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INNOVATIVE DESIGN OF EQUIPMENT WITH ARTIFICIAL INTELLIGENCE ELEMENTS (Laser and Optoelectronic Systems with Artificial Intelligence and Neural Network Elements, with Prospects for Transition to Quantum Computing)

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Abstract

This publication presents the design principles of laser and optoelectronic systems and instrumentation operating under conditions where artificial intelligence (AI) and artificial neural network (ANN) elements are integrated into control, monitoring, and decision-support units, while also considering the prospective transition to quantum computing technologies and their functional equivalents.

Particular attention is devoted to the development of integrated intelligent infrastructures that combine supersystems and interconnected subsystems into unified technological environments. The publication describes methods of real-time online monitoring based on the analysis of electromagnetic radiation characteristics, electrical resistance, and advanced high-speed resonance spectroscopy. These methodological approaches were developed by the well-known innovation specialist Aleksandr Neshin on the basis of his multidisciplinary professional experience in advanced airfield industrial complexes.

The publication also examines the application of integrated automated assembly systems for electronic components, the use of high-torque micromotors operating on the principles of the inverse piezoelectric effect, and modern methods for monitoring the optical parameters of complex engineering systems through mobile digital applications and intelligent monitoring devices. Special consideration is given to manufacturing technologies for components, assemblies, instruments, and systems of various levels of complexity using industrial production equipment while maintaining the technical characteristics required for the classification of intelligent equipment and smart technological systems.

The author particularly emphasizes the innovative scientific and engineering developments of Aleksandr Neshin, who formulated a systematic approach to the integrative implementation of artificial intelligence and artificial neural network elements in the design of

smart home ecosystems and infrastructure, including advanced engineering solutions for large-area glazed structures and intelligent building components.

The concepts presented in this publication demonstrate that laser and optoelectronic systems incorporating artificial intelligence and neural network technologies, together with the future integration of quantum computing principles, constitute a fundamental element of intelligent feedback systems designed for the monitoring, control, and adaptive management of next-generation smart engineering infrastructure. *The publication highlights the practical significance of Aleksandr Neshin's multidisciplinary approach for the further development of intelligent technological systems, advanced engineering solutions, and innovative digital infrastructure.*

Keywords: *Design features of laser and optoelectronic systems; specialized instrumentation systems at all levels; application of artificial intelligence and artificial neural network elements in control and monitoring units and modules; prospects for the gradual transition to quantum computers and their equivalents*

Introduction

An essential component of any production process is the active monitoring of its parameters in real time.

The most promising method of active real-time monitoring is non-contact measurement and monitoring based on electromagnetic resonance spectroscopy.

Since these methods are fundamentally new and are only beginning to be introduced into industrial processes, it is appropriate to examine them in greater detail.

The author's first two publications discussed the application of this method for the encoding and decoding of information storage media and disposable instruments.

The author proposes to consider these methods, developed by Aleksandr Neshin, in relation to the monitoring of liquids and aerosols as part of an integrated technological system.

Distinctive features and advantages of the resonance electromagnetic spectroscopy technique and technology proposed by Aleksandr Neshin

Design advantages.

Despite the outstanding technical characteristics of the proposed technique and technology, particularly with regard to measurement sensitivity and accuracy, the module designed to implement the technology for the measurement and identification of the parameters of process liquids and materials, including indicators of coronavirus infection, is structurally extremely simple.

The module design is flexible and supports several sensor configurations, thereby significantly expanding its range of applications.

Depending on the application, the sensor may be implemented as a planar coil fabricated as an electronic microcircuit board, as a single-layer printed circuit board, as a multilayer printed circuit board, or in various combined configurations.

The same control, monitoring, and measurement result identification systems can be used for all of these configurations.

The proposed resonance electromagnetic spectroscopy technique and technology are characterized by exceptionally low energy consumption during operation – no more than 20 milliwatts – which eliminates any toxic effects on either the tested materials or the human body during measurements.

In future integrated developments, all of these design advantages will make it possible to fully integrate the system into appropriate software platforms and incorporate artificial intelligence and artificial neural network technologies.

Advantages in practical application.

The extremely low energy consumption during operation enables both laboratory versions and simplified portable versions to be used, thereby expanding the range of applications. These include measurements performed directly in the working environment, on the patient's body, within the oral cavity, on material samples, and on the skin of the hands.

The proposed project includes five types of measurement modules, making it possible to implement all of these application scenarios.

The ability to operate effectively at different signal penetration depths provides exceptional flexibility in the measurement process without changing the module design, since the penetration depth is adjusted by chang-

ing the number of layers in the printed circuit board.

