Comparative Method for Indirect Sensitivity Measurement of UHF RFID Reader with Respect to Interoperability and Conformance Requirements

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Abstract. *There is never-ending race for the competitive advantage that forces RFID technology service integrators to focus more on used technology qualitative aspects and theirs impacts inside RFID ecosystem. This paper contributes to UHF RFID reader qualitative parameters evaluation and assessment problematic. It presents and describes in details indirect method and procedure of sensitivity measurement created for UHF RFID readers. We applied this method on RFID readers within prepared test environment and confirmed long term intention and recognized trend. Due to regulations limitations, there is not possible to increase output power over defined limits, but there are possibilities to influence reader sensitivity. Our proposal is to use customized comparative measurement method with insertion loss compensation for return link. Beside the main goal achievement, results show as well the qualitative status of development snapshot of reader. Method and following experiment helped us to gain an external view, current values of important parameters and motivation we want to follow up on as well as compared developed reader with its commercial competitors.*

Keywords

Conformance, interoperability, middleware, quality of service, RFID reader sensitivity.

1. Introduction

Radio frequency identification technology as a part of Auto-ID carriers is available in different forms for industry usage for almost 30 years. By this time it has established a strong position mainly in logistic industry [1] for its great suitability in tracking of goods [2]. RFID utilizes four or five main blocks which create each general RFID system [3]: tag, reader and antenna(s), RF channel, and optionally RFID back-end called Middleware. Its main purpose is to collect, aggregate, filter, format, normalize and report captured and gathered data by read TAGs. RFID Middleware has indisputable role and impact on quality of final service. [4]. There are overall qualitative parameters with significant impact on service, which are combination of used technology capabilities and common readers' parameters and Middlewares [5].

RFID reader faces a unique set of requirements [6]. In this paper we focused on RFID reader as the main and bearing component of whole RFID ecosystem with its main parameters. The most important are transmission power and sensitivity. Sensitivity was chosen because it is possible to influence it within the defined range already in the process of design and development. Other typical UHF operating parameters [7] are:

- Reader transmission power P_r [W].
- System operating wavelength (m), $\lambda = 0.35$ m, for $f = 865.0$ MHz.
- Reader receiver sensitivity S_r [dBm].
- Reader antenna gain G_r [dBi].
- Tag power (sensitivity) requirement P_t [dBm].
- Tag antenna gain G_t [dBi].
- Tag backscatter efficiency $E_t = -20$ dB.

Operational parameters were reflected and are relevant to our method and experiment. The most important one, for the following experiment, was sensitivity.

There are other approaches beside the availability of Digital Signal Processing (DSP) methods suitable for use cases with very low Signal to Noise Ratio (SNR) [8]. The reader sensitivity is the subject worth studying and improving. According to the industry, the reader sensitivity has a strong impact on the performance, stability, security and quality of consequent functions and services within the whole RFID ecosystem.

The main challenge we identified is how to evaluate sensitivity of the developed reader (with not known parameters from vendor) with respect to existing best practices. Sensitivity together with the output power, the reading distance and read rate/speed, are considered as the operational parameters. Reader sensitivity is dependent on several design choices as well. These are HF components and circles sensitivity, antenna layout configuration, that become more important as tag power is forced to lower value [6]. And finally the power is limited by the regulatory body as in Eq. (1), Eq. (2). We still have a chance to influence and improve previously described and explained sensitivity of the reader with respect to certain limitations. Assumed that the local regulations [9] specify that we must not exceed a transmitting power level of:

$$P_{ERPmaxEU} = 2 \text{ W} = 33 \text{ dBm}, \quad (1)$$

$$P_{ERPmaxUS} = 4 \text{ W} = 36 \text{ dBm}, \quad (2)$$

for Europe and for US.

The approach and the structure of the experimental work where we tested the presented method and the procedure in main steps are:

1. Measurement devices calibration and initial setup.
2. RFID reader's configuration.
3. continuous reading tests for all three readers.
4. record and evaluation of captured data.

Our approach was based on comparison and math of known and measured powers. The motivation was to demonstrably compare important parameters of developed RFID reader with the values of same parameters of referred, commercially available ones. The two main outputs are measurement method and reader sensitivity comparison table. Values are results of applied method on readers in testbed.

