The Observation of ELF Electro-Magnetic Field from 3 to 30 cps (part I)

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Abstract

The ELF electro-magnetic field from 3 to 30 cps have been observed at Kakioka and Memambetsu during IQSY. These stations are not so far from commercial electric power line, but the observation can be done by the use of the strong filter, the low noise amplifier with the battery and the very low speed magnetic tape recorder.

The reliability of the received signal was checked by the simultaneous observations at three couples of far separated stations, Kakioka-Tateno, Kakioka-Chihama and Kakioka-Memambetsu.

The received signal consists of the basic oscillation of some mγ and the individual oscillation of about ten mγ or more. The occurrence frequency of this individual oscillation has daily variation, of which maximum is at about 15 h and minimum is at about 02 h (UT).

The sonagram of received signal shows that the ELF electro-magnetic field mainly consists of the Schumann's oscillation.

1. Introduction

The observation of electro-magnetic variation in the extremely low frequency band (ELF) has been carried out for long time. In the earlier year 1937, Watson and Watt observed this variation and many research workers have followed later.

During the IQSY (International Years of the Quiet Sun), the observation of ELF was scheduled as a part of the observation of ultra-quick geomagnetic variation at Kakioka Magnetic Observatory.

Many kinds of methods or apparatuses have been used to observe the ELF. Concerning antenna there are the vertical antenna [L.R. Tepley (1959)[1]; A.G. Jean A.C. Murphy, J.R. Wait and D.F. Wasmundt (1961)[2]; A. Egeland, S. Olsen and G. Gustafassen (1962)[3]], the loop antenna [G.S. Hawkins (1958)[4]; A. Egeland, S. Olsen and G. Gustafassen (1962)[3]], and the earth antenna [L. Lieberman (1956)[5]; K. Sao (1963)][6].

As the antenna is different with every workers, the amplifier or recorder is different as well. But all of them selected carefully the observation site which was far away from the artificial electrical device, such as the commercial power

line. Signals of ELF at such site were considered to be thus not disturbed by artificial noises.

It was very difficult to select such site in the premises of our observatory. The apparatus was designed so as to fit the observation site there.

2. Instruments

In the our early plan, the observation of magnetic variation of ELF band would be carried out at two stations, Kakioka (140°11.5′E; 36° 13.9′N) and Memambetsu (144°11.6′E; 43°54.5′N), but actually the magnetic variation has been observed by the loop antenna at Kakioka and the electric variation has been observed by the earth antenna at Memambetsu.

a) The instruments at Kakioka

i) The antenna and its setting

The loop antenna with high permeability metal core is used for this observation because the loop antenna without core needs to have large dimension. The structural sketch of the used loop antenna is shown in Fig. 1, and its characters are shown in the next table.

The characters of the Antenna

core	material	78% nickel-molybdenum permalloy (TMC-V, Tohoku Metal Industries, Ltd.)
	dimension	0.1 mm × 10 mm × 2000 mm × 100 sheets
coil	wire	Polyvinyl-formal wire, diameter is 1 mm
	No. of turn	pick-up coil 3000 turns
		calibration coil 10 turns
impedance		51.5 Ω at 10 c/s
effective area		0.96×10^7 cm^2

The induced voltage in the antenna is led to the input terminals of the amplifier through the polyethylene vinyl sheathed coaxial cable which is buried in the ground. The sensitivity of the antenna is determined in such a way that it is put into the long solenoid coil which makes known uniform magnetic field. The diameter of the solenoid coil is 30 cm and length is 4 m.

To select setting place of the antenna, it has to be considered that the place

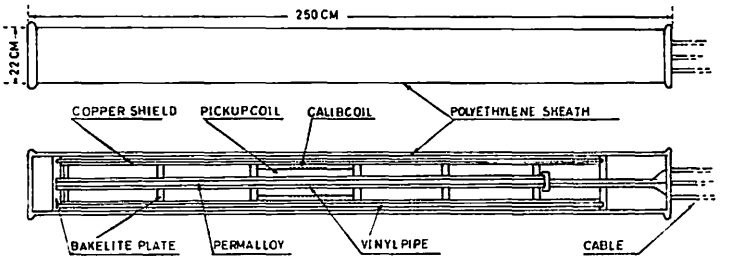

Fig. 1 The antenna of ELF (loop-antenna).

must be not so disturbed by the artificial 50 cps noise, and be convenient for observation.

