IMPACT STUDY OF DISTURBANCE ON READABILITY OF TWO SIMILAR UHF RFID TAGS

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Key words: RFID system, readability, water disturbance, metal disturbance.

Abstract: The radio frequency identification (RFID) is one of the automatic identification technologies describing the system which transmits the data about an object wirelessly using radio frequencies. The system consists of one or more RFID tags, a reader and antenna. Despite the system still presenting a costly solution, its use is on the increase in the supply chain management, especially for the labelling and identification of different packaging. Prior to the packaging labelling, the influence of the material on the radio frequency spreading has to be evaluated. This article describes the readability of two similarly folded dipole UHF RFID antennas in dependence on different packaging. The analysis was performed on three different packaging boxes made of corrugated cardboard. First, the boxes were empty (1), then the boxes had water inside (2) and in the last example, the Al foil was inside the boxes (3). The influence of packaging on the tag readability was determined. The 2-D field signal and the received signal strength were measured. The results showed that both tag antennas have almost the same response when they are labelled onto empty boxes, a slightly less similar response when labelled onto the packaging with water inside, but a quite different response when labelled onto the packaging which contains metal. It was established that although both tag antennas were labelled onto all three types of packaging and are similarly folded dipoles, the Alien tag is more suitable for labelling the packaging containing water and metal.

Študij vpliva motenj na čitljivost dveh podobnih UHF RFID značk

Kjučne besede: RFID sistem, čitljivost, vpliv vode, vpliv kovine.

Izvleček: Radijsko frekvenčna identifikacija (RFID) je ena izmed tehnologij avtomatske identifikacije, ki za prenos podatkov o določenem izdelku uporablja radijske frekvence. Sistem je sestavljen iz ene ali več RFID značk, čitalca in antene. Čeprav tehnologija še vedno predstavlja visok strošek vpeljave se vedno bolj uporablja predvsem v preskrbovalnih verigah, še posebno za označevanje in identifikacijo različne embalaže. Pred označevanjem embalaže z RFID značko, pa je pomembno preučiti vplive materialov na širjenje radijskih frekvenc. Članek opisuje čitljivost dveh podobno "zgibanih" dipolnih UHF RFID anten v odvisnosti od vsebine embalaže. Analiza je bila izvedena na treh različnih embalažnih škatlah narejenih iz valovitega kartona. Prva škatla je bila prazna, druga je vsebovala vrečko z vodo in tretja Al folijo. Tako je bil preučen vpliv embalaže na čitljivost značke. Predstavljen je signal delovanja v 2-D polju in moč signala, ki ga čitalec prejme od značke. Rezultati so pokazali, da imata obe anteni značk skoraj identičen odziv, ko sta nalepljeni na prazni škatli, delno različen odziv, ko sta nalepljeni na škatli z vodo in precej različen odziv, ko sta nalepljeni na škatli z Al. Dokazano je, da je Alien značka kljub temu, da sta si obe znački in njuni anteni med seboj zelo podobni, bolje prilagojena na motnje in zato bolj primerna za označevanje embalaže, ki vsebuje kovinske izdelke ali izdelke z visoko vsebnostjo vode.

1. Introduction

The radio frequency identification (RFID) has been existing for more than half a century /1/; however, even now, the RFID tags are not appropriately priced, compact, mechanically robust and readable from larger distances. Consequently, the RFID technology is still not widespread in our everyday lives. The RFID system consists of one or more RF tags, a reader, antenna and deployment environment /2/. The tags can be different depending on the communication method (active, passive and semi-passive) and operating frequency (low (LF), high (HF), ultra high (UHF)) /3/, and the reader and antenna have to be tuned to the tag frequency. In general, a higher frequency means on the one hand a longer read range and a higher data transfer rate, but on the other, a higher frequency (shorter wavelength) can be easily absorbed by the materials (water, metal) through which it is moving /4/. Many advantages, e.g. low cost (compared to active tags), long reading range and high data transfer, are the main reasons why the passive UHF RFID tags came to be applied in logistics first.

