Proceedings of the Research Institute of Atmospherics,
Nagoya University, vol. 18 (1971)

EXPERIMENTAL RESULTS ON RADIO WAVE PROPAGATION IN THE IONOSPHERE

Tetsuo KAMADA

Abstract

The scientific objective of this experiment is to examine the propagation characteristics of radio waves through the ionospheric plasma. Then, the active experimentation of the propagation of radio signal in the frequency range of 0.5 to 5 MHz was intended in the ionosphere by the mother and daughter type rocket K-9M-29.

The instruments behaved with normally good operation, so that the radio signals through the ionosphere and the radio noises in the ionosphere were observed. The measured separation speed of the mother and the daughter parts was 2.4 m/s. Radio signals from the daughter part were received during about 46 sec. after its separation from the mother rocket. The characteristic frequencies of ionospheric plasma such as the plasma frequency and the cyclotron cutoff, and also radio noises in the ionosphere from 0.5 to 5 MHz were observed.

1. Introduction

Observation of radio noises in the ionosphere which had been carried out with the use of a sounding rocket by our Wave Group was to examine the physical characteristics of the ionospheric plasma from the character of waves which are considered to be excited by the interaction between plasma particles and the earth's magnetic fields. But since it is more important to find out the generation mechanism of natural radio noises, some active experiments such as the artificial excitation of ionospheric plasma etc. were carried out in the ionosphere.

Fortunately, as the development of a sounding rocket having a mother and daughter system had been acheived in the Kappa 9M rocket, it was practicable to carry out the active experiment of exchanging radio waves through the ionospheric plasma.

Then, as the first step of the active experiment, the radio wave propagation experiment through the ionospheric plasma was planned to detect the characteristic frequencies of ionospheric plasma such as: the plasma frequency, the cyclotron cut-off and the upper hybrid frequency. The present paper is intended to report the results of the above experiment.

2. Radio Wave Propagation Experiment

In this radio wave propagation experiment, a frequency sweep oscillator from 0.5 to 5 MHz and a synchronizing signal generator for the mother and daughter connection were loaded on the daughter part, which was separated from the mother part at about 90 km altitude while transmitting the frequency sweep signal. Meanwhile, a frequency sweep receiver from 0.5 to 5 MHz and a synchronizing separator for a sweep synchronizing pulse from the daughter part were loaded on the mother part, in which the transmitted signal from the daughter part were received by whip and loop antennas as synchronized with the sweep oscillator.

A sounding rocket K-9M-29 was launched from Kagoshima Space Center (KSC) at 1920 JST on January 27, 1970 and it reached an altitude of 357 km. Both rocket and instrumentation performances were good and instruments showed normal good operation. The separation of the daughter part was carried out at an altitude of 75 km and also behaved well. The measured separation speed was 2.4 m/s. A transmitted signal from the daughter part was received after about 46 sec. (about a distance of 100 m) from the time of separation.

3. Experimental Results

Fig. 1 shows telemeter output records which indicate the altitude variation of signal intensity received by the mother part. From this record, it was found that transmitted signals from the daughter were received after about 46 sec. from the time of separation. The separation speed was measured to be 2.4 m/s by a magnetic tape method. This corresponds to a distance of 100 m between the mother and daughter, but it does not correspond to the altitude difference between the two parts. Because the trajectory of the daughter part wasn't measured at that time, it was decided to take the same trajectory as the mother.