At first, the distribution of 50 cps noise in the premises of our observatory was investigated. It was carried out with a loop antenna, of which dimension was nearly same as above mentioned, and a detector which was the 50 cps selection amplifier (AV-13, Y.E.W.). Fig. 2 shows the distribution of the vertical component of 50 cps noise which was detected by such way, but the value expressed by the unit of μV is not so accurate that it seems to show the order of it. As this figure shows, the effect of the 3300 V power line is so strong that the antenna place must be far away from this line. (A) point shown in Fig. 2 seems to be in good condition for the observation because the disturbance of 50 cps noise is not so strong and the vacant hut (B) is available near by. Nevertheless the 50 cps rejection filter of -50 db or more must be used to observe natural ELF phenomena at this point.

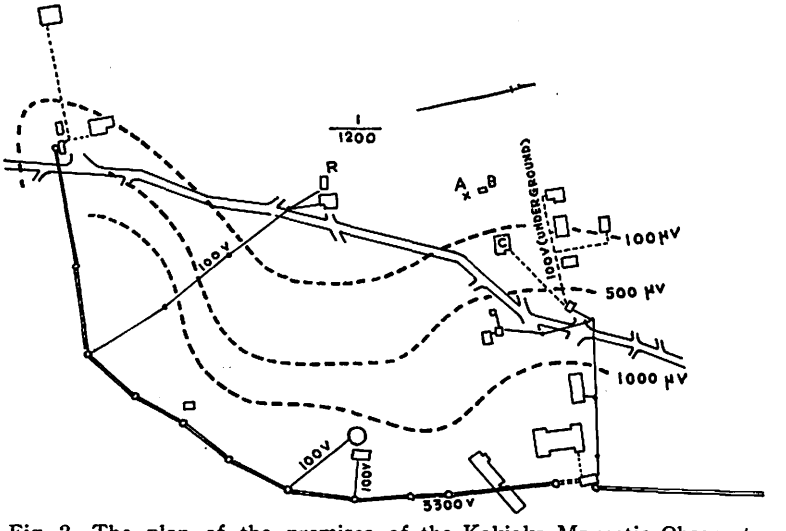

Fig. 2 The plan of the premises of the Kakioka Magnetic Observatory and the distribution of 50 cps noise.

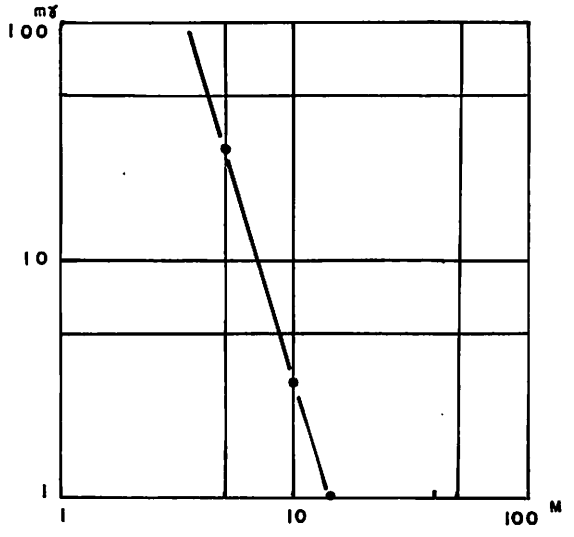

Fig. 3 The rate of decrease of the pulse coming from the artificial noise source.

Again it was necessary to know the order of the noise which was originated from the operation of electrical instrument, such as the on-off of the swich, made in the observation building near the antenna. This was checked as follows. The currents of 54 mA. was supplied intermittently to the loop coil of 1300 turns and 10 cm in diameter. The antenna of ELF detected the pulse due to the switching of the current supplied to the coil. The distance of the coil from the antenna was changed, then the rate of decrease of the detected pulse by the antenna was measured (Fig. 3). It seems from this figure that if the antenna is farther from

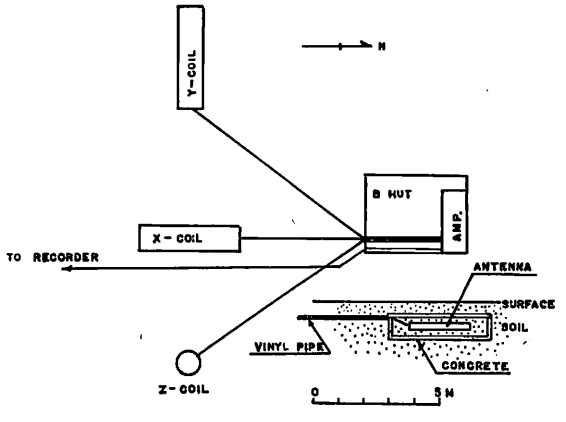

Fig. 4 The arrangement of the loop antenna.

