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K. I. Gringauz
Yu. A. Kravtsov
V. A. Rudakov
S. M. Rytov

(USSR)

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ONCE MORE ABOUT THE POSSIBILITY OF DETERMINING THE LOCAL ELECTRON CONCENTRATION BY THE DISPERSION METHOD WITH THE HELP OF AES AND ON NEW IONIZATION MAXIMA IN THE IONOSPHERE*

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by K. I. Gringauz,
Yu. A. Kravtsov,
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SUMMARY

The question is considered of the possibility of determining the local concentration of electrons by the dispersion method, using artificial Earth's satellites. It is shown that the determination of N_c by such a method leads to unreliable results because of the presence in the ionosphere of horizontal ionization gradients, and on account of the nonstationary state of the ionosphere.

In connection with this the conclusion is derived about the unreliability of the results described in a series of works of Ya. L. Al'pert and others. The unreliability of these results is also determined by the incorrect method for processing experimental data.

author

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In the work [1] we called attention to the fact that measurements of local concentration of electrons N_c in the ionosphere using the dispersion method with the aid of coherent radiowaves emitted from AES [2—6], can not give reliable results. Objections by Ya. L. Al'pert against our conclusions [7] were published almost simultaneously with [1]. However, works [8—12], extending those in references [2—6] and containing new results are also entirely unreliable according to our opinion, and, moreover, even the objections of [7] had already by-passed the fundamental arguments contained in our work [1].

Because of incessant publication of unreliable data on local values of N_c, and also in the interest of future ionosphere research with the aid of coherent radiowaves emitted from AES, we felt that it was necessary to consider again this question in detail.

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* YESHCHE RAZ O VOZMOZHNOSTI OPREDELENIYA LOKAL"NOY KONTSENTRATSII ELEKTRONOV V IONOSFERE DISPERSIONNYM METODOM PRI POMOSHCHI ISZ I O NOVYKH MAKSIMUMAKH IONIZATSII V IONOSFERE.

1. GENERAL REMARKS

Before proceeding with the detailed consideration, we shall clarify the essence of the question in its general traits.

The dispersion method consists in the measurement on the ground of the variations of the reduced phase difference $\delta\Phi$ of two coherent radiowaves with different frequencies, emitted from objects flying in the ionosphere (geophysical rockets, AES), or, which is the same, of the reduced difference of Doppler frequency shifts $\delta\dot{\Phi}$ The observed variations of $\delta\Phi$ depend on the variations of the integral concentration over the entire path S of wave propagation. Thus, measuring the accretion of phase difference $\delta\Phi$ ($\delta\dot{\Phi}$) it is possible to determine the variation of the integral concentration $\int NdS$ for the time of observation. The dependence of $\delta\dot{\Phi}$ on ionospheric parameters in the general case is sufficiently complex. But in particular cases, neglecting separate components of this dependence, one may determine various parameters of the ionosphere (see, for example, [13-16]. Thus, if one may consider that the variation of $\delta\Phi$ is caused by accretion of integral concentration only on account of the displacement of the emitter by a distance ΔS (that is, if it is possible to neglect the variations of the medium over the remainder of the path), the dispersion method allows to determine the parameters of the medium over the portion ΔS , and namely, to find over the interval ΔS the mean value of concentration N_c . Such conditions are fulfilled at reception of waves emitted from a vertically flying rocket, moving with a sufficiently high velocity through a region of the ionosphere with not too small values of N_c .

When utilizing AES, the conditions of the experiment differ radically from the experiments with vertically launched rockets. In this case the local values of N_c are determined quite roughly [17-19]. This is linked not with the measurement precision of $\delta\Phi$ but with limitations of principle in the measurement precision of N_c , determined by the properties of the ionosphere (its nonstationary state and the presence of horizontal irregularity) and by the method's peculiarity. Our 1st remarks bear precisely to that.

The second group of remarks refers to the interpretation of the aggregate of values N , obtained dy the dispersion method, using AES. Even disregarding the accuracy of the found values of N_c and considering them as true, we may not consider the graph obtained as being the altitude distribution of N_c by merely contructing the values of N_c obtained along the satellite orbit, as a function of $\underline{z}_c$ (which is the height of the satellite above ground), inasmuch as the motion of the satellite changes not only the altitude but also the local time and the geomagnetic latitude, upon which the value of N_c at the given height is dependent. For example, in the works [8, 9] only one value of N_c was considered for each flight of the satellite above the measurement point. A graph plotted from similar random (or let it be even correct) values of N not only fails to characterize the altitude distribution of electron concentration in the ionosphere, N_c (z), but it may also convey a wrong representation about this fast-varying and nonuniform region of the atmosphere. The presence on such a graph of any kind of peculiarities (for example, of maxima) does not imply at all that such peculiarities must be present in the real ionosphere.

