Mathematical Modeling of Temperature Characteristics of RFID Tags with their Subsequent Application in Engineering Production

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Abstract **– Present-day and fast development of technologies and their use is unlimited in today´s time. An illustration is the ever-increasing expansion of RFID technology that can be applied to any materials or products in almost every industry. The engineering production is not exception within application in manufacturing. The substance of an RFID technology consists in ensuring early information about the unsuitable state of material, component etc. in engineering production. This article is focused on the issue from the field of radio-frequency identification. Applicability of RFID tags is dependent on conditions of environment in which the system is suggested. The basic characteristics of tags are generally informed by producer but in the case of its specific requirements, it is necessary to verify the application itself or it can be verified by direct experimental method. The aim of measurement is identification and evaluation of qualitative parameters for the RFID tag Confidex depending on temperature of environment. This article contains a description of using devices, selected method of measurement and realization of experiment.**

Keywords **– RFID technology, Temperature, RFID tag Confidex, Qualitative parameters**

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1. Introduction

Mathematical modeling represents the modern scientific discipline which is used (among other things) in the processing of measurement data in technical practice. [1], [2] It can be understood as a set of activities that lead to the representation of the structure or behaviour of the system. These mathematical models can be used in practical work and production but also in basic and applied research in logistics, aerospace, automotive and engineering industries. In recent years it arrived to extensive expansion of an RFID technology in different industries, especially in engineering. Application of this technology simplifies and improves the everyday work. The RFID technology is known from World War II and it is applied in practice in the recent years. It is rapidly developing technology which has not too much accessible references in Slovak and Czech language that should be dealt with in detail. For this reason, the majority of potential domestic communities have not knowledge about possibilities of use of this technology. RDIF system is possible to use in many fields of industry when the emphasis is put on exact and fast processing of information. Modern processing and the use of information lead to increase of accuracy, fast and efficiency of stock, business, logistic and manufacturing processes. This technology gets into the whole supply chain because the requirements of companies are increased for the use of the RFID tags in products and transportation packaging.

2. RFID technology

RFID abbreviation is of English origin and it means Radio Frequency Identification. The identification is realised by radio frequency waves. It is necessary to save information on medium (electronic memory

chip) as with the barcode technology. This chip - so called tag can exist in different forms for example – adhesive sticker, plastic card, bracelet etc. [1], [3]

It exists in the whole scale of systems and elements of RFID which work at the same principle from the point of view of technology.[4] It uses radio communication to two – way transfer of information between medium and receiver which is called reader. Sample RFID system is composed by three parts [5]:

- Tag – medium of information,
- Middleware – programme facilities,
- Reader – technical equipment for communication with information medium.

Figure 1. Elements of RFID system [2]

The tag consists of little chip with antenna and memory. Some kinds of RFID tags enable repeated recording of data. The tags are attached to observed object on the surface or outside of object for purpose of identification. [3]

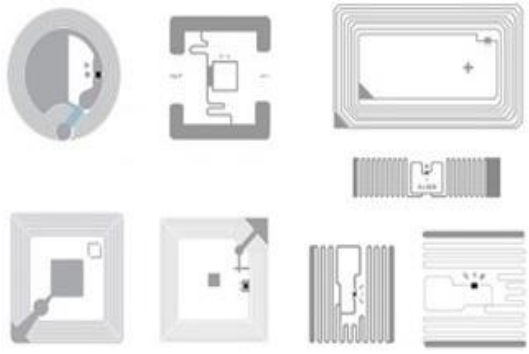

Figure 2. Examples of the most common modification of RFID tags [3]

This technology belongs to the group of the so called automatic identification technologies. This group includes bar code, OCR (Optical Character Readers) and biometrical technologies. The method of the RFID technology works by non-contact forwarding information from tags. One of the RFID technology advantages is provision of information for long distance (several meters). This system has usability in different industries and areas when the emphasis is put on exact and fast processing of information and then from the transfer to its processing.

3. Characteristics of used devices

In this measurement was used the Impinj Multi Reader Software for the control of system hardware parts and which is freely affordable on their website. The Impinj Speedway R420 reading device and the hot-air sterilizer J.P.Selecta Conterm were also used for the provision of the required temperatures. The Motorola AN48 antenna was used for data transmission and the subject of experiment was the RFID tag Confidex 3000319.

