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# Tagged-Item Performance Protocol (TIPP) Tagged-Item Grading: Testing Methodology Guideline

Provides the testing procedures for tagged-item grading

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## Document Summary

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## 1 Introduction

This document defines the test procedures used for TIPP tagged-item grading. It defines the method and criteria to establish that a tagged item meets a specified grade performance level. The method is intended for use by parties performing TIPP validation testing or designing solutions to be used in a TIPP enabled supply chain.

A tagged item is an item that is RFID enabled. The Tagged-Item Performance Protocol (TIPP) Workgroup developed a tagged-item grading system to facilitate the specification of tagged-item performance between users and suppliers. Tagged-item grades were developed to specify the radio frequency identification (RFID) performance of a tagged item. This tagged-item test procedure defines a method and criteria for establishing that a tagged-item meets a specified grade level. The procedure was established and validated to ensure repeatable testing of tagged item performance across test facilities and test operators.

The test procedure does not specify when, by whom, or how frequently the user and supplier should test items. There is currently no certification procedure to validate a party's ability to perform repeatable testing. Rapid innovation in testing equipment and procedures makes the formal certification process or procedure premature. Users may specify a minimum test (or retest) requirement of their suppliers. Suppliers, based on service-level agreements, may determine their own acceptable test requirements that may meet or exceed anything specified by the user.

The test procedure's pass/fail criteria are defined to ensure repeatable and unambiguous results. The related Minimum Success Rate in the grade definitions bring further flexibility in the TIPP methodology to consider the non-deterministic nature of RFID technology. This flexibility may become especially useful in the future as packaging and RFID technologies further integrate with each other.

The pass/fail criteria intentionally do not specify what criteria a user uses to establish the consistency or quality of the tagged-item performance. For example, one user could ask that the supplier verify items periodically to meet their specified performance grade with some small (<1%) tolerance for failures. Another user may sample items through distribution and assess penalties for items failing to meet their specified grade. Yet another might have the technology to measure the grade of every single tagged item through their application and provide pass/fail feedback to their suppliers.

## 2 General Test Requirements

There are several different test protocols within the TIPP Test Methodology. This section describes common procedures and equipment necessary for all the test protocols.

### 2.1 Tagged items for testing

Each tagged item must be uniquely encoded. The tagged items must be encoded such that each identifier (EPC) is unique when compared to all current and future items. Each EPC must be stored in a file along with all of the other information of the submitted item and will be referenced during all performance measurements on the tagged item.

### 2.2 Test equipment

The following is the recommended setup for measuring tagged-item performance. Any setup used for measuring tagged-item performance must be equivalent to the equipment herein:

The test equipment is designed and maintained to produce accurate, consistent, and repeatable radio frequency (RF) measurements. A high-level layout of the test equipment is shown in [Figure 2-1](#). The major components of the setup are:

- the anechoic chamber
- the rotating test platform
- the antennas
- the measurement unit

The **anechoic chamber** is designed to eliminate reflections of electromagnetic waves and provide an interference-free environment to accurately measure the performance of RFID tagged items. The anechoic chamber is vital to ensure test repeatability between different test facilities.

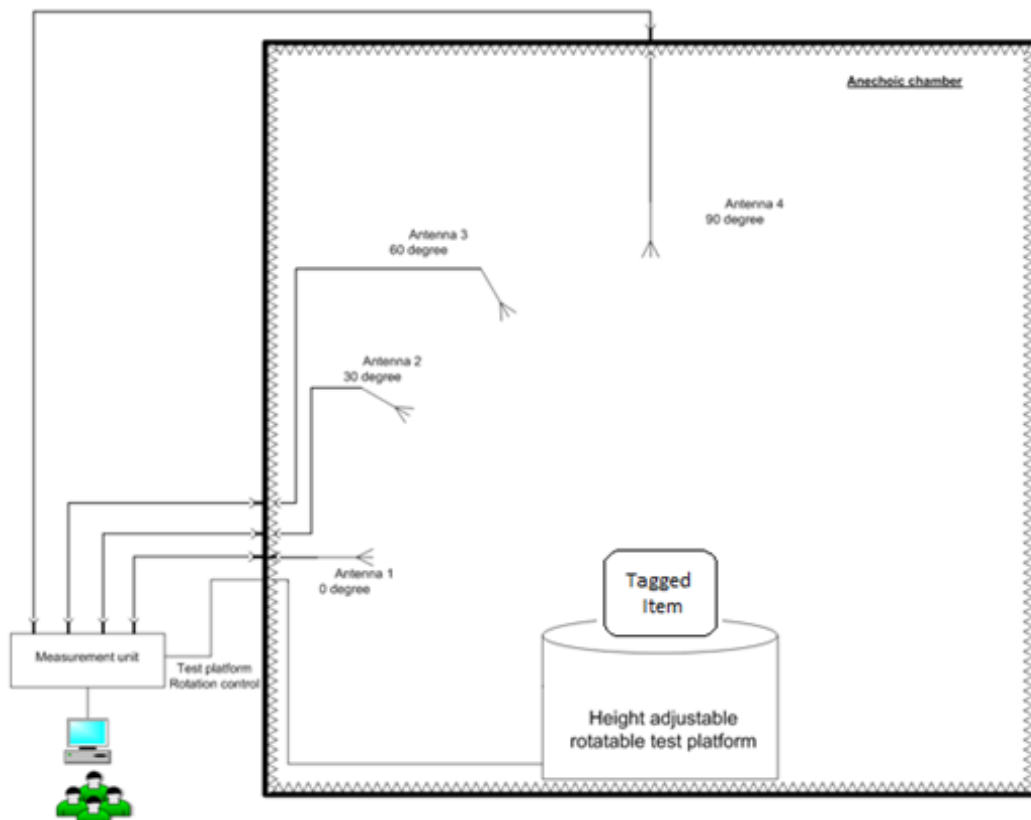
The **test platform** in the chamber can be rotated 360 degrees in 30-degree increments to measure the tag in multiple positions. The height of the test platform is adjustable to accommodate products of different sizes. The test platform structure should be as RF friendly as possible especially avoiding large metal planes and structures that cause unfavorable reflections, and thus compromise test accuracy and repeatability.

