Observations of Geomagnetic and Earth-Current Micropulsations with Periods of about 1 cps

1. On the Observing Apparatus of Geomagnetic Micropulsations

By

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Abstract

As one of the IQSY program of our observatory, we have planned observations of geomagnetic and earth-current micropulsations with periods ranging between 0.2 and 10 seconds. In the present paper we will describe the observing apparatus of short-period geomagnetic micropulsations, pc-1, pc-2 and the shorter side of pi-1 ($\leq$10 sec.) We have installed those apparatus at Memambetsu (43°55′N, 144°12′E) and Kanoya (31°25′N, 130°53′E) and used for continuous observations.

§ 1. Introduction

So far the micropulsations with periods from 0.2 to 10 seconds have been observed mainly in the American Zone or USSR by many research workers. Those micropulsations include three classes of geomagnetic micropulsations, pc–1, pc–2 and pi–1, which were defined in the IAGA–IUGG resolution at the Berkeley General Assembly in 1963. As detecting devices in those observations, earth–current electrodes or induction loop coils have been used. Electrodes have been used by Troitskaya (1957), Heacock and Hessler (1962). Loop coils have been employed by Kato and Saito (19 64), Duffus et al. (1959), Teply and Wentworth (1962) and Benioff (1960). At Memambetsu preliminary observations of micropulsations with longer periods than about 1 second were started at November 1961 by Yanagihara (not yet published) by means of the earth–current measurements. A galvanometer of short period and high sensitivity is used in his observations. Generally speaking, the shorter the period of the galvanometer is, the lower its voltage sensitivity becomes. As the signal voltage is easily made large by the extension of the base length in the earth current measurement, the observation of micropulsations with shorter periods may be possible to some extent without any amplifier. On the other hand increase of the area of loop coil brings inferiority of frequency response due to increase of inductance. The usual effective area of the detector coil is of the order of 10^8 cm^2, so that the signal voltage induced in the coil is $1\,\mu V$ at most. Then generally, some low noise high-gain d.c. amplifier has to be used together with the galvanometer in the measurements by such induction loop coil. As the recorder, the seismic type is ususlly used.

In our way of experiment a test apparatus was installed at Kanoya and temporary observations were made in December 1961, with an air-cored coil. It was found from the results that our early amplifier had too low input impedance to use in the measurement of such minute signals. It was also necessary to improve the filter of the input because the actual man-made noise is considerably large. After some improvement the second test observation was made at Kakioka during the pre-IQSY period from July to December 1963. The final design of the measuring apparatus was decided at the end of the test period based upon the results of the test. The apparatus thus designed are equiped at both stations, Memambetsu and Kanoya, for the IQSY observations. At present those observations are in progress. The whole device is schematically shown in Fig. 1.

