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The 8.4-GHz Low-Noise Maser Pump Source Assembly

R. Cardenas
Radio Frequency and Microwave Subsystems Section

Improved pump source assemblies and new 8.4-GHz low-noise traveling-wave masers (TWMs) were installed at the same time at Deep Space Stations 14 and 43 as part of the Mark IVA DSCC Antenna Microwave Subsystems upgrade. The pump source assemblies are part of the new 8.4-GHz TWMs, which are identified as Block IIA Low-Noise TWMs. Improved reliability of the pump source assemblies was required to meet stress analysis criteria.

I. Introduction

A redesign of the 8.4-GHz low-noise pump source assembly and its controller, described previously in [1] and [2], was made in accordance with stress analysis criteria set by the Microwave Electronics Group in accordance with parts derating requirements set forth in JPL Specification ZPP-2061-PPL [1] The design was also a part of the Mark IVA DSCC Antenna Microwave Subsystems upgrade.

The evaluation of the reliability history of the pump source assembly resulted in a redesign of the modulator and protective circuit, which is a subassembly of the pump source assembly. Figure 1 shows the pump source assembly that is used on the Block IIA TWMs, and Fig. 2 shows the modulator and protective circuit subassembly. In the modulator and protective circuit subassembly, the improvements and changes were made to the components on the two printed wiring boards that comprise the circuit portion of this subassembly.

The protective circuit portion of the modulator and protective circuit subassembly limits the voltage supplied and protects against a reverse polarity voltage to the varactor tuning element and the Gunn bias voltage, thereby protecting the two Gunn-effect oscillators from overvoltage and wrong polarity. The dual Gunn-effect oscillators in the pump source assembly operate at two different frequencies: 19 GHz and 24 GHz. The reason for protecting the Gunn-effect oscillators is to improve the mean time between failures of the maser system. Also, the cost of each Gunn-effect oscillator is high, and the procurement-and-repair time is anywhere from 9 to 18 months.

II. History

The first boards used in the modulator and protective circuit subassembly were hard-wired boards. These boards were based on the pump sources used on R&D masers. The hard-wired boards were reconfigured into a printed wiring board format to facilitate reproducibility; the existing components were used in the same manner as the previous design. Reports from the field pointed out that these particular boards had a reliability problem. The blocking diode, CR1, tended to burn out as a result of inadequate power rating (see Fig. 3), causing failure of the pump source assembly.

During the redesign of the pump source assembly, it became evident that a number of components were not operating

[1] "Preferred Parts List, Reliable Electronic Components," JPL Specification ZPP-2061-PPL (internal document), Jet Propulsion Laboratory, Pasadena, California, July 1982.

within their maximum rating levels. Another problem encountered with the redesign of the modulator and protective circuit subassembly was that some components were no longer readily available from the commercial vendors.

The modulator and protective circuit subassembly's printed wiring boards were redesigned so that the new boards would be interchangeable. Any future upgrades can be made simply by either swapping out or modifying the existing modulator and protective circuit subassembly in the pump source assembly.

III. Design Changes

The design changes described below were made to provide additional protection of the Gunn-effect oscillators from any damage and to upgrade the pump source assembly to meet the stress analysis reliability requirements set by the Microwave Electronics Group in accordance with the requirements of JPL Specification ZPP-2061-PPL.[1]

A stress analysis was carried out, taking into account a number of design constraints that were imposed by the subassemblies involved. In accordance with DSN STD 00001,[2] the TWMs require a type 1 environment that is air conditioned in a manner similar to the tricone environment (25°C to 35°C), thus imposing tolerance requirements on pump source components. It was also necessary to ensure that any changes made to the modulator and protective circuit boards would not require any changes to the existing chassis size.

The stress analysis was made under the worst case tolerance of each of the design parameters, and an evaluation was made by determining the maximum stress on each component compared to the derating factors listed in JPL Specification ZPP-2061-PPL.[1] Data was taken under simulated worst case conditions, and the redesigned modulator and protective circuit subassembly met or exceeded the requirements.

