

Low-Noise Receivers: Microwave Maser Development

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Two S-band maser systems with equivalent input noise temperatures of 2.1 K have been supplied to the Deep Space Network. These masers will be used on 64-m antennas at Deep Space Stations 14 and 43 to meet special requirements of the Mariner Venus/Mercury (MVM73) mission. The masers use a new shortened and cooled signal input transmission line to reduce noise and are equipped with superconducting magnets to provide the best possible stability performance.

I. Introduction

Special requirements for the Mariner Venus/Mercury mission showed a need for S-band masers with improved sensitivity and stability characteristics. Two new systems for DSSs 14 and 43 have been built in response to these requirements. The maser systems have new shortened and cooled input transmission lines which reduce the noise temperature as compared to previous systems. Superconducting magnets are used to improve maser gain, phase, and group delay stability. Optimum maser performance is achieved at 2295 MHz; the maser equivalent input noise temperature is 2.1 K at 2295 MHz. An overall system temperature of 8.3 K was measured during the evaluation of these new systems.

II. Input Transmission Line

A new signal input transmission line has resulted in a substantial reduction of maser equivalent input noise tem-

perature. Previously reported systems (Refs. 1 and 2) were measured to have maser input noise temperatures of between 4 and 8 K at the S-band waveguide interface (2.1 K was contributed by the signal input transmission line). The new signal input transmission line described below contributes 0.4 K to the maser noise temperature. The improvement is achieved by cooling the center conductor of the coaxial line to 4.5 K, by shortening the line length to 18 cm, and by using a very-low-loss vacuum seal.

The new transmission line, assembled with an S-band maser and closed-cycle helium refrigerator (CCR), is shown in Fig. 1. The superconducting magnet, radiation shields, and the vacuum jacket cover have been removed. Figure 2 is a sketch identifying important features of the assembly.

A fused quartz dome provides part of the vacuum seal. The quartz dome is attached and sealed to the WR 430 input waveguide with flexible epoxy. An O-ring vacuum

seal is used between the waveguide and the adapter plate. The waveguide and fused quartz dome assembly can be replaced without disturbing other input line components; it is a field-replaceable assembly.

The coaxial transmission line outer conductor is made of thinwall (0.25-mm) stainless steel tubing; the inside is plated with 0.0025-mm copper and 0.0003-mm gold. This combination gives low microwave loss and adequate thermal isolation. Mechanical support for the transmission line is obtained by clamping a flange at the room temperature end of the outer conductor, between the adapter plate and the WR 430 waveguide. Thermal connections to the 80-K and 4.5-K CCR stations are made with flexible copper straps.

The transmission line center conductor contacts the outer conductor at the 4.5-K SMA connector and at the support clamp (which is thermally connected to the 4.5-K CCR station). A vacuum, common to the CCR vacuum jacket, provides thermal insulation between the coaxial line center conductor and its surrounding parts (outer conductor and quartz dome). The center conductor is made of gold-plated, polished copper. Refrigeration capacity measurements show that the total heat transferred to the 4.5-K CCR station (by radiation to the center conductor and by conduction through the outer conductor) is approximately 100 mW. The voltage standing wave ratio (VSWR) of the transmission line and waveguide assembly is less than 1.15 to 1 from 2050 to 2650 MHz. Q measurements, insertion loss, and temperature gradient calculations were used to determine the 0.4-K noise contribution of this transmission line assembly.

The new transmission line assembly is adaptable to all S-band maser systems presently used in the DSN. The conversion requires installation of a superconducting magnet.

III. Superconducting Magnet

The use of a superconducting magnet, rather than a large, external permanent magnet, has several advantages: (1) it improves maser gain, signal phase, and group delay stability (Ref. 3); (2) the overall package weight can be reduced from 200 to 90 kg; and (3) the size reduction permits connection of the signal input waveguide in close proximity to the 4.5-K CCR station. A Block III maser system (Ref. 1) has been retrofit with a superconducting magnet and is currently used for two-way tracking on the 64-m antenna at DSS 14. (This maser system does not have the new input transmission line.)

