

# The Use of Thermal Radiation for Remote Identification of Liquids in Closed Dielectric Containers

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**Abstract**—Remote determination of substances, including liquids, is an urgent problem, the solution of which requires fundamentally new approaches to both methods and measurement techniques. This is due to the fact that standard liquid analysis methods are mainly spectroscopic methods in various frequency ranges from neutron diffractometry to acoustic spectroscopy, which are very difficult or even impossible to apply in remote sensing. Conventional radar methods are usually unacceptable due to the impossibility of covert removal of information using active location and obtaining data on the composition of the irradiated object based on it. Therefore, at present, methods and techniques of passive location are being used more and more, but in order to solve quite specific problems of remote identification of substances, they must be significantly modernized.

This article discusses a technique and a modernized measuring complex for remote study of liquid electrolytes and non-electrolytes using measurements and subsequent analysis of fluctuations in the temperature difference of the intermediate liquid medium (distilled water) in which the container with the liquid under study is located. To date, there is no clear understanding of how thermally stimulated radiation depends on the composition of a macroscopic body, and also on whether thermal radiation is in equilibrium or non-equilibrium. The investigated object, at a given temperature, emits electromagnetic waves associated with the thermal motion of the molecules and atoms of its constituents. That's, why thermal radiation is random (fluctuation) process, which means that the average value of the electromagnetic field is equal to zero, but other averaged features, such as quadraticity in the field, may differ from zero. The quadratic characteristics of a thermal electromagnetic field determine its energy, which has a finite value other than zero, which can be measured by an appropriate sensor and characterizes the field source — a macroscopic body heated to a certain temperature. The paper presents the results of studies of mixtures of electrolytes and non-electrolytes of various concentrations. An example of non-equilibrium thermal radiation is given. It is shown that it is possible to distinguish between the studied liquids and methods of combining the components of solutions of given concentrations to obtain the given properties of the entire solution.

**Keywords** — *thermal electromagnetic field; differential temperature fluctuations; solution concentration; broadband noise emission; electrolytes and non-electrolytes.*

## 1. INTRODUCTION

Today, increasing interest is being shown in radio thermal-location systems, including by developers of homing systems for high-precision weapons and passive reconnaissance systems. Passive radar systems using electromagnetic waves of radio bands are the most noise-immune due to their secrecy of operation and do not require powerful energy sources. Remaining undetected by means of electronic intelligence, they collect information about the surrounding target environment [1]. The principles and techniques of passive location continue to improve and find application in new areas of industry.

The thermal electromagnetic field is created by the chaotic thermal motion of charged microparticles, of which bodies are built. In macroscopic electrodynamics, an electromagnetic field is considered as a field of macroscopic sources described by volumetric charge and current densities. As applied to the thermal electromagnetic field, this means that its sources are spatio-temporal

fluctuations of the charge and current in physically infinitesimal volume elements of the subject.

Electromagnetic fluctuations or electrical noises are an important part of the fundamental phenomenon of nature — Brownian motion. The theoretical work [2] elucidated the fluctuation nature of this motion and investigated its main statistical regularities.

The study of electrodynamic fluctuations is an important part of modern fundamental and applied science, since it is the fluctuations of the dynamic variables of the system that determine — a large class of the most important physical phenomena such as the Van der Waals interaction of bodies, the Casimir force, which can be considered as a special case of the van der Waals interactions, heat transfer between bodies separated by a vacuum gap, capture of atoms, molecules, coherent material states by electromagnetic traps, and other important physical and chemical phenomena near the surface of condensed media [3]–[5].



Studies carried out in recent decades have shown that fluctuations in liquids are significant not only in the vicinity of critical points, but also determine the structure and properties of liquids.

