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BS EN 50121-2:2006

Railway applications — Electromagnetic compatibility —

Part 2: Emissions of the whole railway system to the outside world

The European Standard EN 50121-2:2006 has the status of a British Standard

ICS 29.020; 29.280; 45.020

British Standards

National foreword

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Applications ferroviaires -
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Partie 2: Emission du système ferroviaire dans son ensemble vers le monde extérieur

Bahnanwendungen -
Elektromagnetische Verträglichkeit
Teil 2: Störaussendungen des gesamten Bahnsystems in die Außenwelt

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

This European Standard was prepared by Technical Committee TC 9X: Electrical and electronic applications for railways. The text of the draft was submitted to the formal vote and was approved by CENELEC as EN 50121-2 on 2006-07-01.

This European Standard supersedes EN 50121-2:2000.

This European Standard is to be read in conjunction with EN 50121-1.

This standard forms Part 2 of the European Standard series EN 50121, published under the general title "Railway applications - Electromagnetic compatibility". The series consists of:

- Part 1 : General
- Part 2 : Emission of the whole railway system to the outside world
- Part 3-1 : Rolling stock - Train and complete vehicle
- Part 3-2 : Rolling stock - Apparatus
- Part 4 : Emission and immunity of the signalling and telecommunications apparatus
- Part 5 : Emission and immunity of fixed power supply installations and apparatus

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2007-07-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2009-07-01

This European Standard has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association and covers essential requirements of EC Directive 89/336/EEC. See Annex ZZ.

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1 Scope

This European Standard sets the emission limits from the whole railway system including urban vehicles for use in city streets. It describes the measurement method to verify the emissions, and gives the cartography values of the fields most frequently encountered.

The limits refer to the particular measuring points defined in Clause 5 and Annex A. These emissions should be assumed to exist at all points in the vertical planes which are 10 m from the centre lines of the outer electrified railway tracks, or 10 m from the fence of the substations.

Also, the zones above and below the railway may be affected by electromagnetic emissions and particular cases shall be considered individually.

These specific provisions are to be used in conjunction with the general provisions in EN 50121-1.

This part of the standard covers EMC for fixed installations and therefore is not relevant for CE marking.

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.

EN 50121-1	Railway applications - Electromagnetic compatibility Part 1: General
EN 50121-3-1	Railway applications - Electromagnetic compatibility Part 3-1: Rolling stock - Train and complete vehicle
EN 50121-5	Railway applications - Electromagnetic compatibility Part 5: Emission and immunity of fixed power supply installations and apparatus
EN 55016-1-1	Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-1: Radio disturbance and immunity measuring apparatus - Measuring apparatus (CISPR 16-1-1)
EN 55022	Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement (CISPR 22, mod.)
EN 61000-6-4	Electromagnetic Compatibility (EMC) Part 6-4: Generic Standards - Emission standard for industrial environments (IEC 61000-6-4, mod.)
CISPR 18	Radio interference characteristics of overhead power lines and high voltage equipment
IEC 60050	International Electrotechnical Vocabulary (IEV)

3 Definitions

For the purpose of this Part 2 of the European Standard, the definitions of IEC 60050 and the following definitions apply.

3.1
apparatus
an electric or electronic product with an intrinsic function intended for implementation into a fixed railway installation

3.2
environment
the surrounding objects or region which may influence the behaviour of the system and/or may be influenced by the system

3.3
external interface
the boundary where a system interacts with any other or where a system interacts with its environment

3.4
railway substation
an installation the main function of which is to supply a contact line system at which the voltage of a primary supply system, and in some cases the frequency, is transformed to the voltage and frequency of the contact line

3.5
railway supply lines
conductors running within the boundary of the railway which supply power to only the railway but are not energised at railway system voltage

4 Emission limits

4.1 Emission from the open railway route during train operation

The emission limits in the frequency range 9 kHz to 1 GHz are given in Figure 1 and the measurement method is defined in Clause 5. For non-electrified lines, the limits are as those given for 750 V d.c.

Annex C gives guidance values for typical maximum field values at fundamental frequency of different electrification systems which may occur. They depend on numerous geometrical and operational parameters which may be obtained from the infrastructure controller.

For urban vehicles operating in city streets, the emission limits given in Figure 1 for 750 V d.c. conductor rail shall not be exceeded.

NOTE It is not possible to undertake complete tests with quasi-peak detection due to the reasons stated in Annex B.

4.2 Radio frequency emission from railway substations

Radio frequency noise emission from the railway substation to the outside environment measured according to the method defined in Annex A shall not exceed the limits in Figure 2.

The limits are defined as quasi-peak values and the bandwidths are those used in EN 55016-1-1:

	Bandwidth
frequencies up to 150 kHz	200 Hz
frequencies from 150 kHz to 30 MHz	9 kHz
frequencies above 30 MHz	120 kHz

The distance of 10 m defined in Annex A shall be measured from the fence of the substation. If no fence exists, the measurements shall be taken at 10 m from the apparatus or from the outer surface of the enclosure if it is enclosed.

Emission of trains shall not enter into the measurement.

NOTE For other kinds of fixed installations like auto-transformers, the same limit and measuring distance shall be applied.

5 Method of measurement of emission from moving trains

The method of measurement is adapted from the EN 55016-1-1 to a railway system with moving vehicles. The background to the method of measurement is given in Annex B.

The electromagnetic fields generated by rail vehicles when operating on a railway network are measured by means of field strength meters with several different set frequencies. The horizontal component of the magnetic field perpendicular to the track and both the vertical and horizontal (parallel to the track) components of the radiated electric field are measured.

5.1 Measurement parameters

5.1.1 The peak measurement method is used. The duration at selected frequency shall be sufficient to obtain an accurate reading. This is a function of the measuring set and the recommended value is 50 ms.

5.1.2 Frequency bands and bandwidths at – 6 dB used for measurements are in accordance with EN 55016-1-1.

These are:

Frequency bands:	9-150 kHz	0,15-30 MHz	30-300 MHz	300 MHz -1 GHz
Bandwidth:	200 Hz	9 kHz	120 kHz	120 kHz

5.1.3 When connected to the antenna, the error of measurement of the strength of a uniform sine-wave field shall not differ more than ± 4,0 dB from EN 55016-1-1 equipment.

5.1.4 The noise may not attain its maximum value as the traction vehicle passes the measuring point, but may occur when the vehicle is a long distance away. Therefore, the measuring set shall be active for a sufficient duration before and after the vehicle passes by to ensure that the maximum noise level is recorded.

