OceanLens ROV Underwater Recharging and Data Transfer

Design, build, and test of a system for wireless underwater charging and data transfer for a remotely operated underwater vehicle, including an autonomous self-docking module.

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EE 447/448 & 497/498

INTRODUCTION

About 95% of the world's oceans are unexplored. ROVs are great tools for exploring these vast spaces, and can also be used to perform unmanned missions to troubleshoot underwater operations. Plenty of these missions are based largely on gathering information, so when the voyage is over, its necessary for the ROV to dump hours worth of data and recharge itself for the next mission.

The proposed ROV has the capability of wirelessly charging and transferring its data. Both of these tasks will be performed simultaneously, during a docking period. This eliminates the need for manual removal of the ROV to fetch the data. The overall system is composed of three main parts: wireless power transfer, wireless data transfer, and slight autonomy for auto-docking.

GOAL OVERVIEW

Mission Statement:

Design, build, and test of a system for wireless underwater charging and data transfer for a remotely operated underwater vehicle, including an autonomous self-docking module.

Deliverables:

- Prototype charging and data transfer system agnostic of ROV platform
- Prototype docking station where charging and data transfer will be activated

PLATFORM

- Sufficient payload capacity for additional systems
  - Positive buoyancy and stability
  - Proper match between thruster power and mass
  - Sufficient mounting space on structure for payloads
- Correctly matched power system:
  - Battery monitor circuits mesh with WiBotic hardware
  - Power capacity (20A steady draw required)
  - Max delivery (100A in bursts <10s)
- Sufficient agility for control goals:
  - Ideally yields holonomic control of vehicle
  - Thruster location + CoB/CoG should minimize cross-coupling between axes

Initial Vehicle Considerations	Final Vehicle Selection
OpenROV - overall structure too small for mounting required hardware	BlueROV2, by Blue Robotics - New kit, loaned to team for project. Successful construction and test launches, and all core functionality confirmed
BAH Year 2 Custom ROV - core issues around buoyancy and stability, power system implementation, and non-holonomic thruster arrangement	

DOCKING STATION

The main purpose of our docking station deliverable is to allow for partial in-air component placement. Full aquatic immersion for simultaneous TX and RX side was not supported by our tests, thus a half-submerged design was implemented.

- Floating central case holds:
  - Wibotic TX box
  - Wibotic TX coil
  - Transmitting antenna
  - DC tether
  - Interior ½" PVC frame to hold components in place for precision
- Components
  - Pelican iM2750 Storm Case
  - ¾" PVC frame
  - Bungee cord for case attachment

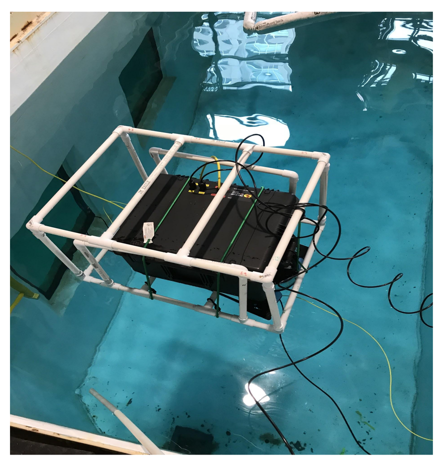
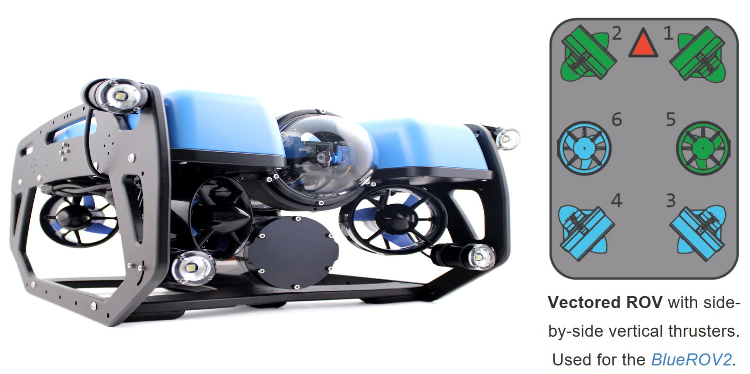


