14. Magnetospheric Cavity Resonance Waves associated with Substorm

By Kiyohumi YUMOTO

Research Institute of Atmospherics, Nagoya University
Toyokawa, Aichi 442

(Communicated by Yoshio KATO, M. J. A., April 12, 1989)

During the magnetospheric substorm onset transient hydromagnetic oscillations, that is called Pi 2 magnetic pulsations, are excited globally in the magnetosphere. Recently, in order to investigate the generation mechanism of global Pi 2 pulsations, Yumoto *et al.* (1989a) have carried out multiple ground-based and satellite observations with high-time resolution data ($\Delta t=1$ sec). An event which occurred at 1153 UT on August 28, 1986, was found to exhibit a unique wave form both in space and on the ground. Fig. 1 shows the magnetic fields at an auroral latitude station College, Alaska ($\lambda=64.86^\circ$, $\phi=212.17^\circ$), at AMPTE/CCE (23.4 MLT, $R\sim 8.1 R_E$) in the magnetotail, and at the Japan-Australia low-latitude conjugate stations, Asahikawa (ASH; $\lambda=43.97^\circ$, $\phi=142.20^\circ$, $L=1.55$), Onagawa (ONW; 38.43° , 141.48° , 1.30), Birdsville (BSV; -25.83° , 139.3° , 1.55), Dalby (DAL; -27.18° , 151.20° , 1.56), and St. Kilda (SKD; -34.70° , 138.50° ,

Fig. 1

2.11). As the arrows indicate, the ground Pi 2 magnetic pulsations started at ~ 1154 UT, ~ 1 min after the onset of the dipolarization, i.e., a step-like variation²⁾ in the H-component magnetic field was observed by the AMPTE/CCE spacecraft located very near the center of the tail current sheet. The southward turning was due to magnetic reconnection and the oscillation was caused by a periodic motion of a neutral line or lines. The ~ 1 -min time lag of the onsets corresponds to the propagation time of transient signals from space to ground. The time lag of ~ 60 s over the distance of $7 R_E$ translates to an average velocity of 750 km/s, which is the same order of the averaged Alfvén velocity in the inner magnetosphere.

We can interpret that hydromagnetic disturbances are launched at the time of field dipolarization in the reconnection (or current disruption) region in the near-earth tail during the substorm expansive phase. The compressional portion of hydromagnetic disturbances at AMPTE/CCE is believed to propagate across the equatorial magnetic field, and to couple into a global magnetic pulsation observed on the ground.

Yumoto *et al.* (1989b) also investigated wave characteristics of global Pi 2 magnetic pulsations detected concurrently on the ground at world-widely separated stations, Syowa (SYW; $L=6.15$, $A=71.44^\circ$, $MLT \simeq UT$), Hermanus (HER; 1.88 , 81.52° , $UT+0.3$ hr), Kakioka (KAK; 1.23 , 210.95° , $UT+9.0$ hr), and in space at AMPTE/CCE. Fig. 2 shows a global Pi 2 event excited at 2310 UT on May 22, 1985. From an inspection of hot electron data from the HPCE instrument

Fig. 2

on board AMPTE/CCE, the spacecraft entered the plasma sheet at $L \sim 7.1$ at ~ 2350 UT on May 22, 1985 (private communication with D. M. Klumpar). The position of AMPTE/CCE at ~ 2310 UT was located in the plasma trough at $L=6.4$ and 22.8 MLT, i.e., near the Syowa-Iceland conjugate area. Before ~ 2317 UT one finds good in-phase relations between B_x (radial out) in space and D component at SYW and between B_y (eastward) and H component, suggesting the

Fig. 3

Fig. 4

ionospheric 90° rotation of the wave polarization axis. After ~ 2317 UT a localized compressional oscillation (B_z) with 140-s period appeared near the magnetic equator at AMPTE/CCE, but the ground variations were decreasing at the time.

