SMART TRANSMITTERS AND RECEIVERS FOR UNDERWATER COMMUNICATION

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Introduction

- Underwater Freespace optical communication—Promising alternative for Short range links.
- Considered to be point to point.
- New optical front-end proposed—the concept of smart transmitters and receivers.
- Smart Receivers—capable of detecting angle of arrival of signals.
- Smart transmitters
  - Electronically steers output beam towards particular direction.
  - Estimates water quality from back scattered light.
Advantages

- Non-mechanical pointing and tracking on a moving underwater vehicle.
- Providing sensory information to underwater vehicles.
- Duplex multi-user system
  - Spatial diversity allows for simultaneous reception from two non co-located transmitters.
  - Monitors optical backscattering while transmitter is active.
Figure: Multi-user reception system scenario with three nodes. A and C are transmitting. B is receiving.
Properties

- Beam attenuation coefficient: ratio of energy absorbed or scattered from an incident power per unit distance.

- Single-Scattering albedo: ratio of scattering coefficient to beam attenuation coefficient.

Study

- A 3.66m long, 1.22m wide, 1.22 m tall indoor water tank constructed.
- Maalox -controls attenuation coefficient of water.
- Nigrosin dyein-controls albedo.
Figure: 1000 gallon water tank built and used for underwater free-space optical communication experiments done in lab at NCSU.
Figure: Relationship between attenuation coefficient and SNR for experiments in laboratory test tank.
Smart Receivers

- Goal: to develop a quasi omnidirectional system that reduces pointing and tracking requirements.

- Characteristics
  - increased FOV.
  - angle of arrival estimation
Design

- 3-D spherical array of lenses all focusing to a 2 D planar array of photodiodes.
- A prototype constructed using seven lenses and seven photodiodes.
(a) Sketch showing light entering through top lens.
(b) Sketch showing light entering through side lens and falling on three photodiodes.
(c) Isometric view.
(d) Top view of solid rendering.
Lens at the receiver

- research in the domain of indoor optical wireless in use of spherical photodiode arrays for increasing FOV.

- Existing optical front-end arrays use:
  - Photodiode arrays with no lenses.
  - Single lens with multiple photodiodes.
  - Multiple lenses focusing on separate photodiodes.

Angle Of Arrival Estimation

- Intensity of light received can be used to estimate the angle of arrival of light.
Photodiode output combining

- Connect the array of photodiodes in parallel.
- An ideal combining technique
  - maintain bandwidth
  - minimize noise
  - maximize SNR

Linear diversity combining techniques

- Equal Gain Combining (EGC)
- Maximum Selection Combining (SEL)
Smart Transmitters

- Characteristics
  - increased directionality.
  - electronic switched beamsteering.

- Design
  - Consists of a truncated hexagonal pyramid with seven LEDs.
  - Each LED is coupled with its own lens that converges the wide FOV of the LED to a narrower beam in a particular direction.
Characterization of the Receiver Lens-photodiode Array

Experiments were conducted for the receiver pointed in all directions and intensities were observed at all photodiode outputs stored as a function of the spherical co-ordinates.

A pan and rotate system. constructed using digital servos.

Seven amplified photodiode outputs digitized using 8 channel digitizer.
Angle of Arrival Estimation

- Involves estimating the direction of arrival of the incident light based on relative output powers observed at each photodiode.
(a) Estimated vs. true angle

(b) Bias of the estimator
Backscatter estimation

Experiments were conducted with amplified detectors as well as the prototype transmitter and receiver to collect and observe a linear relationship between the known attenuation coefficient of the water and the amount of backscattered light collected.
Figure: Results of the backscatter estimation experiment
Results show that design also capable of acting as smart system.

Backscatter estimation experiment demonstrates linear relationship between return beam intensity and channel attenuation coefficient.

smart receivers

- increased field of view
- ability to estimate angle of arrival.

Smart transmitters allows electronic switched beamsteering.