Proposed Upgrade of the Deep Space Network Research and Development Station

Joel G. Smith
TDA Technology Development Office

Continued exploration of the solar system will require continued evolution of capabilities to support deep space communication and navigation. That evolution will rely, as it has in the past, on the development, demonstration, and field testing of new communication and navigation technologies. The existing Deep Space Network (DSN) research and development station, DSS 13, at the Venus site, Goldstone, California, has been instrumental in those prior developments.

However, the present antenna is no longer able to provide the necessary support for new technologies. The 26-meter antenna has good performance at S-band, fair performance at X-band, but is unusable at the anticipated Ka-band (32 GHz). It is not suitable for conversion to beam waveguides, and is not usable as a test bed for demonstrating high efficiency because of structural pliancy (it's too floppy). Additionally, its size and age are increasingly a liability in demonstrations.

A new 34-meter beam waveguide version of the existing DSN high efficiency (HEF) antennas has been proposed for the FY88 Construction of Facilities (C of F) budget. The antenna is to be built at the Venus site, adjacent to the old antenna, and serve as the DSN research and development antenna through the end of the century.

I. Introduction

The growth of the deep space communication and navigation capability that has occurred since inception of the solar system exploration program in the late 1950s has been in response to the increasing demands of that program for more data per second over greater distances. That evolution has come through a variety of improvements: bigger spacecraft antennas, more spacecraft power, higher operating frequencies, better means of modulation and coding, and better ground facilities. These improvements have followed an orderly transition: concept, analysis, laboratory models, field tests, demonstrations, and commitment to mission use.

Fundamental to that process, both for improved spacecraft and ground capability, has been a research and development station within the DSN for testing and demonstrations. The major such site for the last two decades has been the Venus site at Goldstone, California, with its 26-meter antenna, DSS 13.

Research and development have been conducted at other locations in the past within the DSN, but the lower priority of non-flight project status and heavy loading of the network has caused research and development to suffer when attempted on operational stations.

A separate research and development facility is most cost-effective, and that facility must be of sufficient quality that the environment of the test bed parallels the applications environment, and the capability does not mask the required observations.

II. Past Contributions From the Venus Site

The list of new capabilities demonstrated and/or field tested at the Venus station is restricted here to those which are still visible today in the network and which were technically significant achievements.

One of the earliest test beds at Venus was an S-band planetary radar system used for probing Venus (hence, the station name). This verified the "emptiness" of space at S-band and demonstrated wideband (MHz) ranging, ranging codes, and transmission and reception on the same antenna. Additional work at the Venus Site included the unified S-band concept of shared telemetry and tracking on one signal, computer-controlled subsystems, digital on-line signal processing using computers, wideband correlation (a precursor to VLBI), programmable up-and-down links, precision power monitoring, and digitally controlled spectral analysis.

Other examples are low-noise dual mode feeds, dual simultaneous S-band transmissions proposed for Viking commanding (tests showed that intermodulation effects precluded simultaneous transmissions of two narrowly spaced S-band carriers), verification of analytic models for the design of DSS 14 (the Venus antenna was subjected to a "shake" test, and the computed and measured resonant frequency values were compared and found to agree), and verification of telemetry arraying capability with demonstration for Mariner Venus Mercury 1973.

III. Present Contributions From the Venus Site

The Venus station could, until recently, under control from the Jet Propulsion Laboratory, acquire, track, command, and receive telemetry from deep space spacecraft operating on S-band (commanding was limited to the Pioneer 8 spacecraft). These demonstrations (from 1978 through 1984) of the ability to remotely turn on, tune up, control, and turn off a station were instrumental in the decision to develop remote controlled station operation in the DSN.

The X-band uplink system now planned for implementation in the network is based on a prototype built at the Venus station and undergoing tests since 1982. The 20 kW system is remotely controlled and phase stable to 10^{-15} over 10^3 seconds, a good intermediate goal in the effort to stabilize the DSN stations to 10^{-16}.

