Electric pulse of the explosions of the nuclear and trotyl explosive charges

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Abstract

In 1962 with the realization of thermonuclear explosions in space was discovered the previously unknown physical phenomenon, which consisted in the fact that near the earth's surface such explosions cause the electric pulse of very large amplitude and very short duration. Up to now there is no answer to a question, what physical mechanisms bear responsibility for the appearance of this pulse. In this article the explanation of the phenomenon indicated is conducted on the basis of the concept of the scalar-vector potential, which assumes the dependence of the scalar potential of charge on its speed.

Introduction

Explosive processes are characterized by the fast separation of significant thermal energy, with which occurs the strong warming-up of decay products and is formed plasma. Depending on the type of explosion the plasma can have different degrees of ionization. With the nuclear explosions, when the temperature of plasma can reach several million degrees, the degree of ionization of plasma is high. With the realization of explosions by means of the conventional explosives cold plasma with the low degree of ionization is obtained. With the nuclear explosions occurs not only fast separation of significant thermal energy, but also emission of electromagnetic radiation in the wide frequency range. With the explosions of nuclear charges is formed also electric pulse with the high tension of the electric field, whose physical nature up to now completely obscure.

Electric pulse of nuclear explosions

It is earlier into 1957 future Nobel laureate doctor Hans Albrecht Bethe, being based on the theory of dipole emission, predicted that with a similar explosion will be observed the electromagnetic pulse (EMP), the strength of field of which on the earth's surface will comprise not more than 100 V/m. But with the explosion of H-bomb with the TNT equivalent 1.4 Mt. at the height 400 km according to the program *Starfish* occurred that not expected, the tension of electrical it turned out that pour on, beginning from the epicentre of explosion, and further for the elongation of more than 1000 km it reached several ten thousand volt per meters. (Actual chart area and value of tensions pour on given in Fig. 1)

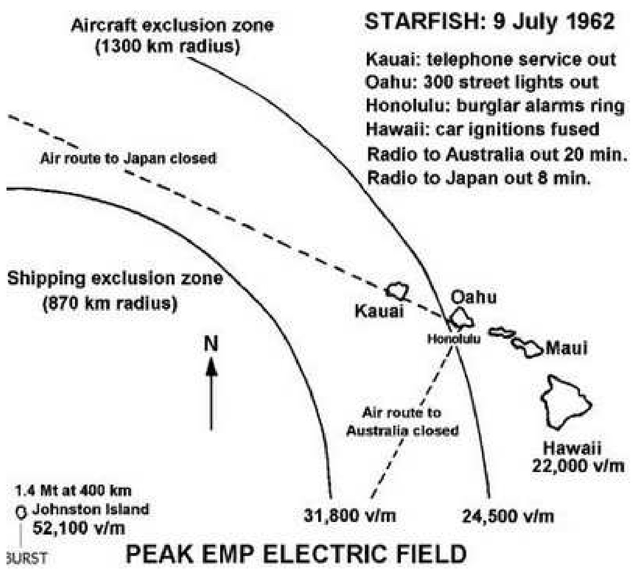

Fig. 1. Map of tests according to the program *Starfish.*

Possibility to refine this question give the data, obtained in the USSR during the tests with the code name *Program K*, when not far from Dzhezkazgan at the height 290 km was exploded H-bomb with the TNT equivalent 300 kt. It was also discovered with the tests according to this program, that the explosion is accompanied not only by electric pulse, but also are caused in the telephone lines and the surface layers of the earth high currents.

Is located the record of the shape of electrical pulse, made at a distance 1300 km from the point of impact (Fig. 3), obtained with the tests according to the program *Starfish.*

