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ON CERTAIN REGULARITIES IN THE FORMATION OF INHOMOGENEITIES IN THE IONOSPHERE AND THEIR RELATIONSHIP WITH PARTICLE "RUN-OUT" FROM OUTER SPACE *

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The results of processing and systematization are presented of the material on radiosignal reception from Soviet artificial satellites of the Earth. As a result of the work performed, it was corroborated that the dissection ("scintillation") of radiosignals emitted from cosmic objects is explained by radiowave diffraction on the inhomogeneities of the ionosphere.

The frequency of radioscintillation appearance depends on the latitude of location of the cosmic object and the time of the day. A relationship is ascertained between the appearance of scintillation and the phenomena of washed out reflections from the F-layer of the ionosphere.

On the other hand, a connection is established between the particle "run-out" phenomenon and the scintillation of radiosignals from AED and other cosmic objects, that is with the presence of inhomogeneities in the ionosphere.

The conclusion is derived that the origin of ionosphere inhomogeneities may be explained by particle "run-out" from outer space, this being at least one of the factors inducing them.

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* O NEKOTORYKH ZAKONOMERNOSTYAKH V OBRAZOVANII NEODNORODNOSTEY V IONOSFERE

When receiving and registering radiosignals from AES and other artificial cosmic objects (CO), it was established that besides radiosignal shape variations, due to the Faraday effect and satellite rotation, irregular variations of fluctuating or blinking character are observed, imparting to the signal a dissected and sometimes "broken" shape. Shown in Fig. 1 is a smooth, nonfluctuating signal, and in Fig. 2 a dissected, scintillating signal.

Various explanations of causes of these "scintillations" were considered during the first years (1957—1959) of radiosignal reception from AES and CO. Among them were the hypotheses of the influence of the ionized cone forming at the motion of the AES in the ionosphere, of the interference between the ordinary and extraordinary waves, the influence of the irregularity of ionization induced by the satellite itself, and others [1—3]. Brought forth was also the hypothesis explaining the scintillation of radiosignals from AES by the influence of ionosphere irregularities over the path of their propagation [4, 5].

A group of Soviet researchers with the participation of the present author conducted over the years 1958—1962 the processing and systematization of large experimental material on radiosignal reception from the Soviet AES.

The material processed involved data of radiosignal reception by eighteen measurement points located in the most different regions of the Soviet Union for various times of the day and the seasons of the year.

Processed also was the material on radiosignal registration by the polar observatory of the Antarctica station "Mirnyy." A large number of sessions of radioreception of the transmitter "Mayak" ($f_1 = 20.005$ Mc/s) installed aboard the third Soviet AES, of radiotransmitters aboard the Soviet AES of the Cosmos series ($f_2 = 19.995$ Mc/s), and also of certain radiotransmitters installed on the manned spaceship-satellites "Vostok" were subject to systematization and research.

The principal form of initial registration was the recording on a magnetic tape tied to the time scale. Examination of all the processed data was materialized on an oscillograph; a substantial part of registrations was reproduced on a film. The total number of processed sessions of radioreception exceeded thirteen thousand.

When conducting the statistical processing the signal was considered as scintillating (fluctuating) when the modulation depth of signal amplitude was (because of signal fluctuation) no less than 25%. The notion was introduced by the frequency of appearance of scintillations (P), determined by the expression

$$P = \frac{\Sigma t_i}{\Sigma T_i},$$

where T_i is the time during which the signal was received; t_i is the fraction of the time T_i over which the signal was scintillating.

Among the many problems formulated during the conducting of the above analysis were: the establishment of statistical regularities of radioscintillation occurrence with respect to the time of the day, the location of the points of reception and of region of cosmic objects' flight, and also the ascertaining of the relationship between the radioscintillations of signals from AES and CO with different geophysical phenomena.

As a result of the work thus conducted the following was established:

1. The occurrence of irregular fluctuations (dissections, scintillations) of radiosignals emitted from cosmic objects during passage of the former through the ionosphere is explained by radiowave diffraction on the irregularities of the ionosphere.

2. The frequency of occurrence of scintillations in a sharply expressed form depends on the latitude of the point of reception and the latitude of the location of the cosmic object at time of radiosignal transmission.

