Noise Temperature of a Superconducting Hot-Electron Mixer

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The receivers based on the electron heating in superconducting films are becoming very attractive for terahertz applications. Due to the absence of spectral limitations and low parasitic reactances the hot-electron mixer may take an advantage over the traditional devices, e.g. SIS mixer and Schottky diode.

Only a few works are known[1-3] where the performance of such a mixer was studied experimentally. The availability of the conversion loss at least less than 10 dB at microwaves and millimeter waves has been demonstrated. Along with this the theoretical evaluation of the conversion gain and noise temperature of a hot-electron mixer has been done in a number of papers[1,4,5]. The results obtained by different authors are not consistent.

In the present paper we calculate the noise temperature of a hot-electron superconducting mixer assuming the Johnson noise and electron temperature fluctuations to dominate over other noise sources. We show that for superconductors with a broad transition $\Delta T_c \approx T_c$ (ΔT_c is the width of superconducting transition, T_c is the critical temperature) the noise temperature $T_M \propto \Delta T_c$ in contrast to [5]. For sharp superconducting transition the noise temperature does not depend on ΔT_c and can be given by the following expression:

$$T_M = 16T_c^3(T_c - T)^{-1}(2B_0 / B - 1)^{-1}$$

where T is the bath temperature, B_0 is the inherent in the superconductor frequency bandwidth determined by the electron-phonon relaxation time $\tau_{c\text{-}ph}$ at $T = T_c$, B is the mixer bandwidth.

Assuming $B_0/B = 5$ one can obtain for Nb mixer with $T = 4$ K and $T_c = 5$ K $T_M \approx 40$K and also for NbN mixer with $T_c = 10$ K $T_M \approx 25$ K.

The difference between B_0 and B arises when the mixer is biased at the point of high conversion gain. The attainment of such an operation mode depends strongly on the film homogeneity.

[1]E. Gershenzon et al., Sov. Phys. Superconductivity 3, 1582 (1990)

[2]H. Ekström et al., Proc. of the 23rd European Microwave Conf., p. 787, 1993

[3]A. Dzardanov et al., Proc. of the Int. Conf. on Millimeter and Submillimeter Waves and Applications, 10-14 Jan. 1994, San Diego, CA, p. 276

[4]F. Arams et al., Proc. IEEE 54, 308 (1966)

[5]D.E. Prober, Appl. Phys. Lett. 62, 2119 (1993)

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