

Australian/New Zealand Standard™

Specification for radio disturbance and immunity measuring apparatus and methods

Part 4.4: Uncertainties, statistics and limit modelling—Statistics of complaints and a model for the calculation of limits for the protection of radio services



AS/NZS CISPR 16.4.4:2012

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Specification for radio disturbance and immunity measuring apparatus and methods

Part 4.4: Uncertainties, statistics and limit modelling—Statistics of complaints and a model for the calculation of limits for the protection of radio services

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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee TE-003, Electromagnetic Interference, to supersede AS/NZS CISPR 16.4.4:2004.

The objective of this Standard is to make a recommendation on how to deal with statistics of radio interference complaints. Furthermore, it describes the calculation of limits for disturbance field strength and voltage for the measurement on a test site based on models for the distribution of disturbances by radiated and conducted coupling, respectively.

This Standard is identical with, and has been reproduced from, CISPR 16-4-4, Ed. 2.0 (2007), *Specification for radio disturbance and immunity measuring apparatus and methods—Part 4-4: Uncertainties, statistics and limit modelling—Statistics of complaints and a model for the calculation of limits for the protection of radio services*.

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<i>Reference to International Standard</i>		<i>Australian/New Zealand Standard</i>	
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11	Industrial, scientific and medical (ISM) radio-frequency equipment—Electromagnetic disturbance characteristics—Limits and methods of measurement	11	Industrial, scientific and medical (ISM) radio-frequency equipment—Electromagnetic disturbance characteristics—Limits and methods of measurement
CISPR/TR			
16	Specification for radio disturbance and immunity measuring apparatus and methods	16	Specification for radio disturbance and immunity measuring apparatus and methods
16-4-3	Part 4-3: Uncertainties, statistics and limit modelling—Statistical considerations in the determination of EMC compliance of mass-produced products	16.4.3	Part 4.3: Uncertainties, statistics and limit modelling—Statistical considerations in the determination of EMC compliance of mass-produced products

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AUSTRALIAN/NEW ZEALAND STANDARD

Specification for radio disturbance and immunity measuring apparatus and methods**Part 4.4:**

Uncertainties, statistics and limit modelling—Statistics of complaints and a model for the calculation of limits for the protection of radio services

1 Scope

This part of CISPR 16 contains a recommendation on how to deal with statistics of radio interference complaints. Furthermore it describes the calculation of limits for disturbance field strength and voltage for the measurement on a test site based on models for the distribution of disturbances by radiated and conducted coupling, respectively.

2 Normative references

The following referenced documents are indispensable for the application 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 60050(161), *International Electrotechnical Vocabulary – Chapter 161: Electromagnetic compatibility*

CISPR 11, *Industrial, scientific and medical (ISM) radio-frequency equipment – Electromagnetic disturbance characteristics – Limits and methods of measurement*

CISPR 16-4-3, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 4-3: Uncertainties, statistics and limit modelling – Statistical considerations in the determination of EMC compliance of mass-produced products*

3 Terms and definitions

For the purposes of this document, the terms and definitions in IEC 60050(161) as well as the following apply.

**3.1
complaint**

a request for assistance made to the RFI investigation service by the user of a radio receiving equipment who complains that reception is degraded by radio frequency interference (RFI)

**3.2
RFI investigation service**

institution having the task of investigating reported cases of radio frequency interference and which operates at the national basis

NOTE Examples include a radio service provider, a CATV network provider, an administration, or a regulatory authority.

**3.3
source**

any type of electric or electronic equipment, system, or (part of) installation emanating disturbances in the radio frequency (RF) range which can cause radio frequency interference to a certain kind of radio receiving equipment

4 Statistics of complaints and sources of interference

4.1 Introduction and history

The previous edition of CISPR 16-4-4 contained, in its Clause 4, a complete reprint of CISPR Recommendation 2/3 on statistics of complaints and sources of interference. However, due to modern technological evolution in radio systems directed towards introduction of digital radio services, and due to increasing use of mobile and portable radio appliances by the public, the traditional CISPR statistics of complaints on radio frequency interference are experiencing a decreasing significance as an indicator of the quality of standardisation work for the protection of radio services and applications. That is why related information in this edition of CISPR 16-4-4 is reduced to the necessary minimum allowing interested parties to continue their complaint-based collation of data on an annual basis.