In this paper there are demonstrated measurement method and cycle in the experimental RFID test bed in details in Section 3. You find here described steps in diagram, testbed schema and situation plan. Main section ends with results, where you find table with measured values, which are discussed. This section is followed by conclusions and proposal for future work in Section 4.

2. Related Works

There is not available straight forward way to assess and compare discussed performance parameters with competition but there are certified methodologies for static and dynamic tests of RFID TAGs' sensitivity measurement and testing available [10], [11]. We studied complementary problems in papers focused on sensitivity of transponders with TAG sensitivity measurement. Industry relies on EPCglobal approved TAG related testing methodologies as well, not only according to [12], [13]. From the RFID hardware certifications perspective it is important to mention two guides: Hardware Conformance Requirements [14] and Hardware Interoperability Test Requirements [15] valid for the Electronic Product Code (EPC) world.

Since there was no indirect method available for readers, we decided to build and test one.

3. Method and Experiment

We decided to confirm our hypothesis that we are capable to assess developed reader parameters such as the sensitivity by considering initial reader setup, with eliminated and compensated the inserted path loss combined with the knowledge of forward and return link budget within testing environment.

Assumptions were confronted with tests and comparison of results with two other readers by the continuous increasing insertion loss within each measurement cycle to find the right value of the sensitivity. The aim of the experiment was to find lowest power and highest level of attenuation by comparing parameters of known readers' parameters with developed reader. The baselines were set by competitive readers Metra and AMS where there are know the key values from product sheets.

The sensitivity of a receiver indicates how great the field strength or the induced voltage U must be at the receiver input for a signal to be received without errors [3]. Method relies on well-known Friis formula[6] customized to testbed needs and suitable to count unknowns in total link energy budget for our specific case. The backscatter communication radio link budget describes the amount of modulated power that is scattered from the RF tag to the reader [14].

Equation defines the initial link budget as:

$$P_{REC} = P_{Tag} + G_R + G_T - \sum Losses - FSL - E_T, \quad (3)$$

where P_{REC} is transmitting power, P_{TAG} is TAG power sensitivity, G_R is reader antenna gain and G_T is TAG antenna gain. FSL is Free Space Loss and E_T is backscatter efficiency.

3.1. Measurement Cycle Details

We prepared measurement cycle in order to test and verify our method as applicable procedure. Steps are depicted in the Fig. 1. It starts with the initial RFID reader Fig. 1(1) configuration and setup. We kept constantly set parameters for each reader Fig. 1(2): reader output transmission power, operational frequency, frequency hopping, swept frequency range and complex impedance match. Continuous reading started Fig. 1(3). And it is processed within testbed shown in the Fig. 3 established from blocks in Fig. 2.

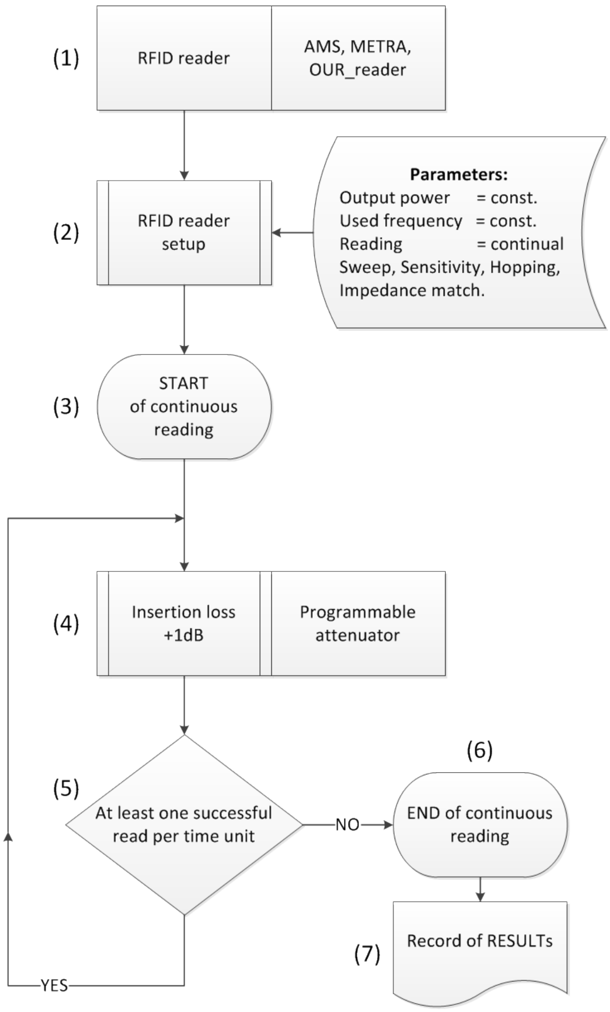

Fig. 1: Diagram of one measurement cycle.

