B-11-2 Large Radio Telescope Project in Japan

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Introduction

In this report we outline plans of Japanese Large Radio Telescope Project and its important technical developements. The plan consists of construction of a 45 m telescope and a 5-element super synthesis telescope with 10m antennas. 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.

Outline of the Project

a) 45-m Telescope

A general purpose parabolic antenna with special enphasis on mm-wave performance.

Surface accuracy : better than 0.3 mm (rms deviation from best fit paraboloid)
better than 0.2 mm for inner 20m diam.

Reflector structure : homologous.

Optics : modified coudé and prime focus.

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

Pointing accuracy : better than 1/1000 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,
10 to 80 GHz parametric amplifiers and cooled mixers in coudé receiver room.
10 frequency bands.

Backend analysers : acousto-optic spectrometers etc.

b) Super-Synthesis Telescope

Five element minimum redundancy interferometer. Element antennas are moved successively from stations to stations.

Baselines : EW and 30° from NS each about 600m long.

No. of stations : 30, with MRA distribution

Element antennas : 10-m paraboloids.

Transportation : mother-daughter transporter on railroads.

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

Local oscillators : phase locked oscillators locked to pahase compensated VHF reference.

Cabling : Underground tunnel >1.5m deep

Correlator backends : wide band analog correlators for continuum and acousto-optic spectral correlators.

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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-wave lengths, b) capabilities to handle spectral information effectively and c) efficient operation of the synthesis telescope.

Important Developements

In this section we describe important technical developements done for this project.

a) Homologous Design for 45-m telescope

Surface accuracy of large diameter parabolic 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 axi-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) Coudě Optics

Radio waves are guided to the ground level through guided beam transmission system. By doing this it bocomes 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 developement , this is an important advantage.

In addition to this advantage we consider a use of Fabri-Perot type channel dropping filters to make simultaneous observations at different frequencies possible. In conjunction with acousto-optic spectrometers described below simultaneous observations of a number of spectral 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 TeO_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 is possible for a single analyser and as such analyser has simple construction, simultaneous operation of 10 analysers is not inpractical. This means more than tenfold increase in analyser capability (bandwidth/resolution).

d) M.R.A. Design

Minimum redundancy configuration of arrays has been discussed for only small number of element antennas. In the present case number of independent baseline samples is large (more than 75) and analytical solution is not possible. We employed random process to find least redundant distribution of antenna stations on the baselines.

Conclusions and Future Developements

Owing to those technical developements the first full scale mm-wave observing facility has become possible. There are however a number of technical problems to be solved for the future improvements of the telescope performance especially in the shorter wavelengths.

Effects of temperature variation and wind loading on the telescope structure will pose most dominant limitations on the surface accuracy and telescope pointing. Even at present the full accuracy is expected only in windless nights. A use of a radome is being considered.

If it is solved, the next limitation will be those posed by the surface measurement and panel accuracies. These problems are being looked into seriously. A design study of laser ranging and angle measurement equipment and feasibility tests of plastic honeycomb panels are in progress.

In the receiver side, reduction of noise in the mm-wave front ends is urged. Tests on cooled Schottky mixers and developement works on Josephson devices are being done.

Image processing is also important especially for an array of such a complicated arrangements like the present case. Studies for efficient baseline arrangements and image restoration for low declination sources are in progress.

During the design study, useful discussions were done with many scientists and engeneers from various establishments. Important contributions due to these discussions are gratefully acknowledged.