TR CISPR 18-3

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TECHNICAL REPORT

INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

Radio interference characteristics of overhead power lines and high-voltage equipment – Part 3: Code of practice for minimizing the generation of radio noise

TR CISPR 18-3:2010(E)

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FOREWORD

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The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

CISPR 18-3, which is a technical report, has been prepared by CISPR subcommittee B: Interference relating to industrial, scientific and medical radio-frequency apparatus, to other (heavy) industrial equipment, to overhead power lines, to high voltage equipment and to electric traction.

This second edition cancels and replaces the first edition published in 1986. It is a technical revision.

This edition includes the following significant technical changes with respect to the previous edition: while the first edition of CISPR 18-3 only covered recommendations for minimizing the generation of radio noise emanating from high-voltage (HV) power systems, this second edition now also covers a new clause providing formulae for predetermination of the radio noise field strength levels from HV overhead power lines with large conductor bundles. Furthermore, Annex A was accomplished with a collation of predetermination formulae developed and used by several institutions around the world. The tables also contain typical examples of radio noise field strength levels obtained during some measurements campaigns at several HV overhead power line constructions.

The text of this technical report is based on the following documents:

DTR	Report on voting
CISPR/B/495/DTR	CISPR/B/503/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This technical report has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the CISPR 18 series can be found, under the general title *Radio interference characteristics of overhead power lines and high-voltage equipment*, on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

This technical report forms the third of a three-part publication dealing with radio noise generated by electrical power transmission and distribution facilities (overhead lines and substations). It contains recommendations for minimizing the generation of radio noise emanating from high-voltage (HV) power systems which include, but are not restricted to, HVAC or HVDC overhead power lines, HVAC substations and HVDC converter stations, hardware, etc., in order to promoting protection of radio reception.

The recommendations given in this part 3 of the CISPR 18 series are intended to be a useful aid to engineers involved in design, erection and maintenance of overhead lines and HV stations and also to anyone concerned with checking the radio noise performance of a line to ensure satisfactory protection of radio reception. Information on the physical phenomena involved in the generation of electromagnetic noise fields is found in CISPR/TR 18-1. It also includes the main properties of such fields and their numerical values. CISPR/TR 18-2 contains recommendations for methods of measurement for use on-site or in a laboratory. It furthermore recommends procedures for determination of limits for the radio noise from HV power systems.

This second edition of CISPR 18-3 was adapted to the modern structure and content of technical reports issued by IEC. The first edition of CISPR 18-3 underwent thorough edition and adaptation to modern terminology. Furthermore its content was adjusted such as to allow for use of the lateral distance *y* for the conduction of measurements in the field.

The CISPR 18 series does not deal with biological effects on living matter or any issues related to exposure in electromagnetic fields.

The main content of this technical report is based on CISPR Rec. No. 57 given below:

CISPR RECOMMENDATION No. 57

CODE OF PRACTICE FOR MINIMIZING THE GENERATION OF RADIO NOISE

The CISPR

CONSIDERING

a) that the radiation of electromagnetic energy from overhead power lines causes interference to sound and television broadcasting,
b) that the level of this noise may be reduced by the design and lay-out of a line,
c) that when defects cause unusually high levels of interference there is need to detect and locate these faults,

RECOMMENDS

That the latest edition of CISPR Publication 18-3, including amendments, be used as guide for minimizing the generation of radio noise caused by overhead power lines.

CISPR/TR 18-1 describes the main properties of the physical phenomena involved in the production of disturbing electromagnetic fields by overhead lines and provides numerical values of such fields.

In CISPR/TR 18-2 methods of measurement and procedures for determining limits of such radio interference are recommended.

This CISPR/TR 18-3 forms a "Code of Practice" to reduce to a minimum the production of radio noise by power lines and equipment.

It provides information which is advisable to follow both when designing various fittings and components and when stringing the conductors and installing the hardware of the line.

It also describes methods of detecting and locating defects resulting in unusually high interference levels, and provides prevention and correction procedures that are generally simple to implement.

Lastly, this Part 3 provides formulae for predicting the most probable radio noise field of a line for various weather conditions, insofar as radio noise is caused by conductor corona.

