Hacking 10Base–T Ethernet for Underwater Optical Communication

UC the Fish

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Introduction

One of the funtional requirements for UC the Fish was modular optic communication, or the communication system should be easy to integrate with devices that need to communicate; a plug–and–play solution.

Nearly every modern computer has at least 10Base–T Ethernet and USB 2.0 connectivity, so any "modular" communication attachement should use one of these protocols–at least at its endpoints. We chose to 10Base–T ethernet, not just at the interfaces but to send the ethernet signal itself through water in the form of intensity of blue light. This allowed us to focus on building blue light transmit and receive hardware instead of attempting to develop light transmit/receive hardware *and* a modulation protocol + logic giving it USB endpoints.

Ethernet allows multiple stations to share a single medium, which is appropriate for water because light spreads in every direction and data cannot be multiplexed over different wavelegth channels. It includes hardware support for cyclic redundancy bit checking, up to 16 retransmission attempts in the case of bit errors or disruption of the medium, and at 10 MHz, ethernet is fast enough for live streaming video.

Unlike USB, a temporary dissruption in the data link does not require renegotiation time and application level link management. Software applications can use the operating system to handle TCP protocol when data integrity and delivery aknowledgement are necessary, instead of writing custom code to ensure control commands reach the sub intact.

Getting the Standard

IEEE Std 802.3 is the standard for Ethernet communication. It is freely available online but is so large it is split into multiple sections. The first section (only 555 pages!) is available at `https://standards.ieee.org/getieee802/download/802.3-2012_section1.pdf`.

Ethernet 101 [1]

More Details from the Standard

Influence on Transmitter/Receiver Design

1. The first component in the light transmitter input and last component of the receiver output should be a 1:1, ethernet approved transformer and standard RJ45 connector.
2. The input impedance of light transmitter must be $100\,\Omega$.
3. The bandwidth of both light transmitter and receiver must exceed $10\,MHz$ by several harmonics, and
4. their phase shift between $5\,MHz$ and $10\,MHz$ should be negligible.
5. The magnitude response of light transmitter + receiver in series, to a $100\,ns$, $585\,mV$ step input, should be $\geq 585\,mV$ when loaded by $100\,\Omega$.

Limitations of Ethernet

[1] Or in other words, an Ethernet Preamble. Hehe.