Jovian Radio Wave Emissions

著者	Oya Hiroshi
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*Jovian Radio Wave Emissions**

HIROSHI OYA

Geophysical Institute, Tohoku University
Sendai 980, Japan

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Abstract: Observation of the Jovian decameter radio waves has currently been carried out using i) 1000 m interferometer system, ii) polarization measurement system, and iii) dynamic spectrum observation system from 21 MHz to 25 MHz. The Jovian hectometer waves have also been observed using satellite JIKIKEN that has a long dipole antenna with length of 102 m (from tip to tip). Using observed data, following results are obtained. I) Radio wave source: The source mechanism of the non-Io related radio wave is largely controlled by turbulent areas of solar wind that are identified from the encounter, to the earth's magnetosphere, that makes trigger effects to the earth's magnetic distrubances. II) Generation mechanism: The position of the main source of the Jovian decameter radio waves are identified to be near the south magnetic pole which mainly indicates the right handed circular polarization. These evidences support the conversion theory for the generation mechanism of the Jovian decameter wave emission. III) Improvement of theory: The previous conversion theory has been improved relating to more realistic model of the planetary plasmasphere, where $f_p/f_c<1$ (f_p and f_c are the plasma frequency and the electron cyclotron frequency, respectively). The large scale irregularity of the plasma distribution makes effective conversion from the electrostatic mode waves to the electromagentic mode waves that can escape to the interplanetary space.

1. Introduction

Since the first identification of the Jovian decameter radio wave emissions (Burke and Franklin, 1955), the observations have been continued almost quarter of a century at several observing stations (Carr, 1961; Ellis, 1965; Warwick, 1967; Alexander, 1967). Though the search from the stand point of the astronomical interests in the Jovian decameter waves has been completed during this period, new interests and objectives have been raised in recent years since the spacecrafts were sent into the Jovian magnetosphere (see the issue of Journal of Geophysical Research Vol. 79, 3489–3700, 1974).

The new subjects are related to the usage of the Jovian decameter waves as a messenger of Jovian ionospheric phenomena where the decameter waves are generated as results of the Jovian magnetospheric disturbances (Oya, 1974; Scarf, 1974). The effects of the Jovian magnetosphere are also detectable by the decameter waves since the energy input from the magnetosphere is an essential factor for the generation of the decameter waves in the Jovian ionosphere. For this purpose a new observing station

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has been opened at Mt. Zao Observatory of Tohoku University (Oya et al., 1975). This new purpose of the study on the planetary plasmasphere is closely related to the study on the terrestrial plasmasphere as well as the study on the interaction of the solar wind with the planetary magnetosphere. That is, we can develop the study on the planetary plasma on the same base as has been carried out for the plasma physics in the earth's plasmasphere.

2. History of the Development

In Table 1, the initial plan of the project that had been presented in early 1974 is given. All the projects have been executed following the plan except for the J-4 project. The J-5 project has been completed by launching EXOS-B satellite; this will provide significant data on the emission of the hectometer radio waves in a low frequency range that gives us important informations on the Jovian plasmasphere.

Table 1. Planning of Projects

Year	Projects	Contents
1974	J–1–B	20MHz, 22MHz, 23MHz, 24MHz
1975	J–1–C	High Gain Pointing
1975	J–1–D	Polarization
1976	J–2	22–30 MHz Wide Sampling
1977	J–3	km Range Base Line Int.
1978	J–4	500–1000 km Range Base Line
1979	J–5	Satellite Base Observations

Two Voyager spacecrafts were launched successfully in late August and early September, 1977. The present projects on Jovian decameter wave emissions will result in cooperative studies with these observations made by Voyagers 1 and 2 for clarifying the physical processes in the Jovian magnetosphere.

In this section a brief survey will be given on the established plan.

J-1-B System — Radiometers at 4 Frequencies

On Oct. 20, 1974, a successful observation of the Jovian decameter wave emissions started at Mt. Zao Observatory of Tohoku University using two-element Yagi antennas at four frequencies, 19.945 MHz, 20.010 MHz, 23.505 MHz and 24.320 MHz.

J-1-C System — 40 m Interferometer

Complete identification of the origin for these decameter wave emissions was carried out using the interferometer system with 40 m spacing. The interferometer observation was started on Dec. 5, 2300 JST, in 1975. An example of Jovian decameter wave emissions detected in an observation interval from Dec. 5, 1975 to Feb. 21, 1976 is given in Fig. 1. Strong emissions given by thick lines are well indicating the coincidence between the trajectory of Jupiter, which is plotted on the plane that consists of local time (ordinate), and the direction angle θ_{EW} (abscissa). Weak emissions are also plotted using thin lines. Though these are indicating a fluctuation, the center position coincides again with the location of Jupiter. Thus, the results give a confirmation that the series of emissions observed were emitted from Jupiter.

