

Multistatic Radar Detection and Tracking of Drones



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Who we are

Dr. M. Schneebeli

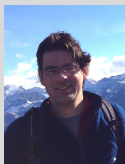


PhD Physics, Bern
 Scientist EPFL,
 Smithsonian, INPE
 (Brazil)

Group head
 MeteoSwiss

Expert in RF
 hardware design and
 microwave remote
 sensing

A. Leuenberger



El. Engineering
 ETH Zurich; MSc.
 Atmospheric Sci.,
 Bern

Software engineer in
 private sector

Scientist
 MeteoSwiss

Expert in radar
 signal processing

Dr. P. Wellig



PhD El. Eng., ETH;
 MAS Proj. Manag.

Engineer in private
 sector

Research program
 leader at armasuisse

Expert in
 surveillance and
 reconnaissance
 technologies

Dr. U. Siegenthaler



PhD Physics,
 University of Bern

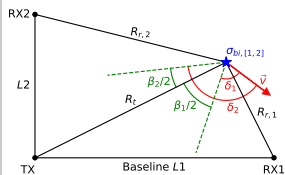
Analysis of antarctic
 ice cores

Scientific project
 manager at
 armasuisse

Expert in signal
 intelligence and
 electronic warfare

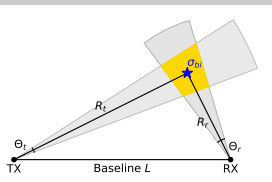
Bi-/Multi-static Radar

Geometry



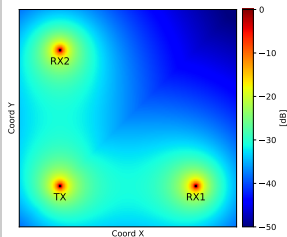
No zero-Doppler condition on both receivers.

Detection area



Detections only possible on RX/TX beam intersection.

SNR range dependence



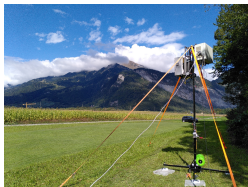
Homogeneous SNR distribution possible.

Main difficulty: Node synchronization in time and space.

- ▶ Clutter peaks for phase synchronization.
- ▶ Target simulators for geometrical and amplitude calibration.

The SAMURAI Radar

- ▶ C-band: 5.2-5.8 GHz
- ▶ 1 transmitter and 2 receivers
- ▶ Transmitter
 - ▶ 100 W peak power
 - ▶ Phased array
 - ▶ -45° – $+45^{\circ}$ scan angle (horizontal)
 - ▶ Pulse compression
- ▶ Receiver
 - ▶ 8 WiFi antennas
 - ▶ Digital beam forming
 - ▶ No resolution in elevation



Transmitter



Receiver

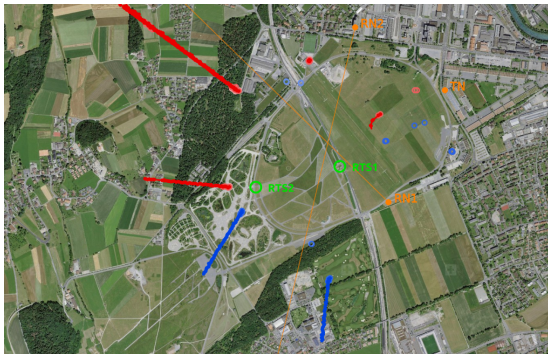
Palindrome Target Simulators

- ▶ 2-12 GHz
- ▶ Two independent receive and transmit channels
- ▶ 100 MHz instantaneous bandwidth
- ▶ Steerable antenna
- ▶ Can be mounted on drones
- ▶ Targets
 - ▶ Multiple static targets per channel
 - ▶ High precision configurable RCS
 - ▶ Moving targets with corresponding Doppler shift
 - ▶ Micro-Doppler modulation
 - ▶ Monostatic target range from 2 to 150 km



Target simulator

Artificially generated trajectories



- ▶ One virtual trajectory per receiver and per target simulator.
- ▶ Allows precise alignment of SAMURAI RX nodes.
- ▶ Multistatic geometry: virtually generated targets do not overlap.

Simulated target overtake

- ▶ Illustrative application of multiple generated targets.
- ▶ Two targets with different speeds.
- ▶ Testing of:
 - ▶ Target separation
 - ▶ Trajectory building



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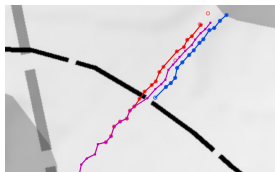
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Track Generation and Fusion with Simulated Targets

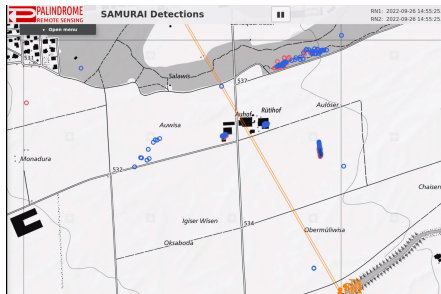
1. Track generation on individual RX nodes.
2. Track fusion.
 - ▶ Prerequisite: precise node alignment.
 - ▶ Tracks of one target are not always detected on both nodes.
 - ▶ Main difficulty: only combine what belongs together.
3. Test track fusion with target simulators in a monostatic geometry.



