THE IDENTIFICATION OF ERRORS IN THE PROCESSES OF SCANNING OF DYNAMICALLY MOVING LOGISTIC UNITS

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1 Introduction

In recent years, RFID technology came to the fore and in many cases replaced older identification technologies (e.g. barcode). Reduced technical and economic requirements enabled its better availability, as well as development of new hardware and software solutions and more opportunities in further research and use. The main objective of RFID technology is an exact identification and keeping records of objects, goods, material, incomplete products etc. [2].

It is used mainly in production, logistics, warehouse management, postal and express services, sale, safety systems etc. In most of the above stated areas, reliability, accuracy and the speed of operation processes is very important; the combination of these parameters can be determinative factor for improving its position on the market. It is the RFID technology, which together with continual development and research of its improvement possibilities and reducing imperfections/errors leads to absolute satisfying and ensuring of these requirements. The potential and possibilities of RFID technology always depend on current technical progress and development; therefore it would be useful to look for solutions, which could improve already implemented technology and its operation conditions without need of procuring a new one.

2 Parameters and conditions of the research

From the viewpoint of practical application, as well as with respect to the dynamic nature of tag scanning, the greatest emphasis in the processes of improving of the existing situation is given on parameters such as e.g. received signal strength indication (RSSI) value, error rate, the speed of scanning tag / object with tag; number, position and the angle between scanning antennas. Individual parameters, to a greater or lesser extent, influence the scanning process; the main objective of presented research, however, is aimed at elimination scanning errors resulting from the relationship between the object with the tag and the value of the reflected signal, that is, change and quantity of reading (or not reading).
of RSSI value is recorded. In general, within dynamic parameters of measurement the speed of tag / object with tag movement is changing, while static parameters, such as number of antennas, performance and the angle between the antennas stay constant during one series of measurement. When defining the relationship between the speed and RSSI value in relation to time, we primarily focus on verification of the following research assumptions – propositions:

- increased speed causes change (reduction) in quantity of reading tag
- constant speed on a specified path does not cause any change (reduction or increment) of RSSI value

The tag placed on the object usually keeps its static position; however, it may change its orientation on selected area, therefore we discuss only its orientation to the antenna. From this point of view, we are mainly interested in influence of particular number of antennas of RFID system and their positioning in the space on the quantity and values of RSSI signal reflected / received from the tag.

2.1 Specification and calculation of RSSI values

The intensity (strength) of reflected RF signal can be also indicated by other than RSSI units, e.g. dBm (decibel-milliwatts), mW (milliwats), or as a percentage. Middleware solution by Aton OnID Company, which was used during the measurement, provides output values of signal reflected from the tag in form of RSSI; therefore, in the following sections we will use this indicator. RSSI is quantitative dimensionless quantity expressing the strength of received signal. Based on this quantity also the RSSI error rate is determined, which indicates the quality of received / reflected signal, while it is true that the lower error rate, the better is reflected signal. [5] Also, the lower final (negative) RSSI value, the better is the intensity of reflected signal, for example, reflected signal with the value –44 is better than the signal with the value –59. In general, RSSI value consists of quantities stated in the following formula 1 [4]:

\[ RSSI = TP + AG1 + AG2 - PL \]  

where \( TP \) ........ transmission power of the source  
\( AG1 \) ........ gain of antenna 1  
\( AG2 \) ........ gain of antenna 2  
\( PL \) ........ path loss in free space

As already stated, RSSI does not use an exactly defined unit (dimension); hardware producers (producing antennas, readers, sensors), however, often give conversion formulas for changing RSSI values to values of signal intensity. In addition, it is possible to define RSSI values in dBm (decibel-milliwatts) as follows:
\[ \text{RSSI [dBm]} = -10 \log_{10}(d) + A \text{ [dBm]} \tag{2} \]

where \( n \) ................. signal propagation constant or path loss exponent (in dBm), may vary from 2 – 4 (free space has \( n = 2 \) for reference)

\( A \) ................. received signal strength in dBm at 1 metre distance without any obstacle

\( d \) ................. relative distance (in metres) between the communicating nodes (from the sender to receiver)