In order to accommodate the evolution in modern radio technology and mobile and portable use of radio receiving equipment, it may be necessary to replace or to gather the complaints-based CISPR statistics by other more modern statistics or means. These new statistics should be based on a systematic annual collation of data about degradation of quality of radio services and reception due to electromagnetic disturbances occurring in the environment. These data will have to be collected and processed, however, primarily by the radio service providers themselves.

4.2 Relationship between radio frequency interference and complaints

Whatever the radio system involved, official complaints usually represent only a small subset of all occurring interference situations. Occasional interference generally does not lead to an official complaint if its duration is brief or if it happens only once in a while. It is only when the same interference situation occurs repetitively that an official complaint is reported. This situation also greatly depends on the conditions of use (fixed or mobile) of the victim radio system.

4.2.1 Radio frequency interference to a fixed radio receiver

Before the wide development of portable radio devices, radio systems that suffered from interference were generally used in fixed locations. This is the case, for example for a TV set in a flat or home: if this TV set is regularly interfered with by radiation or conduction from other equipment located inside or just outside the house, then it is probable that a complaint will be issued. The same applies if a satellite antenna, a fixed radio link, or a cellular phone base station suffers from radio frequency interference.

4.2.2 Radio frequency interference to a mobile radio receiver

The multiplication of portable radio systems such as cellular phones and short range radio systems has changed the conditions regarding interference situations and interference complaints. The ability for the user to move makes it easier to resolve a particular interference case, but makes it more difficult to recognise that an interference case has actually occurred.

4.2.3 Consequences of the move from analogue to digital radio systems

In addition to the conditions of use of the victim radio system, technological evolution in radio services with successive phasing out of analogue and exponential growth of digital applications also has consequences on the number of reported interference cases.

If a digital mobile phone or a wireless LAN receiver cannot receive the signal from the nearest base station or access point because of an unwanted emission from a nearby equipment, the user will never suspect this equipment and will not even consider the possibility of an interference occurring. He will assume that the coverage of the network is poor and will move to another place to make his call or to get his connection. Furthermore, as these systems are generally frequency agile, if one channel is interfered with, the system will choose another channel, but if all other channels are occupied, then the phone will indicate that the network is congested.

busy, and once again, the user will think the network capacity is not large enough to accommodate his call, but he will never suspect an EMC problem.

Generally for analogue systems, one can hear the interference. With digital and mobile systems, interference is much less noticeable (muting in audio reception, or frozen images on the TV set for DVB). In addition, modern digital modulations implement complex escape mechanisms (data error correction, frequency agile systems, etc.) so that the system can already be permanently affected from an EMC point of view before an interference case is actually detected.

4.3 Towards the loss of a precious indicator: interference complaints

The evolutions detailed above – generalisation of mobile use of radio receivers and the move from analogue to digital radio services – will not reduce the number of interference situations, but continues to decrease the probability of getting significant numbers of interference complaints indicating an existing EMC problem. So, along with the growing development of portable digital radio devices, the usefulness of traditional interference complaints statistics to support the CISPR work will continue to diminish in importance.

4.4 CISPR recommendations for collation of statistical data on interference complaints and classification of interference sources

Considering

- a) that RFI investigation services may wish to continue publication of statistics on interference complaints;
- b) that it would be useful to be able to compare the figures for certain categories of sources;
- c) that varied and ambiguous presentation of these statistics often renders this comparison difficult,

CISPR recommends

- (1) that the statistics provided to National Committees should be in such a form that the following information may be readily extracted:
 - (1.1) the number of complaints as a percentage of the total number of sound broadcast receivers or television broadcast receivers or other radio communication receivers in operation in a certain country, or region;
 - (1.2) the relative aggressivity of the various sources of interference in the different frequency bands;
 - (1.3) the comparison of the interference caused by the same source in different frequency bands;
 - (1.4) the effectiveness of limits (CISPR or national) and other counter-measures on items (1.1), (1.2), and (1.3);
 - (1.5) the number of sources of the same type involved in a certain interference case. Interference may be caused by a group of devices, for example, a number of fluorescent lamps on one circuit. In such cases, the number to be entered into the statistics is determined by the RFI investigation service.

