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In connection with mechanism of very low frequency electromagnetic emission generated in seismoactive zone

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Abstract

By helping of model of analogous circuit, created with virtual linear conductors, it is possible to implement monitoring of earth electromagnetic emission of earthquake preparing process by frequency spectrum control. By model it is also possible to connect telluric by nature geoelectric and geomagnetic perturbations caused by rocks polarization with self-generated electromagnetic oscillations of lithosphere-atmosphere-ionosphere system. In case of quite reliable results of observed data diagnostic analyse, it is supposed that the analogous model will be useful by point of earthquake prediction problem.

1. Introduction

There is created theoretical model in the works [11, 12] according to which very low frequency (VLF) electromagnetic emission in /1-1000/ kHz diapason, generated in earthquake focus, may be the manifestation of self-generated electromagnetic oscillations of concrete seismoactive segments of lithosphere-atmosphere-ionosphere system. Such imagination is quite handy although its justice needs empirically to confirm theoretical relation forecasted by model. In order to it is obligatory multilateral diagnostic analyse of VLF emission fixed before earthquake. First of all existence of morphological relation between characteristic linear size of earthquake focus (main fault length) and main (lowest) frequency of VLF emission must be proved. In case of existence of such relation, it must be real perspective of using of VLF emission towards prediction problem of magnitude and time of incoming earthquake occurring.

2. Physical mechanism of earth VLF electromagnetic emission

Because of practical goals, first of all the task of physical mechanism of VLF emission must be realized, the problem of unambiguity of which is actual up to these days. The noted theoretical model is based on electric polarization effect of tense rocks. It is considered that piezo-electric effect, caused by mechanical tension, takes place in rocks in the period of earthquake preparing [14, 19]. In general, charge of polarization must be distributed on some surface which must be enclosed by fault or formed along fractures [18]. It is accepted that geological medium is more or less uniformly tense and homogeneous. Origination and multiplication of heterogeneous structures take place with dynamic process intensification. The one result of this process is joining of micro-cracks, originated chaotic, into main fault with certain direction in the last stage of earthquake preparing. It is believable that effect of polarization reveals maximally during main fault formation. We must note that it is necessary to check the mechanism of VLF emission in such natural conditions where gathering of charge

of polarization is caused by the reason different from the mechanical action on the rocks. Local geomagnetic anomaly at the Black seaside resort Ureki territory may be unique one for this task. By preliminary geophysical data, gathering of polarization charges takes place in the central area of this anomaly. This phenomenon may be connected with magneto-hydrodynamic effect developed in the process of water diffusion at the seaside zone.

Electric polarization belongs to the category of electrostatic phenomena. But if polarization charge is accompanied by electromagnetic emission, we may say that besides electrostatic effect, which creates capacity in the certain space, electromagnetic induction may be existed. It is obvious that such phenomena must be taken into account during analyse of electromagnetic relations inside lithosphere-atmosphere-ionosphere system. Formally, there are various variants of developing of induction effect however towards seismic phenomena we may accept that lithosphere always is the source of induction effect. Because of it, taking into account physical analogy from the theory of electromagnetic oscillations, we may imagine that we touch with natural electromagnetic circuit, component elements of which are connected with lithosphere as atmosphere (ionosphere) as well. [7,8,15,16]. The fact that the upper limit of VLF frequency detected before earthquake is in MHz bounds, may point out minimal size of cluster of earth heterogeneity which may cause notable effect of induction in the atmosphere [6,7,8,15]. It is considerable that there is alternative variant according to which VLF emission's connection with seismic phenomena is not obligatory one. Primary source of electromagnetic induction may be in magnetosphere or in ionosphere, but secondary or response, in lithosphere. For example, such alternative is base of prolongation model of ionospheric SQ-current system in the upper layer of inductive lithosphere [3]. Besides, it is known that cosmic VLF electromagnetic emission is continuously observed in the high latitudes of magnetosphere. In the auroral oval it is conditioned by direct invasion of charged particles of solar wind into polar ionosphere which is implemented from polar cusps with vortex form. VLF emission is observed pretty seldom in the middle and low latitudes in ionosphere level as in earth surface as well in comparison with high latitudes. In spite of it is obvious that earth VLF electromagnetic emission must be reliable separated from the same frequency diapason emission of magnetospheric origination but caused by another mechanism in the middle and low latitudes or especially seismically active latitudinal belt. Such separation is especially simple during disturbed solar wind when the sharp changing of energetic spectrum of captured plasma takes place in the inner structures of magnetosphere. Precondition of generation of megnetospheric VLF electromagnetic emission in the middle latitudes is, in inner magnetic plasma energetic spectrum, increasing of energetic (with $E \approx 10-30\,\text{kev}$) electron density in the main plasma reservoir of magnetosphere, in plasmosphere and its interfacial main radioactive belt, ionosphere. Such electrons with notable quantity appear here only during powerful geomagnetic perturbations, global magnetic storms.

