Proc. NIPR Symp. Upper Atmos. Phys., 1, 204–209, 1988

PRELIMINARY RESULTS OF THE MULTIMODE FM/CW IONOSONDE EXPERIMENT

Kenrou NOZAKI[1] and Takashi KIKUCHI[2]

[1]*Okinawa Radio Wave Observatory, Radio Research Laboratory, Okinawa 901–24*
[2]*Radio Research Laboratory, 2–1, Nukui-Kitamachi 4-chome, Koganei-shi, Tokyo 184*

Abstract: Bottomside ionospheric observation was made with a microcomputer-controlled FM/CW ionosonde at Syowa Station, Antarctica. This ionosonde provides ionograms for the transmitter frequencies from 2 to 16 MHz and also sequential data of virtual height (h') at a fixed frequency with a time resolution of 10 s. Since the peak power of the FM/CW ionosonde is 20 W, continuous observation was possible without disturbing other radio observations and HF radio communications. The continuous observation at a fixed frequency 2.6 MHz shows periodic variations in the virtual height and echo intensity with periods of one to several tens of minutes. Periodic variations with a period of several tens of minutes may indicate a propagation or excitation of internal gravity waves during a geomagnetically quiet period, while a variation with a period of 1 min could be caused by an oscillatory precipitation of energetic auroral particles.

1. Introduction

At Syowa Station, Antarctica, the ionospheric height has been measured with a conventional pulse radar type ionosonde with a peak power of 10 kW (KOSEKI *et al.*, 1980). An interference to other radio observations and communications due to the high radiation power and low ground conductivity restricts the operation of an ionosonde to a quarter-hourly observation.

On the other hand, the pulsed-chirp (pulsed FM/CW) technique (BARRY, 1971) enables us to reduce the transmitter peak power to a factor of 1/1000, which in turn makes possible a continuous operation of the ionospheric sounder. Moreover, the modern ionosonde measures many characteristics of the ionosphere (POOLE, 1985; POOLE and EVANS, 1985; REINISCH, 1986). In these experiments echo intensity was measured for various transmitter frequencies with a dynamic range of 54.1 dB.

The new pulsed-chirp system at Syowa Station consists of receiver, transmitter and controller units in a warmed box settled beneath the antenna, and of a microcomputer controller and recorder units in the observation building. The controller and microcomputer are connected with a 200-m optical fiber cable, to avoid giving interference to other observation and receiving radio noises. The chirp system is controlled by a microcomputer in the building, so that the operation of the system and selection of an operation mode can easily be made by a slight modification of the operation program for the microcomputer. Data obtained by the pulsed-chirp sounder are plotted on a color CRT and monitored quickly. Then the operator can select the most suitable observation parameters from the real time data display. This system was operated routinely from June 14, 1986 to January 14, 1987.

2. Experimental Results

2.1. *h′–t mode*

When the ionosonde is operated at a fixed frequency, the virtual height of a reflected echo is obtained continuously. The transmitter frequency must be chosen experimentally, because an absorption in the ionosphere is great for a lower transmitter frequency and no echo is reflected for a frequency higher than f_oF2. The operation was made at 2.6 MHz with the aid of a $1/2\lambda$ cross-dipole antenna.

According to the FM/CW method, the transmitter frequency was swept linearly from 2.6 to 2.7 MHz in one second. The dechirped signal of which frequency is proportional to the virtual height is sampled at 512 points during 0.86 s in 1 s transmission. The microcomputer needs 6 s for both FFT of the sampled data and plotting of the results on the color CRT display. Thus, data of the h'–t mode was obtained every 10 s, and recorded on a chart from June 14 and stored in the 5 inch floppy diskette from September 19, 1986 to January 14, 1987. The observation was interrupted for 30 s every 15 min when the routine ionosonde was operated.