the source of the pulse than 50 m, the large pulse will not be detected by the antenna. And it was also checked that when the instrument set up in the building C (in the Fig. 2) was operated, no disturbance was detected by the antenna at the A point. Then it was determined that the antenna was set up at the A point and amplifier was installed in the B hut. The recorder was laid in the R hut (Fig. 2) in order to avoid heavy influence.

Fig. 4 shows the arrangement of three antennas of coil which are about 1 m under the ground and separated about 5 m each others.

ii) Amplifier

The characteristics of the amplifier is considered to be as follows when the characters of the antenna is taken into consideration. The input impedance is about

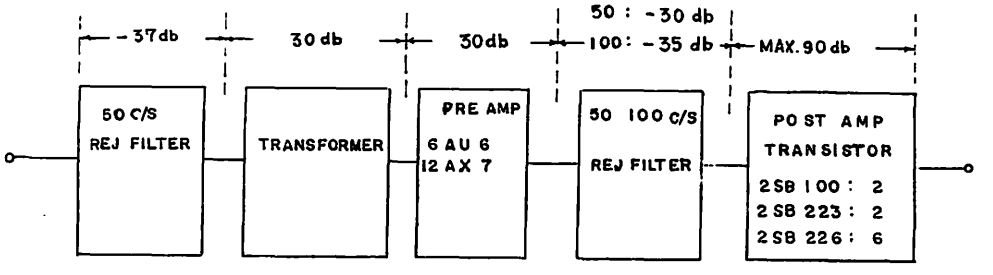

Fig. 5 The block diagram of the amplifier and its' gain for loop-antenna.

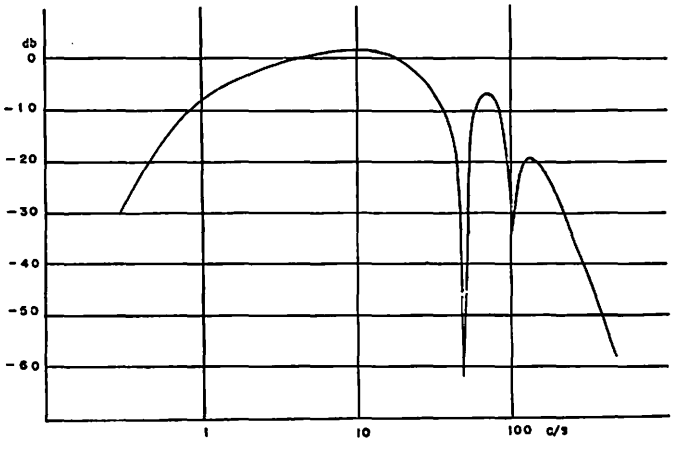

Fig. 6 The frequency response of the amplifier.

50 Ω, the frequency response is flat in the range from 1 to 100 cps and the gain is about 150 db at maximum. But the rejection of 50 cps and the C-R coupling limit

the frequency range from 3 to 30 cps. The construction and the gain of the acutually designed amplifier is shown in the block diagram (Fig. 5). The input transformer, the core of which is high-μ-metal troidal core (TMC-V, Tohoku metal Ltd.), has the gain of 30 db in voltage for the range from 1 to 100 cps. The battery is used as the electric power to avoid the 50 cps hum. Fig. 6 shows the frequency response of the amplifier.

iii) Recorder

The magnetic tape recorder is used, because a visible pen-writing recorder needs large amount of recording paper. Frequency analysis is easy in this case and the necessary wave form of the signal can be reproduced on the pen-writing-oscillograph.

The necessary condition of the recorder considered initially was the following, 1) S/N must be 50 db or more. 2) The frequency response is flat from 1 to 100 c/s. 3) The record must continue automatically through the period of 12 hours or more. The third condition is higher importance for routine observation.

The recorder was designed and manufactured by Shiroyama electronics industrial Co. under the said condition. It has following charactaristics.