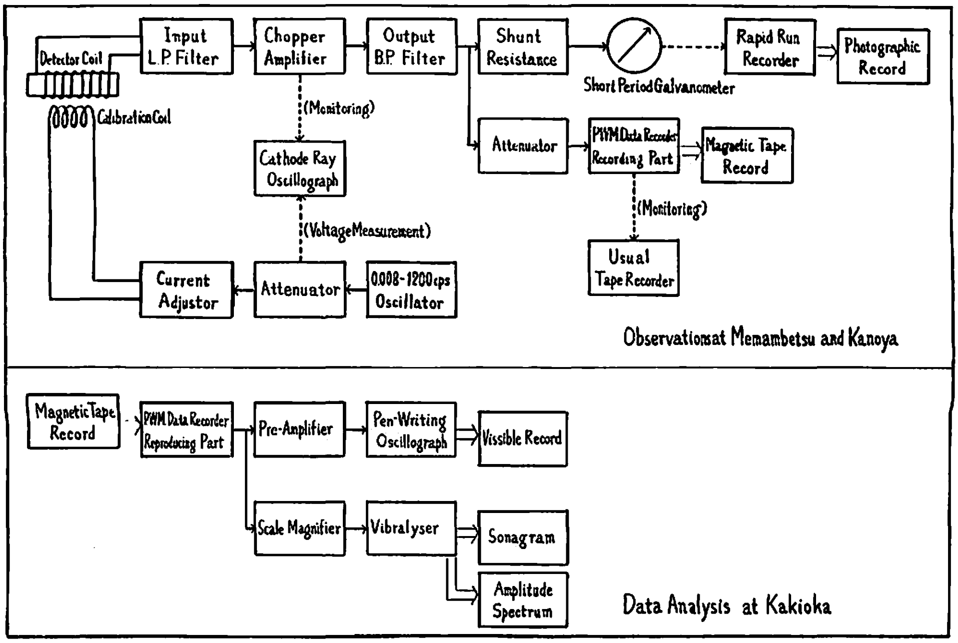

Fig. 1 Measuring and data-analysing apparatus of short period geomagnetic micropulsations.

§ 2. Detecting device

As detector high-mu metal cored coil is used. The high-mu metal is a specially refined 78% nickel-molybdenum permalloy, TMC-V manufactured by the Tokoku Metal Industries, Ltd, which has very high permeability (initial permeability : 30,000–70,000) and low coercive force (0.01 to 0.02 Oersted). The core consists of one hundred sheets of thin slender plate of the metal which is two meters in length, 10 mm in width and 0.1 mm in thickness. Between each sheet a thin miler film is inserted. These are packed in a iron case and put into a P.V.C. pipe. On this pipe spindle-shaped detector winding, which consists of about 20,000 turns of 1 mm copper wire, is wound. The effective area is about 1.0 to 1.2×10^8 cm^2 for 1 cps signal. The inductance and the Ohmic resistance are about 100 henrys and 70 ohms, respectively. The measured effective permeability is about 5,000 to 6,000 which is in agreement with the value deduced from the dimension ratio of the core and the initial permeability of the metal. As described above, the metal plate of the core is made thinner as far as possible. Neverthless the effective permeability shows some undesirable loss for alternating currents owing to eddy currents even for our extremely low frequency range. The effective area curve shown in Fig. 2 starts to be lowered from about 10

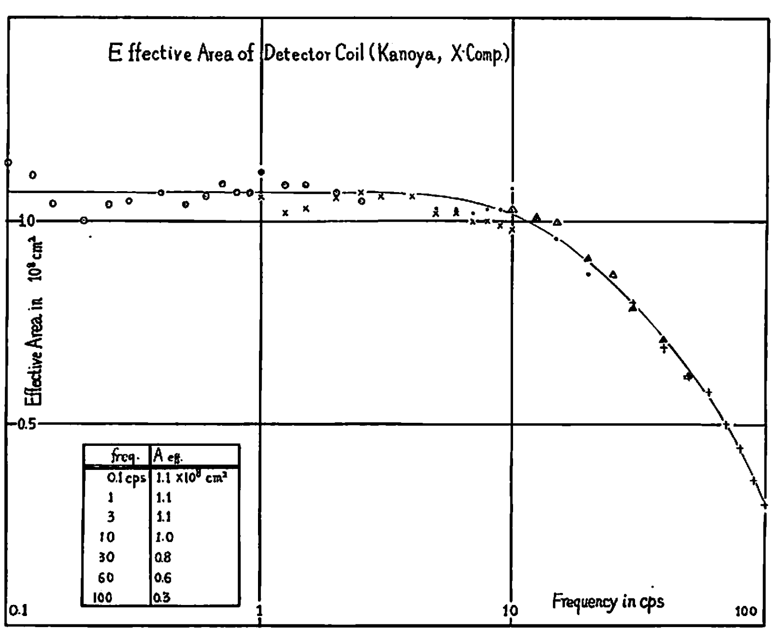

Fig. 2. Frequency response of effective area of detector coil at Kanoya.

cps. In the figure, the difference of the plotted marks is due to that of the dividing resistance of the measuring circuit.

On the middle part of the detector coil a calibration winding of 100 turns of the same wire is wound. Calibration current of 2×10^{-8}A through it induces such an electromotive force in the detector coil, that is equivalent to that for the uniform oscillating magnetic field of about 18 mγ applied around the detector. For the purpose of elimination of undesirable troubles due to external electrostatic induction, the detector is shielded with a copper cylinder which is stretched on the inner wall of an outer P. V. C. pipe.

