Proceedings of the Research Institute of Atmospherics,
Nagoya University, vol. 32(1985)

SHORT NOTE

A HIGH GAIN, BROADBAND, STEERABLE, DECAMETRIC ARRAY TO OBSERVE JOVIAN RADIO EMISSION: II. A 16-ELEMENT ARRAY

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Abstract

A broad band array consisting of 16 (4 X 4) conical log-spiral antennas (right-hand circular polarization) having an expected gain of 19 db has been constructed. The array covers a frequency range of 20-100 MHz. The beam of the array can be steered using time-delay lines both in the E-W and the N-S directions to track a radio source for 6 hours. The radiation pattern of the array was checked by use of a radio signal from the RS-7 satellite at 29.340 MHz. This array is pertinent to spectral observation of Jovian decametric emission.

I. Introduction

The radio emission of Jupiter in the decametric range (DAM) is so intense that it can be observed with a simple antenna such as the Yagi antenna or log-periodic antenna. Since the sensitivity of a simple antenna is not sufficient to make detailed observations of the DAM emission, several large arrays were constructed (Desch et al. 1975; Ellis, 1980; Boishot et al., 1980). Among them, the array at Nançay, France (Boishot et al., 1980) consists of 144 conical log-spiral antennas (72 RH and 72 LH) which covers a frequency range of 10 to 110 MHz. The array has a high gain of 25 db in each polarization. Such a high-gain broadband array has been proved to be very useful in making detailed spectral observations of Jovian DAM emission.

Saturn has been discovered to be another source of VHF radio emission (Warwick et al., 1981; Evans et al., 1983; Burns et al., 1983). Although the peak flux density of the Saturn's VHF emission is estimated to be about 5 Jy (1 Jy = 10^{-26} W $Hz^{-1}sec^{-1}m^{-2}$) at the Earth, the radio emission has not been detected unambiguously by ground-based observations. A broadband spectral observation with a large radio telescope in the HF/VHF range will be important in investigation of the nature of the Saturn's radio emission.

Flare stars (Gruzadyan, 1980) will be new targets for radio astronomy in the HF/VHF range because detailed spectral observations of the flare stars have not yet been attempted. A large broadband radio telescope whose effective area is on the order of 10^5 m^2 is required to study these enigmatic stars. Detailed spectral observations are also important for understanding the nature of time-varying quasars in the HF/VHF range. This paper presents a brief description on the 16-element broadband array which was constructed to study the technical aspects of such a large array and to make an observational study of Jovian DAM emission.

II. 16-Element Broadband Array

II-1. Elements of the Array

A log-spiral conical antenna (Dyson, 1965) is a broadband and low-gain antenna by which one sense of circular polarizations can be received even when the angle between the principal axis of the antenna and an observing radio source is large (Erickson and Fisher, 1974). Thus an array which consists of a large number of log-spiral antennas will be suitable for our purpose. The disadvantage of an array of this type is that two arrays with identical area must be constructed to receive both senses of circular polarizations. The detailed description on the log-spiral conical antenna was given by Dyson (1965). Good erectrical performance of the log-spiral conical antenna is achieved when the cone angle is small (e.g. high front-to-back ratio). An acute cone results in an antenna of great height if operation at low frequencies is desired, because the low frequency limit is set by the wavelength which is approximately equal to the circumference of the base. This causes considerable difficulty in construction as well as high costs. It is known that a smaller cone angle produces narrower angular beamwidth (Dyson, 1965). For the elements of an array, a broad beamwidth is favorable if observations of long duration are desired. As a compromise, an antenna with a cone angle of 20° was selected. It has been confirmed that the antenna performs adequately as an element of the array (Watanabe et al., 1983). The half-power beamwidth is about 80°. The basic parameters of the antenna were given by Watanabe et al. (1983). The approximate gain relative to an isotropic radiator is about 7 db. The frequency range covered is from 20 MHz to 100 MHz, and the axis of the antenna is inclined 20° southward in the meridian plane. Each conducting sheet is approximated by three copper wires (diameter = 1.6 mm) after Erickson and Fisher (1974). The characteristic impedance of the antenna is close to that of a self-conjugate antenna ($60\ \pi$ = 188 ohm). The antenna is connected to a 50 ohm coaxial cable (5D2V) through a common 200:50 ohm broadband barun transformer. Each antenna has a broadband amplifier (MG5157). When the radio frequency interference is strong, a high-pass filter (>21 MHz) is inserted by a switching system.

