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Conformance test methods for RFID enabled tyres

Méthodes d'essai de conformité de pneumatiques RFID

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 31, *Tyres, rims and valves*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document is using passive RFID tags in the UHF RFID band from 860 to 930 MHz.

This document describes the conformance to ISO 20909 minimum reading distance within a specific radio frequency region.

Indeed, different RFID tag attachment solutions can be considered as per ISO 20911 and the tests reported in this document allow the tyre manufacturer to evaluate whether the selected option is suitable or not to grant the RFID enabled tyre minimum transmission performance level.

During the development of this document, attention was paid on the key parameters influencing the test results. However, others still remain non-specified therefore a testing lab can use those parameters to their discretion to perform the test.

The specifications in this document are not intended to limit any additional verification.

The use cases have been simplified by considering a standalone/unmounted tyre and describing a test set-up that can be used throughout the tyre's lifetime and/or the tyre's supply chain.

When conformity decisions are being done across various stakeholders, objective comparisons can be performed using the results obtained applying this document.

Additional use cases and more precise, detailed and traceable testing methodologies may be added in future revision of this document as RFID technology and its adoption moves forward.

Conformance test methods for RFID enabled tyres

1 Scope

This document defines the test methods for validating the conformance of RFID enabled tyres with the minimum reading distance specifications given in ISO 20909.

The two presented methodologies give comparable test results only when the same radio frequency and energy power parameters are used.

Unless otherwise specified, the tests in this document are to be applied exclusively to a standalone RFID enabled tyre.

This document is not intended to set any requirement on mass production quality control, nor on the frequency for testing.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 20909, *Radio frequency identification (RFID) tyre tags*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
standalone tyre
non-mounted tyre

3.2
RFID enabled tyre
tyre featuring an RFID tag by means of an embedded, patch or sticker solution

3.3
measuring distance
d
linear distance between the RFID tag position and the interrogator antenna

3.4
received signal strength indicator
RSSI
indicative, non-calibrated value of the received power at the reader input

Note 1 to entry: This is the power backscattered by the tag towards the reader and measured at the reader input. RSSI is sometimes used to determine a tag's distance, as the signal is stronger from a tag that is closer to the reader antenna, however, the reflections and attenuation due to different materials may distort it.

3.5
turn-on power
$P^{to}_{in, RFID\ enabled\ tyre}$
minimum input of conducted power that the interrogator must provide to its antenna to activate the RFID enabled tyre which is placed at the *measuring distance* (3.3)

3.6
effective isotropic radiated power
EIRP
product of the power supplied to the antenna and the maximum antenna gain in one direction relative to an isotropic radiator (absolute or isotropic gain)

$$EIRP = P_T - L_C + G_a$$

where

P_T is the output power of the transmitter (dBm);

L_C is the cable loss (dB);

G_a is the antenna gain (dBi).

Note 1 to entry: EIRP is limited by local regulation.

3.7
reads per seconds
RPS
indicative, non-calibrated value of the number of valid reads received per second, by an RFID reader, while interrogating an RFID tag for several seconds

3.8
interrogator antenna gain
G_R
unitless gain of interrogator antenna computed from the isotropic gain [10^(dBi/10)]

4 Conformance test methods

4.1 General

Two different test methods are described below. Both can be used to validate the conformance to ISO 20909 minimum reading distance requirement. It is up to the tyre manufacturer to choose one method or the other.

4.2 Open space method

4.2.1 General

This test method validates whether the RFID enabled tyre can be read at the minimum reading distance and can be performed even by using a hand-held RFID reader. The specified test is performed in an open environment as described in 4.2.2.

4.2.2 Testing site

The testing area shall be an open space with no object, wall or people (except the operator according to the details described below) in proximity of the tyre and reader in the range defined in 4.2.3.2 and 4.2.3.3.

Also, there shall be no ceiling or at least no ceiling closer than those distances defined in 4.2.3.2 and 4.2.3.3 from the top of the tyre.

