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A Control System of the Nobeyama Millimeter Array

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Abstract

We have developed a control system of the Nobeyama Millimeter Array which is a radio interferometer for astronomical observations at millimeter wavelengths. The system consists of three sub-systems (MANAGER, ENGINE, and STATUS CONTROLLER). Observers conduct their observations with MANAGER sub-system, which run on a UNIX workstation. ENGINE is a rigid system on an IBM compatible mainframe. It controls the accurate tracking of astronomical radio objects, and acquires a large amount of observed data from a receiver backend. STATUS CONTROLLER consists of several personal computers which control and monitor the receiver system. These sub-systems are connected with an ethernet.

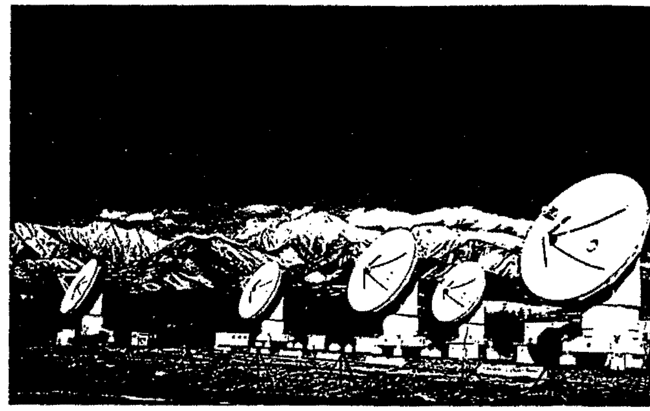

Figure 1: The Nobeyama Millimeter Array.

1 INTRODUCTION

The Nobeyama Millimeter Array (NMA) [1] is a radio interferometer for astronomical observations (Figure 1). The main purpose of the NMA is the high spatial resolution imaging of celestial objects at millimeter wavelengths.

The array has five 10-m diameter antennas which can be moved to various stations along two rail tracks of about 600 m. Averaged surface accuracy for five antennas is 71 μm rms. Each antenna has an Alt-Azimutial mount and is equipped with SIS receivers [2] at 2.6 mm and 2.0 mm wavelengths which contain important molecular spectral lines. The maximum spatial resolution at 2.6 mm wavelength is about $1''$. The receiver backend is a 320 MHz FFT spectro-correlator with 1024 frequency channels per correlation, called as the Nobeyama FX [3].

The most important requirement for a control system of such an interferometer for astronomical observations is to track celestial objects accurately [4]. For an interferometer, the tracking control is much more complicated than that for a single dish telescope. To satisfy this requirement, we constructed a centralized control system for the NMA on an IBM compatible mainframe [5]. However, since the softwares of the system were very rigid, there were some drawbacks in it.

To overcome these drawbacks, we have developed a new control system for the NMA. It is a distributed system, based on a UNIX workstation, an IBM compatible mainframe, and personal computers connected with an ethernet. In this report, we will describe the concept and the structure of the new system.

2 CONTROL FOR OBSERVATIONS WITH THE NMA

2.1 Tracking

Normal observing mode of this array is aperture synthesis[6]. Figure 2 shows a schematic diagram of aperture synthesis observation with two element radio interferometer. A correlator multiplies two radio signals from each antenna and averages the product. When antenna tracking to a celestial object and compensation of optical path difference between two antennas (delay tracking) are done accurately, the correlator output is equal to a spatial Fourier component of the brightness distribution at a projected baseline (u, v). After the synthesis observations at many different baselines, the brightness distribution can be estimated with inverse Fourier transform.

As shown in Figure 3, we use a heterodyne system for a frontend receiver and frequency of the input signal to the delay tracking system is lower than receiving frequency.

