

ABSTRACT

Superconducting quantum processors operate at cryogenic temperatures and are typically evaluated solely via their microwave output signals. This naturally raises the question of whether these signals can be replicated to be statistically indistinguishable from the genuine outputs. This dissertation demonstrates a room-temperature hardware spoofing mechanism made from microwave phase shifters and near-infrared (NIR) LEDs to build an emulated qubit (E-Qubit). Additionally, the research investigates how multiple E-Qubits can be configured into a beamforming phased array designed for physical layer security and covert communications.

The room-temperature E-Qubit aims to emulate the outputs of a real cryogenic superconducting qubit. The E-Qubit enables hardware-in-the-loop emulation of quantum superposition through the interaction of microwave readout electronics and a tunable quantum random number generator (tQRNG) based on quantum shot noise from two LED–photodiode detector pairs. The microwave electronic circuit replicates the resonator topology and phase-shifting dispersive readout of a transmon qubit. An emulator system based on true quantum randomness is demonstrated, replacing the conventional deterministic pseudo-random sampling method. Tunable correlation and anti-correlation between E-Qubits are used to reproduce the output probability distribution of real entangled qubits. The proposed E-Qubit system can be scaled to emulate quantum algorithms and produce probability distributions that are indistinguishable from those of a real superconducting quantum processor.

A quantum random phased array (QRPA) for physical layer covert communication is presented. The QRPA uses true quantum shot noise to temporally mask the beam state. Progressive phase offset between multiple E-Qubits produces a steerable directional beam with an adjustable probability of occurrence. A four-element array simulation verifies the system’s beampatterns, including a directional covert beam that occurs 0.33% of the time. The QRPA system demonstrates a total variation distance (TVD) of 0.0033 across all azimuthal reception angles. A warden operating under the deceptive priors belief state is subject to covert signal detectability blind spots across three angular sections totaling 75° . This work demonstrates that non-deterministic quantum noise can drive tunable beam switching for advanced low probability of detection (LPD) and high-level security applications.