EE 628 - Spring 2019
Project 3, Due Date: April 28, 2019

1 Introduction

High speed, free space optical communication underwater provides advantages for applications with unmanned and autonomous underwater vehicles or underwater sensor networks. However, data fidelity in optical links is highly dependent on the inherent optical properties (IOPs) of the specific ocean environment encountered, since water and suspended particles will absorb and scatter the light as it propagates. Of particular concern to underwater communications are multiple forward scattering events, as these create temporal dispersion and thus inter-symbol interference (ISI). These ISI channels can be modeled as multi-tap FIR filters. The effects of these channels can be mitigated with the help of channel equalization filters. A block diagram representation of the underwater communication system, along with a channel equalizer at the receiver, is shown in Figure 1.

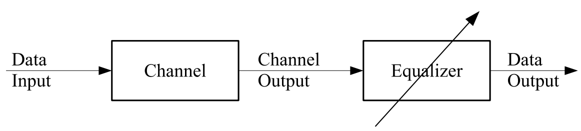

Figure 1: Underwater Digital Communications System. Modulated data is transmitted over a channel. The effects of the channel can be reversed using an equalizer.

Two experiments were conducted. In the first experiment, channels were modeled using a frequency approach, for different levels of turbidity. In the second experiment, for each case of turbidity, digitally modulated data was transmitted through the underwater channel and the received data was recorded.

In this project, given training input data and the recorded output data, you are asked to design equalizers for different levels of channel turbidity, and test their effectiveness.

2 Experimental Setup

In order to assess the effectiveness of an equalizer solution, underwater channels were characterized, through the magnitude and the phase response of turbid underwater optical channels in a lab setting. The turbidity was varied by adding 930 nm diameter polystyrene beads as the scattering agent.

3 Digital Communications

A random sequence of 10^6 points drawn from an OOK constellation were modulated on a 532 nm laser and transmitted through a $d = 3.56$ m long water tank before being detected by a photomultiplier tube with a 50.8 mm diameter aperture and 9 deg field-of-view (full angle). Two sets of experiments were conducted. In the first set of experiments, a high quality, low-noise, large bandwidth photomultiplier was used in order to obtain a "noise-free" receive sequence. In the second set, an inexpensive photomultiplier was used in order to determine the feasibility of low-cost infrastructure for underwater digital communications. The two receivers were used near-simultaneously for each turbidity level. The channel characteristics can be assumed to not have changed between the two sets of recordings. However, the channels will be different for each turbidity level.

Data from the expensive photomultiplier set-up are in "`data1.mat`" and data form the second setup are in "`data2.mat`".

4 Channel Modeling

A digital filter model is used to approximate the experimentally characterized channel response. The model is intended to be accurate, simple to describe, fast to calculate (*i.e.* only requiring a few parameters), and invertible so as to allow for channel equalization.

Your task is to design a channel equalizer that can undo the effects of the channel at the receiver.

5 Hints

1. Evaluate the need for an equalizer
2. Use `data1.mat` to get the "actual filter".
3. OOK is on-off keying. It is a binary modulation scheme encoding data as 1's and 0's.
4. Explore different algorithms to identify which works best. This can be fastest, most accurate, most easily adaptable, etc.