The linearly polarized **antennas** are mounted at angles of 0 degrees, 30 degrees, 60 degrees, and 90 degrees with respect to the floor of the chamber and are named Antenna 1, Antenna 2, Antenna 3 and Antenna 4, respectively. The antennas are mounted with their horizontal polarization plane parallel to the floor of the anechoic chamber. The antennas are directed at a single incident point.

The **incident point** in the center of the test platform is where the reference tagged item to be tested is positioned. The minimum distance between the antenna and the incident point is 0.4 meters. The tagged-item remains in the far field of all four antennas during all the measurements.

**Note:** The combination of horizontally linear test antennas and vertical arranged dipole based tags is a known issue of this test standard that might result in inadequate tag rating although they may be successfully used in the applications.

**Figure 2-1** High level layout of test equipment



The **measurement unit** is effectively a network analyser optimized for measuring the performance of RFID tagged items. The measurement unit can generate, transmit, receive and process UHF<sup>1</sup> RF communication. The measurement unit can operate in the 800 MHz<sup>2</sup> to 980 MHz frequency range, and the frequency of operation can be dynamically controlled in increments of 1 MHz. The output power range of the measurement unit calculated at the incident point of all four antennas should be

<sup>1</sup> UHF = Ultra High Frequency

<sup>2</sup> MHz = Megahertz

from  $-25 \text{ dBm}^3$  to  $15 \text{ dBm}$  at the tag or larger range and can be dynamically controlled in increments of  $0.1 \text{ dB}$ .

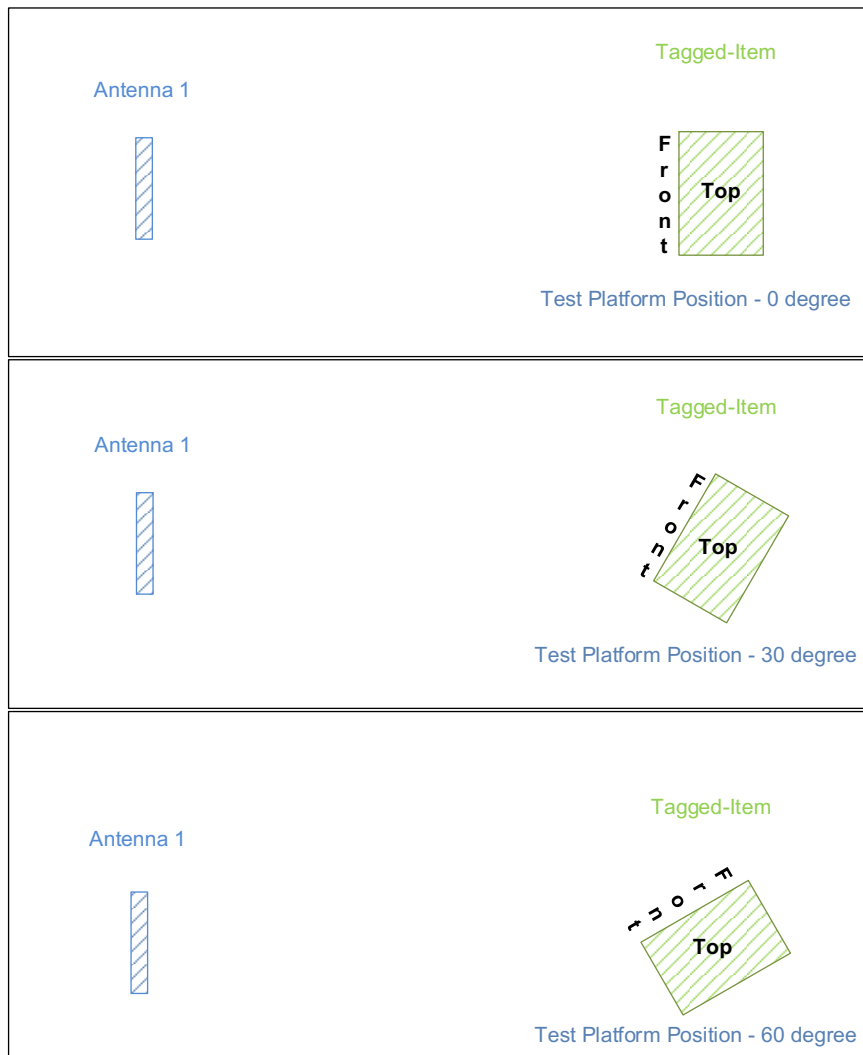
- ✔ **Note:** Power at the tag refers to receivable power with an isotropic antenna ( $0 \text{ dBi}$  antenna gain).

