The Model of Self-generated Seismoelectromagnetic Oscillations of the LAI System

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Abstract

Very low frequency (VLF) electromagnetic radiation (in diapason 1 kHz – 1MHz) in the atmosphere, generated during an earthquake preparation period, may be connected with the linear size characterizing the expected earthquake focus. In order to argue this hypothesis a very simple quasi-electrostatic model is used: the local VLF radiation may represent the self-generated (own) electromagnetic oscillations of interactive seismoactive segments of the lithosphere-atmosphere system. This model qualitatively explains the well-known precursor effects of earthquakes. In addition, using this model after diagnosing existed data makes it principally possible to forecast an expected earthquake with certain precision.

As a physical basis of the working hypothesis is atmospheric effect of polarization charges occurred in surface layer of the Earth, it is possible to test the below constructed model in the Earth's crust, where the reason of polarization charge generation may be different from piezoelectric mechanism, e.g. some other mechanism.

I. Introduction

In a solid medium some considerable accumulation of polarization charge may take place in such an environment where heterogeneity having definite scale lines, is already formed or is being formed. Geological medium is not homogeneous. Progressive increase of tectonic stress is accompanied by formation of inhomogeneous structural sources or by qualitative changes of the medium. It is known that at the final stage of an earthquake preparation some chaotically moving microfractures may be formed as a one-direction main fault. It is possible that maximum electropolarization effect which manifests itself at various times prior to the earthquake, due to structural peculiarities of geological medium, corresponds to this very moment. Polarization effect is often accompanied by electromagnetic radiation. It formally means that besides electrostatic effect which forms capacity, polarization is also accompanied by induction effect. But, while analyzing possibility of induction interaction in lithosphere-atmosphere system it should be taken into account that there are many possibilities of induction effect development. Supposedly, the source of this effect is always lithosphere in connection with seismic phenomena. It is schematically possible that there are certain type electromagnetic circuit (contour) elements connected with the lithosphere, as well as atmosphere. In particular, the fact that the upper limit of VLF (recorded before an earthquake) is of MHz order it may indicate to the minimum size of the Earth heterogeneity cluster which is able to cause electric induction effect in the atmosphere (TakeoYoshino, 1991; Molchanov et al., 1993; Hayakawa et al., 2002). As to ULF diapason, it seems that it is caused by magnetic field perturbations the reason of which may be inside of the Earth as well as current processes in the conductive atmosphere (Bleier, et al., 2009). Though there exists another version according to which the electric oscillations frequency variation in the ionosphere is not necessarily connected with seismic phenomena only. It means that the induction source may be in the atmosphere, but the impact - in the lithosphere. The especially original example of this version is the model of inductive prolongation of the ionosphere SQ current system in the upper lithosphere (Duma et al., 2003).

As we below consider electromagnetic oscillations generated in separate segments of the lithosphere-atmosphere system in quasi-electrostatic approximation, it is possible to operate only with atmospheric electric field without taking into account the atmospheric current. This makes easier to solve the problem of mathematical modeling as it is simple in electrostatic approximation to connect polarization charges with the atmospheric electric field that is broken at the atmosphere-lithosphere boundary. Therefore, the quasi-electrostatic model does not require presentation of the mechanism of electric conduction change in the atmosphere, in particular, assumption of radon emission from the lithosphere to the atmosphere. It is noteworthy that from the point of view of determining the atmospheric current variation mechanism in seismoactive regions, the consideration of this effect does not lead to any universal result which would be equally true for regions with different geological structure. In particular, modification of so called “Frenkel’s model” (Liperovsky et al., 2008) of the atmospheric capacitor (based on radon emission), in opinion of the authors, may be effective only for the Far East region and partially for the Middle Asia region. Though, according to the works (Mikhailov et al., 2004; Smirnov, 2005; Smirnov, 2008) the mechanism of electric conduction variation of the atmosphere is vague even for the Kamchatka region where volcanic earthquakes are especially frequent and the emanation effect of radon is much more probable here than in regions with geological structures different from the Far East, e.g. the Caucasus. Consequently, it is logical to assume that (except special cases) the change of vertical electric current intensity in the atmosphere is chiefly connected with the change of electric field stress. Therefore, a sharp change of electric conduction of the lithospheric medium prior to an earthquake and its subsequent atmospheric effect caused by emanation of charged particles or ionization of the medium may be considered as a special case (Freund, 2006). It seems that such phenomenon is very rare. Otherwise, there would have been some considerable materials quantitatively strengthening, e.g. a qualitative model of VLF radiation constructed on the principle of sharp break of electric conduction of medium (TakeoYoshino 1991).

