Ph.D Research Proposal

Optimise solution to reduce vertical link misalignment in Underwater Wireless Optical Communication systems (UWOC)

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Overview of Presentation

- ❑ Introduction
- ❑ Proposed Ph.D work
  - Objective 1
  - Objective 2
- ❑ Methodology
- ❑ Expected Outcomes

What is the RI of different sea water's

The RI of sea water typically varies between 1.3274 and 1.3745

- (Johnson, Laura et al. 2014) 1.336 to 1.359 RIU Pacific Ocean
- (Xiaohong Quan and Edward S. Fry 1995) 1.328 to 1.351 dependencies (salinity, temperature, wavelength and pressure)
- (G. Seaver 1985) 1.332 to 1.364

Loss of Light

Loss of light (percent) in one metre of seawater*								
	violet		blue-green			yellow	orange	red
wavelength (micrometre)	0.30	0.40	0.46	0.50	0.54	0.58	0.64	0.70
oceanic water, most transparent	16%	4%	2%	3%	5%	9%	29%	42%
oceanic water, least transparent	57%	16%	11%	10%	13%	19%	36%	55%
coastal water, average		63%	37%	29%	28%	30%	45%	74%
*According to Jerlov.								

Loss of Light in Ocean

The attenuation can coefficient be broken into two parts

$$\mathbf{c(z, \lambda) = a (z, \lambda) + b (z, \lambda)}$$

where a is the absorption coefficient (responsible for loss of radiant energy) and b is the scattering coefficient responsible for re-emission of radiation of different directions from the incident one.

$$\mathbf{a_{TOTAL}(\lambda) = a_{w}(\lambda) + a_{ph}(\lambda) + a_{NAP}(\lambda) + a_{CDOM}(\lambda)}$$

The spectral light absorption coefficient of seawater, $a_{TOTAL}(\lambda)$ (m^{-1});

where, spectral light absorption coefficient's are,
w - pure water, **ph** - phytoplankton, **NAP -** Non algal Particles, **CDOM** - colored dissolved organic matter at wavelength (λ)

The scattering coefficient is directly related to the volume scattering function

$$\mathbf{b (z, \lambda) = \int_0 \int^{4\pi} \beta(z, \theta', \varphi', \theta, \varphi, \lambda) \sin\theta' \sin\theta \, d\theta' \, d\theta \, d\varphi' \, d\varphi}$$

where, z = perpendicular direction from water surface pointing downwards, θ = polar angle between propagation of beam and vertical, φ = polar coordinates w.r.t. z,

Prieur and Sathyendranath, 1981; Roesler et al., 1989; Carder et al., 1991

Effect of different physical phenomenon like turbulence and thin layer etc. on light transmission?

