

INTERNATIONAL STANDARD

Active millimetre-wave systems for security screening of humans – General requirements

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INTERNATIONAL STANDARD

Active millimetre-wave systems for security screening of humans – General requirements

INTERNATIONAL
ELECTROTECHNICAL
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**ACTIVE MILLIMETRE-WAVE SYSTEMS FOR SECURITY
SCREENING OF HUMANS – GENERAL REQUIREMENTS**

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Draft	Report on voting
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The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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ACTIVE MILLIMETRE-WAVE SYSTEMS FOR SECURITY SCREENING OF HUMANS – GENERAL REQUIREMENTS

1 Scope

This document applies to security screening systems that utilize active millimetre-wave (MMW) imaging to inspect persons who are not inside vehicles, containers, or enclosures. Specifically, this document applies to systems used to detect objects carried on the body of the individual being screened at a security checkpoint. This document applies to systems that screen people using radiation in the range between 3 GHz and 150 GHz (100 mm to 2 mm).

This document specifies the technical requirements, test methods, and signage of the active MMW systems for security screening of humans.

This document does not specify minimum or baseline requirements of image quality, automated threat recognition (ATR) performance, nor does it specify a minimum detection time.

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.

IEC 60068-2-1:2007, *Environmental testing – Part 2-1: Tests – Test A: Cold*

IEC 60068-2-2:2007, *Environmental testing – Part 2-2: Tests – Test B: Dry heat*

IEC 60068-2-6:2007, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-27:2008, *Environmental testing – Part 2-27: Tests – Test Ea and guidance: Shock*

IEC 60068-2-78:2012, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC 60204-1:2016, *Safety of machinery – Electrical equipment of machines – Part 1: General requirements*

IEC 60204-1:2016/AMD1:2021

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*

IEC 60529:1989/AMD1:1999

IEC 60529:1989/AMD2:2013

IEC 61000-4-2:2008, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61000-4-3:2020, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*

IEC 61000-4-4:2012, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61000-4-5:2014, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*
IEC 61000-4-5:2014/AMD1:2017

IEC 61000-4-6:2023, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61000-4-11:2020, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current up to 16 A per phase*

IEC 61000-6-1:2016, *Electromagnetic compatibility (EMC) – Part 6-1: Generic standards – Immunity standard for residential, commercial and light-industrial environments*

IEC 61000-6-3:2020, *Electromagnetic compatibility (EMC) – Part 6-3: Generic standards – Emission standard for equipment in residential environments*

IEC 61010-1:2010, *Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 1: General requirements*
IEC 61010-1:2010/AMD1:2016

ISO 3744:2010, *Acoustics – Determination of sound power levels and sound energy levels of noise sources using sound pressure-Engineering methods for an essentially free field over a reflecting plane*

ISO/IEC 18033-3:2010, *Information technology – Security techniques – Encryption algorithms – Part 3: Block ciphers*
ISO/IEC 18033-3:2010/AMD1:2021

IEEE Std. C95.1-2019, *Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 kHz to 300 GHz*

IEEE N42.59, *Standard for Measuring the Imaging Performance of Active Millimeter-Wave Systems for Security Screening of Humans* (balloted March 2024)

ICNIRP *Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields* (up to 300 GHz)

3 Terms and definitions

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

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

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

3.1

automated target recognition

ATR

automated software or algorithms used for anomaly detection, which includes threats, but not necessarily identification of particular objects or threats

Note 1 to entry: A MMW system with an ATR is designed to automatically indicate the location of the items carried by an inspected person.

3.2

contrast resolution

measure of the extent to which targets with similar reflectivity can be distinguished as having distinct grayscale values in a MMW image

3.3

contrast scaling

mapping of the reflected signal to the grayscale values in a MMW imaging system

3.4

depth

direction perpendicular to the y-axis and intersecting the centre of the imaging aperture

Note 1 to entry: Figure 4 defines the system axes.

3.5

depth response

full width at half maximum in the depth direction of the reflected signal that is obtained from imaging a thin, highly-reflective object using a MMW system

3.6

detection

action of finding and indicating the location of an item carried or concealed by an inspected person

Note 1 to entry: Only applies to systems with ATR.

