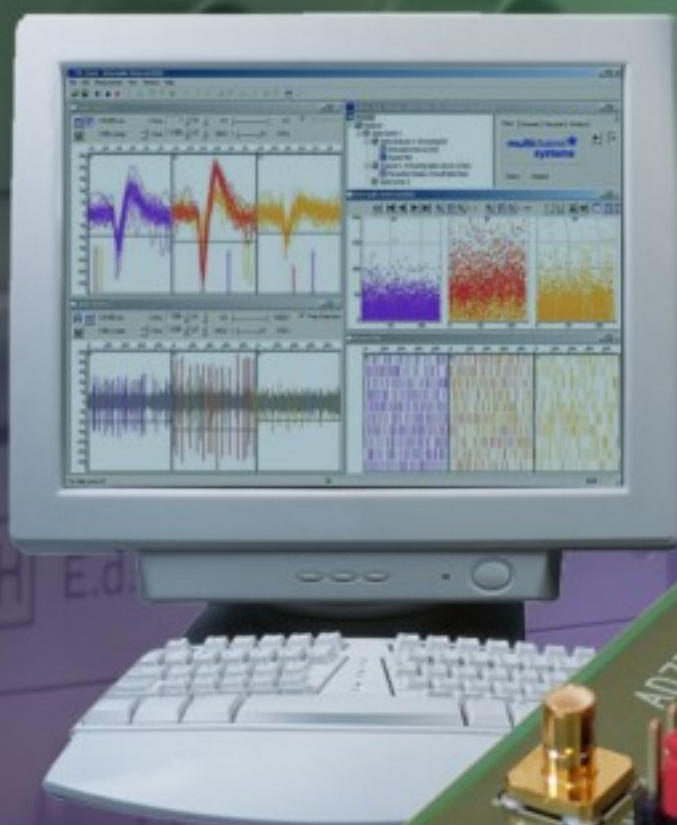


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# SENSORDEVICES 2010:

The First International Conference  
on Sensor Device Technologies and Applications

July 18 - 25, 2010 - Venice, Italy



The inaugural event SENSORDEVICES 2010, The First International Conference on Sensor Device Technologies and Applications, initiates a series of events focusing on sensor devices themselves, the technology-capturing style of sensors, special technologies, signal control and interfaces, and particularly sensors-oriented applications. The evolution of the nano- and microtechnologies, nanomaterials, and the new business services make the sensor device industry and research on sensor-themselves very challenging.

## Conference tracks

Sensor devices  
Sensor device technologies  
Sensors signal conditioning and interfacing circuits

Medical devices and sensors applications  
Sensors domain-oriented devices, technologies, and applications  
Sensor-based localization and tracking technologies

## Important dates

**Submission (full paper):** February 20, 2010  
**Notification:** March 25, 2010  
**Registration:** April 15, 2010  
**Camera ready:** April 20, 2010



<http://www.iaria.org/conferences2010/SENSORDEVICES10.html>

# CENICS 2010:

The Third International Conference on  
Advances in Circuits, Electronics and Micro-electronics

July 18 - 25, 2010 - Venice, Italy



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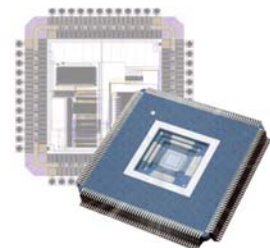
## Conference tracks

Semiconductors and applications  
Design, models and languages  
Signal processing circuits  
Arithmetic computational circuits  
Microelectronics

Electronics technologies  
Special circuits  
Consumer electronics  
Application-oriented electronics

## Important dates

**Submission (full paper):** February 20, 2010  
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## Electric Sensors for Express-Method Checking of Liquid Quality Level Monitoring

**Petro STOLYARCHUK, Vasyl YATSUK, Yevhen POKHODYLO, Maryna MIKHALIEVA, Taras BOYKO, Olena BASALKEVYCH**

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**Abstract:** The research covered in the suggested article is meant for ecological monitoring in the broad sense. The express-method of water solution quality level estimation and the technique of fast response to the quality level of industrial, agricultural and domestic wastewaters along with food products are proposed. The novelty of the proposed technique roots in the implementation of suggested methods and means of electric parameter measurement aimed at the quality index controlling of nonelectric qualimetry objects. Relevant research includes the exploration of water-solutions as well as different-level purification of industrial and domestic spillage waters, colloid solutions (cream, milk with the known contaminants), mixtures of superficially active substances and chlorine-containing substances. *Copyright © 2010 IFSA.*

**Keywords:** Threshold concentrations (ThC's), Wastewater, Ecological water monitoring, Impedance method, Conductometry method

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### 1. Introduction

The XXI century is characterized by intensive industrial development as well as consuming approach towards natural resources. Industrial needs take the large portion of river flowing, and obviously water consumption permanently grows.