The projections of portions of the orbit of the third Soviet AES are brought up on the chart in Fig. 3,** over which were received the nonfluctuating ("smooth") and the scintillating signals* The protions corresponding to the reception of smooth signals are plotted by solid lines, those corresponding to scintillating signals are denoted by dots. It may be seen from Fig. 3 that the region of scintillating radioreception is quite broad, reaching several thousand kilometers in longitude and from 1000 to 1500 km in latitude.

Shown in Fig. 4 are graphs of frequency dependence of scintillating signal appearance on the geographic latitude of the points of radioreception in Moscow, Samarkand, Ashkhabad and Tashkent for the period May-June 1958, and Leningrad for May-November 1958. It may be seen from Figs. 3 and 4 that the regions of scintillating radioreception have the shape of belts.

The region of the most frequent appearance of scintillations is situated in the 55 – 65^{o} Northern latitude range. The scintillations are substantially less frequent in the 35 – 50^{o} belt, and South of the 35^{o} parallel the frequency is on the increase again. Data obtained from the point "Mirnyy" allow the assumption that analogous latitude distribution should also take place in the Southern hemisphere.

3. The belts of most frequent appearance of radioscintillations coincide with the "spurs" or branches of the natural radiation belts.

The high-latitude scintillation region is located under these branches of the outer radiation belt, and the inner scintillation region, beginning from about 35^{o} latitude North coincides with the zone of the inner radiation belt (Fig. 5).

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* The reception data of the 3rd Soviet AES above America, received by points of measurement in USA and sent to Prof. S. N. Vernov by his American colleagues, were kindly made available to us by Prof. Vernov's coworkers.

** For Fig. 3 see the chart at the end of the paper.

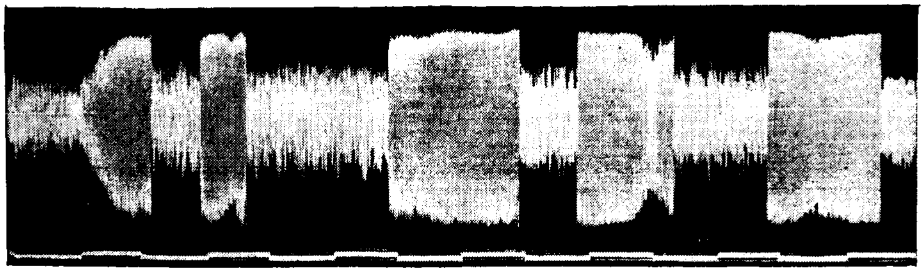

Fig. 1. Registration of a smooth signal

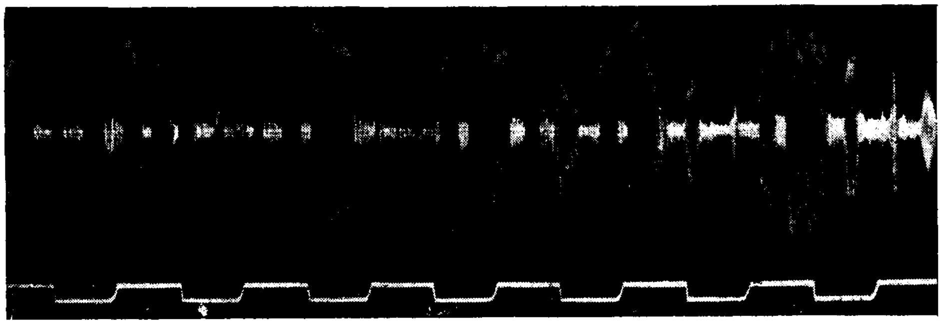

Fig. 2. Registration of a scintillating signal

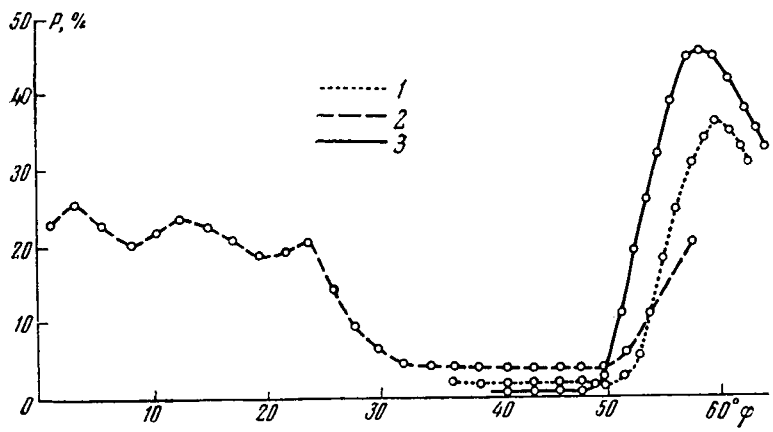

Fig. 4. Dependence of the frequency of occurrence of scintillations on the geographic latitude