We kept the power on the compensated level of 0 dBm, which allowed us to eliminate link path loss and then do the inter-reader sensitivity comparison, for each one of measurement cycles.

At each cycle we increased insertion loss for about 1 dB Fig. 1(4) and visually checked if the successful reading of TAG continued. We set fixed time period for about 10 s as a trigger Fig. 1(5). This is considered internally as an equivalent of BER Eq. (4), bit error rate test, which is one of the most qualitative parameter in area of digital data transmission:

$$\mathrm{BER} = \frac{\text{number of errors}}{\text{number of transmitted bits}}. \qquad (4)$$

We replaced bits with reads within defined time period. If the test failed the experiment relevant to one reader ends Fig. 1(6) and the valid value of inserted attenuation is the one from previous round. Cycle as described is the base stone of this indirect measurement method. After the failure we stopped continuous reading, recorded results Fig. 1(7), replaced reader and jumped back to the point Fig. 1(1).

3.2. RFID Testbed

Our RFID test bed environment in the Fig. 2 consists of PC Fig. 2(1) with installed reader relevant vendor applications for monitoring and management of each reader (METRA software and AMS software suitable as well for AMS reader and developed one). RFID reader itself Fig. 2(2). All readers are in impedance match with interconnected TEM-cell Fig. 2(7). Signal goes in forward and return link through two circulators Fig. 2(3) exactly according their link characteristics. Precise directional coupler Fig. 2(5) separates the power and differentiates forward and return signal direction with one gate connected as a power sensor. We had two options how to measure power of return link either on Power meter Fig. 2(6A) in [mW] or [dBm] or to use Spectrum analyzer Fig. 2(6B) as we can see in the Fig. 4. Chosen analyzer has the advantage of visualization of signal within certain frequency range and for its user friendliness as well.

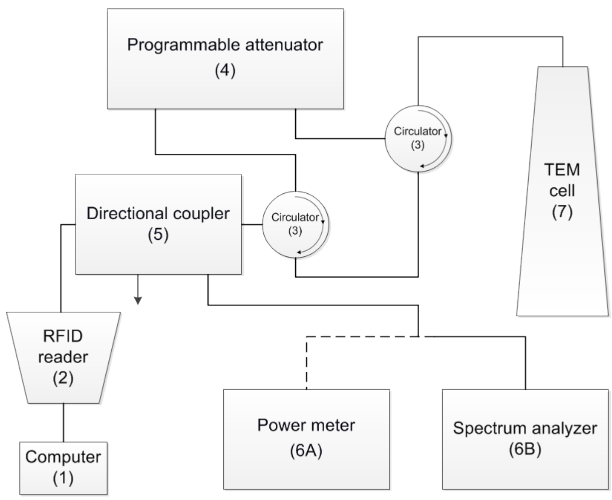

Fig. 2: Block schema of RFID testbed.

List of main components for the experiment:

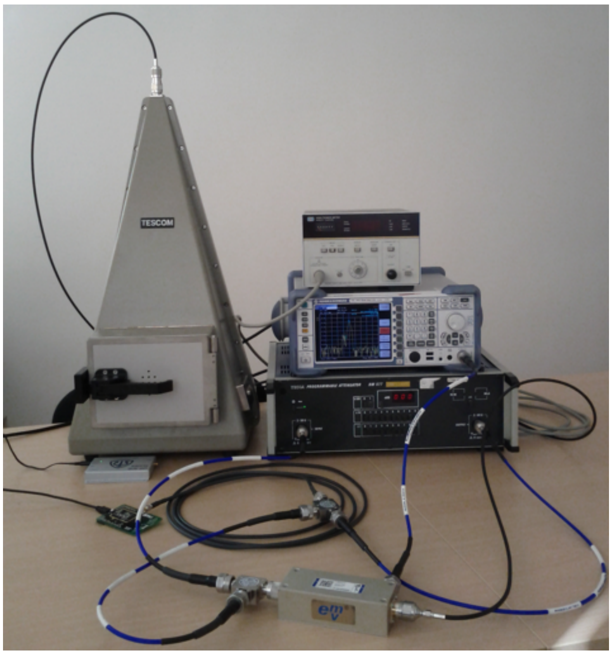

Fig. 3: Testbed situation plan.

