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| **Recommendation ITU-R SM.2028-0**  **(09/2012)** |
| **Protection distance calculation between inductive systems and radiocommunication services using frequencies below 30 MHz** |
| **SM Series**  **Spectrum management** |

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.

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| ***Note***: *This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.* |

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RECOMMENDATION ITU-R SM.2028-0[[1]](#footnote-1)\*

Protection distance calculation between inductive systems and radiocommunication services using frequencies below 30 MHz

(2012)

Scope

This Recommendation addresses the compatibility between inductive systems operating at frequencies below 30 MHz and the existing radiocommunication services and provides a summary of a straightforward procedure to calculate the protection distance to protect radiocommunication services with regard to interference by inductive systems.

Keywords

Protection distance calculation, compatibility, inductive systems

The ITU Radiocommunication Assembly,

considering

*a)* that there is an increasing demand for the usage of inductive systems including induction cooking appliances which are operating at the frequency bands below 30 MHz;

*b)* that there is interference potential of inductive systems to the existing radiocommunication services;

*c)* that the protection distance of radiocommunication services should be established to assess the impact of interference from inductive systems,

noting

*a)* that Recommendation ITU-R SM.1056 considers the latest edition of CISPR Publication 11[[2]](#footnote-2)\*\*, as a guide for the application of limits and methods of measurements for ISM devices in order to protect radiocommunications;

*b)* that Report ITU-R SM.2180 – Impact of industrial, scientific and medical (ISM) equipment on radiocommunication services, introduces applications of ISM equipment, characteristics of radiation and analysis of potential interference to emphasize on the protection of radiocommunication services from ISM equipment,

recommends

**1** that administrations take all necessary precautions to ensure that inductive systems operating on frequency bands below 30 MHz should not cause interference to radiocommunication services;

**2** that in establishing protection method of radiocommunication services, administrations should take into account a calculation procedure of protection distance between inductive system and radiocommunication services, as given in Annex 1.

Annex 1  
  
A method of protection distance calculation

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# 1 Interference scenario model

In general, the effective radiated power level of inductive systems can be calculated from magnetic dipole moment. The magnetic dipole moment which is the product of the total current in the inductive loop multiplied by the surface area can be determined from the measured magnetic field strength at a certain distance by using Maxwell equations. The radiated power level can be applied to existing service as an interferer. The electric field strength of interference from inductive system should be less than the interference limit of electric field strength of victim service. Thereby it is required that the protection distance be defined to protect the existing service. The practical interference scenario is shown in Fig. 1.

Figure 1

Interference scenario model



# 2 Calculation procedure of radiated power of an inductive system

The magnetic field strength *Hm* (A/m)[[3]](#footnote-3) of an inductive system is measured by measurement equipment at a certain distance *d* (metres) and it has two radiation directions as coaxial direction and coplanar direction. The coaxial direction is on the axis of the inductive loop and the coplanar direction is in the plane of the loop. In addition, the radiation direction is determined by the cross-over point of the coaxial curve and the coplanar curve. The cross-over point is positioned at 2.354 × λ*r* (metres) from the magnetic dipole. Here, λ*r* means the radian wavelength which is equal to λ/2π and λ is the wavelength. When the magnetic field strength is measured at a shorter distance than the cross-over point, the magnetic dipole moment *m*1 (Am2) in the coaxial direction can be calculated:

 (1)

When the magnetic field strength is measured at a longer distance than the cross-over point, the magnetic dipole moment *m*2 (Am2) in the coplanar direction can be computed by:

 (2)

The effective radiated power (ERP) (kW) level of an inductive system can be derived:

 (3)

Here, *m* is the maximum of *m*1 and *m*2.

# 3 Calculation of electric field strength limit of a victim service

There are two ways to determine the electric field strength limit of a victim service *Elimit* (dB(μV/m)). One is to consider the noise level and another is to consider the signal-to-noise ratio (*SNR*). The method considering noise level is as follows.

*Enoise* (dB(μV/m)) of a victim service is corrected for the bandwidth of the victim receiver:

 (4)

Here, *bnoise* is the measuring bandwidth of noise, *bvictim* is the bandwidth of victim and *Enoise,b* is electric field strength of noise from Recommendation ITU-R P.372.

In case of broadband interference, the bandwidth ratio (*BWR*) (dB) should be included to calculate the electric field strength limit:

 (5)

The bandwidth ratio is defined:

 (6)

Here, *bmeasuring* is the measuring bandwidth of interferer.

When the bandwidth of the interfering signal is not wider than the victim receiver bandwidth, *BWR* = 0 dB should be assumed.

The method considering *SNR* is as follows.

In the case where the minimum field strength *Emin* (dB(μV/m)) and the *SNR* (dB) are known, the electric field strength limit is calculated:

 (7)

From the electric field strength limit, the magnetic field strength limit *Hlimit* (A/m) can be obtained:

 (8)

# 4 Protection distance calculation for propagation model

The complete coverage range can be divided into four sub-ranges. Usually, the propagation models are described as ground wave model and free space model.

