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INTERNATIONAL ELECTROTECHENICAL COMMISSION

INTERNATIONAL SPECICAL COMMITTEE ON RADIO INTERFERENCE (CISPR)

CISPR Guidance document on EMC of Robots

This guidance document is an updated version of CISPR/1412/INF which was originally prepared by CISPR/S AHG 3. It is intended to give some basic information about robots, some guidance as to which CISPR sub-committee covers which types of robots, and some proposals when carrying out EMC testing on robots.

CISPR may update this guidance to keep pace with technology development and welcomes any suggestions and proposals for improvement.

1 Introduction

With the investment in intelligent manufacturing and the development of intelligent products, robots will become more and more important in the future, and the appearance and application of robots have become a highly valued opportunity. IEC and ISO have spent a lot of time and energy on a continuous basis, citing its robotics industry service standards. It must be ensured that robots meet EMC requirements including the ability to operate normally in the electromagnetic environments in which they are installed and operating. In addition, robots must not interfere with radio services and nearby electronic devices, including radio systems within the robot itself. Although robots can be considered as any other type of equipment when it comes to measuring radio frequency emissions or testing immunity, there are some particular aspects to be taken into account, for example the fact of movable parts of robots.

The robot industry is developing rapidly, with the following standardisation groups active in the field of robotics: ISO/TC 299, IEC/TC 59, IEC/TC 61, IEC/TC 62, IEC/TC 116. The advisory committee IEC ACART is responsible for coordinating the work. It is worth emphasizing that none of these groups have any electromagnetic compatibility capability for the research of robots, and hence CISPR is responsible for the standard work of electromagnetic compatibility of robots, in particular when it comes to measurements of RF emissions.

Therefore, CISPR/S AHG3 was established after the CISPR plenary meeting in 2017. Its responsibilities are:

- to analyse how robotics are already dealt with in CISPR publications
- to advise on whether there is any possibility to align the treatment of robotics in the different publications
- to investigate whether a general recommendation for test setups can be made.

2 Scope

This EMC guidance document applies to robotics dealt with in CISPR publications, advises on aligning the treatment of robotics in the different publications and gives a general recommendation for test setups, referring any issues to CISPR subcommittees. It provides guidance to EMC standards writers on the suitable emission and immunity performance of robotics.

The objectives of this guidance are to identify standards that contain:

- requirements which provide an adequate level of protection of the radio spectrum, allowing radio services to operate as intended in the frequency range 0 to 400 GHz;
- requirements allowing robots to operate as intended in the expected environment
- procedures to ensure the reproducibility of measurement and the repeatability of results.

3 Normative References

CISPR 11: Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement

CISPR 12: Vehicles, boats and internal combustion engines - Radio disturbance characteristics – Limits and methods of measurement for the protection of off-board receivers

CISPR 14-1: Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus - Part 1: Emission

CISPR 14-2: Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus - Part 2: Immunity - Product family standard

CISPR 16-1-1: Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-1: Radio disturbance and immunity measuring apparatus - Measuring apparatus

CISPR 25: Vehicles, boats and internal combustion engines - Radio disturbance characteristics - Limits and methods of measurement for the protection of on-board receivers

CISPR 32：Electromagnetic compatibility of multimedia equipment – Emission requirements

CISPR 35: Electromagnetic compatibility of multimedia equipment – Immunity requirements

ISO 8373: Robots and robotic devices — Vocabulary

4 Definitions, acronyms and abbreviations

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

4.1 robot

actuated mechanism programmable in two or more axes with a degree of autonomy moving within its environment, to perform intended tasks

Note 1 to entry A robot includes the control system and interface of the control system.

Note 2 to entry The classification of robot into industrial robot or service robot is done according to its intended application.

[2.6 in ISO 8373:2012]

4.2 industrial robot

automatically controlled, reprogrammable, multipurpose manipulator, programmable in three of more axes, which can be either fixed in place or mobile for use in industrial automation applications

Note 1 to entry The industrial robot includes: the manipulator, including actuators; the controller, including teach pendant and any communication interface (hardware and software)

Note 2 to entry This includes any integrated additional axes.

[2.9 in ISO 8373:2012]

4.3 service robot

robot that performs useful tasks for humans or equipment excluding industrial automation applications

Note 1 to entry Industrial automation applications include, but are not limited to, manufacturing, inspection, packaging, and assembly.

Note 2 to entry While articulated robots used in production lines are industrial robots, similar articulated robots used for serving food are service robots.

