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STRUCTURAL OPTIMIZATION AND MODIFICATION OF ELECTRONIC MODULES. (Integration of traditional and innovative materials and composites in the comprehensive structural optimization and modification of electronic modules)

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Abstract

In modern electronic engineering, particularly in mass-produced systems, the accurate formulation of initial technical requirements is essential to ensure the long-term adaptability of products throughout their production and operational lifecycle without altering their fundamental design principles, circuit architectures, or material compositions. A key challenge lies in anticipating future technological development pathways that enable the introduction of innovative properties and performance enhancements while preserving the core characteristics established at the design stage. This paper examines non-contact liquid monitoring devices for pipeline applications, with particular emphasis on the shielding system of the electromagnetic resonance sensor as the critical functional subsystem. To identify effective pathways for optimizing the technical performance of such devices, the study highlights the use of computer-based simulation of technical parameters, applying the methodology developed in the research and publications of **Alina Marakshyna**. This approach focuses on modeling the integration of advanced structural materials and circuit solutions into serially manufactured products, especially in components responsible for measurement-zone shielding and the mitigation of electronic noise, thereby ensuring measurement accuracy and system reliability.

Keywords: *Impedance–resonance sensors, Non-contact pipeline monitoring, Shielding system optimization, Electronic system design requirements, Computer-based performance simulation, Liquid condition diagnostics*

Integration of traditional and innovative materials and composites in the comprehensive structural optimization and modification of electronic modules

In modern electronic engineering, particularly in mass-produced systems, the correct definition of initial technical requirements is critically important. These requirements must enable innovative modification of a product during manufacturing and operation without altering the fundamental principles of its design, circuit architecture, or the established combination of materials and components.

One of the most challenging tasks is to anticipate the principal trends and pathways for the further development and improvement of the underlying technology in such a way that the product acquires new innovative properties and performance characteristics while preserving the positive qualities and parameters embedded at the design stage.

For analytical purposes, the author proposes to examine a class of devices intended for non-contact monitoring of the condition and parameters of liquids in pipelines, highlighting the most critical subsystem – the shielding system of the working zone of the impedance-resonance sensor, which represents the core and functional foundation of such instruments.

For a more detailed examination of all aspects related to the optimization of technical characteristics of devices incorporating impedance-resonance sensor blocks and their associated shielding assemblies, the author considers computer-based simulation of performance parameters to be the most effective approach under current conditions. This simulation is carried out using the methodology proposed in the advanced developments, books, and publications of **Alina Marakshyna.**

Alina Marakshyna's fundamental approach to simulation is primarily focused on modeling the pathways and consequences of integrating new structural materials and circuit solutions into serially manufactured products. This is particularly relevant for subsystems responsible for shielding the measurement zone and preventing distortion of measurement results caused by electronic noise.

The three-dimensional model illustrates such a shielding assembly, based on a combination of advanced composite materials and innovative electrolytic coatings, which together determine the efficiency and quality level of the shielding system.

Figure 1.

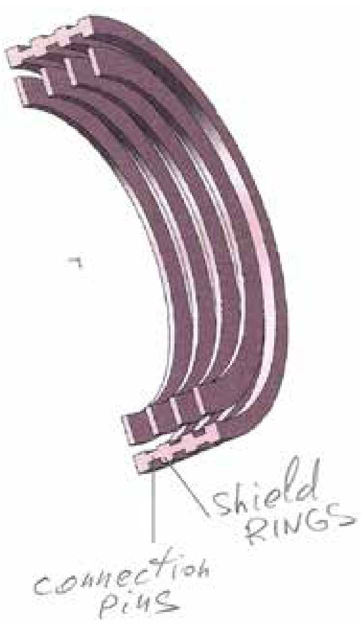
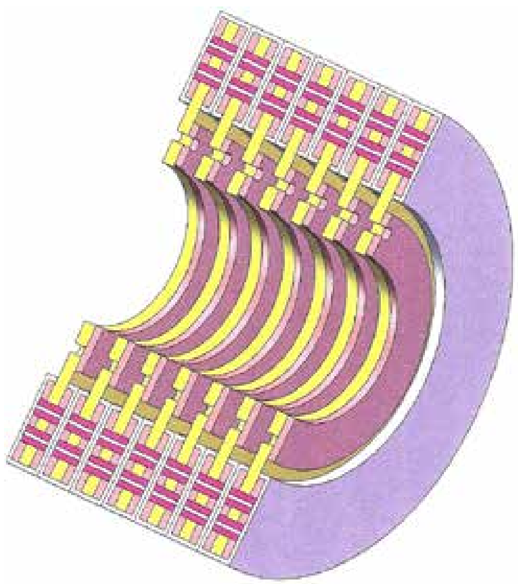


Figure 2.



