial wireless communications
  - “Low” power
- Cons
  - High attenuation in short distance (~60dB/m+)
- Notes
  - Argument in literature about attenuation
  - Commercial systems available

Alternatives – Low Frequency EM

- Pros
  - Travels through water
  - Successfully tested and used
- Cons
  - Massive antennas needed for TX/RX
  - Band owned by military
  - Not practical for small vehicles / two way comms
- Notes
  - Al-Shamma'a, *IEEE Trans on Antennas and Propogation 2004*

Alternatives – Lasers / LED



- Pros
  - High data rates (kbps-Mbps)
  - Low power
- Cons
  - Distance limited due to attenuation (~100m)
  - Narrow bandwidth of light
  - Cloudy water / fish / Line of sight
  - Pointing and tracking
- Notes
  - WHOI working on laser modem (good results)
  - MIT some success with combined acoustic / LED
  - Application Specific

Alternatives - Cables

- Pros
  - Not much environmental effect
  - High data rates
  - Reliable
- Cons
  - Expensive to deploy/recover/repair
  - Not mobile

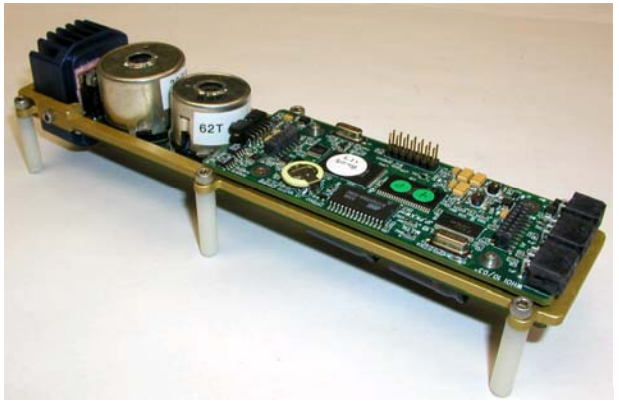
Alternatives – Other

- Magnetic Field Communications
  - Still in development (Canadian company)
  - Short range communications (assume <1km)

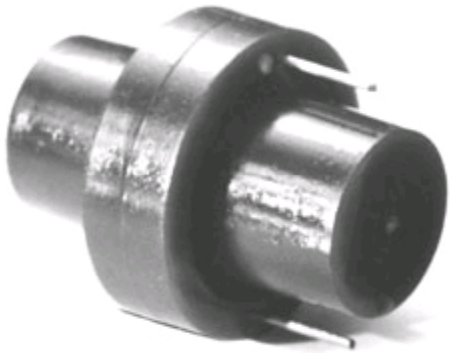
- Other alternatives?
  - Alternative technology may exist

Acoustics is the solution

- Fairly low power
  - ~10-100W Tx
  - ~100 mW Rx
- Well studied
  - Cold war military funding
- Compact
  - Small amount of hardware needed
- Current Best Solution



