Defining Read Point Configuration Terminology for RAIN in Tyre Applications

RAIN Alliance Paper

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Executive Summary

- Internet of Things (IoT) has created a new frontier for transportation and mobility.
- Utilizing these devices and their associated data are the means to achieve "connected" and "intelligent" tyres, vehicles, and infrastructure thus enabling safer, cleaner, and more efficient mobility.
- Virtually all IoT applications require a data connection between the physical and digital worlds, and RAIN RFID is the ideal technology to bridge these realms ([1]).
- The tyre industry has adopted UHF RFID as a data carrier to individually identify each individual tyre ([2]).
- The RAIN Alliance Tyres Workgroup was created in 2020 to "Develop and publish materials related to the use of RAIN RFID in tyres." ([3])
- Stakeholders, both within the RAIN Alliance as well as the broad vehicle and mobility eco-systems, have begun to specify and design solutions to bring to market components and integrated systems to develop and implement the applicable components and systems.
- However, Industry lacks common terminology that binds together the worlds of tyres and automatic identification to aid in the development of solutions.
- Read point configurations consist of items, tags, and readers.
- The objectives of this paper are to define, clarify, and educate regarding the terminology associated with RAIN read point configurations to support tyre solutions.

[1] What RAIN RFID Brings to the Internet of Things
[2] Tire industry on the road to universal RFID standard and/or ISO/TC 31/WG10 RFID tyre tags
[3] RAIN Alliance Tyres Workgroup

Introduction

RAIN RFID is one of the most common wireless technologies for identification purposes. This technology is robust and reliable, and is used to track and identify items in different markets like retail, automotive, tolling, electronic vehicle identification (EVI), pharmaceuticals, food, logistics, etc. The market for the RAIN passive UHF RFID technology is in a strong growth mode, with shipments of RAIN RFID tag chips reaching record volumes of 45.5bn units in 2023 ([4]).

What is RAIN

Since this document is focused on terminology, it is important to align the audience on the term "RAIN RFID", or just "RAIN", which can be used to identify a variety of things, including tags, readers, solutions, applications, and technology ([5]). Let us first focus on how industry describes a tag:

- A RAIN RFID Tag is defined as a *"brand name for a passive UHF tag that follows the ISO/IEC 18000-63 or GS1 UHF Gen 2 standards"* ([6]). (RAIN Alliance 2021)

The tyre industry, through ISO 20910 ([7]), specifies requirements for an RFID tag in tyre applications, including:

- *"technology: only passive ultra high frequency (UHF) RFID tags are used;*
- *global interface: the air interface protocol is ISO/IEC 18000-63, which is equivalent to GS1 EPC Gen2 V2.0.1".* (ISO 2019) ([8])

For the purposes of this document, references to *RAIN RFID Tag* or *RAIN Tag* will be used interchangeably for requirements specified for an *"RFID tag in tyre application"* in ISO 20910.

Benefits of RAIN

One of the most important value-added benefits of RAIN is the ability to read multiple items without line-of-sight and without knowing where the tag is within the item. Therefore, the **tags can be embedded directly in the**

[4] RAIN RFID tag chip shipments forecast to reach 115bn units by 2028, a year-on-year growth of 20.4%
[5] RAIN Brand Guidelines
[6] GS1 EPC Gen2v2 Fact Sheet
[7] ISO 20910:2019(en) Coding for radio frequency identification (RFID) tyre tags
[8] Note: Since the publication of ISO 20910 in 2019, GS1 Gen 2 has been revised; Gen2Vx may be used in the future in ISO

tyre so that it may be identified, located, authenticated, and engaged through its full life cycle. These benefits are why RAIN was introduced by the tyre industry through ISO standards published beginning in 2019-2020, including:

- ISO 20909, which provides terms and definitions for readers and tags, as well as tag configurations. (ISO 2019)
- ISO 20910, which defines the terms and definitions, general requirements and data structure for coding radio frequency identification (RFID) tyre tags. (ISO 2019)
- ISO 20911, which defines the terms and definitions RFID tyre tag classification of the different technologies (embedding, patching, sticking) (ISO 2020)
- ISO 20912, which defines test methods for validating the conformance of RFID enabled tyres. (ISO 2020)

However, ISO TC 31/WG 10 has not yet published a consensus list nor normative references for RFID-enabled tyre use cases. Additionally, there currently exists no common terminology for read point configurations necessary to deliver those solutions. The target audiences for the common terminology include:

- Chip, tag, and reader manufacturers… as well as the integrators, solutions providers, consultants, researchers, and labs who bring it all together.
- Tyre, rim (wheel), and vehicle manufacturers… as well as the distributors, dealers, servicers, retreaders, repairers, operators, inspectors, and recyclers whose operation will benefit from an electronic, uniquely identified tyre.
- Vehicle, transportation, and mobility business leaders who have yet to understand or define the problem for which an RFID-enabled tyre is the solution.