Specially-designed noiseless polyethylene sheath coaxial cables are used as lead wires from the detector and the calibration coil.

The whole detecting device is enclosed with a large polyethylene pipe and each end of the lead wires are connected water-proofly to it by means of new polyethylene-welding technique developed by the Hitachi W. & C., Ltd. The pipe is buried about 1 meter in depth under the ground at the low noise position which is chosen so as to stand apart from power-lines as far as possible.

§ 3. Input Filter and Amplifier

The detector coil is connected to a low noise chopper amplifier through an input filter. External noises in various frequency ranges are much larger than the natural signals of geomagnetic micropulsations. These noises are mainly due to the meteorological conditions or power-lines and the other artificial sources. These undesirable noises have to be eliminated using suitable filters. Our input filter consists of a de-

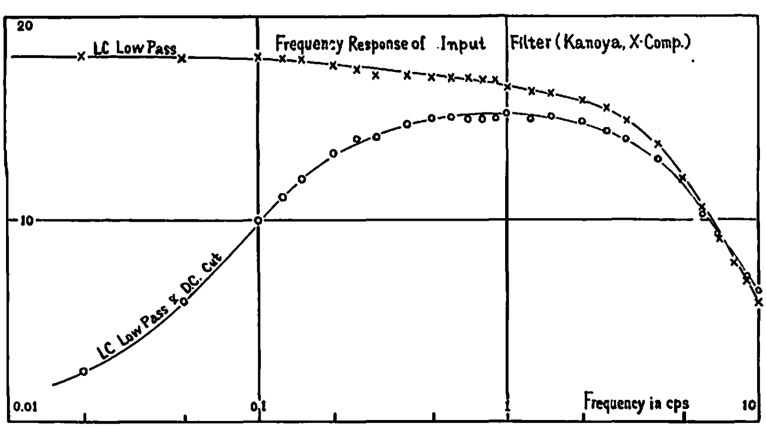

Fig. 3. Frequency response curves of input filter in arbitrary linear scale at Kanoya.

rived-M type 50 or 60 cps rejection filter and a usual LC type low-pass filter. Frequencies of the power line at Memambetsu and Kanoya are 50 cps and 60 cps, respectively. Because of the low input impedance of the chopper amplifier, elements of low impedance have to be used in the filter. Then in choke-coils TMC-V-tape-wound spiral core is used. The tape thickness and width are 0.1 mm and 20 mm, respectively. As condenser metalized paper type is employed. 50 or 60 cycle noises are eliminated by about 80 db. The frequency response curves of the filter are shown in Fig. 3.

When the detector coil is connected to the filter input, one portion of the signal voltage induced in the coil are given to the input terminals dividing due to Ho-Thevenin's theorem. The frequency response curves of the coil connected to various resistances for the filter are shown in Fig. 4. As found from the curves the frequency response is very lowered unless the resistance is higher than about 10 kΩ. On the other hand it is preferable that the source resistance of the amplifier is as small as possible, as it is described later. Therefore, the overall response tends to be lowered unavoidably owing to that the induced voltage is dropped by the impedance of the coil comparable at 1.5 cps to the actual impedance of the filter, about 1 kΩ, which is lower as the source of the amplifier.