The common aperture feed now on the Venus station is a new design now used on the 34-meter HEF antennas, and is being considered for implementation on the 70-meter antennas. It replaces the dichroic plate and small reflector now used. It will allow simultaneous dual transmission (both S- and X-band, up to 20 kW) and reception (both S- and X-band at 25 Kelvin noise temperature). A next generation feed capable of the same performance, but at 100 kW levels, is feasible.

A 7 km optical fiber cable, carrying six separate fibers, with multi-GHz bandwidth capability, was buried roughly five feet below grade from the Echo site to the Venus site. This promises to provide 10^{-17} stable time and frequency standard transfer between stations. The benefits are reduced numbers of Hydrogen maser frequency standards, and the possibility of lower cost navigation by means of connected element interferometry.

IV. Present Antenna Characteristics

The present research and development station at the Venus site (see Fig. 1 for layout) has many key capabilities used in the past and useful in the future. These include: 1) best available radio frequency isolation from operational stations (on the order of 200 dB); 2) suitable control buildings, electronics laboratories, and collimation tower; 3) buried optical fiber link to the Echo site; 4) super-power transmitter test facilities (400 kW); and 5) high bay for feed cone testing.

However, the present research and development station does not have one critical capability needed for the future: a large precision antenna. The present antenna (see Fig. 2) lacks several key characteristics:

(1) It is too pliant (floppy). It has good S-band performance and fair X-band performance, but it cannot be upgraded to serve as a Ka-band test bed. It cannot be converted to serve as a beam waveguide test bed, and it cannot be used as a test bed for improving antenna efficiency.

(2) It is too small. All deep space antennas have been enlarged to 34-meter size or larger. The 26-meter

antenna is too small for cost-effective transfer of technology.

(3) It is too old. The antenna will be 33 years old at planned tear down in 1992. It has been "band-aided" frequently to extend its life. Recently, outrigger beams were added to compensate for a cracked, irreparable foundation to allow DSS 13 to be used through 1992.

V. Proposed New Antenna Characteristics

The antenna selected to replace the present one is a 34-meter diameter design of demonstrated high performance at X-band, with tolerances of 0.025 inch. In fact, it is planned to use the recently constructed 34-meter HEF antennas (Fig. 3) as a model, but modified to incorporate beam waveguide.

Other possible antenna designs were considered. Offset clear aperture antennas were rejected because: 1) the small potential gain-to-temperature (G/T) benefit over a center-fed antenna with improved subreflector and subreflector support; 2) the added cost associated with the non-symmetric construction; and 3) the lack of transfer of that technology to any of the existing DSN antennas.

A stiffer antenna, with tolerances of 0.015 inch, and high performance at Ka-band, was rejected in favor of the more pliant design because: 1) the stiffer antenna cost several million dollars more than the pliant; 2) the pliant antenna with 30 to 50 percent efficient performance at Ka-band can be upgraded to 70 to 80 percent efficient performance by electronic means; and 3) the upgrade of the pliant antennas is a technology that is transferrable to existing DSN antennas.

A smaller antenna was rejected in favor of the 34-meter design because: 1) scaling smaller antenna performance at higher frequency (for example, with a 17-meter antenna at 64 GHz) is not possible due to media properties and receiving equipment unique to deep space communication bands; 2) transfer of 70-meter microwave and pointing is possible over the 2:1 size ratio; and 3) transfer of 34-meter microwave, pointing, and structural technology is straightforward.

The specific beam waveguide design includes either a conventional method (Fig. 4) or a unique "bypass" method (Fig. 5) because, the bypass method allows the 34-meter antenna design to use the same structure as the present HEF antennas; but it does not appear to compromise performance.

The antenna proposal calls for the antenna to be completed under the FY88 C of F budget, up to but not including the subreflector and subreflector supports. These items are to be developed under DSN Advanced Systems Program funding to provide maximum impact on antenna performance.