- **Effect of turbulence in Optical Properties**

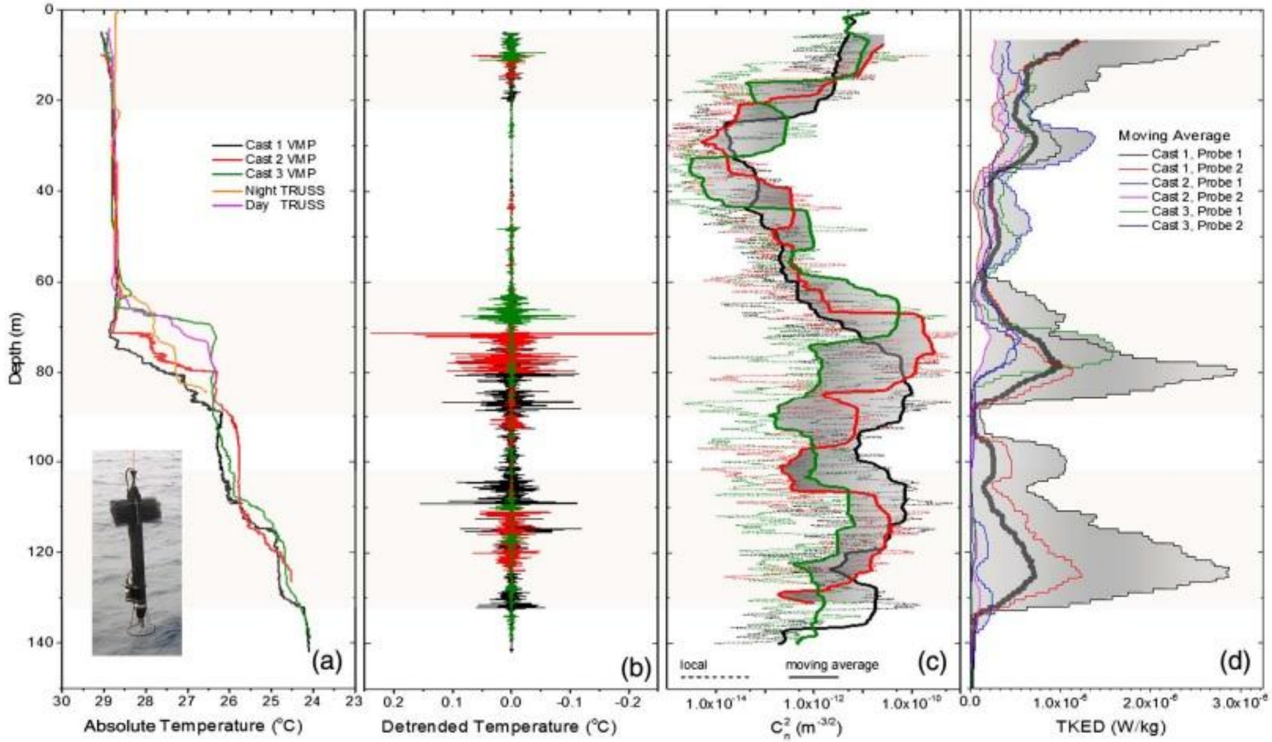
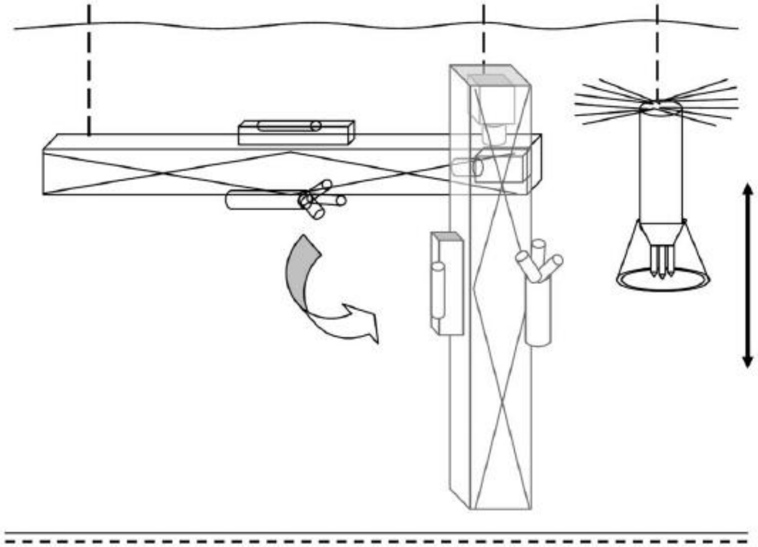
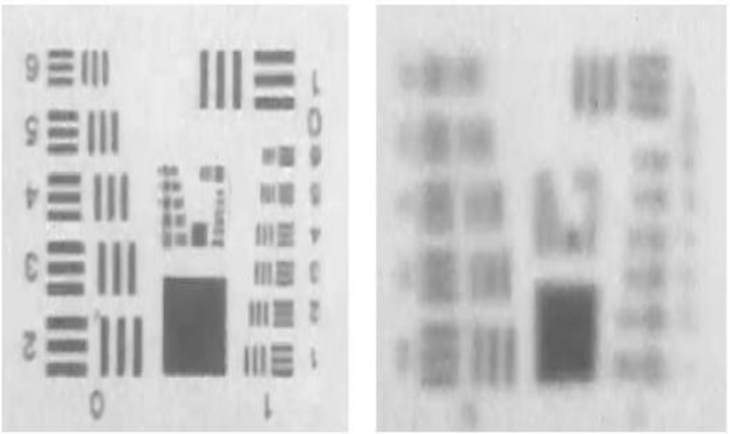


