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NEW RECEIVER AND CONTROL SYSTEM FOR 10-m DIAMETER ANTENNA

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Abstract

Description is made on new feed, front-end receiver, back-end receiver , a data acquisition system, and control system for 10-m diameter dish at Toyokawa. Preliminary results of observations of the Sun and signals from geostationary satellites are shown.

1. Introduction

Observations of intensity and polarization of solar radio emission at frequencies of 9.4, 3.75, 2 and 1 GHz have been conducted with fully-automatic radiometers at Toyokawa Observatory (Torii et al., 1976). For several years, it has been known that these observations were interfered by down-link signals of geostationary satellites, which are used for communications, broadcastings, meteorology information etc. The interferences are seen every year around vernal and autumnal equinoxes, because the Sun apparently passes close to positions of geostationary satellites at those times, and the Sun and a satellite come into the same field of view of the radiometer at 3.75 GHz.

On the other hand, a possibility is examined to use the signals from one of these satellites as a reference point source for the calibration of 3.75-GHz radio interferometer at Toyokawa. For monitoring geostationary satellites and for investigation of spectral and temporal characteristics of signals of geostationary satellites, it is initiated to improve receiver, control, and recorder systems of 10-m diameter antenna at Toyokawa. This antenna was built in 1963 with AZ-EL (azimuth-elevation) mounting, and used to observe brightness distributions of 3-cm radio waves along the milky ways. The antenna was originally driven by an analog coordinate transform unit, which is this time replaced by a micro-computer. Driving motors in two axes are also replaced by a DC servo motor in azimuth axis and by a stepping motor in elevation axis, which are digitally controllable. A wide-band feed and a front-end receiver unit are installed this time to cover wide frequency range of geostationary satellite signals. In Section 2 detailed description is made on the new receiver and telescope control system. The performance of the new antenna system and examples of preliminary observations are presented in Section 3.

2. Outline of the New Telescope Control System and the Receiver System

The new telescope contol and receiver systems consist of a micro-computer, driving units of the azimuth and the elevation axes of the 10-m diameter antenna, a wide-band receiver unit and an interface unit between the computer and antenna drive motors and also a back-end receiver, which are summarized in a block diagram in Fig. 1.

2.1 10-m Diameter Antenna

The antenna, to which the antenna drive system and receiver were installed, is a fully steerable AZ-EL mount type and prime focus type paraboloidal antenna with 10-m diameter. This antenna was built in 1963 by Yamashita et al. for galactic works at centimeter wavelengths. A resurfacing was completed in September 1965, and observation of

Cas-A was carried out. Several galactic sources were observed with a maser amplifier at 9.4 GHz in late 1960's. The antenna has an aperture

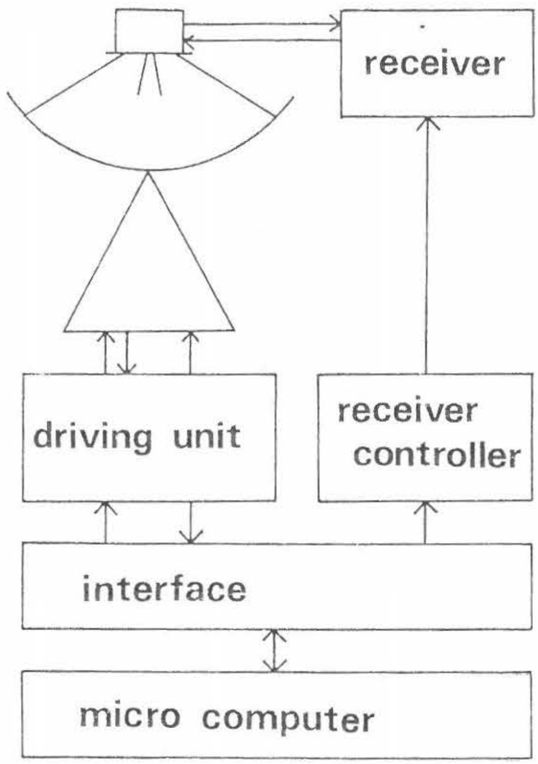

Fig. 1 Block diagram of the overall system

efficiency of approximately 50 % and half power beam width of 14 arcmin at 9.4 GHz (Tanaka, 1965; Yamashita et al., 1968).