RADIO INTERFERENCE CHARACTERISTICS OF OVERHEAD POWER LINES AND HIGH-VOLTAGE EQUIPMENT –

Part 3: Code of practice for minimizing the generation of radio noise

1 Scope

This part of CISPR 18, which is a technical report, applies to radio noise from overhead power lines and high-voltage equipment which may cause interference to radio reception, excluding the fields from power line carrier signals.

The frequency range covered is 0,15 MHz to 300 MHz.

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 (IEV) – Chapter 161: Electromagnetic compatibility*

CISPR/TR 18-1:2010, *Radio interference characteristics of overhead power lines and high-voltage equipment – Part 1: Description of phenomena*

CISPR/TR 18-2:2010, *Radio interference characteristics of overhead power lines and high-voltage equipment – Part 2: Methods of measurement and procedure for determining limits*

ISO/IEC Guide 99, *International vocabulary of metrology – Basic and general concepts and associated terms (VIM)*

NOTE Informative references are listed in the Bibliography.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in the IEC 60050-161 and the ISO/IEC Guide 99 apply.

4 Practical design of overhead power lines and associated equipment in order to control interference to radio broadcast sound and television reception

4.1 Overview

This clause provides guidance on the techniques that may be applied during the design, construction and operation of high voltage overhead power lines and associated equipment in order to keep the various types of radio noise described in this publication within acceptable levels.

4.2 Corona on conductors

During line design, consideration should be given to the geometric parameters of the line, in order to ensure that radio noise due to conductor corona will not exceed a specified acceptable level. The most important parameters are conductor diameter and number of conductors per phase. Others that could be varied, such as distance between phases, height of conductors above ground or spacing of sub-conductors in the bundle, have a smaller effect. In practice they are usually determined by mechanical or insulation requirements.

The quantitative laws that determine the level of radio noise caused by conductor corona are discussed in 4.3 of CISPR/TR 18-1, and in Clause 7 below. These laws normally apply to both stranded and smooth conductors, since the surface unevenness caused by stranding does not, in general, substantially change the noise level, especially when conductors are damp or wet. The existence of scratched or broken strands or deposits of extraneous substances such as dirt or insects on the surface, on the other hand, may lead to severe localised corona discharges, due to high local voltage gradients. This may considerably increase the noise level of the line. For these reasons it is necessary to avoid damage to the conductor surface during construction. It should be handled with great care in transportation and erection and suitable techniques should be used to avoid contact of the conductor with the ground or other objects during stringing. It is also advisable to avoid external greasing of the conductor for protection during transportation and tensioning; when the conductor is loaded, the increase in temperature, especially in hot weather, will cause this grease to run to the outside, gathering dirt and leading to areas with high local gradient and consequent radio noise. When the steel core or inside layers are greased for corrosion protection, a type of grease should be selected that will not migrate to the surface of the conductor even at the highest temperature.

4.3 Corona on metal hardware

Radio noise due to corona on metal hardware, such as suspension clamps, dead-end clamps, yokes, guard rings, horns, spacers, etc., can be controlled. Appropriate shapes and dimensions may be specified during the design stage in order to avoid points of high voltage gradient. All edges and corners should be well rounded, bolt heads should be rounded or shielded and sharp points and protrusions should be avoided. It is also important that the protective galvanized finish on hardware be smooth, particularly at points of maximum voltage gradient.

Guard devices are sometimes installed to protect an insulator string from the destructive effects of a power arc and to improve the distribution of the potential along the string. They also contribute to the reduction of the level of radio noise from the conductor clamps, since they screen sharp points or protrusions on the clamps. The type and dimensions of the guard devices should be chosen in such a way that they do not themselves produce radio noise. For example, the use of simple horns should be avoided at voltages exceeding about 150 kV, and the diameter of tubes forming guard rings should be sufficiently large to ensure that no corona occurs during rain.

Present knowledge seems to indicate, however, that it may be relatively difficult to design guard rings suitable for rainy conditions, even if they are made of multiple tubes. In which case, it may be necessary to devise special arrangements for the yoke so that the string is screened directly by the conductor bundle and is protected from power arcs by suitable devices on the sub-conductors of the bundle.

