Pi 2-associated Ionosperic Doppler Velocity and Magnetic Pulsation at Mid-latitude MAGDAS Station

Akihiro Ikeda[1], Kiyohumi Yumoto[2], Teiji Uozumi[2], Manabu Shinohara[1], Akimasa Yoshikawa[3], Kenro Nozaki[4], Bychkov V.V.[5], Shevtsov B.M.[5]

[1] Kagoshima National College of Technology, Kagoshima, Japan

[2]International Center for Space Weather Science and Education, Kyushu University, Fukuoka, Japan

[3]Department of Earth and Planetary Sciences, Kyushu University, Fukuoka, Japan

[4]National Institute of Information and Communications Technology, Tokyo, Japan

[5]Institute of Cosmophysical Research and Radiowaves Propagation FEBRAS, Russia

Abstract

Ionospheric Doppler velocity (V*) and magnetic horizontal northward component (H) simultaneously detected Pi 2 pulsations at nighttime mid-latitude station (Paratunka, Kamchatka region, Russia; L=2.05). The phase relation between H and V* shows -90 degree at the peak of PSD (power spectral density) of H and V* in the case of Pi 2 on 29 Oct. 2006. This indicates that the cavity mode resonance is maintained in the ionospheric F-region. On the other hand, the Pi 2 on 4 Nov. 2006 shows different peaks of PSD in H and V*. This Pi 2 event can be explained not only by cavity mode.

Introduction

Pi 2 magnetic pulsations, which associate with magnetic storms, are observed globally in the magnetosphere. Pi 2 pulsation is an impulsive hydromagnetic oscillation and its period range is 40 to 150 seconds [*e.g., Saito and Matsushita*, 1968]. The modes of Pi 2 pulsations depend on the latitude and local time of observation [*e.g., Olson*, 1999; *Yumoto and the CPMN Group*, 2001].

Low- and mid-latitude Pi 2 pulsations are explained in terms of the cavity mode resonance in the plasmasphere [*e.g.*, *Sutcliffe and Yumoto*, 1991; *Yeoman and Orr*, 1989]. *Takahashi et al.* [1995] found that magnetic Pi 2 pulsations in the night side sector at L < 4 are dominated by the poloidal components and suggested cavity mode as an explanation. Also *Takahashi et al.* [2001] analyzed the magnetic field and electric field observed by the CRRES satellite. They indicated that the sources of Pi 2 pulsations are poloidal standing waves inside the plasmasphere and Pi 2 pulsations are explained in terms of cavity mode between two reflecting boundaries.

In the present paper, we examined the phase relation between the ionospheric Doppler velocity in the ionospheric F-region detected by an FM-CW (Frequency Modulated Continuous Wave) radar and magnetic Pi 2 pulsations observed by MAGDAS (the MAGnetic Data Acquisition System). Such comparison will provide us better understanding about excitation mechanism of Pi 2 pulsations.

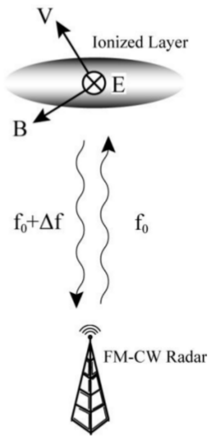

Figure 1. A schematic diagram of the Doppler measurement by an FM-CW radar (after *Ikeda et al.*, 2010a).

Data Set

The present study is based on the data from FM-CW radar located at Paratunka, Kamchatka region, Russia (PTK: Magnetic Latitude = 45.8 degree, Magnetic Longitude = 221.6 degree, L = 2.05, LT = UT + 10.5 hrs). The FM-CW radar is a type of HF radar that can measure the range of target as well as Doppler shift for reflected radio waves from the target (e.g., ionized layer). This application of the FM-CW radar is a variation of a technique developed by *Barrick* [1973] to measure sea scatter. We target the ionospheric F region for Doppler measurement. Our radar is an improved version of the FM-CW radar developed by *Nozaki and Kikuchi* [1987, 1988].

The observed Doppler frequency is represented by

$$\delta f = \frac{v \times 2f_0}{c}, \tag{1}$$

wheref_0 is the transmitting frequency and v is vertical drift velocity of the ionosphere describe by

$$v = \frac{\delta f \times c}{2f_0}, \tag{2}$$

For this study, the transmitting frequency $f_0$was 3.0 MHz. The data of Doppler velocity were digitized with 3-sec sampling.

