

CORRELATION BETWEEN PULSATING AURORA AND VLF EMISSIONS FOR DIFFERENT TIME INTERVALS FROM MIDNIGHT TO LATE MORNING HOURS

I.A. Kornilov, A.A. Lubchich (*Polar Geophysical Institute, Apatity, Russia*)

Introduction

Pulsating aurora, accompanied by VLF emissions and magnetic pulsations is a very typical phenomenon during substorm recovery phase [1]. Pulsations start 10-30 minutes after breakup and often stay active till sunrise, when optical observations are impossible, but from balloon and rocket data it is well known that pulsating electron precipitations responsible for that type of aurora can continue up to noon. Analysis of TV and balloon data has shown that time interval from midnight to noon can be divided into three ranges with different characteristics of pulsations. Just after breakup (00-03 LT) pulsations are rather slow (with periods of about 5-30 sec.), energy of precipitating electrons being about 5-20 keV. Later (02-05 LT) on the top of the slow pulsations appear shot pulses known as microbursts while energy of electrons increases up to 40-60 keV. Aurora also exhibits a high frequency component in the form of various fast motions of auroral forms, 3-Hz modulation of pulsating patches brightness and so on. During late morning hours electron precipitation consists exclusively of microbursts with average energy up to 80-100 keV. In aurora one can see fast flashes of less than 1 second duration and intense pulsations of the same period. TV observations with synchronous record of VLF emissions yield new important information concerning the mechanism of pulsating aurora which is supposed to be an interaction of energetic electrons with different types of electromagnetic and electrostatic waves.

Instrumentation and data processing

Auroral pulsations have been studied by low light TV camera, VLF emissions - by VLF receiver with a loop antenna. All information was synchronously recorded on videotape and processed by computer, using the frame capture videocard and ADC (analog-digital converter) card. Two methods of analysis have been used, i.e. two-dimensional representation of correlation functions and epoch superposition. The total amount of data processed for the period 1993-97 covered more than 100 hours.

Results

Fig.1 demonstrates three types of correlation of auroral pulsations and VLF chorus for different periods of local time. The left panels of the figure are integrated correlation functions, calculated from two-dimensional correlation picture, the right ones are the corresponding fragments of data recordings. The top panel shows an example of postmidnight time interval 23.50-23.10 UT. Optical pulsations are rather slow, with periods of about 5-10 sec. The same periods exhibit VLF emissions. There are no chorus elements, more likely we can see weak, slowly pulsating hiss. Strong magnetic pulsations also occur at that time. Correlation analysis revealed anticorrelation between optical and VLF pulsations, with anticorrelating auroral pulsations lead VLF for about 0.2-0.6 sec.

The interval of early morning hours (03-03.20 UT) is shown on the middle panel of Fig.1. High frequency component with periods of 0.5-2sec. appears in auroral pulsations (mostly fast spreading pulsating patches for that case), though strong traces of the previous period equal to 5-10 seconds still exist. Chorus elements also become pronounced in VLF emissions and can be easily distinguished in VLF dynamic spectra (sonograms). Auroral - VLF correlation is positive, with time delays being concentrated preferably around zero.

Fig.1 (bottom) presents pulsations during the late morning hours (05.00-05.20 UT). There are no more slow auroral pulsations with periods of 5-20 seconds, though VLF and optical pulsations have some tendency to organizing in groups. Auroral pulsations transform to weak, fast flashers of low brightness with periods of 0.3-1sec. VLF emissions are strong, well-developed chorus. Time delays between aurora and VLF become very well pronounced. Integrated correlation function and epoch superposition show two maxima in delays distribution i.e. VLF lead aurora for 2 seconds and aurora lead VLF for 1.5 sec.

