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Information technology — Radio frequency identification device performance test methods —

Part 2: Test methods for interrogator performance

Technologies de l'information — Méthodes d'essai des performances du dispositif d'identification par radiofréquence —

Partie 2: Méthodes d'essai des performances de l'interrogateur

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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of the joint technical committee is to prepare International Standards. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights.

ISO/IEC 18046-2 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 31, *Automatic identification and data capture techniques*.

This first edition of ISO/IEC 18046-2, together with ISO/IEC 18046-1 and ISO/IEC 18046-3, will cancel and replace ISO/IEC 18046:2006.

ISO/IEC 18046 consists of the following parts, under the general title *Information technology — Radio frequency identification device performance test methods*:

— *Part 1: Test methods for system performance*

— *Part 2: Test methods for interrogator performance*

— *Part 3: Test methods for tag performance*

Introduction

Radio frequency identification (RFID) technology has broad applicability to the automatic identification and data capture (AIDC) industry in item management. As a wireless communication technique based on radio frequency technology, the applications cover multiple levels of the industrial, commercial and retail supply chains. These can include

— freight containers,

— returnable transport items (RTI),

— transport units,

— product packaging, and

— product tagging.

Performance tests define test methods that deliver results that allow the comparison of different RFID systems, interrogator and tags in order to select among them for use in a particular application.

The performance characteristics of devices (tags and interrogation equipment) can vary drastically due to application factors as well as the particular RFID air interface (frequency, modulation, protocol, etc.) being supported. Of key concern is the matching of the various performance characteristics to the user application. Additionally, in an open environment, users of such technology demand multiple sources for these devices from technology providers. A key challenge is a method of evaluating the differences between various technology providers' products in a consistent and equitable manner.

This part of ISO/IEC 18046 provides a framework for meeting the above noted concern and challenges. To this end, clear definitions of performance as related to user application of RFID technology in the supply chain are provided. Based on such application-based definitions, test methods are defined with attention to the test parameters required for a consistent evaluation of RFID devices.

Of particular significance, these tests are defined for RFID devices having one antenna. It is common practice to have products with both single and multiple antennas to define an RFID transaction zone sufficient for the application. The defined test methods used are for a single antenna, but can equivalently be extended to equipment with multiple antennas, in order to evaluate performance under conditions more closely matching those of a particular application. However care must be exercised in multiple-antenna measurement since multiple antennas can cause antenna-to-antenna interactions, physical packaging limitations, mutual coupling issues, shadowing issues, directivity issues and other impacts, even with respect to interrogators since these can be limited in size, shape, and mounting method for many RFID applications.

Information technology — Radio frequency identification device performance test methods —

Part 2:
Test methods for interrogator performance

1 Scope

This part of ISO/IEC 18046 defines test methods for performance characteristics of RFID interrogators for item management, and specifies the general requirements and test requirements for interrogators which are applicable to the selection of the devices for an application. The summary of the test reports form a unified tag datasheet. It does not apply to testing in relation to regulatory or similar requirements.

2 Normative references

The following referenced documents are indispensable for the application 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/IEC 18000-2, *Information technology — Radio frequency identification for item management — Part 2: Parameters for air interface communications below 135 kHz*

ISO/IEC 18000-3, *Information technology — Radio frequency identification for item management — Part 3: Parameters for air interface communications at 13,56 MHz*

ISO/IEC 18000-6, *Information technology — Radio frequency identification for item management — Part 6: Parameters for air interface communications at 860 MHz to 960 MHz*

ISO/IEC 18000-7, *Information technology — Radio frequency identification for item management — Part 7: Parameters for active air interface communications at 433 MHz*

ISO/IEC 19762 (all parts), *Information technology — Automatic identification and data capture (AIDC) techniques — Harmonized vocabulary*

ETSI EN 300 330-1, *Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Radio equipment in the frequency range 9 kHz to 25 MHz and inductive loop systems in the frequency range 9 kHz to 30 MHz — Part 1: Technical characteristics and test methods*

ETSI EN 300 330-2, *Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Radio equipment in the frequency range 9 kHz to 25 MHz and inductive loop systems in the frequency range 9 kHz to 30 MHz — Part 2: Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive*

47CFR15, *Code of Federal Regulations, Title 47—Telecommunications, Chapter I—Federal Communications Commission — Part 15: Radio frequency devices*, http://www.fcc.gov/oet/info/rules/

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 19762 (all parts) apply.

4 Symbols and abbreviated terms

$H_{THR\ Identification}$	identification magnetic field threshold
$H_{THR\ Read}$	reading magnetic field threshold
$H_{THR\ Write}$	writing magnetic field threshold
H_{max}	maximum operating magnetic field
$H_{Survival}$	survival magnetic field
Lm	Load Modulation
$E_{THR\ Identification}$	identification electromagnetic field threshold
$E_{THR\ Read}$	reading electromagnetic field threshold
$E_{THR\ Write}$	writing electromagnetic field threshold
$S_{Degradation}$	sensitivity degradation
E_{max}	maximum operating electromagnetic field
$E_{Survival}$	survival electromagnetic field
DUT	device under test
$I_{Rejection}$	interference rejection
G	antenna gain
D	Distance between the tag and the antenna
MPE	Maximum Permissible human Exposure
SAR	Specific Absorption Rate

5 Conditions applicable to the test methods

5.1 Number of interrogator to be tested

Unless otherwise specified, testing shall be performed on 5 randomly chosen interrogators among a population of 20 functional interrogators.

5.2 Test environment

Unless otherwise specified, testing shall take place in air environment of temperature 23 °C ± 3 °C (73 °F ± 5 °F) and of relative humidity within the range of 40 % to 60 %.

5.3 RF environment

The tests shall be performed in a known RF environment.