5.1.5 To cover the full frequency range, antennas of different design are required. Typical equipment is described below:

- for 9 kHz - 30 MHz, a loop or frame antenna is used to measure H field (see Figure 3);
- for 30 MHz - 300 MHz, a biconical dipole is used to measure E field (see Figure 4);
- for 300 MHz - 1,0 GHz, a log-periodic antenna is used to measure E field (see Figure 5).

Calibrated antenna factors are used to convert the terminal voltage of the antenna to field strength.

5.1.6 The preferred distance of the measuring antenna from the centreline of the track on which the vehicle is moving is 10 m. In the case of the log-periodic antenna, the 10 m distance is measured to the mechanical centre of the array.

It is not considered necessary to carry out two tests to examine both sides of the vehicle, even if it contains different apparatus on the two sides, since the majority of the emission is produced by the sliding contact if the train is moving.

Where the tests are carried out at a site which meets all the recommended criteria except that the antennas are not 10 m from the track centreline, the results can be converted to an equivalent 10 m value by using the following formula:

$$E_{10} = E_x + n \cdot 20 \cdot \log_{10} (D/10)$$

where E_{10} is the value at 10 m
E_x is the measured value at D m
n is a factor taken from the table below.

Frequency range	*n*
0,15 MHz to 0,4 MHz	1,8
0.4 MHz to 1,6 MHz	1,65
1,6 MHz to 110 MHz	1,2
110 MHz to 1 000 MHz	1,0

The measured values (at the equivalent 10 m distance) shall not exceed the limits given in Figure 1 for the appropriate system voltage.

Where the physical layout of the railway totally prevents the use of reference distances, a method shall be agreed to suit the particular circumstances. For example, if the railway is in tunnel, miniature antennas can be used on the wall of the tunnel. In such a case, the limits selected shall take into account the method of measurement.

5.1.7 The height above rail level of the antenna centre shall be within the range 1,0 m to 2,0 m for the loop antenna, and within 2,5 m to 3,5 m to the centre of dipole or log-periodic antennas. If the level of the ground at the antenna differs from the rail level by more than 0,5 m, the actual value shall be noted in the test report.

The plane of the loop antenna shall be vertical and parallel to the line of the track. The biconical dipole shall be placed in the vertical and horizontal axis. The log periodic antenna shall be arranged to measure the vertical and horizontal polarisation signal, with the antenna directed towards the track.

Figures 3, 4 and 5 show the positions and vertical alignments of the antennas.

5.1.8 In the case of elevated railway systems, if the antenna heights specified above cannot be achieved, the height of the antenna centre can be referenced to the level of the ground instead of to the rail level. The conversion formula in 5.1.6 shall be employed where D is the slant distance between the train and the antenna. The train shall be visible from the location of the antenna and the axis of the antenna shall be elevated to point directly at the train. A measurement distance of 30 m from the track centreline is preferred for highly elevated railways. Full details of the test configuration shall be noted in the test report.

5.1.9 If tests are being done on a railway with overhead electrified supply, the measuring point shall be at the mid-point between the support masts of the overhead line and not at a discontinuity of the contact wire. It is recognised that resonance can exist in an overhead system at radio frequencies and this may require changes in the values of frequency chosen for measurement. If resonance exists, this should be noted in the test report.

The radio frequency emission will be affected by the state of the railway supply system. Switching of feeder stations and temporary works will influence the response of the system. It is therefore necessary to note the condition of the system in the test record and, if possible, all similar tests should be carried out within the same working day. Where the railway has a track-side conductor rail power supply, the test location should be at least 100 m from gaps in the rail, to avoid inclusion of the transient fields associated with the make and break of collector contact. The conductor rail and the antennas shall be on the same side of the track.

5.1.10 The test sites do not correspond to the definition of a completely clear site because they are influenced by overhead structures, rails and the catenary. However, wherever possible, antennas shall be placed well away from reflecting objects. If overhead power lines are nearby, other than those which are part of the railway network, they should be no closer than 100 m to the test site.

5.1.11 The values measured are expressed as:

- dBµA/m for magnetic fields,
- dBµV/m for electrical fields.

These are obtained by using the appropriate antenna factors and conversions.

5.1.12 Background noise shall be measured at the test site in the absence of train effects. This will give the noise values from the energised power supply conductors. If this is significant, it is advisable to measure also at 100 m from the test site, to identify any high non-railway sources of noise.

5.2 Frequency selection

5.2.1 Selected frequencies

The selection of the actual frequencies to be measured will depend on the circumstances of the test site.

If high signals exist, for example from public broadcasting stations, the selection of test frequencies shall take this into account.

It is recommended that test frequencies are selected so that there are at least three frequencies per decade.

5.2.2 Sweep frequency

In view of the short time available for measurement in one train passage, the use of a sweep frequency measuring technique, in which the peak noise is measured with a peak-hold circuit as the frequency is changed, may offer adequate information concerning generation of noise. There will still remain problems of time because the rate of change of frequency is a function of the bandwidth, due to considerations of accuracy. A sweep analyser will usually set its own sweep rate to meet this requirement. If this method is used, sweep rate as well as bandwidth shall be noted.

5.3 Transients

During the test, transients due to switching may be detected, such as those caused by operation of power circuit breakers. These shall be disregarded when selecting the maximum signal level found for the test.

5.4 Measuring conditions

5.4.1 Weather conditions

To minimise the possible effect of weather on the measured values, measurements should be carried out in dry weather, (after 24 hours during which not more than 0,1 mm rain has fallen), with a temperature of at least 5 ^{o}C, and a wind velocity of less than 10 m/s.

Humidity should be low enough to prevent condensation on the power supply conductors.

Since it is necessary to plan the tests before the weather conditions can be known, tests will have to be made in weather conditions which do not meet the target conditions. In these circumstances, the actual weather conditions shall be recorded with the test results.

5.4.2 Railway operating modes

Two test conditions are specified for the traction mode and are:

a) measurement at a speed of more than 90 % of the maximum service speed, (to ensure that the dynamics of current collection are involved in the noise level) and at the maximum power which can be delivered at that speed.

b) at the maximum rated power and at a selected speed, (particularly if the lower frequencies are of concern).

If the vehicle is capable of electric braking, tests are required at a brake power of at least 80 % of the rated maximum brake power.

5.4.3 Multiple sources from remote trains

For the purpose of limits, the presence of "physically-remote but electrically-near" vehicles out of the test zone is regarded as insignificant when considering radio noise.

5.5 Test report

The test report shall contain the following information.

