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Final Technical Report 3/15/90 to 3/14/93

"Quantum Noise Studies with
Superconducting Tunnel Junction Mixers"

Mark F. Bocko University of Rochester

We have completed our theoretical and experimental investigations of the noise properties of superconducting tunnel junction (SIS) mixers operated as both a phase insensitive linear amplifier and as a phase sensitive linear amplifier. We proposed a technique by which a SIS mixer could be operated as a phase sensitive linear amplifier, i.e., the gain and noise temperature of the amplifier are a function of the the phase of the incoming signal. In this technique two phase coherent local oscillators at different frequencies are combined in the mixer simultaneously so both a phase preserving and phase conjugating mixing process occur resulting in a phase sensitive mixer. Our main accomplishment during this grant has been to demonstrate that the phase sensitive linear amplifier has a signal to noise ratio a factor of at least two greater than the phase in-sensitive linear amplifier, i.e. the equivalent mixer noise temperature is reduced b a factor of two by employing phase sensitive measurement techniques.

A full quantum theoretical analysis of a superconducting tunnel junction mixer was carried out for the phase sensitive measurement technique. It was shown analytically and numerically that factors much greater than our experimentally observed factor of two improvement in the noise temperature of a phase sensitive mixer are possible. Unfortunately the project ended before the regions of parameter space in which the greatest noise reduction is possible were fully experimetally explored.

Work in the latter part of this grant period concentrated on the determination of the relative contributions to the total noise from the preamplifier, the thermal noise and the junction shot noise. We have used the quantum mixing theory and a simplified theory to theoretically predict noise vs. bias voltage curves. By fitting our data to the theoretical models we can deduce information concerning the correlation between the mixer shot noise being converted from the signal, image and IF frequencies. Determination of the degree of correlation between the noise arising from the different sidebands is the key factor in attempting to improve the signal to noise ratio of the two-LO mixer beyond the factor of two already achieved. This work has provided a simple technique to predict and fit SIS mixer noise curves and a method to experimentally determine the degree of correlation among the various sideband contributions to the noise.

In summary this work has contributed to the understanding of quantum and classical noise in superconducting tunnel junction mixers which are the lowest noise detectors available for frequencies from 40 GHz to hundreds of GHz. A novel phase sensitive operating regime for these mixers was proposed and investigated and it was found that the techniques employed further reduced the noise of these detectors below their already nearly quantum limited level.