



Verification of multi-carrier modulation scheme for shallow water acoustic communication

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Improving communication with UUVs in shallow water environment

- Overview
- Programme of the Project
- Conclusion, Future work

Overview



Background:

- The 1st study has shown that the OFDM modulation copes well with multipath but Doppler still remained a problem
- In the 2nd study, improvements were made, and with a simple channel model, better Doppler performance was achieved

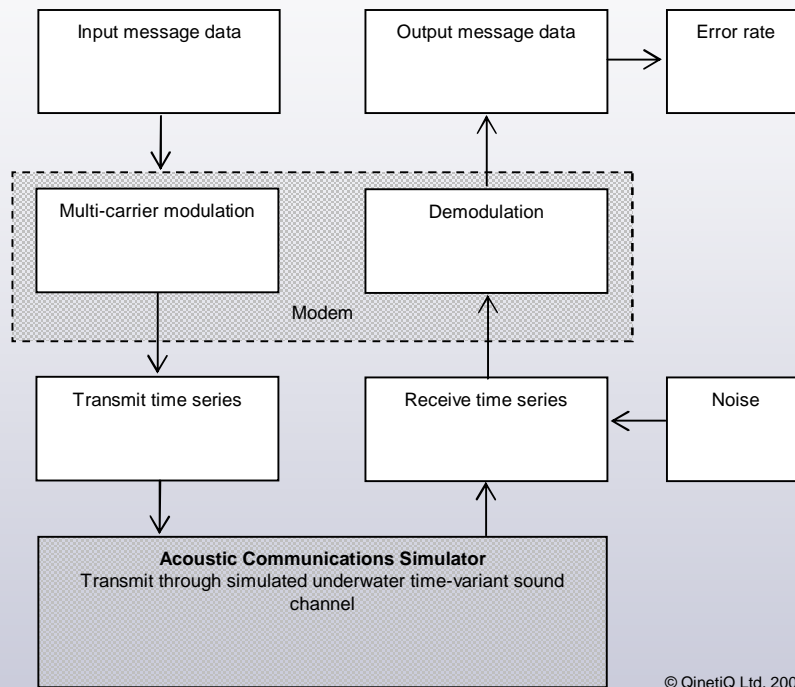
Objectives:

- To verify the performance in a physical environment
- Identify areas for further improvements

The following steps were taken:

- Collaboration with QinetiQ, Winfrith
- Prepare test plan for detailed simulation
- Process the time series
- Receiver architecture & simulation
- Identify areas of improvements

Channel Modelling at QinetiQ

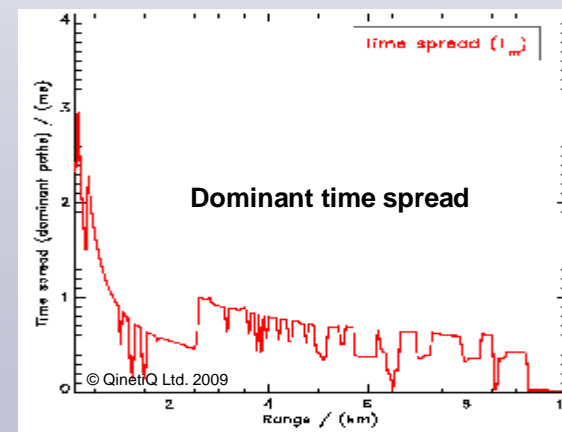
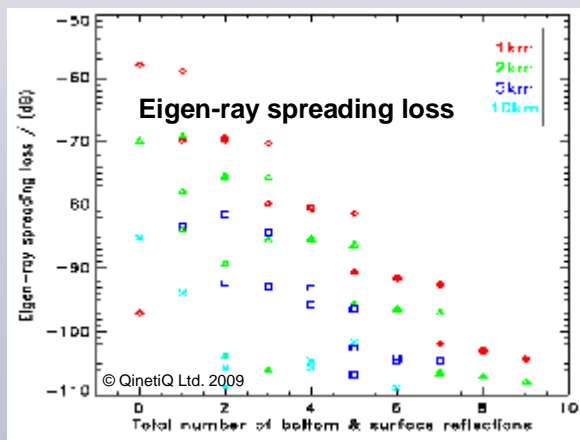
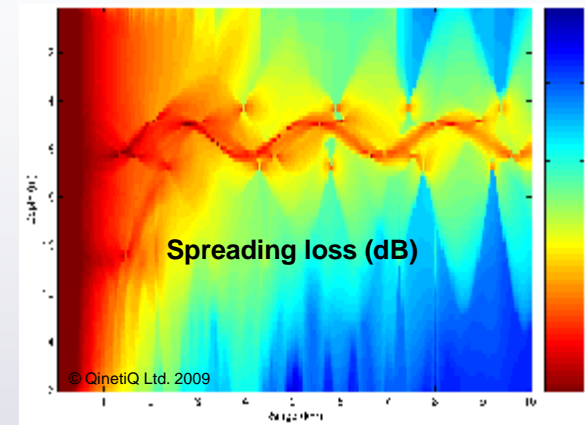
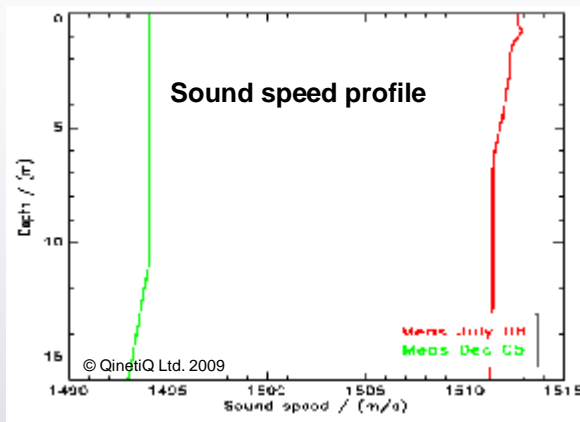