[2.10 in ISO 8373:2012]

4.4 personal service robot

service robot for personal use, service robot used for a non-commercial task, usually by lay persons

EXAMPLES Domestic servant robot, automated wheelchair, personal mobility assist robot, and pet exercising robot.

[2.11 in ISO 8373:2012]

4.5 professional service robot

service robot for professional use, service robot used for a commercial task, usually operated by a properly trained operator

EXAMPLES Cleaning robot for public places, delivery robot in offices or hospitals, fire-fighting robot, rehabilitation robot and surgery robot in hospitals.

[2.12 in ISO8373:2012]

4.6 Primary function

Any function of a robot considered essential for the user or for the majority of users

Note 1 to entry: A robot can have more than one primary function

5 Robot classifications

The variety of robots can be divided into industrial robots and service robots, and service robots furthermore into personal service robots and professional service robots (from ISO 8373:2012 Robots and robotic devices – Vocabulary, robot classification).

Figure 1 shows the robotics classification. The solid line section boxes are based on ISO 8373:2012. The range of professional service robots is large and can be divided into different requirements for personnel based on the use of the site. It is shown as the dotted line boxes in Figure 1.

Note: Personal care robots, medical personal care robots and wearable robots are included in personal service robots. Communication robots are included under public service robots and medical care robots under special robots.

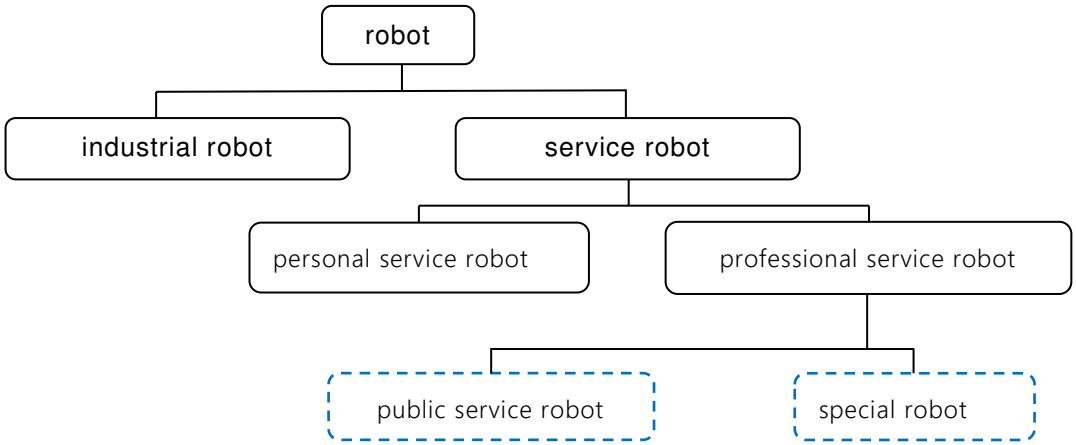

Figure 1 - robot classification structure

6 Description of various types of robots related to EMC

6.1 General EMC aspects

6.1.1 Emissions

Both radiated and conducted emissions of robots and/or robotic devices may be maximized when there are dynamically operating parts such as arms and moving on the basis of the specified modes of operation associated with each function.

For each function or group of functions selected to exercise the robot, a number of representative modes of operation, including low power/standby, should be considered for emission measurement, and the mode(s) that produce(s) the highest emissions should be selected for the final measurement.

6.1.2 Immunity

All aspects of testing robots should be defined and documented by the manufacturer prior to testing according to a test plan. The test plan should contain requirements for immunity testing of robots and/or robotic devices including selection of applicable tests, disturbance levels to be applied during testing, configuration, performance criteria and other necessary details.

The requirements should include selection of the primary function(s), the specific performance criteria relevant to primary function(s) and the mode(s) of operation to be used.

The immunity tests should be carried out individually, in any sequence.

The same sample should be used for all tests relating to particular electromagnetic (EM) phenomena, however, other samples of the robot may be used to test against different EM phenomena.

The description of the tests, the test equipment (for example, generators, amplifiers, transducers and cables), the test methods, the calibration and/or verification methods and the test setups are given in the relevant basic immunity publications.

6.2 Industrial robots

6.2.1 Characteristics of industrial robots

There are many different types of industrial robots depending for example on their differences regarding mechanical structures. Table 1 shows some photos and gives some characteristics of various industrial robots.

