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Railway applications — Electromagnetic compatibility

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

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CENELEC

European Committee for Electrotechnical Standardization
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European foreword

This document (EN 50121-2:2017) has been prepared by CLC/TC 9X, “Electrical and electronic applications for railways”.

The following dates are fixed:

• latest date by which this document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	[2017-11-07]
• latest date by which the national standards conflicting with this document have to be withdrawn	(dow)	[2019-11-07]

This document supersedes EN 50121-2:2015.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC shall not be held responsible for identifying any or all such patent rights.

EN 50121-2:2016 includes the following significant technical change with respect to EN 50121-2:2015:

a) deletion of Annex ZZ.

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

EN 50121, *Railway applications — Electromagnetic compatibility*, consists of the following parts:

— *Part 1: General*;

— *Part 2: Emission of the whole railway system to the outside world* [the present document];

— *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.*

1 Scope

This European Standard is intended to define the electromagnetic environment of the whole railway system including urban mass transit and light rail system. It describes the measurement method to verify the emissions, and gives the cartography values of the fields most frequently encountered.

This European Standard specifies the emission limits of the whole railway system to the outside world.

The emission parameters refer to the particular measuring points defined in Clause 5. 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 system may be affected by electromagnetic emissions and particular cases need to be considered individually.

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

For existing railway lines, it is assumed that compliance with the emission requirements of EN 50121-3-1, EN 50121-3-2, EN 50121-4 and EN 50121-5 will ensure the compliance with the emission values given in this part.

For newly built railway systems it is best practice to provide compliance to the emission limits given in this part of the standard (as defined in the EMC plan according to EN 50121-1).

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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 55016-1-4, *Specification for radio disturbance and immunity measuring apparatus and methods — Part 1-4: Radio disturbance and immunity measuring apparatus — Antennas and test sites for radiated disturbance measurements (CISPR 16-1-4)*

IEC 60050-161, *International Electrotechnical Vocabulary. Chapter 161: Electromagnetic compatibility*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purpose of this document, the terms and definitions given in IEC 60050-161 and the following apply.

3.1.1
apparatus
device or assembly of devices which can be used as an independent unit for specific functions

[SOURCE: IEC 60050-151:2001, 151-11-22]

3.1.2
environment
surroundings in which a product or system exists, including air, water, land, natural resources, flora, fauna, humans and their interrelation

[SOURCE: IEC Guide 109:2012, 3.3]

[SOURCE: IEC 60050-901:2013, 901-07-01]

3.1.3
railway substation
installation whose main function 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

3.1.4
rolling stock
all the vehicles with or without one or more motors

[SOURCE: IEC 60050-811: CDV2015, 811-02-01]

3.2 Abbreviations

For the purposes of this document, the following abbreviations apply.

AC	alternating current
bw	band width
DC	direct current
E	electric (field)
EMC	Electromagnetic Compatibility
FFT	Fast Fourier transform
H	magnetic (field)
HV	high voltage

4 Emission limits

4.1 Emission from the open railway system during train operation

The emission limits in the frequency range 150 kHz to 1 GHz are given in Figure 1 and the measurement method is defined in Clause 5.

Annex B 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 manager.

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

There may be cases in which radio or other railway external services with working frequencies below 150 kHz are in operation close to the railway system. The EMC management plan covers these cases and an adequate level of emission from the railway system on these working frequencies may be found in the values given in informative Annex C hence no guarantee can be given for an undisturbed operation.

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 Clause 5 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 from 150 kHz to 30 MHz	9 kHz
frequencies above 30 MHz	120 kHz

The distance of 10 m defined in Clause 5 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.

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

There may be cases in which radio or other railway external services with working frequencies below 150 kHz are in operation close to the railway substation. The EMC management plan covers these cases and an adequate level of emission from railway substation on these working frequencies may be found in the values given in informative Annex C hence no guarantee can be given for an undisturbed operation.

5 Method of measurement of emission from moving rolling stock and substations

NOTE The method of measurement is adapted from EN 55016–2–3 to a railway system with moving rolling stock and substations. The background to the method of measurement of moving rolling stock is given in Annex A.

5.1 General and specific measurement parameters

5.1.1 General measurement parameters

5.1.1.1 Frequency bands

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

These are:

Frequency bands:	0,15 MHz to 30 MHz	30 MHz to 300 MHz	300 MHz to 1 GHz
Bandwidth:	9 kHz	120 kHz	120 kHz

Other bandwidth for peak measurement can be chosen according to EN 55016-1-1. Data measured with the reference bandwidth shall take precedence.

5.1.1.2 Measurement uncertainty

The measurement uncertainty of the measuring equipment shall comply with the requirements in EN 55016-1-1 and EN 55016-1-4.

Due to the measurement method, the normalized site attenuation may not be considered in the measurement uncertainty.

5.1.1.3 Types of antennas

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

— for 150 kHz to 30 MHz, a loop or frame antenna is used to measure H field (see Figure 3);

— for 30 MHz to 300 MHz, a biconical dipole is used to measure E field (see Figure 4);

— for 300 MHz to 1,0 GHz, a log-periodic antenna is used to measure E field (see Figure 5).

For measurements in the frequency range of 30 MHz to 1 GHz a combined antenna may be used.