Scope

While there exists a whitepaper defining terminology in common use by the RAIN industry ([9]), terms used in the tyre industry ([10]), and several sources that include definitions for RFID-enabled tyres, there is no specific vocabulary nor defined terminology for a ***read point configuration***, which for the purposes of this document is defined as an *Item, a Tag, and a Reader in relation to one another*.

What makes one read point configuration different from another **are specific attributes**, such as distance, angle, quantity, speed, and environmental surroundings.

In scope:

Included in each of the read point configurations defined in this document will at minimum be one Item (a tyre), one Tag, and one Reader (which may include or be connected to one or more antennas), as shown in Figure 1.

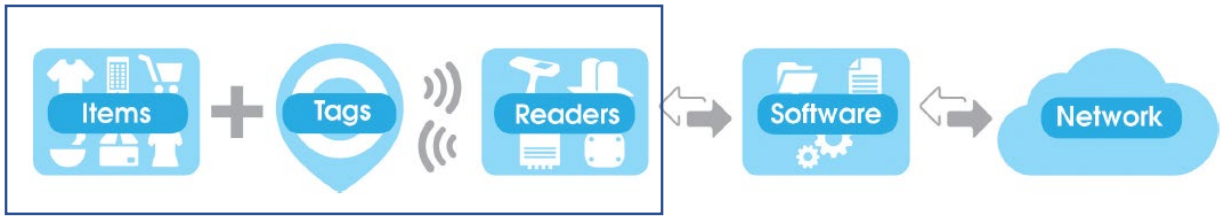


Figure 1 RAIN Alliance – What is RAIN RFID ([11])

Scope will include only reading of EPC (Electronic Product Code) and tag contents, not writing to the EPC (i.e., during encoding or initialization) nor user memory. Writing to tags may be included in a future version of this document.

Those interested in learning more about tags and readers beyond the scope of this document may wish to refer to RAIN Alliance's *What is RAIN RFID? E-Book, Fourth Edition* or *RAIN RFID Reader Sensitivity Testing*.

[9] RAIN Terminology
[10] ISO 4223-1(en) Definitions of some terms used in the tyre industry – Part 1: Pneumatic tyres
[11] What is RAIN RFID?

Out of scope:

- Technical specifications and read-range performance of the tag and reader (e.g., specifying values for distance, speed, power-levels, angles, materials, brands/technologies, etc.).
- Detailed descriptions of cases and events for tracking and traceability of a tire.

The configurations featured below are not intended to be an exhaustive list. Rather, they are representative of those that the Tyre Working Group developed using consensus process. The list of configurations will be expanded and refined in future versions of this document.

"Tyre" and "tire" are often used interchangeably, including within the RAIN Alliance. For consistency, only tyre will be used in this document.

Use cases

RFID-tyres are commonly read along all their life cycle, in different contexts and conditions, for different purposes, such as described in Figure 2 ([12]).