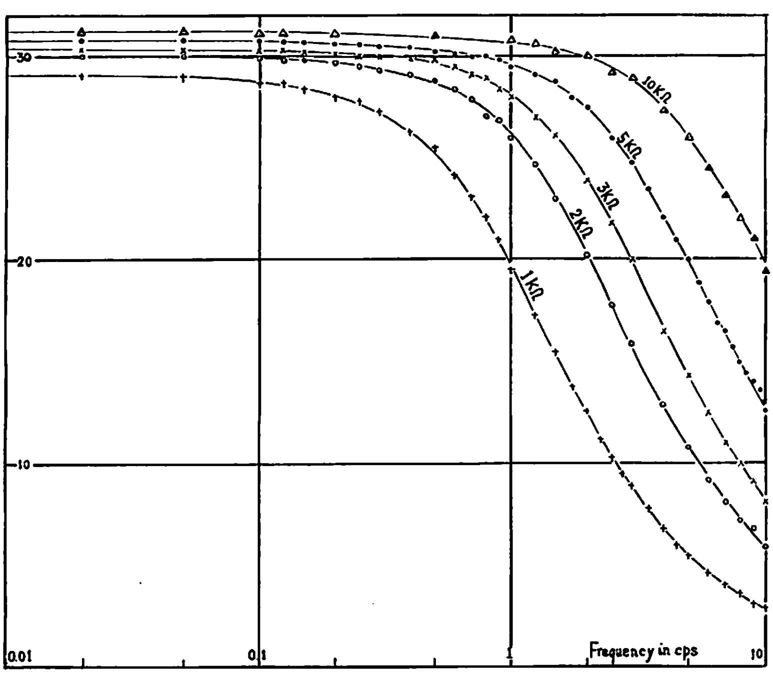

Fig. 4. Frequency response curves in arbitrary linear scale when detector coil is connected to various resistances.

The chopper amplifier is Model 149 Milli-microvoltmeter manufactured by Keithley Instruments Inc., USA. It responds up to 1 cps at $3\mu V$ full-scale range and to 3 cps or more at $10\mu V$ range. But, as shown from the response curve of the input filter, it is difficult to improve the response of the whole device over such higher frequencies. The peak to peak noise of the milli-microvoltmeter is given by $F=6.5\times10^{-4}(R+10)^{1/2}$ in microvolts, where R is the source resistance in ohms. When the input is shorted the noise is less than 10^{-9} volts rms. In the actual case the resistance of the source is of the order of 1 kΩ, and the noise is at most $0.02\mu V$ pp. The actual instrumental noises of the set installed at Kanoya are shown for various source conditions in Fig. 5. The scale of the ordinate shows the equivalent magnetic

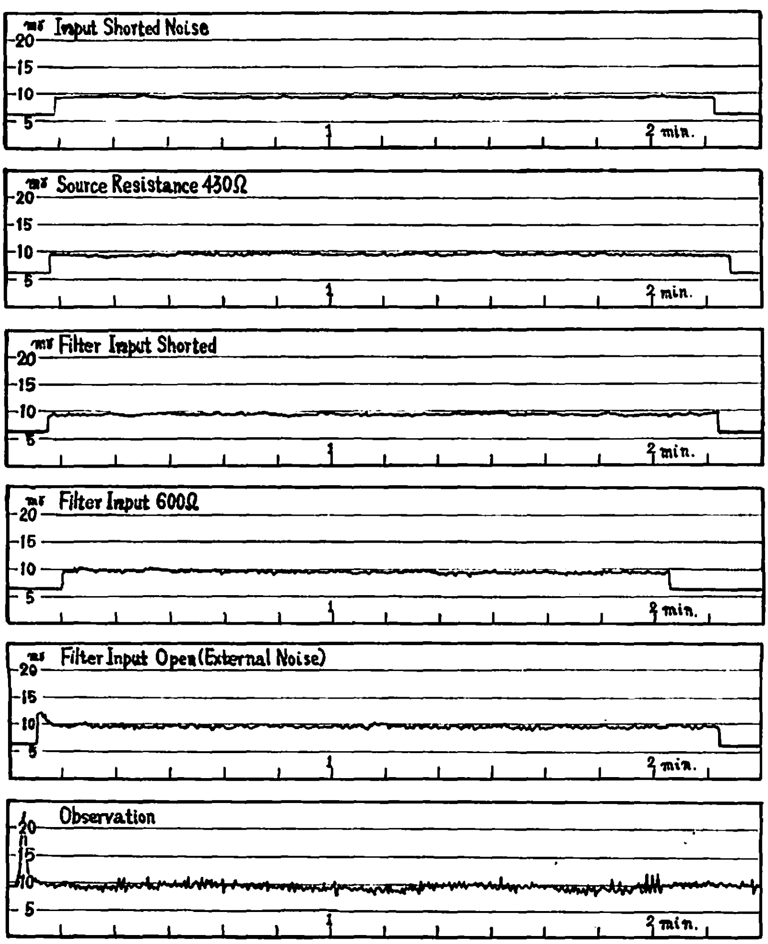

Fig. 5 Instrumental or external noises for various input conditions at Kanoya.

field fluctuation. The negative terminal of the output is earthed, so the circuit is unbalanced. Any other points of the whole circiut of the measuring apparatus is never grounded owing to elimination of the troubles due to so-called two-points earthing.