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

5.1.1.4 Measurement distance and height

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

The preferred distance of the measuring antenna while measuring the emission of the substation is 10 m from the outer fence of the substation, at the midpoints of the three sides, excluding the side which faces the railway system, 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.

Where the antennas are not at 10 m, the results can be converted to an equivalent 10 m value by using the following formula:

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

where

E_{10} is the value at 10 m

E_x is the measured value at D m

n is a factor taken from Table 1 below.

Table 1 — Conversion factor *n*

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.

No measurements are necessary for total underground railway systems with no surface operation (no victim outside this railway system can be affected).

The height above reference 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 measuring antenna above 30 MHz. One measuring height within the given range is sufficient and it is not required to do measurements with several antenna heights within this range. The selected height shall be noted in the test report.

The reference level for the substation is the ground.

The reference level for moving trains is the top of the rail.

If the actual level of the ground at the antenna differs from the top of the rail by more than 0,5 m, the actual value shall be noted in the test report.

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

5.1.1.5 Values of measurement

The values measured are expressed as:

— dBμA/m for magnetic fields,

— dBμV/m for electric fields.

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

5.1.1.6 Antenna position and orientation

The plane of the loop antenna shall be positioned to measure the horizontal component of the magnetic field perpendicular to the track respectively to the wall of the substation. 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 polarization signal, with the antenna directed towards the track respectively to the wall of the substation.

The test locations should whenever possible avoid objects with changing of field characteristic like turnouts, walls and under bridges.

Figures 3, 4 and 5 show the positions and vertical alignments of the antennas as an example for measurements at the track.

5.1.1.7 Ambient noise

At the beginning and at the end of the test series the ambient noise shall be recorded.

If at specific frequencies or in specific frequency ranges the ambient noise is higher than the limit values less 6 dB, the measurements at these frequencies need not be considered. These frequencies shall be noted in the test report.

5.1.2 Measurement parameter for moving trains

This subclause summarizes the specific conditions for the measurement of moving rolling stock.

— It is not considered necessary to carry out two tests to examine both sides of the rolling stock, even if it contains different apparatus on the two sides, as in the majority of cases the level of fields is due to the radiation of catenary and not to the direct radiation from the train. For systems with a third rail, measurements shall be performed at the same side of it.

— 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.

— 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.

— 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 top of the rail. The conversion formula in 5.1.1.4 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 railway systems. Full details of the test configuration shall be noted in the test report.

— If tests are being carried out on a railway system with overhead electrified supply, the measuring point shall be at midspan between the support masts of the overhead contact line and not at a discontinuity of the contact wire. It is recognized 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 shall be noted in the test report.

The radio frequency emission will be affected by the state of the railway system 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 system 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.

— 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 installed well away from reflecting objects. If HV 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.

5.1.3 Measurement parameter for railway substations

This subclause summarizes the specific conditions for the measurement of substations.

— Test configurations: In view of the special geometry of a railway system traction supply system, it is necessary to perform the measurement of emission of electromagnetic fields under normal feeding configuration of the traction supply system.

— 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.

— Each measurement shall be started with a peak max hold sweep. If the limits are exceeded due to the substation then it is required to take a measurement from a quasi-peak over the specific frequency range where these limits have been overrun. It is known that the load condition cannot be reproduced exactly during quasi-peak measurement hence these load conditions should be at least comparable.

5.2 Acquisition methods

5.2.1 General

The electromagnetic disturbances generated by railway network including operating rolling stock are measured by the two following methods:

1) the fixed frequency method;

2) the frequency sweeping method.

The measurement method shall be chosen according to the rolling stock operating modes (see 5.4.2) depending on the train speed.

— For test at high speed the following shall be taken into account.

The fixed frequency method can be used because it allows continuous monitoring at each frequency.

Alternative methods are allowed if the equivalent scan rate is at least that defined in Table 2 which is sufficiently short for such a moving source.

This ensures that the frequency results are measured at least every 5 m of train movement.

At higher speeds a spectrum analysis swept frequency method is unlikely to be practical but FFT techniques may be feasible. The measurement equipment shall comply with EN 55016-1-1.

Table 2 — Scan rate

km/h	m/s	time in s for an observation width of 5 m (scan rate)
60	16,67	0,300
100	27,78	0,180
200	55,56	0,090
300	83,33	0,060
320	88,89	0,056
NOTE Observation width is the part of rolling stock to be observed in given time.		

— When the rolling stock will be moving at a slower speed with the maximum rated power (see 5.4.2) the frequency sweeping method shall be used.

5.2.2 Fixed frequency method

The fixed frequency method consists of measuring the radiated emissions at only some frequencies (it is recommended to take at least 3 frequencies per decade) using the zero span mode of the spectrum analyser or setting the measuring receiver at the frequency to be checked.

The fixed frequencies shall be chosen according to the ambient noise, i.e. in the areas where the ambient field is the lowest.

The measurement of the field level shall be performed for each frequency during a complete passage of the train.

5.2.3 Frequency sweeping method

For the frequency scanning technique, the frequency range shall be divided into several sub-ranges according to the train speed in order to have a relevant sweep time in comparison with the train speed.

The measurement of the field level shall be performed in each sub-range during a complete passage of the train. The max-hold function of the spectrum analyser shall be used.

