64M ANTENNA DESIGN FOR THE USUDA DEEP SPACE CENTER OF JAPAN

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1. Introduction and Background

Travelling in its orbit through the solar system Halley's Comet will, after an absence of 76 years, again be approaching the sun in early 1986. In order to observe the comet when it reappears, the Institute of Space and Astronautical Science has constructed a large 64m antenna for the Deep Space Center located in Usuda, Nagano Pref., Japan. Especially developed for deep space observation, it is a cassegrain-type antenna fed by a wide-band beam waveguide system. In order to realize high surface accuracy of the main reflector, homology design techniques were employed, and the master collimeter system was used to enable high pointing accuracy. The antenna mount is an elevation-over-azimuth wheel-on-track mount, the El axis being driven by dual sector gears and four gear trains, and the Az axis by the

Figure 1 Photograph of Antenna

Table 1 Major Design Performance of the 64m Antenna

1. Antenna Type	: Cassegrain Antenna fed by Beam Waveguide
2. Reflector Diameter	: 64m (Nominal)
3. Antenna Mount	: Elevation-over-Azimuth mount with Wheel-on-Track
4. Antenna Drive	: Dual DC Motor Anti-backlash-drive (Max. Speed 0.5°/sec)
5. Angular Travel	: Az : ±270° El : 5°-92°
6. Surface Accuracy	: 1.5mm rms.
7. Frequency Range	: 1.4GHz- 15GHz
8. Antenna Gain excluding Feed Loss	: More than 61.4 dB at 2.1 GHz (4-Ref. Type) : More than 61.2 dB at 2.1 GHz (5-Ref. Type)
9. Noise Temperature	: Less than 30 K El=90° (including Feed Loss)
10. Wide Angle Directivity	: Better than CCIR Recomendation
11. Power Handling	: 40 Kw CW (S-band)
12. Tracking Modes	: Monopulse, Program and Manual
13. Pointing Accuracy	: 0.003° rms
14. Survival Wind	: 65 m/sec
15. Antenna Height	: 70 m
16. Antenna Weight	: 1900 ton

friction of the dual wheel system on the rail.

A photograph of the antenna and its major performance chracteristics are shown in Figure 1 and Table 1, respectively.

This antenna has proven successful in operations with the test spacecraft MS-T5, and will link up with the Planet-A spacecraft, scheduled for lauching in mid-August of this year to observe Halley's Comet.

In the followings, we introduce the design of the beam waveguide system, feed assembly, main reflector, etc.

2. Design of Antenna and Feed Assembly

2.1 Beam waveguide System

The antenna was designed to realize the performance characteristics required for deep space observation; ie. (1) high efficiency, (2) low antenna noise temperature, (3) good cross polarization (that is, good beam alignment) and (4) good accessibility.

A beam waveguide system is employed so that the electric equipment (low noise amplifier, high power amplifier, etc) will not be affected by the elevation rotation of the antenna. This is very important consideration in very large antennas.

As shown in Figure 2, the basic design is a 4-reflector beam waveguide system with very wide band transmission capability and very low antenna noise temperature performance. However, a fifth reflector combined with a corrugated horn (for S-band use) has been added for a future requirement of multi-purpose.

A) The design for the beam waveguide system employs a beam-mode method which enabled to compromise a cross polarization characteristics, super wide-band transmission capability, and minimum spillover power within the beam waveguide system, within the optimum limits determined by the mechanical structure.

B) The main-and sub-reflector system design employs the shaped reflector method to realize the proper field aperture distribution needed to obtain a high efficiency and a good side lobe levels.

C) The design requires that the master collimeter be positioned at the point of intersection of the azimuth and elevation axis, making it necessary to offset the primary focus relative to the mirror axis of the main reflector. Despite this fact, we have been able to employ a rotationally symmetrical subreflector.