At distances less than a roll-off of 40 dB/decade, *r* > *dtr* and *r* > λ*r* × 2.354, the protection distance (metres) can be calculated:

 (9)

where *dtr* (metres) is the transition distance at the point of intersection between a roll-off of 40 dB/decade and a roll-off of 20 dB/decade.

*Eint* (dB(μV/m)) is interference level at a distance of 1 km and can be calculated:

 (10)

where *Easymptote,*40 (dB(μV/m)) is determined by 40 dB/decade asymptote at 1 km distance for a radiated power of 1 kW as in Recommendation ITU-R P.368 and *ERPdB* (dB(kW)) is obtained by 10log(*ERP*).

At distances of a roll-off of 20 dB/decade, *r* > λ*r* × 2.354, the protection distance is calculated by using the following formula:

 (11)

When the ranges are close to the near field, *r* > λ*r*, the protection distance is determined:

 (12)

When the ranges are within the near field, *r* > λ*r*, the protection distance can be calculated by the following equation:

 (13)

# 5 Flow chart for protection distance calculation

A simple procedure of protection distance calculation is explained in terms of a flow chart:



Table 1 describes the *Easymptote,*40 presented in Recommendation ITU-R P.368.

TABLE 1

Data presented in Recommendation ITU-R P.368

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table of field strength of the 40 dB/dec. roll-off asymptote at the distance of 1 km by an effective radiated power of 1 kW (symbolic value for long path calculation), derived from Recommendation ITU-R P.368 (dB(μV/m)): *Easymptote,*40 | | | | | | | | | | | | |
| Ground type | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| σ | | 1 | 5 | 3e–3 | 30e–3 | 10e–3 | 3e–3 | 1e–3 | 3e–4 | 1e–4 | 30e–6 | 10e–6 |
| ε | | 80 | 70 | 80 | 40 | 30 | 22 | 15 | 7 | 3 | 3 | 3 |
| 10 | kHz | 166 | 166 | 165 | 167 | 165 | 165 | 165 | 164 | 163 | 159 | 151 |
| 15 |  | 164 | 165 | 164 | 165 | 163 | 164 | 164 | 163 | 160 | 154 | 144 |
| 20 |  | 163 | 164 | 163 | 164 | 163 | 163 | 163 | 162 | 157 | 149 | 139 |
| 30 |  | 162 | 163 | 162 | 163 | 162 | 163 | 161 | 158 | 152 | 142 | 132 |
| 40 |  | 162 | 162 | 161 | 162 | 161 | 162 | 160 | 155 | 148 | 137 | 128 |
| 50 |  | 161 | 161 | 159 | 162 | 161 | 161 | 158 | 152 | 144 | 133 | 124 |
| 75 |  | 160 | 160 | 157 | 161 | 159 | 158 | 154 | 146 | 137 | 126 | 119 |
| 100 |  | 159 | 159 | 155 | 160 | 158 | 156 | 150 | 142 | 132 | 121 | 116 |
| 150 |  | 158 | 158 | 151 | 158 | 156 | 153 | 144 | 134 | 124 | 115 | 112 |
| 200 |  | 158 | 158 | 147 | 157 | 154 | 148 | 140 | 129 | 119 | 111 | 109 |
| 300 |  | 157 | 157 | 141 | 155 | 150 | 142 | 132 | 122 | 112 | 107 | 106 |
| 400 |  | 156 | 156 | 136 | 153 | 147 | 135 | 127 | 117 | 107 | 104 | 103 |
| 500 |  | 156 | 155 | 132 | 150 | 143 | 134 | 123 | 113 | 103 | 102 | 102 |
| 750 |  | 154 | 154 | 126 | 146 | 137 | 127 | 117 | 107 | 98 | 98 | 98 |
| 1.0 | MHz | 152 | 153 | 122 | 142 | 132 | 120 | 112 | 103 | 96 | 96 | 96 |
| 1.5 |  | 151 | 153 | 118 | 135 | 124 | 114 | 107 | 98 | 92 | 92 | 92 |
| 2.0 |  | 150 | 152 | 115 | 129 | 119 | 109 | 103 | 95 | 89 | 89 | 89 |
| 3.0 |  | 147 | 151 | 111 | 123 | 112 | 103 | 98 | 93 | 86 | 86 | 86 |
| 4.0 |  | 144 | 149 | 108 | 117 | 107 | 99 | 95 | 90 | 83 | 84 | 83 |
| 5.0 |  | 142 | 148 | 107 | 113 | 103 | 97 | 93 | 87 | 81 | 82 | 82 |
| 7.5 |  | 136 | 146 | 103 | 105 | 97 | 93 | 89 | 84 | 78 | 78 | 78 |
| 10 |  | 132 | 143 | 101 | 100 | 94 | 90 | 87 | 81 | 76 | 76 | 76 |
| 15 |  | 126 | 138 | 97 | 95 | 89 | 87 | 83 | 77 | 72 | 72 | 72 |
| 20 |  | 120 | 134 | 95 | 91 | 87 | 84 | 81 | 75 | 70 | 70 | 70 |
| 30 |  | 113 | 127 | 91 | 87 | 83 | 80 | 77 | 72 | 66 | 66 | 66 |

Here, σ and ε are conductivity and permittivity, respectively.

