

## RECOMMENDATION ITU-R SM.1056-1\*

**Limitation of radiation from industrial, scientific  
and medical (ISM) equipment**

(Question ITU-R 70/1)

(1994-2007)

**Scope**

This Recommendation provides limits of radiation from various ISM devices and gives advice on how to use the limits in Publication 11 of International Special Committee on Radio Interference (CISPR).

**Keywords**

Limitation, radiations, ISM devices, CISPR

The ITU Radiocommunication Assembly,

*considering*

- a)* that No. **1.15** of the Radio Regulations (RR) defines ISM applications (of radio-frequency energy) as operation of equipment or appliances designed to generate and use locally radio-frequency energy for industrial, scientific, medical, domestic or similar purposes, excluding applications in the field of telecommunications;
- b)* that ISM equipment has the potential to cause harmful interference to radiocommunication services and applications throughout the spectrum;
- c)* that for the optimum use of the frequency spectrum, it is necessary to lay down limits of radiation from ISM equipment outside the bands designated for their use;
- d)* that due to the different operating environments and characteristics of ISM equipment several categories of limits are necessary;
- e)* that radio services operating in the bands designated for use by ISM equipment prior to WARC-79 are required to accept harmful interference and that radiation limits are necessary in all other bands to protect radio services;
- f)* that radiation from ISM equipment may be costly and technically difficult to suppress and thus development of suppression requirements must take into consideration physical, technological, economic, operational and safety aspects of ISM usage to avoid unnecessarily severe measures;
- g)* that equipment meeting the radiation limits, which are compromise values, may in some circumstances cause harmful interference; and, there needs to be provisions for measures to be taken to eliminate or reduce interference in individual cases;
- h)* that the legal and administrative provisions differ in different countries and thus administrations have different methods of applying and enforcing limits;

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\* Radiocommunication Study Group 1 made editorial amendments to this Recommendation in the years 2019 and 2023 in accordance with Resolution ITU-R 1.

j) that the International Electrotechnical Commission/International Special Committee on Radio Interference (IEC/CISPR) has developed limits and taken into account the principles outlined in e) and f) and the requirements to harmonize the procedures for the control of interference in order to eliminate technical barriers to trade;

k) that the interference potential depends on the location of ISM equipment within the user's premises and that the measuring distance and the point of reference for *in situ* measurements have to be taken into account;

l) that severe difficulties could arise if different limits were to be recommended by different international bodies for the same class of equipment,

*noting*

a) that, for ISM applications, the frequencies typically used by ISM equipment and some current and future ISM applications are shown in Annex 1;

b) that, although the ITU has designated specific frequency bands for ISM applications, other operating frequencies are also being used where practical constraints do not permit the usage of the designated bands;

c) that CISPR Publication TR 16-4-4 "Uncertainties, statistics and limit modelling – Statistics of complaints and a model for the calculation of limits for the protection of radio services" provides concepts of the derivation of limits;

d) that multimedia equipment (MME) including information technology equipment (ITE) which use RF energy have not been considered by the CISPR as ISM equipment and CISPR Publication 32, contain a guide for the application of limits and methods of measurements for MME;

e) that RF lighting device operating in the ISM frequency bands 2.45 and 5.8 GHz (and 915 MHz band for Region 2 as defined by the RR) have been considered as ISM equipment in CISPR Publication 11, and other type lighting devices are covered in CISPR Publication 15;

f) that domestic induction cookers have been considered to be ISM equipment, but in accordance with the policy to consolidate emission requirements for household electrical products in CISPR 14-1, the requirements for domestic induction cookers have been transferred from CISPR 11 to CISPR 14-1,

*recognizing*

a) that Resolution **63 (Rev.WRC-03)** resolves that to ensure that radiocommunication services are adequately protected, studies are required on the limits to be imposed on the radiation from ISM equipment within the frequency bands designated in the Radio Regulations for this use and outside of those bands, in close collaboration with CISPR;

b) that Resolution **952 (WRC-03)** resolves to invite CISPR to use the definition of ISM application as show in No. **1.15** of RR, until a new definition is developed in ITU-R in collaboration with CISPR,

*recommends*

**1** that administrations may use the latest edition of CISPR Publication 11, including amendments, as a guide for the application of limits and methods of measurements for ISM devices, in order to protect radiocommunications;

**2** that continued cooperation with the CISPR should be initiated to ensure that radiocommunication needs are fully taken into consideration.

## Annex 1

### Industrial, scientific and medical (ISM) applications

#### 1 Introduction

This Annex includes the ITU definition of ISM applications, a list of frequencies typically used by ISM equipment and describes some current and future ISM applications.

#### 2 ISM applications

According to RR No. **1.15**, ISM application is the operation of equipment or appliances designed to generate and use locally radio-frequency energy for industrial, scientific, medical, domestic or similar purposes, excluding applications in the field of telecommunications.

