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Performance characteristics of UHF RFID tags used in identification on liquids

Abstract. *. In this study, the behaviour of electromagnetic waves during communication between reader and tag in RFID system was investigated. The experiments were performed in UHF frequency range using several types of tag's antennas. In order to evaluate the influence of liquid types on RF waves the tag's antennas radiation pattern were measured. First, the preliminary experiments were performed to determine the impact of measuring condition on obtained results. Then, in the main tests the radiation pattern for several alcohols and ketones were measured.*

Streszczenie. *W artykule opisano zachowanie fal elektromagnetycznych podczas komunikacji pomiędzy czytnikiem a etykietą w systemie RFID. Badania przeprowadzono przy użyciu etykiet wyposażonych w różne typy anten pracujących w zakresie UHF. W celu oszacowania wpływu typu płynu na fale elektromagnetyczne wykonano pomiary charakterystyk kierunkowych testowanych etykiet RFID. Przeprowadzono wstępne testy, aby ocenić wpływ warunków pomiarowych na uzyskane wyniki oraz zmierzono charakterystyki kierunkowe etykiet RFID dla alkoholi i ketonów. (**Pomiary charakterystyk etykiet UHF RFID stosowanych w identyfikacji w obecności płynów**).*

Słowa kluczowe: identyfikacja radiowa, RFID, etykieta RFID, płyn, charakterystyka kierunkowa.
Keywords: Radio Frequency Identification, RFID, tag, transponder, liquid, radiation pattern.

Introduction

It is well known that identification techniques have become more and more important at present. They are used commonly in almost every field of industry and services because they lead to improving process efficiency. It causes that work is done more effectively and an operating cost can be reduced. That encourages companies to apply these identification techniques [1, 2].

One of the identification techniques is Radio Frequency Identification (RFID). A RFID system consists of two components [1]:

- tag – located on the identified object,
- reader – a read or write/read device depending on application.

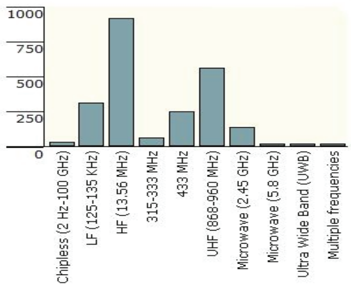
As distinct from bar code, optical character recognition (OCR), voice identification and fingerprints RFID utilizes radio waves to exchanging information between reader and tag. Depending on a method of energy and data transfer following tags are distinguished [3]:

- passive – it does not contain a battery and derives power from electromagnetic field generated by the reader,
- semi-passive – like a passive tag it draws power from radio waves created by the reader, but also uses battery to feed the chip,
- active – a battery delivers power to run the chip and to communicate with the reader.

Nowadays the most popular are passive tags. According to analytics opinion this trend will be continued in the next few years. Moreover, the number of passive tag supplied will be increased a several times to 2018 [4]. It is caused by a great advantage of passive tags. They can be smaller and less expensive than semi-passive and active tags [5].

In RFID system there are used a lot of frequency bands. Among them the most frequently applied are HF and UHF frequency ranges what is showed in Fig. 1. [4]. A read range and a method of data and energy transfer are different for each frequency bands. HF tags work on the basis of inductive coupling with the reader and its read range equals up to 1 m. On the contrary, in UHF frequency range electromagnetic backscatter is applied which makes possible to communicate with the tag up to 5 m [1].

Apart from above features UHF tags are sensitive to metal and liquid. This materials cause reflection and absorption of RF waves, respectively. If the tag is located on metallic surface, it does not absorb enough energy to proper communication. Metallic object detunes the antenna from its resonant frequency or makes shield for electromagnetic waves. To improve exchanging data and energy a special ferrite layer should be added to the tag. Furthermore, liquids absorb the RF power. Like in the case of metallic surfaces the tag has insufficient energy to send information to the reader [6-10].



Rys.1. Frequency bands used in RFID [4]

In this paper, the behaviour of electromagnetic waves during communication between reader and tag in RFID system was investigated. The experiments were performed in UHF frequency range using several types of tag's antennas. In order to evaluate the influence of liquid types on RF wave the radiation pattern were measured and then compared.

