X-Band, Low-Noise, Traveling-Wave Maser

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Four X-band traveling-wave maser (TWM) systems with effective input noise temperatures of 3.5 K and bandwidths varying from 65 to 108 MHz have been supplied to the Deep Space Network. These TWMs are used on the 64-meter antennas at Deep Space Stations 14, 43 and 63 at 8420 MHz to meet the requirements of the Voyager-Saturn encounter. The TWMs use shortened and cooled signal input waveguide to reduce noise and are equipped with superconducting magnets and solid-state pump sources to provide the required stability performance.

I. Introduction

The Voyager encounter with Saturn required increased traveling-wave maser (TWM) sensitivity at X-band. In addition, support of very long baseline interferometry (VLBI) required increased bandwidth at X-band (previous X-band TWMs covered 8395-8445 MHz at the −3 dB points). Three TWM assemblies have been built in response to these requirements and installed at Deep Space Stations (DSS) 14, 43 and 63. A fourth TWM assembly was also built as a spare. The TWMs provide 45 dB net gain with a −3 dB bandwidth varying from 65 to 108 MHz (see Table 1). An effective input noise temperature of 3.5 K and an overall system temperature of 11.0 K were measured during the evaluation of these systems using a low noise horn looking at cold sky. These new X-band TWMs are identified as Block II low-noise TWMs.

II. Design Goals

The following performance design goals were established for the Block II low-noise TWM:

(1) Gain, −43 dB minimum, 46 dB maximum

(2) Bandwidth (−3 dB), > 100 MHz

(3) Gain stability

dB per 10 sec	±0.03
dB per 12 hr	±0.5
dB for tilting	±0.5

Interchangeability with existing Block I TWMs (Ref. 1) was also required.

III. Maser Description

The Block II TWM assembly shown in Fig. 1 is supported by a frame that is similar to the Block I X-band (Ref. 1) and Block IV S-band (Ref. 2) TWMs presently used in the DSN. The Block II TWM assembly is also similar in weight (approximately 80 kg) and size, with the exception of height (the Block II TWM assembly is approximately 10 cm longer). The difference in height and location of the signal input and output waveguide ports required a new dual TWM mounting stand and waveguide to accommodate both Block I and Block II TWMs interchangeably.

Mounted on the TWM support frames (Fig. 1) is a new pump source assembly similar in design to pump sources used on R&D masers not previously reported. Pump energy is provided by two separate Gunn oscillators at 19 and 24 GHz each with approximately 200 mW output.

The frequency is combined in a manner similar to that used on the Block I X-band TWM described in Ref. 1. The modulation and voltage protection design are similar to that used on Block IV S-band masers (Ref. 2) and an R&D TWM (Ref. 3).

The Block II TWM uses a shortened and cooled signal input waveguide assembly (see Fig. 2) that contributes only 0.3 K to the maser noise temperature; previous Block I TWMs (Ref. 1) used an input waveguide assembly that contributed approximately 3.5 K.

A new half-wavelength stripline comb structure similar to that shown in Fig. 3, is used in the Block II TWMs. The compact size of the structure allows several structures to be used in one superconducting magnet. The Block II TWM uses four structures mounted in one superconducting magnet as shown in Fig. 4. The four structures are connected in series to achieve the required gain-bandwidth product. Steel shims are mounted on the top and bottom of the structure over approximately half of the structure length to spread the magnetic field and obtain the desired stagger-tuned bandpass. The halfwave structure and magnet are shown in Fig. 4 mounted to the refrigerator 4.5 K heat station with the low-noise waveguide in its approximate position. The low-noise input waveguide, halfwave structure, isolator assembly and superconducting magnet will be covered in detail in future reports.

IV. Performance

The gain, bandwidth and noise temperature were measured prior to shipment and are listed in Table 1. The noise temperature was measured using a horn and ambient temperature load (microwave absorber). System noise temperature (including feedhorn, maser, and receiver noise temperature contributions) from the 64-meter stations has been reported as low as 19.5 K. All three 64-meter stations (DSS 14, 43 and 63) are within the expected noise temperature goal of 23 K; the Block II X-band TWMs have met or exceeded the performance goals for Voyager-Saturn encounter. The VLBI 100-MHz bandwidth goal has not been met by all Block II TWMs.