The modulator in the measurement unit supports double-sideband amplitude shift keying (DSB-ASK) modulation.

### 2.3 Tagged-Item Placement

Tagged items are measured when placed on the platform with their front and top positioned according to [TIPP Tagged-Item Grading: Test Configuration Guideline](#). Refer to that Guideline for detailed information on the item placement and orientation. When the test protocol requires more than one item on the platform at a time, it defines a reference item to use for orientation and alignment purposes. See the specific test protocol for information on the reference item. [Figure 2-2](#) shows the top view of the measurement setup (View from Antenna 4) at several platform orientations.

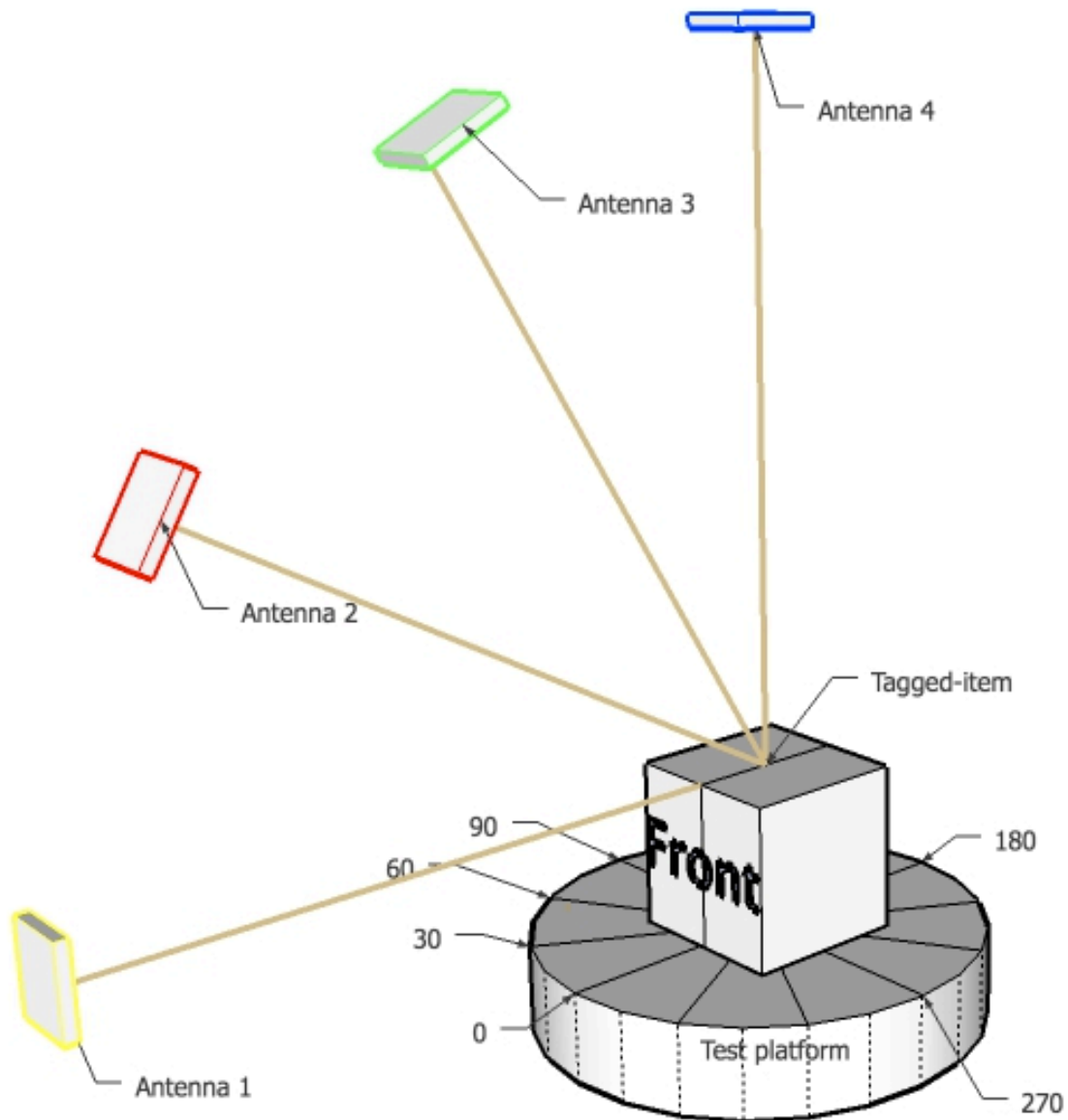
**Figure 2-2** Orientation of the tagged-item – top view



