INFORMATION ON DOCTORAL THESIS

1. Full name: *Xuan Luong Nguyen*
2. Sex: *Male*
3. Date of birth: *July.21, 1979*
4. Place of birth: *Nghe An Province*
5. Amission decision number *2165/QĐ-ĐHKHTN* dated: *August 5, 2022*
   by *Vice President of VNU University of Science*
6. Changes in academic prcess
7. Officical thesis title: "***Research on Enhancing the Detection and Localization of Small-Trace Targets in Radiolocation Systems Using Phased Array Antennas***"
8. Major: *Radio physics and electronics*
9. Code: *9440130.03*
10. Supervisors: *MS. Assoc.Prof.Dr. Thanh Thuy. Dang Thi, University of Science - VNU Hanoi; SS. Dr. Phung Bao. Nguyen , Military Technical Academy - Ministry of National Defense*
11. Summary of the new findings of the thesis

This thesis addresses the challenge of enhancing the detection and localization capabilities of small-trace targets (STT) for multifunctional radar systems employing digital phased array antennas (DPAA). The research integrates theoretical analysis with various approaches, methodologies, and technical solutions, while considering the specific characteristics of the target class in question. The synthesis of these elements aims to improve the performance of radar systems in detecting and determining the coordinates of small-trace targets.

The specific objectives of this research are outlined as follows:

1. To synthesize and analyze small-trace (STT) targets, identify their limitations, and propose detection methods and coordinate estimation techniques suitable for all target objects in radar systems utilizing DPAA integrated with Transmit/receive modules (TRM) arranged on an open surface. This objective includes the development of a system architecture for DPAA, encompassing the

synthesis of radiation and receiving patterns diagrams in detection mode, and determining the coordinates of STT targets. The outcomes of this research must ensure that the signal-to-noise ratio (SNR) is enhanced to meet the requirements for detecting various types of targets.

2. To investigate the TRM model based on quadrature modulation and demodulation techniques applied in radar systems. This involves synthesizing the transmitting and receiving paths structure of TRM based on this approach and proposing technical solutions to optimize the transmitting path for linear amplification. Additionally, the receiving path structure will be refined using an appropriate filtering model (matched filtering) to detect signals with a low SNR, thereby ensuring the effective detection of useful signals reflected from the STT target layer.

3. To analyze and propose methods for measurement and calibration during the manufacturing process to guarantee the quality of the radar system before deployment. The proposing integrated subsystem models for the automatic measurement and calibration of the receiver when interacting with targets, including those within the STT target layer.

4. Finally, to validate the theoretical research findings through simulation and experimental verification.

Given that the research encompasses nearly all fundamental components of the DPAA system in addressing the detection of STT targets, the approach to solving this issue must adopt a holistic, system-wide perspective. This approach should span from the formulation of patterns to ensure effective maintenance, supported by measurement and calibration procedures at both the manufacturing stage and throughout operational use. This comprehensive approach aims to address the limitations of the entire system when interacting with the class of STT targets. The primary focus of this study will be the TRM.

The objective of this thesis is to achieve a synthetic signal-to-noise ratio SNR_{Σ} considerably greater than 1 for the detection problem. Consequently, the novel contributions of this research are as follows:

1. The development and real-time synthesis of various forms of generalized patterns of DPAA. This includes the application of the digital single-pulse method for the DPAA to enhance the accuracy of angular coordinate determination for targets, including those classified as low radar cross-section target layers.

2. Improve the structure of the digital receiving and transmitting module with the receiving path completed according to the fully coordinated filtering model to ensure that there is no loss or distortion of weak signal information reflected from small-trace targets, contributing to improving the quality of detecting all types of targets.

3. Propose a new method of calibrating digital phased array antennas at the manufacturing facility and at the deployment location in an external interference environment to ensure the parameters of the main beam according to technical requirements and minimize the side beams to improve and maintain the quality of detecting and determining the coordinate parameters of targets in general and small-trace targets in particular.

4. Propose a new method for automatically measuring and calibrating the receiving path of digital transceiver modules (after completing the structure) to maintain the conditions for detecting small-trace targets during exploitation and operation, contributing to improving the quality of detection and determining angular coordinate parameters.

