64-Meter to 70-Meter Antenna Extension

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The DSN 64-m antennas are being upgraded to improve their performance by increasing the diameter to 70 m, installing precision panels, and using a shaped surface. Performance improvement is expected to be 1.9 dB at X-band and 1.4 dB at S-band.

This article is the first of a series of articles that will describe the engineering analyses, trade-off studies, and plans that will lead to the performance upgrading of the DSN 64-m antennas. This first article will review the overall concepts and describe some of the approaches used.

The first 64-m antenna was dedicated at Goldstone in April 1966. This was followed by the erection of two additional antennas, one in Australia in July 1972 and one in Spain in January 1973. Following the completion of the 64-m antennas, a DSN Advanced Systems program was started in which potential improvements in the microwave performance were explored. This program resulted in a menu of options considered technically feasible and cost effective. (This work was reported in JPL Document No. 890-47 by J. R. Hall, June 1, 1975.) This menu included:

(1) Install improved feed waveguides, dichroic filters, and travelling wave masers.

(2) Install an X-band dual hybrid horn.

(3) Extend the primary reflector from 64-m to 70-m.

(4) Install a highly efficient shaped primary reflector and subreflector.

Since the first two items were considered the most economical and cost effective, they were implemented to provide a needed performance improvement for the Voyager encounter at Jupiter in 1979.

Drawing on the results of the 1975 study, a 1982 study indicated that it would now be economical to improve the performance of the 64-m antenna by 1.9 dB at X-band and 1.4 dB at S-band by increasing the diameter to 70 m, installing a new precision-shaped surface, adding structural braces, and installing a Y-axis controller. The last two items are intended to compensate for gravity distortions. The structural braces were installed on the Goldstone antenna in 1973 with an improvement in the gain characteristics as a function of elevation angle. The Mark IVA Project, currently being implemented in the DSN, includes the installation of these braces at Australia and Spain, and the installation of the Y-axis controllers at all three antennas.

Figure 1 is an illustration of the antenna that shows the principle elements of the performance upgrade. These elements are:

(1) Extend the diameter from 64-m to 70-m. Enlarge the diameter of the main reflector to 70-m, the maximum practical limit developed in the 1975 study. This includes the following:

(a) Replace and extend radial ribs. The supporting structure beyond the 34-m diameter will be removed and replaced. (The time available to install these changes is very limited and the plan is to replace, rather than rework, the existing ribs. The new ribs will be assembled on the ground before the antenna is removed from service.)

(b) Reinforce reflector backup structure. It is impractical to follow the same philosophy as for the ribs so the necessary reinforcements will be welded on during the downtime.

(c) Reinforce elevation wheel. The elevation wheel, which carries the counterweight, will be strengthened to support the additional counterweight.

(d) Additional counterweights. The added weight of the reflector, quadripod, and subreflector will require additional counterweight.

(2) New surface panels. New reflector surface panels, which will be smoother and fabricated to a shaped surface, will be installed.

(3) Newly shaped subreflector. The larger diameter main reflector will require a larger diameter subreflector. In addition, the subreflector will be of a shaped design and manufactured to a high precision.

(4) New quadripod. The larger subreflector will require the quadripod to be redesigned to carry the additional weight.

(5) Modify microwave feed. A 22-dB-gain X-band feed will replace the existing feed. The existing narrow-band X-band feed was developed to provide a pseudo-shaped beam to be used with a parabolic main reflector surface. It will not perform satisfactorily with a shaped surface.

(6) Add 1-m S-band noise shield. Optimizing performance at X-band results in a significant loss of performance at S-band, caused by an increase in system temperature due to edge spillover. This is compensated for by adding a screen to the edge of the main reflector.

The source of the performance increase is illustrated in Fig. 2. The main difference in performance improvement between X- and S-band is due to the fact that improvement in surface accuracy has little effect at the lower frequency. The physical increase in aperture and the use of a shaped, rather than a parabolic, surface yields the same performance improvement at both frequencies.

There are several decisions and design optimizations required to get the largest performance improvement while keeping the cost within the established bounds. These include the following, each of which will be the topic of a future article.

1. **Subreflector RF optical design.** The feeds of the 64-m antenna are not on the antenna centerline. Three feedcones are mounted offset such that the subreflector must be rotated to "see" each of them as required. The existing configuration is a conventional hyperboloid-paraboloid reflector system, with the subreflector a section of a hyperboloid. When the reflectors are "shaped," to improve illumination efficiency, this subreflector becomes an asymmetric shape, which complicates the design and fabrication, and hence increases the cost. The question then becomes: What is the impact on performance if the subreflector is made symmetrical? Furthermore, is there a surface of revolution that approximates the desired shape close enough so that further economies might be made without compromising the RF performance?

There is also the question of the proper diameter. The larger main reflector requires the diameter of the subreflector to be increased. There is an optimum size based on RF efficiency, noise temperature, weight, and ease of fabrication. Weight affects quadripod design, and as will be pointed out later, this can have a significant effect on the overall performance of the antenna.

