What are we trying to build?  
An effective physical layer communication protocol for underwater communication between 2 nodes.

Layering

Modulation schemes

Problems

-Current data rates are low??

-sever dispersion in tume and frequency, multipath

-susceptibility to doppler impairments

-Robust error control coding

Current technologies and state of the art:

Innovations:

Transmitter side:

QCSK modulation

Error control coding (Turbo codes)

Adaptive tranmission- based on measuring and modelling the actual channel conditions

2 modes- Janus (robust but slow) and the main link mode

Packet structure: IITMSAT?

-channel characterization and channel modelling

Selling points:

-Data rate

-range

-efficiency

Applications:

The proposed Adaptive UWA Modem combines the following features:

- Channel characterization through measurements of environmental parameters such as temperature, and salinity

- Channel modeling (communication parameters) - delay spread, Doppler spread, coherence time, coherence BW, and spatial coherence

- A hybrid transceiver that employs Doppler tolerant waveforms such as Hyperbolic FM to estimate the channel conditions and employs spectrally efficient techniques (such as Index Modulated OFDM and MIMO) for transmission of data

- Incorporation of the latest developments in Forward Error Correction (Turbo codes, Fountain codes)

- Adaptive transmission (3 modes – high data rate (favourable channel conditions), medium data (moderate channel), low date rate (robust) mode (adverse channel) – which optimizes the transmission under each of the channel conditions

Robust DSP techniques need to be employed in the transmitter and receiver in order to meet the demand for high data rate and long range modems for defence and civilian applications.

* 1. Development of the Modem Algorithms (Matlab) – for each of the three modes. This will involve a. Channel modeling – using robust techniques such as Hyperbolic FM for synchronization, resampling, CFO compensation
  2. b. Evaluation of modulation options and receiver algorithms (special focus on Index Modulated OFDM for high spectral efficiency). IM-OFDM is a way by which additional information is carried by the indices of the active/inactive subcarriers.
  3. c. Incorporation of state-of-the-art (Turbo and Fountain codes)

1. Channel modeling - developing simulation models and running tests along with NPOL. The simulation models will use software from the Ocean Acoustics Library (http://oalib.hlsresearch.com) to simulate sample channel responses for a 100~m deep, 5-6 Km long communication channel.

* Integrate information about sound speed variability to improve communication ranges.
* • Use propagation models to predict the channel responses
  1. • Optimal combination of modulation method, transmission rate (BW, Carrier frequency) o High data rate (favourable channel conditions)
  2. o Medium data (moderate channel)
  3. o Low date rate (robust) mode (adverse channel)
  4. • Depending on channel conditions, the modem switches between three modes. The metrics for switching between modes and the switching mechanism will be proposed.
  5. • In the high (and medium) data rate modes, variants of OFDM (including Index Modulated OFDM) will be used. Algorithms for the compensation of Inter Carrier Interference in OFDM will be developed.
  6. • In the low data rate mode, Pulse Compression Waveforms (PCW) will be used. PCW (such as Hyperbolic FM) are tolerant to Doppler Time Scaling encountered in UWA channels and enable accurate time synchronization. These robust techniques will be used in combination with the high and medium data rate modes.
* 
* Adaptive – based on measuring and modeling the actual channel conditions
  1. • Robust modem with three modes o High – Medium – Low data rates with correspondingly increasing ranges
  2. • Optimization of the high data rate with high spectral efficiency modes such as Index Modulated OFDM
  3. • Robust performance (BER < 1.0^-5) via state-of-the-art error correction techniques (Turbo codes, Fountain codes)
  4. • Hybrid operation – robust mode for channel

The need for underwater wireless communications exists in applications such as remote con-trol in off-shore oil and gas industry, pollution and climatemonitoring in environmental sys-tems, defense, collection of scientific data recorded at ocean-bottom stations and unmannedunderwater vehicles, speech transmission between divers,and mapping of the ocean floor fordetection of objects and discovery of new resources. Wireless underwater communicationscan be established by transmission of acoustic waves. The underwater acoustic communica-tion channels, however, have limited bandwidth, and often cause signal dispersion in timeand frequency [1], [2], [3]. Despite these limitations, underwater acoustic communicationsare a rapidly growing field of research and engineering.