NOTE To facilitate comparison of statistics, the method used to determine the number of sources should be stated.

One source may cause many complaints and one complaint may be caused by more than one source. Therefore it is clear that the number of sources and the number of complaints against any classification code may not be related.

For the purpose of these statistics, active generators of electrical energy and apparatus and installations which cause interference by secondary effects (secondary modulation) are included. See also appliances of category B in Table 1;

- (1.6) causes of complaints not related to a source, as e.g. unsatisfactory radio reception due to a lack of immunity of the radio receiving installation or a lack of coverage with wanted radio signals, see also appliances of category K in Table 1;
- (2) that statistics should cover a complete calendar year; they should whenever possible be presented in the following form, see standard forms in Figures 1a to 1d, without necessarily employing more detailed categories than listed in Table 1. It is however not intended to exclude further subdivisions; these may be desirable, but they should fit into the scheme of the standard forms set out below; the code numbers refer to the items listed in Table 1.

4.5 Forms for statistics of interference complaints

1		Radio services with analogue modulation									
1.1		Fixed or stationary radio reception									
Source of interference or other cause of complaint					Number of complaints per radio service from each source						
Classification code			Description		Total number in each identification		Broadcasting ^a			Other services ^b	
							Sound ^c		Television ^c		
							LF/ MF/ HF	II	I		III
A	1	1									
	2	1									
			etc. as indicated in Table 1								
1.1	Fixed or stationary radio reception, analogue modulation		Totals								

a LF = low radio frequency (long waves);
MF = medium radio frequency (medium waves);
HF = high radio frequency (short waves).
These three bands may either be grouped together, as shown, or dealt with separately.

II = Band II (VHF/sound broadcasting);
I = Band I (VHF/television broadcasting);
III = Band III (VHF/television broadcasting);
IV/V = Band IV/V (UHF/television broadcasting).

b The service and band affected should be stated.

c At the time of receipt of complaints of interference, i.e. before they have been investigated fully, it may not be possible to apportion the complaints accurately to the various broadcasting services. If this is so, then the number of complaints should be stated separately for sound broadcasting and television broadcasting.

IEC 1182/07

Figure 1a – Standard form for statistics on interference complaints recommended for radio services with analogue modulation and fixed or stationary radio reception

1		Radio services with analogue modulation							
1.2		Mobile or portable radio reception							
Source of interference or other cause of complaint					Number of complaints per radio service from each source				
Classification code			Description	Total number in each identification	Broadcasting ^a				Other services ^b
					Sound ^c		Television ^c		
					LF/ MF/ HF	II	I	III	IV/V
A	1	1							
	2	1							
		etc. as indicated in Table 1							
1.2	Mobile or portable radio reception, analogue modulation			Totals					
a LF = low radio frequency (long waves); MF = medium radio frequency (medium waves); HF = high radio frequency (short waves). These three bands may either be grouped together, as shown, or dealt with separately. II = Band II (VHF/sound broadcasting); I = Band I (VHF/television broadcasting); III = Band III (VHF/television broadcasting); IV/V = Band IV/V (UHF/television broadcasting). b The service and band affected should be stated. c At the time of receipt of complaints of interference, i.e. before they have been investigated fully, it may not be possible to apportion the complaints accurately to the various broadcasting services. If this is so, then the number of complaints should be stated separately for sound broadcasting and television broadcasting.									

IEC 1183/07

Figure 1b – Standard form for statistics on interference complaints recommended for radio services with analogue modulation and mobile or portable radio reception

2		Radio services with digital modulation									
2.1		Fixed or stationary radio reception									
Source of interference or other cause of complaint					Number of complaints per radio service from each source						
Classification code			Description		Total number in each identification	Broadcasting ^a				Other services ^b	
						Sound ^c		Television ^c			
						LF/ MF/ HF	II	I	III	IV/V	
A	1	1									
	2	1									
		etc. as indicated in Table 1									
2.1	Fixed or stationary radio reception, digital modulation				Totals						

a LF = low radio frequency (long waves);
MF = medium radio frequency (medium waves);
HF = high radio frequency (short waves).
These three bands may either be grouped together, as shown, or dealt with separately.
II = Band II (VHF/sound broadcasting);
I = Band I (VHF/television broadcasting);
III = Band III (VHF/television broadcasting);
IV/V = Band IV/V (UHF/television broadcasting).

b The service and band affected should be stated.

c At the time of receipt of complaints of interference, i.e. before they have been investigated fully, it may not be possible to apportion the complaints accurately to the various broadcasting services. If this is so, then the number of complaints should be stated separately for sound broadcasting and television broadcasting.

