Practical Use the Satellite Low Frequency Wave Experiment Results

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Abstract

Results of the registration of low-frequency emissions intensity, speed of the account quasytrapped and precipitation electrons with energy Ee≥40 keV and density and temperature of ionosphere plasma on the satellite altitude are discussed. By results of researches the complex picture of development of geomagnetic disturbances and storms in low-frequency emissions has been constructed. The complex picture of change of low frequency emissions and other ionosphere plasma parameters has been constructed by preparation and development of processes of seismic activity and earthquakes. Variations of parameters of low frequency emissions reflect environmental contamination processes.

1. Introduction

The natural, very low-frequency (VLF) noise emissions are generally looked upon as radio interference. In fact, these are an effective means for diagnostics and study of dynamic processes taking place in the Earth magnetosphere and ionosphere. They reflect the processes of magnetospheric and ionospheric plasma reconstruction and contain the information about the changes of environmental parameters.

The intensity and spectrum of low-frequency emissions registered at the altitudes of Earth outer ionosphere depend on the medium (density and temperature of ionospheric plasma around the satellite), wherein these emissions are excited and propagated. The waves depend on the streams of energetic particles penetrating into various regions of space and giving rise to these emissions generation, as well as, on the geomagnetic field, determining waves propagation conditions, and on the state of quasi-trapped resonant electrons exciting low-frequency emissions.

The results were obtained at Intercosmos satellites experiments:

- low-frequency emissions and signals in the range of 100 Hz – 20 kHz, waves field magnetic and electric components,
- counting rate of energetic electrons, featuring energies of 40 KeV and over.
- ionospheric plasma density and temperature.

2. Seismo-Active Zones According to Space Data

Shown in Fig. 1, as an example, are the fragments of analogue records of the intensity of noise emissions magnetic component from the output of the channels of receiving equipment spectrum analyzer that were made aboard the satellite two minutes before a heavy earthquake, when the satellite traveled in the vicinity of the "would be" earthquake focus. As we can see, the emission is pulse-type and it is most intensive on frequencies below 1 kHz.

A considerable difficulty arising during selection of satellite-supplied data for processing consists in information selection, for it is not always the case that the satellite travels over the seismo-active region right before or during the earthquake.

During the registration made on Nov.1st, 1978 the air-borne, standard telemetry storing mode was effective aboard the satellite. In case of this mode information points are recorded once in every 0.32 s. One can see small-scale changes of signals structure. In case of other-than-mentioned mode the information is registered once in every 2.56 s. In this case it is only the variations of signal envelope that become registered.

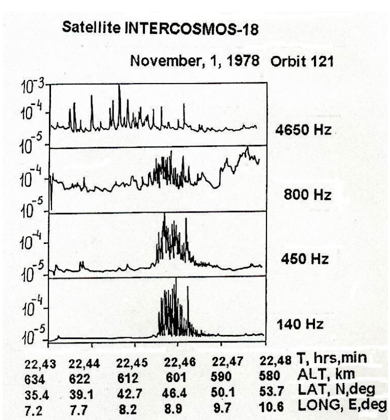

Fig. 1 The fragment of an analogous recording of the magnetic component of low frequency emission field onboard Intercosmos 18 satellite made on November 1, 1978 two minutes before the strong earthquake when the satellite was flying near the future epicenter. Results are registered from an output of channels of a spectrum analyzer in frequency band 0.1 – 20 kHz.

