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RESULTS OF LABORATORY TESTS WITH THE COMSAT PREAMPLIFIER SYSTEM (4.1 GHz MASER)

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Introduction

This report describes the operating features and performance of a low noise, 4.1 GHz preamplifier system obtained from Comsat Corporation.

The preamplifier system includes a traveling-wave maser amplifier, an A. D. Little 400A helium refrigeration system, a second stage ambient temperature parametric amplifier, paramp and maser pump sources, and control racks for the refrigeration and electronic equipment.

Operation

Operational procedures for the preamplifier system are completely described in the manuals accompanying the system. The cool down time after rough pumping is about 8 hours if the liquid nitrogen pre-cooling coil is used and slightly more than twice as long if pre-cooling is not employed. When the J-T valve is properly adjusted, only a minor adjustment need be made once a day. This is necessary because of a slight contaminate build-up on the orifice which could block the J-T valve if left without attendance.

The superconducting maser magnet is quite easy to control. The typical operating point is 5.8 ampere or 873 on the Operating Level dial. A slightly larger current will increase the center frequency. The three maser pump klystrons are mechanically tuned in frequency in order to adjust the pass band. The frequency of each klystron affects only 1/3 of the pass band, and alignment is quite simple. Care must be taken to assure that the maser is not saturated (input less than -65 dBm) or the maser will have very little gain but still exhibit a fine grain band pass structure. The maser flange must also be cold (less than 4.8 °K) or no masing action will result.

The second stage parametric amplifier is quite easy to tune and exhibits a double tuned band pass shape. The paramp and maser klystrons are housed with the paramp in a temperature stabilized box maintained at 130 ± 2 °F. This results in good long-term stability. The four klystrons operate at approximately 30 GHz.

Performance

The performance specifications for the preamplifier system are shown in Table 1.

TABLE 1

Preamplifier Parameters

Input SWR	1.5 to 1 maximum
Output SWR	1.2 to 1 maximum
Gain	30 dB nominal
Frequency Range (1 dB points)	4055 to 4185 MHz
Band-Pass Ripple	± 0.5 dB maximum peak to peak
Noise Temperature	< 10 °K average
Gain Stability — Medium term	± 0.18 dB
— Short term	± 0.05 dB
0.5 dB CW Gain Compression Point (Input Level)	-65 dBm
Delay Distortion (for any single channel)	4.2 nsec maximum
Intermodulation Distortion (dB below signals)	None detectable to -90 dBm level

Our tests indicate that the maser gain is a little more than 21 dB. The paramp gain was set to 10 dB for noise temperature and bandwidth tests, but could be increased above 20 dB with a slight decrease in bandwidth and no apparent degradation of stability. The paramp will tune from 3.95 to 4.25 GHz with better than 10 dB gain. The maser will not tune as far, even at the sacrifice of gain and bandwidth. The lowest 1 dB frequency that could be reached at 15 dB gain was a few megahertz below 4.0 GHz. Similarly, the highest 1 dB frequency reached was a little over 4.2 GHz. This was accomplished by adjusting the magnet current as well as the pump frequencies.

The noise temperature was measured using the Y factor method with a 10.7 MHz test receiver. A sand-filled ambient load and a liquid nitrogen immersed cold load were employed. Since these loads were coaxial, a cold load temperature of 85 °K was assumed in order to account for the waveguide-to-coaxial adapter. A combined second stage and mixer noise temperature of slightly over 1000 °K was measured, owing to an improperly operating mixer/preamplifier. When this 10 °K contribution was subtracted from the system temperature, the maser appeared to have a 7 to 11 °K noise temperature at the center of the Comsat specified frequency. Noise performance of the preamplifier is summarized in Table 2. It should be noted that the noise temperatures measured are conservative and that better loads and a refined measurement technique would certainly shave a few degrees from these results.

TABLE 2

Noise Temperature Performance

1 dB Frequency	Maser Gain	Center Band System Temperature	Calculated Maser Temperature
4050-4190	> 21 dB	17-21 °K	7-11 °K, 9.5 °K Avg.
3995-4060	≈ 15 dB	33 °K	≈ 23 °K
4120-4205	≈ 15 dB	30 °K	≈ 20 °K

Conclusions and Recommendations

To take advantage of the low noise temperature of this preamplifier it is recommended that it be used as a frequency switched radiometer, where a system temperature of 30 °K might be achieved. For continuum observations the load switch could be located between the maser and second stage. The gain stability of the maser might be sufficient to still take advantage of the low system temperature.

For installation on the NRAO 140-foot telescope it is suggested that the maser dewar and temperature controlled klystron package be mounted to a standard Sterling mount flange, but without the rest of the usual front-end box. A cowling would have to be fashioned over the end of the dewar to protect the refrigerator, with access provided for the J-T valve micrometer. The mixer/preamplifier could be mounted in the klystron package and a junction box would permit use of the present telescope cabling for interconnection of the control rack. One additional helium line would have to be installed on the telescope along with the new compressor to complete the 400A refrigeration system.

Telescope installation could be accomplished in about 4 hours if the service tower were available for pre-cooling. The system should be serviced once a day for adjustment of the J-T valve, which could be accomplished in less than 1/2 hour.

Before the system is put on the telescope, there are several items that should be repaired and/or modified. The present remote temperature sensors are inoperative or unreliable, thus leaving a carbon resistor on the maser flange as the only indication of temperature. CTI division of A. D. Little Company has proposed to add a hydrogen and a helium vapor pressure gauge to monitor temperatures, and two helium pressure gauges to monitor the J-T valve differential pressure. These gauge readouts would be located on the dewar and would be used primarily during cool down or servicing of the system.

During these laboratory tests the dewar was opened and disassembled in order to repair the RF output connector. It was noted at that time that the semi-rigid RF cables connected to the maser were pinched or crimped in several places. It is believed that this was done to match the line but probably has much to do with the sawtooth appearance of the maser band pass. Although these sawteeth are less than 1 dB in amplitude, replacement of the maser cables is recommended while the dewar is open for installation of the previously mentioned gauges.

If this preamplifier system is not used for radio astronomy observations, the refrigeration system and dewar would be available for doing research at superconducting temperatures, such as is needed for Josephson junctions.