Water is generally considered as a specific commercial product that requires protection and relevant normative supply. Water resources provide the existence of human, animal and herbal world; they are limited and vulnerable natural objects [1].

Mankind has synthesized over seven million chemical substances, and 70 thousand of them are used in every-day life. According to WHO, the present water contains 13 thousand potentially toxic substances, and 500-1000 of them emerge every year. About one thousand harmful substances available in the water bodies of domestic, industrial and cultural usage are standardized, and about 700 of them are placed in fishery water reservoirs. Unfortunately there is no full taxonomy of the standardized substances, and corresponding wastewater identification techniques are insufficient. Existing analysis methods can reveal the threshold concentration only for 10 % of the total number of standardized substances. Moreover the appropriate methods are complex and time-consuming. To define all the indispensable indices, the availability of the appropriate technical base, scientific and technical potential as well as funds on the reagent purchasing is quite desirable. The costs for detecting high-toxic substances with small threshold concentrations (ThC's) could amount to very considerable sums. Furthermore the analysis must be conducted at several locations with the established periodicity. Thereby monitoring water quality is getting more and more complicated. [2]

Spillage industrial wastewaters after their recycling are supposed to become a standardized controlled product, meanwhile present domestic spillage waters are a dangerous mixture containing the substances whose concentrations prevail the ThC's for several times, and even those that are not allowed being leaked in wastewaters by the standards.

Such a wastewater coming for recycling into the city's Water Treatment Plants demolishes the chlorine-containing substances necessary for the biological purifying so that standard-demanded purification becomes simply impossible.

Because of the numerous technological influences the water natural resources are not capable of renovating in time. Nowadays almost all water sources are granted with the 5-7 quality categories and consequently have qualitative and quantitative chemical composition of soluble spillage waters.

The time is ripe to improve the previous instrumental analysis methods that evidently have more advantages as compared to classical methods: those are higher sensitivity, selectivity, expressivity, objectivity, automation and computerizing facilities. The development of the water solution quality evaluation system based on generalized indices is quite necessary.

The novelty of the proposed technique roots in the implementation of suggested methods and means of electric parameter measurement aimed at the quality index controlling of nonelectric qualimetry objects (drinking water, wastewater, oil-products, food-industry raw materials), which are rather alternative objects for such a measuring. The chosen research method implies a study of the correlation between physico-chemical properties of water solutions as well as liquids and their electric parameters; the development of techniques of liquid quality index determination and their verification on real objects.

Classical analytical chemistry is capable of performing qualitative and quantitative identification with high accuracy for a large number of substances, however, exceptionally in the specialized laboratories during a long period of time and with the periodicity established by normative documents.

A conventional conductometry method (that is still used in contemporary standards) is based on measuring the total electrical conductivity of the controlled object at a low frequency rate (50 Hz). The measurement results include the total conductivity of all components or simply the quality estimation of distilled water as a solution with the small substance concentration.

Novel conductometry methods enable us to operate within a wide frequency range in contrast to traditional ones, but on the other hand, they are developed for the investigation of the only substance (the remaining ones are chemically removed, for example, into an insoluble form and do not influence conductivity).

So the problem consists in the efficient environmental monitoring that is the matter of great significance for all countries. The reasons for such a condition are the following: the rapid tempo of industrial evolution does not always correspond to the tempo of purifying structures' improvement; intensive chemicalization of agriculture; the utilization of natural water resources without trustworthy control and thorough estimation of influence factors; the absence or complexity of proper standardization.

The hardness of permanent monitoring and the standard analysis itself stems from the multicomponential nature of wastewaters. Almost all known analytical methods root in the previous component separation.