Figure 4: Deployed Docking Station & ROV



Figures 5 & 6: BlueROV2 (Left) and Thruster Orientation Diagram (Right)

LESSONS LEARNED

Water Maintenance

- Salinity
  - Evaporation over time changes salinity levels
  - Implemented a salinity sensor
- Electronic Protection
  - Water damage can come from dripping off of a wet enclosure, not just flooding the interior
  - A single droplet of salt water in contact with an exposed electronics is enough to completely fry a board

Components Maintenance

- Strength of Antenna Signal
  - Antenna in use has range powerful enough to span kilometers in air
  - One antenna shares air with Wibotic TX Box in docking station, and can drown the RF signal from Wibotic TX box that enables charging
- Orientation Changes
  - WiBotic Backchannel wifi means coils must be very close to begin charging, only ~2" apart
  - Orientation is not as open ended as it is for coils alone or antennas alone

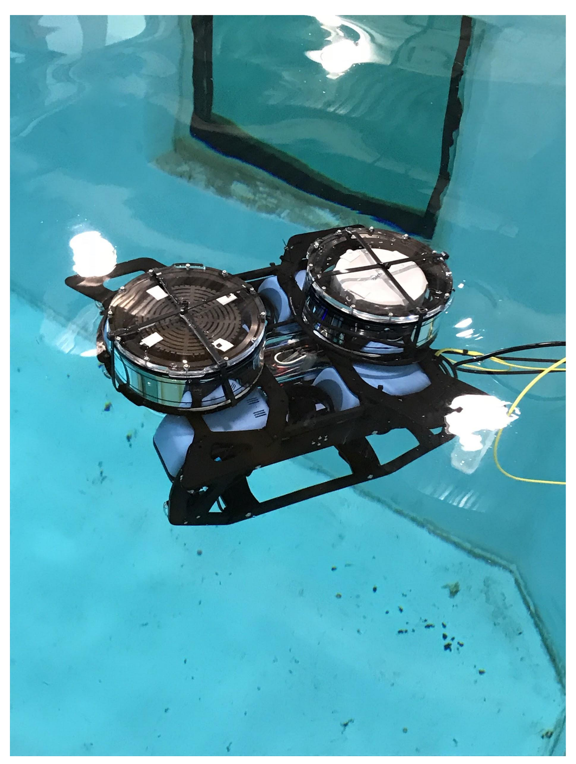


Figure 13: Deployed ROV

WIRELESS POWER TRANSFER

For this portion of the project, we integrated the WiBotic Technology Development Kit with our ROV in order to introduce wireless power transfer. The kit uses two RX/TX coils, a transmitter and receiver box, and an onboard charger to facilitate charging via:

- Impedance matching
- Adaptive tuning
  - Runs continuous analysis of incident/reflected power
  - Allows variable range between coils
  - Allows flexible coil orientation patterns

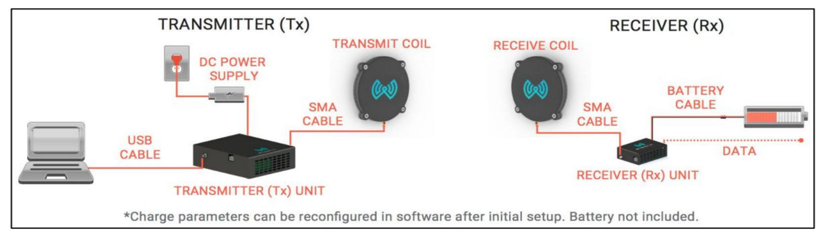
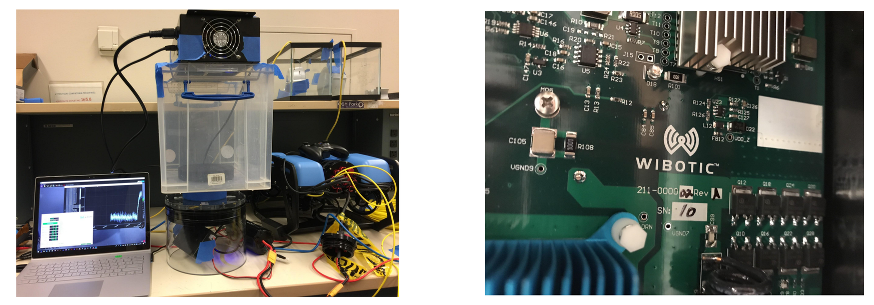