Figure 1 shows an example of variations in the virtual height (lower trace) and echo intensity (upper trace) detected by the h'–t mode during 00–12 LT on October 11, 1986. Sporadic E layer is clearly seen at a height of about 115 km at midnight and at pre-dawn hours. F-layer appears around the sunrise (0630 LT). The height of the F-layer decreases with time, and the echo intensity also decreases because of an increased ionospheric ionization in the morning hours.

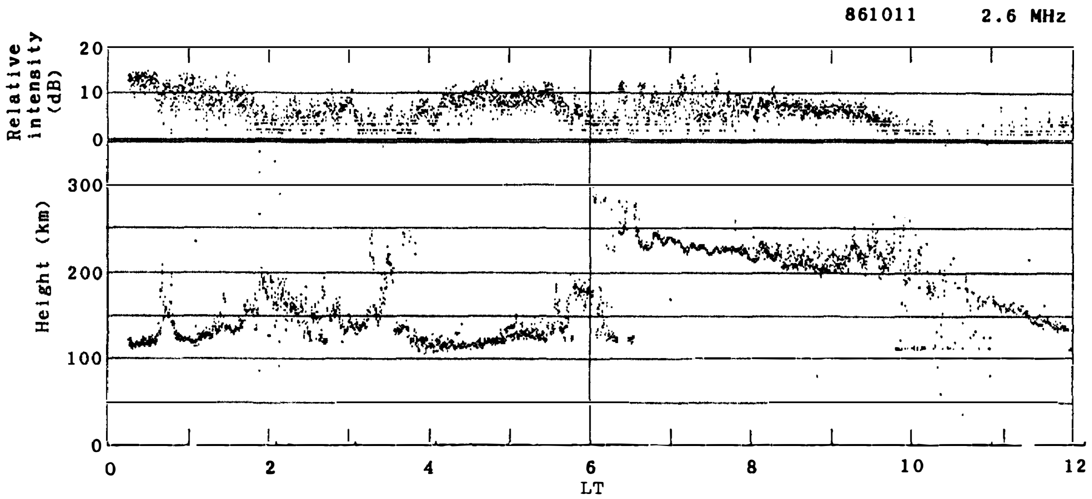

Fig. 1. An example of virtual height (lower trace) and intensity of reflected echo from the Es and F layers detected by a fixed frequency h′–t mode of the pulsed-chirp sounder.

The ionospheric echoes were almost always received when the ionosphere was quiet, so that an effective echo record was obtained during the period of 61% of the whole observation period. Radio wave absorption due to ionizations in the lower ionosphere caused by the solar radiation and energetic particle precipitation is recognized qualitatively on the ionogram as an increase of f_{min}. However, the absorption can be measured quantitatively from the echo intensity of the pulsed chirp signal.

Figure 2 shows a saw-tooth shape oscillation of the virtual height of the *E*-region observed during 0139–0156 UT (0439–0456 LT) on June 19, 1986. The period of oscillation is about 1 min. During this event, the geomagnetic activity was relatively low and no CNA was observed with a riometer. Although no direct evidence of an auroral particle precipitation exists, this short period variation is most likely to be caused by a precipitation of auroral particles, because other candidates such as atmospheric waves cannot explain the short oscillation period of the event. This type of oscillation was also recorded during 0115–0155 UT on October 8, 1986 with a period of 2 min in the height range of 130 to 190 km.

