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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, *et al.*, *Appl. Phys. Lett.* **72**, 2885 (1998). [2]A. Clerk, *et al.,* http://arxiv.org/abs/0810.4729.