2.2 Receiver System

Receiver system consists of a primary feed, a front-end receiver, a back-end receiver, a spectrum analyzer, a digital data recorder, and a chart-recorder, as shown in Fig. 2. Radiowave signals received through the primary feed are amplified and frequency converted to IF signals of 60 MHz in the front-end receiver mounted next to the primary focus. The IF signals are transmitted through a coaxial cable to the back-end receiver and also to the spectrum analyzer in the observation hut. The output signals of the back-end or the spectrum analyzer are recorded on a digital cassette magnetic tape, and monitored by the chart recorder.

Two primary feeds are prepared for observations. One is a coaxially fed double-ridged antenna (pyramidal horn). The specifications are of multi-octave bandwidth from 1 to 12.4 GHz, small physical size of 163 mm wide, 248 mm high, and 202 mm in depth, essentially of constant gain of average 11 dB, of constant impedance with VSWR of 2.5, and observable in linear polarizations. The other feed is a waveguide antenna operating at around 18 GHz.

The front-end receiver, mounted near the primary feed, consists of an isolator, a low noise amplifier , a mixer, and a local oscillator , as illustrated in Fig. 3. It is possible to choose one of five

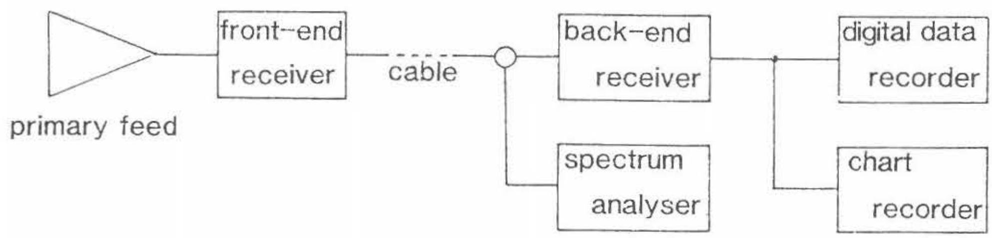

Fig. 2 Block diagram of the receiver

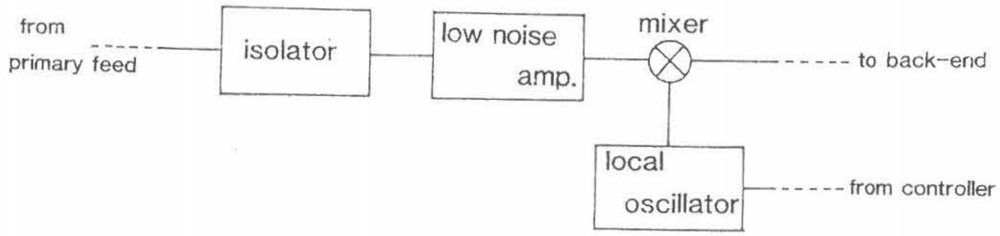

Fig. 3 Block diagram of the front-end receiver

frequency bands of 1 - 2, 2 - 4 ,4 - 8, 8 - 12 and about 18 GHz by the combination of six kinds of isolators, three kinds of low noise amplifiers, four kinds of local oscillators and two kinds of primary feeds.

2.3 Telescope Control System

Telescope control system handles the driver of antenna and the local frequency of the front-end receiver. It consists of azimuth drive unit, elevation drive unit and local oscillator control unit.

2.3.1 Azimuth Drive Unit

Azimuth drive unit controls the servo amplifier and drives the antenna in azimuth plane through gears , a drive wheel and track. It consists of a voltage controller, a down counter and a position detection circuit, as shown in Fig. 4. The voltage controller keeps the voltage in such a way as directed by the data from the micro-computer to change the revolution rate of the DC servo motor. The down counter controls angular distance moved.