The antenna will utilize either an alidade room or pedestal room inside the wheel-and-track to house the electronics. The room envisioned routes the microwave beam received and/or transmitted through multiple fixed mirrors, and movable mirrors to one of several work stations. RF isolation will permit research and development to be done at work stations switched out of the beam waveguide system while transmission/reception occurs at a work station switched in.

VI. Planned Research and Development

The following research and development tasks have been identified so far for the Venus station when the new antenna becomes operable in early 1990.

(1) Demonstration of subreflector and subreflector supports with high antenna efficiencies at X- and Ka-bands.

(2) Demonstration of low threshold acquisition and tracking of spacecraft telemetry.

(3) Demonstration of fast acquisition of X-band spacecraft telemetry.

(4) Demonstration of precision blind pointing at X- and Ka-bands.

(5) Demonstration of comparative reception performance at X- and Ka-band under various weather conditions.

(6) Demonstration of simultaneous dual frequency reception, at both X- and Ka-bands, and tracking of various spacecraft experimental beacons.

(7) Demonstration of improved reception performance of a beam waveguide configuration at X-band in the rain.

(8) Demonstration of the improved reliability, maintainability, operability, and repairability of transmitters and low-noise receivers in a beam waveguide environment.

(9) Demonstration of simultaneous transmission of high power (400 kW) and low-noise reception (−180 dBm) at X-band through beam waveguides.

(10) Demonstration of cryo-cooled multi-element Ka-band array feeds and low-noise amplifiers for higher antenna efficiency.

(11) Demonstration of ultra-stable (10^{-16} to 10^{-17}) station frequency stability.

(12) Demonstration of Ka-band radar.

(13) Demonstration of improved operator monitor and control interfaces.

VII. Conclusion

The new research and development antenna planned to be operable in early 1990 is timely because of the aged state of the present "band-aided" antenna, and because of the needed development and demonstration of Ka-band capability in the DSN in time for use by the Cassini mission in the mid-1990s, and subsequent deep space missions.

This antenna promises to allow the Venus site station to continue its tradition of field testing new capabilities for the operational DSN with a tool sufficient to meet the needs through the end of the century.