§ 4. Output Filter and Recording System

Output of the amplifier is connected to the output filter which consists of a variable cutoff band-pass filter and a twin-T type 50 or 60 cps rejection filter. Suitable frequency responses can be selected in this filter. Some examples are shown in Fig. 6.

The amplified and filtered signals are led into two different recording apparata. One consists of a moving coil galvanometer and a photographic recorder. This is used as a monitor by which the occurrence of interesting short-period micropulsations can be detected. The galvanometer has very short oscillation period and comparatively high voltage sensitivity which are achieved by decreasing the moment of inertia of its suspending system as far as possible together with the use of strong magnet. Its deflection is recorded on photographic paper of 42 cm×90 cm in size wound on the recording drum. In ordinary use the driving speed of the paper is 30 mm/min and the sensitivity is about 3 mγ/mm for 1 cps signals. Each half day record of three components, dX/dt, dY/dt and dZ/dt, is registered on one sheet of the paper.

Another is a four-channel data-recorder of pulse-width-modulation type. It is divided into three parts, two recording parts and one reproducing part. The recording parts are installed at two observing stations, Memambetsu and Kanoya. The reproducing part is equiped at Kakioka and used to reproduce signals of tapes recorded at two observing stations on the pen-writing oscillograph or frequency analyser. The tape is drived with very slow speed of 7.6 mm/sec during observation but the tape speed of reproduce is raised up to 7.6 cm/sec or 19 cm/sec. The frequency response of the data recorder is dc-100 cps in reproduced signals, while dc-10 or 4 cps in the original. In the case of the usual tape-speed of 19 cm/sec the frequency of signals is raised by about twenty-five times, and then the reproduced signals become suitable for our analyser which has the lowest frequency-band of 5 to 500 cps. Namely our most interesting micropulsation pc-1, of frequencies from 0.2 to 5 cps is converted into the signal of 5 to 125 cps. The signal-to-noise ratio of the recorder is more than 45 db. The input impedance and maximum range are 500 kΩ and ± 1 Vpp, respectively. Then the filter output is given directly to the recorder.

§ 5. Device for analytical procedure

The analyser used here is Model 651 A Vibralyser manufactured by Kay Electric

Co., U.S.A. It has three frequency ranges. The lowest range is 5 to 500 cps and its analysing filter bands are 2 cps in narrow band and 20 cps in wide. Firstly, it offers us vibragram analogous to sonagram which is frequency-time display. Making