To characterize the structure of liquids, density fluctuations, anisotropic fluctuations, and concentration fluctuations are essential. Fluctuations are local deviations of liquid properties from the mean value, randomly occurring under the influence of thermal motion and molecular forces. These fluctuations are statistically independent of each other, but they are closely related to thermodynamic dependences and determine the kinetics of molecular processes [6]. So in [7] the differences in the macroscopic molecular dynamics of solutions of weak and strong electrolytes are considered, their fundamentally different behavior in an aqueous medium is shown. Differences in the molecular dynamics and temperature fluctuations of various solutions are enhanced when a velocity field appears in the system, for example, in the case of developed homogeneous isotropic turbulence [8]. In the context of this work, one should also note the theoretical modeling of the role of temperature fluctuations on quantum entanglement in open non-equilibrium systems as a measure of information about the state of the system [9].

The thermal radiation of heated opaque bodies is characterized by a wide continuous spectrum and a quasi-isotropic angular distribution. According to these characteristics, the thermal radiation of opaque bodies differs little from the radiation of a black body. Formally, the Stefan-Boltzmann formula does not limit the spectral range of the Planck radiation. However, the regularities of black-body radiation are well fulfilled only for macrobodies in the optical region of the radiation spectrum. Therefore, studies of the Planck radiation in the radio range [10] and various bodies of the nanometer geometric scale [11] are still ongoing.

Modern phenomenological theories of thermal radiation give the same result for the spectral composition of radiation into a given solid angle as the classical Kirchhoff model of thermal radiation, which describes the properties of the field of traveling or propagating waves, as a limiting case, supplementing the general theory of a fluctuating electromagnetic field with a description of the properties of its quasi-stationary part.

As a rule, the average characteristics of fields in vacuum are recorded in experiments at some distance from heated bodies. The theoretical model assumes that the source of a thermally stimulated fluctuating electromagnetic field is a set of independent emitters emitting waves with random amplitude, phase and polarization, and each elementary emitting volume emits non-monochromatic waves. At the same time, the presence of fluctuations, including temperature, should also be expected in small-sized systems in equilibrium [12]. The resulting field is complex, randomly changing in space and time. In this case, one can introduce the concept of internal and external disorder, which have different effects on the transport dynamics and different dependences on temperature and density [13]. The statistical model of fluctuating electromagnetic fields is based on the central limit theorem [14].

The dynamics of any electromagnetic process, including those of a fluctuation nature, must be described by a system of Maxwell's equations. Therefore, the initial equations are for microscopic strengths of fluctuation fields in a vacuum.

To determine the correlation functions of the field components, the correlation functions of the currents in the system must be known, which are given by the fluctuation-dissipation theorem (FDT) [15], [16]. FDT relates spontaneous fluctuations of system parameters to its dissipative properties. In particular, FDT relates the spectral density of fluctuations of extraneous currents to a part of the permittivity tensor of a substance.

The spectral density of fluctuations of external currents is defined as the Fourier transform of the correlation function of external currents. One of the new areas of application of thermally stimulated radiation and passive location methods is the remote identification of substances. The papers [17], [18] show the possibility of identifying objects under study using passive location methods.

In the present work, the thermally stimulated radiation of the objects under study affects the intermediate medium (distilled water), in which the radiation propagates and changes its temperature fluctuations. These fluctuations are measured using micro-thermopile, processed, and compared with the results obtained for known objects (etalons) [19].

The aim of this work is to study the thermally stimulated emission of mixtures of liquid solutions consisting of two electrolytes, as well as two non-electrolytes of different concentrations, and to determine the practical possibility of remote identification of such solutions.

## 2. METHODOLOGY OF EXPERIMENTAL STUDIES

To identify a substance, it is necessary to determine the special parameters inherent only to this substance, which manifest themselves when interacting with physical factors or dynamic processes. Moreover, for each group of substances, certain factors or processes are characteristic. For solutions of liquids, spectroscopic methods are most often used in various wavelength ranges; for solids, processes are widely used that are accompanied by a change in entropy, release or absorption of heat, which is recorded by the method of differential thermal analysis, which is one of the most highly sensitive modern methods for studying phase transformations, occurring in systems or substances. Thermal analysis continuously records thermal effects by measuring the temperature of a substance at regular intervals. The ambient temperature changes at a constant rate. If, when the temperature of a substance changes, there are no transformations accompanied by thermal effects, then the dependence "temperature — time" (thermograph) has the form of a smooth inclined line. In the case of the occurrence in a substance of one or another transformation, the rate of its temperature change noticeably changes due to the release or absorption of heat in comparison with the environment. On the thermogram, this corresponds to the deviation of the line from its original direction. The method of recording thermal processes in the "temperature–time" coordinates (simple notation) is not sensitive enough [20].

