MMA Memo No. 257

Effect of Refrigerator Temperature on SIS Receiver Performance

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INTRODUCTION

The following memorandum which discussed the performance improvement of the SIS mixer operating at a bath temperature lower than 4.2 K was originally circulated January 28, 1998 by e-mail. Due to the recently renewed interest among the MMA Receiver Group, it is being distributed again as a MMA memo.

MEMORANDUM:

TO: L. D'Addario, A. Kerr, M. Pospieszalski, A. Thompson, J. Webber

FROM: S.-K. Pan

cc: D. Emerson, J. Payne

DATE: Wed, 28 Jan. 1998 09:36:34 -0500 (EST)

SUBJECT: High Frequency Mixer Performance at 2.5 K

The suggested specification for the temperature of the last stage of the refrigerator in the current MMA cryogenics design is 4.0 K nominal with good stability (10mK p-p in 1 minute and 100mK p-p in 1 day) [1]. However, as shown in the following table, further improvements in the performance of the millimeter and submillimeter SIS receivers can be easily achieved by operating the mixer at a bath temperature lower than 4.2 K (*e.g.*, 2-2.5 K).

Frequency (GHz)	TR-DSB (K) @ 4.2 K	TR-DSB (K) @ 2.5 or 2.0 K	References
115	68	64	[2]
239	48	40	[3]
565-690	160-230	decreased by 15%	[4]
780-820	~ 850	decreased by 150-200 K	[5]
800	460	decreased by 100 K	[6]
822	~ 510	409	[7]
1042	1170	840	[8]

In general, the improvement in receiver noise temperature is about 5-10% and 10-15% in the frequency range of 100-300 and 400-600 GHz, respectively, and increases to 20-40% for frequencies above the Nb gap frequency (~700 GHz) [9]. The improvement in the receiver performance at lower temperatures is mainly due to 1) the reduction in the subgap leakage current (lower mixer noise temperature), 2) the increase of the junction's gap voltage (better conversion gain), and 3) the lower loss in the mixer's tuning circuit.

In addition to the noise temperature improvement described above, the performance of the Nb/AlOx/Nb mixer at 2.5 K is also less likely to be affected by the refrigerator's last stage temperature fluctuation. This should improve the receiver's long-term stability in the continuum observation.

Another possible way to improve the high frequency performance of the SIS mixer is developing SIS mixers using new superconducting materials with a higher gap frequency (*e.g.*, NbTiN, gap frequency ~1.2 GHz [10]).

We may want to address these issues in the future MMA Receiver Group meeting.

[1] Larry D'Addario, Agenda for MMA Receiver Group Meeting, January 21, 1998.

[2] Shing-Kuo Pan, Measurement Results, May 21, 1986.

[3] Jacob W. Kooi *et. al*, "A Low Noise 230 GHz Heterodyne Receiver Employing .25 μm Area Nb/AlOx/Nb Tunnel Junctions," *IEEE Trans. Microwave Theory Tech*., vol. 40, no. 5, pp. 812-815, May 1992.

[4] Jacob W. Kooi *et. al*, "A Low Noise 665 GHz SIS Quasi-Particle Waveguide Receiver," *Int. J. Infrared and Millimeter Waves*, vol. 15, no. 3, pp. 477-492, 1994.

[5] D. Hottgenroth *et. al*, "Design and Analysis of a Waveguide SIS Mixer Above the Gap Frequency of Niobium," *Int. J. Infrared and Millimeter Waves*, vol. 18, no. 3, pp. 687-710, 1997.

[6] Michael C. Gaidis *et. al*, "Characterization of Low-Noise Quasi-Optical SIS Mixers for the Submillimeter Band," *IEEE Trans. Microwave Theory Tech*., vol. 44, no. 7, pp. 1130-1139, July 1996.

[7] Jacob W. Kooi *et. al*, "A 850 GHz Waveguide Receiver Employing a SIS Junction Fabricated on 1 μm Si3N4 Membrane," accepted in the *IEEE Trans. Microwave Theory Tech.*

[8] M. Bin *et. al*, "Design and Characterization of a Quasi-Optical SIS Receiver for the 1 THz Band," in *Proc. Seventh Int. Symp. on Space Terahertz Tech*., The University of Virginia, Charlottesville, VA, March 12-14, 1996, pp. 549-560.

[9] Edward Tong, private communication.

[10] Jeff Stern, in *Proc. Eighth Int. Symp. on Space Terahertz Tech*., Harvard University, Cambridge, MA, March 25-27, 1997.