The following changes were made to components of the modulator and protective circuit subassembly (see Fig. 4):

(1) The tolerance value of the key resistors was changed from ±5 percent to ±1 percent. The ±1 percent tolerance was chosen to ensure that under the worst case analysis, the failure protection predictions would be repeatable, as well as to protect the overall circuitry. Resistors were changed to make the circuit performance repeatable. Another resistor was changed from a lower to a higher wattage value to comply with the stress rating.

(2) Transistor Q1 was changed from a lower to a higher breakdown voltage. The collector emitter breakdown voltage of the old transistor was 40 volts, and the applied power supply voltage in some cases may have been greater than this. Reported failures in the field support this finding.

(3) Blocking diode CR1, which protects the Gunn bias circuit from reverse polarity, was changed. This diode, which is no longer made, was the component that failed most often in the field. It was determined under laboratory conditions that the old blocking diode did not meet the environmental requirements and was overheating and burning out. The new diode has a faster-acting reverse recovery time of 25 nanoseconds. A black anodized aluminum block heat sink was added to dissipate the heat from this blocking diode. The heat sink operates at a maximum temperature of 89°C, which is well below the manufacturer's specification for the blocking diode (175°C maximum).

(4) Zener diode VR1 was changed from a higher (-51 volts) to a lower (-45 volts) clamping circuit voltage, limiting the voltage applied to the varactor tuning element in the Gunn-effect oscillator. A second zener diode, VR2, was added in parallel with VR1 to provide redundant protection. Figure 5 is a chart of the output performance of VR1 and VR2.

(5) Removable jumpers JTB1 and JTB2 were added (see Fig. 6). These jumpers allow individual testing of the zener diodes.

(6) The existing printed circuit board was modified to accept the above changes and additions (Fig. 6).

(7) No change was required of the overvoltage protector devices A2 and A3, located in the pump source assembly (see Fig. 1). The overvoltage protector device prevents excessive power dissipation in the Gunn diode and is set at some voltage above the normal operating Gunn bias voltage for each of the Gunn-effect oscillators.

The following changes were also made to the maser pump controller assembly (see Figs. 7 and 8):

(1) Overvoltage protectors OVPPS1 and OVPPS2 were added. The protectors were required (Fig. 8) because the subassembly was not capable of supplying enough protection to the pump source assembly to prevent any wide open supply voltage from being applied to the modulator circuit or the varactor diode of the Gunn-

[2]"DSN Standard Design Requirements, DSIF/GCF/NCS Equipment," DSN Standard 00001 (internal document), Jet Propulsion Laboratory, Pasadena, California, February 1986.

effect oscillator. One overvoltage protector is set across the modulator power supply, which is capable of an output voltage of 120 volts if the output voltage adjusting pot opens. The device is set at 45 volts, which is the maximum voltage required by the modulator circuit. The second overvoltage protector is set across the tuning power supply in the pump control assembly and is set at 70 volts to protect the varactor diode in the event that the adjusting potentiometer for the supply opens. These changes served to further protect the redesigned modulator, the protective circuit subassembly, and the Gunn-effect oscillators.

(2) A zener diode VR3, rated at 82 volts, 50 watts, was added. This zener diode is connected across the tuning power supply output. A heat sink was also added to dissipate the 10 watts of power when this component is activated. This zener diode is a backup for OVPPS2. In the event that OVPPS2 does not fire, this 82-volt diode will limit the voltage so that the current through zener diodes VR1 and VR2 will not rise to a value in excess of its continuous rating. With this protection, the fault may exist indefinitely without damaging the Gunn-effect oscillators or any other component.

The overvoltage protectors and the zener diode make up the overvoltage protection subassembly (shown in Fig. 8).

IV. Conclusions

The redesigned pump source assembly and the pump source controller assembly have met and exceeded the stress analysis criteria defined in JPL Specification ZPP-2061-PPL,[1] as demonstrated by lab stress testing and by successful performance of the equipment in the Deep Space Network. Before any changes were made, approximately nine modulator and protective circuit subassemblies (each containing two boards) had failed and were retrofitted with the new, redesigned modulator and protective circuit subassembly. The retrofitting task began around July 1983. Unfortunately, an exact count was not kept of the number of subassemblies that have been replaced in the Deep Space Network. From June 1986 to September 1987, however, none of the new modulator and protective circuit subassemblies and maser pump source controller subassemblies have failed.