J-1-D System — Polarization

The polarization of the Jovian decameter waves carries important informations that reflect the generation mechanism of the decameter waves. Observation of the polarization started on Oct. 20, 1976 using three-element cross Yagi antenna, that can point Jupiter by manual control system. The data now have currently been accumulated to investigate the generation machanism of the Jovian decameter waves. An example of the polarization measurement is given in Fig. 2.

J-2 System — Dynamic Spectrum

Dynamic spectrum of Jovian decametric radio waves have been observed since Oct. 1978 in frequency range from 21 MHz to 25 MHz.

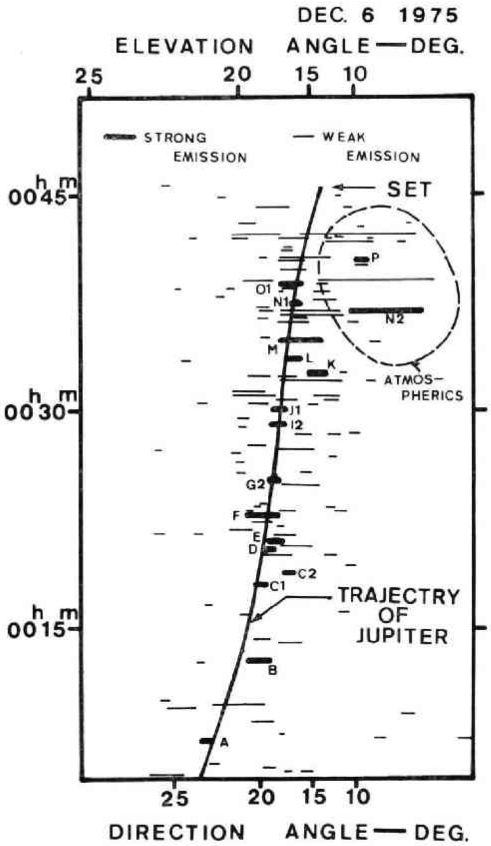

Fig. 1. Result of the interferometer observation carried out on Dec. 6, 1975 using the short-range proto system (40 m baseline).

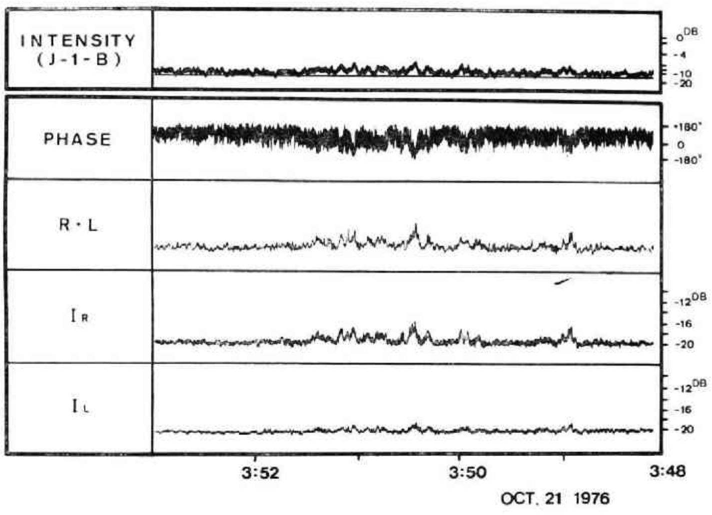

Fig. 2. An example of the polarization measurement data obtained for the emissions from the main source on Oct. 21, 1976.

One of the most important information on the plasma at the source regions is provided by the observed dynamic spectra. An example of the dynamic spectra is indicated in Fig. 3.

