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Abstract

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On Short-Period Oscillations of the Train Type of the Natural Electric Field in the Sea

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During the International Geophysical Year, the study of short-period oscillations of the Earth' s electromagnetic field was widely developed; however, in the literature there is no information on short-period oscillations of the natural electric field in the sea.

In the present work, records of variations of the natural electric field in the Black Sea from May 1959 to May 1961 at a stationary installation were used, as well as materials from expeditionary stations in several seas. The stationary installation consisted of two mutually perpendicular baselines, the longer of which was placed parallel to the shore, in order to eliminate Faraday currents, at a distance of 50 m from the shoreline. Contact with the marine medium was achieved by means of nonpolarizing graphite electrodes. The signal was recorded on EPP-09 electronic potentiometers with a chart speed of 240 mm per hour. Similar electrodes were used in assembling an installation for recording telluric currents in the coastal zone. Comparison of records of trains of oscillations in the sea and in the upper soil layer showed that the field strengths of the former are on average one and a half times greater than those of the latter. Taking into account the conductivities of seawater and of the rocks in the upper part of the coastal region, it follows from this that the current densities in the sea exceed those on land (for the given arrangement of the marine and terrestrial measuring baselines) by several hundred times. The most characteristic field strengths of trains of oscillations of the electric field in the sea are 5–15 mV/km; maximum values reach 35 mV/km. The periods of marine trains of oscillations do not differ from terrestrial ones and vary mainly from 50 to 90 sec. No dependence was found between the magnitudes of amplitudes and periods.

The distribution of the frequency of occurrence of trains of oscillations over the day is similar to the diurnal variations of these oscillations for some mid-latitude stations ([1], [2]). The maximum occurrence of trains of oscillations falls at 22–01 hours local time. The graph of the diurnal variation for the equinoxes has a broader maximum in comparison with analogous graphs for the winter and summer periods. The activation of the processes responsible for exciting trains of oscillations at a definite time of day—22–01 hours local time, or 19–21 hours universal time—is also emphasized by the distribution of active types of trains

Figure 1

Figure 1: Figure 1

of oscillations (oscillations with an amplitude of 15 mV/km or more and series of oscillations with a number of trains not less than three) over the day: the maximum frequency of occurrence of these types of trains of oscillations also falls at the indicated time. In many works of recent years ([2], [3]) the opinion is expressed that the diurnal variation of trains of oscillations is controlled by local time. However, the absence of the "polar-night effect" for trains of oscillations ([4]) and cases of their simultaneous occurrence over enormous areas do not confirm the dependence of the time of excitation of trains of oscillations solely on illumination. In particular, in the materials used, with identical apparatus, cases were noted of synchronous excitation of trains of oscillations in different water areas of the Black Sea and at expeditionary stations in the Baltic and Japanese seas, i.e., over considerable latitudinal and longitudinal intervals.

The seasonal course of trains of oscillations is characterized by a sharp increase in their frequency of occurrence at the equinoxes (Fig. 1). In the equinoctial months the projection of the Earth onto the Sun intersects heliographic latitudes rich in active formations, whereas, as the summer or winter solstice is approached, it intersects regions immediately adjacent to the equator, where the number of active formations decreases sharply. This explains the rise in the level of magnetic activity at the equinoxes, reflected in the graphs of annual changes in activity according to the K-index and the U-measure; moreover, in years close to the maximum of solar activity, an increase in magnetic activity is also observed during the summer-solstice period. A similar character of the seasonal course is found for M-disturbances. Such a similarity in the seasonal changes in the frequency of occurrence of trains of oscillations and in the level of magnetic activity indicates the existence of a connection between them and a common causal dependence on active regions on the Sun. The predominance of the autumn maximum over the spring maximum in the graph of the seasonal course of trains of oscillations can apparently be explained by the different number of formations, in the northern and southern hemispheres of the Sun, that affect the excitation of trains of oscillations.

Fig. 1. Seasonal course of oscillations of the train type.
1 –for increased cases of occurrence of trains; 2 –for trains with amplitude ≥ 15 mV/km; 3 –for series of oscillations with a number of trains not less than three. n –number of cases

The indicated connections and dependencies are also confirmed by the 27-day recurrence in the occurrence of trains of oscillations. To reveal this regularity, a "carpet" of disturbances of the electric field in the sea was first constructed. Each calendar date of the "carpet," bearing the sign of the degree of disturbance of the field divided into 4 conventional units, entered vertically into a sequence of days separated by the synodic rotations of the Sun. The first sequence began

