Proceedings of the Research Institute of Atmospherics,
Nagoya University, vol. 30(1983) −Technical Note−

A HIGH-GAIN, BROADBAND, STEERABLE, DECAMETRIC ARRAY TO OBSERVE JOVIAN RADIO EMISSION: I. A 4-ELEMEENT ARRAY

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Abstract

A broadband array of four conical log-spiral antenna has been constructed as the prototype of a large array to observe Jovian decametric emission. Covered frequency range is 20∿100 MHz. The beam of the array can be steered by time-delay lines therefore is frequency independent. Each log-spiral antenna has similar efficiency as compared with that of a typical dipole. Two examples of spectral observations of Jovian decametric emission are also shown.

I. Introduction

The emission of Jupiter in the decametric frequency range has been observed extensively by various means since the discovery of the emission in 1955 (e.g., Carr and Desch, 1976). The Jovian decametric emission appears in the frequency range of 10∿40 MHz when we observe it on the ground, and exibits fine structures with various duration of 10^{-3}∿ 10^{2} sec in the frequency-time plane. It is therefore essential to make broadband observations with high time and frequency resolution to obtain detailed description of Jovian decametric emission. Since the increase in time and frequency resolution cause the reduction in the signal-to-noise ratio, a high-gain broadband receiving system is required although the intensity of the emission can sometimes be very high. The large (72+72 conical log-spiral antennae) at Nançay (Boischot et al., 1980) seems to have high potentiality. We have planned to construct a large, broadband array and a broadband spectrometer with high time and frequency resolution (e.g., acousto-optical radiospectrometer) to make detailed spectral observations of Jovian decametric emission. This report gives a brief description of a 4-element broadband array which is a prototype of a planned large array.

II. A Conical Log-Spiral Antenna

The element of our array should be low gain, broadband antenna to cover the frequency range of, at least, 20∿40 MHz for usual Jovian decametric radio observations. It seems that a self-conjugate conical log-spiral antenna (e. g., Dyson, 1965) of a type used at the Clark Lake Radio Observatory (Erickson and Fisher, 1965) and at the Radio Astronomy Observatory, Nançay (Boischot et al., 1980) is suitable for our purpose. The antenna of this type has two balanced conducting sheets wound on the surface of a cone. The geometry of the antenna is determined by several basic parameters as indicated in Fig. 1. The parameter θ_0 determines the cone angle, and α is the rate of wrap of the arm. The angular width of the exponentially expanding arms is defined by δ. The radius vector ρ to any point on the arm is given by the formula;

$$\rho = \rho_0 \exp b(\phi - \delta) \qquad (1)$$

where

$$b = \sin \theta_0/\tan \alpha. \qquad (2)$$

The characteristics of the conical log-spiral antenna were extensively investigated by Dyson (1965). The highest front-to-back ratio is obtained when angular width of the arm δ is 90°; i. e., the distance between the conducting sheets is equal to the width of each conductor. An antenna of this type is called as a self-conjugate antenna, and its characteristic impedance is expected to be 60π ($\sim$188) ohm. The measured impedance is close to this theoretical value(Dyson, 1965; Erickson and Fisher, 1974). The front-to-back ratio is improved by a choice of large value of the rate of wrap α. When the cone angle θ_0 is 15°$\sim$20° and the rate of wrap α is 80°, the half-power beam width will be about 80°. The operating frequency range is determined by the size of the base and the truncated top of the antenna. The low frequency limit is set by the wavelength which is approximately equal to the circumference of the base, and the high frequency limit is determined by the circumference of the truncated top. We have adopted the parameters shown in Table 1 for our prototype array to cover the frequency range between 20 and 100 MHz. The axis of the antenna is inclined 20° south in the meridian plane to observe Jupiter in low elevation angle. Each conducting sheets is approximated by three copper wires (diameter=1.6 mm) after Erickson and Fisher (1974) and Boischot et al. (1980). As seen in Fig. 2a, one wire is situated in the center and the other two wires are placed at the edges of each conducter. Thus one antenna has six wires. The cone is formed by 16 nonconducting guys. We also tried another antenna of ten-wires type (Fig. 2b); each conducter is approximated by five wires. Since the cone angle is somewhat large (20°), the characteristic impedance of our antenna will be close to that of a self-conjugate antenna ($\sim$188 ohm). Thus we connected the antenna to a 50 ohm coaxial cable (5D2V) through a common 200:50 ohm wideband barun trans-

