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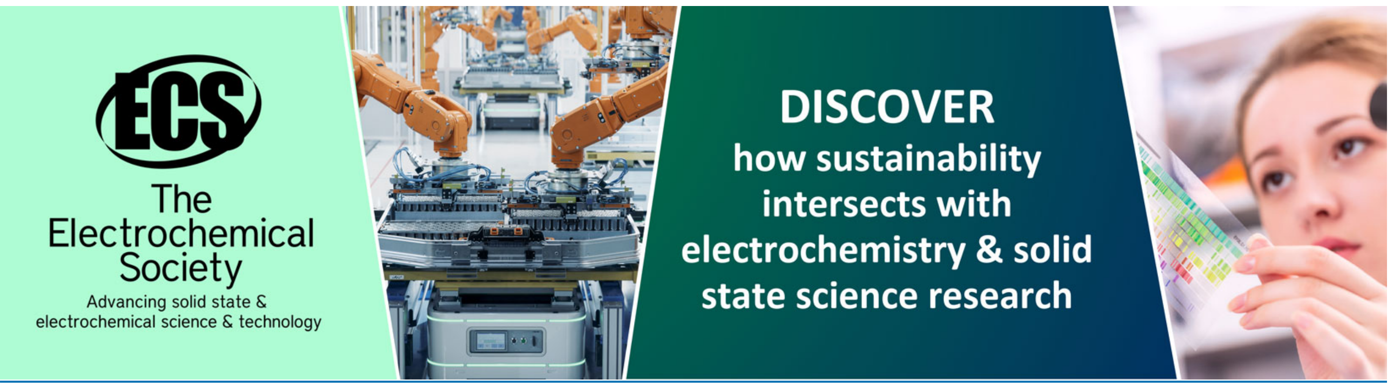

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Modeling time series of RFID signal level in automated system for identification and control of industrial products

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Abstract. The article is devoted to the development of a RFID signal level model using time series for an automated system for the control and identification of industrial products. It describes the developed project for industrial products based on RFID technologies. It describes the developed RFID signal level model. Conducted experimental studies in the laboratory are described in the article.

1. Introduction

One of the most important elements of the quality management system of industrial production, which determines the effectiveness of its work, is an identification mechanism that allows ensuring traceability of products throughout the entire production cycle. Traceability in production helps to ensure compliance with the requirements of state and international quality standards, quickly and purposefully monitor the entire technological cycle of production, which, in turn, minimizes financial consequences. Particularly relevant is the issue of tracing products in the enterprise, if the production cycle consists of many stages implemented in large production areas. The organization of the mechanism for tracing products is possible due to the automation of the control of the movement of industrial products.

Automation of traffic management is currently mainly using two technologies: technical vision and radio frequency identification (RFID). The use of technical vision approaches is complicated by the need for graphic marking of appropriate quality, which is difficult to realize in real production conditions and requires significant financial and human resources. The use of radio frequency identification is less demanding in the process of labeling products. Traffic management, based on radio frequency identification methods, is an advanced information technology for building warehouse accounting systems.

2. Subject overview

Application of RFID technology covers a large number of areas: access control systems, remote control, animal marking, transport logistics, warehouse logistics [1, 2, 3]. The existing RFID tags can be divided into active and passive tags. Active tags have their own power source; due to this the range of their work exceeds passive tags (about 80 m). Passive tags do not have their own power source and receive energy from the RFID reader, which affects the range of their operation (about 5 m). All systems with RFID tags are based on stationary readers (RFID gates or manual) located along the route of production, which is perfectly suited for conveyor lines. The use of this technology at enterprises with no specific way of moving products will require a much larger amount of funds and is likely to be economically unprofitable [4].

Each enterprise has a place or places to store products. Products are moved there by various methods: a forklift, a crane or just a human. When moving, a part of the product can be lost due to various factors, for example, fall from the means of transportation. When storing products, it is possible to move it inside the warehouse without informing about it, which can lead to problems with the localization of the displaced products. To prevent this, it is necessary to use a product control and identification system.

