CISPR PAS 39

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PUBLICLY AVAILABLE SPECIFICATION

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INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

Electromagnetic compatibility (EMC) – Conducted emission requirements on the low voltage AC mains port in the frequency range 9 kHz to 150 kHz for equipment intended to operate in residential environments

CISPR PAS 39:2024-10(en)

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Electromagnetic compatibility (EMC) – Conducted emission requirements on the low voltage AC mains port in the frequency range 9 kHz to 150 kHz for equipment intended to operate in residential environments

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Conducted emission requirements on the low voltage AC mains port in the frequency range 9 kHz to 150 kHz for equipment intended to operate in residential environments

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The text of this Publicly Available Specification is based on the following documents:

Draft	Report on voting
CIS/H/505/DPAS	CIS/H/517/RVDPAS

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

The language used for the development of this Publicly Available Specification is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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- withdrawn, or
- revised.

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INTRODUCTION

This PAS complements IEC 61000-6-3:2020 by the addition of the following:

- addition of normative requirements for conducted emissions at the low voltage AC mains port in the frequency range 9 kHz to 150 kHz;
- addition of an informative annex providing background information on the normative limits;
- addition of an informative annex with recommendations to limit the spectral density of non-intentional emissions (NIE).

The technical content of this PAS was derived from a fragment of the maintenance of IEC 61000-6-3 and, as CIS/H/459/CDV, this fragment received 100 % support from the National Committees.

This PAS is published due to the urgent market needs for these requirements.

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Conducted emission requirements on the low voltage AC mains port in the frequency range 9 kHz to 150 kHz for equipment intended to operate in residential environments

1 Scope

This document is applicable to electrical and electronic equipment within the scope of IEC 61000-6-3:2020, for which no relevant dedicated product or product family EMC emission standard has been published.

It defines low voltage AC mains conducted emission requirements in the frequency range 9 kHz to 150 kHz which are considered essential and have been selected to provide an adequate level of protection to both radio reception and Mains Communicating Systems (MCS) in the defined electromagnetic environment.

The emission requirements in this document are not intended to be applicable to the intentional transmissions and their harmonics from a radio transmitter as defined by the ITU.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

NOTE The normative references in this clause are identical to those published in IEC 61000-6-3:2020.

CISPR 16-1-1:2019, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-1: Radio disturbance and immunity measuring apparatus – Measuring Apparatus*

CISPR 16-1-2:2014, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-2: Radio disturbance and immunity measuring apparatus – Coupling devices for conducted disturbance measurements*
CISPR 16-1-2:2014/AMD 1:2017

CISPR 16-2-1:2014, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 2-1: Methods of measurement of disturbances and immunity – Conducted disturbance measurements*
CISPR 16-2-1:2014/A1:2017

IEC 61000-6-3:2020, *Electromagnetic compatibility (EMC) – Part 6-3: Generic standards – Emission standard for equipment in residential environments*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61000-6-3:2020 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1.1

primary function

any function of an EUT considered essential for the user or for the majority of users

Note 1 to entry: An EUT can have more than one primary function. For example, the primary functions of a basic television set include broadcast reception, audio reproduction and display.

3.1.2

UPS function

power supply function, that provides power during unintentional AC mains power supply interruptions

3.1.3

adjustable speed electric power drive function

a power drive system function that provides adjustable speed AC or DC motor drives and can convert input and/or output voltages (line-to-line voltage).

3.2 Abbreviated terms

For the purposes of this document, the abbreviated terms given in IEC 61000-6-3:2020 and the following apply.

AC	Alternating Current
ACEC	Advisory Committee on Electromagnetic Compatibility
AMN	Artificial Mains Network
AP	Allowance Probability
AV	Average
BPSK	Binary Phase-Shift Keying
CF	Coupling Factor
CF(E)	Electric field Coupling Factor
CF(H)	Magnetic field Coupling Factor
CISPR	International Special Committee on Radio Interference
CM	Common Mode
DC	Direct Current
DM	Differential Mode
EMC	Electro-Magnetic Compatibility
EUT	Equipment Under Test
FS	Field Strength
FSFI	Free Space Field Impedance
FSK	Frequency-Shift Keying

H-Field	Magnetic Field
IEC	International Electrotechnical Commission
ISO	International Standards Organization
IVL	Integral Voltage Level
LED	Light Emitting Diode
LF	Low Frequency
MCE	Mains Communicating Equipment
MCS	Mains Communicating System
NEC2	Numerical Electromagnetics Code 2
NIE	Non-Intentional Emission
OFDM	Orthogonal Frequency-Division Multiplexing
RFI	Radio Frequency Interference
PR	Protection Ratio
QP	Quasi-Peak
UPS	Uninterruptible Power Systems
V-AMN	Artificial Mains V-Network
VLF	Very Low Frequency

4 General

The requirements specified in this document are applicable to an equipment intended to operate in the residential environment. For any additional information needed to assess emissions according to Table 1, refer to IEC 61000-6-3:2020.

5 Documentation for the user

In addition to the requirements specified in Clause 6 of IEC 61000-6-3:2020, the instructions for use of the equipment shall include, where relevant, the notification required by footnote [a] to Table 1.

6 Emission test details

The requirements in Table 1 shall apply.

The following shall be taken into account during the application of the measurements defined in Table 1:

- At transitional frequencies, the lower limit applies.
- Where the limit value varies over a given frequency range, it changes linearly with respect to the logarithm of the frequency.

Table 1 – Requirements for conducted emissions, low voltage AC mains port in the frequency range 9 kHz to 150 kHz

Measurement network	Frequency range MHz	Limits dB(µV)	Measurement specifications	Limitations and restrictions
		Detector		
V-AMN	0,009 to 0,05	120,5 to 110 Quasi-peak	Instrumentation, CISPR 16-1-1:2019, Clauses 4, 5 and 7 Networks, CISPR 16-1-2:2014 and CISPR 16-1-2:2014/AMD1:2017, Clause 4 Method, CISPR 16-2-1:2014 and CISPR 16-2-1:2014/AMD1:2017, Clause 7 Set-up, CISPR 16-2-1:2014 and CISPR 16-2-1:2014/AMD1:2017, Clause 7	None
	0,05 to 0,15	104 to 80 [a] Quasi-peak		

NOTE See Annex A for background information about the normative limits, including recommendations related to the limit application in the frequency range 9 kHz to 150 kHz, and Annex B for recommendations to improve compatibility with MCE by additional assessments.

[a] For equipment with a primary function according to 3.1.2 (UPS function) or 3.1.3 (adjustable speed electric power drive function), the following limits can be applied: 110 dB(µV) to 82,5 dB(µV). When these relaxed limits are applied, it shall be recorded in the test report and a notification shall be added in the user manual of the equipment. The notification shall state that such equipment has a higher risk of interference, and specific measures might be required for its installation and operation, or it can be necessary to disconnect the equipment.

Annex A
(informative)

Background information on the normative limits in the frequency range 9 kHz to 150 kHz

A.1 Derivation of the normative limits

The starting point for the derivation of limits in the frequency range 9 kHz to 150 kHz for residential environment are the compatibility levels contained in IEC 61000-2-2:2002, IEC 61000-2-2:2002/AMD1:2017 and IEC 61000-2-2:2002/AMD2:2018.

The compatibility levels have been defined in the frequency range from 9 kHz to 150 kHz, after long controversial discussions in IEC SC77A, under direct supervision of ACEC, to improve EMC for equipment such as mains communicating systems, electricity meters and clocks supplied by public low voltage AC mains supply systems against disturbances generated by equipment such as switching power converters, switch mode power supplies, photovoltaic inverters, etc.

As explained in Annex D of IEC 61000-2-2:2002, IEC 61000-2-2:2002/AMD1:2017 and IEC 61000-2-2:2002/AMD2:2018, the defined compatibility level curve represents the best currently achievable compromise supported by all stakeholders and has been defined for voltage distortion in differential mode.

The task to derive emission limits from these compatibility levels has been given to a joint working group between CISPR H and IEC SC77A with the following terms of reference:

- Developing equipment emission limits in the frequency range 9 kHz to 150 kHz to accommodate the latest amendments to IEC 61000-2-2 for this frequency range.
- Developing the methodology for emission measurements against the newly developed limits, possibly using measuring equipment and methods from the CISPR 16 series for both differential mode and common mode disturbances. The suitability of the methodology shall be shown.
- Preparing appropriate implementation in standards, i.e. proposing an amendment to the generic standard – which has a pilot function for the product standards – and preparing the implementation into Product/Product Family standards.

Measurements in the 9 kHz to 150 kHz frequency range have been based on the established quasi-peak detector in a 200 Hz bandwidth, as defined in CISPR 16-1-1:2019, with the measuring methods specified in the CISPR 16 series. Accordingly, the same measuring equipment can be used to evaluate both the protection requirements for MCS and the protection requirements for radio services.