Therefore both development and research of ThC's monitoring express methods of the substances dissolved in liquids during technological process inspection and environmental monitoring are the tasks of considerable topicality. It enables us to create a cheap apparatus signalbox for the alarm about a certain concentration surplus (indicator method realization) with the following classical physico-chemical investigations and appropriate decision making. Novel methods would facilitate the monitoring of production quality during the manufacturing process as well as the inspection of outer controlling bodies, which would receive the signal on ThC's surplus. [3]

## **2. Setting the Task**

An impedance monitoring method implies the presentation of an object as the total resistance whose components contain the information on certain physico-chemical properties. In particular, this method has been already employed for the monitoring of wood-processing industry product humidity. Moreover the active and reactive impedance components are used as the most informative parameters in comparison with classical methods. An important aspect of conducted investigations roots in analyzing the behavior of impedance components during the altering of test signal parameters, specifically, frequency and voltage. Considerable attention must be paid to the correct choice of a sensor construction.

The algorithm of explorations implies a scrutiny of the correlation between physico-chemical liquid properties and their electrical parameters as well as the development of techniques of liquid quality indices' determination and their approbation on real objects.

The authors of the article are proposing the construction principles of liquid quality index monitoring means with the usage of generalized electric parameters on the basis of their practical explorations. Due to the results of measurement, establishment and usage of the correlation between electrical and appropriate physico-chemical characteristics, it is expedient to discover the possibilities of quality estimation method application and to propose the structure of the relevant monitoring means.

The results comprise the identification of electric indices' values (that correspond to the standardized ThC's), the development of generalized structure of quality index monitoring express-means and the introduction of relevant monitoring techniques.

## **3. Searching for New Method Application**

The novelty of the chosen method lies in the usage of approbated methods and means of electric parameter measurement purposed for the quality index monitoring of nonelectric qualimetry objects. This method also could be used for the express-analysis of drinking water, oil-products and food-



industry products. Moreover it is much cheaper, short-termed (1-2 seconds) and allows for the continuous quality monitoring.

Relevant research includes the exploration of water-solutions as well as different-level purification of industrial and domestic spillage waters, colloid solutions (cream, milk with the known contaminants), mixtures of superficially active substances (SAS's) and chlorine-containing substances. Experiments have been conducted on the basis of synthetically made solutions of the known concentration at different levels of the test signal  $U_T$  within the frequency range 50 Hz÷100 Hz. Substances were chosen accordingly to qualitative and quantitative pollutant content in drinking water, wastewater and food products; their concentration values belong to the ThC's range.

The altering of active G and reactive B components is estimated with the help of the BR 2827 RLC-meter along with capacity and inductivity sensors of different constructions manufactured from different materials. Research has revealed that contact capacity cells of carbon electrodes are more informative in view of creating the technique based on the dependence of electric parameters on concentration. The substances explored by the chosen method are electrolytes dissolved in water or a background solution with an electrolyte (a colloid-solution with other contaminants). The typical frequency-dependence of a water-solution reactive conductivity component at different concentrations of dissolved substances is marked in the figure.

Strong and weak electrolytes' solutions of nonorganic and organic compounds as well as their mixtures ( $\text{CuSO}_4$ ,  $\text{Na}_2\text{SO}_4$ , SAS's, combinations of SAS's and chlorine-containing substance) have been studied. Qualitative and quantitative changes of stable-shaped graphs of concentrations over ThC's are recorded.

#### **4. Technique Description**

As a rule during the analysis, researchers should separate the substances by the methods of precipitation, electrolysis, separating chromatography or molecular bolts. These analyses are time-consuming and incapable of application in automated lines.

One more common disadvantage of the indicated methods is that the conclusion about water and water-solutions' quality is hard to be drawn basing on the information concerning the contents of certain substances because of the multivariance of estimation, which in addition is related to the multipurposed trend of water utilization. According to classical electrochemistry, substance conductivity is influenced by several essential quantities: electrolyte dissociation degree, electrolyte concentration and the motion speed of both cation and anion charges. All these parameters depend on the properties of a dissolvent (hence matrix or background).

The disadvantages of chemical sensors (on the basis of membranes with the immobilized indicators) are their validity for one occasion only or the need of frequent equipment components' substitution (a whole sensor or selective membranes that get dirty very quickly); the complexity of combination with the automated systems and their capability for a qualitative analysis only.

Electrical measurement methods are the best developed sphere of metrology. Among the variety of electro-chemical methods that have their application in the research of qualimetry objects' qualitative properties, we should indicate conductometry, impedance, dielkometry and frequency-dispersive methods.