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ACS: What is modelled?

- Sea state:
 - Wind speed
 - Wave height
 - Surface motion
- Scattering
- Platform motion
- Thermocline
- Pressure, density
- Bathymetry
- Sea bed parameters
- Links to databases

Example: Weymouth Bay

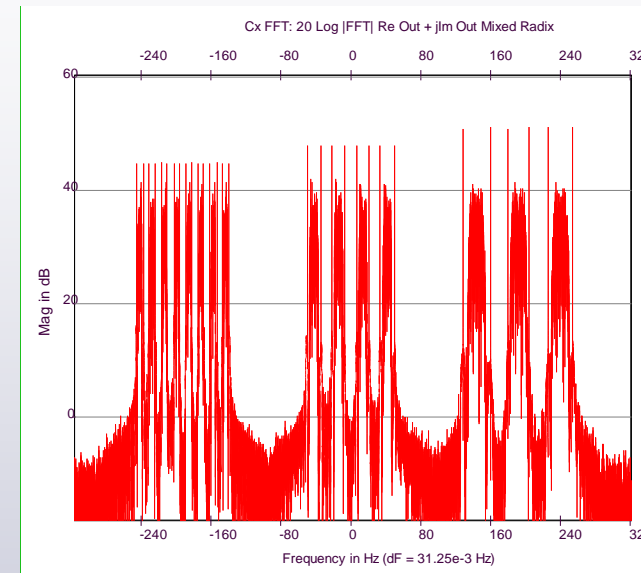


Test Environments & Waveforms



Environment	North Atlantic January	Weymouth January	Strait of Hormuz January
Sea state	5	4	2
RMS wave height	0.79m	0.46m	0.12m
Transmission loss	-60 dB	-65 dB	-56 dB
No of dominant eigen-rays	2	6	9
Total number of eigen-rays	7	23	17
Direct path?	Yes	Yes	No
Multipath time spread	0.58ms	0.54ms	42 ms*
Doppler spread, due to 5m/s Rx motion	0.016Hz	0.015Hz	1.2 Hz
Doppler spread due to surface waves	1.1 Hz	0.35Hz	0.84Hz
Spread factor @ 5m/s	7.e-4	2.e-4	0.05

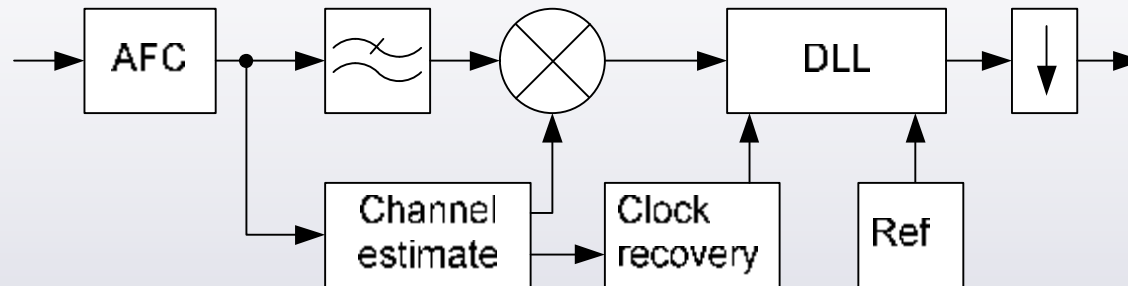
*Note: this rules out 16 Hz symbol rate



Test signal:

