Development of Intelligent RFID-System for Logistics Processes

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***Abstract* — This paper is aimed at the two-stage development of an intelligent RFID system for logistics processes. Stages can be thought of as logical and physical. The logical stage is the study of the radio frequency identification standard EPC Class 1 Generation 2 [1]. This study aims to identify protocol parameters that affect the characteristics of an RFID system. This, in turn, will allow the entire RFID system to be configured to maximize performance. In turn, to the physical - research microstrip antenna. Studies of this kind are applicable to dimensional design. This will enable the antenna size to be smaller.**

Keywords* — *RFID; EPC; antenna; tag; reader; protocol

I. Introduction

An intelligent RFID system is designed for use in the trade of manufactured goods and logistics using RFID technology (860-960 MHz) [2]. The given system allows automate many of the processes that people are doing.

This system allows you to speed up the inventory system at any object of sale or storage of product units, as at the moment most companies use a bar code to record and identify goods, which, in turn, requires much more time.

An intelligent RFID system is a system that allows a person to receive an exceptional service and helps to choose not only the product that the buyer is looking for, but also to offer him additional services and other related products. Such a system can be implemented using RFID technology.

II. RFID-system structure

Radio Frequency Identification System (RFID, Radio Frequency Identification) is a wireless object identification system that uses radio signals to read or write data stored in RFID tags [3], which can be depicted as shown in Figure 1. Any RFID system consists of two main components: tags and readers. In any reader, there must be an element of communication with a tag — an antenna [4].

The structure of any tag can be represented in two parts. The first part of the tag is a chip designed to process and store information, as well as to modulate and demodulate the radio frequency signal. The second part is the antenna, which receives and transmits the signal.

Fig. 1. The structure of an experimental setup of an intelligent RFID system

In passive radio frequency identification systems of the microwave range (860-960 MHz), the reader constantly creates an electromagnetic field that is necessary to transfer energy to the tags. When the reader is required to transmit a message, it transmits a modulated signal, and the rest of the time - a normal sine wave at its carrier frequency. For data transmission, the tag changes the reflection coefficient of its antenna over time, thus modulating the amplitude of the reflected signal. This method of data transfer is called modulation of the reflected signal, or modulation of backscatter.

To identify the product unit, the passive radio frequency identification protocol of the EPC Class 1 Generation 2 standard is used.

III. Logical Stage. Identification of the Tags EPC Class 1 Generation 2

For an inventory of the closest tags, the reader needs to receive from each of all a message that contains the tag identifier. This situation is called the multi-poll task, in which, in the general case, the number of tags is unknown. The most rational way to solve the problem of multiple access in such a situation, provided that the tags are not able to hear each other, using the discrete protocol ALOHA. This protocol is adapted for use in EPC Class 1 Generation 2 [5].

The sequence of messages that are used to identify a tag is shown in Fig. 2. The reader sends a Query message to the first slot (slot 0) to start the process. Each new QRepeat message is fed to the next slot. The reader provides the tags with a range of slots to randomize the transmissions.

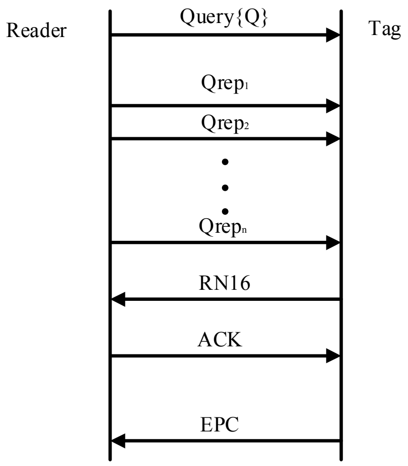


Fig. 2. Example of message exchange for tag identification

Each tag selects a random slot in which it can respond. However, when the tags start responding, they do not immediately send their identifiers to the reader. First, they send a short 16-bit random number in the RN16 message. If there are no collisions, the reader receives this message and sends its own ACK. At this point, the tag receives the slot and sends its EPC ID.

The exchange occurs in this way because the EPC identifiers are long, so collisions that would contain these messages would be very expensive. Instead, a short exchange is used to check for the safe use of the slot tag in order to send its identifier. After successfully sending your ID, the tag temporarily stops responding to new Query messages so that the remaining tags can be identified.

