Antenna Microwave Subsystem

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The Deep Space Net consists of 64-m, 34-m, and 26-m antennas, each with its own characteristics. This article describes the changes that are being made to each under the Mark IV program and additions required for some special spacecraft projects.

I. Introduction

The antenna microwave subsystem includes the antenna feeds, the low-noise amplifiers (LNA), and the transmission paths between them. Various block diagrams later in the article provide a graphic definition of the subsystem. The feeds consist of the feed horn, a polarizer, perhaps an orthomode transducer for polarization diversity, and other specialized components as required by the particular feed. The LNA may be a traveling wave maser (TWM) or a field effect transistor (FET), which may be cooled or uncooled. The transmission path may include switches, a diplexer, couplers for various purposes, and waveguide or semirigid coaxial cable.

Work in the antenna microwave subsystem since the last report has been concentrated on completion of the MK IVA implementation. Specific tasks include: modification of 34-m track antennas to include HEO frequencies; acceptance testing of the feed cone for the new 34-m HEF antennas; modification of 64-m stations to accept International Comet Explorer (ICE) dual-frequency reception and ICE and AMPTE uplink frequencies.

Other tasks include an L-band receive capability for the Venus Balloon mission and design of the 70-m extension for the 64-m stations.

II. MK IVA Status

A. 34-m Standard Antennas

The 34-m standard stations are used for transmitting commands to, and receiving telemetry and metric data (range and doppler) from, deep-space and earth orbiting spacecraft. They will be used to supplement the 26-m stations to be acquired from GSTDN in tracking earth orbiters, although their original design did not allow operation at those frequencies. Modifications are presently underway to extend the S-band frequency range.

These stations have reflector antennas that are 34-m in diameter and Cassegrainian optics and feed horns for S- and X-band frequencies. The antenna mount is hour-angle declination (HA-DEC). Combining of the subreflector illumination paths of the two frequency bands is provided by a dichroic mirror assembly, permitting simultaneous operation at both bands.

In each band, the low-noise amplifier for deep-space frequencies is a maser. Because the earth orbiting spacecraft (S/C) do not require the low system temperature obtainable with a maser, a room temperature FET will be provided for those S/C frequencies at S-band. The microwave subsystem covers the entire X-band range (8400 to 8500 MHz), but receiver components restrict the upper frequency to 8440 MHz.

A 20-kW transmitter capability is provided at S-band. Transmission at X-band would require redesign of portions of the antenna feed and dichroic assembly, and is not planned.

Figure 1 is a simplified block diagram. Only major elements are shown, assemblies being represented by rectangles and transfer switches by circles.

The dichroic assembly allows simultaneous transmission of S-band and reception of S- and X-band signals. Right circular polarization (RCP) or left circular polarization (LCP) can be selected for each of the feeds, but neither has an orthomode; therefore, only one polarization is available at a time. The second maser is, therefore, a backup to the first. Although the diagram shows two X-band masers installed, only Madrid (DSS 61) has this configuration so far.

Modification of these antennas for orbiter frequencies is proceeding in two phases, temporary and final. The temporary phase, now completed, extended the transmit range to 2090 to 2120 MHz and the receive range to 2270 to 2300 MHz. It has been accomplished by replacement of some waveguide components and tuning of the remainder. The final phase will provide a subsystem capable of operating over the frequency ranges of 2025 to 2120 MHz uplink and 2200 to 2300 MHz downlink.

A redesign of certain components, particularly the diplexer, has been necessary to obtain the required bandwidth. The design work has been completed and installation will be completed as scheduled during the MK IV downtime.

A distribution assembly, for each of the frequency bands, is being designed for DSS 42 and will likely be installed at all of the sites.

B. 34-m High-Efficiency (HEF) Antenna

The high-efficiency antennas, so called because the aperture efficiency at X-band is quite high (72%), will be used to supplement the standard 34-m net in tracking deep-space craft. They will also be arrayed with the 64-m antennas to increase the received SNR, thus allowing reception of a higher data rate (Ref. 1).