WHOI Micromodem

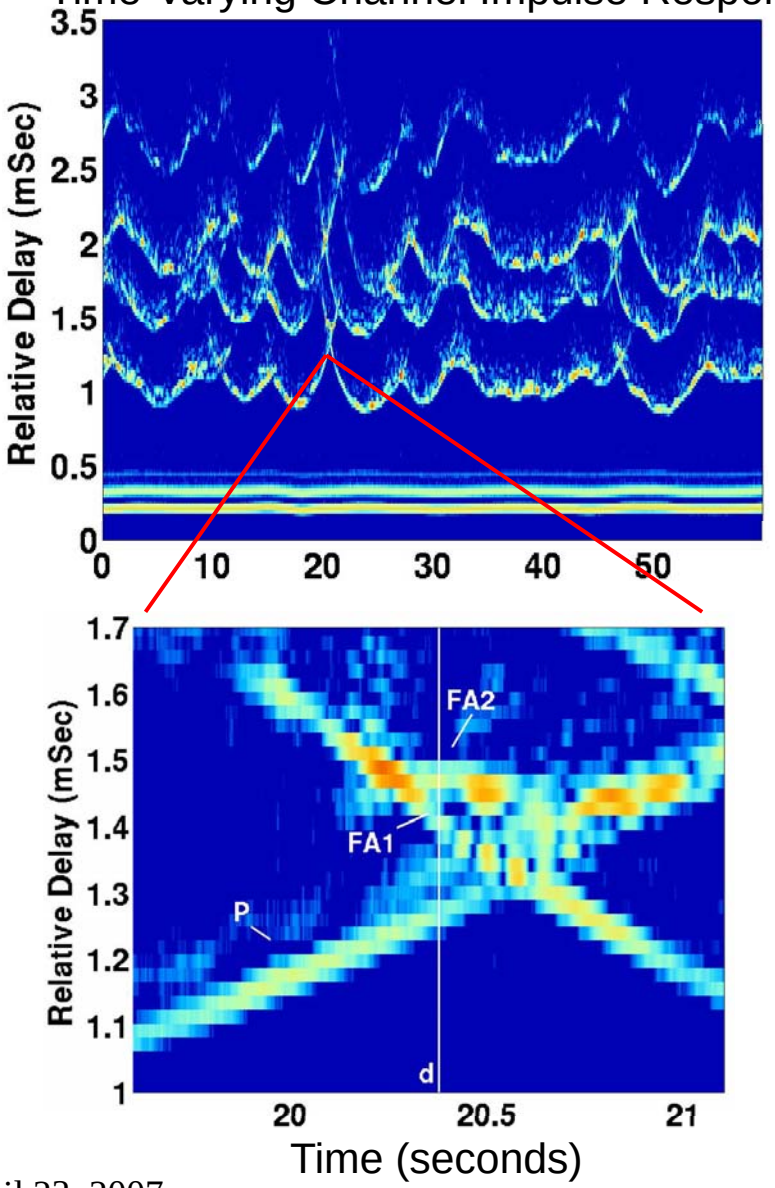


AComms Problems - Channel

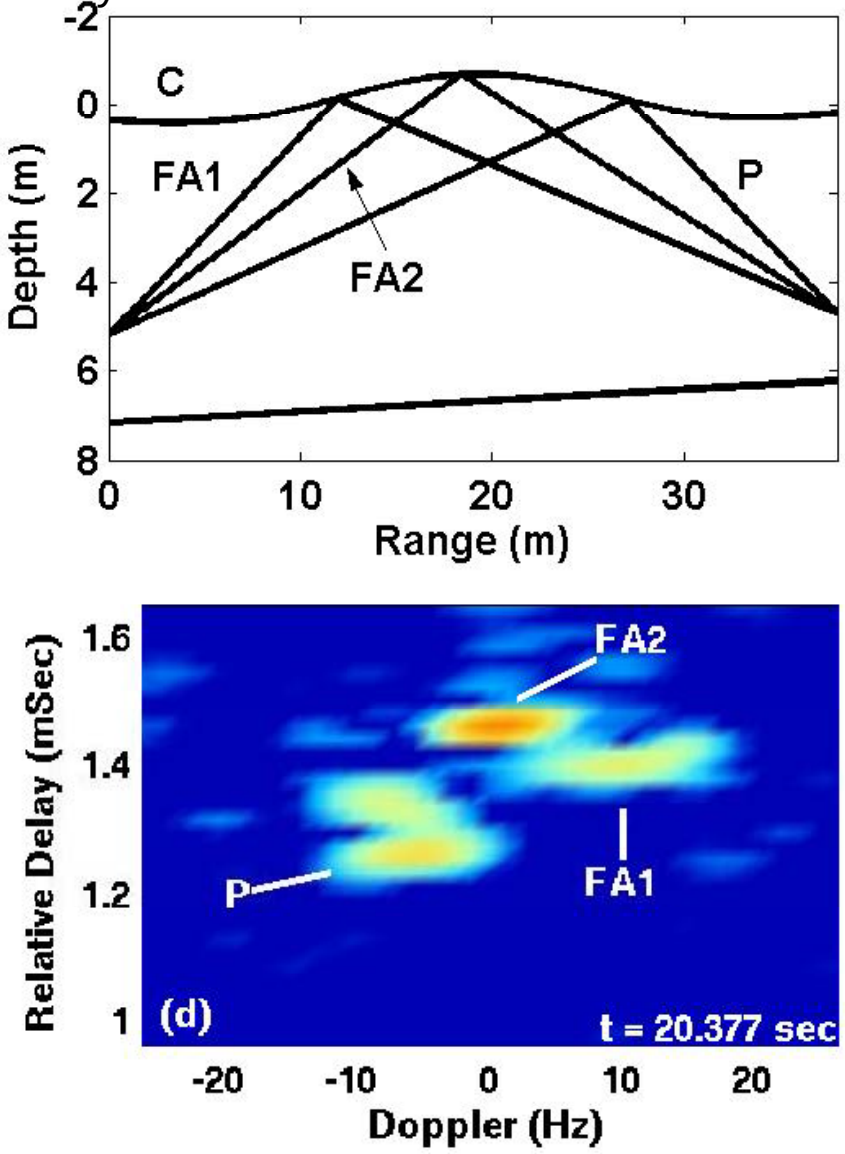
- Channel Tracking
  - Complex, random channel
  - Necessary for reliable communications
- Bandwidth
  - Distance Dependant
  - Band-limited and wide-band
- Speed of Sound / Propagation Paths
  - Shadow Zones
- Attenuation
- Noise
  - Natural and man-made sources
  - Bubbles

