THE OBSERVATION OF ELF-VLF RADIO WAVES WITH SOUNDING ROCKET

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Abstract

Since December 1963, the observation of ELF-VLF Waves in the ionosphere had been carried on by the sounding rockets of L-series type. However, only the data of L-2-2 launched on Dec. 11, 1963, were available, the other observations having been missed by the damages of the rocket or the telemeter system. This paper describes the method of the observation and the data obtained by the L-2-2 Rocket.

1. Introduction

At low latitudes, it is difficult to observe the phenomena of electromagnetic wave, ranging ELF-VLF, in the ionosphere and the exosphere, because of the screen effect of the ionosphere. But, in this range, there are many electromagnetic phenomena such as whistlers or VLF emissions giving the geophysical information in the exosphere. It is, therefore, very important to study such phenomena to develop the space science and technology.

For this purpose, it was planned to observe the electromagnetic wave in the ionosphere or the exosphere with the sounding rocket and to study the effect of the ionosphere and exosphere by comparing with the simultaneous observation on the ground. The frequency range which would be interesting is less than 10 kc/s and the items of observation are divided into two groups. The one is the characteristics of frequency vs time variation of the discrete phenomena such as whistlers, chorus or risers, and the other is the characteristics of the frequency distribution and the time or space variation of the continuous phenomena such as hiss, etc. For the former, the wide band telemeter system up to 10 kc/s is needed and for the latter, many narrow telemeter channels. But the telemeter system under employment in Japan, has the bandwidth of only 200-300 c/s and the channel numbers of 10-12. Moreover, the telemeter channels allocated to an item of observation are 3 or 4 at the most. Therefore, two channels are selected at ELF and VLF bands, respectively and the electromagnetic phenomena of the bandwidth of 200 c/s are telemetered to the ground at these frequencies.

Up to the present, only the data of L-2-2, launched on Dec. 11, 1963, were available, the other observations having been missed by the damages of the rocket or the telemeter system.

This paper describes the data obtained by the L-2-2 Rocket.

2. Observing method

The observing method used in L-2-2 is as follows: As mentioned above, because of narrow telemeter band, 400-600 c/s at ELF band and 3.0-3.2 kc/s at VLF band are picked out for samples covering the whistler band. The characteristics of the frequency vs time variation and the average intensity are measured at these two frequency bands. The block diagram of the observing apparatus is shown in Fig. 1. For the antenna, shown in Photos. 1-2, is used a flying-out whip of 3 meters long and the other input terminal of the receiver is earthed to the body of the rocket. The output from the antenna is supplied to the pre-amplifier installed near the antenna, transformed to low impedance and introduced to the main amplifier by a

