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SOME GEOPHYSICAL PHENOMENA CAUSED BY SOLAR WIND SUDDEN MAGNETIC IMPULSE

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Abstract

Using auroral TV, magnetic pulsations data, VLF recordings at Spitsbergen and Lovozero as well as multisatellite observations, ground-based effects of a sudden impulse in the interplanetary magnetic field have been studied. It was found that sometimes during magnetic impulse (SI) event sharp and isolated activation of VLF emissions definitely lead to magnetic pulsations for several minutes. We suppose that these ground-detected VLF emissions are generated during solar wind irregularity contact with the magnetopause. That gives a new and effective method for direct estimation of the time of interplanetary magnetic field penetration inside the magnetosphere as a difference between VLF and magnetic pulsation detection moments. Reliability of the method is based, in particular, on a very large amount of experimental data.

Schumann resonance response to SI event was also revealed. It was found that Schumann resonance intensity starts increasing after SI and reaches maximum amplitude 2-3 hours after SI. Frequency of the Schumann resonance maximum also changes (from 7.8 to 8.2 Hz) not quite synchronously at Lovozero and Barentsburg. Effects of those types were not distinguished during "normal", not SI-event triggered, breakup.

Introduction

Sharp changes of solar wind parameters (so called sudden impulses, SI) produce many different events inside the magnetosphere, in particular, overall magnetic field increase because of global magnetosphere compression, magnetic pulsations, auroral activations, and noticeable intensification of VLF-emissions. Solar wind magnetic field penetration inside the magnetosphere takes place in the form of Alfvén waves, and magnetic pulsations can be seen both on the ground and satellites [Takahashi, McPherron, 1981; Yumoto et al., 1985; Freeman, Farrugia, 1999; Southwood, Kivelson, 1990]. Maximum of pulsation occurrence is around the noon, and intensity depends on SI amplitude [Kangas et al., 1998]. Common view is that it is Alfvén waves that is the main agent transporting energy from the solar wind inside the magnetosphere.

There are also many papers about SI influence on VLF emissions [Kleimenova, 1981; Yatchmenev et al., 1989]. It was found that during SI VLF-emissions can be detected in a very broad interval of longitudes, sometimes in the whole daytime hemisphere. This fact demonstrates that VLF-emissions are generated in a large and distant source [Mullayarov, Yatchmenev, 1990]. Similar effects were found as well for the middle latitude VLF stations [Mullayarov, Muzlov, 2001]. There have never been any doubts about near-Earth location of VLF-emissions generation process.

In our paper we prove that for SI-event VLF can be generated not only near the Earth, but also at the magnetopause because of different plasma turbulence processes. Some part of emissions with several-second delay can reach the Earth and be detected by ground-based equipment. At the same time, MHD-waves generated during solar wind irregularity contact with the magnetopause make effect on the ground several minutes later. That gives a simple and effective method of measuring the time of solar wind magnetic field penetration inside the magnetosphere. Only in PGI we have many thousand hours of VLF and magnetic pulsation observations.

Existence of the global cavity between conductive ground and ionosphere and persistent thunderstorm activity on the planet form well-known effect of Schumann resonance. Resonator properties are considered to be very stable. First evidence of resonance frequency variations were found by Balser, Wagner, [1962]. Frequency varied by 0.3-0.4 Hz. Resonance variations were also found during sudden ionospheric disturbances [Cannon и Rycroft, 1982], and solar proton events [Roldugin et al., 2003]. Information about magnetic disturbances and Schumann resonance properties is somewhat controversial. On one hand, it was found that maximum frequency slightly decreases with increasing Ap-index [Sao, et al., 1973]; on the other hand, frequency increase by 0.1-0.3 Hz under higher Kp was reported [Satori, Zeiger, 1993]. In our paper we demonstrate that Schumann resonance frequency variations can be also caused by sudden variations of solar wind parameters.

Experimental results

Figure 1 presents behavior of different parameters recorded in a time interval around the SI-event of 15.11.2001 (14.00-16.00 UT). One can see H-component magnetic field variation (a1), long-period magnetic pulsations (a2), integrated VLF emissions (a3), and pulsation spectrograms in a frequency band 0-2.5 Hz for Lovozero (a4) and Barentsburg (a5). VLF-emissions were integrated in the band having a width of 20 % of the central frequency 1.3 kHz. It is seen that there was no VLF activity before the moment of SI, and magnetic pulsations were delayed with respect to VLF by ~6-7 minutes. In this case, a generally accepted mechanism of VLF generation due to near-Earth particle distribution function modification by MHD-waves with a subsequent VLF growth is very doubtful. We can definitely see that VLF generation process is attached to the border of the magnetosphere at the moment of solar wind irregularity contact with the magnetopause. Information about this contact, delivered by MHD-waves, is gained 6 minutes later (15.08). Only at the end of the interval (15.45-16.00) we can see VLF growth caused by near-Earth cyclotron instability development. Unfortunately, we can not confirm magnetopause origin of VLF by direct VLF satellite measurements. Geotail satellite was situated at this time at the dayside close to the magnetopause, and definitely could detect VLF activation (at least, the intensification around 16.00, which is very well pronounced), but data for the moment of interest (15.00-15.10 UT) are absent in INTERNET. Still, tail-located (about -15 Re) Wind-satellite registered a sharp and short-lived increase of VLF-emissions in 5-10 kHz frequency band (the instrumental range being 5-200 kHz). The bottom panel of Fig.1 demonstrates VLF and magnetic pulsations around SI in more details. Higher frequency VLF (4 kHz) reaches maximum amplitude somewhat earlier than 1.3 kHz emission does.