Acoustic Focusing by Surface Waves

Time-Varying Channel Impulse Response

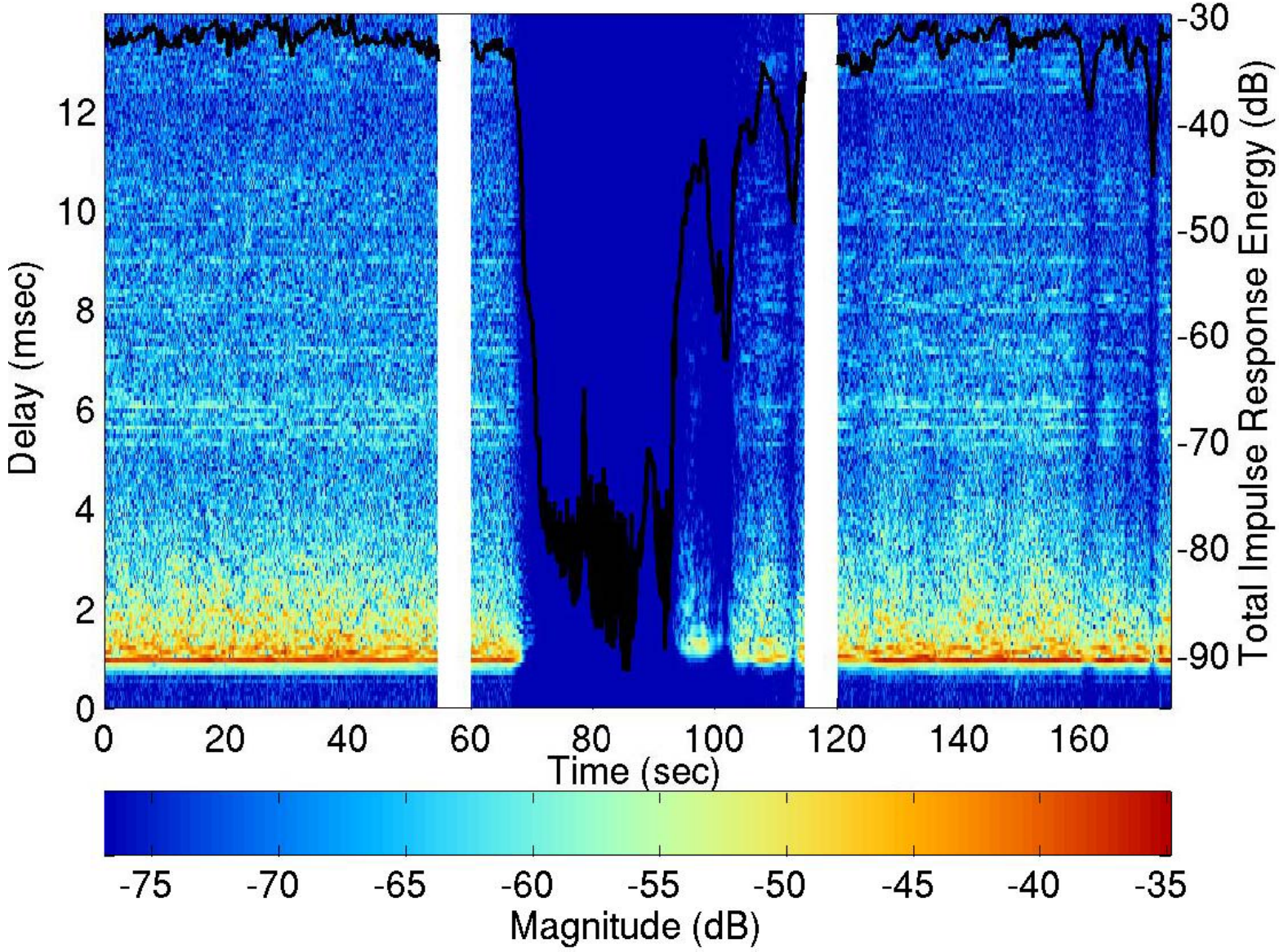


Dynamics of the first surface scattered arrival

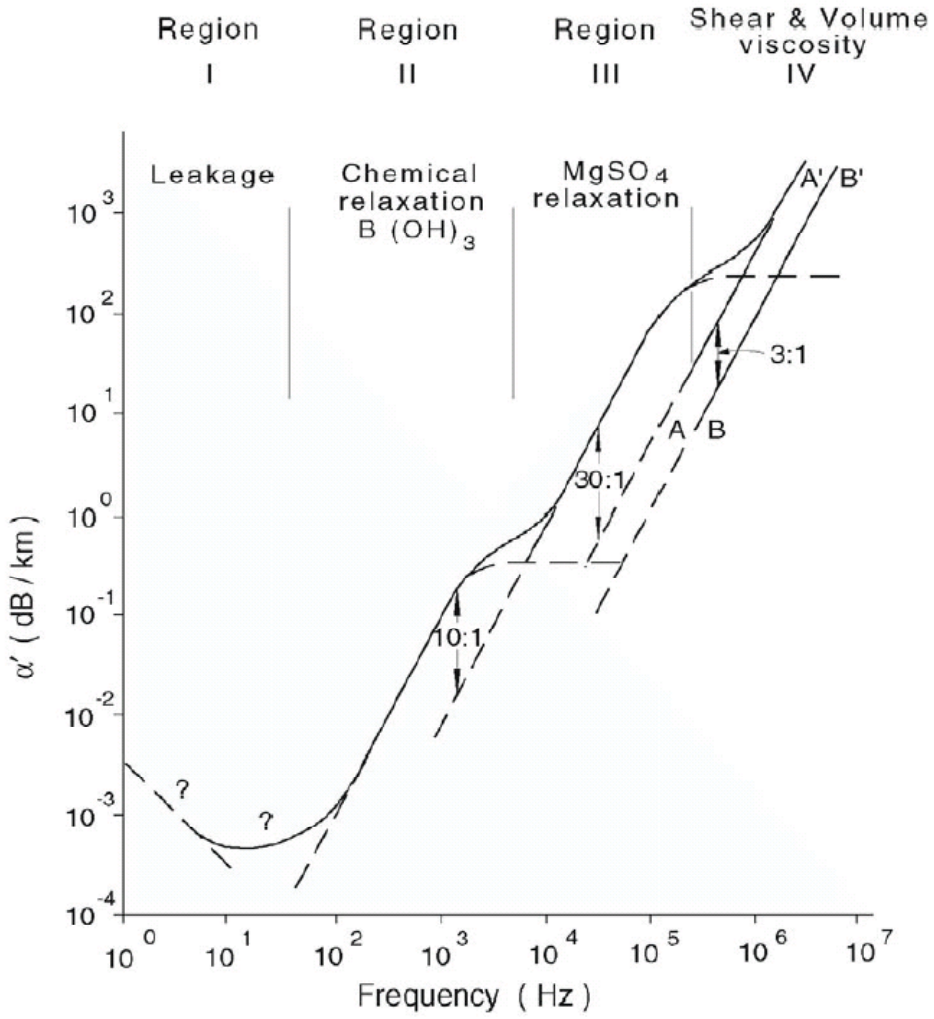


Preisig, 2006

Bubble Cloud Attenuation



Attenuation of Sound in Seawater

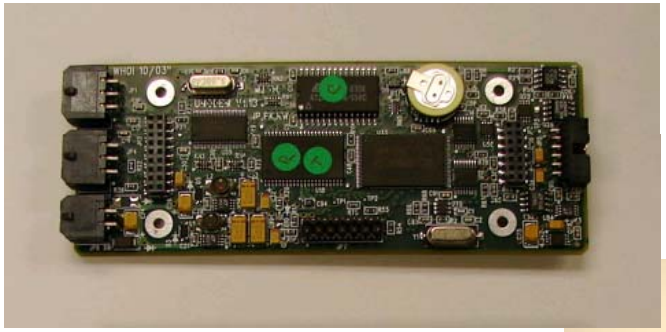


Schmidt, *Computational Ocean Acoustics*

Acomms Problems - Latency and Power

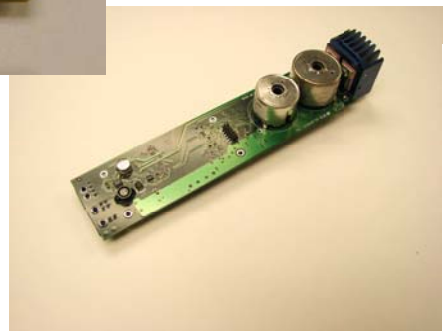
- Propagation of sound slower than light
  - Feedback might take several second
  - Channel changing faster than feedback
- Most underwater nodes battery powered
  - Communications Tx power (~10-100W)
  - Retransmissions costly