Figure 1: WiBotic Charging Operation Diagram

Integration

The largest challenge we encountered was when introducing the backchannel WiFi that allows the WiBotic coils to begin charging to our system. The 2.4GHz channel is used for synchronization between RX and TX sides of the system, but is not optimized for our system. Some of the challenges we encountered were:

- Very small antenna components for the system
- No placement flexibility
- Limited range (Less than charging range)



Figures 2 & 3: WiBotic Testing Setup (Left), Wifi Channel on WiBotic Board (Right)

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WIRELESS DATA TRANSFER

Key Requirements:

- Transfer of 1GB needed per hour of sensing
- Data transferred in 10 minutes at our docking station per hour.
- This yields a goal transfer rate of ~15 Mbs.

Assuming range on the same order of magnitude as the charging range, we assumed goal distance of **0-3 cm**. This meant that our main options were:

- Optical (e.g. laser, LED)
- Acoustic
- RF (range of frequencies)

For our needs, we ended up choosing **RF, (2.4GHz, 802.11 standard)**, largely because:

- Effective at close range
- Directional, ~5dBi of gain
- Lower power draw (3W)
- Low cost

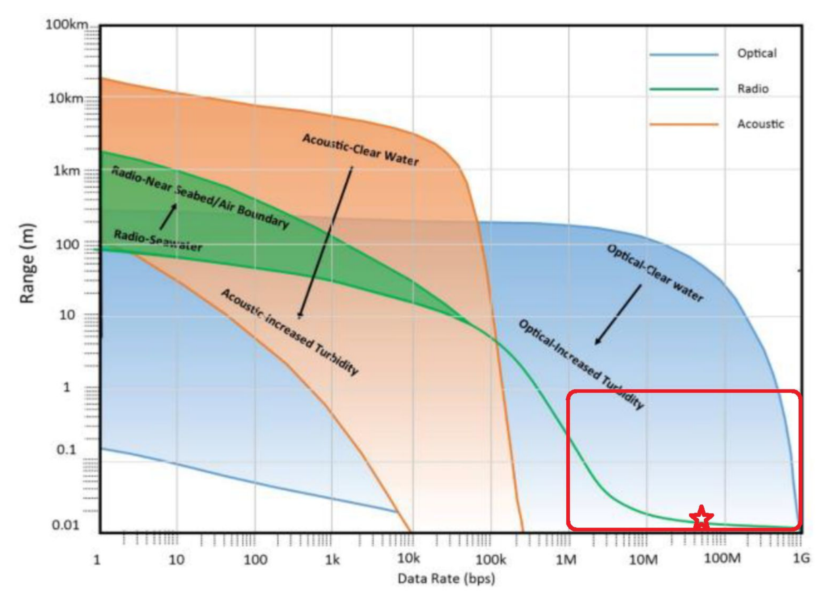

Figure 7: Comparison Graph of Underwater Communication Methods

Testing Setup

- Small lab test tank
- Test progression: Air→ Fresh Water → Salt Water
- Salinity standard of **32-38ppt**
- Milestones:
  - Characterized tank with RF analyzers/signal generators
  - Moved to antennas installed in enclosures
  - Final pool test with dock arrangement

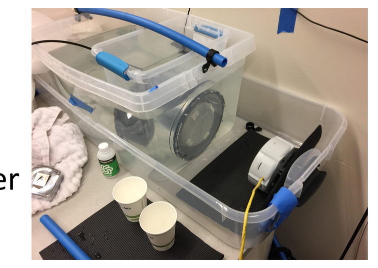

Figure 8: Early Stage Antenna Testing

Results

Test	Speeds	Ranges
Lab Test Tank	60 Mbs	< 2 cm
Pool (Oceanography)	30-50 Mbs	< 3 cm
Overall	Exceeded requirements by 200-400%	< 2 cm