The products made of different materials can be placed inside the RFID tagged packaging. When the packed goods are made of metal, water or they contain high percentage of liquid or metal, the communication between the RFID tag and RFID reader deteriorates. The effective gain (G_{eff}) of the tag antenna (ability to increase the power or amplitude of the signal) can be defined as follows/5/:

$$G_{eff} = D_{\eta\tau} \quad (1)$$

where D is the directivity of the antenna, η is the antenna efficiency and τ is the power transfer efficiency. When the tag is labelled into the vicinity of metal, the directivity of antenna increases, the efficiency decreases and the antenna impedance can change and cause poor power transfer efficiency /5/. When the tag is labelled onto the packaging with liquid or another high dielectric material inside, the directivity increases, while the efficiency decreases due to the dielectric loss. The antennas in such an environment undergo a significant shift in the resonant frequency and may lose efficiency /5/.

The power of the modulated signal that emits from the tag antenna and is received by the reader is proportional to r^{-4} and defined as a modified Friis equation:

$$P_{RX}^{rdr} = P_{TX}^{rdr} T_b G_{rdr}^2 G_{tag}^2 \left(\frac{\lambda}{4\pi r} \right)^4 \tag{2}$$

where P_{RX}^{rdr} presents the signal received by the reader, P_{TX}^{rdr} the signal transmitted from the reader, T_b the modulation efficiency, G_{rdr} is reader gain, G_{tag} tag gain, λ wavelength and r is the distance between the tag and reader.

When the tag is labelled onto the packaging, there are at least four effects the environment or material can have on tag readability, i.e. reflection, absorption, diffraction and interference /6/. The reflection and absorption are present especially when the packed goods are made of metal or liquid material /6, 7/, since metallic items reflect the radio frequency and detune the tag antenna from its resonance frequency. The tag does not absorb enough power from the RFID reader and the antenna cannot absorb enough energy to power up. Liquid materials absorb RF and reduce the strength of the original signal by absorbing or dissipating the power. This causes the tag to have insufficient energy to power up and backscatter the information to the reader.

The metal and water objects obviously have a high impact on tag readability. When tags are labelled onto the packaging that includes such products, the readability of tags can deteriorate or tags may even become unreadable. In our previous researches /7-10/, numerous analyses of tag readability in the vicinity of metal and water were conducted. In this research, the influence of three types of packaging on two different RFID tags readability was evaluated. The 2-D field of RFID tag readability, the signal strength in the line of sight and the signal strength when changing the position of a tag and Al plate were measured.

2. Experimental part

In the experimental part of the research, the measurements of RFID tag readability were performed. The influence of a packed product on the tag readability was analysed. For this purpose, three different cardboard boxes were used, the first being empty, the second with aluminium (Al) foil and the third with a water sack inside. The analyses of readability and signal strength of two different passive UHF RFID tag samples labelled onto all three packaging were conducted. The RFID tag samples (producers Alien (ALN-9649 Squiggle) and Avery Dennison (AD-224)) have a similarly folded dipole antenna shape and size (cf. Figure 1). They all support the EPC Gen 2 protocol and operate at frequencies 860-960 MHz.

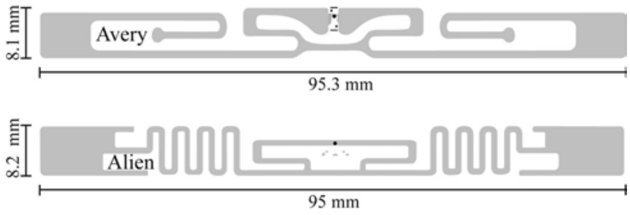

Fig. 1: RFID samples.

The measurements were accomplished in a real environment, i.e. a laboratory with numerous RF noises.

2.1. Encoding/decoding

Prior to the testing, the RFID tags were prepared for printing and encoding using the NiceLabel software. The labels with tag inlays were then printed and simultaneously encoded using the DataMax M Class Mark II UHF RFID printer/encoder. The decoding process was performed using two different RFID readers, namely Motorola RFID MC9090-G (for signal in 2-D field) and IDS-R902 reader (signal strength) with the characteristics as they follow below.