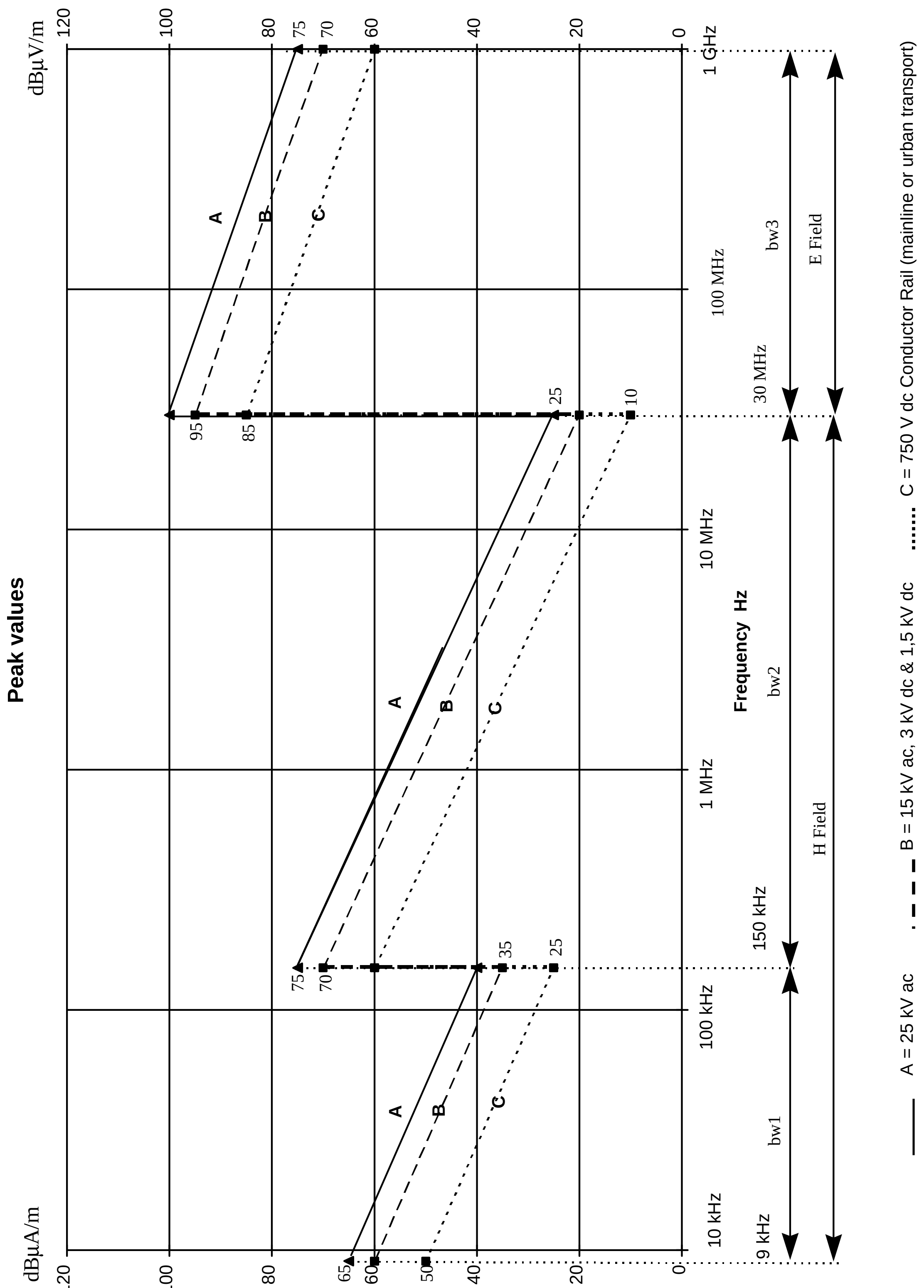
- description of site;
- description of measuring system;
- description of railway vehicle (type and configuration);
- numerical results;
- graphical results where relevant (The results shall include information such as bandwidths, date, time);
- weather conditions;
- name of person in charge at site.

5.6 Antenna positions

Figure 3 shows the position of the antenna for measurement of the magnetic field in the 9 kHz - 30 MHz frequency band.

Figure 4 shows the position (vertical polarisation) of the antenna for measurement of the electric field in the 30 MHz - 300 MHz frequency band. For the measurement of the horizontal field parallel to the track, the antenna is turned by 90°.

Figure 5 shows the position (vertical polarisation) of the antenna for measurement of the electric field in the 300 MHz - 1 GHz frequency band. For the measurement of the horizontal field parallel to the track, the antenna is turned by 90°.



NOTE 1 The discontinuities of the curves are due to changing of the bandwidth of the measurement receiver: bw1 = 200 Hz; bw2 = 9 kHz; bw3 = 120 kHz.