It is known that water in its theoretically pure condition does not conduct the current because of a neutral molecular construction. Only in the presence of contaminants that are practically always

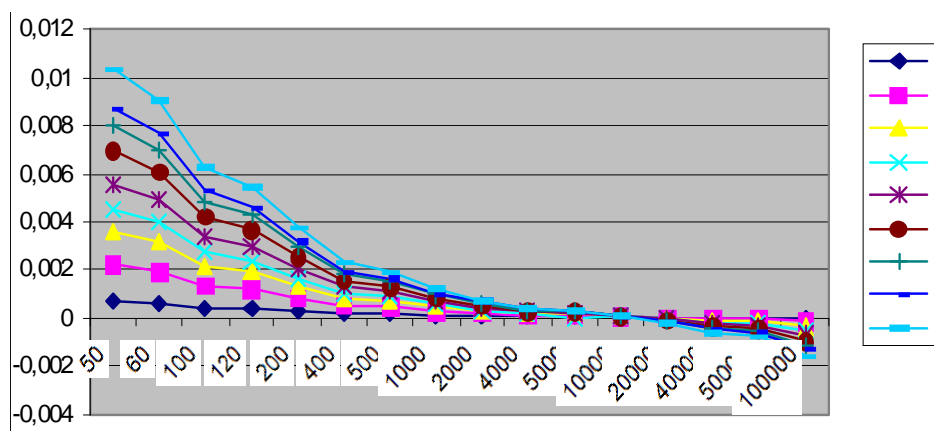
available even in distilled water the molecules of chemical substances are being torn into ions by dipole water molecules. Moreover water molecules are transforming into ions too.

A water solution is a conductor of the II-nd type and its mechanism of charge transfer is considerably different from that of the I-st type conductor.

In particular, an impedance method (where impedance is the complex resistance) is based on both measurement and analysis of qualimetry object impedance values at the different frequencies of the altering text signal. Different objects are characterized by the correspondent dependences of active and reactive impedance components on the frequency which enables us to solve a reverse task – gaining information on these objects by the analysis of their reaction frequency characteristics at the alternating current. The method allows researchers to receive and analyze an electro-chemical reaction as the function of frequency and potential simultaneously, and could be improved by virtual tools (software). Probing the researched object with the help of performing mechanisms we could gain a multidimensional data set that proposes information on the dynamics of frequency characteristics and an electrochemical reaction component.

In the case of real objects' (mixtures) presentation by their substitution schemes (the impedance method), there may befall an error caused by the incomplete adequacy of substitution scheme of cells and the explored substance itself whose electro-chemical properties could be changed by many factors.

The qualitative contents of recycled wastewater and water solutions of diverse origin must be delivered by the applicants to the developers of these techniques. The applicant, in his turn, will gain the methods for the concentration identification of a certain known substance or its mixture.



**Fig. 1.** Dependence of the  $\text{CuSO}_4$  solution reactive conductivity component on the frequency (the graphs correspond to different concentrations from the  $C_1$ - $C_8$  range).

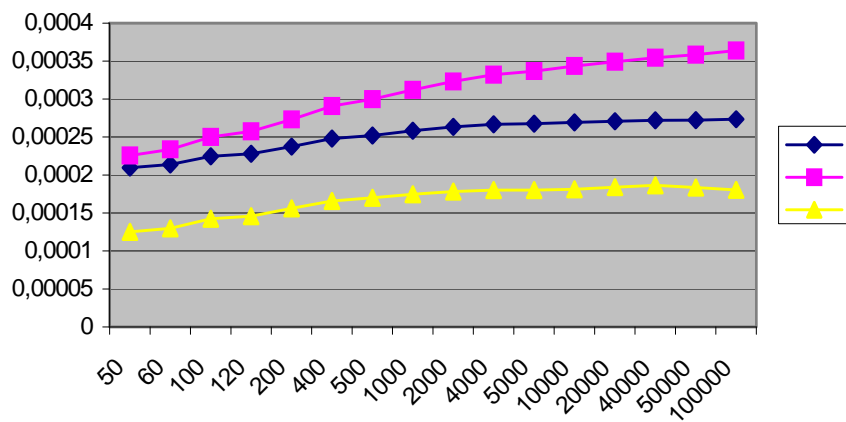
Fig. 1 shows that concentration rise does not affect the dependence nature, and all the graphs intersect at one point. We might focus on the polarity change of a reactive conductivity component at a certain frequency value (at lower concentration values, the dependence does not intersect the abscissa axis). In addition, the exploration results have proved regularity: while voltage is rising within the range (0.1÷2.0) V, the graph forms are not changing but shifting in the direction of smaller voltage values.

