



Report ITU-R SM.2180
(09/2010)

Impact of industrial, scientific and medical (ISM) equipment on radiocommunication services

SM Series
Spectrum management



Documents
Document Sharing Hub

Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

The regulatory and policy functions of the Radiocommunication Sector are performed by World and Regional Radiocommunication Conferences and Radiocommunication Assemblies supported by Study Groups.

Policy on Intellectual Property Right (IPR)

ITU-R policy on IPR is described in the Common Patent Policy for ITU-T/ITU-R/ISO/IEC referenced in Annex 1 of Resolution ITU-R 1. Forms to be used for the submission of patent statements and licensing declarations by patent holders are available from <http://www.itu.int/ITU-R/go/patents/en> where the Guidelines for Implementation of the Common Patent Policy for ITU-T/ITU-R/ISO/IEC and the ITU-R patent information database can also be found.

Series of ITU-R Reports

(Also available online at <http://www.itu.int/publ/R-REP/en>)

Series	Title
BO	Satellite delivery
BR	Recording for production, archival and play-out; film for television
BS	Broadcasting service (sound)
BT	Broadcasting service (television)
F	Fixed service
M	Mobile, radiodetermination, amateur and related satellite services
P	Radiowave propagation
RA	Radio astronomy
RS	Remote sensing systems
S	Fixed-satellite service
SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	Spectrum management

***Note:** This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

Electronic Publication
Geneva, 2011

© ITU 2011

All rights reserved. No part of this publication may be reproduced, by any means whatsoever, without written permission of ITU.

REPORT ITU-R SM.2180

**Impact of industrial, scientific and medical (ISM)
equipment on radiocommunication services**

(2010)

TABLE OF CONTENTS

Page

1	Introduction	2
2	Definition and frequency bands.....	2
3	Applications of ISM equipment	3
4	Characteristics of radiation.....	5
4.1	Induction heating	6
4.2	Dielectric heating.....	7
4.3	Medical applications	8
5	Analysis of potential interference.....	8
5.1	CISPR interference models.....	8
5.1.1	Basic model.....	8
5.1.2	CISPR model for the frequency range below 1 GHz.....	10
5.1.3	CISPR model for the frequency range above 1 GHz	13
5.2	Review of CISPR limits.....	15
5.3	Characteristics and protection criteria of radiocommunication services	18
5.4	Field measurement of radiation	19
5.4.1	Magnetic resonance imaging	20
5.4.2	Induction heating equipment.....	21
5.4.3	Microwave oven.....	21
6	Conclusion.....	22
	References.....	23
	Attachment 1 – Measurement results of MRI.....	24
	Attachment 2 – Measurement results of induction heating equipment.....	30

1 Introduction

The industrial, scientific and medical (ISM) equipment for non-communications applications has been extensively used for various purposes, i.e., drying, melting, heating, welding, thawing, cooking, tempering, soldering, brazing, moulding, imaging, and so on.

Recently, ITU-R developed the Recommendation ITU-R SM.1056 regarding the protection of radio services from the emission radiated by the ISM equipment. The emission limits for ISM equipment recommended by ITU-R has reference to the limits of the International Special Committee on Radio Interference (CISPR) Publication 11. It is known that the limits of CISPR 11 are based on the interference model provided in CISPR 16-4-4.

It is expected that both ISM equipment and radio transceivers are used in close proximity with each other since the number of these RF devices is on the increase. Thus, there is a need to examine impact of the ISM equipment on radio services.

2 Definition and frequency bands

This section is concerned with:

1. the definitions of ISM;
2. the frequency bands;
3. interference from ISM equipment as given in the Radio Regulations (RR).

The following is excerpted from the RR regarding the three items:

1. Definition

“1.15 industrial, scientific and medical (ISM) applications (of radio frequency energy): 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.”

2. Frequency bands

“5.138 The following bands:

6 765-6 795 kHz	(centre frequency 6 780 kHz),
433.05-434.79 MHz	(centre frequency 433.92 MHz) in Region 1 except in the countries mentioned in No. 5.280,
61-61.5 GHz	(centre frequency 61.25 GHz),
122-123 GHz	(centre frequency 122.5 GHz), and
244-246 GHz	(centre frequency 245 GHz).

are designated for industrial, scientific and medical (ISM) applications. The use of these frequency bands for ISM applications shall be subject to special authorization by the administration concerned, in agreement with other administrations whose radiocommunication services might be affected. In applying this provision, administrations shall have due regard to the latest relevant ITU-R Recommendations.

5.280 In Germany, Austria, Bosnia and Herzegovina, Croatia, The Former Yugoslav Republic of Macedonia, Liechtenstein, Montenegro, Portugal, Serbia, Slovenia and Switzerland, the band 433.05-434.79 MHz (centre frequency 433.92 MHz) is designated for industrial, scientific and medical (ISM) applications. Radiocommunication services of these countries operating within this band must accept harmful interference which may be caused by these applications. ISM equipment operating in this band is subject to the provisions of No. **15.13** (WRC-07)”.