Figure 2

Figure 2: Figure 2

on 4 V 1959, the last ended on 28 V 1961. Then the cases of occurrence of trains of oscillations were plotted on the "carpet," with the occurrence of one train of oscillations or of a series of trains not less than 12 hours after the preceding case being counted as a separate case. The tendency of trains of oscillations to concentrate in certain sequences of days, detected on the "carpet," is shown more clearly by the graph (Fig. 2) of the distribution of trains of oscillations and of disturbances of the electric field in the sea by sequences of days. Along the abscissa axis the sequences were plotted, starting with the first; along the ordinate axis, on one scale, the number of trains of oscillations observed during the sequences, and on another scale, the magnitudes of the field disturbance in conventional units for the same sequences. It should be said that comparison of the curve of changes in the disturbance of the electric field shown in Fig. 2

Fig. 2. Distribution of oscillations of the train type by sequences of days.
1 —distribution curve of trains of oscillations; 2 —distribution curve of field disturbance. n —number of cases of trains of oscillations; S —field disturbance in conventional units.

in the sea with the analogous curve for the geomagnetic field, obtained by summing the world indices K first by days and then over the same sequences of days, reveals their close similarity. Despite the fact that each of the sequences constitutes a time interval equal to two years (the sharpness of the 27-day recurrence is lost over the course of such an interval), the graph nevertheless shows abrupt changes in the numbers of trains of oscillations on passing from some sequences to others. These changes become still more pronounced for intervals of time corresponding to 7-8 synodic rotations. Thus, over the sequence from 13 VII 1960 to 22 XII 1960, one case of an indistinct train of oscillations was recorded, whereas in the adjacent sequence from 12 VII 1960 to 21 XII 1960, 8 cases of the appearance of trains of oscillations were observed. From 15 VIII 1960 to 24 I 1961, no clearly expressed case of trains of oscillations was noted in the sequence, whereas from 14 VIII 1960 to 23 I 1961, 6 cases of the appearance of trains of oscillations were observed.

As is seen from Fig. 2, the maxima of the appearance of trains of oscillations seem to frame the most disturbed periods, forming increases in the number of trains of oscillations by sequences preceding and following the maxima of field disturbance. The increase in the frequency of appearance of trains of oscillations "near" disturbed periods prompted a search for qualitative features of these oscillations, excited through electromagnetic storms both of the M-disturbance type and of the SC type. It turned out that in the preceding and following trains of oscillations the amplitudes are, as a rule, considerably higher than in oscillations far removed from disturbed periods. Of the total number of trains of oscillations with amplitude greater than 15 mV/km, about 80%

consisted of oscillations separated from disturbed days by no more than two days, and in most cases by a shorter time interval. On further examination, a characteristic type of train of oscillations was identified, the appearance of which is more often the first signal of a future storm or, more rarely, its final signal. Morphologically, this type is characterized by an abrupt onset of pulsations, whose amplitudes are not less than 10 mV/km and often reach 20–30 mV/km. The periods of these oscillations, in contrast to the others, as a rule do not exceed a minute and vary from 40 to 60 sec. This type is usually represented by a single train, although in some cases series of trains are also observed. The diurnal and seasonal distributions of the oscillations under consideration reveal the same regularities as the analogous distributions for all types of trains of oscillations. They are also similar to the latter in the always positive initial deviation of the first oscillation. About 90% of cases of these oscillations were separated from disturbed days by time intervals of two days or less. The most characteristic intervals between the beginning of the train and the beginning of the disturbance for preceding trains of oscillations of this type were 10–24 h; for following trains, 24–48 h (from the beginning of the disturbance). Among the storms for which no preceding trains of oscillations were observed, disturbances with a sudden onset predominated.

The nature of the seasonal course and the 27-day recurrence in the appearance of trains of oscillations make it convincing that the source of excitation of trains of oscillations on Earth is solar corpuscular streams. Taking into account the activation of trains of oscillations in the vicinity of disturbed days, one may suppose that the regions on the Sun which influence the excitation of oscillations of the Earth' s electromagnetic field of the train type are concentrated mainly near active regions on the solar surface. Identification of these regions and explanation of the origin of trains of oscillations through dispersion of velocities in corpuscular streams that produce, for example, M-disturbances raises objections. From this point of view, the excitation of preceding trains of oscillations separated from storms by an interval of up to two days would be due to the action of the leading front of a corpuscular stream, but

then it would be impossible to explain the appearance of analogous trains of oscillations in the final phase of a disturbance or after its termination. Between the appearance of trains of oscillations and the onset of disturbances, a calm state of the field is often observed, which indicates the separateness of the streams exciting the trains of oscillations. In addition, a number of trains of oscillations are considerably removed from the disturbed periods; this circumstance also does not allow, given the radial nature of the streams, the regions under consideration to be identified. It is known ([5]) that M-disturbances are observed in sequences even in the absence of floccular radiation, which is associated with the preservation of a unipolar magnetic field in the corresponding portion of the solar surface. Like corpuscular streams producing M-disturbances, the streams responsible for the excitation of trains of oscillations may owe their origin to the development of local magnetic fields, whose number and intensity increase near active regions. The considerable stability of the appearance of trains of oscillations in sequences of days should be linked with the formation of magnetic flux tubes above the source of radiation, by analogy with M-disturbances ([5]).

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