2. MEASUREMENT PRECISION OF LOCAL ELECTRON CONCENTRATION BY THE DISPERSION METHOD UTILIZING AES

As is well known, the phase difference $\delta\Phi$ of two coherent oscillations with frequencies ω_1 and ω_2, reduced to the frequency ω_1, is written in geometrical optics approximation in the form

$$\delta\Phi \equiv \Phi_1 = \frac{\omega_1}{\omega_2}\Phi_2 = a\int_0^{r_c} N\,dS, \qquad a = \frac{\omega_1}{c}\frac{2\pi e^2}{m}\left(\frac{1}{\omega_2^2} - \frac{1}{\omega_1^2}\right). \tag{1}$$

Differentiating (1) with respect to time, it is possible to obtain the expression for the derivative of phase difference $\delta\dot\Phi$, lying at the basis of the dispersion method for measuring N_c. We shall write this expression in a form utilized in

$$\delta\dot\Phi = a\left\{-\frac{N_c\dot z_c}{\cos\varphi_0} + \left([\bar N_R] + \left[\frac{\partial\bar N}{\partial x}\right]\right)\left(\dot r_c + \frac{\dot z_c}{\cos\varphi_0}\right) - \left[\frac{\partial\bar N}{\partial y}\right]\dot y_c - \int_0^{r_c}\frac{\partial N}{\partial t}\,dS\right\}, \tag{2}$$

where z_c and y_c are the velocity components of the AES along the axes z and y; z_c is the radial velocity conponent; φ_0 is the angle between the vertical and the visual ray; dS is the element of ray's length. In the plane ionosphere approximation we have

$$[\bar N_R] = \frac{1}{z_c}\int_0^{z_c} N\,dz, \qquad \left[\frac{\partial\bar N}{\partial x}\right] = \frac{1}{z_c\cos\varphi_0\sin\varphi_0}\int_0^{z_c}\frac{\partial N}{\partial x}z\,dz,$$

$$\left[\frac{\partial\bar N}{\partial y}\right] = \frac{1}{z_c\cos\varphi_0}\int_0^{z_c}\frac{\partial N}{\partial y}z\,dz.$$

It follows from expression (2) that the experimentally measured value of depends on the local concentration N at the place of location of the satellite, as well as on the horizontal ionization gradients $\partial N/\partial x$, $\partial N/\partial y$ and the nonstationary state of the ionosphere along the whole ray. In order to determine N_c with the aid of (2) it is required that the terms of this expression, taking into account the horizontal gradients and the nonstationary state of the ionosphere, be small by comparison with the terms dependent on N_c. The works [2—12] are precisely based upon this assumption; however, in case of utilization of AES, it is not justified. Let us consider separately the role of horizontal gradients and that of the nonstationary state of the ionosphere.

Influence of Horizontal Gradients. - According to (2) the determination of N_c is possible if there is a simultaneous fulfillment of the conditions valid for the stationary ionosphere *

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* For the sake of simplicity the term $[\bar N_R]$ in condition (3) is dropped, which alleviates the fulfillment of this condition. In reality, for $[\bar N_R] > N_c$ which takes place at great altitudes, for example, z > 2000 km) $[\bar N_R]$ determines $\delta\dot\Phi$ to a greater degree than N_c.

$$N_c \gg \left| \frac{\cos\varphi_0}{\dot z_c}\left(\dot r_c + \frac{\dot z_c}{\cos\varphi_0}\right)\left[\frac{\partial\bar N}{\partial x}\right]\right|, \qquad (3)$$

$$N_c \gg \left| \frac{\cos\varphi_0}{\dot z_c}\dot y_c\left[\frac{\partial\bar N}{\partial y}\right]\right|. \qquad (3a)$$

It is easy to see that

$$\left[\frac{\partial\bar N}{\partial x}\right] \geqslant \frac{1}{z_c}\int_0^{z_c}\frac{\partial N}{\partial x} z\,dz \sim \int_0^{z_c}\frac{\partial N}{\partial x}dz \quad \text{and} \quad \left[\frac{\partial\bar N}{\partial y}\right] \sim \int_0^{z_c}\frac{\partial N}{\partial y}dz.$$

This is why we may utilize for the evaluation of gradient terms the data

$$\int_0^{z_c}\frac{\partial N}{\partial x}dz \quad \text{and} \quad \int_0^{z_c}\frac{\partial N}{\partial y}dz,$$

which, according to the results of various experiments [4, 6, 9, 11, 14, 17, 20], may lie within the limits from 10^9 to $10^{11}\text{cm}^{-2}\ \text{km}^{-1}$.

For the smallest of the values brought out $[\partial\bar N/\partial x] \sim [\partial\bar N/\partial y] \sim 10^9\ \text{см}^{-2}\ \text{км}^{-1}$ and for the typical for AES "Cosmos" series' velocities $\dot z_c \sim 0{,}5$ and $\dot r_c \sim \dot y_c \sim 5$ km.sec inequalities (3) require that there be $N_c \gg 10^5\ \text{см}^{-3}$. As for the maximum values 10^{11} $\text{cm}^{-2}\text{km}^{-1}$, it is necessary to have $N_c \gg 10^7\ \text{см}^{-3}$. Hence it follows that even for the smallest measured gradients the determination of N_c is possible only in a small altitude range, close to the F-region maximum. At maximum known values of gradients the measurements of N_c are impossible in any part of the ionosphere*.

Let us clarify now how conditions (3) were fulfilled in the experiments by Ya L. Al'pert and others. In the discussed cycle of works [4—10], and also in [11, 12] the quantitative estimates of horizontal gradients are given only in [4, 6], and the influence of these gradients on the measurement of N_c was considered only in [6].