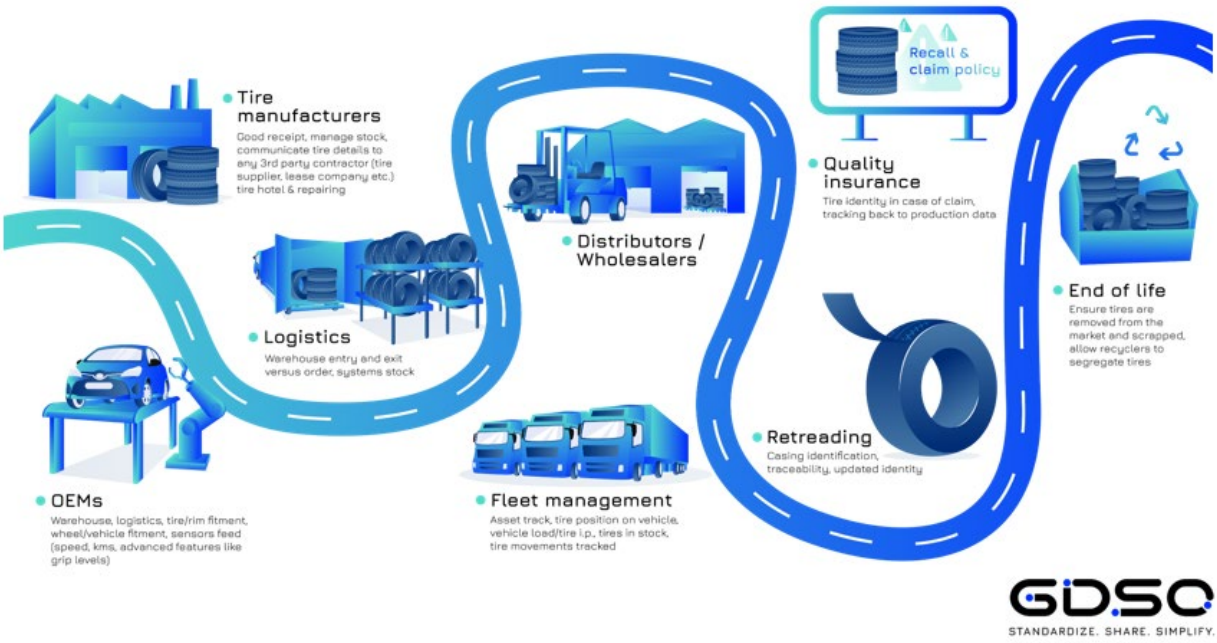


Figure 2 Description of use cases along the value chain (©GDSO Used with permission of Global Data Services Organization)

[12] Global Data Service Organization

Just thinking about operations during manufacturing of the tyre, inventory tracking, delivery tracking, retailing, mounting on a vehicle, usage on a vehicle, maintenance, or end-of-life-tyre management, it is clear that the use cases associable with a RFID-enabled tyre are many and can significantly differ one to another. The term ***use case*** also addresses the purpose of the RFID-tyre reading operation. A use case is characterized by a specific context and purpose of the reading operation. The relationship of read point to use case can be a matrix of one or more reading point configurations, in one-to-many and many-to-one possible combinations. A read point configuration limits itself to define the relevant physical characteristics to determine the interaction of the RFID tag with the reader. The physical characteristics that are in scope of defining a read point configuration allow for distinguishing from another read point configuration.

A given read point configuration may be found in several use cases. Using the illustration above, it may be necessary to move tyres through an operation in various use cases, which might be satisfied by a variety of read point configurations.

Tyre Read Point Configuration Terminology

Table 1 illustrates the tyre configurations likely to be encountered by the different types of read points described in this document. Each Configuration and Read Point will be individually defined following the table.

		TYRE CONFIGURATIONS					
		SINGLE NON-WHEEL-MOUNTED TYRE	SINGLE WHEEL-MOUNTED TYRE	VEHICLE-MOUNTED SINGLE TYRE	VEHICLE-MOUNTED DUAL TYRE	STACKED NON-WHEEL-MOUNTED TYRE	STACKED WHEEL-MOUNTED TYRE
READ POINTS	STANDALONE TYRE	•	•	N/A	N/A	N/A	N/A
	HANDHELD READER	•	•	•	•	•	•
	HANDHELD TYRE	•	•	N/A	N/A	N/A	N/A
	CONVEYOR	•	•	N/A	N/A	N/A	N/A
	ROLLING GATE	•	•	N/A	N/A	N/A	N/A
	VEHICLE PRODUCTION LINE	N/A	N/A	•	•	N/A	N/A
	DRIVE-BY GATE	N/A	N/A	•	•	N/A	N/A
	DRIVE OVER	N/A	N/A	•	•	N/A	N/A
	ONBOARD VEHICLE	N/A	N/A	•	•	N/A	N/A
	STACKED INVENTORY	N/A	N/A	N/A	N/A	•	•

Table 1 Tyre Configurations to Read Points

Legend:

•	Shows valid intersection between tyre configuration and read point
N/A	Shows where intersection between tyre configuration and read point is not applicable (as of publication date)

TYRE CONFIGURATIONS

The Item in the Tyre Read Point Configuration starts with at least one tyre. The configuration may contain a single tyre or multiple tyres. Whether a single tyre is physically resting on its tread or on a sidewall are variables specific to given read point configurations.