A partial list of ISM applications and equipment include:

##### *Induction heating equipment (below 1 MHz)*

- domestic induction cookers
- metal melting
- billet heating
- tube welding
- soldering and brazing
- component heating
- spot welding
- selective surface heat treating of metal parts
- semiconductor crystal growing and refining
- seam bonding of autobody surfaces
- package sealing
- heating strip steel for galvanizing, annealing and paint drying

##### *RF dielectric heating equipment (1-100 MHz)*

- veneer and lumber drying
- textile drying
- fibreglass drying
- paper and paper coating drying
- plastic pre-heating
- plastic welding and moulding
- food post baking and drying
- meat and fish thawing
- foundry core drying
- glue drying
- film drying
- adhesive curing
- material preheating

##### *Medical equipment*

- short-wave and microwave diathermy and hyperthermia equipment
- electrical surgical units (ESU)
- magnetic resonance imaging (MRI)
- ultrasonic diagnostic imaging

##### *Microwave equipment (above 900 MHz)*

- domestic and commercial microwave ovens
- food tempering, thawing and cooking
- UV paint and coating curing
- rubber vulcanization
- pharmaceutical processing

##### *Miscellaneous equipment*

- RF excited arc welders
- spark erosion equipment

##### *Laboratory and scientific equipment*

- signal generators
- measuring receivers
- frequency counters
- flow meters
- spectrum analysers
- weighing machines
- chemical analysis machines
- electronic microscopes
- switched mode power supplies (not incorporated in an equipment)

## 2.1 Current applications

The frequencies currently employed for industrial, scientific, medical and other non-communications applications cover a very wide spectrum including frequencies other than those designated by the RR. A number of ISM equipments use frequencies of undefined tolerance and stability and some of them use frequencies allocated to the safety services and radionavigation services. Table 1 provides a summary of some of the ISM applications in various frequency bands.

TABLE 1  
ISM equipment in current use

Frequency (MHz)	Major applications	RF power (typical)	Estimated No. in use
Below 0.15	Industrial induction heating (welding and melting of metals) Ultrasonic cleaning (15-30 kHz) Medical applications (ultrasonic diagnostic imaging)	10 kW-10 MW 20-1 000 W 100-1 000 W	> 100 000 > 100 000 > 10 000
0.15-1	Induction heating (heat treating, package sealing, welding and melting of metals) Ultrasonic medical diagnostics	1 kW-1 MW 100-1 000 W	> 100 000 > 100 000
1-10	Surgical diathermy (1-10 MHz dampened wave oscillator) Wood gluing and wood curing (3.2 and 6.5 MHz) Valve induction generators production of semi-conductor material RF arc stabilized welding (1-10 MHz dampened wave oscillator)	100-1 000 W 10 kW-1.5 MW 1-200 kW 2-10 kW	> 100 000 > 1 000 > 10 000
10-100	Dielectric heating (the majority operate on frequencies in the ISM bands at 13.56, 27.12 and 40.68 MHz, but many also operate on frequencies outside the ISM bands) <ul style="list-style-type: none"> <li>– ceramics</li> <li>– foundry core drying</li> <li>– textile drying</li> <li>– business products (books, paper, gluing and drying)</li> <li>– food (post baking, meat and fish thawing)</li> <li>– solvent drying</li> <li>– wood drying and gluing (veneer and lumber drying)</li> <li>– general dielectric drying</li> <li>– plastic heating (die sealing and plastic embossing)</li> </ul> Medical applications <ul style="list-style-type: none"> <li>– medical diathermy (27 MHz)</li> <li>– magnetic resonance imaging (10-100 MHz in large shielded rooms)</li> </ul>	15-300 kW 15-300 kW 15-200 kW 5-25 kW 10-100 kW  5-400 kW 5-1 000 kW 1-50 kW (most < 5 kW)	< 1 000 < 1 000 > 1 000 > 1 000 < 1 000  > 10 000 > 100 000 > 10 000
100-1 000	Food processing (915 MHz) Medical applications (433 MHz) RF plasma generators Rubber vulcanization (915 MHz)	< 200 kW	< 1 000  < 1 000
Above 1 000	RF plasma generators Domestic microwave ovens (2 450 MHz) Commercial microwave ovens (2 450 MHz) Rubber vulcanization (2 450 MHz) RF excited ultraviolet curing	600-1 500 W 1.5-200 kW 6-100 kW	> 200 million  < 1 000

## 2.2 Future applications

Investigations into new non-communication applications of electromagnetic energy for improving industrial processes are dramatically increasing throughout the world. These investigations are not limited to the ISM bands. Selection of the application frequency for production apparatus is based on many factors, which include, but are not limited to:

- availability of a suitable power source,
- RF interference potential and containment costs,
- safety considerations,
- availability of a suitable ISM frequency, and
- frequency optimization for the particular operation.

A number of new applications promise significant social and economic benefits, which may not be available by any other process and also promise significant savings in energy and the environment.

Areas of recent investigations include:

### 2.2.1 Induction heating

While not a new application, new high-flux induction generators are encouraging a number of applications, such as:

- refining of very pure semi-conductor material,
- melting of metals, particularly vacuum melting for the aerospace and automotive industries.