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 minimize the possible effect of weather on the measured values, measurements should be carried out in dry weather, (after 24 h during which not more than 0,1 mm rain has fallen), with a minimum temperature of 5 °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 be carried out in the weather conditions found. In these circumstances, the actual weather conditions shall be recorded with the test results.

5.4.2 Railway system 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.

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;

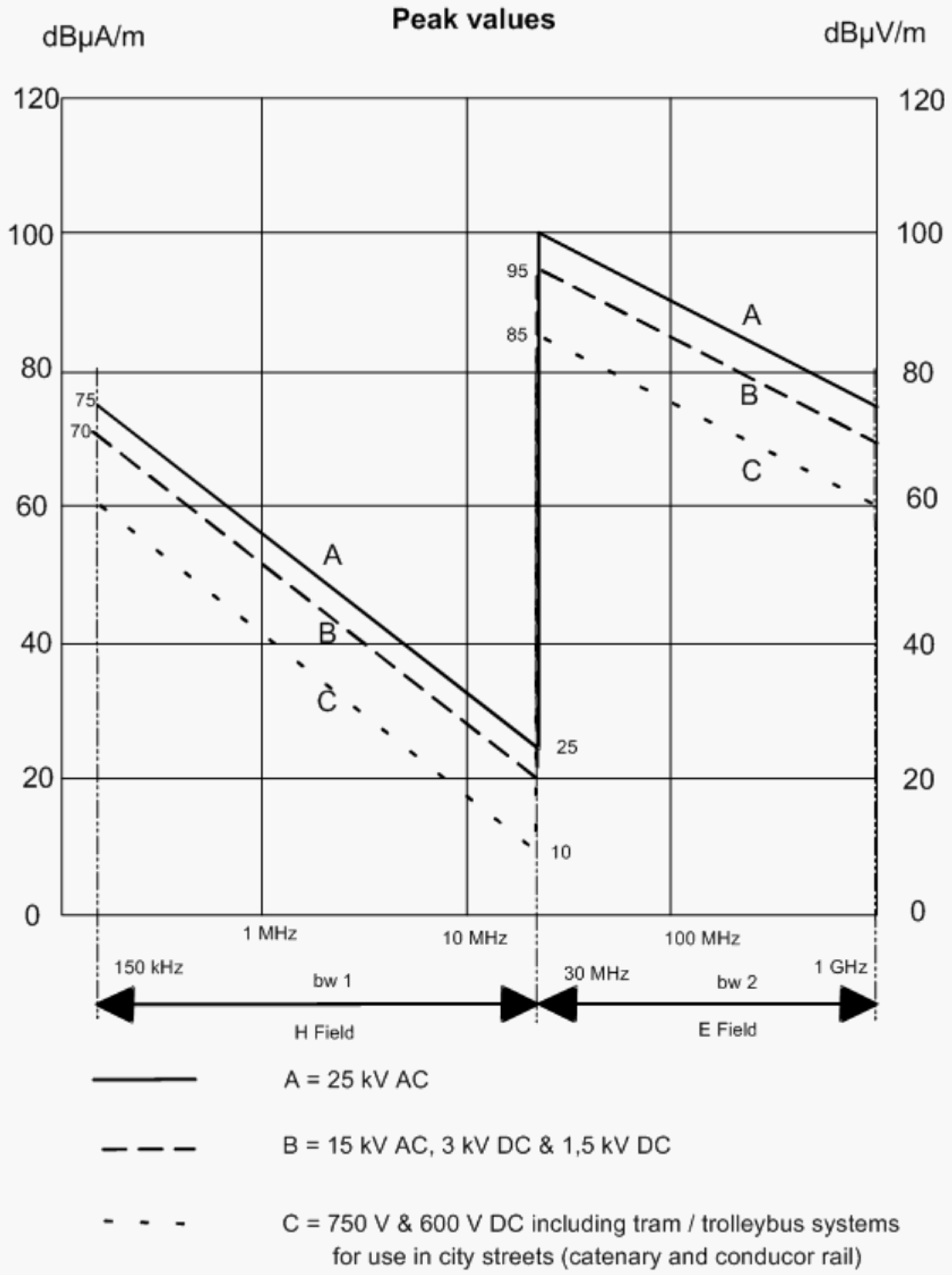
— description of railway vehicle (type, configuration and mode of electric braking);

— numerical results;

— graphical results where relevant (the results shall include information such as bandwidths, date, time, ambient noise and excluded frequencies (see 5.1.1.7));

— weather conditions;

— name(s) or equivalent identification of person(s) authorizing the test report.



