

Quantum Electromagnetics

Quantum Microwave Engineering for the Second Quantum Revolution: Designing Antennas, Cryogenic Circuits, and Front-Ends

MONDAY · Quantum Fundamentals for RF Engineers

Objective: Fundamental quantum concepts tailored for an RF engineer.

09:00 – 10:30 · Fundamentals: What is “Quantum” in RF?

- Microwave photon and energy discretization
- Harmonic oscillator as an LC circuit
Speaker: T. Roth (Purdue University)

11:00 – 12:30 · Quantum Mechanics for the RF Engineer

- From voltages to creation/annihilation operators
- Hilbert space as signal state space
- Phase & amplitude uncertainty (Standard Quantum Limit)
Speaker: T. Roth (Purdue University)

14:00 – 15:30 · Introduction to Entanglement in RF

- Non-classical correlations in microwave signals
- EPR (Einstein-Podolsky-Rosen) states in circuits
Speaker: L. E. García Muñoz (UC3M)

16:00 – 17:30 · Software Class: Visualizing Entanglement

- Simulation of entangled states
 - Thermal noise degradation (Python / QuTiP)
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TUESDAY · Quantum Hardware and Front-Ends

Objective: Designing RF chains operating at 10 mK.

09:00 – 10:30 · Microwave Engineering at 10 mK

- Thermal loading challenges

- Cryogenic attenuators, isolators, circulators
- Dielectric loss management
Speaker: Systems Engineer (Bluefors)

11:00 – 12:30 · Amplification at the Quantum Limit

- Traveling Wave Parametric Amplifiers (TWPAs)
- Wave mixing and noise squeezing
Speaker: Gabriel Santamaría

14:00 – 15:30 · Superconducting Cavities and Resonators Design

- High-Q factors (millions)
- Kinetic inductance in thin films
Speaker: Gabriel Santamaría

16:00 – 17:30 · Quantum Hardware Architecture & Packaging

- Cryogenic PCB design
- Microstrip-to-coax transitions
- Magnetic & IR shielding
- Wire-bonding vs Flip-chip
Speaker: Specialist from IBM Quantum / Keysight Technologies

WEDNESDAY · Quantum Optimization for Antenna Engineers

Objective: Applying quantum computing to electromagnetic problems.

09:00 – 10:30 · Quantum Computing: From Qubits to Algorithms

- How quantum systems solve complex problems
Speaker: P. Rocca (ELEDIA @ UniTN)

11:00 – 12:30 · Quantum Annealing & Antenna Optimization

- Radiation pattern synthesis
- Beamforming in complex environments
Speaker: G. Gradoni (University of Nottingham)

14:00 – 15:30 · Masterclass I: Computational Quantum Electromagnetics

- Atomistic modeling of light-matter interaction
- Density Functional Theory
Speaker: A. Boag (Tel Aviv University)

16:00 – 17:30 · Masterclass II: Computational Quantum Electromagnetics

- Quantum EM scattering
 - Characteristic mode basis
Speaker: A. Boag (Tel Aviv University)
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THURSDAY · Quantum Communications & Radar

Objective: Long-range applications and secure systems.

09:00 – 10:30 · Quantum Communications: QKD & Networks

- Quantum Key Distribution (QKD)
- RF and optical links
- Entanglement-based protocols
Speaker: L. E. García Muñoz (UC3M)

11:00 – 12:30 · Quantum Radar & Illumination

- Detection via entanglement correlations
- Performance in noisy environments
Speaker: L. E. García Muñoz (UC3M)
Reference: *Quantum Radar* – Marco Lanzagorta

14:00 – 17:30 · Industrial Round Table: The Future of RF

- Industry perspectives and roadmap
Participants: Indra · Airbus · IBM · ISDEFE
Moderator: E. Sánchez (EU Quantum Flagship)
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FRIDAY · Metrology, Testing & Future Trends

Objective: Validation methodologies and future outlook.

09:00 – 10:30 · Beyond Maxwell: Entangled Photons in RF Engineering

- Insights from Nobel Prize research
- Implications for RF systems
Speaker: Alain Aspect

11:00 – 12:30 · Rydberg Field Sensors

- RF measurement without antennas

- Atomic sensing and NIST standards
Speaker: Gabriel Santamaría

14:30 – 16:30 · Final Challenge: Quantum Link Budget

- Quantum vs classical radar comparison
- Practical system calculation exercise