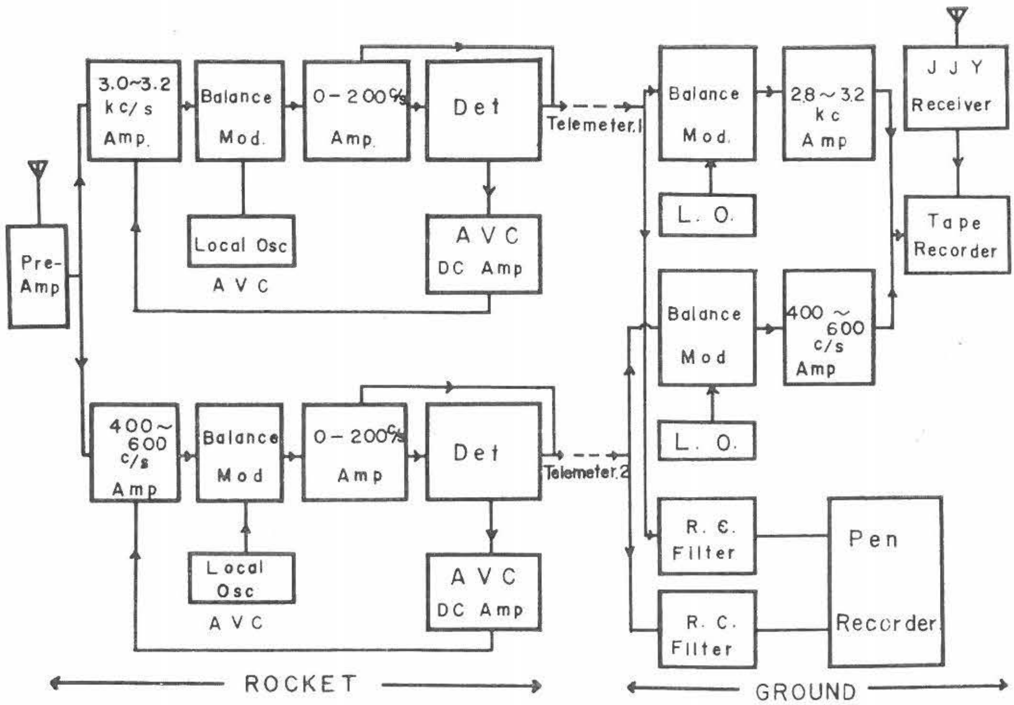

Fig. 1. Block diagram of observing apparatus

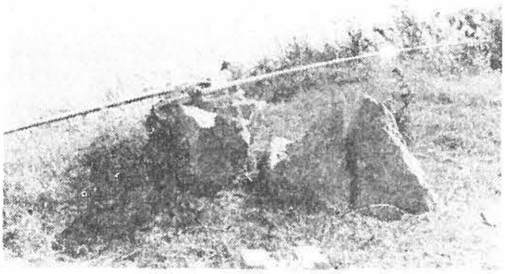

Photo. 1. Whole view of antenna

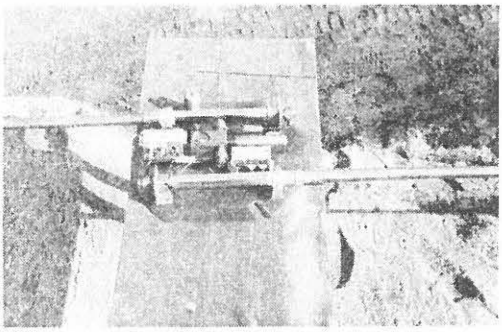

Photo. 2. Flying-out apparatus of antenna

teflon coaxial cable of about 70 cm. The effective capacity of the antenna is 30 pF and the effective height 1.4 m. The main amplifier is of the straight system and has the gain of about 100 db. The dynamic range of this amplifier is 60 db. As an example, the amplitude characteristics of the amplifier of 400-600 c/s channel are shown in Fig. 2. Photos. 3-4 show this transisterized amplifier constructed by print circuit technique. Considering the effects of spin or precession of the rocket, it was decided that the charging time constant should be 30 mSec., the discharge time

