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Standard Test Method for Determining the Performance of Passive Radio Frequency Identification (RFID) Transponders on Loaded Containers[1]

This standard is issued under the fixed designation D7435; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method determines the readability of radio frequency identification (RFID) transponders placed on loaded containers that are manually handled or mechanically handled by material handling equipment such as fork trucks, pallet jacks, and automated guided vehicle systems. The results of these tests are intended to be used for qualitative purposes.

1.2 Test results solely reflect the performance of the specified RFID system and the specified loaded container. Results are not intended for performance analysis of the RFID system, in part or in whole.

1.3 This test method is intended for use in laboratory settings that simulate, as closely as is practicable, the distribution environment of the product being tested.

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D996 Terminology of Packaging and Distribution Environments

D4332 Practice for Conditioning Containers, Packages, or Packaging Components for Testing

E337 Test Method for Measuring Humidity with a Psychrometer (the Measurement of Wet- and Dry-Bulb Temperatures)

3. Terminology

3.1 *Definitions*—Terms and definitions used in these test methods may be found in Terminology D996.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *critical transponder distance*—the distance between the transponder and the interrogator antenna at which a transponder becomes undetectable by an RFID system, when moving the RFID transponder out of the read field.

3.2.2 *direct line of sight*—an unobstructed visible path from one object to another.

3.2.3 *empty container*—the shipping case of the loaded container, excluding the product as well as the primary, secondary, and/or tertiary packaging shall be considered the empty container.

3.2.4 *firmware*—a series of programmable instructions, stored in read only memory (ROM), which controls the capabilities of an interrogator.

3.2.5 *loaded container*—the loaded container shall consist of a production run or individually prepared packaging system, to include the product as well as the primary, secondary, and/or tertiary packaging up through the shipping case level.

3.2.6 *radio frequency identification (RFID)*— a wireless data communication technology that uses radio waves to transfer data from one source to another.

3.2.7 *read field*—the area in which an RFID transponder is capable of responding to the interrogator. The outermost boundary of the read field correlates to the critical transponder distance. The distance between the critical transponder distance and the transponder acquisition distance represents an area of RF energy that may or may not be sufficient to activate a passive transponder.

3.2.8 *RF*—the energy used by RFID systems to activate transponders and wirelessly transfer information.

3.2.9 *RF enhancing*—a substance or material that, when in the presence of radio waves, creates constructive interference, causing the amplitude of the radio waves to increase. Ultimately, the resulting wave experiences an increase in

[1] These test methods are under the jurisdiction of ASTM Committee D10 on Packaging and is the direct responsibility of Subcommittee D10.17 on Auto-ID Applications.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

intensity and power, and thus, the wave retains higher energy at a farther distance from the interrogator antenna.

3.2.10 *RF inhibiting*—a substance or material that causes a significant reduction in the effectiveness of radio waves that reach an RFID transponder.

3.2.11 *RF transparent*—a substance or material that has little or no significant impact on the performance of an RFID system.

3.2.12 *software*—an array of logic, displayed as an application, used to access and control a device.

3.2.13 *transponder acquisition distance*—the distance between the transponder and the interrogator antenna at which a transponder is first detected by an RFID system, when moving the transponder into the read field.

4. Summary of Test Method

4.1 *Read Field Mapping*—This procedure is used to determine the read performance of the RF system inclusive of the reader/antenna and transponder with an empty container. The testing is conducted with the RFID transponder specimen moving both toward and away from the RFID antenna. The strength of signal and overall read field may vary from system to system and differ from location to location depending upon the various interferences.

4.2 *Testing the Product/Package System*— This procedure is used to determine the transponder readability in the established read field of the system while affixed to the product loaded container. The testing involves the product/package combination. The testing is conducted with the filled case of the product moving both toward and away from the RFID antenna.

5. Significance and Use

5.1 Many materials used in the production of goods can have an adverse affect on the performance of an RFID system. This test method qualifies the performance of an RFID system applied to a loaded container relative to the performance of the same RFID system applied to an empty case. Comparison of these two elements of this test method will identify the compatibility of the RFID systems and the product being tested.