<sup>3</sup> dBm = Decibel-milliwatts



**Figure 2-3** Tagged-item at 0-degree test platform position



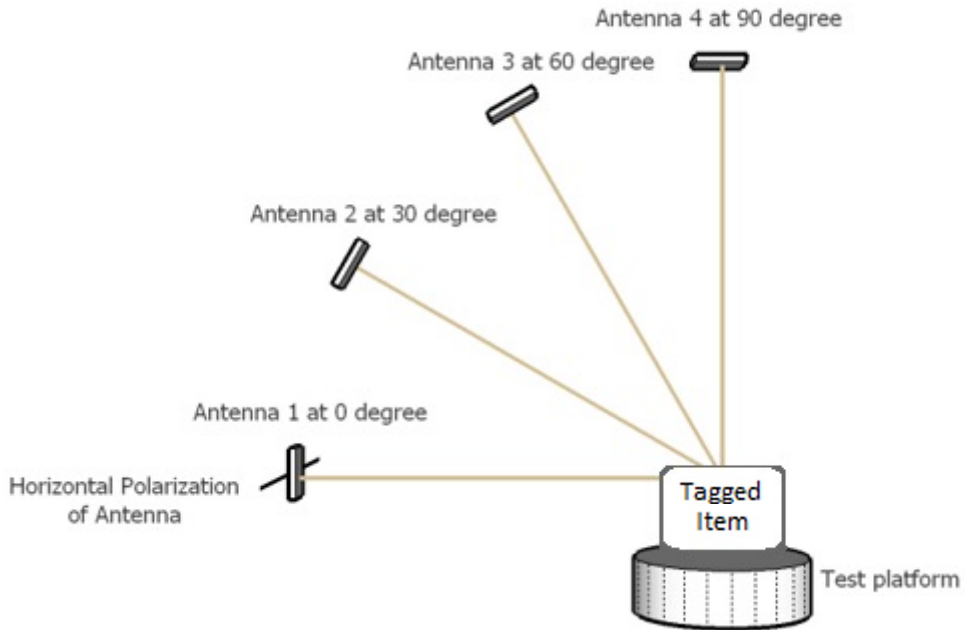
## 2.4 Test Variables

Two primary variables are altered during the testing: test platform position and measurement antenna. A description with example values for each is discussed below.

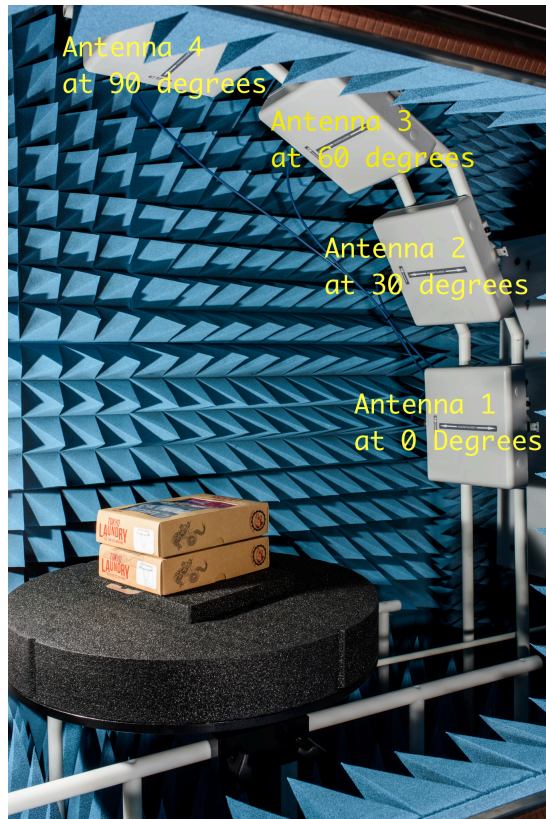
- **Test Platform Position** - The test platform makes a full 360 degrees rotation with increments of 30 degrees.
- **Measurement Antenna** - At each test platform position, the tagged item is measured with four antennas. As shown in [Figure 2-4](#), the antennas (named Antenna 1, Antenna 2, Antenna 3 and Antenna 4) are mounted at 0 degrees, 30 degrees, 60 degrees and 90 degrees with respect to the test platform.