By assuming that the v is caused by the frozen-in effects in the ionosphere, we can estimate the east-west ward electric field (Ey). The equation of the frozen-in effect is described

$$\mathbf{E} = -\mathbf{V} \times \mathbf{B}, \tag{3}$$

where is east-west electric field (Ey), and is the horizontal component (H component) of the ambient magnetic field intensity in the ionosphere, and v is obtained by FM-CW radars. A schematic diagram of the Doppler measurement by an FM-CW radar is shown in Fig. 1.

In order to compare the radar data with ionospheric Ey, we analyzed ground magnetometer data obtained at PTK. This station is a part of the MAGnetic Data Acquisition System of the Circumpan Pacific Magnetometer Network (MAGDAS/CPMN) [*Yumoto and the MAGDAS Group*, 2006 and 2007].

Data Analysis

Pi 2 on 29 Oct. 2006

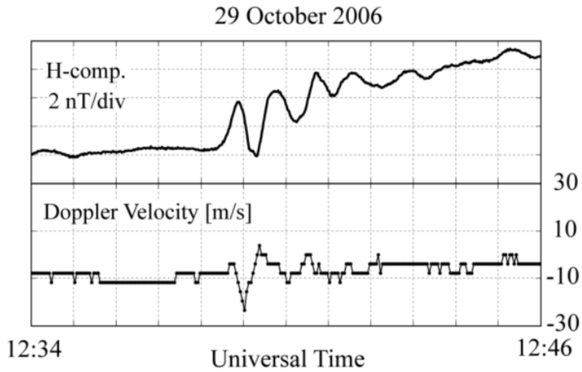

Figure 2. Pi2 pulsation on on 29 Oct. 2006.

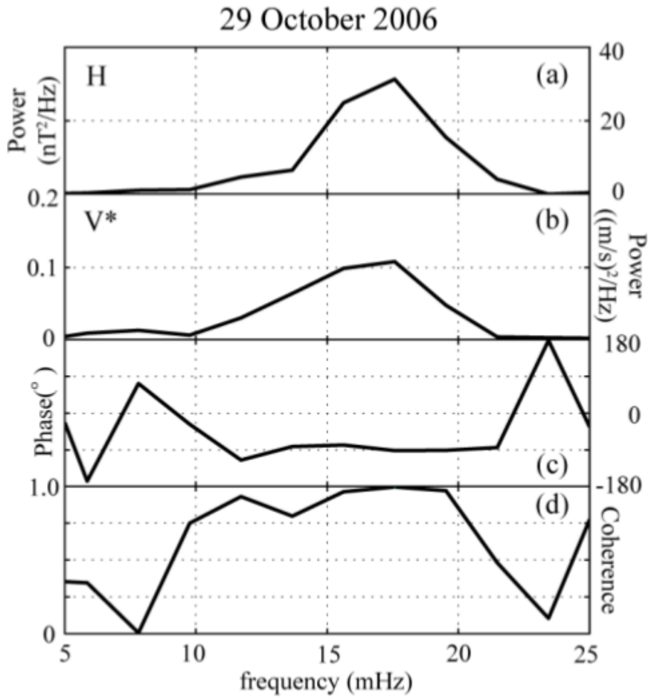

Figure 3. Spectral property of the Pi 2 on 29 Oct. 2006.

Figure 2 shows a nighttime Pi 2 event that was observed on 29 October 2006. This event was examined by *Ikeda et al.* [2010b]. During this event, PTK was located in the pre-midnight sector (2304-2316 LT). The upper panel shows the ground magnetic horizontal northward component (H) and the bottom panel shows downward Doppler velocity (V*) obtained by the FM-CW radar. During this event, V* was observed at the virtual height of about 300 km. We can see Pi 2 pulsations in H and V* simultaneously.

Using 512-point FFT, we obtained spectral property between H and V* shown in Fig.3. The panel (a), (b), (c), and (d) in Fig. 5 show PSD (power spectral property) of H, PSD of V*, phase difference (Pha) of H-V*, and coherence (Coh) of H-V*. A dominant spectral peak is seen at 16.9 mHz in both H and V*. At 16.9 mHz, the Coh is 0.99 and Pha is -91 degree. This means that V* leads H by 91 degree.