2.1.1. Motorola RFID MC9090-G reader

The Motorola reader has an integrated linearly polarized antenna that can emit the RF waving at approximately 70° zone measured from the nose of device. The reader operates at the UHF frequency 865.7-867.5 MHz. The reader supports the EPC Gen 2 standard and has the output power of 0.5 W (27 dBm).

2.1.2. IDS-R902 reader

The IDS reader consists of the IDS reader and Poynting Patch A0025 antenna that measures the received signal strength from the tag. The reader is based on the IDS-R902 circuit and supports the ISO18000-6C or EPC Gen2 protocol. It uses the UHF frequency at the frequency of 867 MHz. The reader output power is +26 dBm (0.4 W) and the output impedance is 50 Ω. The reader uses amplitude shift keying and has the maximum input sensitivity of -76 dBm. The antenna emits the signal that is circularly polarized, the antenna gain is 6.5 dBi and the input impedance is 50 Ω.

2.2. 2-D field signal measuring

All three types of packaging were labelled separately with all RFID tag samples. Using the Motorola reader, the tag readability or non-readability in different positions (x, y) in one quadrant was measured (cf. Figure 2). The measurements were carried out at centimetre intervals on the horizontal plane in the direction of the antenna radiation and perpendicularly to it.

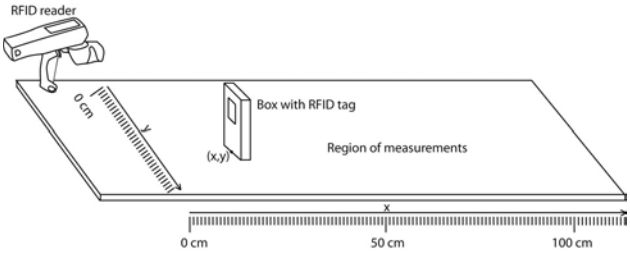

Fig. 2: Signal measurement in 2-D field.

2.3. Received signal strength

The tags were separately labelled onto all three types of packaging and the tag received signal strength (in dBm) was measured using the IDS reader. Firstly, the signal strength was measured in the straight line of sight between the tag and reader antenna. Afterwards, the signal strength when changing the position of a tag and Al plate was analysed.

2.3.1. Signal strength – straight line tag-reader

The signal strength backscattered from the tag antenna was measured at distances from 0 cm to the largest distance where the tag still responded on each cm. The measurements were performed in a straight line between the tag and reader antenna as it is seen from Figure 3.

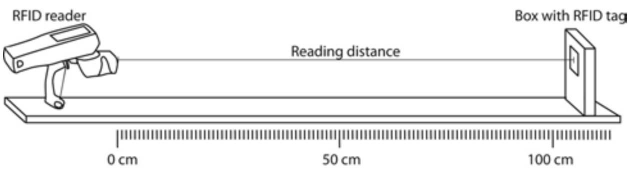

Fig. 3: Measurements of backscattered signal power from RFID tag labelled onto different packaging.

2.3.2. Signal strength – changing the position of tag and Al plate

Similarly, the backscattered signal strength at different distances between the RFID tag labelled onto an empty corrugated board packaging and Al plate was measured. The measurements were conducted at each cm from 0 to 40 cm as it is presented in Figure 4.

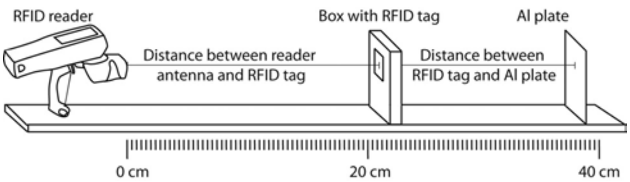

Fig. 4: Measurements of backscatter signal when changing the positions of RFID tag and Al plate.

