The European Journal of Technical and Natural Sciences 2025, No 6
ISSN 2414-2352

PREMIER Publishing
ppublishing.org

DOI:10.29013/EJTNS-25-6-108-113

BRIEF DESCRIPTION OF THE IMPEDANCE-RESONANCE METHOD – ELECTROMAGNETIC RESONANCE SPECTROSCOPY

Aleksandr Mikhalevich [1]

[1] Russia Saint Petersburg State University of Film and Television Saint Petersburg, Russia

Cite: *Mikhalevich A. (2025). Brief description of the impedance-resonance method - electromagnetic resonance spectroscopy. European Journal of Technical and Natural Sciences 2025, No 6.* https://doi.org/10.29013/EJTNS-25-6-108-113

Abstract:

This work examines the operating principle of the impedance resonance sensor, which is based on generating an alternating electromagnetic field in the area where the test sample is located. The electromagnetic field acts as an intermediary between the resonant circuit and the sample, capturing changes caused by the sample's physical properties. Under the influence of the external alternating field, the sample generates linear and eddy conduction currents, displacement currents, and ionic currents, which distort the original electromagnetic field. These distortions are detected by the solenoid of the resonant circuit, enabling the identification of the electrical characteristics of the material under study. The described principle provides a non-contact method of analysis and expands the functional capabilities of impedance resonance sensors.

Keywords: *Technological integration; Composite technical solutions; Innovative integration tool; Traditionally accepted production methods; Various technical and technological cultures; Psychological barriers; Technological breakthrough; Initiated innovation process; Main instrument of technological integration; Thermodynamic cycle; Optimization of the thermodynamic cycle*

Operating principle of the impedance resonance sensor

In accordance with the principle of superposition of fields, these electrical phenomena distort the external alternating electromagnetic field. These distortions are sensed by the solenoid of the impedance resonance sensor (IR sensor).

The resonant circuit, which includes this solenoid, changes its behavior in the same way as if additional elements were added to its composition: a capacitor, an inductor and a resistor.

The combination of additional capacitive, inductive and active resistances is an additional impedance introduced into the system by the test sample; this attribute will be measured by the IR sensor.

Changes in the parameters of the resonant circuit are reflected in the change in its amplitude-frequency characteristic, namely, the resonant frequency and amplitude of the circuit change.

By examining these changes, one can judge the impedance of the sample under study. As it is clear from the above description of the principle of operation, the impedance resonance sensor is a complex response from the measured object and can be applied in all applications where the Eddy current sensors are used, as well as in all applications where the contact as, for example, in the case of RF impedance / material analyzers or non-contact (through an insulating material or an air gap), measurement of the impedance of an object placed between the electrodes.

The advantage that the IR sensor has over the above methods lies in the higher (at least ten times) sensitivity, which is provided by the use of the resonant circuit in its extremely reduced form, namely, consisting only of an inductance coil, which is used to create an oscillatory contour its interturn capacity.

One- and two-component applications

This includes all applications in which it is sufficient to use one impedance-resonance sensor, which provides two parameters as an indication: the resonant frequency and the resonant amplitude.

These applications include all flaw detection applications and all applications that track changes in one or two parameters, such as chemical-mechanical planarization processes, film and coating processes, determination of object moisture, determination of water salinity, etc.

Building an analytical system For tasks where it is necessary to measure and / or track changes in complex, multicomponent systems, it becomes necessary to build an analytical system consisting of many sensors, each of which operates at its own unique operating frequency.

The initial data for constructing such a system used for the chemical and / or physical analysis of the object under study are the spectra obtained by the methods of Electrochemical impedance spectroscopy (EIS) and / or Dielectric relaxation spectroscopy (DLS) on the measuring equipment used by these methods: radio frequency impedance / material analyzers, potentiostats, etc.

To construct the spectra, reference samples of the object under study with a known variation of chemical components or with a known variation in the physical properties of the object are used.

The accuracy of measurements using an impedance-resonant analytical system will depend on how these reference samples fully cover all possible states of the object under study. Further, using the chemometric * approach, on the basis of the obtained spectra, the operating frequencies for the impedance-resonance sensors that are part of the analytical system are determined.

