
Code of practice for

Abatement of radio interference from overhead power lines

Code de bonne pratique pour la suppression des perturbances radioélectriques
des lignes d'énergie aériennes

Richtlinie zur Verminderung der Funkstörung durch Überland-Starkstromleitungen

Contents

	Page		Page
Foreword	Inside front cover	Tables	
Cooperating organizations	Back cover	1. Broadcast frequencies and wavelengths	1
Code of practice		2. Interference field strength attenuation laws	8
Section one. General		3. Limits of radio noise field strength	9
1. Scope	1	4. Examples of calculations of limits of radio noise field strength	10
2. References	1	Figures	
3. Definitions	1	1. Typical noise values 0.2 MHz to 10 MHz measured at a distance of 20 m from nearest conductor	3
Section two. Radio interference and means of reducing its effects		2. Pin type insulator and method of attachment of the conductor	5
4. Generation and characteristics of radio noise	2	3. Lateral attenuation from mid-span position, multiple sources of 1 MHz	6
5. Limits of radio noise field strength	8	4. Lateral attenuation from tower position, single source of 150 MHz	7
6. Methods of measurement of radio noise field strength	8	5. Limits of radio noise field strength: 0.5 MHz to 1.6 MHz	9
7. Measures to minimize the generation of radio noise	11	6. Arrangement of apparatus for measurement of radio noise field strength in frequency range 0.15 MHz to 1.605 MHz	10
8. Remedial measures if interference is experienced	11	7. Arrangement of apparatus for measurement of radio noise field strength in frequency range 40 MHz to 250 MHz	10
Appendices		8. Improvement of signal-to-noise ratio by orientation of receiving aerial	13
A. The calculation of the potential gradient at the conductor surface of a single phase overhead line, with earth return	14		
B. The prediction of the strength of the radio noise field to be expected adjacent to a proposed overhead line	14		

Foreword

This British Standard code of practice has been prepared in order to provide information on the many factors involved in protecting the reception of radio and television broadcasting from interference caused by overhead power lines. It is hoped that the code will also aid the consideration of problems of interference with other radio services. The information given should be of assistance where means of avoiding or abating radio noise are being considered. Recommended limits of the radio noise field from overhead power lines are given, together with methods of measurement.

There are also recommendations on the design, construction and maintenance of the lines in order to minimize interference. Information is also given that

will be of assistance when planning the route of a proposed line.

It is intended that, when more experience has been gained in the use of the measuring methods described and the applications of the limits given, a British Standard specifying limits and methods of measurement of radio noise from overhead power lines will be prepared.

The International Special Committee on Radio Interference (CISPR) has not, as yet, recommended limits on the radio noise field from overhead power lines, but the methods of measurement given in this code are generally in agreement with those given in CISPR Publication 1, Second Edition, 1972, and in CISPR Report no. 44.

British Standard Code of practice for

Abatement of radio interference from overhead power lines

Section one. General

0. Introduction

The limits of radio field strength recommended in this code are calculated to give a satisfactory degree of protection to the reception of broadcasting, within the recognized service areas of the appropriate transmitters, in the low and medium frequency bands and the very high frequency (VHF) television bands, in the least favourable conditions that are likely to be generally encountered. The limits given are intended to provide guidance at the planning stage of a line, and standards against which the performance of the line may be checked after construction and during its life.

Details of frequencies and wavelengths used in sound radio and television sound broadcasting are given in table 1.

1. Scope

This code gives information on the generation and characteristics of radio noise from overhead power lines operating at voltages above 1 kV. The code is restricted to a.c. lines at 50 Hz since d.c. overhead lines are little used in the United Kingdom, and special considerations apply to them. All 50 Hz voltages are given in r.m.s.

values. Recommended limits and methods of measurement of the radio noise field in the immediate vicinity of the power line are given for the frequency ranges 0.15 MHz to 1.6 MHz and 40 MHz to 250 MHz.