It is interesting to note that Gunn-effect oscillator failure has not been directly connected to modulator and protective circuit board failure, but since the new boards have been installed, it has been noted by the Cognizant Operations Engineer that fewer Gunn-effect oscillators have been replaced because of failure. According to a previous MTBF analysis initiated by R. Stevens and C. P. Wiggins in October 1983, 16 percent of the total failures in the TWM/CCR system were the result of miscellaneous electronic failures. The pump source assembly was a fraction of that percentage.

Acknowledgments

The improvements made to the modulator and protective circuit subassembly described in this article are the product of much hard work by A. P. Wagner of the JPL Electric Power Systems Section. Special thanks are due to him for his initial reliability analysis of the modulator and protective circuitry. The author also wishes to thank D. L. Trowbridge for his continuous support and guidance in this effort, as well as the members of the Microwave Electronics Group under the supervision of S. M. Petty.

References

[1] D. L. Trowbridge, "X-Band, Low-Noise, Traveling-Wave Maser," *DSN Progress Report 42-60*, vol. September–October 1980, Jet Propulsion Laboratory, Pasadena, California, pp. 126–131, December 15, 1980.

[2] D. L. Trowbridge and J. Loreman, "S-Band Ultralow Noise Traveling-Wave Maser," *Deep Space Network Progress Report 42-53*, Jet Propulsion Laboratory, Pasadena, California, pp. 148–154, October 15, 1979.