The antennas are directed at a single incident point. This incident point is where the reference tagged item to be tested is positioned, and can be seen in [Figure 2-3](#), [Figure 2-4](#) and [Figure 2-5](#). The antennas are mounted such that the incident point is exactly above the centre of rotation of the testing platform as shown in the figures below.

**Figure 2-4** Antenna configuration



**Figure 2-5** Example of testing environment and antenna configuration



## 2.5 Grade Tables

Each grade contains one or more tables of sensitivity and backscatter power. Each table has rows corresponding to the platform rotation angle (0-330 degrees) and columns corresponding to the antenna angle (#1-#4). The optional minimum pass/fail percentage brings an additional dimension to the grade tables.

The combination of a specific row and column is denoted in this document as an orientation.

Blank orientations signify that the grade has no performance requirement at that specific rotation and antenna angle and do not require any test action.

Non-Blank orientations require executing the specific test protocol defined by the grade with the test fixture configured for that platform rotation and antenna angle.

## 2.6 Pass/Fail criteria with minimum success rate

When qualifying a tagged item against a known grade, items must pass the specification as per the test procedure below. To meet the grade, an individual tagged item must satisfy both of these conditions:

- At each orientation where the sensitivity is defined, the tagged-item test procedure must measure a value less than or equal to ( $\leq$ ) the value specified in the grade. That is, the sensitivity must be as good as or better than specified by the grade level. If the minimum success rate for a particular orientation is specified below 100%, then the portion of passed orientations against all the defined orientations in that row or column must be as good as or better than the defined minimum success rate for that row or column.
- At each orientation where sensitivity and backscatter power is defined, the tagged-item test procedure must measure a backscatter power (at the specific sensitivity level) greater than or equal to ( $\geq$ ) the value specified in the grade level. If the minimum success rate for a particular orientation or test antenna is specified below 100%, then the portion of passed orientations against all the defined orientations in that row or column must be as good as or better than the defined minimum success rate for that row or column.

## 2.7 Measurement Gen2 Standard Settings

The following **Gen2 physical layer parameters** must be used for executing the command sequence defined below. The parameters used for testing must fall within these ranges. All other parameters must be as specified within the Gen2 standard.

- Modulation = DSB-ASK
- Tari<sup>4</sup> = 12.5  $\mu$ s (or optional 25  $\mu$ s)  $\pm$ 1%<sup>5</sup>
- BLF = 250 - 320 kHz

The following **Gen2 standard parameters** must be used in the measurement command sequence defined below.

- M<sup>6</sup> = 4 (value of 10<sub>2</sub> in *Query* command)
- Truncate = disabled (value of 0<sub>2</sub> in *Select* command)
- TRext<sup>7</sup> = 0<sub>2</sub> is recommended
- T<sub>4</sub> = 2.0 - 2.5 RTcal

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<sup>4</sup> Reference time interval for a data-0 in Interrogator-to-Tag signalling. The mnemonic "Tari" derives from the ISO/IEC 18000-61 (Type A) specification, in which Tari is an abbreviation for Type A Reference Interval.

<sup>5</sup> microsecond ( one-millionth of a second)

<sup>6</sup> Number of subcarrier cycles per symbol

<sup>7</sup> TRext chooses whether the Tag to Reader Preamble is prepended with a pilot tone. The value of 0 indicates that there is no pilot tone.

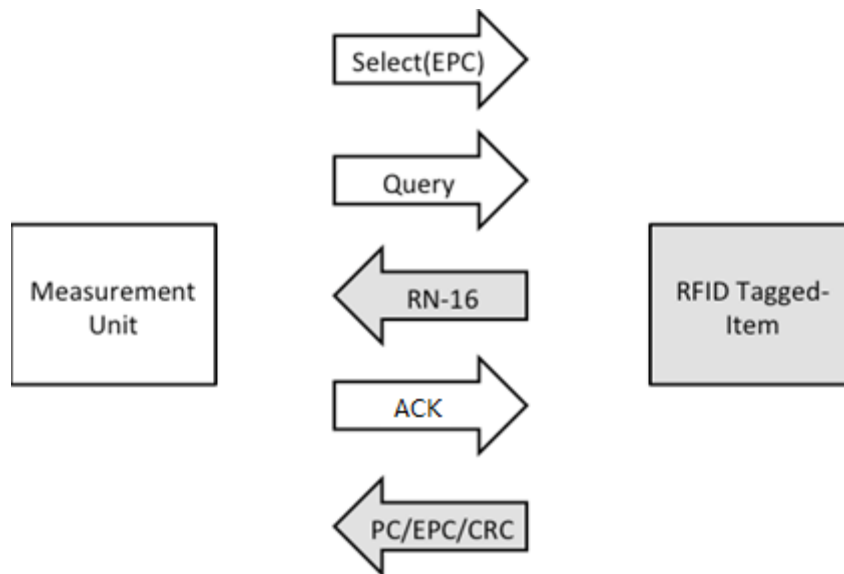
## 2.8 Measurement Command Sequence

The following measurement command sequence must be used.