For measurements of propagative UHF interrogators (ISO/IEC 18000-6, ISO/IEC 18000-7) an anechoic chamber is the recommended test environment.

For measurement of inductive interrogators a typical laboratory environment is sufficient, where consideration is given to minimize the impact of electromagnetic sources that may influence the results.

5.4 Pre-conditioning

Where pre-conditioning is required by the test method, the identification interrogators to be tested shall be conditioned to the test environment for a period of 24 hours before testing.

5.5 Default tolerance

Unless otherwise specified, a default tolerance of ± 5 % shall be applied to the quantity values given to specify the characteristics of the test equipment (e.g. linear dimensions) and the test method procedures (e.g. test equipment adjustments).

5.6 Total measurement uncertainty

The total measurement uncertainty for each quantity determined by these test methods shall be stated in the test report.

NOTE Basic information is given in ISO/IEC Guide 98-3.

5.7 Test result reporting

Each test result shall be reported with the number of samples, minimum value, maximum value, mean value and standard deviation.

For measurement curves additionally to the curves on minimum value, maximum value, mean value and standard deviation, the individual curves of 5 randomly selected measured devices shall be shown in a figure as well.

5.8 Test communication parameters

All the tests can be done for various communication parameters (forward and return link). The test conditions shall be recorded in the test report.

5.9 Test equipment limits

Test equipment for survivability field maximum level shall be able to handle the maximum level declared by the product vendor. It shall be ensured that the test equipment is not limiting the performance measurement.

5.10 Human exposure to EMF

High magnetic or electromagnetic field strength may exceed the limits of maximum permissible human exposure to EMF, which should be considered accordingly. FCC guidelines for MPE and SAR or EC 1999/519/CE are examples for relevant documents.

6 Setup of test equipment for interrogator test

6.1 Test apparatus and test circuits for ISO/IEC 18000-3 interrogators

The specification for ISO/IEC 18000-3 tags and interrogators specifies an operating frequency of 13,56 MHz ± 7 kHz. Since both the interrogator and the tag may be shifted by 516ppm and potentially in opposite directions, the interrogator must function with a tag simulator that may be ±1032ppm (14 kHz) relative to the nominal centre frequency of the interrogator under test.

This frequency adjustment will be made using only the tag simulator's signal source since there may be no convenient way to adjust the frequency of the interrogator being evaluated. The relative Interrogator to Tag frequency shift is still achieved using this method.

For convenience in setting up the signal source in the tag simulator, use a low carrier frequency at 13,546 MHz, a nominal centre frequency at 13,560 MHz, and a high carrier frequency at 13,574 MHz for all frequency offset tests.

The set up of all test equipment shall be in an anechoic chamber or some other fully characterized and controlled location that is free from interference sources and propagation influences, such as significant signal reflections, absorptions, or blockages.

Unless otherwise specified, all the tests should be run using a known reference antenna attached to the tag simulator.

The tag simulator used for these test shall be able to receive interrogator commands and transmit tags replies compliant with ISO/IEC 18000-3. The command decoder must provide a signal to trigger a properly timed response from the code generator so that the entire assembly acts as a tag simulator.

The output of the decoder in the tag simulator is also connected to a computer and appropriate monitoring software so that it can display the tag commands as received from the interrogator being tested in order to confirm that it is sending correct commands.

The timing of the interrogator's transmitted signal and modulation can be monitored using the output of the tag simulator's receiver attached to a storage scope that has sufficient memory depth to allow the capture of complete interrogator/tag transactions.

The interrogator is connected to a control and monitoring computer that allows issuing of wakeup and command transmissions. This software should also provide display of decoded data received by the interrogator to confirm that it is able to properly decode and output received tag responses.

Unless otherwise specified, the recommended test distance between the interrogator's location and the reference antenna attached to the tag simulator should be 75 % of the maximum working distance which can be obtained with the interrogator under test and the tag simulator.

6.2 Test apparatus and test circuits for ISO/IEC 18000-6 interrogators

The test apparatus and test circuits for ISO/IEC 18000-6 interrogator tests will be the subject of future work and are not covered in this international standard.

6.3 Test apparatus and test circuits for ISO/IEC 18000-7 interrogators

The specification for ISO/IEC 18000-7 tags and interrogators specifies an operating frequency of 433,920 MHz (±20ppm), which is approximately ±8,7 kHz. Since both the interrogator and the tag may be shifted by 20ppm and potentially in opposite directions, the interrogator must function with a tag simulator that may be ±40ppm (approximately 17,4 kHz) relative to the nominal centre frequency of the interrogator under test.

This frequency adjustment will be made using only the tag simulator's signal source since there may be no convenient way to adjust the frequency of the interrogator being evaluated. The relative Interrogator to Tag frequency shift is still achieved using this method.

For convenience in setting up the signal source in the tag simulator, use a low carrier frequency at 433,900 MHz, a nominal centre frequency at 433,920 MHz, and a high carrier frequency at 433,940 MHz for all frequency offset tests.

The set up of all test equipment shall be in an anechoic chamber or some other fully characterized and controlled location that is free from interference sources and propagation influences, such as significant signal reflections, absorptions, or blockages.

Unless otherwise specified, all the tests should be run using a known reference antenna attached to the tag simulator through a splitter/combiner of a known loss as shown in Figure 1.