Fig.2 presents some changes in Schumann resonance properties after SI, detected in Lovozero and Barentsburg. We can see spectrograms of magnetic pulsations similar to those presented in Fig.1 but plotted in a broader frequency band (0-10 Hz) and for longer time interval 12.00-24.00 UT (a1 and b1). Schumann resonance is seen in the spectrograms as a broad white band with varying intensity at frequency of ~8 Hz. The horizontal 5-Hz lines are magnetometer's calibrating signals. The linear plots (a2, a3 and b2, b3) present the results of spectrogram integration along the frequency axis, the integration range marked by the vertical lines to the left from a corresponding spectrogram. The plots show average intensity variations of magnetic pulsations and Schumann resonance in Lovozero and Barentsburg inside the marked frequency bands. It is necessary to note that in frequency integration we use not a single component of magnetic pulsations but module of two horizontal components X and Y. So, variations of Schumann amplitude are rather unusual (the resonator pumping by global thunderstorm activity is very stable). Though separate variations of magnetic pulsation intensity in a resonator frequency band for both X and Y components are rather typical, they always vary in anti-phase, with the average energy being conserved (polarization is changed). May be this interesting effect is observed, because we have no data

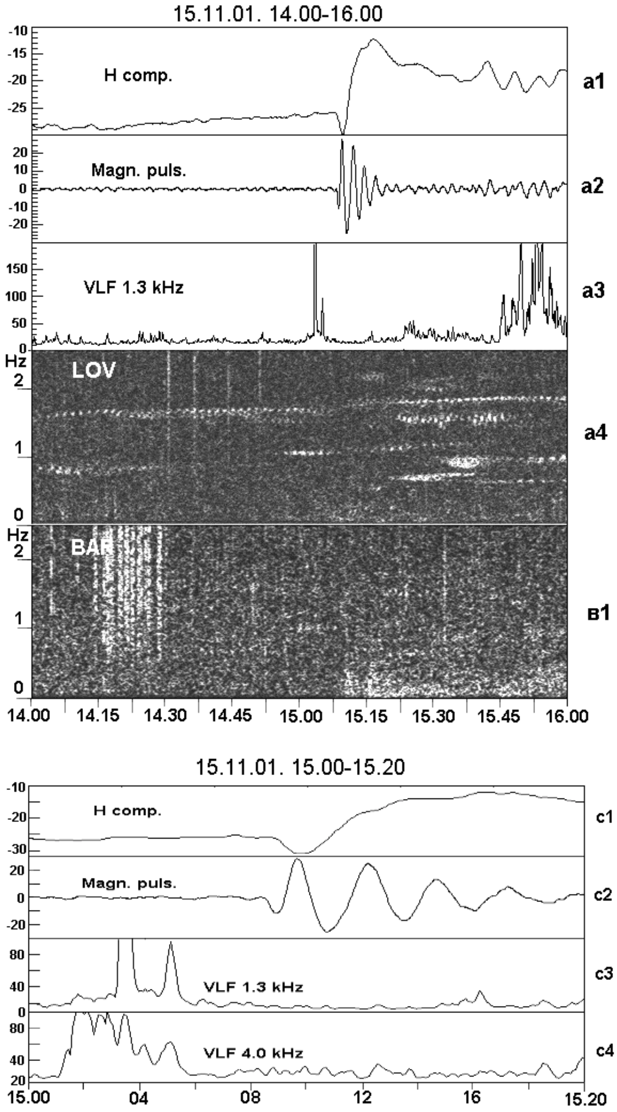

Fig.1. Observations of magnetic field variation (a1), magnetic pulsations (a2) and VLF-emissions (a3) in Lovozero. FFT-spectrograms for Lovozero (a4) and Barentsburg (b1). Data fragment with higher time resolution (c1-c4).