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Let us consider the results of measurements of low-frequency noise over a seismically active region (see Fig. 2) during preparation of two heavy earthquakes that shook Iran on Dec.7, 1979 at 9.12 UT (φ=35N°, λ=56.8°E, magnitude M=5,5) and at 9.24 UT (φ=34N°, λ=59.8°E, magnitude M=5,8). Their focuses depth was ~30 km. Shown as an example in terms of geographical co-ordinates (latitude-longitude) are the projections of the orbits of «Intercosmos 19» satellite complete circuits 4080-4087 in the northern (over and near the earthquakes focus) and in the southern (magneto-conjugate) hemispheres, whereupon noise bursts were observed. Plotted on the map are also L-shells and geomagnetic meridians. The Fig. 2 relates only to one frequency, however the similar bursts were observed in the whole range of the frequencies registered. The amplitude and, especially, the duration of bursts observation tend to increase, when approaching the focus in terms of time and longitude. Prior to the earthquake one could witness the changes, compared to those usually observed in the given area, variations of emissions field magnetic and electrical components, after the earthquake the electrical component was prevalent. Noise bursts were also observed in the magneto-conjugate region, however the observation zone was much narrower. One's attention was attracted by the fact that the registered bursts were, sort of, extended all along the earthquake focus L-shell, over the epicentral region and in the magneto-conjugate region as well.

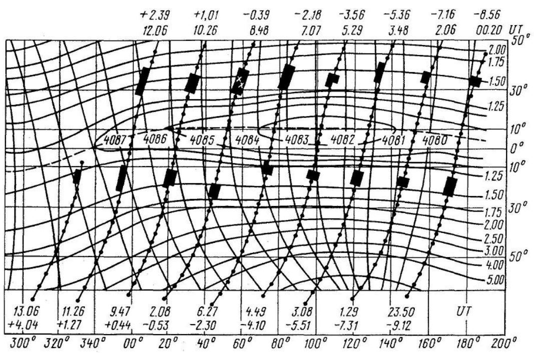

Fig. 2 Projection of the "Intercosmos 19" satellite orbits in the period of preparation of two strong earthquakes on Dec.7, 1979 at 9.12 UT (φ=35N°,λ=56.8°E, magnitude M=5,5) and at 9.24 UT (φ=34N°, λ=59.8°E, magnitude M=5,8). Position of the earthquake epicenter is marked by a cross (x). Projection of the satellite orbits on December 7, 1979 (orbit 4080-4087) in the northern (over and near the earthquakes focus) and in the southern (magneto-conjugate) hemispheres, are marked by dotted line. Minute marks are pointed and parts of orbit projections are blackened, where variation of emission intensity, associated, to our mind, with the development of seismic event, was observed. Absolute time values (ΔT) and time difference related to time moment t_0 (sing – minutes – before the earthquake, sing plus – after the earthquake) are pointed out near the every hystogram

Earlier we received data on global space-time distribution of intensity of natural (daily, latitude and altitude in terms of absolute units), low-frequency emissions in different geomagnetic perturbation conditions. The Fig. 3 supports this thesis and.5 illustrates the results of statistical processing of satellite-supplied data on the changes of low-frequency noise intensity in different geomagnetic activity conditions for a period of 4 month-operation of the «Intercosmos» series satellites (for quiet-time conditions - index Kp≤2, for moderate perturbation - 3-≤Kp≥4+ and for big magnetic storms - index Kp≥5-). The Fig. depicts the average statistical scatter of noise intensity. Various symbols are used to designate the values of registered noise bursts at the 4650 Hz-channel output for specific earthquake cases (earthquake dates are stated at the Fig. bottom on the right.). As seen from the mentioned Fig., the noise intensity bursts associated with development of seismic activity are well in excess of the noise level observed in the given space region.

The satellite-supplied data permitted us not only to analyze the individual events, but also to obtain statistical characteristics by way of formalizing the data processing with the help of modern computing facilities. When obtaining statistical regularities, we placed a number of restrictions, namely, selection was made of sufficiently heavy earthquakes of magnitude M>5.5 and depth of no less than 60 km, consideration was given only to relatively low-latitude earthquakes (geomagnetic latitude – less than 45°). As a result the following was found:

- noise emissions intensity increased several hours prior to strong earthquakes (magnitude of M>5.5), with the satellite traveling in the vicinity of the quake focus;
- amplitude of noise bursts increased on approaching the epicentre as to longitude and main shock time);
- prior to the earthquake one could witness noise field magnetic, as well as electrical components, after the earthquake electrical component prevailed;
- frequency range, wherein one could observe an abnormal increase of noise bursts intensity varied from several Hertz to 20 kHz, and, might be more than that (20 kHz was the upper range of equipment used);
- zone of reliable noise bursts observation amounted to Δφ=±3° in terms of latitude and to Δλ=±60° in terms of longitude. The regions of observation could be described conventionally as «noise belts».
- observed effect reliability calculated on the basis of statistical processing the experiment results amounted to 85-90%.