AUTONOMY

ROV would head straight towards the 'Target' and dock itself. Due to autonomy being the stretch goal, currently the ROV recognizes the target whereas a python script manipulates the ROV position to move forward whenever the target is acquired. The basic implementation involved:

- Camera recognition to detect the pre-determined symbol using OpenCV libraries
- Machine learning to create Haar cascades for specific symbol (bullseye)
- Implement logic on Raspberry Pi and send commands to the ROV via Mavlink protocol

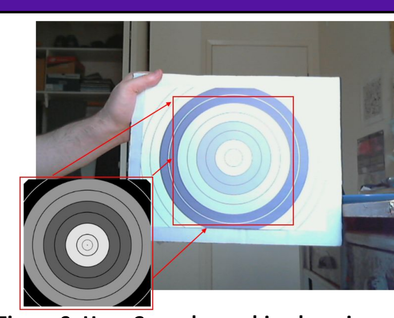

Figure 9: Haar Cascade machine learning approach detecting bullseye

Figure 10: Target Detected using Python and OpenCV

Future Implementation Plan:

- Robotics Operating System (ROS) for architecture
- MATLAB/Simulink used for ROS nodes
- OpenCV vision recognition
  - Pre-determined symbol (ie arrows, bullseye) set to trigger vision recognition
  - Enables circular translate or advance mode
- ROV movement
  - High-level PID loop to drive per-motor
  - Drive until park position is achieved (else backoff and retry)
- On-Board Application
  - Logic executed via Raspberry Pi
  - Ideally tetherless

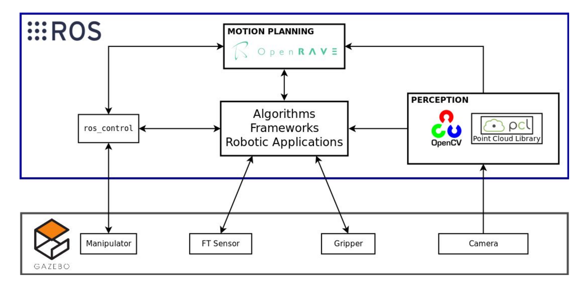

Figure 11: High level system structure

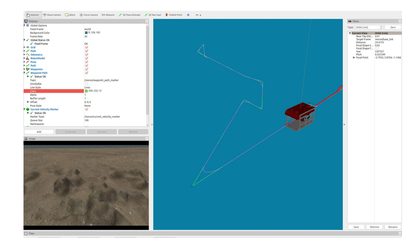

Figure 12: ROS simulation

CONCLUSION

- Goal: Demonstrate a prototype for wireless underwater charging and data transfer technologies that is functional in at least partially submerged aquatic environment. (*Stretch goal:* Autonomous dock detection and movement)
- Wireless charging
- Wireless data transfer
  - According to the tests that were conducted, the data transfer setup is promising up to 10cm range underwater
- Autonomy (Stretch Goal)
  - Camera recognition acts as trigger
  - Short, specific drive into dock as opposed to full autonomy
- Docking Station
  - Enables separation of in-air vs submersible

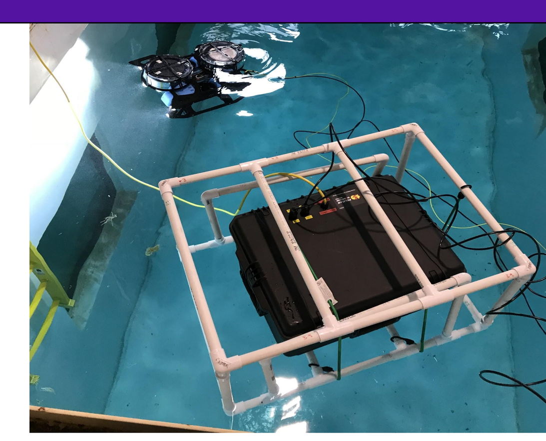

Figure 14: ROV & Docking Station