An estimate $[\partial\bar N/\partial x] \sim [\partial\bar N/\partial y] \sim 10^{10}\ \text{см}^{-2}\ \text{км}^{-1}$ is given in [4] (AES "Cosmos"), whereupon, according to (3), condition $N_c \gg 10^6\ \text{см}^{-3}$ must be satisfied. Meanwhile, as may be seen from Table 1 of work [4], the found values of N_c did not exceed $2.3 \cdot 10^5\text{cm}^{-3}$ and consequently, the obtained values of N_c cannot be considered as reliable. In [6] the horizontal gradients are estimated by the data of ionospheric stations, hundreds of kilometers distant from one another. At such distances, not only the value of the gradient, but its sign also may change. Besides, ionospheric stations allow the finding of gradient values only in the lower part of the ionosphere, whereas it follows from nowhere that the horizontal gradients are identical in its upper part (in the work [20]for example, substantial gradients were revealed precisely in the upper part of the ionosphere). The decrease of gradients with height does not stem from the graphs plotted in Fig.8 of work [6] of $\partial N/\partial y$ from **z**, obtained from data of ionospheric stations. But even for the values $[\partial\bar N/\partial y] \sim 10^9\ \text{см}^{-2}\text{км}^{-1}$ brought out in [6] the mean value of the ratio of the rejected term $a|[\partial N/\partial y]\dot y_c|$ to $|\delta\Phi|$ according to 15 measurements (Table 4, of [6]), equal to 0.8, is found to be inadmissibly great.

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* Note that for the fulfillment of conditions (3) at the point where $\dot r_c + \dot z_c/\cos\varphi_0 = 0$, the same values of N_c are required, inasmuch as the automatic fulfillment of condition (3) does not facilitate the fulfillment of condition (3a).

As a result, we reach the conclusion that the influence of horizontal gradients limits the region of a somewhat reliable determination of N_c to heights, close to the F-region maximum. The utilization of AES with elongated orbit does not improve the situation, inasmuch as at great altitudes the precision of determination of N_c is beginning to be influenced by the nonstationary state of the ionosphere and the smallness of N_c.

Influence of the Nonstationary State of the Ionosphere. In order to make possible the neglect of the stationary state of the ionosphere, the term

$$\int \frac{\partial N}{\partial t} dS$$

in (2) must be significantly smaller than the term containing N_c, whence at $\cos\varphi_0 \neq 0$ there must be

$$N_c \gg \left| \frac{\cos\varphi_0}{\dot{z}_c} \int_0^{r_c} \frac{\partial N}{\partial t} dS \right|.$$

According to the experimental data obtained to-date, the nonstationary term

$$\left| \int \frac{\partial N}{\partial t} dS \right|$$

reaches the values $(1 - 5)\cdot 10^9 \text{cm}^{-2}\text{sec}^{-1}$ [21—25]. Postulating

$$\left| \int \frac{\partial N}{\partial t} dS \right| = 10^9 \text{см}^{-2} \text{ and } \cos\varphi_0 = 1,$$

we find from the inequality (4) that reliable measurement of N_c is possible if $N_c \gg (1/\dot{z}_c)\cdot 10^9\ \text{см}^{-3}$ ($\dot{z}_c$ being expressed in cm/sec). At $\dot{z}_c \sim 0{,}5—2$ км/sec (the AES "Cosmos" and "Electron") it is necessary that $N_c \gg (0{,}5—2{,}0)\cdot 10^4\ \text{см}^{-3}$.

Therefore, the nonstationary state of the ionosphere imposes on measurements of N_c somewhat lesser limitations than the horizontal gradients. However, the contribution of nonstationary state to N_c becomes prevailing at measurements at greater heights, namely when condition (4) hinders the measurement of N_c by the dispersion method. Note that this was already pointed out in [13]. This takes place because the local concentration N_c decreases as the altitude increases, with the consequence that the precision of measurement of N_c drops (contrary to the unfounded assertion by Ya. L. Al'pert in [7], where it is stated that the term of Eq. (20) where N_c is included, "... stands there mainly in experiments at great distances from the Earth..."). The condition ($N_c \gg (0{,}5—2{,}0)\cdot 10^4\ \text{см}^{-3}$) brought out above for satellites of types "Cosmos" and "Electron", limits the admissible region of measurements to altitudes $z_c < 800 - 1600$ km, where $N_c \gtrsim 2\cdot 10^4$ cm^{-3} and above which measurements of N_c are impossible even in the absence of horizontal gradients. It is clear that the measurement of N_c by the dispersion method at distances of several Earth's radii (as proposed in [5] is devoid of any sense, inasmuch as for $N_c \leqslant 10^2\ \text{см}^{-3}$ velocities $\dot{z}_c \gtrsim 100$ км/sec would be required for the fulfillment of the inequality (4).

Note here the incorrectness of still another assertion in [7], where it is said that the role of the nonstationary term

$$\int \frac{\partial N}{\partial t} dS$$

is small, because it is a slowly varying function of time t by comparison with the other terms of (1)... (in our numeration it would be (2). Indeed, when determining N_c what is important is the absolute value of separate terms in (2) and not the relative rate of variation. Thus the ideas of [7, 9, 10] on the slowness of the above expression's variation cannot be a basis for disregarding the nonstationary state.