Fig. 5. (a) Temperature profile as measured by the VMP for three consecutive casts. Also shown is the temperature profile as measured by the slow temperature probe mounted on the TRUSS. (b) High spatial frequency temperature variation of the detrended profiles in (a). (c) Index of refraction structure constant calculated from the detrended temperature data shown in (b) (dashed lines) and moving average of C_n^2 over the length of the TRUSS (8.75 m) (solid lines). (d) TKED as calculated from the shear probes of the VMP for the fast casts. The insert in (a) shows the VMP.

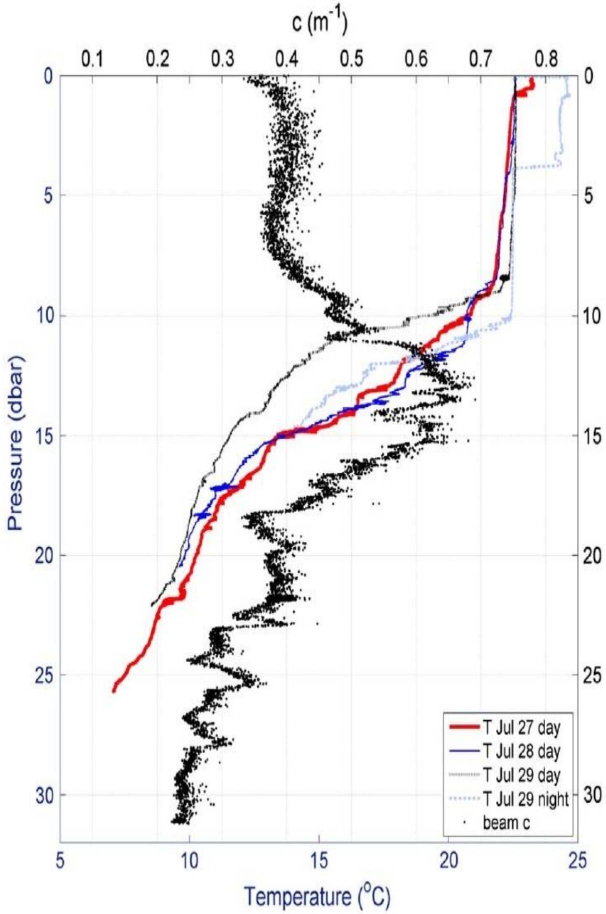
(Nootz G et al.2016)

Experimental Setup





(a) (b)



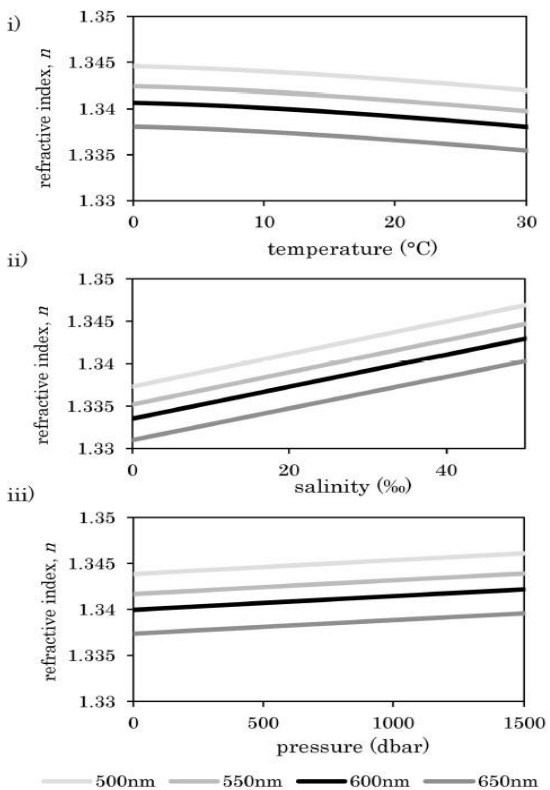
Optical properties (beam-c at 532 nm) and temperature profile

a) The left was taken at 2.8 m depth with no obvious optical turbulence
b) The right was from 8.7 m under conditions of similar turbidity but strong optical turbulence