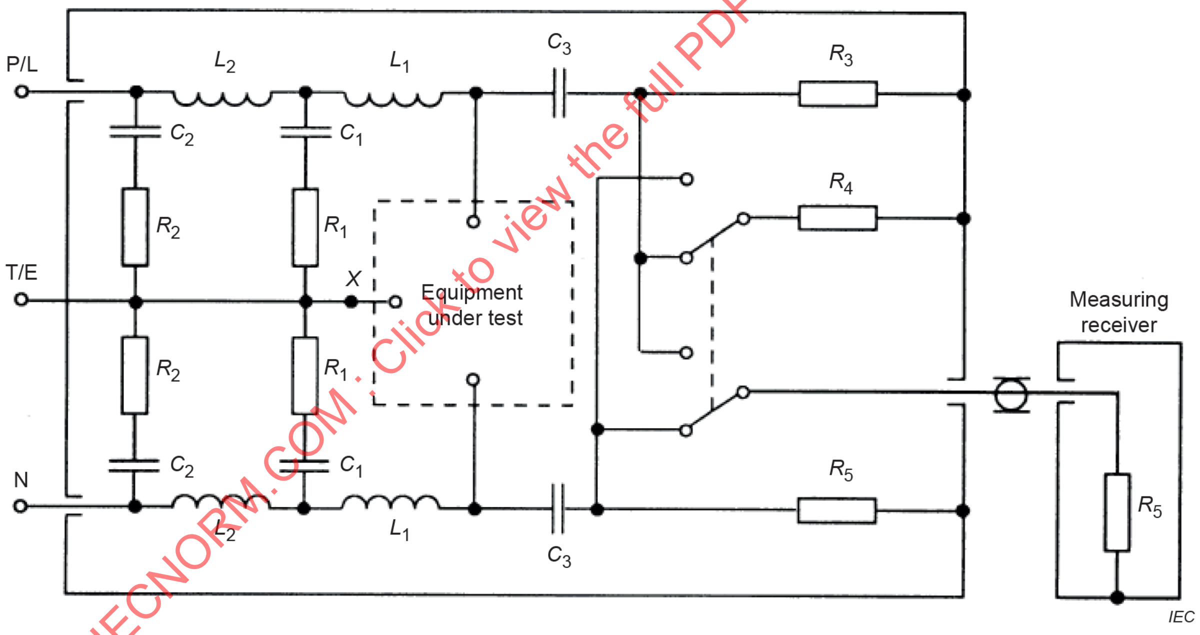
Since the CISPR method is based on the measurement of unsymmetrical voltages (i.e. voltage referenced to earth using the V-AMN, see Figure A.1), the calculation of the limit values is based on the recommendations from the Note in 4.12.1 of IEC 61000-2-2:2002, IEC 61000-2-2:2002/AMD1:2017 and IEC 61000-2-2:2002/AMD2:2018, which is quoted as follows.

NOTE Based on the following assumptions, an emission margin equal to or higher than 3 dB between the equipment emission limits in differential mode for non-intentional emissions and the corresponding compatibility levels, or a difference equal to or higher than 9 dB (3 dB for the emission margin +6 dB for the conversion factor between the unsymmetrical voltages and the voltage in differential mode) between the equipment emission limits for unsymmetrical voltage distortion and the compatibility levels in differential mode given in 4.12.2 and 4.12.3, is sufficient:

- for each bandwidth of 200 Hz, the probability that the compatibility level is exceeded is lower than 5 %;
- at a given location, the disturbance level in a same bandwidth of 200 Hz does not result from more than two pieces of equipment generating non-intentional emissions close to the emission limit at the same time;
- non-intentional emissions from different equipment are generated independently from each other.

The 6 dB conversion factor is based on the very worst-case assumption that the EUT produces only differential mode emission. The compatibility levels in IEC 61000-2-2:2002, IEC 61000-2-2:2002/AMD1:2017 and IEC 61000-2-2:2002/AMD2:2018 are given only for symmetrical voltage (line to neutral) and in this case the measured unsymmetrical voltage is only half of a hypothetically produced 100 % symmetrical disturbance voltage. In reality, the unsymmetrical voltage is made by the combination of both differential mode and common mode disturbance voltages. Accordingly, the fixed 6 dB conversion factor gives an additional margin for the protection of mains communicating systems.

In summary, the normative limits for unsymmetrical voltage in the frequency range 9 kHz to 150 kHz have been set 9 dB lower than the compatibility levels for this frequency range, as suggested in IEC 61000-2-2:2002, IEC 61000-2-2:2002/AMD1:2017 and IEC 61000-2-2:2002/AMD2:2018.



SOURCE: CISPR 16-1-2:2014 and CISPR 16-1-2:2014/AMD1:2017, Figure 5.

Figure A.1 – Example of a V-AMN

Footnote a in Table 1 gives a slight relaxation of the limits for some equipment. This relaxation of the limits is based on the assumption that all such equipment is not used by more than 5 % of all customers connected to the same medium voltage / low voltage transformer. In case of interference generated by equipment, using this relaxation, the connection of such equipment might be restricted, for example by the distribution system operator.

For equipment widely used in household environment and consequently expected to be present in a high percentage of residential installations and with several units per installation (e.g. lighting equipment), in the frequency range 50 kHz to 150 kHz, it is recommended to apply a quasi-peak limit decreasing linearly with the logarithm of the frequency from 90 dB(μV) at 50 kHz to 80 dB(μV) at 150 kHz, in line with existing limits for lighting equipment in CISPR 15:2018.

A.2 Radio protection analysis

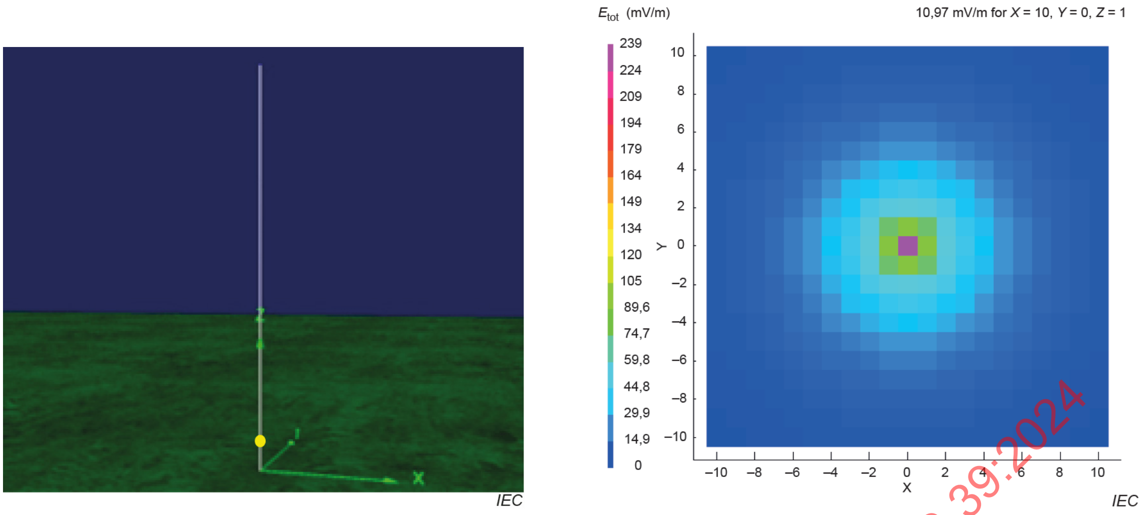
A.2.1 General

As explained in detail, the limits in the frequency range 9 kHz to 150 kHz were derived from the compatibility levels in IEC 61000-2-2:2002, IEC 61000-2-2:2002/AMD1:2017 and IEC 61000-2-2:2002/AMD2:2018 for protection of MCS operation. Additionally, those limits are also intended to protect radio reception in that frequency range. Therefore, the following considerations do not derive a whole new set of limits, but model the field strength expected at the frequencies of radio services at the given protection distance, when radio frequency emission having an amplitude equal to the limits specified in this document is injected into the mains grid and radiated by the cables of the grid. Since the V-AMN does not separate common and differential mode disturbance voltages, for these calculations, it is assumed that the measured value from the V-AMN is based on a disturbance voltage from the EUT, produced either 100 % in common mode or 100 % in differential mode. This would represent the worst case for each analysis.