These antennas are being installed during Mark IV. They differ from the 34-track stations primarily in having an elevation over azimuth mount (AZ-EL), a single feed horn for both frequency bands, and no transmitter. The common feed horn eliminates the need for a dichroic mirror assembly and makes the implementation neater but does require compromises.

Figure 2 is a simplified block diagram. Either RCP or LCP may be selected from the S-band output of the S-X combiner. The X-band output is followed by an orthomode transducer that provides the possibility of simultaneous RCP and LCP. The initial implementation uses only one port of the orthomode because only one maser and receiver are installed. Future additions will include a diplexer, an X-band transmitter (Ref. 2), a second maser and a wide band FET for VLBI use.

The X-band LNA in these cones is a BLK II maser that has been transferred from the 64-m station. Two new X-band masers, BLK IIA, have been built for the 64-m stations to replace the BLK II units. These masers have been transferred to operations.

The S-band LNA is a room-temperature FET designed primarily for VLBI use. There are plans to replace it with a cooled FET to reduce the system noise temperature from a projected value of 110 K to about 50 K. This will make the station more suitable for spacecraft use.

The cone assemblies for the new 34-m antennas have been accepted from the contractor and have been transferred to operations. These cones provide for reception at S- and X-bands through a common feed horn. The design is optimized for X-band, therefore the antenna does not have as high a level of efficiency at S-band as is possible to achieve.

Performance measurements of the complete antenna are scheduled for this summer.

C. 64-m Antennas

The 64-m stations are used for transmitting commands to and receiving telemetry and metric data from spacecraft in deep space. They are also providing backup support to AMPTE.

The 64-m stations have three feed cones installed on a structure at the center of the reflector. The feeds are 120° apart on a circle. Selection of a feed is made by rotation of the (asymmetric) subreflector. A dichroic mirror assembly, half on the S-band and half on the X-band cone, permits simultaneous use of S- and X-band frequencies. The third cone is devoted to R&D or host country work. The planetary radar system also uses the third cone.

Figure 3 is a simplified diagram of the X-band portion of the subsystem. The orthomode provides the capability of simultaneous RCP and LCP. No changes are being made to these units.

Figure 4 is a simplified block diagram showing the S-band portion of the 64-m subsystem. Assemblies that were changed during Mark IVA are identified with a solid triangle in the lower right corner.

The S- and X-band feeds each have orthomodes and two masers, thus permitting simultaneous reception of RCP and LCP. Differentially rotatable quarter-wave plates in the S-band feed allow any angle of linear polarization to be selected instead of circular for those spacecraft that use linear polarization. Because of changes for MK IV, autotracking of the polarization vector is no longer possible.

The S-band waveguide is cooled to allow transmission of CW at up to 500 kW. There is presently no X-band transmitter and major changes to the feed system will be required when one is added.

The microwave subsystem covers the earth orbiter X-band frequency range, but not the S-band transmit frequencies below 2090 MHz because of high VSWR. The nominal lower downlink frequency limit is 2270, but the second ICE frequency of 2217 has been provided for by the replacement, at DSSs 14 and 63 only, of the second maser by a new, BLK V, maser that was built especially for this purpose.

Special modifications are required to the 64-m stations to accommodate ICE, AMPTE and Venus Balloon/Halley Pathfinder missions. These changes include extension of the transmit bandwidth (from 2090 to 2120 MHz with limitations) (Ref. 3), extension of the maser bandwidth (2200 to 2320 MHz in the new, BLK V, maser) and the addition of L-band (Ref. 4).

The 64-m stations must be able to transmit in excess of 100 kW to ICE at 2090 MHz and 20 kW to AMPTE at three frequencies between 2090 and 2105 MHz. All of these frequencies are beyond the original design capability of the station, the VSWR being too high for the transmitter. Extensive measurements have preceded the design of a matching section that provides an excellent match at 2090 and 2110 to 2120 MHz. The sections have been completed and sent to the complexes. This permits the stations to transmit at high power (>20 kW) at the match frequencies, but not between 2091.5 and 2109 MHz. AMPTE requirements for transmission at 2093 and 2103 MHz are being met by installation of isolators in the low-power transmitter output waveguide. The S-band preamp filter (SPF) was retuned to accommodate the new transmitter frequency range (2090 to 2120 MHz).