The ground and the ceiling shall minimize electromagnetic reflections during the measurement in order to ensure the accuracy of the test result.

— No atmospheric event (such as snow and rain) shall take place at the testing area during the measurement.

— No environmental change shall occur during the measurement.

— There shall be at least a free space of 2-m radius (excluding testing equipment and device under test) around the tyre on the horizontal plane.

— Personnel should be prohibited to be in the proximity of a 2-m radius around the test setup.

— The operator shall remain behind the reader (and not between the reader and the tag).

— In general, the permeability and permittivity of supporting equipment like tyre stand and others should be low to not influence test results.

To prevent any interference, it is recommended to set up a site survey in order to detect any use of radio frequency within the RFID frequency band. This can be done with a spectrum analyser and a UHF antenna to ensure that the radio frequency transmission levels are at least 10 dB smaller than the backscattering signal from the RFID enabled tyre.

4.2.3 Testing layout

4.2.3.1 General

Two testing layouts are defined. It is up to the tyre manufacturer to choose one or the other, depending of the RFID tag implementation/position.

4.2.3.2 Testing layout for the RFID in/on the tyre sidewall

The layout is depicted in Figure 1.

The minimum distance, h_1, between the tag position and the ground shall be at least at 1,5 m or 5 times of the minimum reading distance defined in ISO 20909, whichever is the lowest.

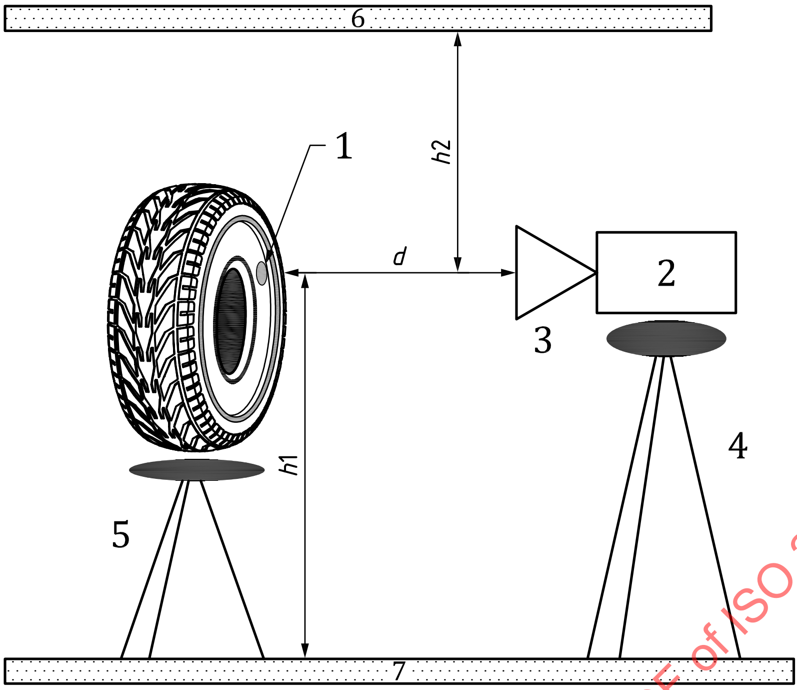
The tyre shall be put directly on the ground or on a stand in the testing site, unmounted from the rim.

The minimum distance, h_2, between the tag position and the ceiling shall be at least 1,5 m or 5 times of the minimum reading distance defined in ISO 20909, whichever is the lowest.

The area where the RFID tag is located shall be horizontally aligned with the reader's antenna as per the following description. To locate the RFID tag, the operator monitors the RSSI or RPS. Once the largest RSSI (or RPS) is obtained, the alignment between the tyre and the reader's antenna is adequate.

NOTE The largest RSSI can be unreliable for short distance between tag and reader. Instead a local maximum or minimum of the RSSI can indicate an adequate alignment.