New track

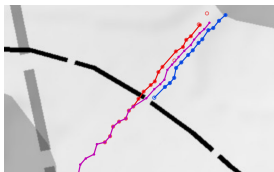


Aborted track

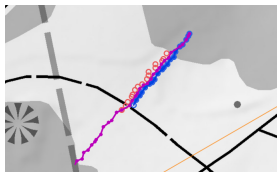


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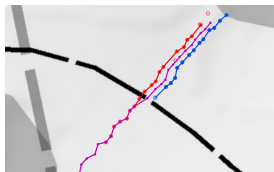
New track



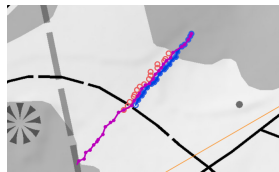
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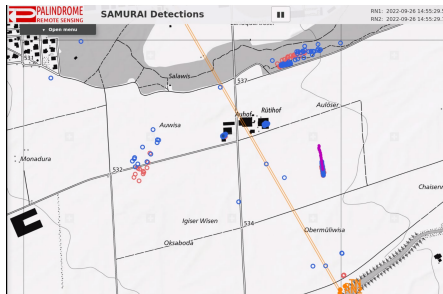
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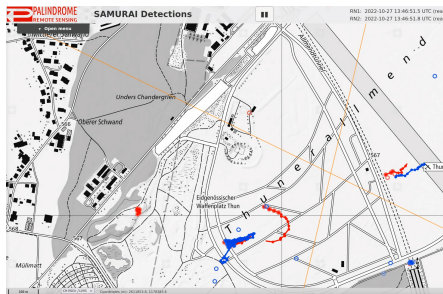
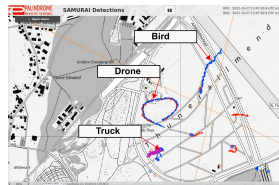
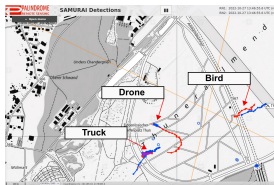


Aborted track



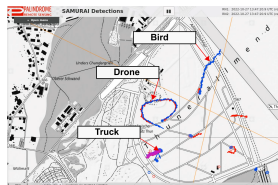
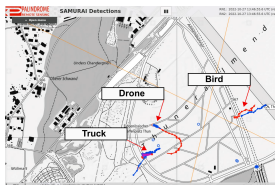
Detection of Real Targets

- ▶ DJI Phantom 4 drone
- ▶ Birds (similar RCS as DJI drone)
- ▶ Truck
- ▶ Multistatic advantages:
 - ▶ No zero Doppler condition on both RX nodes.
 - ▶ Less blind zones.
 - ▶ Detection redundancy.
 - ▶ SNR distribution over detection area.



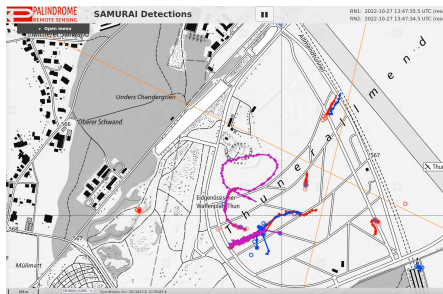
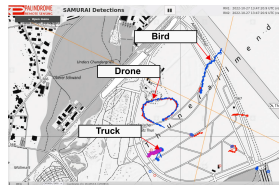
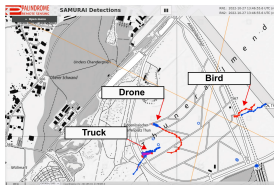
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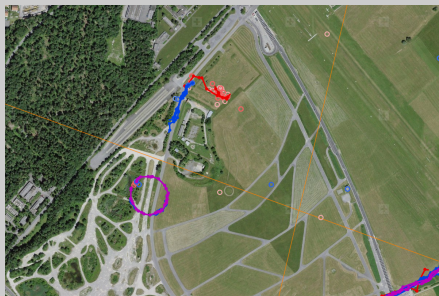
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Real Targets, further examples

Drone and Truck



- ▶ Drone on circular pattern.
- ▶ Uninterrupted track building.
- ▶ No simultaneous detection of the truck with both RX nodes.