A new maser has been designed and built to receive the second ICE frequency of 2217 MHz. These masers will be installed in the tricone position at DSSs 63 and 14. Reception at this frequency requires another filter in the transmitter waveguide to reject klystron beam noise at this new receive frequency. These filters, and a matching section, have been built and will be installed on schedule.

The DSN is committed to providing tracking and telemetry support to the Venus Balloon/Halley Pathfinder mission. Spacecraft transmission will be at 1668 MHz, a frequency well outside the normal DSN band. To accommodate this frequency, a new approach has been taken. The design includes a new feed horn mounted to the outside of the XRO cone, dual cooled FET amplifiers, and an upconverter to convert the signal to S-band. The converted signal is put into an unused port in the maser select assembly and follows the normal S-band signal path from that point.

Figure 5 is a simplified block diagram. The second FET is a backup to the first and only one polarization (RCP) is provided. LCP can be provided by unbolting one of the polarizer segments, rotating it and rebolting it in place.

Although each refrigerator (CCR) is capable of holding two S-band and two X-band FETs, it can hold only one of the larger L-band FETs. Therefore, separate CCRs are required for the main and the backup FET. Since each CCR requires a compressor, two new compressors have been obtained, one each for DSS 43 and 63. The other CCR at those sites will use the spare DSN compressor that is located, with the operational compressors, on the antenna structure. At DSS 14, the DSN spare and the R&D compressor will both be used. Switching of helium lines will be required to bring R&D or radar equipment back on line.

III. Studies

A. 70-m Extension (Ref. 5)

Selection of a feed for the X-band cones has been made. Studies of material for the noise shield have been completed. Other RF studies are continuing within the limits of available resources.

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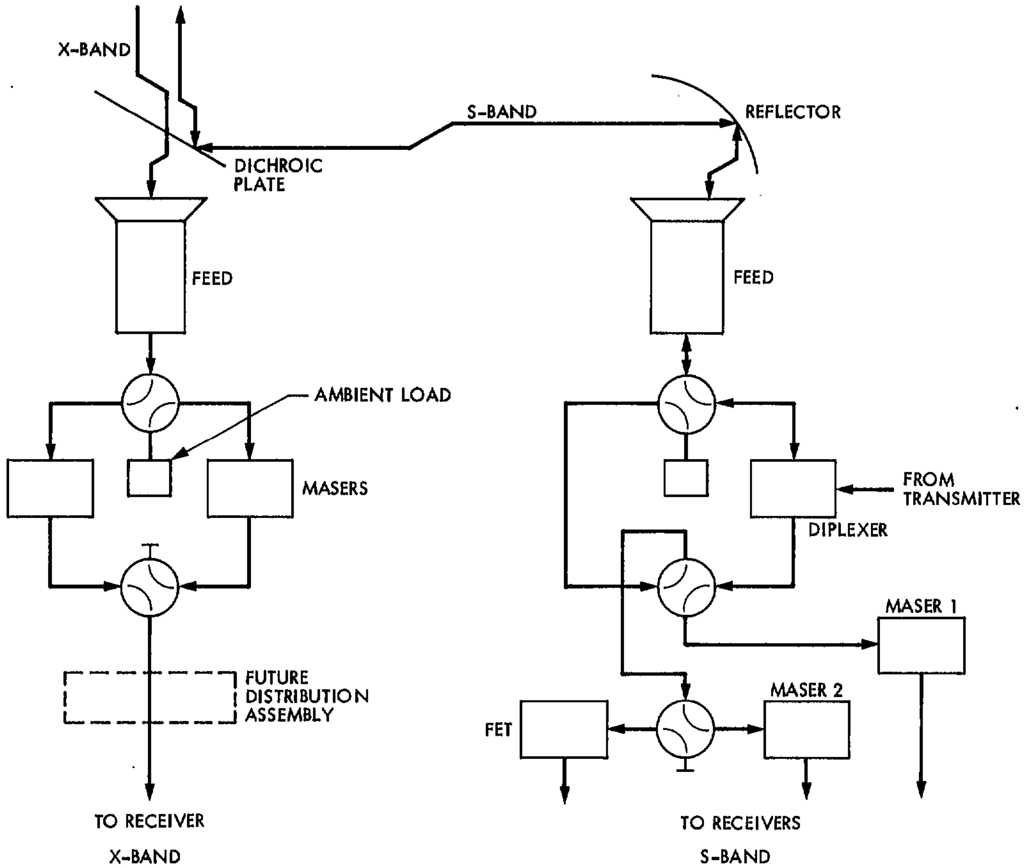