Table 1. Parameters of RFID reading device

Parameters of RFID reading device	
Model	Impinj Speedway R420
Frequency	UHF 860-960 MHZ
Protocol	EPC Global UHF Class 1 Gen 2 (ISO1800-6C)
Output power of transmission (POE)	from +10 to +30 dBm
Output power of transmission	from +10 to 32,5 dBm
Maximum out power sensitivity	-82 dBm

Figure 3. RFID reading device - Impinj Speedway R420

Table 2. Parameters of RFID antenna

Parameters of RFID antenna	
Model	Motorola AN480
Range of frequency	865-868 Mhz
Gain	6 dBi max
Resistance	50 Ω
Polarization	horizontal and vertical

Figure 4. RFID antenna - Motorola AN480

Table 3. Parameters of Confidex 3000319

Parameters of Confidex 3000319	
Frequency	860 - 960MHz
Type	EPC Class1 Gen2
Chip	Impinj Monza4 QTTM
Working temperature	from -40°C to +85°C
Resistance	UV radiation and seawater

Figure 5. RFID tag Confidex 3000319

4. Methodology

The number of readings [6] was chosen as representative quantitative parameter. The other quantitative parameters are speed of reading and distance (range) where the measured tag was recognized and fully readable.

Values of the following parameters were recorded during all of the measurements:

- Number of readings (TotCnt).
- Speed of tag reading (RDRate).
- Difference between the first and the last reading of tag (t_{tx}-t_0).

The speed of tag reading was evaluated in system according to the equation:

$$RDRate = \frac{TotCnt}{t_{tx} - t_0} \quad (1)$$

1 000 measurements were realized during the time - 2 seconds in interval 1 second, during all of the measurements of the concrete dependences. Afterwards, their arithmetic means are implemented into the created dependences. The next table presents the measurement conditions.

Table 4. Measurement conditions

Distance in evaluation of critical operational temperature [m]	5
Distance in evaluation of selected temperatures influence to reading distance [m]	1 – 5 (distance 1)
Room temperature [°C]	25
Pressure [kPa]	102,4
Humidity [%]	62

5. Evaluation of critical operational temperature

This part of article is focused on the evaluation of the measurements of the so called critical temperature. [6], [7]. The aim of the measurement was to determine whether there is a decline of values of selected qualitative parameters or dysfunction at lower temperature as it is indicated by the producer. The tag was warmed-up from room temperature to chosen temperatures for insurance of predetermined conditions.

Table 5. Values of tag qualitative parameters in stability test at temperature levels close to critical temperature – distance 0.5 m

Temperature [°C]	**Number of readings**	**RDRate**	**t_{tx}-t_0**
25	66.0	33.70	1.9584
50	57.0	29.26	1.9471
70	63.3	32.32	1.9574
80	61.9	31.73	1.9502
90	63.5	32.49	1.9550

The above mentioned table presents values which were measured in critical temperature test during measurement of the tag Confidex. It was constructed as a graph from these values (Fig. 6). It is evident that the highest number of readings was at 25°C from the results in Table 5. The manufacturer states that the maximum working temperature of this tag is 85°C. This temperature was exceeded by 5°C. It is necessary to point out that the temperature was exceeded but it will not ripen to drop-out of tag. In a given case, the measured temperatures achieved better values than at lower temperatures. It is possible to observe that the value of the parameter (difference between the first and the last reading of tag) is near 1.95 seconds for all of the temperatures. Finally, it is possible to observe

that the RFID tag Confidex shows total functionality when the temperature is 80°C and 90°C. This situation is without decrease of qualitative parameters' values and it is used for application with requirements for this high temperature.

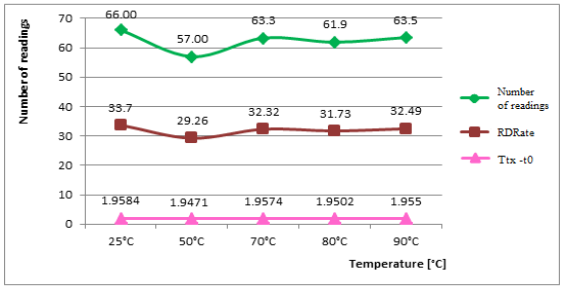

Figure 6. Graph of qualitative parameters' values of tags for temperature dependence in critical temperature test

6. Influence evaluation of selected temperatures on reading distance

This part describes realization of measurements which are focused on influence evaluation of the temperatures [7], [8] on the reading distance of a tag. It was selected room temperature for this evaluation and it was constructed the graph (Fig. 7) according to measured values (Table 6). This graph presents that the highest value was measured in 1 meter distance and the lowest value was measured in 9 meters distance.