A.2.2 Radio protection analysis for common mode disturbance injections

A.2.2.1 Derivation of coupling factor by simulation

For the case at hand, a conducted limit line shall be derived based on the protection requirements of the radio services given in field strength values in the requested protection distance (which for residential environments is a distance of 10 m). At first a representative radiation model shall be defined. In a residential environment, electronic or electrical devices are typically connected to some wire in the house and will via connection to the installation topology around the house (including all possible directions) finally terminate in the circuit breaker box. From the viewpoint of which cable topology would possibly have the maximum radiation efficiency, a vertical wire (i.e. a vertical antenna) would represent the worst case of a possible common mode radiator. With respect to the length of such a wire, a length of 30 m is estimated as the worst case in typical residential environments. Therefore, the coupling factor for a 30 m long vertical antenna (see Figure A.2) was chosen to represent the worst possible coupling situation for common mode injection. Any real installation, where the low voltage line would take a respective path around the house connecting power outlets, switches, lamps and other appliances, would radiate less than the scenario chosen.



a) Simple vertical wire fed with 1 V CM voltage at the yellow dot

b) Electric field strength distribution in 1 m height

Figure A.2 – Worst case common mode radiator for residential environment

A simulation with a finite momentum solver NEC2 for the several frequencies and a feed of 1 V of CM voltage at the bottom of the structure results in the coupling factor values shown in Table A.1 and Figure A.3. The value of 1 V is chosen for simplicity, as this calculation is only meant to determine the CF of the radiating structure, which is the ratio of the field strengths and the injected radio frequency voltage. As two different field types are emitted, a coupling factor is needed for both electric *CF*(E) and magnetic *CF*(H) fields. The latter can be converted to units of the electrical field in order to compare their magnitude.

Table A.1 – Simulation results for the coupling factor for both field types

Frequency MHz	***CF*(H)** 1/Ω/m	**FSFI** 1/m	***CF*(E)** 1/m	**Maximum *CF*** 1/m
0,009	$4{,}28 \times 10^{-6}$	$1{,}61 \times 10^{-3}$	0,013 3	0,013 3
0,010	$3{,}89 \times 10^{-6}$	$1{,}47 \times 10^{-3}$	0,013 3	0,013 3
0,020	$2{,}23 \times 10^{-6}$	$8{,}41 \times 10^{-4}$	0,013 3	0,013 3
0,030	$1{,}80 \times 10^{-6}$	$6{,}79 \times 10^{-4}$	0,013 3	0,013 3
0,040	$1{,}68 \times 10^{-6}$	$6{,}33 \times 10^{-4}$	0,013 3	0,013 3
0,050	$1{,}69 \times 10^{-6}$	$6{,}37 \times 10^{-4}$	0,013 3	0,013 3
0,060	$1{,}75 \times 10^{-6}$	$6{,}60 \times 10^{-4}$	0,013 3	0,013 3
0,070	$1{,}86 \times 10^{-6}$	$7{,}01 \times 10^{-4}$	0,013 3	0,013 3
0,080	$1{,}98 \times 10^{-6}$	$7{,}46 \times 10^{-4}$	0,013 3	0,013 3
0,090	$2{,}12 \times 10^{-6}$	$7{,}99 \times 10^{-4}$	0,013 3	0,013 3
0,100	$2{,}27 \times 10^{-6}$	$8{,}56 \times 10^{-4}$	0,013 3	0,013 3
0,110	$2{,}43 \times 10^{-6}$	$9{,}16 \times 10^{-4}$	0,013 3	0,013 3
0,120	$2{,}59 \times 10^{-6}$	$9{,}76 \times 10^{-4}$	0,013 3	0,013 3
0,130	$2{,}76 \times 10^{-6}$	$1{,}04 \times 10^{-3}$	0,013 3	0,013 3
0,140	$2{,}95 \times 10^{-6}$	$1{,}11 \times 10^{-3}$	0,013 3	0,013 3
0,150	$3{,}17 \times 10^{-6}$	$1{,}20 \times 10^{-3}$	0,013 3	0,013 3

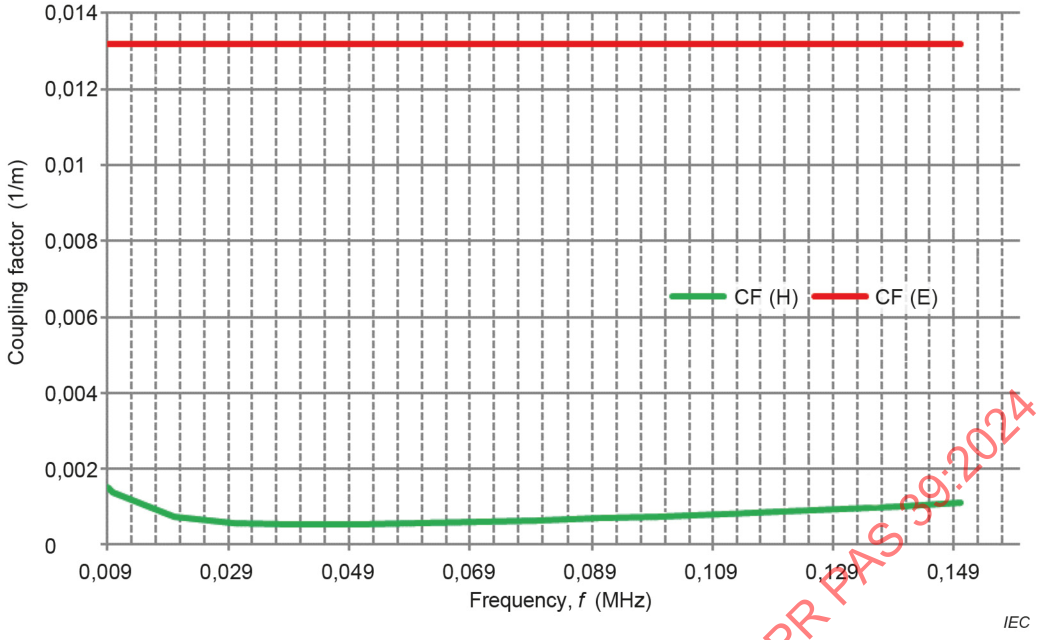


Figure A.3 – Simulation results for the coupling factor for both field types

The coupling factors were calculated by finding the maximum field strengths on a cylinder with radius of 10 m (protection distance) and a height of 30 m divided by the feed voltage of 1 V. The cylinder is emulating the use of a turntable in a typical EMC measurement, which however in the case at hand is not necessary as the chosen object is of rotational symmetry. The *CF* for the magnetic field is multiplied by the free space field impedance ("FSFI" in Table A.1), so both field types can be compared. As expected for a short (compared to the wavelength) wire antenna capacitive coupling prevails in the nearfield, and thus the maximum coupling is provided by the electrical field *CF*(E), compared to the magnetic field *CF*(H), for all frequencies in question.

Using the limits specified in Table 1 and the *CF*s derived above, the disturbance field strength which would be produced at the protection distance in the worst case can now be calculated. The results are given in Table A.2 and Figure A.4.

Table A.2 – Worst case disturbance field strength at 10 m distance

Frequency MHz	**Limit** dB(µV)	***CF*** 1/m	***CF*** dB(1/m)	**Electrical field** dB(µV/m)
0,009	120,5	$1,3 \times 10^{-2}$	-37,7	82,8
0,010	119,9	$1,3 \times 10^{-2}$	-37,7	82,2
0,020	115,6	$1,3 \times 10^{-2}$	-37,7	77,9
0,030	113,1	$1,3 \times 10^{-2}$	-37,7	75,4
0,040	111,4	$1,3 \times 10^{-2}$	-37,7	73,6
0,049	110,1	$1,3 \times 10^{-2}$	-37,7	72,4
0,050	104,0	$1,3 \times 10^{-2}$	-37,7	66,3
0,060	100,0	$1,3 \times 10^{-2}$	-37,7	62,3
0,070	96,6	$1,3 \times 10^{-2}$	-37,7	58,9
0,080	93,7	$1,3 \times 10^{-2}$	-37,7	56,0
0,090	91,2	$1,3 \times 10^{-2}$	-37,7	53,4
0,100	88,9	$1,3 \times 10^{-2}$	-37,7	51,1

Frequency MHz	**Limit** dB(µV)	***CF*** 1/m	***CF*** dB(1/m)	**Electrical field** dB(µV/m)
0,110	86,8	$1,3 \times 10^{-2}$	-37,7	49,1
0,120	84,9	$1,3 \times 10^{-2}$	-37,7	47,2
0,130	83,1	$1,3 \times 10^{-2}$	-37,7	45,4
0,140	81,5	$1,3 \times 10^{-2}$	-37,7	43,8
0,150	80,0	$1,3 \times 10^{-2}$	-37,7	42,3