Example Hardware

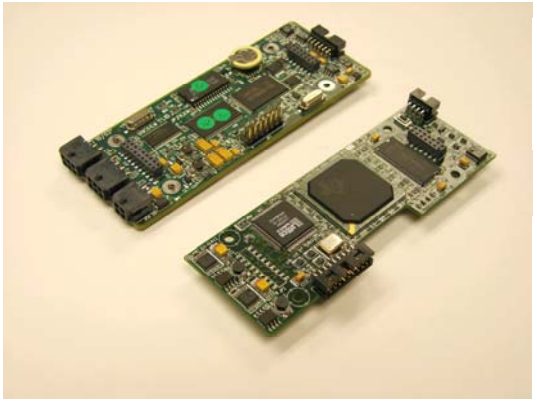


WHOI Micromodem

Power Amp



Micromodem in action

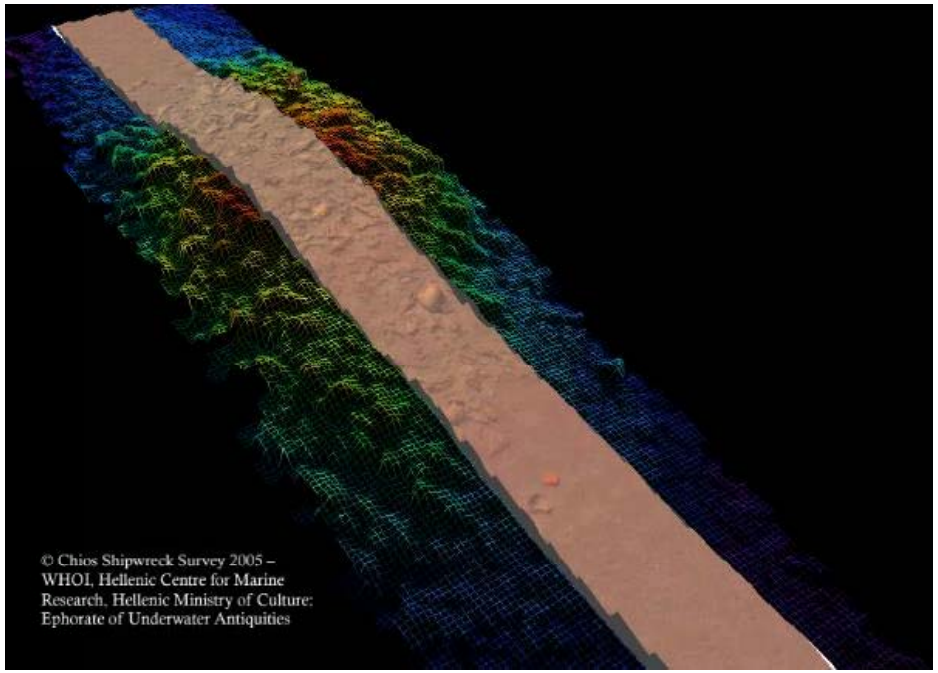


Daughter Card / Co-processor

Micromodem Specifications

DSP	Texas Instruments TMS320C5416 100MHz low-power fixed point processor
Transmit Power	10 Watts Typical match to single omni-directional ceramic transducer.
Receive Power	80 milliwatts While detecting or decoding an low rate FSK packet.
Data Rate	80-5400 bps 5 packet types supported. Data rates higher than 80bps FSK require additional co-processor card to be received.