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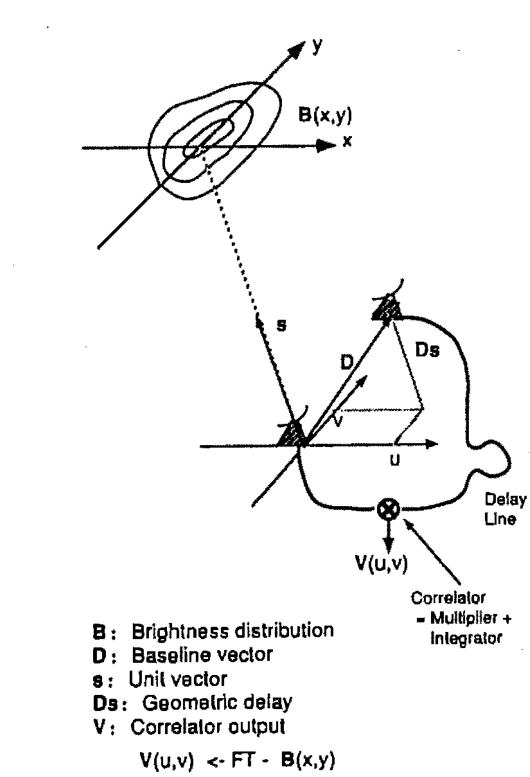

Figure 2: Aperture synthesis observation with two element interferometer.

Since, in such a case, the delay tracking cannot compensate the phase difference due to the path difference, exactly, it is necessary to compensate residual phase by controling the phase of LO with a fringe rotator (phase tracking).

Therefore, for aperture synthesis observations with the NMA, we must control the antenna tracking, the delay tracking, and the phase tracking. Since the resolution of the delay tracking system is finite, control sequences of the delay tracking and the phase tracking are very complicated. These control accuracies affect the qualities of radio images obtained with the aperture synthesis observations[4].

2.2 Tuning of the Receiver System

The receiver system of the NMA consists of SIS mixers, LO oscillators, IF amplifiers, and a reference signal synthesizer. Before each observation, observers must optimize many parameters of each component of the receiver system. This task which is called as "tuning" is very important for sensitivities. At higher frequencies, the tuning becomes much more important and its sequence is very complicated. These know-hows of manual tuning must be programmed for each device in the control software.

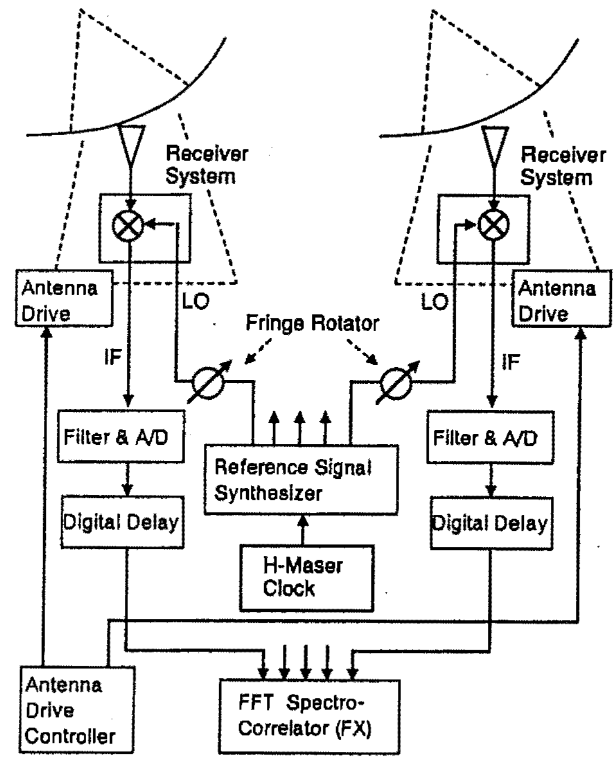

Figure 3: Hardware system of the NMA.