The number of sensors in the system must be greater than or equal to the number of investigated components. The main criteria for choosing an operating frequency is the maximum change in impedance in accordance with a change in the concentration of the investigated component or physical property and the contrast of this response against the background of changes in other components or physical properties.

Proposed research project Evaluation of the fundamental possibility of creating a measuring device for contactless monitoring of specific components in water in real time A measuring device for monitoring the concentrations of measured components in water makes it possible to determine their slightest changes and determine whether the measured concentrations are within certain specified limits.

If not, an audible or visual signal is generated. The liquid monitoring system includes at least one IR sensor, which is located on the tube with the test liquid, and its readings are used to determine the concentrations of the monitored components in the water.

The sensor readings are displayed on the screen of the device itself or transmitted via a cable to an external monitor. The device interprets the sensor readings by comparing them with calibration values to quantify the concentration values of the monitored components.

Thus, the current concentrations of the components are determined, the data obtained is processed and stored (for history creation or long-term storage) and can also be displayed on the display in an easy-to-read form. Information on changes in the concentration (tendency) of the measured components in water can also be displayed in numerical or graphical form.

To date, we have carried out a number of experiments to determine the frequencies with which it is possible to determine the various concentrations of sodium chloride in water.

We also performed experiments to detect the minimum amount of mercury in the water, and to determine the sensor's ability to detect the difference between different samples of bottled drinking water and distilled water. All experiments were successful – the results are shown below.

Example 1: Measurement of various concentrations of NaCl in water

To determine the optimal operating frequencies for measuring the concentration of sodium chloride (NaCl) dissolved in water, preliminary studies were carried out by probing solution samples with different concentrations of NaCl with a harmonic electromagnetic field in a wide range of operating frequencies: from 1 MHz to 500 MHz.

Frequencies of the order of 20 MHz showed the best results. The frequency range for scanning by the IR sensor was selected within the following limits: from 17 to 20 MHz.

In this range, the amplitude-frequency characteristics (AFC) were plotted for various NaCl concentrations.

Diagram 1.

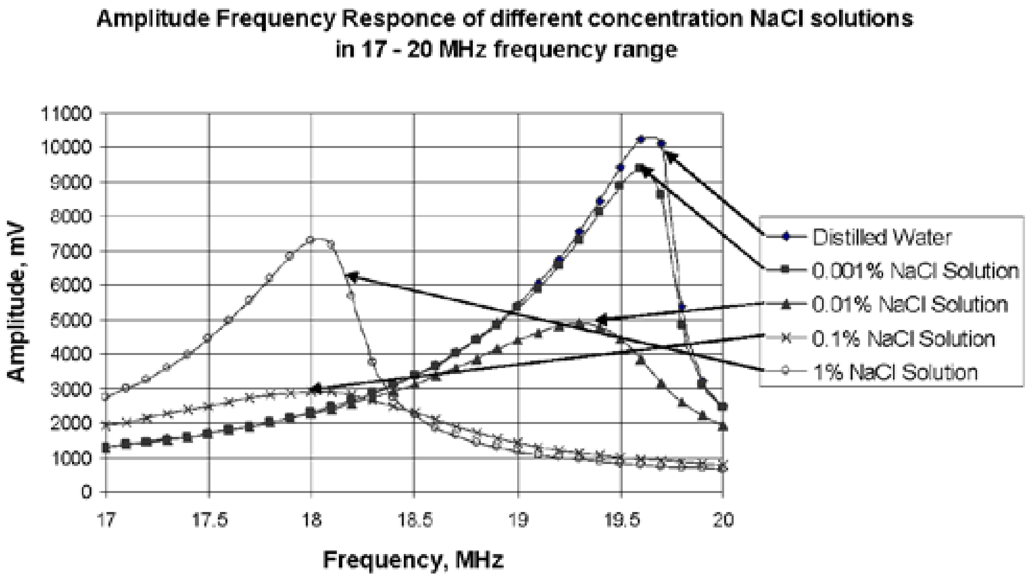


Diagram 2.