2.2 Feed Assembly

The Feed assembly is of the S-band type shown in Figure 3. The feed assembly has transmit and receive ports which can be used simultaneously, and right-hand circular/ left hand circular polarization changes are made by rotating the polarizer. In addition, the feed assembly has been constructed to pick up angular error signals for the auto-tracking system by means of

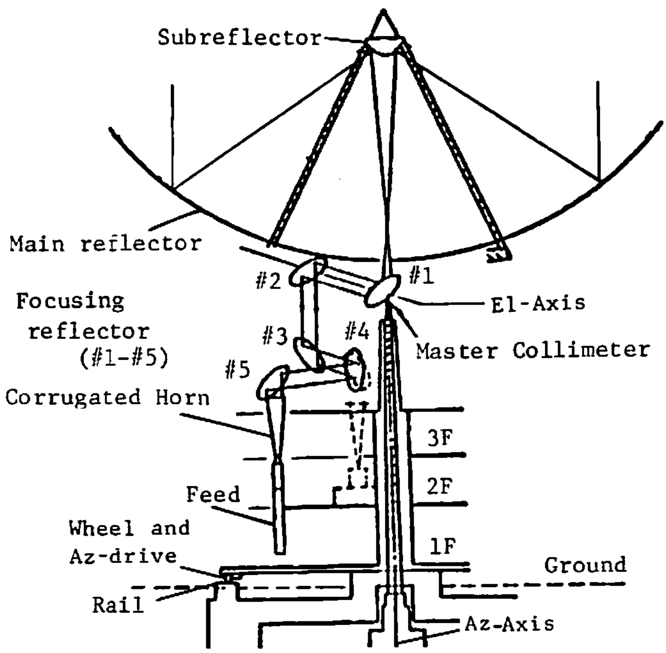

Figure 2 Antenna Configuration

TE_{01} mode and TM_{01} mode- coupler.

In order to realize low loss, the inside of the feed assembly has been electrically plated with copper and silver, and pressurized dry air is supplied. Measured loss is about 0.14dB receive-band.

The power handling is 40 KW CW without requiring external forced air cooling. Measured temperature rise is about 26°C.

3. Design of Main Reflector

The surface error of the main reflector consists of the surface panel manufacturing error, setting error at site including measuring error, and errors due to loads such as, gravity, wind and solar heating.

In the case of large and fully steerable antennas, the error due to gravity is dominant. Therefore the reduction of gravitational error is essential.

For this purpose, homology design techniques were employed which reduced the total surface error to 1.5 mm rms, a level which was decided upon in consideration of the planned use of the antenna in the X-band range in the near future.

Homology design technique is based on the following concept. It has been proven through investigation that the actual deformation due to gravity is not necessarily random but is primarily a result of factors which can be estimated, such as the rotation and parallel movement of the paraboloidal axis, and the change of focal length (refer to Figure 4. h_1-h_4 are called homology parameters).

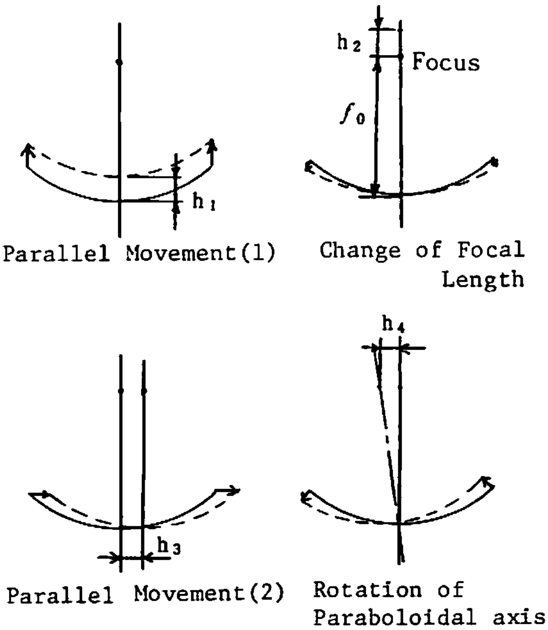

Figure 4 Homology Parameters

In the estimation of surface error, such deformations are almost negligible, if the position and rotation of the subreflector can be adjusted.