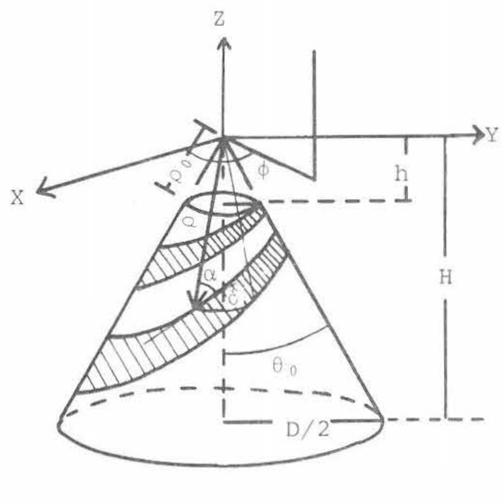

Fig. 1. Conical log-spiral antenna and associated parameters.

Table 1
Parameters of a Test Log-Spiral Antenns

θ_0 = 20°	H = 7.0 m
α = 80°	h = 1.1 m
δ = 90°	D = 2.4 m
ρ_0 = 1.17 m	d = 0.4 m

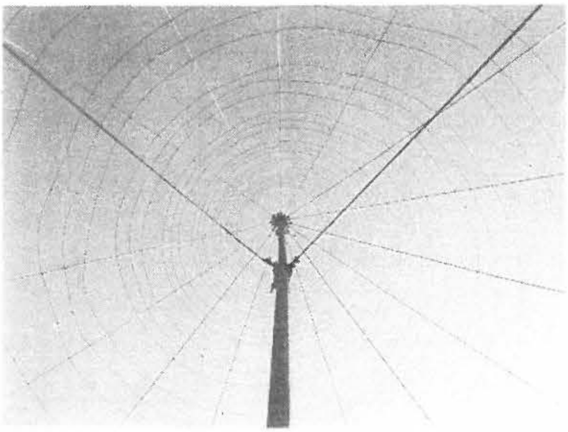

Fig. 2a. Test Antenna of Six-Wires Type.

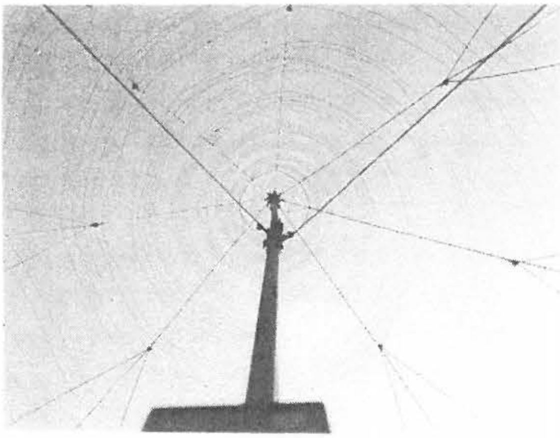

Fig. 2b. Test Antenna of Ten-Wires Type.

former whose characteristics are very flat in the frequency range of 1 ∿100 MHz.

We measured broadband characteristics of the antenna using a circuit analyser (HP8754A) with a return-loss bridge although the measurement was very limited one because of a practical reason. There is the six meter coaxial cable and the 200:50 ohm transformer between the antenna and the analyser. Thus we can only know the performance of the antenna through these components. The voltage standing wave ratio (VSWR) was determined by a broadband return-loss measurement. At a frequency between 20 and 100 MHz, VSWR was well below 2.0, and a typical value was 1.6. In the frequency range below 20 MHz, VSWR grew rapidly. Similar result was obtained for the antenna of ten-wires type.

