Performance of a Passive UHF RFID Tag in Reflective Environment

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Introduction
The deployment of passive ultra-high frequency (UHF) radio frequency identification (RFID) is rapidly increasing at the moment. The need for identifying various types of objects in different environments sets challenges to RFID system design. One of the common challenges is reflecting environment such as metallic shelves, cold-storage rooms etc. In this paper we simulate these reflective environments with a Faraday gage.

The vicinity of metal has direct effects to the tag antenna parameters such as the input impedance [1]. In addition, reflections from the metallic environment cause multi-path propagation between the tag and the reader. This may have a significant effect on the power transmission between the tag and the reader, as multi-path propagation causes constructive and destructive interferences according to relative signal phases [2,3].

The propagation between reader and tag is based on the modulation of a CW (carrier wave)-signal send by the reader. The tag can modulate the CW- signal by changing its radar cross section (RCS). The change in RCS is realized by switching the input impedance of the RFID IC chip between conjugate matched state and low impedance state [2].

The two most crucial limiting factors to the read range of a passive RFID tag are power delivery to the IC chip and backscatter signal strength detected at the receiver of the reader. Power delivery to the tag is limited by communication regulations and thereby the tag antenna design determines the delivered power to the IC chip. Usually limit to backscatter signal strength is sensitivity of reader unit, which is the minimum signal strength that reader can reliably detect and decode. In many cases the power delivery to the IC limits the read range more than the backscatter signal strength [4].

In this paper we study the effects of highly reflective environment to the backscatter signal of passive UHF tag and propagation between reader and tag. Reader unit’s adaptive power adjustment is also discussed.
Measurement setup

Set of three different tags with two different IC were measured (presented in the Fig.2). Avery & Dennison AD-222 tag with Impinj chip, RSI IN-38 with NXP ucode gen 2 chip and self made bowtie type tag with Impinj Monza chip. Measurements were carried out in highly reflective environment a Faraday gage, where all the walls and the roof were metal. The dimensions of the chamber were: length 2,4m width 1,2m and height 2,3m. The measured tag and transmitter/receiver antennas were placed one meter above ground and positioned as shown Fig.1. The modulated backscatter signal power, RCS and threshold power levels were measured with Voyantic Ltd. Tagformance measurement system [5], using linearly polarized transmitter/receiver antennas with gain of 9,5 dBi. The measurements were done using query commands to activate IC-chip. Previous measurements such as in [6] were carried out only with CW signal.

![Figure 1. Measurement setup top view.](image1)

![Figure 2. Tag antennas (left to right ad-222, RSI ID Technologies IN-38, Bowtie)](image2)

Results

The power transmission between the tag and reader unit was analyzed by measuring threshold power to frequencies of 855MHz-980MHz. Threshold power indicates the lowest transmitted power in dBm at given distance, to activate the tag. The threshold power of bowtie tag in an anechoic chamber is presented in Fig.3 and threshold powers for all three tags in a highly reflective environment are presented in Fig.4. These results suggest that threshold power may vary significantly depending on the reflectivity of the environment.

![Figure 3. Threshold power of the bowtie tag in anechoic chamber and reflective chamber.](image3)

![Figure 4. Threshold power levels at reflective chamber.](image4)
The received backscattered signal powers for measured tags at two different frequencies are presented in Fig. 5 and in Fig. 6. The results show that when the transmitted power is increased above a certain value the received backscattered signal power starts to drop as in Fig. 5. The received backscattered signal power may also behave as Fig. 6, where it does not decrease as smoothly as in Fig. 5.

Backscatter signal power is derived by the changes in radar cross section of the tag (RCS). An expression to RCS, derived from the classical radar equation is given in [7] as

$$\sigma = \frac{P_r (4\pi)^3 R^4}{\left(\frac{G_t G_r}{\lambda^2}\right)}$$

where R is distance between the transmitter/receiver antennas and the tag, G_t and G_r are gains of the transmitter and receiver antennas, P_r is the received power and P_t is transmitted power.

The RCS values for measured tags are presented in Fig. 5 for 866 MHz and in Fig. 6 for 915 MHz. Results show that the RCS of the tags is reduced as the transmitted power is increased.
These results suggest that in reflective environments adaptive power adjustment in the reader unit may give better results. As in propagation between reader and tag threshold power levels vary significantly. Also in backscatter propagation between tag and reader unnecessary high power levels degrade the backscattering properties of the tag rather than give more reliable response.

**Conclusions**

Backscattering properties and power delivery between reader and tag of three UHF RFID tags with two different IC-chips were studied in a reflective metallic faraday gage environment by measuring threshold power, backscattered signal power and RCS. The results establish that highly reflective environment caused significant variations in threshold power levels and increase in the power level of the reader’s signal may impair the backscattering properties of the tag rather than give more reliable response. This suggests that in applications where one needs to identify objects in reflective environments adaptive power adjustment in the reader unit may give better results.

**References:**