Homology design technique is a method which aims to suppress the effect of random deformation even if

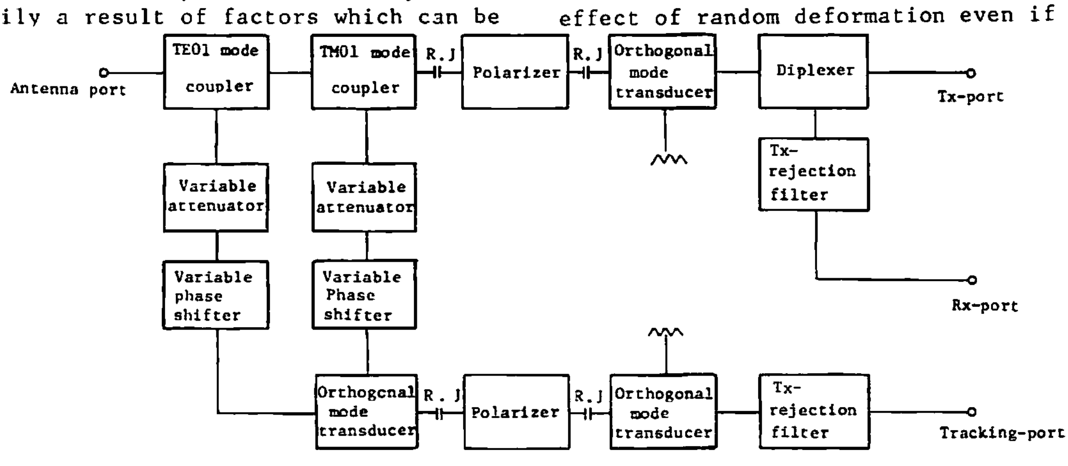

Figure 3 S-band Feed Assembly Configuration R.J : Rotary joint

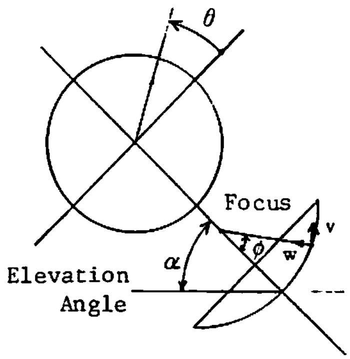

Figure 5 Coordinate

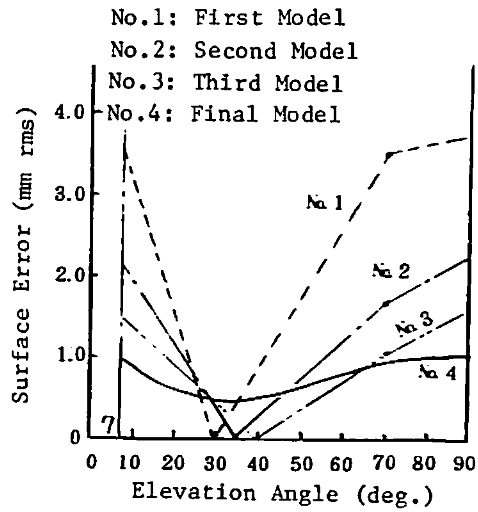

Figure 6 Surface Error due to Gravity

this increases the total amount of deformation caused by the above known and quantifiable types of deformation. To do so, it is necessary to create a paraboloidal surface where deflections w and v satisfy the equation (1) whose coordinate is shown in Figure 5.

$$w+\frac{\sin\phi}{1+\cos\phi}\cdot v=\left(h_1-h_2\cdot\frac{1-\cos\phi}{1+\cos\phi}\right)+\left(h_3\cdot\frac{\sin\phi}{1+\cos\phi}+h_4\cdot\frac{(3+\cos\phi)\cdot\sin\phi}{1+\cos\phi}\right)\cdot\cos\theta \quad .....(1)$$

It is obvious that a reflector backing structure which has a small and rigid center hub and axisymmetrically allocated outer structure is a desirable solution from the structural point of view.

However, in practice, the existense of the large S-band beam waveguide limits the application of the technique. Even with this limitation, we have been able to effectively employ homology design technique.

By optimizing the size of the center hub and the relative rigidity of the radial members and hoop members in the outer structure, gravitational error has been suppressed to 1.0 mm rms which corresponds to total surface error of 1.5 mm rms in the elevation angle range between 7° and 90°, as shown in Figure 6.

4. Acknowledgments

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5. References

1. Hoerner, S. :"Homologous deformation of tiltable telescope" J. of the Structural Division ASCE, 90, No. ST5 (1967)
2. S.Betsudan, K.Katagi, S. Urasaki : "Design Method of Four-Reflector Type Beam-waveguide Feeds" IECE of Japan, Vol. J67-B No6 (1984)