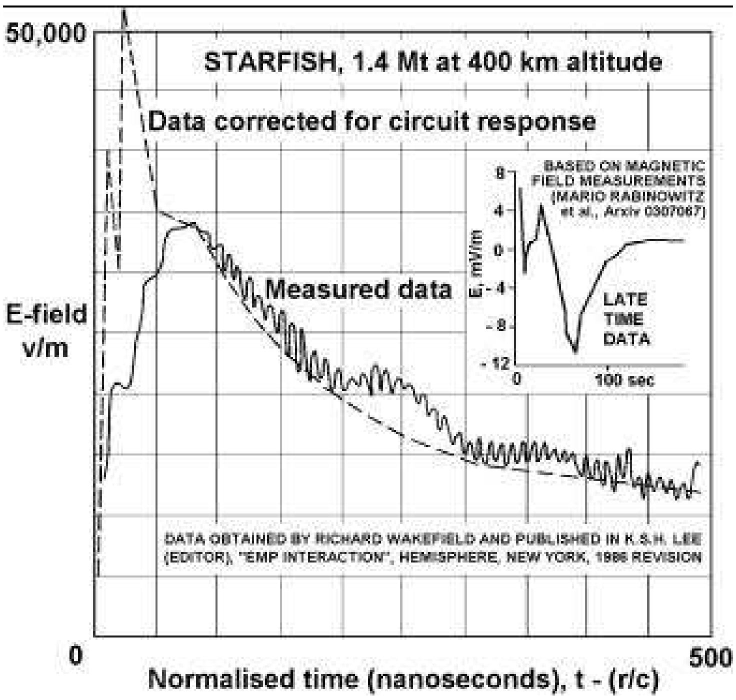

Fig. 2 Experimental dependence of amplitude EMI on the time, obtained with the tests according to the program *Starfish.*

Until most recently in the scientific journals was absent article with the explanation of this phenomenon. This indicates that the fact that there is no theory, which could give answer to the presented question.

Is known that the problem of this phenomenon attempted together with his students to solve and academician I. B. Zeldovich [1]. However, in the existing sources there is no information about the fact that this problem was solved by it.

And only in 2013 appeared the first publication, in which was given an attempt at the explanation of the phenomenon [2]. In the work it is shown that as a result nuclear explosion appears not the electromagnetic, but electric pulse, the vector of electric field of which is directed toward the point of impact. For explaining physical nature of electric pulse are used the concept of scalar-vector potential, the assuming dependence of the scalar potential of charge on its relative speed. The bases of this concept were placed in work [3], and it underwent its further development in works [4-7].

In Fig. 2 solid line showed the dependence of the pulse amplitude on the time, recorded on the oscilloscope face, obtained with the tests according to the program *Starfish*, and dotted line showed the shape of pulse, corrected taking into account the parameters of the input circuits of oscillograph.

With the detonation the products of explosion heat to the high temperature, and then occurs their gradual cooling, during which the explosive energy returns to environment. The dependence of the pulse amplitude on the time repeats the process indicated, and possible to assume that precisely the temperature of plasma determines its amplitude. In the time of the detonation of the charge T_1 ~ 25 ns is a sharp increase in the pulse amplitude, and then there is a slower process, with which in the time T_2 ~ 150 ns the amplitude decreases two. We will consider that the sum of these times represents the time, for which it occurs the emission of a basic quantity of energy, obtained with the explosion.

If we consider that one ton of trotyl is equivalent ~4.6×10 J, then with the explosion of bomb with the TNT equivalent 1,4 Mt. are separated $\sim 6.44 \times 10^{15}$ J. Consequently explosive force in the time interval indicated will compose $\sim 3.7 \times 10^{22}$ W. For the comparison let us point out that the power of the radiation of the Sun $\sim 3.9 \times 10^{26}$ W.

Let us examine a question, where how, in so short a time, can be the intake, isolated with this explosion. With the explosion in the atmosphere the energy is expended on the emission and on the creation of shock wave. In space shock wave is absent, therefore explosive energy is expended on the electromagnetic radiation.

In accordance with Stephan-Boltzmann equation the power, radiated by the heated surface, is proportional to the fourth degree of its temperature:

$$P = \sigma S T^4 ,$$

where σ - Stefan-Boltsman constant, and S - area of radiating surface.

In order to calculate temperature with the known radiated power it is necessary to know the surface of radiating surface. As this surface let us select sphere with the surface ~3 m^2. Knowing explosive force and size of radiating surface, we find the temperature of the cloud of the explosion

$$T = \sqrt[4]{\frac{P}{\sigma S}}$$

with the explosive force ~3.7×10^{22} W we obtain the value of temperature equal to ~ 8.6×10^6 K.

