Induction of a Current by a Super High Frequency Apparatus During Motion of a Free Charge

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مُقدِّمة

تناول الموضوع الظواهر الفيزيائية لأجهزة الترددات فوق العالية وارتباطها بالشحنات المحمولة للنظم المتذبذبة وكذا التوصل إلى أن تيارات الحمل لها أسباباً أمثل لظهور التيارات الموجهة لتلك النظم وخارج دائرة الإلكترون والتي عندها تتسارع الجزيئات المشحونة .

كما تم إيضاح ظاهرة تعد ذات أهمية لأجهزة الترددات فوق العالية وهي أن نبضات التيارات التوجيهية الناتجة عن الشحنات المفرغة خارج الدائرة والمتكونة في الشريحتين (I) ، (II) ، كما تم التوصل إلى معادلة لحساب التيارات التوجيهية (الموجهة) والتي تختلف فيها السعة عن سعة تيارات الحمل بالمعامل (M) معامل تفاعل الحقل الإلكتروني مع حقل الترددات فوق العالية للفتحات ، ويختلف أيضاً من خلاله شكل التيار التوجيهي وتيار الحمل ، كما توصلنا إلى أن التيارات التوجيهية وتيارات الحمل يمكن لها أن تتطابق في حالة التيارات المستمرة (الثابتة) لأن جميع ثوابتها متساوية ، كما أظهرت التطبيقات تقارباً كبيراً .

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ABSTRACT

This study was about the physical processes that are going on in electronic super high frequency apparatuses and that are connected with motion of charge carriers in vibrating systems . The cause that stimulates the current reaches the convection current, which is induced in vibrating system and in an external circuit of the electrode, near which charged particles transit . Also it had showed a process which is very important for electronic superhigh frequency appearatuses , it is that a pulse of induced current in an external circuit of a vacuum charge, formed by to plane grids (I) , (II) . We had reached at a formula to calculate the induced current where the amplitude of the variable component differs from the cinvection current by the factor (M) which is the factor of the reaction of electronic field to the electronic superhigh frequency field for the holes .

It differs also from the shape of the induced current and the convection current . And we reached at that convection and induced currents which may be identified only in the situation of constant currents since their constant components are identical – as the applications showed great similarity .

PROPOSED WORK

Physical processes, occurring in electronic superhigh frequency apparatuses, are linked with motion of charge carrier in vibrating systems. Let us assume that free charges move under the action of voltages – constant voltage Uo and variable (alternative) (superhigh frequency) voltage $U_m \sin \omega t$. The charge transfer is a convection current [1] . Its density is equal to the product of charge density ρ by velocity v, and the value of the convection current is

$$i_k = \rho \, vS,$$

Where S is the cutest of transit-time channel with a charge density or the cutest of election beam, if an electron flow is considered.

If charged particles move in a continuous flow under the action of voltage U_O, then the convection current, penetrating through any cutest of the transit-time channel, does not change with time and is constant. When free charges interact with electromagnetic waves of resonators and slow-wave structures, then they accelerate or decelerate depending on which is the half-period (accelerating or decelerating) of the high frequency electric field they get in [2] . The process of change of the charges velocity relatively to their average velocity v_o which is determined y he constant voltage U_0 is called velocity modulation [3] .

In this case the charge velocity is represented by the sum of the constant and the variable components :

$$v = v_0 + \sin \omega t,$$

Where v_m is the amplitude of the variable component of the velocity, which is defined by the amplitude of superhigh frequency *Um.*

Convection current is also expressed as a sum of constant and variable parts : $i_k = I_0 + I_{mk}\,\omega^{t,}$

which can be derived by substitution of (2) into (1)

The convection current is the cause that stimulates the current induced in the vibrating system and in the external circuit of the electrode, near which charges, that are flying to the electrode, attract charges of the opposite sign containing in it and repulse like ones . Let us assume that the charged particles, for instance , an electron bunch , do not sink on the electrode but fly aside if . Under the action of the flying- by electron bunch in the electrode and in its external circuit free charges move , that is to say an impulse (momentum) of induced current arises, which is not connected with sediment of a charge on the electrode . After the flying-by of the electron bunch the equilibrium of free charges in restores and the induced current ceases .

Let us consider induction of current in tile external circuit of a vacuum gap that is formed by two plane grids (fig. 1,) .

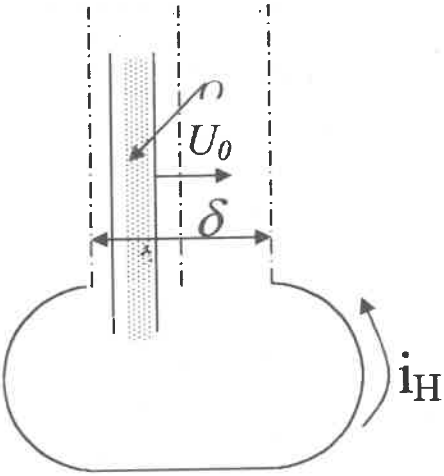


Fig –1 (A vacuum gap that is formed by two plane grids)

We consider the gap ideal, that is transparent for electrons trolls and screened from external electromagnetic field . At first let us take a gap, whose grids are short-circuited by an an external conductor, owing to which an electridc field in the gap is absent, nd hages, rought nto he gap, move within it with invariable velocity. The summarized nduced urrent n he external circuit of the plane gap of width δ , when n charges q_i are moving in it with velocity vi, according to the Shokly-Rameau formula [4] is determined by expression (4) :

$$i_k=\sum_{i=1}^{n} v_i q_i / \delta = Q v_o / \delta,$$

because $v_i = v_0 =$ const.