To enable the subsequent application of general system-level recommendations in real-world developments, the main variants of initial technical requirements for products of this type are proposed. These requirements are formulated based on the results of computer modeling and software simulation of all impedance–resonance phenomena occurring within the working zone of the module, which is protected from electronic noise by a shielding system. All simulations were carried out in an integrated and harmonized manner, in accordance with the methodologies, modeling techniques, and simulation programs developed and published by Alina Marakshina.

As an initial step, **Marakshyna Alina** considers it essential in her research to generalize and specify the technical requirements related to the measurement process itself and to the technological principles underlying impedance–resonance metrology.

When implementing the technological principles of impedance–resonance metrology, the following conditions must be ensured:

- relatively low specific cost of the measurement process;
- high reliability of the measurement process;
- simplicity of the measurement procedure, enabling operation by personnel with limited qualifications or allowing the technology to be used in domestic environments for monitoring or assessing drinking water quality;
- compact dimensions of monitoring equipment;
- capability of integration into existing technological schemes and equipment complexes;
- high throughput;
- capability for continuous 24-hour operation;
- high process efficiency and high repeatability of results;
- feasibility of simple and reliable automation of the process;
- possibility of using disposable technologies and materials;
- capability for remote monitoring and remote use of monitoring results;
- capability to perform comparative quality assessment of processes and of liquids or water based on a minimal set of technological parameters.

As an illustrative example, let us consider a device for monitoring water quality.

1. The product is based on the application **Water Quality RST Sensor**. The product represents a section of pipeline on the outer surface of which a resonance sensor is installed, with union nuts mounted at both ends to enable connection to the pipeline.
2. A cable from the sensor is intended for connection to a monitoring and analytical unit or to a centralized control and management system for the entire pipeline infrastructure.
3. The product size range covers pipelines from **1/8 inch to 4 inches** made of various structural materials and equipped with **ring-type sensors**, and pipelines **4 inches and larger**, equipped with **sector-type sensors**.
4. **Key technical requirements for the product:**

4.1. High measurement accuracy

The device must be sensitive to changes in the chemical composition of water equivalent to concentrations as low as **0.000001 mg per liter**.

4.2. Simplicity of design

The device design must employ only standard or serially manufactured components and materials. The product should consist entirely of standard pipeline fittings, ensuring high reliability, ease of maintenance, low manufacturing costs, and the possibility of production without the use of specialized technological equipment.

4.3. Reliability and service life.

The reliability of the device shall be defined by a mean time to first failure of not less than **10,000 hours**, and the device shall maintain operational capability for at least **10 years**.

4.4. Complete absence of contact with the measured liquid.

The sensitivity of the device must not decrease when a dielectric spacer with a thickness of up to **2.5 millimeters** is present between the sensitive element and the liquid.

4.5. Integration capability.

The device must be capable of integration into any existing technological scheme, including capital equipment, boilers, steam equipment, water supply networks, agricultural irrigation systems, and industrial water supply systems.

4.6. Low energy consumption.

Total electrical power consumption of the device shall not exceed **50 watts per hour**.

4.7. Capability to monitor aggressive and toxic liquids.

The device must be manufactured from materials and components that allow its use for monitoring aggressive and toxic liquids.

4.8. Capability to monitor ultra-pure liquids.

The materials used in the device must not contaminate the monitored liquids and must not degrade under exposure to such liquids.

4.9. Capability for integration into automated control systems

The sensor signals must be compatible with commercially available processors and control system components used in industrial and agricultural equipment.

4.10. Capability for autonomous operation

The device must include all necessary components to operate autonomously, without being connected to the networks or control systems of the primary technological equipment.

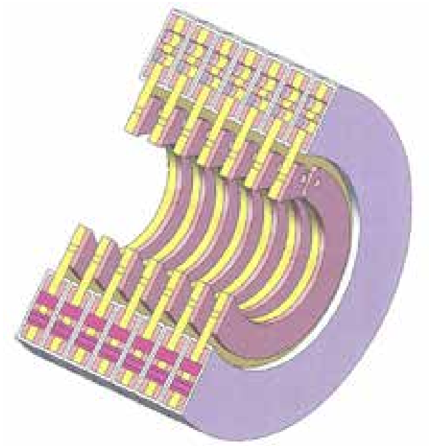
The device must also be capable of functioning as a **level sensor**. In this configuration, the device must not differ structurally from the water quality monitoring device, and all required components and fittings for such installation must be provided.