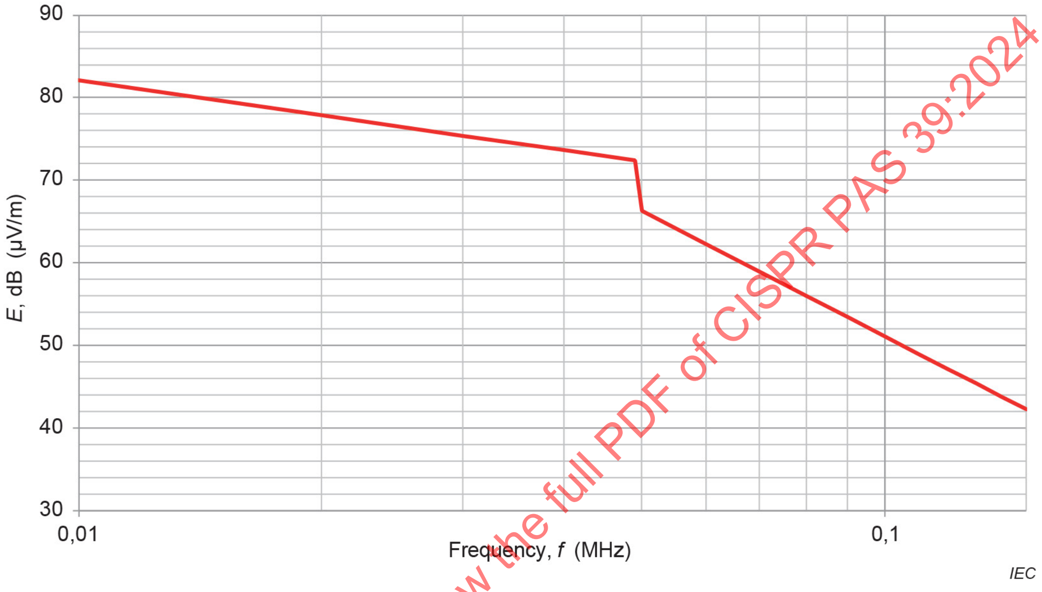


Figure A.4 – Worst case disturbance field strength at 10 m distance

A.2.2.2 Application of the disturbance model CISPR TR 16-4-4

Equation (37) from CISPR TR 16-4-4:2007, CISPR TR 16-4-4:2007/AMD1:2017 and CISPR TR 16-4-4:2007/AMD2:2020 is the basis for the limit calculation:

$$E_{\text{limit}} = \mu_{\text{w}} - R_{\text{p}} + \mu_{\text{p1}} + \mu_{\text{p2}} + \mu_{\text{p3}} + \mu_{\text{p4}} + \mu_{\text{p5}} + \mu_{\text{p6}} + \mu_{\text{p7}} + \mu_{\text{p8}} + \mu_{\text{p9}} + \mu_{\text{p10}} + t_{\beta} \times \sigma_{\text{i}} - t_{\alpha} \times \sqrt{\left(\sigma_{\text{p1}}^2 + \sigma_{\text{p2}}^2 + \sigma_{\text{p3}}^2 + \sigma_{\text{p4}}^2 + \sigma_{\text{p5}}^2 + \sigma_{\text{p6}}^2 + \sigma_{\text{p7}}^2 + \sigma_{\text{p8}}^2 + \sigma_{\text{p9}}^2 + \sigma_{\text{p10}}^2\right)} \quad (A.1)$$

This equation is based on ten probability factors P1 to P10 (μ_{P1} to μ_{P10} in Equation (A.1)) and parameters of the wanted signal μ_w and R_p, which are entries in the IEC Radio Services Database. Table A.3 describes the meaning of the probability factors, their values, the respective values for their variations and an explanation for the values, for those radio services in the database, which can be expected to be operated near products falling in the scope of this document.

The derivation of values for the probability factors from the model, described in CISPR TR 16-4-4:2007, CISPR TR 16-4-4:2007/AMD1:2017 and CISPR TR 16-4-4:2007/AMD2:2020 is debatable. Instead of fixed values for some of the probability factors a range of values between μPi_a and μPi_b (such as *i* takes one of the following values: 1, 4, 7 or 9, depending on targeted probability factor) has been given. Accordingly, also a range of values for the final results of the estimations has been given. Further considerations have not been necessary, because the application of the more stringent parameters showed, that the new limits proposed in this document for this frequency range are also sufficient for the protection of the radio services.

Table A.3 – Probability factors and respective rationales

Probability factor	**Meaning**	μ_{Pi} dB	σ_{Pi} dB	**Explanation**
P1a	Directivity source	0	0	Emitter at these wavelengths have no directivity as the antennas are always (short) monopole antennas.
P1b	Directivity source	6	0	The probability of having vertical wires and horizontal wires for emitting disturbances is about 50 %. Only vertical wires cause radiation, horizontal wires are attenuated by the earth.
P2a+b	Directivity victim	6	8	Time signal receivers usually use ferrite rod antennas with a dipole radiation pattern as described in CISPR TR 16-4-4:2007, CISPR TR 16-4-4:2007/AMD1:2017 and CISPR TR 16-4-4:2007/AMD2:2020, 5.6.5.2.1.2, leading to a directivity of 6 dB. The value for σPi is taken from the same clause as 8 dB.
P3a+b	Stationary	0	0	Time signal reception usually is stationary, as are ripple control receivers.
P4a	Frequency correlation	3	3	Typical emitters in this frequency range (e.g. LED lighting, switch mode power supplies) are broadband (including their harmonics and dithering) and usually affect many frequencies in the range 9 kHz to 150 kHz at the same time. It is estimated that about half of the frequency range is affected. The variance can reach from narrowband to full spread of the spectrum.
P4b	Frequency correlation	10	3	The practical experience of measuring EMC potential of typical electronic devices shows, that not more than 10 % of the spectrum is disturbed (including harmonics) by a noise level which almost reaches the level of the limit. The 10 dB are still very conservative.
P5a+b	Harmonics	0	0	The harmonics are considered under P4 already.
P6a+b	Disturbing signal produces significant effect	0	0	Typical disturbers in this frequency range are switched mode power supplies and alike, that generate a wide signal. In contrast time signals are very low in bandwidth, so it can be assumed, that the disturbance channel of the victim is always filled.
P7a	Time Correlation	13,8	0	Time signal receivers usually only synchronize once a day. Thus, reception of 1 hour out of 24 hours is sufficient.
		3	0	For the amateur radio service allocation it can be assumed, that only night time reception is worthwhile in the frequency range, thus leading to μ_{P7} of 3 dB.
P7b	Time correlation	30	5,5	Time signal receivers usually synchronize only once a day, one minute is sufficient for time signal reception. So a probability of one minute out of 24 h is assumed as 0,1 %.
		9	3	At 137 kHz there is also a radio service used by radio amateurs. It is assumed that a radio amateur is using his service not more than 3 h a day. Therefore the probability is 12,5 %.
P8a+b	Location correlation	3	3	It is assumed that every second household has a time signal receiver.
		60	3	For the amateur radio service allocation, it was assumed, that only one amateur among 1 000 people exists. Since the LF band is very special with respect to antenna construction, only about one in a thousand of amateurs actually use this band, leading to a μ_{P8} of 60 dB.

Probability factor	**Meaning**	μ_{Pi} dB	σ_{Pi} dB	**Explanation**
P9a	Edge of service	3	3	Long wave reception usually is ground wave propagation, thus a basic approximation could be based upon a simple circularly response and the ratio between the two different coverage areas.
P9b	Edge of service	10	3,2	The range of radio services, especially in the long wave range, can be assumed as a circular area. The further a receiver is away from the transceiver, the weaker the signal becomes. At a certain point of attenuation of the signal the receiver can be assessed as operated on the edge of the service. Time signal receivers have a coverage of round about 1 000 km. Receivers operated at a distance of more than 900 km are estimated to be at the edge of this service. Probability for a receiver to be within this edge can easily be calculated by the ratio of these two coverage areas. In this long wave time receiver situation a probability P9 of 20 % is calculated.
P10a+b	Building attenuation	0	0	Most time signal receivers are inside houses as are typical emitters. Thus, no building attenuation can be considered in this frequency range.

Radio services, that would be expected very far away from any product falling in the scope of this document (passive lightning detectors, VLF and LF navigation and communication) are vastly predominated by location correlation. Receivers of those services are at least 1 000 m away from any disturber. Considering a signal attenuation of at least 20 dB/decade, the location correlation would allow at least 60 dB allowance of probability.

Equation (A.1) is applied to all radio applications listed in the database to calculate the maximum tolerable noise levels and the required field strength limits, including consideration of the probability factors, the radio sensitivity and the protection ratio. Table A.4 provides a summary of these calculations and includes the sum of the probability factors, known as the allowance probability AP.

In the following Table A.4, the following radio services are not considered relevant because there is no planned reception in the residential locations:

- Passive lightning locators
- VLF Navigation (Alpha)
- VLF Marine (communication)
- LF Marine communication

Additionally, the historic VLF transmitter is not considered relevant, because it transmits only 2 days per year.

Table A.4 – Calculations of the required field strength limit

Radio service	Frequency		Sensitivity	PR	Location	Tolerable noise	Method a		Method b	
	Start	Stop					AP	FS Limit	AP	FS Limit
	kHz	kHz	dB(μV/m)	dB		dB(μV/m)	dB	dB(μV/m)	dB	dB(μV/m)
Standard frequency and Time signal service	19,95	20,05	60	12	Worldwide	48	21	69	56	104
	39	41	60	12	Japan	48	21	69	56	104
	49,25	50,75	60	12	Russia	48	21	69	56	104
	59	61	60	12	UK, USA, Japan	48	21	69	56	104
	65,85	67,35	60	12	Russia	48	21	69	56	104
	68,25	68,75	60	12	China	48	21	69	56	104
	77,25	77,75	60	12	Germany	48	21	69	56	104
	99,75	102,5	60	12	China	48	21	69	56	104
LF fixed land based	129,1	139	60	12	Germany, Hungary	48	21	69	56	104
Amateur radio	135,7	137,8	-17	10	Worldwide	-27	65	38	70	43

NOTE The field strengths for both methods in Table A.4 were calculated using Equation (A.1) and the values provided in Table A.3, while $t\alpha$ and $t\beta$ are 0,84, while σi was set to zero, not considering any measurement variation. On Figure A.5, the middle point of the frequency service is used.