IEC 1184/07

Figure 1c – Standard form for statistics on interference complaints recommended for radio services with digital modulation and fixed or stationary radio reception

2			Radio services with digital modulation										
2.2			Mobile or portable radio reception										
Source of interference or other cause of complaint							Number of complaints per radio service from each source						
Classification code			Description			Total number in each identification	Broadcasting ^a					Other services ^b	
							Sound ^c		Television ^c				
							LF/ MF/ HF	II	I	III	IV/V		
A	1	1											
	2	1											
		etc. as indicated in Table 1											
2.2	Mobile or portable radio reception, digital modulation			Totals									
a LF = low radio frequency (long waves); MF = medium radio frequency (medium waves); HF = high radio frequency (short waves). These three bands may either be grouped together, as shown, or dealt with separately. II = Band II (VHF/sound broadcasting); I = Band I (VHF/television broadcasting); III = Band III (VHF/television broadcasting); IV/V = Band IV/V (UHF/television broadcasting). b The service and band affected should be stated. c At the time of receipt of complaints of interference, i.e. before they have been investigated fully, it may not be possible to apportion the complaints accurately to the various broadcasting services. If this is so, then the number of complaints should be stated separately for sound broadcasting and television broadcasting.													

IEC 1185/07

Figure 1d – Standard form for statistics on interference complaints recommended for radio services with digital modulation and mobile or portable radio reception

Figure 1 – Standard forms for statistics on interference complaints

For RFI investigation services which would like to issue reports on statistics of interference complaints it is recommended to use the classification of interference sources set out in Table 1. Use of this classification will facilitate comparison of RFI situations observed in different countries.

Table 1 – Classification of sources of radio frequency interference and other causes of complaint

Classification code	Description of the source
A	Industrial, scientific, and medical (ISM) RF apparatus (CISPR 11)
A.1	Industrial, scientific, and medical (ISM) RF apparatus (group 2) inclusive microwave ovens and RF lighting appliances
A.2	Other industrial or similar apparatus (group 2) as e.g. arc welding equipment or spark generating apparatus (EDM), etc.
A.3	Other industrial or similar apparatus (group 1) as e.g. generators, motors, convertors, semiconductor controlled devices, etc.
B	Electric power supply, distribution and electric traction (CISPR 11, CISPR 18)
B.1	Power supply installations (AC or DC voltages exceeding 100 kV) as e.g. overhead power lines, generating and switching stations, converting stations, etc.
B.2	Power supply installations (AC or DC voltages 1 kV to 100 kV) as e.g. overhead power lines, generating and switching stations, converting stations, etc.
B.3	Low voltage (LV) power supply and distribution (AC or DC voltages up to 1 kV)
B.4	Electric traction as e.g. for railways, tramways, or trolley buses
C	Low power appliances as normally used in households, offices and small workshops (CISPR 14)
C.1	Motors in household appliances e.g. in electric tools, vacuum cleaners, etc.
C.2	Contact devices, thermostats, etc.
C.3	Semiconductor controlled appliances (less than 1 kW load)
D	Gaseous discharge and other lamps and luminaries (CISPR 15)
	Fluorescent lamps and luminaries, neon advertising signs, self-ballasted lamps, etc.
E^a	Radio broadcast receiving installations (CISPR 13, CISPR 25)
E.1	Sound broadcast receivers for fixed or mobile use
E.2	Television broadcast receivers for fixed or mobile use
E.3	Cable television installations (CATV)
F^a	Radio communication systems (ITU Recommendations)
F.1	Radio broadcast or communication transmitters for fixed or mobile use
F.2	Radio communication receivers for fixed or mobile use
G	Ignition systems of internal combustion engines (CISPR 12)
	Cars, motor bikes, boats, trucks, etc. if propelled by electrical means or internal combustion engines or both, exclusive electric traction vehicles
H	Information and communication technology (ICT) appliances (CISPR 22)
H.1	Wire-bound telecommunication terminal equipment (TTE) and telecommunication equipment (TE) in the infrastructure of networks as e.g. in telecommunication centres, wire-bound LAN, etc.
H.2	Data processing equipment (DPE) such as e.g. computers and ancillary equipment
H.3	Radiation from wire-bound telecommunication networks
I	Identified sources other than those specified (IEC 61000-6-3 and IEC 61000-6-4)
K	Other causes of complaint
K.1	Lack of immunity of radio receiving installations or other appliances
K.2	Lack of coverage of wanted radio service (weak or faulty wanted signals)
^a Only those complaints belong to the statistics where a radio broadcast receiving installation (E) or a component of a radio communication system (F) was identified as causing the interference.	