According to (4) the pulse of the induced current in the external circuit of the gap in question , that is penetrated by electronic layer moving with velocity v_0, is trapeziform (see fig 2,) .

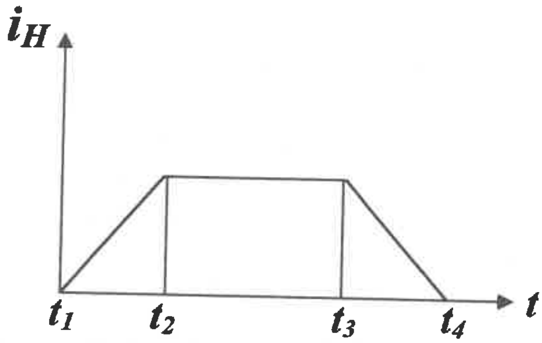


Fig – 2 (The pulse of the induced current)

In begins in the moment t_4 when the last frontier of the layer exits from the grid II. Durations of wave fronts correspond to time-intervals during which an electron layer passes through grids of the gap. During the time $t_3 - t_2$ the induced current does not vary according to the expression (4), since the charge in the gap Q and its velocity v_0 remain constant .

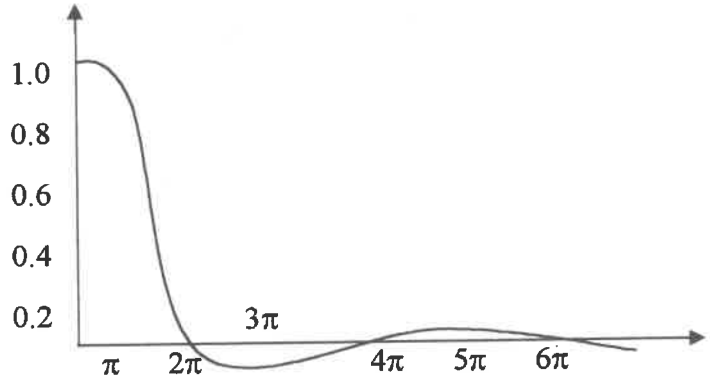
Let us imagine now that the gap is a frequency component of a superhigh frequency resonator, and a high frequency voltage $v_m \sin wt$ acts in it, and as a result the induced current acquires an alternate component : $i_H = I_o + I_{mH} \sin \omega t = I_o + MI_{mk} \sin \omega t.$

Here I_{mH} is the amplitude of the variable component of the induced current, which differs from the amplitude of the convection current by a factor *M*, called the coefficient of interaction of the electron beam with high frequency field of the gap . This coefficient depends on time $\tau=\delta/v$, and more precisely, on the transit angle $\theta=\omega\tau$ of the gap by electrons with velocity *v*, and is determined by tile expression : $M=\dfrac{\sin(\theta/2)}{\theta/2}$

The transit angle θ determines what portion of the period of high frequency oscillations *T* makes up transit time according to the expression $\theta=2\tau\pi/T$. The value of the transit angle corresponds to the variation of the voltage phase that is applied to the gap, during the time of transit of this gap by an electron . The dependence $M(\theta)$, calculated according (6) , is represented in Tab. 1 and fig. 3.

Tab. 1(The dependence $M(\theta)$)

θ	0	π	2π	3π	4π	5π	6π
M	1	0.64	0	- 0.21	0	0.13	0



It follows from (4) and (5) that convection and induced currents can be identified only by constant currents, since their constant components are equal . Variable components of these currents are close only on low frequencies, when the transit time is considerably less than the period of high frequency oscillations, and the interaction coefficient is close to one $(M \longrightarrow 1)$. In general case the amplitude of the induced current is less than the amplitude of the convection current, although the amplitude of the convection current in this case does not vary. By a large θ, when the transit time becomes commensurable with the oscillations period, the amplitude of the induced current diminishes to very small values . If , where m = 1,2,3, …, then M = 0 , and the variable component of the induced current is absent . In is explained by the fact that , when the transit time in the gap corresponds to an integer number of periods, then the gap does not guarantees velocity modulation of the charge carries. Each charge during the transit time is accelerated and decelerated by the electric field in identical manner, the induced current remains constant according with (4) .

In real superhigh frequency apparatuses the periodical function of convection current has a complex form and may be represented as a sum of a series of current harmonics in form (4)

$$ik = I_0 + \sum_{i=1}^{\infty} (I_{1i} \sin \omega t + I_{2i} \cos \omega t),$$

And accordingly the induced current is expressed in the form:

$$i_H = I_0 + \sum_{i=1}^{\infty} Mr(I_{Ii}^{\sin i\omega t} + I_{2i}^{\cos \omega t}),$$

Where M_I . As the coefficients of interaction are different for different numbers of harmonics, the form of the induced current differs from that of convection current . In distinction from spatial harmonics (3) the time ones characterize standing waves having different (multiple frequencies) .

Conclusions :

1. physical processes, that are going on in electronic superhigh frequency apparatuses and that are connected with motion of charge carriers in vibrating systems, have been considered .
2. Convection current is the cause that stimulates the current, induced in a vibrating system and in an external circuit of the electrode , near which charged particles fly by (transit) .
3. Under the action of a flying electron bunch in the electrode and in its external circuit free charges interlace, that is , a pulse of induced current arises which is not connected with sediment of a charge on tile electrode.
4. The induction of a current in an external circuit of a vacuum charge, formed by two plane grids, has been considered .

5. A formula has been deduced in an external circuit for calculation of induced current, where the amplitude of the variable component differs from that of convection current (I_{mk}) by a factor M.
6. It is deduced that convection and induced currents may be identified only in situation of constant currents, since their constant components are identical .

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