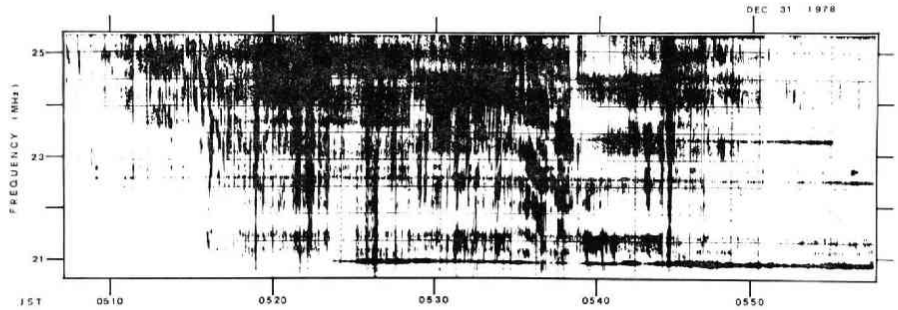

Fig. 3. An example of the dynamic spectrum of the Jovian decameter radio waves in a frequency range from 21 MHz to 25 MHz. The observation was made for the early source; fine structures of the frequency shift contain important information to analyze the movement of the source region.

J-3 1 km Base Line Interferometer

For accurate identification of the Jovian decameter waves, a new long base line interferometer system has been constructed; the test operation of this system started in August, 1977. The length of the base line is 1.03 km, that is equivalent to 69 wavelengths. Each antenna (see Fig. 4) of this long base line is designed to achieve the

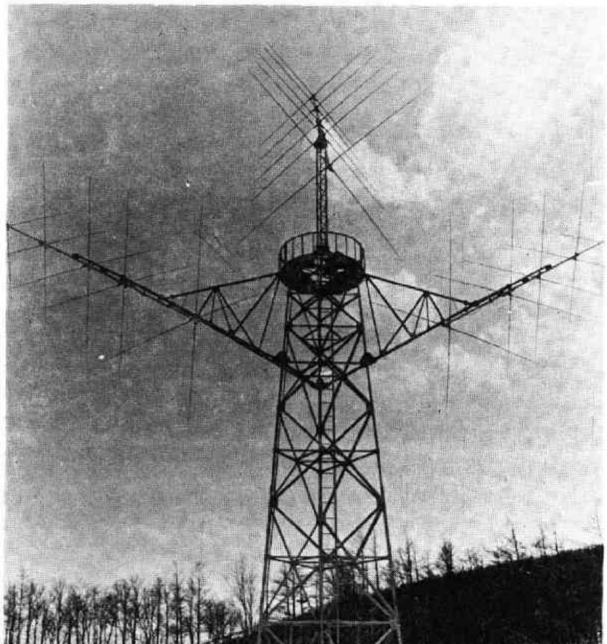

Fig. 4. One of the J–3 antennas; 3 sets of 5-element Yagi are used to track Jupiter by switching the set from one to another. Each antenna has the gain of 10 dB in the maximum direction.

high directivity using three sets of 5-element Yagi that has the gain of 10 dB at the maximum. The system has capability to detect the phase differences $\pm 3°$. This system provides informations for source positions of the Jovian decameter waves whether the source is located in the northern hemisphere or in the southern hemisphere.

J-5 Satellite-Base Observations

JIKIKEN (EXOS-B) was successfully launched on Sept. 16, 1978, and the observation of radio waves with swept frequency receiver from 10 kHz to 3 MHz and a point frequency at 5 MHz are currently carried out using long deployments antennas (102 m tip to tip). Many interesting results are accumulated to clarify the feature of Jovian radio wave emission in a frequency range that is completely impossible to observe on the earth's surface.

3. Important Results

3.1 *Interaction with Solar Wind*

The accumulated data from Oct. 1, 1974 to Mar. 30, 1977 were used to investigate relations of the decametric radio wave emissions to turbulent areas of the interplanetary magnetic fields, that were identified using ΣK_p indices of geomagnetic field disturbances. Auto-correlation spectra for ΣK_p and for the occurrence of the Jovian decameter wave emissions JDW, with cross-correlation between ΣK_p and JDW, give confirmation to a model that the rotating sector boundary of the interplanetary magnetic field encounters first with the earth's magnetosphere producing the geomagnetic field disturbances and after certain period, the boundary encounters with the Jovian magnetosphere that enhances the emissions of the decameter radio waves from the so-called main source. The result gives a clue to solve the origin of the energy for the main source relating to the dynamical behavior of the Jovian magnetosphere. In Fig. 5, the cross-correlation between JDW and ΣK_p is indicated.

