# Examining the Stability of Small Barbell Buoys

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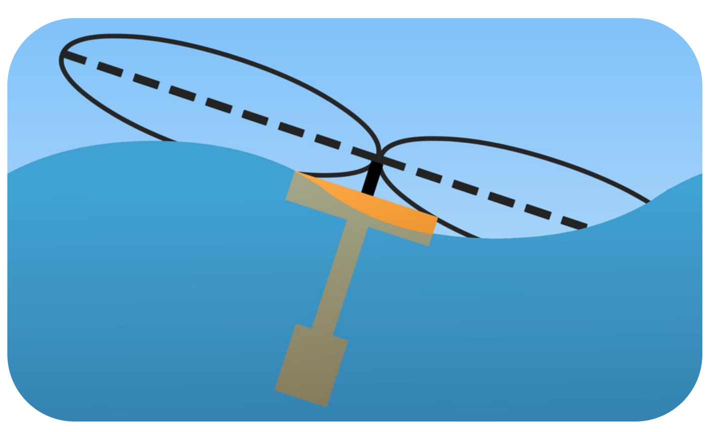
## Project Overview

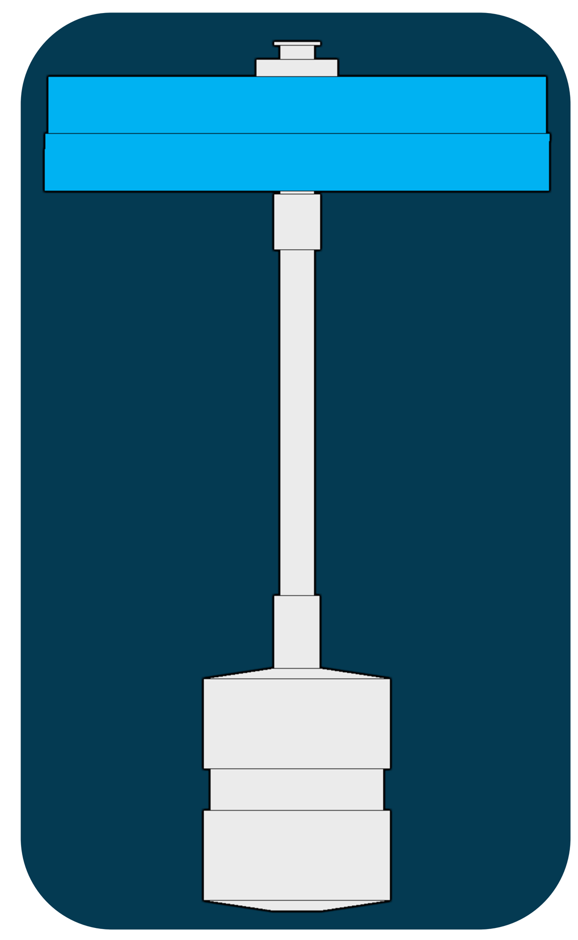
### Why Use Smaller Buoys for Communication?

- Allows for ease of storage and deployment
- Reduces cost of manufacturing

### The Challenge

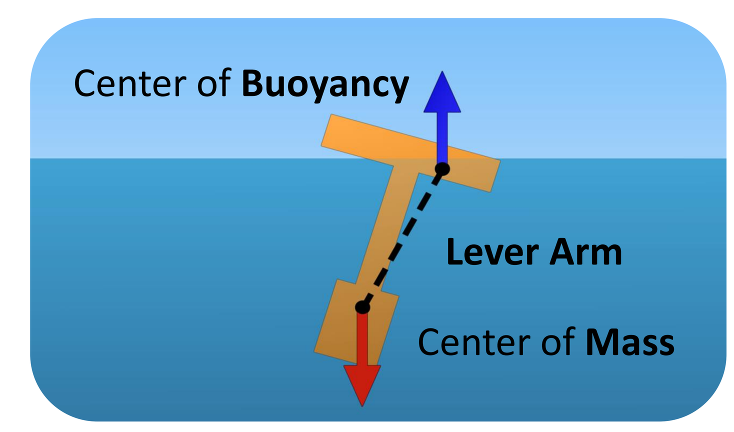
- Increased susceptibility to wave motion leads to more communication downtimes when antenna is angled incorrectly