3. Results and discussion

In the first part of the research, the evaluation of tag (labelled onto different types of packaging) readability ("yes/no") in the 2-D horizontal field was performed using the Motorola reader. The 2-D field figures were sketched and after that, the backscattered power (in dBm) coming from the tag antenna was measured with the IDS reader. In both cases, the differences in the response when different tags were labelled onto different packaging were evaluated. The results from both readers were compared and the correlation was observed. In the end, the backscattered power (dBm) from the tag antenna differentiating the position of the tag and Al plate was measured.

3.1. RFID tag labelled onto empty box

As Figure 5 shows, the reading distances of Alien and Avery tags are almost the same. The Alien sample has a larger uniform 2-D reading area (i.e. the clear grey-coloured area) closer to the reader than Avery. The Avery sample reading distance is only 3 cm shorter than the Alien sample reading distance in the direct line and 4 cm shorter in the perpendicular direction. The shape and size of samples are comparable, thus it can be seen that with no interruption (tag is labelled onto an empty corrugated box), the reading distances are almost the same. Comparing the results of 2-D sketches with the backscattered signal strength (cf. Figure 6), it is obvious that Alien and Avery have very similar signal strength, but a considerably shorter reading distance than in Figure 5. The reason for the mentioned deviations are the readers which have different characteristics (antenna polarizations (Motorola has a linearly and IDS a circularly polarized antenna), power and gain).

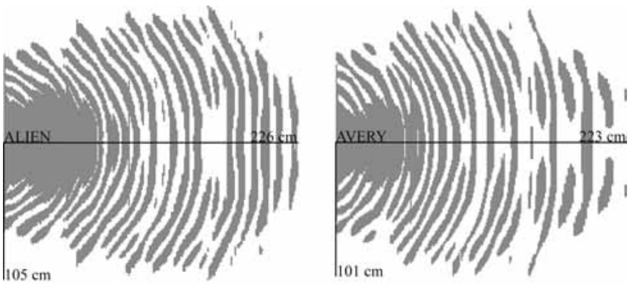

Fig. 5: 2-D horizontal field of readability of samples labelled onto empty boxes.

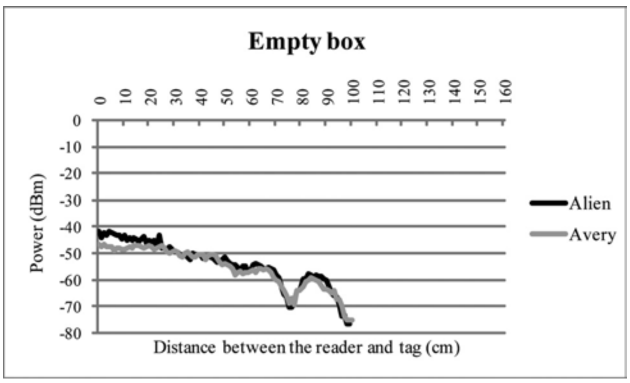

Fig. 6: Backscattered signal strength measured when tags were labelled onto empty box.

3.2. RFID tag labelled onto box with Al

Labelling the packaging that includes metal products or products that include metal can present a serious challenge for tag reading. The nearness of the metal substantially worsens the reading range and the behaviour of the RF waving. The reflection of waves causes shorter reading ranges and lowers the backscattered power strength. Comparing Figures 7 and 5, it is obvious that the reading range decreases twofold at both samples. The Alien sample shows a more uniform 2-D field (cf. Figure 7) in contrast to Avery, which has periodic reading/no-reading areas when increasing the distance between the tag and the reader.

The same deterioration was detected at the backscattered signal strength shown in Figure 8. All samples communicate with the reader only up to the distances of about 80 cm. Close to the reader nose (less than 10 cm), the signal is weak, reaching the maximum at 10 cm and monotonically decreasing by 20 dBm in the next 60 cm. There is a constant 10 dBm difference in the signal strength between the Alien (higher) and Avery (lower) labels during the whole range of readability.

