A MODULATED MULTIBAND Pc1 EVENT OBSERVED BY POLAR/EFI AROUND THE PLASMAPAUSE

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ABSTRACT

We study an electromagnetic ion cyclotron (EMIC) wave event observed simultaneously by the Electric Field Instrument (EFI) on board the POLAR spacecraft and by the Finnish pulsation magnetometer chain on April 25, 1997, when the two were in a good conjunction. EFI recorded waves at two frequency bands from L = 4.3 (in the outer plasmasphere) to L=6.2 (just outside the plasmapause). Both bands were observed in several conjugate stations on ground. The waves showed repetitive variations in amplitude, corresponding to classical Pc1 pearls. The repetition period was the same on ground and in space. Moreover, the repetition period of Pc1 pearls coincided with the period of simultaneous Pc4 waves observed by POLAR and on ground. The observations suggest that Pc1 pearls (EMIC waves in general) are modulated by Pc4 waves rather than result from the bouncing of a wave packet from one hemisphere to another.

INTRODUCTION

Electromagnetic ion cyclotron waves have been studied for a long time both by ground and satellite observations. One common type of ground EMIC waves consists of a long chain of repetitive bursts of waves called pearls or structured Pc1 waves. Despite their frequent appearance on ground, very few pearls have been observed in space. This may be due to several reasons. It was recently noted (Mursula et al., 1994) that pearls were constrained to a rather narrow latitude range of about half a degree only. Taking into account the non-continuous occurrence of pearl activity in this narrow latitude range with a typical pearl duration of about 30s and a repetition period of about 2 minutes, this would imply a rather small probability to detect these waves even if the satellite crosses the wave region. Moreover, the orbit of most satellites has not been optimal for pearl detection. At ionospheric altitudes only single pearls, not a chain of several pearls, can be observed. On the other hand, most high-altitude satellites (e.g. geostationary satellites) either stay at too high invariant latitudes in order to detect pearls located close to the plasmapause, or cross the relevant L-shells too promptly to observe a chain of pearls.

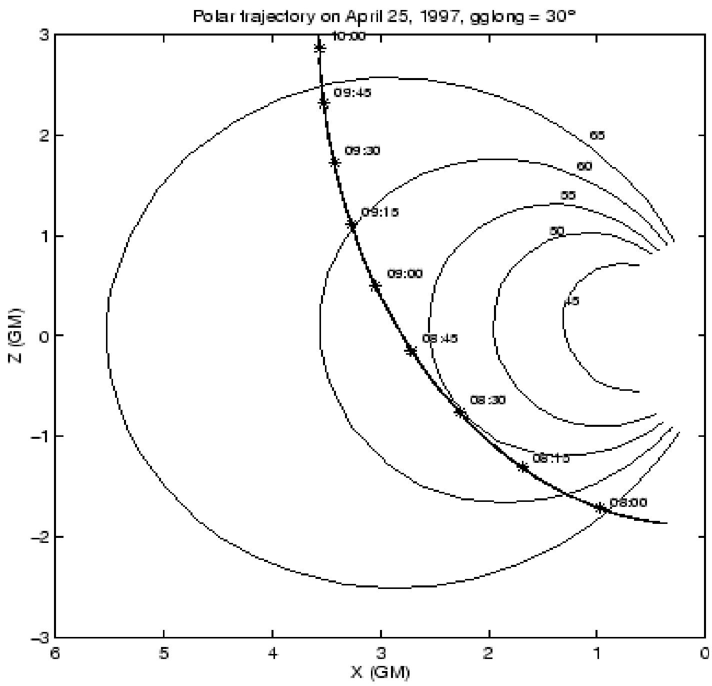

Fig. 1. POLAR north-bound orbit on April 25, 1997, in the inner magnetosphere between 55° and 65° INVlat.