### Our Solution: Barbell Buoy

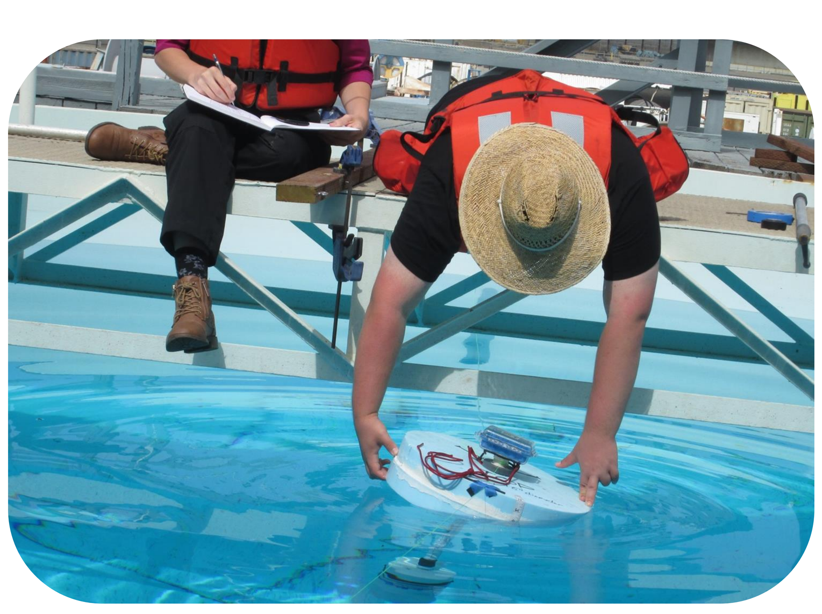
- Design maximizes the length of the lever arm to increase stability
- Fabricated a prototype with interchangeable components
- Variable floatation diameters and rod lengths allow broader analysis




## Testing in Dive Tank

| Six Barbell Configurations Tested | | |
|---|---|---|
| 18" D x 31.4" H | 18" D x 35.4" H | 18 D x 39.4 H |
| 24 D x 31.4 H | 24 D x 35.4 H | 24 D x 39.4 H |

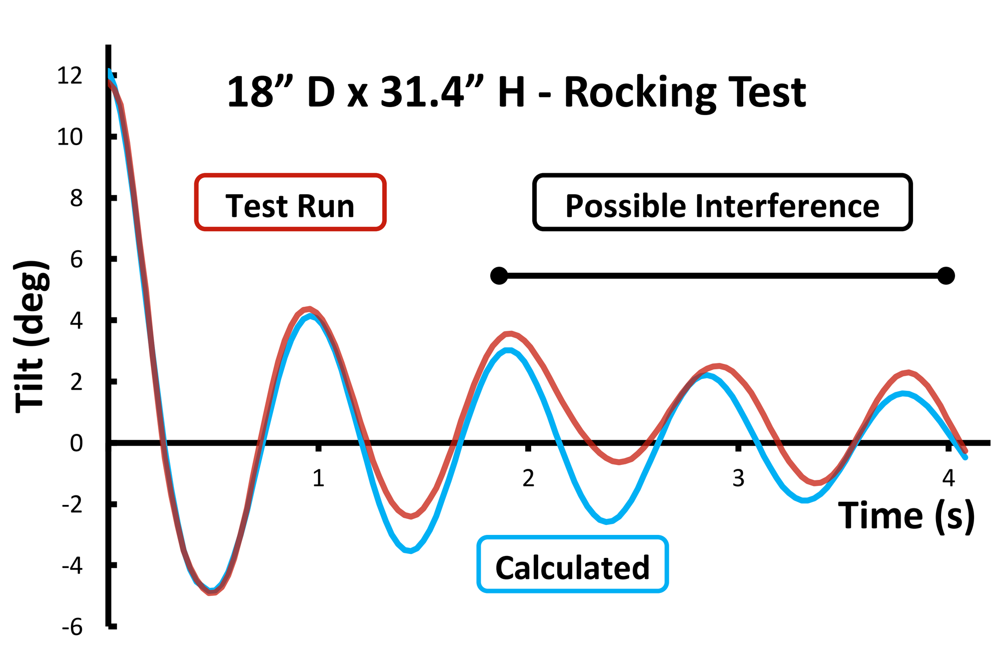
- Displaced buoy to record dynamic responses
- Used an inertial measurement unit to record tilt and vertical acceleration