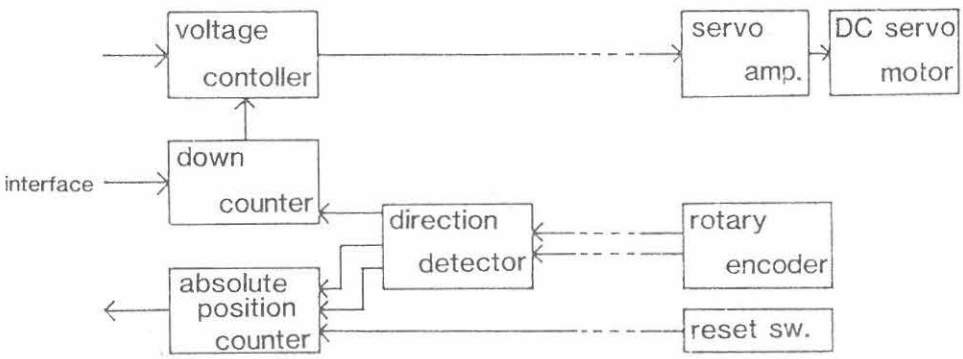

Fig. 4 Block diagram of the azimuth drive unit

The angle of azimuth axis is detected by a position detection circuit, which consists of a rotary encoder, a direction detector and an absolute position counter. The rotary encorder is of incremental type and connected to an azimuthal slave wheel. The position detection circuit determines absolute azimuth position as follows:

i) To detect the rotation direction of the antenna, using two pulses with different phase (90 degrees) from the rotary encoder;

ii) To count up or down according to the detected pulse of the absolute position counter;

iii) To read out the content of its counter.

The initial setting of the counter can be done by crossing a marker of the central meridian.

2.3.2 Elevation Drive Unit

Elevation drive unit controls the driver of stepping motor and drives the antenna in elevation plane through a gear and a chain. It consists of a pulse generator, a down counter and an absolute position counter, as shown in Fig. 5. The stepping motor used for elevation axis is of four-phase hybrid type, and its electrical driver is of uni-polar chopper type. The pulse generator consists of a digital-to-analog and a voltage-to-frequency converter and a gate circuit, and it controls the pulse transmitted to the stepping motor.

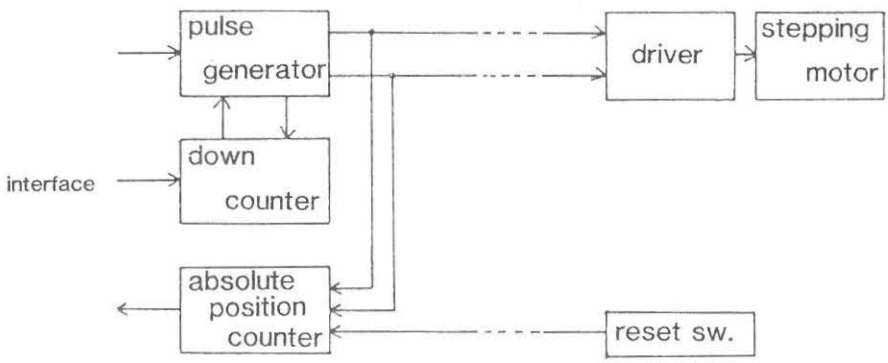

Fig. 5 Block diagram of the elevation drive unit

The pulse rate is changed up to 10 k pulse per second. Acceleration up and deceleration down of the stepping motor is carried out by the pulse rate of the generator assigned by software. The down counter controls the angular distance moved in elevation plane. The absolute position of elevation is determined by reading out the absolute position counter, as is done in the azimuth drive system. However, it counts the pulse transmitted to the stepping motor , since the stepping motor can rotate certain angle and stop with high accuracy without a feedback circuit.

The initial setting of the counter can be performed by crossing a marker of the zenith.

2.3.3 Local Oscillator Control Unit

Local oscillator control unit consists of a digital-to-analog converter and drivers of oscillators. The local frequency of the front-end receiver is controlled by the data set to the digital-to-analog converter. It is also possible to change the local frequency by manual operation controlling this circuit.

2.4 Software

On designing the software, considerations are made that it is flexible, easy to be transferred to other hardware. A high-level language is easy to develop programs, and a user can also modify or develop his own programs. The micro-computer used in this system, NEC PC-8001, has a powerful 'BASIC' language, which is employed to describe our software.

The software to control antenna driver, receiver, and data recorder consists of eight tasks or subroutines, which are 1) to drive antenna in azimuth plane, 2) to drive in elevation, 3) to display antenna position of azimuth plane, 4) to display antenna position in elevation , 5) to select the observing frequency, 6) to handle data recorder , 7) to track the Sun, and 8) to make a cross scanning. The obseravtion is initiated by running the main program, which include all the above eight subroutines, which then asks the user to key in appropriate parameters to jump into the necessary subroutine to control the antenna or the receiver or the recorder. Thus an observer can steer the antenna to arbitrary direction by keying in data of azimuth and of elevation of the radio source. The tracking of the Sun is performed automatically by giving time, date and starting time, since necessary ephemeris table are loaded with sufficient accuracy.

