Influence of the Ionosphere on the Spectral Structure of *Pc* 1 Geomagnetic Pulsations

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The dynamic spectra of several series of geomagnetic *Pc*1 pulsations ("pearls") appearing simultaneously at an observation station and having about equal group delay times are examined. The difference between the center frequencies of the series of "pearls" on the sonograms for the twelve events examined amounted to 0.20-0.50 Hz. An interpretation of the observed phenomenon is presented, with the resonance properties of the ionosphere Alfven resonator taken into account.

Introduction. Geomagnetic *Pc*1 pulsations ("pearls") are a widely known geophysical item and have been well-investigated experimentally and theoretically [1]. In recent years papers have appeared on investigations of the generation of these pulsations in a nonuniform magnetic field [2, 3] and the red-violet asymmetry in the creation of the "pearl" satellites has been detected and interpreted as the result of the decay of an Alfven wave into Alfven and ionic sound [5].

In the experimental investigation of the spectral characteristics of geomagnetic *Pc*1 pulsations main attention was accorded to the analysis of the narrow band of frequencies in principle forming the largest oscillation amplitude. However, this approach did not permit consideration of features of the spectrum in a broad frequency range. Moreover, analysis of the *Pc*1 spectra shows the presence of several series operating simultaneously in the frequency range ∿ 0.5-2.5 Hz [6]. An interpretation of this phenomenon is given in this paper, based on the frequency-dependence of the ionosphere coefficient of reflection of *Pc*1 pulsations.

Observations. Analysis was made of the dynamic spectra of "pearls" recorded at the observatories of Sogra (USSR, L = 3.6) and Kergelen (France, L = 3.7) during 1965-66, and Nurmiyarvi (Finland, L = 3.3) during 1977. In each case 2-3 series of "pearls" were observed having different center frequencies and about equal group delay times. Each series represents a train of structural elements on the sonogram describing the multiple transit of the source region by the wave packet owing to reflection from the conjugate ionospheres. The difference between the center frequencies of the series of "pearls" for these events amounted to 0.2-0.5 Hz. As an example, Fig. 1 shows a typical case recorded at the Nurmiyarvi observatory on December 7, 1977. The figure shows that three series of "pearls" were observed at 0330 UT with center frequencies of 1.2, 1.57 and 1.94 Hz with a group delay time of τ = 77 seconds. The length of each series did not exceed 15 minutes. The series of "pearls" with center frequency 1.57 Hz had the greatest amplitude.

Usually the series with the greatest amplitude is selected for further detailed examination. Therefore the effect of the simultaneous appearance of several series is overlooked. In this paper every "pearl" spectrum is analyzed and a possible interpretation of its multi-frequency nature is given.

Interpretation. To interpret the phenomenon described above we consider the reflection of the Alfven wave from the ionosphere. In [7-9] it is shown that the earth's ionosphere layer of thickness ∿ 1500 km forms a resonator for Alfven waves in the *Pc*1 region. For waves moving earthward from the magnetosphere, the Alfven resonator is a reflecting layer with a reflection coefficient having an oscillatory dependence on frequency. This dependence is most clearly expressed for the nighttime ionosphere [8, 9]. The behavior of the reflection coefficient is shown qualitatively in Fig. 2. According to [8, 9] the minima of the reflection coefficient correspond to the natural modes of the ionosphere Alfven resonator. The distance between cycles of the reflection coefficient in frequency depends on latitude and is of the order of 0.3-0.8 Hz for waves in the range of Hz [9].