1. The frequency response for recording and reproducing : flat, from 1 to 100 cps ±3 db
2. The tape speed : for recording, 7.6 mm/sec ±1%
   : for reproducing, 19 cm/sec or 7.6 mm/sec
3. The recording method : A-C biased recording
4. The reproducing method : Variable reluctance head and Velocity head
5. Number of channel : 2 channels
6. The recording hours : 12 hours or more by 7-inch tape (370 meters length)
7. Input impedance and level : 100 kΩ or more, and 0.2 Vrms at natural condition
8. Output impedance and level: 500Ω or less, and 5 Vrms at natural condition
9. S/N : 40 db
10. Distortion factor : 4%

This recorder is not enough to satisfy our plan concerning the number of channel, S/N and the distortion factor, so that another magnetic tape recorder, PWA-23, SONY, which has four channels but whose recording hour is about half an hour is used together with this sometimes.

The overall construction of the observational equipment is shown in the block

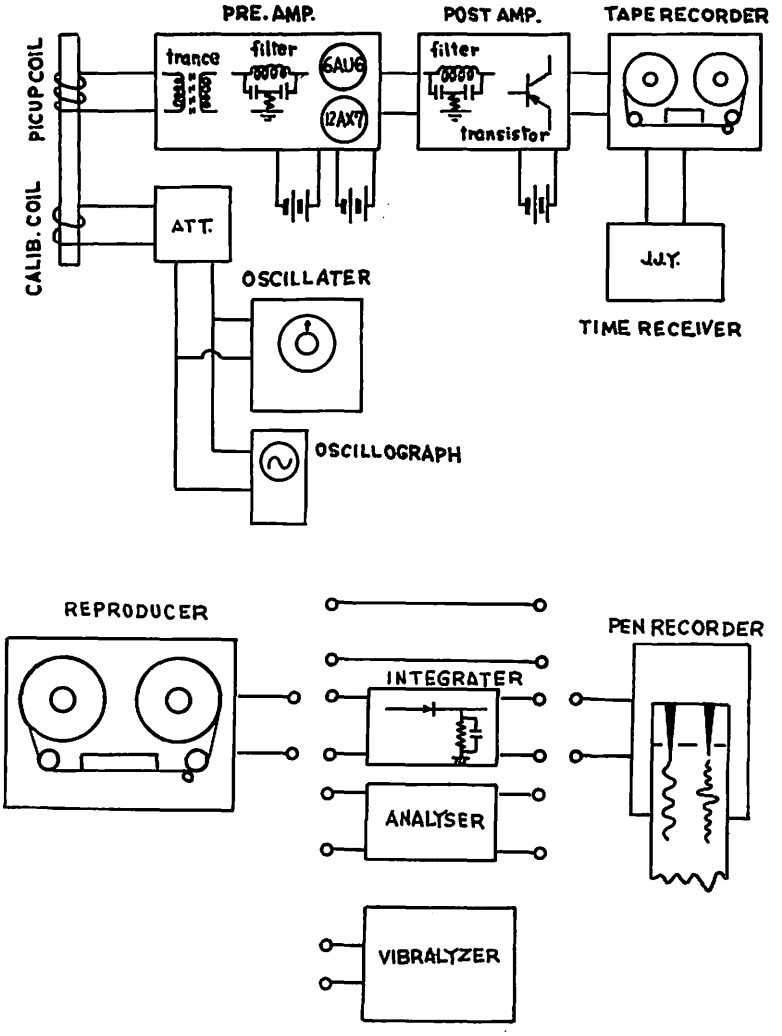

Fig. 7 The overall construction of the observational equipment with the loop antenna.

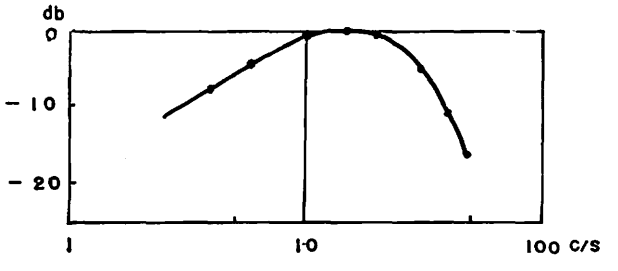

Fig. 8 The overall frequency response of the equipment with the loop antenna.

diagram of Fig. 7, and the overall frequency response is shown in Fig. 8.

b) The instruments at Memambetsu

The observation of Memambetsu is carried out with the instruments of earth-current for micropulsation measurement. But the pass-band of the filter of this instruments was different initially with ELF, so it was necessary to change this filter to fit the ELF band.