Selection of observing frequency is done by a few key strokes to specify the necessary command. The data recorded on a cassette magnetic tape are converted to a floppy disk by an off-line media-conversion oriented micro-computer. Reduction of data and display of reduced data on a cathode-ray-tube are performed on another off-line micro-computer in our laboratry.

3. Performance of the Overall System and Examples of Observations

Driving ranges, driving speeds in azimuth and elevation and also angular resolution of the antenna are summarized in Table 1.

item	azimuth	elevation	
driving range	$540 \sim -540$	$10 \sim 170$	(deg.)
driving speed			
min.	0.001	0.002	(deg/sec.)
max.	1.024	0.53	
angular resolution	1.02×10^{-3}	5.3×10^{-5}	(deg.)

Table 1 Performance of the overall system

The observed antenna pattern in an azimuth plane and in an elevation plane obtained by scanning a geostationary satellite are shown in Fig. 6 and in Fig. 7. The sidelobe levels are as low as -20 dB and -16 dB, respectively.

Two geostationary satellites are presently found to interfere our 3.75-GHz solar observations. One is the japanese communication satellite (CS) at 135 degree east over the equator, and the other is an unknown satellite at 85 degree east. Preliminary observations of radio signals of these satellites are being done, and some examples of time profiles will be shown.

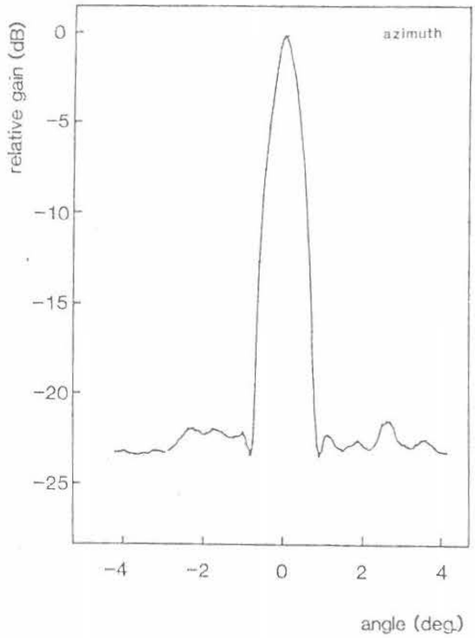

Fig. 6 Antenna pattern along azimuth angle obtained by scanning the geostationary satellite at 3.44 GHz

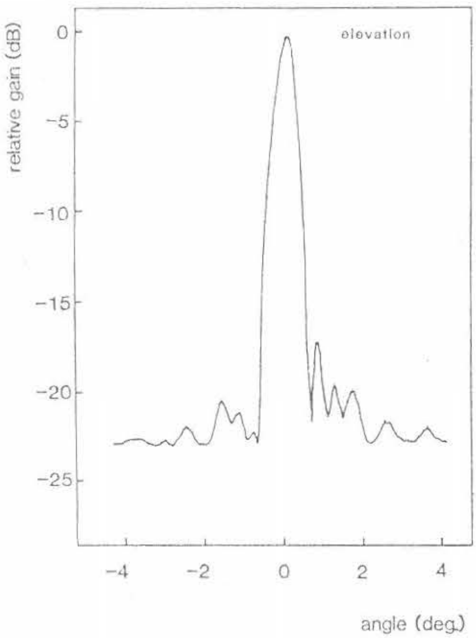

Fig. 7 Antenna pattern along elevation angle obtained by scanning the geostationary satellite at 3.44 GHz

The intensity of the signals of the satellite 135E at 3.75 GHz is almost stationary and constant as shown in Fig. 8. The equivalent antenna temperature is about 340 degrees Kelvin. Strong signals are received at 3.95 and 4.02 GHz and occasionally at 3.82 GHz.