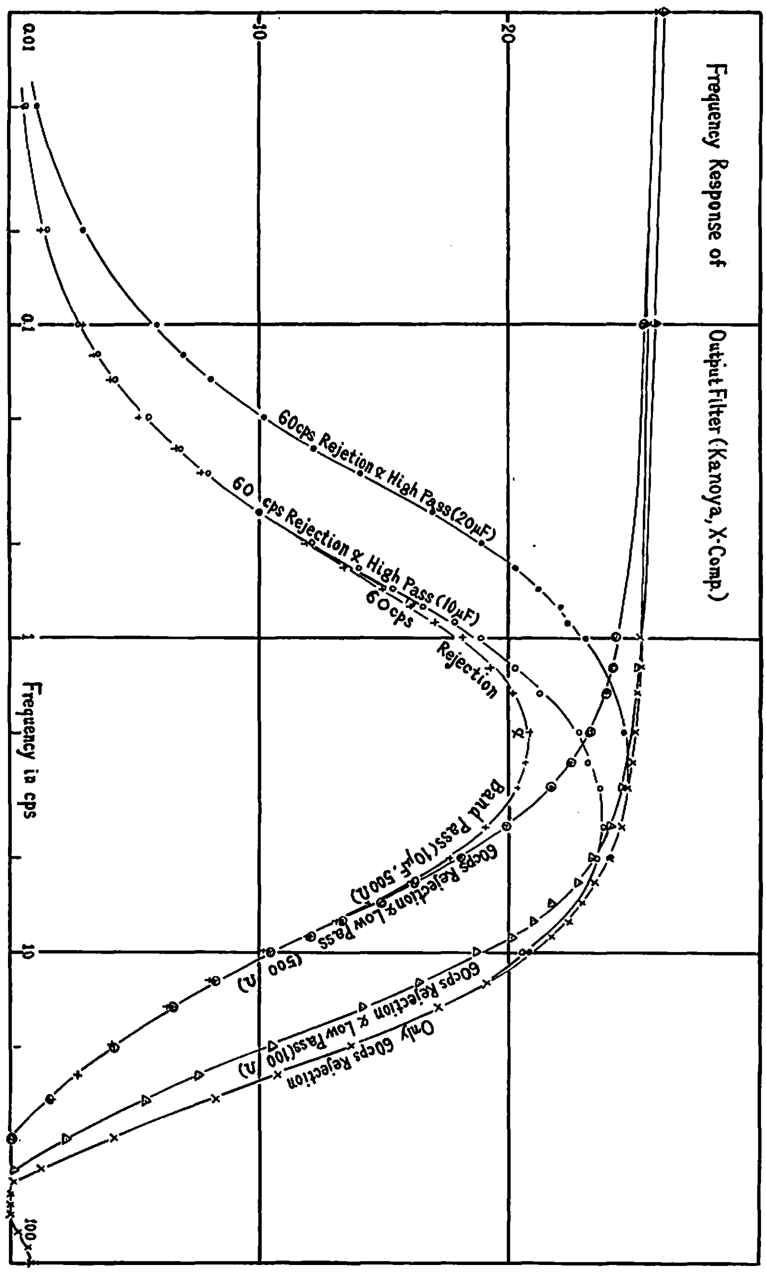

Fig. 6. Frequency response curves of output filter in arbitrary linear scale at Kanoya in some conditions which are shown in arbitrary scale.

use of Model 667A Scale Magnifier together with the analyser, the vertical frequency scale of selected portion of the diagram is expanded by the factor of 10. That is favourable for more detailed frequency analysis. Secondly another diagram of different type can be obtained. It shows the power intensity of each frequency at our required instant. The tape-records are converted into the vissible paper-records too with the most adequate time scales for the purposes of vector-analysis and others.

§ 6. Overall Characteristics

As shown in Fig. 5 the overall instrumental noise is less than 1 or 2 mγ for 1 cps, even when the input terminal of the input filter is open. The positions of detector are chosen so as to minimize the external noise as possible. But the external noises are usually 2 mγ in night hours and increase to 5 mγ in daytime, at both observing stations. It seems that the increase of the noise intensity in the daytime is mainly due to that of various man-made origins. And it frequently exceeds 10 mγ or more in the case of the meteorological disturbance, for example the thunderstorm occured in the vicinity. The measurements have to be stopped for a while in such

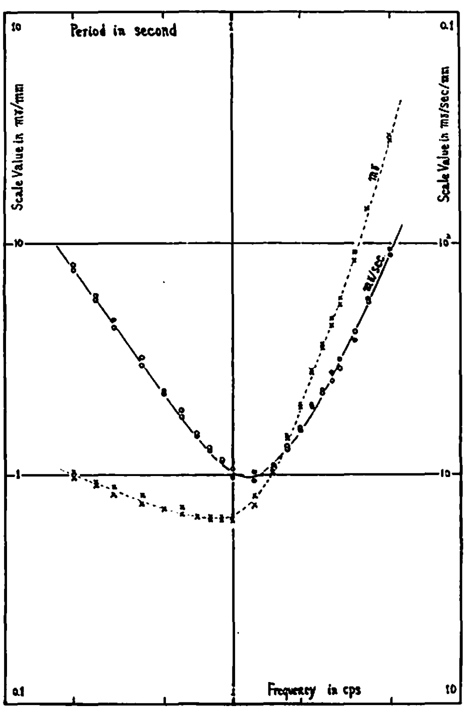

Fig. 7. Overall response curve of the whole device at Kanoya.