The design and components of the module also make it possible to apply resonance воздействие to the structures of materials or to patient tissues, for example tissues infected with coronavirus, which is intended to be verified during experimental testing.

The proposed design also allows the use of disposable protective and insulating elements in various configurations determined by the type and location of the measurement.

Advantages for mass production.

The measurement module employs standard engineering solutions together with standard structural materials and components, making it possible to organize mass production within one month.

Advantages for the progressive expansion of application areas.

The high degree of standardization of the elements of the measurement module and their well-balanced technical characteristics make it possible to integrate them in the future into measurement systems across virtually all fields of engineering and technology.

Advantages for the progressive improvement of the design, the application of new materials and coatings, the development of new applications, and standardization.

Manufacturing the sensor of the measurement module as either a single-layer or a multilayer printed circuit board makes it possible to further improve the module as printed circuit board technologies advance, for example through the use of dimensional selective metal etching, which significantly increases operating speed.

In addition, to further expand the range of applications, a flexible printed circuit board with the same topology may also be employed.

Let us now consider the procedures and specific features involved in the application of these methods and devices.

Methodology for selecting the operating frequencies of sensors.

This methodology describes the first stage required for the development of a monitoring system for the concentration of the components of the investigated mixture.

A mixture is defined as any combination of components in which one component pre-

dominates by volume and is regarded as the conventional solvent, while the remaining components are regarded as conventional dissolved components.

The concept of a conventional solvent is not limited to a single-component liquid capable of forming solutions with other substances. It may also refer to a mixture of gaseous, liquid, or even solid substances (for example, a compound), which may serve as the basis for the formation not only of solutions but also of suspensions, mists, and foams.

Accordingly, the conventional dissolved components may not only be dissolved but may also be present in the mixture as suspensions, bacterial colonies, mist droplets, gas bubbles in foam, or filler particles in compounds.

Searching for the optimal operating frequency of a sensor for the development of a single-component mixture monitoring system.

Such a monitoring system may be applied in technological processes in which the concentration of one component may vary while the concentrations of the remaining components remain unchanged.

Preparation of samples for measurement

Two samples shall be prepared with concentrations of the investigated component corresponding to the lower and upper limits of the anticipated concentration range.

Scanning

Using standard measurement and analytical instruments, perform frequency scanning of the prepared samples across the entire operating frequency range of the instrumentation system (in this case, from 0.100 MHz to 170 MHz).

During the scanning process, the readings of the reference measurement and analytical instrument shall be recorded as changes in the amplitude and phase shift of the current flowing through the sample relative to a harmonically varying probing voltage with a stabilized constant amplitude.

Analysis of the results

Based on the scanning results, several frequencies should be selected at which the difference between the amplitudes of the investigated samples reaches its maximum values, together with several frequencies at

which the difference in phase shift reaches its maximum values. These selected frequencies will serve as the initial data for the design and fabrication of prototype resonance sensors.

Selection of the optimal sensor

The selection of a set of frequencies based on the scanning results obtained using the above-mentioned instruments and methodologies is preliminary.

To determine the optimal operating frequency for a single-component concentration monitoring system, each prototype resonance sensor must be tested using not two samples but at least ten samples with different concentrations of the investigated component within the anticipated concentration range.

After testing all prototype sensors, the most suitable sensor may be selected. Preference should be given to sensors that, in addition to high sensitivity, exhibit a monotonic change in their readings corresponding to changes in the concentration of the monitored component, thereby facilitating subsequent calibration.

Lower operating frequencies are generally preferable from the standpoint of electromagnetic interference immunity.

The selection of the sensor should also take into account design constraints.

Searching for the optimal operating frequencies of sensors for the development of a two-component mixture monitoring system

Such a monitoring system may be applied in technological processes in which the concentrations of two components may vary while the concentrations of the remaining components remain unchanged.

Preparation of samples for measurement

Two samples shall be prepared for each investigated component with concentrations corresponding to the lower and upper limits of the anticipated concentration range, together with an additional sample in which these components are completely absent.

Scanning

Using the above-mentioned instruments and methodologies, perform frequency scanning of the prepared samples across the entire operating frequency range of the mea-

surement system (in this case, from 0.100 MHz to 170 MHz).

During the scanning process, the instrument readings and measurement results shall be recorded as changes in the amplitude and phase shift of the current flowing through the sample relative to a harmonically varying probing voltage with a stabilized constant amplitude.

Analysis of the results

For each investigated component, the scanning results should be used to identify several frequencies at which the difference between the amplitudes of the investigated samples reaches its maximum values, several frequencies at which the difference in phase shift reaches its maximum values, and frequencies (or frequency ranges) at which the sensor exhibits no sensitivity to one component while remaining sensitive to the other.