As in the case of conductors, it is important to avoid damage to the hardware during manufacture, transportation, construction and maintenance by handling them with great care at all times.

4.4 Surface discharges on insulators

4.4.1 Clean or slightly polluted insulators

The radio noise produced by these insulators under dry conditions can be controlled by:

– the use of insulators of suitable design, especially as regards their geometry and the characteristics of the material at the more critical areas, or

– the use of guard devices designed to improve the distribution of voltage on the surface of the insulator or along the insulator string.

In insulator design, the use of conducting glaze, for example, improves the distribution of the surface voltage gradient on the insulator. In the design of a guard device, a metal ring as close as possible to the insulator, or to at least the first two or three insulators at the line end of an insulator string, may considerably improve the voltage distribution on the insulator or along the insulator string and reduce radio noise. The ring, however, shall remain compatible with other requirements such as insulation withstand, protection of the insulators from power arcs, screening of the clamps, etc. (see 4.3).

The radio noise produced in damp weather, fog or rain is usually more difficult to control than the noise under dry conditions. It is, however, seldom a critical factor in line design, since the increase in noise due to water droplets on the insulators is usually less important than the corresponding increase in noise produced by the conductors.

4.4.2 Very polluted insulators

Under dry conditions, in addition to the phenomena that cause noise on a clean insulator, other phenomena of the corona type may occur due to surface unevenness created by pollution deposits, as mentioned in 6.1 of CISPR/TR 18-1. Under these conditions even careful design of the various parts of an insulator may be of little benefit. Stress control devices suitable for improving the voltage distribution on the insulator or along the insulator string, however, may considerably improve the radio noise performance.

When the polluted insulator surface is wet, radio noise is generated by sparks across the dry bands, created by the leakage currents, as discussed in 6.1 of CISPR/TR 18-1. Occasionally, this noise has very high frequency components. It may affect both sound and television reception and is difficult to control. The only practical remedy is to limit the leakage current activity on the surface of the polluted insulator. This may be achieved by:

a) diminishing the voltage stress on the insulator – for example by using a longer surface creepage path than is necessary for electrical withstand;

b) using special types of insulators such as those made of organic material or coated with semi-conducting glaze, or designs with a longer creepage path such as fog type units, special shapes, etc.;

c) coating the insulators with silicone grease.

4.5 Spark and microsparks due to bad contacts, commutation effects

Remedial measures for eliminating or reducing these types of radio noise are described in Clause 5 below and in 8.4 of CISPR/TR 18-1 respectively.

4.6 Defects on power lines and associated equipment in service

Even if all possible precautions have been taken during design and construction of a power line or substation to keep radio noise within acceptable limits, defects may occasionally occur during operation, resulting in intolerable noise. This may be caused by breakage of strands on the conductors, damage to clamps or insulators or accumulation of pollution on conductors and insulators. In general, these defects shall be eliminated in order that the power system may operate properly, whether or not they are sources of radio noise. In fact, the occasional noise caused by such defects may result in detection and location of potential power system faults.

These abnormal noise sources may be located by various instruments such as radio noise measuring sets, television receivers or ultrasonic and optical detectors. Location will often be easier when the noise affects television reception, since at very high frequencies longitudinal attenuation along the line is very high. When only low and medium frequency radio broadcasts are affected, location of the noise source may require the recording of the longitudinal attenuation of the radio noise field strength, combined with optical, ultrasonic or ultraviolet devices, as discussed in Clause 5.

5 Methods of prediction of the reference level of an overhead line

5.1 General

This publication has been written to provide the engineer in the field with the theoretical and practical background necessary to deal with radio interference problems. Technical aspects have been dealt with in part 1 and many of the aspects discussed are dealt with in this clause in a simplified manner to bring together the theoretical and practical issues.