3.7

detection time

time duration from the initiation of the scan to the display of the automatically-generated detection result

Note 1 to entry: For a system without ATR, detection time refers to the time duration from the initiation of the scan to the display of the acquired image.

3.8

effective depth resolution

measured spatial resolution in the depth direction

3.9

false alarm

alarm where no item is carried by an inspected person

Note 1 to entry: Only applies to systems with ATR.

3.10

horizontal illumination coverage

measure of the visible width of a vertical cylinder in the x-z plane in a MMW image

Note 1 to entry: Figure 4 defines the system axes.

3.11

lateral resolution

measure of the extent to which closely spaced objects can be separately distinguished in directions lateral to the plane of the test object

Note 1 to entry: The resolution criterion is a modulation transfer function (MTF) of at least 0,2 in an imaged test pattern.

3.12**minimum detectability**

size of the smallest sphere consistently detected above noise in a MMW image

3.13**system**

instrument under test, specifically a security screening device, that uses millimetre-wave radiation to detect items carried or concealed by inspected persons

3.14**vertical field of view**

measure of the vertical extent of the inspection volume using the image signal response from a uniform object

3.15**vertical illumination uniformity**

measure of image signal homogeneity measured vertically along an extended uniform object

4 Requirements and tests**4.1 Environmental conditions**

Unless otherwise specified, the environmental conditions at the test location shall be as described in 4.3.1 of IEC 61010-1:2010. The temperature shall be between 15 °C and 35 °C. The relative humidity shall not be more than 75 %. The air pressure shall be between 75 kPa and 106 kPa.

4.2 Major test instruments and tools

Table 1 describes the technical requirements of the major instruments and tools recommended for the tests.

Table 1 – Major instruments and tools

Line	Instrument name	Technical requirements
1	Ground resistance tester	Range: 0 to 1 Ω Precision: ± 3 %
2	Insulation resistance meter	Rated voltage: 500 V Range: 0 to 500 M Ω Precision: ± 10 %
3	Leakage current tester	Range: 0,03 mA to 20 mA Precision: ± 5 %
4	Dielectric tester	Range: 0 kV to 5 kV
5	Sound level meter	Frequency range: 25 Hz to 8 kHz. The measurements shall be made with an A-weighting filter applied.
6	Spectrum analyser and connecting antenna	The frequency range shall cover the working frequency range of the system. The polarization mode of the measurement antenna shall be the same as that of the system.

4.3 Appearance and structure

4.3.1 Requirements

The appearance of the system shall comply with the following requirements:

- a) For a system that requires the person to adopt specific posture during inspection, appropriate guidance shall be provided, for example, footprint or standing posture illustrations.
- b) The ingress protection level of the system should be at least IP20, complying with 5.1 of IEC 60529:1989.

4.3.2 Test method

Compliance of the requirements from 4.3.1a) shall be checked by inspection of the system and documentation.

Test the protection level of the system according to Clause 13 of IEC 60529:1989. Determine whether the test result complies with the requirements in 4.3.1b).

4.4 Functionality

4.4.1 Requirements

4.4.1.1 Basic screening

The system shall be capable of performing a basic screening procedure in a non-contact manner.

4.4.1.2 Access control

The system shall use a role-based access control methodology. For example, the roles of operators and administrators would generally possess different levels of access control.

4.4.1.3 Privacy protection

If privacy protection is desired, necessary methods should be applied for the purpose of personal information protection and anonymization. Examples include displaying the scanned subject as an avatar image or blurring the inspected person's face in the millimetre-wave image.

4.4.1.4 Data security

The system shall not store images persistently or allow displaying or exporting images unless required for a specific use case. If images are generated, the system shall prevent these images from being accessed, in any way, by unauthorized personnel. If images are stored, they shall be encrypted using a standardized state-of-the-art cryptographic method.

For selection of state-of-the-art cryptographic methods, it is recommended to consider ISO/IEC 18033-3:2010 as well as applicable recommendations by national authorities.

4.4.1.5 Network communication

If network communication is desired, the system should provide networking capabilities to implement a series of functions such as equipment status monitoring, operation parameter adjustment, alarm related data upload, etc.

