УДК 681.586

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THE RESEARCH OF PIEZOELECTRIC ELECTRODES FOR VIBROACOUSTIC INTERFERENCE THERAPY

The possibility of controlling of the energy of interference oscillations by changing beat frequency to reduce irritant effect is considered. The procedure of joining of two methods properties in vibroacoustic interference therapy (the use of two oscillations interference in vibroacoustic therapy) is offered. In the proposed method of vibroacoustic interference therapy sinusoidal signals are used. The frequency of one of them is constant, and that of the second one changes within 2.8–3.2 kHz. The amplitude of output interference signal forms the so-called beating, which is determined by the difference of input signals' frequencies. Most frequently piezoelectric transducers are used for vibroacoustic physiotherapy. The paper investigates piezoelectric electrodes for vibroacoustic interference therapy. Physical model of piezoelectric radiator is offered and researched. The dependences of voltage from frequency and sound pressure from frequency are built. The oscillogram of the result of two oscillations influence on physical model of piezoelectric radiator for vibroacoustic interference therapy is shown. The proposed method allows to reduce human body habituation to therapeutic procedures.

Key words: *vibroacoustic therapy, interference, piezoelectric element, projector.*

Therapy is an area of clinical medicine that studies the origin, treatment, diagnostics and prevention of diseases of internal organs. Therapy is a common name of conservative methods of treatment, which includes all non-surgical treatments [1].

Vibrotherapy (*lat*. Vibrare – to tremble, to oscillate + *gr*. Therapeia – treatment, therapy) is a method of therapeutic effects of low frequency mechanical vibrations carried out by direct contact of the projector (vibrator) with the tissues of a patient [2].

Vibroacoustic physiotherapy is one of types of vibrotherapy, at which, for therapeutic and prophylactic purposes, a contact effect of microvibration with sound frequency (20 Hz–20 kHz) is used.

Interference therapy method is simultaneous action on a patient with two dissimilar currents that are fed to the body through two pairs of electrodes to cross their ways inside of the tissue [3].

As a result of the interference, instead of two medium frequency currents inside of the tissue a new low-frequency alternating current (interference current) is formed [2]. The amplitude of this current, periodically changing, forms the so-called beating, the number of which is determined by the difference of currents' frequencies. The number of beating during the procedure may be constant or periodically change by the program that is specified (Fig. 1).

In the method of interference therapy alternating sinusoidal currents with frequencies, ranging from 3000 to 5000 Hz, are used. The frequency of one of them is constant, and that of the second one automatically changes within the limits up to 200 Hz [3].

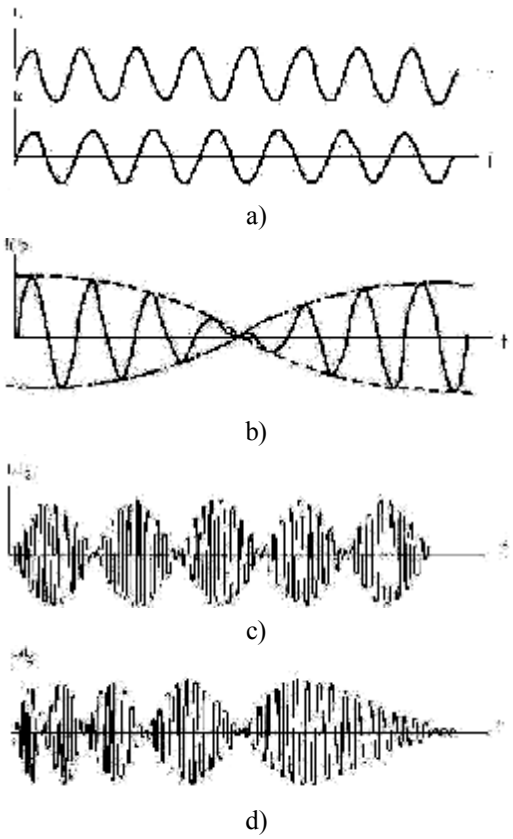

Fig. 1. Graphic representation of two primary currents (a); the process of formation of interference currents in tissues (b); interference currents with a constant number of beats (c); interference currents with the spectrum of beats (d)

One variant of block diagram of the device for interference therapy is shown in Fig. 2 [1].