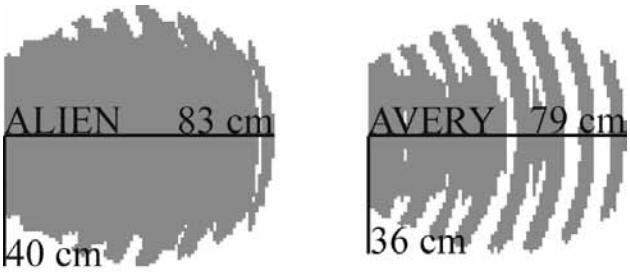

Fig. 7: 2-D horizontal field of readability of samples labelled onto boxes with Al inside.

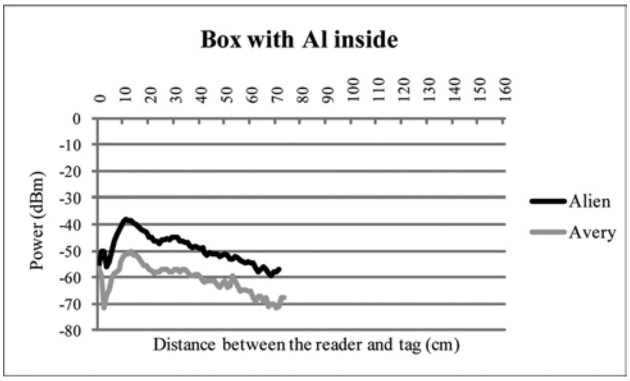

Fig. 8: Backscattered signal strength measured when tags were labelled onto box with Al inside.

3.3. RFID tag labelled onto box with water

When the tags were labelled onto boxes containing water, some unexpected results arose. The total reading area was larger than when the tags were labelled onto the packaging with Al inside, while the backscattered signal strength was lower. In this way, we proved that water absorbs RF and reduces the strength of the original signal by absorbing the power. This causes the tag to have insufficient energy to power up and backscatter the information to the reader. Focusing on the images of the 2-D field of readability (cf. Figure 9), Alien shows better readability in the x and y direction than Avery.

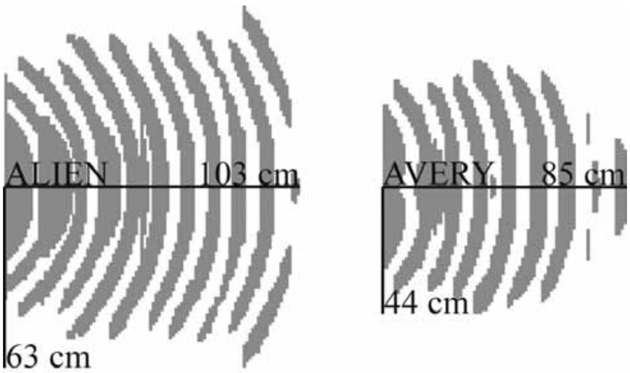

Fig. 9: 2-D horizontal field of readability of samples labelled onto box with water inside.

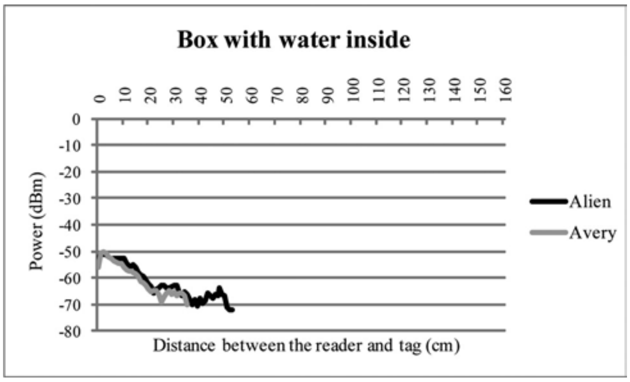

Fig. 10: Backscattered signal strength measured when tags were labelled onto box with water inside.