SINGLE NON-WHEEL-MOUNTED TYRE & SINGLE WHEEL-MOUNTED TYRE

Tyres may be without a wheel or may be mounted on a wheel.

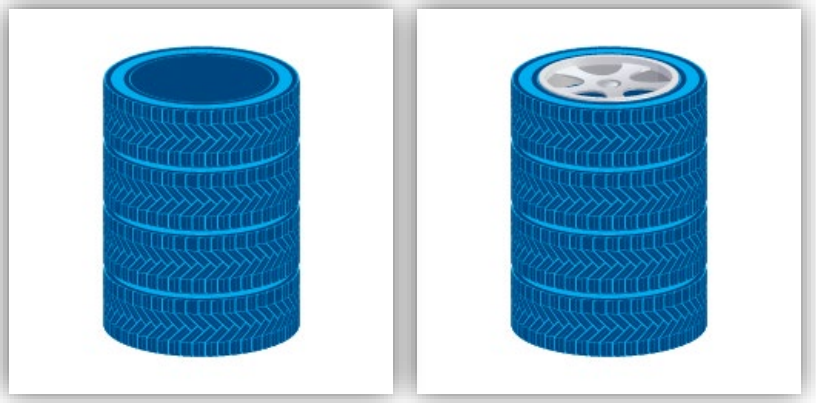
VEHICLE-MOUNTED SINGLE TYRE

Tyre-wheel assembly which is mounted on axle without another tyre on the same end of the axle.

VEHICLE-MOUNTED DUAL TYRE

A dual is one variable that has reserved terminology. (ISO 2021) A dual tyre fitment is where two matched tyres are placed on each end of a single axle.

STACKED NON-WHEEL-MOUNTED TYRE & STACKED WHEEL-MOUNTED TYRE



With the exception of a dual, when there are multiple tyres in a read point configuration they will be organized into a stack. Stacks may be arranged horizontally (e.g., on a rack) or vertically (e.g., on a pallet). Stacks may be wheel-mounted or not. ([13])

For RAIN Tags, ISO 20911 (ISO 2020) specifies RFID tag classification and attachment, including embedded tags, patches, and stickers/labels. How and where the tag is attached to the item, the tyre, such as whether on the tread or sidewall—and which sidewall—are variables for the read point designer to consider.

RAIN Readers are available in many different configurations. All readers accomplish some basic tasks and may have additional features. All RAIN readers can communicate with the RAIN tags.

For terminology, there are two basic types of readers, which come in many different variations. As shown in "Appendix – Terms & Definitions", readers are generally classified as "fixed" or "portable". A "handheld" reader can be one type of portable reader.

Fixed readers typically mount to a fixed location (e.g., near a door, on a forklift truck etc.) and can communicate with one or many antennas ([14]).

[13] Complex tyre configurations, such as "lacing" or "piles" or "pyramid", may be considered for future versions of this document.
[14] Readers

For read points configuration definition, when referring to the reader, the most critical elements can be the placement and/or the movement of the antenna(s).

READ POINTS

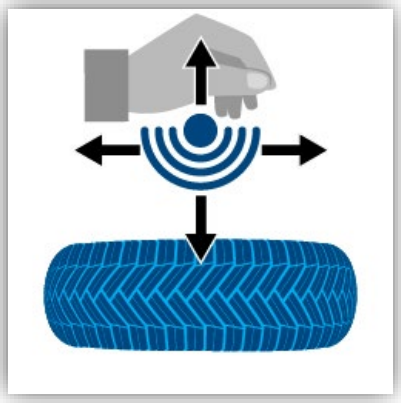
STANDALONE TYRE

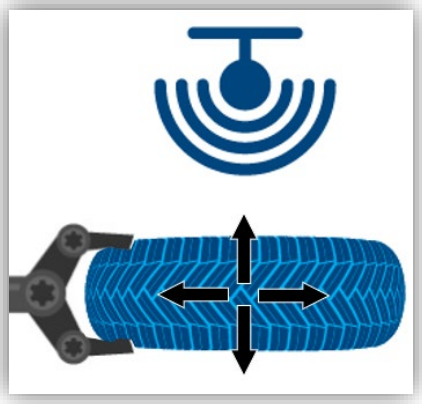
Static single tyre and reader/antenna(s), where neither the tyre nor the reader moves. This read point category may be more present during analytical phases such as tyre or read point design and setup. For example, when applying methodologies described in ISO 20912:2020 Conformance test methods for RFID enabled tyres (Ibid).