- Damped oscillations describe buoy motion:

$$Angle = Ae^{-Rt} \sin(Dt)$$

- Where **A** = initial amplitude, **R** = damping ratio, **D** = damped frequency

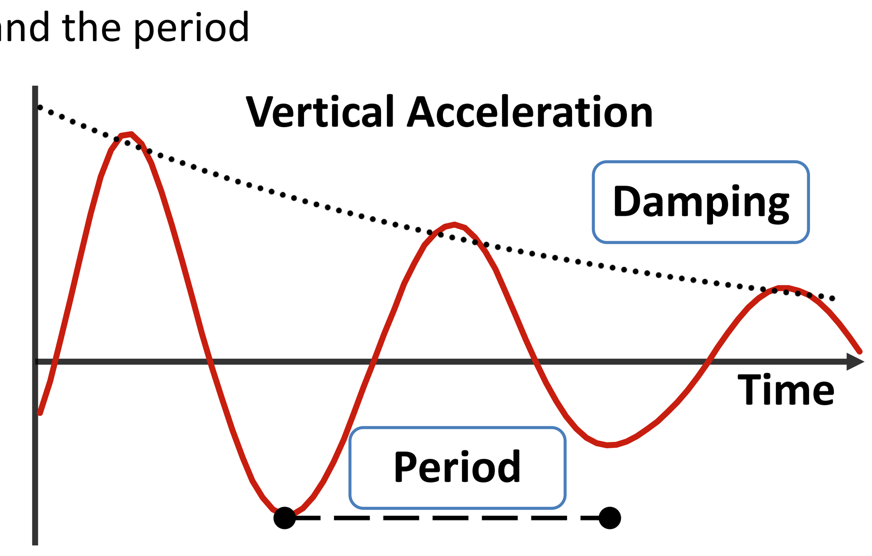



- Hypotheses: Interference could originate from either ambient reflected waves or systematic axial rotation

## OrcaFlex Simulations

### Matching Model to Prototype

- Recreated buoy model in OrcaFlex, an offshore marine structure design software
- Tuned parameters by matching simulated tests to experimental tests
- Determined inputs by matching the damping curve and the period