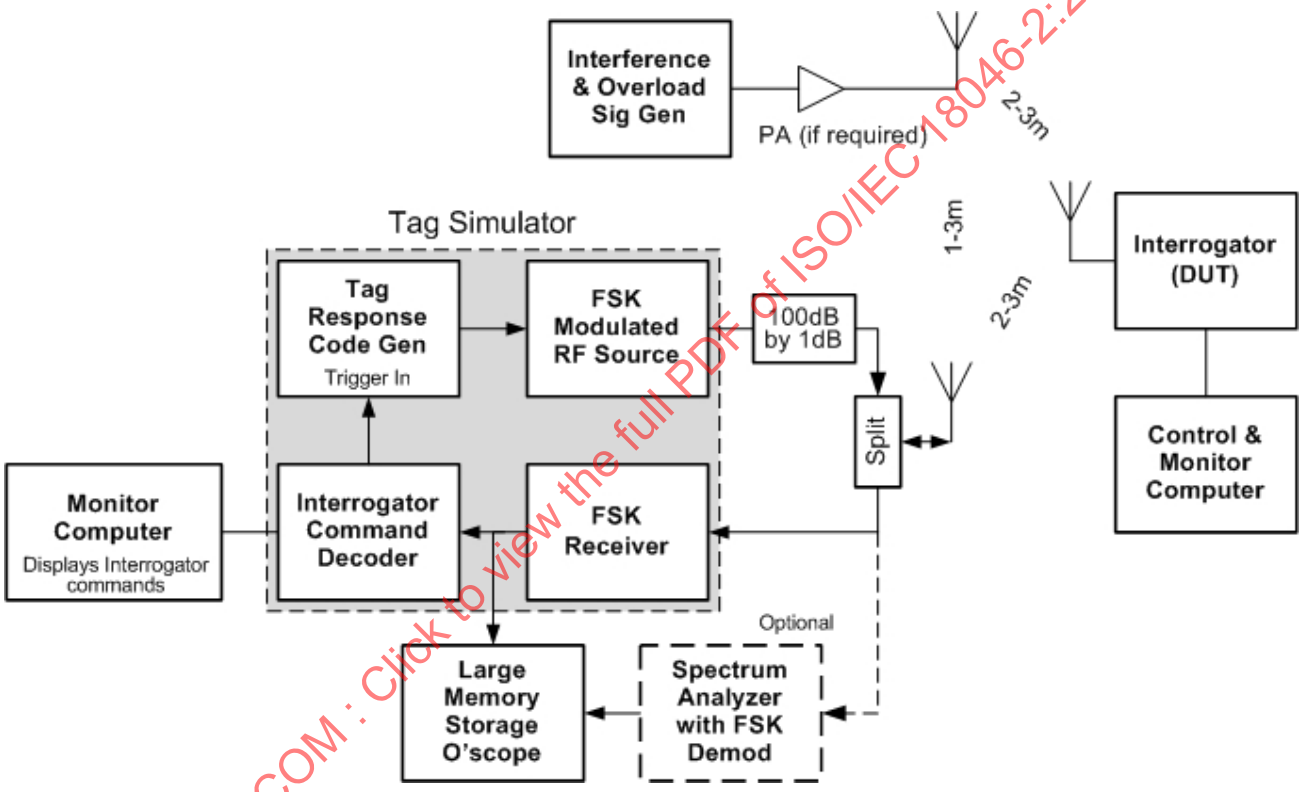

Figure 1 — Test Setup for ISO/IEC 18000-7 Interrogator Measurements

A second reference antenna is located in the place of the interrogator at its test location and shall be connected to a spectrum analyzer at the beginning of testing with the tag simulator's signal source set to 0 dBm output to establish the field strength at the test site where the interrogator will be placed.

Calculation of field strength is as follows:

field strength = 107 + (PR + AF + |LC|)

Where 107 is dB above 1uV at 0dBm, PR = power received on the spectrum analyzer, AF = antenna factor of the reference antenna, and |LC| = loss of cable in dB (absolute value).

Example: PR = -35 dBm, AF = 22dB, LC = |-1,2dB|

FS = 107 + (-35 + 22 + 1,2) = 107 + (-11,8) = 95,2dBuV/m

The field strength at 0 dBm reference level shall be used during interrogator sensitivity testing.

The tag simulator used for these test consists of an ISO/IEC 18000-7 compliant code generator, an FSK modulated 433,920 MHz signal source, an FSK 433,920 MHz receiver, and an ISO/IEC 18000-7 compliant decoder. The decoder must provide a signal to trigger a properly timed response from the code generator so that the entire assembly acts as a tag simulator.

The step attenuator shown in the diagram allows adjustment over a 100 dB range in 1 dB steps. The 100 dB of output level change can be adjusted solely using the step attenuator or, as a practical matter, using the level setting capabilities of both the attenuator and the FSK signal source.

The output of the decoder in the tag simulator is also connected to a computer and appropriate monitoring software so that it can display the tag commands as received from the interrogator being tested in order to confirm that it is sending correct commands.

The timing of the interrogator's transmitted signal and modulation can be monitored using the output of the tag simulator's FSK receiver attached to a storage scope that has sufficient memory depth to allow the capture of complete interrogator/tag transactions.

The interrogator is connected to a control and monitoring computer that allows issuing of wakeup and command transmissions. This software should also provide display of decoded data received by the interrogator to confirm that it is able to properly decode and output received tag responses.

Unless otherwise specified, the recommended test distance between the interrogator's location and the reference antenna attached to the tag simulator should be 2 meters, minimum, with 3 meters preferred. This will provide sufficient distance to ensure Far Field conditions at the interrogator's location yet not require use of a test site exceeding practical dimensions. A 3 meter test distance is recommended since this is a common regulatory test distance and is also a distance at which many reference antennas have been calibrated for Antenna Factor. This distance also meets the Far Field criteria at a frequency of 433,920 MHz.

7 Functional tests for inductive interrogators as defined in ISO/IEC 18000-2 and ISO/IEC 18000-3

7.1 Interrogator Sensitivity in Listen Mode (Receiving Mode)

7.1.1 Purpose

This test determines the minimum level of modulated carrier at the antenna of the interrogator that can be detected by its receiver.

7.1.2 Test procedure

The Load modulation of the tag simulator is set to the nominal level: 0

The tag simulator is positioned on the axis of the interrogator's antenna. The distance between the tag simulator and the interrogator's antenna (D) is equal to 75 % of the $E_{THR\ identification}$ distance.