After transmitted signals from the daughter could not be perceived, transmitted

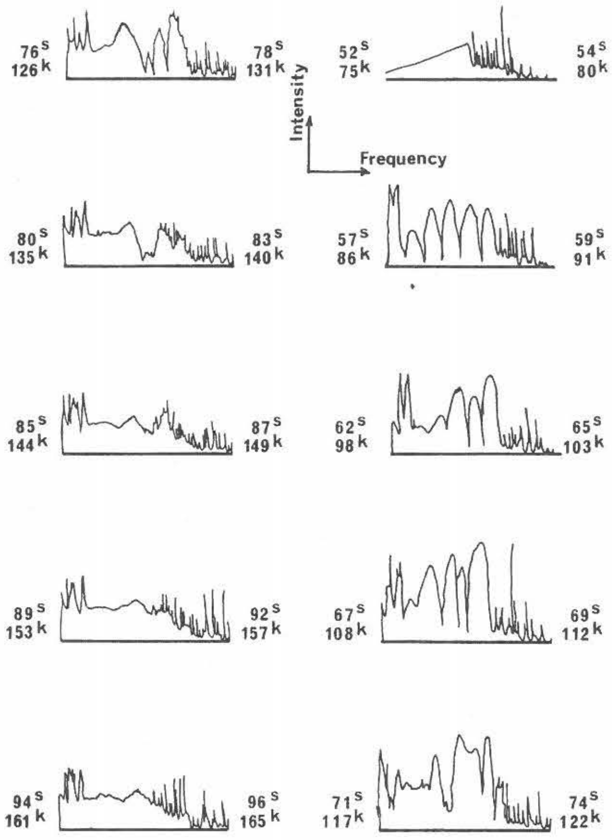

Fig. 1. Altitude variation of signal intensity received at the mother rocket.

signals from the ground station and radio noises appeared clearly. The transmitted signals from the ground station also disappeared from the one beyond the critical frequency of ionosphere and, finally, only radio noises in the ionosphere were received above an altitude of 250 km.

It was found from these results that the intensity of radio noises for the frequency range from 1 to 5 MHz in the ionosphere is stronger on the lower side of the ionosphere than on the upper side and also stronger in the lower frequency range than in the higher one. The appearance of the intensity of radio noises versus altitude are shown in Table 1 and Fig. 2.

As shown in Fig. 1, the remarkable absorption of the received intensity of signal which came from the transmitter loaded on the daughter part is seen at a special frequency component and moreover some frequency shift of this absorded point is

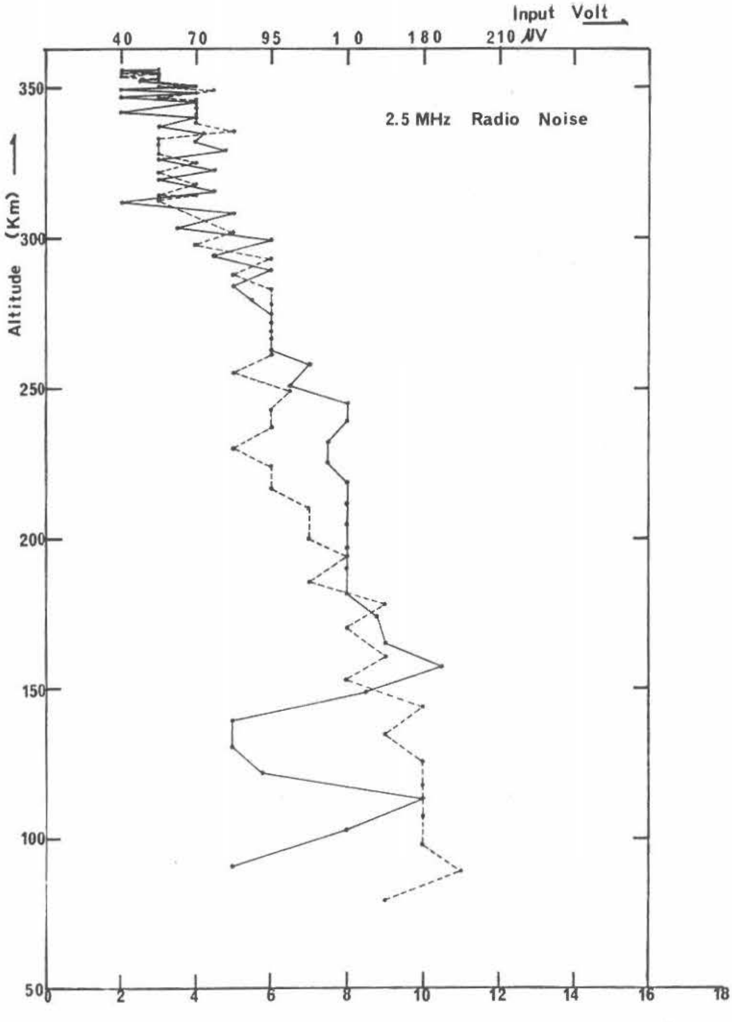

Fig. 2. An example of the altitude distribution of radio noise (on 2.5 MHz) in the ionosphere.