In order to increase the sensitivity, the method of differential thermal analysis is used, in which, in addition to changing the temperature of the test sample, the temperature difference between the test substance and the standard is recorded. For the standard, a substance was chosen that does not have phase transformations in the temperature range under study. The installation for differential thermal analysis with automatic recording of the sample temperature and the temperature difference between the sample and the standard, called the Kurnakov pyrometer, turned out to be so successful that it has been preserved to this day. The changes concern only individual nodes [21].

Temperatures are recorded using two identical thermocouples connected in series with each other by identical wires. At the same temperature of the hot junctions of a differential thermocouple, the currents arising in it will be directed towards each other and, if they are equal, will be compensated. In this case, the differential thermocouple meter will not show any deviation. The differential record on the thermogram will be in the form of a straight line parallel to the time axis (zero or base line). With the manifestation of the thermal effect in the substance, a temperature difference will arise between the substance under study and the standard. Differential recording is combined with a simple recording, thus obtaining two simultaneously: a simple one for determining the temperatures of the effects and a differential one for increasing the sensitivity of the setup [22]. The differential thermal analysis method cannot be used for remote identification of substances, since it requires direct exposure of the substance and standard to changing temperature. One of the options for modifying this method for remote measurements is not the measurement of temperatures, but the measurement of fluctuations in the differential temperature of the intermediate medium, which is at a constant (room) temperature, in which a sample of the test substance is placed in a dielectric container. An intermediate medium without a sample of the object under study serves as a standard. The asymmetry of differential temperature fluctuations is determined by the properties of the sample under study. In addition, broadband noise radiation in the millimeter wavelength range can be used to increase this asymmetry [19]. In test tubes with a diameter of  $\varnothing = 16$  mm filled with distilled water, test tubes  $\varnothing = 7.5$  mm were placed, one of which contained the test substance, and the other was empty and was the standard. Thermocouple junctions were placed in the intermediate medium, which was distilled water. Microsplits of copper — constantan thermocouples were created by laser soldering and had an area  $S \approx 0.015$  mm<sup>2</sup>. The fluctuations of the differential temperature were measured by a specially designed hardware complex, which makes it possible to ensure the measurement accuracy of 0.03° C [23]. Considering the speed of the 12-bit ADC, as well as the sample size of several thousand data, the system provides the specified absolute measurement error by removing information with a frequency of 1-2 seconds. At the same time, the measuring complex makes it possible to eliminate random components of the error due to statistical processing of the measurement results, including the choice of the duration and

values of the polling time for a given channel, based on a given error depending on the level of external noise [24]. The software of the complex allows you to perform, among other things, the following functions:

- display of differential temperature and its display in real time in numerical and graphical form;
- making notes and comments during the experiment;
- storage of records of differential temperature on the hard disk;
- loading and displaying previously saved records.

To increase the asymmetry of differential temperature fluctuations (contrast), the measuring complex uses a broadband noise signal generated by the Oratoria-IV solid-state noise generator with technical characteristics:

- operating frequency band – 56...68 GHz ;
- noise power spectral density (NPSD) – 10...18 W/Hz ;
- non-uniformity of NPSD –  $\pm 1.5$  dB ;
- integrated power –  $10^{-10}$  W/cm<sup>2</sup> .

In the future, this "backlight" will be referred to as EHF-irradiation (extremely high-frequency — irradiation).

In addition to the millimeter-wave noise generator, to simulate the non-equilibrium state of liquids, a low-frequency generator with a frequency of 100 kHz can be used, generating a signal (meander) with a variable amplitude of 0...10 V, the voltage of which is applied to a capacitor, which is a conductive strip attached to opposite walls of a test tube with a diameter of  $\varnothing = 7.5$  mm and isolated from the intermediate medium. This effect will be referred to as low-frequency irradiation.

