A MODEL FOR THE OPTIMUM PERFORMANCE OF NBN HEB MIXERS

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HEB mixer technology has matured considerably in recent years. Now attention shifts how to optimize HEB mixers for specific applications. Hot spot models indicate for NbN to exhibit a broad valley of comparable mixer performance within a (length times width) interval between 100nm x 1µm and 1µm x 10µm. Nevertheless experiments indicate that small volume mixers tend to perform worse and the experimentally found optimum is located around 300nm x 4µm HEB on 35Å thick NbN for some 250nW available LO power. Here two reasons are identified why smaller devices perform worse: First, contact resistance under the antenna pads gives rise to an effective length of the HEB exceeding the physical length. This explains partially the absence of bandwidth widening though diffusion in short NbN HEBs. Secondly, HEBs exhibit an unstable area in a region of operating points. There voltage bias creates a current exceeding the critical current even at the thickest point on the bridge. The HEB becomes normal conducting reducing the bias current. If this reduced current is smaller than the largest critical current path on the bridge, the bridge resistance drops to zero and the process starts anew. Such relaxation oscillations occur, whenever the current during the normal conducting phase in a relaxation cycle does not provide sufficient heating power to reduce the maximum critical current on the bridge below the minimum current flowing during the oscillation. If enough heating power is dissipated a barrier where superconductivity is suppressed (by excess current) forms across the bridge. For higher bias voltages this suppressed region turns into a hot spot where the quasiparticle temperature exceeds the critical temperature. Obviously the most sensitive operating points are located where the resistance changes due to a small heating change are largest. These points are close to the instability region. The closer to the instability region a HEB is successfully biased, the better performance it shows. For large devices the onset of instability and the point where a hot spot is created are widely separated leaving a large voltage range to bias the device resulting in an easy task to find the best point leading to better measured noise and gain. For smaller devices (made of the same film and under comparable operating conditions), this ”optimum valley” shrinks due to a less varying film across the bridge making it is difficult to find suitable operating points before the element starts oscillating resulting in worse measured noise and gain performance. The device model presented here treats the unstable region based on a distribution of the critical current and the critical temperature across the HEB. The subsequent large signal model is solved numerically and inserted into a small signal equivalent which is integrated numerically together with the circuit relations. Since both resistivity and critical temperature depend on temperature they are (partially correlated) sources of fluctuation noise. This requires the expression for the fluctuation noise to be changed. Quantum noise is still under discussion and not included in the model yet.

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