To investigate whether the proposed limit is able to protect the respective radio application, the field strength limits shall be compared to the derived limit line from A.2.2.1, which is shown in Figure A.5.

Each green or blue dot represents a radio applications tolerance value for protection. As long as the service can tolerate a higher disturbance field strength than produced by the product (green or blue dot above the limit line) the application is protected against such a scenario. This is true for most of the radio applications. Two standard frequency and time signal services and the amateur radio service are 6 dB to 8 dB below the line. However, considering the worst-case approximation of the coupling factor, a good protection should be provided for those as well.

Although this evaluation applying the introduced model for the common mode coupling situation is based on various input parameters and contains statistical processes it leads to calculated limit values comparable to the proposed limits in the frequency range 9 kHz to 150 kHz. With respect to CISPR TR 16-4-4:2007, CISPR TR 16-4-4:2007/AMD1:2017 and CISPR TR 16-4-4:2007/AMD2:2020, 5.3.6.3, the working group found consensus on the limit line depicted as a red line in Figure A.5. The final conclusion for common mode disturbance injections is, that the new limits proposed in this document are also acceptable for the protection of radio services.

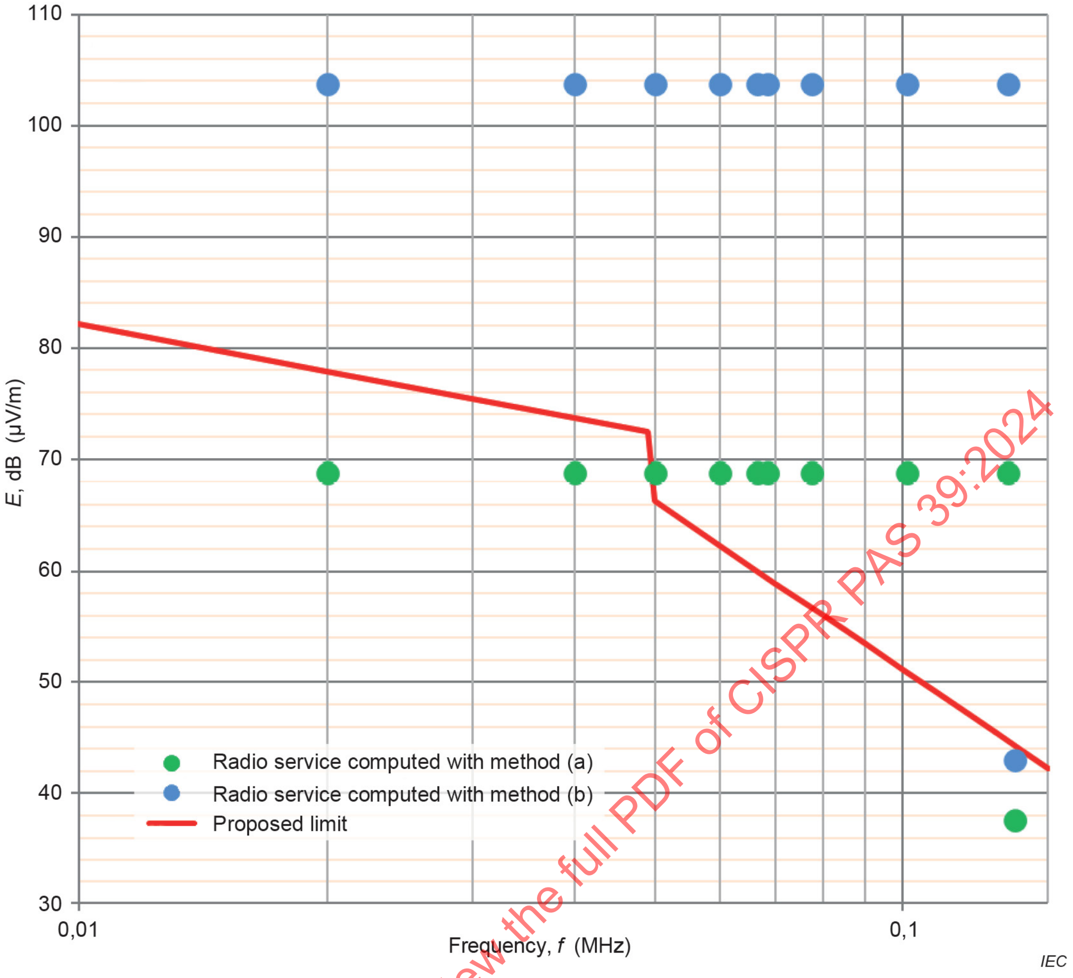


Figure A.5 – Proposed field strengths limits compared to protection needs of radio applications

A.2.3 Radio protection analysis for differential mode disturbance injections

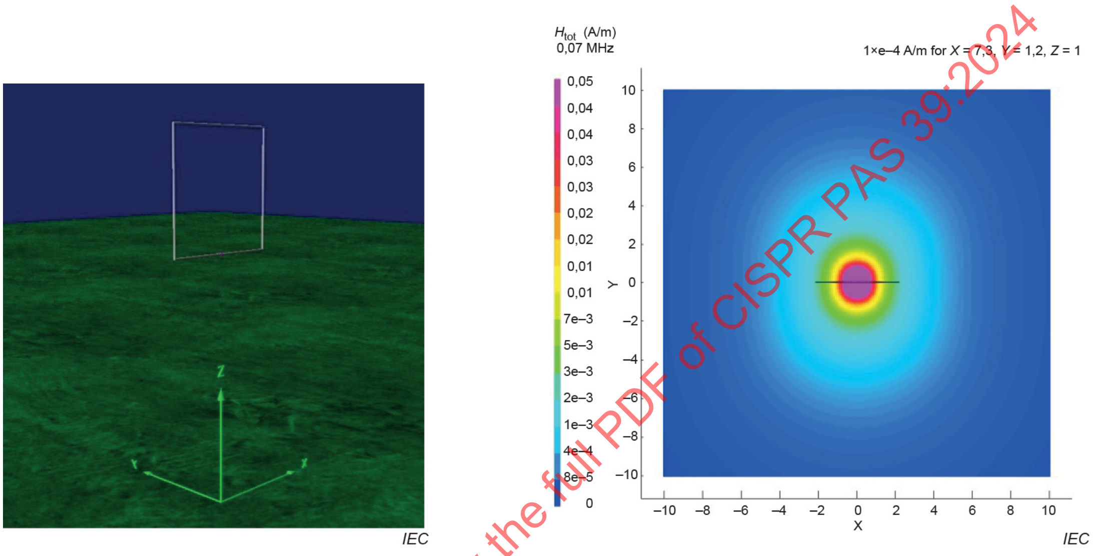
A.2.3.1 Derivation of coupling factor by simulation

Generally, a differential mode source in a mains line system can cause significant field strength values in the vicinity or at greater distance due to two different phenomena.

One effect is that some of the differential mode energy is coupled to common mode current by mode conversion. Those conversions can happen, if significant phase shifts to the parallel running wires of a house installation appear. For example, this can occur at a typical light switch, where the phase is led through the switch and thus introduces an asymmetry in cable length to the system. But due to the fact that the smallest wavelength (for 150 kHz) is two kilometers, typical length differences in residential areas are much smaller and the effect of this coupling method for this frequency range is negligible.

The second phenomenon however has the capability to have a significant impact. If a differential mode signal is coupled into a cable topology presenting loop-shaped sections, the opposing currents within such loops will no longer cancel out each other and their magnetic field components will thus provide a residual disturbing magnetic field. That kind of loops could occur around a circuit breaker box or other installations inside houses in residential areas.

To investigate this effect with respect to radio protection, a model is needed as well as a respective coupling factor between the disturbance current and the magnetic field at the protection distance (which for residential environments is a distance of 10 m). For this investigation three different square-shaped current loops are used. The side length of the loops are 20 cm, 50 cm and 100 cm and they are mounted vertically with their centre at a height of 1,3 m above a conducting ground (see Figure A.6). The loops are fed with 1 A of differential mode current and the maximum of magnetic field strength values is determined on a cylinder surface with a radius of 10 m (protection distance) and a height of 15 m. To calculate the coupling factor the detected maximum field strength is divided by the feed current of 1 A. The simulation was performed with a finite momentum solver NEC2 for several relevant frequencies. Figure A.6 also shows the field strength distribution at 70 kHz for a 50 cm square-shaped wire loop at a height of 1 m.



a) Simple 50 cm loop fed with 1 A DM current (feeding point is the pink dot)

b) Magnetic field strength distribution at 1 m height

Figure A.6 – Worst case differential mode radiator for residential environment

The resulting coupling factors are shown numerically and graphically in Table A.5 and Figure A.7. It should be noted, that the coupling does not change over frequency, because the loop size is very small against the wavelength and thus the current in the loop never significantly changes phase angle. The larger the loop area, the stronger the coupling becomes. This shall be considered, when the worst-case selection is revisited for final approval of the model.