Then, the Load modulation is increased from 0 to the level where the interrogator starts to recognize the identification data from the tag simulator.

7.1.3 Test Report

The test report shall give the measured minimum Load modulation Lm interrogator. All parameters shall be recorded according to the example in Table 1

Table 1 — Parameters recorded for Sensitivity measurement

Test: Interrogator Sensitivity in Listen Mode (Receiving mode)	
Temperature:	Humidity:
Interrogator Type:	Interrogator ID:
Air Interface Protocol between Interrogator and tag:	
Test Results	
Lm Minimum	**xx,xx**

7.2 Interference rejection ($I_{Rejection}$)

7.2.1 Purpose

This test determines the interference rejection ability of the interrogator.

This test determines the minimum distances between two identical interrogators (same devices) at which the DUT can read the tag without disturbances.

7.2.2 Test procedure

The waveform generator shall be set to the required operating frequency of 125 kHz or 134,2 kHz or 13,56 MHz respectively for ISO/IEC 18000-2 or ISO/IEC 18000-3 and the waveform generator amplitude shall be set to a value below the identification magnetic field threshold. This amplitude is typically zero.

The tag simulator is positioned on the axis of the interrogator's antenna. The distance between the tag simulator and the interrogator's antenna (D) is equal to 75 % of the $E_{THR\ identification}$ distance.

A second interrogator (identical to the DUT) is positioned near the DUT. The test covers two positions: Face to face and side by side.

The test configurations are shown on Figure 2.

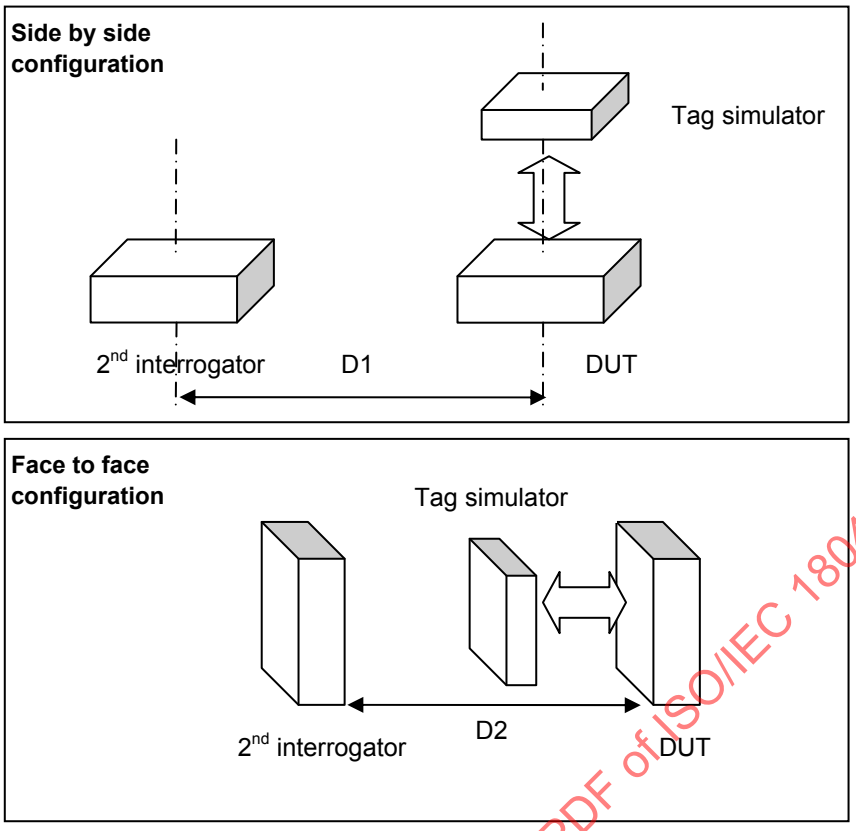

Figure 2 — Test configurations

The dialog between the DUT and the tag simulator is monitored.

The 2nd interrogator is moved to the DUT up to errors detected in the dialog between the DUT and the tag simulator.

The dialog must be alternatively read commands and write commands from the DUT to the Tag simulator.

7.2.3 Test report

The test report shall give the measured minimum distance between the two identical interrogators. All parameters shall be recorded according to the example in Table 2.

Table 2 — Parameters recorded for Interference rejection distance

Test: Interrogator Sensitivity in Listen Mode (Receiving mode)	
Temperature:	Humidity:
Interrogator Type:	Interrogator ID:
Air Interface Protocol between Interrogator and tag:	
Test Results	
Distance D1 (side by side)	**xx,xx**
Distance D2 (face to face)	**Xx.XX**

7.3 Maximum Electromagnetic field exposure ($ME_{exposure}$)

7.3.1 Purpose

This test determines the maximum value of the electromagnetic field generated by another interrogator at which the DUT ceases to operate.

7.3.2 Test procedure

The electromagnetic field generated for the test is similar to the field generated by the DUT (same frequency/modulation/protocol). The strength of the electromagnetic field is limited to the maximum allowed value (ETSI EN 300 330-1/2 or 47CFR15).

Exposure time for this test is 1 min for each step of the test. The DUT must be able to read a tag after each exposure period.

7.3.3 Test report

The test report shall give the measured maximum Electromagnetic field exposure. All parameters shall be recorded according to the example in Table 3.

Table 3 — Parameters recorded for Maximum Electromagnetic field exposure

Test: Maximum Electromagnetic field exposure ($ME_{exposure}$)	
Temperature:	Humidity:
Interrogator Type:	Interrogator ID:
Air Interface Protocol between Interrogator and tag:	
Test Results	
$ME_{exposure}$	**xx,xx A/m**

7.4 Ratio between field radiated and power consumption

7.4.1 Purpose

This test determines a ratio between the field radiated and the power consumed by the interrogator.