1 — Moscow, 2 — Samarkand, Ashkhabad, Tashkent, 3 — Leningrad

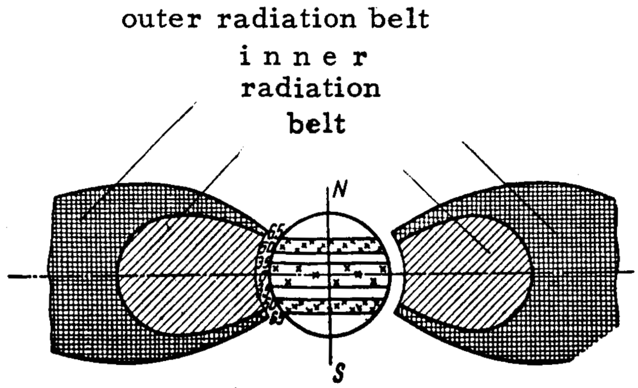

Fig. 5. Branches of radiation belts and zones of distribution of scintillations (x)

4. The frequency of occurrence of radioscintillations is essentially dependent on the time of the day. At nighttime the frequency is substantially greater. From Figs. 6, a, b, c, in which the dependence P of scintillation occurrence on time of the day is plotted, one may see that the occurrence of scintillating signals in the middle of the night may reach 60% of the totality of scintillations observed in a 24-hour period. For the Southern point, at Samarkand (Fig. 6, d), the daily dependence lacks a well defined character.

5. An unambiguous link is ascertained between the frequency of occurrence of scintillations (that, is of presence of ionosphere irregularities) and the phenomenon of F-blurrings, that is, of washed out reflections from the F-layer of the ionosphere.

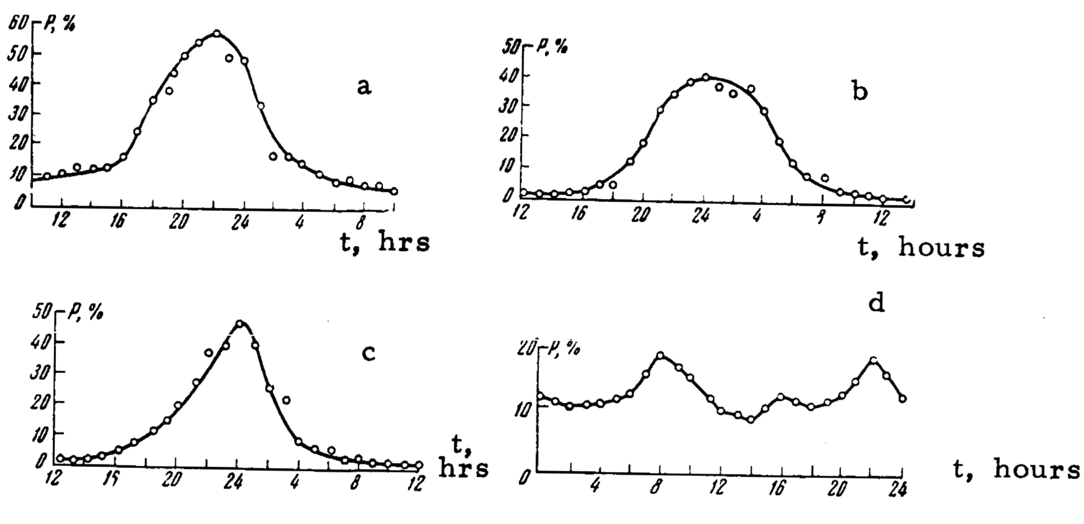

Fig. 6. - Dependence on the time of the day of the frequency of scintillation occurrence

a. May-June, Moscow; b – Sept.-Nov., Leningrad; c – June-August, Leningrad; d – May-June, city of Samarkand

We compared the data of direct observations of the time of scintillation occurrence of AES radiosignals and of the registration time of F-blurring. A good agreement was found between the passage of smooth (nonscintillating) signals with the absence at that time of F-blurring events and the observations of scintillations with the presence of F-blurrings.