In the concept of scalar- vector potential, the scalar potential of charge it is determined from the relationship

$$\varphi(r) = \frac{g\ ch\frac{v_\perp}{c}}{4\pi\ \varepsilon_0 r} , \tag{1}$$

where r - the distance between the charge and the observation point, $v_\perp$ - the component of the charge rate g, normal to the vector $\vec{r}$, ε_0 - dielectric constant of vacuum.

According to the estimations at the initial moment of thermonuclear explosion the temperature of plasma can reach several hundred million degrees. At such temperatures the electron gas is no longer degenerate and is subordinated to the distribution of Boltzmann. The most probable electron velocity in this case is determined by the relationship

$$v = \sqrt{\frac{2k_Б T}{m}} , \tag{2}$$

where T - temperature of plasma, $k_Б$- Boltzmann constant, m- the mass of electron.

Using relationships (1) and (2), and taking into account with the expansion in the series of hyperbolic cosine the terms $\sim \frac{v^2}{c^2}$, we obtain the value of increase in the scalar potential at the observation point

$$\Delta\varphi \cong \frac{Nek_Б T}{4\pi\varepsilon_0 rmc^2}, \tag{3}$$

where N - quantity of electrons in the cloud of explosion, e- electron charge. We determine from the formula the tension of radial electric field, which corresponds to this increase in the potential:

$$E = \frac{Nek_Б T}{4\pi\varepsilon_0 r^2 mc^2} = \frac{\Delta q}{4\pi\varepsilon_0 r^2}, \tag{4}$$

where

$$\Delta q = \frac{Nek_Б T}{mc^2} \tag{5}$$

is an equivalent charge of explosion.

One should say that with the warming-up of plasma the ions also acquire additional speed, however, since their mass considerably more than the mass of electrons, increase in their charges can be disregarded.

For enumerating the quantity of electrons it is necessary to know a quantity of atoms, which with the warming-up formed the cloud of explosion. Let us assume that the total weight of bomb and launch vehicle, made from metal with the average density of the atoms $\sim 5\times 10^{22}$ 1/sm^3, is 1000 kg. General a quantity of free electrons in the formed plasma, on the assumption that all atoms will be singly ionized with the specific weight of the metal ~ 8 g/cm^3, will comprise $\sim 5\times 10^{27}$.

In accordance with formula (4) the tension of radial electric field at a temperature of the cloud of the explosion ~8.6×10^6 K will comprise: in the epicentre of the explosion ~6.9×10^4 V/m, at a distance in 870 km from the epicentre ~1.2×10^4 V/m and at a distance 1300 km from the epicenter ~6×10^3 V/m. It is evident that in the epicentre the computed values of electrical pour on on the earth's surface they are close to the experimental values. The ratio of design values to those measured they comprise: in the epicentre of explosion ~1.3, at a distance 870 km from this place ~0.4, at a distance 1300 km ~0.25. Certainly, are unknown neither the precise initial of the temperature plasma nor mass of bomb and launch vehicle, in which it undermine nor materials, from which are prepared these elements. Correcting these data, it is possible sufficiently simply to obtain values pour on those being approaching experimental values. But calculated three-dimensional dependence pour on strongly it is differed from experimental results. Let us attempt to explain the reason for such divergences.

Let us first examine the case, when charge is located above the metallic conducting plane (Fig. (3) The distribution of electrical pour on above this plane well known [9].

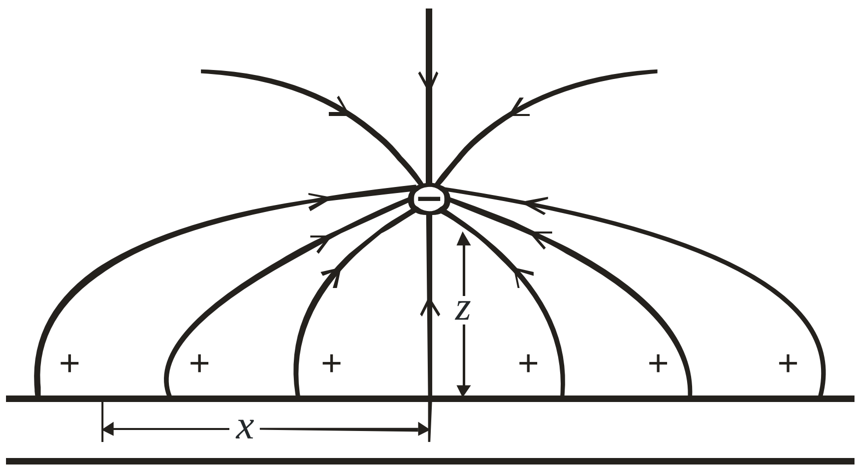

Fig. 3. Negative charge above the limitless conducting plane.