The main problem facing the reader is to determine such a number of slots in order to avoid collisions, while not using too many slots, since performance depends on it. In the case when the reader sees too many unresponsive slots or too many slots with collisions, he can send a QAdjust message to reduce or increase the range of slots that the tags meet. The RFID reader has the ability to perform other operations on the tags. For example, he can select a subset of tags before completing an inventory round, for example, collect answers from tags on trousers, and leave mark tags on T-shirts intact. In addition, the reader can write data to the tags that have been identified. This function can be used to record a sales outlet or other relevant information.

IV. Model of the Mechanism of Interaction of the Reader and Tags of the Standard EPC Class 1 Generation 2

Based on the analysis of the EPC Class 1 Generation 2 standard, the main parameters affecting the probability of reading the tag, the time before the first reading and the probability of collision have been identified: Tari (the duration of the symbol 0 transmitted by the reader), Q (determines the number of slots), M (the number of characters per bit transmitted by the tag, determines the method of encoding the data tag) [6]. In addition, the BER (Bit Error Rate), depending on the signal-to-noise ratio, has a significant influence on the reading probability, however, further errors in the transmission of responses of the tags were modeled using the probability of delivering the entire response, specified by a single number from 0 to 1. Also, various parameters of the environment have their impact, including the number of tags in the reading zone.

Having listed all stages of interaction between a tag and a reader, an algorithm for interaction between the tag and the reader with the specified parameters is constructed. With the help of this algorithm, the performance of the entire system and the impact of some parameters on its performance are evaluated.

There are two global loops in the algorithm - the first one at the very beginning of the algorithm, where the current round is checked and in the case of a false value, the entire program ends; the second cycle is at the end of the algorithm and it, in turn, checks the slot number, the maximum number of which depends on the parameter Q. If the check is successful, the transition to the next slot occurs, otherwise a new round begins.

The Python 3 programming language has been selected as the modeling tool.

The program can work in two modes: verbose and silent, depending on the value of the verbose flag. Verbose mode consistently displays the current state of the system when changing the slot number, allowing you to see the behavior of the model system. An example of the output of the program in verbose mode is shown in Figure 3.

Quiet mode is used to increase performance when collecting large statistics.

```
Slot #0: tag slots: [0, 4, 3, 1], replying tags: [0]
rand_prob_rn16: 0.663372206621, rand_prob_response: 0.32853822558 Nreads: [1, 0, 0, 0]
Slot #1: tag slots: [-1, 3, 2, 0], replying tags: [3]
rand_prob_rn16: 0.129102955665, rand_prob_response: 0.0600701499913 Nreads: [1, 0, 0, 1]
Slot #2: tag slots: [-2, 2, 1, -1], replying tags: []
rand_prob_rn16: 0.0112167051978, rand_prob_response: 0.80056084106 Nreads: [1, 0, 0, 1]
Slot #3: tag slots: [-3, 1, 0, -2], replying tags: [2]
rand_prob_rn16: 0.444906606086, rand_prob_response: 0.200729044623 Nreads: [1, 0, 1, 1]
Slot #4: tag slots: [-4, 0, -1, -3], replying tags: [1]
rand_prob_rn16: 0.230082829093, rand_prob_response: 0.980009411561 Nreads: [1, 0, 1, 1]
Slot #5: tag slots: [-5, -1, -2, -4], replying tags: []
rand_prob_rn16: 0.585127825531, rand_prob_response: 0.645691181161 Nreads: [1, 0, 1, 1]
Slot #6: tag slots: [-6, -2, -3, -5], replying tags: []
rand_prob_rn16: 0.992297794529, rand_prob_response: 0.817763539632 Nreads: [1, 0, 1, 1]
Slot #7: tag slots: [-7, -3, -4, -6], replying tags: []
rand_prob_rn16: 0.301692475314, rand_prob_response: 0.981824264728 Nreads: [1, 0, 1, 1]
```

Fig. 3. Protocol modeling

Having analyzed the output data in Fig. 3, it is possible to point out some points. Since the specified parameter Q was equal to 3, the number of slots will not exceed 8, since $2^3 = 8$. In the tag tag array, tags get numbers, which means in which slot they will respond. The array of replying tags shows which label is responsible in the current slot. For example, in slot 0 there will be a zero mark. Since the simulation is simplified, the transmission of RN16 and ACK messages can be simulated by the probability that rand_prob_rn16 and rand_prob_response show us. But if these random probabilities are smaller than the given probabilities of probability_rn16 and probability_response, respectively, then the tag is not read. More clearly, this procedure is shown in Fig. 4. This can also be seen on the example of the fourth slot.