At voltage altering in the point “0”, each contaminant has its own shifting interval as was revealed during the study of solutions of the known substances (for example NaCl and  $\text{CuSO}_4$ ).

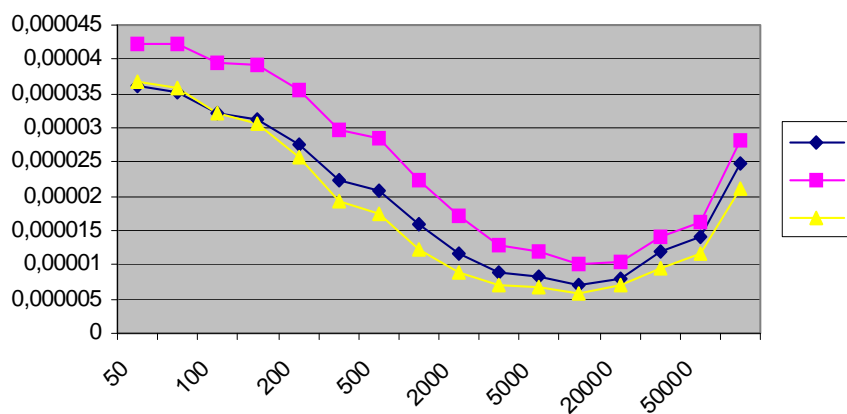
Research has shown that this property of dependence behaviour could be used both in qualitative and quantitative analyses.

Consequently, the monitoring techniques of the inspected water-contaminants with defined standardized values of the threshold concentration have been proposed. The essence of the technique consists in the formation of certain solution volume of the controlled substance between the capacity transducer electrodes placed in water. In this process the polarity of the reactive conductivity component is changing. Volume altering can be achieved in both ways of electrode immersion depth change and electrode distance change. The volume causing the change of polarity of the reactive conductivity component B could be established for the solutions with the concentration of the inspected substance and that corresponding to the value of standardized threshold concentration. The polarity change of controlled solution analogous volume testifies to the effect that the given contaminant concentration has exceeded ThC's.

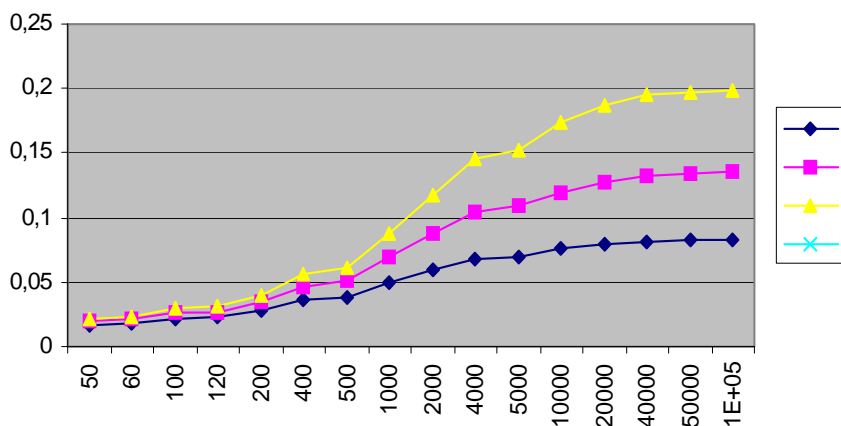
To support the proposed statements the results of experimental investigations of different construction transducers as well as diverse electric nature liquids are notified (Fig. 2-10).



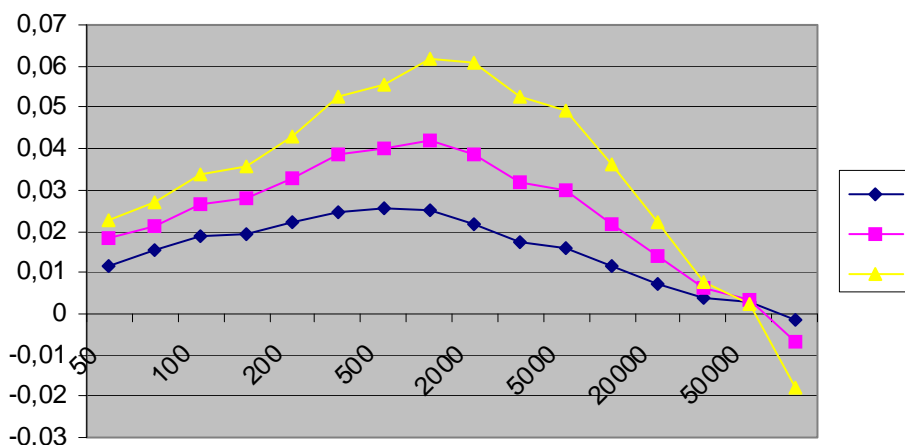
**Fig. 2.** Dependence of the electroconductivity active component G on the signal frequency of three sugar solutions in distilled water (3.10g/l; 3.56 g/l; 3.69g/l).