5.2 This test method is intended for systems used exclusively within the United States. Additional test standards from ISO or other standards bodies may apply to internationally handled goods and may include additional test scenarios not outlined in this test method.

6. Interferences

6.1 RFID systems are subject to interference from metal, water, and ambient RF energy. If significant levels of any of these interferences are present in the immediate testing area, the observed read field will be affected. Due to uncontrolled variation in testing facilities, numerical values for interference cannot be stated. Possible sources of interference shall be documented in the final report.

6.1.1 Documentation of interference shall include information regarding, material, size, and location relative to interrogator antenna.

6.2 If significant levels of interference are unavoidable, testing shall be conducted in such a manner that interferences remain unchanged throughout testing.

7. Atmospheric Conditions

7.1 Testing shall be conducted at the standard conditioning atmosphere of 23 ± 1°C (73.4 ± 2°F) and 50 ± 2 % relative humidity unless otherwise noted as per 13.1.1.

7.2 The exact measurement of temperature and relative humidity of the testing atmosphere shall be made as close to the specimen being exposed as is possible. (See Test Method E337 for a detailed description of methods.) The temperature and relative humidity indicated at the control point may not be representative of conditions elsewhere in the conditioned space due to local effects or deficiency in air circulation. Tolerances at the controller usually must be smaller than those at the specimen.

8. Apparatus

8.1 *Case Stand*—The case stand shall be constructed of an RF neutral material (wood or plastic, ideally) that can support the weight of the full case unit load, allow for case height adjustment, and allow for controlled movement along the radian being tested.

8.2 *Antenna Stand*—The antenna stand shall be a stationary support constructed of an RF neutral material (wood or plastic, ideally) that can support the weight of the antenna being used while allowing for antenna height adjustment.

8.2.1 *Protractor*—A large protractor shall be placed at the base of the antenna stand to visually guide the operator along the radian being tested.

8.3 *RFID System:*

8.3.1 *Interrogator*—A manufactured device that communicates with RFID transponders via antennae and communicates transponder information to the host computer.

8.3.2 *Interrogator Antenna*—A manufactured device that emits RF energy to transponders and receives information from transponders in the form of reflected RF energy.

8.3.3 *Transponder*—A microchip with a small conductive antenna that receives RF energy from the interrogator antenna and reflects the information on the microchip back to the interrogator antenna in the form of RF energy.

8.3.4 *Host Computer*—Any computer with the proper software to communicate with and operate the RFID interrogator.

8.4 *Empty Container*—The shipping case of the loaded container, excluding the product as well as the primary, secondary, and/or tertiary packaging shall be considered the empty container.

9. Test Specimen

9.1 A case unit load test specimen shall consist of a case unit load representative of a production run package, or components of an assembled packaging system, to include primary, secondary, and/or tertiary packaging up through the shipping case level.

9.2 An RFID transponder specimen shall be a randomly selected transponder from a controlled RFID transponder inventory that:

9.2.1 Is compatible with the entire RFID system.

9.2.2 Is appropriate for the product being tested.

9.2.3 Has been pre-validated as meeting a controlled minimum standard of transponder signal strength and efficacy.

10. Conditioning

10.1 Test specimens shall be conditioned at the standard conditioning atmosphere of 23 ± 2°C (73.4 ± 3.6°F) for a minimum of 24 h prior to testing (see Practice D4332) unless otherwise noted as per 13.1.1.

11. Procedure

11.1 *Mapping the Read Field:*

11.1.1 *Determining the Critical Distance Read Field of the Empty Container:*

11.1.1.1 Assemble RFID system.

11.1.1.2 Affix RFID transponder to the empty container in a manner that approximates how the transponder will be affixed on the case in a production scenario. For example, if the transponder will be applied flush to the packaging, it is important to approximate this in the test versus using tape or other temporary method of affixing the transponder.

(1) The location and antenna orientation of the transponder on the empty container shall be documented and held constant throughout testing.

NOTE 1—Transponder placement was observed to be an important variable affecting the readability of the transponder affixed to the product/package system.

11.1.1.3 Mount the interrogator antenna to the antenna stand. Record the distance from the floor to the center of the interrogator antenna.

