Proc. NIPR Symp. Upper Atmos. Phys., 3, 86–90, 1990

TYPE 5 ECHOES OBSERVED BY VHF DOPPLER RADAR AT THE AURORAL IONOSPHERE

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Abstract: A new type of coherent radar echoes from the auroral E region, which shows a narrow spectrum peak around 12 Hz, has been observed by 50 MHz VHF Doppler radar at Syowa Station during severe magnetic disturbances. The appearance of new type echoes are restricted to post-midnight hours. Plasma waves responsible for these echoes seem to propagate obliquely to the magnetic field.

1. Introduction

Since 1982, auroral E region irregularities have been observed at Syowa Station, using a 50 MHz VHF Doppler radar. In general, coherent radar echoes observed at high-latitude E regions can be classified into four types from the shape and the peak frequency of their Doppler spectra. Type 1 echoes have a narrow spectrum peak near the ion acoustic frequency, and they are caused by the plasma waves associated with two-stream instabilities. Type 2 echoes with broad spectra and a low mean Doppler frequency are believed to be generated by plasma waves associated with the gradient drift instabilities. These two types of echoes are almost identical to those observed in the equatorial electrojet. Type 3 echoes are characterized by a narrow spectrum peak near the gyrofrequencies of E region ions, and associated with electrostatic ion cyclotron waves (EIC) (FEJER *et al.*, 1984; PRIKRYL *et al.*, 1987). Field-aligned currents (FACs) play an important role for the generation of type 3 echoes. Type 4 echoes are reported more recently and are formed with narrow peaks at high Doppler frequencies showing harmonic structures of EIC waves (PRIKRYL *et al.*, 1988).

In addition to these four types of echoes mentioned above, we observed a new type of coherent radar echoes which have narrow spectrum peaks well below the cyclotron frequencies of E region ions. In this paper, observational results are shown for these new type echoes, which we call type 5 echoes.

2. Observations

The radar system used for the present observation is a coherent pulsed Doppler radar with the frequency of 50 MHz. This radar has two antenna beams, one directing toward the geomagnetic south (GMS) and the other toward the geographic south (GGS). At Syowa Station (69°00′S, 39°35′E), the direction of the geographic south is deviated about 30° toward west from the geomagnetic south. Antenna beamwidth is about 4° in the horizontal plane. Observational parameters are 333 Hz pulse repetition frequency, 128 FFT points and 20 integration number. Therefore the maximum detectable Doppler frequency and doppler resolution are ±166 Hz and 2.6 Hz, respectively.

Figure 1 shows an example of new type spectra reported in this paper. In this figure, the upper panel shows the time variations of Doppler spectra observed by GMS beam at a range of 240 km. The second panel shows time variations of the mean Doppler frequency for the first panel by dots and amplitude of echoes by vertical lines. The full scale for dots is ±500 m/s and the scale is arbitrary for vertical lines. The middle panel shows variations of H component of the geomagnetic field. The 4th and 5th panels show the results for GGS beam at a range of 300 km. A severe magnetic disturbance started at 0415 UT on September 5, 1984. After the start of this severe magnetic disturbance, narrow spectrum peaks appeared in the GMS observation with the peak frequency around 12 Hz. At Syowa Station, the gyrofrequency of molecular ions is about 22 Hz. Thus, the center frequency of narrow peaks shown in Fig. 1 is about the half of the frequency of typical type 3 echoes.