“**5.150** The following bands:

13 553-13 567 kHz	(centre frequency 13 560 kHz),
26 957-27 283 kHz	(centre frequency 27 120 kHz),
40.66-40.70 MHz	(centre frequency 40.68 MHz),
902-928 MHz	in Region 2 (centre frequency 915 MHz),
2 400-2 500 MHz	(centre frequency 2 450 MHz),
5 725-5 875 MHz	(centre frequency 5 800 MHz), and
24-24.25 GHz	(centre frequency 24.125 GHz)

are also designated for industrial, scientific and medical (ISM) applications. Radiocommunication services operating within these bands must accept harmful interference which may be caused by these applications. ISM equipment operating in these bands is subject to the provisions of No. **15.13**.”

3. Interference from ISM equipment

“**15.12** § 8 Administrations shall take all practicable and necessary steps to ensure that the operation of electrical apparatus or installations of any kind, including power and telecommunication distribution networks, but excluding equipment used for industrial, scientific and medical applications, does not cause harmful interference to a radiocommunication service and, in particular, to a radionavigation or any other safety service operating in accordance with the provisions of these Regulations¹.

15.13 § 9 Administrations shall take all practicable and necessary steps to ensure that radiation from equipment used for industrial, scientific and medical applications is minimal and that, outside the bands designated for use by this equipment, radiation from such equipment is at a level that does not cause harmful interference to a radiocommunication service and, in particular, to a radionavigation or any other safety service operating in accordance with the provisions of these Regulations¹.”

3 Applications of ISM equipment

In accordance with Recommendation ITU-R SM.1056, examples of ISM applications are as follows:

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 auto body surfaces.
- Package sealing.
- Heating strip steel for galvanizing, annealing and paint drying.

¹ **15.12.1** and **15.13.1** In this matter, administrations should be guided by the latest relevant ITU-R Recommendations.

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).

Table 1 shows various applications of ISM equipment by operating frequency.

TABLE 1
Example applications of ISM equipment

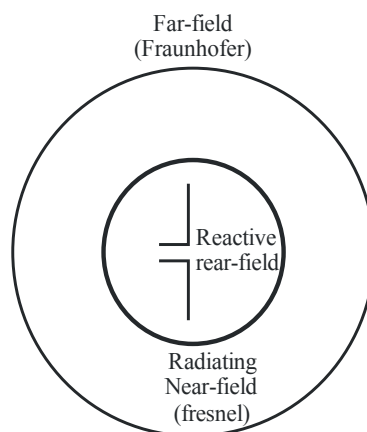
Frequency (MHz)	Applications
Below 0.15	Industrial induction heating (welding and melting of metals) Ultrasonic cleaning (15-30 kHz) Medical applications (ultrasonic diagnostic imaging)
0.15-1	Induction heating (heat treating, package sealing, welding and melting of metals) Ultrasonic medical diagnostics
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)
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): – Ceramics – Foundry core drying – Textile drying – Business products (books, paper, gluing and drying) – Food (post baking, meat and fish thawing) – Solvent drying – Wood drying and gluing (veneer and lumber drying) – General dielectric drying – Plastic heating (die sealing and plastic embossing) Medical applications: – Medical diathermy (27 MHz) – Magnetic resonance imaging (10-100 MHz in large shielded rooms)
100-1 000	Food processing (915 MHz) Medical applications (433 MHz) RF plasma generators Rubber vulcanization (915 MHz)
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

4 Characteristics of radiation

In general, the radiation characteristics of ISM equipment depend on operating frequency, waveform of RF source, structure of radiator, surrounding structure of radiator, etc. Also, the radiation characteristics depend on distance from ISM equipment. Using the conventional antenna theory, the space surrounding a radiator is subdivided into three regions:

- a) reactive near-field;
- b) radiating near-field (Fresnel);
- c) far-field (Fraunhofer) regions as shown in Fig. 1. Therefore, the radiation characteristics impacting on radiocommunication devices may be different according to the distance between radiators and victims.

