Informatization of Rail Freight Transport by Applying RF Identification Technology

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Abstract. The purpose of the paper is to outline advantages and obstacles of RFID application in informatization of the rail freight transport. Development and improvement in the field of information technologies and automatization are the pillars towards increase of operations and transaction effectiveness in rail freight transport. This research analyzes and describes range of RFID technology application in rail freight transport. Subsequently, we designed the experiment to test a functionality of the RFID system. In order to ensure the reliable results, we used railroad model that reflects infrastructure of the actual railroad together with station interlocking system, line signaling and level crossing systems managed via unified active control place. For experimentation purpose Taguchi design of experiment was applied to analyze the variation of the essential controllable factors. However, it has to be kept in mind that final effect of the experiment depends on a level of physical resemblance between inputs and reality.

Keywords: Cargo · Transport · RFID · Experiment · Taguchi · Telematics

1 Introduction

One of the systems that successfully develops and fits into the concept of transport telematics is automated identification working on the basis of radiofrequency identification technology. From the current open literature and other sources it is evident that RFID technology has a wide-range of application in almost every field of our life. Figure 1 depicts current usage of RFID technology in transport. Considering the fact that it is expected from the rail transport to be driving force in transport of materials of heavy and power industry, the problem of traceability improvement of materials transported by railroad is actual and on place. Use of RFID in the rail transport (only 17 %) shows the extensive possibilities to enhance innovative research into traceability improvement in rail freight transport.

The intention of the paper is to identify and describe major application areas where RFID technology is used in the rail transport. The second part of the paper is dedicated to experiment where we test the functionality of the RFID system. [2].

R. Giaffreda et al. (Eds.): IoT360 2014, Part II, LNICST 151, pp. 64–69, 2015.
DOI: 10.1007/978-3-319-19743-2_10

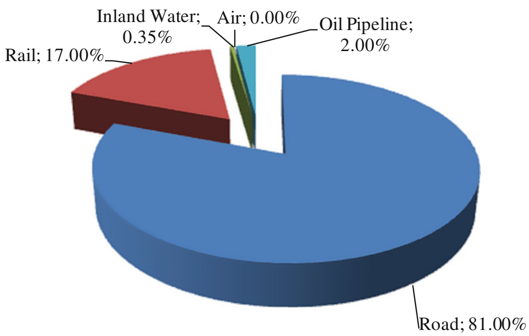

Fig. 1. Use of RF identification technology in transport in the world [3]

2 Background and Motivation

Focusing on rail transport we depicted the main application areas of RFID technology in rail freight transport. We identified five main domains: traceability of the cargo, positioning of the train unit in cooperation with GPS and within the train unit, automated data collection of the shipment, smart wagons.

The RFID tag is attached on specific place where the functionalities of the tag and whole RFID system are established. Consequently, traceability and automated data collection by employing RFID tags can be used in terms of rail freight transport for train unit, individual wagons, cargo care, or particular product. In tracking and tracing of the shipment in rail freight transport GPS space-based navigation system is widely used in rail freight transport that it can localize RFID tag with GPS module mounted on the transport unit.

The motivation of the paper is the fact that wagons identification is nowadays still done manually by workers on entering to the station. These workers have to do a visual inspection of the train unit and railroad consignment notes. After this procedure another staff member input data into information system. Applying RFID technology the ID of train unit and wagons would be automatically loaded into information systems through RFID gate that would be located on entering the station.

In summary automatic RF identification for the rail transport offers many advantages i.e. accurate evidence of the wagons, automatic maintenance and quality control, increased safety for operator and maintenance staff etc. These and others advantages are based on studies of good practices of successfully implemented RFID technology into rail industry.

For the experimental purposes we used the training simulator with the railroad model set where we analyzed the reading performance of the RFID tag attached on the transport unit.

3 Analysis of the Reading Performance of RFID System

In the experiment we tested the reading performance of the RFID system for railroad model set to find out the factors that affect the reading performance of the RFID significantly. In our RFID system configuration the RFID tag is mounted on the moving object and the RFID reader with antenna are stationary. We decided to apply design of experiments using the Taguchi Approach [1]. In the experiment, we took into consideration all possible factors. Consequently, we included three controllable factors and two noise factors. This RFID system configuration works in ultra high frequency (UHF) spectrum specifically within the 860 to 960 MHz band. The Impinj RFID reader and the software (multireader 6.4) were used. UHF RFID-tag AD 223 is weather resistant, and for special purposes it can be encapsulated in the package with thermally and chemically resistant silver coating.