4.4.1.6 Self-test and fault diagnosis

The system shall have self-test capability to diagnose faults. The system or its documentation shall provide information, such as fault codes or error messages, that can be used to trace faults when system malfunction occurs. The faults may include MMW transceiver failure, abnormal image or mechanical movement failure (if applicable) and should be recognisable by the user, for example, by display of an error message or perceptible alarm. The tester is encouraged to test other fault conditions if they are important for their system type or use case.

4.4.1.7 ATR

A system with an ATR should be capable of automatically detecting anomalies including threat objects.

4.4.2 Test method

4.4.2.1 Basic screening test

Perform a screening following the standard operating procedure. The screening shall produce a result with no error messages. The specific nature of the screening result will vary from system to system. For example, the result could be an image on a screen of what was scanned or an avatar representation of the screening result.

NOTE 1 Some systems will produce an error message, unless there is a properly-posed (possibly moving) body to in the inspection area.

NOTE 2 This requirement and test method are used to show the system provides basic functionality during some of the environmental and electrical tests.

4.4.2.2 General function test

Operate the system according to the operation manual, and check whether the results meet the requirements of 4.4.1.2 to 4.4.1.5.

4.4.2.3 Self-test and fault diagnosis test

The man-made fault conditions described in Table 2 shall be applied to the system if applicable. Some tests may not be applicable to some systems, for example, some systems may not have mechanically-moving parts. In general, to protect both the system and personnel, the fault should be initiated when the system is turned off. After forcing the fault, initiate a scan. Check whether, at any point during the start-up procedure, during the scan, or after the scan, the system indicates an error or a corresponding fault message.

Table 2 – Man-made fault conditions

Line	Fault	Example of man-made fault method	Example of fault information
1	MMW transceiver failure	Unplug the data communication cable	Indicate error or fault message
2	Abnormal images	Block more than a quarter of MMW transceivers with metal	Indicate error or fault message
3	Mechanical movement failure	Disconnect a control cable for mechanical movement components	Indicate error or fault message
NOTE Table 2 is not intended to be comprehensive and the manufacturer can provide more specific illustrations for fault diagnosis in the instructions.			

4.4.2.4 ATR test method

The ATR test is used to evaluate whether the ATR provides basic functionality and is no substitute for detailed threat-based testing. It is not intended as quantitative measure of ATR performance.

Detailed threat-based testing requires large numbers of scans of various threat scenarios upon which statistical analyses are performed. This test only provides detection results and false-alarm results, rather than rates, to evaluate nominal ATR functionality.

There are six test items (see Table 3) and four test positions (see Table 6) for the ATR test. The items in Table 3 were chosen to be suitable for systems where the ATR is intended to alarm on all undivested items and the targets of greatest interest are weapons and explosives. If this is not the case, then additional items may be chosen that are suitable for the use case of the system. Report any additions to the standard requirements.

- a) Place the test item at the test position on the body. Scan the body using the system and note whether the item was detected.
- b) Repeat step a) for all 24 combinations of test items and test positions.
- c) Report how many of the 24 test-item and test-position combinations were detected (e.g. 18/24).
- d) Collect 18 scans where no test items are present on the body. Report the number of scans where false alarms occurred (e.g. 2/18).

NOTE More than one test item can be placed for each detection.

Table 3 – ATR test items

Code	Test items	Material	Size or specification
a	rectangle non-metallic object	polyvinyl chloride (PVC)	100 mm × 80 mm × 10 mm
b	L-shaped metal object	aluminium or steel	Figure 1
c	ceramic bar partially covered with plastic	ceramic	Figure 2
d	metal bar covered with plastic	aluminium or steel	Figure 3
e	disc shape non-metallic object enclosed within thin plastic film	135 g salt (NaCl)	Ø100 mm approximate
f	plastic bottled liquid	water	100 ml