Values are 10 m from the railway track

Figure 1 — Emission limits in frequency range 150 kHz to 1 GHz

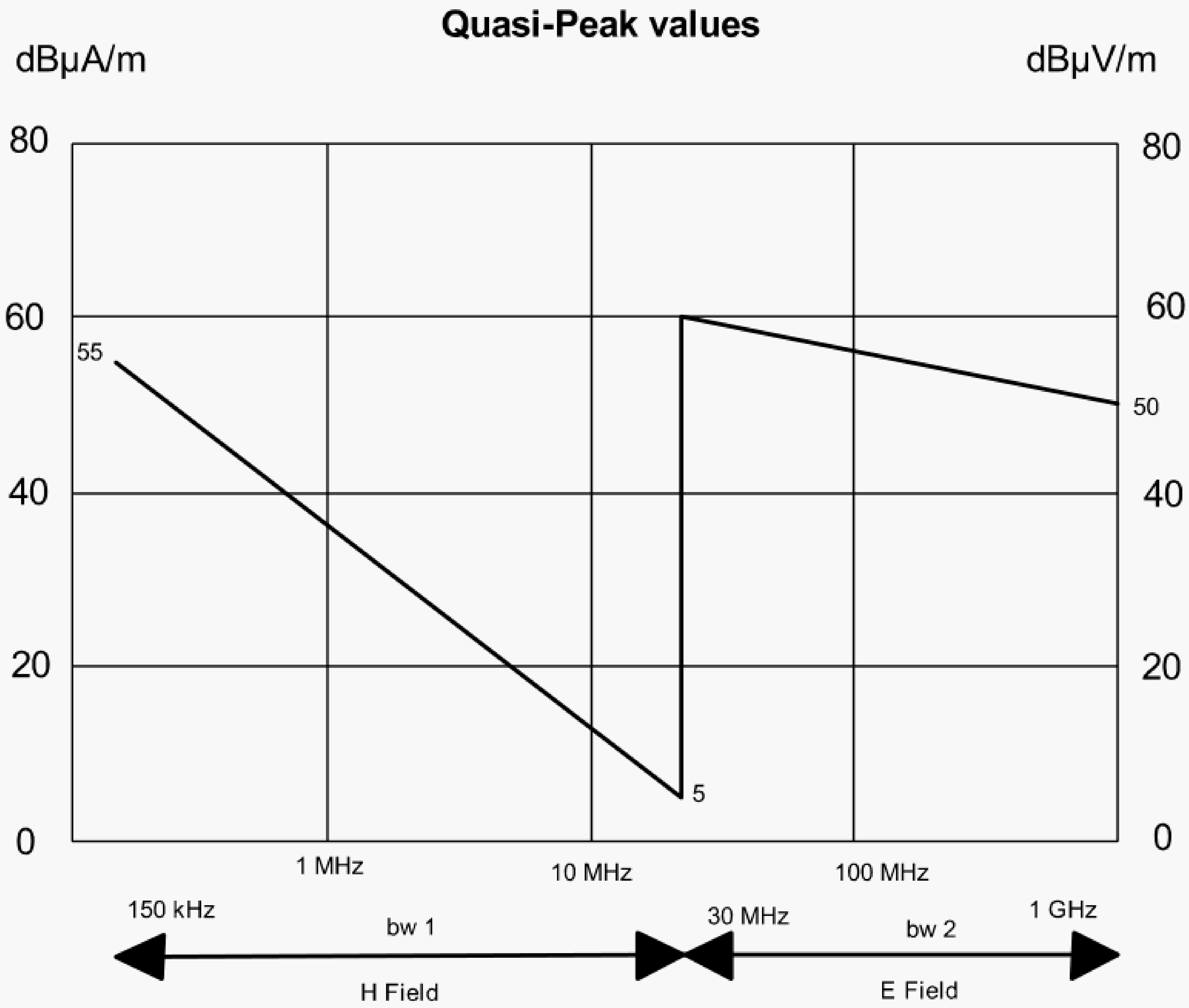


Figure 2 — Emission limit for substations

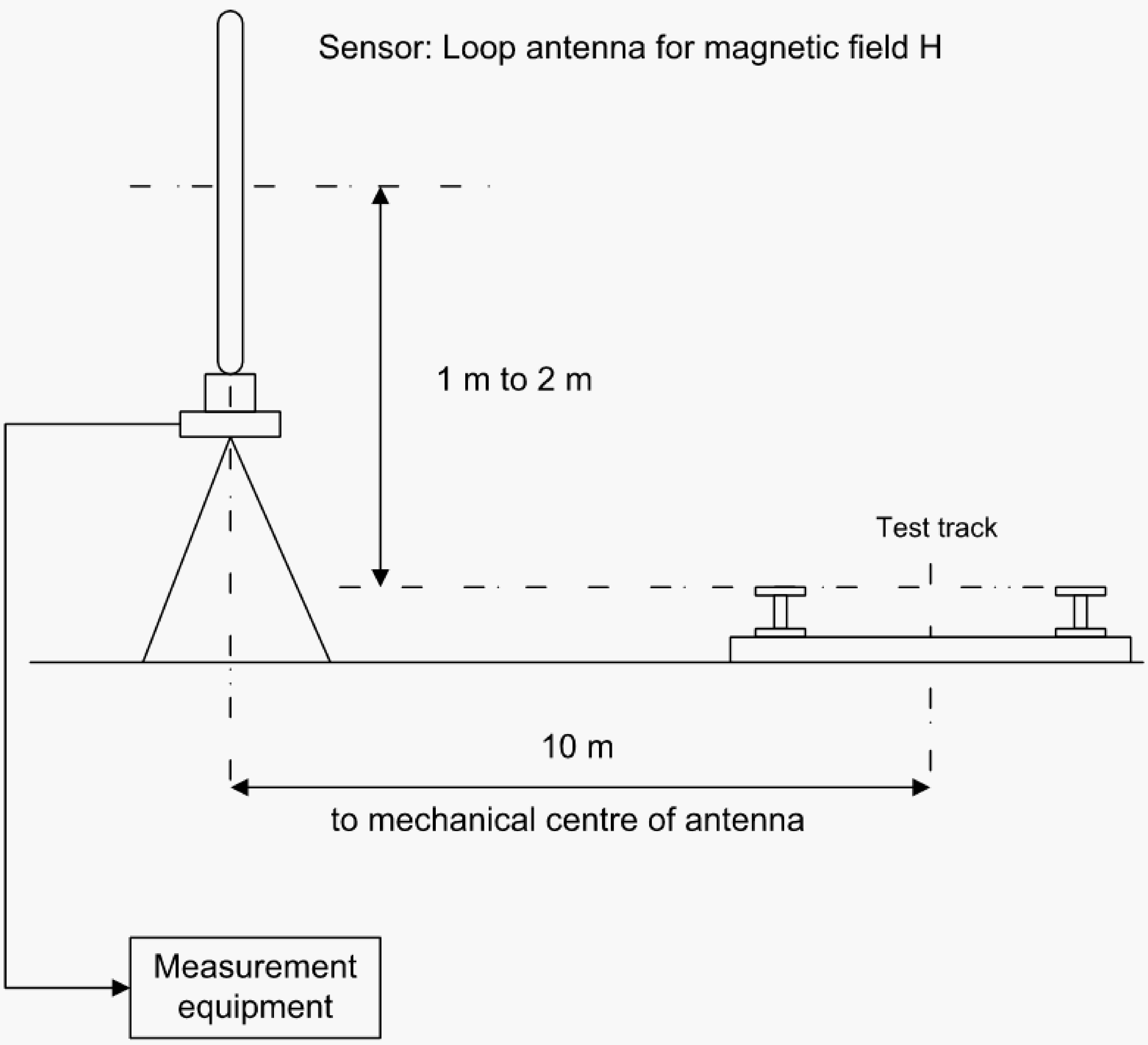


Figure 3 — Position of antenna for measurement of horizontal component of magnetic field in the 150 kHz to 30 MHz frequency band