Errors in the Determination of N_c by the Method of Pair Equations. In the works [4, 6] N_c was determined only at the points where $\dot r_c + \dot z_c/\cos\varphi_0 = 0$, in which expression (2) allows to relate directly N_c and $\delta\Phi$ neglecting the terms with $\partial N/\partial y$ and $\partial N/\partial t$. But in the works [4, 6] the values of N_c were determined for arbitrary points of the orbit by way of resolving a "chain of equations". Let us consider also this method of determination of N_c.

Assume, as in [6] that the horizontal ionization gradient $\partial N/\partial y$ and the non-stationary state of the ionosphere do not contribute notably to $\delta\Phi$ and let us reject the corresponding terms in (2). Then, it will follow from (2), at points where $\dot r_c + \dot z_c/\cos\varphi_0 \neq 0$,

$$\delta\Phi = a\left\{-\frac{N_c \dot z_c}{\cos\varphi_0} + N_R\left(\dot r_c + \frac{\dot z_c}{\cos}\right)\right\} \tag{5}$$

with two unknowns N_c and $N_R \equiv [N_R] + [\partial N/\partial x]$ (at the two points where $\dot r_c + \dot z_c/\cos\varphi_0 = 0$, the term with N_R drops off, and a single equation is obtained with one unknown N_c). In the works [4, 6] a requirement is imposed to the quantities N_c and N_R that the interval Δt between two readings of $\delta\Phi$, be constant, after which Eq. (5) is written for the moments of time t and t + Δt, and from the obtained pair of equations N_c and N_R are determined unilaterally. In [11, 12] N_c is determined in about the same way.

The formulation itself of the problem about the <u>unilateral</u> determination of N_c and N_R from a <u>single</u> equation (5) at superimposition on N_c and N_R (in the given case the condition of constancy of N_c and N_R in the interval Δt) does not arouse any objections on our part (which are ascribed to us in [7]) inasmuch as the additional condition fulfills in a certain sense the role of the <u>second</u> equation for N_c and N_R. The objection is aroused by the fact that the <u>quantitative</u> conditions of smallness, at fulfillment of which N_c and N_R, determined by approximate method of pair equations are close to the true values, are not formulated in [4, 6], and it is not verified whether or not these conditions are fulfilled in reality. Meantime, there basis to consider that under conditons of real ionosphere, N_c and N_R are vary- g insufficiently slowly to make the method of pair equations inapplicable.

To make this more convincing we shall consider the following example. We shall assume that the ionosphere is stationary and plano-stratified ($N = N(z)$, $\partial N/\partial t = \partial N/\partial x = \partial N/\partial y = 0$) and that, both the dependence N (z) and the motion of the AES are given. According to the given values of N_c and coordinates of the AES, we shall compute with the aid of (5) the function $\delta\Phi(t)$ and, utilizing it, we shall resolve the inverse problem, that is, we shall determine the local concentration of N_c by the method of pair equations, comparing afterward the values of obtained with the initial ones. Such a calculation was conducted by us for the typical values of the parameters: a) the orbit of the satellite lies in the plane (x, z), whereupon at the time t = 0 the satellite is at the point z_0 = 400 km, x_0 = —300 km, with its velocity components being z_0 = 0.5 km/sec, x_0 = 8 km/sec and constant in the 0 — 10 sec interval; b) for $z > z_0$ the concentration N (z) decreases exponentially by the law $N(z) = 3\cdot 10^5 \exp[-(z - z_0)/h]$ cm^{-3}, where h = 200 km; c) the integral concentration to the altitude z_0 is

$$\int_0^{z_0} N(z)\,dz = 4.5\cdot 10^{12}\ cm^{-2}.$$

The calculation by the method of pair equations (these being written for the times t = 0 and t = 10 sec, i. e . interval assumed in [4]) gave N_c = 1.62 · 10^5 cm^{-3}, i.e. the relative error is 45% Such a high error is precisely conditioned by the fact that in the example considered the conditions of slowness of N_c and N_R variation are not fulfilled.

For Eq. (5), written in the form $A(t)x(t) + B(t)y(t) = F(t)$, the conditions of slowness may be formulated as follows. If $x(t)$ and $Y(t)$ are the true values of any two physical quantities and $\bar{x}(t)$ and $\bar{y}(t)$ are values determined from the system of pair equations

$$A(t)\bar{x}(t) + B(t)\bar{y}(t) = F(t), \quad A(t+\Delta t)\bar{x}(t) + B(t+\Delta t)\bar{y}(t) = F(t+\Delta t), \qquad (6)$$

the relative errors $|(x - \bar{x})/x|$ and $|(y - \bar{y})/y|$ at $\Delta t - 0$ will be small only at fulfillment of the inequalities

$$\left|\frac{x-\bar{x}}{x}\right| = \left|\frac{B}{x}\frac{Ax'+By'}{A'B-B'A}\right| \leqslant 1, \quad \left|\frac{y-\bar{y}}{y}\right| = \left|\frac{A}{y}\frac{Ax'+By'}{A'B-B'A}\right| \leqslant 1, \qquad (7)$$

where A, B, A', B' are related to the moment of time <u>t</u>. Conditions (7) must be satisfied for any quantities Δt, as small as desirable.