7.4.2 Test procedure

The Load modulation of the tag simulator is set to the level obtained as a result of test 7.1. (Interrogator Sensitivity in Listen Mode (Receiving Mode).

The tag simulator is positioned on the axis of the interrogator's antenna. The distance between the tag simulator and the interrogator's antenna (D) is equal to 1, 5, 10, 50 and finally 100 centimetres.

— Measurement of the average power consumption of the interrogator when transmitting during 1 second: P1 in W (Watt).

— Measurement of the field strength: Hfield in A/m.

The ratio between the field radiated and the power consumed is equal to Hf/P1.

7.4.3 Test report

The test report shall give the ratio between the field radiated and the power consumed by the interrogator. All parameters shall be recorded according to the example in Table 4.

Table 4 — Parameters recorded for Injected Power into the antenna

Test:Power injected into the antenna of the interrogator	
Temperature:	Humidity:
Interrogator Type:	Interrogator ID:
Air Interface Protocol between Interrogator and tag:	
Test Results	
Ratio (1 cm)	**xx,xx**
Ratio (5 cm)	**xx,xx**
Ratio (10 cm)	**xx,xx**
Ratio (50 cm)	**xx,xx**
Ratio (100 cm)	**xx,xx**

7.5 Field strength distribution

7.5.1 Purpose

This test determines the axial measure of the Electromagnetic field strength generated by the interrogator at the place of the measurement antenna.

This test determines the 3D map of the electromagnetic field generated by the interrogator.

Interrogators are grouped (as defined below) according to local regulations ETSI EN 300 330-1/2 and 47CFR15. In order to ease user comparison, 5 groups are defined:

— Class A interrogator with radiated H-field level between 80 and 100 % of the maximum radiated H-field allowed by local regulations;

— Class B interrogator with radiated H-field level between 60 and 80 % of the maximum radiated H-field allowed by local regulations;

— Class C interrogator with radiated H-field level between 40 and 60 % of the maximum radiated H-field allowed by local regulations;

— Class D interrogator with radiated H-field level between 20 and 40 % of the maximum radiated H-field allowed by local regulations;

— Class E interrogator with radiated H-field level between 0 and 20 % of the maximum radiated H-field allowed by local regulations.

7.5.2 Test procedure

Measurement shall be done using local regulations test procedure (ETSI EN 300 330-1/2 and 47CFR15). This test gives a table of field strength measurements.

Measurements are performed every 1 centimetre in the normal direction if the value measured is higher than 0,15 A/m. Measurements in other directions are performed every 1 centimetre for positions in the normal

direction having a measured value higher than 0,15 A/m. Measurements in other directions have to be done if the value measured is higher than 0,15 A/m.

7.5.3 Test report

The test report shall give a table of electromagnetic field measurements. This would allow the user to estimate the read range in all directions in front of the interrogator antenna. All parameters shall be recorded according to the example in Table 5.

Table 5 — Parameters recorded for Injected Power into the antenna

Test:Power injected into the antenna of the interrogator						
Temperature:	Humidity:					
Interrogator Type:	Interrogator ID:		Interrogator group:			
Air Interface Protocol between Interrogator and tag:						
Test Results						
Normal direction – Z : 1	**Other Directions X and Y**	**Y=xx**	**Y=-1**	**Y=0**	**Y=1**	**Y=xx**
	X=xx	**xx,xx**	**xx,xx**	**xx,xx**	**xx,xx**	**xx,xx**
	X=-1	**xx,xx**	**xx,xx**	**xx,xx**	**xx,xx**	**xx,xx**
	X=0	**xx,xx**	**xx,xx**	**xx,xx**	**xx,xx**	**xx,xx**
	X=1	**xx,xx**	**xx,xx**	**xx,xx**	**xx,xx**	**xx,xx**
	X=xx	**xx,xx**	**xx,xx**	**xx,xx**	**xx,xx**	**xx,xx**
Normal direction – Z : xx	**Other Directions X and Y**	**Y=xx**	**Y=-1**	**Y=0**	**Y=1**	**Y=xx**
	X=xx	**xx,xx**	**xx,xx**	**xx,xx**	**xx,xx**	**xx,xx**
	X=-1	**xx,xx**	**xx,xx**	**xx,xx**	**xx,xx**	**xx,xx**
	X=0	**xx,xx**	**xx,xx**	**xx,xx**	**xx,xx**	**xx,xx**
	X=1	**xx,xx**	**xx,xx**	**xx,xx**	**xx,xx**	**xx,xx**
	X=xx					

8 Functional tests for interrogators as defined in ISO/IEC 18000-6

8.1 General

Function tests for ISO/IEC 18000-6 propagative interrogators will be the subject of future work and are not covered in this part of ISO/IEC 18046.

8.2 Inductive UHF interrogators

The special case of functional tests for inductive interrogators as defined in ISO/IEC 18000-6 shall follow that of the ISO/IEC 18000-3 as detailed in Clause 7.

9 Functional tests for 433,920 MHz propagative interrogators as defined in ISO/IEC 18000-7

9.1 Identification electromagnetic field threshold ($E_{THR\ Identification}$) and frequency tolerance

9.1.1 Purpose

This test determines the electromagnetic field threshold level required at the interrogator for tag identification when using an ISO/IEC 18000-7 interrogator functioning in Master-Slave mode (Interrogator Talks First or ITF).

The identification electromagnetic field threshold, $E_{THR\ Identification}$, is the minimum electromagnetic field arriving at the interrogator that allows the interrogator to identify a tag reliably. For the purpose of this test, "reliably" means 10 reads out of 10 sequential read attempts.