Current Micromodem Applications - Seabed



WHOI, 2005

- Low Rate Communications (256 bps, 32 bytes per packet)
  - Telemetry return – XYZ, Roll, Pitch, Heading, Goal #
  - More complex telemetry not possible
- Polling scheme (crude)
  - No interrupt for Commands
- Only one command - abort

More Current Micromodem Applications

- Autonomous Kayaks
- PLUSnet (gliders, AUVs)
- ONR (Remus)

WHOI Acoustic group

Other Current Acomms Applications

- Science
  - Geological / bathymetric surveys
  - Underwater archeology
  - Ocean current measurement
  - Deep ocean exploration
- Government
  - Fish population management
  - Costal inspection
- Industry
  - Oil field discovery maintenance

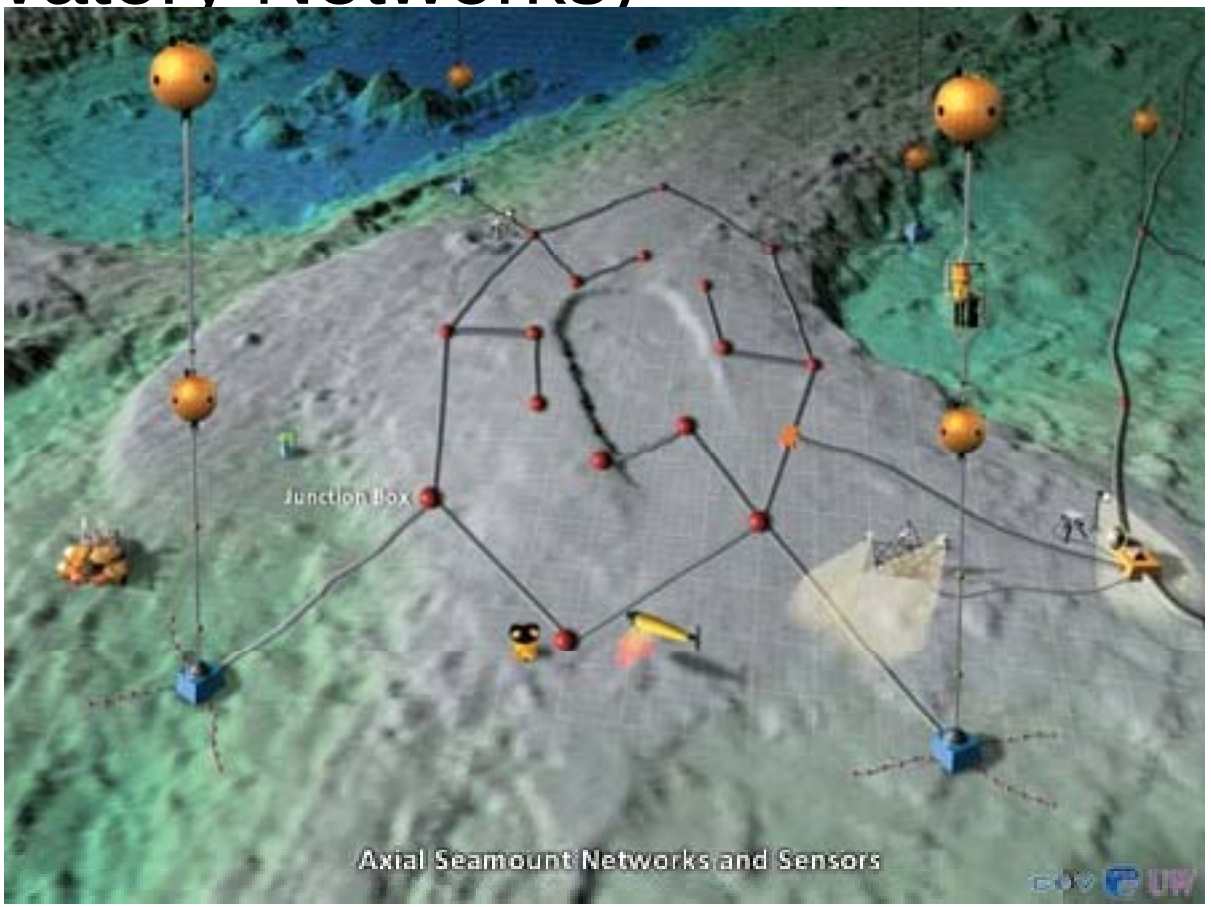
Future Applications

- Jaguar and PUMA (Arctic exploration)
  - Still primitive

WHOI, 2006

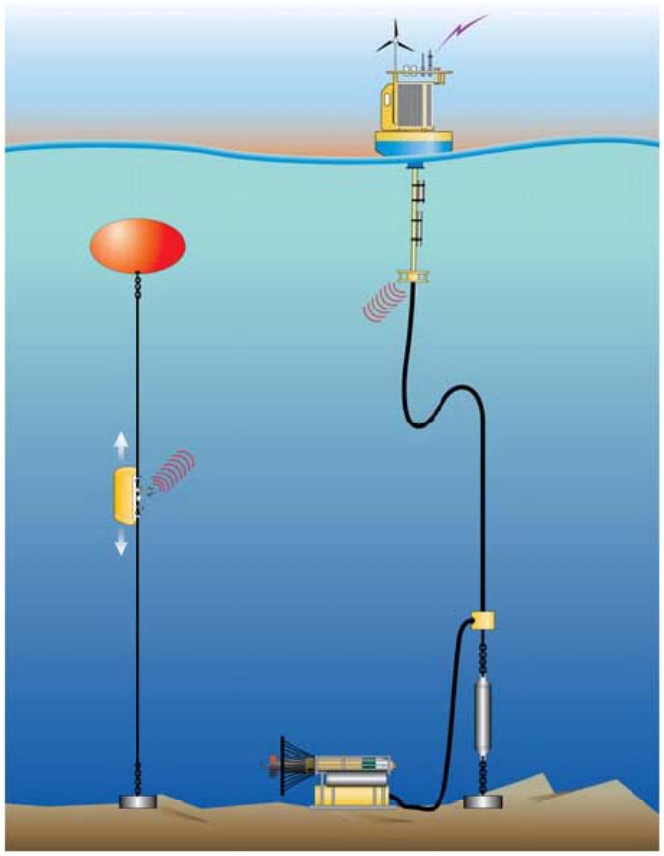
Future Applications -ORION

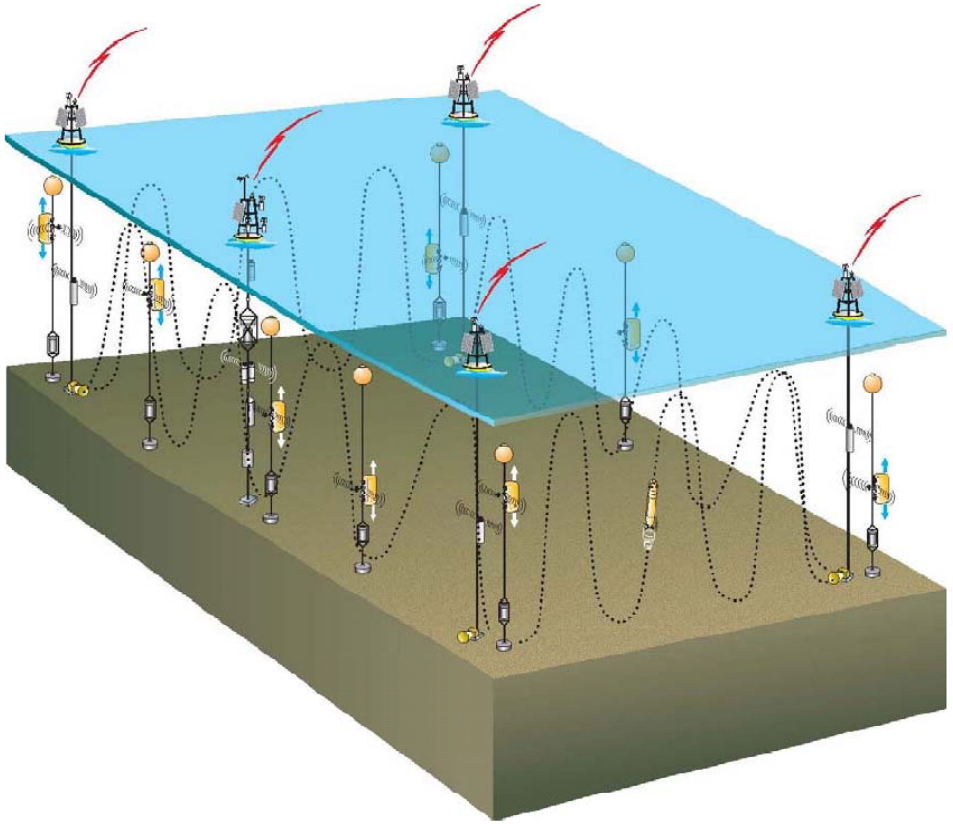
- ORION (Ocean Research Interactive Observatory Networks)



WHOI, 2005

Future Applications – ORION





ORION Project Literature

Applications planned / in development

- Ocean observation system
  - Costal observation
- Military
  - Submarine communications (covert)
  - Ship inspection
- Networking
  - Mobile sensor networks (DARPA)
- Vehicle deployment
  - Multiple vehicles deployed simultaneously