11.1.1.4 Place the empty container on the case stand such that a direct line of sight exists between the interrogator antenna and the transponder.

(1) Adjust the height of the case stand such that the distance from the floor to the center of the transponder is equal to the height recorded in 11.1.1.3.

11.1.1.5 Place the case stand along the +90° radian, as close to the antenna stand as possible.

11.1.1.6 Slowly, move the case stand along the radian, away from the interrogator antenna, at a consistent speed until the RFID system no longer detects the transponder.

NOTE 2—Transponder detection is usually indicated by the graphical user interface on the host computer screen.

11.1.1.7 Record the critical transponder distance.

11.1.1.8 Repeat steps 11.1.1.5 through 11.1.1.7 for all radii in the in the ±90° spectrum at increments of 15°.

NOTE 3—Testing may also be done at increments of less than 15° depending upon the level of precision desired.

11.1.2 *Determining the Transponder Acquisition Read Field of the Empty Container:*

11.1.2.1 Place the case stand along the +90° radian at a distance that exceeds the corresponding critical transponder distance by 5 ft.

11.1.2.2 Slowly, move the case stand along the radian, toward the interrogator antenna, at a consistent speed (equal to the speed used in 11.1.1.6) until the RFID system first detects the transponder.

11.1.2.3 Record the transponder acquisition distance.

11.1.2.4 Repeat steps 11.1.2.1 through 11.1.2.3 for all radii in the in the ±90° spectrum at increments of 15°.

11.1.3 *Determining the Critical Distance Read Field of the Loaded Container:*

11.1.3.1 Assemble the loaded container to include the product as well as the primary, secondary, and/or tertiary packaging, using the empty container as the shipping case.

11.1.3.2 Place the case stand along the +90° radian, as close to the antenna stand as possible.

11.1.3.3 Slowly, move the case stand along the radian, away from the interrogator antenna, at a consistent speed (equal to the speed used in 11.1.1.6) until the RFID system no longer detects the transponder.

11.1.3.4 Record the critical transponder distance.

11.1.3.5 Repeat steps 11.1.3.2 through 11.1.3.4 for all radii in the in the ±90° spectrum at increments of 15°.

11.1.4 *Determining the Transponder Acquisition Read Field of the Loaded Container:*

11.1.4.1 Place the case stand at a distance that exceeds the critical transponder distance by 5 ft.

11.1.4.2 Slowly, move the case stand along the radian, toward the interrogator antenna, at a consistent speed (equal to the speed used in 11.1.1.6) until the RFID system first detects the transponder.

11.1.4.3 Record the transponder acquisition distance.

11.1.4.4 Repeat steps 11.1.4.1 through 11.1.4.3 for all radii in the in the ±90° spectrum at increments of 15°.

11.2 *Mapping the Read Field Envelope :*

NOTE 4—Read field envelope testing is an optional portion of this test method, not required for compliance with this test method.

11.2.1 Perform all steps outlined in mapping the read field (11.1), except 11.1.1.4*(1)*, beginning with the center of the transponder at a height of 1 ft from the floor.

NOTE 5—If the transponder location does not allow the transponder to be adjusted to this height, begin testing at 2 ft and note this change in the final report.

11.2.2 Raise the height of the case stand by an additional 1 ft and again repeat all steps outlined in mapping the read field, except 11.1.1.4*(1)*.

11.2.3 Repeat step 11.2.2 until the height from the floor to the center of the transponder is 6 ft.

12. Interpretation of Results

12.1 *Graphical Representation:*

12.1.1 The acquisition distance and the critical distance for both an empty container and a loaded container should be graphically displayed in separate scaled diagrams representing the ±90° quadrant around the interrogator antenna (Fig. 1).

NOTE 6—Additional composite graphs may be produced to include acquisition and critical distances on the same diagram (Fig. 2) or 3-D images if read field envelope testing is performed (Fig. 3).

