EARTHQUAKE EFFECTS IN THE PULSATIONS OF GEOMAGNETIC FIELD

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Abstract. Anomalous changes in the behaviour of Pc1 geomagnetic pulsations and oscillations with the spectrum resonance structure (SRS) occurred few minutes before or after an earthquake have been found. In all cases the changes happened following the ULF electromagnetic pulse and were observed either as a sudden stop of oscillations, or as their sharp intensification. SRS reflects the ionosphere resonance properties that can be sharply modified due to effect of an earthquake on ionosphere. Changes in the resonance properties can be a reason of the effects in Pc1s as well. It is supposed that the effects in two types of emissions (Pc1 and SRS oscillations) are the consequence of the complex processes in the upper atmosphere, including precipitation of the charged particles into the ionosphere caused by the interaction of ULF electromagnetic pulse of lithospheric origin with the radiation belt.

Introduction. SRS structure is caused by the ionospheric Alfvén resonances (IARs) that are an interesting wave phenomenon well described in the literature [Polyakov and Rapoport, 1981; Belyaev et al., 1990; Bösinger et al., 2002]. The IARs formation region is located between two bends of the plasma density profile: in the lower part of the ionospheric F region and at altitudes of about 1000–3000 km. In this region, Alfvén waves are entrapped and form standing waves [Belyaev et al., 1999]. The quality factor of the resonator can attain a value of 5–10.

Structured Pc1 emissions are also well known phenomenon. Discrete packets of ion cyclotron waves are generated in the equatorial region of magnetosphere; they bounce between conjugate ionospheres penetrating partially to ground and being observed there as Pc1 pulsations.

Data. We studied Pc1 pulsations and local particularities of IAR manifestation at the Geophysical Observatory Borok (58.0°N, 38.2°E) and at the Mondy Sayan Observatory (51.6°N, 100.9°E). A typical example of a good-developed ionospheric Alfvén resonance pattern observed at Borok is demonstrated at the upper panel of Figure 1. Before 1600 UT we see some unstructured wave activity in the frequency range below 4–5 Hz, then several clearly defined bands with approximately equidistant values of frequency arouse from the diffused stain. Their frequencies slowly increase until local night. This event was observed at magnetically quiet time: Kp index did not exceed value of 2. Similar picture is seen at the central panel of Figure 1, plotted basing on data from Mondy. The bottom panel is an example of Pc1 frequency-vs-time display.

For Borok, magnetic tape records for periods 1973 to 1977 and 1985 to 1988 were analysed. Solar activity was low all these years. For Mondy, we used digital recordings with 64 Hz sample rate for several months in 2010. We studied IAR and Pc1 properties on the base of spectrograms. Time-frequency display of signals in the range between 0 and 5–9 Hz allowed us to search for the IAR events and then measure their frequency and dynamic particularities graphically. To analyse Pc1 emissions a narrower range was used. Main dependences of IAR characteristics at Borok are the...
same as those obtained from the observations at other sites: night time occurrence, preference for low magnetic activity, prevalence of $Y$- over $X$-component. Here we would like to attract one’s attention to the response of IAR resonant structure and Pc1 regime to external effects.

**Results.** Among other IAR characteristics at Borok and Mondy we have checked a response of the resonances intensity and frequency variations to the ionosphere disturbances caused by some external impacts. We found that remote earthquakes have their effects in the regime of IAR. It is worth to note that there were different types of IAR response to the seismic effects. Let us consider them in more details.

For example, Figure 2 shows a sharp disappearance of IAR structure after a pulse observed almost simultaneously with a remote earthquake. Here and afterwards arrow below a plot denotes time of an earthquake; digits below a figure show the earthquake universal time (hour, minute, second), geographic coordinates (latitude and longitude), depth of the seismic focus, and the earthquake magnitude. In Figure 3 we see a different type of the seismic effect. After the earthquake-connected pulse the spectrum resonance structure suddenly appears. At last, in Figure 4 the pulse from a remote earthquake erased not only IAR structure, but the whole background as well.

Structured Pc1 emissions are also affected by electromagnetic pulses from the earthquakes. The example shown in Figure 5 is a clear illustration of a sudden commencement of Pc1 series after an earthquake. A similar case observed at the Mondy observatory we see in Figure 6. Note that this time the seismic focus was located at very large depth. In Figure 7 we show an opposite case of Pc1 emission cease simultaneously with an earthquake-connected pulse.
Sometimes a pulse from earthquake makes two operations at once: it brings to a stop the spectrum resonance structure and initiates Pc1 emission. In Figure 8 a single event is displayed in two different time resolutions of spectrogram. Pc1 structure is not seen because in order to resolve IAR structure we had to choose a regime of plotting which did not resolve structure patterns of Pc1.

But in the other case we see that a remote earthquake can cease simultaneously both the IAR SRS and Pc1. In Figure 9 we again give two different spectrograms of a single event. Bottom panel shows Pc1 emission in more details.
At last we show that very similar effects can be observed from impulsive irregular emissions of PiB type without any earthquake. Top panel in Figure 10 illustrates breaking of IAR structure caused by PiB pulsations. Bottom panel shows detailed spectrogram of these pulsations.

**Conclusions.** Thus, the available experimental data yield evidence for the presence of an IAR and Pc1 response to far earthquakes. At first glance, the results presented above are contradictory and do not allow a general reasonable interpretation. However, let us consider data published by various authors. As is rightly noted in [Afraimovich and Perevalova, 2006], an earthquake is a complex source of acoustic and electromagnetic impact on the ionosphere. According to an idealized model [Rudenko and Uralov, 1995], a crustal earthquake source generates a spherical elastic wave that, arriving at the Earth’s surface, excites an acoustic wave in the atmosphere. The source of the ionospheric response is not the epicenter but a region in the overlying ionosphere. The signal from an earthquake is transmitted along the Earth’s surface in the atmosphere and ionosphere by waves of different types and velocities. This does not exhaust the subject. An earthquake, acting on overlying layers of the atmosphere, causes intense disturbances in the global electric circuit that produce electromagnetic waves propagating at the speed of light and transmitting information on the seismic event. This is indirectly supported by observations of the response of variations in the Earth’s electrostatic field to the catastrophic earthquake of December 26, 2004 [Röder et al., 2005]. Röder et al. reported on a high-amplitude electric signal recorded in Italy almost simultaneously with the main shock at the Sumatra epicenter.

Thus, our results do not contradict data of various authors on different types of the earthquake impact on the ionosphere. On the contrary, they expand the spectrum of possible electromagnetic manifestations of seismic processes.

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**References**