The orbit of the POLAR satellite is better suited for pearl detection at mid-latitudes than e.g. equatorial satellites with similar apogee/perigee. This is due to the fact that a polar orbit traverses L-shells rather slowly at low magnetic latitudes. This virtue of the POLAR orbit is depicted in Figure 1 when

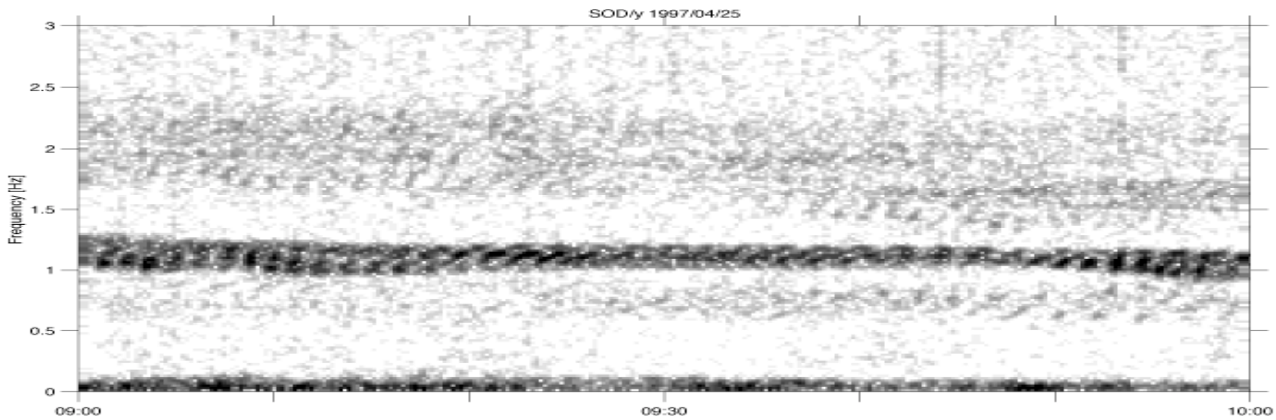

Fig. 2. Dynamic spectrum of magnetic observations at Sodankylä (L=5.1), Finland, during the latter half of the POLAR conjunction time.

slowly at low magnetic latitudes. This virtue of the POLAR orbit is depicted in Figure 1 when POLAR was flying northwards on April 25, 1997, crossing the invariant latitudes between 55° and 65° at about 08-10 UT in the 1130 MLT sector. Throughout this time, the POLAR footpoint was in a fair conjunction with the Finnish searchcoil magnetometer network.

OBSERVATIONS

During this POLAR pass, the Finnish searchcoil network observed strong Pc1 activity on ground. In Figure 2 we have depicted the dynamic spectrum of Pc1 waves observed during the latter half of the POLAR conjunction time (09-10 UT) at Sodankylä (L=5.1). Three Pc1 wave bands were detected with different frequencies and amplitudes. The strongest band (to be called S1) at about 1 Hz was rather narrow and consisted of a chain of separate pearls. The other band (S2) was broader, weaker and had a mid-frequency at about 2 Hz. The mid-frequencies of both bands were decreasing slowly with time. The third wave band (S3) was very weak and had the lowest frequency of about 0.75 Hz.

The EFI instrument on POLAR uses three orthogonal pairs of spherical probes to measure the vector electric field with time resolution of 40 samples/s in the nominal operation mode (see e.g. Harvey et al., 1995). EFI observed EMIC waves already in the southern hemisphere at about 08 UT. However, since the satellite crosses L-shells very quickly close to its perigee, the observations are more clear in the northern hemisphere, and we will concentrate here on the interval after the crossing of the magnetic equator. Figure 3 shows the spacecraft potential and the dynamic spectrum of the azimuthal electric field component from 0910 UT to 0950 UT. EFI observed two bands of EMIC waves which both started at about 0915 UT. One band (to be called P1) was rather short but strong and had a frequency of about 1 Hz. The other band (P2) was longer and had a frequency which was decreasing continuously from about 2.3 Hz to 1.5 Hz. Both bands consisted of separate bursts of waves. The higher frequency band had its maximum amplitude at about 0938 UT. (The magnetometer observations on POLAR (not shown) verify that the waves indeed are electromagnetic).

The spacecraft potential (see Figure 3) drops from about -1.5V at 0916 UT to about -3V at 0934 UT, corresponding roughly to a tenfold decrease in plasma density. This proves that POLAR crossed the plasmapause during this time. Accordingly, the EMIC wave growth region extended from the outer plasmasphere through the plasmapause to the plasma trough just outside plasmapause. This is in a very good agreement with the earlier results on the connection of Pc1 pearls with plasmapause by ground (see e.g. Roth and Orr, 1975; Webster, and Fraser, 1985) and satellite (Erlandson and Anderson, 1996) observations.