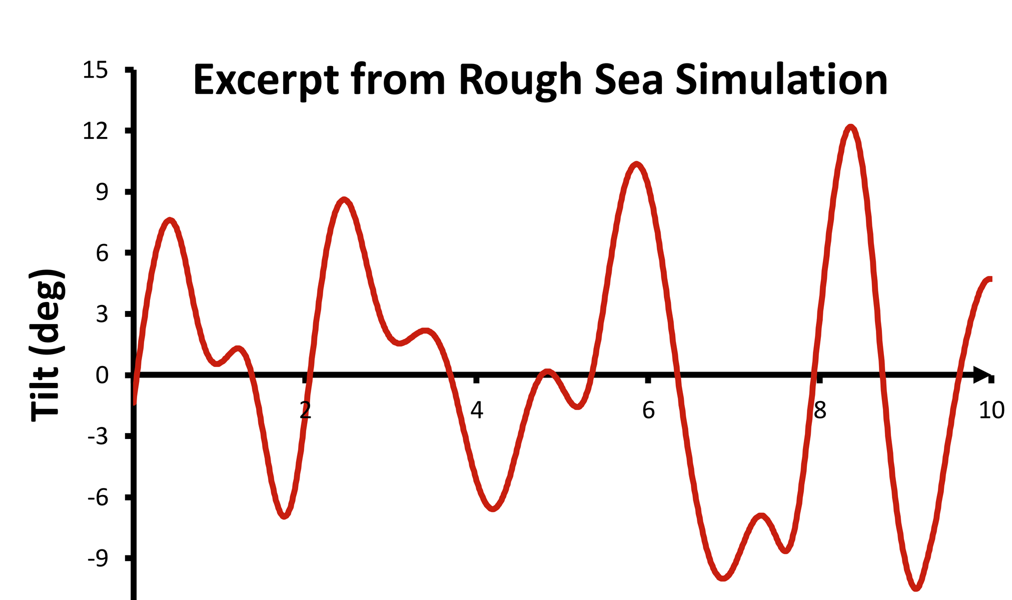

**Damping factors include:**

- Viscous drag against surface of buoy
- Added mass from inertia of water
- Dynamic restoring force and restoring torque
- Radiation as buoy heaves and generates waves

- Radiation damping accounts for 55% of the simulation's damping effects

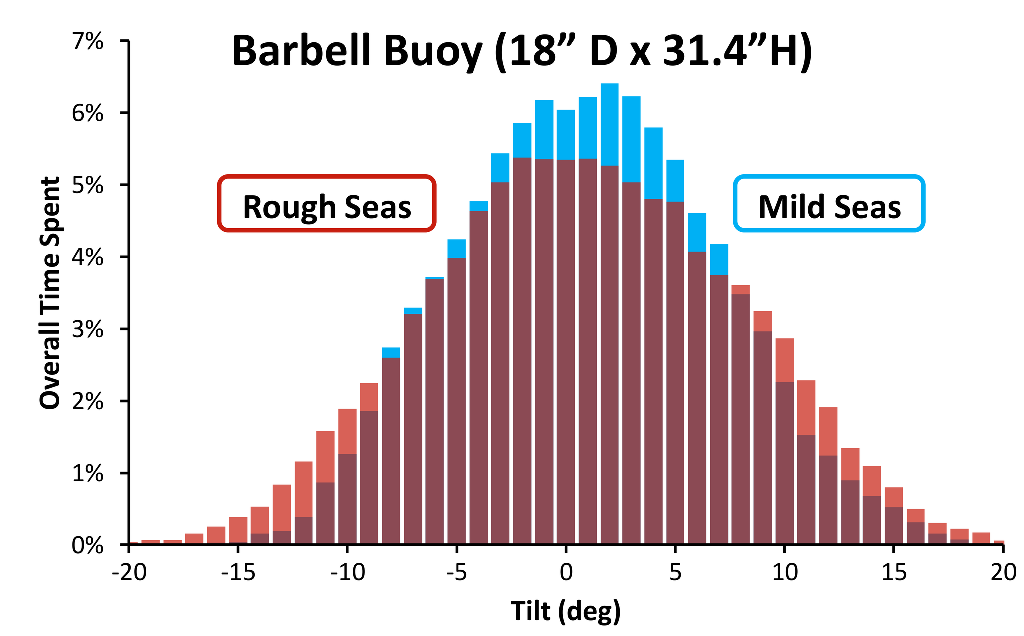
### Simulating Capabilities

- Simulated buoy in sea states 2 through 5 for mild to rough operating conditions
- Simulation was 15 minutes long, sampled at 100 Hz
- The roughest sea state tested has 7.9 ft. waves with a period of 6.8 seconds, and 24 knot winds