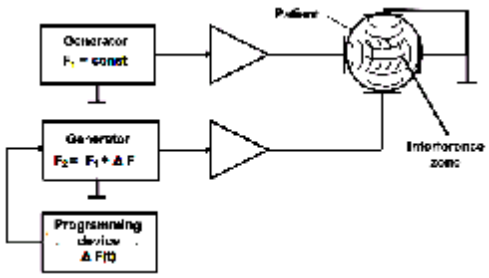

Fig. 2. Block diagram of the device for interference therapy

It has been proposed to apply the interference of two oscillations in vibroacoustic therapy (vibroacoustic interference therapy (VIT)).

Most frequently piezoelectric transducers [7–9] are used as the projectors for vibroacoustic physiotherapy.

The **purpose** of this work is to investigate piezoelectric electrodes for vibroacoustic interference therapy.

As is well known, due to inverse piezoelectric effect upon the application of sinusoidal electric field forward and backward traveling waves of displacement, strain and stress can appear that in steady state produce a standing wave. Naturally, if we initiate in solid state of piezoelectric element several traveling waves by applying the principle of superposition, we obtain algebraic addition of energy flows at every point of excited volume [4].

Output signal from piezoelectric element, on which due to direct piezoelectric effect electrical charge is induced, is proportional to the total value of mechanical stress acting in the zone of the electrode.

One variant of piezoelectric radiator's construction is shown in Fig. 3.

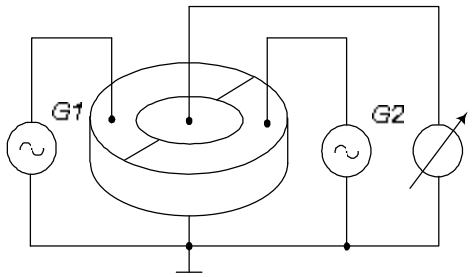

Fig. 3. Piezoelectric adder

By adding of two voltages $U_{in1} = U_{m1}\sin(\omega t + \varphi_1)$ and $U_{in2} = U_{m2}\sin(\omega t + \varphi_2)$ of identical frequency ω we will receive:

$$U_{out} = k_1 U_{in1} + k_2 U_{in2} = U_m \sin(\omega t + \varphi), \quad (1)$$

where

$$U_m = \sqrt{k_1^2 U_{m1}^2 + k_2^2 U_{m2}^2 + 2U_{m1}U_{m2}k_1k_2\cos(\varphi_2 + \varphi_1)}, \quad (2)$$

$$tg\varphi = \frac{k_1 U_1 \sin\varphi_1 + k_2 U_2 \sin\varphi_2}{k_1 U_1 \cos\varphi_1 + k_2 U_2 \cos\varphi_2}. \quad (3)$$

Here k_1 and k_2 are the factors that determine voltage ratio of output to every input. The values of these coefficients are determined by the electrodes' geometry and the material used for the chosen mode of oscillation (mechanical quality factor, electromechanical coupling coefficient, piezoelectric modulus etc.). For the simplest de-

signs of summing transformers (bars, plates and disks) the coefficients k_1 and k_2 are determined by the ratio:

$$k_1 = p\frac{A_1}{A} \text{ and } k_2 = p\frac{A_2}{A}, \quad (4)$$

where A_1, A_2, A are the areas of input and output electrodes; p is the constant coefficient for the given structures and material of the adder; at certain parameters of the adder coefficients k_i may have values considerably greater than one.

Practical interest is represented by cases, when $\varphi_1 - \varphi_2 = 0$ or $\varphi_1 - \varphi_2 = \pi$. In these cases

$$U_m = \sqrt{k_1^2 U_{m1}^2 + k_2^2 U_{m2}^2 \pm 2U_{m1}U_{m2}k_1k_2} = \\ = k_1 U_{m1} \pm k_2 U_{m2}. \quad (5)$$

