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ACOUSTICAL EMISSION OF MEGACYCLE REGION IN MODEL OBJECTS

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If investigations of thermal acoustical radiation in megacycle frequency region from biological objects are conducted, a question on possibility of existence of nonthermal acoustical sources is considered. Measurements of acoustical emission generated nonthermal sources are conducted with the help of high-performance method developed for thermal acoustical radiation registration. Ice melting and bubbles generation in water are considered as model objects. The acoustical signal parameters for both cases are similar: impulse period is more than ten microseconds, impulse amplitude is more than the thermal radiation in some times. The signal frequency is different – tens of impulses in minute (for ice melting) and hundreds of impulses in second (for bubbles generation).

Sound signals from human body are well known. Source of acoustical signals in megacycle region is thermal acoustical radiation. With registration of possible nonthermal acoustical emission in high-cycle region one can obtain important medical and biological information, but it is necessary to proof experimentally the existence of such emission.

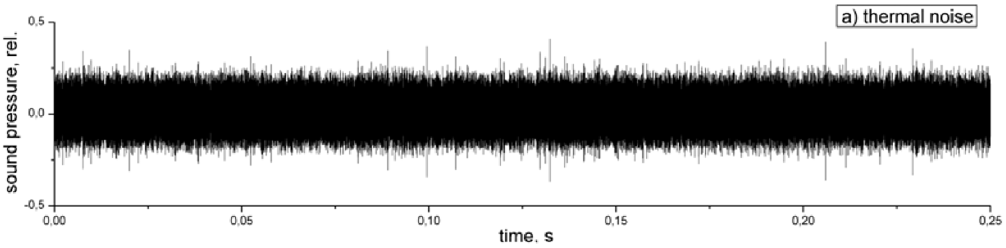
The aim of this investigation is to use high-performance method developed for thermal acoustical radiation registration for measurements of nonthermal acoustical emission. We propose to use the following model objects:

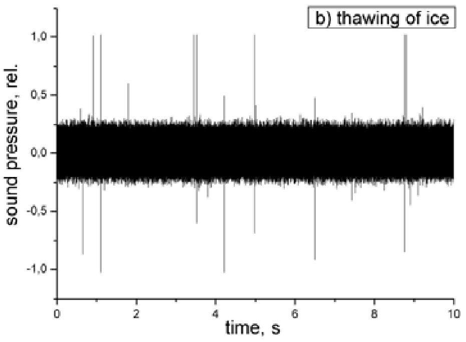
1) ice in water (acoustical signals are generated by ice melting);
2) special tablets in water (they generate many bubbles).

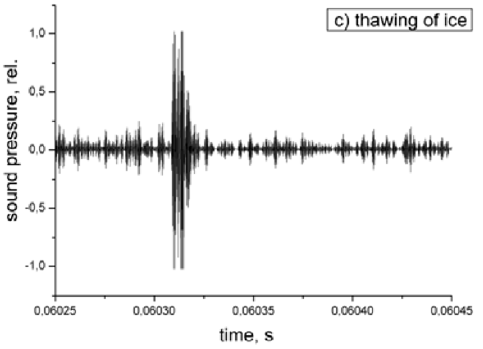
This choice of model objects is detected because of some reasons. First, a role of change of phase state of lipids in cell membrane functioning is considered in biology [1, 2]. As well known, the lipids as the base of biological membranes can be in two phase states. For physiological conditions the state is liquid crystal. If external conditions are changed, with temperature decreasing or with addition of Ca^{2+} ions, the lipid state can pass to gel. If acoustical emission exists by ice melting it can exist with lipid state transformations too. Second, sometimes there is possibility of the cell membrane breakdown in the result of vital activity of biological objects. This process is similar to process of thin water film breakdown of bubbles. If acoustical emission exists during thin water film breakdown then it can exist during the cell membrane breakdown too.

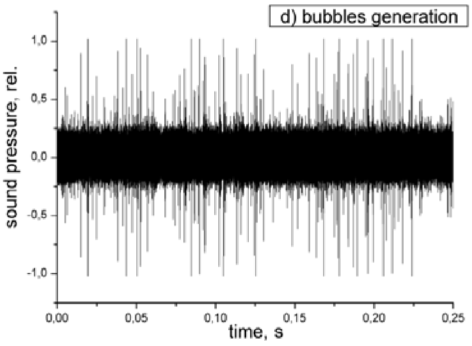
Earlier the acoustical emission of these model objects was yet measured. For example, acoustical emission with ice melting was observed in A.D.Mansfeld's laboratory (IAP of RAS) [3] and V.I.Mirgorodskij's laboratory (FIRE of RAS) [4]. Acoustical signals during thin water film breakdown were measured by V.I.Passechnik and A.V.Erofeev [5]. In our investigation we lean upon earlier obtained data, but use modern high-cycle registration of signals. This method allows us to get a series of new results.