W. Hou et al 2012

RI dependencies on Physical parameters in Pacific Ocean.!

(Johnson, Laura et al. 2014)



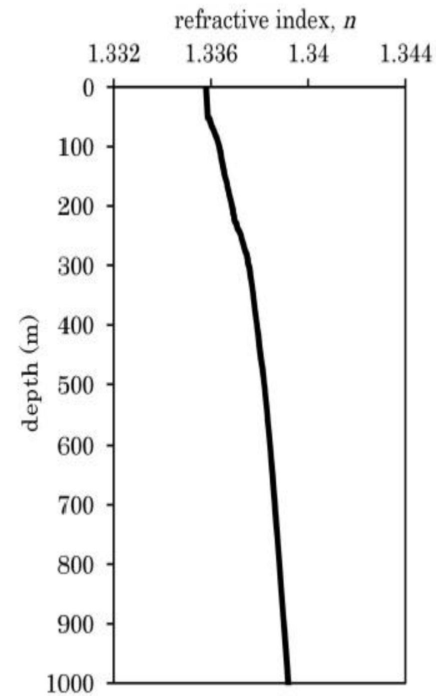


Fig. 3. Estimated refractive index profiles for the Pacific Ocean data at 500nm.

- Effect of scattering has not been taken into account in this study is the
- Two assumptions are made during this study
  - The bulk (or volume-averaged) refractive index is used instead of an exact local index of refraction
  - The ocean in question is completely still, so no refractive fluctuations occur due to turbulence

Proposed Ph.D work

Objective 1- Measurement of RI of Different water Densities

Refractive Indexes of Marine Particles

**Note : All refractive indices are given relative to seawater, whose refractive index is 1.36 in vacuum. (RI of Pure Water : 1.33)*

❑ The living organic materials have lower refractive indexes close to unity, which is due to their high water content, while inorganic materials have relatively higher refractive index.

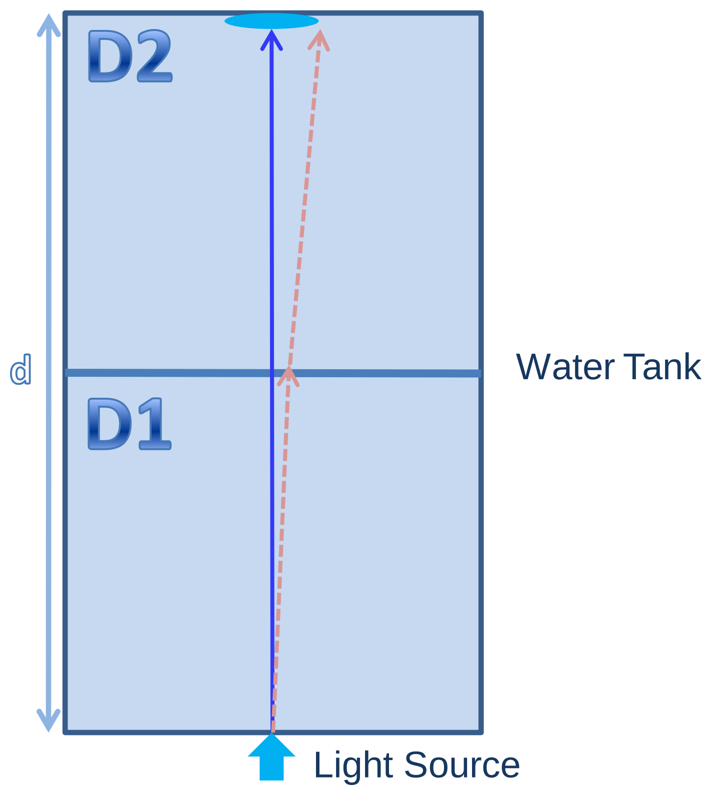
❑ Most oceanic particles*	1.0	-	1.26
❑ Phytoplankton*	1.02	-	1.07
❑ For regions with high Chlorophyll*	1.04	-	1.05
❑ Regions of Sediment and suspended matter*	1.14	-	1.18
❑ Regions with inorganic mineral component*	1.10	-	1.12