The H-component Pi 2 pulsations in the nightside hemisphere show nearly anti-phase relation between high- and low-latitude ground stations, while the D components show nearly in-phase relation between SYW and HER. On the other hand, both the H- and D-component Pi 2 pulsations at low latitudes indicate in-phase relations between HER in the nightside southern hemisphere and KAK in the dayside northern hemisphere. These phase relations, especially at low latitudes on the dayside, can be explained by considering neither the equivalent ionospheric current system of the magnetospheric substorm nor the substorm current wedge model on the nightside.

It is also noteworthy that dominant periods (~ 135 s) of the global Pi 2 pulsations before 2317 UT on the ground at the world-widely separated stations from $L=1.2$ to 6.9 on the night and dayside, and in the plasma trough at AMPTE/CCE are all identical. The observed dominant periods can be interpreted by considering an implicit eigen frequency of the magnetospheric cavity wave.

The author further examined statistically if Pi 2 magnetic pulsations observed at various latitudes and longitudes on the night and dayside have the common wave characteristics. Fig. 3 shows one example of global Pi 2 events simultaneously detected on the dayside at high (SYW) and low latitudes (HER) and on the nightside at low latitude (ONW). The arrow indicates substorm-associated Pi 2 onset determined by the ONW induction magnetogram in the local nighttime. It is found that even though Pc 3 magnetic pulsations are activated during the local daytime, and bury the substorm-associated Pi 2 components in the sinusoidal magnetic variations, the amplitude-time record at HER after having been passed through a Pi 2 frequency-range filter shows the corresponding, clear transient daytime oscillations. The author has checked statistically to see if Pi 2's occur during the local daytimes at ONW and at HER for the 82 events which were selected during the local nighttimes at HER and at ONW, respectively, from August 3 to September 4, 1986. Most of ($\geq 95\%$) the corresponding daytime Pi 2's could be identified at the low latitudes, therefore, the substorm-associated Pi 2 magnetic pulsations are concluded to be indeed a global phenomenon.

The wave characteristics of global Pi 2 pulsations detected at the world-widely separated stations, i.e., (1) the high occurrence probability of daytime Pi 2's at low and middle latitudes, (2) the identical period in the inner region ($L \leq 7$) bounded by the plasma sheet, and (3) the nearly schematic in- and anti-phase relations of H and D components, cannot be interpreted by only considering the Alfvén field-line resonance wave in the nightside auroral zone, but suggest a global field-line oscillation coupled with the magnetospheric cavity resonance wave.

The conclusion obtained from the globally coordinated observations is schematically summarized in Fig. 4, illustrating a possible scenario for the excitation and propagation mechanisms of the substorm-associated global Pi 2 magnetic pulsations. During the substorm expansion onset hydromagnetic impulsive disturbances are launched at the time of the field dipolarization in the reconnection or current disruption region (solid area) in the near-earth plasma sheet. A portion of the disturbances can propagate along the field line in the Alfvén mode to the high-latitude ionosphere, and contribute to a localized high-latitude Pi 2 pulsation on the nightside. On the other hand, the compressional impulsive signals with a broad-band frequency can propagate across the ambient magnetic field into the dayside magnetosphere, and excite a cavity resonance mode in the whole inner region bounded by the plasma sheet (indicated by a thick line in Fig. 4). The magnetospheric cavity resonance wave further couples into a global field-line oscillation with a discrete frequency, which can be observed as a global Pi 2 pulsation at world-widely separated ground stations.

Acknowledgement. The author expresses his sincere thanks to Prof. Yoshio Kato, M. J. A., for his keen interest, kind encouragement, and suggestive comments throughout the course of this investigation.

References

- 1) Yumoto, K. *et al.* (1989a): J. Geophys. Res., **94** (in press).
- 2) Yumoto, K., and K. Takahashi (1989): Proc. NIPR Symp. Upper Atmos. Phys., **2** (in press).
- 3) Yumoto, K. *et al.* (1989b): (submitted to J. Geophys. Res.).