The detail of this instruments will be reported in the final report together with the ultra-quick-run observation of earth-currents. Here it is outlined briefly.

i) Antenna

This antenna is what is called the earth antenna, ot which the span of the

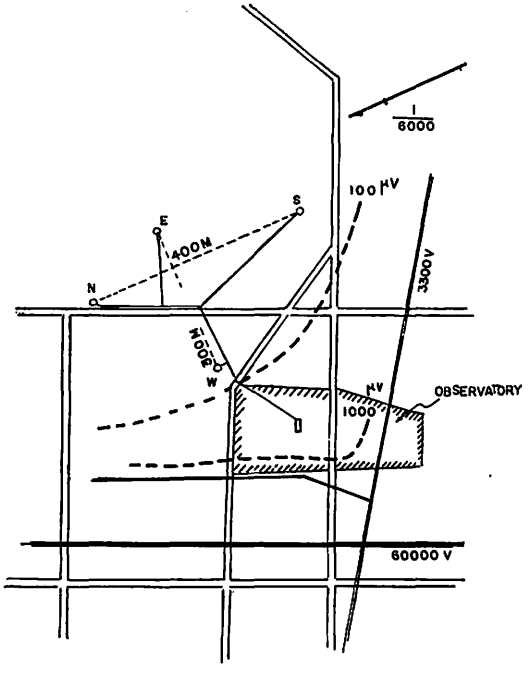

Fig. 9 The plan of the Memambetsu observatory and its neighborhood, and the distribution of 50 cps noise.

base line of North-South direction is 400 m and that of East-West direction is 300 m. Three carbon rods (M1-K, Matsushita Communication Ind. Co. Ltd.) are used as one electrode which is buried 2.5 meters under the ground.

The arrangement of electrodes, the position of power lines and the distribution of vartical component of 50 cps noise around the Memambetsu observatory are shown in Fig. 9.

ii) Amplifier

The earthing of the instrument is most troublesome matter when the earth antenna is used. It is necessary that the recorder's earth is separated from the antenna electrodes as much as they can. In this instrument, this separation is done by the use of a solid state amplifier and coupling tramsformer. But this transformer's response is the next trouble. The response is satisfied by the use of TMC-V troidal high-μ-metal core specially designed for this use.

iii) Recorder

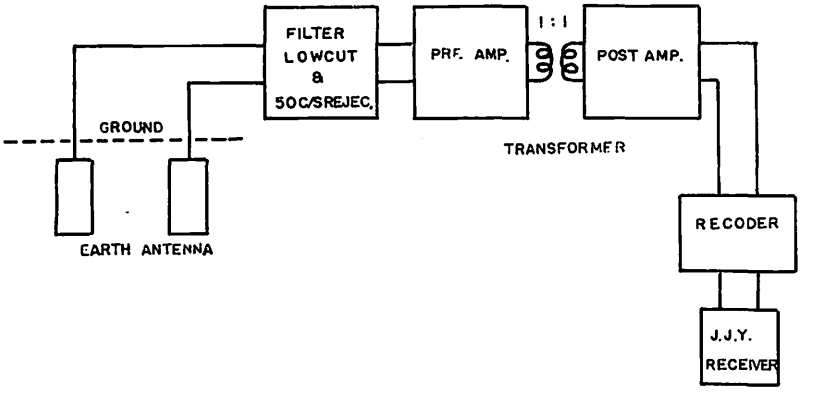

Fig. 10 The overall construction of the equipment with the earth-antenna.

