RAIN RFID
Reader Sensitivity Testing

RAIN RFID Alliance
Whitepaper

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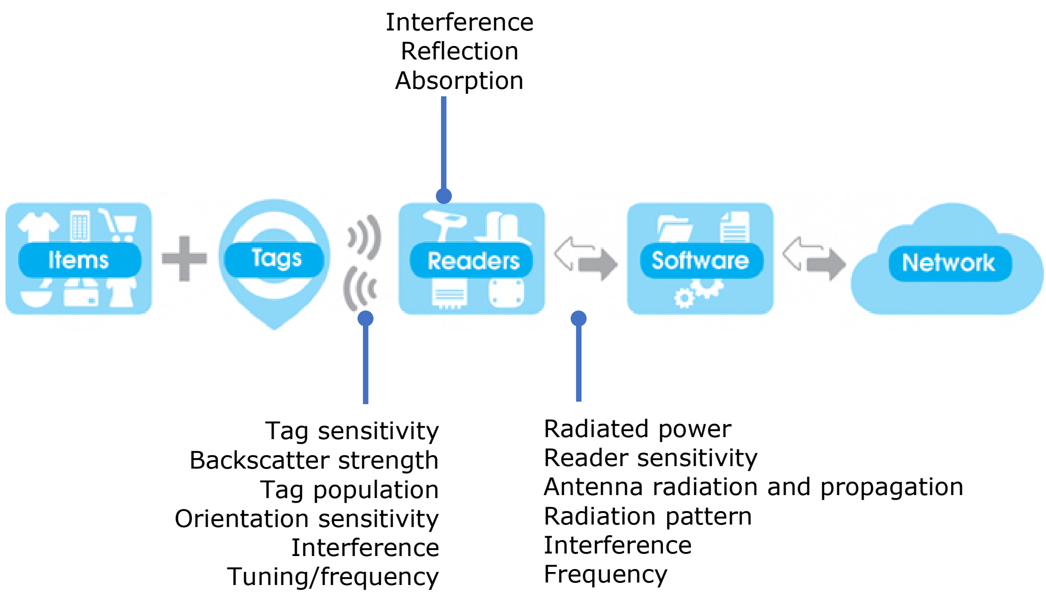
1. Introduction

A RAIN RFID system consists of items, tags, readers, software, and a network. Deployments have many moving parts, but the technology, standards, and business eco-system have all evolved to such a level of maturity that successful deployments are routine around the world.

While there may be many components, the end-user is only really interested in the behavior of the system as a whole. This is what matters, and its success can be measured by the two essential requirements; inventory accuracy and inventory speed.

Many factors impact the system performance of a RAIN RFID deployment. In this document we will focus exclusively on the tag-reader interaction; namely the RF performance. While other components are important, they will not be discussed here. The illustration below indicates the scope of this work and lists some of the issues that might impact the RF link.



In this document we narrow our attention further to the issue of reader sensitivity. We outline a proposal for testing RAIN RFID readers and a means of reporting reader sensitivity in a consistent and replicable manner.

2. Goals for this Work

While tag testing plays a vital and essential role in RAIN RFID deployment it does not, in itself, give a guarantee of success. The same will apply for any proposal for reader testing. The goal of this work is to provide more information to the system integrator, but guidance will still be necessary for an appropriate interpretation of this data. Not all readers are intended to be used in the same way and so data without commentary is unlikely to capture the full story.

Looking forward, one might envisage a classification of readers according to their performance, features, and/or their intended application. This is something that could make purchasing and deployment even easier than it is today. It seems inevitable that reader sensitivity will be one of the factors in such a classification and we start with this issue.

It should be noted that recording a single value for reader sensitivity could be an over-simplification. To avoid this, reader manufacturers are encouraged to report additional sensitivity figures, if they feel a single figure is not entirely representative. In addition, future iterations of this work will give the opportunity to refine or extend this testing proposal and this will likely lead to a more complete classification of RAIN RFID readers.

3. RAIN RFID Reader Sensitivity

Today several reader manufacturers report reader sensitivity. Among those that do, it is doubtful that there is a consistent way of measuring that figure. Our goal therefore is to outline a simple, repeatable, and verifiable test that can be applied consistently to all readers.