Table 6. Values of tag quantitative parameters at 25°C temperature - selected reading distances

Distance [m]	Number of readings	RDRate	t_{tx}-t_0
1m	66.0	33.70	1.9584
2m	65.3	33.36	1.9572
3m	65.6	33.55	1.9557
4m	65.9	33.54	1.9551
5m	56.2	28.79	1.9526
6m	61.9	31.54	1.9612
7m	61.2	31.28	1.9565
8m	32.1	17.77	1.8115
9m	11.8	19.84	0.6912
10m	39.6	23.45	1.7068

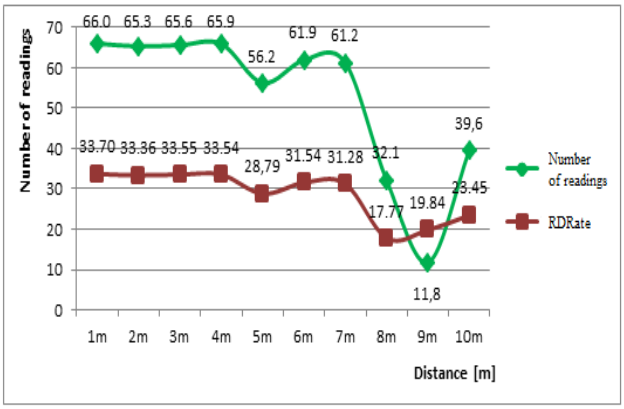

Figure 7. Graph of tag quantitative parameters at 25°C temperature - selected reading distances

Qualitative parameters of a tag were measured by temperature of the surrounding environment which was increased. Reading of the tag was decreased from 10 m to 3 m distance after the increasing of the temperature to 50 °C. The highest value was measured in 3 m distance (Fig. 8).

Table 7. Values of tag quantitative parameters at 50°C temperature - selected reading distances

Distance [m]	Number of readings	RDRate	t_{tx} - t_0
1	57.0	29.26	1.9471
2	37.8	20.30	1.8245
3	57.6	29.45	1.9565

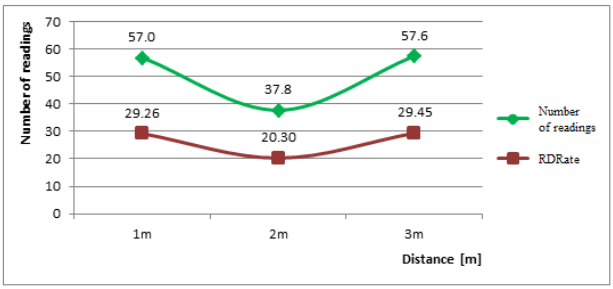

Figure 8. Graph of tag quantitative parameters at 50°C temperature - selected reading distances

The graph (Figure 9) presents influence of temperature (70°C) to tag reading distance. The lowest value of reading was measured in 2 m distance. Difference value of reading between the first and the third measurement is 45.3. Figure 9 presents that distance increasing deteriorates readability at 70°C. If the distance is more than 3 m, the tag Confidex is not detectable under the mentioned conditions.

Table 8. Values of tag quantitative parameters at 70°C temperature - selected reading distances

Distance [m]	Number of readings	RDRate	t_{tx}-t_0
1m	63.3	32.32	1.9574
2m	10.2	9.78	1.1674
3m	18.0	16.54	1.3294

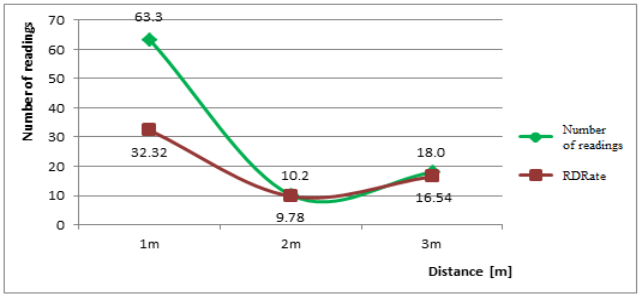

Figure 9. Graph of tag quantitative parameters at 70°C temperature - selected reading distances

Figure 10 presents the measurement graph of the tag Confidex at 80°C. It describes that maximum range is 2 m distance at this temperature. If the distance is higher the tag Confidex is not detectable under the mentioned conditions. This result informs that the tag is possible to be measured from 1 meter distance not from more.