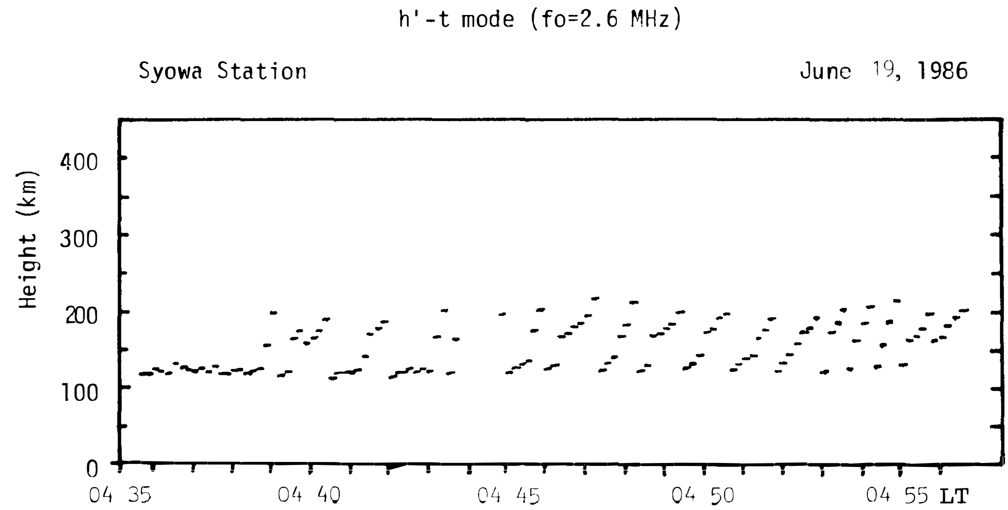

Fig. 2. Saw-tooth type ionospheric oscillation with period of about 1 min.

Electron density irregularities in the *E*-region associated with geomagnetic Pc 5 pulsations were observed with a 50 MHz auroral Doppler radar (IGARASHI *et al.*, 1985). SUTCLIFFE and POOLE (1984) derived vertical pulsating motions of the ionosphere associated with Pc 3 from Doppler frequency observation using a digital chirp ionosonde, and they discussed two models for explaining the observational results. Figure 3 shows oscillations in the virtual height and echo intensity with longer period. A weak substorm started at 2337 UT on October 12, 1986, without accompanying CNA. Simultaneously with the substorm onset, an ionospheric oscillation occurred with a period of 7 min. The amplitude of the oscillation in the virtual height is about 70 km. It is observed that the oscillation in the echo intensity is in anti-phase of that in the virtual height. This suggests that the oscillation in the echo intensity is attributable to a change in the length of propagation path, rather than to an extra ionization in the lower ionosphere. A geomagnetic micropulsation is associated with this oscillation, but the period is much shorter. Therefore, the ionospheric oscillation in Fig. 3 may be associated with atmospheric oscillations.

Figure 4 shows an oscillation in the echo intensity with periods of 5–7 min. The

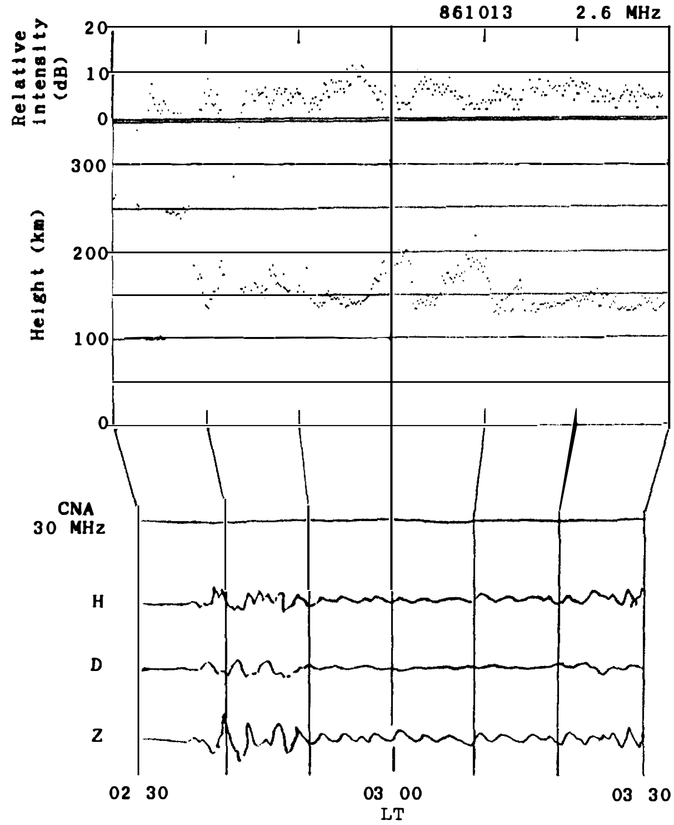

Fig. 3. Ionospheric oscillation associated with a weak substorm. The negatively correlated oscillation in the echo intensity may be due to a change in the path length in the ionosphere.