For symmetric construction $k_1 = k_2 = k$. Thus,

$$U_m = k(U_{m1} \pm U_{m2}). \quad (6)$$

For n inputs, using the method of induction, we can obtain:

$$U_m = \left[\begin{array}{l}\kappa_n^2 U_{mn}^2 + 2k_n U_{nm} k_{1,2,3,\ldots(n-1)} U_{m1,2,3\ldots(n-1)} \times \\ \times\cos(\varphi_m - \varphi_{1,2,3\ldots(n-1)}) + k_{1,2,3\ldots(n-1)}^2 U_{m1,2,3\ldots(n-1)}^2\end{array}\right]^{1/2} \quad (7)$$

$$tg\varphi = \frac{k_n U_{nm}\sin\varphi_n + k_{1,2,3\ldots(n-1)}U_{m1,2,3\ldots(n-1)}\sin\varphi_{1,2,3\ldots(n-1)}}{k_n U_{nm}\cos\varphi_n + k_{1,2,3\ldots(n-1)}U_{m1,2,3\ldots(n-1)}\cos\varphi_{1,2,3\ldots(n-1)}} \quad (8)$$

where $U_{m1,2,3\ldots(n-1)}$ and $\varphi_{1,2,3\ldots(n-1)}$ are determined by the formulas through $U_{m1,2,3\ldots(n-2)}$ and $\varphi_{1,2,3\ldots(n-2)}$ etc. Thus

$$k_i = p\frac{A_i}{A}. \quad (9)$$

One of the main parameters of piezoelectric adders effectiveness is transfer coefficient of electrical signal. Transfer coefficient is the ratio of adders' maximum output signal amplitude to maximum amplitude of the summed signals [4].

For experimental research electroacoustic transducer ZP-19 has been used. Its voltage and sound pressure amplitude-frequency characteristics (AFC) are shown in Fig. 4 and 5 respectively.

The process of two oscillations interference, according to Fig. 3, is shown in Fig. 6.

As can be seen from Fig. 6, the amplitude of output interference signal, periodically changing, forms the so-called beating, the number of which is determined by the difference of input signals' frequencies.

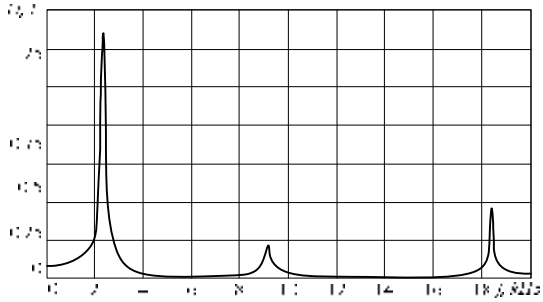

Fig. 4. Experimental voltage AFC of piezoelectric transducer

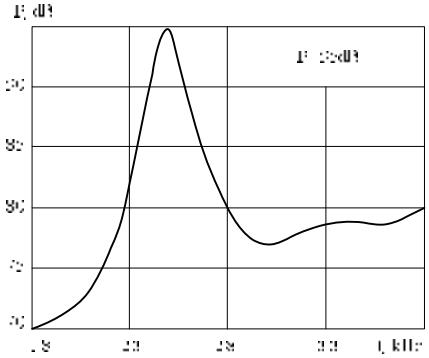

Fig. 5. Experimental sound pressure AFC of piezoelectric transducer

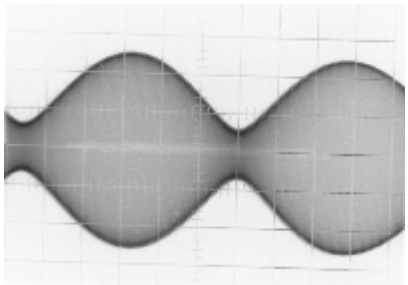

Fig. 6. Oscillogram of piezoelectric radiator

Conclusions:

1. The method of the use of two oscillations interference in vibroacoustic therapy (vibroacoustic interference therapy) is offered.

2. Piezoelectric electrodes for vibroacoustic interference therapy are investigated.

3. The amplitude of output interference signal forms the so-called beating, which is determined by the difference of input signals' frequencies.

4. Physical model of piezoelectric radiator is offered. Its voltage and sound pressure characteristics from frequency are determined.

5. The oscillogram of the result of two currents influence on physical model of piezoelectric radiator for vibroacoustic interference therapy is shown.

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