NOTE 2 Values are 10 m from the railway track

Figure 1 - Emission limits in frequency range 9 kHz to 1 GHz

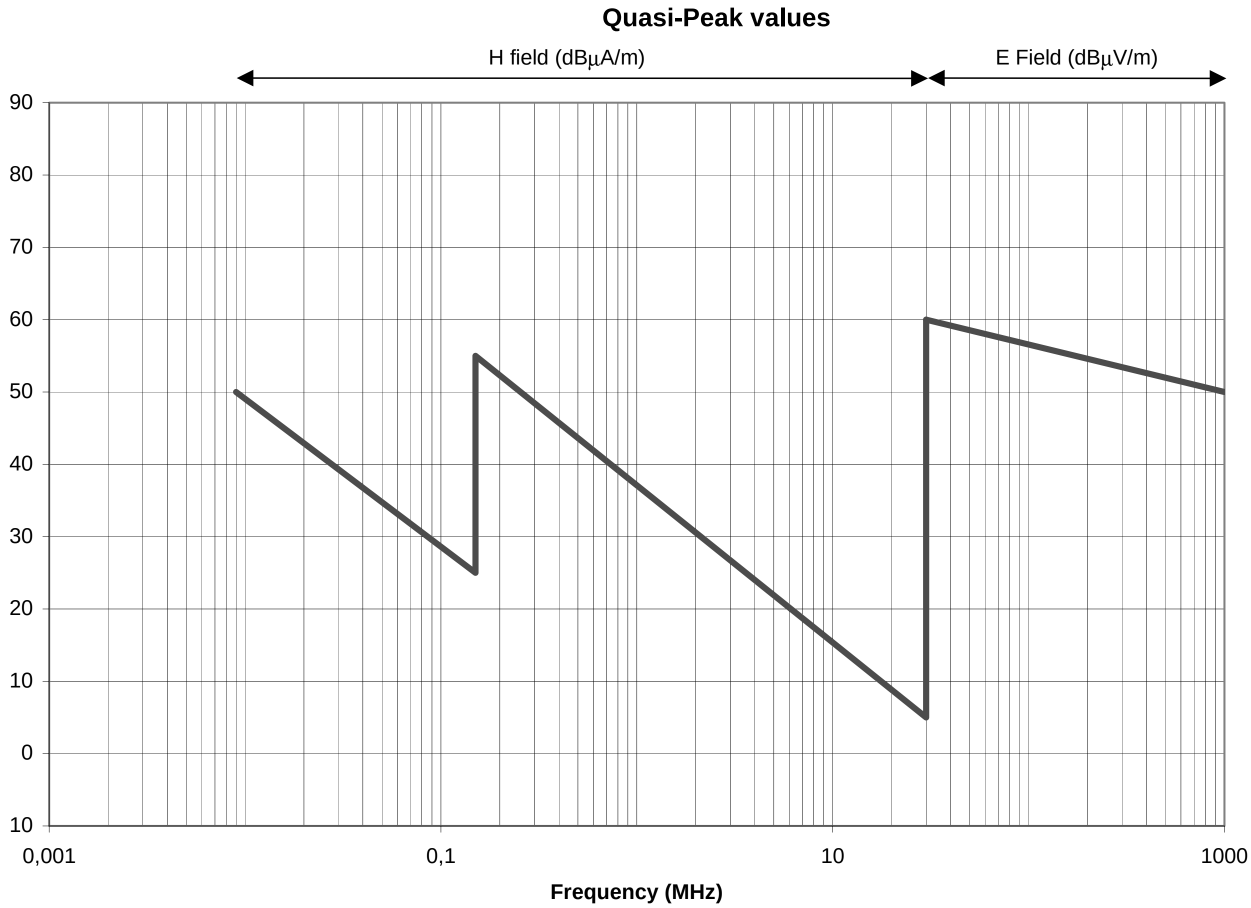


Figure 2 - Emission limit for substations

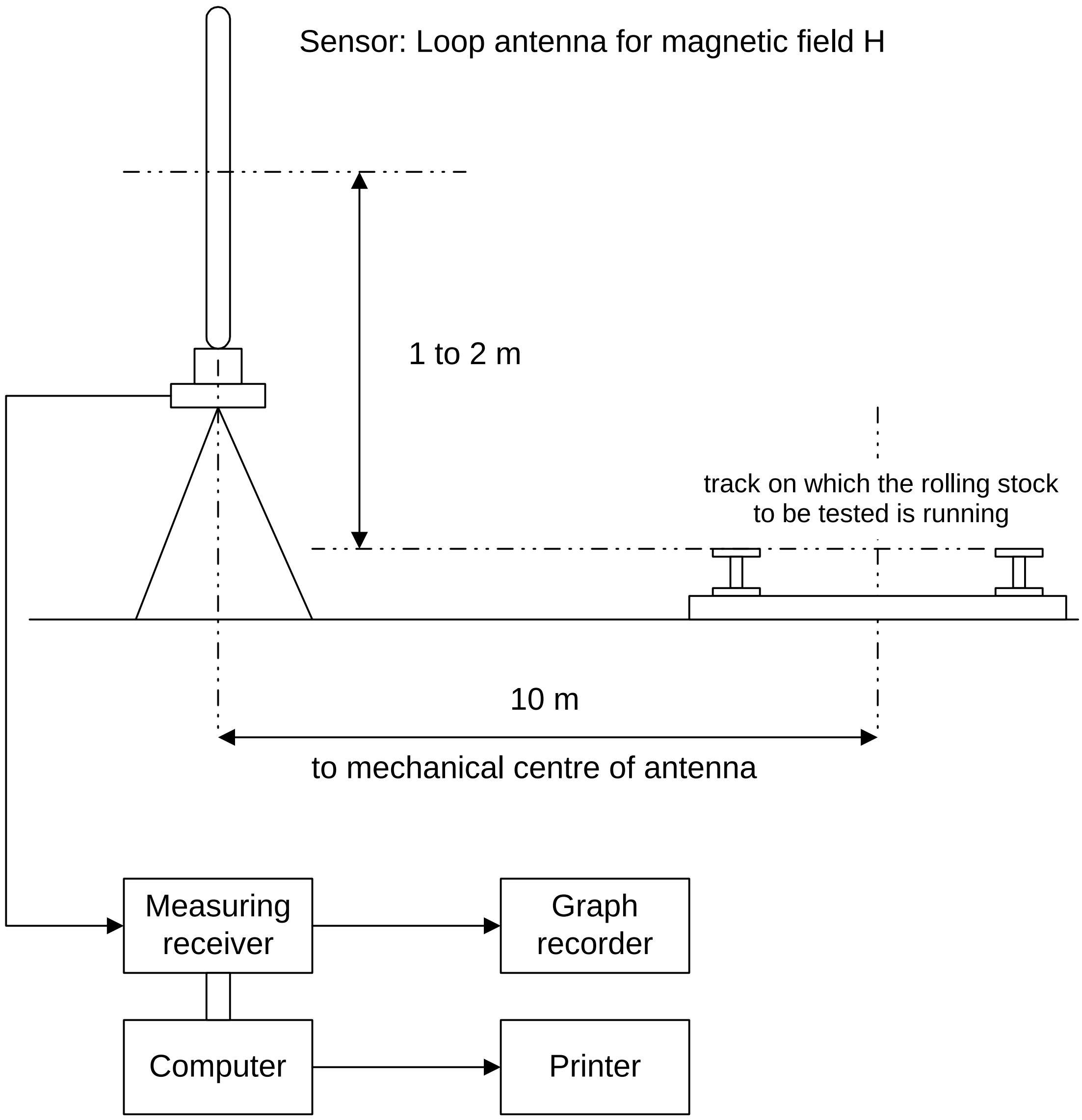


Figure 3 - Position of antenna for measurement of magnetic field in the 9 kHz to 30 MHz frequency band