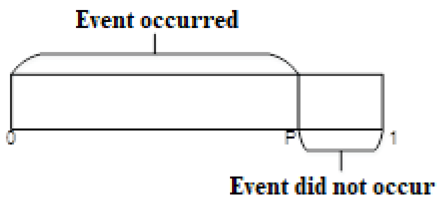


Fig. 4. Conditions for successful reception of RN16 and ACK messages

In our case, the point P is the given probability probability_rn16. And in the fourth slot, rand_prob_rn16 was on the interval from P to 1, therefore, the tag could not be read. The Nreads array is filled in as you read the kth label. It shows how many times the kth mark has been read. For example, in slot 1, the third label was read once. In addition, there may be a situation where several labels correspond - a collision, Fig. 5. Consider a fragment from another simulation.

```
Slot #6: tag slots: [1, -1, 0, 0], replying tags: [2, 3]
rand_prob_rn16: 0.118445909685, rand_prob_response: 0.655278295454 Nreads: [0, 1, 0, 0]
Slot #7: tag slots: [0, -2, -1, -1], replying tags: [0]
rand_prob_rn16: 0.630547376136, rand_prob_response: 0.424770146466 Nreads: [1, 1, 0, 0]
```

Fig. 5. Collision

In slot 6, two tags respond at once, so none of them will be read.

V. PHYSICAL STAGE. THE ANTENNA DESIGN

Microstrip antennas are widely used in modern RFID systems. The main advantages of these antennas are small dimensions and weight, ease of manufacture and cheapness. The design of the common microstrip antenna is shown in Fig. 6.

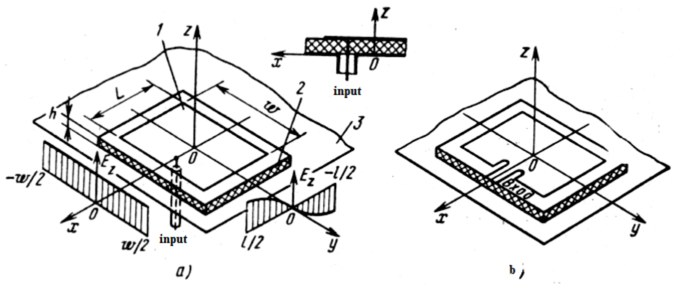


Fig. 6. The design of the microstrip antenna excited by a coaxial line (a), a strip line (b)

The antenna comprises a conductive patch (1), a dielectric substrate (2) and a conductive ground plate (3). A stripline or a coaxial line can be used to feed these antennas [7]. Microstrip antennas are capable of emitting circularly polarized electromagnetic waves. This is important for RFID systems where labels are not in a same plane and have the chaotic arrangement.

The proposed in this paper antenna consists of a dielectric substrate of policor with 1mm width and 9.8 dielectric constant. Four identical half-wave dipoles made of copper with 35 microns thick, each made in form of a periodic microstrip line symmetrically arranged on a substrate. Reduce the dimensions of the antenna without changing the frequency is possible due to the using of the periodic meander lines. In order to better matching the antenna with feeding line and surrounding space the conductors width linearly decreases from the center to the periphery. Dimensions of the whole structure do not exceed 200 × 200 mm. The suggested antenna is shown in the Fig. 7.