Experimental

In order to measure radiation pattern of tag's antennas a special stand was built. It consists of following components:

- a desk,
- a RFID reader with a rack,
- a measuring table, which can be fluently moved in horizontal plane,
- an angle gauge,
- a measuring ruler,
- a tested object.

A tested object was a RFID tag taped on a 1 litre glass bottles filled with alcohols (isopropyl alcohol, ethyl alcohol, benzyl alcohol, 1-butyl alcohol, ethylene glycol, glycerine) or ketones (acetone, 3-pentanone). Some tested tags were presented in Fig. 2. To provide repeatability of performed measurements the reader was installed on the rack. During the experiments the whole construction was stable and did not influence on the obtained results. Moreover, the accuracy was increased by the measuring table with the angle gauge taped on it.

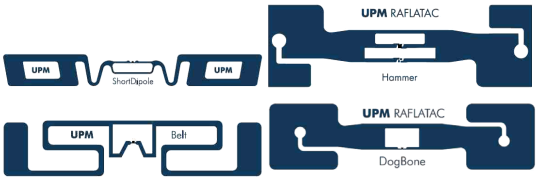


Fig. 2. Examples of UHF tags used in performed tests

First measurements were carried out with the bottle filled with isopropyl alcohol to evaluate an influence of measuring conditions on the results. The experiments concerned orientation of tag, bottle volume and glass type of the bottle.

Preliminary measurements

As mentioned above before the measurements of radiation patterns preliminary tests were performed. Firstly, the relationship between tag orientation and read range was investigated. The tag Short Dipole (UPM Raflatac) was taped on a 1 litre bottle made from dark glass and filled with isopropyl alcohol. The results for horizontal and vertical orientation are presented in Fig. 3.

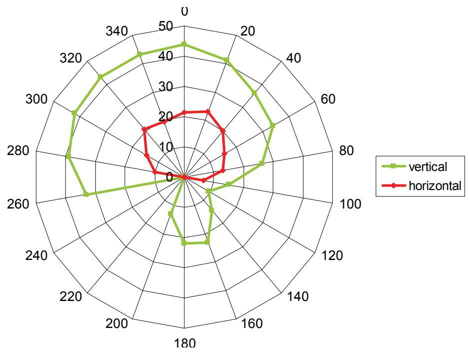


Fig. 3. A graphic presentation of the influence of tag orientation on read range in RFID system

Vertical orientation of tag resulted in twice larger read range compared to horizontal alignment. Furthermore, if it was taped horizontally there is no possibility to communicate with the reader for the angle range 100 ÷ 280 °. For another orientation the tag was not read for 200 ° and 260 °. It is probably caused by bending of the tag. Electromagnetic wave reached the antenna not so effectively and the smaller amount of energy powered up the tag. To next experiments vertical orientation were chosen because it provided larger read range compared to horizontal alignment.

Secondly, the influence of glass type on read range in RFID system was investigated. Similarly like in the previous test Short Dipole was taped vertically on a 1 litre bottle. The results presented in Fig. 4. showed that there is no difference between bright and dark glass. For some angles a small difference can be observed but it is caused by measuring inaccuracy.

Thirdly, it was investigated if a bottle volume has an impact on the behaviour of electromagnetic waves. To perfomed this experiment a 1 liter bottle made from dark glass filled with isopropyl alcohol and Short Dipole were applied. Based on measured read ranges it was affirmed that bottle volume does not influence on RF wave directly. However, a bottle diameter impacted electromagnetic waves. It was observed especially in the backward lobe of obtained radiation pattern. If a bottle was wider, more energy was attenuated by liquid and less energy powered up the chip's circuitry. The results were presented in Fig. 5.