2. Model description

It is known that during earthquake preparation period the piezo-electric effect caused by mechanical stresses is observed in rocks (Mognaschi, 2002; Triantis et al., 2008). Generally, polarization charge is to be distributed on a certain surface that is either limited by a fault or formed along faults (TakeoYoshino 1991). As the Earth surface has conditionally negative potential with respect of the atmosphere, the segment of the lithosphere where an earthquake is prepared may be considered as negatively charged before piezo-effect. In ordinary conditions, as a rule, it is accepted that the Earth is charged negatively and the atmosphere – positively. Polarity change takes place in the period of earthquake preparation, i.e. it means that the Earth surface/atmosphere boundary is very positively charged just before earthquakes, which is proved by experiments (Bleier, et al., 2009). This very effect is considered in our model.

As the result of tectonic stress increase some heterogeneity will originate in this segment, or positive charge areas which, like “Frenkel’s generator”, will cause inductive polarization at certain height of the atmosphere. According to the model, in the focal area of the expected earthquake, at the final stage of its preparation, against the background of numerous fractures, a main fault of definite linear size is being formed. Thus, it may be represented as a linear wire the length of which considerably exceeds the characteristic size of its section. A conductor of the same size but with the opposite polarity is to occur in the atmosphere by induction. It is obvious that such a model is inverse, or it may be assumed that the initial conductor is in the atmosphere and the secondary i.e. the induced one – in the lithosphere. Operation of the linear conductors is noticeable enough as the atmospheric discharges (lightning) are linear phenomena and not areal. Formally, in case of two distant from each other horizontal conductors with opposite polarities in the lithosphere and the atmosphere, a structure resembling a capacitor is to be formed and possibly locked by vertical atmospheric electric field. As electromagnetic induction is the reason of generation of such spatial formation, i.e. it has certain inertia like usual oscillatory circuit, there must exist the characteristic frequency of self-generated electromagnetic oscillation of this system. Tompson's formula obtains the main frequency. The existance of its overtones which take place in practice must not be excluded. The spectrum of overtones depends on the linear sizes of the resonance area.

Thus, the using physical analogy with linear conductors while explaining the mechanism of VLF atmospheric electromagnetic radiation connected with seismic activity is quite logical. Such analogy does not considerably distort quantitative results, e.g. due to disregarding areal effect in model condenser capacity. In addition, the general picture is not to change qualitatively even when in a seismically active region a system formed by several electromagnetic circuits instead of one, is considered.

Usually, the system capacity C is concentrated in the capacitor, and the inductance L – in the coil in the electromagnetic oscillatory circuit. In such a circuit the capacity and inductance of the connecting wires as well as the coil capacity, are disregarded. When electromagnetic dissipation is disregarded the main self-generated oscillation frequency of the circuit is defined by the well-known Tompson's formula

$$\omega^2 = \frac{1}{L \cdot C} \qquad (1)$$

which is more precise when capacity outside the condenser and inductance outside the coil are less. It is obvious that the self-generated (characterizing) frequency of the oscillatory circuit increases when capacity and inductance decrease. In this case the capacity and inductance of connecting wires become considerable. Therefore, at very high frequencies there is no necessity of a condenser and a coil as the inter-self-generated capacity and the inductance of the connected wires (linear conductor) is absolutely sufficient for the generation of oscillations (Fig. 1). At the same time, it is not necessary that virtual wires were tied strictly in the circuit frame. It means, the circuit is transformable and may be presented in an open state. The main thing is the existence of the locking mechanism of wires the function of which is performed by the components of the atmospheric electric field in the given model. From the viewpoint of physical analogy, this means that if we charge two conductors with similar charges but opposite signs and then lock them some current and connected with it magnetic field will appear in the system. As conductors have inductance the electromotive force of induction will also occur, i.e. a circuit with all parameters is formed in which electromagnetic oscillations are generated.

Thus, presented model qualitatively explains the generation mechanism of very low frequency electromagnetic waves in previous periods of an earthquake and indicates to the source of disturbance of the atmospheric vertical electric field. As this field has the function of circuit locking we should envisage that it is disturbed by oscillation frequency of the circuit as well as according to characterizing time of ohmic damping. As for ULF, the oscillations in this diapason are the pulsations of the magnetic field and the most probable reason of their generation is the sharp changing of the electric conductivity of the upper atmosphere the cause of which may be, for instance, radon emanation (Bleier, 2009).