Acomms – Research Thoughts

- Communications and Ranging
  - Intimately tied
  - Common solution
- Underwater Networking
  - Short jumps, larger bandwidth, higher freq.
  - Complex Routing Algorithms
- Multiple AUV
  - Resource Sharing
  - Efficient message passing

My Current research

- Channel Coding
  - LDPC Codes

$$H = \begin{pmatrix} 0&0&1&0&1&0&0&0&0&0&0&1&0&0&1&0&0&1&0&0 \\ 1&0&0&0&0&0&1&0&1&0&0&0&0&1&0&0&1&0&0&0 \\ 0&1&0&0&0&1&0&0&0&0&1&0&1&0&0&0&0&0&1&0 \\ 0&0&0&1&0&0&0&1&0&1&0&0&0&0&0&1&0&0&0&1 \\ 0&1&0&0&0&0&0&1&0&0&0&1&0&0&0&1&0&1&0&0 \\ 0&0&1&0&1&0&0&0&0&1&0&0&1&0&0&0&0&0&1&0 \\ 1&0&0&0&0&0&1&0&0&0&1&0&0&0&1&0&1&0&0&0 \\ 0&0&0&1&0&1&0&0&1&0&0&0&0&1&0&0&0&0&0&1 \end{pmatrix}$$

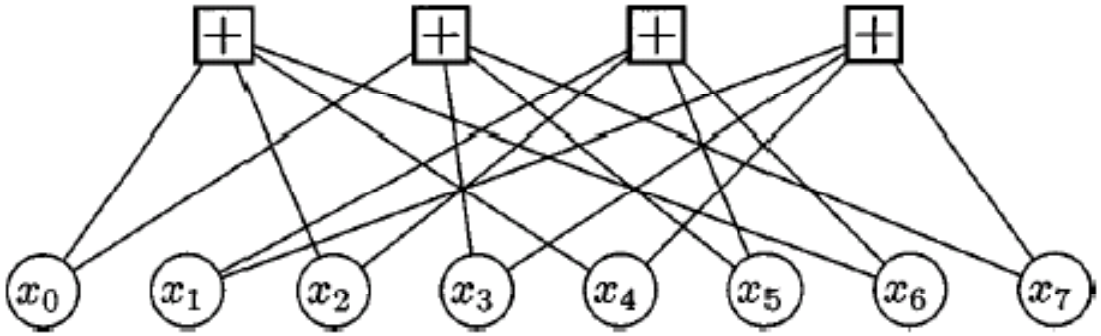


Fig. 17. A factor graph for a LDPC code.

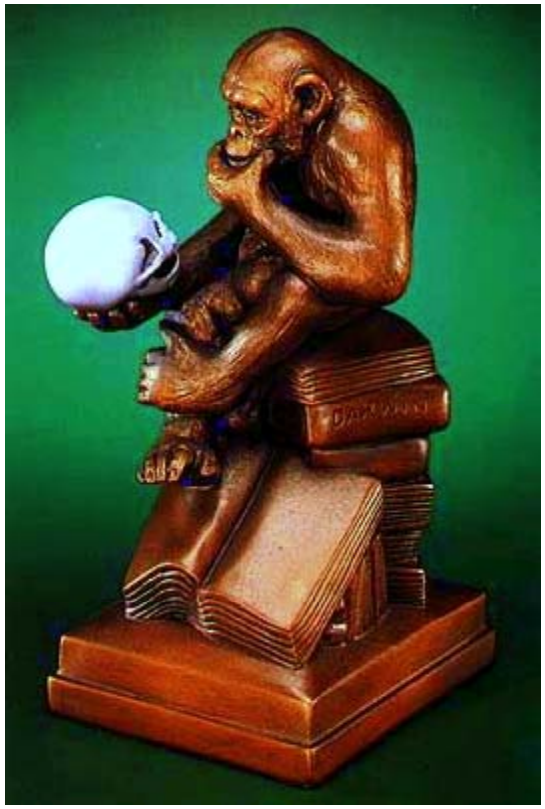
Kschischang, *Trans of Info Theory, 2001*

Conclusions

- Acoustic communications
  - Current “best” solution (most universal)
  - Still not an easy problem

- Acomms research and Application
  - Many exciting things happening
  - Much more to come

Questions?



http://www.ukuleleman.net/2005_08_01_ukemanspeaks_archive.html