USUDA DEEP SPACE STATION WITH 64-METER-DIAMETER ANTENNA

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Introduction

Institute of Space and Astronautical Science (ISAS), Japan, constructed a new deep space ground station with a 64-meter-diameter antenna at Usuda, Nagano Prefecture, in 1984. The objective and the role of the station are to communicate with and collect data from spacecraft launched into interplanetary space. On January 8, 1985, ISAS launched the first Japanese interplanetary probe "Sakigake." "Sakigake" is one of the two spacecraft constituting the ISAS's PLANET-A program for Halley's Comet exploration (Ref. 1). Tracking of "Sakigake" has become the first task of the Usuda Station. This paper describes the functions and the facilities of the Usuda Station, including the performance of the 64-meter-diameter antenna.

Deep Space Communication

The functions of deep space communications are: (1) Telemetry for scientific and spacecraft engineering data returns, (2) Command for spacecraft control, and (3) Doppler and range measurements for determination of spacecraft trajectories. Since the range between interplanetary spacecraft and earth is extremely large (the order of 1-10 astronomical unit), deep space stations must have extremely sensitive and powerful instruments for communications, such as a large antenna, a low-noise amplifier and a high-power transmitter.

Design of Usuda Station

We have designed the communication system of the Usuda Station so that (1) it can fully support the PLANET-A mission and (2) it has capabilities to track future Japanese interplanetary spacecraft which will require higher-rate telemetry and spacecraft of foreign coutries.

The features of the design of the Usuda Station are: (1) Full capability of S-band tracking and data aquisition, (2) High efficiency and high tracking performance of the 64-meter-diameter antenna, and (3) Ability of remote station-operation control as well as mission control from ISAS, Tokyo.

We selected the location of the station to be away from man-made electrical interference and interference with the microwave ground communication network. The station is situated at the foot of the Kita-Yatsugatake, being surrounded by low hills.

Figure 1 shows the 64-meter antenna of the Usuda Station. Figure 2 is the block diagram summarizing the main facilities and their interrelation.

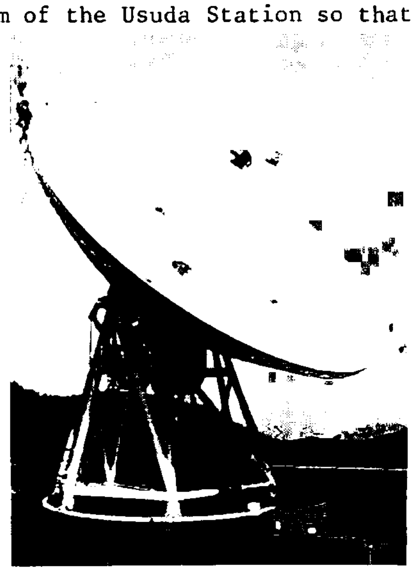


Fig. 1 The 64-meter antenna of Usuda Station.

64-Meter-Diameter Antenna

The antenna is the Cassegrain type with beam waveguide feed. The main and secondary reflectors are shaped ones. Figure 3 shows the structure of the antenna. Table 1 gives the summary of the performance.

The design of the main reflector is to allow "homologous deformation", and the resultant displacement of the focal point is compensated for by corresponding displacement of the subreflector, under computer control.

The surface distortion attained (1.5 mm rms) is small enough for X-band operations, which we will plan in the near future.

The beam waveguide system consists of five reflectors. The S-band corrugated horn for simultaneous transmit and reception is fed through the fifth reflector; besides another conical horn is being installed as a low-noise receiving feed at the position to be fed by the fourth reflector. The fourth reflector switches the beam according to the operation required.

Facilities for Communications and Station Control

The table 2 summarizes capabilities and performance of the subsystems for communications. The total system provides two-way phase coherent communications with spacecraft at S-band (2.1 GHz uplink and 2.3 GHz down-link.)

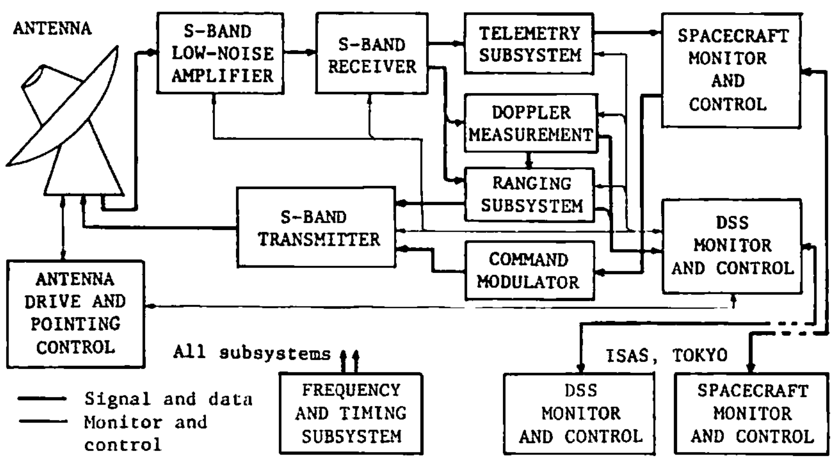
The subsystems include the low-noise parametric amplifiers with a noise temperature of 8 K, the phase tracking receiver which can maintain phase lock with a carrier of -170 dBm, transmitter amplifier with a power output up to 40 kW, subcarrier demodulation assembly, maximum likelihood convolutional decoder, command modulator, doppler and range measurement subsystems, and frequency and timing subsystem.