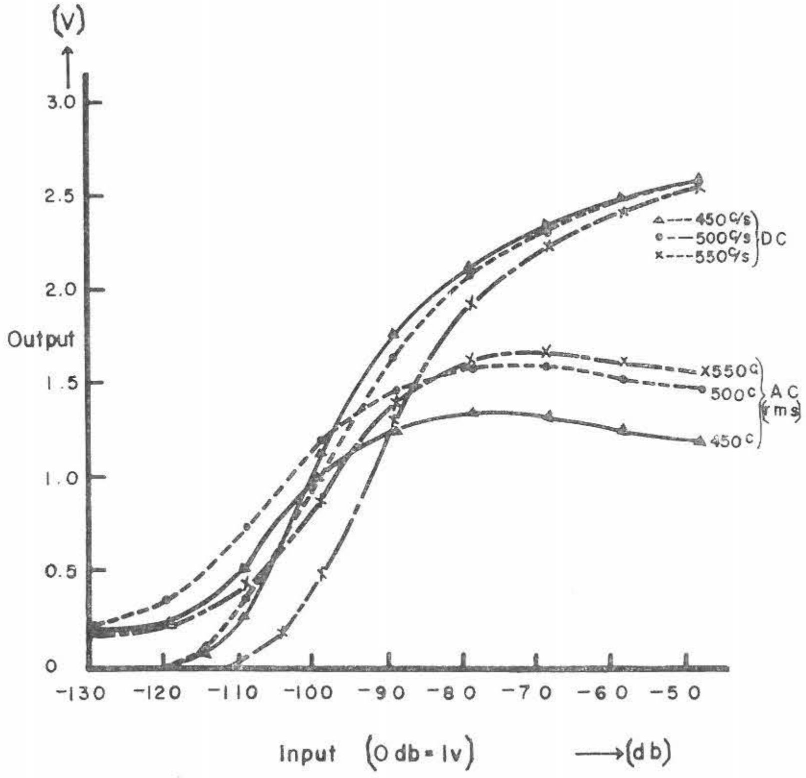

Fig. 2. Amplitude characteristics of 400~600c/s band

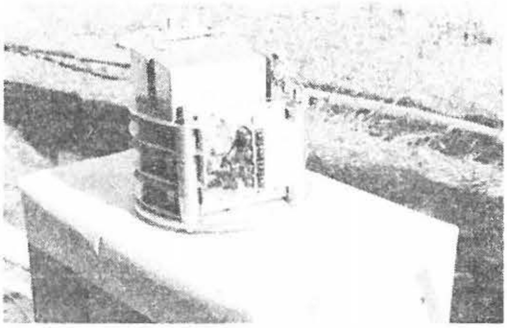

Photo. 3. Main observing apparatus

Photo. 4. Print circuit of the receiver

constant 0.2 Sec. and the time constant of AVC circuit 1.5 Sec. The receiving signals of 200 c/s bandwidth at 400-600 c/s and 3.0-3.2 kc/s were detected by the detecting time constant described above, transformed into D. C. outputs and supplied to two input terminals of the telemeter transmitter, respectively. Besides, this receiving signals of 400-600 c/s and 3.0-3.2 kc/s were transformed into two frequency ranges of 30-200 c/s by the balanced modulators and superposed on the above D. C. output signals, telemetered to the ground, respectively. By this method, 4 telemetering signals were transmitted by 2 telemeter channels.

At the ground station, these signals from the telemeter system were divided into 4 channels by filters and 2 signals of D. C. were supplied to the pen-recorder and again, 2 signals of 30-200 c/s were transformed into 400-600 c/s and 3.0-3.2 kc/s by means of injecting local oscillating frequencies of 400 c/s and 3.0 kc/s, respectively. And these outputs were recorded by the tape-recorder of two channels. The tape-recording signals were analysed by the Sona-graph.

3. Observing results

3. 1. Whistler observation

Simultaneous observation on the ground was carried out at Higashi-Kushira, 17 km away from Kagoshima Space Center. Fortunately, from Dec. 9, the whistlers have been observed in the afternoon at Higashi-Kushira. Because the launching time was decided at 14.00 J. S. T., the chance for observing the whistlers increased. On 3.0-3.2 kc/s band, the whistlers were detected distinctly, but on 400-600 c/s band, no whistler could be observed because of high interfering noises. It was, therefore, impossible to measure the difference of dispersion of whistlers between the rocket and the ground. The dispersions of whistler observed at Higashi-Kushira were 25 on Dec. 9, 10 and 30 on Dec. 11. An example of Sona-gram of whistler observed at Higashi-Kushira is

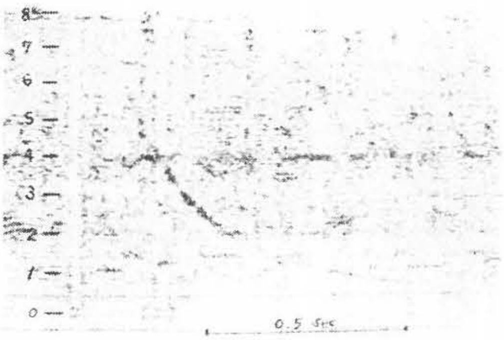

Photo 5. Whistler observed at Higashi-Kushira

Photo. 6. Whistler observed by rocket

Table 1. Comparison of observing whistler between the rocket and the ground.

Time	Altitude	Rocket	Higashi-Kushira
14h 00m 48s	53km	×	○
57s	74km	×	○
01m 48s	180km	○	○
03m 26s	335km	○	○
04m 59s	397km	○	○
06m 39s	382km	×	○
* 07m 12s	361km	○	×
* 16s	358km	○	×
* 50s	326km	○	×
08m 19s	290km	○	×
* 24s	285km	○	×
42s	258km	○	×
43s	256km	○	×
* 52s	240km	○	×
* 59s	230km	○	×
09m 18s	190km	○	○
32s	160km	○	○
10m 30s			○
42s			○
56s			○

* shows uncertain whistlers
○ shows receiving of whistler
× shows none of whistler

shown in Photo. 5. On the rocket, the whistlers observed on the ground were entirely detected. Moreover, the other whistlers missed on the ground were detected. An example of the record of whistlers observed by the rocket on 3.0-3.2 kc/s is shown in Photo. 6. But, in the latter half of the flight, interfering noises due to a trouble of the telemeter were mixed up with the telemeter signal. Therefore, the results obtained may be somewhat uncertain, but are shown in Table 1.