Table 4 – ATR test positions

Code	Test positions on body
A	chest
B	waist
C	arm
D	leg

Dimensions in millimetres

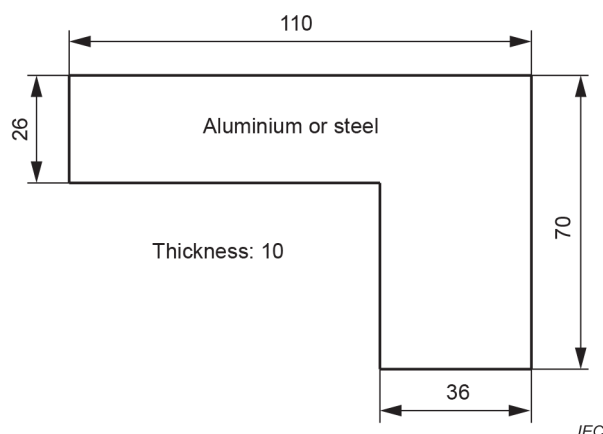


Figure 1 – L-shaped metal object

Dimensions in millimetres

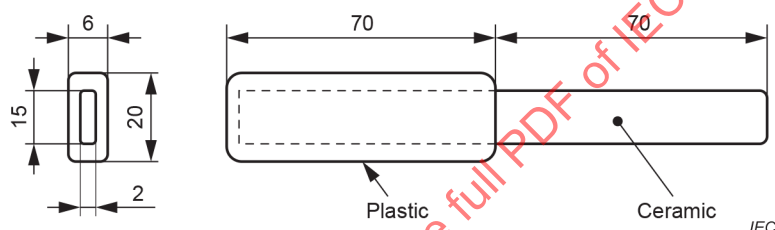


Figure 2 – Ceramic bar partially covered with plastic

Dimensions in millimetres

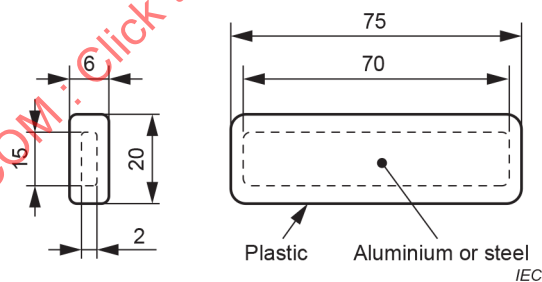


Figure 3 – Metal bar covered with plastic

4.5 Performance

4.5.1 Imaging performance test methods

The imaging performance of the MMW system shall be characterized using methods specified in IEEE N42.59TM. Perform the following test methods and report the quantities itemized below:

- Lateral resolution: report the horizontal and vertical $\overline{MTF20}$ and $\sigma_{\overline{MTF20}}$ using the methods described in 4.3 of IEEE N42.59.
- Effective depth resolution: report $\bar{d}$ using the methods described in 4.4 of IEEE N42.59.
- Depth response: report the average depth response width, $\bar{W}$, using the methods described in 4.4 of IEEE N42.59.

- d) Horizontal illumination coverage: report the mean width of the horizontal illumination profile, $\bar{w}$, using the methods described in 4.5 of IEEE N42.59.
- e) Vertical illumination uniformity: report the vertical illumination uniformity metrics using the methods described in 4.5 of IEEE N42.59.
- f) Contrast scaling and contrast resolution: report π_i , $\bar{r}_i$, and $\overline{\Delta r_i}$ for all the measured standards. Report the *RMSE* contrast scaling using the methods described in 4.6 of IEEE N42.59.
- g) Minimum detectability: report the minimum detectable sphere size using the methods described in 4.7 of IEEE N42.59.

4.5.2 Detection time test method

Operate the system as described in 4.4.2.4. Record the duration of the scan where a detection occurs, starting from when the scan is initiated to when the detection is completely presented. Repeat at least three times and report the mean duration.

4.6 Power requirements and testing

4.6.1 Requirements

- a) The supply voltage or voltage range, frequency or frequency range shall be stated according to 5.4.2 of IEC 61010-1:2010 and IEC 61010-1:2010/AMD1:2016.
- b) The system shall operate correctly with the conditions of supply according to 4.3 of IEC 60204-1:2016.

4.6.2 Test method

The test conditions for AC, DC (battery) and DC (from converting equipment) supplies are listed in Table 5. For other cases, please refer to 4.3.1 of IEC 60204-1:2016.

For the conditions that meet the type of supplies, test the system according to 4.4.1.1.