The horizontal component of electric field on the surface of this plane is equal to zero, and normal component is equal:

$$E_{\perp} = \frac{1}{2\pi\varepsilon_0}\frac{zq}{\left(z^2 + x^2\right)^{\frac{3}{2}}} \tag{6}$$

where q - magnitude of the charge, z - distance from the charge to its epicentre, x - distance against the observation points to the epicentre.

Lower than conducting plane electric fields be absent, but this configuration pour on equivalent to the presence under the conducting plane of the positive charge of the same value and at the same distance as initial charge. They indicate that in the conducting plane the charge sees its mirror reflection. The pair of such charges presents the electric dipole with the appropriate distribution of electrical pour on. This configuration pour on connected with the fact that charge, which is been located above the conducting plane, it induces in it such surface density of charges, which completely compensates horizontal and vertical component of the electric field of charge in the conducting plane and lower than it. The dependence of the area of the charge density from the coordinate x also is well known [9]

$$\sigma(x) = \varepsilon_0 E_{\perp} = \frac{1}{2\pi}\frac{zq}{\left(z^2 + x^2\right)^{\frac{3}{2}}}. \tag{7}$$

If we integrate $\sigma(x)$ with respect to the coordinate x, then we will obtain magnitude of the charge, which is been located above the conducting plane. In such a way as not to pass the electric fields of the charge q through the conducting plane, in it must be contained a quantity of free charges, which give summary charge not less than the charge q. In this case two cases can realize. With the low charge density, which occurs in the poor conductors, it will arrive to move up to the significant distances significant quantities of charges. But in this case of charges it can and not be sufficient for the complete compensation. With the high charge density, it is possible to only insignificantly move charges in the plane. This case realizes in the metallic conductors.

If we periodically draw near and to move away charge from the plane, then in it will arise the periodic horizontal currents, which will create the compensating surface charges. The same effect will be observed, if charge at the particular point can be born and disappear. If at the assigned point above the plane charge suddenly in some time arises, then, so that the fields of charge would not penetrate through the conducting plane, in the same time on the conducting plane the compensating charges, which correspond to relationship must appear (4). This means that the strength of currents, which create the compensating charges, there will be the greater, the greater charge itself and the less the time of its appearance. However, with the low charge density can realize another case. With a very rapid change in the electric field the charges will not have time to occupy the places, which correspond to the complete compensation for electrical pour on, and then the fields of external charge partially will penetrate through conductor, and compensation will be not complete. Specifically, this case realizes in the case of the explosion of nuclear charge in space, since between it and earth's surface is located the ionosphere, which possesses not too high a conductivity (Fig. 4).

If charge will appear at the indicated in the figure point, thus it will gather under itself the existing in the ionosphere free charges of opposite sign for compensating those pour on, which it creates in it. However, if a total quantity of free positive chargex in the ionosphere will be less than the value of charge itself, or their displacement is insufficient in order to fall into the necessary point at the assigned moment, then their quantity will not be sufficient for the complete compensation pour on the appearing charge and its fields will penetrate through the ionosphere. In this case the penetrated fields, in view of the screening effect of the ionosphere, can be less than the field above it. In this case maximum compensation pour on it will occur in the region, situated directly under the charge. This process will make the dependence of electrical pour on from the distance by smoother, that also is observed during the experiment. Entire this picture can be described only qualitatively, because are accurately known neither thickness of the ionosphere nor degree of its ionization on the height. But even if are known these parameters, then bulky numerical calculations are necessary for the solution of problem.