The Select, Query and ACK commands (specified in Gen2 standard) are used to measure the performance of tagged items. A combination of Select, Query and ACK commands can be used to individually test a specific tag EPC number in a population of multiple tags present in the test environment. The EPC number is specified for all the performance measurements even if only a single tagged item is measured. This process prevents the accidental substitution of items.

As shown in [Figure 2-6](#), the measurement unit sends a Select command with the EPC value of the tag to measure. The Select command is followed by a Query command for which the tag should reply with a random number. The test system then generates an ACK<sup>8</sup> command. Finally, the tagged-item backscatters the PC<sup>9</sup>, EPC and CRC<sup>10</sup>. The PC, EPC and the valid Packet CRC are used to validate the tag response, and thus measure the tagged-item performance.

**Figure 2-6** Communication between measurement unit and RFID inlay



## 2.9 Equipment calibration and maintenance

The following procedures are recommended to calibrate and maintain a tagged-item test facility:

The transmitter of the test equipment is calibrated using a power meter with a power trace in the entire operational frequency and power range. Both the I and Q channels and their phase difference in the receiver is calibrated through the entire frequency range, for example, by connecting the calibrated transmitter to the receiver.

A calibrated network analyser is used to measure the Scattering parameters of each antenna and cable combinations for the frequency range of 800 MHz to 980 MHz in increments of 1 MHz. The free-space loss in the chamber for the distance between the antennas and the incident point is calculated using the Friis equation. The loss of each antenna and cable combination combined with the corresponding free-space loss is used to calculate the total loss between the measurement unit and the incident point in both directions.

At the start of the day, the equipment is warmed up until a consistent series of measurements is observed. This process can be done, for example, by repeatedly measuring a tag using the test equipment for the set time and a consistent sensitivity measurement is observed.

The equipment and the environment are operated and maintained between 20°C to 26°C and 40% to 60% relative humidity.

<sup>8</sup> Acknowledgement

<sup>9</sup> Protocol control and optional Extended Protocol Control (XPC)

<sup>10</sup> Cyclic redundancy check

### 3 Test Protocols

This section defines the test protocols used within the TIPP methodology. TIPP grade nomenclature uses the first letter of the grade to define the test protocol.

When not specified in the specific test protocols below, reference Section 2 for general protocol details.

#### 3.1 S-Grade Test Protocol

The S-Grade Test Protocol defines the test procedure to validate TIPP S-Grades. S-Grades establish performance requirements for single tagged-items.

##### 3.1.1 Tagged Items

S-Grade Tagged-item testing requires an item-sample of 30 tagged-items, unless otherwise specified by the user. These items meet the tagging requirements of Section 2.1.

##### 3.1.2 Read Sensitivity

Read sensitivity of a tagged item, measured in dBm, is the minimum amount of power the tagged item requires to complete a successful command sequence (See Section 2.7).

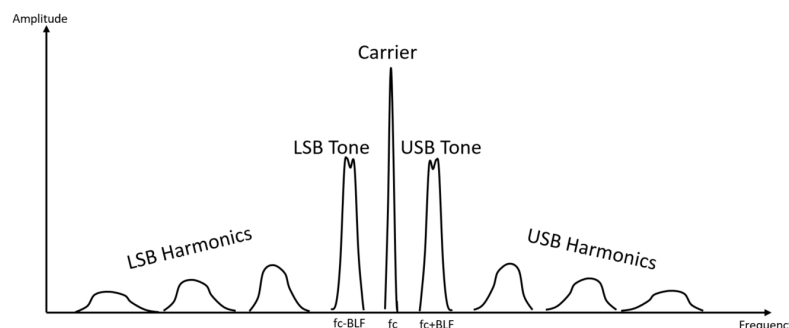
The read sensitivity can be established by repeating the command sequence while adjusting the power sent from the measurement unit until there is a response from the tag. The sensitivity is the lowest value at which the tag can be read at all forward powers equal to or larger than that value. Sensitivity can be calculated from this power level by adding the measurement unit antenna gain, and subtracting cable loss, free space loss and any other losses in the measurement unit.

The read sensitivity at a given orientation is the worst (highest) read sensitivity across the measured frequency range.