In case of using omnidirectional antenna, RSSI value (in dBm) is expressed also by means of the formula (3), which in greater degree accepts losses caused by signal propagation, whether in free area or within antenna downspout of the transmitter or receiver. [4]

\[ \text{RSSI [dBm]} = P_t + G_t + G_r - L_o - L_t - L_r - R_e - A \tag{3} \]

where \( P_t \) ................. represents output power of the transmitter (in dBm)

\( G_t \) ................. gain of the transmitting antenna (in dBm)

\( G_r \) ................. gain of the receiving antenna (in dBm)

\( L_o \) ................. loss due to the propagation in free space (in dBm)

\( L_t \) ................. loss of the antenna downspout at the transmitting end (in dBm)

\( L_r \) ................. loss of the antenna downspout at the receiving side (in dBm)

\( R_e \) ................. reserve (in dB)

\( A \) ................. indicates the value of the antenna attenuation (in dB)

### 2.2 Specification of speed of the handling equipment

As we have mentioned earlier, the presented research is aimed, first of all, on simulation of dynamically changing value of the speed. From practical point of view, given parameter represents the speed of movement of various handling devices, such as forklift truck, pallet truck, or belt conveyor, by means of which we perform transport and handling units manipulations in RFID gate area. In this case, the transport unit is represented by the plastic crate with the tag placed on its front side.

**Fig. 1 Definition of the speed of the handling equipment**

![Speed Range Diagram](source: Authors)
The analysis of speed values of crate containing tag moving on linear line and their comparison with the speeds of handling units movement is based on the Figure 1, which defines the relationship of pre-defined speeds of laboratory measurement and approximate speeds of selected handling units movement. Maximum speed of object movement that can be reached on linear line is 2.0 m/s; we have tested ten possible variants of speed with the intervals of 0.2 m/s in order to evaluate the change of RSSI value with regards to the speed. Thus, minimum speed of scanned tag movement was 0.2 m/s and maximum speed was 2.0 m/s. For particular handling units speed simulation we give the range of its maximum, or, in case of belt conveyor, standard operation speed. After reaching stated speed, the speed of the object containing tag was in certain part of measurement constant, while the relative distance between the tag and antennas was changing.

Maximum speed of forklift truck movement (it is not in the defined range on Figure 1) is, depending on the type, in the range of 3.6 m/s – 8.6 m/s (13 – 31 km/h); when talking about pallet truck, this speed is limited by maximum walking speed of the operator, that is approximately 1.4 – 1.7 m/s (5 – 6 km/h). Standard operational speed of conveyor belt, depending on frequence of frequency changer, ranges from 0.05 m/s to 0.9 m/s (3 – 54 m/min). Exact specification of individual handling units enables us taking appropriate measures, which could eliminate possible errors and imperfections in processes, during which goods, products, etc. are handled.

3 Simulation of scanning of logistic units using RFID technology

All sets of measurement were performed in the AIDC Lab laboratory at the University of Žilina. The used system included the Motorola FX7400 (4 ports) reader, various number of Motorola AN480 antennas (the combination of different positions of 1 – 3 antennas), and used UHF frequency bandwidth in the range specified for Europe (865.6 – 867.6 MHz). For speeding up and simulation of consignment unit (object containing tag) movement, linear line was used, which was approximately 6 metres long. For the measurement were selected following three different types of tags (see Table 1):

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Type of tag</th>
<th>Dimensions (length x width x height)</th>
<th>Current ID at the time of measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTF M-Prince Tag</td>
<td>plastic UHF</td>
<td>90 x 34 x 6 mm</td>
<td>1234 0000 0000 0000 0000 0000 0000</td>
<td></td>
</tr>
<tr>
<td>Hella Company sticky tag</td>
<td>UHF label</td>
<td>60 x 40 x 1 mm</td>
<td>4830 3130 3431 3731 3730 3037</td>
<td></td>
</tr>
<tr>
<td>Alien ALN-9540-02 Squiggle</td>
<td>UHF label</td>
<td>97 x 11 x 1 mm</td>
<td>E200 3411 B802 0114 1224 4113</td>
<td></td>
</tr>
</tbody>
</table>

Source: Authors
During the measurement five test variants with different number and orientation of antennas were realized. Within each variant ten transits were simulated (ten speed levels of linear line as shown on Figure 1) for two positions (horizontal and vertical position at the object) of each of the three tags; RSSI values as well as change of speed in time were recorded (start → acceleration → constant speed → slowing down → stop). Tag was located on front side of the plastic crate and the scanning took place only when moving from the beginning to the end of the linear line.