Table 1 – Various industrial robots

No.	Classification of industrial robots	Photo	Characteristics
1	Rectangular robot Cartesian robot		Robot whose arm has three prismatic joints, whose axes are coincident with a Cartesian coordinate system
2	SCARA robot		Robot which has two parallel rotary joints to provide movement in a selected plane
3	Spine robot		Robot whose arm is made up of two or more spherical joints
4	Parallel robot Parallel link robot		Robot whose arms have links which form closed loop structures
5	Collaborative robot		Robot designed for direct interaction with a human

6	Articulated robot		Robot whose arm has three or more rotary joints

Articulated robots are the most common and complicated robots. They are generally designed with several axes and can perform multi-direction movement with a large workspace. A typical articulated robot comprises the manipulator and the controller including teaching pendant and communication interface, is shown in Figure 2.

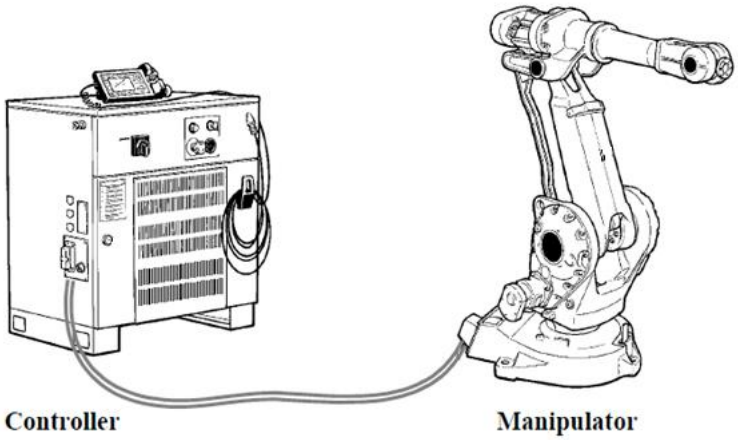

Figure 2 - Typical Articulated robot

6.2.2 EMC related matter

When a robot is dynamically operating (for example, arms of industrial robot are moving), the radiated emission of the robot may be maximized. However, emission levels of the robot under such operating mode cannot always exactly be measured due to time constraints and RBW of QP detector defined CISPR 16-1-1.

6.3 Personal Service Robots

6.3.1 Characteristic of Personal Service Robots

Personal Service Robots may be different from household robots. In order to understand the robot form more intuitively, the following pictures show representative samples.

				
Domestic helper robots	Education entertainment service robot	Old-age support service robot	Personal transport service robots	Personal safety robots or intelligent housekeeper

6.3.2 EMC related matter

Personal Service Robots usually work with people closely, and the performance degradation caused by low immunity may lead to personal safety issues. In addition, the load specification, coexistence of a variety of functions, and functional combinations used during the test will affect the test results.

6.4. Public service robots

6.4.1 Characteristic of Public service robots

This kind of robot usually works in a public place, such as a hotel, hospital, bank, venue, stadium, restaurant, etc. It is more complicated than the household environment. In order to understand the robot form more intuitively, the following pictures show representative samples.

			
Hotel service robot	Bank service robot	Venue service robot	Catering service robots

6.4.2 EMC related matter

In near future, new measurement methods using high frequency sampled time domain measurements, for example, analyzing an exact QP value by using FFT processing may be necessary for correctly measuring RF emissions.

6.5 Special robots

6.5.1 Characteristics of special robots

Special robots may be used by a professional person or be used in an extreme environment. In order to understand the robot form more intuitively, the following table shows representative samples.

				
Underwater robot	Flying robot	Power Robot	Military police robot	Medical robot

6.5.2 EMC related matter

There are many kinds of special service machines, and the actual working conditions are complex. It may be difficult to simulate the actual operation mode during testing.

7 Requirements for EMC standardization of robots

The basic concept covered here is to map the EMC requirements from existing CISPR product family standards for robots. While these publications are voluntary unless specified by a National or regional authority, a manufacturer may choose to apply the standard to demonstrate that the requirements given within the standard are met.

7.1 Ports on robot

The requirements for robots are contained in the CISPR product family or generic standards. Emission requirements are applied on a port by port basis for specific working conditions. Figure 3 shows a view of the ports that might be found on robots.