##### 3.1.3 Backscatter Power

Backscatter power is the amount of power reflected back from the tagged item when a successful command sequence is completed at the tagged item at a specific sensitivity level. Considering that the backscatter signal includes several spectral components as illustrated in Figure 3-1, the backscatter signal in TIPP includes only the double sideband components that carry the modulated data, but not the carrier itself.

**Figure 3-1** Spectral components of backscatter signal. LSB represents lower side band and USB represents upper side band.



Since the upper and lower side bands cover an area in the spectrum rather than a particular fixed frequency, the spectral limits are defined as following:

Lower side band:  $f_c - (BLF \times 1.5)$  to  $f_c - (BLF \times (1-7/(16 \times M)))$

Upper side band:  $f_c + (BLF \times (1-7/(16 \times M)))$  to  $f_c + (BLF \times 1.5)$

Taking an example for BLF=320 kHz and M=4 this yields

Lower side band:  $f_c - 480$  kHz to  $f_c - 285$  kHz; and

Upper side band:  $f_c + 285$  kHz to  $f_c + 480$  kHz

The measurement time shall cover at least 10 symbols of the tag reply, preferable from the preamble.

Backscatter signal power level is calculated by compensating the power measured at the receiver of the measurement unit with the loss/gain during the transmission. Both Sensitivity and Backscatter power will be the same across different test setups because they are the power required and the power reflected back 'from' the tag. All the variables like distance between the antenna and tag, antenna gain, loss in the cables, etc. are part of the calibration and are not represented in this variable.

The backscatter power at a given orientation is the worst (lowest) backscatter power across the measured frequency range. When validating a tagged item meets a grade level, the backscatter power measurement must be performed at the read sensitivity level contained in the grade specification (see the grade specifications defined in the document entitled [TIPP Tagged-Item Grading: Grade Definitions Guideline](#) document).

### 3.1.4 Measurement Parameters

A tagged item is measured for parameters that reflect the performance of the tagged item. The parameters measured are not focused on any single use case, but rather a variety of use cases to provide a complete profile of the tagged item. These parameters are measured in a variety of test configurations, which are described in [TIPP Tagged-Item Grading: Grade Definitions Guideline](#) document.

- **Frequency Range:** Each antenna measures the tagged item for the range specified in the grade in increments of 1 MHz inclusive of the frequency ranges specified within the grade. For example, if the grade specifies  $F_1$ - $F_2$  and  $F_3$ - $F_4$ , the item must be tested for  $F_1$ ,  $F_2$ ,  $F_3$ ,  $F_4$ , at least every 1 MHz between  $F_1$  and  $F_2$ , and at least every 1 MHz between  $F_3$  and  $F_4$ .
- **Power Range:** The tagged items are measured for response from -25 dBm sensitivity in increments of 0.1 dB until there is a successful response from the tag for each of the frequencies required by the grade definition.

The read sensitivity and associated backscatter signal are measured during the test process.

### 3.1.5 Tagged Item Placement

Each item is tested individually. The single item under test is considered the reference item as described in Section [2.3](#).

### 3.1.6 Measurement Procedure

Test Protocol:

- At each orientation with valid sensitivity, inventory the tagged-item using the command sequence in Section [2.8](#), the Gen2 Parameters defined in Section [2.7](#), and establish the tagged-item sensitivity as in Section [3.1.2](#)
- If backscatter power is specified for the orientation establish the tagged-item backscatter power as in Section [3.1.3](#)
- Apply the pass/fail criteria specified in Section [2.6](#)

### 3.1.7 Pass/Fail

If all the 30 samples pass the criteria specified in Section [2.6](#), the tagged-item meets the grade level.

## 3.2 M-Grade Test Protocol

The M-Grade Test Protocol defines the test procedure to validate TIPP M-Grades. M-Grades establish a performance requirement for stacked items in a 2-item configuration. Some M-Grades (depending on category) also establish a performance requirement for stacked items in an 11-item configuration.

### 3.2.1 Tagged Items

M-Grade Tagged-item testing requires an item sample of 30 tagged-items, unless otherwise specified by the user. These items meet the tagging requirements of Section [2.1](#).

### 3.2.2 Measurement Parameters

See Section [3.1.4](#).

### 3.2.3 Read Sensitivity

See Section [3.1.2](#).

### 3.2.4 Backscatter Power

See Section [3.1.3](#)

### 3.2.5 2-Stack Tagged Item Placement

The reference item for positioning is the lower tagged item in the 2-item stack.

### 3.2.6 2-Stack Measurement Procedure

Follow the test procedure of Section [3.1.6](#) for the lower item in the 2-stack configuration.

### 3.2.7 2-Stack Pass/Fail

If all the 30 samples placed as the lower item pass the test procedure of Section [3.2.6](#), the tagged-item meets the grade level.

### 3.2.8 11-Stack Tagged Item Placement

The reference item for positioning is the middle tagged item in the 11-item stack.