The reference level of a line is the strength of the radio noise field at a reference frequency of 500 kHz and at a direct distance of 20 m from the nearest conductor of the line. Where the voltage gradient in the air at the surfaces of the conductors of a normal line is greater than about 12 kV/cm to 14 kV/cm, depending on conductor diameter, the radio noise performance of the line is determined by the performance of the conductors. The number and diameter of the conductors per phase of a proposed line are often decided by the current-carrying capacity required or by economic considerations and usually a prediction of the reference level is required for a particular weather condition. If a line is designed with the conductors at a high surface gradient very little can be done to reduce the noise level once the line has been constructed.

Figure B.14 of Annex B of CISPR/TR 18-1 gives the correction to be applied to a radio noise level relating to a measurement frequency other than 500 kHz.

Where the voltage gradient in the air at the surfaces of the conductors of a line is less than about 12 kV/cm, the radio noise level is usually determined by the insulators and hardware. In this case the radio noise performance of the line is inherently good and it is usually desirable to preserve this good quality by selecting insulators and hardware of a matching quality. Most of the methods of prediction or predetermination are concerned with the conductor noise and do not apply to lines where the conductors are at a low surface gradient. None of the methods applies to sparking sources at loose or imperfect contacts.

5.2 Correlation of data given elsewhere in this publication

This clause contains information about the correlation of the radio noise voltage at the line and the resulting radio noise field strength at ground level at a certain lateral or direct distance slant to the respective line.

a) Methods relating to noise from conductors

   Subclause 5.3 of CISPR/TR 18-1 gives a survey of methods of prediction or predetermination, both analytical or semi-empirical and empirical or comparative. The analytical method relies on the results of measurements carried out on a short length of sample conductor in a test cage and involves highly complex analyses. The sample conductor can be tested with any desired surface condition and the radio noise voltage measured by a circuit given in 4.5 of CISPR/TR 18-2. However, for a.c. lines, a reliable prediction of the reference level due to conductor corona can be calculated only from the wet test since in this case the number of individual corona sources per unit length is sufficiently high to represent a statistically satisfactory sample. For d.c. lines, reference should be made to 8.2 of CISPR/TR 18-1 for the calculation of the noise level.

   The simple comparative formulae referred to in 5.3 of CISPR/TR 18-1 rely on the results of radio noise field strength measurement carried out on an existing line of similar design. These formulae take into account the effects of any difference between the reference and proposed lines such as the differences in surface voltage gradient or conductor diameter. If the design of the reference and the proposed lines are similar and the operating conditions, such as air pollution, etc., are also similar a fairly accurate prediction may be obtained of the reference level to be expected from the proposed line due to conductor corona. The effects of weather may also be determined by taking measurements on the reference line in a variety of weather conditions.

In 5.4 and Annex B of CISPR/TR 18-1 is given a catalogue of radio noise field strength profiles resulting from conductor corona for certain designs of single circuit overhead line. The profiles are correct when the value of the voltage gradient in the air at the surfaces of the conductors of the lines are sufficiently high to produce radio noise and the values of the field strength, at a measurement frequency of 500 kHz, are given for both heavy rain and average fair weather conditions; the heavy rain conditions producing a higher field strength of between 17 dB and 25 dB. The profiles show the attenuation of the field with distance normal to the lines for distances out to 150 m.

b) Method relating to noise from insulators and/or fittings

Subclause 6.2 of CISPR/TR 18-1 gives a correlation between the radio noise voltage generated by a hardware or component of a line, when measured in accordance with the procedure given in 4.5 of CISPR/TR 18-2, and the level of the reference field. This correlation applies where the line has a single noise source, for example a broken insulator, or where multiple sources are uniformly distributed along the line. The method, which includes a semi-empirical formula, is particularly useful where the conductors of a proposed line are to operate at a low surface gradient and a prediction is required of the reference level to be expected from the insulators of the line. When the measurement procedure given in 4.5 of CISPR/TR 18-2 is carried out on insulators they are usually in a clean and dry condition, since this condition is normally specified, but the procedure is not restricted to measurements on clean and dry objects and specially polluted sample insulators could be tested when damp and when dry and the results inserted into the formula to predict the reference level of a proposed line.

c) Methods relating to aggregate noise from the conductors, insulators and/or hardware.