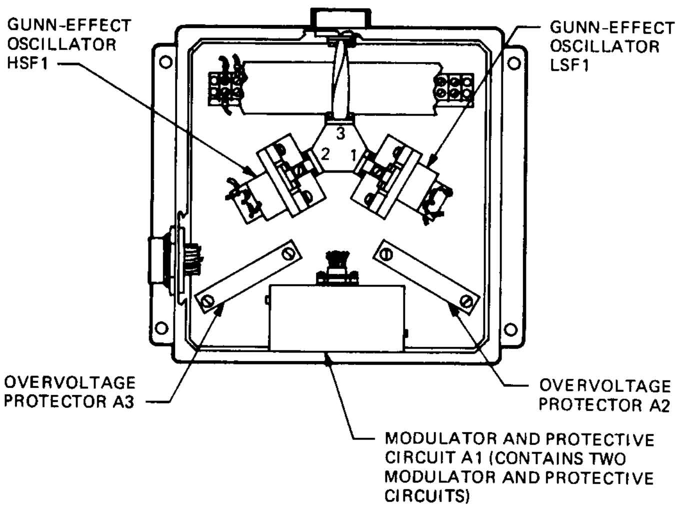

Fig. 1. The 8.4-GHz low-noise pump source assembly

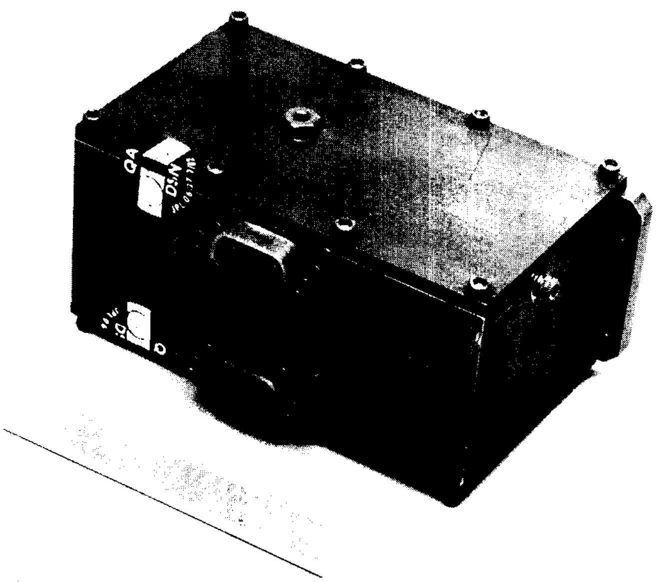

Fig. 2. Modulator and protective circuit subassembly

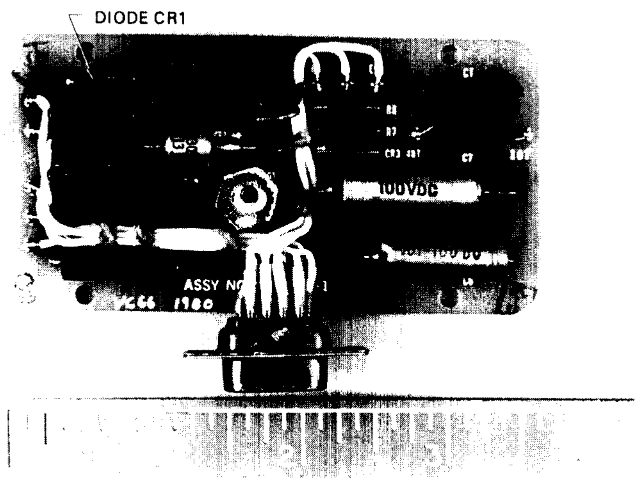

Fig. 3. Modulator and protective circuit printed wiring assembly with burned-out diode CR1 (rating: 45 ± 1 percent)

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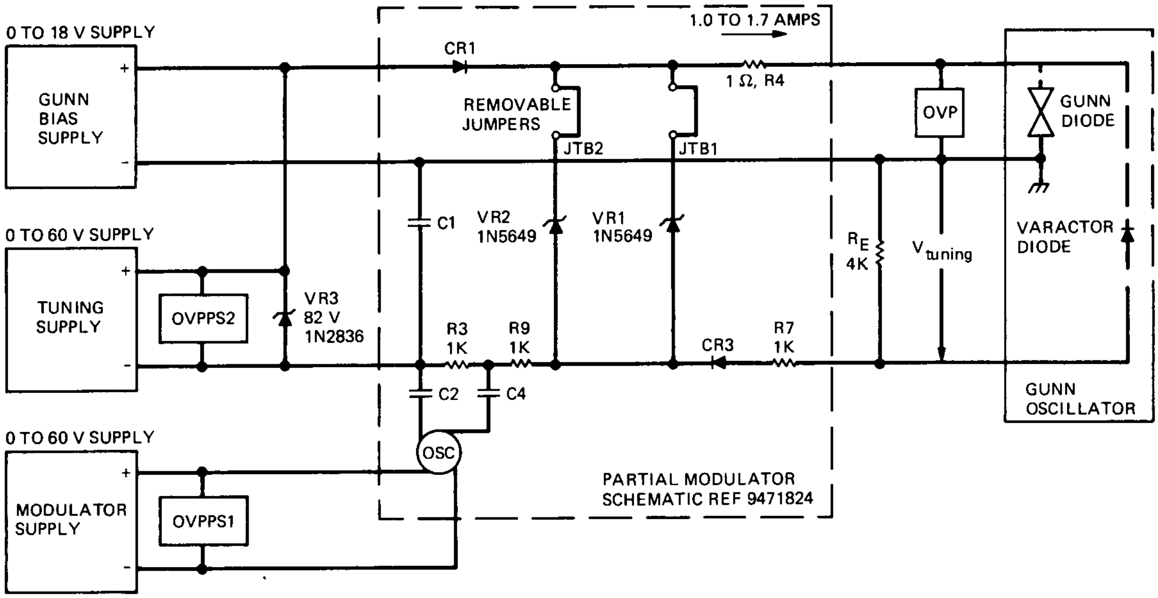

Fig. 4. Simplified schematic of overall pump source assembly

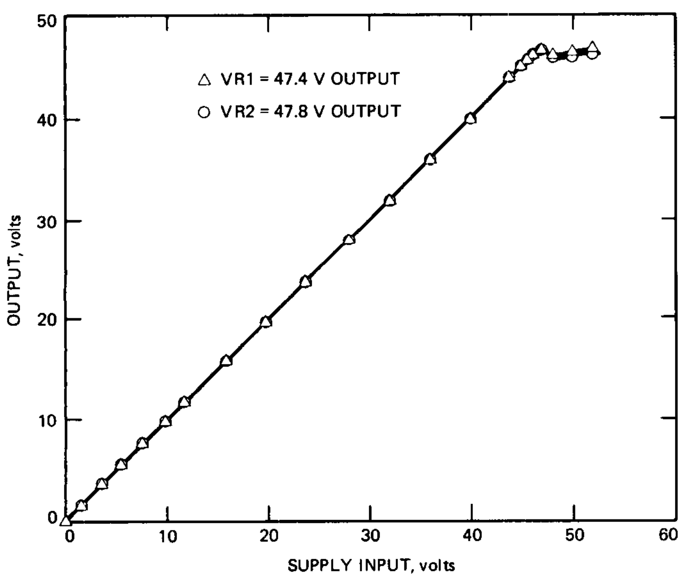

Fig. 5. Clamping voltage test data for modulator and protective circuit subassembly zener diodes VR1 and VR2