2.3 Operational requirements

Generally, astronomical observations with radio telescopes are serieses of many short observations of different celetial objects. In typical aperture synthesis observations with the NMA, of which duration is 6 ~ 10 hours, a 10 ~ 15 minutes observation of standard objects is taken every 30 ~ 60 minutes in order to monitor complex gain variation of the array. Such observing sequences depend on observational requirements of observers. Thus, it is desireble that the control system provides an environment where observers can easily realize their observing sequences.

Since we have many observers who are inexperienced in the NMA, a friendly human interface is very important for the control system. Quick display of backend data, observing parameter menus, and multi windows are very effective for smooth operations.

3 OLD CONTROL SYSTEM

The old control system of the NMA was a centralized system, which ran on an IBM compatible mainframe and two mini-computers. Main control tasks (sequence control of observing modes, tracking control, data acquisition, human interfaces, etc.) ran on the mainframe. A terminal of the mainframe was used as a telescope operator console. The mini-computers managed communication be-

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tween the mainframe and each device of the array which was connected with the mini-computers via GPIB. Hydrogen maser clock was supplied to the mini-computers so that tracking parameters were sent to the tracking devices at the exact time. With this system, we realized high tracking accuracy and high reliability of array control [5].

However, since softwares of the system were complicated and not flexible, there were following drawbacks in it:

1. To add functions for new devices takes very long time.
2. It is difficult for observers to develop control programs for their own observing sequences.

In particular, since the progress of the receiver system is very rapid, it was difficult to develop control programs for various receiver tuning methods. Besides these drawbacks, it is hard to find out good graphical user interfaces (GUI's) for IBM compatible mainframe. To overcome these problems, we have developed a new control system of the NMA.

4 NEW CONTROL SYSTEM

The new control system of the NMA, which is shown in Figure 4, is divided into three sub-systems (MANAGER, ENGINE, and STATUS CONTROLLER). MANAGER subsystem as a telescope operator console provides the human interface. A UNIX workstation has been introduced in this sub-system, because of its high graphic capabilities and multi-window environment. ENGINE sub-system tracks astronomical objects and acquire the data from the backend. Tuning of the receiver system is realized with STATUS CONTROLLER sub-system. Several personal computers are used for this sub-system, because of their simplicity of programming and reduced costs. These subsystems are connected with an ethernet.

4.1 MANAGER

MANAGER runs on a UNIX workstation, Fujitsu S-4/370 (SPARC 370 compatible) with a main memory of 32 MByte. Functions of MANAGER are as follows:

1. Making command tables (OBSERVATION BOOK) for various observing sequences and sending them to ENGINE.
2. Communicate with ENGINE by using of a SOCKET interface.
3. Providing flexible GUI based on the X-Window to observers.
4. Acquisition of the monitoring data from each device.
5. Displaying the backend data quickly.

Figure 5 shows the software structure of MANAGER. There are several standard programs (OBS.BOOK generators) which make standard OBSERVATION BOOKs in

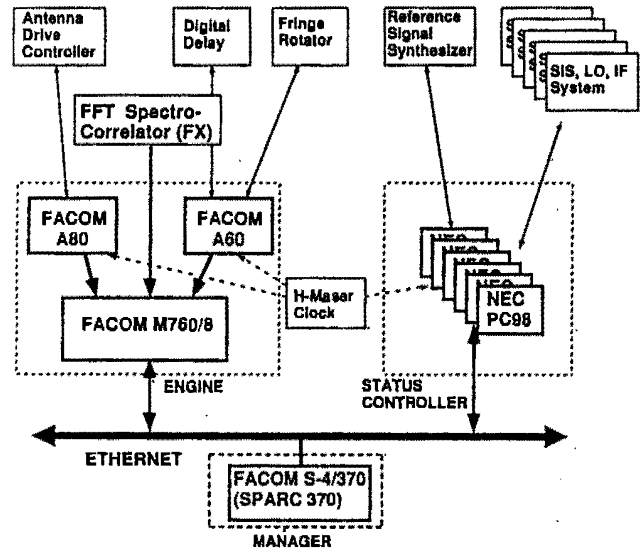

Figure 4: New control system of the NMA.

this sub-system. Since these programs are not directly connected with real-time control tasks, it is easy for observers to make new ones for their observational requirements. The SOCKET interface system between the workstation and the mainframe was developed by Fujitsu.