Thus, the disturbance of the atmospheric electric field must have high and low frequency components. At the same time, in spite of disregard of ohmic resistance effect in the circuit, due to electromagnetic radiation, there undoubtedly is some energy loss the intensity and propagation direction of which depends on the form and spatial size of the circuit.

3. Theoretical basis of the model

Let us admit that the length of horizontal, opposite polarity conductors is l, the characteristic quantity of the conductor section is a, the distance between the conductors is h. It is known that when $h>>a$ the inter-capacity of conductors is:

$$C \approx \frac{\pi\varepsilon_0}{\ln\left(\frac{h}{a}\right)} l$$

and mutual induction of conductors $L \approx \frac{\mu_0}{\pi}\ln\left(\frac{h}{a}\right) l$ (it is assumed that relative electric and magnetic constants $\varepsilon' = \mu' = 1$).

Postulation of the very same section is not strict limitation because if the wires have different a and b sections we receive (Landau, et al., 1957):

$$L \sim \ln\frac{h^2}{ab}$$

Thus, because the product of absolute dielectric and magnetic constants is $\varepsilon_0\mu_0 = \frac{1}{c^2}$, according to the (1) formula of the self-generated electromagnetic oscillations of the circuit we have

$$\omega = \left(\varepsilon_0\mu_0 l^2\right)^{-\frac{1}{2}} = \frac{c}{l} \qquad (2)$$

where c is the light velocity, and the product of the absolute dielectric and magnetic constants

$$\varepsilon_0 \mu_0 = \frac{1}{c^2} \qquad (3)$$

Let us assume that l changes in (1-100) km interval that corresponds to the characteristic size of the fault length in the earthquake focus.

According to the Eq. (1) the diapason of the self-generated electromagnetic oscillation frequency change of the analogous circuit is ω=3 (10^3 - 10^5) Hz. It is obvious that there is the quantitative agreement with the frequently recorded very low frequency atmospheric electromagnetic radiation spectrum during earthquake preparation period (Kachakhidze et.al., 2010).

As for atmospheric electric field which is the lock of polarized lines, certain freedom of circuit form exists here: if the locking is vertical, then according to our result, the height does not matter (Fig.1). In case of an open circuit, the locking mechanism is presented by the horizontal component of the atmospheric field, and the conductor length may exceed the considerable linear sizes of the polarization area depending on inhomogeneity scale of the atmosphere. In case of horizontal circuit the positively polarized conductor may be coupled with the opposite sign conductor having any length. Such topology of the circuit is quite handy if we take into consideration that electromagnetic precursors of earthquakes often appear quite far from the epicenters of main shocks (Tramutoli et al., 2001; Kachakhidze et al., 2003; Dunajecka et al., 2005; Tramutoli et al., 2005; Pulinets et al., 2006; Pulinets et al., 2007; Liperovsky et al., 2008).

Thus, under the assumption, polarization of deep fault density and changing of free charges caused by polarization is the reason of creation of the linear-wire-like charged structure near the Earth surface.

For qualitative modeling of this effect we use approximation of the plane electromagnetic layer. For this goal we profile the Earth by a vertical XOZ positive semi-plane. Z axis is directed vertically upwards, X – horizontally along the fault. z=0 corresponds to the accumulation level of the polarization charges and z=h_0 – level of the linear wire. We have a general equation

$$div\, \vec{j} = -\frac{\partial}{\partial t}\rho \qquad (4)$$

where $\vec{j}$ is the density of the current, ρ - the density of the free charges corrected by permittivity.

The equation (4) is true everywhere including the points of the current source. It is known that if not taken into account the polarization effect and the vector-potential changing of the magnetic field a homogeneous equation relevant to the Eq.(4) is true, and it is transformed into equation of electric potential by Ohm's law

$$\vec{j} = \sigma\vec{E} = -\sigma grad\varphi \qquad (5)$$

where φ is the electric potential, $\vec{E}$ - the tension of the electric field, σ - the specific electric conductivity. Thus, from the Eq. (4) by using Eq. (5) we receive

$$div(\sigma grad\varphi) = \frac{\partial\rho}{\partial t} \qquad (6)$$

Modeling of the character of electric conductivity changing is necessary in order to analytically solve the Eq. (6). For this purpose $\sigma = \sigma_0 e^{-kz}$ is a handy relation (where k and σ_0 are constants). For instance, in order to present a geo-electric effect caused by deep thermal source a solution of homogeneous equation relevant to the Eq. (6) is received by using this model type [Wait, 1982]. Thus, according to the Eq. (6) we have the following equation:

$$\frac{\partial^2\varphi}{\partial x^2} + \frac{\partial^2\varphi}{\partial z^2} - k\frac{\partial\varphi}{\partial z} = \sigma_0^{-1} e^{kz}\frac{\partial\rho}{\partial t} \qquad (7)$$