- one's attention was attracted by the influence of the earthquake focus depth. With its depth less than 100 km, noise bursts were observed reliably over the quake focus. In case of greater depths the burst amplitude was smaller. When the earthquake source was under the ocean, its forerunners were very weak, in such cases only the effect of residual action could be registered

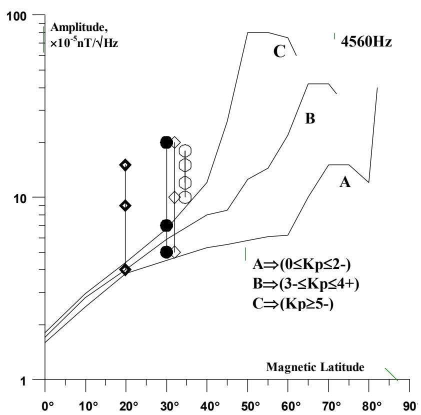

Fig. 3

Middle latitudinal dependence of the low frequency noise intensity on frequency 4,65 kHz for various geomagnetic activity conditions.

According to the data from the two simultaneously traveling satellites (Intercosmos – Bulgaria 1300 and Oreol 3) the observation of noise intensity variations over the focus of impending earthquake confirms the detected effect. Fig. 4 illustrates the magnetic meridian plane passing through the earthquake focus. Marked on this plane in terms of geographic latitude (φ) and altitude (h) are the portions of projections of those satellites orbits and the grid of lines L(h,φ)=const, where L is McIlwain parameter. The latitude of earthquake focus is showed in the Figure. Measurements were made on the satellite at night. In these conditions the level of natural, low-frequency emissions at low and equatorial latitudes is usually insignificant, therefore the separation of seismic activity-associated noise is facilitated. Satellites carrying the same (or almost the same) type of equipment traveled at different altitudes. The flight altitude of the Intercosmos – Bulgaria 1300 satellite was 890 km, while that of the Oreol satellite - ~1970 km. The effect was registered on both satellites.

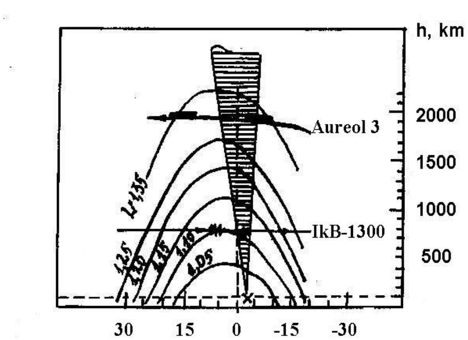

Fig. 4 The plane of a magnetic meridian passing through an earthquake epicenter in coordinates: a geographic latitude (φ) and altitude (h) the parts of projections of orbits of these satellites and gird of lines L(h, φ)=const, where L is parameter McIllwain,are marked. The latitude of an earthquake epicenter is marked by cross (X).

The availability of successive measurements from two satellites traveling over the same earthquake preparation region, despite the difference in equipment used made it possible to conclude that seismo-ionospheric noise had existed for a long time over the impendent earthquake epicenter before the main shock occurred. Therewith, the frequency range of registered noise was rather broad - from 0.1 Hz (Intercosmos-Bulgaria 1300) up to 20 kHz, - upper frequency of the Oreol 3 equipment range [16].

A study was made of the integrated picture of geophysical processes development over the earthquakes preparation regions.