The block diagram of the measuring complex was showed on Fig. 1 [24].

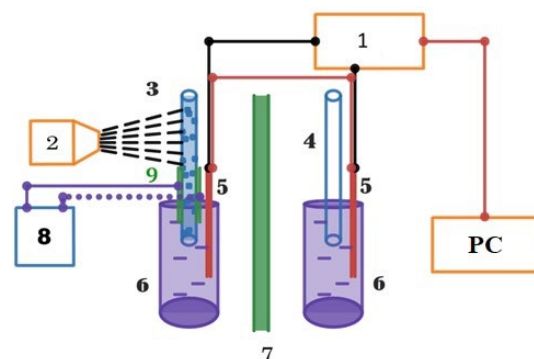


Fig. 1 Block diagram of the measuring complex: PC – personal computer; 1 – differential and absolute thermocouple meter ; 2 – noise generator; 3 – test tube with the test substance; 4 – test tube with a standard; 5 – thermocouples; 6 – test tubes with distilled water; 7 – dividing partition; 8 – low-frequency generator G5-54; 9 – capacitor.

Differential temperature fluctuations were measured for 20 minutes without external noise exposure to the test sample, 20 minutes with external noise exposure, and 20 minutes after external noise exposure.

Differential temperature fluctuations were measured between a test tube with distilled water (with an intermediate medium) into which a container with the test solution was placed and an intact test tube with water. The received series of signals were analyzed based on their Fourier spectrum. (FFT – Fast Fourier Transtition)

The maximum error of the results did not exceed 18%.

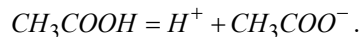
### 3. RESULTS OF EXPERIMENTAL STUDIES

#### A. Substances

In the work, liquid mixtures of two solutions were studied: two non-electrolytes - soda solutions and sugar solutions; two electrolytes - a solution of kitchen rock salt and an aqueous solution of food grade acetylsalicylic acid.

The following appropriate components were used to prepare the solutions:

- Rock salt ( $NaCl$ ) using on kitchen is made according to DSTU 3583:2015. Granulometric composition of kitchen rock salt of the first grinding, first grade: up to 1.2 mm inclusive — not less than 85%, over 2.5 mm — not more than 3%;
- Soda baking (sodium bicarbonate)  $NaHCO_3$  complied with GOST 32802-2014. Food additives. Sodium carbonate E500. The baking soda particles had a size of 0.1 mm;
- Granulated white granulated sugar, category 3 corresponded to DSTU 4623-2006 (GOST 31361-2008). The granulated sugar crystals had a size of the order of 1 mm;
- vinegar — a solution of acetic acid obtained by oxidizing alcohol in the process of acetic acid fermentation or diluting food acetic wood chemical acid (a product of the dry distillation of wood). DSTU EN 13189:2019 Food grade acetic acid. Product made from materials of non-agricultural origin. Definition, requirements, marking (EN 13189:2000, IDT) Apple cider vinegar — 9% aqueous solution of food grade acetic acid — weak electrolyte



Solutions of appropriate concentrations were prepared as follows. way: the components were collected in a reference volume and dissolved in 100 ml of distilled water at room temperature (18...20° C). The change in concentration was carried out by changing the number of reference volumes of the substance dissolved in 100 ml of distilled water. Solutions of a specific concentration were mixed in a measuring tube using a measuring syringe, which made it possible to measure the output signal for a solution of each concentration.

#### B. Solutions of non-electrolytes.

Solutions from food water ( $NaHCO_3$ ) were used as objects of research. and granulated sugar (chemical substance sucrose  $C_{12}H_{22}O_{11}$ ). Both substances dissolve well in water, forming saturated solutions with a solubility coefficient of 203.9 g of sucrose per 100 g of water and 9.59 g of baking soda per 100 g of water at a temperature of 20° C. Aqueous solutions of sucrose and soda are non-electrolytes. To prepare a mixture of solutions, solutions were used, the mass fractions of which are

$C_a = \frac{m_a}{m} \cdot 100\%$  [where  $C_a$  is the mass fraction of substance "a";  $m_a$  – mass of substance "a";  $m$  is the total mass of substances] corresponded to:

1. 4.76% sugar solution and 6.54% soda solution;
2. 19.04% sugar solution and 8.75% soda solution;

The total volume  $V$  of the mixture of solutions was 8 parts of the components of the corresponding concentrations, that is,  $V = n \cdot \alpha + (8 - n) \cdot \beta$ , where  $\alpha$  is one volume of a sugar solution of a given concentration;  $\beta$  – one volume of a soda solution of a given concentration;  $n$  is the number of volumes of sugar solution.