DISCUSSION

The two EMIC bands observed by POLAR correspond to the two higher frequency and more intense Pc1 bands observed at Sodankylä. We calculated the model values of the ion gyrofrequencies and found that the P1 band was below and the P2 band above the equatorial and local He+ gyrofrequency. Moreover, the decrease of the P2 frequency with increasing latitude follows roughly the decrease of the calculated He+ gyrofrequency. Despite fairly similar maximum amplitudes in

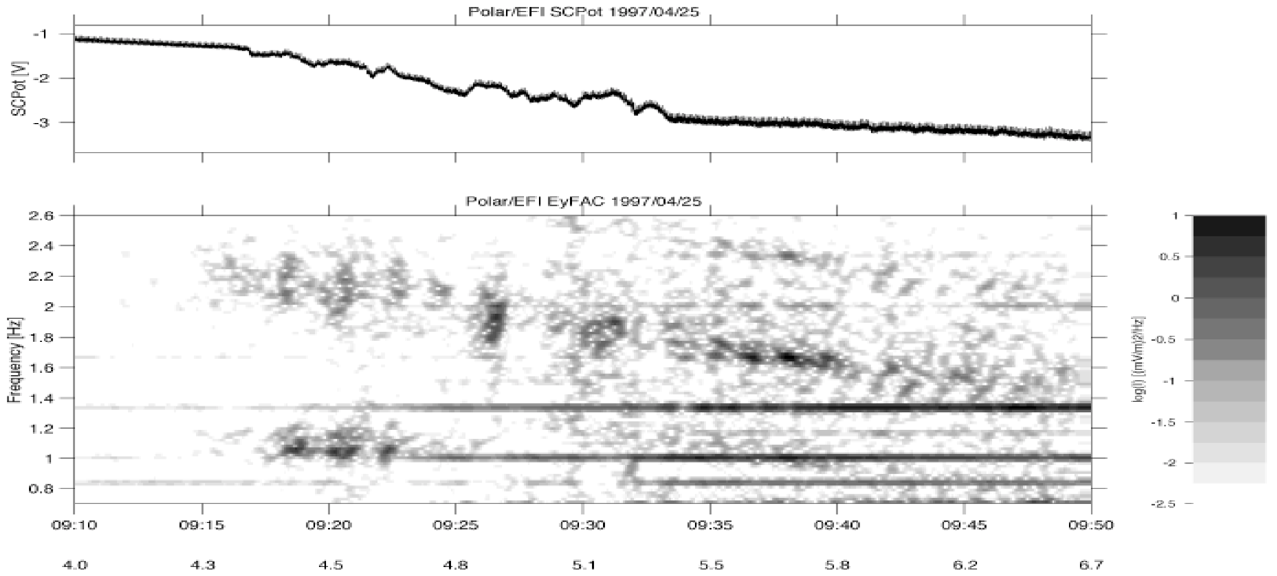

Fig. 3. Spacecraft potential and dynamic spectrum of the azimuthal electric field component. (Straight horizontal lines in the spectrum are unphysical harmonics of the spin residual).

space, P1 is observed considerably stronger on ground. This is probably because waves below the heavy ion gyrofrequency can freely propagate to the ground while those above it encounter the heavy ion stop band and may be greatly suppressed at low altitudes (see e.g. Young et al., 1981). The overall frequency range of P2 waves corresponds very well to the frequency range of the S2 band. (We also note that S1 band was seen at all ground stations but S2 only in the two higher latitudes stations, in agreement with the higher latitude of P2 waves).

Figure 3 also shows that in the inner edge of the plasmapause, waves with frequencies below the He+ gyrofrequency (P1 band) were dominating. Outside the plasmapause, the main wave power was above the helium gyrofrequency (P2 band). This corresponds well to the dependence of the EMIC wave growth in the different wave bands on plasma density (Kozyra et al., 1984). A higher density tends to favour the growth below the heavy ion gyrofrequency.