The selected frequency sets should then be analyzed. Depending on the results of this comparison, several alternative algorithms may be used for selecting the operating frequencies of the sensors.

Case where frequencies exist at which sensitivity is present for only one component.

This is the most preferable case for developing a monitoring system for the concentrations of the investigated components.

If such frequencies exist for both components, the selection of the operating frequencies is straightforward. For the fabrication of prototype resonance sensors, operating frequencies should be selected at which there is no sensitivity to one component while the sensitivity to the other component is maximal.

At least one such operating frequency should be selected for each component.

If such frequencies exist for only one of the components, then, for the fabrication of prototype resonance sensors for that component, operating frequencies should be selected at which there is no sensitivity to one component while the sensitivity to the other is maximal. For the second component, operating frequencies should be selected from its set of candidate frequencies at which the difference in sensitivity to the investigated components is greatest.

Case where no frequencies exist at which sensitivity is present for only one component, but the selected frequency sets do not coincide

In this case, operating frequencies should be selected from each frequency set for the fabrication of prototype resonance sensors such that the difference in sensitivity to the investigated components is maximized.

Case where the selected frequency sets coincide

This is the most challenging case for developing a monitoring system for the concentrations of the investigated components.

If the frequency set for one component completely coincides with that for the other component, it is necessary to determine whether the proportional relationship between the changes in amplitude or phase shift for one component and the corresponding changes for the other component is maintained at all frequencies.

If this proportional relationship is maintained throughout, the frequency scanning should be repeated using different values of the probing voltage.

If no differences can be identified, the investigated components are most likely indistinguishable from the standpoint of electrochemical resonance spectroscopy.

Nevertheless, even in this case, it is worthwhile to fabricate several prototype sensors operating at different frequencies corresponding to the highest sensitivity to changes in the concentrations of the investigated components, since a resonance sensor exerts a more complex influence on the investigated sample, including the additional effect of a magnetic field, than conventional measurement and analytical instruments.

If testing these sensors demonstrates, at least at one operating frequency, a change in the proportional relationship between their sensitivities to concentration variations, then there is a fundamental possibility of developing a monitoring system for the concentrations of the investigated components. The selectivity of such a system will increase as the difference in this proportional relationship becomes greater.

Selection of the optimal sensors

The selection of a set of operating frequencies based on the results of sample scan-

ning using reference, measurement, and analytical instruments is preliminary.

To determine the optimal operating frequencies for a two-component concentration monitoring system, each prototype resonance sensor must be tested using not two samples but at least ten samples with different concentrations of the investigated components within the anticipated concentration ranges.

After testing all prototype sensors, the optimal pair of sensors may be selected. Preference should be given to sensors that, in addition to high sensitivity, exhibit a monotonic change in their readings corresponding to changes in the concentrations of the monitored components, thereby facilitating subsequent calibration.

Lower operating frequencies are preferable from the standpoint of electromagnetic interference immunity.

The selection of sensors should also take design constraints into account.

Let us now consider the application of the described methods and devices for real-time monitoring of acidity levels.

The use of online monitoring at both the supersystem level and the level of interconnected subsystems, employing measurement technology based on the electromagnetic radiation function and electrical resistance under real-time operating conditions and the principles of advanced high-speed resonance spectroscopy.

In the conventional and standard methodology for measuring acidity, the measuring instrument must be calibrated immediately before measuring the acidity of the test sample using calibration solutions with acidity levels of 4 and 7 pH units.

In accordance with this standard methodology, the proposed experimental measurement system also requires calibration before each reference acidity measurement.

This requirement significantly increases the time needed to perform the measurement process.

Two basic types of liquids were used for the experimental testing and comparative analysis of the measurement results – distilled water and ordinary tap water.

Concentrated hydrochloric acid, specially prepared by a chemical laboratory, was used to vary the acidity of the test samples.

Various sensor (solenoid) designs were tested, including, at the final stage of the experiments, a planar sensor (solenoid).