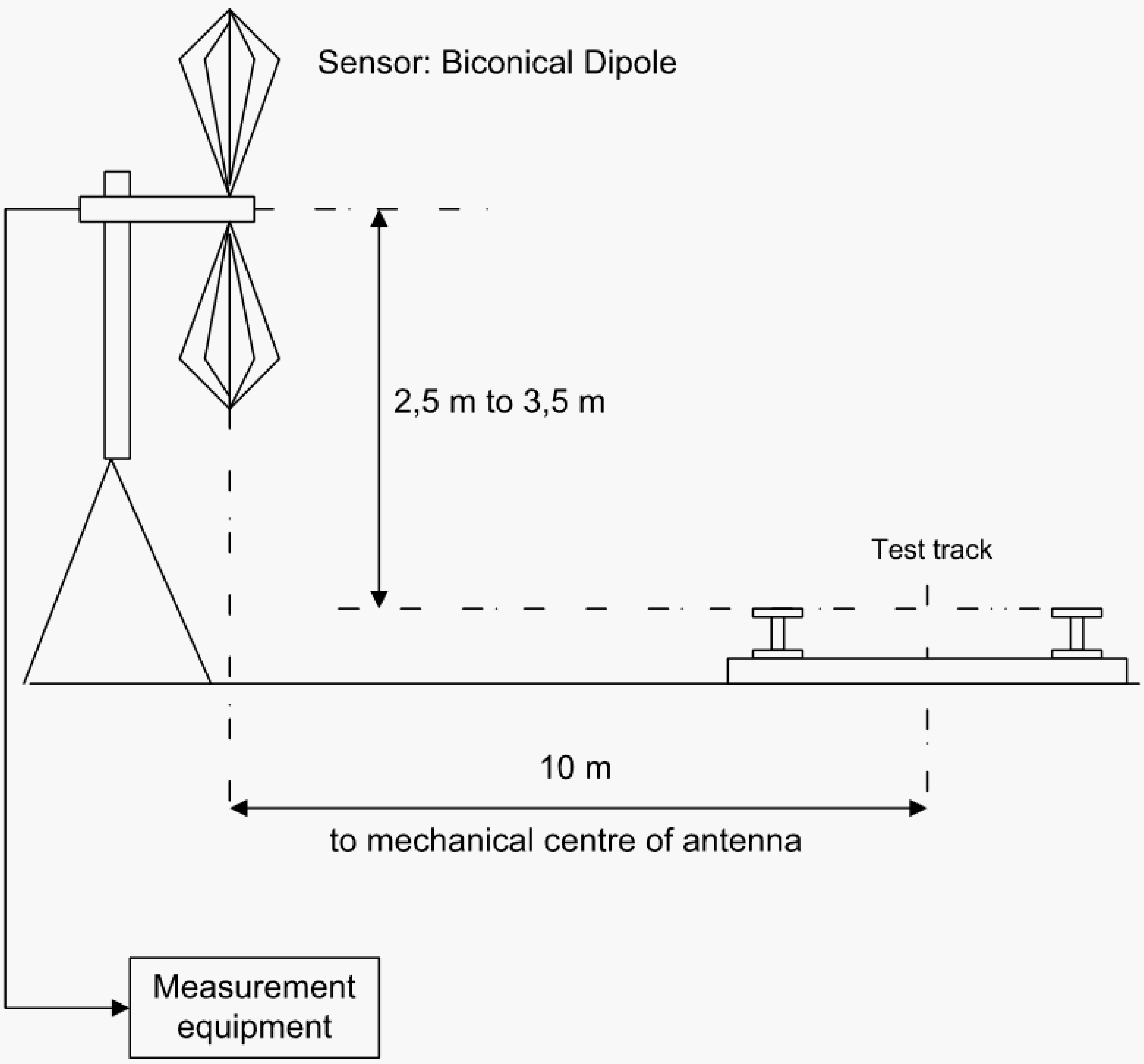


Figure 4 — Position (vertical polarization) of antenna for measurement of electric field in the 30 MHz to 300 MHz frequency band

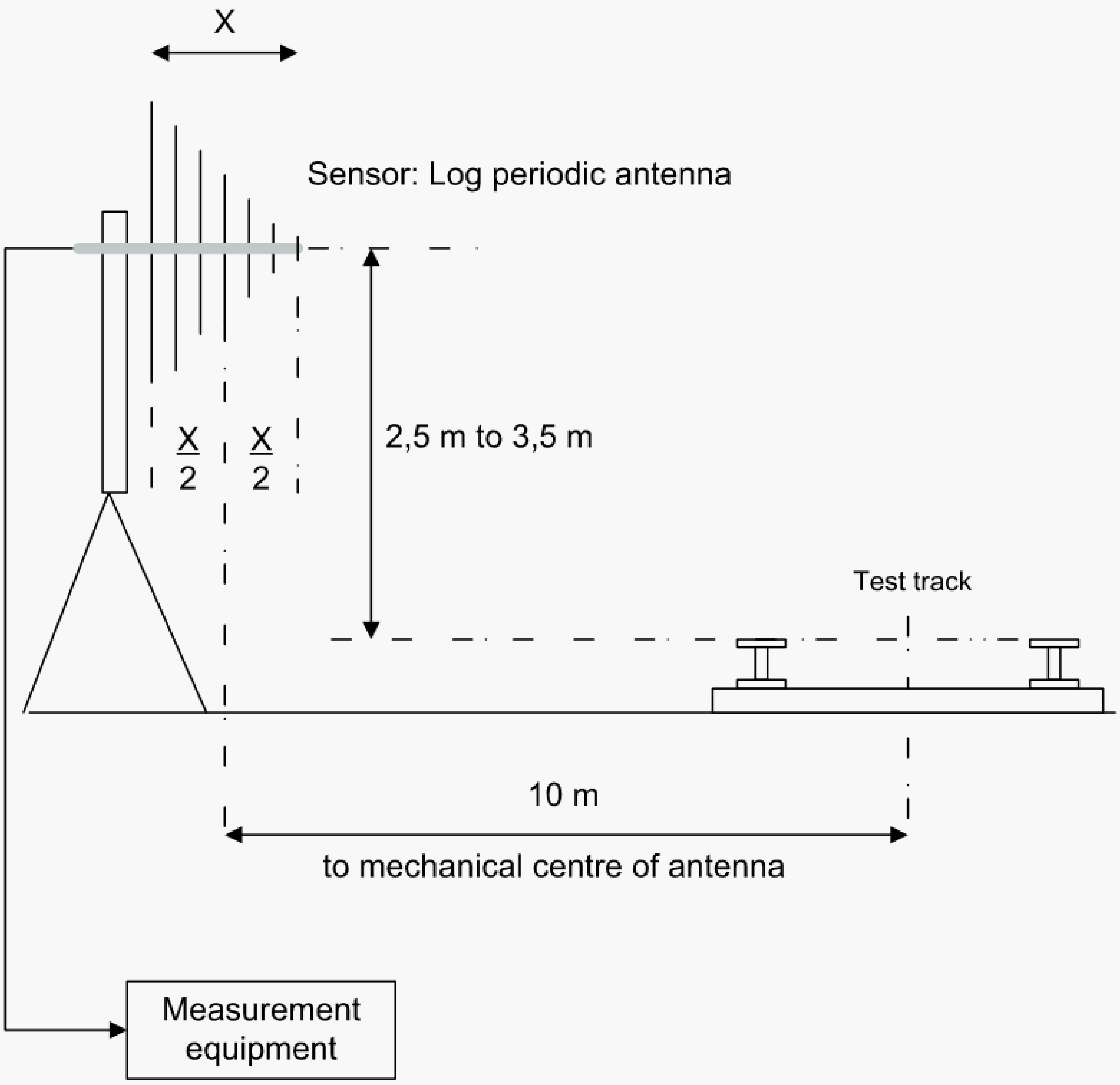


Figure 5 — Position (vertical polarization) of antenna for measurement of electric field in the 300 MHz to 1 GHz frequency band

Annex A
(informative)

Background to the method of measurement

A.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.

A.2 Requirement for a special method of measurement

For frequencies above 150 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 system.

This method of measuring railway system noise does not always use the quasi-peak method of EN 55016-1-1 because measurements conducted on the basis of that method are not sufficient (due to the moving source) to enable the full extent of the disturbances affecting other systems in the vicinity to be identified.