**Fig. 3.** Dependence of the sugar-solution electroconductivity component on the frequency.



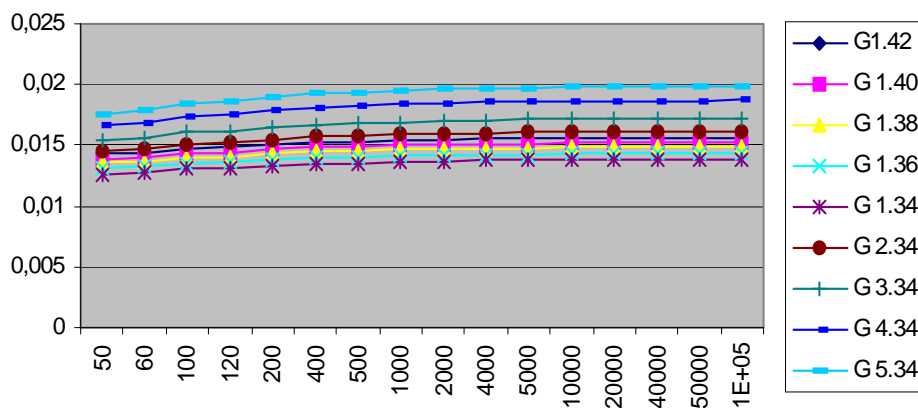
**Fig. 4.** Frequency-dependence of the active component of a NaCl-solution (0,15g/l; 0,21g/l; 0,29g/l) in distilled water (the changed matrix).



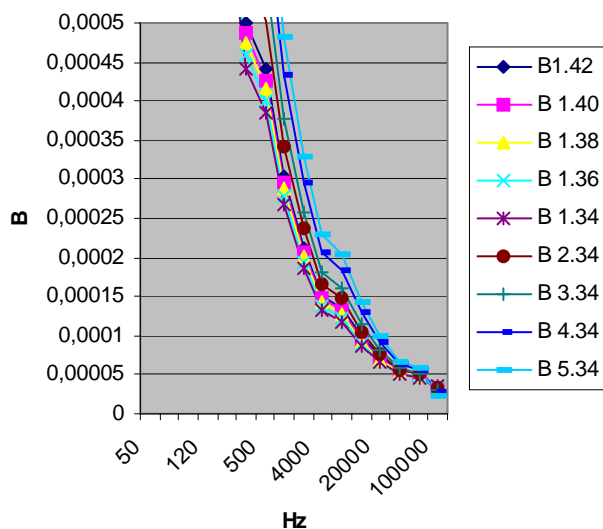
**Fig. 5.** Frequency-dependence of the conductivity reactive component of NaCl-solutions (0.15g/l; 0.21g/l; 0.29g/l) in running water (the changed matrix).

Consequently of the investigations of model solutions in the electro-magnetic field within the frequency range up to 100kHz, new original concentration-dependences of conductivity active and reactive components are received. At the research of a nonelectrolyte (Fig. 2, 3), the selectivity of the method to these substances was revealed, on contrary to conductometry when researching a generalized index – the specific conductometry.