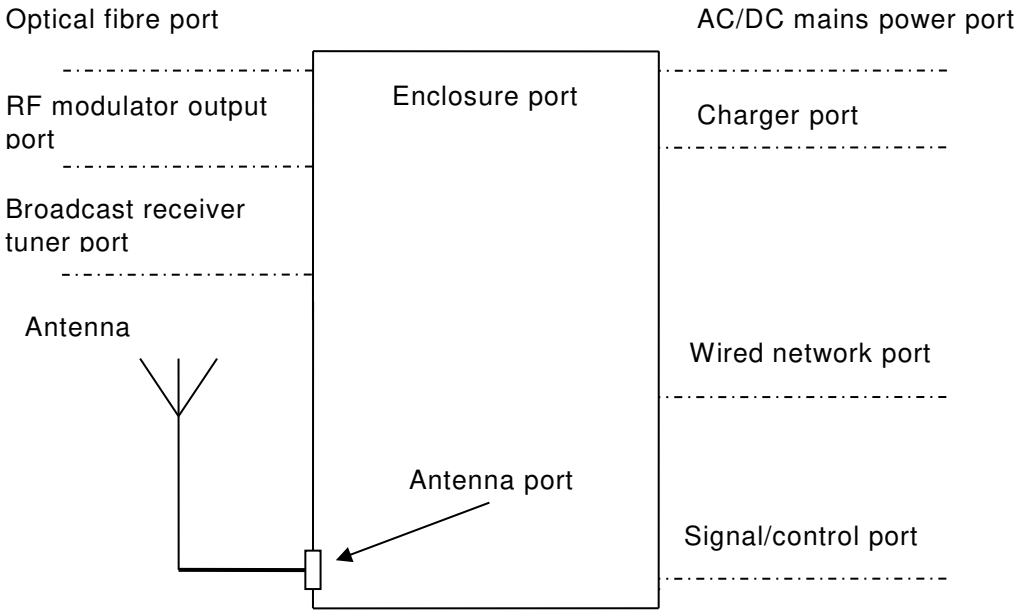

Figure 3 - Ports that may be found in robots

While the ports may be specifically input or output, it is expected that in many cases for robots, ports will be both input and output.

Emission limits and test methods relevant to robots should be clarified in the specific product family standards (see Table 2) or, where no product family standard exists, in the generic standards.

7.2 Operation modes related to EMC

7.2.1 General

A robot should be tested in the operating mode producing the largest emission in the frequency band being measured, consistent with normal applications.

For some robots the operating conditions might be defined in detail by the product committee. An example is the definition of operating conditions for robotic cleaners described in CISPR 14-1:2016 clause A.8.11.

The configuration of the test sample should be varied to achieve maximum emission consistent with typical applications and installation practice. Pre-testing may be used to reduce test time.

Care should be taken during pre-testing or while creating operating conditions specified in product standards for robots and the following items which are specific for robots should be taken into consideration:

– Some robots could change their size and shape
– Robots can dynamically react to input signals and environmental parameters so that setting an operating mode in the laboratory consistent with normal application is sometimes not possible
– Some more general robots can have nearly an unlimited number of operating modes. It is not possible to test all these operating modes. A qualified selection is necessary.

7.2.2 Emission

In most cases the operating modes to be applied when performing measurements should be selected considering the following steps:

– Maximize the size of the robot
– All motors, sensors and electric tools attached to the robot should preferably be in continuous operation during measurements. Motors should be operated at normal speed consistent with normal applications.
– The operating mode and settings selected should be clearly described and repeatable

In most cases the implementation of a special EMC test mode by the manufacturer is the preferred method to establish a repeatable operating condition for the robot. This EMC test mode should establish all the items as listed above.

For robots with wheels an idle roller can be used to allow operation without movement of the robot.

7.2.3 Immunity

A robot should be tested in the expected most susceptible operating mode, for example identified by performing limited pre-tests. This mode should be consistent with normal applications. The configuration of the test sample should be varied to achieve maximum susceptibility consistent with typical applications and installation practice.

Robots can often perform a large number of primary functions. The manufacturer should list all primary functions of the product and either do the testing of the robot with all these primary functions active at the same time or consecutively.

As an alternative, similar to the emission testing a special EMC test mode, implemented by the manufacturer, should be used which has all sensors active and all actuators in motion. Special software should be used to monitor all sensor signals during the test and to check if they are within the specifications as defined by the manufacturer.

“Idle” or "standby" mode is a necessary test mode for immunity tests, where unexpected movement or other function must not occur.

8 Division of robots to sub-committees

The following Table 2 lists various types of robots and indicates the appropriate emission standard to be applied for specific types. For cases where no CISPR product family standard is indicated the application of generic emission standards should be considered.