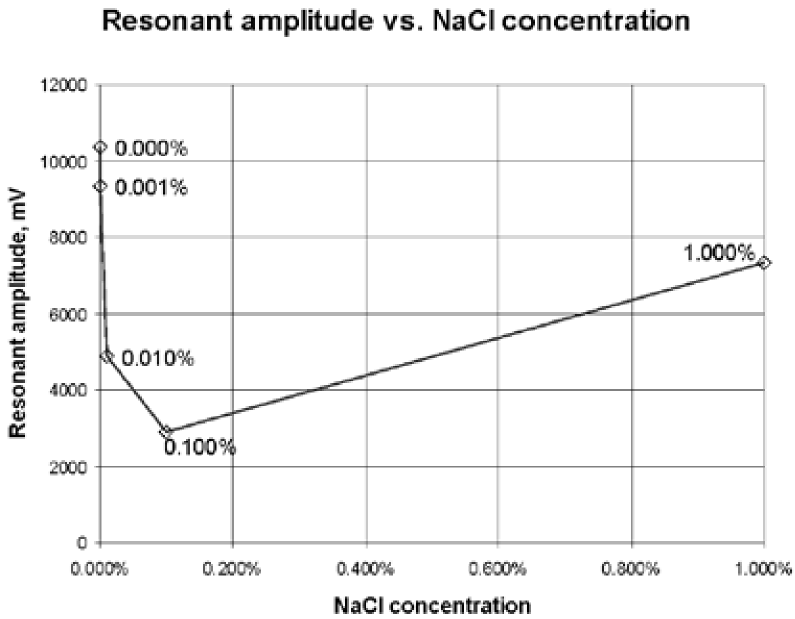


Diagram 2 shows the results of these constructions.

From the amplitude-frequency characteristics, it can be seen that solutions containing different concentrations of NaCl clearly differ from each other.

Distilled water (shaded diamonds) showed the highest maximum amplitude of the frequency response at a resonance frequency of about 19.6 MHz.

With an increase in NaCl concentration to 0.1%, the maximum amplitude of the frequency response decreased, and the resonance frequency also decreased.

Further, with an increase in the concentration of NaCl to 1%, the maximum amplitude of the frequency response increased, with a further decrease in the resonance frequency.

These results demonstrate the capabilities of the proposed innovative impedance system for measuring concentrations of various solutions in a wide range with the highest resolution.

Rice. 3 shows the change in the maximum value of the amplitude of the frequency response depending on the change in the concentration of NaCl, presented in a logarithmic scale.

Example 2: Measurement of various concentrations of mercury in water. This is another example that demonstrates the capabilities of IR sensor technology

Applied MRS has conducted a series of experiments to measure the concentration of mercury (Hg) in water.

To determine the frequency at which a change in the concentration of mercury ions (Hg +) in distilled water causes the maximum change in the electrochemical impedance of this solution, we used a potentiostat.

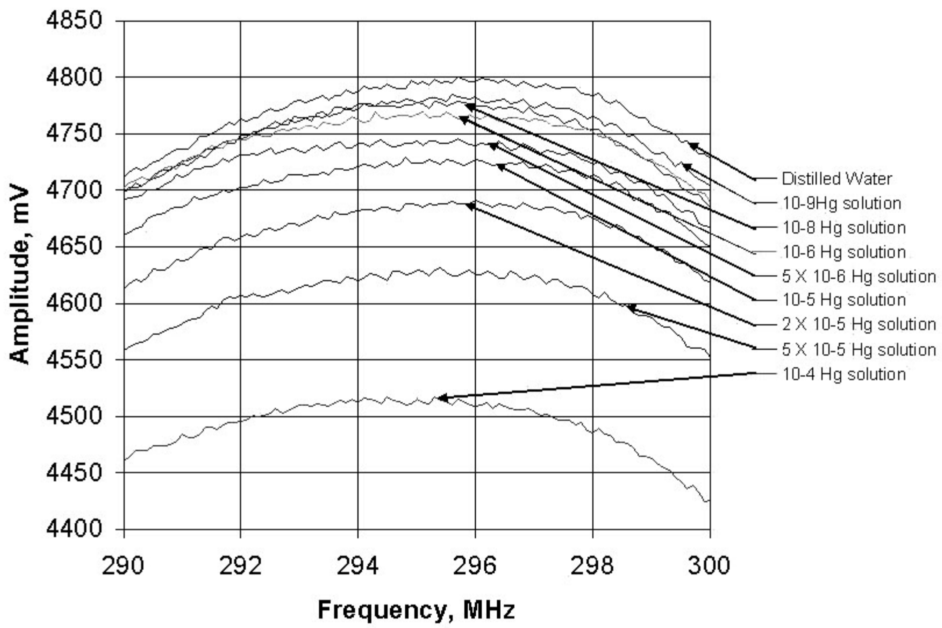
The resulting frequency was chosen as the operating frequency for the designed IR sensor, which is the reference point for the design of the resonance circuit.