From the Eq. (7) the modeling picture of the electric potential distribution in the vertical electropermeance layer may be determined by the method which was used for vertical profile of the Earth's atmosphere [Khantadze,1973]. For this purpose we use a simple profile which is equipotential by horizontal direction

$$\varphi(z) = \varphi_\infty\left(1 - e^{-nz}\right) \qquad (8)$$

where φ_∞ is the atmosphere potential far away from the vertical electropermeance layer, n - the unknown number. According to the Eq. (8), $\varphi(0) = 0$ and there is only one component of electric field tension

$$E_Z = -\frac{\partial\varphi}{\partial z} = -E_{0z}e^{-nz} \qquad (9)$$

where $E_{0z} = n\varphi_\infty$ is characteristic value of the electric field tension.

The character of the free charge density changing depended on the polarization effect is presented by the following model:

$$\rho = \rho_0 e^{-\frac{t}{t_0}} e^{-(k+n)z} \qquad (10)$$

here ρ_0 is the characteristic value, t_0 – the characteristic time of the charge change.

By using the (8) and (10) expressions, from the Eq. (7) we receive a characteristic equation for n

$$n^2 + kn - a = 0, \qquad (11)$$

where
$$a = -\rho_0 t_0^{-1} e^{-\frac{t}{t_0}} \sigma_0^{-1} \varphi_\infty^{-1} \qquad (12)$$

In order to simplify the (12) expression we assume that $t = 0$ and use the Eq. (4) to which the below cited characteristic equation corresponds

$$\frac{j_{oz}}{h_0} = \frac{\sigma_0 E_{oz}}{h_0} = -\frac{\rho_0}{t_0} \qquad (13)$$

where j_{oz} is the characteristic value of the electric current density. As $\varphi_\infty = n^{-1} E_{oz}$ by using the Eq. (13) we receive $a = h_0^{-1} n$ (the sign of E_{oz} has no principal meaning for qualitative estimation).

Thus, if we assume that $n = h_0^{-1}$ and put the sign "+" (according to physical viewpoints) before the discriminant of the Eq. (11) we will have

$$n = -\frac{k}{2} + \sqrt{\frac{k^2}{4} + h_0^{-2}} \qquad (14)$$

In particular, in case $k = h_0^{-1}$ the characteristic parameter of vertical changing of the electric potential $n \approx 0{,}6 \cdot h_0^{-1}$. When $t \neq 0$ the second member under the root in the Eq. (14) is corrected by the numerical factor $e^{-\frac{t}{t_0}}$ which causes the decrease of n. By above described way it is possible to model such a vertical layer, the quasi equipotentiality of which, different from the relevant layer of the Eq. (8) profile, is destructed in all directions. For instance, we may use the following expressions:

$$\varphi = E_0 \left(x - l_0 e^{-nz} \cos mx \right) \qquad (15)$$

$$\rho = \rho_0 e^{-\frac{t}{t_0}} e^{-(k+n)z} \cos mx \qquad (16)$$

where E_0 is the characteristic value of the electric field tension.

As a result of the Eq. (16) we have two components of the electric field tension

$$E_x = -\frac{\partial \varphi}{\partial x} = -E_0 \left(m l_0 e^{-nz} \sin mx + 1 \right) \qquad (17)$$

$$E_z = -\frac{\partial \varphi}{\partial z} = -E_0 l_0 n e^{-nz} \cos mx \qquad (18)$$

where l_0 is the linear scale of horizontal heterogeneity of charge density, m –a wave number.