Altitude (km)	Frequency Component (MHz)		
	1 ～ 2.5	3 ～ 3.5	4
100	110 μ v	100 μ v	50 μ v
150	170 μ v	100 μ v	40 μ v
200	150 μ v	80 μ v	25 μ v
250	110 μ v	70 μ v	10 μ v
300	80 μ v	50 μ v	5 μ v
350	45 μ v	45 μ v	0 μ v

Table 1. Altitude distribution of the intensity of radio noise.

also seen at a certain altitude. Then, this special frequency component may be considered to correspond to the characteristic frequency of the ionospheric plasma.

In general, the characteristic frequencies of ionospheric plasma are the plasma frequency, the gyro-frequency, the cutoff frequency, the upper hybrid frequency, etc. in the region of quasi-free space waves. The correlation between these characteristic frequencies and the electron density in the ionosphere is shown in Fig. 3.

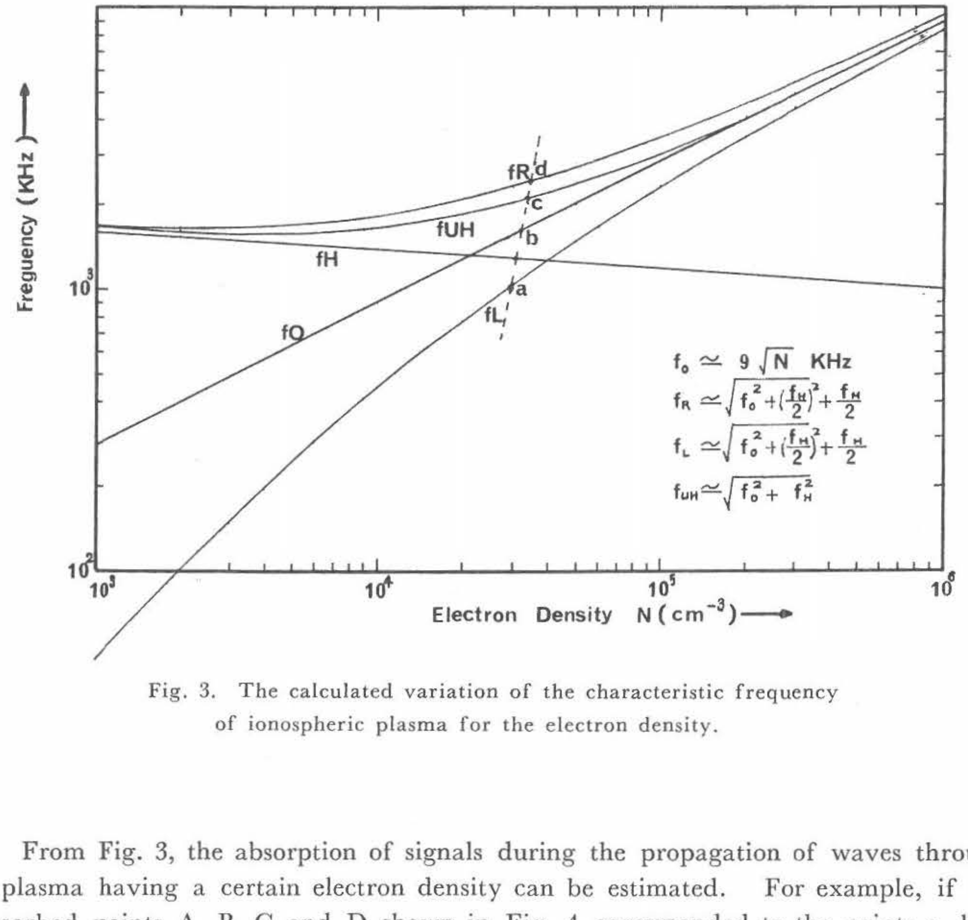

Fig. 3. The calculated variation of the characteristic frequency of ionospheric plasma for the electron density.