Frequency-dependent attenuation, multipath propaga-tion, and low speed of sound (about 1500 m/s) which results ina severe Doppler effect, makethe underwater acoustic channel one of the most challengingcommunication media.

his device used a single-sideband (SSB) suppressed carrier amplitude modulation in the 8kHz-11 kHz frequency range

Specifically, these techniques may beclassified according to (1) the signal design, i.e. the choice of modulation/detection method,and (2) the transmitter/receiver structuree, i.e. the choice of array processing method andthe equalization method, if any

Synchronization??

3.UNDERWATERCHANNELMODELSInordertob eabletop erformunderwateracousticcommunication,itisimp ortanttounderstan dwhathapp en stothesignalonitswayfr omthetransmitt ertothereceiver;knowledgeofthephysicalpr op ertiesoftheunderwat ermediumiscr ucialandplaysakeyr oleindesigningcommunicationsystems.Verysimplemod elswillb eusedher etosimulat etheUWAchannel’sambientnoise,transmissionlossduetogeomet ricalscatter ingandab sorption,reverb erationduetomultipat h,andDopplerspreadingd uetorelativemotion.Duetother an domnatureoftheunderwat ermediastatisticalmo delsar eusedtomo deltheAUWchannelforsimulationofcommunicat ionssystems.Manyr esearchersusetheAdditiveWhiteGaussianNoise(AWGN)tomo deltheambientnoiseinunder waterchannels.2,5 ,10 ,11 ,22I ns om eca s es,au t h or sal sou set h eG a u ss ia ndistributiontomo delthephaseshiftort hetimedelay.2Someauthorsb elievethatthedelayandthephaseshiftarestableenoughthattheycanb econsideredtob edeterministic3;wefollowt hisappr oach.Duetofad ingmultipat hcharacteristicsoft heunderwat erchannel,manyresearchesh avepr eferr edtomo deltheunderwaterchannelusingnon-Gaussianmo dels.Some,aswed o,b elievet hatthechannelamplituderesp onsecanb emod eledbyaRayleighdistr ibution2,2 5alt houghtherearestilld isagreements.4

Communication based on feedback from the receiver side thru Janus protocol.

Synchronization??

Packet Structure.

Abstract—Progress in underwater acoustic telemetry since1982 is reviewed within a framework of six current researchareas: 1) underwater channel physics, channel simulations, andmeasurements; 2) receiver structures; 3) diversity exploitation;4) error control coding; 5) networked systems; and 6) alternativemodulation strategies. Advances in each of these areas as well asperspectives on the future challenges facing them are presented.

Company collobarations:

Planys technologies

C. Channel ModelingA good understanding of the com-munications channel is important in the design and simulation of a communica-tion system. A good review of channel modeling work prior to the year 2000 has been presented in Bjerrum-Niese and Lutzen (2000).

Spatial Modulation

Equalization

Recently, many academic and industrial researchers have worked on the improvement of UWC systems by augmenting them with state-of-the-art information and communication technologies. There have been reports of new results and insight on the fundamental theories and practical implementations of UWC systems, i.e., UWC channel models and estimation, digital signal processing, advanced transceiver design, multiple access (MAC), and routing and upper-layer protocols, aswell as successful cross-layer design implementations

Market feasibility checks:

Current technologies in the market:

Different specs for vertical and horizontal

Horizontal mode- less forgiving

The Evaluation parameters (data rate, range, SNR, BER and other features) depend on the following factors

Depth

Directivity of the antenna

Frequency

|  |  |
| --- | --- |
| Operating Range | 3500 m |
| Frequency Band | 18 - 34 kHz |
| Transducer Beam Pattern | horizontally omnidirectional  (18/34 and 18/34D) hemispherical (18/34H) |

**Connection**

| Acoustic Connection | up to 13.9 kbit/s |
| --- | --- |
| Bit Error Rate | less than 10-¹⁰ |