The tyre sidewall surface containing the RFID tag shall be directed towards the reader’s antenna.



Key

d	linear distance between the RFID tag position and the reader's antenna, that is at least 2 times the minimum reading distance as defined in ISO 20909	2	reader
h_1	distance between the tag position and the ground	3	reader's antenna
h_2	distance between the tag position and the ceiling	4	reader's stand
1	RFID tag location	5	tyre stand
		6	ceiling
		7	ground

Figure 1 — Open space testing layout for the RFID tag in/on the tyre sidewall

4.2.3.3 Testing layout for the RFID in/on the tyre tread

The layout is depicted in Figure 2.

The tyre shall be put directly on the ground or on a stand on testing site, unmounted from the rim.

The minimum distance, h_1, between the tag position and the ground shall be at least the 1,5 m or 5 times of the minimum reading distance defined in ISO 20909, whichever is the lowest.

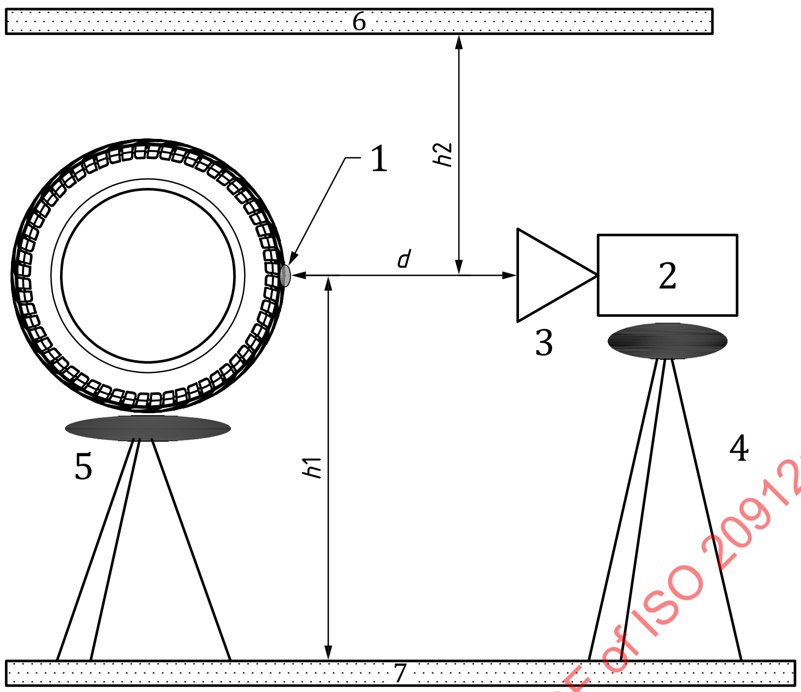
In case a tyre stand is required, it shall be made of non-metallic (radio frequency conducive) material to prevent electromagnetic interference.

The minimum distance, h_2, between the tag position and the ceiling shall be at least 1,5 m or 5 times of the minimum reading distance defined in ISO 20909, whichever is the lowest.

The area where the RFID tag is located shall be horizontally aligned with the reader's antenna as per the following description. To locate the RFID tag, the operator monitors the RSSI or RPS. Once the largest RSSI (or RPS) is obtained, the alignment between the tyre and the reader's antenna is adequate.

NOTE The largest RSSI can be unreliable for short distance between tag and reader. Instead a local maximum or minimum of the RSSI can indicate an adequate alignment.

The tyre area surface containing the RFID tag shall be directed towards the reader’s antenna.



Key

d	linear distance between the RFID tag position and the reader's antenna, that is at least 2 times the minimum reading distance as defined in ISO 20909	2	reader
h_1	distance between the tag position and the ground	3	reader's antenna
h_2	distance between the tag position and the ceiling	4	reader's stand
1	RFID tag location	5	tyre stand
		6	ceiling
		7	ground

Figure 2 — Open space testing layout for the RFID tag in/on the tyre tread

4.2.4 Testing equipment

An RFID hand-held reader is required that is able to read the RFID tag according to EPC Class1 Gen2 protocol or the RFID protocol of ISO/IEC 18000-63.