Table A.5 – Calculations of the required field strength limit

	20 cm	**50 cm**	**100 cm**	**20 cm**	**50 cm**	**100 cm**
Frequency MHz	***CF*(H)** 1/m	***CF*(H)** 1/m	***CF*(H)** 1/m	***CF*(H)** dB(1/m)	***CF*(H)** dB(1/m)	***CF*(H)** dB(1/m)
0,009	$1,33 \times 10^{-5}$	$8,33 \times 10^{-5}$	$3,32 \times 10^{-4}$	-97,5	-81,6	-69,6
0,010	$1,33 \times 10^{-5}$	$8,33 \times 10^{-5}$	$3,32 \times 10^{-4}$	-97,5	-81,6	-69,6
0,020	$1,33 \times 10^{-5}$	$8,33 \times 10^{-5}$	$3,32 \times 10^{-4}$	-97,5	-81,6	-69,6
0,030	$1,33 \times 10^{-5}$	$8,33 \times 10^{-5}$	$3,32 \times 10^{-4}$	-97,5	-81,6	-69,6
0,040	$1,33 \times 10^{-5}$	$8,33 \times 10^{-5}$	$3,32 \times 10^{-4}$	-97,5	-81,6	-69,6
0,050	$1,33 \times 10^{-5}$	$8,33 \times 10^{-5}$	$3,32 \times 10^{-4}$	-97,5	-81,6	-69,6
0,060	$1,33 \times 10^{-5}$	$8,33 \times 10^{-5}$	$3,32 \times 10^{-4}$	-97,5	-81,6	-69,6
0,070	$1,33 \times 10^{-5}$	$8,33 \times 10^{-5}$	$3,32 \times 10^{-4}$	-97,5	-81,6	-69,6
0,080	$1,33 \times 10^{-5}$	$8,33 \times 10^{-5}$	$3,32 \times 10^{-4}$	-97,5	-81,6	-69,6
0,090	$1,33 \times 10^{-5}$	$8,33 \times 10^{-5}$	$3,32 \times 10^{-4}$	-97,5	-81,6	-69,6
0,100	$1,33 \times 10^{-5}$	$8,33 \times 10^{-5}$	$3,32 \times 10^{-4}$	-97,5	-81,6	-69,6
0,110	$1,33 \times 10^{-5}$	$8,33 \times 10^{-5}$	$3,32 \times 10^{-4}$	-97,5	-81,6	-69,6
0,120	$1,33 \times 10^{-5}$	$8,33 \times 10^{-5}$	$3,32 \times 10^{-4}$	-97,5	-81,6	-69,6
0,130	$1,33 \times 10^{-5}$	$8,33 \times 10^{-5}$	$3,32 \times 10^{-4}$	-97,5	-81,6	-69,6
0,140	$1,33 \times 10^{-5}$	$8,33 \times 10^{-5}$	$3,32 \times 10^{-4}$	-97,5	-81,6	-69,6
0,150	$1,33 \times 10^{-5}$	$8,33 \times 10^{-5}$	$3,32 \times 10^{-4}$	-97,5	-81,6	-69,6

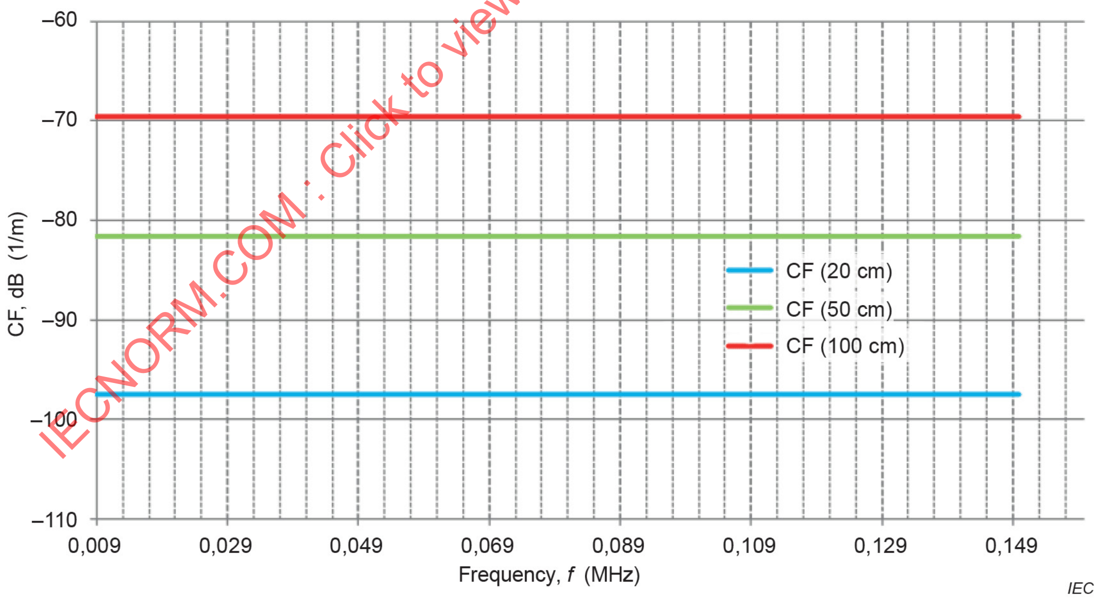
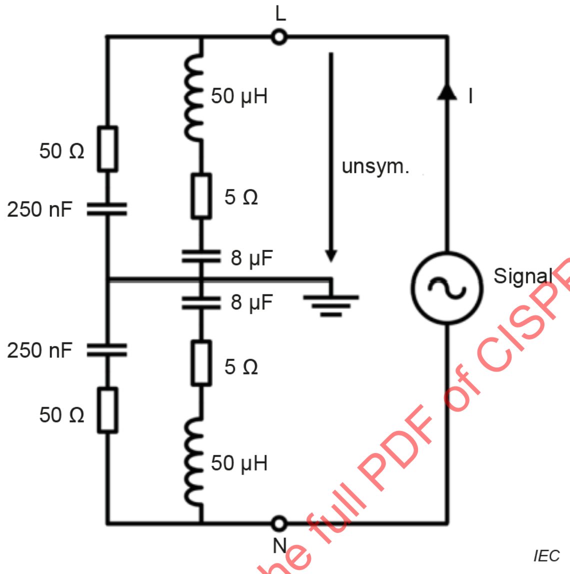


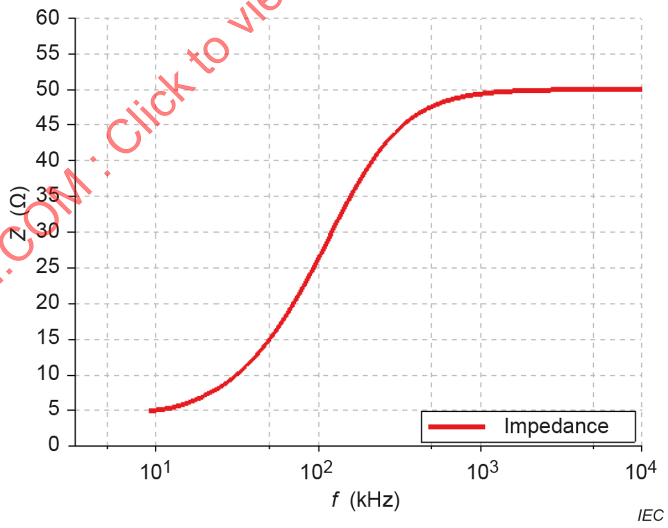
Figure A.7 – Simulation results for the coupling factor for differently sized loops

A.2.3.2 Determination of the injected current

The limits for conducted disturbance, specified in this document, are given as disturbance voltage measured with an AMN as defined in the CISPR 16 series. A typical circuit diagram of such an AMN is shown in Figure A.8. For frequencies above 1 MHz, this AMN presents an unsymmetrical impedance of 50 Ω. Thus, for those frequencies the voltage limit can be converted to a current limit needed for simulated injection into the current loop by subtracting 34 dB (= 20 log10(50 Ω)). However, as for lower frequencies the 50 µH-coil presents a low impedance and the 250 nF-capacitor becomes less conductive, the real impedance presented in the test case is lower than 50 Ω.



a) Circuit diagram of an V-AMN



b) Input impedance of an V-AMN

Figure A.8 – Properties of a V-AMN

In consequence, the conversion between voltage and current limits becomes frequency dependent and shall be determined for each frequency. The result is given in Table A.6, especially showing the converted current limit, which will be used for injection to find the respective disturbance field strength in the protection distance.