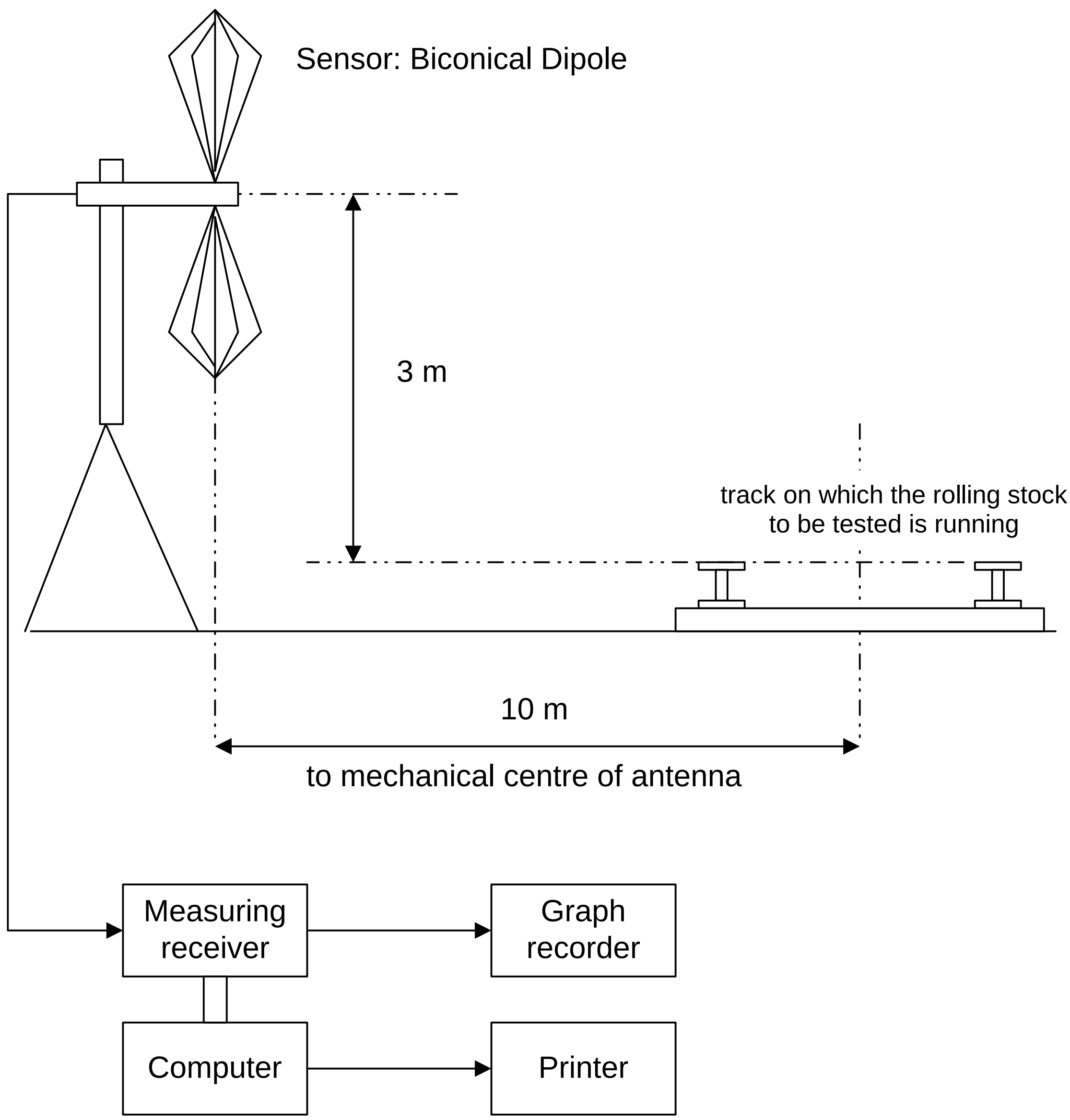


Figure 4 - Position (vertical polarisation) of antenna for measurement of electric field in the 30 MHz to 300 MHz frequency band

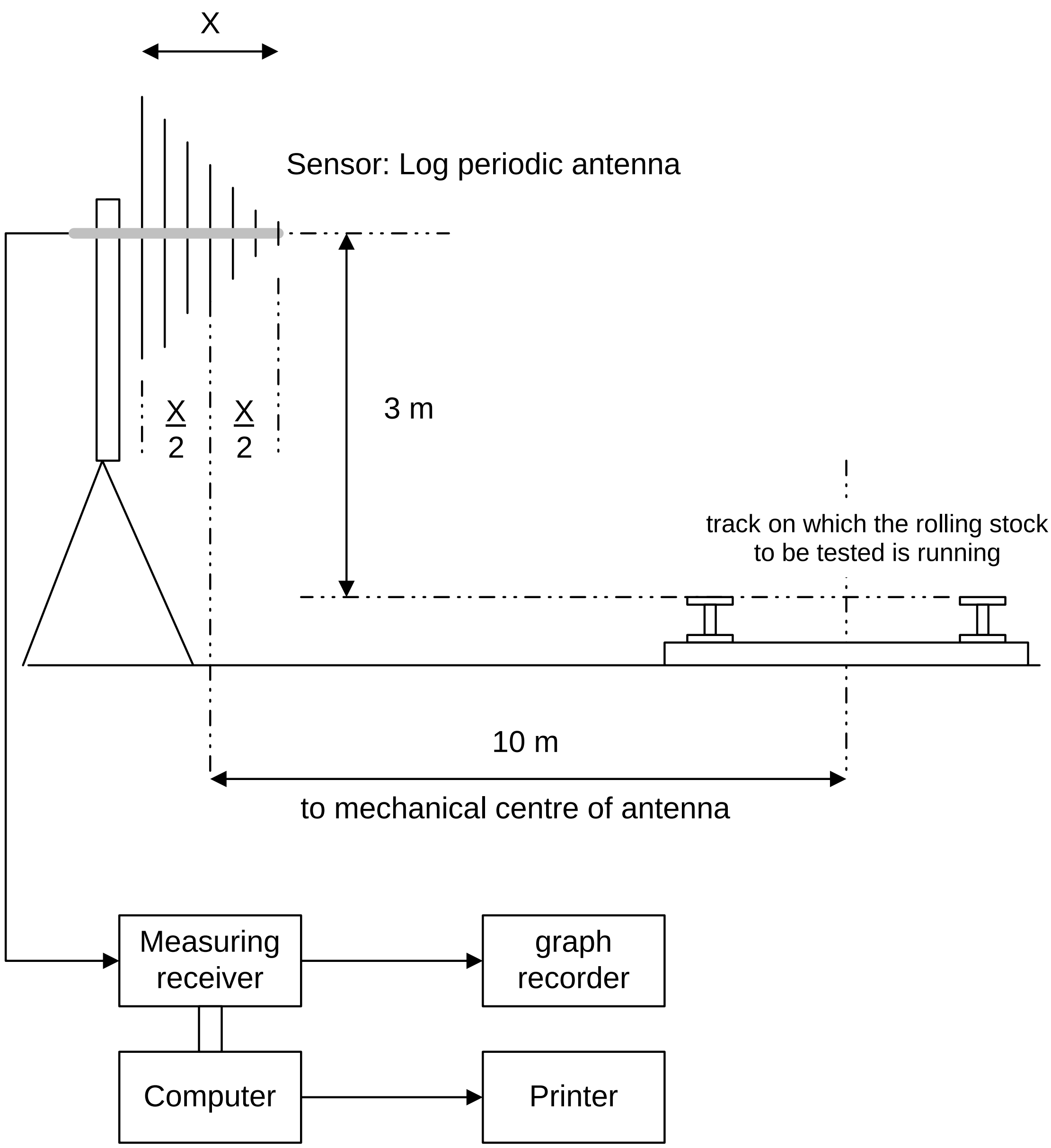


Figure 5 - Position (vertical polarisation) of antenna for measurement of electric field in the 300 MHz to 1 GHz frequency band

Annex A
(normative)

Method of measurement of electromagnetic emission from railway substations

A.1 Positions for tests

In view of the special geometry of a railway traction supply system, it is necessary to define the conditions for the measurement of emission of electromagnetic fields under normal load conditions.