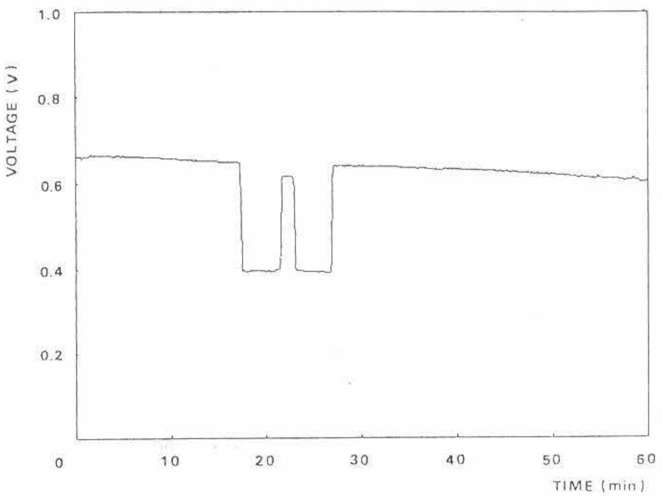

Fig. 8 Time profile of intensity of the radio emission of the satellite at 135 degree east, measured at 3.75 GHz on Nov. 24, 1982.

The signals of the satellite at 85 E fluctuate with a period of 80 seconds and an amplitude of 900 degrees Kelvin in the equivalent antenna temperature as shown in Fig. 9. The mean equivalent antenna temperature is about 24800 degrees Kelvin. The 85E satellite also emits strong signals at 3.44 and 3.60 GHz.

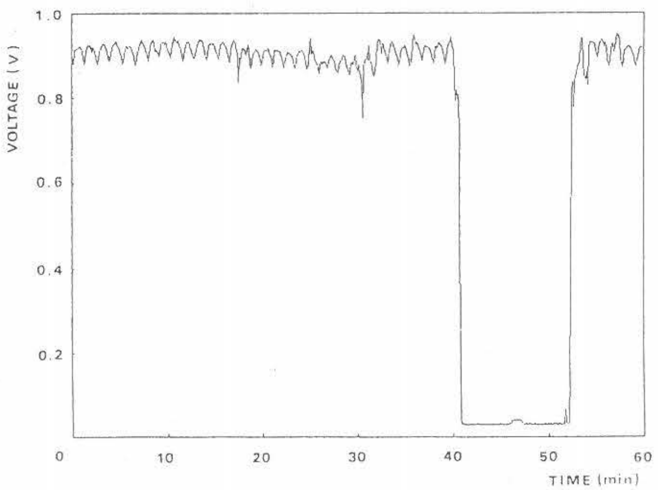

Fig. 9 Time profile of intensity of the radio emission of the satellite at 85 degree east, measured at 3.64 GHz on Nov. 24, 1982.

An example of solar observations with the new system is shown in Fig. 10, where a small enhancement of intensity is recorded, which is identified as a burst by the routine observations. The aperture efficiency is estimated close to 50 % at this frequency.

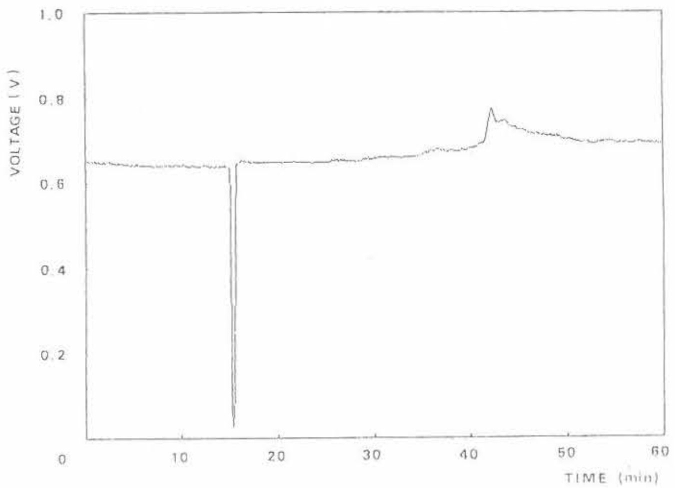

Fig. 10 An example of the solar observation at 3.75 GHz measured on Nov. 16, 1982.

4. Conclusions

A new telescope control system and a new receiver system are completed to give an improved performance of the 10-m diameter antenna. It is possible to observe strong radio sources such as the Sun and communication satellites in a wide frequency band. Performance with respect to the antenna drive is summarized in Table 1, which is sufficient for the observations of the Sun and geostationary satellites. Total receiver noise-figure is estimated to be about 4.8 dB in 2 - 4 GHz band.

Acknowledgment

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