The formative process of some simultaneous series of "pearls", observed as a rule in the early morning hours [10], may appear as follows. The Alfven waves excited in the magnetosphere with a sufficiently broad spectrum, on incidence in the ionosphere are reflected in the frequency regions corresponding to the maxima of the reflection coefficients. The reflected waves will again be amplified in the magnetosphere and return after reflection from the conjugate ionosphere. This process is repeated and hence the waves attain the quite large amplitude required for passage through the ionosphere to be recorded at earth. The ratio of the signal amplitudes recorded on earth and at satellites is usually of the order of 0.01-0.05 [11]. The selective reflection of wave spectra

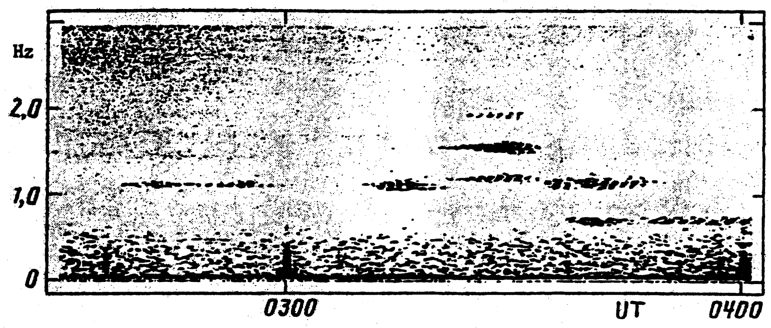

Fig. 1. Sonogram of the *Pc*1 pulsations ("pearls") on December 7, 1977 at the Nurmiyarvi observatory.

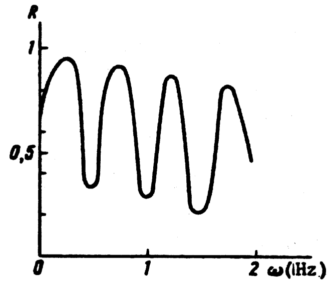

Fig. 2. Qualitative frequency-dependence of the reflection coefficients of Alfven waves from the ionosphere.

with an oscillatory structure of the reflection coefficient from the ionosphere, their further reinforcement and penetration of earth, also should lead to the appearance of several simultaneous series of "pearls" observed at the earth. The difference between the center frequencies in Fig. 1 is close to the distance between the cycles of the reflection coefficient. Those portions of the spectrum that correspond to minima of the reflection coefficient will clearly be absorbed in the ionosphere. Finally, for a more detailed study of this effect, simultaneous observations of series of oscillations at earth and satellites are necessary.

Discussion. To explain the appearance of several series of "pearls" another mechanism can also be considered in principle. Thus, for example, the simultaneous arrival of several series of different frequencies at an observing station is possible from different regions of generation. However, in this event the group delay times of the wave packets in each series should differ owing to passage through regions with different geophysical conditions. The observed equality of the group delay time for all series of "pearls" in Fig. 1 attests to the fact that the wave packets of each series are propagated over the same path, i.e., they have the same generation source. With the method proposed in [12, 13] the source region of the pulsations (L = 3.5-4.0) can be localized. Thus, the mechanism stated does not explain the phenomenon shown in Fig. 1.

Another mechanism for the appearance of several series may consist of the influence of heavy ions (O^+ and He^+) on the generation and propagation of Alfven iono-cyclotron waves. As known (see, e.g., [2, 14, 15]) the presence of heavy ions leads to the formation of gaps in the spectrum of the pulsations near their gyrofrequency. At the shells $L \approx 3.5$-4.0 the equatorial gyrofrequencies of helium and oxygen are $\omega_{He^+} \approx 2.1$ Hz, $\omega_{O^+} \approx 0.53$ Hz. If the heavy ions exert an influence on the appearance of several simultaneous series, the so-called high- and low-frequency portions of the wave spectrum would be concentrated in the vicinity of the gyrofrequency, in which case the separation in frequency between the branches relating to He^+ and O^+ would be about 1.5 Hz. This would be a completely different picture than that shown in Fig. 1. Therefore, this mechanism in this case is also unsuitable.

Conclusions. Thus, of the possible interpretations considered for the simultaneous appearance of several series of "pearls" with different center frequencies and like group delay times, it can be considered that only consideration of the resonance properties of the ionospheric Alfven resonator permits explaining the nature of the phenomena described here.

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