IF bandwidth of NbN Superconducting Tunneling Junction Mixers

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I. Introduction

Besides the sensitivity nearly approaching the quantum limit, the intermediate-frequency (IF) bandwidth is of particular interesting for SIS mixers for radio astronomy research. In this paper, we are going to present the characteristic of IF bandwidth of two type of NbN SIS mixers, Long distributed junctions and Parallel-connected twin junctions. Firstly, the relative mixer gain are measured with different IF load impedance (25Ω, 50Ω, 75Ω) for both two SIS mixers. And also the mixers gain with different IF load impedance is simulated to get the optimum IF load impedance over a relative large IF bandwidth (2-15GHz). Finally, an IF matching circuit is designed and measured associating with SIS mixers, the measurement results show that the mixers gain are flatter over a large IF bandwidth than with 50Ω IF load impedance.

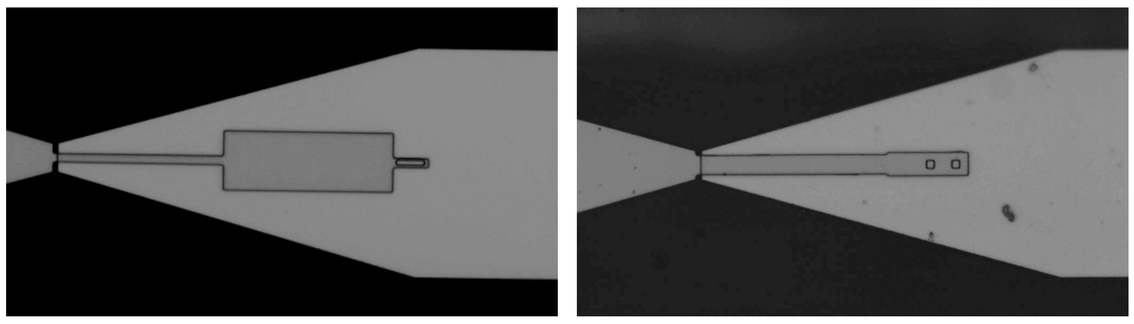
II. Optimum IF Load Impedance

According to Tucker's quantum theory of mixing separated the mixer conversion gain into a coupling factor C_{IF} and intrinsic mixer gain factor L_0

$$G_{mix} = C_{IF} L_0 = \left(\frac{4 G_{IF} G_L}{\left| Y_{IF} + Y_L \right|^2} \right) \cdot \left(\frac{G_s}{G_{IF}} \frac{\left| Cf_{10} \right|^2}{\left| Cf_{00} \right|^2} \right)$$

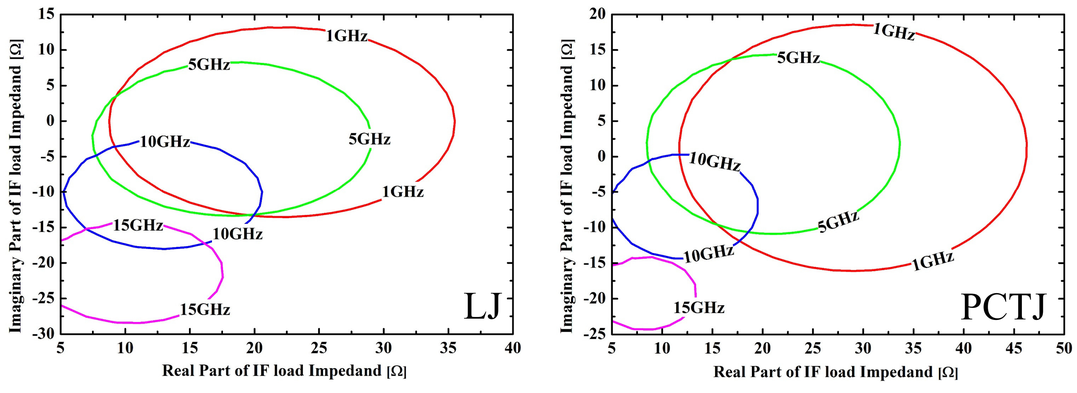
Cf_{01} and Cf_{00} are cofactors of the augmented matrix $|Y'_{mm'}|$

Junctions parameter



Long distributed junctions (LJ) *Parallel-connector twin junctions (PCTJ)*

Parameter	LJ	PCTJ
J_c (kA/cm^2)	11.2	11.4
V_{gap} (mV)	5.34	5.32
R_n (Ω)	5.76	6.94



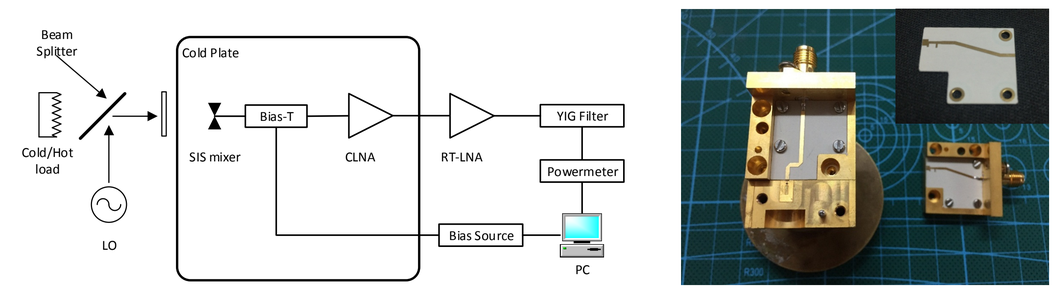
IF load impedance for the optimum mixers conversion gain

1. The imaginary part of IF load impedance for optimum conversion gain is negative at a relatively high frequency.
2. IF output impedance of SIS mixers which including the RF choke filter are positive.
3. SIS junctions exhibit capacitive impedance at IF frequency.
4. RF choke filter introduces inductive impedance at high frequency.
5. The imaginary part of IF load impedance should be negative to achieve the matched condition.