If desired, the same equipment as stated in 4.3.3 can be used in place of an RFID hand-held reader.

4.2.5 Testing method

The reader shall be set up in order to radiate a power at frequencies that are within the authorized frequency band.

NOTE 1 Legal requirements can apply to the power.

NOTE 2 Local requirements define the authorized frequency band.

The reader shall send a command or a set of commands in order to read the RFID enabled tyre UII including SGTIN96 successfully without errors.

NOTE As part of the PCWord, the CRC is automatically backscattered once the tag has been inventoried. Therefore “without errors” implies that the verification of the value of the CRC was successful according to the EPC Class1 Gen2 or ISO/IEC 18000-63 protocol.

For local regulations requiring frequency hopping, the interrogation interval shall be at least 3 s. This is to allow a portion of the frequency to hop and to provide a fixed time interval for average RSSI/RPS calculations.

After interrogation, the average RSSI or average RPS shall be recorded.

4.2.6 Conformance assessment

The test result is based on pass/fail criteria. The RFID enabled tyre is deemed to have passed the test if the reader decodes the RFID enabled tyre UII successfully without errors.

If the test is not successful, then the distance shall be reduced down to, but not lower than, the distance stated in ISO 20909 and the test shall be repeated.

As the reader specification and the power setting may undermine the test result, it is up to the operator to reconsider the reader model and the power settings in line with 4.2.5 if needed.

It is recommended to list in a test report the main parameters used to assess the conformance, as stated in Annex A.

4.3 Semi-anechoic method tailored to UHF frequencies

4.3.1 General

This test method verifies if RFID enabled tyre maximum reading distance is greater or equal than the conformance reading distance stated in ISO 20909. The specified test is conducted in a closed/indoor environment using anechoic panels and a fixed reader and stepping power levels.

