Correlating optical emissions, quasi-periodic VLF emissions and magnetic Pc3 pulsations

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Abstract

Regular magnetic pulsations of about 30-40 s periods (Pc3) have sometimes one-to-one correlation with quasi-periodic VLF emissions. It shows that the hydromagnetic wave can modulate the local parameters in space strongly enough that suitable conditions for particle interaction are formed. About a half of wavelength phase delay is usually seen between quasi-periodic VLF emissions and ULF wave on the ground because of difference in propagation velocity of waves. Wave-particle interaction should cause particle precipitation, which on the other hand should cause detectable optical emissions.

We have made simultaneous recordings of optical emissions, VLF emissions and magnetic pulsations at Porojärvi in Northern Finland at L-value of 6.1 on January 1993. Optical emissions were recorded by a simple wide angle photometer based on silicon photo diode without any filtering. On January 15, 1993 in late morning hours about 0555 UT a strong Pc3 event occurred and it continued several hours. Optical pulsation started at 0605 UT and continued to 0720 UT when the too much sunlight stopped the optical measurement. During that about one and half hours we could see correlating periodic variations both in optical emissions and VLF emissions simultaneously with Pc3 magnetic pulsation. Perfect correlation between VLF waves, optical emissions and pulsations was temporarily seen after sun rising.

1. Introduction

Pc3 domain waves are believed to be generated in the solar wind outside the magnetosphere by solar wind protons. The waves propagate into the magnetosphere and can be detected also on the ground. The periods are of the order of 30-40 seconds and at least on the ground the waveform is quite regular and monochromatic. Period seems to be well related to the solar wind speed and it has been found that f(mHz)≈6B (nT), where B is the IMF magnitude [1-3]. Engebretson et al. [4] showed that this relationship also appears to be true for some of the high-latitude pulsations.

Near and inside the plasmasphere these waves give rise to a set of other phenomena. One is the generation of quasi-periodic VLF-waves [5-8]. This is seen as periodically changing intensity and spectral structure of various hiss and chorus components at least in the frequency domain from a few hundred Hz to a few kHz. The observed time delays between the wave phases of Pc3 waves and the periodic variation of VLF waves indicate, that the region where the modulation takes place is somewhere in the equatorial zone near the plasmapause or in plasmasphere.

If we believe on the explanation given by Troiskaya et al. [2] that the magnetic waves are originally generated outside the magnetopause, then necessarily the magnetic wave is the source wave and the behaviour of the VLF waves is only a modulation caused by the magnetic wave. The growth of VLF waves gets the energy from the energetic particles in wave-particle interactions and as a result precipitation of particles to the atmosphere is possible. The precipitation of electrons having energies of tens or hundreds of keV can be detected on the ground easily by measuring the D-layer absorption of HF waves e.g. by riometers. Precipitation of electrons at lower energies are often observed by measuring optical emissions from E- and lower F-layer altitudes.

We have done measurements of magnetic pulsation, optical pulsations, VLF, and absorption pulsation in January 15, 1993 at Porojärvi having L-value of about 6.1.

2. Instrumentation

Magnetic pulsation was measured by 2-component induction coil magnetometer. Optical pulsation was measured by a simple photo diode wide-angle (about 45 degrees) nonfiltered photometer having response from about 500 to 1050 nm. VLF was measured by 2-component VLF-receiver with 1000 turn*m^2 areas and bandwidth from 0.250 to 9.250 kHz. These instruments were located in Porojärvi (69°10′N, 21°28′E), which is near the widely known Kilpisjärvi measuring station. For absorption measurements we have used our nearby riometer stations which are Kevo, Kilpisjärvi and Ivalo.

3. Observations

In the morning and noon hours on January 15, 1993 a strong Pc3 event took place. The Pc3 type magnetic pulsation event commenced at about 0551 UT and continued for several hours. The pulsation event was strong and peak–to– peak amplitudes were temporarily in excess of 10-15 nT. Pulsations were structured changing often in amplitude in time scales of a few minutes or tens of minutes. For most of the time practically one-to-one correlation was found between quasi-periodic VLF-events and Pc3 pulsations a couple of hours later in the same morning (Figure 1). The strongest magnetic pulsation observed about 40 s after VLF chorus variation. That is in agreement with the difference of the propagation velocity of ULF and VLF waves if the interaction has assumed to take place at equatorial region.