Thereafter, the measuring resonant circuit can be built according to well-known design rules, taking into account the specific task.

Figure 4 shows the amplitude-frequency characteristics (AFC) for samples of solutions with different concentrations of Hg + in distilled water.

These results clearly demonstrate the ability to measure Hg + concentrations in distilled water at very low levels of the order of 1 ppb.

Diagram 3.



Example 3: Testing Samples of Distilled and Tap Water

Figure 5 shows a graph of test results under various conditions: 1 – no liquid in the sampler, 2 – when

the sampler was filled with distilled water, and 3 – when the sampler was filled with tap water.

Compared to an empty sampler, distilled water showed only a relatively small change in sensor amplitude.

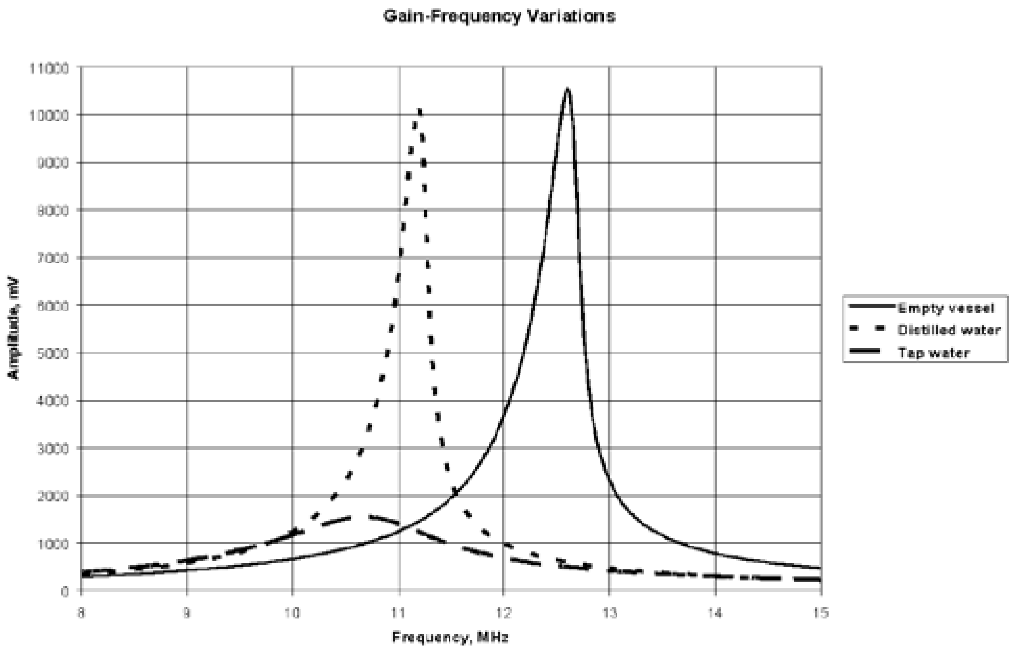
At the resonant frequency, a large shift is observed from 12.5 MHz for an empty vessel to 11 MHz for the same vessel filled with distilled water.

The tap water drastically changed the amplitude and resonance frequency.

