

Metrology for and with Superconducting Quantum Electronics: from Qubits and Josephson Metamaterials to Quantum Electrical Standards

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Superconducting quantum electronics offers a common platform for quantum computing, microwave sensing, and primary electrical metrology. We present the Quantum Electronics group at INRiM, emphasizing metrology for and with superconducting circuits.

The group covers the full chain from modelling and cleanroom fabrication to cryogenic packaging, microwave readout, calibration, and uncertainty evaluation. Recent results include the realization and measurement at INRiM of transmon qubit chips, with dispersive readout used to assess coherence, qubit-resonator coupling, and readout performance, providing a testbed for superconducting qubits and readout chains.

In parallel, we develop Josephson metamaterials and traveling-wave parametric amplifiers as quantum-limited components and quantum resources. Their characterization addresses gain, bandwidth, added noise, scattering parameters, squeezing, and two-mode correlations, and connects to programmable microwave cluster states generated by multi-tone pumped Josephson metamaterials.

A complementary line links this toolbox to primary electrical standards. We realize and measure dual Josephson devices exploiting dual Shapiro steps, targeting quantum-accurate current plateaus in the nA range. This activity also connects to INRiM's Josephson voltage metrology programme, spanning programmable quantum voltage standards, DC/AC and sampled-power applications, calibration services, and international validation through BIPM comparisons.

The distinctive element is the integration of device physics with traceable electromagnetic measurements: calibrated cryogenic microwave chains, reference-plane transfer to the device, calculable thermal-noise sources, quantum-device benchmarking, uncertainty budgets, and interlaboratory comparisons. This approach aims to turn superconducting quantum electronics into reproducible measurements, bridging fundamental experiments, calibration services, standardization, and industrial validation.

Acknowledgements

This work was supported by the European projects MiSS, funded by the European Union through the Horizon Europe 2021–2027 Framework Programme under Grant Agreement ID 101135868; AQuanTEC and MetSuperQ, namely the 23FUN05 AQuanTEC and 23FUN08 MetSuperQ projects, funded by the European Partnership on Metrology, co-financed by the European Union's Horizon Europe Research and Innovation Programme and by the Participating States; and QuTest, funded by the European Union's Horizon Europe research and innovation programme under Grant Agreement No. 101113901. This work was also supported by the Italian projects CalQuStates, a PRIN 2022 project funded by the European Union – Next Generation EU, Mission 4 Component 1, CUP E53D23002210006; Quantum Radar, CUP ZAE31B3A7C, funded by the Italian Ministry of Defence; and by the Italian Ministry of University and Research (MUR) through the continuing nature project “NEXT GENERATION METROLOGY”, under the allocation of the Ordinary Fund for research institutions (FOE) 2023, Ministry Decree No. 789/2023.