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OBSERVATIONS OF IONOSPHERIC ALFVÉN RESONATOR BANDS IN HIGH LATITUDES

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Abstract. Ionospheric Alfvén resonance structures were detected during four days in Lovozero (for 15 days of observation). In all four days the resonance occurred in the evenings between 1600 – 2100 UT and lasted for several hours, in one case it was observed also in the early morning. The structure have 6-12 rising tones in the 0-5 Hz range with the frequency spacing of ~0.4-0.8 Hz and frequency growth rate of ~0.25 Hz/hr. Their intensity is below the noise level, with the *D* component being stronger than the *H* component. Sometimes the resonance structures were accompanied by considerably stronger Pc1 pearl pulsations with the same frequency growth rate.
A case of probable artificial pulsation 1-1.5 Hz at 26 February 1999 is described.

Introduction

Geomagnetic Pc1 pulsations (frequencies from 0.2 to 5 Hz) are commonly related to either Alfvén or magnetosonic wave modes. The Alfvén mode is guided. Its group velocity is directed along the external magnetic field. The magnetosonic mode is isotropic. The group velocity of the both modes in the cold plasma is equal to the Alfvén velocity $V_A = B/(4\pi\rho)^{1/2}$ where B is the magnetic field, ρ is the plasma density. The typical value of V_A in the magnetosphere and ionosphere is 1000 km/s.

So called pearl pulsations have the largest amplitude in the Pc1 frequency range. They are commonly considered to be originated in the far magnetosphere and to propagate earthward as an Alfvén mode. In the ionospheric *E* region (heights 90-140 km) they are converted into the magnetosonic mode, which then propagates horizontally in the ionospheric *F*2 region waveguide [Tepley and Landshoff, 1966].

Polyakov and Rapoport [1981] predicted ionospheric Alfvén resonance pulsations, which present standing Alfvén waves in the ionospheric *F* region (heights 140-1000 km). The pulsations are expected to contain two or four non-equidistant harmonics in the Pc1 frequency range.

The ionospheric Alfvén resonance was discovered experimentally in middle latitudes in Gorkiy by Belyaev et al.. [1987, 1990]. The authors used the horizontal and vertical magnetic induction coils as antennas. They have detected the resonance structure of the spectrum with several (up to 6) narrow emission bands in the frequency range of 1 to 5 Hz. The amplitude appeared to be considerably smaller than that of the pearl pulsations.

Bering and Benbrook [1995] registered intensive sine-like 2.3 Hz oscillations of the electric field by balloons at high Antarctic latitudes during local polar day and presumed their Alfvén resonance origin. But big intensity and single frequency make us classify them as pearl pulsations. At high latitudes, the Alfvén resonance, or Spectral Resonance Structure (SRS), was observed by Belayaev et al. [1997] in Kilpisjarvi, on the north of Finland. They reported that usually 3-4 spectral maximums were seen, the frequency spacing between the spectral peaks in the SRS being between 0.5 and 1.5 Hz and the ratio of the signal in the spectral maximum and minimum being about two.

Thus, the morphology of this phenomenon has not been known well at present. It is of interest not only because of being unexplored, but as an indicator of conditions in the upper ionosphere. In particular, the diagnostics of F region is important in heating experiments on artificial Pc1 generation. The aim of this paper is to check the SRS occurrence during observations in Lovozero.

Experimental technique

After the summer of 1996 the registration of electromagnetic emission in the 0-10 Hz range at four channels is carried out in Lovozero observatory (geographic coordinates 67.58 N, 35.04 E). The sensors are two induction coils with 240 000 turns per each one wound around ferroalloy core. Two channels measure the north-south and east-west components of the magnetic field, and two others measure the circular clockwise and anti-clockwise waves. Digital sampling lag is 50 millisecond, or 20 Hz frequency, using a 12-bit analog-to-digital convertor. The 5 Hz frequency test signal is added to the coils uninterruptedly. The

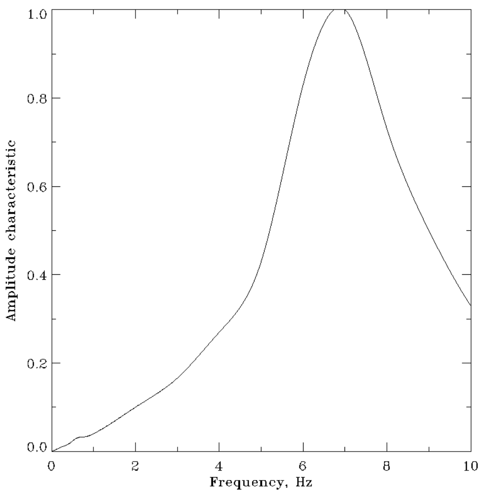

Fig. 1. Amplitude vs. frequency characteristics of *D*-channel of the ELF station in Lovozero.

amplitude versus frequency characteristic of D-channel is shown in Fig.1.