*(Stanly 1971, Carder 1972)

Performing Laboratory Experiment:

- Refractometer/Abbe-refractometer
- Analytical Method using Concave Lens

Setup to measure Δr



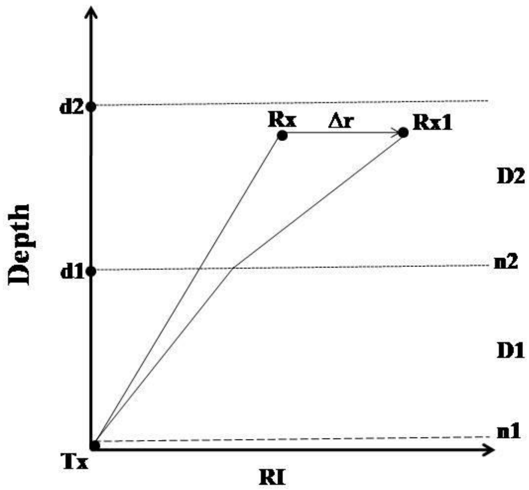
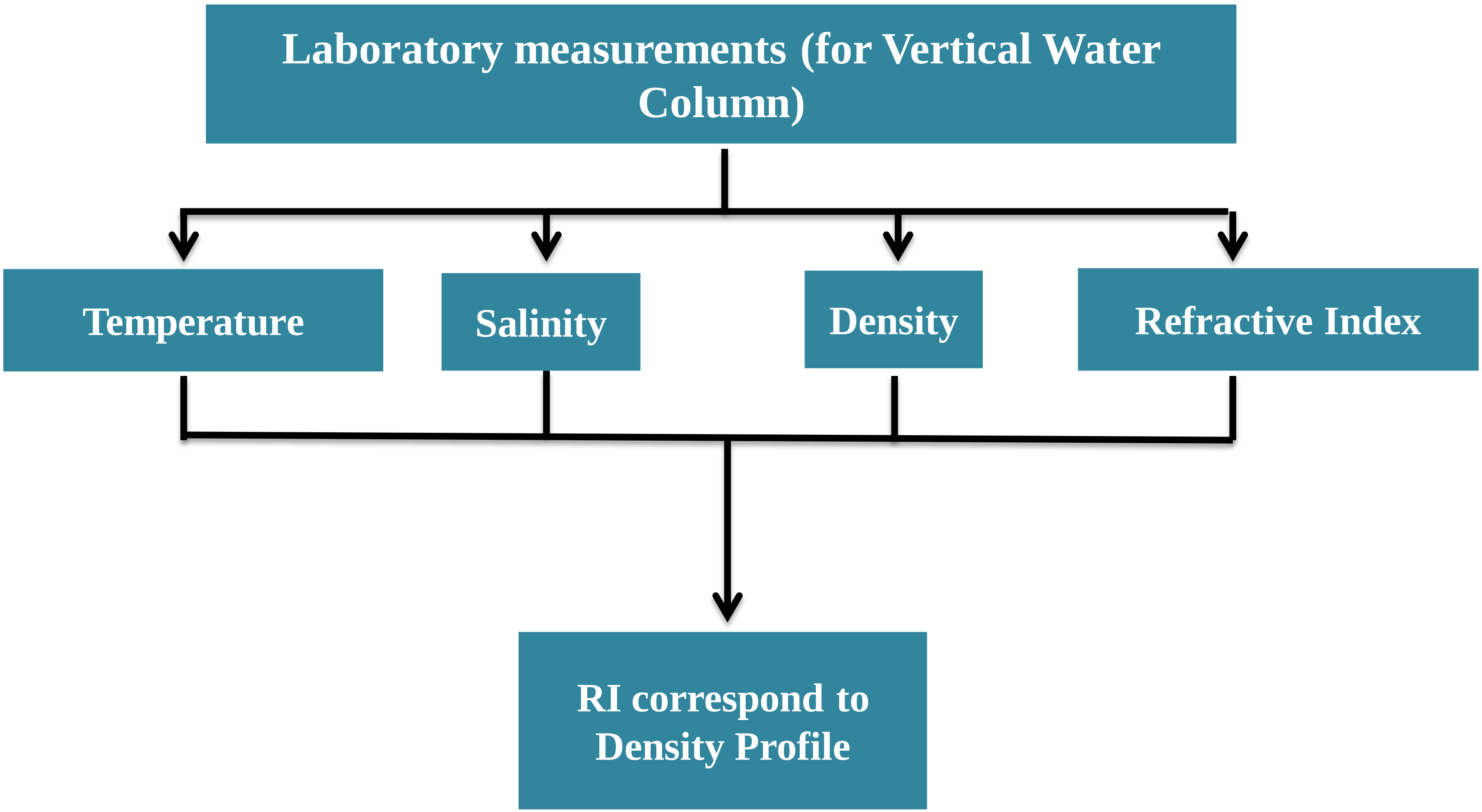
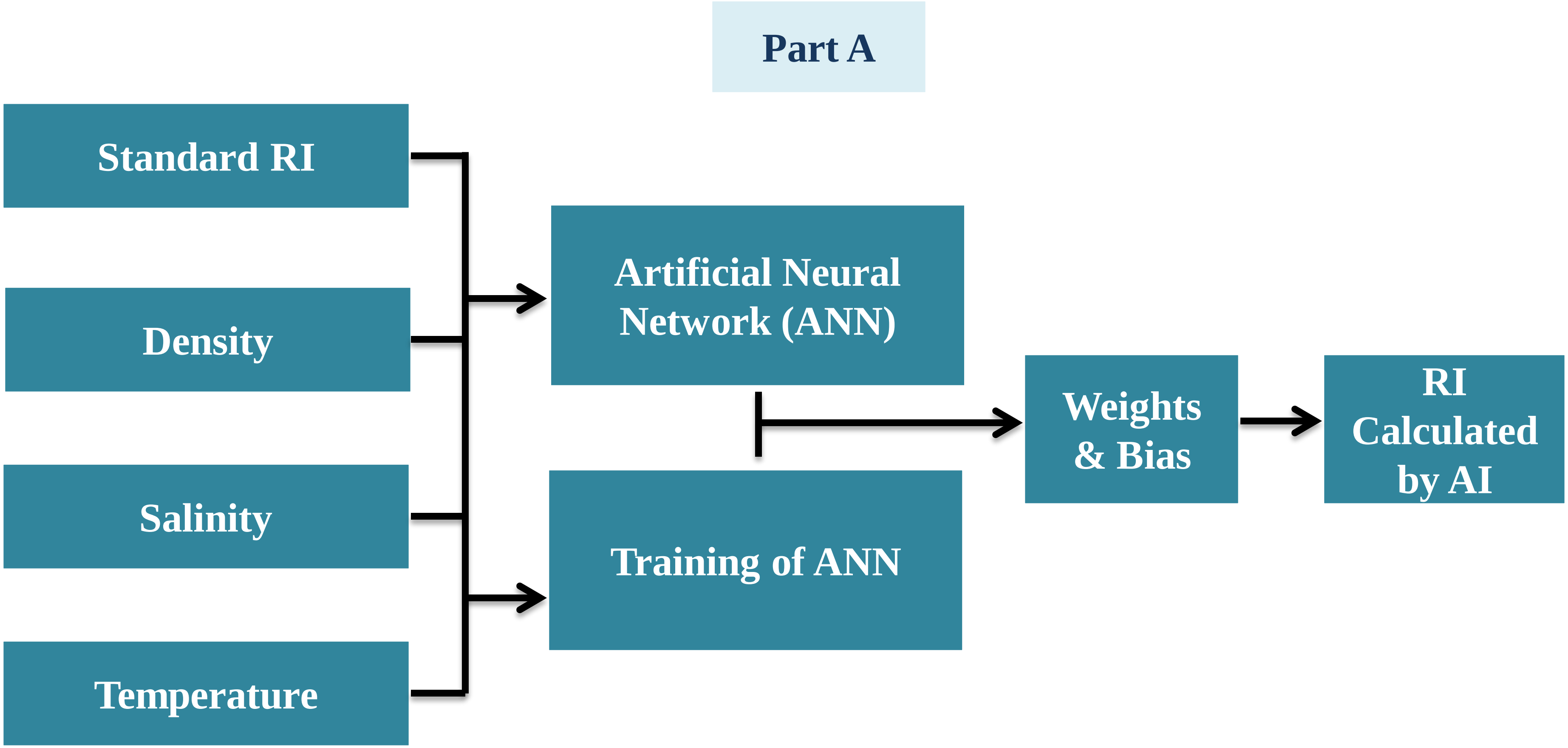