Fig. 2 shows the dependences of the relative amplitudes of the first harmonics of the Fourier expansion (maximums in the spectrum) of fluctuations in the differential temperature of distilled water, in which a container with a mixture of solutions consisting of  $n$  volumes of sugar solutions 4.76% and  $(8 - n)$  volumes of soda solution 6.54 was placed %, where  $n$  varies from 0 to 8. The upper curve corresponds to the values of the relative amplitudes under external broadband noise exposure to electromagnetic radiation ( $\lambda \approx 5$  mm), the lower curve — without external exposure.

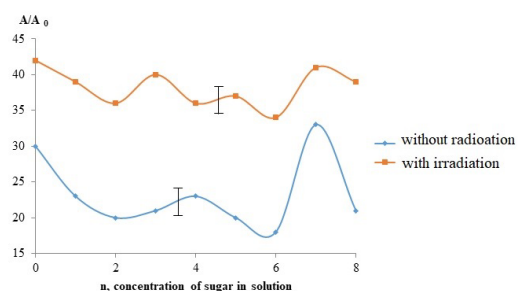


Fig. 2 Dependences of the relative amplitudes of the first harmonics of the Fourier expansion for a mixture of solutions based on 4.76% sugar solutions and 6.54% soda solutions.  $n=0$  corresponds to zero sugar concentration and 6.54% soda solution,  $n=8$  - 4.76% sugar concentration and zero soda concentration

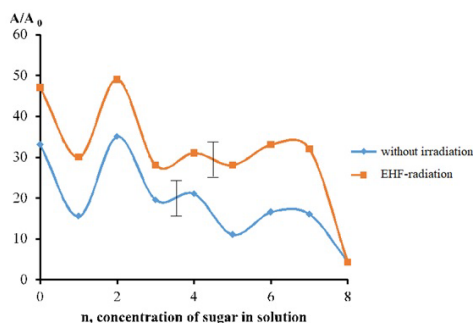


Fig. 3 Dependences of the relative amplitudes of the first harmonics of the Fourier expansion for a mixture of solutions based on 19.04% sugar solutions and 8.75% soda solutions.  $n = 0$  corresponds to zero sugar concentration and 8.75% soda solution,  $n = 8$  - 19.04% sugar concentration and zero soda concentration

Fig. 3 shows the dependences of the relative amplitudes of the first harmonics of the Fourier expansion of fluctuations in the differential temperature of distilled water, in which a container with a mixture of solutions consisting of  $n$  volumes of sugar solutions 19.04% and  $(8-n)$  volumes of soda solution 8.75% was placed, where  $n$  varies from 0 to 8. For this option, the amount of soda exceeds the value at which a saturated solution is formed. The upper curve corresponds to the values of the relative amplitudes under external broadband noise ( $\lambda \approx 5$  mm) exposure, the lower curve - without external exposure.

Increasing the concentration of solutions qualitatively changes the dependence of the relative maximum amplitude on the volume of sugar. At the same values of relative amplitudes, with an increase in the concentration of solutions, the presence of peaks in the values of the received signals in the equilibrium state of a mixture of solutions is clearly traced.

Fig. 4 shows the dependence of the relative maximum spectral amplitude measured signals from sugar concentration for a mixture based on 4.76% sugar solutions and 6.54% soda solutions with low-frequency irradiation. Comparing Fig. 4 with curve 2 in Fig. 2, one can note their qualitative difference. Those LF and EHF irradiation have a fundamentally different effect on temperature fluctuations — fluctuation properties of the density of liquid scintillating clusters.

