Tactical Drone Detection and Tracking Using Machine-Learned Radio Interferometry: Lessons From Ukraine

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The utility of inexpensive radio-controlled drones has never been clearer than during the present conflict in Ukraine. Remote-controlled aircraft—quadcopters, small planes, and even balloons—provide a cheap and disposable source of reconnaissance, surveillance, and munitions-deployment. As a result, the need arises to accurately detect and track drones in an ever-changing and chaotic environment. Current anti-drone solutions use unreliable visual detection or expensive, cumbersome, and inflexible radio-based tracking. In response to the increased prevalence and agility of drone-based threats, new tracking methods are required. Using off-the-shelf hardware, I designed and tested a low-cost drone detection and geolocation system using radio interferometry. I built custom antenna-switching circuitry using a high-speed RF switch IC, which modulates a four-antenna array into an open-source software-defined radio running on Linux. I wrote custom signal-processing algorithms in python to compute detection attributes: manual processing—using phase-sample counting, k-means clustering, and density-based grouping (DBSCAN)—and regressive neural networks. Using the principles of radio interferometry, my algorithms analyze the phases and magnitudes of UHF radio signals from a drone, in the array of antennas. The system estimates drone bearing, range, and altitude—alerting users and graphically displaying crucial information. Using machine learning, my system can learn to use geometrically complex, non-standard antenna arrays. This adaptability allows for a wide variety of configurations and applications. To measure accuracy and confirm utility, I tested my system in the field using drone hardware identical to that used in Ukraine.

Awards Won:
Third Award of $1,000
Qorvo: Qorvo Innovator Award - 3rd Place
Air Force Research Laboratory on behalf of the United States Air Force: Glass trophy and USAF medal for each recipient
Air Force Research Laboratory on behalf of the United States Air Force: First Award of $750 in each Regeneron ISEF Category, FOR 2023 ONLY: EBED WILL HAVE TWO
Patent and Trademark Office Society: Second Award of $500
Office of Naval Research on behalf of the United States Navy and Marine Corps: The Chief of Naval Research Scholarship Award of $15,000