



Aero Sense Phase II — AI-Enhanced ELF Radio Receiver for Unmanned Aerial System Detection and Localization

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The increased use of Unmanned Aerial Systems (UAS), or drones, requires the development of effective detection and localization methods to mitigate escalating privacy and security risks. Traditional active sensing techniques (visual, acoustic, radar, RF) are susceptible to discovery or evasion. Aero Sense Phase 02 addresses this gap by proposing an AI-enhanced passive sensing system that capitalizes on the Extremely Low Frequency (ELF) magnetic signatures emitted by Brushless DC (BLDC) motors. Building on the foundation of Phase I, this study extends the detection range (beyond 10 m) and introduces a crucial localization functionality within a predefined target area. The methodology involves designing and testing optimized receiver antennas to capture these weak ELF signals, despite challenges posed by high ambient noise. Multiple circular and octagonal loop antennas were designed and experimentally characterized indoors and outdoors. The analog front end, including a 1.65 V bias and passive 3:1 attenuation network, reliably conditioned bipolar signals up to 10 Vpp into the 0–3.3 V ADC window without clipping across 1–7 kHz. Drone signatures were analyzed using the Spectral Correlation Function (SCF) computed via the FFT Accumulation Method, which clearly separated drone-present and environment-only cases and revealed distinct spectral patterns for different drone models. These SCF images formed the input to CNN models, which were used to localize the drone in a real-world 5 m × 5 m grid, where a customized EfficientNetB0 reached approximately 85–98% cell-level accuracy. The results confirm that ELF-based passive sensing combined with SCF and deep learning is a viable alternative for short-range UAV detection and coarse 2D localization.

Keywords: Analog circuits, Antenna theory, Cyclostationary process, Fast Fourier transforms, Noise cancellation