While testing should be simple, RAIN RFID reader manufacturers will design their readers for different use-cases. The reader's sensitivity will be a result of design choices in the receiver electronics and signal interpretation software. Signal amplification, filtering and other functionality will all determine the receiver sensitivity.

It is worth noting that reader sensitivity does depend on the RF environment. In particular, sensitivity can depend on interference from external sources and on reflections from static objects. For example, a reader's sensitivity can degrade as more readers operate in close proximity. Additionally, reflections of a reader's transmitted signal emanating from large (usually metal) objects near the antenna generate 'self-jammer' signals into a reader's receiver and can degrade receiver sensitivity.

It might be observed that the efficiency of almost all electronics components used in RF systems depends on the frequency. Receiver sensitivity will be no different. However, in practice, this dependency can be set aside since RFID frequency bands within a region are relatively narrow relative to component specifications.

For some RAIN RFID readers, a design goal has been to minimize their physical size. As a result, the smallest components are used, and these components are packed close to each other. In some cases, this leads to internal self-jamming where the receiver picks up the signal from the transmitter. If a reader has no cancellation mechanism to remove the self-jammer, the signal can appear as a noise equivalent and degrade sensitivity. Without cancellation, the higher the transmit power, the higher the noise, and the reader sensitivity is degraded. Although this might not be the case for all readers, there can be a severe impact on other readers.

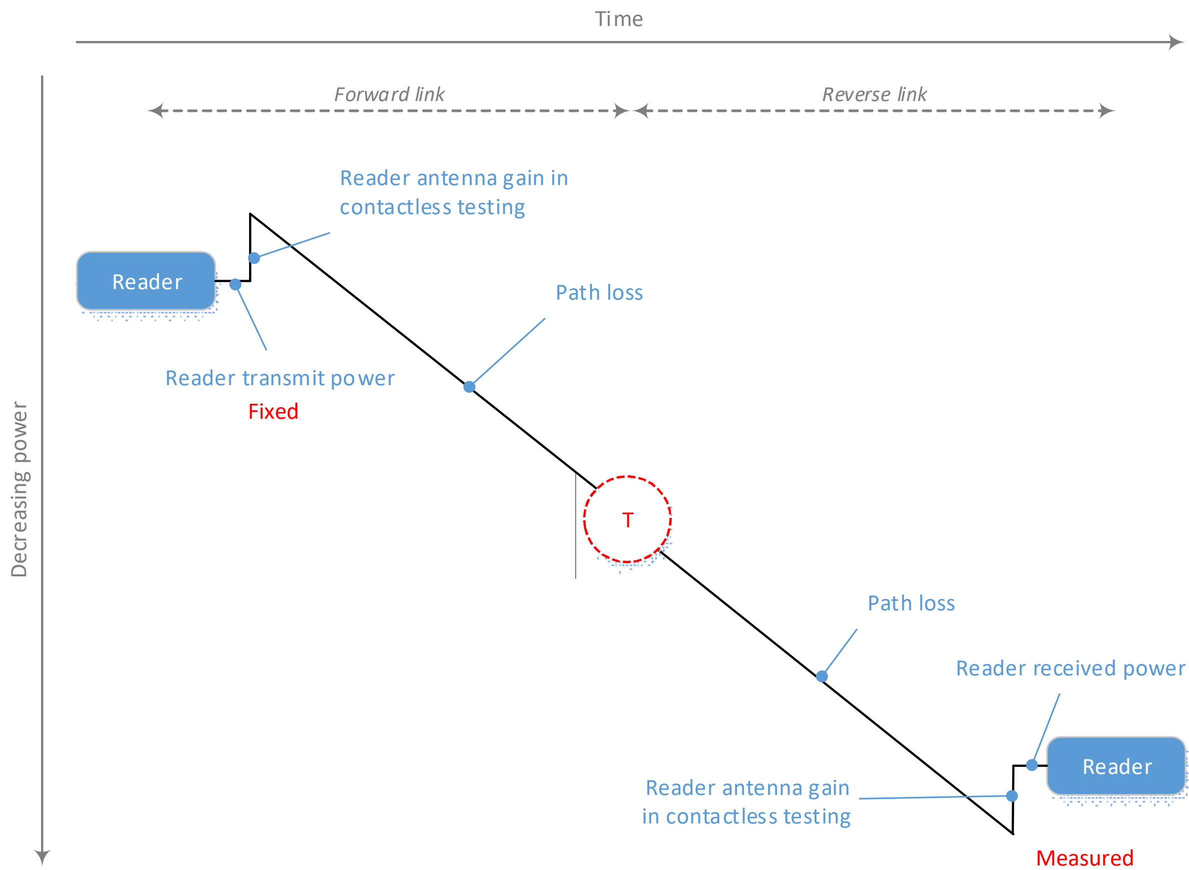
The RAIN RFID air interface[1] describes several parameters related to communication between a reader and a tag. A reader may be optimized for a certain parameter combination and have lower sensitivity with some other parameters. Some parameters, in particular tag parameters, include tolerances. For example, the BLF frequency tolerances are described in Table 6.9 of the Gen2v2 standard. Reader sensitivity at the extremes of the allowed tolerances may be different from reader sensitivity at the nominal BLF frequency. Such values shall be taken into consideration during system design by proper product selection.

