100-kW X-Band Transmitter for FTS

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During the month of July 1971 a 100-kW X-band transmitter was installed on the Venus Deep Space Station's 9-m antenna. This transmitter replaces the experimental 25-kW transmitter formerly used at this station to transmit timing signals via the Moon to five other tracking stations in the Deep Space Network. Primary results of this change are an improved signal-to-noise ratio, higher reliability, and a change from the experimental frequency of 8.450 GHz to the operational frequency of 7.1495 GHz.

I. Introduction

The frequency-time synchronization (FTS) network underwent a scheduled shutdown during the month of July 1971. During this period the 8.450-GHz 25-kW transmitter was removed from the DSS 13 9-m antenna and replaced by a newly designed 7.1495-GHz 100-kW transmitter.

The purpose of the 100-kW X-band transmitter is to broadcast frequency-timing signals, using the Moon as a passive reflector, to five other stations in the Deep Space Network (DSN) as well as the U.S. Naval Observatory in Washington, D.C. The five DSN stations which form a part of this one-way link are located at Goldstone, California (DSS 14), Madrid, Spain (DSS 61), Johannesburg, South Africa (DSS 51), Woomera, Australia (DSS 41), and Weemala, Australia (DSS 42).

A block diagram of the 100-kW X-band transmitter is shown in Fig. 1. This transmitter utilizes some components of the experimental 25-kW X-band transmitter. Those components which were utilized from the older transmitter are the 500-kW motor-generator, the vacuum disconnect switches, the high-voltage transformer, the rectifier, the choke and the local and remote control racks. All other components are new.

A description of the overall FTS system can be found in Refs. 1, 2. A description of the receiving antennas of the forementioned stations is given in Ref. 3.

II. Antenna-Mounted Equipment

A view of the modified 9-m antenna is shown in Fig. 2. All of the transmitter equipment now mounted on the antenna is new. These units include the buffer amplifier, klystron assembly, the heat exchanger, water manifold, and control instrumentation.

A. Buffer Amplifier

Except for its beam supply, the buffer amplifier shown in Fig. 1 is a self-contained antenna-mounted unit. In addition to power amplification, it performs the following functions in the transmitter: provides a means of remotely varying the drive to the 100-kW klystron, provides a method of quickly ($<10\,\mu s$) removing drive from the 100-kW klystron when arcs occur in the klystron or in other waveguide components, and provides a test point for monitoring drive power. The minimum drive power to the buffer amplifier is +17 dB, and its nominal output is +30 dBmW (1 W).

B. Klystron Assembly

The 100-kW klystron assembly consists of a VA-879G klystron, a VA-1949A focus magnet, body and collector current sensors, filament transformer, and a cathode cooling fan. This assembly is capable of delivering 100-kW average power continuously and under certain limited test conditions can deliver 150 kW. The klystron is tunable between 7100 and 7200 MHz, and the present operating frequency is 7149.9 MHz.

C. Water Manifold

The water manifold distributes the cooling water to the body, collector, and magnet of the klystron; to the RF water load; and to the waveguide. Additionally it serves to control and monitor the pressure and flow rates to each of these distribution points.

D. Control Instrumentation

The antenna-mounted control instrumentation provides limited local control of the transmitter, and provides monitoring of the forward, reflected, and drive power of the klystron assembly. Other functions it houses are the vacion pump power supply and the arc detector circuits. All of these functions are sent from this instrumentation to the ground-based local-control console and the remote-control console.

E. Water-to-Air Heat Exchanger

All of the previously discussed equipment is located in the electronics room of the antenna. This room is located directly below the vertex of the reflector and within the elevation (bull) gear of the 9-m antenna. This room is visible in Fig. 2, which shows the modified 9-m antenna.

Also visible in Fig. 2 is the new heat exchanger which is on the antenna alidade. It was necessary to place the heat exchanger on the alidade, rather than on the ground as it was in the old transmitter, to avoid problems of bringing the water lines through the cable wrapup.

A pure water system was necessary for the VA-879G klystron rather than an ethylene-glycol solution. Winterization is provided by heaters in the surge tank which, together with the pumps, are controlled by outside air temperature.

Other major components of the heat exchanger are the two 29,840 W (40-hp) pumps, two 7460 W (10-hp), 1.22-m (48-in.) fans and an eight-layer-deep core. Weight of the entire heat exchanger system is 66,150 kg (30,000 lb).