Fig. 1. Simplified block diagram, 34-m standard stations

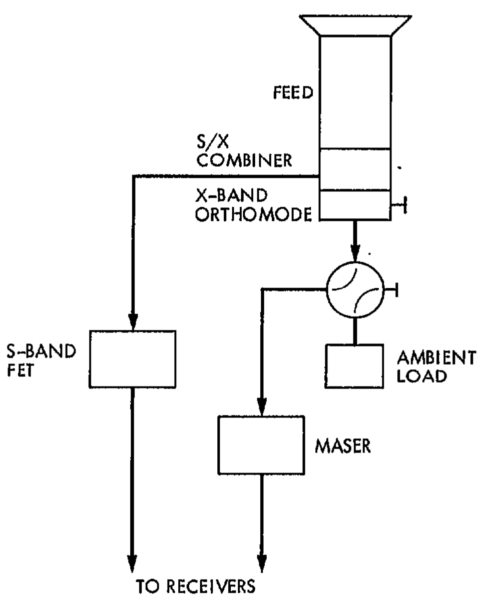

Fig. 2. Simplified block diagram, 34-m HEF stations

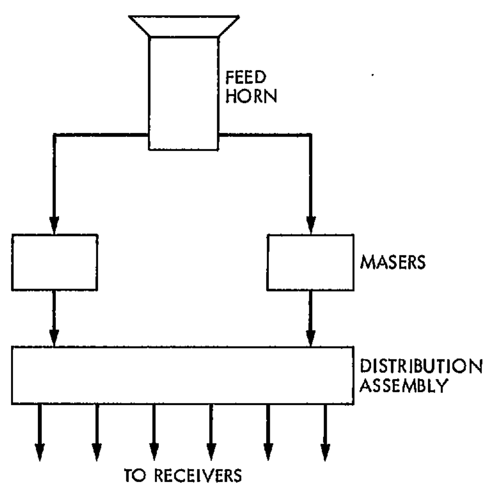