It may be seen from (7) that the error in the determination of <u>x</u> and <u>y</u> by the method of pair equations will be small for a slow variation of $x(t)$ and $y(t)$ (smallness of derivatives $x'(t)$ and $y'(t)$). In the above considered example the determination of N_c by the method of pair equations the inequalities (7) are not fulfilled, whereupon the calculation of the error $(N_c - \bar{N}_c)/N_c$ with the aid of (7) precisely gives the above figure of 45%. In real conditions this error may be either greater or smaller. However, here the essential is that at real variations it is not possible to verify the validity of the assumption of the slowness of N_c and N_c variation, and this means that the reliability of the obtained values of N_c remains in doubt.

The above arguments lead to the conclusion on the impossibility of reliable determination of N_c by the dispersion method with the aid of AES. This conclusion was precisely derived by us in [1] ; however, in Ya. L. Al'pert objections it acqui- the following form: " ... in the balance, the arguments brought up in [1] amount to the assertion that the local value of electron concentration N_c cannot be determined as a result of processing of continuous registrations of Doppler shifts of frequency $\delta\Phi(t)$ of two coherent radiowaves [7].

The summary of the above referred to viewpoint is incorrect for two reasons. First of all, our assertion is not an <u>argument</u> but a <u>conclusion</u> , which is based upon arguments expounded above and also previously, in [1] , and incidently, not rejected in [7]. Secondly, we consider that the possibility of reliably determining N_c from continuous registrations of $\delta\Phi(t)$ is not at all impossible in all cases, but only at substantial horizontal velocity of the emitter. For example, during experiments with vertically launched geophysical rockets the determination of N_c by the dispersion method is quite possible, which is corroborated by numerous works, including our own [13, 26].

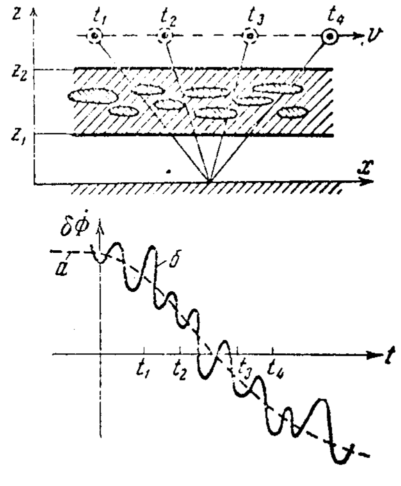

Fig. 1

Let us bring forth a simple example "based upon the physical understanding of the essence of the method of measurements of $\delta\Phi$ and of the properties of the ionosphere" [7]. Assume that the satellite flies above an ionized region located between the altitudes z_1 and z_2 (Fig. 1), whereupon the local concentration near the satellite is zero. It may be seen that in this case the dispersion measurements will give a registration of $\delta\Phi(t)$ with all the characteristic peculiarities of those obtained in [4, 6, 8 — 12]. In the case of horizontally-uniform ionosphere ($\partial N / \partial x = \partial N / \partial y = 0$) $\delta\Phi$ will vary smoothly, and, passing through zero will change sign (Figure 1, curve a). But if the ionized region contains irregularities, the course of the curve $\delta\dot{\Phi}(t)$ may vary within broad limits. Analyzing the data of our example on the basis of registration of $\delta\dot{\Phi}(t)$ made in [6, 10, 27], the assumptions that "each quasiperiodical variation of $\delta\Phi(t)$ registered in the form of continuous readings, is mainly and most often caused by the variation of local concentration, that is, at intersection by the emitter of an irregular formation along the orbit of the AES" [10], we would have obtained some values $N_c \neq 0$, while according to the assumption $N_c = 0$.

The example just considered illustrates our principal conclusion about the impossibility to reliably determine N_c in case of experiments with AES, and to subdivide the contributions by various factors to the quantity $\delta\Phi$ registered during dispersion measurements. (These conclusions of ours are analogous to the remarks by A. N. Krylov on the influence of various sorts of factors on the results of measurements (see [28], p.389). Such a conclusion was already stated in the works [14, 17 — 19].

3. INTERPRETATION OF THE RESULTS OF MEASUREMENTS

Besides the fact that the values of N_c obtained in [4, 6, 8, 9] are questionable, their method of utilization for plotting the graphs of the indicated works alongside with the conclusions derived therefrom also invite substantial objections. This is why we should like to call attention to still other incorrect situations in the works under discussion [4, 6, 8, 9]

Altitude-temporal Distributions $N_c(z, t)$ and their Maxima. The values of N_c found in [8] are represented in the form of a single altitude course of electron concentration, whereupon each curve is plotted by the values of N_c obtained at different days and times, and above different geographic points (only one value of N_c is obtained for one flight of the satellite, i. e., only one, or two points at the most for the curve $N_c(z, t)$ per day. (Note that although the altitude-temporal distribution must depend on two arguments, z and t, the dependence on time t is in no way reflected in the graphs for $N_c(z, t)$ in the works [8, 9]. Thus, for example, one of the curves of Fig. 5 in [8], encompassing the altitudes from 431 to 1215 km, was plotted by 40 points for 37 days (from 18 February to 25 March 1964) in the interval from 0900 to 1800 hours, whereupon, as follows from Table 1 of that work, the range along the horizontal x_c reached 1006 km. Under the conditions of real ionosphere, being essentially nonuniform and nonstationary medium, the assortment of such disparate experimental points of N_c linked with one curve, cannot in any way characterize the true properties of the ionosphere and do not allow to outline any "spatial regularities" of the ionosphere, sumilar to those brought out in [6, 8, 9].