Subclause 5.2 of CISPR/TR 18-1 gives information on the use of test lines. Where conditions relating to a new design of line are such that they cannot be related to data available from an existing line the expected performance is sometimes studied on a relatively short test line. Such test line studies are particularly useful when a new system, for operation at a much higher voltage than hitherto, is in the planning stage. The radio noise performance of the experimental line is monitored in a range of weather and atmospheric conditions so that the performance of the proposed line can be assessed under the conditions which it will experience in service. This could also include the effects of insulator pollution. Other important data, such as corona loss and acoustic noise performance, can also be obtained from the test line at the same time.

In 5.4 of CISPR/TR 18-2 a method is given whereby the reference level of a line may be found which will protect a given broadcast signal strength at a given distance from the line for 80 % of the time with 80 % confidence.

5.3 CIGRÉ formula

A simple direct formula has also been evolved for predicting the level of the radio noise field strength to be expected from the conductors of a line. The formula, which is empirically based, gives the most probable level to be expected from aged conductors in fair weather at a direct distance D_0 of 20 m from the nearest conductor at a measurement frequency of 500 kHz. The formula is derived from lines operating at voltages between 200 kV and 765 kV and at maximum voltage gradients between 12 kV/cm and 20 kV/cm. Strictly, the formula gives the noise from one phase conductor or bundle of a line and the effects of the other conductors may be taken into account by a summation process; however, for a number of designs of lines within these ranges, it is found that only a small error is introduced if only the conductor producing the highest noise at the measuring point of a three-phase line is considered; usually this is the nearest conductor but not necessarily so in all cases.

The formula is

$$E = 3{,}5\ g_{max} + 12\ r - 30, \qquad \text{in dB}(\mu\text{V/m})$$

where

E is the level of the radio noise field strength in dB(μV/m) at a direct distance D_0 of 20 m from nearest conductor of proposed line;

g_{max} is the maximum gradient of the r.m.s. voltage at the conductor surface, in kV/cm;

r is the radius of conductor or sub-conductor, in cm.

This matter is considered in more detail in Annex A.

5.4 Determination of 80 % level

The 80 % level for a line may be predicted by calculation [2, 3][*] or, if the line exists, the 80 % level may be determined with a high degree of confidence, by measurement. Methods of determining the 80 % level are as follows:

1) for an existing line the 80 % level may be determined, with a high degree of confidence, from the all-weather distribution curve obtained by measurements made over a period of one year.
2) if the all-weather distribution curve is not available, or in the case of a proposed line, the results of measurements made one line of similar design in a similar climate and pollution environment could be used.
3) from the figures mentioned in 4.3.4 of CISPR/TR 18-1 it is seen that, on average, the 80 % level for a line is 10 dB greater than the 50 % level. Therefore, if the 50 % level is known the 80 % level may be estimated.
4) the 80 % level may be predicted by adding 5 dB to 15 dB, depending on the climate, to the fair-weather level estimated from the simple formula given in 5.3 above.

5.5 Conclusions

The particular method of prediction to use in the case of a particular proposed line will depend on whether the interest is in conductor corona or noise due to insulators and/or hardware that is whether the conductors are to operate at a voltage gradient greater than about 14 kV/cm or less than about 12 kV/cm. For voltage gradients in between these values both the conductors and the insulators may contribute to the noise level of the proposed line.

The simple comparative formula referred to in item a) of 5.2, the catalogue of radio noise field strength profiles referred to also in item a) of 5.2 and the CIGRÉ formula given in 5.3 are all simple to use and, provided they are used within their inherent limitations, they should give reasonably accurate indications of the reference level to be expected from the conductors of a proposed line. It should be borne in mind that owing to the variable nature of radio noise and its dependency on the effects of weather, atmospheric conditions, pollution, etc., it is often difficult to measure the reference level of a line with any high degree of accuracy and reproducibility.

The method referred to in item b) of 5.2 relating to noise from insulators and/or hardware has not, as yet, become established practice for the case of specially polluted test insulators but the method would appear to have promise for this case. If a test line, referred to in item c) of 5.2, is available, together with the time required to carry out experimental work, the likely reference level from a proposed line may be obtained with a good degree of accuracy for the particular conductor, insulators and hardware proposed.

[*] The figures in square brackets refer to the Bibliography.