3. Scheme of analogous circuit model

Symbolically earth surface has negative potential towards atmosphere because of it the very segment of lithosphere where the earthquake is preparing, may be accepted as negatively charged one until piezo-effect. In result of tectonic stress increasing, heterogeneity will appear in this segment or places with positive charges, which like "Frenkels generator," will cause inductive polarization in some altitude in atmosphere.

In quasi-electrostatic approximation, which is in agreement with lithosphere-atmosphere-ionosphere circuit model (with analogous conductors), it is possible to operate with large-scale atmospheric electric field as circuit closer. Such imagination especially makes easier mathematical modeling of inductive interaction inside lithosphere-atmosphere-ionosphere system. In quasi-electrostatic approximation it is natural to connect polarization charges with atmospheric electric field. Because of it is not necessary to take into account factor of atmospheric electric conductivity and to imagine its mechanism of changing, for instance, to accept radon emission from lithosphere to atmosphere. It makes easier the picture in

seismoactive regions where radon atmospheric effect is not accompanied by one-valued result which would be equally just for regions with different geological structures.

Exactly, this is the essential demerit of atmospheric condenser which is based on radon emission or the substantial demerit of "Frenkel models" last modification [13].

So, we accept that in the incoming earthquake focus, with multitude cracks background, at the last stage, the main fault creates which may be identified with linear conductors. The conductor, with the same length but with opposite polarity, must be created by induction in the atmosphere. It is obvious that this model is universal because formally it is acceptable that primary conductor is created in the atmosphere but secondary – in lithosphere. To operate with linear conductors is pretty obvious because if there are two distant horizontal conductors with inter opposite polarity in lithosphere and in atmosphere, the electric interaction is possible between them. Namely, it may be created the structure like condenser which will be locked by vertical atmospheric field (Fig. 1a).

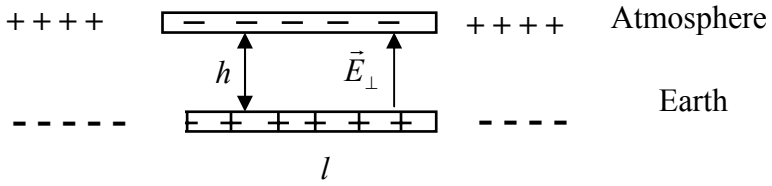

Fig 1 a. The first variant of analogous circuit.

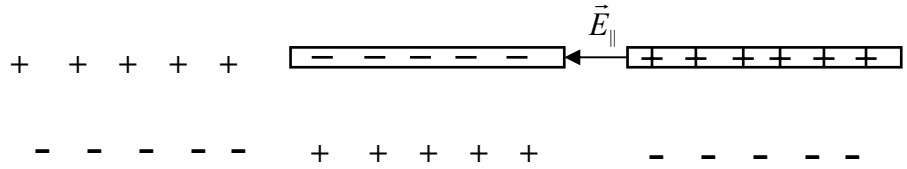

Fig 1 b. The second variant of analogous circuit.

Like ordinary circuit of oscillation, atmospheric circuit will have certain inertia which is the pre-condition of generation of self-generated electromagnetic oscillations. By physical point inertia means that if we charge two conductors with opposite but the same charges and lock it, the current and magnetic field connected with it will appear in this system. Because the conductors have inductance the electromotive force of induction will be appeared also or will be created circuit and generation of electromagnetic oscillations will occur. The qualitative changing of this picture must not be happened even in case when the system comprised by several electromagnetic circuits may be created in the seismic active area. For instance, we may imagine that the line of polarization of generator rocks of primary circuit, directed along deep faults, is the one of them conductor. The conductor along the earth surface is parallel to it but the circuit is locked by orthogonal electric field. By this imagination secondary circuit is inductive response in the atmosphere of primary circuit. In any cases it is possible to generate of self-generated electromagnetic oscillations the mechanism of which is just for any quantity of circuits. For justice, it is pretty enough to remember that usually, in electromagnetic oscillatory circuit the system capacity C is concentrated in capacitor, and inductance L – in the coil. In such circuit capacity and inductance of connecting conductors, as well as capacity of the coil, are disregarded. When electromagnetic dissipation is disregarded, circuit's self-generated oscillations frequency is defined by well-known Tompson's formula