According to the equations (17) and (18) it seems that if $m = l_0^{-1}$ and $n < m$, the maximal value of the first member of E_x always exceeds the maximal meaning of E_z. Taking into account this fact, in case of $t = 0$ and in addition to it if we assume that the fault length $l \approx h_0$, like the characteristic Eq. (13) we will have

$$\frac{\sigma_0 E_0}{l} \approx \frac{\rho_0}{t_0}\cos\frac{x}{l_0} \qquad (19)$$

Taking into account the Eq. (19), putting the (15) and (16) expressions in the Eq. (4) and solving the characteristic equation we receive:

$$n = -\frac{k}{2} + \sqrt{\frac{k^2}{4} + l_0^{-2} + l_0^{-1} h_0^{-1}} \qquad (20)$$

Thus, we may conclude that in the limit of the vertical electromagnetic layer model, in the proximity of exponential changing of electric conductivity, the change of the electric parameters of the virtual linear conductor supposed near the Earth surface, depends only on the linear parameters of the polarized layer and its generation level.

Thus, the (14) and (20) expressions are relevant to the arising moment of the polarization. But, according to the Eq.(10), for the completeness of the presented model, it is necessary to take into consideration the factor $e^{-\frac{t}{t_0}}$ which consists of the characteristic time t_0. For example, the same parameter figures in the model expression of the density change of the surface polarization charge generated as a result of the piezoelectric effect in an earthquake focus. This equation is given in the work [Ikeya et al., 1997]:

$$q(t) = \alpha \Delta\Sigma \left[\left(\frac{\varepsilon\eta}{\tau - \varepsilon\eta} \right) \left(e^{-\frac{t}{\tau}} - e^{-\frac{t}{\varepsilon\eta}} \right) \right] \qquad (21)$$

where α is the piezoelectric coefficient, $\Delta\Sigma$ - the stress drop in the earthquake focus caused by displacement, η - the specific resistance of the medium, τ - the characteristic time of displacement, $\varepsilon\eta$ - the characteristic time of the charge density pulsation, $\varepsilon = \varepsilon' \varepsilon_0$.

Theoretically, any characteristic time in the Eq. (21) is relevant to the (10) expression. It is obvious, that due to the solid and electric features of the medium, in case $\varepsilon\eta$ and τ are incommensurable parameters, then it is correct to use the larger one out of the two.

4. Discussion

The considered model and formula (2) make us able to discuss the process of earthquake preparation, its occurrence time and phenomena related with it not only qualitatively but quantitatively with certain accuracy. We have possibility to reliably answer the following questions:

I. What does the certain sequences of MHz and KHz frequencies mean in the spectrum of emission?

We created a pretty simple electrodynamic model of VLF emission. By this model the electric dipoles originated on the cracks surfaces finally set on the main fault during the process when the cracks join and form a fault. By the time some separate cracks may act as termoionized canals with different electric conductivity.

It is possible that the total length of the canal with high electric conductivity (the fault length by geological point of view), is related with the VLF electromagnetic emission according to the (2) formula. It may lead to purposeful monitoring in order to keep an eye on origination of the main fault and process of its length change.

Particularly, in case of having electromagnetic emission to the extent of 1 MHz the characteristic length of the fault is not more than 300 m (according to linear relation in the formula (2); As electromagnetic emission appears in KHz – the length of the fault begins to increase, e.g., in case of 10^5 Hz – the length l is already equal to 3 km.

Thus, it is obvious what causes so often observed sequences of the MHz and KHz frequencies in the electromagnetic emission spectrum. It may mean that during earthquakes preparing period, before origination of the main fault there are plenty of cracks to which electromagnetic emission with characteristic MHz frequencies correspond, and as the cracks begin to join in the main fault a range of KHz frequencies appear in the electromagnetic spectrum. It is natural that such opinion is not unique as the source of generation of the same diapason of VLF may be another electromagnetic phenomena which develop in the upper atmosphere and ionosphere. Their distinction is possible only by means of reliable morphological analyses of data.

II. Estimation of the fault length in the focus and the intensity of the expected earthquake.

The formula (2) supposes one-digit relation between ω and l. It is clear that linear relation (idealized by model imagination) between these values must be distorted in the real medium. Changing of the distortion coefficient must be estimated by means of analysis of the experimental data. It is expected that the distortion coefficient has different meaning for the fixed value of ω (in the limits of certain errors) in different regions, i.e. in different geological media.

Thus, in a real medium the formula (2) is expressed as follows:

$$\omega = \beta \frac{c}{l} \qquad (22)$$

as $\beta(\omega)$ is the coefficient depended on the frequency and geological characteristics of the medium, it must be determined independently for any seismoactive region or local segment.