Table 9. Values of tag quantitative parameters at 80°C temperature - selected reading distances

Distance [m]	Number of readings	RDRate	t_{tx}-t_0
1m	61.9	31.73	1.9502
2m	4.5	8.62	0.6395

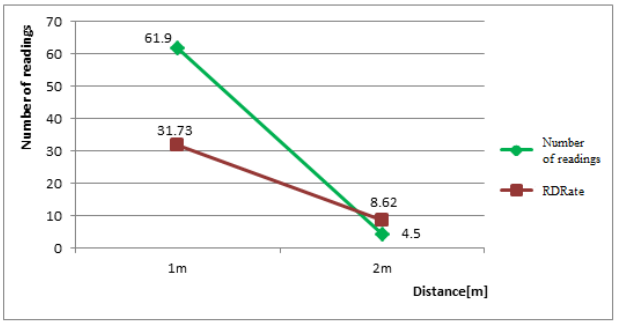

Figure 10. Graph of tag quantitative parameters at 80°C temperature - selected reading distances

The values from Table 10 are presented in Figure 11 and they show that the tag Confidex is possible to measure only in 1 meter distance. This tag is readable without problems in this distance.

Table 10. Values of tag quantitative parameters at 90°C temperature - selected reading distances

Distance [m]	Number of readings	RDRate	t_{tx}-t_0
1m	63.50	32.49	1.955
2m	3.28	3.26	0.408

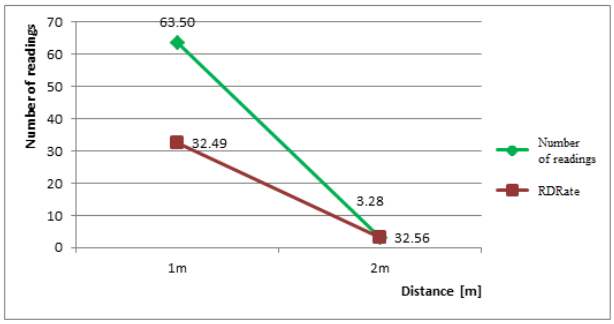

Figure 11. Graph of tag quantitative parameters at 90°C temperature - selected reading distances

On the basis of the measurements results, it is possible to conclude that the RFID tag Confidex is suitable for application in the cases of increased protection. However, it should be noted that its scope is decreased by increasing of the temperature.

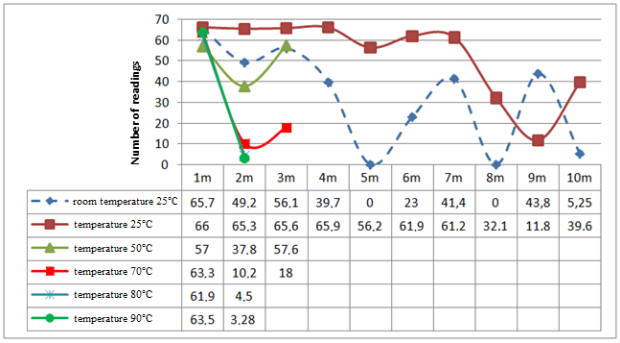

Figure 12. Dependence of Confidex 3000319 tag range from ambient temperature

7. Conclusion

The main reason of application of the RFID technology in engineering production is not only the effort to increase the efficiency but also increasing of the safety. Integration of the RFID tags in engineering production provides many important characteristics about production, used materials etc. When the RFID technology is selected, it is necessary to put emphasis on conditions under which it will work. [5], [9] The functionality of the RFID tag can be affected by material, temperature and other influence or not

influence factors at the wrong choice of the RFID technology. Therefore, it is the reason excused to realize a testing of selected technology before application. It allows avoiding undesirable effects which influence qualitative and quantitative parameters of the RFID tags. It is possible to realize measurements of these parameters in connection with other types of tags in the next research.

Acknowledgements

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