"WATSON-FOCK DIFFRACTION FIELD" AND ULTRARELATIVISTIC ELECTRON PRECIPITATIONS INTO THE POLAR MIDDLE ATMOSPHERE

*The report is devoted
to the 110 birthday anniversary of academician V. A. Fock*

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A year after the end of the Great Native War an academician Vladimir Aleksandrovich Fock published a work "Radio Wave Diffraction Around Earth" [1], which was reproduced in [2]. I hold this little book in soft cover in my hands at first in my life more than 40 years ago when I became an initiating young specialist at the Physics Department of Leningrad State University, at which prof. V. A. Fock was the chief of the Theoretic Physics Department. At those time I appreciated the text as science history and could not imagine that after 20 years of my scientific activity I should return to the Fock's work in order to prove on the base of the RAS Polar Geophysical Institute experimental data, gotten by Beloglazov M. I., an existence of a new geophysical phenomena in an auroral region [3]. The data are the results of on ground measurements of radio signal amplitudes and phases.

The essence of the phenomena is a spontaneous ultrarelativistic (with energy ~ 100 MeV) electron precipitation into the polar middle atmosphere with a time scale equal to some minutes - several hours and with a spacious scale equal to several thousand km. Such precipitations manifest themselves through anomalous variations of the amplitudes and phases of the VLF radio signals generated and received on ground. The anomaly manifests itself in the absence of the second "ionosphere" ray in a receiving signal and, as a result of it, in the qualitatively similar behavior at a disturbance of the signals with distance for different frequencies in the band 10 – 14 kHz and at the distance from a source near 900 km. The pointed precipitation generates the X-ray and γ-ray streams, the intensity of which is enough for ionization of the middle atmosphere very significant in the 10 – 40 km altitude interval. Such characteristic peculiarity is absent for all other geophysical disturbances (the auroral electron and solar proton precipitations, the solar X-ray flares). So a sporadic D layer of electric conductivity in the middle atmosphere appears in addition to the regular D layer of ionosphere. Sometimes an effective height h of the "ground – ionized layer" wave guide diminishes in two times, i. e., it becomes equal to 30 km instead of 60 – 80 km [4].

This publication is an answering on the question: what is the relationship between a ground diffraction wave ("Watson-Fock diffraction field") and an electron precipitation?

"The Watson-Fock diffraction field", which is a quite strict consequence of the Maxwell equations for a boundary problem with a sphere of great dimensionless radius and a radio source on it, quantitatively describes the field in the region of half-shade and shade. An initial mathematical expression for the wave in shade on ground was gotten by Watson due to his famous transformation of the P. Debye serious. V. A. Fock gave more accurate mathematical expression for the wave [1]. Due to these obstacles we use a term "Watson-Fock diffraction wave". Near 40 years ago this wave was tabulated by my teachers Gunninen E. M., G. I. Makarov, V. V. Novicov and S. T. Rybachek [5], so in our investigations Beloglazov and I had possibility to use the ready numerical values for the on ground diffraction wave.

After 55 years, when the experimental proof of ionosphere existence was gotten due to the fact of first order interference existence between the direct ray and the wave reflected from above [7], Beloglazov M. I. and I collided with the following experimental fact. Sometimes (very rarely, 16 time for 10 years) in the conditions of a pure "geophysical calm" the amplitudes of radio signals from a band of several kHz and from a most powerful radio navigation source diminished at more than several or ten times at the distance of ~ 900 km. At such distance an on ground receiving point is located in the shadow region relatively to an on ground source (the shadow is caused by a spherical Earth surface). The Watson-Fock diffraction wave does not depend on the electric properties of the middle atmosphere. The pointed experimental fact that a signal disappears, when the apparatus with 20 Hz receiving band is used, may mean only one thing. The Watson-Fock diffraction wave is compensated by a wave, which reflects from a sporadic layer of atmosphere electric conductivity with an effective altitude ~ 30 km. This value is gotten by solving an inverse problem relative to such layer parameters, for which full compensation takes place [8]. In normal conditions and in the cases of all other geophysical disturbances, as it follows from the Maxwell equations, the wave, reflected from above, is described by the geometry optics approximation. But in conditions of our abnormal disturbance "the signal from above" becomes of the diffraction nature too [9]. So the phase and amplitude conditions for the compensation become qualitatively different from the optics conditions. The stated thought is revealed in the following.