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.

A.3 Justification for a special method of measurement

Fields are not measured using the method of EN 55016-1-1, but 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 AC railway systems 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 some quasi-peak detector systems up to 1 s 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.

A.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 for measurements above 1 GHz.

A.5 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 system 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.

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

A.6 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. The values of n listed in 5.1.1.4 are known to be adequately accurate since the value of n for 100 MHz was specifically measured for a railway system and was found to be 1,25, for distances up to 100 m.

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.

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.

A.7 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)).

A.8 Repeatability of results

A special problem with measurements of railway system radio frequency emissions is that the source is moving along the railway system. 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.

A.9 Railway system conditions

A.9.1 Weather

When the railway system 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 railway systems, 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.

A.9.2 Speed, traction power

To give some valid comparison, noise measurements of a moving vehicle are 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.

A.9.3 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 recognizes 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.

A.10 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.

Related to the permitted emission from this test, it shall be mentioned that trains may operate in multiple and thereby generate more noise.

Annex B
(informative)

Cartography — Electric and Magnetic fields at traction frequencies

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

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

Table B.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 top of the rail)

System	**Freq.**	**E-field**		**H-field**		**Reference conditions**	**Reference documentation**
	Hz	**(V/m)**	**(dBµV/m)**	**(µT)**	**(dBµA/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/TR 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 36.01
3 kV	0	50	154	28	147	*I*c = 3 000 A, U = 3,6 kV Aerial wire	ITU(T) Directives CIGRE WG 36.01
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 36.01
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 36.01

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 AC supply frequency or 300 Hz and 600 Hz ripple of DC supply) may be in the order of 5 % of the fundamental.

The magnetic fields at AC harmonic frequencies range up to 10 % of the fundamental or up to 2 % at 300 Hz and 600 Hz for DC 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 C
(informative)

Emission values for lower frequency range

In the early 1990s measurements of emission from railway systems and vehicles in railway systems were undertaken to get information about the values to be expected in the neighbourhood of railway systems. It was particularly noted that the results of magnetic field measurements, at 10m distance, gave a poor reproducibility for frequencies below 150 kHz due to several reasons.

Due to the large variation in measured value (up to 20 dB) on the same vehicle depending on the location and other circumstances the reproducibility could not be achieved and its usefulness is in question.

Since these emission values were published in the first editions of EN 50121-2 the graphs are shown in this informative annex without being a requirement to be fulfilled.

