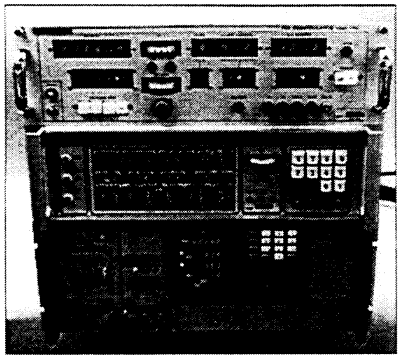

FIGURE 2A. COMMERCIAL EQUIPMENT (MICRODYNE RECEIVER, AYDIN SUBCARRIER DEMODULATOR, AND DSI BIT SYNCHRONIZER) IS TESTED PRIOR TO INTEGRATION IN THE DEEP-SPACE TERMINAL ELECTRONICS RACK.

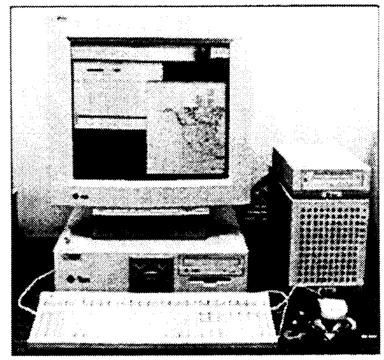

FIGURE 2B. THE ULTRA 2 SUN WORKSTATION, WITH MODIFIED LEO-T SOFTWARE, PROVIDES HIGH-LEVEL STATION AUTONOMY AND AUTOMATION FOR THE DEEP-SPACE TERMINAL.

Based on preliminary measurements, the operating noise temperature of the DS-T system, with the HEMT amplifier at an antenna elevation angle of 30 degrees and 90 percent weather availablity, is estmated to be around 29 kelvins, both in receive-only and transmit-and-receive modes. This compares well with the operating noise temperature of 29 (39) kelvins for DSS-25, with MASER LNA and receive-only (or transmit-and-receive) conditions with similar weather and elevation.

Autonomous, Automated Operations

The software for automated operation of the terminal is based on the modifications to the LEO-T software. The latter was developed by SeaSpace Inc., with input from JPL, and is now available from the same vendor. It is expected that the automation software for DS-T will also be commercially available from a commercial vendor at the completion of the task.

The terminal provides TCP/IP interfaces for reliable networking with remote users over commercial communication links. Uplink commands can be sent in real time from the mission operations to the terminal for uplink to the spacecraft, or can be stored at the terminal for uplink during a future pass. Spacecraft telemetry received by the terminal is forwarded, electronically, to destinations designated for each spacecraft.

After the initial set-up, the terminal autodials an electronic navigation bulletin board at JPL (on a daily basis) and retrieves SPK (Space Planetary Kernel) files supplied by JPL Navigation. Based on the SPK files, the terminal automatically generates satellite view periods, antenna-pointing predicts, and receiver/transmitter frequency predicts.

The auto scheduler uses the view periods and user defined tracking priorities to continuously track multiple spacecraft of interest. For every scheduled pass of the spacecraft, the auto scheduler wakes up the terminal a few minutes before scheduled tracking. The terminal executes the automated, unattended, pre/in/post-pass uplink/telemetry reception routines and then waits for the next scheduled spacecraft.

Schedule and Demonstrations

DS-T implementation takes place in two phases. Phase one, already started, includes station autonomy and telemetry implementation, and is planned for completion by December 1997. A one-month telemetry reception demonstration is planned, using MGS as the spacecraft of opportunity. During this demonstration, the terminal will autonomously track the spacecraft, receive, and process telemetry data. Plans for the addition of uplink have been finalized; long lead items will be ordered in FY 97, and the work completed in FY 98. DS1 is considered the first spacecraft of opportunity for autonomous, uplink/downlink demonstration.

Applications

DS-T development provides an opportunity to explore low-cost approaches that reduce the hourly costs of DSN services for future DSN implementations. The DS-T concept is considered the baseline option for the DSN Network Simplification Plan, to simplify DSN operations and reduce costs. In addition, the DS-T prototype provides a flexible testbed for autonomous, unattended operations, user-initiated services, direct delivery of data to the principal investigator, and application of communication protocols to deep space.

DSN Photonic Antenna Remoting

RADIO ASTRONOMY

George Lutes

The NASA/JPL Deep Space Network (DSN) was established to track spacecraft that travels beyond Earth orbit to other planets and sometimes beyond our solar system.

The DSN consists of three major Deep Space Communications Complexes (DSCCs) that are located approximately every 120 degrees around the Earth.

There is one in the Mojave Desert in California, one in Spain, and one in Australia. Each of these complexes includes several Deep Space Stations (DSSs) that have a receiver, transmitter, and a large antenna. One DSS in each DSCC has a 70-m antenna, and the other DSSs have 34-m antennas.

In the early years of the DSN, each DSS within a DSCC was autonomous, and had a transmitter, receiver, signal processing equipment, and personnel to operate it. This arrangement was inefficient, and became even more so as the amount of data to be processed grew over the years, so central Signal Processing Centers (SPCs) were installed in each DSCC.

Eventually, when technology permitted, the operators and much of the equipment in the DSSs migrated to the central Signal Processing Center (SPC). Sometimes the equipment migrated toward the SPC in steps. For example, the introduction of the beam waveguide (BWG) antenna permitted equipment that was formerly, physically located on the antenna structure to be moved to the ground. The next logical step in this progression is to move as much of this equipment as possible to the SPC.