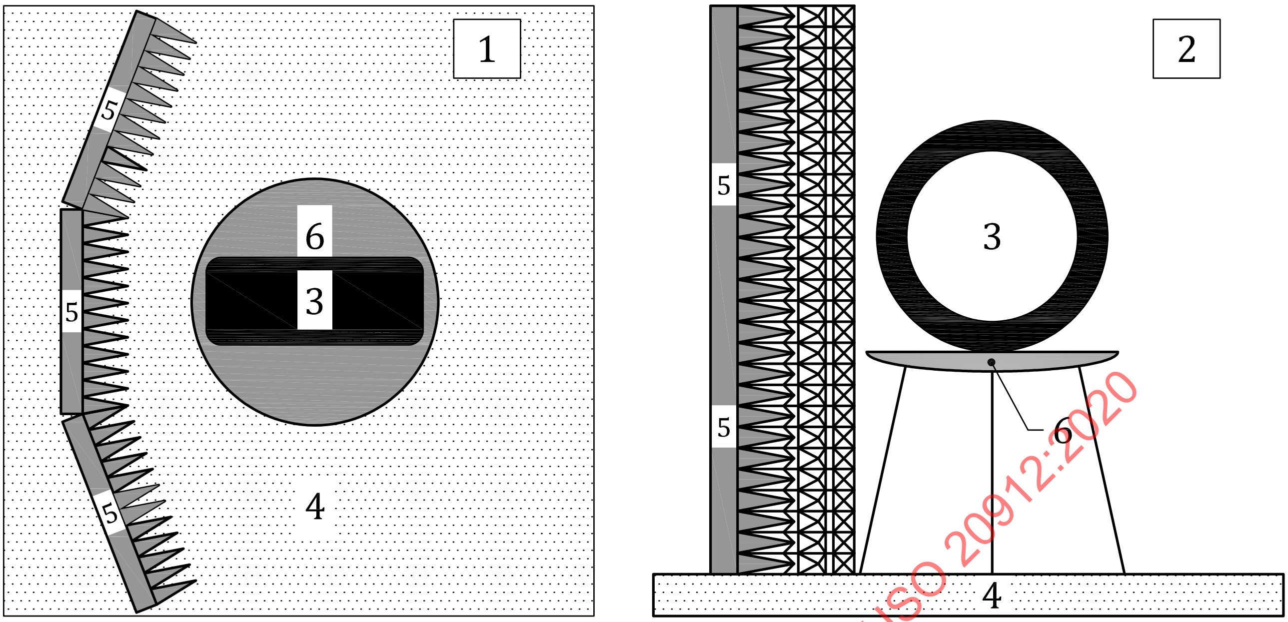
4.3.2 Testing site and layout

The testing site shall be such as the following.

a) No electromagnetic interference may occur during the test; to prevent any interference, it is recommended to set up a site survey in order to detect any use of radio frequency within the RFID frequency band. This can be done with a spectrum analyser and a UHF antenna to ensure that the radio frequency transmission levels are at least 10 dB smaller than the backscattering signal from the RFID enabled tyre.

b) A non-metallic stand is used for the RFID enabled tyre during its measurement as per 4.2.3; such a stand shall allow changing the position of height, rotation, as well as being able to move horizontally back and forth. In general, the permeability and permittivity of supporting equipment like tyre stand and others should be low to not influence the results.

c) Anechoic panels, able to absorb energy in all directions in the appropriate frequency band, shall be positioned behind the RFID enabled tyre so that they extend over it in height and width, as shown in Figure 3.



Key

1	top view	4	ground
2	side view	5	anechoic panel
3	RFID enabled tyre	6	tyre stand

Figure 3 — Top view and side view sketches of anechoic panels

4.3.3 Testing equipment

The following equipment is required:

— an output power, interrogator-verified, to be traceable back to national and international standards, power level adjustable with ± 1,0 dB accuracy, able to read/write the RFID tag according to EPC Class1 Gen2 protocol or ISO/IEC 18000-63 RFID Protocol;

— an antenna for the interrogator — a circular polarized antenna should be used in order to guarantee reception in all orientations of the antenna;

— for the interrogator and the antenna, a mounting bracket made of non-metallic material or an element made with a material able to prevent as much as possible stray radio frequency reflections and allowing the antenna to be rotated at any angle;

— a computer or other system that controls the testing procedure;

— a testing software used to control the interrogator operations.

An equivalent integrated device where all the above-mentioned functions are present may be used alternatively.

4.3.4 RFID enabled tyre measurement

To measure the RFID enabled tyre, the following steps apply.

a) Locate the tag positioning, interrogating the RFID enabled tyre by performing reads within the authorized frequency band defined by local regulations; the operator monitors the RSSI or RPS. The largest RSSI (or RPS) is obtained where the RFID tag is located.

NOTE The largest RSSI can be unreliable for short distance between tag and reader. Instead a local maximum or minimum of the RSSI can indicate an adequate alignment.