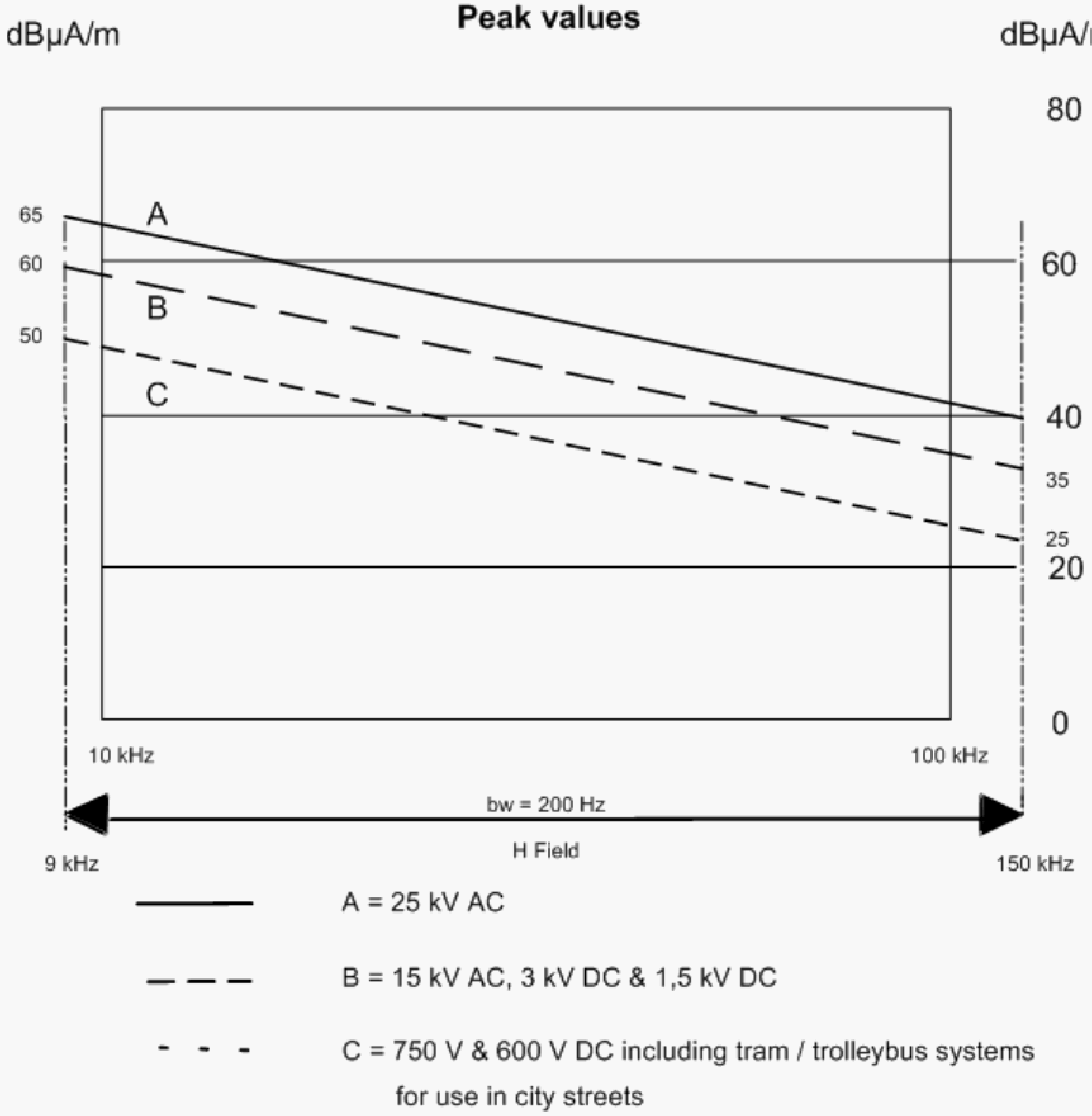


Figure C.1 — Emission values for the open railway system route

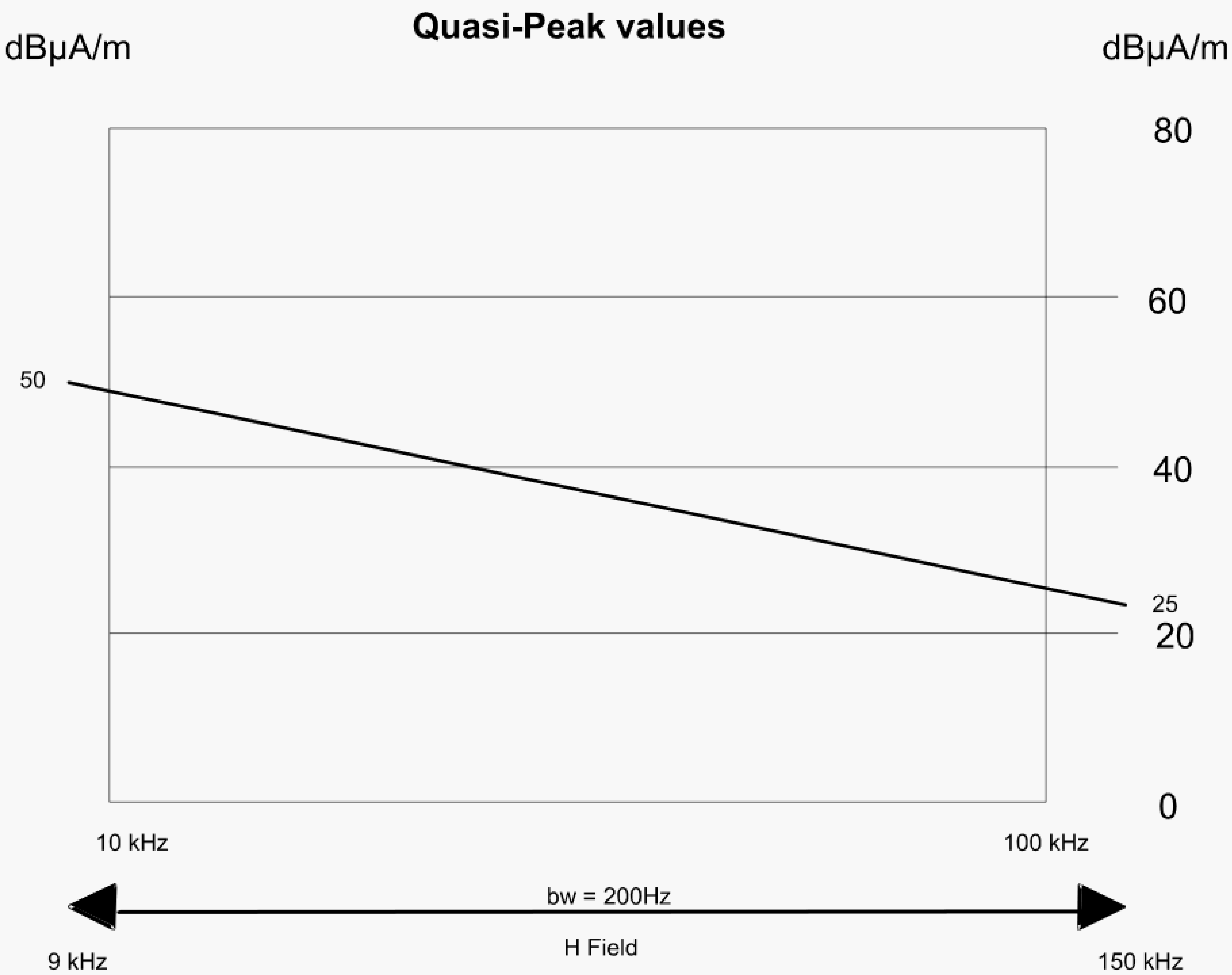


Figure C.2 — Emission values for railway substations

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[9] IEC/TR 61000–2–7, *Electromagnetic compatibility (EMC) — Part 2: Environment — Section 7: Low frequency magnetic fields in various environments*

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