The S3 band was not observed in POLAR. This may result from the fact that the spin harmonics (straight lines in Fig. 3) get stronger below 1 Hz and seriously limit the observability of waves. The other possibility is that the source of these waves was at later MLT than reached by POLAR at high latitudes during this pass. This is supported by the fact that the S3 band gets stronger with time (see Fig. 2). This also agrees with the result that such low-frequency EMIC waves maximize in the afternoon high-latitude magnetosphere (Anderson et al., 1992).

The repetition period of pearls on ground during the time of POLAR observations was about 100 s. A very similar repetition period was obtained for the bursts of the P1 band. According to the bouncing wave packet model of pearl formation, the repetition period at POLAR should be twice that on ground. Therefore, this result gives a strict upper bound on the intensity of possible EMIC waves returning from below after the ionospheric reflection, in agreement with earlier observations at lower altitudes (Erlandson et al., 1992). Moreover, the repetition period of P2 band bursts at the time of P1 was also the same, suggesting that the modulation of P1 and P2 band waves was due to the same cause. Slightly later, during the time of maximum P2 amplitude, the P2 repetition period was somewhat shorter, about 80s.

A very interesting observation is depicted in Figure 4 which shows the wave form and dynamic spectrum of the radial electric field component. Almost sinusoidal long-period Pc4 waves are detected around the magnetic equator at about 0850 UT, and some less harmonic but still clearly visible waves thereafter until 0940 UT. (Similar weak Pc4 waves were also observed on ground; not shown here). The period of these long-period waves changes from about 60-70 s at equator to about 80-100 s at 0910-0920 UT, decreasing slightly thereafter. It is very interesting that the period of these long-period waves during the observations of P1 waves coincides with the repetition period of P1 and P2 bursts at that time. Even later, the small decrease of repetition period of P2 bursts correlates with the

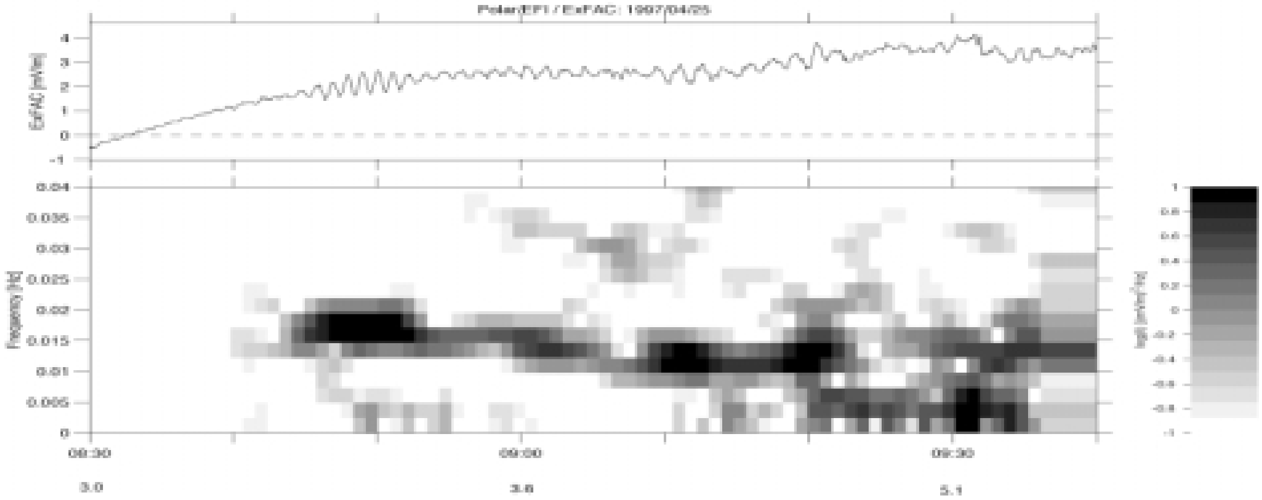

Fig. 4. Wave form and dynamic spectrum of the radial electric field component around and north of the magnetic equator.

small simultaneous decrease of Pc4 wave period. These observations strongly support the idea of EMIC waves being modulated by long-period Pc3/4 waves (see e.g. Plyasova-Bakounina et al., 1996; Mursula et al., 1997; Rasinkangas and Mursula, 1998), rather than being due to a bouncing wave packet.

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