A normal first order interference minimum at the 500 and 600 km distances from a source at night and

day time conditions correspondently is a result of a situation when a "ground – ionosphere – ground" ray pass is longer on a half wave length in air than a ray pass along ground. An abnormal zero order interference minimum at the 900 km distance is due to the anti phase state of the Watson-Fock diffraction wave to the "ground – ionosphere – ground" ray with one reflection from above. This anti phase state is realized due to two causes. The first cause is an equality of the phase of the diffraction on ground wave to the phase of the "ground – ionosphere – ground" geometric pass although their geometry optics passes are significantly different. But the ray moves practically in vacuum with the phase velocity of light and the diffraction wave propagates with the effective phase velocity larger than the light velocity. So due to this situation the wave and the ray may be in phase. Then there is second cause, which makes them in anti phase. In the discussing situation a vertically polarized ray reflects from the inhomogeneous conducting atmosphere layer at an extremely sliding angle. According to the numerical solutions of the Maxwell equations [10, 11] the argument of the reflection coefficient from the effective height is near π The definition of an effective height h is following: it is a height relative to which the reflection coefficient argument is equal to π. So we described the causes due to which the anti phase anomaly of zero order takes place in a case of ultra relativistic electron precipitation and at a distance 1.5 times longer than in a case of normal interference minimum.

An anti phase condition is necessary but not enough one for full compensation. The amplitude condition demands the equality of the ground diffraction wave and "ionosphere ray" amplitudes. The fulfillment of this demand is not trivial. In normal conditions the ray amplitude near two times greater than the diffraction wave amplitude [9]. In the cases of the solar proton precipitations the ray amplitude does not become lesser [12, 13]. In our case of extremely sliding angle of first ray incidence on an ionized lay, the smallness of a reflection coefficient may be realized only due to the existence of inhomogeneous large scale ($z \approx 10 - 40$ km) layer of conductivity, which we call a sporadic D-ionization layer. The most real cause of ionization at such wide height interval is the flood of bremsstrahlung X - rays and γ - rays, which are generated by the precipitating ultrarelativistic electrons due to them negative acceleration at the altitudes near $40 - 45$ km. If the energy of an electron is near 100 MeV it will be stopped at the altitude at which the atmosphere pressure is equal to 50 g / cm^2.

According to [14] if an electron with energy $70 - 80$ MeV penetrates into oxygen or nitrogen gas at atmosphere pressure then more than 50% of its energy transforms into X - rays and γ - rays.

The lust nontrivial item of the report is following. If we consider geometric optics interference then it is clear that in order to escape from an interference minimum it is sufficient to move a receiver in space. But in our case if a receiver moves away from a source the field continues to attenuate due to the curvature of the wave guide with a low effective height h. Due to h lowness and the Earth curvature the "ground – ionosphere – ground" turns into a diffraction ray [9] and the phase difference between two diffraction waves stays unchanged, i. e. anti phase, if a receiver moves in the direction opposite to a source. So there is no contradiction with the second version of radio wave propagation theory due to which the field in a wave guide is described by the normal waves [15]. In our abnormal conditions of attenuation only one normal wave achieves a receiver and it attenuates monotonously for greater distances. So the sum of the Watson-Fock diffraction on ground wave and the diffraction "ground – layer of conductivity – ground" wave approximately is equivalent to one normal wave.

The ideas represented are the ideological carcass of an indirect proof of a new geophysical event [3, 4, 16, 17]. Future experimental direct measurements on the spacecrafts should to support our statement about ultrarelativistic electron precipitations.

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