ON THE PROPAGATION VELOCITY OF SHORT-PERIOD OSCILLATIONS OF THE EARTH’ S ELECTROMAGNETIC FIELD OF THE Pc-1 TYPE (“PEARLS”)

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ON THE PROPAGATION VELOCITY OF SHORT-PERIOD OSCILLATIONS OF THE EARTH' S ELECTROMAGNETIC FIELD OF THE Pc-1 TYPE ("PEARLS")

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Oscillations of the Pc-1 type are characterized by a regular, almost sinusoidal form; their period lies within $\sim$ 0.3–4 sec, the duration of the oscillations is from tens of minutes to several hours, and the amplitude is usually modulated with a period of the order of 2 min. Variations Pc-1 in the magnetic field have an amplitude from 10^{-3} to 10^{-2} γ in middle and equatorial latitudes and up to 1 γ in the auroral zone.

According to present views, oscillations of the Pc-1 type owe their origin to packets of hydromagnetic waves moving along magnetic lines of force from one magnetically conjugate point to another (in conjugate points their reflection occurs). It is considered that oscillations of the Pc-1 type propagate only along sufficiently distant magnetic lines of force with $10 > L \geq 4$, intersecting the Earth' s surface in a zone situated between latitudes 60–72° ([1]). This belt of latitudes is the immediate source of Pc-1 oscillations, whence they propagate toward the equator along a waveguide formed by the ionospheric F_2 layer. At every point of the lower boundary of this waveguide, transformation of hydromagnetic waves into electromagnetic waves takes place, which are recorded at the Earth' s surface. Since the propagation velocity of hydromagnetic waves in this waveguide, according to theoretical estimates, should be of the order of 500 –1000 km/sec, one may expect a noticeable difference in the arrival times of Pc-1 oscillations at stations situated along one longitude.

In order to detect such a delay, in the spring of 1966 registration of short-period oscillations of the electromagnetic field was carried out at the stations Sogra (Arkhangel' sk Region), Borok (Yaroslavl' Region), and Ashkhabad. As sensors, induction coils with a photoelectric fluxmeter ([2]) were used; recording was done on photographic paper with a sweep of 10–20 mm/sec; time marks every 0.1 sec were supplied from quartz clocks having a daily drift of ± 0.1 sec.

To determine the time shifts, segments of simultaneous recording at two or

Fig. 1. Example of simultaneous recording of variations of the magnetic field at the Borok and Ashkhabad stations. 30 III 1966, 23 h 56 min GMT

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Fig. 2. a —graph of the cross-correlation function between the H_S components of Sogra and Borok; b —the same between the H_S components of Borok and Ashkhabad

Figure 2: Fig. 2. a —graph of the cross-correlation function between the H_S components of Sogra and Borok; b —the same between the H_S components of Borok and Ashkhabad

three stations with oscillations having envelopes close in form were used. Such segments are not always encountered, even at the Sogra and Borok stations, which are located only 700 km from one another. Correlation of oscillations at Ashkhabad with oscillations at Sogra and Borok is a very rare case. It is noteworthy that poor correlation of oscillations between stations is always accompanied by poor correlation between components at each station. The most probable explanation for the absence of good correlation, in our opinion, is the presence, as a rule, of not one but two or several regions in the belt 60—72°, which are the source of *Pc*-1 oscillations. In this case Sogra and Borok in the majority of cases are considerably closer to one of the regions than to all the others. Oscillations from the nearest region predominate at these two stations, which creates favorable conditions for the existence of good correlation between the oscillations at Borok and Sogra. The distances from the sta-

tions from Ashkhabad to these regions, as a rule, should differ little from one another, and therefore oscillations from them arrive here with amplitudes of the same order, forming a complex interference pattern.

During the experiment several hours of simultaneous recording at Sogra and Borok were obtained, and several tens of minutes of recording at all three stations with good correlation of the oscillations. A sample of such a recording is shown in Fig. 1. To determine the time shifts, the ordinates of simultaneous records were digitized at intervals of 0.1 sec, and then normalized cross-correlation functions between the components of two stations were calculated.

Fig. 1. Example of simultaneous recording of variations of the magnetic field at the Borok and Ashkhabad stations. 30 III 1966, 23 h 56 min GMT

Fig. 2. *a* —graph of the cross-correlation function between the H_S components of Sogra and Borok; *b* —the same between the H_S components of Borok and Ashkhabad

Figure 2 shows graphs of the cross-correlation functions between the H_S components of Borok and Sogra (*a*), Ashkhabad and Borok (*b*). From consideration

Fig. 3. Envelopes of Pc-1 oscillations at Borok, Irkutsk, and Ashkhabad. 30 March 1966.

Figure 3: Fig. 3. Envelopes of Pc-1 oscillations at Borok, Irkutsk, and Ashkhabad. 30 March 1966.

of these graphs the following conclusions may be drawn:

1. The Pc-1 oscillations pass through Ashkhabad approximately 3.3 sec later than through Borok, which corresponds to an apparent wave-propagation velocity of approximately 800 km/sec (the true group velocity of the wave must be smaller).
2. The Pc-1 oscillations reach Borok 0.2 sec later than Sogra. If the east-west components of the oscillations at Borok and Sogra are correlated, the time shift is reduced to 0.1 sec. This value lies within the observational error.

The absence of a noticeable time shift between the Pc-1 oscillations at Sogra and Borok can be interpreted in two ways. One may suppose that, during the passage of the observed series of Pc-1 oscillations, both stations were located in a region which as a whole was the source of these oscillations. O. M. Barsukov, in comparing several simultaneous records of Pc-1 oscillations made at Borok and Lovozero (Murmansk Region), established the absence of a time shift between these oscillations > 0.1-0.2 sec. ([3]). Comparing our results with the conclusions of

Fig. 3. Envelopes of Pc-1 oscillations at Borok, Irkutsk, and Ashkhabad. 30 III 1966.

O. M. Barsukov, it can apparently be asserted that the diameter of the region that is the source of the Pc-1 oscillations is of the order of 1000 km.

Another explanation is also possible, however. The sources of all the Pc-1 oscillations observed by us and by O. M. Barsukov may have lain somewhere sufficiently far to the west or east of both stations, so that the distances and travel times of the waves from the source to them were approximately the same. Further observations will help establish which of these assumptions is correct.

In conclusion, it is necessary to mention the observed cases of good correlation of Pc-1 oscillations at Borok and Irkutsk (Fig. 3 shows the envelopes of these oscillations). Unfortunately, the low sweep speed of the record does not make it possible to speak with certainty about the presence of a time shift between the oscillations at Borok and Irkutsk. However, the fact of good correlation of separate groups of oscillations makes it possible to suggest the same mechanism of propagation of Pc-1 oscillations both from north to south and in the latitudinal direction, i.e., along the ionospheric waveguide.

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Note: Figure translations are in progress. See original paper for figures.