Table A.6 – Conversion from voltage limit to current limit for injection

Frequency	**AMN impedance**		**Limit**	
MHz	Ω	dB(Ω)	dB(µV)	dB(µA)
0,009	4,9	13,8	120,5	106,7
0,010	4,99	14,0	119,9	105,9
0,020	7,06	17,0	115,6	98,6
0,030	9,72	19,8	113,1	93,4
0,040	12,43	21,9	111,4	89,5
0,049	14,83	23,4	110,1	86,7
0,050	15,09	23,6	104,0	80,4
0,060	17,64	24,9	100,0	75,1
0,070	20,06	26,0	96,6	70,6
0,080	22,33	27,0	93,7	66,8
0,090	24,44	27,8	91,2	63,4
0,100	26,4	28,4	88,9	60,4
0,110	28,21	29,0	86,8	57,8
0,120	29,87	29,5	84,9	55,4
0,130	31,39	29,9	83,1	53,2
0,140	32,77	30,3	81,5	51,2
0,150	34,04	30,6	80,0	49,4

These current limits were now injected into the three different current loops as described in A.2.3.1. Table A.7 and Table A.8 show the detailed calculation resulting in three different sets of disturbance field strength at the victim's position in a protection distance of 10 m. This was done by calculating the magnetic field (H-Field) [dBµA/m] for all three loop sizes by adding the coupling factor *CF* [dB(1/m)] to the calculated current limit [dBµA]. As a disturbance situation is very much in the far field of the respective radio transmitter, the magnetic field strength can be displayed in units of the electric field [dB(µV/m)] by adding 20 log(377) = 51,5 dB (free space impedance), which makes the comparison with the respected protection needs of the radio services in Figure A.9 much easier.

$$H\left[\mathrm{dB\mu A/m}\right] = Limit\left[\mathrm{dB\mu A}\right] + CF\left[\mathrm{dB}\left(1/\mathrm{m}\right)\right] \tag{A.2}$$

$$H_E\left[\mathrm{dB\mu V/m}\right] = H\left[\mathrm{dB\mu A/m}\right] + 51{,}5\ \mathrm{dB} \tag{A.3}$$

$$CF\left[\mathrm{dB}\left(1/\mathrm{m}\right)\right] = 20\log_{10}\left(CF\left[1/\mathrm{m}\right]\right) \tag{A.4}$$

Table A.7 – Disturbance field strength calculation for 20 cm and 50 cm loops

		20 cm loop				**50 cm loop**			
Frequency MHz	**Limit** dB(µA)	***CF*** 1/m	***CF*** dB(1/m)	***H*-Field** dB(µA/m)	**H_E-Field** dB(µV/m)	***CF*** 1/m	***CF*** dB(1/m)	***H*-Field** dB(µA/m)	**H_E-Field** dB(µV/m)
0,009	106,7	$1{,}33 \times 10^{-5}$	-97,5	9,2	60,7	$8{,}33 \times 10^{-5}$	-81,6	25,1	76,6
0,010	105,9	$1{,}33 \times 10^{-5}$	-97,5	8,4	59,9	$8{,}33 \times 10^{-5}$	-81,6	24,3	75,8
0,020	98,6	$1{,}33 \times 10^{-5}$	-97,5	1,1	52,6	$8{,}33 \times 10^{-5}$	-81,6	17,0	68,5
0,030	93,4	$1{,}33 \times 10^{-5}$	-97,5	-4,1	47,4	$8{,}33 \times 10^{-5}$	-81,6	11,8	63,3
0,040	89,5	$1{,}33 \times 10^{-5}$	-97,5	-8,0	43,5	$8{,}33 \times 10^{-5}$	-81,6	7,9	59,4
0,049	86,7	$1{,}33 \times 10^{-5}$	-97,5	-10,8	40,7	$8{,}33 \times 10^{-5}$	-81,6	5,1	56,6
0,050	80,4	$1{,}33 \times 10^{-5}$	-97,5	-17,1	34,4	$8{,}33 \times 10^{-5}$	-81,6	-1,2	50,3
0,060	75,1	$1{,}33 \times 10^{-5}$	-97,5	-22,4	29,1	$8{,}33 \times 10^{-5}$	-81,6	-6,5	45,0
0,070	70,6	$1{,}33 \times 10^{-5}$	-97,5	-26,9	24,6	$8{,}33 \times 10^{-5}$	-81,6	-11,0	40,5
0,080	66,8	$1{,}33 \times 10^{-5}$	-97,5	-30,8	20,7	$8{,}33 \times 10^{-5}$	-81,6	-14,8	36,7
0,090	63,4	$1{,}33 \times 10^{-5}$	-97,5	-34,1	17,4	$8{,}33 \times 10^{-5}$	-81,6	-18,2	33,3
0,100	60,4	$1{,}33 \times 10^{-5}$	-97,5	-37,1	14,4	$8{,}33 \times 10^{-5}$	-81,6	-21,2	30,3
0,110	57,8	$1{,}33 \times 10^{-5}$	-97,5	-39,8	11,7	$8{,}33 \times 10^{-5}$	-81,6	-23,8	27,7
0,120	55,4	$1{,}33 \times 10^{-5}$	-97,5	-42,2	9,3	$8{,}33 \times 10^{-5}$	-81,6	-26,2	25,3
0,130	53,2	$1{,}33 \times 10^{-5}$	-97,5	-44,3	7,2	$8{,}33 \times 10^{-5}$	-81,6	-28,4	23,1
0,140	51,2	$1{,}33 \times 10^{-5}$	-97,5	-46,3	5,2	$8{,}33 \times 10^{-5}$	-81,6	-30,4	21,1
0,150	49,4	$1{,}33 \times 10^{-5}$	-97,5	-48,2	3,3	$8{,}33 \times 10^{-5}$	-81,6	-32,2	19,3

Table A.8 – Disturbance field strength calculation for 100 cm loop

		100 cm loop			
Frequency MHz	**Limit** dB(μA)	***CF*** 1/m	***CF*** dB(1/m)	***H*-Field** dB(μA/m)	**H_E-Field** dB(μV/m)
0,009	106,7	$3{,}32 \times 10^{-4}$	-69,6	37,1	88,6
0,010	105,9	$3{,}32 \times 10^{-4}$	-69,6	36,3	87,8
0,020	98,6	$3{,}32 \times 10^{-4}$	-69,6	29,1	80,6
0,030	93,4	$3{,}32 \times 10^{-4}$	-69,6	23,8	75,3
0,040	89,5	$3{,}32 \times 10^{-4}$	-69,6	19,9	71,4
0,049	86,7	$3{,}32 \times 10^{-4}$	-69,6	17,1	68,6
0,050	80,4	$3{,}32 \times 10^{-4}$	-69,6	10,8	62,3
0,060	75,1	$3{,}32 \times 10^{-4}$	-69,6	5,5	57,0
0,070	70,6	$3{,}32 \times 10^{-4}$	-69,6	1,0	52,5
0,080	66,8	$3{,}32 \times 10^{-4}$	-69,6	-2,8	48,7
0,090	63,4	$3{,}32 \times 10^{-4}$	-69,6	-6,2	45,3
0,100	60,4	$3{,}32 \times 10^{-4}$	-69,6	-9,2	42,3
0,110	57,8	$3{,}32 \times 10^{-4}$	-69,6	-11,8	39,7
0,120	55,4	$3{,}32 \times 10^{-4}$	-69,6	-14,2	37,3
0,130	53,2	$3{,}32 \times 10^{-4}$	-69,6	-16,4	35,1
0,140	51,2	$3{,}32 \times 10^{-4}$	-69,6	-18,4	33,1
0,150	49,4	$3{,}32 \times 10^{-4}$	-69,6	-20,2	31,3

As the application of the disturbance model in CISPR TR 16-4-4:2007, CISPR TR 16-4-4:2007/AMD1:2017 and CISPR TR 16-4-4:2007/AMD2:2020 has already been discussed in detail in A.2.2, this is not repeated here. The green and blue dots shown in Figure A.9 each represent a radio application in the frequency range 9 kHz to 150 kHz.

As long as the service can tolerate a higher disturbance field strength than produced by the product (green or blue dot above the limit line) the application is protected against such a scenario. This is true for most of the radio applications. The standard frequency and time signal service on 20 kHz is somewhat affected for loops of 1 m, which are very rare.

