New applications for autonomous aerial vehicles (drones) in coastal oceanog

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Introduction & Applications

- Autonomous aerial vehicles (drones) offer new approaches for observing the coastal ocean.
- Newly developed technologies allow drones to fly programmed, accurate flight trajectories.
- We describe the use of small drones for two applications to improve observations of the coastal ocean.

Applications

1. *Antenna pattern measurements (APMs) of high frequency (HF), direction-finding oceanographic radars.*
   - Accurate measurement of surface currents by direction-finding radars requires measurement of the directional response of receive antennas.
   - APMs are typically conducted using small research vessels which are costly and often limited by sea state.
   - APMs can be conducted using drones at greatly reduced costs and are not limited by sea state.
2. *Water sample collection for calibrating time series obtained from moored oceanographic instruments.*
   - Long-term observations of water properties in the coastal ocean are typically measured using moored sensors that require calibration by bottle sampling.
   - Our application is water sample collection for pH sensor calibration as part of the Santa Barbara Coastal Long Term Ecological Research (SBC LTER) project.
   - Bottle sampling from small boats is costly and often limited by sea state.
   - We are developing a method to obtain bottle samples by drones which offers the advantages of lower cost and more frequent sampling.

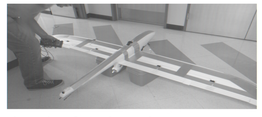
Drones

We have experimented with two types of drones: 1) fixed-wing airplanes; 2) quad-rotor aircraft (quad-rotors). Due to evolving flight regulations and ease of use, we are focusing future development on quadrotor drones.

Airplane drone

- The airplane was commercially available from an on-line hobby store and originally configured to be radio-controlled by a human operator.
- Foam construction provides flotation in the event of a water landing.
- Modifications enabled automated flight control and reduced weight.
- Payload was a miniature radio signal source.
- Characteristics:
  - wingspan: 2.40 m
  - fuselage length: 1.35 m
  - mass: 2.56 kg
  - air speed: 17 km hr^{-1}
  - stall speed: 14 km hr^{-1}
  - flight duration: 1.5 hr

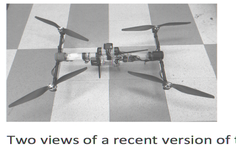
Ed Romero holding the airplane drone used for antenna pattern measurements.



Underside of airplane showing copper tape that forms the ground plane for the signal source

Quad-rotor drone

- A series of quad-rotor drones were constructed in our laboratory. A recent version is shown below.
- Fuselage is a clear plastic tube that also provides floatation in the event of a water landing.
- Components and fixtures on quad-rotor drones made with 3-D printer.
- Quad-rotors robotically take-off, fly a programmed flight plan, and land at take-off point.
- Radio control can be used by a human operator at any time
- Characteristics:
  - rotor diameters: 0.42 m
  - fuselage length: 0. 61 m
  - mass: 1.8 kg
  - air speed: 0 – 4 km hr^{-1}
  - flight duration = 40 minutes

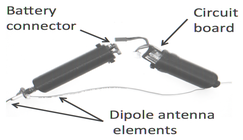


Two views of a recent version of the quad-rotor drone used for antenna pattern measurements. Modifications are ongoing for water sampling.

Payloads

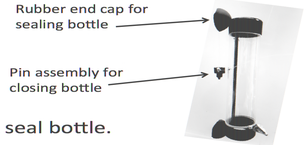
Radio signal source for HF radar antenna pattern measurement

- Signal source carried by airplane and quad-rotor drones.
- Signal source transmitted power: 10 mW
- Frequency range of signal source: 3 – 50 MHz
- Monopole antenna used on airplane. Antenna length = 5.5 m.
- Dipole antenna used on quad-rotor. Antenna length = 2 x 2.1 m.
- Signal source mounted in tubular case made with a 3-D printer.
- Frequency stability: A few 10's of Hz during APMs.