Pi 2 on 4 November 2006

Figure 4 shows a nighttime Pi 2 event that occurred on 4 November 2006. This event was also examined by *Ikeda et al.* [2010]. The format of the Fig. 4 is the same as that of Fig. 2. During this event, V* was obtained at the virtual height of about 250 km.

The spectral property of the Pi 2 on 4 Nov. 2006 is shown in Fig 5. The most dominant frequency of H is 7.8 mHz, but that of V* is 19.5 mHz (see Fig. 5 (a) and (b)). However the second peak of V* is 7.8 mHz which is same as that of H. If we focus on 7.8 mHz, the Pha is about -90 degree.

Discussion and Summary

According to the box model of a cavity mode by *Takahashi et al.* [2001], the phase difference between Bz (magnetic field compressional component) and Ey (electric field azimuthal compo-

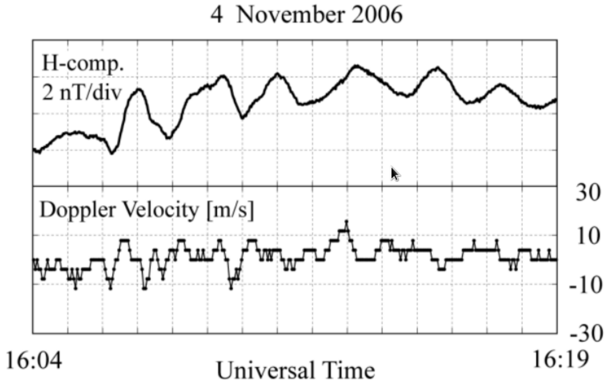

Figure 4. Pi2 pulsation on on 4 Nov. 2006.

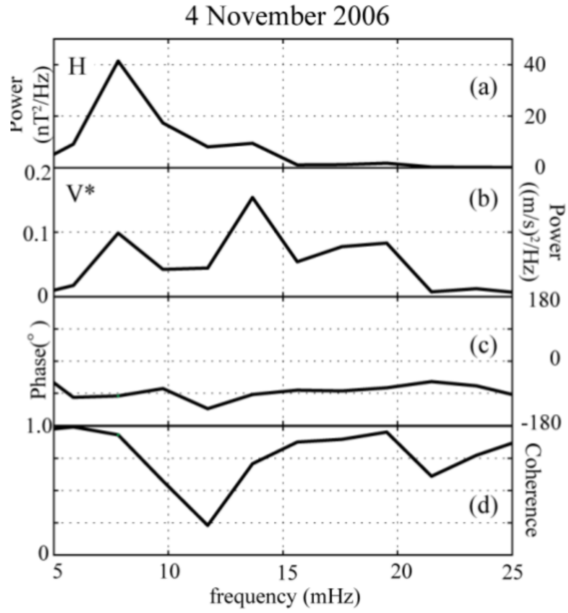

Figure 5. Spectral property of the Pi 2 on 4 Nov. 2006.

nent) is -90 degree at the inner boundary. This value is almost same with the Pha of H-V* at 16.9 mHz (peak of H and V*) on 29 Oct. 2006. We therefore conclude that the Pi 2-associated V* is caused by ExB drift in the ionosphere and the Pi 2 on 29 Oct. 2006 was explained in terms of cavity mode.

The peaks of PSD of H and V* are 7.8 mHz, and 19.5 mHz in the case of the Pi 2 on 4 Nov. 2006. The second peak of V* is 7.8 mHz which is same as the peak of H. At 7.8 mHz, Coh of H-V* is about -90 degree. Thus it seems that the Pi 2 oscillation at 7.8 mHz was excited by the cavity mode. In the case of 19.5 mHz, there is no remarkable peak in H. It is worth to compare V* with high-latitude H to examine the excitation mechanism for Pi 2-associaed V* at mid latitude.

Acknowledgement

This work was supported by Grant-in-Aid for Young Scientists (B) (25800277) and the Grant-in-Aid for Overseas Scientific Survey (18253005). We acknowledge National Institute of Information and Communications Technology (NICT). This work was also supported by JSPS Core-to-Core Program, B. Asia-Africa Science Platforms.

References

1. Ikeda A., A. Yoshikawa, M. G. Cardinal, K. Yumoto, M. Shinohara, K. Nozaki, B. M. Shevtsov, V. V. Bychkov, Q. M. Sugon, and D. McNamara (2010), Ionospheric observation using FM-CW radar array, Advances in Geosciences, Vol.21: Solar & Terrestrial Science, Ed. Marc Duldig, 379-391.