The records of about fifteen days were examined on the availability of SRS. Each 5-minute interval of a day record was transformed by FFT method and the received spectrogram for all the day from 0 to 10 Hz was glanced over. The first mode of Schumann resonance near 7.8 Hz was well pronounced always. But the SRS was hardly seen.

Experimental results

The SRS has been detected only after subtraction of mean spectrum from each 5-min realisation of FFT. The mean spectrum is obtained for each day by averaging of spectra for quiet intervals, i.e. for time periods without pearl Pc1 or strong Pi1 pulsation events. The thick line in Fig. 2 shows the mean spectrum for the case of 17 September 1998. It is an average of 5-min spectra in the time interval of 0820 - 2050 UT. The thin line represents the spectrum for 1925 -1930 UT. The resonance structure is seen here in the high-frequency part of the spectrum. Its amplitude is smaller than that of the mean spectrum and is near the noise level.

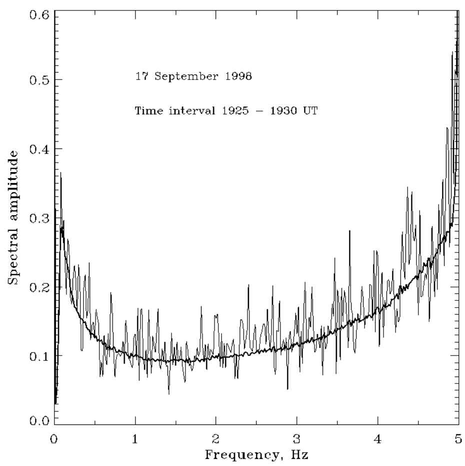

Fig. 2. The mean spectral amplitude on the ELF *D* channel for quiet period of 17 September 1998 (thick line) and the amplitude spectrum over a 5-min interval (thin line).

The dynamic spectrogram with subtracted mean spectrum for this day is shown in Fig. 3. The SRS is detected between night hours 1600 and 2100 UT. One can count about 12 rising tones in the 0-5 Hz frequency range, so the frequency spacing is about of 0.4 Hz. The ratio of maximum and minimum, as may be determined from Fig. 2, does not exceed 1.2, so the SRS in Lovozero could not be seen without the subtraction of the mean spectral amplitude. The frequency grows with time, the growth rate being of ~0.25 Hz per hour. The illegibility of the SRS in low frequencies may be due to the roll-off of low-pass filter, see Fig.1.

Another case (11 November, 1998) is shown in Fig. 4. The SRS appears again between 1600 and 2000 UT. The tones are also rising, but their number is 6 only and the frequency spacing is 0.8 Hz. After 2100 UT the pearl Pc1 happened. Note that it has the same rate of the frequency growth (~0.25 Hz/hr) as the SRS has.

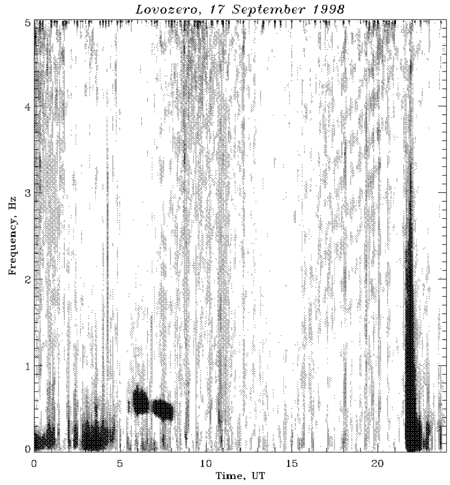

Fig. 3. The dynamic spectrum of the ELF *D* component on 17 September, 1998.