A.2 Substation load

A feature of railway substations is that the load can change widely in short times. Since emission can be related to load, the actual loading of the substation shall be noted during emission tests.

A.3 Method of measurement

Emission shall be measured at a distance of 10 m from the outer fence of the substation, at the midpoints of the three sides, excluding the side which faces the railway, unless this side is more than 30 m from the centre of the nearest electrified railway track. In this case all four sides shall be measured. If the length of the side of the substation is more than 30 m, measurements shall be taken additionally at the corners.

The accuracy of the measuring equipment for the radio frequency tests shall not differ more than ± 4,0 dB from the requirements of EN 55016-1-1.

At each measuring position, the following shall be measured:

a) the maximum radio emission at a frequency in the neighbourhood of 1 MHz (selected on site to avoid other transmissions), measured by vertical plane loop antenna, noting the orientation of the antenna. The loading of the substation shall be at least 30 % of the rated load. The base of the loop antenna shall be between 1 m and 1,5 m above ground.

b) the radio emission over the frequency range 9 kHz to 30 MHz, measured with the loop in the maximum orientation position as under a). The loading of the substation shall be at least 30 % of the rated load during these measurements.

   NOTE It is accepted that the fixed antenna position may result in values being less than the absolute maximum at some frequencies.

c) the maximum radio emission over the frequency range 30 MHz to 300 MHz, measured typically by vertical dipole or vertical biconical antenna. The loading of the substation shall be at least 15 % of the rated load during the measurements. The centre of the antenna shall be 3 m above ground.

d) the maximum radio emission at a frequency in the neighbourhood of 350 MHz (selected on site to avoid other transmissions), measured typically by vertical polarised log-periodic antenna, noting the orientation of the antenna. The loading of the substation shall be at least 15 % of the rated load. The centre of the antenna shall be 3 m above ground.

e) the radio emission over the frequency range 300 MHz to 1 GHz, be measured typically with the log-periodic antenna in the maximum orientation position as under d). The loading of the substation shall be at least 15 % of the rated load during these measurements. The centre of the antenna shall be 3 m above ground.

Annex B
(informative)

Background to the method of measurement

B.1 Introduction

This annex describes a method of measuring the electromagnetic noise emitted by a railway network when railway vehicles are moving on the network. Existing methods are not considered to be appropriate because the vehicles may be moving at significant speeds. A separate document (EN 50121-3-1) covers the case of stationary and slow moving vehicles. Both traction and trailer vehicles should be examined since the trailers may contain electric equipment which can emit noise. It is also necessary to test diesel traction vehicles since they may contain sources of radio emission. The method allows an assessment to be made of the disturbance which would be caused to other users of the electromagnetic spectrum. The document describes a reference method of measurement.

B.2 Requirement for a special method of measurement

For frequencies above 9 kHz, there is a standard method of measuring radio fields and this is described in EN 55016-1-1.

A railway network has particular features which make necessary the use of a special method of measurement. These features include a rapidly moving source and the possibility of radiation from the long antenna formed by the electrical supply conductors of an electrified railway.

The example given in Figure B.1 shows the time variation of emission from a moving train with many transient events.

This method of measuring railway noise does not follow the quasi-peak method of EN 55016-1-1 because measurements conducted on the basis of that method are not sufficient to enable the full extent of the disturbances affecting other systems in the vicinity to be identified. The method of EN 55016-1 is only designed to protect radio communication from interference and takes no account of electronic safety systems such as those used beside the railway track or at airports, where short-time transients may cause interference. If the EN 55016-1-1 method were to be selected as a basis for European Standards, it would still be necessary to apply peak detection methods to meet the needs of local industry and undertake realistic simulation exercises. In the case of railways, this need for double testing would lead to difficulties.

It appears difficult to establish an exact link between the values obtained with the peak and quasi-peak methods, in view of the fact that the disturbances created by the vehicle may be almost constantly sinusoidal at the working frequency of some of the on-board ground-to-train transmission equipment, or a series of repeated pulses for other sources, for example the pantograph/overhead line contact. However, in all cases, the value measured with a peak detection system will be greater than or equal to the value obtained with a quasi-peak system in accordance with EN 55016-1-1.

B.3 Justification for a special method of measurement

Fields are not measured using the method of EN 55016-1-1, but are made with peak detection within a short time window, 50 ms being recommended, at the selected frequency because :

- this gives a better representation of the effect on any system (electronic or computer), whereas the weighting principles applied with quasi-peak detection are only representative of interference in relation to radio transmission, the time window of 50 ms will capture the peak emission from a.c. railways which tends to occur at current reversals. On 16,7 Hz, these reversals are 33 ms apart and one will always be detected within the 50 ms window.

- it is also faster, for with some quasi-peak detector systems as much as 1 second is necessary because of the requirements of galvanometer-type instruments. This is far too long in the case of a moving train,
- it gives the maximum value that could be measured with the method of EN 55016-1-1 and is representative of the "worst possible case" for interference to radio transmission.

B.4 Frequency range

Although the railway vehicle and sliding contact current collection are also sources of noise above 1 GHz, the emission levels are low and attenuation with distance is high. Therefore no proposals are made at present for measurements above 1 GHz.