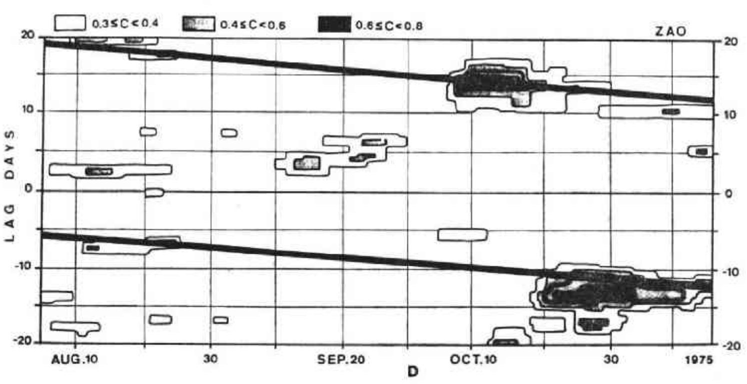

Fig. 5. Dynamic cross-correlation analysis for the occurrence of Jovian decameter wave emissions and ΣK_p indices of geomagnetic disturbances.

3.2 *Location of Decameter Wave Source*

Locations of Jovian decameter wave sources are so decided as the main source is near the south magnetic pole while the early source is near the north magnetic pole. The results are obtained from the data of the decameter radio wave occurrence observed at the earth's surface being compared with recent observations of the Jovian magnetic field map that is obtained using GSFC fluxgate magnetometer on the Pioneer 11 spacecraft (Acuna and Ness, 1975). The theory on the origin of the decameter waves, which claims that the Jovian decameter waves are produced as a result of the plasma wave conversion into the electromagnetic wave, predicted that the main source should be located at the magnetic south pole to give a selfconsistent interpretation on the observed right-handed circular polarization of the emitted waves from the main source (Oya, 1974). The theoretical prediction is confirmed by this work.

4. Improvement of Theory

The Jovian plasmasphere is characterized by a condition $f_p/f_c<1$ where f_p and f_c are the plasma frequency and the electron cyclotron frequency, respectively; in this case the conversion from the (RX) mode to the (LO) mode takes place through the large scale irregularity of the plasma density distribution. Our recent study indicates that the conversion takes place with proportion to N_1/N_0 where N_1 and N_0 are the irregularity component, and background of the plasma density, respectively. In Fig. 6, the dispersion curves of the electromagnetic waves for the case of $f_p/f_c=0.2$ are reproduced. The portion where two curves for the (R-X) and the (L-O) modes located with small distance is significant for the conversion under the condition of the irregular plasma density distribution. The result gives a significant improvement on the previous theory (Oya, 1974), because the conversion of several 10% can take place without meeting the layer where the radio wave frequency becomes equal to the local plasma frequency.

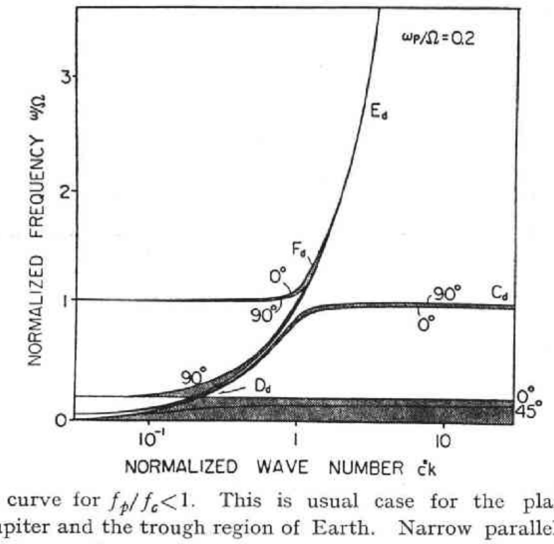

Fig. 6. Dispersion curve for $f_p/f_c<1$. This is usual case for the planetary plasmasphere especially in Jupiter and the trough region of Earth. Narrow parallel curves of the R-X and the L-O modes can be connected when the plasma distribution indicates large scale irregularities.

The large scale irregularities of the plasma density may exist in the Jovian plasmasphere, because they can be observed in the earth's plasmasphere along the trough region that is connected to the plasmapause. The JIKIKEN satellite detected very large irregularity where N_1/N_0 takes a value of, sometimes, about 70%.

5. Conclusion

Observation of the Jovian decameter radio waves during five years using interferometer observation system, polarization measurement system, and dynamic spectrum measurement system have provided enough data for investigation of the origin of the Jovian decametric radio waves. It is almost confirmed that the source of the decameter radio waves has an electrostatic nature at the very origin and that can be converted into the (R-X) mode electromagnetic wave. The most important process to make conversion from this (R-X) mode to the (L-O) mode is the large scale irregularities in the plasma. The same mechanism can be applied to the earth kilometric radio wave.

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