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Designing cleaner microwave environments for superconducting quantum circuits

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Superconducting electronics are central to emerging, high-impact quantum technologies. Operating in the microwave regime, these systems require cryogenic environments and electromagnetic shielding to suppress unwanted electromagnetic interactions, blackbody radiation and quasiparticle interactions that can degrade coherence (Krinner et.al, 2019) or introduce experimental interference.

On-chip design has long been explored to improve device performance, with significant advances achieved, e.g., through using novel device geometries (Corcoles et.al, 2015) and novel materials to reduce system losses and enhance qubit coherence (Place et.al, 2021), or deep substrate etching to reduce dielectric loss (Bruno et.al 2015). Recently, however, more attention is being given to the environment immediately around the device. As on-chip performance has improved, it is now reaching the point where devices can be limited by their packaging and interconnects, if not designed carefully enough (Huang et.al 2021).

In this work, we explore how a device's microwave environment and physical connections to microwave control electronics contribute to loss. Using electromagnetic modelling, we analyse the impact of shielding geometries, connector placement, microwave interfaces, and on-chip features such as airbridges on propagating modes and impedance mismatches, to cause microwave reflections and loss. In describing the approach we take for integrating superconducting devices into larger systems without compromising performance, we consider where careful design of the packaging and interconnects can be expected to reduce loss and interference, enabling better utilization of high-performance devices. We also explore trade-offs between electromagnetic optimization and practical constraints imposed by precision machining of shielding and packaging and on-chip processes, such as airbridge nanofabrication.

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