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

where L is a coil inductance, C is a condenser capacity. Formula (1) is more precise as capacity outside the condenser and inductance outside the coil are the lesser. Besides, the oscillatory circuit's own (characterizing) frequency increases with capacity and inductance decreasing. But in this case capacity and inductance of connecting conductors become considerable. Formula (1) is correct also in case when circuit is not isolated and is close to other conductors. In such case it is possible changing of circuit inductance as capacity as well. It means that influenced polarization will be created but self induction effect caused by neighbouring current circuit (circuits) may be added to inter- induction effect. .Such influence will be especially well revealed in case when the first circuit is electrical neutral (condenser is not charged) but current flows in second one. Inter induction may be notable in isolated circuit but in the limits of high frequencies. In such case obligation for being of condenser and coil in order for arising of electromagnetic oscillations in circuit will not be at all because inter capacity and inductance of connected conductors (linear conductors) will be enough for generation of oscillations. In case of induction it is not necessary that connected conductors were tied in circuit frame. It means that the circuit may be presented in open state which factual will create atmospheric (ionospheric) electromagnetic antenna (Fig. 1b).

The main thing is existence of locking mechanism of circuit with virtual conductors in any cases. Such function in atmosphere will be presented by atmospheric electric field but in depth of earth – telluric electric field.

So, presented model quantitatively explains mechanism of generation of very low frequency electromagnetic waves in the periods before earthquakes and points out the source of perturbation of atmospheric vertical electric field. Because this field carries out circuit locking function, we must take into account that its perturbation must be occurred by circuit oscillation frequency as by characteristic time of ohmic attenuation as well. At the same time, in spite of neglecting of ohmic resistance effect directly in circuit, no doubt that it will be losing of energy because of electromagnetic emission, intensity and direction of spreading of which will be depended on circuit geometry and linear sizes.

4. Analytic shape of the model

Let's say that the length of parallel, opposite polarity conductors is l, characteristic size of section is a, distance between conductors is h. It is assumed that relative electric and magnetic constants for air $\varepsilon = \mu = 1$ (we use SI – system). It is known that inter capacity of conductors, when $h >> a,$ is:

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

but inter induction of conductors:

$$L \approx \frac{\mu_0}{\pi} ln\left(\frac{h}{a}\right) l .$$

So, we will have expression for self-generated oscillations frequency of electromagnetic circuit from formula (1):

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

where c is velocity of light, but the result of multiplying of absolute dielectric and magnetic constants

$$\varepsilon_0 \mu_0 = \frac{1}{c^2}$$

Let's assume that interval of changing of main fault length l in the earthquake focus is (1-100) km. From formula (2) we'll receive that change diapason of analogous circuit's self-generated electromagnetic oscillation frequency is ω=3 (10^3 - 10^5) Hz. As a rule, frequency of generated electromagnetic VLF emission in earthquake focus changes in diapason 1kHz – 1MHz. So it is obvious quantitative agreement with characteristic values of lowest (main) frequency of very low frequency atmospheric electromagnetic emission fixed before earthquake.

By the model there is certain freeness in circuit geometry: if the circuit is locked its chain will be tied by vertical component of atmospheric electric field. In case of open circuit it will be induced additional conductor conditioned by horizontal component of atmospheric electric field.

In this case the length of additional conductor may significantly outnumber the length of the main conductor and this one will be depended on linear scale of atmosphere heterogeneity (Fig. 1b).

Such geometry of analogous circuit may be handy in case when VLF emission reveals in earthquake focus as in distances far away from epicenter as well [9,13,14, 17].

In order to manifest adequacy of analogous circuit model with experimental data let's consider some examples (L'Aquila, China, Haiti earthquakes).

Formula (2) is for ideal case. In reality must be nonlinear connection

$$l = \beta \frac{c}{\omega} \ , \qquad (3)$$

β is caused by geological behaviors of region and electric properties of medium. We use (3) formula for some retro-analyse in case, when coefficient $\beta = 1$.