The Usuda Station has two complete sets of station-operations control assembly and spacecraft monitor and control assembly, one in the Usuda Station and the other in ISAS, Tokyo. We have confiremd that remote control and operations from ISAS are quite satisfactory through the tracking of "Sakigake".

Conclusions

We have presented the functions and the facilities of the Usuda Deep Space Station and its main features. The station and its facilities will contribute to the scientific exploration of the solar system that Japan has

Fig. 2. Facilities of Usuda Station. (DSS= Deep Space Station)



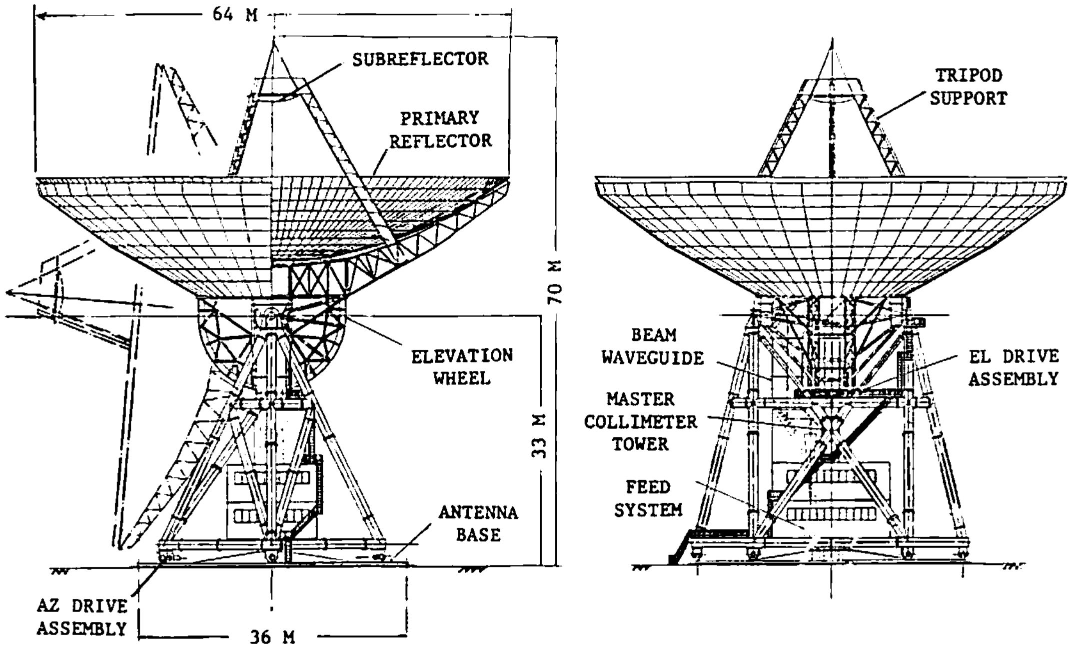


Fig. 3. Structure of Antenna

Table 1. Performance Summary of Antenna

Type of antenna	Cassegrain antenna with beam waveguide feed
Type of mounting	Azimuth-elevation
Diameter of main reflector	64 meter
Surface distortion	1.5 mm r.m.s.
Frequency	S-band (2.1-2.3 GHz) and X-band (7.1-8.5 GHz)
Antenna drive	Anti-backlash dual motor drive
Feed system	S-band corrugated conical horn, higher mode coupler and branching filter (Another conical horn is being installed as a receiving feed system.)
Antenna gain	62.6 dB at 2293 MHz
Aperture efficiency	77 % at S-band
3 dB beamwidth	0.13° at S-band
Polarization	RHC or LHC
Antenna noise temperature	12 K at 2290 MHz and elevation angle of 90° (measured at the corrugated horn input). System noise temperature, including noises from the transmission line and the low-noise amplifier, is 30 K.
Pointing accuracy	0.003 deg r.m.s.
Tracking	Program or automatic

Table 2. Capabilities and Performance Summary of Subsystems.

S-band Low Noise Amplifier	
Type	Helium-gas-cooled parametric amplifier followed by three-stage FET amplifiers
Frequency range	2280-2300 MHz
Noise temperature	8 K
S-band Receiver	
Frequency range	2280-2300 MHz
Loop noise bandwidth	Selectable among 3, 10, 30, 100, 300 Hz and 1 kHz
Input carrier power-range	-85 to -170 dBm
S-band Transmitter	
Frequency	2111.607253 MHz and 2112.289352 MHz (Tunable from 2105 to 2120 MHz)
Power amplifier	Water-cooled five-cavity klystrons
Transmitting power	Selectable among 200W, 2kW, 20kW and 40kW (In the case of 40kW, two klystrons are combined.)
Telemetry Subsystem	
Subcarrier frequency	100 Hz to 1 MHz
Symbol rate	5 sps to 200 ksps
Decoder	Maximum likelihood decoder (Constraint length = 7 and rate = 1/2)
Command Modulator	
Command signal	PN code
Subcarrier modulation	PCM (PN) - PSK
Subcarrier frequency	100 Hz to 16.384 kHz
Doppler Measurement Subsystem	
Type	Two-way coherent doppler measurement
Counting	Continuous, non-destructive counting
Resolution	0.01 cycle
Ranging Subsystem	
Type	Binary coded sequential acquisition ranging
Code frequencies	∿500 kHz to ∿1 Hz

just started in recent years and also contribute to growing international cooperation in data aquisition from interplanetary spacecraft.

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Reference

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