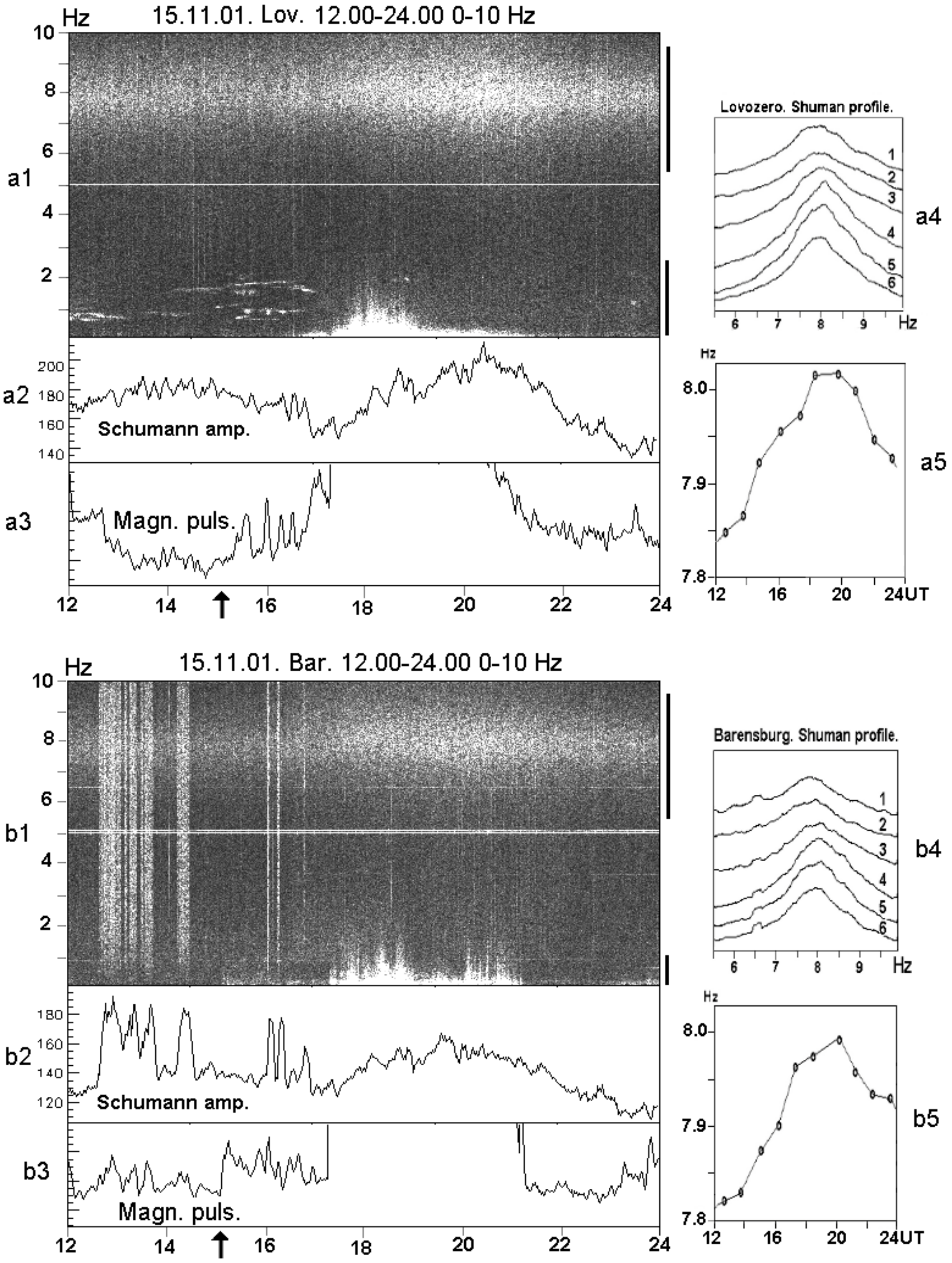

Fig.2. Spectrograms of magnetic pulsations for Lovozero (a1) and Barentsburg (b1) in a frequency band 0-10 Hz. Corresponding pulsation (a3, b3) and Schumann (a2 and b2) amplitudes. Frequency - integration is inside the bands, marked by the vertical lines. Results of 2-hours time-integration (resonance profiles), and resonance maximum variations (a4, b4 and a5, b5).

on the component in the vertical direction, where energy may be redistributed. It is also possible that resonator Q-factor has variations, and so energy leakage from the resonator can vary. Some indications of this one can see in a4 and b4, where changes of resonance curve half-width are visible. These plots are the results of 2-hours integration along the frequency axis (Schumann resonance profiles). The plots also demonstrate obvious shift in resonance maximum, which is shown in more details in a5 and b5. The resonance maximum changes from 7.85 to 8.05 Hz synchronously with amplitude variations. It is interesting to note that for Barentsburg, the resonance frequency maximum is always at somewhat lower frequency than for Lovozero (0.03-0.04 Hz). We also studied Schumann resonance variations after normal, not SI-triggered, breakup and did not find any special features of Schumann resonance behavior. The only interesting finding is that after strong breakups there is some tendency to resonance splitting, which was earlier reported by Labents [1998].

Conclusions

It is probable that the observed VLF emissions were generated during solar wind irregularity contact with the magnetopause, which can give a new method of direct time measurement of solar wind magnetic field penetration inside the magnetosphere. For 15.11.2001 this time is about 6-7 minutes. It was found that Schumann resonance amplitude increases after SI and reaches maximum after 2 hours. The resonance frequency changes from 7.8 to 8.2 Hz, not quite synchronously at Lovozero and Barentsburg. Those effects were not distinguished after normal, not SI-triggered, breakup.

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