The heat exchanger is capable of dissipating 490 kW of heat at ambient air temperature of 32.2°C (90°F) and below, and 340 kW of heat at ambient air temperature of 51.5°C (125°F) and below. This latter condition is the amount of heat dissipated when the transmitter is supplying 100 kW into the RF water load. Normal flow rate is 0.0884 m^3/s (140 gal/m).

III. Ground-Mounted Equipment

Major transmitter units mounted on the ground are the beam power supply, the local-control console and the remote-control console.

A. Beam Power Supply

The beam power supply is located in proximity to the base of the antenna. This supply is a modification of the beam supply of the old transmitter. Modifications include additional protective circuits for the power supply and a crowbar for klystron protection. The function of the crowbar is to quickly ($<10\,\mu s$) remove both RF drive and beam voltage from the klystron in the event of arcing within the klystron or waveguide components or in the event of excessive reflected power back into the klystron. Should either event occur, the crowbar opens three vacuum switches to disconnect the output of the 500-kW motor generator set and fires an ignitron to discharge the beam supply output through a resistor to ground. Simultaneously with this action the crowbar also closes (50-dB isolation) two crystal switches in the buffer amplifier to remove RF drive to the klystron. Maximum output of the beam supply is 48.6 kV and 10 A.

B. Local and Remote Control Consoles

The local and remote consoles each provide for complete control of the transmitter. The local console is in a building about 30 m from the antenna, and the remote console is in the operations building of DSS 13. These units are similar to the configuration used for the old 25-kW transmitter.

IV. System Testing

System testing is now under way. Good data correlation has been achieved at all receiving DSN stations. The reported signal-to-noise ratio is now in excess of 10 dB at all receiving stations. Signal-to-noise ratios using the old system normally ran between 6 to 8 dB. This improvement is particularly significant, because the old receiving system had a noise figure between 7 and 8 dB. This increase in noise figure is a result of changing from a tunnel diode to a crystal mixer in the receiver first stage. This change was a tradeoff for improved reliability.

References

1. Higa, W. H., "Time Synchronization via Lunar Radar," accepted for publication in the *Proceedings of the IEEE,* May 1972.
2. Coffin, R. C., Emerson, R. F., and Smith, J. R., "Time Synchronization System," in *The Deep Space Network,* Space Programs Summary 37-45, Vol. III, pp. 72–75. Jet Propulsion Laboratory, Pasadena, Calif., May 31, 1967.
3. Kron, M., "Four-Foot HA-Dec Time-Synchronization Antenna Mount," in *The Deep Space Network,* Space Programs Summary 37-46, Vol. III, pp. 109–113. Jet Propulsion Laboratory, Pasadena, Calif., July 31, 1967.