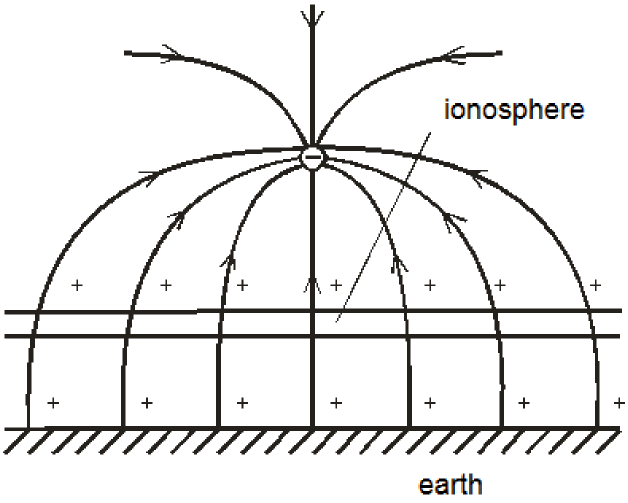

Fig. 4. Negative charge above the earth's surface with the presence of the ionosphere.

The sphericity of the ionosphere also superimposes its special features on the process of the appearance of the compensating surface charges. This process is depicted in Fig. 5.

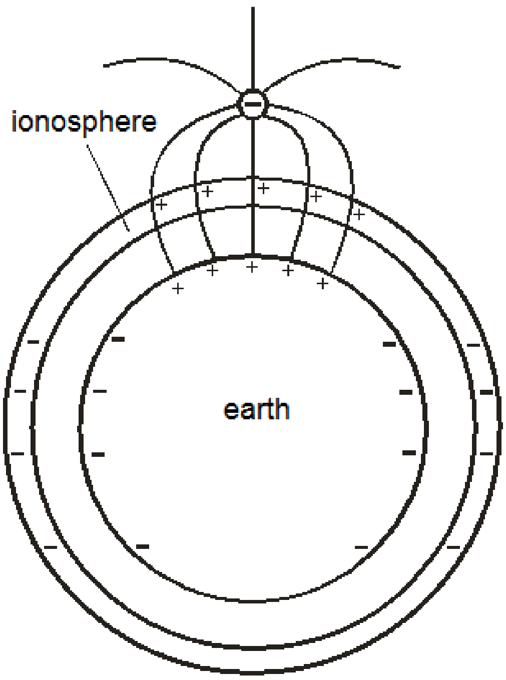

Fig. 5. Negative charge above the earth's surface with the presence of the ionosphere.

The tendency of the emergent charge to gather under itself the compensating charges will lead to the longitudinal polarization of the substantial part of the ionosphere. The compensating positive chargex in the ionosphere will in essence appear directly in the epicentre, where they will be in the surplus, while beyond the line-of-sight ranges in the surplus will be negative charges. And entire system charge - the ionosphere - the earth will obtain additional dipole moment.

the model examined speaks, that nuclear explosion will lead not only to the appearance OF [IEP] in the zone of straight visibility, but also to the global ionospheric disturbance. Certainly, electric fields in space in the environments of the explosion, where there is no screening effect of the ionosphere, have high values and present large danger to the automatic spacecraft.

In accordance with relationship (4) the pulse amplitude is proportional to the temperature of plasma, therefore, according to the graph, depicted in Fig. 2, it is possible to judge the knocking processes of nuclear charge and the subsequent cooling of the cloud of explosion. From the figure one can see that two peaks are visible in the initial section of the dependence of the amplitude of electric field. The first peak presents nuclear blast, which ignites thermonuclear charge, the second peak presents the knocking process of thermonuclear fuel. The rapid decrease, which characterizes the process of cooling cluster, further goes. It is evident that it occurs very rapidly. Naturally to assume that this is that period, when basic energy losses are connected with the radiant losses caused by the rigid X-radiation.

Thus, the presence of the pulse indicated they are the properties of explosion itself, but not second phenomenon.