Figure Showing Optical Light Path, where,
Tx – Transmitter Rx & Rx1 Receiver
d1-d2 depths D1-D2 Water Densities
n1-n2 points where RI changes
Δr difference between expected and actual optical path

Approach


Laboratory measurements (for Vertical Water Column)
Temperature
Salinity
Density
Refractive Index
RI correspond to Density Profile

Objective 2- Optical Water channel modeling for Density and Refractive Profile in Vertical Link

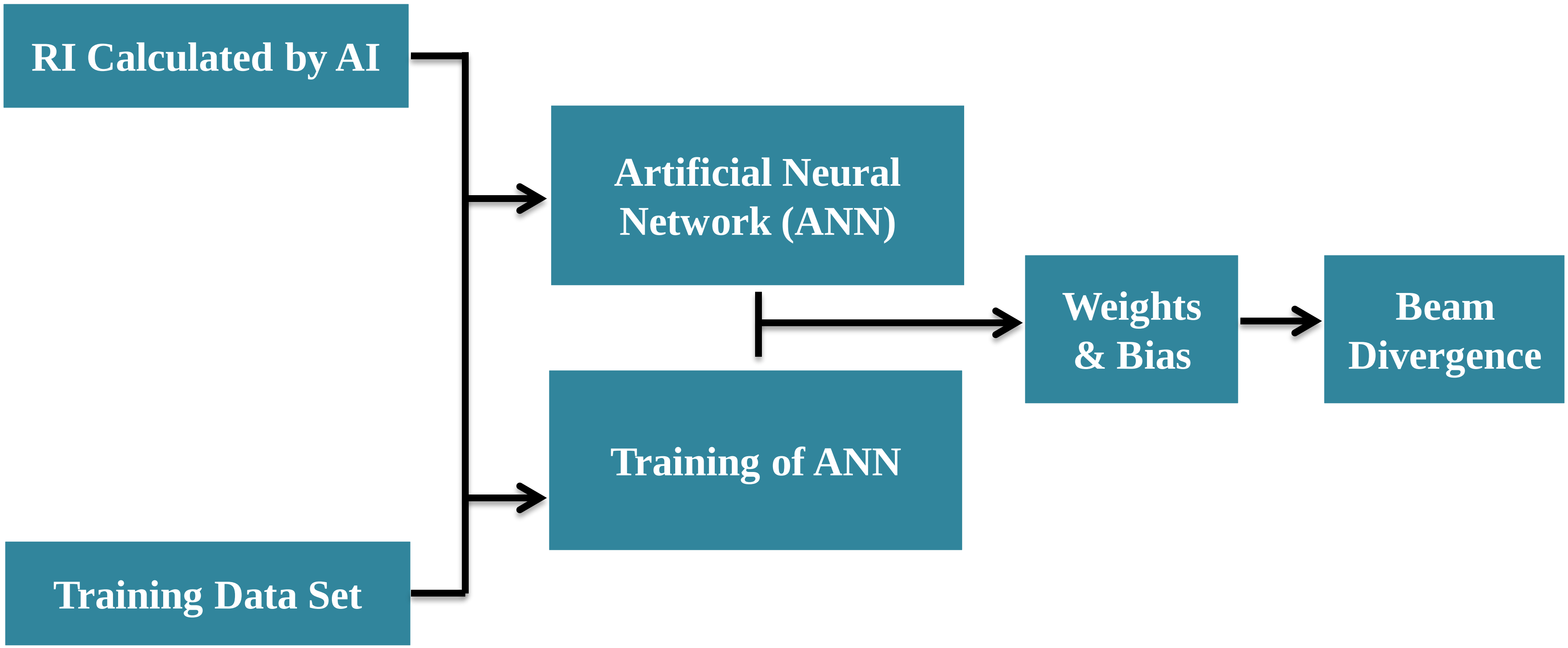


Part A:

Y_1 = Tansig $(IW_1 * W_d + B_{i1})$

RI = $\sum LW_1 * Y_1 + B_{o1}$

Part B



Part B:

$$Y_2 = \text{Tansig}\,(IW_2 * RI + B_{i2})$$

$$\theta = \sum LW_2 * Y_2 + Bo_2$$

Optical measurements (Satellite or in situ), Density

↓

Absorption and/or scattering

↓

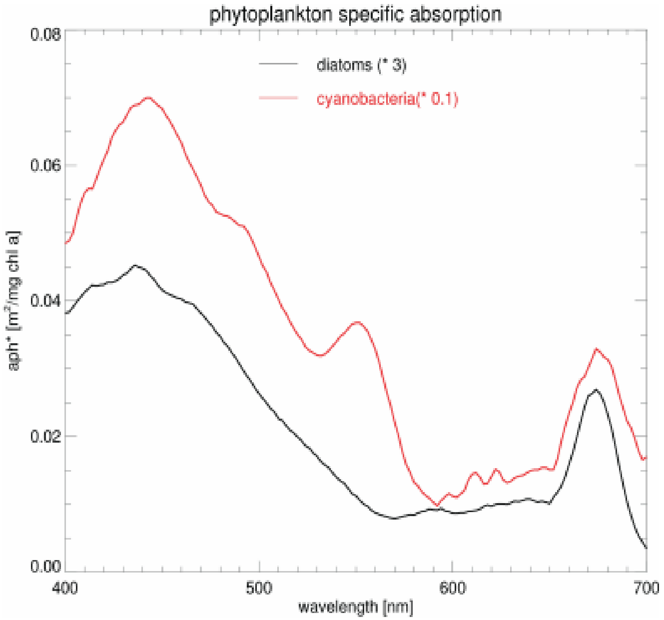
Water leaving radiance, reflectance (Rrs)or reflectance ratio

↓

AI Algorithm
+
Satellite data or in situ optical data

↓

Index of Refraction



Expected Outcomes

Objective 1:

1) Refractive index of water body in vertical column with different densities of water will be studied and reported.

2) Study will provide us with the better understanding of modeling in vertical communication links.

3) Relation between different water bodies (different densities) and Refractive Index can be formulate

Objective 2:

1) One can derive transmitter-receiver (Tx/Rx) position by just knowing Water Density profile.

2) The use of ANN in UWOC system will provide cost and energy efficient solution Underwater Wireless Optical Communication Systems.

3) ANN will be used to derive RI, Δd and θ remotely instead of field survey every time, by knowing density profile of water column and to do manual measurements.

Thank You …