IV. Maser for SMT Cone

The maser currently in use in the S-band megawatt transmit (SMT) cone at DSS 14 uses the new input transmission line and achieves a noise temperature of 2.1 K at 2295 MHz. The maser comb structure is of the Block III type, with modified ruby shape (loading) to achieve a wide tuning range. The maser can provide more than 40 dB net gain at any frequency between 2250 and 2400 MHz. A maximum gain/bandwidth product is obtained when the maser is centered at 2285 MHz. Excess gain can be traded for bandwidth by use of field staggering coils within the superconducting magnet. A frequency response flat within 1 dB from 2270 to 2300 MHz is available at 42 dB net gain.

V. Maser for DSS 43

A second maser with a noise temperature of 2.1 K has been built for use at DSS 43. A previously built maser comb structure (Ref. 2) was used to save on system construction time and cost. The maser is not capable of the large gain bandwidth product achieved by the maser for the SMT cone. The maser provides an 8-MHz, 1-dB bandwidth at 44 dB net gain at 2295 MHz center frequency. The pump klystron used with the DSS 43 system is identical to those presently used with Block III maser systems and does not provide 2388-MHz operation. The low forward loss of this particular maser is equal to that of the SMT cone unit, and identical noise performance at 2295 MHz is achieved.

VI. Noise Temperature Measurements

Comparative system temperature measurements of masers described here have been made. A photograph of the maser CCR package for the SMT cone, with horn and ambient temperature microwave-absorbing material, is shown in Fig. 3. Precision power measurements with and without the absorber material over the horn resulted in a total operating system noise temperature of 8.4 K. Best estimates of noise contributions for the parts of the system are given in Table I. Measurements of the maser system previously used with the SMT cone showed a total operating system temperature of 10.7 K. Laboratory measurements using a liquid-helium-cooled waveguide termination indicated a 4.4-K maser noise temperature for the older SMT maser (Ref. 2).

Measurements of the maser for DSS 43 gave the lowest overall noise temperature values. The system was measured in the same configuration as that planned for in-

stallation on the 64-m antenna at DSS 43. A calibrating coupler and polarizer were included in the waveguide system. The slight loss of these components was offset by

the use of a better horn than was used in the earlier tests. A total operating system temperature of 8.3 K was measured.

References

1. Trowbridge, D. L., "Block III Maser Implementation Program," in *The Deep Space Network Progress Report*, Technical Report 32-1526, Vol. XVIII, pp. 130-135, Jet Propulsion Laboratory, Pasadena, Calif., Dec. 15, 1973.
2. Clauss, R., and Quinn, R., "Low Noise Receivers: Microwave Maser Development," in *The Deep Space Network*, Space Programs Summary 37-58, Vol. II, pp. 50-52, Jet Propulsion Laboratory, Pasadena, Calif., July 31, 1969.
3. Clauss, R., Wiebe, E., and Quinn, R., "Low Noise Receivers: Microwave Maser Development," in *The Deep Space Network Progress Report*, Technical Report 32-1526, Vol. XI, pp. 71-80, Jet Propulsion Laboratory, Pasadena, Calif., Oct. 15, 1972.

Table 1. Noise contributions for the SMT maser evaluation system

Part of system	Noise contribution, K
Sky (includes atmosphere and cosmic background)	4.9
Horn and mode generator	1.2
Maser	2.1
Follow-up receiver	0.2
Total operating system temperature	8.4