No limits have been given to protect reception in the high frequency band because no reliable information is at present available about the signal-to-noise ratios that are acceptable. No limits have been given for the ultra high frequency (UHF) bands because site measurements and service experience have shown that levels of noise from power lines are so low that interference with television reception is very unlikely.

2. References

The titles of the standards publications referred to in this standard are listed on the inside back cover.

3. Definitions

For the purpose of this code, the definitions given in BS 4727 : Part 1 : Group 09 : 1976 apply, together with the following.

overhead power lines. The supporting structures, conductors, insulators and associated fittings of overhead power lines up to the curtilage of the associated substations.

Table 1. Broadcast frequencies and wavelengths

Type of broadcast	Frequency	Wavelength
<i>Sound radio</i>	MHz	m
Low frequency (long wave)	0.15 to 0.255	2000 to 1176
Medium frequency (medium wave)	0.525 to 1.605	571 to 187
High frequency (short wave)	2.3 to 26.1	130.4 to 11.5
Very high frequency (band II FM)	87.5 to 100	3.4 to 3.0
<i>Television</i>		
<i>Very high frequency</i>		
Band I	41 to 68	7.3 to 4.4
Band III	174 to 223	1.7 to 1.35
<i>Ultra high frequency</i>		
Band IV	470 to 582	0.64 to 0.52
Band V	582 to 960	0.52 to 0.31

NOTE. The frequencies currently authorized for broadcasting in the United Kingdom do not extend over all of the HF, VHF and UHF bands listed above.

Section two. Radio interference and means of reducing its effects

4. Generation and characteristics of radio noise

4.1 General. The basic causes of radio noise from power lines are:

- (a) corona discharges in the air at the surface of conductors and fittings, and
- (b) sparking, for instance on the surfaces of insulators and at loose or imperfect contacts.

4.2 Corona discharges in the air at the surface of conductors

4.2.1 Corona discharges consisting of pulses containing radio frequency components are sources of radio noise, particularly when these occur during the positive half cycle of the voltage wave. These current pulses are injected into, and propagate along, the conductors, giving rise to electromagnetic fields in the vicinity of the power line.

4.2.2 The possibility of a corona discharge taking place at the surface of a conductor is dependent upon:

- (a) the nominal electric stress or potential gradient in the air at the conductor surface, which is a function of the system voltage, the type of conductor, e.g. circular or segmental stranding, the conductor diameter, and the spacing of the conductor from earth and other phase conductors (but see 4.2.3).

The potential gradient may be calculated by using the formulae given in appendix A and a measure of the dependency of the strength of the radio noise field on the potential gradient may be gained from the formulae given in appendix B;

- (b) the condition of the conductor surface, i.e. the degree of smoothness or roughness, the presence or absence of pollution, water droplets, etc.

- (c) atmospheric conditions. A reduction in the barometric pressure or an increase in the ambient temperature can reduce the breakdown strength of air and thereby increase the likelihood of a corona discharge taking place on a conductor. However, in the United Kingdom, atmospheric conditions such as rain, fog, frost or a falling air temperature, which can lead to the formation of ice or water droplets on the conductor, are considered to be more significant.

4.2.3 For otherwise constant conditions, the electric stress at a conductor surface can be reduced by employing a larger diameter conductor or, more economically, by using two or more subconductors in the form of a bundle. In this arrangement there is an optimum spacing between subconductors at which the maximum stress is at its lowest value, for example about 300 mm for 275/400 kV lines. In a bundle formation only a small part of the surface of each subconductor is at the maximum stress, thereby reducing radio noise.

4.2.4 For lines below about 100 kV, radio noise due to conductor corona is insignificant. Above this voltage the stress in the air at the surface of the conductors is of such a value that the radio noise produced by the conductors may be significant, particularly in rain or whenever water droplets are present on the conductors. The curves of figure 1 give an indication of the change in the strength of the radio noise field between dry and damp conditions for a 400 kV line with $4 \times 400 \text{ mm}^2$

conductors per phase. It should be borne in mind, however, that these curves give the aggregate noise from all sources, i.e. corona discharges in the air at the conductors and fittings, and sparking on the surfaces of the insulators.