According to the «Oreol 3» satellite data there were registered simultaneous intensity bursts of low-frequency emissions (0.01 – 20 kHz) and counting rate of energetic electrons flow over the earthquake focus (near L- shell of earthquake focus) 4 hours 48 minutes before the main shock occurred. An analysis was made of a considerable amount of information at the «Oreol 3» satellite orbits, that were at relatively low altitudes, below the lower trapped radiation boundary, over the epicentral earthquake zones and beyond them, at night, when a low background of counting rate was registered. It was found that in 20 of selected cases of particles increasing precipitation accompanied by intensive bursts of low-frequency emissions, in 18 cases – abnormal bursts coincided with the presence of earthquakes.

The ionospheric plasma response was registered over the focus zone and in the magneto-conjugate hemisphere. The «Intercosmos 19» satellite registered the simultaneously observed abnormal bursts of intensity of low-frequency noise and flows of precipitating electrons ($E \geq 40$ keV) recorded 1 hour 20 min before in the conjugate hemisphere.

To characterize the dependence of two random values X и Y in practice use is made of dimensionless value of correlation factor R. After making a correlation analysis of simultaneous intensity bursts of noise and energetic particles streams, we receive information on the sufficiently high degree of similarity ($R \geq 0.6$-0.8) of the envelope shape of intensity bursts of noise and energetic particles. Signals enter the magneto-conjugate region at the expense of channeled propagation.

The examples given above confirm the fact that an earthquake may be one of the possible causes of energetic particles precipitation from a radiation belt along with other causes, such as, radiation belts instability, for example, those associated with trapped particles anisotropy, magnetic storms, operation of ground-based transmitters, etc.

The picture thus created shows the in-time development of electromagnetic and electric phenomena, accompanying the manifestations of seismic activity.

3. Time Sequence of Seismic Activity Manifestations

- Many days, possibly months, before the earthquake there come about perturbations of geoelectric field, as events continue to develop, the amplitude grows and oscillations character changes in the seismic focus.
- Then the registration of geomagnetic field perturbations is started.
- After this there come about the perturbations of atmospheric electrical potential.
- Several days or hours before the earthquake there come about changes of ionosphere parameters, changes of critical frequencies and concentration changes.
- Several hours or days before the earthquake there come about the variations –amplitude increase of natural pulse electromagnetic Earth's field according to ground data.(EIEMPZ).
- Tens of minutes – hours before the earthquake geomagnetic pulsations P_S (0.02-1 Hz) take place.
- Tens of minutes – hours before the earthquake the intensity of electromagnetic emissions (EME) increases at satellite-flight altitudes.
- Luminous effects arise.

4. Conclusion
Statistical Characteristics of the Size of Ionosphere Zones of Response to Earthquakes Preparation Process

Determined are the space-and-time values of the zone of abrupt changes of ionospheric plasma parameters over the regions of main seismic shock preparationa (earthquake moment). The results of research statistics are listed below in Table 1.

Table 1 Space-and-time values of the zones of seismo-ionospheric anomalies observation at upper ionosphere altitudes

	Range	Zones size	Time (up to)
Parameter	ELF/VLF	$\Delta\varphi=\pm 3^o$ $\Delta\lambda=\pm 60^o$	Several hours
Electrons	$Ee \geq 40$ KeV	0.1 L	2.5-3 hours
Plasma density		$\pm 3^o$	Days

Thus, the effect of noise growth over the impendent earthquake epicentre in the range 0.1-20 kHz, detected for the first time according to «Intercosmos 19» satellite data was confirmed by the results of signals analysis on «Intercosmos 18», «OGO 6», and later on «Oreol 3» satellites.

It was found, that earthquakes preparation processes were accompanied by the changes of ionospheric plasma parameters:

-low-frequency emissions intensity,

-density of quazi-trapped and precipitation electrons flow,

-changes of ionospheric plasma density and temperature.