HANDHELD READER

Reader/antenna movement is generated by a human or robotic hand.

This read point category may be the most commonly used in various RAIN applications.





HANDHELD TYRE

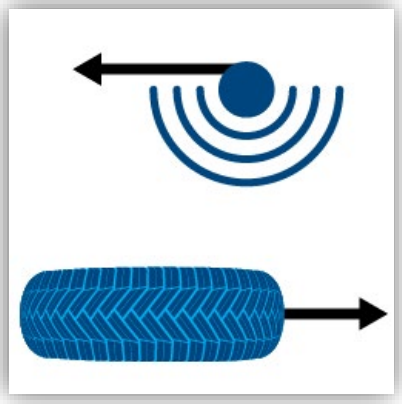
Individual tyre is in motion by a human or robotic hand or other means of conveyance, such as a hand-cart, in proximity to a fixed reader/antenna.

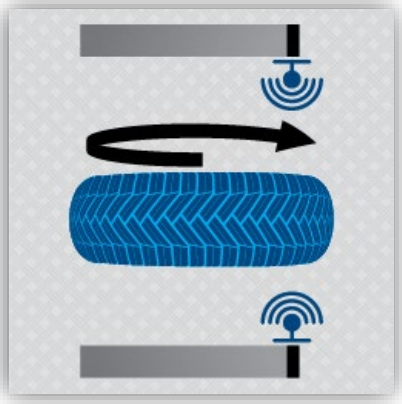
This may be present, as an example, when loading or unloading a tyre pallet or laced tyres where each tyre is in transit.

CONVEYOR

Relative movement between the tyre and/or the reader/antenna(s) in translation (linear motion).

Includes reader/antenna(s) set onto "conveyor belts" and, also variants where the tyres are in a vertical position while suspended and moved through a "chain" system.





ROLLING GATE

Tyre rolling in proximity to a fixed reader/antenna(s).

Typically present at loading or unloading "gates" of trailers in the supply chain or at specific gates of tyre storage or sales areas where inventory (ins and outs) must be accurately tracked ([15]).

VEHICLE PRODUCTION LINE

Fixed antenna with vehicle passing through and tyres not rolling.

Antennas may be located in various positions to optimize read performance. Key attribute is that vehicle is lifted while vehicle is in movement. Vehicle type could include medium- and heavy-duty vehicle production lines.

[15] This read point category would be one of the most specific to the tyre industry since it implies a human skill to safely "launch" the tyres in the desired direction and through the "rolling gate".

DRIVE-BY GATE

Tyre-mounted on vehicle passing through a fixed gate/gantry.

Framework or structure with antennas positioned in which the vehicle drives by. Key attribute is that wheels are rotating while vehicle is moving.

DRIVE OVER

Tyre-mounted on vehicle passing over fixed reader(s)/antenna(s) in or on the ground.

Antennas embedded in object placed on ground or directly within ground surface on which the vehicle drives over. Key attribute is that wheels are rotating while vehicle is moving.

ONBOARD VEHICLE

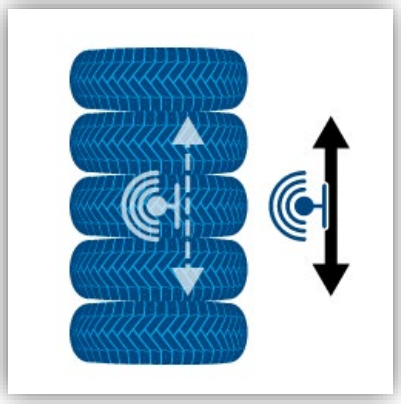
Reading system embedded inside or attached to the vehicle.

Such a solution would allow to communicate with the tag from the vehicle, potentially at rest and/or while moving.

STACKED INVENTORY

Stacked tyres are read by portable and/or fixed readers in a variety of systems.

This category can include multiple system variants so to access to each tag inside the stack. This would include reader/antenna moving from the outside of the stack and/or moving inside the stack when possible (e.g., reader on fixed mount or attached to drone, etc.).



Going Beyond Read Point Definitions

The purpose of this document is to define terminology and high-level definitions of read points. It is acknowledged that multiple variations may exist and their corresponding specifications must be more precisely defined in order to design and configure scalable solutions.