- 8KHz to 16 KHz transmit BW
- 4Hz, 8Hz, 16Hz symbol rates
- QPSK modulation
- 1Hz-16 Hz Guard Band for pilots

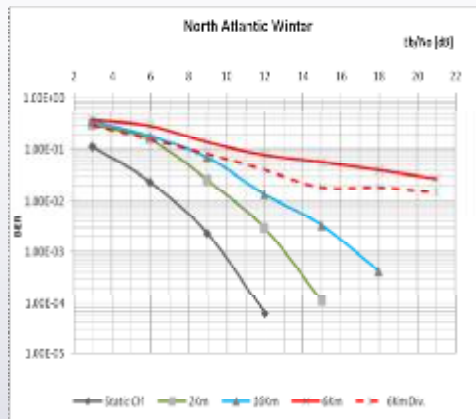
Receiver Architecture



Key features:

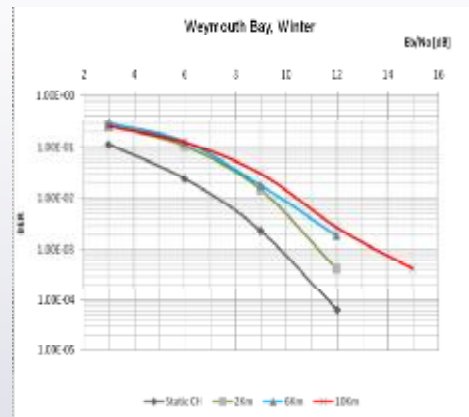
- 8KHz-16KHz real signal is down-converted to complex BB (not shown)
- AFC shifts channel by the average frequency of the USB/LSB pilots
- RRC filtered data is de-rotated by the average phase of USB/LSB pilots
- Data re-sampled with recovered clock (from pilots)
- Early-Late synchronisation in Delay Locked Loop

Simulation results in 3 environments



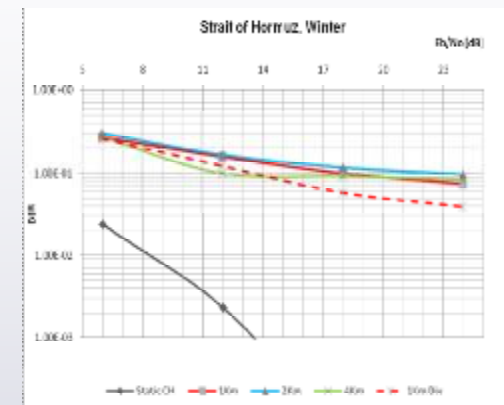
Benign channel

- 10^{-2} to 10^{-3} BER apart from 6Km case
- 15 dB Eb/No is necessary
- AFC tracking affects BER
- 2-6dB improvement with diversity
- 1bit/s/Hz throughput with QPSK



Typical channel

- 10^{-2} to 10^{-3} BER, better than benign case
- 12dB Eb/No is required
- Less frequency variation hence AFC works better
- 1bit/s/Hz throughput with QPSK



Complex channel

- Very poor BER
- Loses sync frequently but the problem is now understood
- AFC tracking also deteriorates the BER
- Diversity helps but still can not recover the signal

Outstanding issues



AFC problem

- Current Guard-Band is not adequate, AFC loop adds in excess noise
- A few pilots with greater GB should pre-tune frequency groups using coarse AFC
- Modify TX time series and re-simulate channel

Synchronisation problem

- Following a fade, a burst of errors occur due to unnecessary sync loss followed by re-acquisitions
- This is due to phase ambiguity arising from the use of 2 pilots
- Further investigation on existing data should be carried out first
- Search for alternative solution; a candidate is Transparent Tone In Band
- New TX time series to be re-simulated
- Modified timing recovery to be analysed

Conclusions



Current Status

- Good results were obtained using the proposed technique in benign and typical environments
- In complex environment the performance is not satisfactory due to AFC and synchronisation problems

Recommended Future Work

1. Further investigation to solve the synchronisation problem using present data
2. Implement coarse AFC and modify frequency plan to allow pre-tuning
3. Following successful completion of steps 1-2, re-simulate the environment