# 6 Example

This section shows an example of the protection distance between induction cooking appliances (interferer) and AM broadcasting receivers (victim) at 30 MHz using the presented calculation method.

CISPR Publication 14-1[[4]](#footnote-4) contains the limit of radiation generated by induction cooking appliances and the radiated H-field limits of CISPR Publication 14-1 in Table 2 and Fig. 2 are used for the interference level of induction cooking appliances. The external radio noise is used as the protection criteria of AM receiver in this example. Note that the protection criteria may be changed depending on a variety of victim receiver performance criteria.

TABLE 2

Limits of the magnetic field strength

|  |  |
| --- | --- |
| Frequency range (MHz) | Limits at 3 m distance quasi-peak (dB(μA/m)) |
| 0.009 ~ 0.07 | 69 |
| 0.07 ~ 0.1485 | 69 decreasing linearly with logarithm of frequency to 39 |
| 0.1485 ~ 4 | 39 decreasing linearly with logarithm of frequency to 3 |
| 4 ~ 30 | 3 |
| The limits of this apply to induction cooking appliances intended for commercial use and those for domestic use with a diagonal diameter of more than 1.6 m.  The measurements are performed at 3 m distance with a 0.6 m loop antenna as described in § 4.2.1 of CISPR 16‑1-4.  The antenna shall be vertically installed, with the lower edge of the loop at 1 m height above the floor. | |

Figure 2

Limit of the magnetic field strength



The interference level of 18 dB(μA/m) for induction cooking appliance is determined according to frequency of AM broadcasting (1 MHz) in Fig. 2. In this case, the limit of magnetic field strength of 18 dB(μA/m) can be assumed to be measured at the distance of 3 m.

In CISPR Publication 14-1 for induction cooking appliances, the measuring bandwidth is 9 kHz for frequency range from 150 kHz to 30 MHz and the measuring distance is 3 m. Therefore, it is defined that *bmeasuring* is 9 kHz and *d* is 3 m. *Easymptote,40* of 120 dB(μV/m) is obtained from 1 MHz frequency and ground type 6 in Table 1.

The noise level approach is used to get *Elimit*. The *Enoise,b* of 9 dB(μV/m) and the *bnoise* of 2.7 kHz are given in Recommendation ITU-R P.372. The *bvictim* of 4.4 kHz is used for AM broadcasting. The *Enoise* of 11.12 dB(μV/m) and *BWR* of 3.11 dB are calculated by using equations (4) and (6), respectively. Then *Elimit*, maximum allowable interference level, is obtained as 14.23 dB(μV/m) by using equation (5).

When the electric field strength at 1 km distance from ERP of 1 kW is given as 109.5 dB(μV/m) for the roll-off of 20 dB/decade in Recommendation ITU-R P.368 and *Easymptote*,*40* is 120 dB(μV/m), the *dtr*of 3 349.65 m is computed by 1000 ×10–(109.5 – 120)/20. Finally, the protection distance (*r*) is obtained by computing the effective radiated power (*ERPdB*) and the magnetic dipole moment (*m*) as in § 4.

TABLE 3

Calculation of protection distance

|  |  |
| --- | --- |
| Input data | |
| Frequency | 1 000 kHz |
| Magnetic field strength (*Hm*) | 18 dB(μA/m) |
| Measuring distance (*d*) | 3 m |
| *Easymptote,*40 from Rec. ITU-R P.368 (see equation (10)) | 120 dB(μV/m) |
| Electric field noise level from Rec. ITU-R P.372 (*Enoise, b*) | 9 dB(μV/m) in 2.7 kHz |
| Bandwidth of the victim receiver (*bvictim*) | 4.4 kHz |
| Measuring bandwidth (*bmeasuring*) | 9 kHz |
| **Result** | |
| Maximum allowable interference level (*Elimit*) | 14.23 dB(μV/m) |
| Transition distance (*dtr*) | 3 349.65 m |
| Bandwidth ratio (*BWR*) | 3.11 dB |
| Maximum direction | Coaxial |
| Magnetic dipole moment (*m*) | 0.001344 Am2 |
| Effective radiated power (*ERPdB*) | –141.58 dB(kW) |
| Protection distance (*r*) | 25 m |

1. \* Radiocommunication Study Group 1 made editorial amendments to this Recommendation in the years 2019 and 2023 in accordance with Resolution ITU-R 1. [↑](#footnote-ref-1)
2. \*\* The emission requirements for domestic induction cookers have been transferred from CISPR Publication 11 to Publication 14-1 with no technical changes. [↑](#footnote-ref-2)
3. The unit of the limits and measurement of the magnetic field strength quoted in dB(μA/m) is equivalent to 20 log H (A/m) + 120. [↑](#footnote-ref-3)
4. The emission requirements for domestic induction cookers have been transferred from CISPR Publication 11 to Publication 14-1 with no technical changes. During the transition period, from November 2011 to June 2015, both standards were in effect on these appliances. [↑](#footnote-ref-4)