Fig.2 (left part) presents an example of aurora - VLF correlation function evolution for time interval 01.40-05.20 UT. Pulsations are slowly and continuously transforming from anticorrelating with VLF to correlating with zero time delay and further to correlating with time delays of 1-2 seconds. The right panels of Fig.2 (B and C) shows the results of epoch superposition. For the time period 05.07-05.20 of Jan.27 one can see that chorus are leading auroral pulsations for about 2 seconds and (though this effect is somewhat weaker) pulsations are leading chorus for 1.5 seconds, in agreement with the correlation analysis (Fig.1). Fig.2.(B) shows an important result, namely, that high correlation

coefficient between auroral pulsations and VLF chorus occurs not for the whole data sets, but particularly for the individual pulsation pulses. In Fig.2 (C) epoch superposition is presented for postmidnight hours (23.00-23.20 UT). Like in Fig.1, pulsations and chorus are anticorrelating with aurora leading chorus for about 2 seconds.

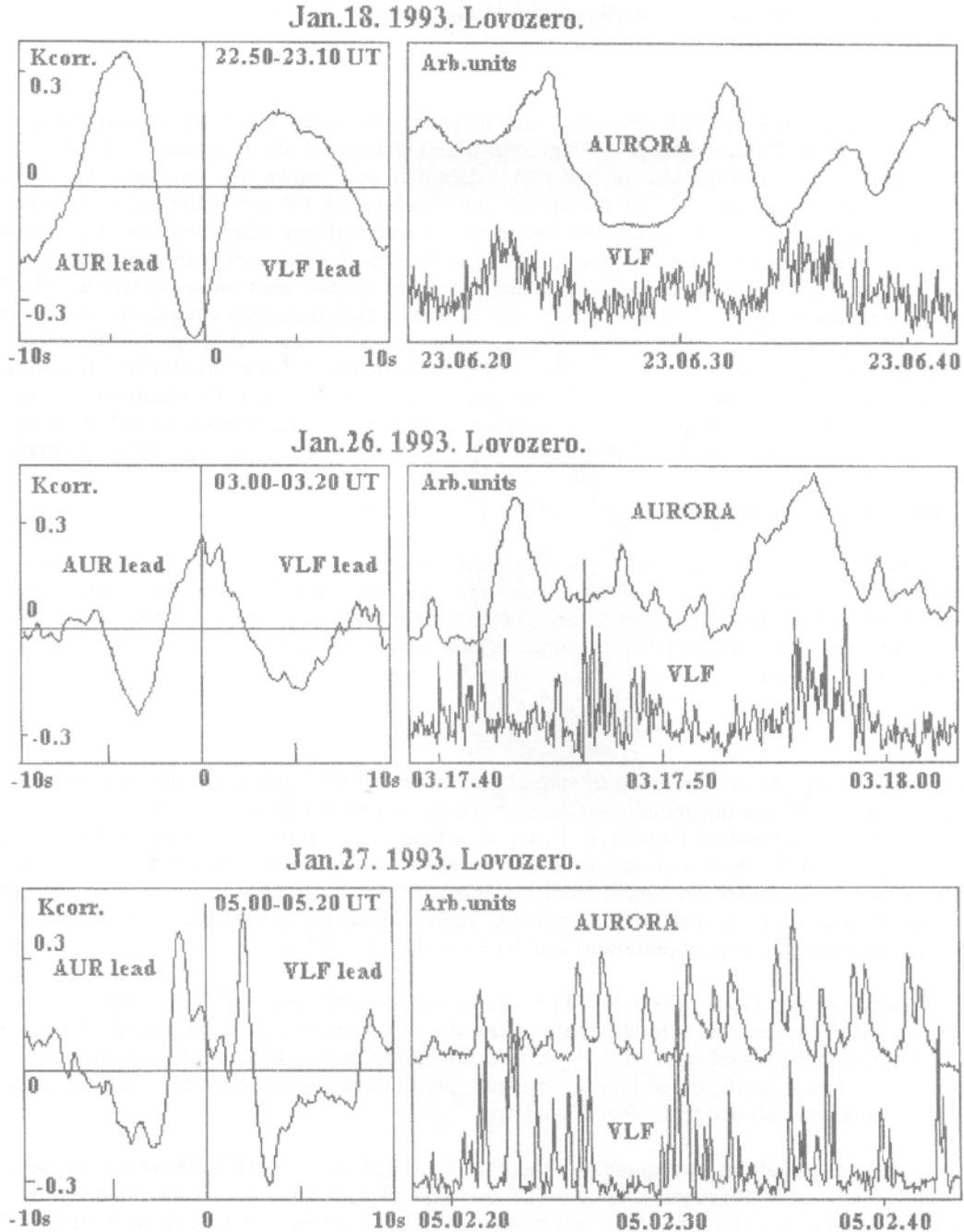


Fig.1. Three types of correlation between auroral pulsations and VLF chorus (left) and examples of data recording (right).