Table 2 – Various types of robots and applicable CISPR standards

No	Type		Sub-committees	Standards involved	Note
1	industrial robot	industrial robots (Rectangular robot/Cartesian robot/ SCARA robot/ Spine robot/ Parallel robot/Parallel link robot/ Collaborative robot/ Articulated robot	CIS/B	CISPR 11	work in the assembly line
2	industrial robot/ special robots	Automatic Guided Vehicle	CIS/B	CISPR 11	Which works in the industrial environment
3	special robots	Inspection Robot	CIS/B	CISPR 11	
4	special robots	Security robot	CIS/B	CISPR 11	
5	personal service robot	Domestic helper robots	CIS/F	CISPR 14-1/14-2	Domestic helper robots, such as household cleaning robots are already in CISPR14-1, but immunity requirements are not given in CISPR 14-2. Beyond doubt, it is in the field of CISPR/F
6	personal service robot	Education entertainment service robot	CIS/I	CISPR 32	Education entertainment service robot (excluding a toy of a humanoid.) are similar with the Audio & Video products. So, it is suggested it is in the field of CISPR/I.
7	personal service robot	Old-age support service robot	need to be discussed	No standard	Old-age support service robot, it usually helps older people to eat or move.
8	personal service robot	Personal transport service robots, such as self-balancing human transporters.	need to be discussed	No standard	

9	personal service robot	Personal safety robots or intelligent housekeeper	CIS/F	CISPR 14-1/14-2	Personal safety robots or intelligent housekeeper is similar as a mobile web camera, in fact it sometimes integrated with the clean robots. So, it is suggested it is in the field of CISPR/F.
10	public service robots	Hotel service robot	need to be discussed	No standard	All these kinds of robots have one common is used in the light industrial business environment. So IEC61000-6-2/-6-4 may be used, but the test status and test set-up should be researched. So, it may be in the field of CISPR/H or not and needs to be discussed.
11	public service robots	Bank service robot	to be discussed	No standard	
12	public service robots	The venue service robot/	to be discussed	No standard	
13	Catering service robots	Catering service robots	to be discussed	No standard	
14	personal service robot	underwater robot	need to be discussed	No standard	
15	special robots	Flying robot		No standard	
16	special robots	Military police robot		No	

9 General considerations of EMC for robots in standards

For robots which are already in the scope of the various CISPR sub-committee standards, amendments might be needed to address and clarify the following items (if not done already):

(1) Add the following definitions in clause 2, Terms and definitions:

- robot
- industrial robot
- service robot
- professional service robot
- service robot for professional use
- rated load

(2) Limits of electromagnetic disturbances for robot

(3) Measurement requirements

- Configuration of robot under test
- Load conditions of robot under test
- Operation mode of robot under test, especially for movable and autonomy feature robot

(4) Immunity requirements

- Configuration of robot under test
- Load conditions of robot under test
- Operation mode of robot under test, especially for movable and autonomy feature robot
- Test Level
- Evaluation of test results

More and more robots are being developed with new names and some new functions. The existing terms and definitions in the ISO standard cannot meet the variations and the combinations of robots. But in fact, not all the changes are related to EMC. The following aspects are the main influencing factors:

- Product parameters: rated voltage, rated current, rated power, max speed, rated load;
- Consideration of the electromagnetic environment where a robot is intended to operate

10 Remaining areas to be studied

Following a review of the content of relevant IEC EMC standards and scope of CISPR subcommittees, it can be concluded that only some types of robots are covered by published CISPR standards. There might some supplements to standards needed to clarify the information which is mentioned in Clause 8. Some areas of concern for some type of robot still exist.

The remaining areas of concern for the robots are robots which CISPR subcommittees cannot cover, such as

- Flying robot
- Underwater robot
- Non-industrial Automatic Guided Vehicle (AGV)
- Personal transport service robots
- Old-age support service robot

Experience with this document will indicate whether there is sufficient need to develop any new limits and test methods for new types of robots. Existing work is concentrated on analyzing the current situation and describing the appropriate compatibility levels. Based on this work it will then be possible to develop new test methods and limits which could be applied.

11 Recommendations/Options

As summary of the above guidance, it can be concluded that parts of the EMC requirements will be well covered after supplementary information is added into some standards. This means, for a robot that clearly falls into a certain sub-committee according to Clause 8, the corresponding chapter supplementary technical requirements should be added to the existing CISPR publications (for example to give the details of the test requirements for the robot products in the next editions of CISPR11, CISPR 14-1, or CISPR 32).

Not all robot products fall within the technical range of existing sub-committees. Hence it might be useful that a relevant working group is set up to carry out standard technical requirements to supplement the technical content of existing publications.