V. Future Development

Future development is planned to produce a repeatable gain-bandwidth product design. A post-amplifier, as part of the maser package, will be added to adjust the package gain to the desired value while achieving wide bandwidth and minimizing follow-on noise contribution (< 0.5 K). Supporting research effort is planned using a X4 scaling of the X-band slow structure at 32 GHz. Study of the fields and modes with the X-band structure are planned to insure proper pump saturation and signal inversion ratios.

Acknowledgement

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References

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Table 1. TWM performance

SN	Gain, dB	−3dB bandpass, MHz	Frequency, MHz	Noise temp. within bandpass, K
2001	47	90	8400-8490	3.1 to 3.5
2002	46	108	8396-8504	3.30
2003	44	65	8400-8465	3.1 to 3.7
2004	47	84	8398-8482	4.5 to 4.8[a]

[a]Serial number 2004 demonstrated the same system temperature at DSS 14 (19.5 K) as achieved with SN 2002. The 4.5 to 4.8 K measurements were made during hot and humid weather and may include a source of error caused by an unknown atmospheric contribution which should be calibrated in the future.

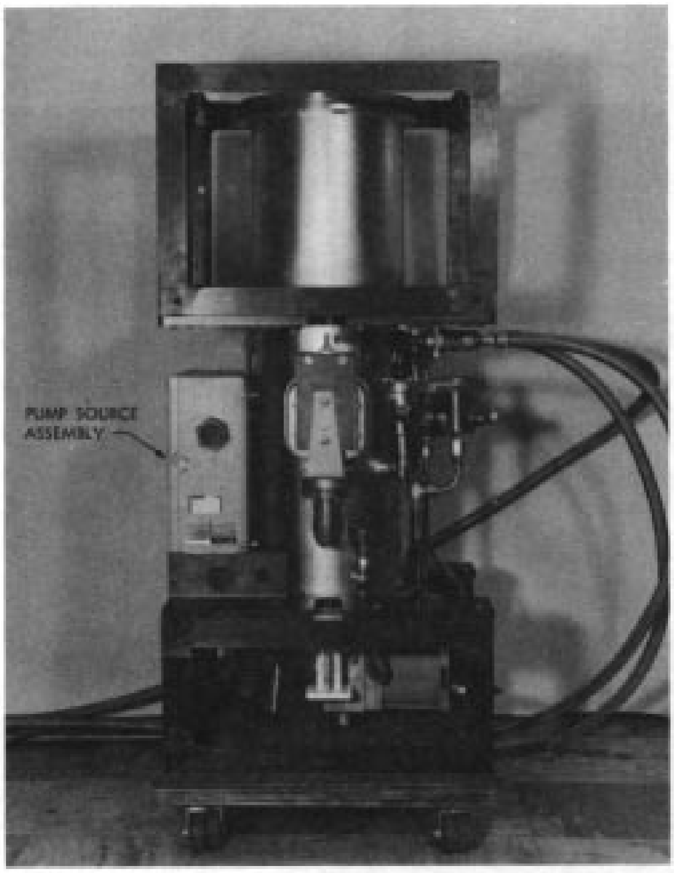

Fig. 1. X-band Block II traveling-wave maser assembly

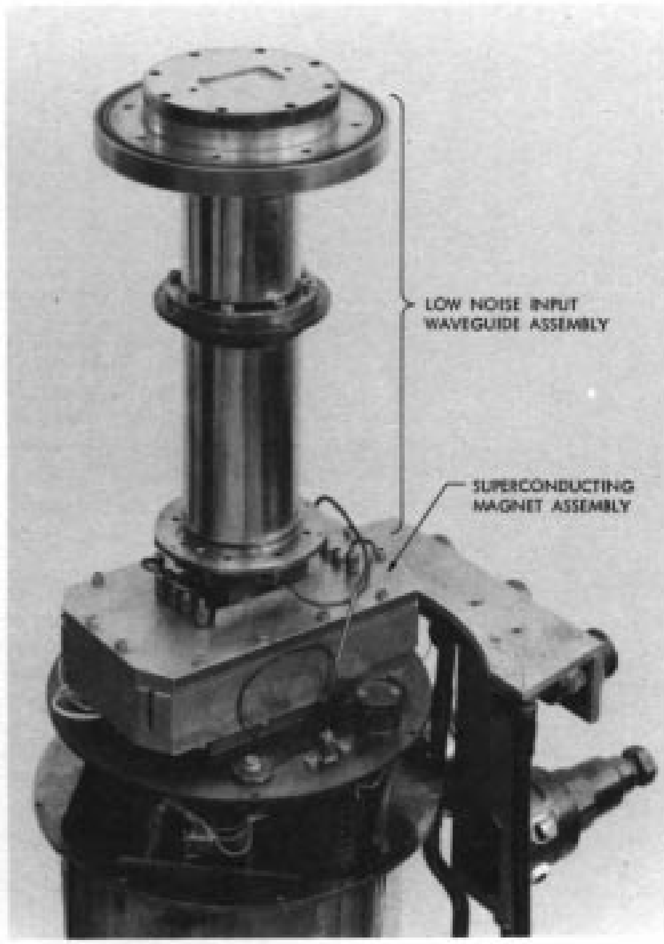

Fig. 2. Low-noise input waveguide, structure assembly and superconducting magnet mounted on helium refrigerator 4.5 K heat station

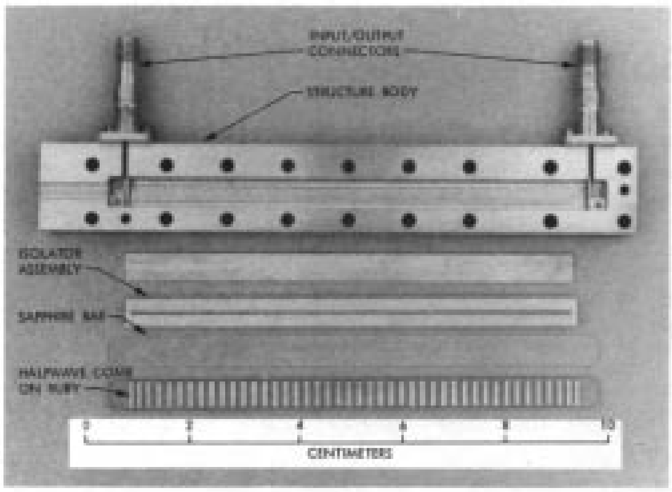

Fig. 3. X-band halfwave stripline comb structure

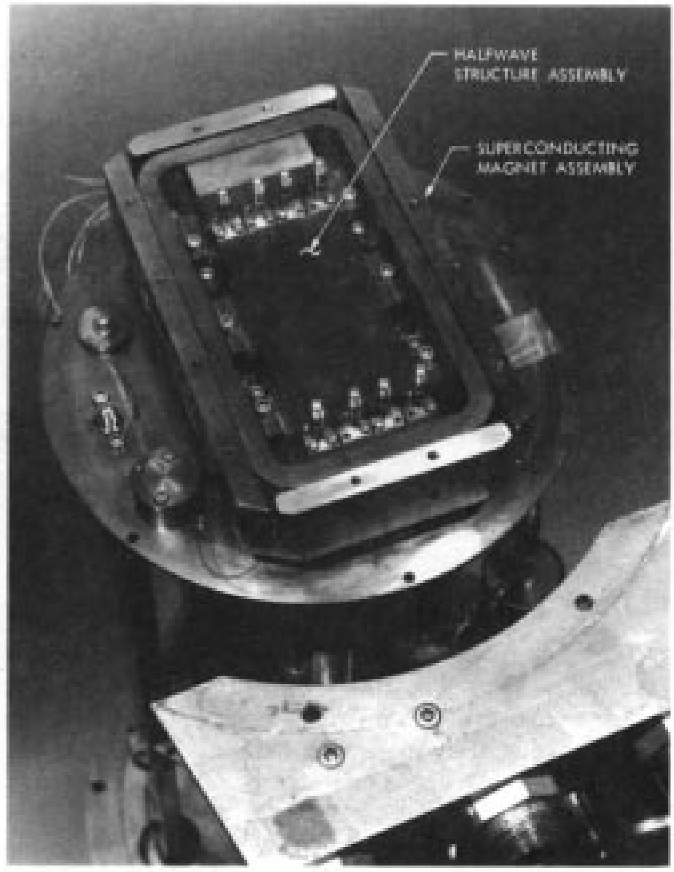

Fig. 4. X-band halfwave structure assembly mounted superconducting magnet