It is quite difficult to measure actual antenna gain of the conical log-spiral antenna because there is no radio source intense enough to receive by one spiral antenna. Instead of the measurement of antenna gain, we compared the efficiency of our antenna with those of half-wave dipoles at 16, 30, and 100 MHz. Each dipole was situated 1/4 wavelength above the ground plane. The procedure was very similar to that adopted by Erickson and Fisher (1974). We compared the noise level of output of the spiral antenna with those of the dipoles when we observed the galactic background at these three frequencies. Since the directivity of the spiral antenna is considered to be similar to that of a dipole, and the galactic background is randomly polarized, the difference in the output level will be the difference in the efficiency of the spiral antenna and the dipole. The cable loss was adjusted with an accuracy of $\pm$ 0.3 db. All the measurements were made in nighttime to avoid man-made interferences. We used a field strength meter (ML518A) with a broadband preamplifire (gain=25 db, and noise figure=4.5 db) and a pen-recorder for the observations at 30 and 100 MHz. In the case of the observation at 16 MHz, we used above-mentioned preamplifire and a receiver (NRD-515). The result is shown in Fig. 3. It will be seen in this figure that the efficiency of the spiral antenna was slightly lower (about -0.2 db) than those of the dipoles at 30 and 100 MHz. When we take into account uncertainty in measurements of transmission loss of the cable and the transformer, it will be concluded that the spiral antenna has similar efficiency to that of a typical dipole within the operating frequency range. The efficiency of the spiral antenna at 16 MHz (this frequency is well below the low frequency limit) was about 6 db lower than that of the dipole. This means that part of the received power will be absorbed by the ground in the frequency range below 20 MHz. Similar result was obtained for the spiral antenna of ten-wires type as shown in Fig. 3. It will be concluded that the spiral antenna of six-wires type seems to be suitable for our purpose because of easiness in construction.

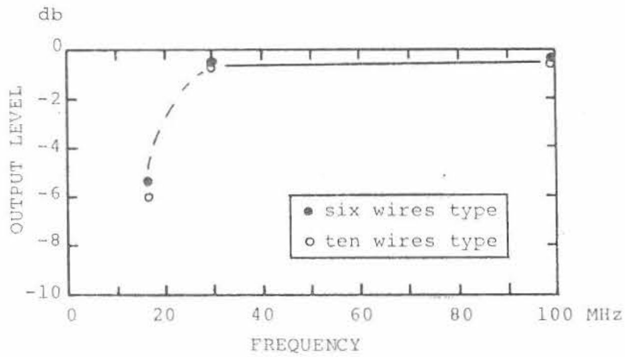

Fig. 3. Frequency dependency of output noise level of conical log-spiral antennae as compared with those of dipoles at 16, 30, and 100 MHz.

III. A 4-element Broadband Array

We have constructed a prototype array in the E-W direction which consists of four conical log-spiral antennae of a type described in the previous section. A picture of the array is shown in fig. 4. The spiral is wound to receive the right-handed circular wave. The spacing between each element is 8.3 m. This spacing produces grating beams at the frequencies above 23 MHz. The gain of the array will be about 12db.