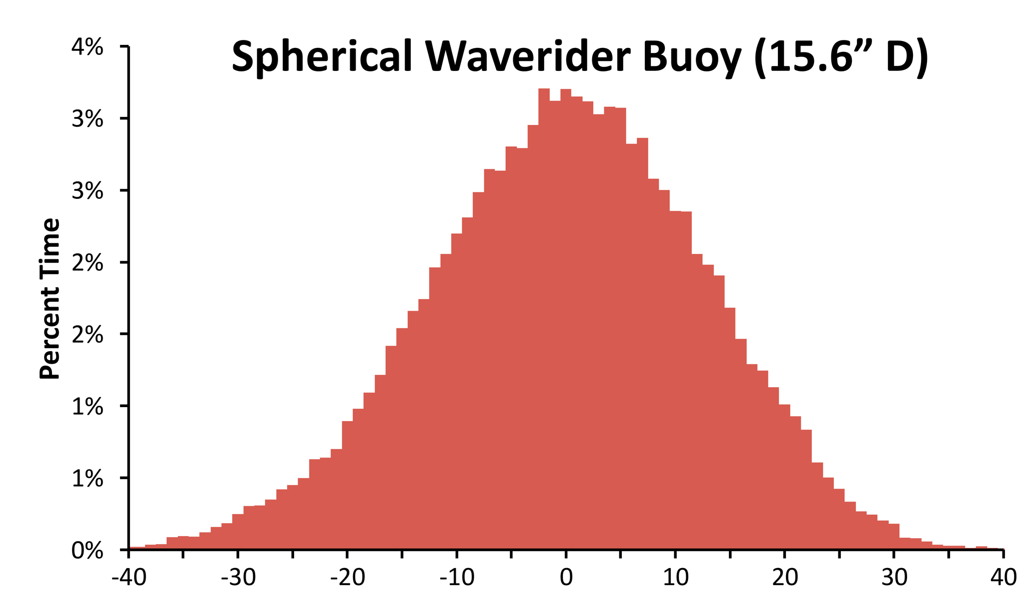



## Results

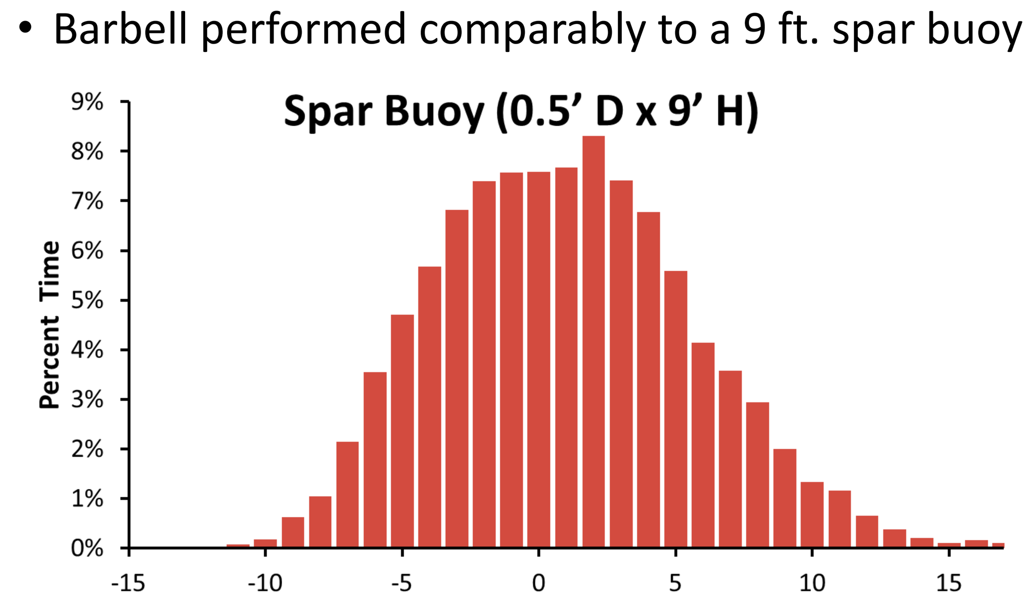
- Even in the roughest conditions, buoy was within 20 degrees tilt of equilibrium for 99.9% of the time




- Barbell demonstrated less tilt than the control, a DWR-G4 with 40 cm diameter, weighing 17 kg




- Barbell performed comparably to a 9 ft. spar buoy




## Conclusions

- Barbell buoys show promise as a stable platform for radio communications
- The shape can be further optimized, and future research may consider variations of the flotation top, or telescoping rods.