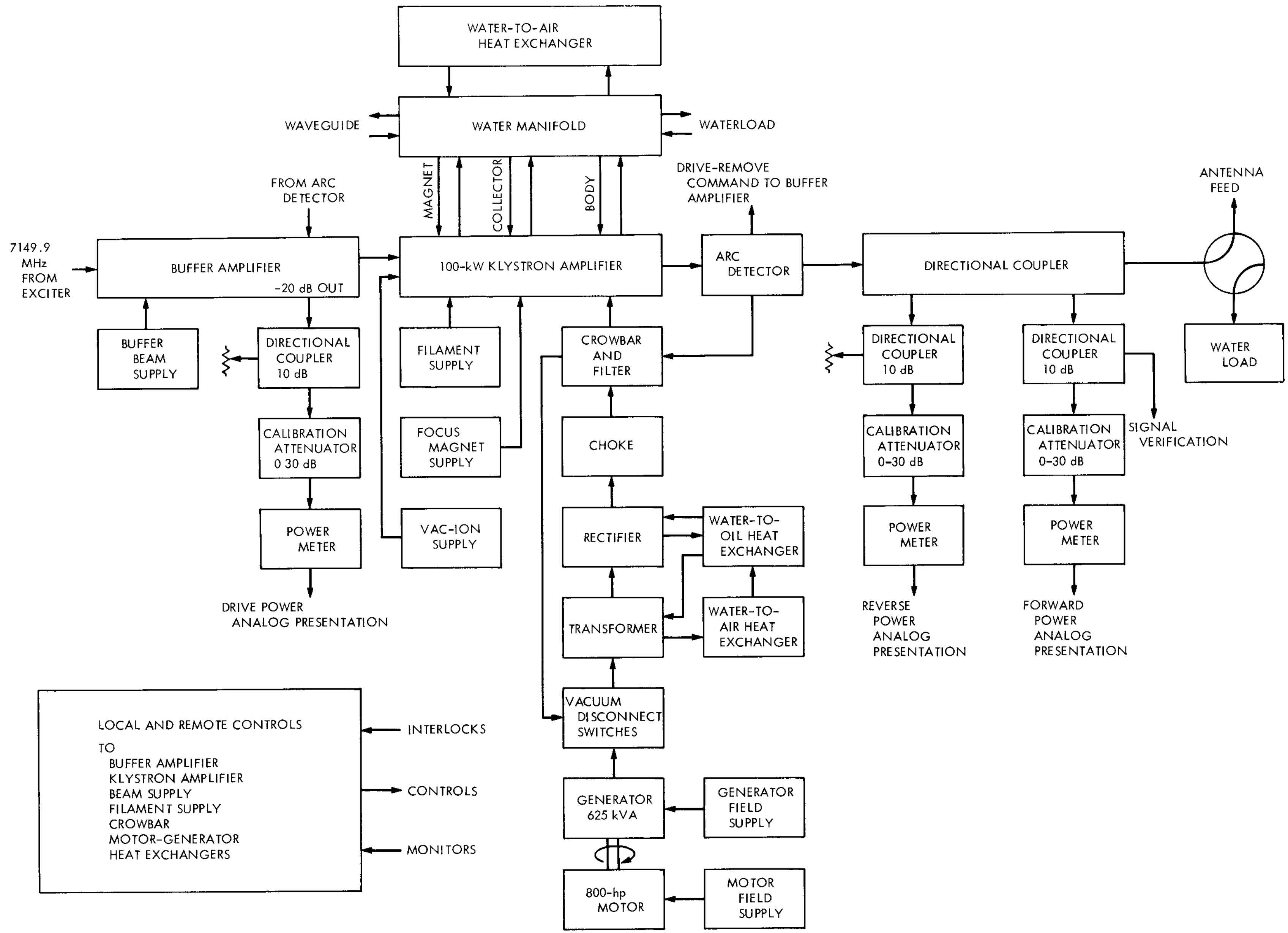

Fig. 1. Block diagram of 100-kW X-band transmitter

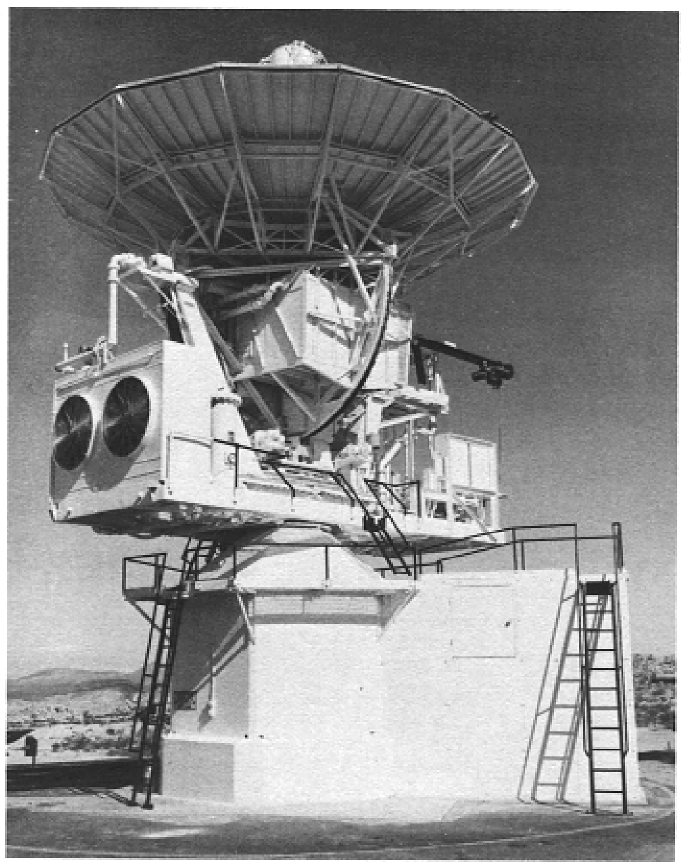

Fig. 2. View of modified 9-m antenna