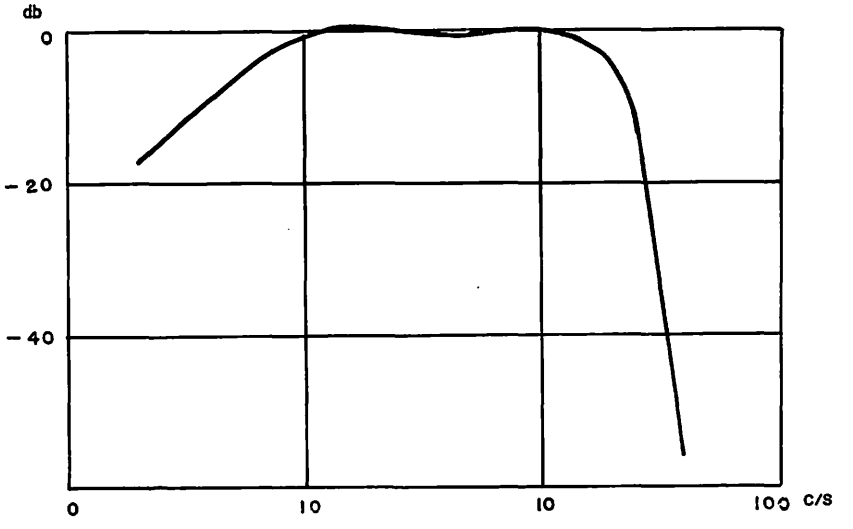

Fig. 11 The overall frequency response of the equipment with the earth-antenna.

The Shiroyama's magnetic tape recorder is used again.

The block diagram of the overall construction of this equipment is showen in Fig. 10, and the overall frequency response is showen in Fig. 11.

3. Preliminary observation

a) The reliability of the received signal

The frequency band of the ELF is near the 50 cps which is the frequency of

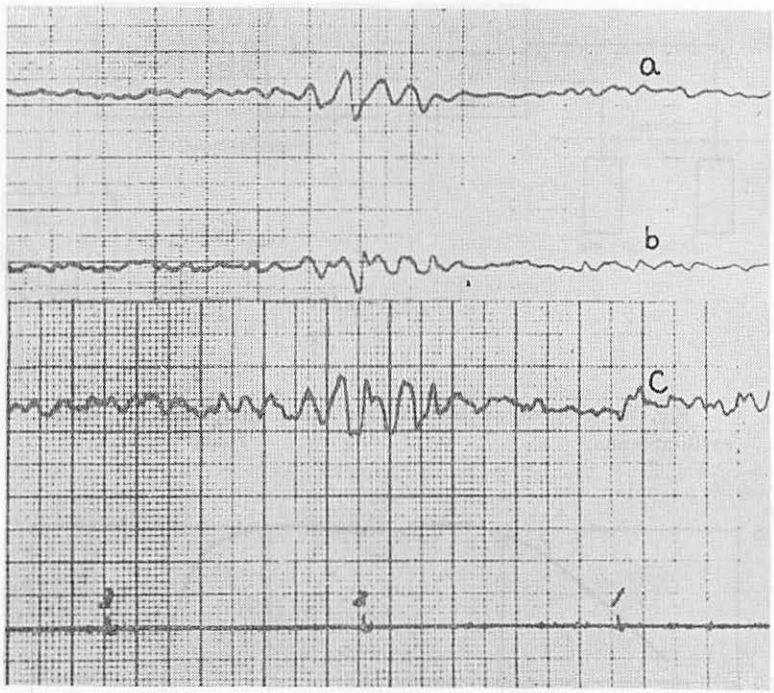

Fig. 12 An example of the record on Sep. 21, 1963 at Kakioka and Tateno.

commercial electric power, so that it is most troublesome matter whether or not the received signal is disturbed and lost its reliability by the noise which is originated from artificial electrical device. The reliability of the received signal will be directly justified by the comparison of signals which are received simultaneously at two separated stations.

The first simultaneous observation was carried out at Kakioka and Tateno (140°08′; 36°15′N), which is about 20 km apart from Kakioka, on Sep. 20-21, 1963. The observation at Tateno was disturbed by the instrumental trouble. But

the correspondency between the signals at two stations was 90% or more. And the comparison between the signals received by the loop antenna and the earth antenna was carried out too. Fig. 12 shows an example of the records at this time. a) is the record by the earth antenna at Kakioka. b) is the record by the loop antenna at Kakioka and c) is that by the loop antenna at Tateno.

Next simultaneous observation was done as a joint research with the Nagoya University on Nov. 28, 1963 at Kakioka and Chihama, which is the seashore in the Sizuoka Prefecture. The distance from Kakioka is about 250 km. Chihama is in the so-called sand hill region and very far away from the commercial power line. Therefore the observation at Chihama seems to be not disturbed by artificial noises. The signals at the both stations are in good correlation. It is confirmed then that the received signal at Kakioka is not so disturbed by artificial noises.