1) Wenchuan earthquake (May 12, 2008, M 8.0, depth $\approx$19 km., 31.021N, 103.367E). According to formula (3) EM emission main frequency before considered earthquake was 1.024 kHz which corresponds to the length of fault in earthquake focus $l \approx 300$ km.

Our goal is to calculate theoretical magnitude in order to what we use Ulomov's formula for earthquakes with $M \succ 5.0$ [21]

$$\lg l = 0{,}6\, M - 2{,}5\,, \qquad (4)$$

according to which $M \approx 8{,}1$, which is practically in a good agreement with the real magnitude of earthquake [22].

2) L'Aquila earthquake (6 April 2009, M 6.3, depth $\approx$10 km, 42.35N, 13.38E). For this earthquake $l \cong 15$ km [2].

The main EM emission frequency before earthquake was 20, 27 kHz. Formula (3) gives the same meaning for this fixed frequency. It is interesting that we got the same l by Ulomov's formula.

3) Haiti earthquake (12 January 2010, M 7.0, depth$\approx$13 km, Latitude18.46, Longitude 287.47). There is no determined the fault length in focus caused by earthquake because, as it seems, the new fault overlaid the old fault.

Our model is capable of solving the reverse task. Namely, because $M = 7{,}0$ [1] from Ulomov's formula [21] $l \approx 50$ km, to which (from formula 3) corresponds $\omega \approx 6$ kHz.

It is known that in this case electromagnetic ULF waves, in frequency range (0–20 kHz), were recorded by the satellite DEMETER [1], concerning a time period of 100 days before and 50 days after this earthquake.

So, we may get 10 kHz as main characteristic frequency for which $l \approx 30$ km.5

5.Telluric effects of rocks deep polarization

Low virtual conductor is located on the earth surface by formalism of analogous circuit. But main fault in the earthquake focus along which polarized surface (conductor) creates,

is always depth. Due to it, there is the problem of an outing of earth VLF electromagnetic emission from earth depth connected with skin-effect. In paper [11] the scheme of prolongation of depth polarized conductor in direct to earth surface is given by model, which gives vertical electrical profile of earth section. In order to plot down relevant analytic electrodynamic picture it is enough to postulate only electric conductivity of medium and changing of character of polarization charge density. Let's assume that electric conductivity σ from the fault plane to earth surface decreases, ρ density of polarization charge attenuates in time and these both processes occurs by exponential law:

$$\sigma = \sigma_0 e^{-kz} \quad , \quad \rho(t) = \rho_0 e^{-t/t_0} \tag{5}$$

where $\rho(t)$ is the density of polarization charge on the fault level, ρ_0 - characteristic value, Z - vertical ccordinate, σ_0 - characteristic value of electric conductivity, k - logarithmic decrement of attenuation, t_0 - characteristic value (logarithmic decrement).

Parameter n which defines model picture of vertical distribution of electric field potential, is the searching value of the task and depends on the fault length and depth of bedding. Accordingly, it points out changings of telluric electric and magnetic fields from the fault level to earth surface.

The such simple analyse shows that virtual conductor in the earth surface qualitively is the electrodynamical reflection of polarization line created on the fault. Because of it this model, for concrete meanings of fault and medium parameters, with certain accuracy, may be used for estimation of geomagnetic characteristics (telluric) connected with electric current and characteristics of geomagnetic variations (pulsations). Principally, it is possible to determine density of polarization charge which is obligatory one for energy estimation of earth VLF emission.

So, according to [11], the mechanism of generation of electromagnetic emission must be directly connected with the effect of depth rocks polariozation in the epicentral area of incoming earthquake which must be accompanied by perturbations of telluric current and its accompanying electric and magnetic fields. Similar phenomana are fixed many times in the period before earthquakes. It is found that geoelectric variations (pulsations) caused by seismic activity are accompanied by geomagnetic variations [20]. The last ones are fixed by certain backwardness of phase which is connected with electric conductivity of medium. In general, we may say that the effect of medium magnetic viscosity appears active in earth, like space. Its value, mostly, may define frequency spectrum of geomagnetic pulsations of ionospheric origination [12]. Consequently, in spite of not having possibility to use telluric electromagnetic parametre data as earthquake indicator yet, morphological analyse of their changing may be pretty enough for seismic prediction problem.