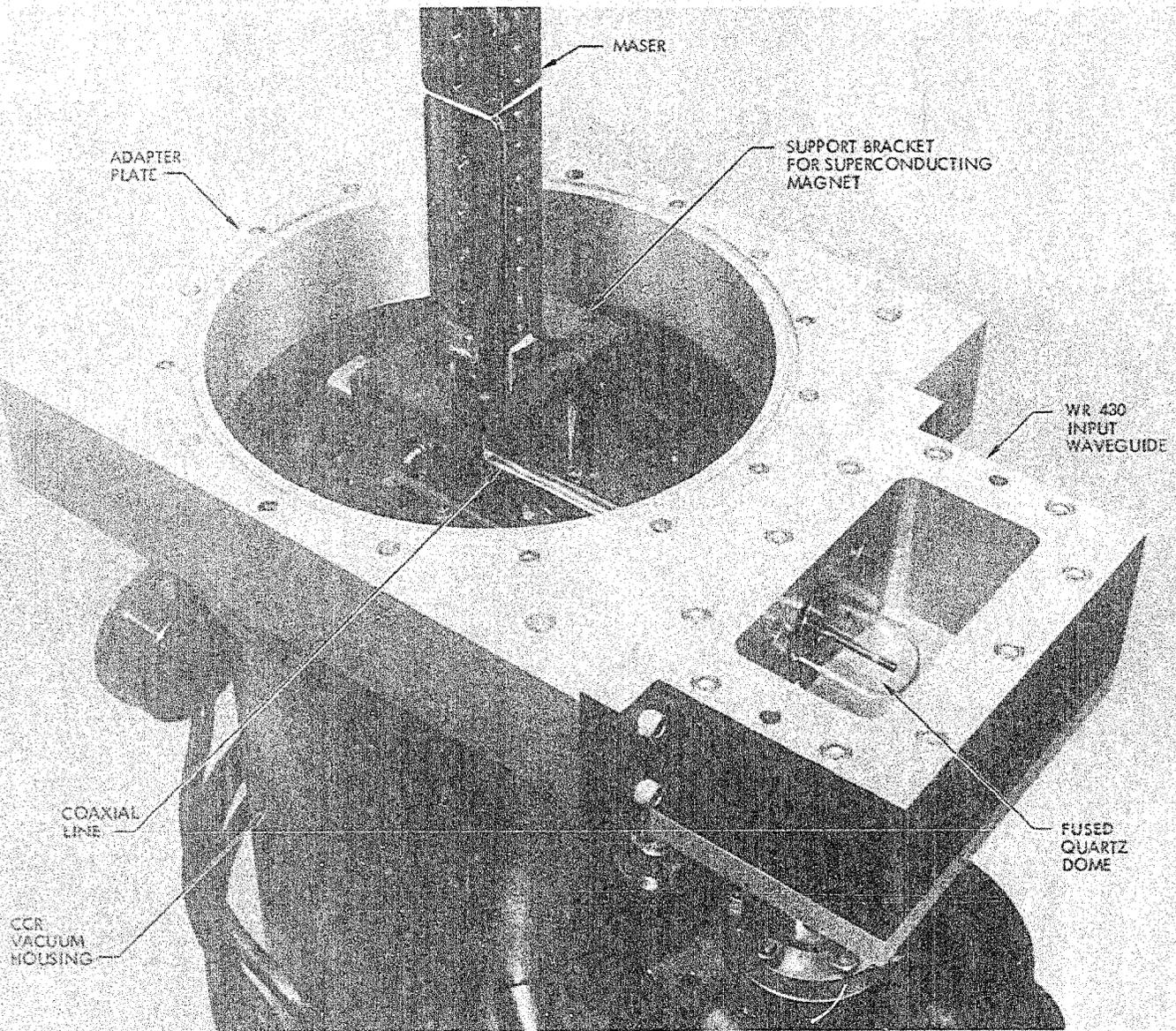


Fig. 1. Signal input transmission line for 2.1-K S-band maser

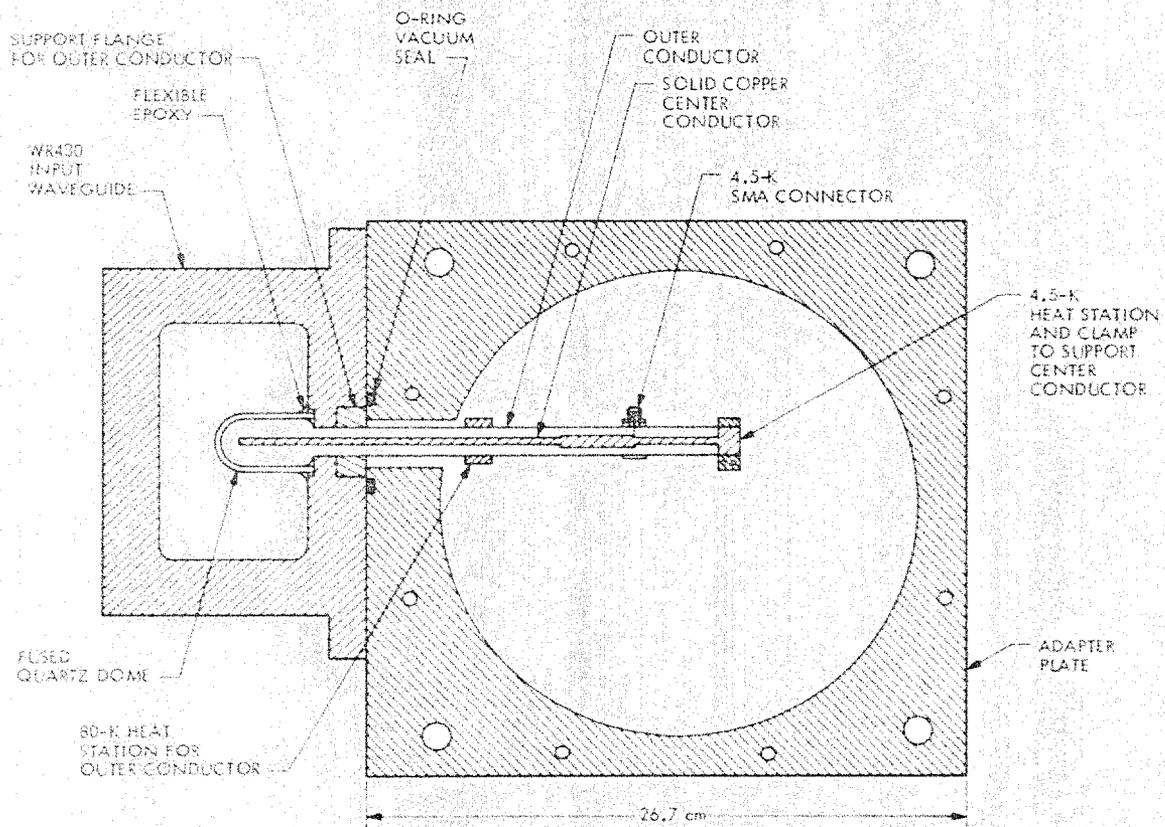