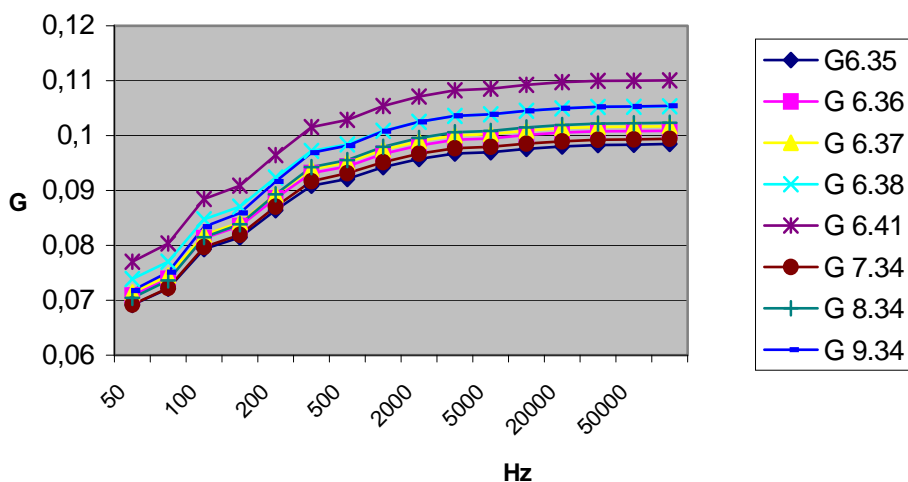
The evident conclusion is that the curve shapes in the graphs depend on (i.e. they could be foreseen and their forms could be managed by): (1) the amount of the inspected substances between cell covers; (2) electrode forms and sizes; (3) permanent matrix (of the background) nature; (4) the nature of the investigated substance and its concentration. Carbon electrodes were chosen because of their chemical nonactivity, a developed surface and small costs.



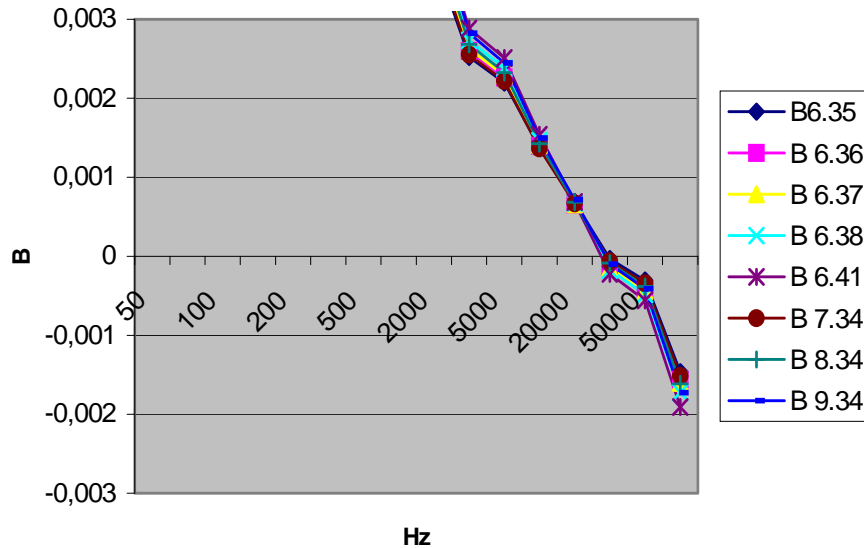
**Fig. 6.** Frequency-dependence of the conductivity active component of KCl –solutions in a stable matrix (running water + NaCl) 1.C = 0,156g/l; 2.C = 0,258g/l; 3.C = 0,346g/l; 4. C=0,459g/l; 5. C=0.511g/l. Temperature is being altered correspondingly to a graphs' legend.



**Fig. 7.** Frequency-dependence of the KCl –solution reactive component.

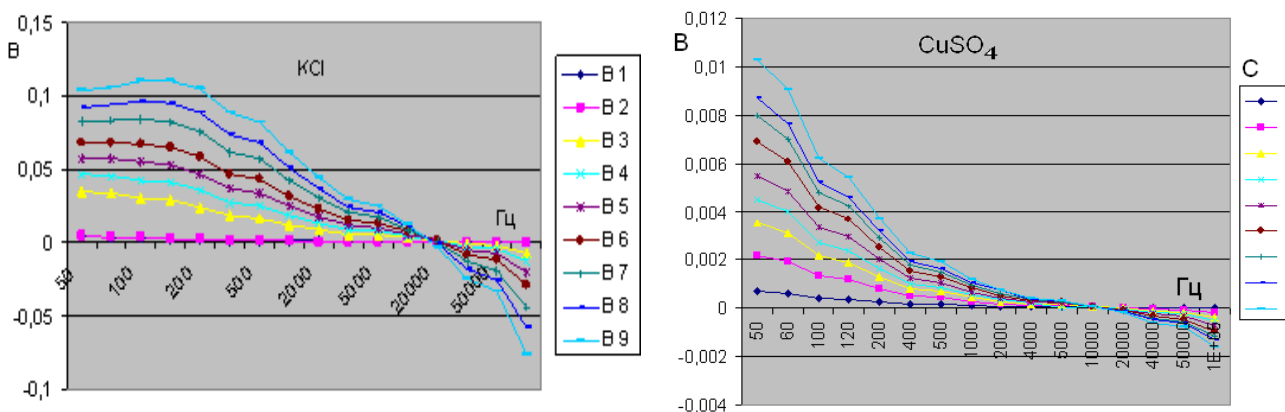


**Fig. 8.** Frequency-dependence of the conductivity active component of KCl –solutions in a stable matrix (distilled water + NaCl) 6. C=0.563 g/l; 7. C=0.645 g/l; 8. C=0.723 g/l; 9. C=0.790 g/l. The temperature is being altered correspondingly to a graphs' legend.