9.1.2 Test procedure

To determine interrogator sensitivity ($E_{THR\ Identification}$), the following procedures shall be performed:

1) Test shall be run based on the test apparatus and test setups outlined in 6.2. Set the tag simulator's frequency to 433,920 MHz. Begin by placing the tag simulator's antenna to vertical polarization.

2) Set the tag simulator's attenuator to 30 dB to provide the interrogator with a moderate signal level. Confirm that the interrogator reads the tag simulator response at this level.

3) Increase the tag simulator's attenuator by 1 dB step until the interrogator does not read the tag simulator response.

4) Decrease the attenuator setting until the interrogator reads the tag simulator response 10 times out of 10 attempts.

5) Record this attenuator level in the box provided for attenuator setting for vertical polarization.

6) Convert the attenuator setting into dBμV/m by subtracting this setting from the field strength level at 0 dBm measured in 6.2. Place this into the ETHR Identification (dBμV/m) box in the vertical polarization column.

7) Repeat steps 2 through 4 with the tag simulator's antenna horizontally polarized.

8) Record this attenuator level (unsigned) in the box provided for attenuator setting under the column for horizontal polarization.

9) Convert the unsigned attenuator setting into dBμV/m by subtracting the setting from the field strength level at 0 dBm measured in 6.2. Place this into the ETHR Identification (dBμV/m) box in the horizontal polarization column.

10) Repeat steps 2 through 9 after increasing the centre frequency to 433,940 MHz. However in this case place the data into the boxes provided for 433,940 MHz instead of 433,920 MHz.

11) Repeat steps 2 through 9 after decreasing the centre frequency to 433,900 MHz. However in this case place the data into the boxes provided for 433,900 MHz instead of 433,920 MHz.

12) The measurements in steps 1 through 11 shall be performed on all interrogators. The ETHR Identification value shall be the greatest electromagnetic field strength noted out of all measurements.

If one interrogator is clearly lower in sensitivity than all others, i.e. it requires more signal before it will respond, then it should be removed from the tests and replaced with another interrogator.

9.1.3 Test report

The test report provides data recorded for the system's lower, nominal, and upper tolerance limits. The environmental conditions and communication parameters shall be recorded according to the example in Table 6.

Table 6 — Parameters recorded for $E_{THR\ Identification}$ measurement

Test: Identification electromagnetic field threshold ($E_{THR\ Identification}$) at centre frequency and ±40ppm)		
Temperature: deg (C)	**Humidity: %**	
Interrogator Protocol:	**Interrogator UII:**	
Forward Link		
Deviation (kHz): 50 kHz, nominal	**Data Rate: 27 kbps**	**Data Coding: Manchester coding**
Command: Collect with UDB		
Return Link		
Data Rate: 27 kbps	**Data Coding: Manchester coding**	
Test Results		
Centre Frequency	**fc + 40 ppm**	**fc – 40 ppm**
433,920 MHz	**433,940 MHz**	**433,900 MHz**
Attenuator Setting : dB	**Attenuator Setting: dB**	**Attenuator Setting: dB**
$E_{THR\ Identification}$: dBuV/m	**$E_{THR\ Identification}$: dBuV/m**	**$E_{THR\ Identification}$: dBuV/m**
ID:	**ID:**	**ID:**

9.2 Reading/Writing electromagnetic field threshold ($E_{THR\ Read/Write}$) and frequency tolerance

9.2.1 Purpose

This test determines the electromagnetic field threshold level at the interrogator that allows a tag reading or writing. To successfully read/write tag data, the command shall be transmitted correctly by the interrogator with maximum antenna output power allowed by the regulatory environment. The reading/writing electromagnetic field threshold, $E_{THR\ Read/Write}$, is the minimum electromagnetic field at the interrogator that allows tag reading/writing.

9.2.2 Test procedure

Tests shall be run at signal source set as specified in 6.2. The electromagnetic field of the signal source shall be set below the level that allows a interrogator to read the tag simulator's response to a read or write interrogator command, then it shall be increased to a level where it is possible to read the tag simulator's ID and to read or write the memory contents. For this test, the tag's simulator's memory shall be any available memory that permits both reading and writing.

To determine the electromagnetic field threeshold ($E_{THR\ Read/Write}$), the following measurement procedures shall be performed:

1) Test shall be run based on the test apparatus and test setups outlined in 6.2. Set the tag simulator's frequency to 433,920 MHz. Begin by placing the tag simulator's antenna to vertical polarization.

2) Set the tag simulator's attenuator to 30 dB to provide the interrogator with a moderate signal level. Confirm that the interrogator reads the tag simulator response at this level.

3) Increase the tag simulator's attenuator by 1 dB step until the interrogator does not read the tag simulator's response.

4) Decrease the attenuator setting until the interrogator reads the tag's simulator response 10 times out of 10 attempts.

5) Record this attenuator level (unsigned) in the box provided for attenuation setting for vertical polarization.

6) Convert the unsigned attenuator setting into dBμV/m by subtracting this setting from the field strength level at 0 dBm measured in 6.2. Place this into the ETHR Read /Write(dBμV/m) box in the vertical polarization column.

7) Repeat steps 2 through 4 with the tag simulator's antenna horizontally polarized.

8) Record this attenuator level (unsigned) in the box provided for attenuation setting under the column for horizontal polarization.

9) Convert the unsigned attenuator setting into dBμV/m by subtracting the setting from the field strength level at 0 dBm measured in 6.2. Place this into the ETHR Read/Write (dBuV/m) box in the horizontal polarization column.

10) Repeat steps 2 through 9 after increasing the centre frequency to 433,940 MHz. However in this case place the data into the boxes provided for 433,940 MHz instead of 433,920 MHz.

11) Repeat steps 2 through 9 after decreasing the centre frequency to 433,900 MHz. However in this case place the data into the boxes provided for 433,900 MHz instead of 433,920 MHz.

