Underwater Electromagnetic Communications Using Conduction – Simulation and Experiment

Arsen Zoksimovski  
Northeastern University  
Boston, MA, USA  
zoksimovski.a@husky.neu.edu

Milica Stojanovic  
Northeastern University  
Boston, MA, USA  
m.stojanovic@neu.edu

Daniel Sexton  
GE Global Research  
Niskayuna, NY, USA  
sextonda@ge.com

Carey Rappaport  
Northeastern University  
Boston, MA, USA  
c.rappaport@neu.edu

ABSTRACT
In our previous research in underwater electromagnetic communications, we showed that magnitude variation with frequency, and time-invariance of the channel, motivated the design of an orthogonal frequency division multiplexing (OFDM) system with unequal bit loading, which is the subject of our current research in simulation and experiment. We have also found analytically estimated symbol error rate (SER) sensitivity to range variations based on the experimental results from the previous experiment and devised a simple range estimation technique based on the phase model of the measured channel. In addition, we have included channel coding, namely low-density parity check (LDPC) codes, in our simulations. This channel coding solution performs well in low SNR conditions and is expected to be useful in extending the physical range of operation.

Categories and Subject Descriptors
B.8.2 [Hardware]: Performance and Reliability – performance analysis and design aid.

General Terms

Keywords
Underwater RF, bit loading

1. INTRODUCTION
In our previous experiment we obtained phase vs. frequency curves at 35cm and 50cm distance, based on the model fitting to the original measurements in a tank [1]. We created a simple model of range dependence of the phase by interpolating between those two curves and by extrapolating to distances shorter than 35cm and longer than 50cm. One way to improve upon the channel estimation and range estimation is to explore the invariance of the channel. Preliminary results in our experiment indicated that the SER is highly sensitive to range variations. With the range deviation of just 1cm from the nominal (expected) value of 0.1m, SER rises from $10^{-5}$ to $10^{-2}$. The observed and modeled range dependence of the channel magnitude was nearfield like, or inverse cubic. Preliminary results in our experiment with the new equipment are showing significantly better, or less lossy, channel magnitude vs. frequency and range. Therefore, we are feeling optimistic that the new equipment has created significantly less severe conditions and a part of our expectations is highly improved SER sensitivity.

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. To copy otherwise, to republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee.

\$15.00$
2.2 Description
The new experimental setup serves for experimental analysis of
data throughput, including unequal bit loading transmission, and
utilizing phase information to estimate range. The dimensions of
the experimental 40-litter water tank are 85x45x20 cm. By
controlling the amount of salt in the tank, we vary salinity of the
water in steps of 20ppm to measure the effect of conductivity on
the channel and the system performance. The copper electrodes
are 3cm long and 7mm in its widest diameter. They are attached
to solid wires, which are held by two sliding bars across the tank
that control distance adjustment between the transmitter and the
receiver. The hardware consists of Altera's DE2-115 development
board with Cyclone IV type FPGA and an expansion card for D/A
and A/D conversion.

Altera Quartus II Web Edition FPGA design software is used for
system design and its SignalTap II Logic Analyzer tool is used for
data collection. Data have already been collected at transmitter-
receiver distances between 10cm and 40cm. The measured
channel magnitude looks like a low-pass filter, with attenuation
varying between -3dB at 100kHz and -8dB at 6.35MHz.

We have implemented OFDM systems of 1024 QPSK modulated
subcarriers and 1024 QAM-16 modulated subcarriers, measuring
channel magnitude and phase and evaluating BER at distances
between 10cm and 40cm. One of the benefits of the measured
channel frequency response is properly selecting the number of
bits per subcarrier in the unequal bit loading solution. We will
experiment with bit-loading in the channels by analyzing
throughput and measuring the bit error rate (BER), as well as
measuring the effect of range estimation error on the system
performance.

3. PRESENTATION
The poster shows the experimental equipment, including the
hardware and the software tool from Altera that is used to drive
the experiment, acquire data and display received signals. Measurement results, such as channel magnitude and phase at
several distances between the transmitter and the receiver, as well as
different water conductivities, will also be shown. In addition,
we will illustrate the range estimation based on the phase model
of the channel and finally the communication system performance, such as BER for 2- and 4-bit quadrature amplitude
modulation (QAM) and variable number of bits per symbol (bit
loading).

4. ACKNOWLEDGMENTS
This research was made possible by the Student Program at
GE Global Research, Grant No. G0003357, through Research
Partnership to Secure Energy for America (RPSEA) project
08121-2902-03. Assistance was also provided by NSF CNS-
1212999 and ONR : N00014-09-1-0700. We are extending our
thanks to Altera Corporation for providing a development board
and an AD/DA data conversion card for our experiment.

5. REFERENCES
[1] Zoksimovski, A., Sexton, D., Stojanovic, M., and Rappaport,
C. Underwater Electromagnetic Communications Using
Conduction - Channel Characterization. In Proceedings of
the Seventh ACM International Conference on Underwater
Networks and Systems, WUWNet ’12, pages 20:1-20:7, New
York, NY, USA, 2012.
C. Underwater Electromagnetic Communications Using
Conduction - Channel Characterization. J. Ad Hoc Networks
and Physical Communication (Elsevier), Joint Special Issue
on Advances in Underwater Communications and Networks,
Accepted for publication, Jun 2014.