FIGURE 1
Field regions of an antenna



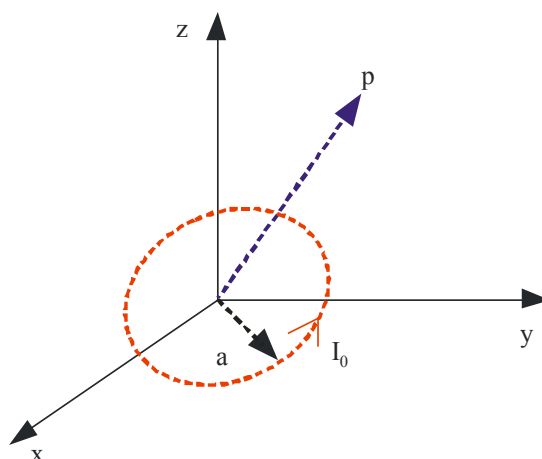
Report SM.2180-01

4.1 Induction heating

Induction heating is a process which is used to bond, harden, or soften metals or other conductive materials with the application of the transformer theory. When an alternating electrical current is applied to the primary of a transformer, an alternating magnetic field is created. According to Faraday's Law, if the secondary of the transformer is located within the magnetic field, an electric current will be induced, which is called an eddy current. In basic induction heating equipment, the coil serves as the transformer primary and the target conductor to be heated becomes a short circuit secondary.

Since the shape of the induction heating coil is similar to a circular loop antenna, the radiation characteristics of induction heating coil are also similar to those of a circular loop antenna. Especially, since the operating frequency for induction heating is lower than 1 MHz, the wavelength is greater than 300 m, which is very large compared with the radius of induction heating coil. Therefore, the induction heating coil can be considered as a small circular loop antenna.

FIGURE 2
Geometry for circular loop antenna



Report SM.2180-02

When a radiocommunication system locates near the induction heating coil ($kr \ll 1$), the predominant electromagnetic fields to influence the device can be approximated as:

$$H_r = \frac{a^2 I_0 \cos \theta}{2r^3} e^{-jkr} \quad (1)$$

$$H_\theta = \frac{a^2 I_0 \sin \theta}{4r^3} e^{-jkr} \quad (2)$$

$$E_\phi = -j \frac{ka^2 I_0 \sin \theta}{4r^2} e^{-jkr} \quad (3)$$

$$E_\phi = E_r = E_\theta = 0 \quad (4)$$

where a is the radius of induction heating coil, k is the wave number, and r is the measurement distance.

The two magnetic fields are in time-phase. However, they are in time quadrature with that of the electric field. Therefore, there is no time-average power flow associated with them. Also, as $r \rightarrow 0$ the strength of the magnetic field is extremely more dominant than that of the electric field. Therefore, equations (1)-(4) are referred to the quasi-stationary magnetic fields.

When measurement position is away from the induction heating system ($kr \gg 1$), the predominant electromagnetic fields can be approximated as:

$$H_\theta = - \frac{(ka)^2 I_0 \sin \theta}{4r} e^{-jkr} \quad (5)$$

$$E_\phi = \eta \frac{(ka)^2 I_0 \sin \theta}{4r} e^{-jkr} \quad (6)$$

$$E_r = H_\phi = E_r = E_\theta = 0 \quad (7)$$

The electric and magnetic fields are in time-phase and inversely proportional to r . The electric and magnetic fields of the small loop in the far-field region are perpendicular to each other and transverse to the direction of propagation. They form a uniform spherical plane wave whose wave impedance is equal to the intrinsic impedance of the medium.

4.2 Dielectric heating

Dielectric heating equipment is to heat targeted dielectric material such as food, textile, lumber, etc. This is accomplished by using microwave radiation to heat polarized molecules within dielectric materials. Dielectric heating equipment consists of a RF power generator such as magnetron, a cavity or chamber, a waveguide, and a RF power controller. In general, the cavity is composed of metal plates and the microwaves produced by magnetron are reflected within the metal wall of the cavity where they are absorbed by dielectrics.

If the dielectric heating equipment is totally enclosed in a metal structure, no radiation is supposed to be emitted from the equipment. Since dielectric materials are placed through a door in the cavity, microwave leakage occurs through the small gap caused by the opening and closing of the door, which serves as aperture antennas. Thus, the radiation characteristics of dielectric heating equipment are similar to those of aperture antennas.

For example, wavelength of microwaves for dielectric heating equipment is around 10 cm~30 m. Domestic microwave ovens use 2.45 GHz and its wavelength is about 12.2 cm. Since this wavelength is not greater than the dimension of the equipment, the aperture size or length becomes comparable to wavelength. The radiation emitted from the dielectric heating equipment may act as the radiation from a phased array antenna.

4.3 Medical applications

Magnetic resonance imaging (MRI), or nuclear magnetic resonance imaging (NMRI), is primarily a medical imaging technique most commonly used in radiology to visualize the internal structure and function of the body. Unlike computed tomography (CT), it uses no ionizing radiation, but uses a powerful magnetic field to align the nuclear magnetization of (usually) hydrogen atoms in water in the body. Radio frequency (RF) fields are used to systematically alter the alignment of this magnetization, causing the hydrogen nuclei to produce a rotating magnetic field detectable by the scanner. Usually, MRI system is installed in a large shielding room to protect outer electromagnetic fields and also emission of RF field outside.