12) The measurements in steps 1 and 11 shall be performed on all interrogators. The ETHR Read value shall be the greatest electromagnetic field strength noted out of all measurements.

If one interrogator is clearly lower in sensitivity than all others, i.e. it requires more signal before it will respond, then it should be removed from the tests and replaced with another interrogator.

9.2.3 Test report

The test report provides data recorded for the system's lower, nominal, and upper tolerance limits. The environmental conditions and communication parameters shall be recorded according to the example in Table 7.

Table 7 — Parameters recorded for $E_{THR\ Read}$ measurement

Test: Identification electromagnetic field threshold ($E_{THR\ Read}$) at centre frequency and ±40ppm)		
Temperature: deg (C)	**Humidity: %**	
Interrogator Protocol:	***Interrogator UII:***	
Forward Link		
Deviation (kHz): 50 kHz, nominal	**Data Rate: 27 kbps**	**Data Coding: Manchester Coding**
Command: Collect with UDB		
Return Link		
Data Rate: 27 kbps	**Data Coding: Manchester Coding**	
Test Results		
Centre Frequency	**fc + 40 ppm**	**fc – 40 ppm**
433,920 MHz	**433,940 MHz**	**433,900 MHz**
Attenuator Setting : dB	**Attenuator Setting: dB**	**Attenuator Setting: dB**
$E_{THR\ Read/Write}$: dBuV/m	**$E_{THR\ Read/Write}$: dBuV/m**	**$E_{THR\ Read/write}$: dBuV/m**
ID:	*ID:*	*ID:*

9.3 Sensitivity Directivity ($S_{Directivity}$)

9.3.1 Purpose

This test determines the interrogator's sensitivity to various orientations, such as azimuth and elevation (see Figure 3). This, of course, is a determination of the directivity of the interrogator. It shall be determined under all conditions for which the interrogator is designed. This may include the interrogator being mounted on a metal surface such as the wall of a metal building. A sheet metal reflector of 20 × 20 inches can be used to simulate this situation so that the assembly can be rotated conveniently. A interrogator may also be used on a metal or wooden pole where a more omnidirectional pattern can be expected.

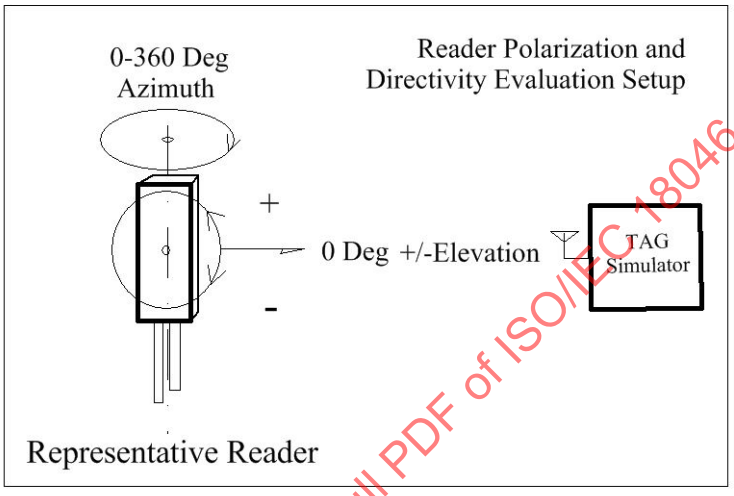

Figure 3 — Measurement setup for sensitivity directivity.

9.3.2 Test procedure

To determine the sensitivity directivity of a interrogator, $S_{Directivity}$, the following measurement procedures shall be performed:

1) Test shall be run based on the test apparatus and test setups outlined in 6.2. Set the tag simulator's frequency to 433,920 MHz. Begin by placing the tag simulator's antenna to vertical polarization. Adjust the interrogator to the azimuth or elevation angle being evaluated.

2) Set the tag simulator's attenuator to 0 dB to provide the interrogator with a full signal level. Confirm that the interrogator reads the tag simulator response at this level.

3) Adjust the tag simulator's attenuator until the interrogator does not read the tag simulator response properly.

4) Decrease the attenuator setting until the interrogator reads the tag simulator response 10 times out of 10 attempts.

5) Record this attenuator level (unsigned) in the box provided for attenuation setting for vertical polarization.

6) Convert the unsigned attenuator setting into dBμV/m by subtracting this setting from the field strength level measured in 6.3. Place this into the ETHR xx degrees (dBμV/m) box in the vertical polarization column.

7) Repeat steps 2 – 4 with the tag simulator's antenna horizontally polarized.

8) Record this attenuator level (unsigned) in the box provided for attenuation setting under the column for horizontal polarization.

9) Convert the unsigned attenuator setting into dBμV/m by subtracting the setting from the field strength level measured in 6.3. Place this into the ETHR xx degrees (dBμV/m) box in the horizontal polarization column.

10) Repeat steps 2 through 9 after at every 15 degrees increment from 0 to 345 degrees in azimuth, while the elevation is fixed at 0 degrees. Record in the appropriate ETHR xx degrees (dBμV/m) values in box for azimuth angle in the Test Report.

11) Repeat steps 2 through 9 after at every 15 degrees increment from 0 to ±90 degrees in elevation, while the azimuth is fixed at 0 degrees. Record in the appropriate ETHR xx degrees (dBμV/m) values in box for elevation angle in the Test Report.

12) The measurements in steps 1 and 11 shall be performed on all interrogators. SDirectivity shall be graphed for azimuth and elevation for each interrogator on a common graph.

If one interrogator is clearly lower in sensitivity or shows extreme directivity or nullling pattern problems compared to others, then it should be removed from the tests and replaced with another interrogator.

9.3.3 Test report

The test report provides data recorded for the unit's normal operating situation. Record results according to the example in Table 8.