To justify the rightfulness of the curves $N_c(z, t)$ in [8], it is stated: " If for any reasons, and particularly for those considered below, there emerge from time to time, and for short periods, in specifically local regions of the ionosphere excessive numbers of electrons by comparison with the undisturbed value of N_c, or if there occurs in two adjacent regions a concentration of electrons ine one, and rarefaction in the other, next to it, this spatial regularity can be measured during prolonged measurements. It is possible that the dependence $N_c(z, t)$ makes apparent such a constantly acting in height, but not necessarily in time, local variability of electron concentration."

Included here are at least two incorrect assertions. First of all, if reference is made to lengthy measurements, during which short-term events are revealed (similar, for instance, to sporadic formations of the E_s-type layer), during pauses between these events there must be registered values corresponding to the normal, undisturbed state of the medium, whereupon a significantly greater number of measurements must correspond to pauses than to periods responding to the exclusive short-term events. However, such "undisturbed" points (Fig.5 of [8]) are totally absent, and all the determined values of N_c at one point lay over a single curve, quasiperiodical in height; the number of points in the minima corresponds approximately to the number of points in the maxima of the curve, and also to the number of points between maxima and minima. This obviously could not have taken place at prolonged observations of short-lived events. Secondly, the terminology "lengthy observations" cannot be applied to the observations described in [8]. In reality, only 40 values of N_c were determined in Moscow for 1½ months, which refer to different altitudes (from 431 to 1215 km). It is clear that because of the scarcity of the points obtained that refer to large time intervals and to various altitudes, such observations should be called not lengthy, or prolonged, but episodical observations in the course of a prolonged time interval.

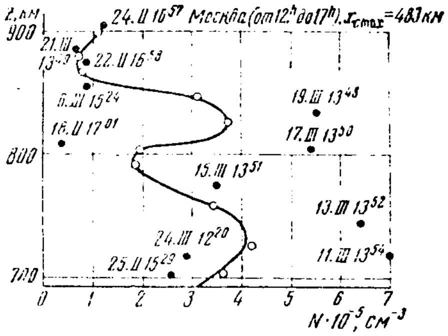

Fig. 2

However, although the curves $N_c(z, t)$ do not characterize the real properties of the ionosphere, far-reaching conclusions are derived on their basis in the works [6, 8, 9]. Thus, it is stated in [8]: "The altitude course of $N_c(z, t)$, plotted in Fig. 5 for the combination of individual values of N_c, corresponding not only to various heights z_c, but also to different values of the horizontal coordinates (x_c, ψ_c) and time t_c in the course of a day, as well as of one month, has led, as may be seen, to a qualitatively new character of electron concentration's dependence on height" (underscoring is ours). Such a type of qualitatively new results are included in particular in the work [6], where communication was made of the detection of a new ionization maximum reaching 90 – 95 % of the F-region maximum, and disposed 120 – 140 km higher than the latter. The presence of this maximum is corroborated in the works [8, 9], in which it is also communicated about the detection of a series of alternating maxima and minima, recurring every 120 – 160 km. Besides, the ionization maximum at ~ 650 km was discovered by the authors of [12].

In connection with the new ionization maximum it is stated in the work [6] : "... the results of other measurements, where an analogous maximum was observed, are unknown to us..", whence it is clear that here the question evolved about the discovery of an earlier unknown phenomenon of nature. It is natural that such a type of phenomena requires steady attention, and the more so, since they would have a practical value (for example, for radiocommunication between AES).

Let us examine the way the authors of [8, 9] managed to the detection of the quasiperiodical structure of the ionosphere.

Plotted in Fig. 2 is a two-hundred kilometer portion of the curve $N_c(z, t)$ (see Fig.5 of [8]), constructed according to observation data in Moscow. Here figure also the primary experimental points (black circles) from Table **4 of** [8] shown alongside with them are the date and the time of measurements during **the** 36-day period, from 18 February to 24 March 1964. It may be seen that 10 "averaged" points were obtained by a certain "cross-averaging" of 12 scattered experimental points, without any detailed description of the procedure to permit arriving at them. Precisely these "averaged" points (white circles) were used for plotting the solid curve for $N_c(z, t)$. Analogously processed in [8] were all the primary data obtained in Novosibirsk, which fitted precisely the graph plotted by the "averaged points". There is no explanation of any kind in the work [8] in reference to the above.

The phsyical sense of the "averaged" values of N_c is not clear. If every primary experimental value of N_c corresponds to a certain specific point of space and moment of time, we may wonder to what corresponds the average of the two values of N_c measured, for example, between 17 March at 13 50 hrs and 18 February at 17 01 hours ? It makes hardly any sense to try to clarify the meaning of such an "averaged" value of N_c if, moreover, we take into account that the experimental points were obtained over various geographic points distant by more than ~ 400 km from one another, and under entirely different states ofthee ionosphere as a whole (which can be seen from the scattering of the values of N_c in the F-region maximum (refer to Table 4 of 8).

Therefore, the curves $N_c(z, t)$, as much as their maxima are devoid of any physical sense, and this is why there is not necessity to have recourse for their explanation to a series of hypotheses, such as assumptions of "standing plasma waves", of "laminar, quasiperiodical structure of processes in the ionosphere" and others. This viewpoint is still more strengthened by the fact that no new maxima above the F-region maximum have been uncovered during the numerous experiments (see below).

