LARGE RADIO TELESCOPE PROJECT IN JAPAN

H. TANAKA*, K. AKABANE*, M. MORIMOTO*, N. KAIFU* AND M. ISHIGURO**

ABSTRACT

In this report we outline the Japanese Large Radio Telescope Project and its important technical developments. The telescope consists of a 45-m steerable paraboloid and a super synthesis telescope with 5 movable 10-m dishes. Construction work commenced in April 1978 and will be complete early in 1982. The telescopes are for common use by Japanese researchers from various institutions.

Introduction

Solar radio observation in Japan started in 1949 at Mitaka near Tokyo, and in the past 25 years various solar radio interferometric observations were well promoted to a unique level in the world. We see at present the Toyokawa microwave heliograph, the Nobeyama meterwave large solar interferometer, and other advanced instruments of several stations in Japan.

Japanese radio observation of cosmic radio sources started in 1963 fifteen years later than the start of solar observation. Microwave observations of some diffuse HII regions were made with the help of an experimental space communication antenna. Since 1969, a mm-wave observation has also been started mainly looking for interstellar molecules.

Since 1969, Japanese project of large radio telescope has been proposed.

Outline of the Project

a) 45-m Telescope

A general purpose paraboloid with special emphasis on mm-wave performance.

Surface accuracy: better than 0.25mm (rms deviation from best fit paraboloid) better than 0.2mm for inner 20m diameter.

Reflector structure: homologous.

Optics: Gregorian modified coude and prime focus.

Mounting: Az/El with angle readout using a "master collimator."

Pointing accuracy: better than 1.5/1000 deg.

Wind loading: reduced accuracy $>$7m/s, drive to stow $<$ 20m/s, survival $<$ 60m/s.

Receiver frontends: 1.1 to 5 GHz parametric upconverters in prime focus cabin, 8 to 90 GHz parametric amplifiers and cooled mixers in coude receiver room. 10 frequency bands.

Backend analysers: acousto-optic spectrometers etc.

b) Super-Synthesis Telescope

Five element antennas movable successively from stations to stations.

Baselines: EW 560m long and 33° from NS 520m long.

Stations: 30, with quasi MRA distribution.

Element antennas: 10-m paraboloids.

Transportation: mother-daughter transporter on railroads.

Receiving frequency: 22GHz for initial installation. mm-wave in the future.

Local oscillators: locked oscillators to phase compensated VHF reference.

Cabling: underground tunnel $>$1.5m deep.

Correlator backends: wide band analog correlators for continuum, and acoustooptic spectral correlators.

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* Tokyo Astronomical Observatory, University of Tokyo, Japan.
** Research Institute of Atmospherics, Nagoya University, Japan.

K. Akabane is the speaker at the Symposium (September 27-28, 1978) *c) Computers*

Central computer for master control and secondary processing, local computers for 45-m telescope and super-synthesis telescope for local control and primary processing.

d) Site

Nobeyama, Nagano Pref. 138° 28′E, 35° 57′N and 1350m above sea level.

Design Principles

Although the telescopes are designed to be of general purpose for common use, special emphasis is placed on performance in mm-waves. Observations in these wavelengths of synchrotron radiation from compact high energy radio sources, thermal emission from dense ionized clouds and a number of molecular lines will provide important information for understanding structure and evolution of the Galaxy and galaxies, formation of the stars and mass ejection from them, chemical evolution of the universe and other interesting phenomena.

In this context design studies were directed to obtain a) very high surface accuracy for best possible performance in mm-wavelengths, b) capabilities to handle spectral information effectively and c) efficient operation of the synthesis telescope.

Important Developments

Important technical developments done for this project are as follows.

a) Homologous Design for 45-m Telescope

Surface accuracy of large diameter párabolic reflectors of conventional design is limited mainly by the gravitational deformation due to its own weight. This limitation can be overcome if a structure deforms from a paraboloid to another paraboloid and a proper adjustment of focus is made. That such a structure can exist has been proved mathematically by von Hörner. It is called as homologous structure.

This principle is adopted to the 45-m telescope design. Problems to realize a homology in a practical structure was solved by successive approximations. We started with an axis-symmetric structure of the dish with a small rigid center hub and radial trusses. Gravitational deformation and its deviation from the best-fit paraboloid were calculated to adjust the structure for the next step. After several trials it was shown that a structure whose deformation causes rms deviation from the best-fit paraboloid of less than 0.15 mm was possible.

b) Coude Optics

Radio waves are guided to the ground level through guided beam transmission system. By doing this it becomes possible to use a large front-end room that offers conditions nearly identical to those in laboratories. Considering that the mm-wave electronics is now under a very rapid development, this is an important advantage.

In addition to this advantage, we consider the use of Fabri-Perot type channel dropping filters to make simultaneous observations at several frequencies. In conjunction with acousto-optic spectrometers described below simultaneous observations of a number of sectral lines will become possible.

c) Acousto-optic Radio Spectrometer

For spectral line observations, filterbank or digital correlator type analysers are commonly used. Each type has its own technical limitations; as the former uses separate filters for each frequency channel the system tends to be very complex while a very high clock frequency is necessary for the latter to obtain a wide bandwidth. Thus their performance is insufficient for use in mm-wave spectroscopy. We developed a new type of analyser "acousto-optic" spectrometer for this purpose.

If signal is converted to ultrasonic waves in a T_eO_2 crystal illuminated by a parallel ray of laser light. Spectral information contained in the ultrasonic waves is transferred to the first order diffracted light and analyzed by means of photo diode array. More than 1000 simultaneous spectral channels are possible for a single analyser and, as such analyser has a simple structure, simultaneous operation of 10 analysers is not inpractical. This means more than tenfold increase in analyser capability (bandwidth/resolution). This technique is to be extended to spectro-correlator for the super synthesis telescope.

d) M.R.A. Design

(1) The efficient use of a small number of antennas for a high resolution super synthesis telescope has long been discussed. Since analytical solution of optimum MRA configuration cannot be obtained for a large number of elements, we employed random procedure to find most efficient distribution of stations. In our case, boundary conditions are (a) the number of antennas is limited to 5, (b) the number of stations is limited to 30, (c) and the baseline configuration has no possibility of change due to the land problem. The final solution has the following features.

For EW array with 17 stations, (1) four kinds of 5-element grating MRA are possible with maximum spacings of 120m, 180m, 367m, and 540m.

(2) Higher density toward the cross point favors various low-resolution observations, (3) no unit-spacing stations to facilitate the design of foundation, (4) full synthesis is possible up to maximum spacing with 13 holes and up to 333m without holes.

For NS array with 13 stations, (5) grating synthesis with 45-m paraboloid is possible up to 390m spacing, (6) southern closely spaced stations from a quasi grating-compound mode and also improve two-dimensional (u-v) coverage, (6) and yet full synthesis is possible with only 2 holes.

Under Development

There are a number of technical problems to be solved for the improvement of the telescope performance especially in the shorter wavelengths.

Effects of temperature variation on the telescope structure will pose one of the dominant limitations on the surface accuracy and telescope pointing. The use of a shade on the back structure of 45-m telescope is being studied.

The surface measurement is also one of the dominant problems for the 45-m telescope. Theodolite with laser range finder with accuracies of 1 second and 0.2mm is under development. Hundreds of targets are expected to be measured efficiently.

Image processing is also important especially for an array of such a complicated arranements like the present case. Studies of arrangement process for efficient synthesis and also of image reconstruction techniques for incomplete and noisy data are in progress.