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 **Code:** 9520208

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 to enhance the detection, classification and tracking of targets in complex clutter environments. The research objects are two representative classes - FMCW radar for low-altitude surveillance and pulsed radar for long-range surveillance, with three specific clutter types considered: phase noise caused by transmit-receive leakage, discrete clutter from birds and ground vehicles, and non-Gaussian, non-homogeneous composite passive clutter.

2. Research methods employed

The dissertation adopts an integrated, multi-layered approach - synchronously combining theoretical analysis and simulation, design and fabrication of RF hardware, signal processing combined with machine learning, together with experimental verification on operational radar systems; ensuring synchronous development of clutter-mitigation solutions from hardware to algorithms under real operating conditions.

3. Main results and conclusions

The dissertation has proposed three scientific-technical solutions and conducted one experimental verification on operational radar systems:

The first contribution: Phase noise reduction through high-isolation antenna design. The dissertation proposes a slotted-waveguide antenna array structure with high directivity integrated with a polarization filter grid. Unlike most existing studies that address phase noise at the transmitter or post-processing stage, which increases the complexity of digital processing, the proposed solution tackles the problem directly at the hardware design level. The transmit-receive isolation reaches 85 dB, distinctly exceeding the ≤ 80 dB level reported in representative international publications in the same frequency band, thereby significantly improving the range and velocity measurement stability of FMCW radar.

The second contribution: Discrete clutter filtering and UAV classification in low-altitude surveillance. The dissertation develops the DDDCR processing chain that exploits the micro-Doppler features of drone propellers, combined with a traffic map and machine learning models to discriminate UAVs from birds, cars and motorcycles. Unlike previous studies that mainly focus on biological-target discrimination or require continuous illumination, the proposed method operates effectively under the short scan cycles of surveillance radar. Results: 97% of discrete clutter is removed and 100% of test drones are correctly classified; DJI Phantom 4 is stably detected at 3.5 km, with classification range improved 1.6 to 3.2 times depending on the flight scenario compared with the commercial Elvira radar (1.1 km).

The third contribution: Composite clutter processing in long-range pulsed surveillance radar. The dissertation develops a multi-beam processing algorithm combined with a two-stage CFAR adaptive to clutter clusters, using HDBSCAN clustering and Bernstein-polynomial approximation of the non-Gaussian probability density function to determine the optimal local threshold for each clutter region. Unlike conventional CFAR detectors based on the assumption of fixed and homogeneous distribution - prone to performance degradation in real environments - the proposed method adapts flexibly to the actual statistical characteristics. On a 3D surveillance radar with 360 km range, the target SNR increases by about 8 dB (at 70 km range) and the number of false alarms decreases by more than 90% compared with conventional CA-CFAR; the proposed method maintains the continuity of the target trajectory when entering the clutter region - a result that none of the benchmark algorithms achieved.

The fourth contribution: Experimental verification on operational radar systems. The proposed solutions have been integrated and evaluated on the FMCW radar prototype for low-altitude surveillance and the 3D long-range surveillance radar, meeting real-time requirements. The results have been published in 02 ISI/SCOPUS-indexed international journals, 04 international scientific conferences, and 01 domestic patent.

4. Conclusions

The dissertation has successfully addressed the multi-layered clutter-mitigation problem for high-resolution radar in both FMCW and pulsed classes, with two core arguments: high-isolation antenna hardware design for phase noise reduction - distinct from existing studies that mainly focus on the transmitter or post-processing stage; and adaptive detection algorithms based on clutter clustering - overcoming the limitations of conventional CFAR. Integrating micro-Doppler features with machine learning is an effective direction to discriminate UAVs from moving discrete clutter.

Future work: ensuring phase stability among transmit-receive elements, applying deep learning to further exploit micro-Doppler features, and extending experiments to multiple radar configurations under various terrain conditions.

Date: ………………...

ON BEHALF OF THE SUPERVISORS	**PhD CANDIDATE**
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	Tran Vu Hop

CERTIFICATION BY THE TRAINING INSTITUTION

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