Table 8 — Parameters recorded for $S_{Directivity}$ measurement

Test: Sensitivity directivity ($S_{Directivity}$)		
Mounting Material:		
Temperature:	Humidity:	
Interrogator Protocol:	Interrogator UII:	
Forward Link		
Deviation: 50 KHz nominal	**Data Rate: 27 kbps**	**Data Coding: Manchester coding**
Command: Collect with UDB		
Return Link		
Data Rate: kbps	Data Coding:	
Test Results: Azimuth @ 0 degree elevation		
Azimuth (degree)	**Attenuator Setting (dB)**	**Sensitivity (dBμV/m)**
0		**$E_{Survival}$**
15		
:		
345		
Test Results: Elevation @ 0 degree azimuth		
Elevation (degree)	**Attenuator Setting (dB)**	**Sensitivity (dBμV/m)**
0		
15		
:		
90		

9.4 Interference rejection ($I_{Rejection}$)

9.4.1 Purpose

This test determines the interference rejection ability of the interrogator.

9.4.2 Test procedure

A interrogator is placed in the test setup, and the tag simulator's level is set to 3 dB above the $E_{THR\ Read}$ level as determined in measurements reported in 9.2. This provides the interrogator with receive levels that have a 3 dB margin.

A second signal source acts as an interference signal and is attached to an antenna equivalent to that used for the tag simulator. The recommended test distance between the interrogator's location and the two source antennas should be the same and at minimum 2 meters, with 3 meters preferred. The two source antennas should also be equal in gain and separated from each other by at least one wavelength to reduce interactions between them.

First an unmodulated/modulated signal from the interference source is set to 433,920 MHz is set to 20 dB below the $E_{THR\ Read}$ level. This should still allow the tag simulator responses to be read by the interrogator.

The interference level is then increased until the interrogator is no longer able to decode the tag simulator's signal. This is considered the interrogator's On Channel $I_{Rejection}$ level. This test is repeated for the 1st adjacent channels (±250 kHz) and 2nd adjacent channels (±500 kHz).

To determine the interference rejection of the interrogator in the presence of unmodulated and modulated interference signal, the following measurement procedures shall be performed:

1) Test shall be run based on the test apparatus and setup outlined in Clause 6.2 using two identical vertical polarized reference antennas. One antenna connects to the tag simulator. The other connects to the interference signal source as shown in Figure 1.

2) Set the tag simulator's attenuator level to the ETHR Read setting for the interrogator being evaluated. Confirm that the interrogator reads the tag simulator response 10 out of 10 times.

3) Readjust the attenuator level to 3 dB below that of the ETHR Read level. This increases the level into the interrogator by 3 dB.

4) Adjust the level of the unmodulated interfering source to 20 dB or more below the ETHR Read level. Confirm that the interrogator still reads the tag simulator's signal 10 out of 10 times.

5) Increase the level of the unmodulated interfering source by 1 dB steps until the interrogator can no longer read 10 out of 10 read attempts from the tag simulator.

6) Record the value 1 dB lower than this level as the Co-channel Rejection (unmodulated) level.

7) Repeat steps 2 through 5 with the interference source 250 kHz higher in frequency (433,170 MHz). Record the value 1 dB lower than this level as the Upper 1st Adjacent Channel Rejection (unmodulated).

8) Repeat steps 2 through 5 with the interference source 500 kHz higher in frequency (433,420 MHz). Record the value 1 dB lower than this level as the Upper 2nd Adjacent Channel Rejection (unmodulated).

9) Repeat steps 2 through 5 with the interference source 250 kHz lower in frequency (433,670 MHz). Record the value 1 dB lower than this level as the Lower 1st Adjacent Channel Rejection (unmodulated).

10) Repeat steps 2 through 5 with the interference source 500 kHz higher in frequency (433,420 MHz). Record the value 1 dB lower than this level as the Lower 2nd Adjacent Channel Rejection (unmodulated).

11) Repeat steps 2 through10 except that the interference signal source is modulated with a 1 kHz tone set to 50 kHz deviation and record the corresponding results for the case of modulated interference signal.

These measurements shall be performed on all interrogators. The interferer electromagnetic field value recorded shall be the smallest one of all measurements done.

9.4.3 Test report

The test report shall provide data recorded for On Channel, 1st Adjacent Channel (±250 kHz), and 2nd Adjacent (±500 kHz) channels. Record the results according to the example in Table 9.

Table 9 — Parameters recorded for $I_{Rejection}$ measurement

Test: Interference rejection ($I_{REJECTION}$)					
Mounting Material:					
Temperature:		Humidity:			
Interrogator Protocol:		Interrogator UII:			
Forward Link					
Deviation: KHz	Data Rate: kbps	Data Coding:			
Command:					
Return Link					
Data Rate: kbps		Data Coding:			
Test Results @ 433,92 MHz centre frequency					
Interferer Frequency Offset	**0 Hz**	**250 khz**	**-250 kHz**	**500 kHz**	**-500 kHz**
Unmodulated Interference Rejection (dBμV/m)					
Modulated Interference Rejection (dBμV/m)					

9.5 Maximum operating electromagnetic field ($E_{Max\ Operating}$)

9.5.1 Purpose

This test determines the maximum electromagnetic field ($E_{Max\ Operating}$) at the interrogator that still allows tag identification.

9.5.2 Test procedure

Tests shall be run at 433,920 MHz, nominal centre frequency with the tag simulator's output raised from 0 dBm to 10 dBm. The attenuation level of the tag simulator's output shall be set to 30 dB. This attenuation level should allow the interrogator to collect 10 out of 10 tag simulator responses. The attenuation level will then be raised to a level where the interrogator ceases to respond to commands or to the full signal level available from the test source, whichever comes first. Full signal level is defined as 0 dB attenuation at 10 dBm output from the tag simulator. It is not necessary to provide a signal higher than this level.