2. **Noise Shield.** Designing an antenna for more than one frequency is a compromise. Originally this antenna was designed for optimum performance at S-band. In the years that followed, X-band was added, and new antennas now being built for the DSN are optimized for X-band. Early performance analyses of the 70-m antenna showed that when the system was designed for the higher frequency, noise from edge spillover almost negated other improvements at S-band. One way to avoid this is to include a flange around the edge of the subreflector, and, in fact, this has been done on some of the DSN antennas in the past. The trouble with this approach is that this tends to be frequency sensitive; that is, while it may help at S-band and has no effect at X-band, it may have deleterious effects at K-band. Another solution is to install a "noise shield" around the edge of the main reflector, such as was done on the 100-m antenna in West Germany. It must also be remembered that the 1975 study showed that diameters much over 70-m required extensive drive modifications. Therefore, any added shield must be designed to not only have the desired RF performance but to minimize the impact on structural and mechanical performance.

3. **Feed configuration options.** Figure 3 illustrates the feed configurations under consideration. The shape of the reflectors is dependent on the characteristics of the horn used to illuminate the main reflector. Three X-band horns are under consideration: (1) the horn currently in use on the 64-m antennas,

(2) the new X/S horn being installed on the new 34-m antennas, or (3) the standard 22-dB-gain horn used on the 64-m antennas until 1979. Since the horn currently in use was designed to provide quasi-shaped performance, it is not practical to consider it in the design of a shaped surface. However, it is practical to consider it as a temporary feed for a reflector shape based on one of the other two (i.e., the 22-dB standard horn or the X-S common aperture feed). Therefore, there are the six possible configurations shown in Fig. 3.

4. **Quadripod design.** The quadripod performs a difficult function: it must support the subreflector in a fixed position and be relatively invisible to the RF beam. It also is used as a "crane" during the removal of the subreflector and feedcones. Thus, a design must be found that provides adequate stiffness and strength while minimizing the RF blockage.

5. **Operating environment.** The 1975 study pointed out that 70-m was about the maximum diameter that could be considered before significant changes would be required in the antenna drive system. The original 64-m antenna design provided for maximum antenna motion in either axis of 0.5 degrees per second. After the antenna was built, the maximum operational velocity was set to 0.25 degrees per second. Maximum operating wind velocity for the 64-m antenna is 88 km/h (55 mph). At that point, there is sufficient drive torque to move the antenna to the stow position. A 70-m antenna, with a 1-m noise shield, could encounter attitudes at which it could stall at wind velocities below 88 km/h (55 mph), though not for both axes simultaneously. The problem becomes one of identifying the controlling factors and either modifying the design or instituting acceptable operational restrictions.

6. **Construction.** In considering when to upgrade the 64-m antennas, careful consideration had to be given to the support of on-going and planned deep-space missions. Figure 4 is a plot of Deep Space Network loading for Priority 1 support. A characteristic of Priority 1 support requirements is that they are essentially inflexible and must be fully met on the committed and planned schedule. There is only one opportunity before the Voyager encounter at Neptune: mid-1986 to the end of 1987. This means that only eighteen months are available to modify in succession the three antennas. Each will require six months to remove the outer rib assemblies, remove the quadripod and subreflector, strengthen the backup structure, replace the outer ribs, quadripod and subreflector, install and set the new surface panels, and perform the necessary tests. The accomplishment of this task, in such a short time, will require a careful and well thought-out detailed construction plan.

1. EXTEND 64-m TO 70-m
   REPLACE AND EXTEND RADIAL RIBS
   REINFORCE REFLECTOR BACK UP STRUCTURE
   REINFORCE ELEVATION WHEEL
   ADDITIONAL COUNTERWEIGHTS
2. NEW SURFACE PANELS, SHAPED
3. NEW SUBREFLECTOR, SHAPED
4. NEW QUADRIPOD
5. MODIFY MICROWAVE FEED
6. ADD 1-m S-BAND NOISE SHIELD