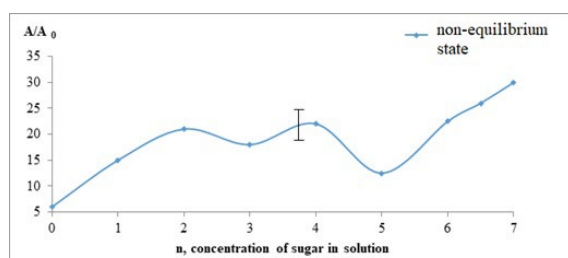
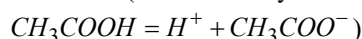


Fig. 4 Dependences of the relative amplitudes of the first harmonics of the Fourier expansion for a mixture of solutions based on 4.76% sugar solutions and 6.54% soda solutions in a non-equilibrium state.  $n = 0$  corresponds to zero sugar concentration and 6.54% soda solution,  $n = 8$  - 4.76% sugar concentration and zero soda concentration.

### C. Electrolyte solutions

The objects of research were solutions with kitchen rock salt ( $NaCl$ ) and 9% aqueous solution of food grade acetic acid (weak electrolyte



Both substances dissolve well in water, forming a saturated solution with a solubility coefficient of 35.9 g of salt ( $NaCl$ ) per 100 g of water and an unlimited amount of vinegar per 100 g of water at a temperature of  $20^\circ C$ . Solutions with kitchen stone salt ( $NaCl$ ) and food vinegar acids are electrolytes. To prepare a mixture of solutions, solutions were used, the mass fractions of which corresponded to: 6.54% salt solution and 9% acetic acid solution.

The total volume  $V$  of the mixture of solutions was 8 parts of the components of the corresponding concentrations, that is,  $V = n \cdot \gamma + (8-n) \cdot \delta$ , where  $\gamma$  is one volume of a salt solution of a given concentration;  $\delta$  — one volume of a solution of acetic acid 9% concentration;  $n$  is the number of volumes of salt solution ( $NaCl$ ).

Fig. 5 shows the dependences of the relative amplitudes of the first harmonics of the Fourier expansion of fluctuations in the differential temperature of distilled water, in which a container with a mixture of solutions consisting of  $n$  volumes of 6.54% salt solutions and  $(8-n)$  volumes of 9% acetic acid solution was placed, where  $n$  varies from 0 to 8. The upper curve corresponds to the values of the relative amplitudes without external broadband noise impact, the lower curve — with EHF irradiation ( $\lambda \approx 5$  mm).

The main features of the dependences of the relative amplitudes of the first harmonics of the Fourier decomposition of electrolyte solutions are the presence of sharp amplitude peaks, which are suppressed by external broadband noise exposure to electromagnetic radiation.

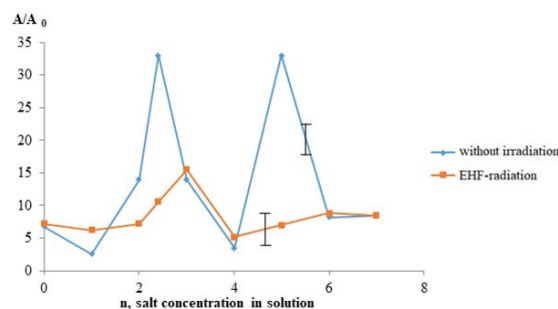


Fig. 5 Dependences of the relative amplitudes of the first harmonics of the Fourier expansion for a mixture of solutions based on 6.54% salt solutions ( $NaCl$ ) and 9% acetic acid solutions.  $n = 0$  corresponds to zero  $NaCl$  concentration and 9% soda solution,  $n = 8$  - 6.54% salt concentration and zero acid concentration.