- Certified TEM Cell Tescom TC-5060A/B UHF.
- Programmable attenuator TESLA BM577.
- Power meter Hewlet Packard 436A.
- Power sensor Hewlet Packard 8481A.
- Spectrum analyzer Rohde Schwarz 9 kHz – 6 GHz.
- Coaxial Circulator UIYCC 3232A800T900 NF.
- Ultra-broadband Directional coupler DC3010A.
- RFID UHF tags (ISO 18000-6C/EPC Class 1 Gen 2, ISO18000-6B anti-collision support).

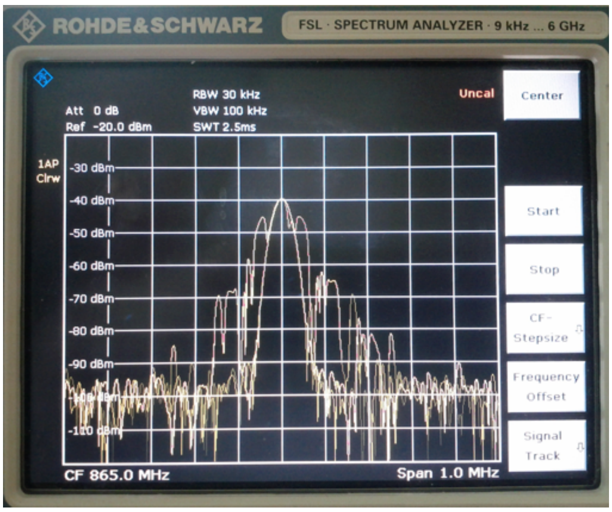

Fig. 4: Spectrum analyzer and return link power visualization.

3.3. Results

Table 1 shows parameters, relevant figures from data sheets, where applicable, and measured and counted results for each type of reader. Final values were achieved by repeated test and budget calculations for each reader during cycles with custom loss compensation and with respect to link power budget in return link direction.

Tab. 1: Comparison of data sheet values with values measured and counted results. DR=developed reader.

RFID Reader	Sensitivity datasheet [dBm]	TX power [dBm]	Sensitivity measurement [dBm]
AMS	-90	20	-90
METRA	-63	25	-63
DR	NA	20	$-63-3=-66$

Results of the practical experimental work confirmed the hypothesis from introduction as well as the real figures supported our indirect measurement method. During test with developed reader we were able to increase insertion loss for about -3 dBm more than at Metra reader. The appropriate link budget math with final sensitivity of -66 dBm is emphasized in Tab. 1.

4. Conclusion

The method and procedure together with experiment approach presented in this paper were developed and tested on three different UHF RFID readers. Results were intended to help to watch important parameters of RFID reader prototype during development and especially in level of achieved sensitivity as well as to give us direction how to compare developed reader with external commercial products with sensitivity focus. Interesting is the impact of fully managed sensitivity on overall quality of service to whole RFID ecosystem with Middlewares due to increasing demand for efficiency, speed and accuracy of reading. It is directly visible from the results that we are for about 24 dBm from the project goal with level of -90 dBm.

We experimented with placement of Directional coupler represented by block Fig. 2(6B) in Fig. 4 and at the end we decided to put it as close as possible to evaluated reader, to eliminate an impact of additional loss.

Requirements for future work were identified as need of improved triggers (from manual to automated) inside the "read error rate test" (RER). We want to be able to exactly recognize and record first fail period of time and incorporate statistical mechanisms.

The goal of each development team is to be able to influence positively the sensitivity which is supported by the visible trend at competitive readers. Achieved and measured sensitivity values at reader contributed to our motivation to continue in development.

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