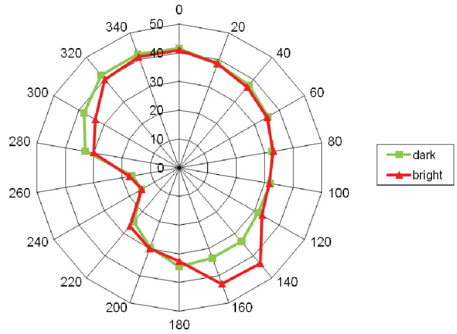


Fig. 4: A graphic presentation of glass type influence on read range in RFID system

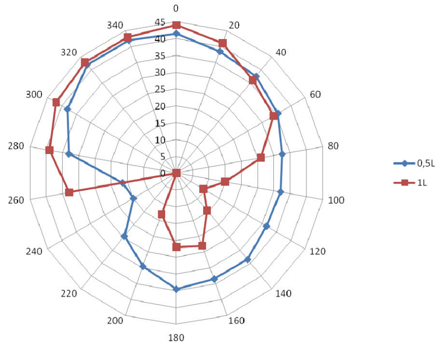


Fig. 5. A graphic presentation of bottle volume influence on read range in RFID system

For the further experiments, following settings were chosen:

- tag orientation – vertical,
- bottle volume – 1 liter,
- glass type – dark.

Main measurements

The preliminary measurements described above provided the knowledge about the impact of measuring conditions on the obtained results. In the second section bottles were filled with alcohols and ketones to determine the influence of type of liquid on electromagnetic waves. Radiation pattern were measured according to procedure used in the first tests. After carried out all experiments three groups of liquids can be distinguished (Tab. 1). For each group one radiation pattern (Fig. 6 - 8) is presented which shows general relationship between read range and liquid type.

Table 1. Tested liquids grouped by the influence on electromagnetic waves

Group 1	Group 2	Group 3
isopropyl alcohol	ethylene glycol	acetone
1-butyl alcohol	ethyl alcohol	3-pentanone
benzyl alcohol		
glycerine		

Table 2 presents numerically an attenuation of RF waves depending on tag and liquid type. It was defined in the following way:

(1) $$T\,[\%] = \frac{D_0 - D_{180}}{D_0} * 100\%$$

where: D_0 – read range for the angle 0°, D_{180} – read range for the angle 180°.

Table 2. A comparison of an attenuation of RF waves depending on tag and liquid type

Tag/Liquid	Short Dipole	Rafsec Short Dipole	DogBone
Isopropyl alcohol	50	50	48
Benzyl alcohol	40	22	24
1-butyl alcohol	49	42	41
Ethyl alcohol	100	100	100
Ethylene glycol	100	100	100
Glycerine	46	21	45
Acetone	0	0	1
3-pentanone	0	3	20

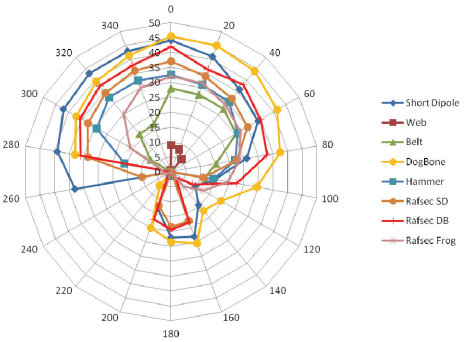


Fig. 6. A comparison of obtained radiation pattern for various tags taped on a bottle filled with isopropyl alcohol – group 1

On the basis of measured radiation pattern (Fig. 6) it can be affirmed that the highest read range was obtained for Short Dipole and DogBone and the lowest for Web. The third tag (Web) was not almost readable on the bottle with alcohol. In this connection, it was passed over in the next experiments because it was not suitable for the identification of liquids. Smaller read range for Web was probably connected with its shape. It was square and not so long like Short Dipole and DogBone. Therefore, electromagnetic waves were not so effectively "catched" by its antenna.

Moreover, radiation pattern of dipole antenna should resemble the figure 8. The Fig. 7 showed that backward lobe of measured pattern was attenuated. It was the result of liquid's effect. RF waves were attenuated when they go through a bottle.