4.2.5 To illustrate the major factors involved, formulae for the calculation of the potential gradient at the surface of a conductor are given in appendix A for both a single conductor and a bundle conductor arrangement, for the hypothetical case of single-phase earth return only. In a three-phase line the calculations are more complicated because of the need to take into account the effects of the other conductors. Normally, computer programmes are used for both single and double circuit three phase lines.

4.2.6 Except for a few special designs, the maximum potential gradient at the conductor surface of lines in the United Kingdom of 132 kV and above, lies between 9.5 kV/cm and 13 kV/cm. The quoted gradients are usually the average for the three phases, and the conductors are assumed to be smooth cylinders at mean heights above ground. The potential gradients for lines of 11 kV and 33 kV in the United Kingdom are so low that the air at the surface of the conductors is not stressed sufficiently to cause corona discharge, even in rain. A simple formula for the prediction of the radio noise field due to corona to be expected adjacent to a proposed line, compared with that from a reference line, is given in appendix B. A simple direct formula is also given. As indicated in 4.2.3, the potential gradient at the surface of a subconductor in a bundle arrangement is not uniform at all points on its circumference and a maximum occurs on the outside of the bundle on a line passing through the centres of two conductors and the bundle centre. This spatial maximum value of the potential gradient should not be confused with the time-related peak value.

4.2.7 Where the potential gradients at the surfaces of the conductors of a line are low (less than about 12 kV/cm to 13 kV/cm), and these surfaces are free from water droplets and other projections, corona discharges on the conductor surfaces are of less significance and the radio noise performance of the line is largely determined by the quality and cleanliness of the insulators. At still lower potential gradients the condition of the surfaces of the conductors becomes largely irrelevant as far as radio noise from corona is concerned. In the design of conductor fittings, such as spacers and dampers, a possible approach is to make their corona performances at least equal to that of the conductors. Such an approach would not, however, be suitable for conductors with low potential gradients when it may be more appropriate to relate the corona performances of the fittings to that of the insulators.

4.3 Radio noise from insulators and insulator sets

4.3.1 Suspension and tension insulator sets for use in the United Kingdom on transmission lines of 132 kV and above comprise one insulator string, or two or more strings suitably connected together, complete with fittings for attachment to the supporting structure and to carry the line conductors, and the sets also include arcing horns and stress control fittings. Radio noise can be caused by corona discharges in the air at the surfaces of the fittings, or by local sparking on the surface of the string insulator units or internal discharges in voids in the insulating material of these units.

