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Improved Equivalent Circuit for Hot Electron Bolometer Mixers Fed by Twin Slots

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Abstract

Series-fed coplanar waveguide embedding circuits are being developed for terahertz mixers using, in particular, submicron-sized superconducting devices, such as hot electron bolometers as the nonlinear element. Although these mixers show promising performance, they usually also show a considerable downward shift in the resonating frequency, when compared with simulations using simplified models. This makes it very difficult to design low-noise mixers for a given THz frequency. This shift is principally caused by parasitics due to the extremely small details (in terms of wavelength) of the device, and by the electrical properties of the RF choke filter in the IF/DC line. In this paper, we present an improved equivalent network model of such mixer circuits which agrees with measured results at THz frequencies. We first develop a method to calculate the characteristic impedance and the propagation constant of the coplanar waveguide, etched between two semi-infinite media (air and silicon), that connect the receiving slot antennas to the superconducting device. In the formulation we take into account, for the first time, the power leakage due to radiation. We then describe the procedure to calculate the reactances due to the detailed geometry of the mixer device and circuit, and we correct the input impedance calculated with a commonly used simplified network. We find excellent agreement by comparing our model results with a complete set of measured data for seven mixers in the range between 500 GHz and 3 THz. Finally, we analyze the features of our model and propose possible further improvements. Useful guidelines for designing THz mixer circuits are also given.