3.4. Signal strength – changing position of RFID tag and metal plate

The strength of the signal the tag backscatters to the reader antenna is very different, depending on the distance between the tag and antenna, and between the tag and Al plate. As Figures 11 and 12 show, the power varies from −75 to −30 dBm. The majority of signals respond with the power between −65 and −45 dBm. The Alien has slightly higher signal strength than the Avery tag. At all samples, it is also seen that the highest variability of power is detected when the tag is placed in the vicinity of the reader antenna and the Al foil is in close proximity to the RFID tag.

4. Conclusions

The RFID technology can facilitate the logistics, inventory or selling much faster and more accurate than barcodes or any other automated identification systems. When the

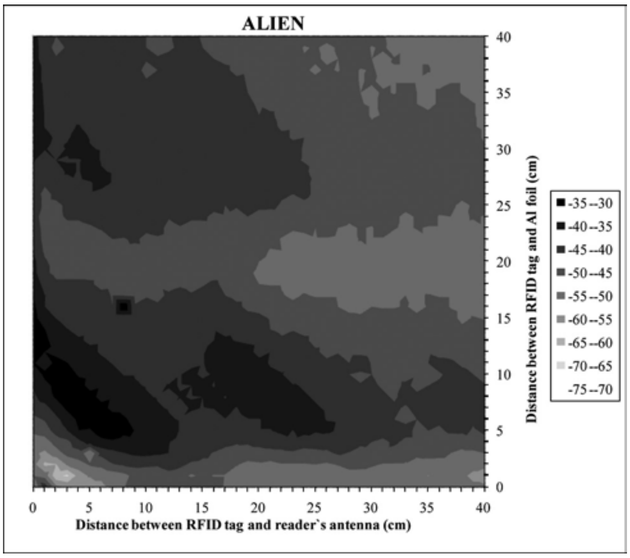

Fig. 11: Signal strength for Alien tag.

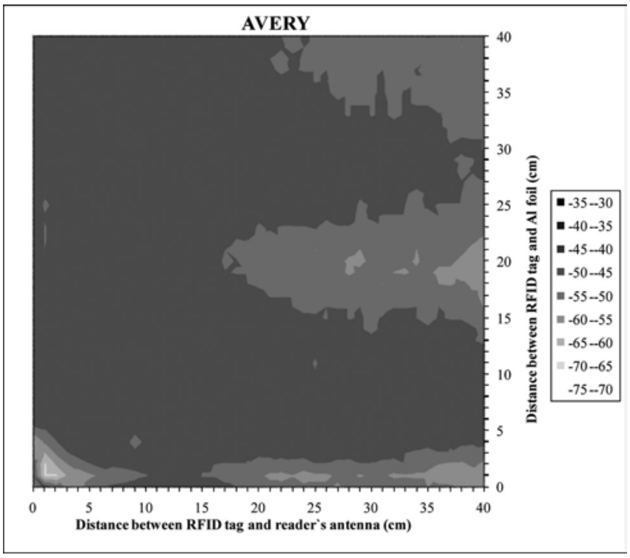

Fig. 12: Signal strength for Avery tag.

packaging and products that are packed are not made of metal or water, the passive UHF RFID tags work very well. The reading distance is long enough for the reading from at least 1 m, the backscattered signal strength is high and there is no particular reason for not using the RFID technology for labelling such products. Different characteristics are observed when the packed products are made of metal or contain a large amount of liquid. In that case, the reading distances shorten and the backscatter strength power becomes much lower. Despite both antennas are folded dipoles and are quite similar in shape and size, the Alien antenna works better than Avery and it seems more adjusted for the labelling onto metal- or water-containing, respectively, products. The total appropriateness of using RFID tags for labelling such products is questionable. In the research, two different passive UHF RFID tags were tested. The results showed that the type of reader antenna influences substantially the tag readability or backscatters the signal strength. The antenna polarization, efficiency and directivity are the most important for antenna gain and consequently, for the reading of frequencies and distances. Apart from the reader antenna, the shape, orientation and the size of tag antenna are of great importance as well.

5. Acknowledgements

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