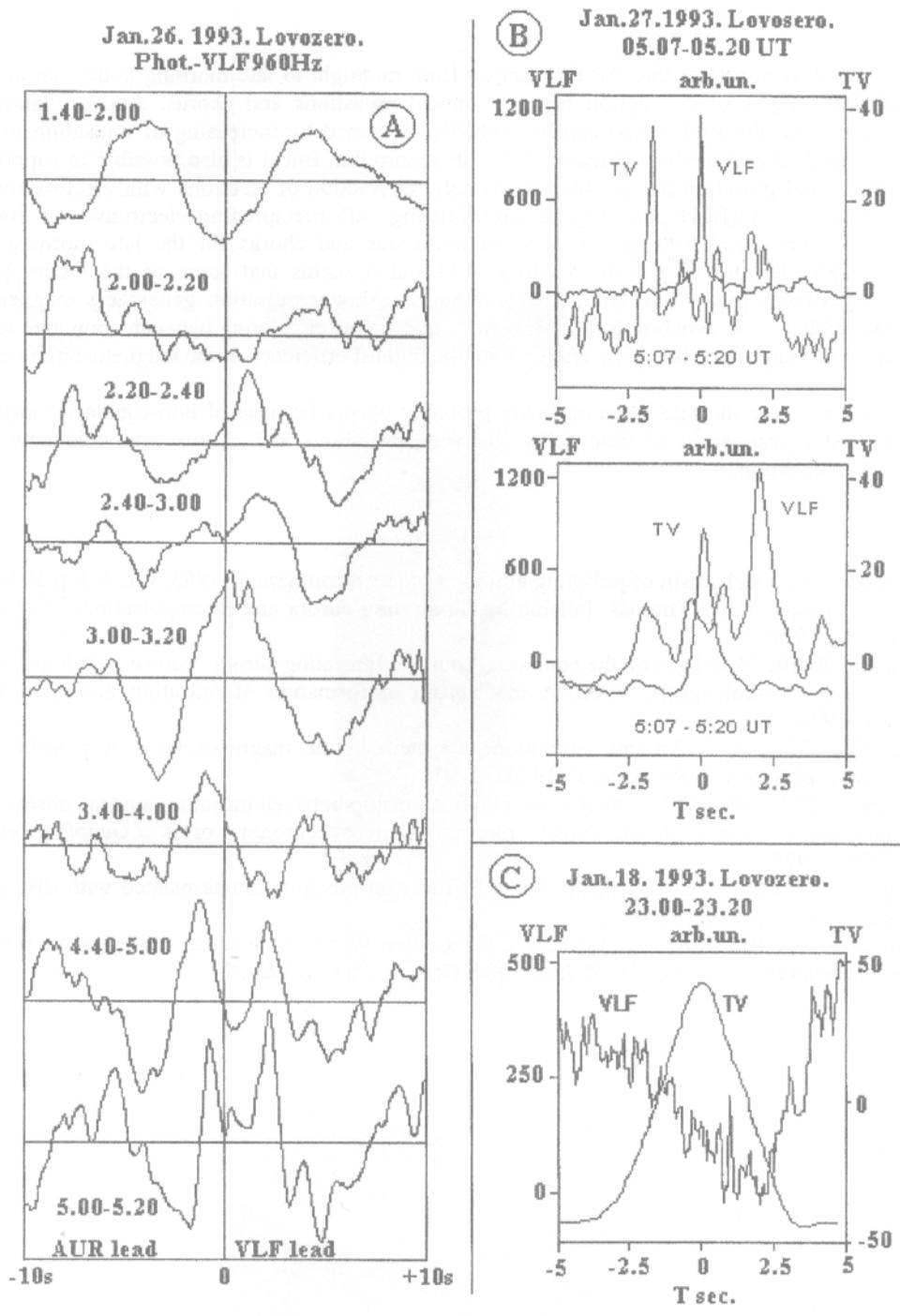


Fig. 2. Evolution of photometer-VLF chorus correlation function (A) for Jan. 26 and aurora-VLF epoch superposition (B and C).

Discussion

The results presented demonstrate that the time period from midnight to late morning hours can be divided into three ranges with different types of correlation between optical pulsations and chorus. Anticorrelation between auroral pulsation and chorus for the first period can be probably explained by increasing of ionisation in the ionosphere in pulsation maxima and, consequently, increasing of VLF absorption. But it is also possible to suppose another type of instability during initial pulsation period interval, namely, interaction of electrons with electrostatic hiss-type waves. Indeed, electrostatic waves (ECH pulsating hiss), correlating with precipitating electrons were found in experiment [2,3]. Sharp, well pronounced time delays between pulsations and chorus for the late morning hours can not be explained by modern theories of pulsating aurora [4,5] and it seems that some of the theory predictions are not confirmed by experiment [6]. Probably, in the late morning hours pulsation generating magnetosphere system is involved in some global-scale synchronisation. Electrons and waves circulating between conjugate ionospheres interact in such a manner that suggest exchange by energy with the highest efficiency at the magnetospheric equator.