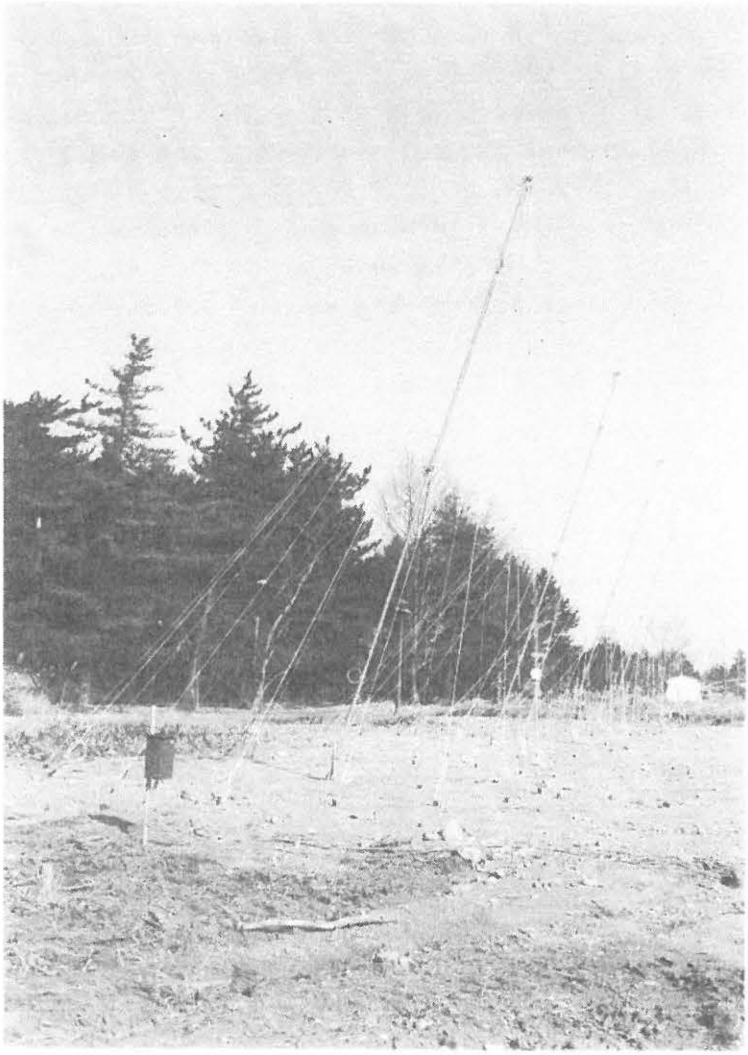

Fig. 4. A 4-element array.

Each spiral antenna has a broadband preamplifire (MG5157) whose noise figure and gain are 4.5 db and 25 db respectively. The beam of the array can be steered in the E-W dirction by a 4-bit changer of time delay lines, thus the array is of "panchromatic". The step of the beam shift is about 7°, and we can track Jupiter for about five hours centered at the meridian passage. Beam control is made by a timer and a ROM network. Investigation of performance of the array is in progress.

Output of the array is processed by a spectrum analyser (MS62A), which is a swept-frequency spectrograph, and recorded by a facsimile recorder and a magnetic taperecorder. The sweeping range is 20∿40 MHz at a rate of 6/sec. The 3 db width of the swept passband is 30 kHz.

Ⅳ. Spectral Observations Of Jovian Decametric Emission

Preliminary spectral observations of Jovian decametric emission have been made to check the performance of the 4-element array. As indicated in the previous section, time resolution of our observation was not high enough to see the spectral patterns with very short duration such as S bursts. We focused on spectral patterns with time scales of longer than a few seconds. Recorded magnetic tapes were processed by a computer (ACOS 700) through a A-D converter with a rate of 30 k/sec. Two examples of CRT output of the computer are shown in Figs. 5 and 6. These examples were obtained during an Io-A event occurred on February 12, 1983 (JST). The first example (Fig. 5) shows several broadband emission patterns with duration of about 10 sec. Genova and Lebranc (1981) suggested that the spectral patterns with time scales of this order are produced by interplanetary scintillations. The second example (Fig. 6) is an short-lived (about 30 seconds) and narrow band emission feature occurred around 25 MHz. It showed interesting split in direction of the frequency axis.

Ⅴ. Concluding Remarks

It has been confirmed that the conical log-spiral antenna is an excellent element of a broadband array. This antenna has similar efficiency to that of a typical dipole. Although the detailed investigation of performance of the 4-element array is in progress, capability of the broadband array in observations of Jovian decametric emission seems to be proved.