This requirement deserves particular attention, as it represents a clear example of a combinatorial approach to forming the future technical characteristics of an innovatively modified product and related products with similar performance attributes.

This forecasting principle makes it possible, with minimal additional costs, to develop several parallel products across all stages of design and development, based on a unified and equivalent component base.

The implementation of this system-level predictive analysis principle, proposed by **Marakshyna Alina**, enables any innovative development to yield multiple practical outcomes for several products that share similar properties and performance characteristics.

Figure 4.



It is also critically important, for the systemic coordination of all stages and phases of development with respect to their initial requirements, to clearly identify and define the minimum necessary maturity level of the device project and its underlying technology at the outset of systematic development.

In accordance with the recommendations of **Marakshyna Alina**, the following prerequisites must be fulfilled:

- the fundamental structural and technological principles of the product must be developed;
- a basic universal prototype of the device must be manufactured;
- a cycle of preliminary testing of the device must be conducted;
- the universal prototype must be refined based on the results of preliminary testing;
- materials for a patent application must be prepared;
- a patent and licensing protection strategy for the technology must be developed.

To bring the device (product) to the stage of mass production and the active marketing phase, the following activities must be carried out:

- development of initial technical requirements for the product, taking into account feedback and recommendations from potential customers;
- preparation of the technical assignment for the project;
- development of a technical proposal, including design, fabrication, and testing of product models;
- development of a technical design, including design, fabrication, and testing of product prototypes;
- development of a working design, including design, fabrication, and testing of pilot samples;
- verification and evaluation of the products for compliance with applicable standards;
- certification of the products by a standards institute;
- production of an initial pilot batch;
- pilot industrial operation of the initial batch;
- development of a marketing strategy;
- preparation of a production and commercialization program for the market adaptation period, development of a warranty service system, identification

of a strategic partner, and execution of the first phase of active marketing.

As readers may note, at all stages the system follows the core principle articulated in the developments and publications of **Marakshyna Alina**, namely the principle of **horizontal and vertical combinatorial integrative development**.

Devices for impedance – resonance monitoring of water quality and other liquids must be fully suitable for effective operation within the following key industrial sectors, which represent the primary consumers of this technology and its subsequent extensions.

Primary Industrial Sectors – Core Consumers of the Technology

- Pharmaceutical industry
- Microbiological industry
- Semiconductor manufacturing
- Microelectronics
- Power engineering, including nuclear power plants
- Industrial air-conditioning systems
- Water treatment and water purification across all industrial sectors, as well as residential, industrial, and public buildings and facilities
- Fine chemical technology
- Cosmetic product manufacturing
- Production of alcoholic and non-alcoholic beverages
- Food industry
- Greenhouse agriculture
- Agricultural irrigation technologies
- Electroplating and electrochemical industries
- Oil extraction and production

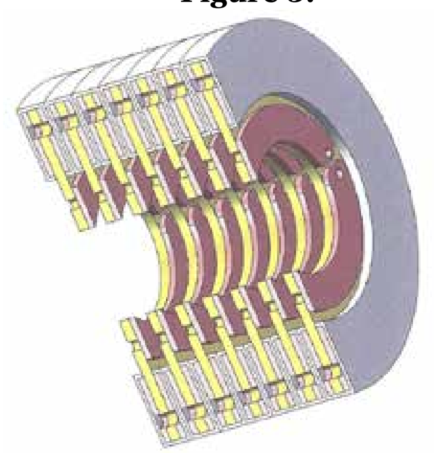
Innovative Combinatorial Mass-Market Products Expected as Project Outcomes

1. **Household indicator for tap water purity.**
2. **Industrial indicator for tap water purity.**
3. **Pipeline sensor for non-contact monitoring of liquid conductivity**, manufactured on the basis of industrial polyvinyl chloride (PVC) pipeline components; operating diameters: 1/16, 1/8, 1/4, 3/8, 1/2, 3/4, 1, 1–1/4 inches, and further in 1/4-inch increments up to 4 inches; intended for integration into automated process control systems.
4. **Pipeline sensor for non-contact monitoring of liquid conductivity**, manufactured on the basis of industrial polypropylene pipeline components; operating diameters as specified in item 3; intended for integration into automated process control systems.
5. **Autonomous pipeline sensor for monitoring liquid conductivity**, manufactured on the basis of industrial polyvinyl chloride (PVC) pipeline components; operating diameters as specified in item 3.
6. **Autonomous pipeline sensor for monitoring liquid conductivity**, manufactured on the basis of industrial polypropylene pipeline components; operating diameters as specified in item 3.
7. **Pipeline sensor systems**, analogous to items 3–6, manufactured on the basis of industrial polycarbonate pipeline components.
8. **Pipeline sensor systems**, analogous to items 3–6, manufactured on the basis of industrial pipeline components made of Teflon, composite polymer materials, thermosetting plastics, polymers with various fillers, and heat-resistant materials.
9. **Sensor systems integrated into automated control complexes** for non-contact monitoring of liquid quality in pipelines with diameters greater than 4 inches; pipelines manufactured from polyvinyl chloride (PVC), polypropylene, heat-resistant polymers, and thermosetting plastics.
10. **Sensor systems**, in accordance with items 3–9, intended for monitoring the condition of liquids supplied to agricultural irrigation systems.
11. **Sensor systems**, in accordance with items 3–9, intended for monitoring the condition of liquids in irrigated agriculture complexes.
12. **Sensor systems**, in accordance with items 3–9, intended for monitoring the condition of liquids in greenhouse agricultural complexes.
13. **Non-contact level sensor systems with horizontal mounting configuration;**