The principle of RFID systems for product control and identification is to attach RFID tags to the product and track its movement using RFID readers. There are ready-made software and hardware systems for monitoring and identification systems based on RFID technologies: PCT Invent (Russia, St. Petersburg), HID Global (USA, Austin), Impinj (USA, Washington), GAO RFID (Canada, Toronto). Their main disadvantage is the possibility of reading only in certain areas due to use of the target RFID gate.

This disadvantage is not the main problem. Although systems using RFID technology do not suffer from problems typical of technical vision systems (the visibility of a label, the influence of image brightness), they have a number of problems associated with the physical principles of the technology: absorption, reflection, refraction [5, 6]. The above-mentioned problems can lead to loss of signal from the RFID tag due to its location behind the structure, the appearance of metal objects, the physical properties of the product itself. The solution of these problems is individual for each enterprise.

Unlike the existing systems, the developed system uses an approach that allows tracing the complete cycle of product movement, schematically shown in Figure 1:

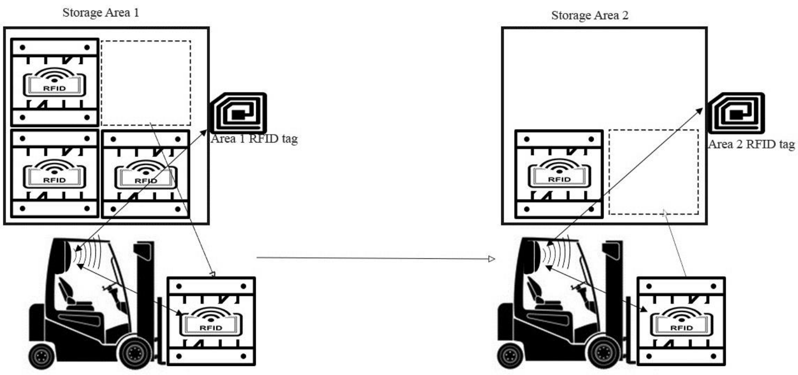

Figure 1. A schematic representation of the product identification and control system

The main difference in the system being developed is the placement of the RFID reader on the product transport device [7]. As in other approaches, products are labeled using RFID tags. Instead of readers, RFID tags are fixed in different places to locate products (warehouse shelves, exits and others places). Together, these solutions allow tracing products movements.

To develop an RFID traffic control system, it is necessary to solve a number of problems. Simulating the arrival of data is one of these tasks. To solve this problem, a model based on time series was developed.

3. RFID data modeling using time series

The time series obtained from the read data will differ in the acquisition time [8]. RFID reader regularly accumulates data from a set of identification marks. As a result, for each identifier, time series $\{y_i\}_{i=1}^{N}$, is formed, containing the values of the radio signal levels received from the label. If one denotes the dynamic signal level variable as $y(t)$, then:

$$y_i = y(t_i), t_i = t_0 + (i-1)\tau, i = 1,..., N, \quad (1)$$

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where τ – some constant step in time, t_0 – the initial time instant [9].

To obtain a time series model, let us approximate the data received from the RFID reader during system testing. Following formula will be used for the approximation:

$$f(x) = a - b\ln x \tag{2}$$

where *a* and *b* – the coefficients for the model RFID reader, x – distance to the RFID reader in meters.

The results of the approximation are shown in Figure 2.