On the Determination of the Spectrum of Irregularities. Although the present paper is devoted to the question of the possibility of finding the local concentration of N_c, it is impossible to forego some remarks as regards the determination of the spectrum of irregularities from the registrations.

During the determination of local concentration, *smoothed curves* were utilized in the works [4, 6, 8, 9] for $\delta\Phi(t)$. In reality, the curves $\delta\Phi(t)$ undergo more or less significant variations, from the analysis of which the spectrum of irregularities has been found in the works [4, 6, 10], and also in [27]. However, here too the basis of the analysis consisted in the earlier mentioned proofless assumption about the variations of $\delta\Phi$ as being induced mainly by the variation of local concentration along the orbit of the AES. This assumption is not evident by any means. (As an example of another interpretation of registrations of $\delta\Phi$ let us point to the work [29] , in which it is considered that the variations of are determined by the variations in the entire thickness of the ionosphere at below the satellite (see also [1]).

From the basic formula (2) it may be seen that the variations of $\delta\dot{\Phi}$ may to an equal degree be unduced by the variations of N as well as be the variations of the quantities $[\bar{N}_R]$, $[\partial\bar{N}/\partial x]$, $[\partial\bar{N}/\partial y]$. This is why any irregularity, encountered on the path of wave propagation from the emiiter aboard the AES to the point of reception, independently from the altitude at which it is disposed, will be manifest on the registered value of $\delta\dot{\Phi}$ It is sufficient to figure out several satellite rotating around the Earth along orbits located at different heights, but moving, contrary to all laws of mechanics, synchronously relative to the observation point, finding themselves at each moment of time on one and the same visual ray. In this imaginary experiment, one and the same irregularity, situated below all the satellites, must, according to [4, 6, 10, 27] be ascribed simultaneously to several different heights. Hence may be visualized the senselessness of the assumption made in [4, 6, 10, 27] about the fact that mainly ionospheric irregularities along the orbit induce the variations of $\delta\dot{\Phi}$. (Note that in the work 30 conclusion was drawn on the basis of analysis of amplitude fluctuations of radiosignals from AES taken at saattered point, that the irregularities of the ionosphere are disposed mainly near the F-region maximum. Note also that the works [4, 6, 10, 27] and the work [30] were all based upon observations of the same signals from the same AES). At the same assumption neither the spectrum of irregularity dimensions, nor the values of the relative fluctuations of electron concentration $\Delta N_c/N_c$ can be correctly determined.

4. COMPARISON OF DATA OBTAINED BY DIFFERENT METHODS

Taking into account what has been said in sections 2 and 3 on the precision of N_c determination in the works [6, 8, 9, 11, 12] we might even not touch upon the question of comparing the curves $N_c(z, t)$ with the data of other experiments, though similar comparison in the works [6, 8, 9, 11, 12] would have been quite relevant. It seems, that the authors of the indicated works, having detected new ionization maxima, should have attempted to find the cause of such substantial discrepancies from the results of other experiments, and in particular, the cause of absence of the second ionization maximum with $N \sim 0{,}9 \div 0{,}95\, N_{\max F}$ in the results of measurement byother methods. However, about all the experiments, besides the dispersion experiments from AES, it is stated in [7] that in them "another value of the local value of electron concentration is determined, than in the works [1—7] " (according to our numbering [2—6]), inasmuch as"the values of N_c determined in our experiments, characterize a very small part of the ionosphere with linear dimensions of the order of the wavelength ", while "in most of the experiments described in literature, the averaging of N by larger regions is really the element lying in the very method of measurements or of processing their results. But this is incorrect. In the longitudinal direction (along the AES orbit) the dimensions of the region of averaging for the dispersion experiments in [4, 6, 8—12] are not of the order of the wavelength λ, as is stated in [7] , but of the order of several kilometers or tens of kilometers, inasmuch as at determination of N_c smoothed curves $\delta\Phi(l)$ are used, on which are averaged the variations of N_c with spatial dimensions of precisely such an order.

As to the transverse dimensions of the region of averaging, which at dispersion measurements is of the order of λ, at sounding measurements it is substantially less than $\lambda \sim 3$ m (f= 90 Mc) in the experiments of [4—6, 8—12]), but at experiments with incoherent scattering and at impulse radiosounding from the ground and from satellites, this dimension is considerably greater than $\lambda \sim 15$ м ($f = 20$ Mc). Meanwhile, the various experiments (except for those of [4, 6, 8—12] with various dimensions of averaging region provide well conforming results, as may be seen, for example, from Fig. 3, borrowed from [31], see also [32—37]).