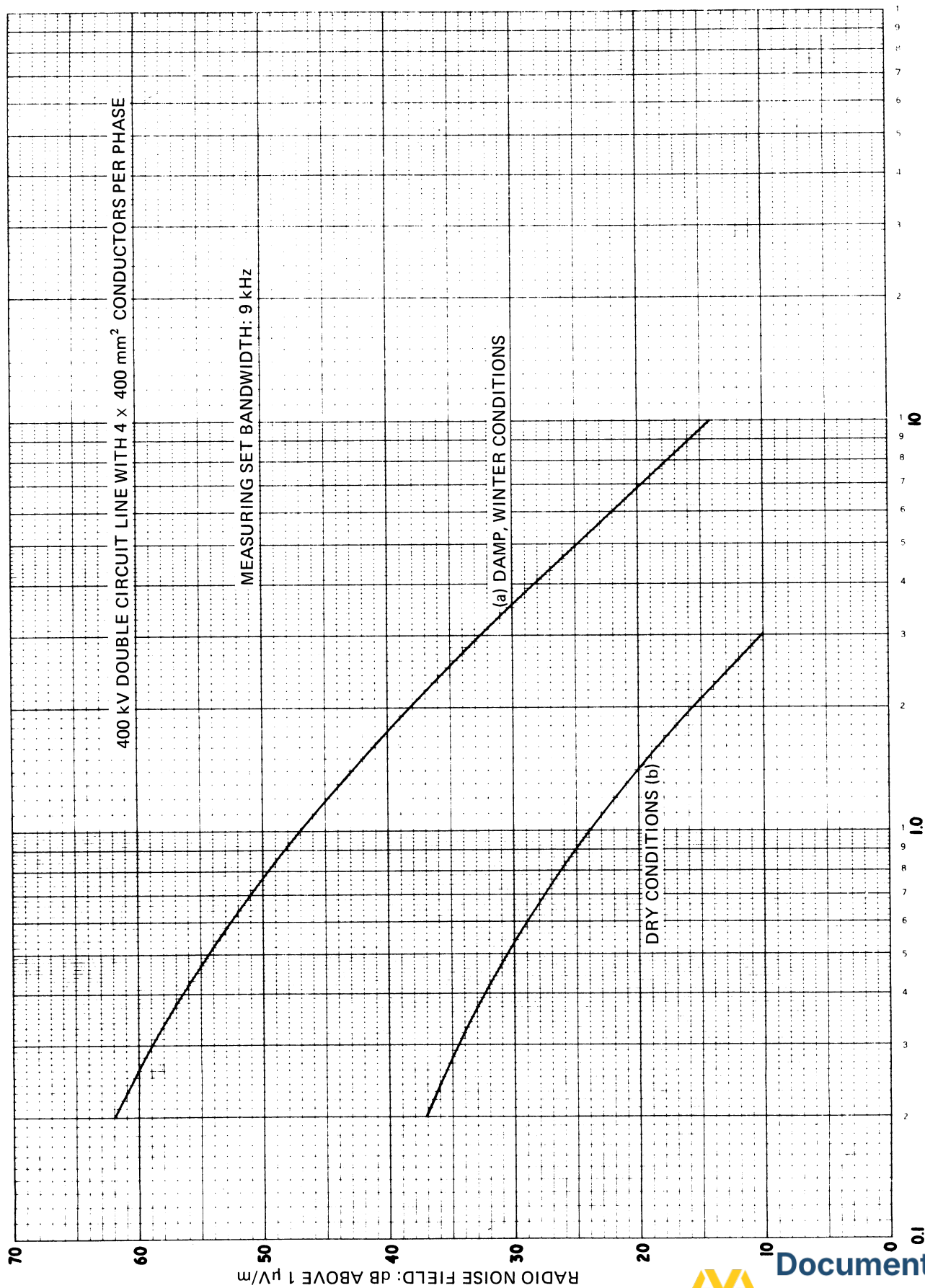


Figure 1. Typical noise values 0.2 MHz to 10 MHz measured at a distance of 20 m from nearest conductor

4.3.2 The potential gradient across the surface of a string insulator unit is not uniform. The maximum stress is usually in the vicinity of the pin cavity and under certain conditions sparking can occur in this region. The geometry of the insulator has a significant effect on the voltage gradient and the application of correct design principles will ensure that the maximum stress is not excessive.

4.3.3 The voltage distribution over an insulator string is also non-uniform; the string insulator units at the line end of the insulator string are the most highly stressed and are therefore the most likely to produce radio noise. The voltage distribution can be greatly improved by suitable stress control fittings attached to the insulator set.

4.3.4 It is usual practice for the radio noise performance of complete suspension and tension insulator sets to be measured when type tests are conducted at a high voltage laboratory. These tests are made on clean dry insulators and some increase in radio noise must be expected under certain service conditions; for example, when the insulators become polluted and then moistened by dew, light rain, or fog. Pollution can also have the effect of modifying the voltage distribution over the insulator string. To give some assurance that a satisfactory radio noise level will be achieved under service conditions it is usual to make the laboratory measurements at voltages up to 1.4 times the system's highest voltage to earth, pending the formulation of a more realistic method of simulating service conditions in respect of pollution and humidity (see BS 5049).

4.3.5 In the case of porcelain string insulator units it has been found that radio noise can be produced by discharges in small voids in the porcelain. The application of suitable manufacturing procedures reinforced by adequate quality control can ensure that the porcelain is free from voids. Another possible source of trouble is imperfect contact between the caps and pins of insulator strings.