Since the RF coil in MRI forms a curved rectangular loop, the radiation characteristics are similar to a loop antenna. Wavelength of RF signal for MRI is around 3 m~30 m and comparable to the size of RF coil. Therefore, the radiation characteristics are similar to those of a general loop antenna.

The shielding room where MRI locates can be considered as a cavity with small gaps and cables for communication and power supply. The RF coil in MRI becomes a source to excite the cavity and the radiation outside the shielding room occurs through the small gaps and cables. Therefore, the radiation characteristics of MRI are similar to an aperture antenna and a wire antenna.

5 Analysis of potential interference

This section covers:

1. CISPR interference models;
2. CISPR 11 limits;
3. results from some field measurement of radiation.

5.1 CISPR interference models

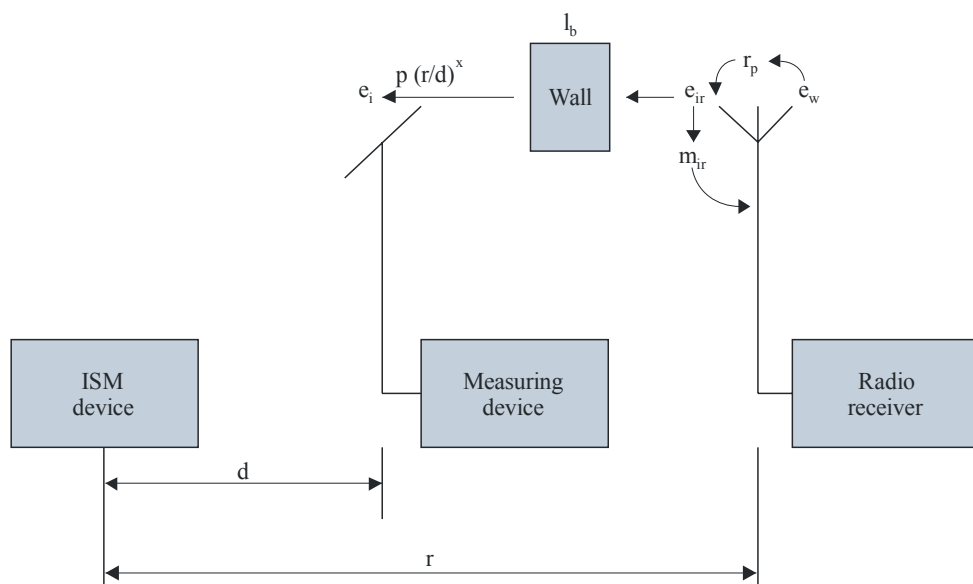
This section outlines the probabilistic interference model developed by CISPR in order to protect radiocommunication receivers in close proximity to ISM devices. CISPR 16-4-4 provides two models for 1 GHz below or above to determine the limits of radiations emitted by ISM devices by using probability theory. These CISPR models are useful tools for evaluating the impact of ISM devices on the radio services.

5.1.1 Basic model

The CISPR models are based on the statistical approach. Figure 3 illustrates the basic CISPR model to determine radiation limits for ISM devices. In Fig. 3, e_w is the wanted signal field strength to be protected at a distance of r m in the position of the victim receiver antenna; e_{ir} is the permissible interference field strength in the position of the victim receiver antenna and it is computed by $e_{ir} = e_w / r_p$, here r_p is protection ratio; m_{ir} is the factor for polarization match between polarization of

e_{ir} and polarization of the victim receiver antenna; l_b is the screening factor of buildings or other obstacles; d is the distance between the measuring device and the ISM device; x is the wave propagation coefficient.

FIGURE 3
Block of CISPR model for the calculation of limit of ISM device



Report SM.2180-03

Using these parameters, regulated disturbance field strength for the sources of disturbance at a distance of d , denoted by e_i , is computed as:

$$e_i = p [(e_w/r_p) m_{ir} l_b (r/d)^x] \quad (8)$$

where:

p is the complex statistical probability factor, which is computed by the product of $p_1 \cdot p_2 \cdot p_3 \cdot p_4 \cdot p_5 \cdot p_6 \cdot p_7 \cdot p_8 \cdot p_9 \cdot p_{10}$ as follows:

- p_1 : the probability that the major lobe of the radiation is in the direction of the victim receiver;
- p_2 : the probability of directional receiving aerials having maximum pick-up in the direction of the disturbing source;
- p_3 : the probability that the victim receiver is stationary;
- p_4 : the probability of equipment generating a disturbing signal on a critical frequency;
- p_5 : the probability that the relevant harmonic is below a limit value;
- p_6 : the probability that the type of disturbing signal being generated will produce a significant effect in the receiving system;
- p_7 : the probability of coincident operation of the disturbing source and the receiving system;