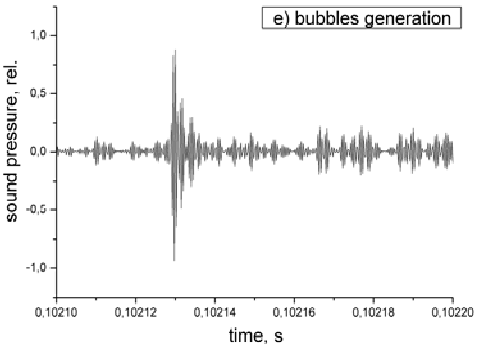
The scheme of measurements. Receivers of signals were acoustothermometers, developed group under V.I.Mirgorodskij [6] and S.N.Antonov [7] management. The mean frequency of a reception was about f = 1.8 MHz, and passband – about Δf = 350 kHz. Diameter of the receiver was a = 9 mm. The receiving signal is amplified and moved in 12-bit ADC with the maximal frequency of digitization of 30 MHz. The factor of losses acoustothermometers made about 2.5 (i.e. if intensity of a useful signal (temperature of researched object) is increased at 10 % then the measured signal grows by 4 %). A source of emission (pieces of ice of various weight on the average about 300 mg and tablets UPSARIN-UPSA with vitamin C, "UPSA Bristol-Myers Skvibb" France) is placed in area of the acoustothermometer aperture on distance of several centimeters from a surface of the receiver. Let's notice, that the used scheme of measurements assumes only registration of short signals (characteristic time is about $1/f \approx 0.5$ μs) in narrow frequency range that does not give an opportunity to measure a spectrum of acoustic emission. However the similar scheme is quite suitable to reception of an initial reference point.











Experimental results and their discussion. In figures typical experimental records are submitted. On the figure a) the signal of thermal acoustic radiation which is normally distributed concerning zero pressure is represented. The full size noise makes 6σ, where σ is standard deviation of pressure. Presence of separate rare fluctuations of the pressure exceeding 3σ is connected to the big size of sample of the data – on the figure 10^6 measurements are shown.

Results of measurement of the acoustic emission caused thawing of ice are below presented. On the figure b) on a background of thermal noise separate significant acoustic signals of this emission are visible. It enables to estimate frequency of pulses – about 1 pulse in a second. On the schedule c) one signal is submitted in large scale. It enables to estimate duration of one pulse – about 20 μs.

On the lowermost figures presents the results of measurement of the acoustic emission arising at formation of gas bubbles. We shall note, that in this experiment in the aperture of the receiver there was a tablet from which surface upwards there left bubbles, but not border water – air where they burst. That is acoustic emission arises not only at break of a film of a bubble (as shown in work [5]), but also at formation of bubbles. The figure d) enables to estimate frequency of occurrence of pulses – about 250 pulses in a second. Visual supervision shows, that this number is approximately equal to the number of bubbles formed for 1 s. The schedule e) allows to estimate duration of one pulse – about 10 μs.

We shall note, that usage of high-frequency ADC has allowed to consider in detail separate acoustic signals (see figures c) and d)), that is important for detection of their parameters.

The calibration of signals on pressure can be executed, using a ratio obtained V.I.Passechnik [8]:

$$\langle p^2 \rangle = \rho\, c\, k\, T\, \Delta f \,/\, S, \qquad (1)$$

Where $\langle p^2 \rangle = \sigma^2$ – mean square of pressure caused by thermal acoustic radiation of a body, heated up to temperature $T = 290$ K; $\rho = 1000$ kg/m^3 – density of water; $c = 1500$ m/s – speed of sound in water, k – Boltzmann constant; $S = \pi\, a^2 \,/\, 4 = 0.64$ cm^2 – area of the receiver. As a result of calculations is obtained, what standard deviation the value of pressure, approximately equal to 1/6 of value of a noise track, makes about $6 \cdot 10^{-3}$ Pa. It is visible from the figures, what the maximal pressure of a non-thermal acoustic emission (both at a melting of ice, and at a blistering) exceeds a noise track approximately in 1.5 times, i.e. pressure makes about $50 \cdot 10^{-3}$ Pa.

For an estimation of parameters of acoustic emission we used expression for pressure p the acoustic wave created by a volumetric source on distance $r \approx 5$ cm from a source [9]:

$$p = \rho\, V'' \,/\, (\, 4\, \pi\, r\,), \qquad (2)$$

where V'' is the second derivative on time of change of volume of a source.

Let's estimate the size of the moved volume V caused registered emission. For this purpose we shall consider, that the second derivative of volume is approximately equal to

$$V'' \approx (\, 2\, \pi f\,)^2\, V, \qquad (3)$$

As the result we have got that the measured acoustic emission causes the accelerated change of volume $V \approx 0.25$ μm^3 or causes movement of structure with the characteristic linear size about 0.6 microns. For comparison: the linear size of erythrocyte makes about 10 microns, and volume – about 300 mkm^3.

A conclusion. The research shows, that nonthermal acoustic emission in megacycle region is reliably registered in the chosen modeling objects. The numerical analysis shows, that for realization of emission it is necessary synchronous fast (with characteristic time less than 1 μs) the accelerated movement of a cubic micrometer of substance. The question on an opportunity of similar emission in biological objects demands continuation of experimental researches.

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