12.2 *Comparative Analysis:*

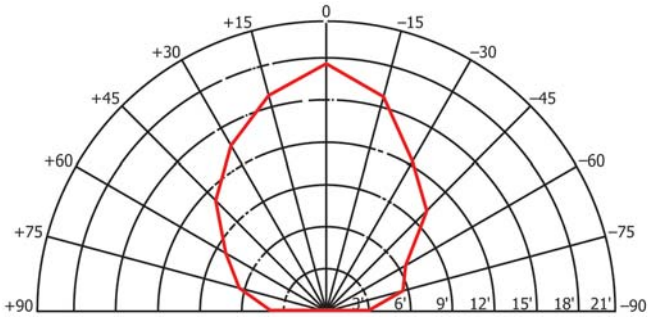

FIG. 1 Example of an Individual Graphical Representation

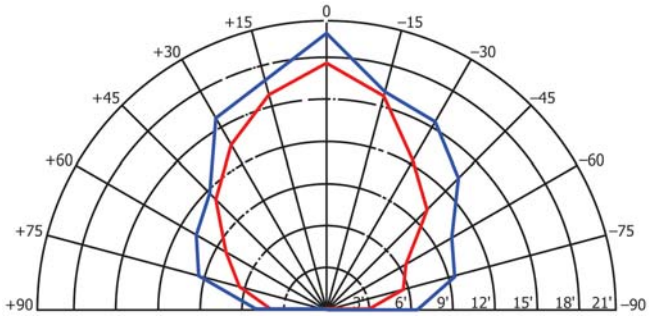

FIG. 2 Example of a Composite Graphical Representation

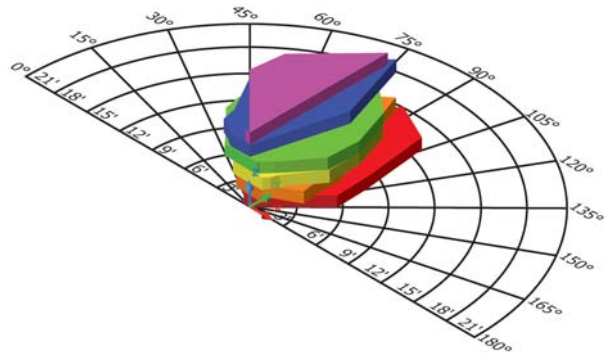

FIG. 3 Example of a 3-D Read Field Envelope Graphical Representation

12.2.1 If the RFID transponder is detected at smaller distances than when affixed to the empty container, the loaded container is considered to have RF-inhibiting characteristics.

12.2.2 If the RFID transponder is detected at greater distances than when affixed to the empty container, the loaded container is considered to have RF-enhancing characteristics.

12.2.3 If the RFID transponder is detected at equivalent distances than when affixed to the empty container, the loaded container is considered RF-transparent.

13. Report

13.1 Report the following information:

13.1.1 A statement that the test was conducted in compliance with these test methods or a description of any deviation(s) from these test methods.

13.1.2 Identification of the RFID system including:

13.1.2.1 Identification of the make, model, and firmware version of the interrogator.

13.1.2.2 Identification of the make and model of the interrogator antenna.

13.1.2.3 Identification of the make and model of the transponder.

13.1.2.4 Identification of the make, model, and software version (where applicable) of the host computer.

13.1.3 Description of the product, internal packaging, shipping container, and closure system, where applicable.

13.1.4 The temperature and humidity conditioning prior to testing.

13.1.5 Graphical representations of the observed read fields (individual or composite) including:

13.1.5.1 Critical transponder distance for the empty container.

13.1.5.2 Transponder acquisition distance for the empty container.

13.1.5.3 Critical transponder distance for the loaded container.

13.1.5.4 Transponder acquisition distance for the loaded container.

13.1.5.5 Read field envelope, if applicable.

14. Precision and Bias

14.1 *Precision*—Based on replicate testing in one laboratory using Alien Gen 2 'Squiggle' transponders and a Sensormatic Agile 2 reader, the pooled standard deviation of acquisition distance was 3.1 in. The pooled standard deviation of critical distance was 3.4 in. These estimates of within-laboratory repeatability may vary with other equipment, transponders, test conditions, an so forth.

14.2 *Bias*—The procedures in this test method have no bias because there are no accepted reference materials or procedures.

15. Keywords

15.1 critical transponder distance; mapping; packaging; radio frequency identification; read field; RFID; transponder; transponder acquisition distance