Table 5 – Test conditions of the supplies

Line	Type of supplies	Voltage	Frequency
1	AC supplies	Rated voltage. If a range is stated, then use the middle of the range.	Rated frequency. If a range is stated, then use the middle of the range.
2		0,9 of minimum rated voltage	0,95 of minimum rated frequency
3		0,9 of minimum rated voltage	1,05 of maximum rated frequency
4		1,1 of maximum rated voltage	0,95 of minimum rated frequency
5		1,1 of maximum rated voltage	1,05 of maximum rated frequency
6	DC supplies (from batteries)	Rated voltage. If a range is stated, then use the middle of the range.	
7		0,85 of minimum rated voltage	
8		1,15 of maximum rated voltage	
9	DC supplies (from converting equipment)	Rated voltage. If a range is stated, then use the middle of the range.	
10		0,9 of minimum rated voltage	
11		1,1 of maximum rated voltage	

4.7 Safety

4.7.1 Electromagnetic radiation safety

4.7.1.1 Requirements

The system shall meet the exposure control limit requirements while working as specified in Table 7 of IEEE Std. C95.1TM-2019 and Table 5 of ICNIRP guidelines.

4.7.1.2 Test method

The test shall be performed using the following method to determine whether the test result complies with the requirements.

- Test principle

Measure the millimetre-wave power emitted by the system under test using a spectrum analyzer and a measurement antenna. Calculate the millimetre-wave power density at the receiving antenna's position using the following formula:

$$S_{\text{eq}} = \frac{P}{A_{\text{eff}}} = \frac{P}{G \frac{c^2}{4\pi f^2}} = \frac{4\pi f^2}{G c^2} P$$

where

P is the measured power;

A_{eff} is the effective area of the measurement antenna;

G is the gain of the antenna under a certain test distance;

f is the frequency;

c is the speed of light.

The distance between the millimetre-wave measurement antenna and the transmitting antenna of the system under test is usually shorter than the far-field distance. Therefore, the gain (G) of the antenna in the formula needs to be determined by measurement according to the antenna distance.

- Test positions

The equivalent electromagnetic power density at the specified position is measured based on the location where the person is scanned in the inspection area.

The coordinate system is as specified in Figure 1 and Figure 2 of IEEE Std. C95.1-2019.

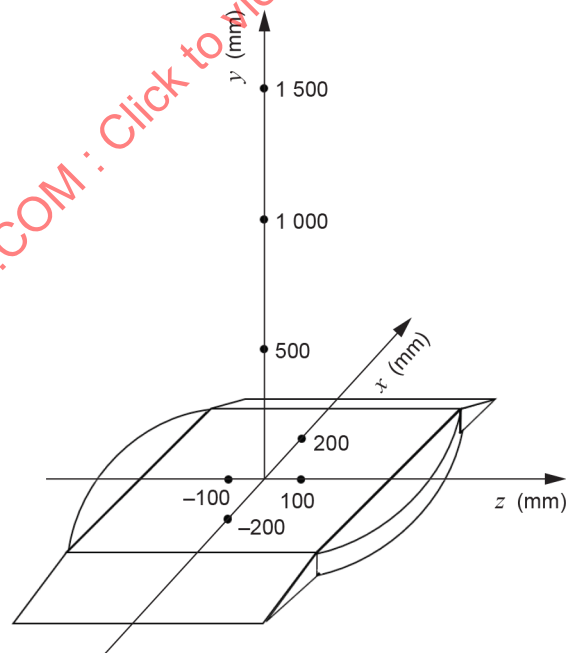
For systems where the scanned person is stationary, the positions are specified in Table 6 and Table 7 using the coordinate system shown in Figure 4 (consistent with Table 2 of IEEE Std. C95.1-2019). For systems where the scanned person is in motion, such as walk-through systems, measurements shall be made at multiple positions representative of where the person is imaged e.g. entrance, center and exit positions at the heights specified in Table 6.

Table 6 – The specified positions inside the system

Coordinates mm		$z = -100$	$z = 0$	$z = 100$	50 mm from the front surface of the system
$y = 500$	$x = -200$				
	$x = 0$				
	$x = 200$				
$y = 1000$	$x = -200$				
	$x = 0$				
	$x = 200$				
$y = 1500$	$x = -200$				
	$x = 0$				
	$x = 200$				

Table 7 – The specified positions outside the system

Positions or coordinates mm	$y = 500$	$y = 1000$	$y = 1500$
Entrance or one side of inspection area			
Exit or the other side of inspection area			



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NOTE The person stands on the $y = 0$ plane with their body centred about the y axis and facing in the positive z direction. Some key positions specified in Table 6 are shown.