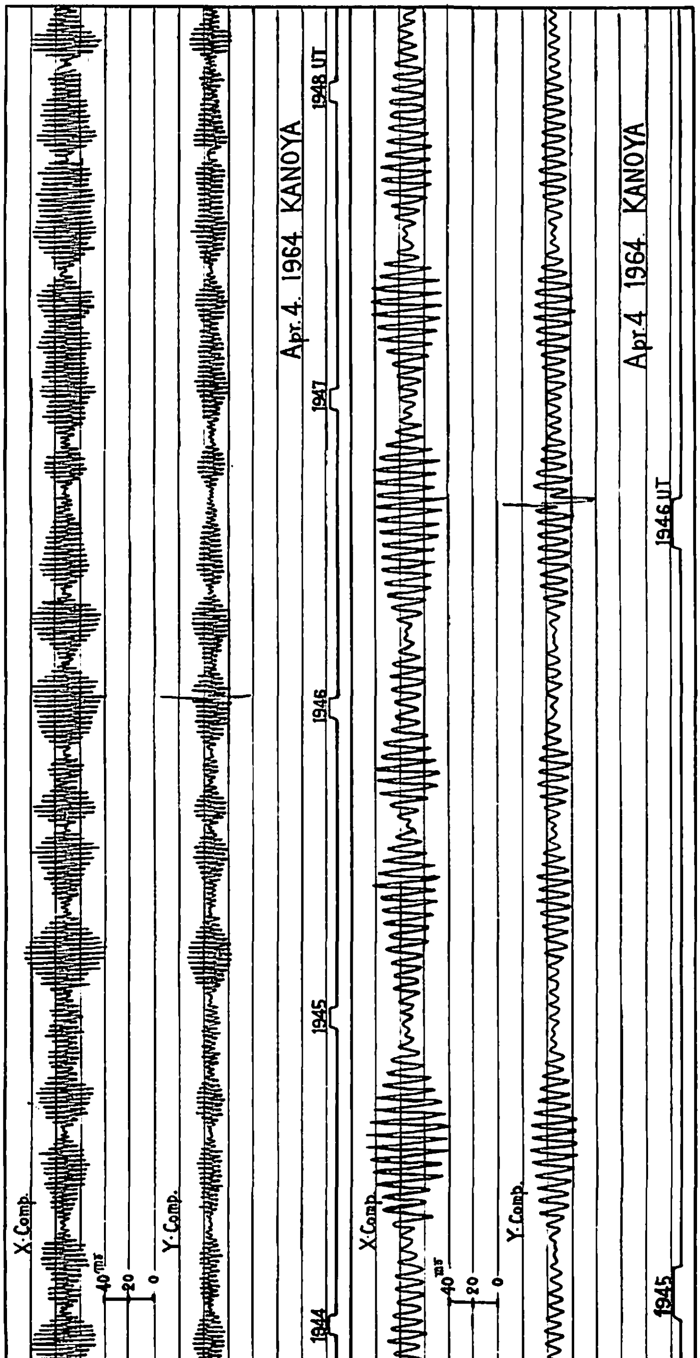

Fig. 8. An example of pc-1 pulsation at Kanoya.