### 2.2.2 Plasma chemistry

The ISM bands at 27 MHz, 915 MHz and 2450 MHz, as well as other frequencies are being investigated in the following plasma chemistry experiments:

- diamond growing,
- ceramic processing and sintering,
- raw material processing.

### 2.2.3 Medical treatment

Some recent investigations include:

- acceleration of chemical analysis using 2450 MHz,
- local radiation treatment for cancer on frequencies below 400 MHz (hyperthermia),
- tissue fixation,
- magnetic resonance imaging using 10 to 100 MHz in specially shielded rooms,
- treatment of hyperthermia.

### 2.2.4 Material and food processing

- environment space heating using 5800 MHz,
- recovery of oil from shale using frequencies below 10 MHz,
- disposal of hazardous waste using microwave frequencies like 2450 MHz,
- bulk thawing and cooking at 915 MHz, 2450 MHz and 5800 MHz,
- clothes drying at 2450 MHz,
- soil remediation,
- medical waste sterilization,

- pasteurization and sterilization of foods,
- treatment of refuse (13.56 MHz and 2 450 MHz).

### 2.2.5 Power transfer

Most experiments on transfer of energy have occurred at microwave frequencies, e.g., 2 450 MHz, 5 800 MHz and higher.

- Solar power satellite experiments are continuing at 2 450 MHz and 35 GHz;
- transfer of power to an aircraft at 2 450 MHz;
- electrified roadway – a number of energy transfer stations embedded in the roadway to recharge electrically powered vehicles passing overhead (915 MHz and 2 450 MHz);
- electromagnetic (EM) propulsion systems below 1 MHz.

## 3 Radiation levels inside the bands designated for ISM applications

### 3.1 Rationale

There are at least five reasons for setting in-band limits for ISM equipment, which are:

- to control bio-effects;
- to minimize out-of-band emissions for the protection of radio services;
- to minimize in-band emissions for the protection of radio services operating in the ISM bands;
- to minimize radio emissions for the protection of adjacent band radio services;
- to minimize radio emissions to protect electronic or radio services operated in the immediate vicinity of ISM equipment.

The limits and methods of measurement and methods employed for bio-effects compliance are outside the scope of the ITU and the CISPR and therefore bio-effect could not be used for setting in-band limits. However, it has been observed that, in many cases, compliance with the biological effects limits has not substantially reduced radiation levels at CISPR measuring distances.

It should be noted reducing in-band radiation does not necessarily reduce out-of-band radiation, and that the out-of-band radiation can increase through suppression of in-band signals.

In-band limits to protect in-band radio services have not been considered because the services to be protected have not been specified. Furthermore, the setting of restrictive limits will decrease the usefulness of the ISM bands for industrial purposes. The result of this would be to encourage the use of ISM equipment in frequency ranges more suitable to their processes, but detrimental to radio services.

The use of in-band limits to protect radio services adjacent to the ISM bands or to protect electronic or radio equipment in the vicinity of ISM operations is more properly dealt with as an equipment immunity issue. Therefore, this is best resolved by ensuring necessary distance separation or by incorporating adequate immunity characteristics in potential victim equipment. However, the calculation and realization of immunity is practical only if the field strengths to be encountered in practice are known. For this reason, the following table of measured levels of radiation based on measurements in a number of different countries is supplied.

### 3.2 ITU designated ISM bands and measured levels

Some measurements of the radiation levels generated by ISM equipment in the bands designated for their use have been carried out in different countries and at different locations. Table 2 gives a survey of the results.

TABLE 2  
Range of measured levels of field strength from ISM equipment  
in the ITU-designated ISM bands

Frequency band	Centre frequency	No. of appropriate Footnote to the Table of Frequency Allocations of the ITU RR	Range of measured field strengths (dB( $\mu$ V/m)) <sup>(1)</sup>
6.765-6.795 MHz	6.78 MHz	5.138	80-100
13.553-13.567 MHz	13.567 MHz	5.150	80-120
26.957-27.283 MHz	27.12 MHz	5.150	70-120
40.66-40.70 MHz	40.68 MHz	5.150	60-120
433.05-434.79 MHz	433.92 MHz	5.138 (Region 1), 5.280	60-120
902-928 MHz <sup>(2)</sup>	915 MHz	5.150 (Region 2)	60-120
2 400-2 500 MHz	2 450 MHz	5.150	30-120
5.725-5.825 GHz	5.8 GHz	5.150	No information
24.00-24.25 GHz	24.125 GHz	5.150	No information
61.00-61.50 GHz	61.25 GHz	5.138	No information
122-123 GHz	122.5 GHz	5.138	No information
244-246 GHz	245 GHz	5.138	No information

<sup>(1)</sup> The field strength is that existing at a distance of 30 m from the boundary of the building in which the ISM equipment is situated. Therefore the actual distance between the ISM equipment and the measuring point is not known.

<sup>(2)</sup> 896 MHz in the United Kingdom.

## 4 Sources for more information

- Journal and Symposium Reports of the  
International Microwave Power Institute  
13542 Union Village Circle  
Clifton, VA 22024  
United States of America
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