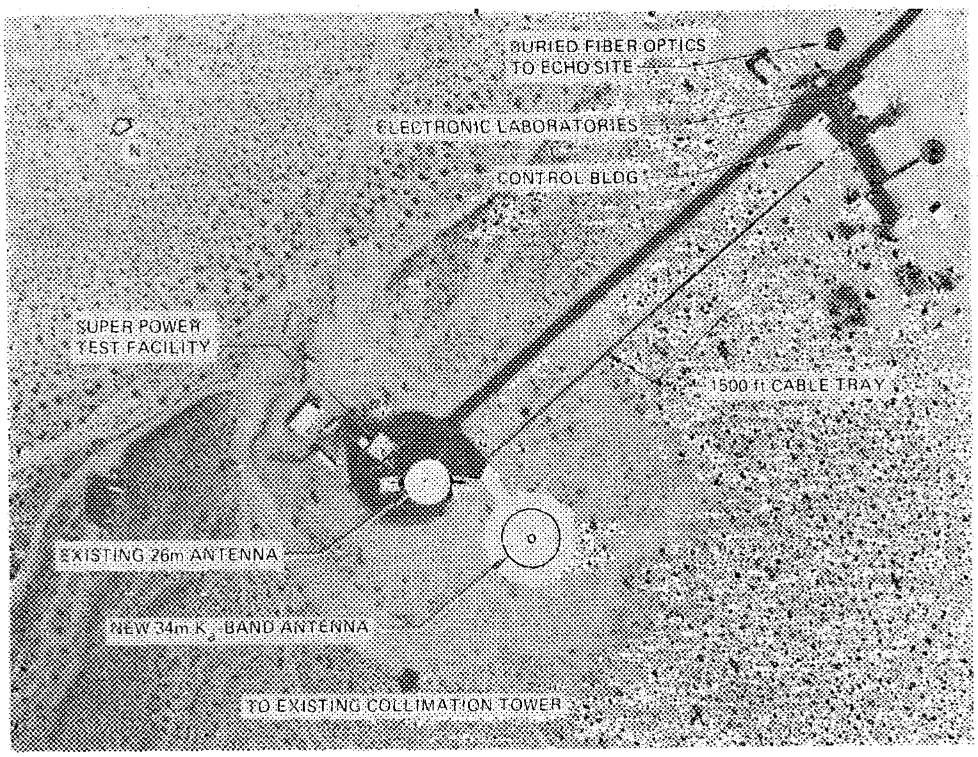

Fig. 1. Layout of R&D station

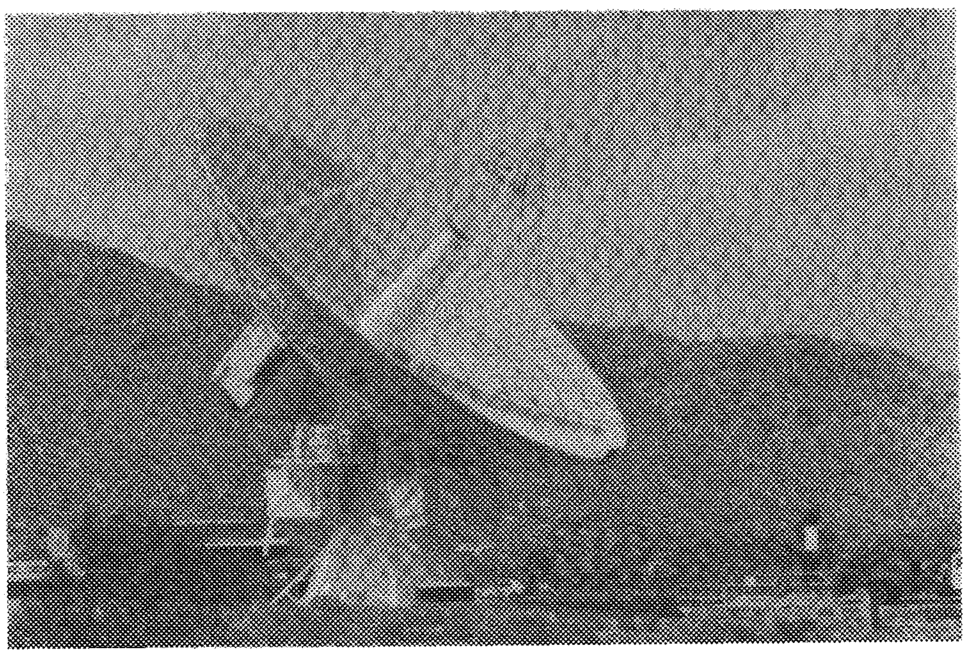

Fig. 2. Present R&D antenna

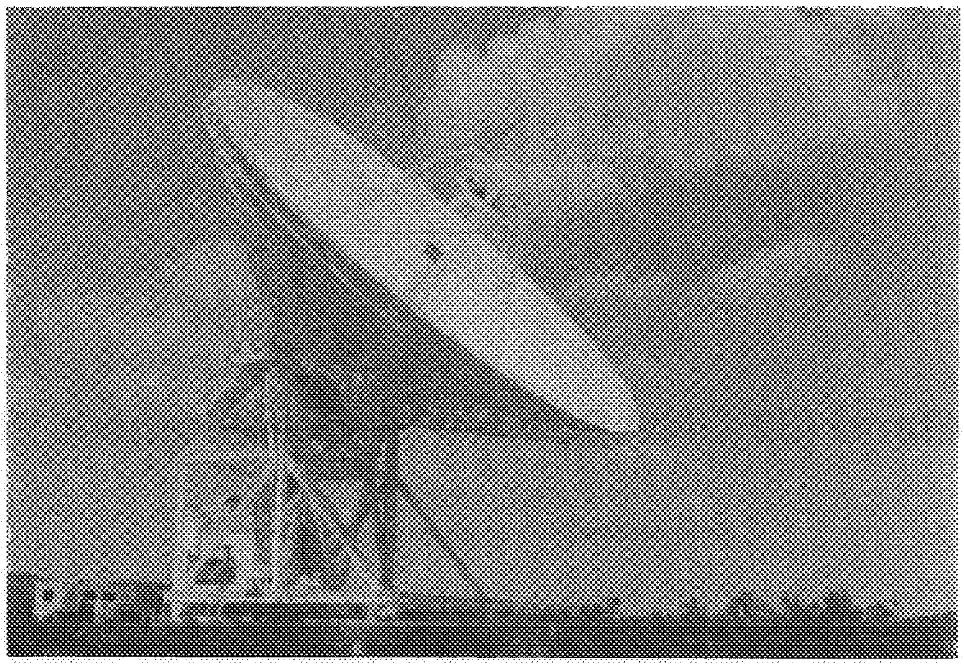