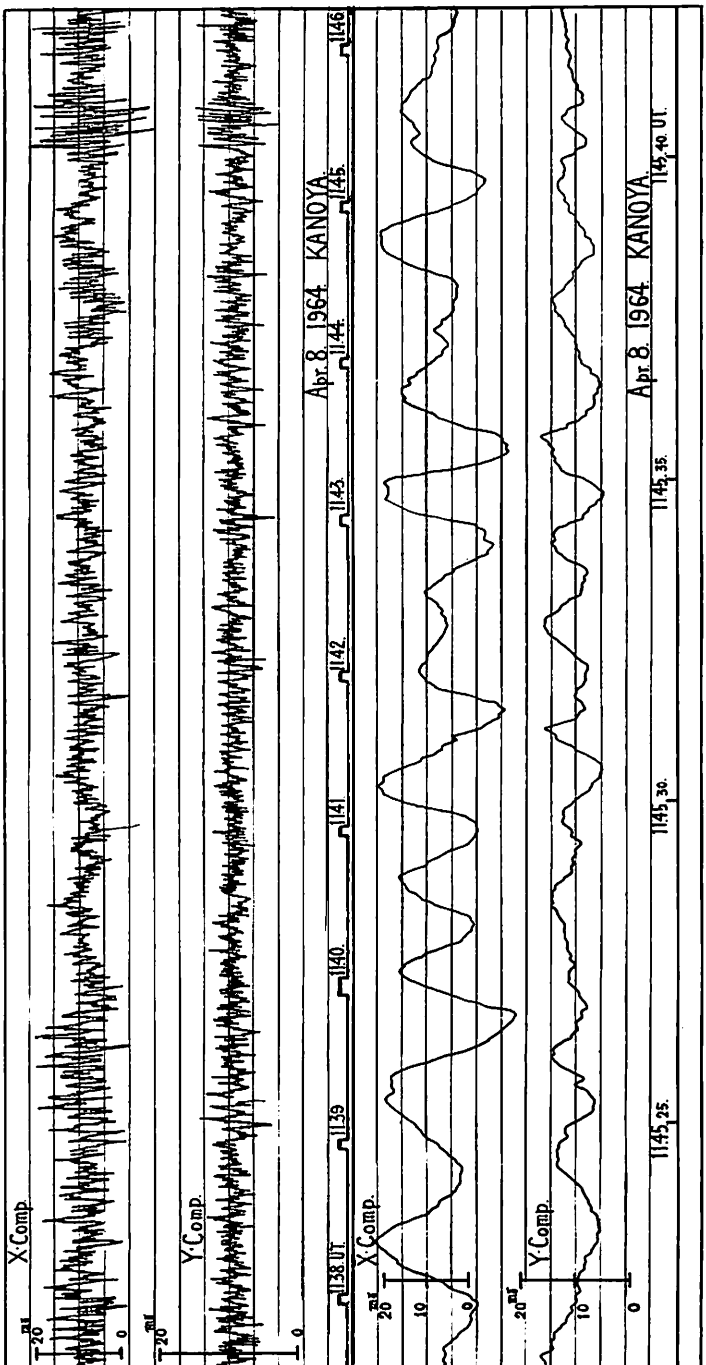

Fig. 9. An example of pi-1 pulsation at Kanoya.

severe condition because the excessive noise may damage the measuring circuits.

The overall response curve of our device is shown in Fig. 7.

The lowering of response at the d.c. side is due to the d.c. cut character of the output filter. In our observations such character is chosen in order to diminish the intensity of micropulsations with longer periods such as pc-3 and pi-2.

The ordinary double amplitudes of the interesting micropulsations are several ten milli-gammas at both observing stations. But in the most distinct phenomena they attain to about 100 milli-gammas. Then overall signal-to-noise ratio is generally, 20 to 30 db. Although the overall sensitivity can be increased without serious difficulty, the accuracy of measurement is not increased by higher sensitivity but determined mainly by signal-to-noise ratio.

Some examples of pc-1 and pi-1 recorded with the data recorder are reproduced in Figs. 8-9. In the lower half of each figure one portion with expanded time scale is shown.

As described above the external noises at both stations become, occationally, still considerably large. Moreover those noises may include the same frequency as our interesting natural signals. The fact seems to be due to that our apparatus has the maximum response at about 1 cps and that the circuit, especially the input circuit, is unbalanced at present. Therefore the adoption of some balanced circuit should be taken into consideration in the near future.

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1 cps 附近の地磁気地電流脈動の観測

1 地磁気短周期脈動の観測装置について

河村 譜 柏原静雄

概 要

柿岡地磁気観測所における IQSY 観測事業の一環として，周期1秒附近の地磁気，地電流脈動の観測が計画された。この報告では，そのうちの地磁気脈動の観測装置について述べる。これらの装置は女満別，鹿屋両出張所に設置され，現在観測が続けられている。