The scientific and practical significance of this thesis lies in its contribution to enhancing the detection capabilities and coordinate determination of targets, particularly STT targets, in radar systems utilizing modern DPAA. The research results offer valuable solutions that can be applied to the design, research, and manufacturing of advanced multifunctional radar systems equipped with DPAA. Additionally, certain independent findings from this research can be utilized to improve, refine, and modernize key

components in radar systems that employ older-generation DPAA. Specifically, the work contributes to the optimization of algorithms for multi-beam pattern formation, achieving higher processing speeds to better meet real-time demands in handling MTSTT. Moreover, the thesis supports the design and manufacture of new power amplifiers and TRM for integration into DPAA systems, as well as the enhancement of signal processing and accumulation algorithms.

12. Futher research directions

Radiolocation systems utilizing DPAA represent advanced system integration products, particularly within the armed forces and, more specifically, the National Air Defense Force. Consequently, the development of new products, as well as the improvement and enhancement of existing ones, is an essential and ongoing process. Several potential directions for further research, building upon the findings of this thesis, include:

+ Expanding the Operational Frequency Range: conducting surveys and expanding the operating frequency range during the completion phase to integrate the research results into real-world products, in line with the required scale and specifications.

+ Optimization of System Software and Processing Algorithms: Continuing to refine and optimize system software and processing algorithms, particularly through the integration of artificial intelligence (AI). This is especially relevant for radar systems with large numbers of TRM, aimed at improving quality, operational efficiency, and resource optimization.

+ Apply the development orientation of design, manufacture, and synthesis of radar measuring equipment according to the soft configuration approach to promote and expand their multifunctional capabilities in responding to many different types of objects that need to be monitored.

+ Development of Radar Measuring Equipment: exploring the design, manufacture, and integration of radar measuring equipment using a soft configuration approach. This would serve to enhance and expand the multifunctional capabilities of

radar systems, enabling them to respond effectively to a variety of objects requiring monitoring.

13. Thesis-related publications

1. **Xuan Luong N**., Dang T., Phung Bao N., Van Bac N. (2022), "Research and Design of an X-Band UHF Power Amplifier", *Journal of the Russian Universities. Radioelectronics*. ISSN 2658-4794. 25(5):56-66. https://doi.org/10.32603/1993-8985-2022-25-5-56-66.

2. **Nguyen, Xuan Luong**, Thanh Thuy Dang Thi, Phung Bao Nguyen, and Viet Hung Tran (2024), "Receiving Paths Improvement of Digital Phased Array Antennas Using Adaptive Dynamic Range", *Electronics,* 13, ISSN: 2079-9292, no. 21: 4161. https://doi.org/10.3390/electronics13214161, (WoS, Q2).

3. **Nguyen, Xuan Luong,** Nguyen Trong Nhan, Thanh Thuy Dang Thi, Tran Van Thanh, Phung Bao Nguyen, and Nguyen Duc Trien (2024), "Phased Array Antenna Calibration Based on Autocorrelation Algorithm", *Sensors* 24, ISSN: 1424-8220, no. 23: 7496. https://doi.org/10.3390/s24237496, (WoS, Q1).

4. **Nguyen Xuan Luong**, Dang Thi Thanh Thuy, Nguyen Phung Bao (2024), "Nghiên cứu ứng dụng AI engine trong thiết kế bộ tích lũy tương can đa kênh sử dụng FFT của ra đa mảng pha số", *Hội nghị khoa học Vật lý 2024* do trường VNU tổ chức.

5. **Nguyen Xuan Luong**, Nguyen Trong Nhan, Tran Van Thanh, Dang Thi Thanh Thuy (2025), "Calibration of phased array antenna with the minimum point finding method of the array factor", *Indonesian Journal of Electrical Engineering and Computer Science.* Vol.38, No.2, May, 2025, pp. 854-864, ISSN: 2502-4752, DOI: 10.11591/ijeecs.v38.i2.pp854-8i2, (Scopus, Q3).

6. **Xuan Luong Nguyen**, Nguyen Trong Nhan, Tran Van Thanh, Phung Bao Nguyen (2025), "Autocorrelation Method of Phased Array Antenna Calibration Based on Far-Field MeasurementMeasure", *Journal of the Russian Universities. Radioelectronics*. ISSN 2658-4794 (có giấy tiếp nhận đăng trong năm 2025).

7. Nguyen Trong Nhan, **Xuan Luong Nguyen**, Phung Bao Nguyen (2025), “Automatic calibration of the receiving line of the information and control systems in real-time”, *Scientific and Technical Journal of Information Technologies, Mechanics and Optics*. Issue 3, Volume 25, 2025, (Scopus, Q4).

Date:

On behalf of academic supervisors **PhD. Student**

Nguyen Xuan Luong