Taking as an example a Conveyor, a read point designer might want to know the exact environment and description of the tyres in the corresponding read zone before proposing a solution. There may be multiple attributes for an optimal solution for cost, complexity, and scalability. Beyond generic specifications about the physical constrains (geometry, radio frequency friendliness within and around the read zone, ingress protection, etc.), and applicable standards and regulations, there may be key questions to consider about the tyres, including:

- What is the maximum speed of the tyre on the conveyor?
- What is the position of the tag in or on the tyre? For example, are the tyres positioned randomly on the conveyor?
- Does the system need to be able to discern reading a single tyre without also reading other tyres unintentionally? For example, is there a need to "insulate" or "isolate" each tyre within the "read zone" in order to manage sorting?

Of critical importance, and relevant to each read point configuration, is whether the solutions designer has information about the tyre configuration. For example, what are the types and sizes of tyres? There are many attributes about the tyres that will significantly determine optimal read performance. Questions to consider include:

- Is the source of the tyre known? For example, is the supply and source of tyres predictable? …or… Is it possible to receive a mixed supply of tyres from unknown sources, including some tyres which may not be tagged?
- Are tyres expected to be commercial tyres (e.g., truck and bus) or consumer tyres (e.g., passenger and light vehicle), which have different sizes, types of construction, and material compositions?
- Is there information known about read range performance of the tyres?

Summary

RFID and tyres is not a new concept. Both technologies are quite mature, with innovations on tyres dating back more than 100 years ([16]) and to the 1940s and '60s for RFID ([17]). Efforts to integrate tags into tyres started in the early 2000s; however, it was not until the four ISO standards were published in 2019 and 2020 and the RAIN Alliance Tyres Workgroup was created in 2020 that global industry adoption started to gain momentum ([18]) ([19]).

Read point configuration design is a critical part of leveraging RAIN technology to satisfy various use cases. One barrier to adoption has been that as use cases or business problems are discussed, there has been no shared terminology for describing how the technologies come together with optimal performance, cost, and scalability. There was no common terminology for how the ecosystem of RFID experts and tyre experts could communicate… with each other… and to their customers and partners.

This paper aims to define and inform about common terminology so that we, together, can accelerate deployment of innovative solutions for RAIN and tyres. As the ecosystem comes together towards broad industry adoption, the terminology and configurations will evolve and improve. The authors of this document, through collaboration and consensus approach, arrived at what are the most common terms as of the publication of this document. Future versions of this document will incorporate advances in design of new read point configurations, along with their corresponding terminology.

[16] History | Tire (Wikipedia)
[17] History of RFID
[18] Start Your Engines! RAIN RFID Makes Its Mark On The Tyre Industry
[19] The Key to Global Tyre Identification: A Guide

Appendix – Terms and Definitions

Items / Tyres:

- ☐ RFID enabled tyre (ISO 20912): tyre featuring an RFID tag by means of an embedded, patch or sticker solution (Ibid)
- ☐ standalone tyre (ISO 20912): non-mounted tyre (Ibid)
- ☐ rim (ISO 4223-1): part of the wheel on which the tyre is mounted and supported (ISO 2017)
- ☐ test rim (ISO 4223-1): rim on which the pneumatic tyre is fitted for specific testing (Ibid)
- ☐ wheel (ISO 4223-1): rotating load-carrying member between the tyre and the axle, usually consisting of two major parts, the rim and the wheel disc, which may be integral, permanently attached or detachable (Ibid)
- ☐ dual wheel (ISO 3911:2021) wheel with sufficient inset and configuration so that two such wheels, when assembled with each other, support two tyres on one end of an axle (Ibid)
- ☐ tread (ISO 4223-1): part of a tyre which comes into contact with the ground (Ibid) (Ibid)
- ☐ carcass (ISO 4223-1): part of a tyre other than the tread and the sidewall rubber which, when inflated, bears the load (Ibid)
- ☐ Tyres, Valves and tubes – List of equivalent terms – Part 1: Tyres (ISO 3877-1) (ISO 1997)

Tags: RAIN tags (RAIN Technology [20]): items that are attached to the "thing" that needs to be identified; the tag is made from an integrated circuit (tag chip) and an antenna mounted on a substrate

- ☐ embedded RFID tyre tag (ISO 20909): RFID tyre tag that is applied into the tyre and cannot be removed without damaging the tyre (Ibid)
- ☐ RFID tyre patch (ISO 20909): RFID tyre tag that is applied onto the tyre and cannot be removed without the risk of damaging the tyre (Ibid)
- ☐ RFID tyre sticker (ISO 20909): RFID tyre tag that is usually post-cure, applied to the tyre and can be removed without damaging the tyre (Ibid)