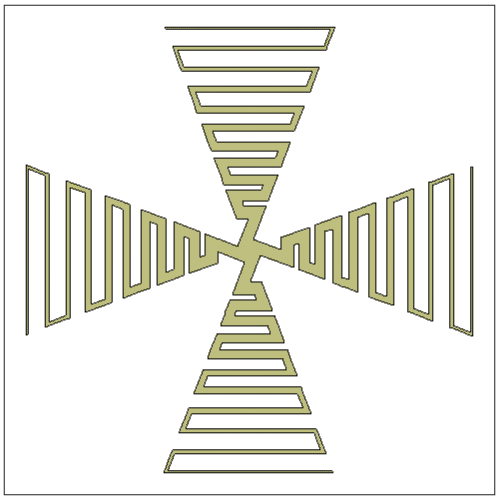


Fig. 7. The design of the quadrupole microstrip antenna

This antenna has a left-side circular polarization and a uniform radiation pattern in a wide frequency range, with overall dimensions much smaller than the maximum operating wavelength [8].

VI. The Obtained Results

AWR Design Environment was used for simulation and getting the antenna characteristics. Fig. 8 shows the reflection coefficient (parameter S11). There are minimums of signal reflection at the resonant frequencies of the antenna in range 866-915 MHz. From Fig.9 the standing wave ratio doesn't exceed 1.8 in the operating frequency range. Together, these characteristics show that the antenna could be well matched with standard 50 Ohm input.

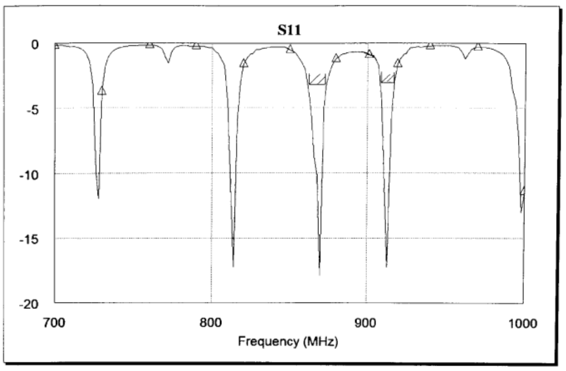


Fig. 8. The reflection coefficient

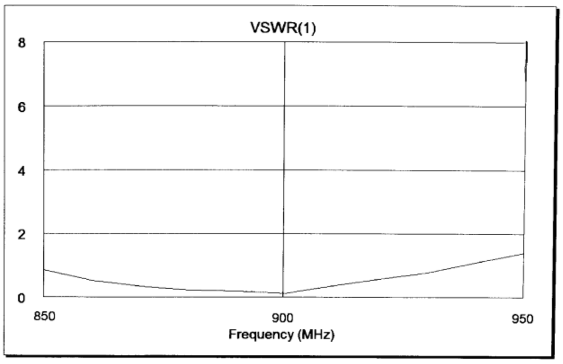
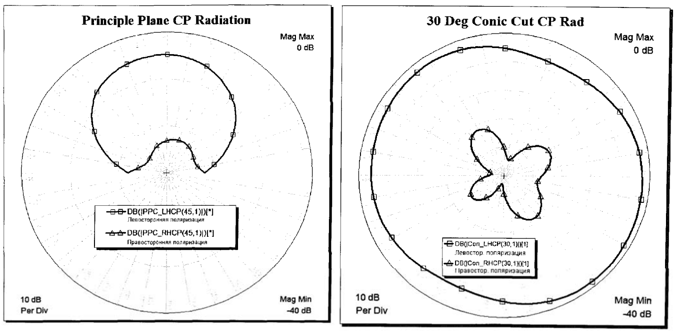


Fig. 9. The dependence of the VSWR on the frequency

Fig.10 shows the antenna radiation patterns in two principle planes. The antenna has a clearly expressed left-sided polarization, which indicates improved cross-polarization properties.



a в

Fig. 10. Antenna radiation patterns in the xz(a) and xy(b) planes

VII. Conclusions

In this paper the parameters of the EPC Class 1 Generation 2 protocol were determined, which affect the following characteristics of the RFID system: probability of tag identification, probability of collision, average time to the first successful tag identification. The model and algorithm of interaction between the reader and tags were determined and their modelling was performed. The results of the study of this antenna show that its characteristics are suitable for the identification of radio frequency tags in the frequency range of 866-915 MHz and can be used by RFID-systems for logistics processes. Moreover, this antenna has smaller dimensions and improved cross-polarization characteristics that makes the antenna appealing to RFID systems.

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