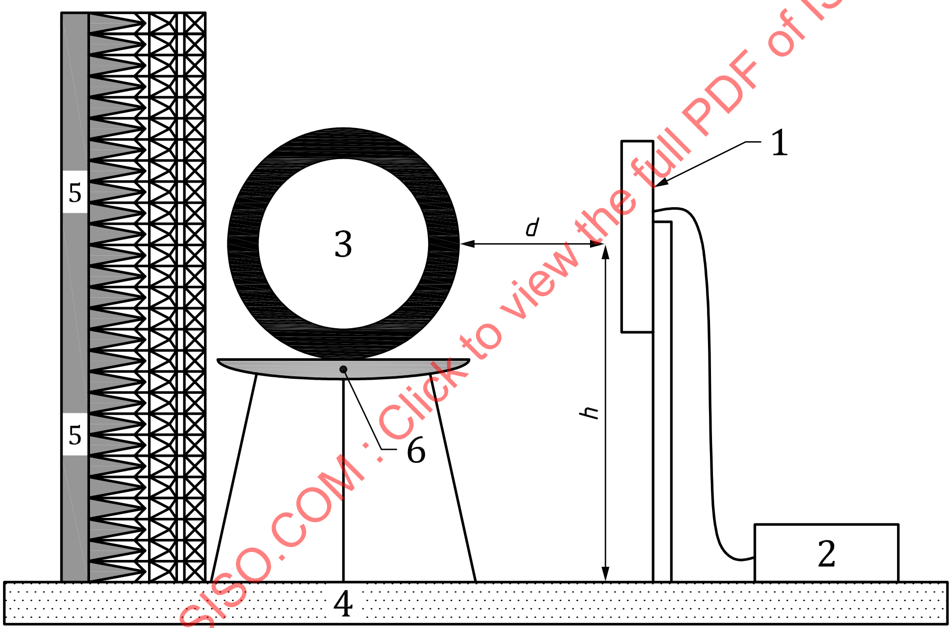
b) Put the RFID enabled tyre in front of the reader antenna, so that the area where the RFID tag is located faces and is aligned with the reader's antenna at a distance between 0,5 and 1,0 m, then to be considered the measuring distance, *d*, in Formula (1). A tyre stand can be used to reach the minimum height of 1,0 m from the ground, it shall not create any interference, as per Figure 4.

c) Interrogate the RFID enabled tyre for the UII including SGTIN96 within the frequency band of interest and within the power limit (as both are defined by local regulations). Step the power from the RFID Reader's minimum power setting (usually 10 dBm) by using increments of max 1 dB until the UII including SGTIN96 is first detected without errors. At that point, register the following parameters:

   1) UII including SGTIN96 code

   2) Turn-on power $P^{to}_{in,\ RFID\ enabled\ tyre}$

When frequency hopping applies, the interrogation time should be long enough to ensure completion of the frequency hopping table (refer to the reader manufacturer for specific device information).



Key

d	measuring distance	3	RFID enabled tyre
h	height vs the ground	4	ground
1	reader's antenna	5	anechoic panel
2	reader	6	tyre stand

Figure 4 — Equipment sketch

4.3.5 Testing method

To evaluate RFID enabled tyre reading performance, the following parameters are required:

— the maximum transmit EIRP used

— the interrogator antenna gain G_R (unitless ratio)

The maximum reading distance is computed, as given in Formula (1):

$$d_{max} = d\sqrt{\frac{EIRP_{max}}{P^{to}_{in,\text{RFID enabled tyre}} \times G_R}} \quad (1)$$

where

d_{max}	is the maximum reading distance, in metre (m);
$EIRP_{max}$	is the maximum effective isotropic radiated power, in Watt (W);
G_R	is the interrogator antenna gain;
d	is the measuring distance, in metre (m);
$P^{to}_{in,\text{RFID enabled tyre}}$	is the minimum input of conducted power that the interrogator must provide to its antenna to activate the RFID enabled tyre which is placed at the measuring distance, in Watt (W).

NOTE Application of $EIRP_{max}$ presupposes awareness of applicable legal requirements.

The steps reported in 4.3.4 and 4.3.5 can be automated by using an equivalent integrated device; in that case, the following parameters shall be reported:

— $EIRP_{max}$

— d_{max}

If available, the following shall be also added:

— $P^{to}_{in,\text{ RFID enabled tyre}}$

— G_R

Annex B provides some explanations about the relation between antenna gain, conducted power and radiated power while reporting factual examples.

4.3.6 Conformance assessment

The RFID enabled tyre is deemed to have passed the test if the maximum reading distance is equal or greater than the conformance reading distance stated in ISO 20909.