5 A model for the calculation of limits

5.1 Introduction

A harmonized method of calculation is an important precondition for the efficient discussion of CISPR limits by National Committees and the adoption of CISPR publications.

5.1.1 Generation of EM disturbances

CISPR publications are developed for protection of radio communications and often several types of radio networks are to be protected by a single emission limit.

Most electrotechnical equipment has the potential to interfere with radio communications. Coupling from the source of electromagnetic disturbance to the radio communications installation may be by radiation, induction, conduction, or a combination of these mechanisms. Control of the pollution of the radio spectrum is accomplished by limiting at the source the levels of appropriate components of the electromagnetic disturbances (voltage, current, field strength, etc.). The choice of the appropriate component is determined by the mechanism of coupling, the effect of the disturbance on radio communications installations and the means of measurement available.

5.1.2 Immunity from EM disturbances

Most radio receiving equipment has the potential to malfunction as the result of being subjected to EM disturbances.

Protection of equipment is accomplished by hardening the appropriate disturbance entry route except for the antenna input port, for in-band disturbances. The choice is determined by the mechanism of coupling, the effect of the disturbance on the electronic equipment and the means of measurement available.

5.1.3 Planning a radio service

Before planning a radio communication service, it is necessary to decide upon the reliability of obtaining a predetermined quality of reception. This condition can be expressed in terms of the probability of the actual signal-to-interference ratio R at the antenna input port of a receiver being greater than the minimum permissible signal-to-interference ratio R_p needed to get a predetermined quality of reception α . That is:

$$P[R(\mu_R; \sigma_R) \geq R_p] = \alpha$$

where

$P [\]$ is the probability function;

$R(\mu_R; \sigma_R)$ is the actual signal-to-interference ratio as a function of its mean value (μ_R) and standard deviation (σ_R);

R_p is the minimum permissible signal-to-interference ratio (protection ratio);

α is a specified value representing the reliability of communications.

This probability condition is the basis for the method of determining limits.

5.2 Probability of interference

In order to make recommendations to protect adequately the radio communications systems of interest to the ITU, considerable attention is paid within CISPR to the probability of interference occurring. The following is an extract from CCIR Report 829 ¹⁾.

5.2.1 Derivation of probability of interference

The Radio Regulations, Volume 1, Chapter I, Definition 1.166, defines interference as "the effect of unwanted energy due to one or a combination of emissions, radiations, or inductions upon reception in a radio communication system, manifested by any performance degradation, misinterpretation, or loss of information which could be extracted in the absence of such unwanted energy".

5.2.1.1 Probability of instantaneous interference

Let

- A denote "The desired transmitter is transmitting";
- B denote "The wanted signal is satisfactorily received in the absence of unwanted energy";
- C denote "Another equipment is producing unwanted energy";
- D denote "The wanted signal is satisfactorily received in the presence of the unwanted energy".