One final issue worth highlighting is the statistical nature of RFID operation. A reader might correctly interpret 1% of the messages from a tag when the reader receives a signal of strength, say, -75 dBm. The same reader might correctly interpret 99% of messages when the signal strength is -67 dBm. However, during continuous inventory, a reader will transmit the inventory command over 100 times per second; indeed, such re-trying is an essential feature of RAIN RFID. So for many applications the net success rate for tag reading can be very high even if, as for the first case, a large proportion of tag-to-reader messages will fail.

[1] Current versions see [1] and [2]

4. RAIN RFID Reader Testing

The following schematic provides an overview of the anticipated signal power levels during a reader-tag-reader interaction, whereas the test setup shall consist of one reader and one tag (reference tag, tag emulator, …). The forward and reverse path loss will be identical for our purposes.



The reader receiver performance test shall be done according to ISO/IEC 18046-2. According to this test reader sensitivity is tested with variations of multiple parameters. While a single test result has some value, a matrix of tests might use difference reference settings, reader configurations, and RAIN air interface parameter values. Both conducted and radiated tests are possible, but it should be noted that the goal of reader testing is to provide a measure of the reader sensitivity that would be witnessed in a typical use-case scenario.

For reader testing the reader manufacturer chooses and records values of Tari, BLF, M, TRext, DR, RTcal, and TRcal[2].. The reader manufacturer also

[2] Some values are inter-related

chooses the output power, an operating frequency, and any other relevant settings for the reader.

All these values are fully documented and chosen from the range of values allowed by the RAIN air interface while complying with all local regulatory restrictions.

The received power that is available to the reader is varied as part of the testing process.[3] For example, an attenuator or variable backscatter could be used to simulate the *path loss* during an interaction, allowing the tester to vary the power received at the reader even though the transmit power is fixed.

A single test consists of the sequence of actions. The *receiver sensitivity* is specified to be the smallest signal strength (measured in dBm) for which the reader successfully passes 90% of a minimum of 100 consecutive tests comparing at least the RN16 and ACK, or ensure that the reader received a correct CRC-16 of the UII/EPC. The selected criteria shall be noted.

The received power is specified as the sum of the power of both side bands, which would be detected by a receiver with carrier filtered. Harmonics are not included.[4]

For a conducted test, the emitted power and measurements of the received power are specified at the input/output of the reader.

For a radiated test the emitted power is specified as an EIRP value which is equivalent to using a unity-gain antenna (0 dB) positioned at the plane of the reader receiver's (integrated) antenna. The received power is measured at the same plane. Additional tests can be conducted on other reader antenna combinations as appropriate.