From Fig. 3, the absorption of signals during the propagation of waves through a plasma having a certain electron density can be estimated. For example, if the absorbed points A, B, C and D shown in Fig. 4 corresponded to the points a, b, c and d denoted in Fig. 3, these absorbed points are illustrated by the characteristic frequency of f_L, f_O, f_{UH} and f_R, respectively, where f_L, f_O, f_{UH} and f_R denote: the left handed cutoff cyclotron frequency, the plasma cutoff frequency, the upper hybrid frequency and the right handed cyclotron frequency, respectively.

There are three kinds of frequencies seen from the plasma cutoff frequency from both the absorbed points and Fig. 3. Then, three kinds of plasma frequency weıe obtained and the electron density was calculated from these plasma frequencies and

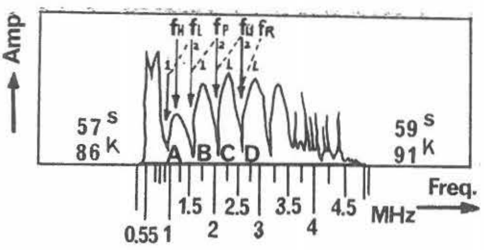

Fig. 4. An example of the frequency spectrum of signal received at the mother rocket.

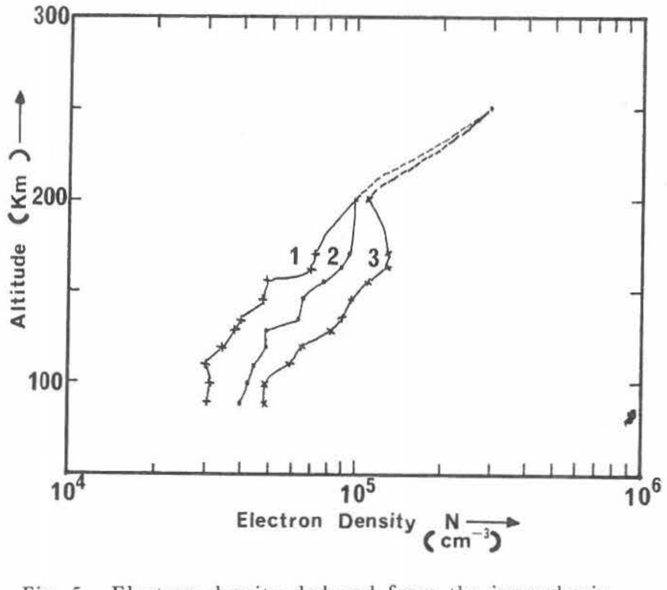

Fig. 5. Electron density deduced from the ionospheric plasma frequency observed by K-9M-29 rocket.

plotted against the altitude. These results are shown in Fig. 5. In Fig. 5, the electron densities at an altitude of 200 and 250 km are deduced from the critical frequency found from the fade-out of signals from the ground station.

The estimation of which altitude distribution of electron density is more plausible was made by the comparison of the measured results of the electron density in the ionosphere obtained at the same time by the VLF Doppler technique and the Langmuir probe technique in this K-9M-29 rocket and it was decided that curve 1 in Fig. 5 is most plausible. Therefore, I feel inclined to think these absorption by the characteristic frequency of ionospheric plasma. If this interpretation were correct, it would be, perhaps, the first time to observe both the plasma and the cyclotron cut-off phenomena in the ionosphere.

It was a certained that such an active propagation experiment is one of the most useful methods to examine the character of the ionospheric plasma, but many problems awaiting solution remain for the future.

Acknowledgements

It should be acknowledged that the rocket experiment was successfully carried out with great support from Prof. T. Obayashi, Prof. K. Hirao and the rocket group of the Institute of Space and Aeronautical Science, University of Tokyo. The author wishes to thank Dr. I. Kimura for his discussion and is also grateful to Miss A. Nakajima for the help in preparing this report.

Reference

Kimura, I. and K. Hirao: Report of COSPAR Symposium, (May 1970).