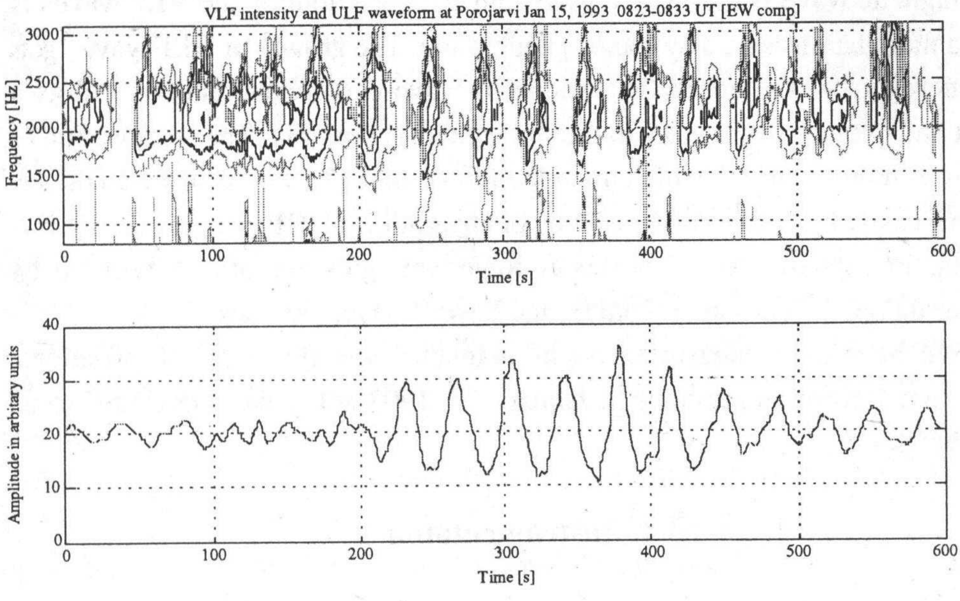

Figure 1a. Intensity variation of VLF chorus bursts in the frequency range of 0-3.1 kHz at 0823-0833 UT are shown as a contour plot in upper panel and EW component of magnetic field variation with arbitrary units is shown in lower panel.

Optical pulsation was noted for the first time at about 0600 UT. The pulsation clearly correlated with Pc3 and there is practically not doubt that those two phenomena were closely coupled. The recording of optical pulsation stopped at 0722 UT (0922 LT), when the background light finally caused the detector amplifier to saturate. An example of the magnetic and optical pulsation is shown in Figure 2 for period a little before the detector system saturated. The intensity variation is small but, however, several times stronger than necessary in order to be detectable. The figure is done by computer processing the direct penrecorder traces. It is interesting to note that for all the period when the correlation was found, the ambient light level is so high that the usual photomultiplier based systems cannot be used.

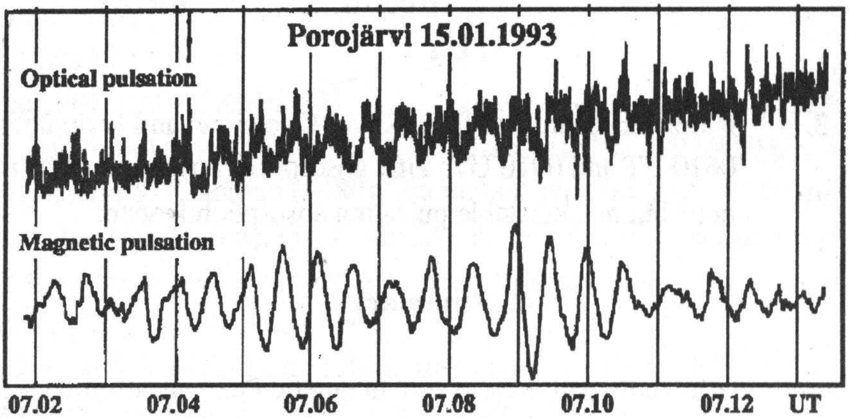

Figure 2. Simultaneous optical and magnetic pulsations measured at Porojärvi between 0702 UT and 0713 UT. The clearest correlation can be found during the time interval 0704-0711 UT. The amplitude scales of both recordings are arbitrary.

There are several riometer stations in Northern Finland. Figure 3 shows the absorption measured in Kilpisjärvi, Kevo and Ivalo. One can conclude that there is absolutely no indication of pulsating absorption.

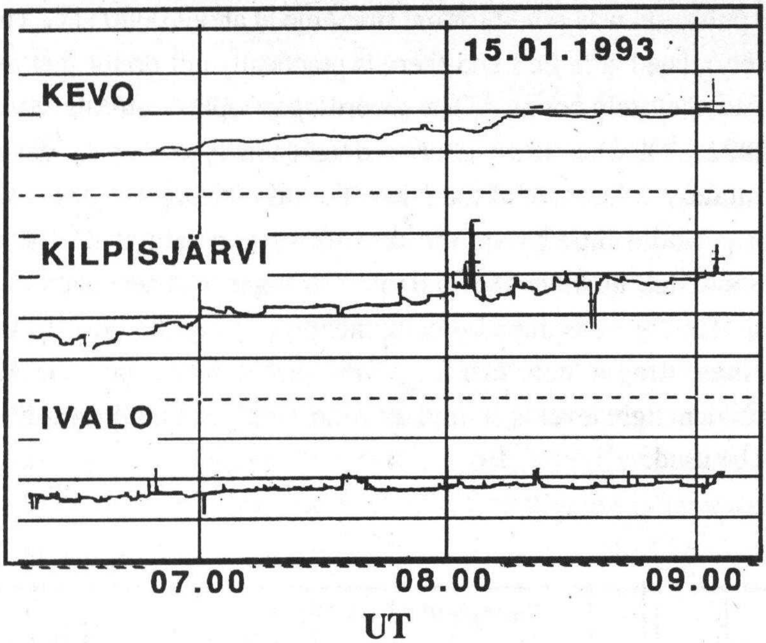

Figure 3. Riometer recordings from Kevo, Kilpisjärvi and Ivalo between 0610 UT and 0910 UT. Tiny absorption variation can be noticed but no detectable pulsating absorption is seen.

4. Summary

Clear correlation between optical and magnetic Pc3 pulsation was found during an event when Pc3 correlated most of time perfectly with periodic VLF-emissions. No indication of pulsating absorption was noted.

As a summary it seems that Pc3 wave caused modulation of VLF-waves and it caused periodic intensity variation of low energy (perhaps from hundreds of eV to some keV) precipitating electrons in the late morning hours. Within the detectability of the available instruments it did not cause periodic variation of precipitation of high energy electrons in tens of keV range.

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