Fig. 3. Simplified block diagram, 64-m station X-band

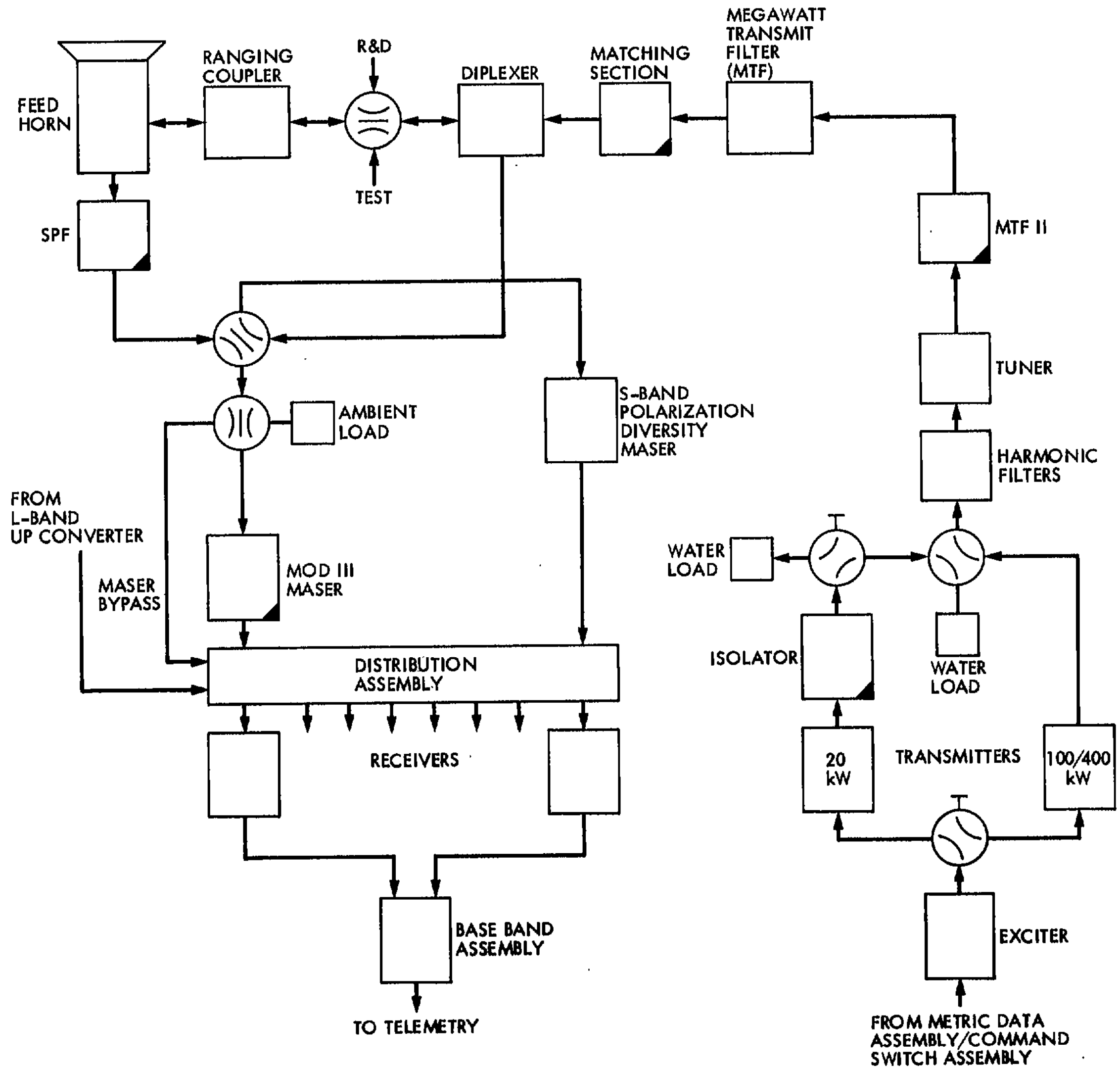

Fig. 4. Simplified block diagram, 64-m station S-band

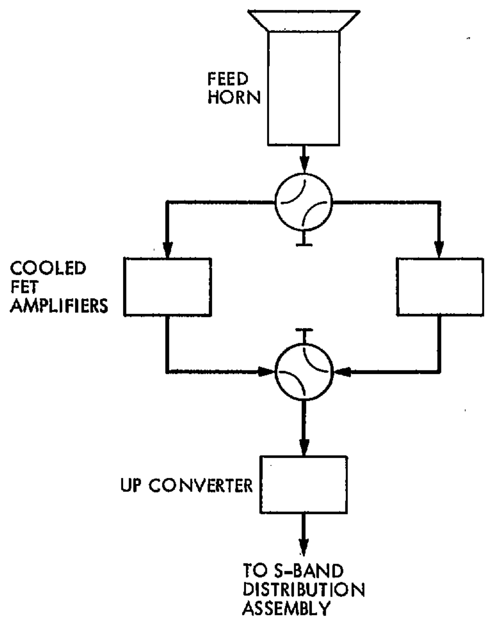

Fig. 5. Simplified block diagram, 64-m station L-band