Noise Temperature of a Superconducting Hot-Electron Mixer

Andrey I. Elantey* and Boris S. Karasik*

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\cite{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\cite{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 $\Delta T_c = T_c$ ($\Delta T_c$ is the width of superconducting transition, $T_c$ is the critical temperature) the noise temperature $T_M \propto \Delta T_c$ in contrast to \cite{5}. For sharp superconducting transition the noise temperature does not depend on $\Delta T_c$ and can be given by the following expression:

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

where $T$ is the bath temperature, $B_0$ is the inherent in the superconductor frequency bandwidth determined by the electron-phonon relaxation time $\tau_{c-ph}$ 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 $T_M = 40$K and also for NbN mixer with $T_c = 10$ K $T_M = 25$ 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.

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*Andrey I. Elantev and Boris S. Karasik are with the Moscow State Pedagogical University, 29 Malaya Pirogovskaya str., Moscow 119435, RUSSIA.