### 3.2.9 11-Stack Test Procedure

Follow the test procedure of Section [3.1.6](#) for the middle item in the stack.

### 3.2.10 11-Stack Pass/Fail

If all the 30 samples placed in the middle pass the test procedure of Section [3.2.9](#), the tagged-item meets the grade level.

## 3.3 J-Grade Test Protocol

By default, the J-Grade Test Protocol defines the test procedure to validate TIPP J-Grades. J-Grades establish a performance requirement for densely stacked items.



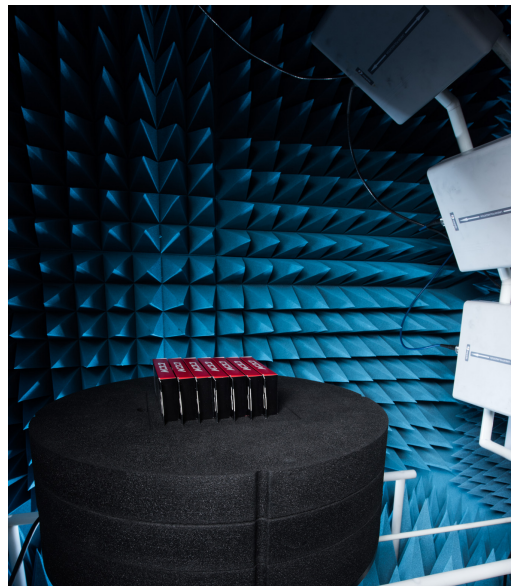
### 3.3.1 Tagged Items

J-Grade Tagged-item testing requires an item sample of 30 tagged-items, unless otherwise specified by the user. Out of that item sample set a subset of 7 tagged-items is randomly picked to build the item stack, unless another stack size is specified in the grade definition table.

### 3.3.2 Tagged Item Placement

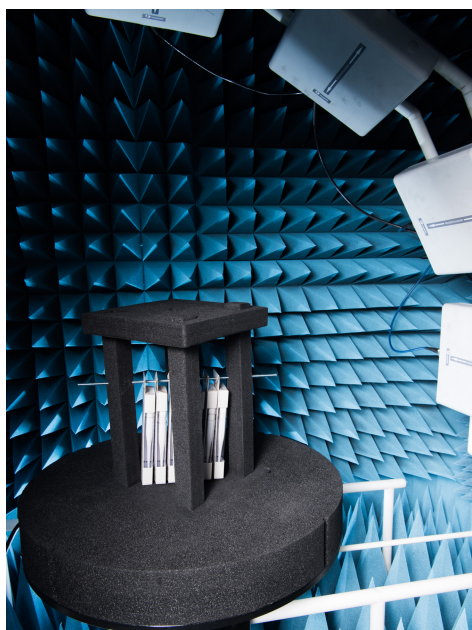
The stack is oriented horizontally with the front of the stack, facing antenna 1 at rotation 0 degrees. The orientation reference tag is the center-tag in the stack and should be placed at the incident point according to Section 2.3. An example is shown in [Figure 3-2](#).

**Figure 3-2** An example stack



For hanging items, a suitable test fixture may be required to allow a natural orientation of the product as shown in [Figure 3-3](#).

**Figure 3-3** An example Test Fixture for hanging items





### 3.3.3 Tagged Item Measurement

At each orientation in the grade table and applying the J-grade measurement parameters defined in Section [3.3.5](#):

- Inventory tags using the command sequence in Section [2.8](#) and the Gen2 Parameters defined in Section [2.7](#) using a transmit power that produces a power at the incident point equal to the sensitivity level specified for the orientation.
- If backscatter power is specified for the orientation:
  - If all tags answered with backscatter strength larger than or equal to the value specified in the orientation for all frequencies specified in the grade definition, the test at this orientation is considered a pass.
- If backscatter power is not specified for the orientation:
  - If all tags answered for all frequencies specified in the grade definition, the orientation is sufficient.

### 3.3.4 Pass/Fail

- Apply the criteria of Section [2.6](#)

### 3.3.5 Measurement Parameters

**Frequency Range:** Each antenna measures the tagged items only for the region specified within the grade definition. For the narrow ETSI region the only test frequency is 866.9 MHz. For the wider band FCC region the test frequencies are 902.0 MHz, 915.0 MHz and 928.0 MHz. If there is no region defined in the grade definition, then all the ETSI and FCC test frequencies will be tested.

If the UHF regulatory frequency band is different from ETSI or FCC, other test frequencies can be defined in the grade in the following logic:

- For a frequency band narrower than 5 MHz, a single test frequency in the center of the band should be utilized.
- For a frequency band wider than 5 MHz but narrower than 15 MHz, the two frequencies at the start and end of the band should be utilized.
- For a frequency band wider than 15 MHz, the three frequencies at the start, center and end of the band should be utilized.