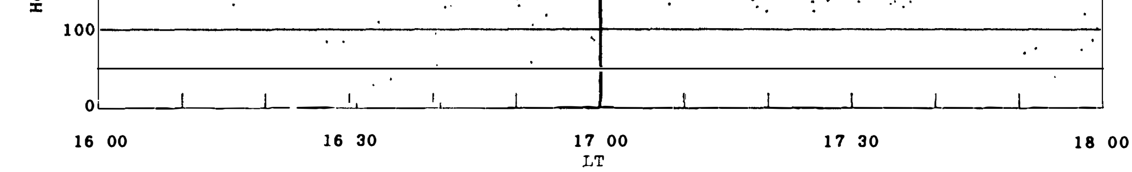

Fig. 4. Periodic oscillation in the echo intensity observed at geomagnetically quiet time, 1640–1730 LT, on October 10, 1986. The period of oscillation is 5–7 min.

geomagnetic activity was very low, and no CNAs were observed during the period of this event. It must be noted that less significant oscillation is observed in the virtual height compared with the oscillation in the echo intensity. These results suggest that the variation in the echo intensity is a result of absorption in the lower ionosphere caused by a weak particle precipitation which could not be detected with a riometer.

2.2. *Ionogram mode*

An ionogram was obtained with the pulsed-chirp sounder by increasing the transmitter frequency by a step of 100 kHz. The upper part of Fig. 5 shows an ionogram in the frequency range 2.0–4.0 MHz and the height range 0–450 km. For comparison, an ionogram obtained with a conventional ionosonde is shown in the lower part of Fig. 5. It is observed that both ionograms are very similar to each other. Moreover, the pulsed-chirp sounder provides information on the echo intensity. The split of the echo trace at 3.5 MHz observed with the conventional ionosonde is also clearly seen as a height change in the echo intensity on the ionogram obtained with the pulsed-chirp sounder.