During the IQSY, the simultaneous observation at Kakioka and Memambetsu has been carried out on the RWD (Regular World Day) since Sep. 1964. As a method of the analysis of the received signal, the signal is integrated with the rectifier whose time constant is 3 second, then this rectified voltage is recorded on pen-writing-recorder. An example of this record is shown in Fig. 13. As this figure shows, the signals observed at both two stations are in good agreement. Thus the

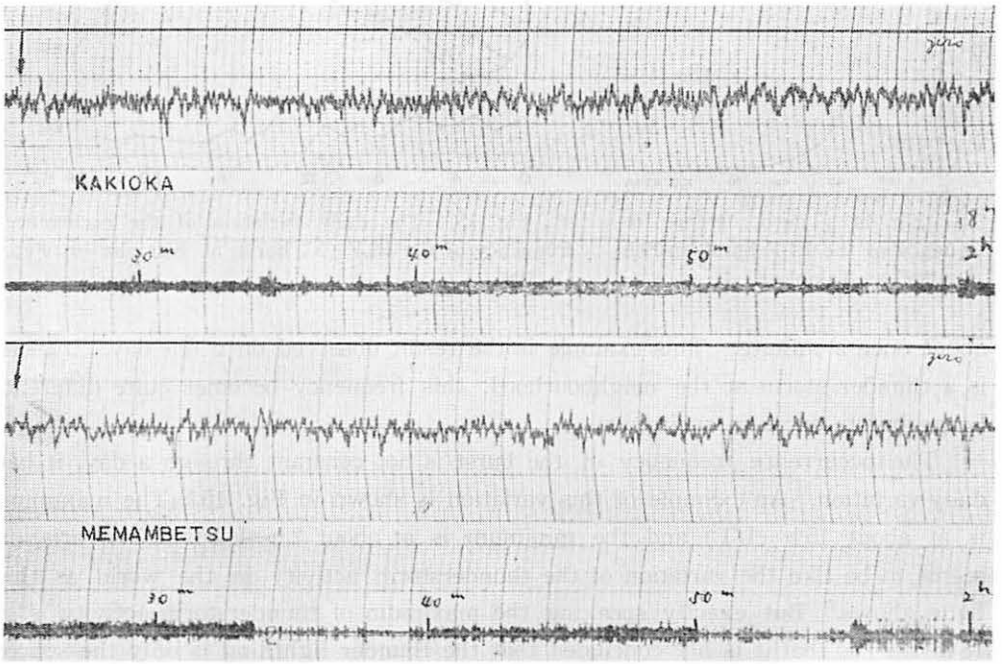

Fig. 13 An example of the integrated record at Kakioka and Memambetsu Feb. 10, 1965.

received signals at both stations seem to have good reliability.

b) Some characters of signal

i) Occurrence frequency of the burst

The received signal consists of basic oscillations of some $m\gamma$ and the individual regular or irregular oscillation of about ten $m\gamma$ or more. Here this individual signal will be called burst. An example of the occurrence frequency of the burst is shown in Fig. 14. It seems that the burst, which has intensity of 40γ or more, occurs

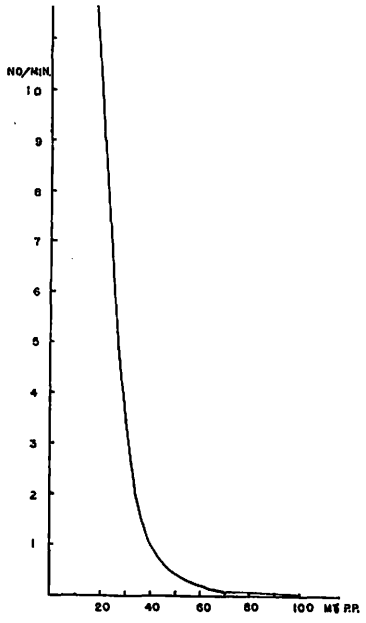

Fig. 14 The occurrence frequency of the ELF burst on Feb. 3, 1965 at Kakioka.