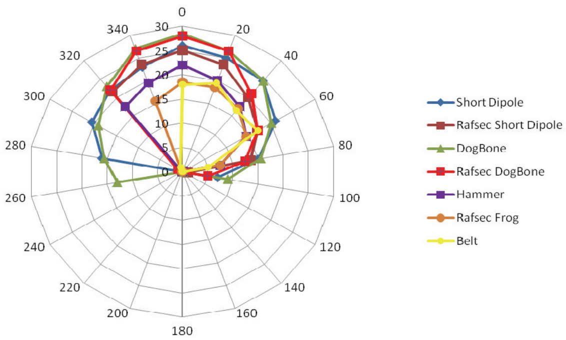


Fig. 7. A comparison of obtained radiation pattern for various tags taped on a bottle filled with ethyl alcohol – group 2

The radiation pattern for second group of liquids differed significantly from the measurements for the first group. The backward lobe was fully attenuated and read range was about 33 % smaller than for isopropyl alcohol (DogBone). It showed that the second group of liquids has different influence on electromagnetic waves than the first one. Ethyl alcohol and ethylene glycol caused larger attenuation of RF waves and the tag can not be read if it was taped opposite the reader.

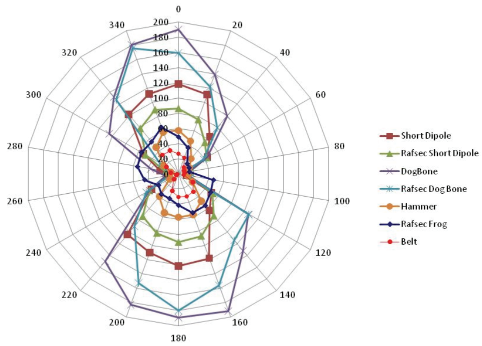


Fig. 8. A comparison of obtained radiation pattern for various tags taped on a bottle filled with acetone – group 3

The third group of liquids also influenced on electromagnetic waves in different way. The backward lobe of its radiation pattern did not yield to attenuation. Probably it was a result of a carboxyl group (Fig. 9) which is characteristic for ketones.

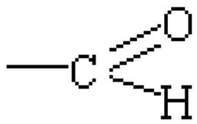


Fig. 9. A carbonyl group [11]

To verify this statement the test was performed for another ketone 3-pentanone. Fig. 10 shows its radiation pattern.

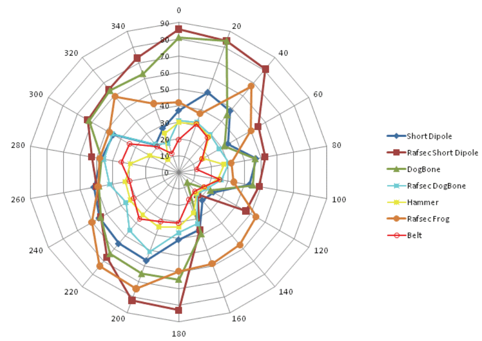


Fig. 10. A comparison of obtained radiation pattern for various tags taped on a bottle filled with 3-pentanone – group 3

The radiation pattern obtained for 3-pentanone had not the same shape like acetone. It was more irregular and the backward lobe was not attenuated. Based on the results it can be drawn the conclusion that ketones caused much less attenuation of RF waves than alcohols.

Conclusions

In this paper, the influence of liquid on the read range in UHF RFID system was investigated. The measuring stand was designed and built in order to measure radiation patterns for various type of liquids and tags. The preliminary tests were carried out to check the effect of measuring conditions on received results.

The highest read range was obtained for elongated RFID tags, i.e. Short Dipole, DogBone, Rafsec Short Dipole and Rafsec DogBone, so it can be an another important factor in selection of tag for identification of liquid.

The results showed that there is a significant difference in an attenuation of RF waves between alcohols and ketones. Also bottle diameter impacted electromagnetic waves.

Moreover, it was observed that an increase in the number of carbon atoms resulted in larger read range for alcohols. As for ketones this trend was not seen.

To sum up, the results of performed tests described in this report showed that type of liquid is essential factor for choosing tags suitable for identification of liquids.

This study was focused on alcohols and ketones, but there is variety of liquids which may have various influence of electromagnetic waves. It makes a great opportunity for further research.

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