B.5 Comments to bandwidth

Bandwidths other than those given in 5.1.2 are available in suitable measuring equipment, such as 300 Hz for the 9 kHz to 150 kHz band, and 7,5 kHz or 10 kHz for 0,15 MHz to 30 MHz. In the 9 kHz to 150 kHz band, the bandwidth is small, but this is valuable since it improves the ability to find specific sources of noise. In the 0,15 MHz to 30 MHz range, the difference between 7,5 kHz, 9 kHz and 10 kHz will not be significant in terms of identification. If bandwidths other than those given above are used, the results shall be converted to the approved bandwidth on the basis that the noise is impulsive in nature

B.6 Accuracy of the measurement equipment

The accuracy value ± 4 dB given in 5.1.3 is chosen since it is known that a test repeatability of ± 10 dB or more is found for nominally similar conditions. The measuring sets defined in EN 55016-1-1 are very accurate but this accuracy is unreal when the emission varies so much between tests. The use of measuring apparatus of less accuracy may be permitted (sweep frequency analysers for example), where it has been verified that the results do not differ more than ± 4 dB from EN 55016-1-1 apparatus. Sweep analysers are available with peak and quasi-peak detection, and bandwidths given in EN 55016-1-1.

B.7 Antenna positions

There are options for choosing the distance of the antenna from the centre-line of the track. The usual distances used for radio frequency tests are 1 m, 3 m, 10 m and 30 m. A value of 1,0 m is impossible and if 3 m is chosen, there is a possibility that the vehicle body will have a very strong local effect and this may give a false impression of the field at greater distances. A distance of 10 m is preferred since, with an electric traction supply, the sliding contact is directly viewed by the antenna and body effects are less. Another standard distance is 30 m and this may be easier to provide at particular sites, but the signal strength is lower and local noise may make it more difficult to obtain values of railway noise. Hence, the distance selected for measurements is 10 m in relation to the centre line of the track on which the vehicles are running.

NOTE Steps should be taken to ensure that the measuring equipment and any associated power supply and apparatus does not affect the readings.

B.8 Conversion of results if not measured at 10 m

The values of n are based on observations made with overhead power lines and are for open country sites. In built-up urban areas, higher values of n will be found. The values of n listed in 5.1.6 are known to be adequately accurate since the value of n for 100 MHz was specifically measured for a railway and was found to be 1,25, for distances up to 100 m. EN 55022 uses -20 dB per decade of distance (n = 1), but this is a special case for a conducting ground plane.

When testing at 10 m, it is important to recall that the induction field and the radiation field have different characteristics near to the source. If the distance is small compared to the wavelength, the induction field will predominate. The position with respect to a point source at which these two fields have equal magnitudes is at a theoretical distance of (wavelength/2π). Hence, if 10 m is taken as the measuring distance, all tests below about 5 MHz are in the near field where the magnetic induction signal dominates. Results are then most accurately expressed in A/m. In the near field, the E field is low and is not usually a cause of disturbance. With an extended source such as a train, the near field zone may extend further than the “point source” theory would suggest.

For the purposes of this method, the ampere per metre fields are converted to volts per metre by multiplying by the impedance of free space (120 π ohm).

A single height is used for the dipole and log-periodic antenna since variable height cannot be used as is usual for emission testing.

The position of antennas in the middle between masts reduces the screening effect of the masts and the local transients due to sparking which are commonly found at the mast, where the mechanical impedance may change suddenly. Similarly, booster transformers, overlaps, section insulators, neutral sections and other major irregularities should be avoided.

B.9 Measuring scales

On the log scale: 1 µV/m is 0 dBµV/m and 1,0 V/m is 120 dBµV/m. (A similar relationship applies for µA/m and dBµA/m).

Limit values may be expressed in A/m and V/m and these can be derived as necessary.

Electrical field strength in dBµV/m = magnetic field strength in dBµA/m + 51,5 if the measurement is taken in the far field (51,5 = 20 $\log_{10}$(impedance of free space wave)).

B.10 Repeatability of results

A special problem with measurements of railway radio frequency emissions is that the source is moving along the railway. This makes it difficult to collect a large number of results from the trackside and it is therefore necessary to define the conditions for measurement so that some degree of repeatability can be achieved.

To reduce the chance that remote vehicles will produce significant emissions at the test point, by phenomena such as resonance, any other vehicles supplied on the same catenary or supply rail should be at sufficient distance from the test point. For catenary supply, a distance of 20 km is suggested and for supply rail systems a distance of 2 km.

Even under these conditions, substantial variation between test results is to be expected.

B.11 Frequency selection

Another consideration, due to the movement of the vehicle, is that measurements at different frequencies across the required range are difficult due to the short time of the test. Three methods can be used to allow sufficient data to be captured. Tests can be done at several selected frequencies during one train passage; a frequency sweep technique can be used during one train passage; or one frequency is measured for each passage, requiring many passages of the train.

To obtain short time windows, use can be made of computer driven measuring sets in which the frequency is reset and held only long enough to take a reading. This allows 5 or more frequencies per second to be measured. To give adequate cover of the spectrum, a minimum of at least three frequencies per decade should be examined.

In the range 9 kHz to 150 kHz, the traction equipment may be a source of noise at clearly identifiable frequencies. It is desirable that a search be made in this range to find these noise maxima and to measure at these frequencies. Note that radio signals from outside transmitters can be found, even at these low frequencies, and these should be identified and avoided. For frequencies above 150 kHz, it is not considered necessary to make a separate search for characteristic frequencies from the vehicle.
Another option would be to use fewer frequencies and assume a linear characteristic. However this linear assumption is not soundly based, since the vehicle may produce strong signals at a specific frequency and additionally the overhead may exhibit resonant behaviour. The use of three frequencies per decade is therefore the minimum requirement and it is advantageous if more frequencies can be used.

B.12 Railway conditions

B.12.1 Weather

When the railway is an outdoor network, weather will affect the level of radio noise which is produced. For HV power lines, the noise increases by about 20 dB during rain. With railways, the noise from the pantograph contact may reduce with rain, as the carbon film on the contact wire is removed, giving a closer contact between wire and pantograph. If ice has formed on the supply conductor, increased arcing will take place and give increased noise. If the wind velocity is high, the mechanics of the overhead conductor will be affected and the contact between wire and pantograph will be affected. The effect of weather on the emission of noise from railway vehicles is not yet fully understood.

B.12.2 Speed, traction power

To give some valid comparison, noise measurements of a moving vehicle shall be made under specified conditions when the vehicle is travelling at some selected proportion of its maximum speed and, if it is a traction vehicle, is delivering some selected proportion of its continuous rated power. Values for these proportions need to be selected and this process needs to take into account the operating envelope of the vehicle. An ideal provision is that the vehicle should operate at the condition which produces the maximum radio noise, but since there is as yet no method by which this can be defined, such a requirement is not used.