[20] RAIN Alliance / Our Technology / Tags

Readers: RAIN readers (RAIN Technology): All RAIN Readers can communicate with the RAIN tags and learn their identity; most can also write to the tag; there are two basic types of reader, though these come in many different variations: fixed and portable

- ☐ reader (ISO 20909): electronic device using wireless method to communicate with RFID tags according to specific protocols for data exchange; aka, RFID interrogator (Ibid)
- ☐ fixed reader (GS1 CBV): any fixed read point configuration (reader and antennas) for the purpose of capturing EPC data (e.g., Door way or conveyor read point) (GS1 2010)
- ☐ mobile reader (GS1 CBV): any non-fixed (portable) reader configuration (reader and antennas) for the purpose of capturing EPC data (e.g., Hand held or forklift reader) (Ibid)
- ☐ reader antenna: The reader antenna is crucial for the RF interface of the reader. Different antenna designs have different properties and the optimal choice will depend on the application and the environment of use. (RAIN Alliance 2016)
- ☐ handheld reader (Gartner): portable devices that can communicate with RFID tags (Gartner n.d.)
- ☐ portal reader (Gartner): fixed in one location, where RFID tags pass through and communicate with the reader (Ibid)
- ☐ mounted readers (Gartner): placed on mobile equipment, such as forklifts, cranes, drones, etc., and often communicate with tags in fixed locations (Ibid)

RAIN Antennas (RAIN Technology): there are two antennas in a RAIN system:

- ☐ the first antenna is the one connected to the Tag Chip, this antenna can be of many different shapes, sizes and capabilities (RAIN Alliance n.d.)
- ☐ the second antenna is associated with the reader and again can be of various shapes and sizes; reader antennas can be horizontally, vertically, or circularly polarized (Ibid)

Miscellaneous:

- ☐ "where" dimension (GS1 CBV): consists of two identifiers that describe different aspects of where an event occurred (Ibid)
- ☐ read point (GS1 CBV): the location where the "event" took place; the location where the RFID reader read the tag (Ibid)
- ☐ business location (GS1 CBV): the location where the subject of the event is assumed to be following an event (Ibid)

- ☐ "why" dimension (GS1 CBV): consists of two identifiers and a list of business transaction identifiers, which collectively provide the business context or "why" the event occurred (Ibid)
- ☐ dock / door (GS1 CBV): one or more doors where trucks or rail cars are loaded (shipping) or unloaded (receiving); used to load or unload trailers or vans (Ibid)
- ☐ conveyor belt (GS1 CBV): a continuous moving strip or surface that is used for transporting [a] single … or a load of objects from one place to another (Ibid)
- ☐ loading dock (GS1 CBV): a parking bay, partly enclosed by a raised platform, at which trucks are loaded or unloaded; e.g., in a warehouse site (Ibid)
- ☐ entrance gate (GS1 CBV): a point of transport access into a yard or other arrival area (Ibid)
- ☐ exit gate (GS1 CBV): a point of transport from a yard or other departing area (Ibid)
- ☐ gate (GS1 CBV): a point of transport… not indicated specifically as an entrance or exit point (Ibid)
- ☐ portal (RFID Journal Glossary): an RFID interrogator gateway used in manufacturing settings; forklifts or other methods are used to transport items through a portal reader to collect RFID tag data (RFID Journal n.d.)
- ☐ read point verification spot (GS1 CBV): a point at which a tagged object's location has been verified by an associated read of a separate fixed location… used when there is a business process to capture the current location of an object at rest (typically with a mobile reader) (Ibid)
- ☐ reading distance (ISO 20909): perpendicular distance between interrogator's antenna and tyre surface (Ibid)
- ☐ measuring distance (ISO 20912): linear distance between the RFID tag position and the interrogator antenna (Ibid)

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Background and Contributors

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ABOUT THE RAIN ALLIANCE

The RAIN Alliance is a consortium of companies that together want to create a smarter and more sustainable world by using RAIN technology to connect trillions of everyday items across their entire lifecycle, simply and inexpensively. The technology is based on the EPC Gen2 UHF RFID specification, incorporated into the ISO/IEC 18000-63 standard.

Join the RAIN Alliance to help drive awareness and foster market adoption of RAIN technology. For more information, visit www.RAINRFID.org.

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