4.3.6 For voltages up to 33 kV pin type insulators are widely employed and, with this type of insulator, sparking can occur where the conductor rests in the top groove and at the binding wire or stirrups in the side groove. Typical binding arrangements for bare and insulated conductors are shown in figure 2(a) and (b) respectively. This sparking is most likely to occur in dry weather; in wet weather the water bridges the small gaps between the live metal and the insulator and the radio noise is reduced or eliminated. The problem can be avoided during manufacture by the application of a layer of conducting glaze to the head of the insulator. As an alternative to the pin type insulator a solid core line post insulator can be used which has a relatively low capacitance and an inherently good radio noise performance.

4.3.7 The method of measuring radio noise from insulators is given in BS 5049. The practice for tension and suspension insulator sets is for the complete set to be type tested to verify compliance with the specified radio noise requirements. Subsequently, sample tests are carried out on individual string insulator units to provide a check on production quality. Sample tests are also carried out on pin type insulators.

4.4 Sparking at imperfect contacts

4.4.1 If electrical contact between a conductor and a fitting is imperfect, for example through inadequate contact pressure, or by corrosion of the contact surfaces,

the fitting can assume a potential which is lower than that of the conductor. The potential of the fitting is largely determined by the capacitance across the point of discontinuity, the capacitance between the fitting and earth, and the voltage of the conductor with respect to earth. This difference of potential between the conductor and the fitting can cause sparking at the point of discontinuity, resulting in the generation of short duration pulses which contain components extending into the VHF band.

4.4.2 In wet weather, noise generated in this manner usually disappears because the comparatively small gaps involved become bridged and made conducting by moisture, and as a result this type of noise is often referred to as 'dry noise' to distinguish it from corona noise which usually becomes more pronounced in wet weather. Dry noise may also result from acts of vandalism such as lengths of wire or chain that have been thrown onto live conductors or fittings.

4.5 Line characteristics and radio noise levels

4.5.1 When a corona discharge occurs at a point on a conductor, or sparking occurs on the surface of an insulator, short duration pulses of current are injected into the conductor. These pulses, which travel along the conductor in both directions, induce lower amplitude pulses into the other conductors and a complex pattern of conductor-to-ground and conductor-to-conductor propagational modes results. Because the earth, with its relatively high resistivity, is involved, the attenuation of the conductor-to-ground modes is high, but since the attenuation of the conductor-to-conductor modes is low, particularly for the lower frequency components, these latter modes propagate to much greater distances along the line.

4.5.2 For a frequency of about 1 MHz, the attenuation over the first kilometre along the line from a noise source can be as high as 10 dB, depending mainly on the earth resistivity, and then, after a few kilometres, when the conductor-to-conductor modes become dominant, the longitudinal attenuation can fall below 1 dB/km.

4.5.3 The fields can emanate from the conductors, supporting structural metal work, and insulators and fittings, depending on the frequencies present in the noise source or sources. Noise fields at frequencies up to about 10 MHz emanate from the conductors and towers, and at higher frequencies from the insulators, fittings and smaller structural members.

4.5.4 The aggregate radio noise field measured at a point near a line, with either single or multiple sources, is the summation of all the individual noise fields at that point, at the measurement frequency.

4.5.5 The curves of figure 1 show some typical spectra of the radio noise field in the frequency range 0.2 MHz to 10 MHz for a 400 kV double circuit line with a bundle of four subconductors per phase each having an overall diameter of 28.6 mm and a maximum surface potential gradient of 11.9 kV/cm. Curve (a) represents the mean of results obtained at a number of different test sites, 20 m from the nearest conductor, over a period of a few days, and in damp conditions in winter which are normally conducive to the generation of higher levels of radio noise, especially at the lower frequencies. Curve (b) shows the considerable reduction in the levels of noise in dry weather. The curves give the aggregate noise from all sources, i.e. corona discharges in the air