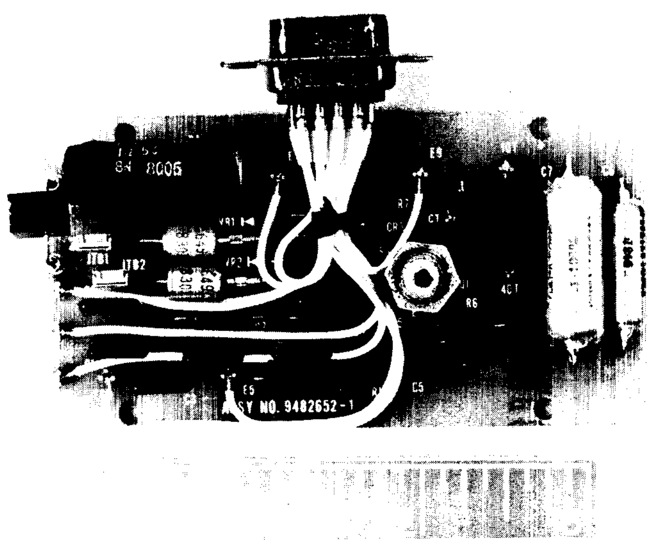

Fig. 6. Modulator and protective circuit printed wiring assembly

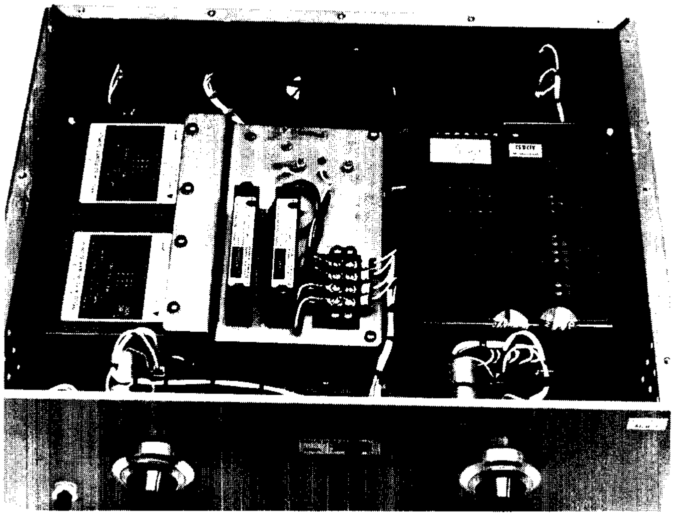

Fig. 7. Pump control with overvoltage protection subassembly installed

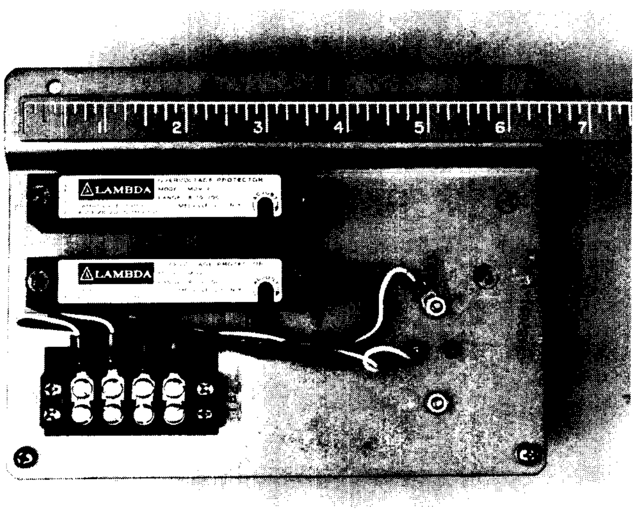

Fig. 8. Overvoltage protection subassembly

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