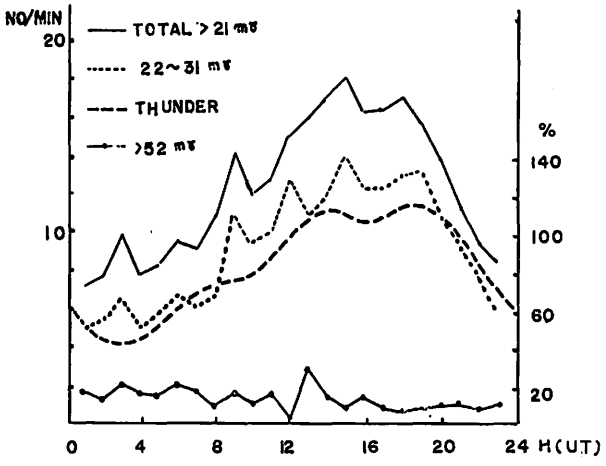

Fig. 15 The daily variation of the occurrence frequency of the ELF (X) burst at Kakioka on Feb. 17, 1965.

about once a minute. This example is the result observed on a fine day. If there is a thunder storm at the neighbourhood, this frequency becomes quite different. Large bursts occur in succession.

The occurrence frequency of the burst is not constant through a day, it has daily variation. An example of this variation is shown in Fig. 15. The maximum is at about 15 h (UT) and the minimum is at about 2 h (UT). This variation seems to be like the variation of the thunderstorm activity in the world as this figur shows. But exactly speaking the maximum of thunderstorm activity is at 18 h (UT) so that it is not concluded that the thunder lightning is only the source of the ELF burst.

ii) Frequency analysis of the signal

As the phenomena of the electro-magnetic variation in the ELF band, the

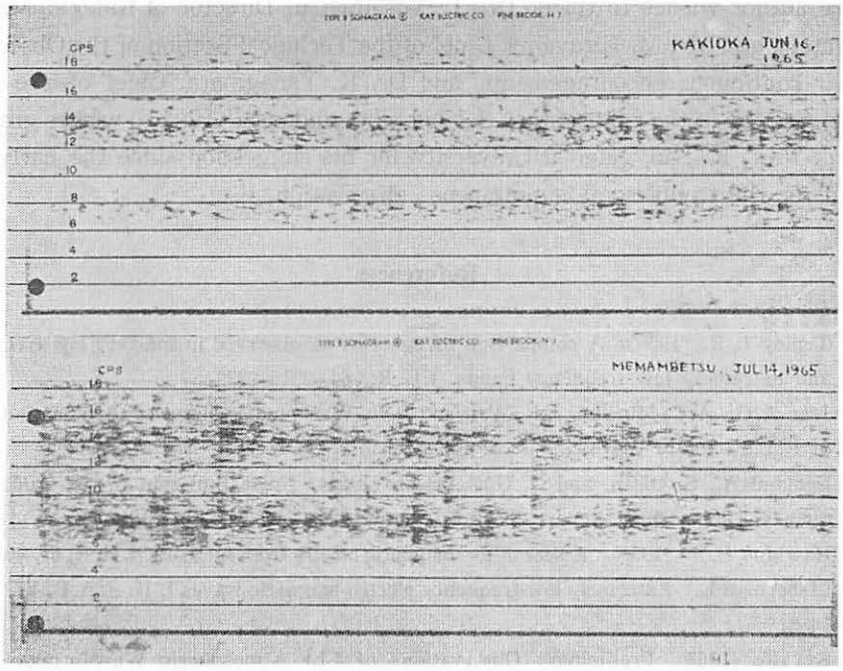

Fig. 16 An example of sonagram of received signal at Kakioka and Memambetsu.

Schumann's oscillation is well known. An example of frequency analysis of the signal with the Vibralyzer, Kay Electric Co, is shown in Fig. 16. As this sonaglam shows, it can be said that the signal mainly consists of frequency of about 8 cps and 14 cps. These frequencies are consistent with the Schumann's oscillation.

3. Conclusion

The instrument which is used during the IQSY is reported. The more detailed analysis of the signal will be reported in the next paper.

Here it is concluded that the observation of the ELF can be carried out at the station which is not so far from commercial electric power lines, and that the received signal mainly consists of the Schumann's oscillation.

Acknowledgements

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ELF 帯電磁場 (3-30 cps) の観測 (I)

近 藤 五 郎

概　　要

IQSY 期間中用いた ELF 観測の装置について報告する。ELF 帯は商用電源周波数に近いので，それの混入によって受信信号の有意性が失なわれるのが最大の懸念であったが，フイルターの使用によって一応観測出来た。この有意性は，柿岡一館野，柿岡一女満別，とくにいわゆる砂丘地帯である千浜と柿岡との同時観測によって確められた。

この電磁変化の細かい分析は次に報告する予定であるが，とくにこの周波数帯の電磁波はいわゆる 8 c/s, 14 c/s のシューマン振動から成り立っていることが確められた。