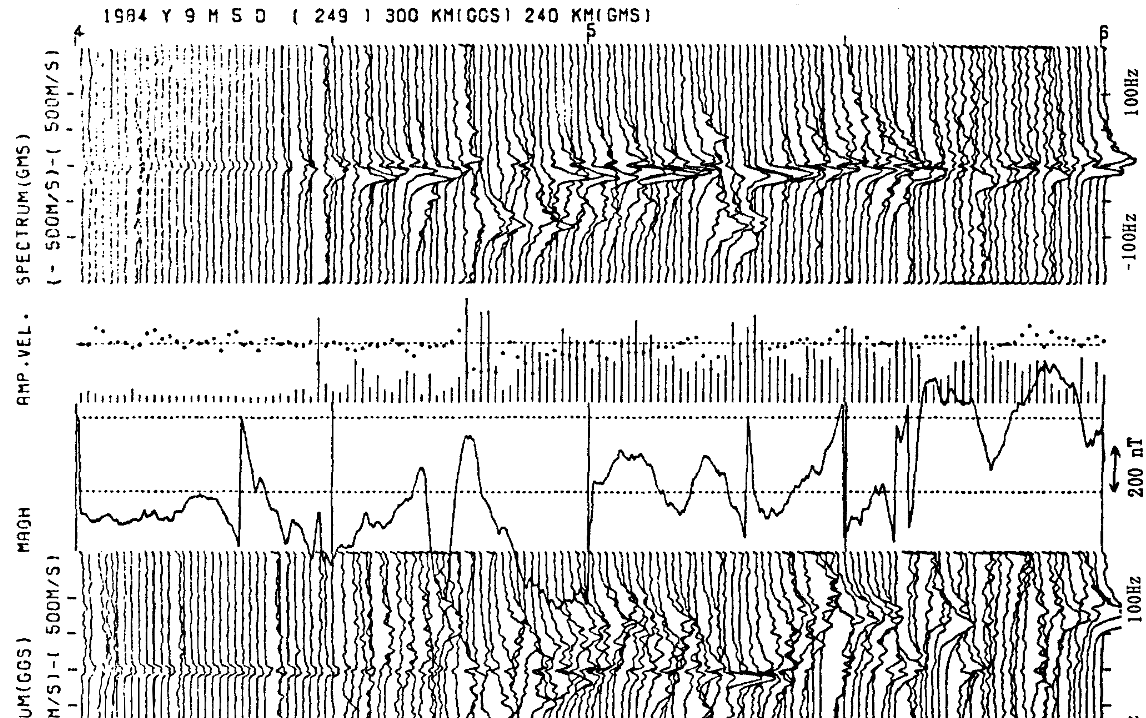

Fig. 1. An example of type 5 echoes observed on September 5, 1984 associated with severe magnetic disturbances. The vertical scale for Doppler frequency ranges from −166 Hz to 166 Hz, which corresponds to Doppler velocity from −500 m/s to 500 m/s.

In the observation of coherent echoes by VHF radar, aspect angle dependences become very important because irregularities due to plasma waves are thought to be distributed along the magnetic field. Figure 2 shows the results of Doppler spectrum observations by GMS beam for the same interval of Fig. 1, at three ranges 240 km, 255 km and 285 km. Aspect angles for these ranges at an altitude of 110 km are 85.5°, 87.1° and 89.7°, respectively. Near the aspect angle of 90.0°, type 2 echoes are dominant. With a decrease in the aspect angle, type 2 echoes die out and type 5 echoes become conspicuous. These results indicate that the plasma waves responsible for type 5 echoes propagate obliquely to the ambient magnetic field.

The occurrence of type 5 echoes is investigated with the data set obtained in 1984. Total observation intervals in 1984 are about 83 days during April 25–October 8. In Fig. 3, the H component geomagnetic field variation at Syowa Station are shown on the days of distinct type 5 echo recording. Thick horizontal lines indicate the intervals of type 5 echo appearances. It is seen from this figure that type 5 echoes are observed during the intervals of H component decreases. In addition, the appearances of type 5 echoes are restricted during the morning hours. Since the structure of FACs changes markedly around midnight, local time dependences of type 5 echoes will suggest an overwhelming role of precipitating particles for the generation of type 5 echoes.