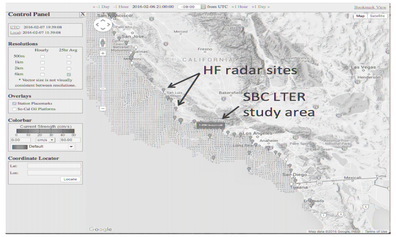
Bottle for water sample collection

- Sampling bottle carried by quad-rotors:
- Mass of bottle sample = 0.3 kg
- Sample volume = 1 liter
- Bottle is tripped when float pulls pin to release end caps & seal bottle.



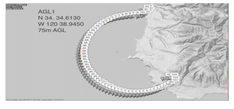
Study area

- A total of 55 antenna pattern measurements have been made by drones for HF radars operated by the Southern California Coastal Ocean Observing System (SCCOOS).
- Bottle samples for pH sensor calibration will be collected at moorings operated by the Santa Barbara Coastal Long Term Ecological Research (SBC LTER) project.



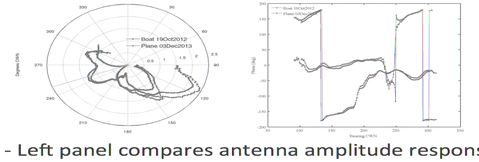
Antenna pattern measurements

- To measure antenna patterns of oceanographic radars, radio signal sources are carried in circular arcs around radar sites.
- We determined that airplane & quad-rotor drones can maintain circular flight paths within a few meters.



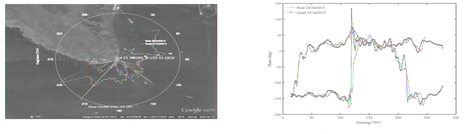
- Typical waypoint pattern for drone flight path.

Antenna patterns: Boat vs. airplane



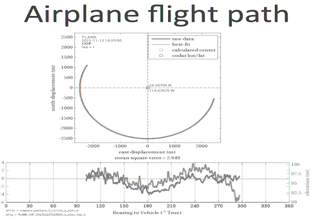
- Left panel compares antenna amplitude response measured by airplane (blue) and boat (red).
- Right panel is similar, but compares phase response.

Antenna patterns: Boat vs. quad-rotor



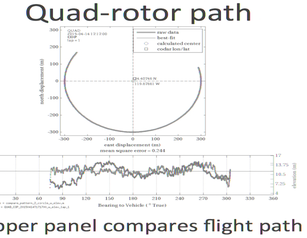
- Left panel compares antenna amplitude response measured by quad-rotor (red) and boat (green).
- Right panel is similar, but compares phase response.
- Deviation in quad-rotor pattern at 120° bearing caused by breakwater.

Airplane flight path



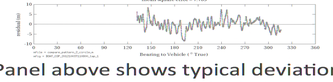
- Upper panel compares circular flight path of airplane to circle with 2.5 km radius.
- Lower panel shows altitude (red) and deviation from circular path (blue).

Quad-rotor path



- Upper panel compares flight path of quad-rotor to circle with 300 m radius.
- Lower panel shows altitude (red) and deviation from circular path (blue).

Boat path



- Panel above shows typical deviations of boat path from a circle during antenna pattern measurements.
- These are much larger than deviations of the drones.

Water sample c

- An important design requ
is the capacity to collect an
- Moorings with pH sensors
to 2 km offshore.

Modifications to the quad-
water sample collection.

- One modification is instal
LIDAR for precise altitude c
ocean.
- A camera will guide samp

Undergraduate

- The UCSB project to develo
provides internship opportu
engineering students.
- Students learn about the a
flight control and 3-D printin
- They gain design experienc
such as Solid Works.

Erinn Sloa
developme
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Lance Low
in HF rada

Robert Pa
for drones

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Alexande
prototype
Capstone

Summary and

1. Small autonomous aeri
to boats for measuring an
2. More research is neede
such as range & altitude a
3. Drones can provide rap
for calibrating temporary
oil spills. This capability w
Santa Barbara Channel in
4. Development is contin
water samples in the coas
as pH sensors.

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