6. Perspectives of model's practical using

Formalism of virtual conductors makes partly easier consideration of various problems in connection with earthquakes. Namely, model of analogous circuit may be used for following tasks:

1. Accumulation of surface polarization charges in near ground layer conditions existence of „displacement current" which may be accompanied by thermal effect in the epicentral area of earthquake for quantitive estimation of which it is necessary to determine relation among thermodynamical parametres of medium and electric constant [5]. It is natural that polarization charges will also influence on atmospheric electric potential gradient changing of which may be taken like one electromagnetic indicator of seismic activity [10] .

2. It is possible to connect short-periodic geomagnetic pulsations accompaning ionospheric perturbations with earth VLF emission by analogous circuit. Relaxation of polariza-

tion charges in this segment of lithosphere-atmosphere-ionosphere system in earth surface layer must cause intensification of telluric curent and generation of geomagnetic and geoelectric fields pulsations.

3. The magnitude of incoming earthquake may be deternined by empiric formula of relation between earthquake magnitude and linear sizes of focus. It is obvious that as exact will be formula of connection between length of fault in focus and magnitude, as exact will be determined magnitude of incoming earthquake.

4. After diagnostic, in case if it will be found that the main frequance of VLF electromagnetic emission is more or less the same, the model of analogous circuit let us fix the time of earthquake occurring with certain accuracy.

5. It is possible to arise several analogous circuits connected with each other in atmosphere (ionosphere) by induction and to join them with one system which may be the reason of spreading of VLF emission in the distances quite far away from earthquake epicenter, which is observed pretty often.

7. Conclusion

By using of lithosphere-atmosphere-ionosphere electromagnetic interaction model, presented in this paper, it is possible qualitatively to explaine mechanism of VLF electromagnetic emission generetad during earthquake preparing process and to connect its main (lowest) frequency with main fault length in the earthquake preparing process. In case if diagnostic analyse of experimental data confirms existence of morphological connection suggested by model, we will get VLF electromagnetic emission as electromagnetic indicator showing the stage of developing of seismic activity. Besides, by model it is principally possible to connect telluric by nature geoelectric and geomagnetic perturbations, caused by rocks polarization, with self-generated electromagnetic oscillations of certain segments of lithosphere. Using (3) formula, by VLF electromagnetic emission main frequency changing in time, in case of reliable determination of earlier main fault characteristic length in the seismic active regions with different geological structure, it will be principally possible to transform indicator model into prognostic.

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К вопросу о механизме генерации очень низко-частотного электромагнитного излучения в зоне сейсмической активности

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Резюме

При помощи модели аналогового контура, составленного из виртуальных линейных проводов, принципиально возможно осуществить мониторинг процесса подготовки землетрясения путем контроля частотного спектра земного очень низкочастотного электромагнитного излучения. Модель также позволяет связать геоэлектрические и геомагнитные возмущения теллурической природы, вызванные поляризацией пород, с собственными электромагнитными колебаниями системы Литосфера-Атмосфера-Ионосфера. В случае достаточной надежности результатов диагностического анализа данных наблюдений можно предполагать, что модель аналогового контура окажется полезной с точки зрения проблемы прогноза землетрясений.

სეისმური აქტივობის ზონაში გენერირებული მეტად დაბალი სიხშირის ელექტრომაგნიტური გამოსხივების მექანიზმთან დაკავშირებით

ზურაბ ა. კერესელიძე, ნინო კ. კაჭახიძე, მანანა კ. კაჭახიძე

რეზიუმე

ვირტუალური ხაზოვანი სადენებით შედგენილი ანალოგური კონტურის მოდელის დახმარებით პრინციპულად შესაძლებელია განხორციელდეს მიწისძვრის მომზადების პროცესის მონიტორინგი მიწისმიერი მდს ელექტრომაგნიტური გამოსხივების სიხშირული სპექტრის კონტროლის საშუალებით. მოდელის საშუალებით შესაძლებელია აგრეთვე ქანების პოლარიზაციით გამოწვეული ტელურული ბუნების გეოელექტრული და გეომაგნიტური შეშფოთებების დაკავშირება ლითოსფერო-ატმოსფერო-იონოსფერო სისტემის საკუთარ ელექტრომაგნიტურ რხევებთან. დაკვირვების მონაცემების დიაგნოსტიკური ანალიზის შედეგების საკმარისი სანდოობის შემთხვევაში სავარაუდოა, რომ ანალოგური კონტურის მოდელი სასარგებლო აღმოჩნდება მიწისძვრის პროგნოზირების პრობლემის თვალსაზრისით.