NOTE It is sufficient that the RFID enabled tyre conforms to the ISO 20909 minimum reading distance requirement for at least one frequency channel within the band of interest.

If the test is not successful, then the test shall be repeated reducing the measuring distance, *d*, down to but not lower than the distance stated in ISO 20909 or than the stand-off antenna specification, whichever is greatest.

It is recommended to list in a test report the main parameters used to assess the conformance, as stated in Annex A.

Annex A
(informative)

Conformance test report for RFID enabled tyres

It is recommended to use a test report listing the main parameters, as shown in Table A.1, provided as an example for an application case carried out with the open space method.

Table A.1 — Example of a test report for RFID enabled tyres

Parameter	Unit	Value	Accuracy
Tyre size / model		255/65 R16 XYZ ABCD	
Tyre RFID SGTIN		123456.9876543.12345678900	
Date		2018/05/30	
Test location		Address	
Operator name		FULL NAME	
Test method		Open space	
Closest wall or object distance from tyre or antenna	m	5	±0,5
RFID tyre area height from ground	m	1,7	±0,05
RFID tyre area distance from ceiling	m	3,5	±0,2
Reader references		Brand / model / S/N	
Radio regulations applicable for the reader		ETSI	
Reader power setup	mW	500	Manufacturer spec
Tested parameters RADIATED POWER or P^{t0}_{in}, G_R	mW	100	As recorded during the test
Reader frequency band	MHz	865–868	
Tyre-antenna distance setup	m	0,30	±0,01
UII read test passed		Y	
RSSI (or RPS)	dBm (or unit)	−50	RSSI (or RPS) as provided by the reader device used for testing
$EIRP_{max}$	dBm	33	
d_{max}	m	11	
$P^{t0}_{in,\ RFID\ enabled\ tyre}$	dBm	8	
G_R		4	
ISO 20909 minimum read distance compliance		Y	

Annex B
(informative)

Radiated power

B.1 Generality

Regulations generally define the way the radio spectrum can be shared between different wireless technologies and applications. For one specific application, regulations basically define:

— the available frequency bands;

— the duty cycles;

— the maximum radiated power.

The purpose of this annex is to explain the relation between antenna gain, conducted power and radiated power while providing factual examples.

B.2 Antenna gain

Depending on the shape and structure of an antenna, it usually does not radiate the same amount of electromagnetic power in all directions.

Antenna gain is usually defined as the ratio of the power produced by the antenna from a far-field source on the antenna's beam axis to the power produced by a hypothetical lossless isotropic antenna, which is equally sensitive to signals from all directions. Usually this ratio is expressed in decibels, and these units are referred to as "decibels-isotropic" (dBi). As a consequence, the gain of an isotropic antenna is 1 (0 dBi).

As it is impossible to build a perfect isotropic antenna, an alternative definition compares the received power to the power received by a lossless half-wave dipole antenna, in which case the units are written as dBd. Since a lossless dipole antenna has a gain of 2,15 dBi, the relation between these units is:

$$G\ (\text{dBd}) = G\ (\text{dBi}) - 2{,}15$$

where G is the gain.

B.3 Conducted power

Every single radio frequency (RF) generator (e.g. RFID reader) is able to deliver a power to its load (whatever it is; ohmic resistance or antenna). This is called the conducted power. Depending on the value of the load (in ohm), this conducted power will vary.

Usually, the manufacturers of RF generators indicate the conducted power range (min/max values) or a fixed value when conducted power cannot be changed. These values are given as an example for a 50-ohm load.

The conducted powers can be given in Watts, dB or dBm. The relation between these units is as follows:

$$P\ (\text{dB}) = 10\ \log\ [P\ (\text{W})] \text{ and } P\ (\text{dBm}) = 10\ \log\ [P\ (\text{mW})]$$

Thus, a power of 1 Watt corresponds to 0 dB and to 30 dBm