

THE ABSTRACT OF DOCTORAL THESIS

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Dissertation title: Enhancing clutter filtering capability and improving the quality of high-resolution radar systems.

Scientific field: Telecommunications Engineering

Major: Telecommunications Engineering

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Postgraduate training institution: VNU University of Engineering and Technology - Vietnam National University, Hanoi.

1. Research objectives and subjects of the dissertation

The dissertation investigates clutter-mitigation solutions for high-resolution radar (HRR) systems in FMCW low-altitude and pulsed long-range surveillance radars, addressing three clutter types: phase noise caused by transmit-receive leakage, discrete clutter from birds, ground vehicles and structures, and non-Gaussian, non-homogeneous composite passive clutter, each treated at the layer of its origin.

2. Research methods employed

The dissertation combines theoretical analysis and simulation, design and fabrication of RF hardware, signal processing combined with machine learning, and experimental verification on operational radar systems.

3. Main results and conclusions

The dissertation has achieved three scientific contributions:

The first contribution: Phase noise reduction for FMCW radar through high-isolation antenna design. The detection-quality requirement is reduced to a single hardware metric (isolation ≥ 82.25 dB); the transmit-receive leakage is decomposed into two independent paths, controlled by a slotted-waveguide array combined with a polarization filter grid and a horn aperture, solving phase noise at the hardware level instead of at the transmitter or post-processing stage. The measured isolation reaches 85 dB over the 8,900–9,500 MHz band, about 5 dB higher than microstrip antennas in representative publications.

The second contribution: Discrete clutter filtering and UAV classification in low-altitude surveillance. The DDDCR module with a hierarchical Top Model combines two features with complementary effective ranges (propeller micro-Doppler spread and trajectory matched against a traffic map) with machine learning, suited to short scan cycles. Tested with DJI Phantom 4: 97% of discrete clutter is removed, 100% of drones are correctly classified; classification range is 3.5 km (road-crossing) and 1.7 km (along-road), improved 1.6 to 3.2 times over the Elvira radar (1.1 km).

The third contribution: Composite clutter processing in long-range pulsed surveillance radar. Multi-beam processing is combined with a two-stage adaptive CFAR: HDBSCAN clusters clutter regions and Bernstein polynomials approximate the non-Gaussian distribution to set local thresholds, replacing the homogeneous-clutter assumption of conventional CFAR. On a 360 km 3D surveillance radar, target SNR increases by about 8 dB at 70 km (representative of the test flight path) and false alarms decrease by more than 90% versus CA-CFAR; the detection probability in the clutter region is 0.86 versus 0.14–0.42 for six benchmark algorithms with continuous target tracking.

The solutions have been integrated and verified on domestically developed radars in operation, meeting real-time requirements; results are published in 02 ISI/SCOPUS journals, 04 international conferences and 01 domestic patent.

4. Conclusions

The dissertation has addressed the multi-layered clutter-mitigation problem for high-resolution radar by treating each clutter type at the layer where it originates: phase noise at the RF hardware layer, discrete clutter at the feature layer, composite clutter at the adaptive detection-threshold layer. High antenna isolation is a prerequisite for exploiting micro-Doppler features. Results are specific to the tested configurations.

Future work: transmit-receive phase stability; larger datasets prioritizing drone-bird discrimination with deep learning; automated digital map updating; wider field tests with real-time load assessment.

ON BEHALF OF THE SUPERVISORS

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CERTIFICATION BY THE TRAINING INSTITUTION

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