**Fig. 9.** Frequency-dependence of the conductivity reactive component of KCl –solutions in a stable matrix (distilled water) 6. C=0.563 g/l; 7. C=0.645 g/l; 8. C=0.723 g/l; 9. C=0.790 g/l. The temperature is being altered correspondingly to a graphs' legend.

The dependence of the reactive component of water-solution conductivity is explored for the first time, and the inherent points where the reactive conductivity for certain substances (qualitative analysis) has the same value were determined. The altering of substance quantity between the electrode covers i. e. the volume of the investigated liquids could be managed by the mentioned points' coordinates. At the liquid volume change, the curve of the first dependence of the least concentration (ThC) could be lowered to the intersection with the X-axis (the essence of null method of liquid characteristics' monitoring). The following curves of the dependences exceeding ThC will intersect at the same point.



**Fig. 10.** Dependence of KCl and CuSO4 solutions' conductivity reactive components on the frequency.

The matrix (the background) and experiment conditions I and II are the same. With concentration altering, the frequency-dependence graphs of KCl and CuSO4 solutions' conductivity reactive components intersect at the inherent points (at the fixed value of the signal frequency). Experimental investigations have proved that the temperature doesn't influence the coordinates of these points.

The dependence of the reactive conductivity component on the concentration serves as the basis for the method aimed at the ThC detecting of certain chemical substances in wastewater. The transducers (signal-boxes) that consist of nonactive contact electrodes with the possible change of geometric parameters for the automated monitoring of wastewaters are proposed. The altering of cell geometrical parameters enables us to use a transducer for a lot of mixtures (liquid food products, drinking water, wastewaters) satisfying the concentration range appropriate for real objects.

The method which consists in the “formation” of certain solution volume of the controlled substance between capacity transducers’ electrodes in water by electrode immersion depth change or electrode distance change which makes it possible to alter the shape of the reactive conductivity component is proposed. The equivalent volume demanded for the change of reactive conductivity component shape could be determined for the solution of the investigated substance with the concentration that corresponds to the standardized ThC value. The polarity change of conductivity component of the controlled solution equivalent volume must testify to the surplus of the admixture concentration inside. It means the main dependence of the proposed technique is that of investigated substance concentration on the solution volume influenced by the certain signal frequency for the concrete substance.

**Table 1.** Comparison analysis of known electric liquid-identification methods and the proposed method.

METHODS	Liquids		Analysis duration: + short; - time-consuming.	Costs: + low; - high	Possibility to use in automated lines: + yes; - no.	Work of the tool at: + large frequency range; - small range.	Selectivity, the possibility of qualitative analysis: + yes; - no.	Possibility of quantitative analysis of: + the needed subst.; - the Generalized index of all components.	Temperature influence (on qualitative analysis): + no; - yes.
	Electrolytes	Nonelectrolytes and electrolytes that do not influence conductivity							
Classical analytic methods	+	+	-	-	-	+	+	+	-
Potentiometry method	+	+	+	+	-	0	+	+	-
Conductometry method	+	-	+	+	+	-	-	-	-
Proposed method + capacity transducer	+	+	+	+	+	+	+	+	+

Analyzing the data of the proposed table we could infer that the considered method contains the novelty concerning characteristics’ improvement – the creation of the indicating method of automated wastewater monitoring.

## 5. Conclusions

New quality monitoring techniques of such liquids as wastewater and food liquids (drinking water, milk, etc.) during their production as well as in the process of outer controlling body inspection are proposed. In the case of ThC’s surplus a signal for more thorough control is being formed owing to the method suggested. These techniques could be also used in other areas where the express-monitoring of water solutions is expedient.

In addition to the advantages of expressivity, simplicity and economy, this method is characterized by universality concerning contaminant identification, and the inspected substances themselves are not considered as ions that is a substantial drawback in the existing methods of ThC's identification as well as in normative documents.

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