2. Ikeda, A., K. Yumoto, T. Uozumi, M. Shinohara, K. Nozaki, A. Yoshikawa, V. V. Bychkov, and B. M. Shevtsov (2010), Phase relation between Pi2-associated ionospheric Doppler velocity and magnetic pulsations observed at a midlatitude MAGDAS station, J. Geophys. Res., 115, A02215, doi:10.1029/2009JA014397.

3. Olson, J. V. (1999), Pi2 pulsations and substorm onsets: A review, J. Geophys. Res., 104, 17,499-17,520.

4. Nozaki, K., and T. Kikuchi (1987), A new multimode FM/CW ionosonde, Mem. Natl Inst. Polar Res., Spec. Issue, 47, 217-224.

5. Nozaki, K., and T. Kikuchi (1988), Preliminary results of the multimode FM/CW ionosonde experiment, Proc. NIPR Symp. Upper Atmos. Phys., 1, 204-209.

6. Saito, T., and S. Matsushita (1968), Solar cycle effects on geomagnetic Pi2 pulsations, J. Geophys. Res., 73, 267-286.

7. Sutcliffe, P. R., and K. Yumoto (1991), On the cavity mode nature of lowlatitude Pi2 pulsations, J. Geophys. Res., 96, 1,543-1,551.

8. Takahashi, K., S. Ohtani, W. J. Hughes, and R. R. Anderson (2001), CRRES satellite observations associated with low?latitude Pi2 pulsations, J. Geophys. Res., 106, 15,567-15,581.

9. Takahashi, K., S.?I. Ohtani, and B. J. Anderson (1995), Statistical analysis of Pi2 pulsation observed by the AMPTE CCE spacecraft in the inner magnetosphere, J. Geophys. Res., 100, 21,929.21,941.

10. Yeoman, T. K., and D. Orr (1989), Phase and spectral power of mid?latitude Pi2 pulsations: Evidence for a plasmaspheric cavity resonance, Planet. Space Sci., 38, 1,367-1,383.

11. Yumoto, K., and the CPMN Group (2001), Characteristics of Pi 2 magnetic pulsations observed at the CPMN stations: A review of the STEP results, Earth Planets Space, 53, 981-53,992.

12. Yumoto, K., and the MAGDAS Group (2006), MAGDAS project and its application for space weather, in The Solar Influence on the Heliosphere and Earth's Environment: Recent Progress and Prospects, edited by N. Gopalswamy and A. Bhattacharyya, Quest, Mumbai, India.

13. Yumoto, K., and the MAGDAS Group (2007), Space weather activities at SERC for IHY: MAGDAS, Bull. Astron. Soc. India, 35, 511-522.

Вариации электрического и магнитного поля, связанные с Pi2

Акихиро Икеда[1], Кийохуми Юмото[2], Манабу Шинохара[1], Теиджи Йозуми[2], Кенро Нозаки[3], Акимаса Йошикава[4], Бычков В.В.[5], Шевцов Б.М.[5]

[1] *Национальный коледж технологий города Кагошима, Япония*
[2] *Международный центр исследования космической погоды и образования, Университет Кюшу, Фукуока, Япония*
[3] *Национальный институт Информационных и коммуникационных технологий, Коганей, Токио, Япония*
[4] *Отдел наук о земле и планетах, Университет Кюшу, Фукуока, Япония*
[5] *Институт космофизических исследований и распространения радиоволн ДВО РАН, Россия*

В начале магнитосферных суббурь глобально в магнитосфере возникают пульсации Pi 2 с диапазоном периодов от 40 до 150 секунд [например Saito, 1968]. Pi 2 исследуются с помощью антенн магнитометров на земле и с космических аппаратов [например Yumoto et al., 2001]. Тем не менее, характеристики электрических пульсаций Pi 2 в ионосфере еще не были четко описаны.

В данной работе мы сфокусировались на изучении связи ионосферной Доплеровской скорости в F-области, определяемой с помощью радара FM-CW (радар частотно-модулироемой непрерывной волны), магнитными пульсациями Pi 2б наблюдаемыми с помощью системы MAGDAS (Система сбора магнитных данных) [Yumoto and the MAGDAS Group, 2006 и 2007], и на среднеширотной станции PTK (Магнитная широта: 45.8 градусов, Магнитная долгота: 221.6 градусов, L=2.05).