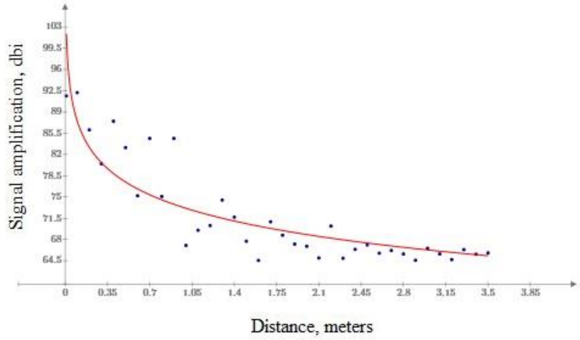

Figure 2. A graph of the distance from signal amplification

As a result of the approximation, a relationship was found between the distance and the amplification of the signal. Coefficients *a* and *b* for the test reader are 73.141 and 6.245, respectively. In describing the model, in addition to this dependence, it is necessary to take into account noise and interference. The signal from the label, even if the tag is kept at the same distance from the RFID reader, will be subjected to various effects: absorption, reflection, refraction. Let us consider this as an additive hindrance. It is also worth considering that when moving, the mark can be screened and this will create an impulse noise.

Based on the above-mentioned study of the results of reading, the identifiers of the marked products, the value of dynamic variable $x(t)$ will be determined by the formula:

$$y(t) = \begin{cases} a - b\ln x(t) + \alpha \text{ if } \beta > 0 \\ y_{\min} \text{ else,} \end{cases} \tag{3}$$

where $x(t)$ – a dynamic variable, which determines the distance between the RFID reader and the identification mark; $y_{\min}$ – background level of the radio signal; α – random component, distributed by Gaussian, which specifies additive noise in the radio signal; β – a sign of the presence of noise emitted by various products, structures or production units.

Based on the model described above, let us generate the data. The result of the generation is shown in Figure 3.

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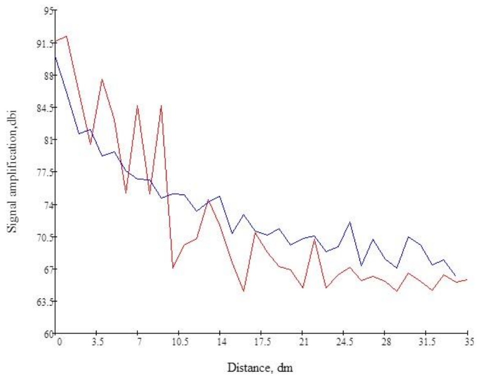

Figure 3. A graph of the distance from signal amplification with testing and modeling data

The red line shows the values of the test data, the blue line – those of the simulated data. The mean square deviation of the test data set is 7.825, the simulated set is 8.065. The average of the test data set is 70.156; the simulated set is 73.364. Therefore, the data obtained by means of the simulation correspond to the test data, which confirms the correctness of the obtained model [10].

4. Experimental research

The developed model of RFID tags data was used to test the algorithms of the automatic control and product identification system. During the experimental studies, many different types of situations that are close to production were modeled. The results are shown in Figure 4. Examples of situations are:

- movement between two storage areas;
- move between three or more storage areas;
- movement between storage areas with the presence of "noise" (other RFID tags, which are not labeled storage areas)
- movement between storage areas with partial overlap with non-metallic and metallic barriers.

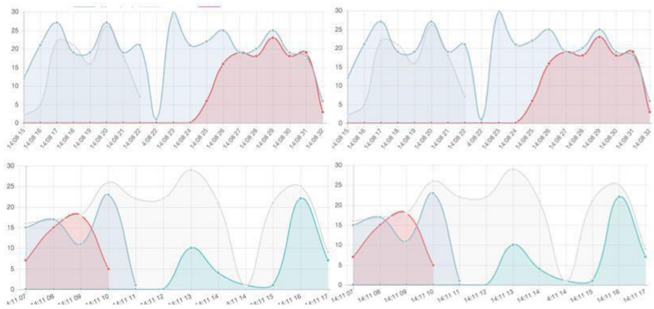

Figure 4. The results of experimental studies

Experimental studies have shown the correctness of the algorithm to determine the current storage area in the laboratory.

5. Conclusion

In the course of the work, the available approaches to the construction of control systems and product identification based on RFID technology were considered. A model of an automated system based on the placement of readers on means of moving products is presented. A mathematical model is developed on the basis of time series for testing this system. Experimental studies were carried out, in which the developed model was applied.

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