All of these statements refer to the same small-time period. Then, according to the definitions, interference means "A and B and C and D*", where D* is the negation or opposite of D: Let $P(x)$ denote the "probability of x" and $P(x|y)$ denote the "probability of x, given y". Then, the probability of interference during the small-time period is

$$P(I) = P(A \text{ and } B \text{ and } C \text{ and } D^*) \quad (1)$$

It can be shown that this can be expressed in terms of known or computable quantities:

$$P(I) = [P(B|A) - P(D|A \text{ and } C)] P(A \text{ and } C) \quad (2)$$

It may be preferable to consider the probability of interference only during the time that the wanted transmitter is transmitting. This probability is:

$$P'(I) = P(B \text{ and } C \text{ and } D^* | A) \quad (3)$$

which can be reduced to:

$$P'(I) = [P(B|A) - P(D|A \text{ and } C)] P(C|A) \quad (4)$$

5.2.1.2 Discussion of Equations (2) and (4)

First, consider the difference between Equations (2) and (4). The probability of interference can be interpreted as the fraction of time that interference exists. In Equation (2), this fraction is the number of seconds of interference during a time period divided by the number of seconds the wanted transmitter is transmitting during the time period. This second fraction is larger than the first unless the wanted transmitter is on all the time. $P(B|A)$ is just the probability that a wanted signal will be correctly received when there is no interference, often expressed as the probability that $S/N \geq R$ where S is the signal power, N is the noise power, and R is the signal-to-noise ratio required for satisfactory service. In some services, this probability is called the reliability, and is often computed when the system is designed. It can

¹⁾ The former CCIR Reports 656, 670, and 829 are no longer available.

be computed if system parameters (for example, transmitter and receiver location, power, required S/N) are known using statistical data on transmission loss (for example, Recommendation 370 ²⁾) and statistical data on radio noise (for example, ITU-R Rec. P.372-6 and Report 670 ³⁾).

Many systems, such as satellite or microwave relay point-to-point systems, are designed so that $P(B|A) \approx 1$. In other services, such as long-distance ionospheric point-to-point services, or mobile services near the edge of the coverage area, $P(B|A)$ may be quite small. In this latter case, the probability of interference will not be small regardless of the other probabilities.

$P(D|A \text{ and } C)$ is the probability that the wanted signal will be correctly received even when the unwanted energy is present. It can be computed if there is sufficient information about the location, frequency, power, etc. of the source of unwanted energy. For examples, see the references in Report 656 ³⁾.

Notice that it has been assumed that $P(D|A \text{ and } C) \leq P(B|A)$; that is, if the signal can be received satisfactorily in the presence of unwanted energy, then it can surely be received satisfactorily in the absence of the unwanted energy. Thus $P(I)$ cannot be negative.

$P(A \text{ and } C)$ is the probability that the wanted transmitter and the source of unwanted energy are on simultaneously. In some situations, the wanted transmitter and source of unwanted energy may be operated independently. For example, they may be on adjacent channels, or beyond a coordination distance. In this case, $P(A \text{ and } C) = P(A)P(C)$, where $P(A)$ is the fraction of time that the wanted transmitter is emitting, and $P(C)$ is the fraction of time that the unwanted source is on.

In other situations, the operation may be highly dependent. For example, the transmitters may be co-channel stations in a disciplined mobile service. In this case $P(A \text{ and } C)$ is very small, but perhaps not zero, because a station can be located so that it causes interference even when it cannot hear the other transmitter.

The two transmitters might both operate continuously. For example, one might be part of a microwave point-to-point service, and the other a satellite sharing the same frequency band. In this case, $P(A \text{ and } C) = 1$, and the probability of interference depends entirely on the factor in square brackets in Equation (2).

Similarly, $P(C|A) = P(C)$ if the transmitters operate independently. $P(C|A)$ is very small if the two transmitters are co-channel stations in a disciplined land mobile service; and $P(C|A) = 1$ if the unwanted transmitter is on all the time.

In general, all the terms in Equations (2) and (4) affect the probability of interference, although their relative importance is different in different services.

5.3 Circumstances of interferences

In this part, general criteria are laid down for establishing disturbance limits for the purpose of preventing radio frequency interference (RFI) to happen. In this case, a distinction is made for areas where close coupling exists between noise sources and victim equipment, and for areas with remote coupling.