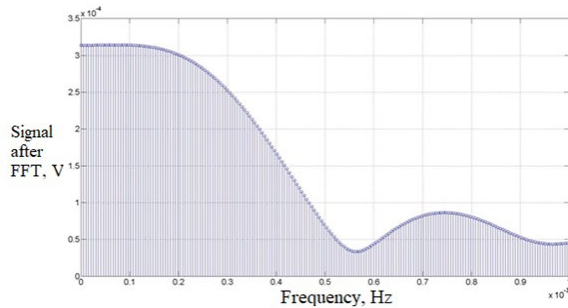


Fig. 6 Fourier expansion for a mixture of solutions based on 4.76% sugar solutions and 6.54% soda solutions at  $n = 7$ , low-frequency exposure and broadband noise electromagnetic radiation

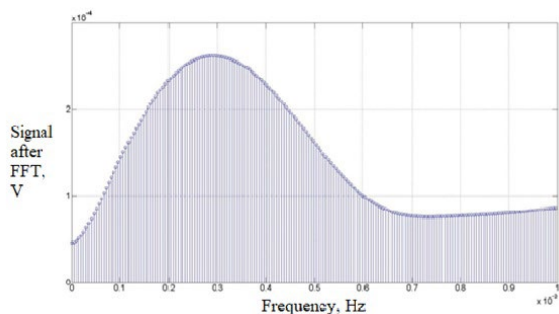


Fig. 7 Fourier expansion for a mixture of solutions based on 4.76% sugar solutions and 6.54% soda solutions at  $n = 7$  and low-frequency exposure

#### 4. THE DISCUSSION OF THE RESULTS. IDENTIFICATION OF SOLUTIONS.

The study of mixtures of non-electrolyte solutions in the equilibrium state shows that an increase in the total concentration of solutions leads to a sharper dependence of the received signal on the change in the concentration of the mixture. Comparing the dependences of the relative values of the maximum amplitudes of the Fourier expansions for the differential temperatures of the intermediate medium, it can be seen that on Fig. 2 these dependences change little with a change in the concentration of the mixture of solutions, and on Fig. 3 these changes are larger and sharper, however, they are suppressed when one concentration of the solution is significantly exceeded (sugar) over another at  $n \approx 7 \dots 8$ . The results of measurements of the same liquids in a nonequilibrium state show not only a decrease in the amplitude of the received signal, but also a qualitative change in the entire dependence.

The study of mixtures of electrolyte solutions in the equilibrium state showed that the applied external broadband noise effect for them is large and suppresses the fluctuations of the solution, reducing the received signal. The dependence of the maxima of the relative amplitude on the concentration of the mixture of solutions is sharp and large in magnitude. Identification of a mixture of solutions can be done by comparing the amplitudes and dispersion dependences with the "library" of known dependences obtained under similar conditions. But it is much easier to identify for each mixture of solutions by comparing them in modulus of the Fourier expansion

amplitudes. Fig. 6 and Fig. 7 shows the Fourier expansion for a mixture of solutions based on 4.76% sugar solutions and 6.54% soda solutions at  $n = 7$ . On Fig. 7— only low-frequency exposure. The shape of the Fourier expansion spectrum is used as a parameter for identification.

The use of broadband noise radiation and low-frequency "meander" voltage in the measuring complex makes it possible to visually distinguish mixtures of solutions.

#### CONCLUSIONS

It is proposed to supplement the measuring complex for remote study of liquids by analyzing fluctuations of the differential temperature of the intermediate medium in which the test sample is placed with a low-frequency (100 kHz) regulated voltage generator of 0...20 V of the "meander" type applied to the capacitor, made in the form of conductive strips on opposite walls of the test tube with the liquid under study, which made it possible to carry out measurements in a non-equilibrium mode, that is, the imposition of an electric field changes the probability of jumps of charged particles in the direction of the field and against the field, thus migration of cations and anions occurs.

Solutions of non-electrolytes do not conduct electric current due to the fact that the molecules are in an undissociated state, that is, in the form of neutral molecules. The hydrated sucrose molecule is converted into an associate of glucose and fructose, which is more than 4 times greater than the hydrated soda molecule. Thus, a mixture of sugar and soda solutions is a mixture of very different molecules, therefore, at low concentrations of solutions, when the interaction between molecules is small, concentration fluctuations are small. At high concentrations, the interaction between molecules increases, concentration fluctuations increase, which leads to an increase in the received thermal signal.