14. **Non-contact level sensor systems with vertical mounting configuration;**
15. **Integrated systems combining level sensors and quality monitoring sensors.**

As follows from the presented material, in accordance with the methodology proposed and developed by **Marakshyna Alina** in her publications, focusing and concentrating attention on the most critical product element from the standpoint of technology and its core development principles makes it possible – through deeper elaboration – to achieve both horizontal and vertical integration of tasks and principles that are aligned in terms of technological and structural identification. This approach enables attainment of the ideal final result, even in the case of parallel development streams.

Figure 3.



The author of this article initially considers shielding issues to be the most critical for impedance–resonance sensor systems and measurement and control instrumentation.

Problems related to uncontrolled and unmanageable so-called electronic noise represent a real obstacle to the further development of non-contact measurement and monitoring technologies and devices. The accuracy of determining the parameters of the resonance signal is a decisive factor in the systemic assessment of the accuracy of actual measurement results. This accuracy is a direct function of the reliability and sophistication of the sensor shielding system.

At the same time, shielding based on traditional principles does not provide the required level of accuracy and necessitates additional, workaround technical solutions that are far removed from the most advanced and innovative concepts in this field.

Applying the same methods and approaches to innovative project organization, product development, and optimization as formulated by **Marakshyna Alina**, the author of this publication arrived at a sufficiently optimal framework of stages and phases for the development of a household device for monitoring drinking water quality.

Stages and phases of development of a household drinking water quality monitoring device

Initial technical requirements

- Initial technical requirements for the materials of the device;
- Initial technical requirements for anti-corrosion and decorative coatings permitted for use in the device design;
- Initial technical requirements for elements involved in installing the device into a residential water supply system;
- Initial technical requirements for the ideology and concept of drinking water quality monitoring;
- Initial technical requirements for the system of identification and interpretation of monitoring results and sensor readings.

Technical proposal

- Calculation and explanatory report for the technical proposal stage;
- Block diagrams and schematic diagrams of project components at the technical proposal stage;
- Models, mock-ups, and physical prototypes of the device;
- Project presentation prepared for the technical proposal stage.
- Technical assignment
- Formation of the project developer company;
- Development and preparation of all foundational corporate documentation;
- Formation of working groups to execute the project;
- Development and approval of the technical assignment for design and engineering.

Development and approval of the technical specification for the product; development of the technical characteristics of the new product; development of the technical specification for manufacturing pilot prototypes of the product. Development of the technical specification for all stages of testing of the new product.

Development of the technical specification for the industrial design of the new product, including packaging, storage, transportation, and the structure and format of operational documentation.

Development of the technical specification for pilot and pre-production documentation.

Development of the technical specification for the patent and licensing protection strategy of the new product and the underlying technology.

Conceptual (Preliminary) Design

- Calculation and explanatory report for the conceptual design of the device;
- Schematics, diagrams, and general arrangement drawings;
- Mock-ups, models, and prototypes at the conceptual design stage;
- Presentation materials for the conceptual design stage.

Technical Design

- Calculation and explanatory report for the technical design of the device;
- Schematics, diagrams, and general arrangement drawings of device subassemblies;
- Models of components and fragments of the device, including versions intended for installation;
- Presentation materials for the technical design stage;
- Materials for invention and patent applications.

Working (Detailed) Design

- Calculation and explanatory report for the working design of the device and all its components;
- A complete set of technical documentation for the device and its installation variants;
- Models, prototypes, and experimental samples;
- Presentation materials for the working design stage;
- Materials for invention and patent applications.

Development of a business plan. Development of an implementation program and search for strategic partners for pilot-industrial operation. Manufacturing of an initial pilot batch of devices for pilot-industrial operation.

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