Fig. 2. Important features of the transmission line assembly

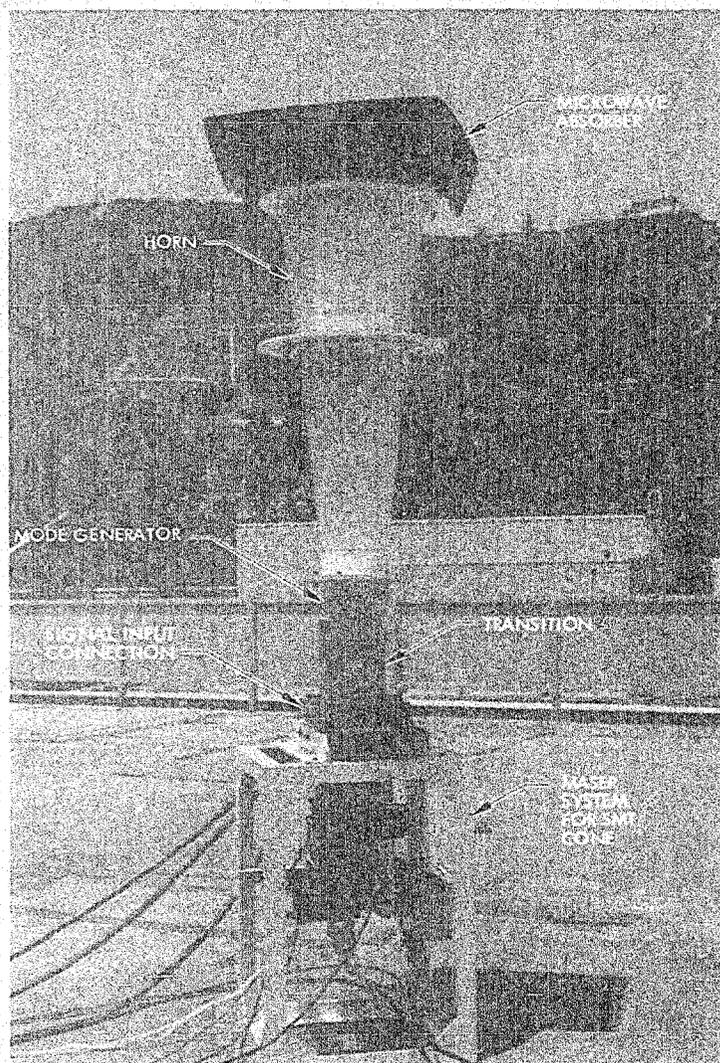


Fig. 3. SMT maser system used for noise temperature evaluation