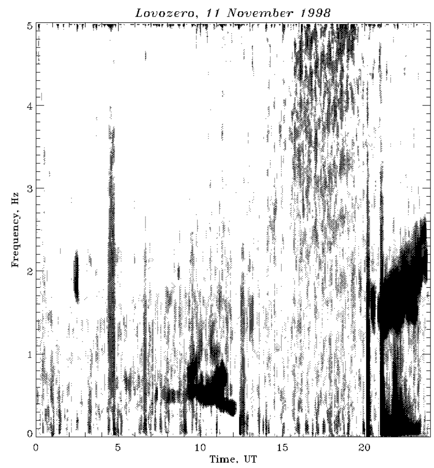

Fig. 4. The dynamic spectrum of the ELF *D* component on 11 November, 1998.

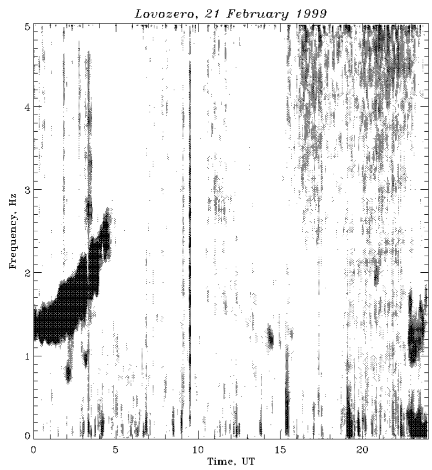

Fig. 5. The dynamic spectrum of the ELF *D* component on 21 February, 1999.

Jorma Kangas reported us about the SRS occurrences in Oulu observatory, Finland, on 21 and 26 February, 1999. Oulu is situated about 500 km westward from Lovozero. In the both cases the SRS are seen in Lovozero too.

The event of 21 February 1999 is presented in Fig. 5. The SRSs occur between 1600 and 2300, the number of rising modes is 8, the frequency spacing is 0.6 Hz. At early morning hours 0000-0500 UT, the pearl Pc1 took place. Its frequency grew from 1.3 Hz to 2.5 Hz. Thus both the value and sign of the frequency variation coincide for the two phenomena. Belyaev et al. [1987, 1990] presented the SRS cases with falling frequency in the morning. The question about similarity of temporal frequency changes for Pc1 and SRS is not solved.

Behaviour of both *H* and *D* components for the 26 February event is shown in Fig. 6. The SRS is more pronounced in the *D* component. This circumstance is observed not only in this day. It takes place in Lovozero also for usual Pc1 events. This day the rising tones with the frequency spacing 0.6 Hz were seen in the interval 1600-2100. In the early morning hours 0000 – 0400 two slowly falling tones with the frequency spacing about 0.8 Hz seems to have appeared.

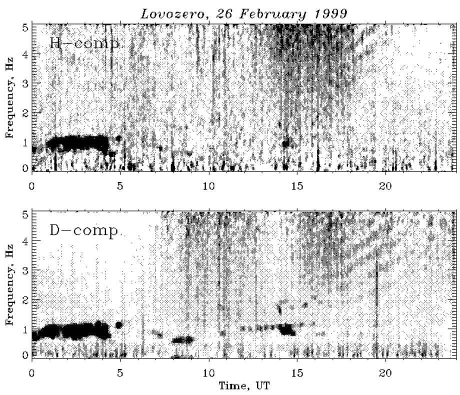

Fig. 6. The dynamic spectra of the ELF *H* and *D* components on 26 February, 1999.

The peculiar feature of this case is a strange signal between 1200 and 1600 UT. It has very narrow dashed tone linearly rising from 1 Hz to 1.5 Hz and looks like artificial Pc1 produced by modulated radio heating experiment in Tromso, see the review of Stubbe [1996].

However, according to a personal communication of M. Rietveld, there was no any heating experiment in Tromso this day. On 26 February the geomagnetic pulsation activity occurred. Except cases of natural Pc1 at 0000 - 0400, 0800 – 0900, 1400 – 1500 UT, there were also Pc3 pulsations near 0800 and 1200 UT with 30s period, and Pc4-5 at 0720 and 1230 with period of 120-150 s.

Conclusions

The spectral resonance structure (SRS) was registered at the high-latitude observatory of Lovozero. In most cases the SRS occurred from evening till midnight and looked like 6-12 rising tones in the 0-5 Hz range with the frequency spacing of ~0.4-0.8 Hz and frequency growth rate of ~0.25 Hz/hr. The SRS intensity is weak, below the noise level.

On 26 February, 1999 at 1200-1600 UT, an artificial signal was observed.

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