By means of the formula (22), for a concrete ω or for the central frequency (in case of having a bunch of frequencies) we may estimate the intensity of the expected earthquake with certain accuracy. In such a case it is obligatory to know the empiric relations between earthquake magnitude and fault length for separate regions.

III. The change in the atmospheric electric field as an earthquake precursor.

According to the model some locking mechanism of virtual wires must exist. The components of the atmospheric electric field may function as such mechanism.

According to the experimental data, in many cases, change in the atmospheric electric field obtains anomalous character for several days or hours prior to an earthquake occurrence. Particularly, the character of changes in the atmospheric electric field potential gradients that had appeared before the $M \geq 4.5$ earthquakes of the Caucasus (132 events) was studied. In order to reveal the precursor effect a strict method of "filtration" was carried out, which excludes all possible influences capable to change this parameter. Anomalous changing of potential gradient of the atmospheric electric field takes place during a period of 10 days to several hours prior to an earthquake occurrence (Kachakhidze, 2000; Kachakhidze et all., 2009).

These changes were expressed in the form of outbursts. It is possible that perturbation of atmospheric electric field reaching its maximal value, appears like a reason of "vertical locking" of schematic electromagnetic contour in consequence of which the vertical components of the atmospheric electric field return to their background meanings.

The phenomenon of electromagnetic induction between the Earth and the atmosphere may reoccur as the source of perturbation like polarized fault may exist for a certain period.

There is another version as well as it is possible to imagine the contour in an open form in which the horizontal component of the atmospheric electric field functions like a “locking mechanism”. In such a case the length of the wire may significantly exceed the linear sizes of the polarization area because in case of horizontal locking the positively polarized wire may tie to a wire with any length and the opposite sign. Such a contour typology schematically coincides with the fact that the atmospheric electric precursors of earthquakes often appear quite far away from epicenters (Kachakhidze et al., 2003; Dunajecka et al., 2005; Pulinets et al., 2006; Liperovsky et al., 2008).

IV. Possibility of estimation of earthquake occurrence time

Formation of approximately same type faults with same linear scales is expected in different seismoactive regions with similar geological structure under the same tectonic stress. Supposedly, in such cases almost similar spectrum of electromagnetic emission must be generated.

Consequently, if the change character of the frequency spectrum before earthquakes occurrence is known for any region, the model will let determine the assumed time of an earthquake occurrence for a concrete event with certain accuracy. It is obvious that the precision of the β coefficient has the main significance for determining the fault length and relatively the magnitude of the expected earthquake.

Thus, the diagnostic task is created: in case of existence of retrospective data of electromagnetic emission for some geological medium there is a possibility to recheck the accuracy of earthquake occurrence time by observing the changes in electromagnetic spectrum.

V. Foreshocks. Earthquakes with certain intensities correspond to VLF electromagnetic emission with certain frequencies. It means that foreshocks are also characterized by self-generated frequency spectrum of electromagnetic emission (mainly, in the diapason of MHz).

Thus, we may conclude that in the limit of the electromagnetic circuit (contour) scheme constructed with virtual linear wires, it is principally possible to control the process of earthquake preparation and occurrence by means of monitoring the changes in the electromagnetic emission frequency spectrum.

5. Summary

This work offers the original model of the self-generated electromagnetic oscillation of the local segment of the lithosphere-atmosphere system. In the authors’ opinion the model simplifies the physical analyses of the nonlinear effect. The results of this effect are admittedly reflected in the electromagnetic picture which expresses the relation of the lithosphere-atmosphere-ionosphere system. The model in a qualitative sense explains the mechanism of VLF electromagnetic emission revealed in periods prior to earthquake occurrence and reasons of anomalous changes in the atmospheric electric field potential gradient. Besides, it corroborates the possibility of monitoring the main shock expectation by observing foreshocks. Correspondingly, the model makes it principally possible to determine the intensity of an expected earthquake, the time of its occurrence, location and linear sizes of the focus with a certain accuracy.

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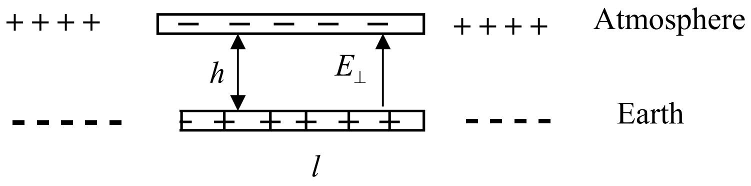

Figure 1. Analog contour