II-2. Array

A square array of 4 X 4 elements was constructed as an extension of the 4-element array (Watanabe et al., 1983). A photograph of the 16-element array is given in Fig. 1. When a spacing is used that allows a physical area equal to the effective area of the element, only a small amount of mutual coupling is present (James, 1976). The effective area of 7 db gain log-spiral conical antenna is about $0.42\ \lambda^2$, which is about 60 m^2 at 25 MHz. This leads to a minimum spacing of about 8 m at this frequency. Thus spacings of 8.3 m in the

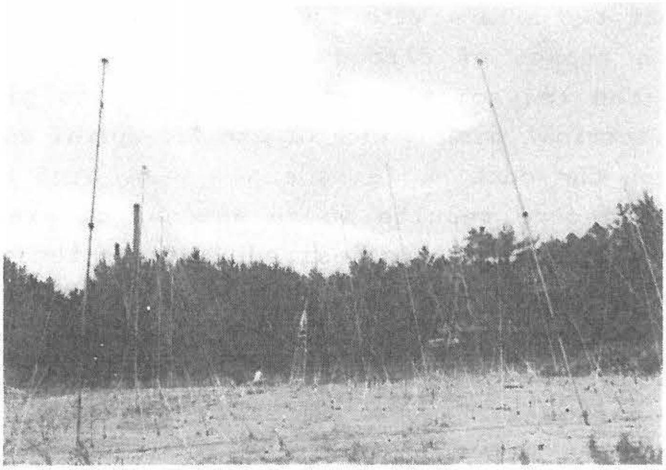

Fig. 1. A photograph of the 16-element array.

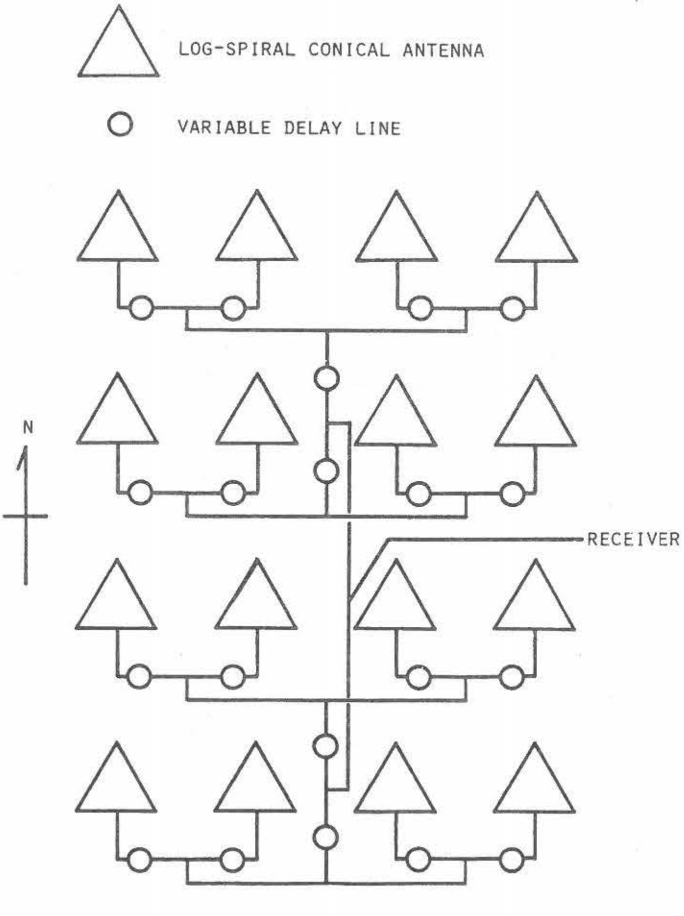

Fig. 2. A block diagram of the receiving system.

E-W direction and 8.9 m in the N-S direction were selected, taking into account accessibility. The covered area of the array was 1023 m^2 (31 m X 33 m), and the effective area was expected to be 6.8 λ^2. Thus the gain of the array is about 19 db.

It is necessary to steer the beam of the array in such a way that the direction of the beam is frequency-independent. This can be achieved through the usage of time-delay lines when the product of the time difference and the bandwidth is less than unity (Christiansen and Högbom, 1969). If observation of a radio source for $\pm$ 4 hours centered at the central meridian passage of the radio source by an array whose E-W dimension is 30 m is desired, the maximum bandwidth is about 10 MHz. This limitation was not important for our purpose because the bandwidth of the passband of a swept-frequency spectrometer is on the order of 10 kHz in the case of Jovian DAM observation.