3.1 Design of Parameter Diagram and Experiment

While designing and establishing a static P-diagram (Fig. 2), we identified possible noise factors. Considering these factors and other relevant circumstances, we finally selected and set two uncontrollable factors: the cargo on the wagon and existence of electromagnetic interferences nearby. In the experiment we also assumed three controllable factors to be adjusted by the users. The final parameter diagram is depicted in Fig. 4 below.

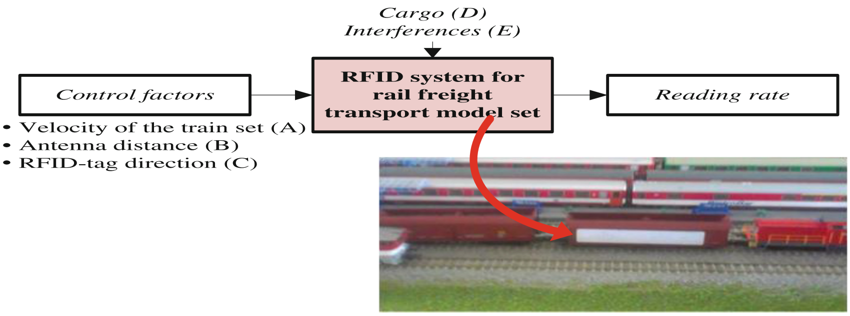

Fig. 2. Static P-diagram

In the study we selected L9 orthogonal array for the controllable factors (parameters) with three levels of parameter settings, and L4 orthogonal array was chosen for two noise factors, where each factor is given by two levels. The selected controllable and noise factors are given in Table 1. For this RFID test, the reading rate was chosen as quality characteristic. We also analyzed the impact of RFID-tag orientation on the wagon and distance from the reader on output reading rate.

For controllable factors we used The L9 orthogonal array with three columns and nine rows, which is in total of 36 trials. Where each selected parameter was assigned to a column and nine controllable parameter combinations were tested.

The advantage of the Taguchi approach for design of experiments is that only nine experiment trials are required to explore the entire parameter space using L9. The experimental layout of controllable parameters using L9 orthogonal array is shown in Table 2. For noise factors we used The L4 orthogonal array with two columns and four

Table 1. Factors and levels

Parameter designation	Parameter	Range [unit]	Level 1	Level 2	Level 3
A	Velocity of train unit	40–126 [kmph]	40	80	126
B	Distance of Antenna	0,5–3 [m]	0.5	1	3
C	Direction of RFID tag	–	Long Edge	Upper	Short Edge
D	Interferences	0,1	none	with interferences	–
E	Cargo	0,1	empty	with cargo	–

rows, which resulted in four samples for each experiment run (Table 3). Our study focuses on maximization of the signal to noise ratio that means the less quality loss of reading rate. The SN equation is expressed by Eq. 1.

$$SN = -10\log_{10}\left(1/n\sum_{i=1}^{n}1/y_i^2\right) \tag{1}$$

Table 2. Combinations of controllable parameters

Expt. No.	Velocity of train unit [kmph]	Distance of Antenna [m]	Direction of RFID tag
	A	B	C
1	40	0.5	Long Edge
2	40	1	Upper
3	40	3	Short Edge
4	80	0.5	Upper
5	80	1	Short Edge
6	80	3	Long Edge
7	126	0.5	Short Edge
8	126	1	Long Edge
9	126	3	Upper

Table 3. Combinations of uncontrollable parameters

Noise factor /Sample No.	1	2	3	4
Interferences D	none	none	with interferences	with interferences
Cargo E	empty	with cargo	empty	with cargo

3.2 Results

Each control factor of given experiment is adjustable and has three levels. In the experiment, we observed SN ratio, which is the most important measurement of variation in the RFID quality characteristic (reading rate). The summarized data with reading rate translated into SN ratio is listed in Table 4.