All antennas of RFID gate had circular polarization and remained static during the measurement; their distance to the object with the tag was changing only as a result of the movement of this object on linear line. RFID gate was located in the middle of total length of linear line (6 metres), in order to ensure sufficient space for moving off and finishing of the object with the tag being scanned, and to prevent scanning immediately after starting corresponding processor of control application (Aton OnID), or after stopping.

Early tag reading (without movement of the crate containing the tag) was ensured also by regulating the power of individual antennas, which was by means of the software reduced to 25% of overall emitting power. The number and placement of antennas, as well as the distance between these antennas and the linear line / tag, the angle between them and horizontal surface / crate with the tag can be seen in the following Table 2, which represent the variants of antennas’ deployment of the tested RFID gate (distinguished by different colours of antennas).

Tab. 2 Specification of variants of antennas’ deployment

<table>
<thead>
<tr>
<th>Variant</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (green colour)</td>
<td>One antenna (Antenna 1) at the distance of 1 metre from the linear line (tag)</td>
</tr>
<tr>
<td>B (blue colour)</td>
<td>Two against each other built antennas, each at the distance of 1 metre from the linear line</td>
</tr>
<tr>
<td>C (red colour)</td>
<td>Two antennas, where Antenna 1 (AN1) is at the distance of 1 metre from the linear line and the second antenna (AN2) is above the linear line at the distance of 1.2 metre from the tag</td>
</tr>
<tr>
<td>D (grey colour)</td>
<td>Three antennas; the antennas AN1 and AN3 are placed opposite each other at the distance of 1 metre from the linear line and the location of Antenna 2 (AN2) is similar to variant C, above the linear line (1.2 metre distance)</td>
</tr>
<tr>
<td>E (black colour)</td>
<td>Two against each other rotated antennas (AN1 and AN2), which are inclined at the angle of 45 degrees with respect to the vertical plane</td>
</tr>
</tbody>
</table>

Source: Authors

4 The impact of the change of speed to the errors of scanning

According to recent studies by Hunt, Puglia A. and Puglia M. (2007), Jones and Chung (2008) and also based on physical properties of electromagnetic waves, there were assumptions that first research proposition is true; without the need to perform the
measurement. By means of measurement we found out that within speed range from 0.2 m/s to 2.0 m/s, the quantity of tag 1 reading has exponentially leaping course, which was even more noticeable at lower speeds. The quantity of reading is decreasing, while with increasing speed this course becomes even and constant.

4.1 Analysis and evaluation

As we can see on the following Figure 2, the change of speed has the greatest influence on the quantity of reading when comparing the reading by speed 0.2 m/s (v1) and 0.4 m/s (v2), where the loss of read values is nearly 50%, e.g. variant A (vp – vertical position): v1 / 108 values → v2 / 56 values (48% change), variant B (hp – horizontal position): v1 / 83 values → v2 / 44 values (47% change) or variant C (hp): v1 / 60 values → v2 / 31 values (48% change).

Fig. 2 The quantity of reading tag 1 – horizontal and vertical position (variants A, B, C, D, E)

Despite the fact that according to parameters, tag 1 should have better readability in horizontal plane, best values (greatest quantity of reading) were achieved in vertical position on the crate. In this regard, it is also appropriate to assess the change of the number of reading values that occurred as a result of change in the position and orientation of second
antenna between variants B and C (28% decrease of the quantity of values at speed 0.2 m/s). Tag 1 responded to changes relatively less flexibly when distant from the RFID gate (slow change of RSSI with values around –65 to –72) and in case of variant E (vp) (45° orientation of the antennas to the tag, vertical position of tag on the crate) the tag was not scanned at all.