²⁾ ITU-R Rec. P.370-7, *VHF and UHF propagation curves for the frequency range from 30 to 1000 MHz. Broadcasting Services* was withdrawn in 2001.

³⁾ The former CCIR Reports 656, 670, and 829 are no longer available.

5.3.1 Close coupling and remote coupling

Although an ill-defined borderline exists between areas of close and remote coupling these concepts are generally used in the following terms.

Close coupling refers to a short distance between noise source and receiving antenna (for example, 3 m to 30 m) which is the case for residential sources interfering with broadcasting and land mobile receivers in residential areas. In general, frequencies up to 300 MHz are considered.

Remote coupling refers to longer distances, usually in the range of 30 m to 300 m, which are normal between professional or semi-professional sources and receivers as in the case of individual areas. The relevant frequency spectrum is much broader: 9 kHz to 18 GHz.

For the statements given above, it follows that some similarity exists between close coupling and near-field radiation conditions on the one hand and between remote coupling and far-field radiating conditions on the other hand. However, these concepts do not fully correspond since at frequencies below 1 MHz remote coupling may occur under near-field conditions whereas for frequencies above about 30 MHz close coupling may occur under far-field conditions. In the majority of practical situations, however, the good correspondence between close/remote coupling and near/far-field conditions is useful in evaluation of coupling aspects.

It should be noted that field-strength measurements, which are normally used for evaluating remote coupling characteristics, are actually carried out under near-field conditions in the lower end of the frequency range.

Whereas close and remote coupling are generally used to describe a direct coupling path between noise source and receiving antenna by means of electric, magnetic or radiation fields, an additional coupling mode is conduction coupling. In this case, the noise signal is conducted by the mains network from the mains output of the source to the mains input of the receiver, see also Figure 3, paths a1 and a2. Inside the receiver the noise signal is coupled from the mains port(s) to sensitive circuits of the receiver, as e.g. to its antenna port, or to its IF amplifier circuitry. This must be taken into account when determining the receiver's immunity requirements to injected in-band RF disturbances at its mains port.

Some well-known differences exist between near-field and far-field radiation characteristics, and therefore also for most close and remote coupling cases.

- Under far-field conditions with free-space propagation the relation between electric and magnetic components of the field is fixed and well defined, the relation under near-field conditions is rather undefined, if the source and coupling path characteristics are not known.
- Under far-field conditions the attenuation formula is

$$a = \frac{E_1}{E_2} k \left(\frac{d_2}{d_1} \right)^x, \quad \text{or} \quad a = \frac{H_1}{H_2} k \left(\frac{d_2}{d_1} \right)^x \quad (5)$$

NOTE The attenuation factor a describes the relation of the field strength E_1 (or H_1) found at distance d_1 to the field strength E_2 (or H_2) found at distance d_2 . Factor k may e.g. be interpreted as an additional attenuation factor introduced by a wall allocated between the measurement locations at distances d_1 and d_2 .

where

a = attenuation factor;

E_1, H_1 = absolute value of the field strength observed at a location still in the far field, but close to the source;

- E_2, H_2 = absolute value of the field strength observed at a location in a more remote distance d_2 than d_1 , from the source;
- k = correction factor (in the range 1 to 10) counting e.g. for the screening effectiveness of buildings the noise source is allocated in, or for other absorbing obstacles allocated in between the considered locations at the distances d_1 and d_2 ;
- d_1 = small distance in the far field range, but close to the location of the source;
- d_2 = measurement distance more remote from the source;
- x = propagation coefficient, which is 1 in free-space propagation and somewhat higher (1 to 1,5) for non-free-space propagation.

Under near-field conditions the propagation coefficient x is more complex and dependent on the magnetic or electric component with typical values between 2 and 3.

For this reason, it is much easier to develop a model for remote coupling conditions than for close coupling situations and for conduction coupling paths. Such a model is necessary to derive emission limits for a general interference environment.

5.3.2 Measuring methods

The measuring method is of major importance for specification of a radio frequency disturbance limit. Several measuring methods are applied and a short survey is given in the following paragraphs. In all measurements, the measuring instrument is a selective microvoltmeter (CISPR receiver) as specified for the relevant frequency range.