Therefore, the inconsistency of the assertion in [7] about the nonequitability of the comparison of values of N_c obtained by different methods, is obvious. Incidently, such a comparison of data of dispersion measurements by satellites with those of impulse soundings from AES "Alouette" of incoherent scattering and rocket soundings were conducted in the works [7, 8, 10] without any reservations.* These data are, however, compared in [8] not with the curve $N_c(z, t)$ itself, but only with the curve tangent to the minima of $N_c(z, t)$, and with "the mean secant of the dependence $N_c(z, t)$. The same goes for [7, 10] , where a certain (smoothed-averaged" curve $N_c(z, t)$, having maintained from the curve $N_c(z, t)$ only one new maximum, is compared. But even this comparison, borrowed from [7] , with denotations 1) for $N_c(z, t)$; 2) for N_i^+ ; 3) for the incoherent scattering and, 4) for Alouette, in Fig. 4, demonstrates the difference of principle in the course of the curves (presence of two maxima on the curve $N_c(z, t)$, while only one maximum is seen on the other curves). We cannot fail to notice also that though the curves are indeed in good agreement at heights beyond 2200 km, at $z < 1200$ km the values of N diverge by a factor of 20.**

Note that the deep minimum in the graph for $N_c(z, t)$, emphasized as being an important property of this curve and detected at 620 - 630 km above Moscow, Sverdlovsk and Novosibirsk, corresponds to the ionization maximum at that height (~ 650 km) above Khar'kov by the authors of [12] , whereupon in the latter no "quasiperiodical structure"of any kind was noted at heights up to 1 800 km. Nor could this cause any perplexity.

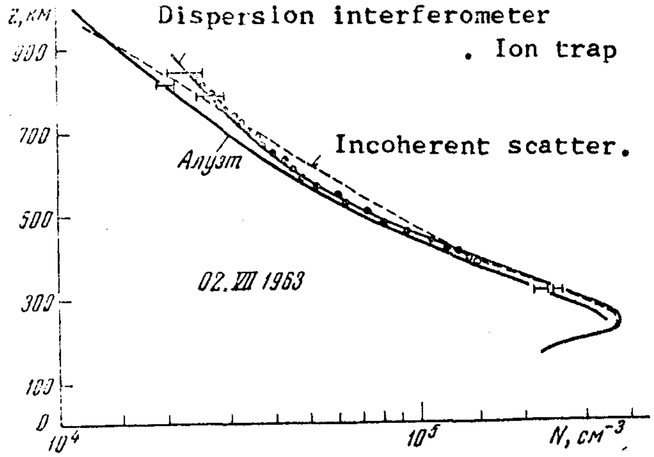

Fig. 3

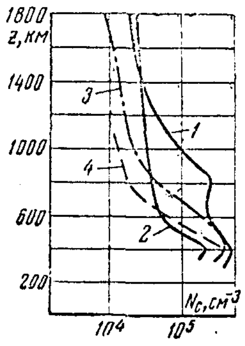

Fig. 4

Thus, comparison of space-time dependences $N_c(z, t)$ with the data of other experiments shows that only the curves for $N_c(z, t)$ have a quasiperiodical structure and numerous maxima. Taking into account the accuracy of the curves $N_c(z, t)$ (see sections 2 and 3), we consider that even if the maxima of N existed in reality, in the upper ionosphere, the dispersion measurements with the aid of AES, described in [2—12], are the least convenient for their exposure.

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* The comparison made in [6] with the data of ground ionospheric stations is not considered here. Note only a significant discrepancy between the data of the latter and those of dispersion methods with AES.

In conclusion we should like to express regrets that Ya L. Al'pert evidently seeks to avoid any constructive discussion of the substance of this question, namely in his work [7]. For example, in connection with our analysis in [1] of the role of horizontal gradients he limits himself to the remark that this argument is obvious. Here we are in complete agreement with him, but we do not consider that the obviousness of the argument makes it fallacious and allows it to be ignored. It would seem, to the contrary, that whenever an obvious argument springs up against any concept, the more so should the insistent defender tend to refute this argument by its sssence. However, the stand taken by the author of [7] can hardly contribute to the establishment of the truth.

CONCLUSIONS

The above allows us to derive the following conclusions:

1) The precision in the determination of electron concentration N_c in the ionosphere by the dispersion method with the aid of coherent radiowaves emitted from an AES is quite low on account of the influence of ionosphere's irregularity and nonstationary state. This is why the values of N_c determined by such a method, are unreliable. As the height increases above the F-region maximum, the errors in the determination of N_c rise, for the contribution of N_c to the measured quantity $\delta\Phi$ drops on account of the decrease of N_c, while the contribution by the nonstationary state of the ionosphere does not decrease.

2) Neither the data of the dispersion measurements themselves, nor the data of the ground network of ionospheric stations allow to estimate the error in the determination of N_c in each concrete case.

3) The determinations of the local concentration by the dispersion method with the aid of AES is not appropriate, since there exist other, more reliable methods of determination of N_c. Obviously, this does not imply the uselessness of studying coherent radiowaves from AES, which allow to obtain a series of other valuable data on the ionosphere (for example, on the integral concentration and its variations, and also on ionospheric irregularities).

4) By virtue of the above-noted unreliability of the values of N_c obtained by the method indicated, the conclusions derived in [4—6, 8—12] are found to be doubtful. In these works there is no really reliable analysis of the precision of measurements and the series of data required for such an analysis are lacking. But the numerical data, brought up in these works, are not evidence that the conditions, at which the determination of N_c is possible, were observed.

5) The image of the values of N_c in the form of a unique altitude dependence obtained during single, episodical measurements on various days and times of the day, and over different geographic points, is unlawful. Such a dependence is devoid of physical sense.

***** THE END *****

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VOLT TECHNICAL CORPORATION
1145 19th st NW
D.C. 20036. Tel: 223-6700

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