The reader manufacturer may report measured values for the reader sensitivity for a variety of parameter sets, provided all operational parameters are fully specified and the measurements can be reliably and independently replicated based on these parameters. It is recommended to test BLF variation and tag backscatter phase variation. A more rigorous test is to test at the reader's worst specified acceptable return loss at any angle.[5]

[3] For a reference tag it might be difficult to only vary the reverse path, as the power at the tag has to remain constant and high enough to avoid as much influence of transponder sensitivity as possible.
[4] Details are defined in ISO/IEC 18046-2
[5] An advanced test would be required to cover multiple defined phases.

It shall be confirmed that the reader always checks for the correctness of the CRC-16. above. This confirmation may be provided by a reader manufacturer statement. This confirmation may also be provided by detecting a different reader reaction when an EPC with correct and an EPC with incorrect CRC are presented to the reader. Note that if, during a test, the reader reports as received any EPC that has not been issued by the test equipment then that test is failed.

The reader manufacturer needs to state whether the reader always checks for the correctness of the CRC-16. For those interested in testing this, it would be sufficient to detect a different reader reaction when correct and incorrect EPC/CRC combinations are presented.

5. Conclusion

RAIN RFID reader manufacturers are encouraged to provide data on the reader's receiver sensitivity. This would then become available to the RAIN community. This data should consist of at least one measurement of reader sensitivity, where the measurement is provided under documented conditions so that it can be replicated. Optionally, the reader manufacturer may provide further details, additional background information, or any other relevant data.

Depending on feedback from the community, some refinements and/or narrowing of the specification of the testing procedure may be introduced in future versions. It might also be interesting to expand a single data value for reader sensitivity into multiple values. While some simplicity would be lost, it would allow reader sensitivity to be profiled across a range of parameter values.

Further work in RAIN might move towards the idea of grading or classifying readers so that the end-user will have some insight into which readers are best suited for which roles. However, this would-be additional work beyond this first step of establishing a means of reporting reader sensitivity.

6. References

[1] EPC™ Radio-Frequency Identity Protocols, Generation-2 UHF RFID, Specification for RFID Air Interface, Protocol for Communications at 860 MHz – 960 MHz[6]

[2] ISO/IEC 18000-63 "Information technology — Radio frequency identification for item management — Part 63: Parameters for air interface communications at 860 MHz to 960 MHz Type C"[7]

[3] ISO/IEC 18046-2:2020, Information technology — Radio frequency identification device performance test methods — Part 2: Test methods for interrogator performance[8]

[6] https://www.gs1.org/standards/epc-rfid/uhf-air-interface-protocol

[7] https://www.iso.org/advanced-search/x/title/status/P,U/docNumber/18000/docPartNo/63/docType/0/langCode/ics/currentStage/true/searchAbstract/true/stage/stageDateStart/stageDateEnd/committee/sdg

[8]https://www.iso.org/advanced-search/x/title/status/P,U/docNumber/18046/docPartNo/2/docType/0/langCode/ics/currentStage/true/searchAbstract/true/stage/stageDateStart/stageDateEnd/committee/sdg

Background and Contributors

The procedure for RAIN RFID Reader Sensitivity Testing specified in this document was developed within the RAIN Solutions Workgroup. Frequent updated drafts were available for comment to the entire Workgroup and contributors from the following RAIN Alliance members either played a major role in shaping the final document or provided feedback to earlier versions:

V1:

- CISC Semiconductor
- Embisphere
- Impinj
- Lyngsoe Systems
- NXP Semiconductors
- RR Donnelly
- Voyantic
- Zebra Technologies

V2:

- CISC Semiconductor
- Race Result
- Clairvoyant Technology
- Impinj

For any feedback or questions about this document, please contact: rain-reader-testing@rainrfid.org.

ABOUT RAIN RFID ALLIANCE

The RAIN RFID Alliance is an organization supporting the universal adoption of RAIN UHF RFID technology. A wireless technology that connects billions of everyday items to the internet, enabling businesses and consumers to identify, locate, authenticate, and engage each item. The technology is based on the EPC Gen2 UHF RFID specification, incorporated into the ISO/IEC 18000-63 standard.

Join the RAIN RFID Alliance to enable connectivity for your business and consumers: identify, locate, authenticate, and engage items in our everyday world. For more information, visit www.RAINRFID.org.

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