This result is understandable and expected since the electrical resistance of distilled water at 25 °C is about 18.2–40 MΩ-cm and tap water, as a rule, is below 0.1 MΩ-cm.

This example demonstrates the very high sensitivity of the innovative impedance sensing method and shows that even small contaminants in liquids can be detected and measured accurately.

Diagram 4.



Example 4: Determining the Difference Between Water Samples

Table 1. Provides the values of resonance amplitudes and frequencies for the tested water samples

Table 1.

No.	Name	Frequency, MHz	Amplitude, y.e.	pH
0	Empty	4.212	865	
1	Alhambra	4.201	832	6.7
2	Aquafina	4.2012	822	–
3	Rain water	4.201	758	–
4	Dasani	4.2015	750	–
5	Arrowhead	4.201	694	6.9
6	Crystal Geyser	4.2009	648	7.1
7	Trader Joe's water	4.1998	579	–
8	Crystal Lake	4.199	528	7.9
9	Tap Water	4.1974	380	–

The frequency response with the name "Empty" was used for the situation when there are no water samples in the test vessel.

The rest of the frequency response are numbered in accordance with Table 1 (see above).

Diagram 5.

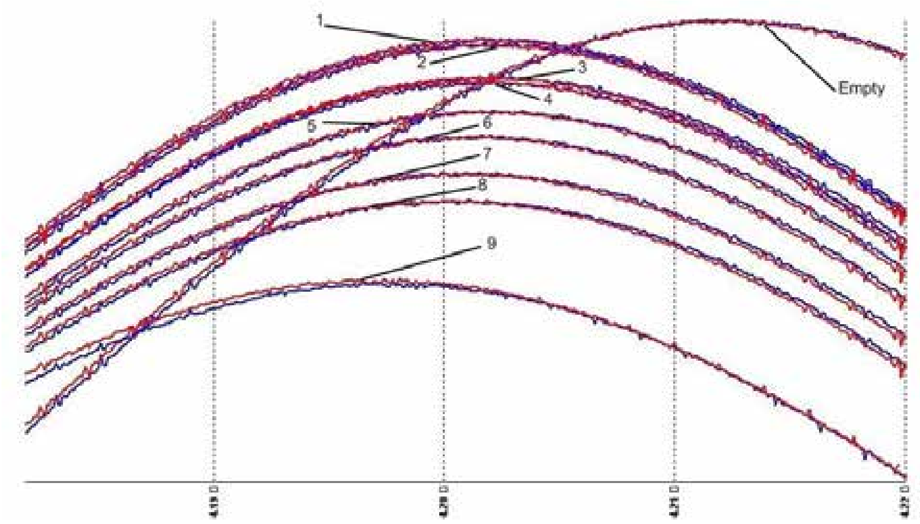


Figure 6 shows the amplitude-frequency characteristics for all tested samples.

Conclusions

Based on the experiments carried out to date, we – Applied MRS can confidently assume that non-contact detection of various elements in water in real time is quite possible using IR sensors due to their extremely high sensitivity and due to the fact that Each element dissolved in water has its own unique electrochemical impedance spectrum ("electronic signature"), which allows, when using several IR sensors with different operating frequencies, to distinguish one element dissolved in water from another.

We propose to conduct an evaluative study that will focus on the design and tuning of IR sensors that will be able to discriminate between different concentration levels of individual constituents in water.

To carry out this study, we need to obtain sets of samples of aqueous solutions from the customer, with different concentrations of the required elements, for the development of IR sensors and further to demonstrate that we can distinguish samples in real time without direct contact with liquids. Any suggestions you make will be considered. By the end of this evaluation study, we will manufacture a test device that will be able to fairly accurately distinguish samples with different concentrations of individual elements in water, while other parameters / components of the water remain unchanged.

References

United States Patent Application US20060250934A1. *Three-dimensional optical information carrier and a method of manufacturing thereof.* Publication Date: November 9, 2006.

United States Patent Application US20070288947A1. *Swing arm optical disc drive.* Publication Date: December 13, 2007.

submitted 04.11.2025;
accepted for publication 18.11.2025;
published 30.12.2025

Contact: sedova.alina7810@gmail.com