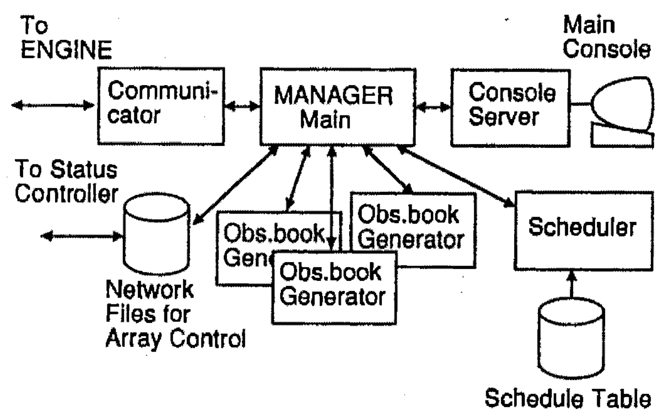

Figure 5: MANAGER.

4.2 ENGINE

ENGINE runs on an IBM compatible mainframe (Fujitsu M760) and two mini-computers (Fujitsu A80 and A60). This hardware structure is the same as that of the previous control system. The followings are functions of ENGINE:

1. Executing observing sequences in an OBSERVATION BOOK from MANAGER.

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2. Calculating accurate tracking parameters for every 400 ms.

3. Sending the paramters to each device at the exact time.

4. Acquiring the data from the backend and applying the realtime correction to these data by using of control parameters.

Software structure of ENGINE is shown in Figure 6. There are three main tasks on M760, which share a common memory area to communicate each other quickly. This sub-system is very rigid so that it is possible to realize the accurate tracking control and data acquisition without data losses. Softwares of tracking control and data acquisition are simple and compact compared to those of the previous system.

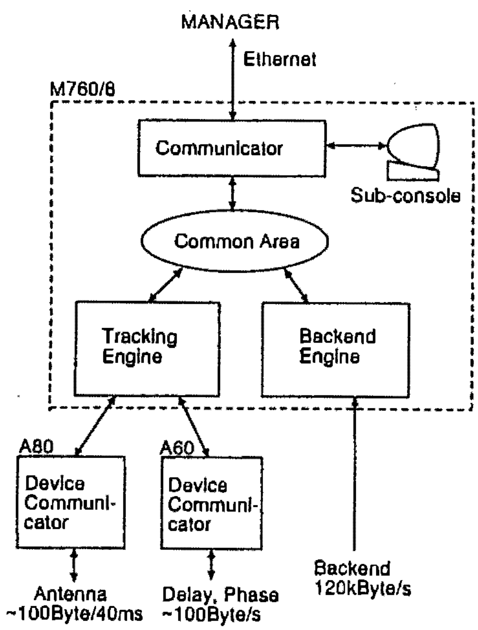

Figure 6: ENGINE.

4.3 STATUS CONTROLLER

Functions of this sub-system are as follows:

1. Controling and monitoring many components of the receiver system.

2. Communicating with MANAGER through NFS.

This sub-system consists of 6 MS-DOS 80286-based personal computers (NEC PC9801). Personal computers with MS-DOS do not have a multi-tasking environment. However, programming is so easy on each personal computer that duration for the software developement is very short. Actually, a receiver engineer wrote the software for the tuning by himself. Thus, the software can use his know-how of the receiver system.

5 SUMMARY

We have developed a new control system of the Nobeyama Millimeter Array. While the old system was a centralized one, we have constructed a distributed control system which consists of three sub-systems. Thus, the new system will provide a friendly GUI's for observers and flexible viroments for adding new functions. The developement has almost completed and has been be used for observations from the end of 1991.

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