Established also is the indentity of the frequency dependence of radioscintillation occurrence and F-blurrings in the time of the day. Thus, in Fig. 7 it is clearly seen that the daily dependence of the frequency of oscillation occurrence (n_F) and F-blurrings (τ) in percent to the total number of observations has an analogous character.

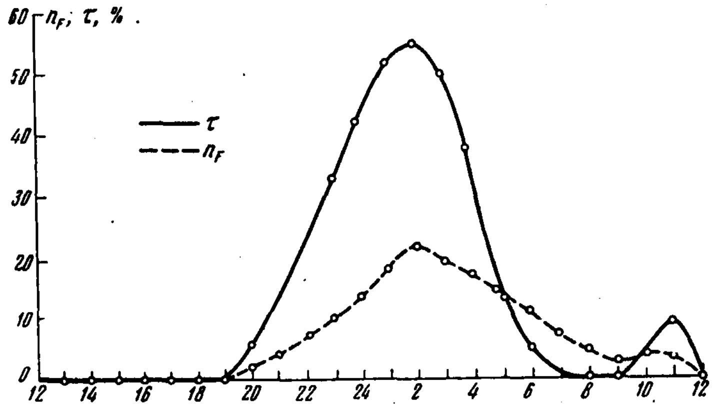

Fig. 7. Daily dependence of scintillation occurrence and F-blurrings (Moscow, July-Sept. 1958)

Unfortunately, systematized experimental data on cosmic electron fluxes, particulary in the region of low energies ($E \leqslant 10$ kev), and on the dependence of these fluxes' intensity on latitude and the time of the day, are still scarce. However, various experimental data show that the mean value of particle run out intensity at high latitudes is substantially (by several orders according to some data) exceeding the value of the fluxes, running out in middle and equatorial latitudes.

It may be considered as unambiguously established that the most intensive particle run out, as well as the presence of irregularities, are characteristic of high-latitude regions (near 65° geomagnetic latitude); the intense particle run out corresponds to the zones situated under the "spurs" (branches) of radiation belts [6, 7].

The data obtained with the aid of the American satellite "Injun-1", confirm also that a particularly amplified run out of particles is observed near the high-latitude boundary of the radiation belt.

The study of the available experimental data on the dependence of the intensity of electron fluxes on the time of the day shows that for higher altitudes and fluxes in the energy region above 50— 100 kev this intensity is higher in daytime than at night. As to the fluxes of lower energies (below 40 kev), the most interesting from the standpoint of their effect upon the ionosphere, here the intensity of fluxes at nighttime exceeds substantially that of daytime.

Thus, the Evans measurements conducted with the aid of an oriented AES [8] have shown that the intensity of electron fluxes in the energy region 0.08 - 24 kev in nighttime exceeds substantially the intensity of fluxes observed in daytime.

During the launchings of high latitude American rockets of the type, the intensity of fluxes at night was found to by one order higher than in daytime [9].

In the equatorial regions of the middle latitudes the dependence for fluxes of low energies lacks any specific character if one refers to the presently available data. It should be note that signal scintillations (that is, the frequency of ionosphere irregularity occurrence, see for example, Fig. 6d) for the southern regions do not have sharply expressed daily dependence either, which is different from whar is observed in high-latitude regions.

CONCLUSIONS. Comparison of experimental data obtained as a result of investigations of scintillations of AES signals and of certain geophysical phenomena, allows to draw the following conclusions:

1. The origin of ionosphere irregularities and the F-blurring are related phenomena and they may explained, at least in part, by particle run out from outer space, including the branches or "spurs" of radiation belts.

2. The regions of greatest occurrence of inhomogeneities and, as should be assumed, the regions of particle escape (run out) are quite broad, reaching from 1000 to 1500 km in the latitude direction and several thousand kilometers in longitude. The most intense occurrence of irregulatities is observed in the 65 - 55^{o} latitude range.

3. The formation of irregularities in the ionosphere and, as we assume, the intensity of particle escape with low energies have a noticeably expressed daily dependence; at the same time, at high latitudes the presence of inhomogeneities (or irregularities) in nighttime exceeds significantly their occurrence in daytime; according to presently available data no daily dependence is observed in the middle latitude and equatorial zones.

4. The investigations conducted allow furthermore the practical conclusion that the most practical zones for communication with cosmic objects in short waves where the influence of radiosignal scintillation is minimal, lie in the latitude region 35 - 45^{o}. Consequently, inasmuch as feasible, precisely these zones have to be utilized for radiocommunications with astronauts.