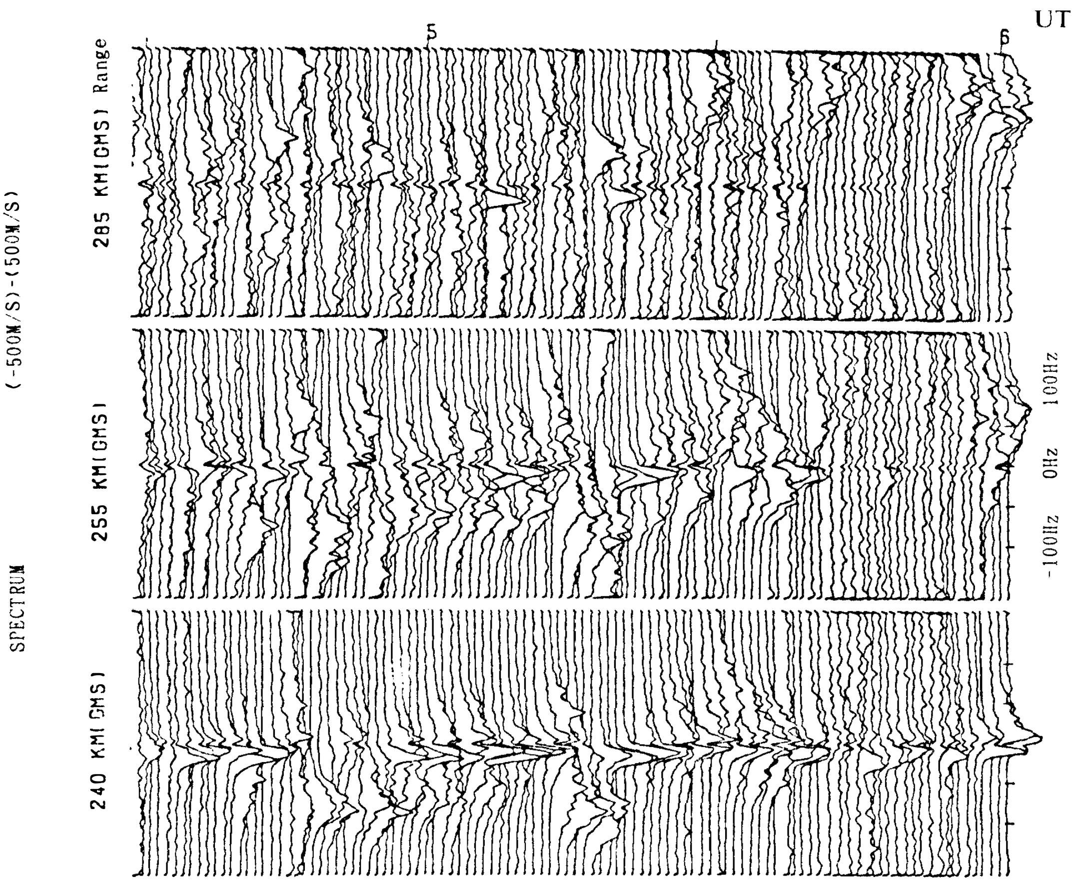

Fig. 2. Aspect angle dependences of type 5 echoes. Range values 245, 255 and 285 km correspond to aspect angles 85.5, 87.1 and 89.7, assuming the altitude of 110 km.