A major milestone in the progression of equipment to the SPC was the introduction of fiber optics (FO) into the DSN by the Time and Frequency Systems Research Group. FO systems were developed in response to the need for a means to distribute ultrastable frequency reference signals from the SPC to outlying DSSs, and had an important impact.

Prior to the 1980s, free-space microwave transmission systems were used to transmit signals, including frequency reference signals, between the SPC and remote DSSs. However, the stability of frequency reference signals improved dramatically with the development of the Hydrogen maser (H-maser) frequency standard. The H-maser generates signals that are stable to 1 part in 10^{15} for 1,000 seconds averaging time. This is equivalent to a clock that loses a second in 32 million years. Free-space microwave transmission was no longer stable enough to transmit the signals generated by the H-maser.

These terrestrial microwave links were also beset by a number of other problems. The need for more bandwidth on these links was growing, but federal regulations would not permit more bandwidth to be used. The links were susceptible to outage, due to lightning and wind, and maintenance costs were high.

By the late 1980s, ultrastable FO links carried all of the frequency reference signals from the SPC to the outlying DSSs. Shortly thereafter, virtually all of the signals at the DSCCs, both analog and digital, were carried by the FO links.

Subsequent studies, developments, and demonstrations in the DSN by the TFSR Group have shown that FO links can provide high-fidelity transmission of microwave signals up to 40 GHz between DSSs. It is now possible for most of the receiver electronics for the down link, and the transmitter electronics for the uplink, to be moved to the SPC.

The result is a number of important advantages. For instance, an entire DSCC can be reconfigured, nearly instantaneously, from within the SPC. A single set of spares for the equipment located at the SPC can back up all of the DSSs in an entire DSCC. Less test equipment and fewer personnel are needed to service a DSCC. Some of the equipment moved to the SPC is redundant and can be eliminated. Travel between DSSs will be reduced. The antennas in a DSCC can be arrayed in real time in any configuration.

Using commercial equipment, based on technology pioneered by the TFSR Group, the Communications Ground Systems Section implemented the migration of much of the uplink and downlink to the SPC.

A major remaining milestone is to move everything in the downlink after the low-noise amplifier to the SPC. This requires an FO system with very high dynamic range and has been difficult to achieve over the required tens-of-kilometers in distance. Dynamic range is the ratio between the largest and smallest signals that can be handled simultaneously.

In 1994, the TFSR Group used the best available optical components, at the time, to perform a one-day downlink remoting demonstration at DSS-13.

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In this demonstration, the signal from the low-noise amplifier was transmitted through 12 km of optical fiber before going to the rest of the downlink.

The experimenters knew from calculations that this fiber optic link would slightly degrade the dynamic range of the receiver. However, station personnel did not notice any difference in receiver performance when operating in this configuration. While in this configuration the station successfully tracked the Magellan spacecraft.

Since 1994, optical components have improved considerably and it is now possible to meet the required dynamic range. The TFSR Group has designed a new system based on higher efficiency microwave optical modulators, higher power semiconductor lasers, and higher output power wideband microwave photodetectors (Figure 1).

This new link will be used for an upcoming, long-term demonstration of downlink remoting. Station personnel will operate interchangeably between the standard station configuration and the demonstration configuration, for as long as a year, and report any differences that are observed. When this demonstration is successful, it will add another capability to the set of tools available to the DSN in its quest to become more efficient and responsive to its customers.

As this migration of personnel and equipment to the SPC nears completion, the DSSs will have considerably less equipment to maintain and operate, and a new paradigm for the unified DSCC will emerge. A DSCC will perform as a single unit instead of a group of subunits, as it has in the past. Instead of being assigned to a particular DSS, most of the electronics/photonics will be assigned to the DSCC to be used interchangeably, where needed.

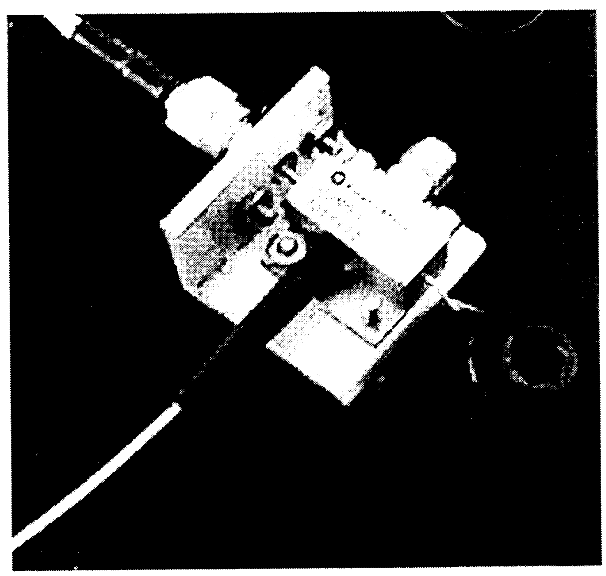

FIGURE 1. A WIDE BANDWIDTH MICROWAVE PHOTODETECTOR THAT CAN BE OPERATED WITH UP TO 10 mW OF OPTICAL POWER AT ITS INPUT, COMPARED TO 1 OR 2 mW FOR PREVIOUSLY USED PHOTODETECTORS. THE INCREASED OPTICAL POWER CAPABILITY CAN RESULT IN AS MUCH AS 100 TIMES MORE SIGNAL POWER OUT OF THE DETECTOR, WHICH IN TURN INCREASES THE DYNAMIC RANGE OF THE FIBER OPTIC LINK.