Fig. 3. Proposed R&D antenna

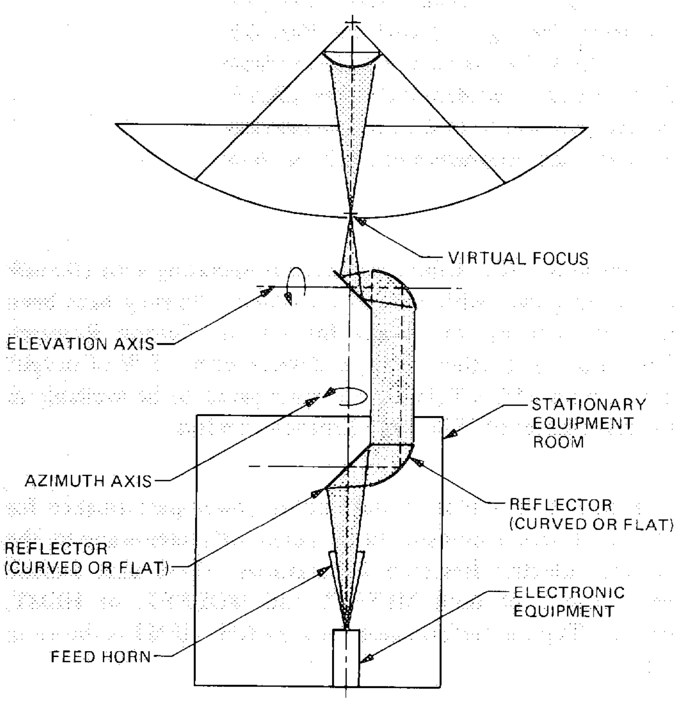

Fig. 4. Conventional beam waveguide

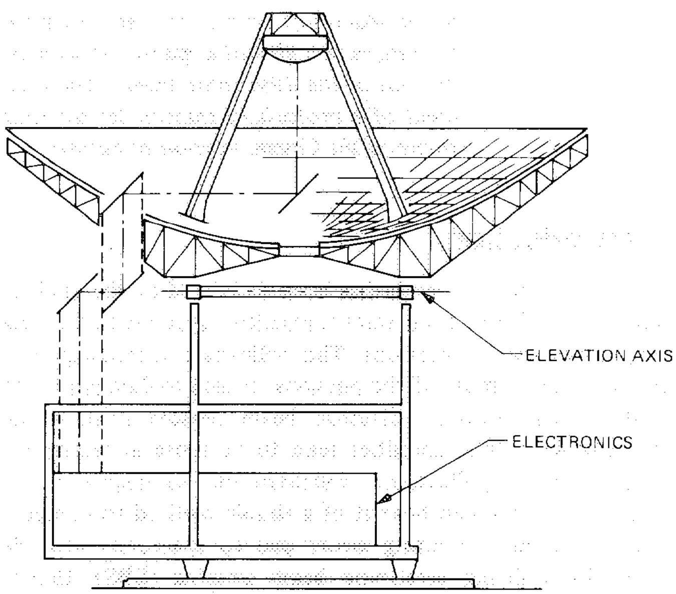

Fig. 5. Lateral bypass beam waveguide