B.12.3 Multiple sources from remote trains

In real cases, more than one traction vehicle may be within the disturbance zone of an affected object. For the purpose of limits, the presence of "physically-remote but electrically-near" vehicles out of the test zone is regarded as insignificant when considering radio noise. This recognises that the sources are moving and that although the remote vehicles are sources of noise, the attenuation with distance for the higher frequencies is normally high. When fields at the lower frequencies of measurement are considered, the attenuation is low and all vehicles within the zone of influence (which may extend several km) can affect the noise level. The effect of addition is however within the repeatability error of the tests and the emission from a single train can be assessed against the limit.

B.13 Number of traction vehicles per train

When traction vehicles are coupled, the contact quality of the trailing pantographs can be disturbed and a higher noise emission may occur. If tests are to be done in the maximum train consist, with coupled vehicles, they should be the subject of a specific request. The permitted emission from this test shall take into account the fact that trains may operate in multiple and thereby generate more noise.

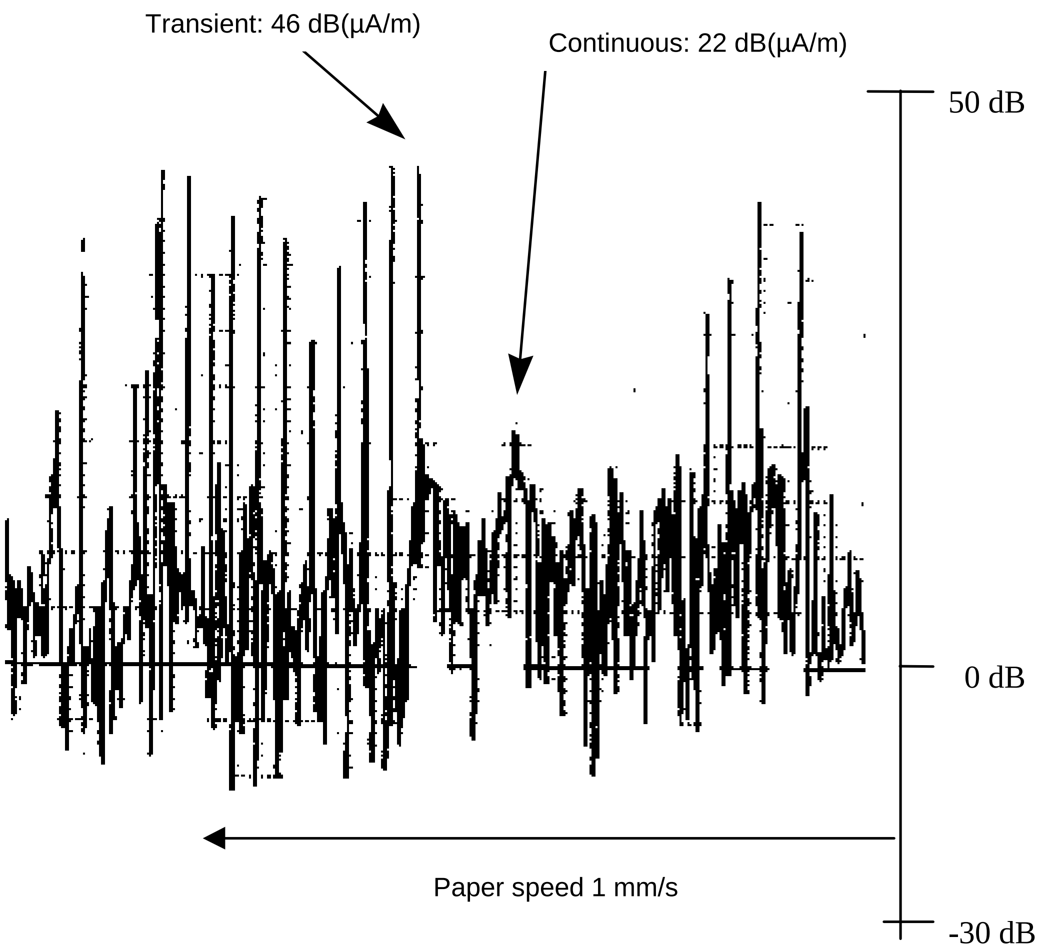


Figure B.1 - Time variation of emissions from a moving train with many transient events

Annex C
(informative)

Cartography - Electric and Magnetic fields at traction frequencies

Table C.1 gives typical numerical values of quantities describing the emission of the railway to the outside world (cartography).

The quantities given are the electric field E and the magnetic field H of the d.c. or the a.c. fundamental component, calculated for conductor arrangements regarded to be typical for the respective type of electrification.

Table C.1 - Typical maximum electric and magnetic field values at fundamental frequency of different electrification systems

(Calculated values for 10 m distance from the centre line of the nearest track, 1 m above rail level)

System	Freq.	E-field		H-field		Reference conditions	Reference documentation
	Hz	**(V/m)**	(dBμ**V/m**)	**(μT)**	(dBμ**A/m**)		
750 V to 1 200 V conductor rail	0	<10		46	151	*I*c = 4 000 A 50 % return current in rails	
600 V to 750 V catenary	0	35		15		*I*c = 1 000 A 50 % return current in rails	IEC 61000-2-7
1 500 V catenary	0	63	156	111	159	*I*c = 8 000 A U = 1 800 V No aerial wire	ITU(T) Directives CIGRE WG 3601
3 kV	0	50	154	28	147	*I*c = 3 000 A, U = 3,6 kV Aerial wire	ITU(T) Directives CIGRE WG 3601
15 kV	16,7	750	177	40	150	*I*c = 2 000 A, RMS U = 17,25 kV No aerial wire	ITU(T) Directives CIGRE WG 3601
25 kV	50	1 000	180	16	142	*I*c = 1 500 A, RMS U = 27,5 kV With feeder wire autotransformer	ITU(T) Directives CIGRE WG 3601

NOTE Double track assumed for calculation. Ic = current in one conductor rail or catenary of each track

The electric fields at harmonic frequencies (mainly third and fifth harmonic of a.c. supply frequency or 300 Hz and 600 Hz ripple of d.c. supply) may be in the order of 5 % of the fundamental.

The magnetic fields at a.c. harmonic frequencies range up to 10 % of the fundamental or up to 2% at 300 Hz and 600 Hz for d.c. systems.

The lateral decrease of the electric and of the magnetic fields may be assumed to decrease linearly with distance.

The magnetic field can be calculated linearly with the current.

Annex ZZ
(informative)

Coverage of Essential Requirements of EC Directives

This European Standard has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association and within its scope the standard covers all relevant essential requirements as given in Article 4 a) of the EC Directive 89/336/EEC.

Compliance with this standard provides one means of conformity with the specified essential requirements of the Directive concerned.

WARNING: Other requirements and other EC Directives may be applicable to the products falling within the scope of this standard.

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