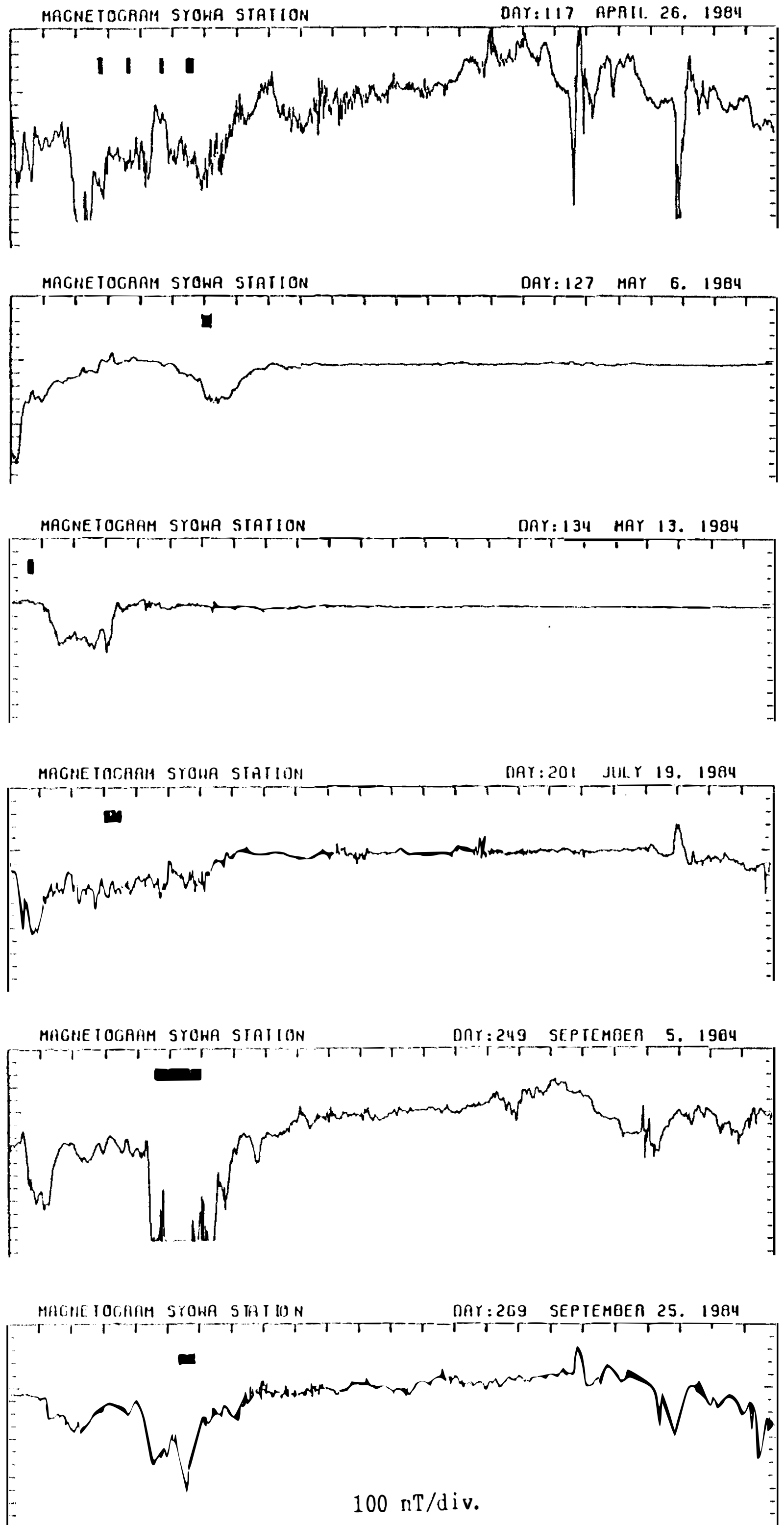

Fig. 3. Variations of geomagnetic H component at Syowa Station on the days of distinct type 5 echoes in 1984. The scale is 100 nT per division.

3. Discussion and Conclusion

In this paper, observational results are shown for new type coherent echoes observed by a VHF Doppler radar, which have a narrow spectrum peak well below the ion gyrofrequencies. These echoes appear during morning hours in association with severe magnetic disturbances. It is well known that FACs may lead to an excitation of obliquely propagating waves of electrostatic mode. However these theories of EIC waves can explain only type 3 echoes. Recently, it has been reported that the transverse localized electric (TLE) fields can affect the excitation of EIC waves (GANGULI and PALMADESSO, 1988). Under a severe auroral display, there may exist strong TLE fields, which may lead to an excitation of type 5 echoes. Another possibility for type 5 echoes is an ion-streaming instability (PERKINS, 1976). However, further theoretical investigations are desirable for the explanation of type 5 echoes.

In our observations, type 5 echoes appear distinctly in the GMS beam. In this direction, aspect angles change markedly with range values. In general, such a situation is not suitable for the radar observation because the area of possible observations for radar echoes becomes narrow. Therefore, many previous observations avoided such a situation. This unique condition may be related to the fact that previous observations did not detect type 5 echoes.

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(Received July 31, 1989; Revised manuscript received January 25, 1990)