Water as a solvent in sucrose solutions consists of two parts: water, which forms the solution itself, and water, which participates in hydration. To the coordination number of hydration of sucrose (number water molecules directly included in the first hydration sphere of an ion of a given type) decreases with an increase in its concentration in solution [25], [26]. Therefore, with an increase in the concentration of sucrose, the proportion of free water increases and the level of the received (thermal) signal decreases.

The relaxation times of sucrose and soda solutions, as well as mixtures of these solutions ( $\sim 10^{-9}$  sec) are many orders of magnitude shorter than the duration of the applied low-frequency electric field ( $\sim 10^{-5}$  sec), so this mode can be considered as non-equilibrium. In this case, the level of the received thermal signal is greater than without external influence, but less than when exposed to broadband noise radiation.

Electrolyte solutions conduct electric current due to the fact that when a substance is dissolved in water, hydrated ions are formed. The electrostatic interaction between ions weakens to a minimum upon dilution due to an increase in the distance between them and the presence

of hydration shells. With an increase in the electrolyte concentration, the amount of free water not bound into hydrate shells decreases, the distance between the ions decreases, and the interaction between them increases. In a mixture of ions, various types of complexes are formed due to electrostatic interaction, that is, the neutralization of the ion charge can be carried out in various ways, which increases the concentration fluctuations, which leads to an increase in the received thermal signal.

With a smooth change in the concentration of electrolyte solutions, the need to neutralize the ion charges leads

to the appearance of concentration fluctuation maxima, which, with high ion mobility, can be suppressed (ordered) by external factors (broadband noise radiation).

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## Використання теплового випромінювання для дистанційної ідентифікації рідин у закритих діелектричних контейнерах

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*Анотація*—Дистанційне визначення речовин, у тому числі і рідин, є актуальним завданням, вирішення якого вимагає принципово нових підходів як до методів, так і до техніки вимірювань. Пов'язано це з тим, що стандартні методи ґрунтуються на коливальних властивостях компонентів рідини: від атомів до клатратних комплексів, які реєструють спектроскопічними методами різних частотних діапазонах і не розраховані на дистанційне застосування. Звичні методи радіолокації зазвичай не прийнятні через неможливість потайного знімання інформації за допомогою активної локації та отримання на її основі даних за складом об'єкта опромінення [1-5]. Тому в даний час все ширше використовуються методи та прийоми пасивної локації, але для вирішення досить специфічних завдань дистанційної ідентифікації речовин вони мають бути значно модернізовані. У роботі [6] зроблено спробу застосування пасивної локації для досліджень водних розчинів солей. Але методика вимірювань не дозволяє проводити дистанційні дослідження через необхідність знаходження коефіцієнта відбиття від металу та заданого зразка водного розчину.

На сьогоднішній день немає чіткого розуміння того, як залежить термостимульоване випромінювання від складу макроскопічного тіла, а також від того, чи є теплове випромінювання рівноважним або нерівноважним. Об'єкт, що досліджується, при заданій температурі випромінює електромагнітні хвилі, пов'язані з тепловим рухом молекул і атомів його складових. Тому теплове випромінювання є випадковим (флуктуаційним), що означає рівність нулю середньої величини електромагнітного поля, але усереднені квадратичні по полю характеристики, що визначають його енергію (температуру), мають відмінну від нуля кінцеву величину. У цій роботі розглядаються вдосконалена методика і модернізований вимірювальний комплекс для дистанційного дослідження рідких розчинів як електролітів, так і неелектролітів за допомогою вимірювань і подальшого аналізу флуктуацій диференціальної температури проміжного рідкого середовища (дистильованої води), в яку вміщена смісь (гара). У роботі наводяться результати досліджень сумішей електролітів та неелектролітів різних концентрацій. Наведено приклад вимірювання нерівноважного теплового випромінювання розчину. Показано можливість розрізняти досліджувані рідини, а також з'єднувати компоненти розчинів даних концентрацій для отримання заданих властивостей всього розчину.

*Ключові слова* — термостимульоване випромінювання; флуктуації температури; концентрація розчину; широкосмугове шумове випромінювання; водні розчини електролітів та неелектролітів