<https://evologics.de/acoustic-modem/18-34>

### ECHNICAL SPECIFICATIONS

#### General

| Operating Depth |  |
| --- | --- |
| Delrin housing | 200 m |
| Aluminium Alloy housing | 2000 m |
| Stainless Steel housing | 2000 m |
| Titanium housing | 6000 m |
| Operating Range | 6000 m |
| Frequency Band | 15 - 27 kHz |
| Transducer Beam Pattern | wide-angle, 120 degrees |

#### Connection

| Acoustic Connection | up to 9.2 kbit/s |
| --- | --- |
| Bit Error Rate | less than 10-¹⁰ |
| Internal Data Buffer | 1 MB, configurable |

<https://evologics.de/acoustic-modem/15-27>

**General**

| Operating Depth |  |
| --- | --- |
| Delrin housing | 200 m |
| Aluminium Alloy housing | 2000 m |
| Stainless Steel housing | 2000 m |
| Titanium housing | 6000 m (10000 m for 7/17D) |
| Operating Range | 8000 m (10000 m for 7/17D) |
| Frequency Band | 7 - 17 kHz |
| Transducer Beam Pattern | hemispherical (7/17)  directional, 80 degrees (7/17D) hemispherical (7/17W) |

**Connection**

| Acoustic Connection | up to 6.9 kbit/s |
| --- | --- |
| Bit Error Rate | less than 10-¹⁰ |
| Internal Data Buffer | 1 MB, configurable |

Horizontal

Our specs:

Depends on applications. We are trying to make it as versatile as possible.

Tradeoff between range and data rate

Range: 1-5 Km

Depth: 2000m

Horizontal:

Directivity: omnidirectional??

<https://dspcommgen2.com/aquacomm-underwater-wireless-modem/>

<http://www.teledynemarine.com/acoustic-modems>

|  |  |
| --- | --- |
| **Parameter** | **Details** |
| Data rates | 100 or 480 bits per second depending on model |
| Bit Error Rate | 10-6 bit error rate or better |
| Acoustic Doppler Tolerance | High immunity to noise and to multi-path and Doppler fading. Acoustic Doppler tolerance of +/- 5ms-1 (approximately +/-10 knots) |
| Bandwidth | Broadband operation 16Khz to 30Khz. Other operational bandwidths available |
| Range | Underwater acoustic modems tested to 3km range. Longer ranges possible up to 5km. Available in high power version with 30W transmit power. |
| Modulation | Direct sequence spread spectrum / OFDM |
| Error detection | CRC16 error detection |
| Through water communications protocol | ·         Confirmed packet delivery with error detection. If the transmitting end does not receive an acknowledgement, it will resend the data two more times. Number of retries is configurable.  ·         Transparent data transfer mode – ideal for instrumentation  ·         Low power – transparent data transfer mode (consumes 1/10th the stand by power) |
| Addressing | Uniquely addressable. Six digit numeric address set through host command. Million possible addresses. |
| Receive sensitivity | Ability to set the receive sensitivity |
| Transmit power | Ability to set the transmit power level |
| Physical size | 8cm x 7cm x 1.5cm (excluding Transformer ) |
| Electronics | Digital signal processor based |
| Power supply input voltage | DC 5V to 12V |
| Current consumption @ 6V DC | 24mA (nominal) in normal wake operation 2.4mA in power save receive Less than 150uA in sleep model |
| External connections | 10 pin KK header to connect power, host communications, reset line and wake up line 2 pin terminal to connect hydrophone transducer |
| Host communications | ·         RS232 serial communications. 9600 baud (default),1 start bit, 1 stop bit, no parity 4800, 2400 or 1200 baud programmable Either TTL voltage levels (3.3V) or RS232 voltage levels selectable·         Optional RS485 available |
| Host command | Simple ASCII command set to configure and command the modem |
| Temperature range | -5 degC to +50 degC |

<https://www.sonardyne.com/product/underwater-acoustic-modems/>

channel estimation-pilot coding

synchro, control and stuff

equalization

feedback from receiver

more than 2 modes??

Like long beacon or something

Specific applications- based on that?