

Course Title: Quantum Radar & EW Systems
Credit Hrs: 3
Prerequisites: Quantum Mechanics, Quantum Sensing & Precision Metrology, Electromagnetic theory and Classical radar principles, UG level linear algebra and complex vector spaces

Course Overview:

This course provides an advanced study of quantum radar and electronic warfare systems, focusing on defense and precision sensing applications. Students learn the principles of quantum radar, including quantum illumination, entangled-photon detection, and quantum-enhanced lidar, along with classical radar limitations and stealth detection. Course covers theoretical analysis, derivations, quantum signal processing, and practical considerations such as noise, decoherence, and environmental effects.

Course Objectives:

1. Understand quantum radar principles and advantages
2. Master quantum sensing for defense applications
3. Design electronic warfare countermeasures using quantum technology

Course Learning Outcomes: Students will be able to:

- Analyze quantum radar performance advantages
- Design quantum illumination systems
- Implement quantum-enhanced target detection
- Develop electronic warfare applications

Course Contents

Week	Contents
1	Classical radar fundamentals, range equations, SNR, detection probability, and limitations due to thermal noise and low-reflectivity targets. Introduction to quantum advantages, entanglement, and correlations. Derivation: SNR and detection probability comparison (classical vs quantum radar).
2	Classical radar challenges, including stealth and low-observable targets. Quantitative derivation of detection probability limits. Discussion of how quantum correlations improve detection.

Week	Contents
3	Quantum illumination (QI) theory: entangled signal-idler photon pairs, hypothesis testing (H_0 : no target, H_1 : target present), and effect of decoherence. Derivation: Helstrom bound for minimum error probability.
4	Quantum illumination performance analysis under noisy conditions. SNR improvement over classical systems. Conceptual examples of low-reflectivity target detection using QI.
5	Entangled-photon radar systems: SPDC photon generation, idler storage, and coincidence detection. Performance metrics: detection probability and false-alarm probability. Derivations: two-photon correlation functions under lossy channels.
6	Practical considerations for entangled-photon radar: environmental losses, detector efficiency, and comparison with classical radar. Simulation exercises for entangled-photon detection.
7	<u>Midterm Exam</u>
8	Quantum-enhanced lidar and ranging: single-photon and NOON-state lidar systems, phase estimation, and ranging resolution limits. Derivation: distance measurement precision formulas under standard quantum and Heisenberg limits.
9	Stealth target detection using quantum sensors. Error probabilities for low-reflectivity targets. Conceptual simulations and quantitative comparison between classical and quantum detection.
10	Quantum electronic warfare techniques: jamming, counter-detection, and secure communication interference. Derivation: effect of quantum correlations on SNR and interference mitigation strategies.
11	Signal processing for quantum radar: quantum filtering, correlation analysis, spectral decomposition, and reconstruction of entangled-photon signals. Noise suppression techniques and practical simulation exercises.
12	Military implementation: system-level design, resource optimization, simulation of operational scenarios, and practical deployment

Week	Contents
	considerations. Derivation: quantitative assessment of detection performance under realistic conditions.
13	Case studies of quantum radar and EW applications in defense. Performance evaluation, error analysis, and operational scenario modeling.
14	Advanced quantum radar techniques: Multi-mode entangled photon sources Quantum target tracking and adaptive measurement strategies Optimization of quantum radar performance under environmental noise
15	Quantum radar integration and applications: Quantum radar network concepts and cooperative sensing, Hybrid classical-quantum radar systems, Signal processing optimization for multi-target detection and error analysis for multiple targets
16	<u>Final Exam</u>

Textbooks/ References:

- Lanzagorta, M. "Quantum Radar" (2011)
- **Brandsema, M. J. – Quantum Sensing and Metrology (2020)**
- **Mandel, L. & Wolf, E. – Optical Coherence and Quantum Optics (Cambridge, 1995)**
- **Caves, C. M. – Quantum Limits on Measurement and Phase Estimation (Phys. Rev. D, 1981)**
- **Skolnik, M. – Radar Handbook (3rd Edition, McGraw-Hill, 2008)**
- **Oppenheim, A. & Schafer, R. – Discrete-Time Signal Processing (3rd Edition, 2009)**

Assessment & Marking Scheme

- Assignments: 10%
- Quizzes: 10%
- Midterm Exam: 30%
- Final Exam: 50%