Table 4. Experiment results with S/N ratio

Expt. run	Factors		DxE	Sample 1	Sample 2	Sample 3	Sample 4	Mean	S.D.	S/N
	A	B	C							
1	1	1	1	18.80	18.80	15.70	15.70	17.25	1.790	24.63
2	1	2	2	19.60	19.60	18.50	18.50	19.05	0.635	25.59
3	1	3	3	21.30	21.30	19.10	19.10	20.2	1.270	26.07
4	2	1	2	15.20	15.20	10.00	10.00	12.6	3.002	21.45
5	2	2	3	16.50	16.50	14.50	14.50	15.5	1.155	23.75
6	2	3	1	20.30	20.30	18.20	18.20	19.25	1.212	25.65
7	3	1	3	17.10	17.10	14.60	14.60	15.85	1.443	23.92
8	3	2	1	20.60	20.60	18.20	18.00	19.35	1.446	25.68
9	3	3	2	17.80	17.80	16.30	16.30	17.05	0.866	24.61

The overall mean reading rate is 17.34. From the practical point of view it is needed only one RFID tag read. The overall mean S/N ratio is 24.58 dB. To find an optimal combination of parameters setting, we extracted S/N figures of each level of each control factor from the experiment results and expressed it in the form graph diagram shown in Fig. 3. Subsequently, we distinguished the optimum settings of control factors. The bold numbers in Fig. 3 represent optimal level combination for each control factor.

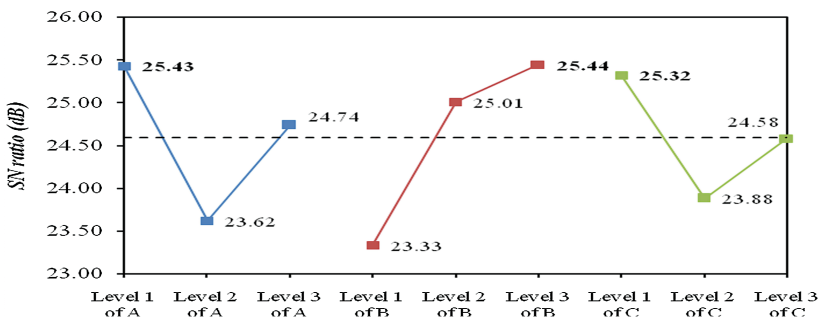

Fig. 3. SN effect plot for control factor

Subsequently, the interaction among control factors was analyzed. An interaction between control factors occurs when the effect of one control factor is dependent on another control factor. From the Fig. 4 it is evident that only one significantly interaction occurred between control factor A and C, particularly.

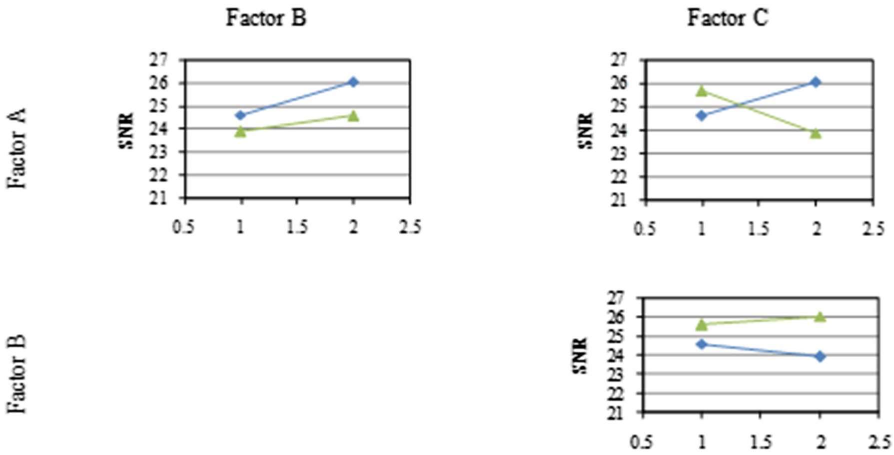

Fig. 4. SN effect plot for control factor

4 Conclusion

The subsequent conclusions were drawn from the presented study. The analysis of experiment results showed that the velocity of model of electric locomotive, distance of the antenna from RFID tag, and direction of the tag are these parameters that affect the reading performance of the system. Specifically, parameters A_1, B_3, and C_1 performed as the best combination in experiment. Subsequently, we verified the existing interaction between velocity of the train set and the RFID-tag direction. The results are valid within the above range of the controllable parameters and for specified RFID system configuration. In the experiment RFID components were adapted to the conditions of railroad model.

Research reported in this paper was supported by EU Structural Funds within the project"Promotion & Enhancement of Center for Research on Transportation" ITMS code 26220220160.

„We support research activities in Slovakia / Project is co-financed by the EU"

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