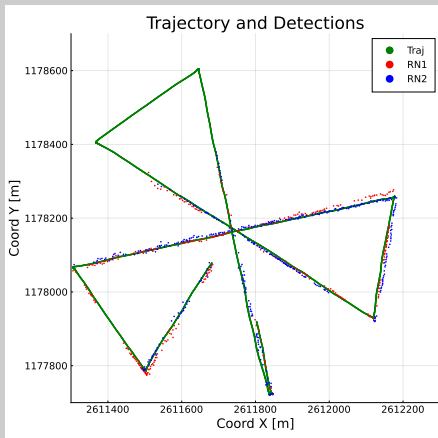
Swarm of Birds



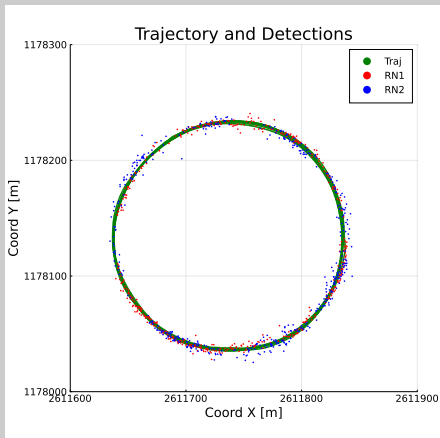
- ▶ No concurrent detection of other objects possible within swarm.

Detection evaluation

Star pattern

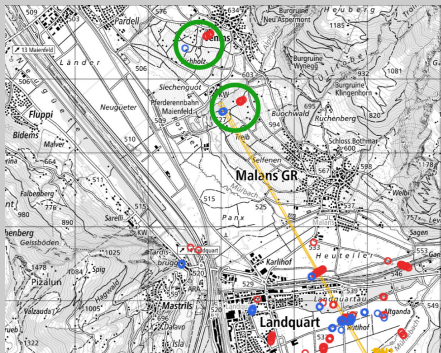


Circular pattern

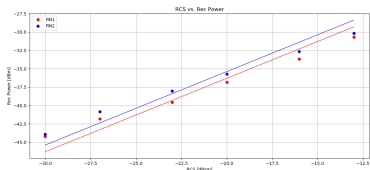


Radar calibration

Calibrated virtual targets



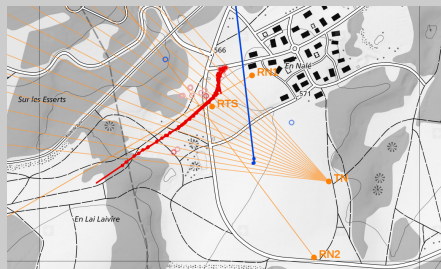
Target RCS vs. received power



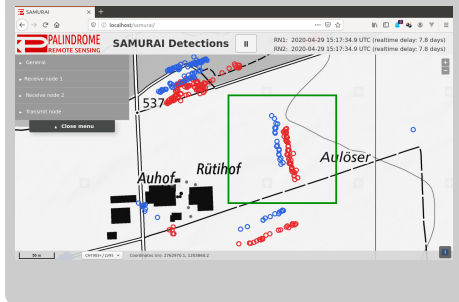
- ▶ Above curves are range corrected.
- ▶ Apply calibration curves to measured (signal power, range) pairs.

RCS measurement DJI Phantom 4

Bi-static



Monostatic



- ▶ Monostatic RCS: -30 dBm^2 (with high fluctuations of $\pm 10 \text{ dB}$)
- ▶ Bi-static RCS: To be further evaluated (Difficulty: Radar needs to be re-calibrated for every change in the set-up)

Conclusion and Outlook



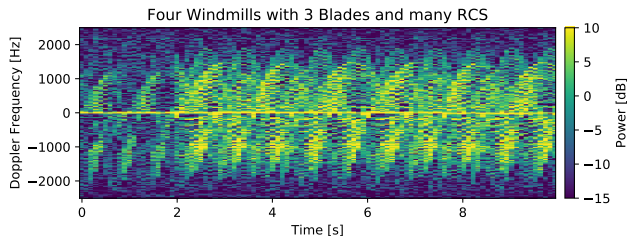
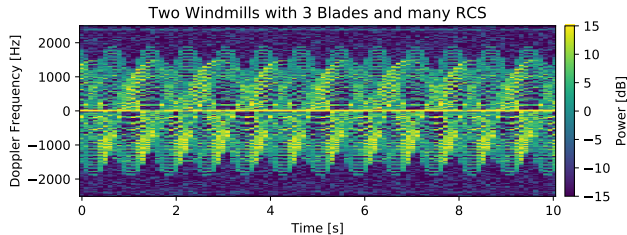
Conclusion

- ▶ Demonstration of successful multistatic detection and tracking of small targets.
- ▶ Crucial synchronization between nodes.
- ▶ Target simulator approach allows: geometrical calibration, absolute RCS measurements, testing of trajectory and track fusion process, simulation of complex targets.

Outlook

- ▶ Multistatic RCS statistics of drones.
- ▶ Improved target identification.
- ▶ Drone-mounted target simulator (end of 2023).
- ▶ Clutter simulation with target simulator.

Radar Measurements of Generated Wind Farm Signatures



- ▶ Implement simulated Amplitude-Doppler signatures into target simulator.
- ▶ Signatures are modulated on outgoing signal.
- ▶ Multiple wind turbines within one range gate or at subsequent range gates are possible.