A 4-bit (1:2:4:8) variable delay line is connected to each antenna of the 16-element array. The line loss at 30 MHz is 0.6 db. The length of the line is changed by a switching circuit which is similar to that developed by Kojima et al. (1982) for a UHF radio telescope. The length of the line is controlled by a ROM network with a typical time step of 30 min. A radio source can be tracked for about 6 hours around its central meridian passage. The variable time-delay lines were installed in the N-S arm to steer the beam in the meridian plane over a range of $\pm$ 45° centered at the zenith. A bias is added by a set of delay lines when radio sources with low elevation angle are observed. A block diagram of the array is shown in Fig. 2.

The radiation pattern of the 16-element array was checked using the beacon signal of the RS-7 satellite at 29.340 MHz. The N-S passage of the satellite at about 22 UT on Sep. 29, 1983 (Orbit No. 7858) was received by the main beam of the array which was pointed at the zenith. The output of the receiver, which is proportional to the electric field strength, is shown in Fig. 3. The satellite passed about 8° to the west of the zenith. The HPBW (half power beam width), which is reduced from the observed radiation pattern is about 21° ignoring the effect of ionospheric absorption. Although there are several unknown factors (e.g. the radiation pattern of the satellite), the observed HPBW of the array is approximately equal to the theoretical value.

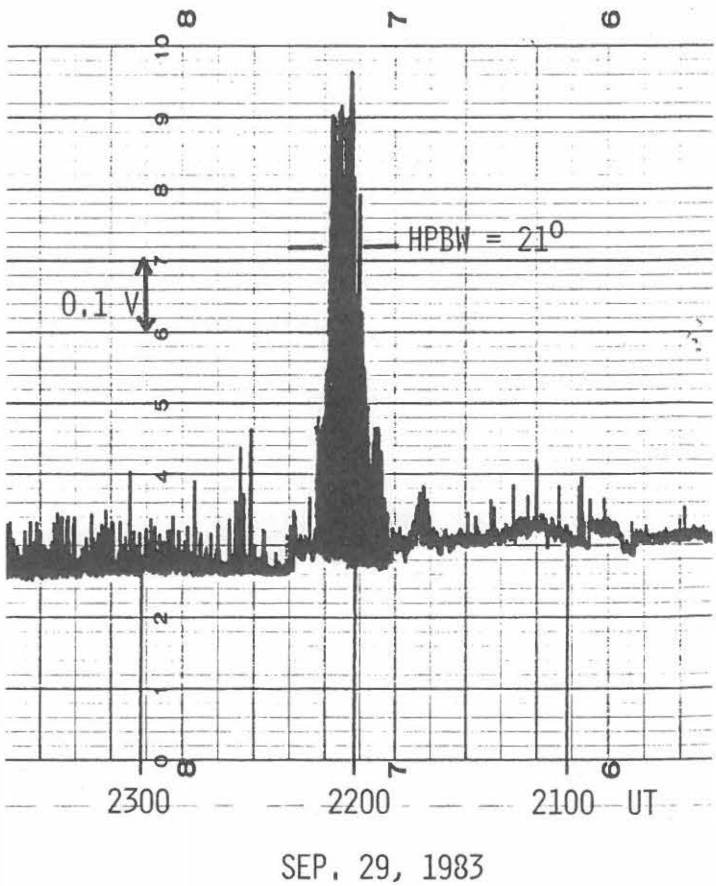

Fig. 3. Recording of the beacon signal of the RS-7 satellite at 29.340 MHz for the Orbit No. 7858. Output level is proportional to the received electric field strength.

Ⅲ. Concluding Remarks

The characteristics of the 16-element array are summarized in Table 2. Although detailed investigation of the performance of the 16-element array is in progress, provisional observations show that the array can be used to make spectral observation of Jovian DAM emission. Since it is a flexible instrument, it can be utilized for various purposes, including ionospheric and magnetospheric sciences.

Table. 1. Characteristics of the 16-element array

Type of Antennas	Log-Spiral Conical Antennas
Polarization	RH Circular
Number of Antennas	16
Total Covered Area	1023 m^2
Effective Area	6.8 λ^2
Gain	19 db
Frequency Range	20 to 100 MHz
Tracking time	6 Hours
Sensitivity	1000 Jy

Acknowledgements

One of the authors (T.W.) would like to acknowledge Dr. M. J. Mahoney and Mr. Stig Johansson of Clark Lake Radio Observatory, University of Maryland for their valuable suggestions. The authors wish to acknowledge valuable comments received from referees.

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