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Multi-frequency modes in superconducting resonators: Bridging frequency gaps in off-resonant couplings CHRISTIAN KRAGLUND ANDERSEN, KLAUS MØLMER, Univ of Aarhus — A SQUID inserted in a superconducting waveguide resonator imposes current and voltage boundary conditions that makes it suitable as a tuning element for the resonator modes. If such a SQUID element is subject to a periodically varying magnetic flux, the resonator modes acquire frequency side bands. We calculate the multi-frequency eigenmodes and these can couple resonantly to physical systems with different transition frequencies and this makes the resonator an efficient quantum bus for state transfer and coherent quantum operations in hybrid quantum systems. As an example of the application, we determine their coupling to transmon qubits with different frequencies and we present a bi-chromatic scheme for entanglement and gate operations. In this calculation, we obtain a maximally entangled state with a fidelity $F = 95\%$. Our proposal is competitive with the achievements of other entanglement-gates with superconducting devices and it may offer some advantages: (i) There is no need for additional control lines and dephasing associated with the conventional frequency tuning of qubits. (ii) When our qubits are idle, they are far detuned with respect to each other and to the resonator, and hence they are immune to cross talk and Purcell-enhanced decay.

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