3. 2. Average level of electromagnetic wave

An example of the telemetering record of average level of electromagnetic wave is shown in Fig. 3. As shown in this record, on 3.0-3.2 kc/s band, the average level recorded the value of 32 db (0 db = 1 micro-volt/meter and so on) at the altitude of 105 km in 70 Sec. after launching, and thereafter, this level did not exceed 0 db and the telemeter signals faded away after recording 48 db on descending near the sea in 610 Sec.

On the other hand, on 400-600 c/s band, the average level recorded the saturating value of more than 70 db at the altitude of 100 km in 68 Sec., when the rocket penetrated into the ionosphere and showed the value of 39.5 db at 130 km in 78 Sec.

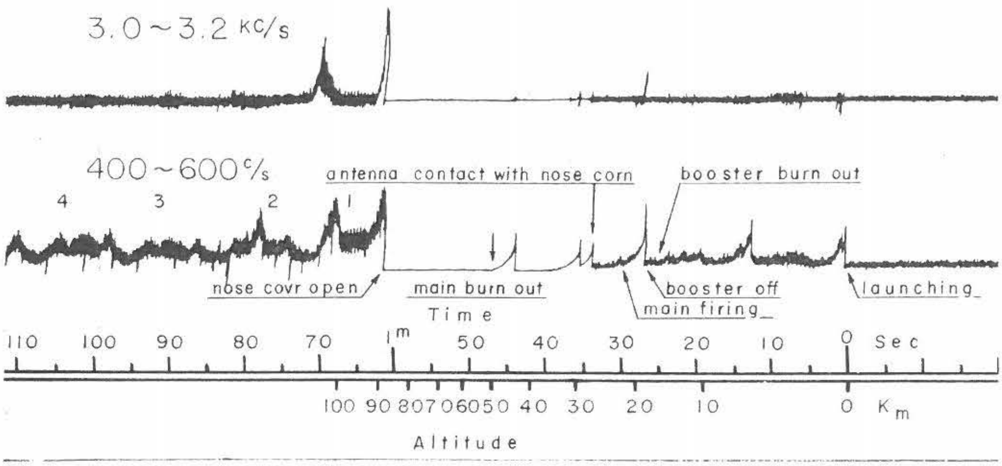

Fig. 3. Record of average level

After that, the recording level repeated the oscillation between maximum and minimum values. The maximum values of the record became greater with increasing altitude of the rocket, but the minimum values were almost constant. And the db values of maximum were proportional to the altitude in both ascending and descending of the rocket. These results are shown in Figs. 4–5. These periods of the record are in agreement with that of the precession of the rocket, but the wave forms of the record contain tolerable harmonics which is considered perhaps due to the effect of the body of the rocket. From these observing results, it may be suggested that the electromagnetic wave having uniform wavefront exists in the ionosphere and its intensity increases with the altitude. It has been shown that the strong electromagnetic waves below 1 kc/s have been measured by foreign workers. Therefore, the wave of 400–600 c/s band observed by us is to be regarded as the same one as obtained by foreign workers. In order to confirm this fact, it is clear that more detailed observations with the sounding rockets are needed.

4. Conclusion

For L-3-1 Rocket, launched in July, 1964, the same method was employed as for L-2-2, but no data could be obtained because of the damage of the telemeter. In order to measure the value of dispersion and the frequency band of hiss, more than two sampling channel numbers are needed for covering the measuring frequency range. Therefore, by L-3-2, scheduled for Jan. 1965, the observation of radio wave in the ionosphere will be made at 5 frequencies of 500 c/s, 1 kc/s, 1.5 kc/s, 3.5 kc/s and 8 kc/s, and by L-3-3, scheduled for March 1965, the observation will be made at 500 c/s, 1 kc/s, 2 kc/s and 3.5 kc/s. To avoid the interfering disturbances from other