In connection with the above it appears also that the further investigation and study of ionosphere irregularities, their spatial distribution, their dimension, their time dependence on the daily and seasonal basis and others may substantially help not only the investigation of the structure and the state of the ionosphere, alongside with the propaaation of radiowaves, but also the questions of particle escape from the outer space when studying radiation belts.

*** THE END ***

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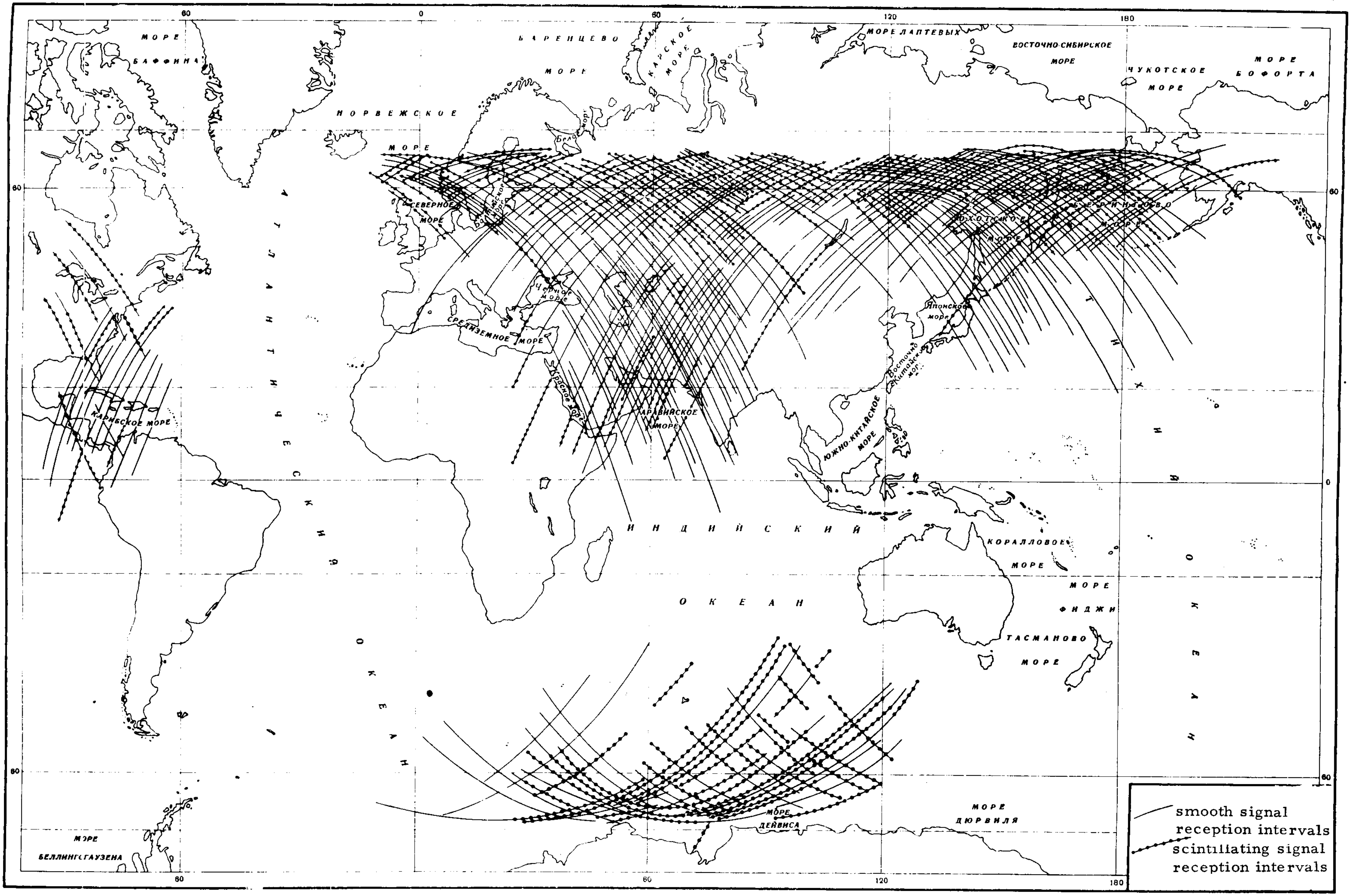

Fig. 3. - Zones of reception of smooth and scintillating signals