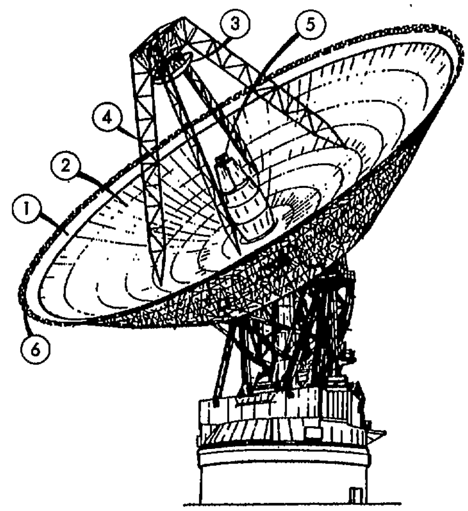

Fig. 1. Modifications to be made to the 64-m antenna

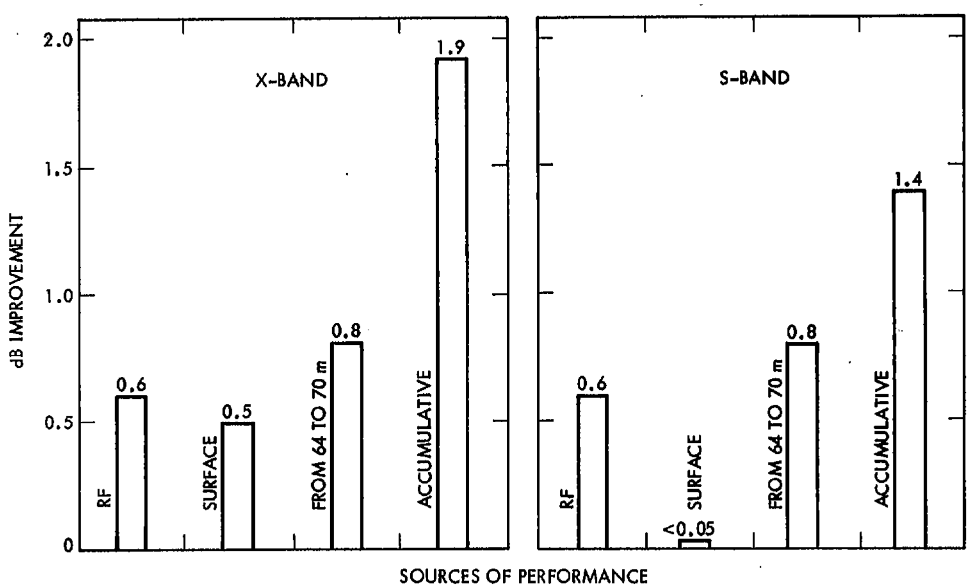

Fig. 2. Sources of performance increase for 70-m antenna

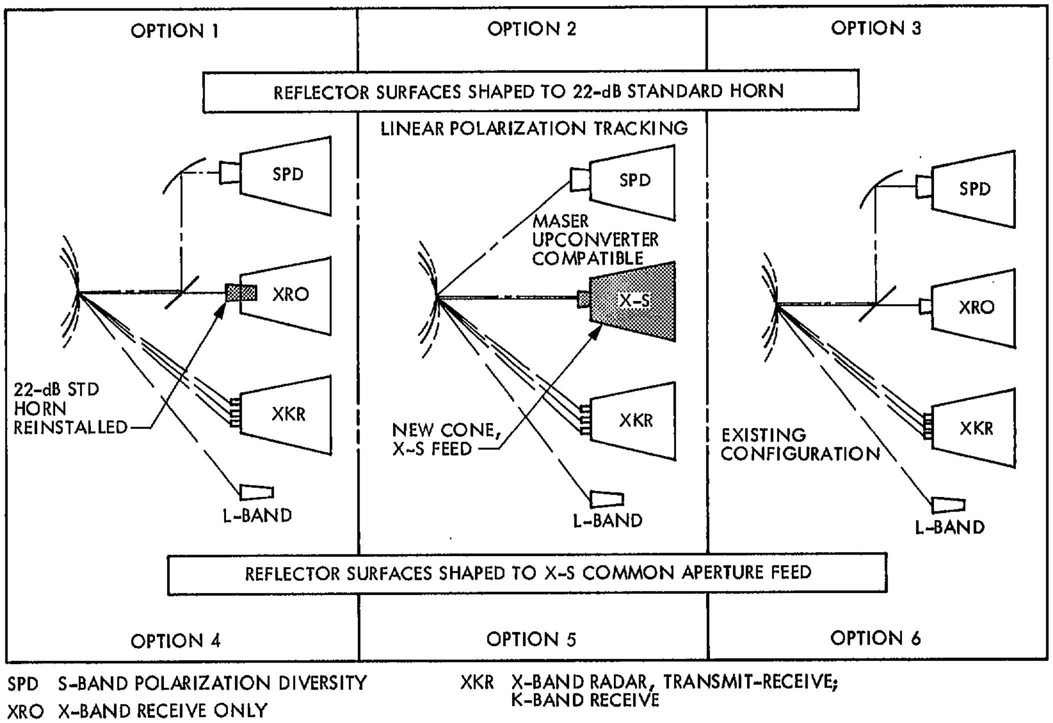

Fig. 3. Feed configurations for 70-m antenna

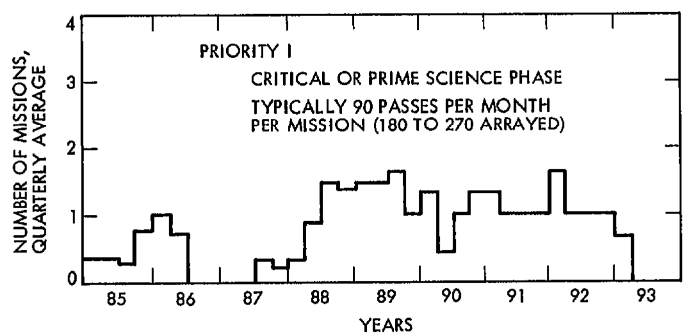

Fig. 4. Network loading