Now should be made one observation apropos of term itself the electromagnetic pulse (EMP), utilized in the literary sources. From this name should be excluded the word magnetic, since. this process presents the propagation only of radial electrical pour on, and in this case magnetic fields be absent. It is known that the amplitude of the electric field of pulse can reach values ~50000

V/m. But if pulse was actually electromagnetic, then the tension of magnetic field would compose ~ 1.3×10^2 A/m (for obtaining this value should be the tension of electric field divided into the wave drag of free space), and its power would be ~5 MW, which is commensurate with the power of small power station.

It is another matter that electric fields can direct currents in the conducting environments, and these currents will generate magnetic fields, but this already second phenomenon.

Since the tension of electrical pour on near the nuclear explosion it is great it can reach the values of the breakdown tension of air (300000 V/m), with the explosions, achieved in immediate proximity from the earth's surface, this can lead to the formation of lightning, that also is observed in practice.

Let us note that the concept of the scalar- vector potential of thus far general acknowledgement did not obtain, but the fact that it satisfactorily explains the phenomenon examined, increases chances by its acknowledgement. One cannot fail to note that this concept explains also the electrization of the superconductive windings and tori during the introduction in them of direct currents [5,8], other theories cannot explain what.

Electric pulse of the explosion of trotyl charge

Of if the principle of the formation of electric pulse examined is accurate, then the usual explosions, with which is formed cold plasma, they must be accompanied by the appearance of electric pulse, although less intensive than with the nuclear explosion.

The disintegration of the molecule of trotyl with its detonation occurs according to the following diagram:

$$C_7H_5O_6N_3 = 2H_2O + 3.5CO + 1.5N_2 .$$

If each of the molecules, that was released during explosion will be singly ionized, then upon decay the molecule of trotyl will be isolated 7 free electrons. Consequently, with the detonation of one mole of trotyl will be isolated $7N_A = 4.2\times10^{24}$ of the electrons, where N_A - Avagadro number. With the explosion of trotyl the temperature of the cloud of explosion reaches 3500K. If all molecules of disintegration obtain single ionization, then the maximum strength of field of electric pulse composed

$$E = 3.7\times10^9 \frac{1}{r^2} \text{ V/m.}$$

At a distance of 100 m of the point of impact the tension of electric field there will be the wound of 3.7×10^5 V/m. and if the degree of ionization composes only 0.01%, will be and even then obtained the strength of the field 37 V/m, which is completely sufficient for registering the pulse. The importance of this method consists in the fact that by studying the topology of pulse, it is possible to judge the knocking processes and subsequent relaxation of the cloud of explosion. Obviously, electric pulse must accompany the entry of projectile into different solid obstacles, since. in this case strong local warming-up to target with the formation of plasma occurs. Consequently, it is possible to draw the conclusion that in those places, where the plasma of any form is formed, must appear electric pulse.

In the scientific literature there are no communications about the appearance of electric pulse with the explosions of conventional explosives, but this can be connected with the fact that this question no one was investigated.

It is known that the electro-welding creates the strong radio reception disturbances, but these interferences very rapidly diminish with the distance. Micro-bursts it is possible to consider sparking in the poor contacts in the electrical networks, in the contact systems of electric transport means or the collectors of direct-current motors. But, since the amplitude of electric pulse rapidly diminishes with the distance, electric transport does not present special interferences for the radio reception.

The lightning also heat plasma to the high temperature and are created the radio reception disturbances. There is an opinion that very channel of lightning serves as the antenna, which radiates the radio waves over a wide range of frequencies. But so whether this? With that length, which represents the track of lightning, this antenna must have excellent characteristics and reliably emit not only in the short-wave, but also in the long-wave radio-frequency band. But this would mean that with any lightning stroke in any place of the terrestial globe in our receivers the interferences would appear. But since they second-by-second in the world beat hundreds of lightning, entire ether would be oppressed by interferences. This it does not occur for that reason, that the plasma cylinder of lightning emits not radio waves, but electric pulses from all its sections. In this case the excess charges, which arose in different sections of the channel of lightning, see their mirror reflection under the earth's surface, forming the appropriate dipoles, whose fields diminish inversely proportional to the cube of distance.

Is that which is written in this paragraph, thus far only theoretical prerequisites. But if they will be confirmed experimentally, then will be not only just once confirmed the viability of the concept of scalar- vector potential, but also will be opened way for developing the new procedures of a study of the processes, proceeding with different explosions.

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