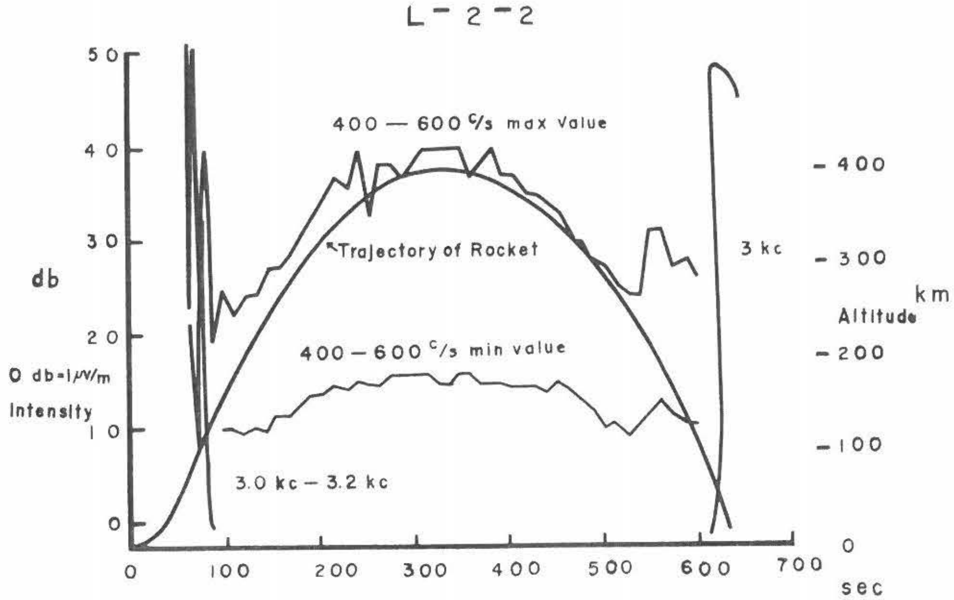

Fig. 4. Intensity of average level

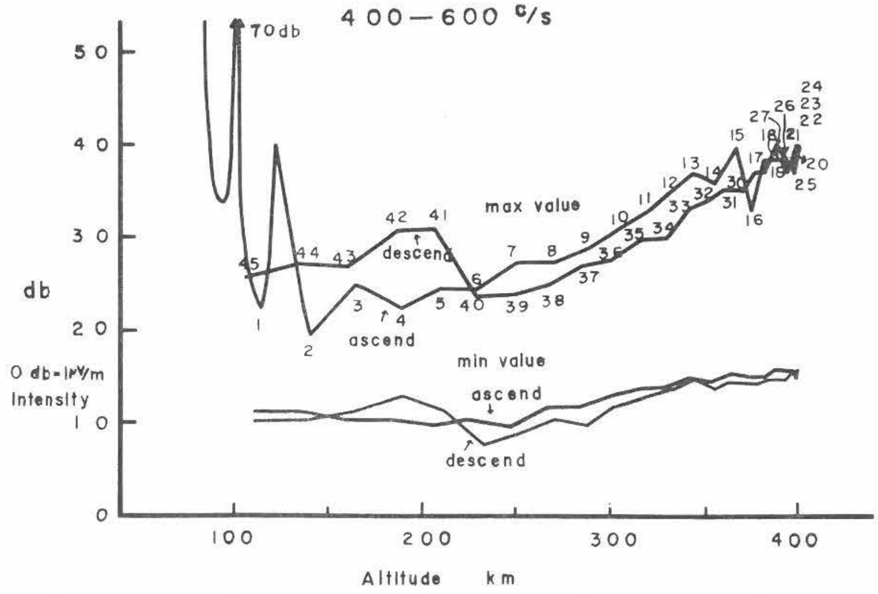

Fig. 5. Average level vs. altitude characteristics

apparatus ridden together, the rocket of exclusive use for observing the radio wave phenomena has been urgently needed. On the other hand, because of the unknown characteristics of the whip antenna in the plasma, a loop antenna for loading on the rocket must be used for quantitative measurement of the intensity of radio wave.

In order to solve these troubles, it is decided that the rocket of exclusive use for observing the radio wave phenomena be launched in Feb. 1965. In this rocket, the loop antenna of 1.3 meters square and a wide band telemeter of from 400 c/s to 10 kc/s will be installed.

More detailed observations with these rockets will be carried on for studying the radio wave phenomena in the ionosphere or exosphere.

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Reference

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