Near-Quantum-Limited SQUID Amplifier
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The SET (Single-Electron Transistor), which detects charge, is the dual of the SQUID (Superconducting QUantum Interference Device), which detects flux. In 1998, Schoelkopf and co-workers introduced the RFSET, which uses a resonance circuit to increase the frequency response to the 100-MHz range. The same year saw the introduction of the Microstrip SQUID Amplifier\(^1\) (MSA) in which the input coil forms a microstrip with the SQUID washer, thereby extending the operating frequency to the gigahertz range. I briefly describe the theory of SQUID amplifiers involving a tuned input circuit with resonant frequency f. For an optimized SQUID at temperature T, the power gain and noise temperature are approximately \(G = f_p/\pi f\) and \(T_N = 20T(f/f_p)\), respectively; \(f_p\) is the plasma frequency of one of the Josephson junctions. Because the SQUID voltage and current noise are correlated, however, the optimum noise temperature is at a frequency below resonance. For a phase-preserving amplifier, \(T_N = (1/2 + A)hf/k_B\), where Caves’ added noise number \(A = 1/2\) at the quantum limit. Simulations based on the quantum Langevin equation (QLE) suggest that the SQUID amplifier should attain \(A = 1/2\). We have measured the gain and noise of an MSA in which the resistive shunts of the junctions are coupled to cooling fins to reduce hot electron effects. The minimum value \(A = 1.1 \pm 0.2\) occurs at a frequency below resonance. On resonance, the value \(A = 1.5 \pm 0.3\) is close to the predictions of the QLE, suggesting that this model may fail to predict the cross-correlated noise term correctly. Indeed, recent work suggests that a fully quantum mechanical theory is required to account properly for this term\(^2\). This work is in collaboration with D. Kinion and supported by DOE BES. \(^1\)M. Mueck, \textit{et al.}, \textit{Appl. Phys. Lett.} \textbf{72}, 2885 (1998). \(^2\)A. Clerk, \textit{et al.}, http://arxiv.org/abs/0810.4729.