Time delay asymmetry for the late morning hours probably occurs because of non-equatorial location of the source [7,8], so a detailed investigation of time delays between pulsations and chorus can yield new information about pulsation source localization.

References

1. A.D. Johnstone. The mechanism of pulsating aurora. *Annales Geophysicae*, 1983, v.1, 4-5, p.397- 410.
2. I.A. Ward, M. Lester, R.W. Thomas. Pulsing hiss, pulsating aurora and micropulsations. *J.Atm.Terr. Phys.*, v.44. N11, p.931-938. 1982.
3. M.P. Gough, A.Korth. New light on the equatorial source of pulsating aurora. *Nature*. v.298. p.253-255. 1982.
4. Demekhov, A.G., Trakhtengerts, V.Yu. A mechanism of formation of pulsating aurora, *J.Geophys.Res.*, v.99, p.5831-5841, 1994.
5. Davidson, G.T., Chiu, Y.T. An unusual nonlinear system in the magnetosphere: A possible driver for auroral pulsations. *J.Geophys.Res.*, v.96, p.19353-19362, 1991.
6. R.J. Nemzek, R. Nakamura, D.N. Baker et al. The relationship between pulsating auroras observed from the ground and energetic electrons and plasma density measured at geosynchronous orbit. *J.Geophys.Res.* v.100, No. A12, p.23935-23944. 1995.
7. Rosenberg, T.G., Hellivell, R.A., Katsubrakis, J.P. Electron precipitation associated with discrete VLF emissions. *J.Geophys.Res.*, v.76, p.8445, 1971.
8. Khrustchinsky, A.A., Kornilov, I.A., Lazutin, L.L., Riedler, W, On the location of the source for X-ray microbursts. *Proc.Conf. Acivments of the IMS*. 26-28 June 1984, Graz, Austria. p.325-327.