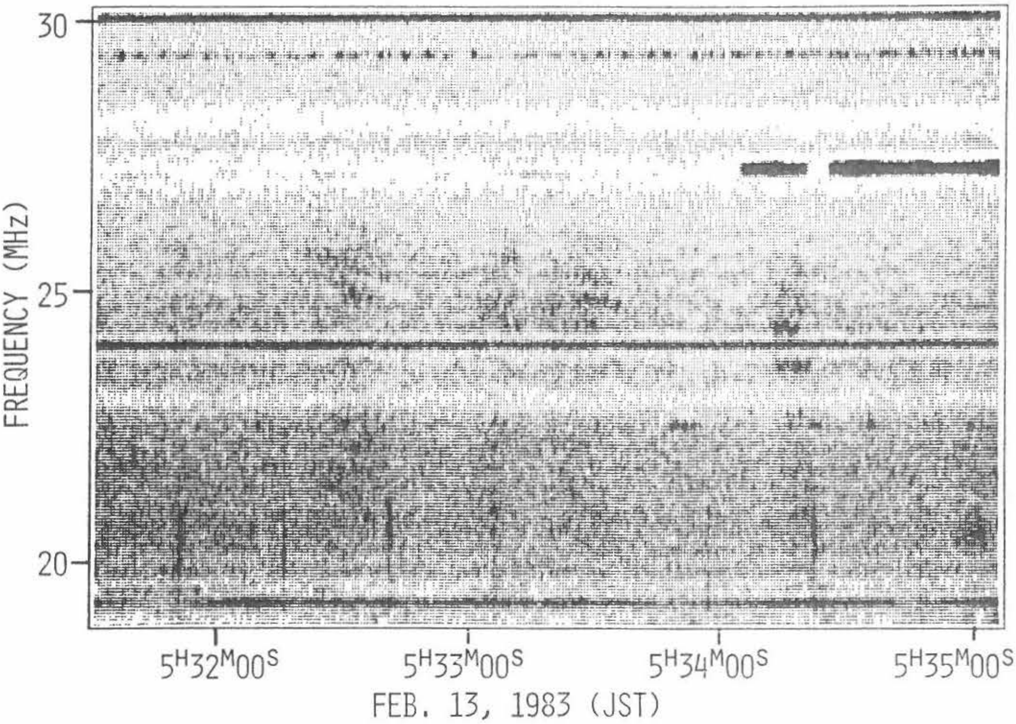

Fig. 5. Broadband Jovian decametric emission.

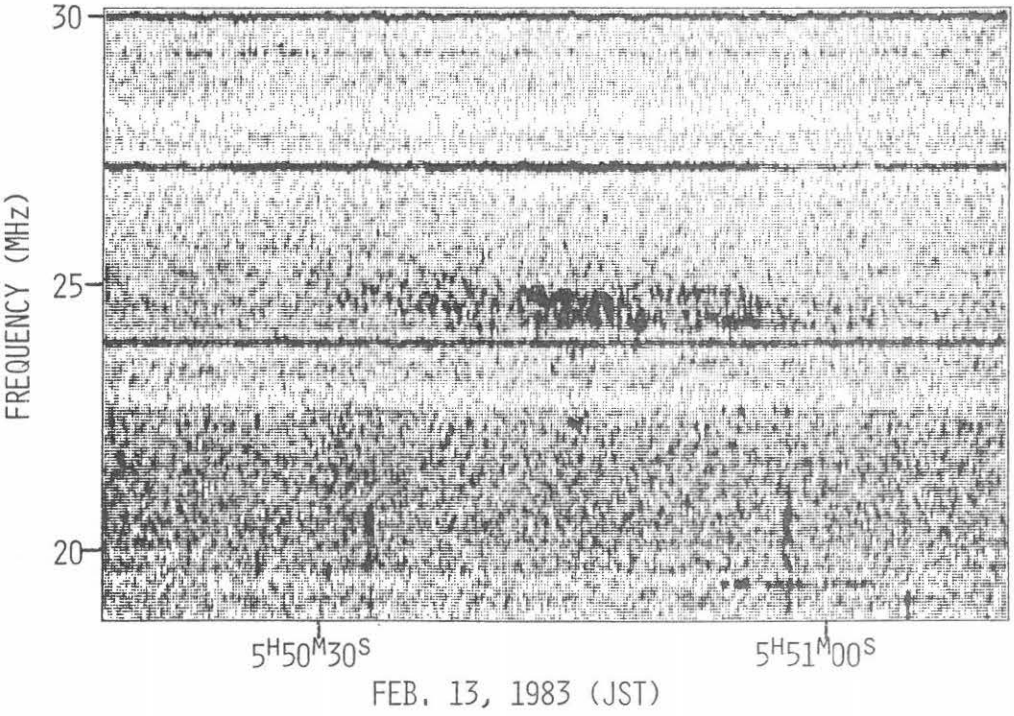

Fig. 6. Short-lived, narrow band Jovian decametric emission

Acknowledgment

The authors wish to express their thanks to Professor T. Nakai for his support in the spectral observations. Thanks are also due to the valuable suggestions received from referees.

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