5.3.2.1 Disturbance voltage/current at mains ports

In the lower frequency range up to about 30 MHz, the mains network may conduct any injected RF energy to nearby users connected to the mains and/or couple part of the RF energy to nearby antennas in the electric, magnetic or radiation mode. Electric or magnetic field coupling to nearby antennas in this frequency range, however, is in most cases of minor importance compared with conduction coupling through the mains network. Because of the RF output voltage conduction mainly coupling through the mains network, the RF output voltage at the mains port is used as a measure for the interfering potential of almost any type of source in this frequency range. This permissible RF output disturbance voltage at the mains port of the source determines the minimum immunity requirements of the victim receiver against injected in-band RF disturbances at the receiver's mains port.

This disturbance voltage at mains ports is measured by means of an artificial mains network which isolates the source from the mains at RF frequency and which furnishes a standardized RF load to the source. For measurement of conducted disturbances, the artificial mains network generally recommended by CISPR is a 50 Ω /50 μ H V-network which introduces a parallel impedance of 50 Ω /50 μ H between each live or neutral wire of the mains port and reference ground.

Although not recommended by CISPR yet, the asymmetric current in the mains cable, measured by means of a current probe, might be used as a measure for the radiation capability of the source as already specified for telecommunication lines.

Current probe measurements of the asymmetric disturbance current in the mains cable require the mains port to be terminated with a suitable artificial mains network. This network should simulate the typical common mode impedance and RF unbalance (e.g. given as longitudinal conversion loss (LCL)) of the mains network and should decouple incoming common mode disturbances from the mains network side.

5.3.2.2 Disturbance voltage at signal ports

Imperfections of the symmetry in circuits carrying wanted symmetrical signals will produce unwanted asymmetric signals at the related ports and cables connected thereto. In asymmetric (coaxial) ports unwanted external currents can be conducted in the outer surface of the screen because of imperfect screening. These asymmetric signals and external screen currents may couple energy by inductive or radiation fields to nearby or remote antennas.

The asymmetric voltages can be measured by means of an artificial loading network. In this case the use of an asymmetric artificial network (AAN) instead of a V-network is preferred.

5.3.2.3 Disturbance power measurements with the absorbing clamp

The asymmetric RF current in a lead or on the outer surface of the screen of a screened cable will radiate energy to nearby or remote antennas depending on frequency, length and configuration of the connected cable. This is particularly important at VHF and UHF in which frequency ranges the external lead of the appliance has a length which is in the order of a half wavelength or longer.

The absorbing clamp is a device which gives measuring results in a good correspondence with the disturbance power that can be radiated from the external lead of the appliance.

Under this condition the disturbance power conducted through the mains lead and measured by the absorbing clamp is a good measure for the disturbance potential. If the dimensions of the source are not small compared with wavelength, a larger part of the disturbance's energy will be radiated directly and the absorbing clamp measurement is less reliable.

Because broadband disturbance is, in general, of less importance at frequencies above 300 MHz the absorbing clamp is recommended for the measurement of small appliances in the frequency range 30 MHz to 300 MHz.

5.3.2.4 Field-strength measurement

The field strength caused by disturbance sources is likely to be the most straightforward criterion for the interference potential of such a source, because it is more directly comparable with the wanted field strength at the antenna of a radio receiver particularly for remote coupling analysis.

A source radiates RF energy from its case or cabinet if a coupling path exists between internal noise source and external case or cabinet and if the dimensions of the case or cabinet are of the order of one wavelength. For practical reasons the electric component of the field is measured in the frequency range above 30 MHz (by means of dipole antennas) and the magnetic component of the field below 30 MHz (by means of loop antennas).

Field-strength measurements have a number of practical drawbacks. The influence of surrounding reflections should be eliminated which is usually met by using an open area test site (OATS). Such a test site introduces inaccuracies by variable reflections from the operator and from the ground (influence of moisture and season) and by interference from ambient transmitter fields. It also increases the work time due to poor weather and other climatic conditions. These drawbacks can be partly eliminated by use of anechoic rooms in the frequency range above 30 MHz.

Another drawback of field-strength measurements is the complex EUT radiation pattern which also depends on the test set-up. It therefore requires measurements in various directions and an accurately specified test set-up.