Figure 4 – Diagram of the coordinate system

- Test procedure

For a system with non-circularly polarized transmitting antenna, the measurement antenna should adopt the same polarization direction as the transmitting antenna of the system. There is no direction requirement for a system with circularly polarized transmitting antenna. The spectrum analyzer shall be set to peak detection mode, the maximum holding state, and continuous frequency scanning mode. The scanning time of the spectrum analyzer shall be long enough to ensure the repeatability of the measurement results. For the test of a discontinuous multifrequency system, the bandwidth resolution of the spectrum analyzer shall be less than the step frequency of the system.

Operate the system in normal scan mode. Repeated scans may be needed for the measurement.

For a multifrequency system, record the measured maximum value of all operating frequencies. For a monofrequency system, record the maximum value of the operating frequency.

4.7.2 Electrical safety

The system shall be compliant with the electrical safety requirements in Clause 6 of IEC 61010-1:2010 and IEC 61010-1:2010/AMD1:2016.

4.7.3 Mechanical safety

The system shall be compliant with the mechanical safety requirements in Clause 7 and Clause 8 of IEC 61010-1:2010 and IEC 61010-1:2010/AMD1:2016.

4.8 Electromagnetic compatibility

4.8.1 Electromagnetic Immunity

4.8.1.1 Requirements

Perform the following 6 immunity tests: electrostatic discharge, RF electromagnetic field radiation, electric fast transient pulse group, surge (impact), induced conduction disturbance of RF field and voltage sag, short interruption, and voltage change. The immunity performance of the system shall meet the requirements described in Table 1, Table 2 and Table 4 of IEC 61000-6-1:2016.

4.8.1.2 Test method

a) Electrostatic discharge immunity test method

The test of electrostatic discharge immunity of the system shall be carried out according to IEC 61000-4-2:2008.

b) Radiated, radio-frequency, electromagnetic field immunity test method

The test of radiated, radio-frequency, electromagnetic field immunity of the system shall be carried out according to IEC 61000-4-3:2020.

c) Electrical fast transient/burst immunity test method

The test of electrical fast transient/burst immunity of the system shall be carried out according to IEC 61000-4-4:2012.

d) Surge immunity test method

The test of surge immunity of the system shall be carried out according to IEC 61000-4-5:2014.

e) Immunity to conducted disturbances, induced by radio-frequency fields test method

The test of immunity to conducted disturbances, induced by radio-frequency fields of the system shall be carried out according to IEC 61000-4-6:2023.

f) Voltage dips, short interruptions and voltage variations immunity test method

The test of voltage dips, short interruptions and voltage variations immunity of the system shall be carried out according to IEC 61000-4-11:2020.

4.8.2 Electromagnetic interference

The radiated and conducted emissions shall meet the requirements of IEC 61000-6-3:2020.

4.9 System noise

Measure the noise using an A-weighted sound level meter at any point 1 m away from the outer surface of the system when the system is performing a scan. It is allowable to turn off audible alarms during the test.

The test of system noise using the A-weighted measurements and the criteria for background noise shall be carried out as described in 4.2 of ISO 3744:2010.

4.10 Environmental compliance testing

4.10.1 General

It is suggested to perform the test on the whole machine for assessment of the system. However, when the specifications of components of the system, including MMW transceiver array, power supply unit, internal computers and displays are changed, then it is acceptable to check compliance using the following method:

- a) Assemble the new system configuration with the new components and test the system according to 4.4.1.1.
- b) Remove the new components from the system and test them according to 4.10.2.
- c) Reinstall the new components in the system and test the system according to 4.4.1.1.

Ensure the system and new components have no visible rust or mechanical damage caused by the test.

4.10.2 Environmental tests

The environmental tests are specified in Table 8. Determine whether the test results comply with the requirements. Ensure that condensation does not form on the system during the test. The high and low operating temperature, storage temperature and humidity values shall be chosen based on the maximum and minimum values given in the system specifications. If no such values are available, then it is acceptable to test based on the requirements for the intended use of the system.