The quantity of reading for tag 2 has again exponentially leaping course depending on the speed, while it decreases continually with increasing speed. This tag from Hella Company responded more dynamically in the electromagnetic field of RFID gate, as well as with change in distance from the antennas, when the quantity of reading at speed v1 both in horizontal and vertical position is greater on average 72% when compared to the first tag (e.g. variant B (vp): v1 (t1) / 91 values → v1(t2) / 305 values (70% increase), variant D (hp): v1 (t1) / 54 values → v1(t2) / 158 values (66% increase) or variant E (hp): v1(t1) / 73 values → v1(t2) / 269 values (73% increase)). Changing the position of second antenna from vertical to horizontal (variant B → variant C) caused about 50% increase in the quantity of reading in horizontal position of the tag and also about 50% decrease in the quantity of reading in vertical position of the tag.

This decrease or increase decreases with increasing speed. According to the estimated orientation of the tag antenna, the readability should be better in the horizontal position of the tag on the crate, but this hasn’t been confirmed by measurement. RSSI values ranged from –53 to –77, when tag already has not responded to antenna signal. In variant E there were no problems with reading of the tag. As in case of previous tags, the quantity of reading of tag 3 has again exponential course, which decreases with increasing speed. Tag 3 has characteristics similar to those of the second tag and it has flexibly responded to the change of distance from the antennas, when maximum values of the quantity of reading are around the value 350. The difference occurs at the RSSI value that is within the range from –43 to –64; when it is exceeded then no more tag is scanned.

Based on these results, the truth of first research assumption, which states that increased speed causes change (reduction) in quantity of tag reading, has been verified. This change in quantity of reading has an exponential course, which in response to the increase of speed is almost constant (at the maximum possible speed of linear path from 1.6 to 2.0 m/s).

The following Figure 3 shows the course of RSSI values depending on time. All values are for horizontal tag 1, but with different variants of antenna position (A, B, C, D and E) and in the time interval of 3 seconds.
4.2 The identification of errors

Correction or complete elimination of RFID identifiers scanning errors always depends on possibilities and conditions of the particular RFID system. Based on performed measurements and gained results, we have defined the following scanning errors:

- wrong position of the tag on the postal crate / wrong orientation of the tag to the antennas
- wrong change of the position or orientation of RFID antennas
- inadequate speed of the movement of the object with tag (too high)
- wrong tag for required speed of the movement
- inadequate or too large antenna performance

5 Conclusions

Correct operation of each RFID system in logistics is influenced by many parameters, which are connected with the requirements for its reliability, accuracy, robustness, as well as easy operability. In practice, it is not always possible to ensure all parameters of the ideal system, as there are negative influences of the setting, as well as technical restrictions leading to various limitations and errors, which have to be taken into consideration. The elimination of these errors or restrictions represents the way of increasing the potential of using modern technologies and contributes to sustaining high standard of products and services, which are dependent on the application of these technologies.
In the article, we focused on the simulation of dynamic scanning parameters, which change in dependence on time: the speed of moving object with tag, received signal strength indication (RSSI) value, quantity of reading, etc. The results are comprised of verification of two research assumptions, specification of main scanning errors together with the possible ways of their correction; and partial specification of basic elements and parameters of the RFID system.

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References


Resume

The aim of the research presented in this paper is to find possible ways of corrections of errors and scanning of static RFID identifiers, which are located on dynamically moving logistic transport units. The main reason for examination of these issues and for its testing is looking for solutions, which will be able to improve current systems of automation and processing of consignments, goods and material, increase in accuracy and reliability. Laboratory measurement includes simulated operation parameters of the real RFID gate, as well as machine equipment of the logistic chain, such as conveyor belt, pallet truck, and forklift truck. Combination of these devices and RFID gate, together with the need for performing scanning and identification of particular goods and material create specific conditions for the formation of the bottleneck, which subsequently needs to be eliminated; or set the rules for its 100% use.

Key words

Dynamic movement, conveyor belt, logistic unit, radio frequency identification, tag

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