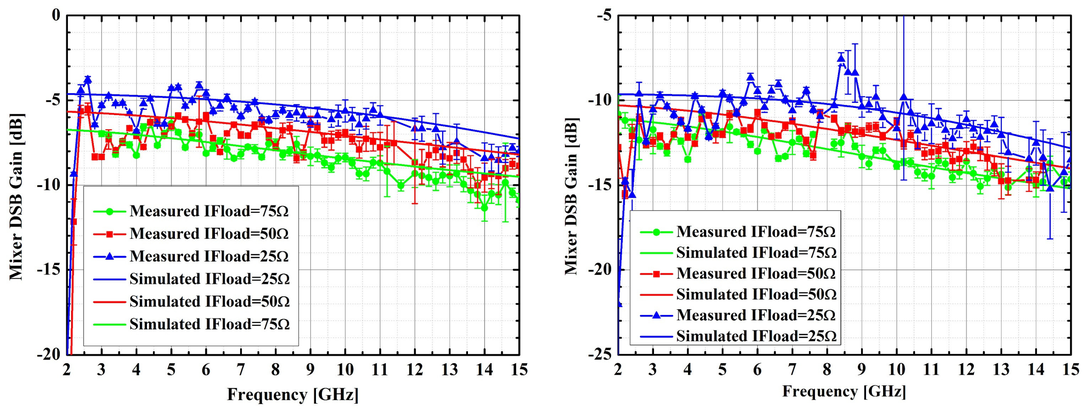
III. Measured Gain Bandwidth

The relative conversion gain G_r, defined as the product of mixer conversion gain and gain of RF path

$$G_r = G_m G_{RF} = \frac{P_h - P_c}{\left(T_h - T_c \right) k_B G_{IF} B}$$

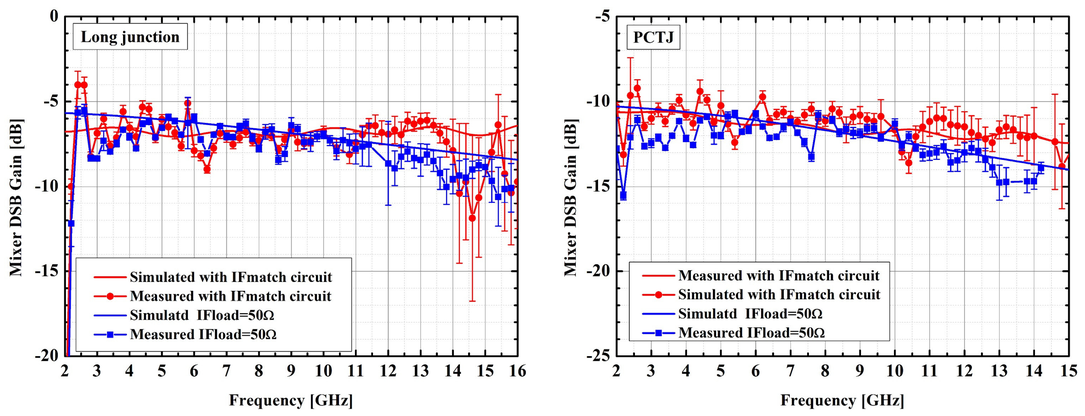


Measurement setup and Mixers Block



Simulated and Measured relative gain bandwidth of SIS mixers loaded by microstrip lines with different characteristics impedance Z_0=25Ω, 50Ω, 75Ω

Z_0	3dB roll-off frequency (GHz)	
	LJ	PCTJ
25Ω	16.6	15.0
50Ω	16.0	12.5
75Ω	15.6	11.0



Simulated and Measured relative gain bandwidth of SIS mixers loaded by matching circuit and 50Ω

IF load	3dB roll-off frequency (GHz)			
	LJ		PCTJ	
	Theory	Measured	Theory	Measured
50Ω	16.0	~13.7	12.5	~12.0
Matching circuit	19.5	>15.0	19.0	>15.0

III. Conclusion

In this paper, we have investigated the characteristics of IF bandwidth of SIS mixers of long distributed junctions and parallel-connected twin junctions. The theoretical analysis shows that the IF output of SIS mixers exhibiting inductive impedance, to achieve a wide IF band, the IF load impedance should be capacitive to compensate the mixer's output impedance. Then, the gain bandwidth of SIS mixers were measured with different IF load impedance and a designed IF matching circuit, at a high frequency end, the mixer gain were improved when terminated by IF matching circuit.