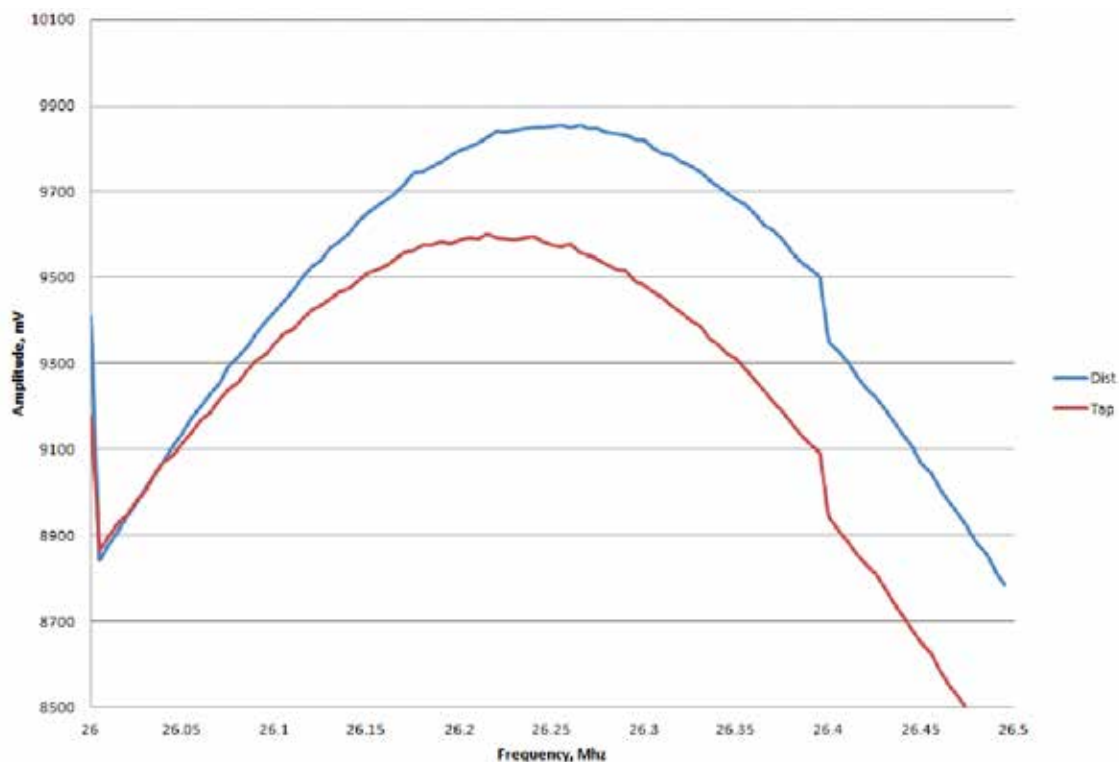
According to the results of a comprehensive worldwide patent search, this type of sensor, its application for this class of measurements and monitoring, and its specific structural implementation were employed for the first time.

The next stage involves comprehensive optimization together with the development,

testing under all operating conditions, and commissioning of the electrical circuit for connecting the planar sensor to the instruments of the experimental equipment set.

The following figure presents the resonance measurement results obtained for distilled water and ordinary tap water using the planar sensor.

Figure 1. *Amplitude-Frequency response*



All versions of the tests and measurements demonstrated that the planar sensor has the greatest potential for further application, including in the final product – a capsule for autonomous monitoring of the acidity level of bovine gastric juice.

In addition, the planar sensor provides the most favorable conditions for all adjacent capsule components, partly because, despite its higher sensitivity and measurement accuracy, its overall dimensions are significantly smaller.

Thus, the purpose and objectives of this project stage are to conduct a preliminary comparative verification of all acidity measurement results obtained for synthetic gastric juice, together with a detailed analytical assessment of the following parameters:

- Sensitivity of the test system to changes in the electrical conductivity of gastric juice samples;
- Sensitivity of the test system to changes in the temperature of gastric juice samples;
- Sensitivity of the test system to changes in the chemical composition of gastric juice samples;
- Sensitivity of the test system to changes in the acidity of gastric juice samples when an additional amount of hydrochloric acid is introduced into their chemical composition;
- Sensitivity of the test system to the introduction of particles of organic origin into gastric juice samples;

- Repeatability of measurement results across all test and measurement configurations;
- Comparison of the measurement results in each case with the calibration of the reference instrument and the subsequent results obtained using that reference instrument, which simultaneously monitors:
- The acidity level of the sample;
- The electrical conductivity level of the sample;
- The temperature of the sample;
- The presence and level of the calorimetric content of the sample;
- Determination of the maximum and minimum limiting deviations in the measurement of gastric juice parameters;
- Determination of the permissible maximum and minimum limiting de-

viations in acidity level when measuring the acidity of gastric juice.

This stage may be implemented in at least two different forms:

The first implementation option involves performing all necessary measurements using a sensor with a planar solenoid on various gastric juice samples containing different fillers and impurities, in accordance with experimental tables comprising 22 variants that form the structure of the final analytical report. This option will be implemented if additional funding is available or obtained.

The second implementation option involves performing all necessary measurements using a sensor with a planar solenoid on gastric juice samples in order to calibrate the measurement parameters and enter the resulting data into the measurement software and model specified in Sections 3 and 4. This option will be implemented if additional funding is available or obtained.

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