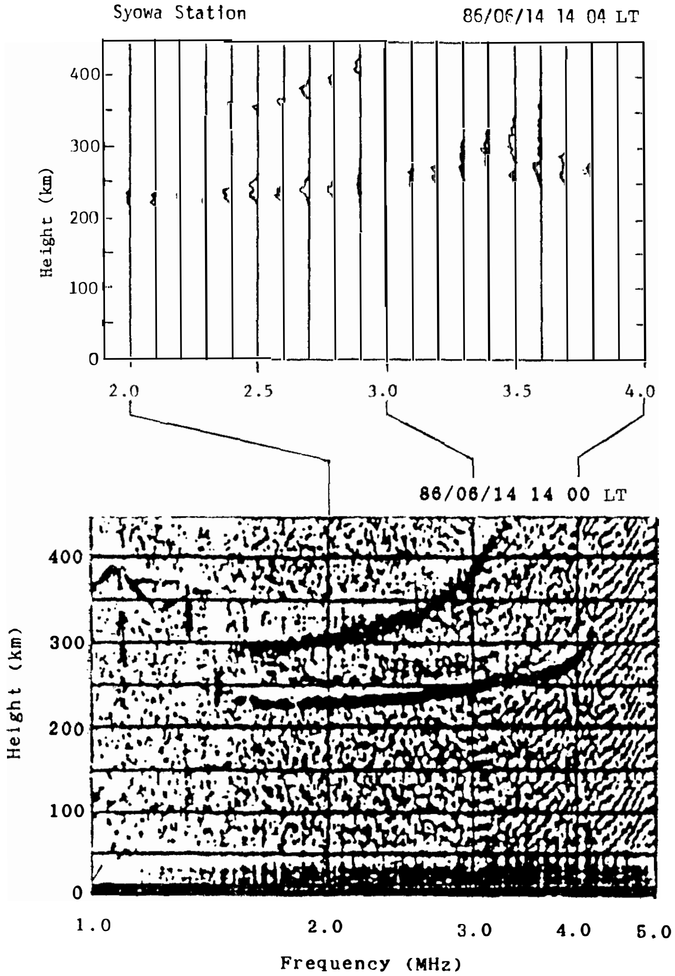

Fig. 5. Ionograms obtained with the pulsed chirp sounder (top) and with the conventional pulse radar ionosonde (bottom) at approximately the same time. Two reflection layers are clearly observed on both ionograms. Echo intensity is given by the pulsed-chirp sounder as the deviations from the vertical lines.

3. Conclusion

The pulsed FM/CW technique enabled us to observe the ionosphere continuously without giving any serious radio interference, because the transmitter power was 20 W.

This system is controlled by a microcomputer which supplies real time data of the virtual height and echo intensity both in the ionogram and h'–t modes.

The h'–t mode observation provides data of oscillations in the virtual height and echo intensity. Oscillations in the ionospheric F-region with a period of several tens of minutes may indicate a propagation or excitation of atmospheric waves during geomagnetically quiet periods. On the other hand, shorter period ($\sim$1 min) oscillations in the ionospheric E-region suggest a weak precipitation of energetic auroral particles. It must be emphasized that the measurement of the echo intensity provides a sensitive detection of ionization due to an energetic particle precipitation which is too weak to be detected with a riometer. In the measurement of absorption with the pulsed-chirp sounder, the intensity of the transmitter wave is constant, while for the riometer observation, diurnal and seasonal changes in the galactic cosmic radio noise should be taken into account in the analysis of data.

In future, a function of measuring the Doppler frequency of the reflected echo will be added to the pulsed-chirp sounder. This will enable us to observe vertical velocity of the reflecting layer, in addition to the virtual height and echo intensity.

Acknowledgments

The authors thank Y. KURATANI and A. SUZUKI of the Radio Research Laboratory for their support to our experiment.

References

BARRY, G. H. (1971): A low-power vertical-incidence ionosonde. IEEE Trans. Geosci. Electron., **GE-9**, 86–89.

IGARASHI, K., OGAWA, T., KURATANI, Y., FUJII, R. and SATO, N. (1985): 50 MHz auroral doppler radar observation associated with PC 5 geomagnetic pulsations. Mem. Natl Inst. Polar Res., Spec. Issue, **36**, 104–113.

KOSEKI, T., TAKEUCHI, T., ISHIZAWA, K., ITO, S. and KURATANI, Y. (1980): 9-B·gata denrisô kansokuki (The 9-B type ionosonde of the Radio Research Laboratories). Denpa Kenkyûjo Kihô (Rev. Radio Res. Lab.), **26**, 679–691.

NOZAKI, K. and KIKUCHI, T. (1987): A new multimode FM/CW ionosonde. Mem. Natl Inst. Polar Res., Spec. Issue, **47**, 217–224.

POOLE, A. W. V. (1985): Advanced sounding 1. The FM/CW alternative. Radio Sci., **20**, 1609–1616.

POOLE, A. W. V. and EVANS, G. P. (1985): Advanced sounding 2. First results from an advanced chirp ionosonde. Radio Sci., **20**, 1617–1623.

REINISCH, B. W. (1986): New techniques in ground-based ionospheric sounding and studies. Radio Sci., **21**, 331–341.

SUTCLIFFE, P. R. and POOLE, A. W. V. (1984): Low latitude Pc 3 pulsations and associated ionospheric oscillations measured by a digital chirp ionosonde. Geophys. Res. Lett., **11**, 1172–1175.

(Received June 1, 1987; Revised manuscript received September 1, 1987)