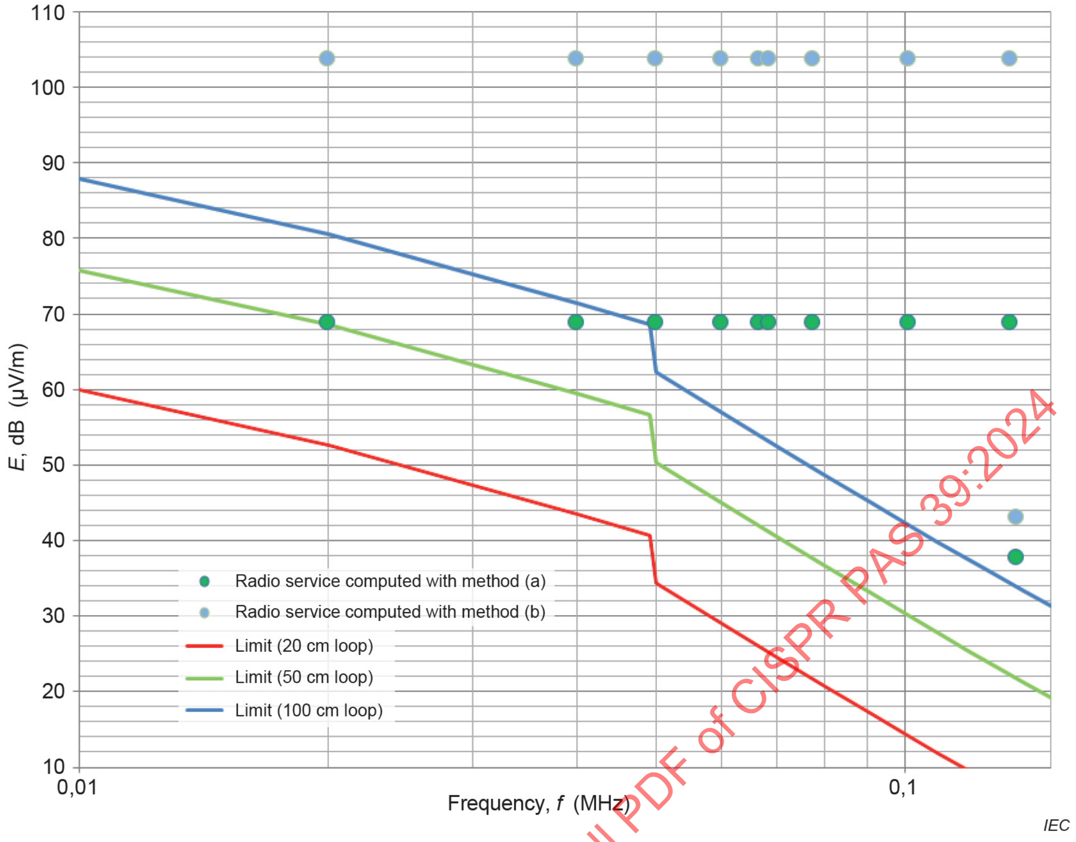


Figure A.9 – Proposed field strengths limits compared to protection needs of radio applications

Although this evaluation applying the introduced model for the differential mode coupling situation is based on various input parameters and contains statistical processes, it leads to calculated limit values comparable to the proposed limits in the frequency range 9 kHz to 150 kHz. With respect to CISPR TR 16-4-4:2007, CISPR TR 16-4-4:2007/AMD1:2017 and CISPR TR 16-4-4:2007/AMD2:2020, 5.3.6.3, the working group found consensus on the limit line depicted as blue line in Figure A.9.

The final conclusion for differential mode disturbance injections is that the new limits proposed in this document are also acceptable for the protection of radio services.

Annex B
(informative)

Spectral density of non-intentional emissions (NIE) in the frequency range 9 kHz to 150 kHz

B.1 Introduction of Integral Voltage Levels (IVL) for the limitation of the spectral density of NIE

In addition to quasi-peak limits for the NIE amplitude, given for single 200 Hz frequency windows, it is recommended to improve the electromagnetic compatibility between NIE and MCS in the frequency range 9 kHz to 150 kHz by limiting the spectral density of NIE. A detailed rationale for this recommendation is given in Clause B.3.

For this purpose, the concept of IVL is introduced. Measurements for determining the IVL should be performed with an AV detector and a measurement bandwidth in band A as specified in Clause 4 and Clause 7 of CISPR 16-1-1:2019.

The IVL should be calculated according to the following formula:

$$\mathrm{IVL}_{f_{\mathrm{start}}\text{-}f_{\mathrm{stop}}}\left[\mathrm{dB}(\mu\mathrm{V})\right]=20\,log\frac{\sqrt{\frac{\Delta f_{\mathrm{step}}}{200\ \mathrm{Hz}}\sum_{f_{\mathrm{start}}}^{f_{\mathrm{stop}}}U_{\mathrm{AV}}^{2}(f)[\mathrm{V}]}}{1\ \mu\mathrm{V}} \tag{B.1}$$

where:

$\mathrm{IVL}_{f_{\mathrm{start}}\text{-}f_{\mathrm{stop}}}\left[\mathrm{dB}(\mu\mathrm{V})\right]$	IVL in the frequency range $f_{\mathrm{start}} - f_{\mathrm{stop}}$ in dB(μV),
$U_{\mathrm{AV}}(f)[\mathrm{V}]$	Disturbance voltage in V, without conversion to dB, measured at each frequency step with the AV detector according to Clause 4 and Clause 7 of CISPR 16-1-1:2019 and with a 200 Hz bandwidth,
Δf_{step}	Frequency step size: this value shall be 100 Hz or lower in accordance with the requirements in CISPR 16-2-1:2014 and CISPR 16-2-1:2014/AMD1:2017 to reduce measurement uncertainty for narrowband signals. A frequency step size of 100 Hz is equivalent to a 50 % overlapping of adjacent 200 Hz windows.

NOTE 1 The IVL was originally derived for the use of no-gap and non-overlapping 200 Hz windows. But according to the CISPR 16-2-1:2014 and CISPR 16-2-1:2014/AMD1:2017 method at least a 50 % overlapping of adjacent windows is necessary, due to the –6 dB selectivity of a CISPR 16-1-1:2019 RFI receiver. The ratio "Δf_{step} /200 Hz" gives a correction for this overlapping. This correction is valid for arbitrary step sizes. With the step size of 100 Hz this correction is –3 dB. With a step size of 50 Hz (75 % overlapping), this correction would be –6 dB. The correction accounts for the ratio of the total spectral power received with overlapping to the reference spectral power that would have been received without overlapping.

The formula is meant to sum only the emissions that are present at the same time, so ideally the values of U_{AV} (f)[V] should be taken from the same scan.

NOTE 2 Fluctuating NIE could be problem for the calculation of IVL. For fluctuating NIE calculating the IVL from a single scan in the most representative operating mode of the EUT gives the correct result. Calculating IVL from repeated measurements on fluctuating NIE with a "max hold" function always gives a result, which is too high.

NOTE 3 The calculation of the IVL is based on AV measurements, therefore it is independent from the comparison of QP measurements with the normative limits.

NOTE 4 More information about the bandwidth can be found in CISPR 16-1-1:2019, Subclause 4.5 and Annex A. The reference bandwidth of 200 Hz is equivalent to an effective power bandwidth of 166 Hz.

B.2 Recommended maximum IVL for NIE

In the following tables different maximum IVL, calculated according to Equation (B.1) are recommended for general equipment and equipment covered by footnote [a] to Table 1.

Table B.1 – Recommended maximum Integral Voltage Levels

Frequency range (kHz)	Recommended maximum IVL, AV-detector
9 kHz to 30 kHz (f_{start} = 9,1 kHz; f_{stop} = 30 kHz)	123 dB(µV)
30 kHz to 50 kHz (f_{start} = 30,1 kHz; f_{stop} = 50 kHz)	115 dB(µV)
50 kHz to 95 kHz (f_{start} = 50,1 kHz; f_{stop} = 95 kHz)	104 dB(µV)
NOTE For general equipment, the evaluation of IVL above 95 kHz is not necessary because in this frequency range the normative limits are already significantly lower than the MCE signal levels. The frequency range below 50 kHz was split into two sub-ranges with different IVLs because MCS operation typically starts above 30 kHz.	

Table B.2 – Recommended maximum Integral Voltage Levels for equipment covered by footnote [a] to Table 1

Frequency range (kHz)	Recommended maximum IVL, AV-detector
9 kHz to 50 kHz (f_{start} = 9,1 kHz; f_{stop} = 50 kHz)	126 dB(µV)
50 kHz to 150 kHz (f_{start} = 50,1 kHz; f_{stop} = 150 kHz)	112 dB(µV)
NOTE For equipment covered by footnote [a] to Table 1, higher IVLs have been defined for the same reason the footnote was introduced. See Clause A.1.	

The recommended IVL in Table B.1 and Table B.2 are the result of measurements on numerous pieces of equipment as well as long and intense discussions in the Joint Working Group JWG-6 between CISPR SC/H and IEC SC/77A and represent the best available compromise supported by all stakeholders.

NOTE The recommended maximum IVL values reported in Table B.1 and Table B.2 correspond to the IVL of a hypothetical broadband disturbance spectrum where all U_{AV} (f)[V] points have a constant margin below the normative limits defined in Clause 5, Table 1 in each frequency range identified in Table B.1 and Table B.2. Such margin includes the difference between measurements performed with QP and AV detectors, and an additional margin to the normative limits which allows for a minimum Signal-to-Noise-Ratio for MCE signaling. A higher margin has been set for higher frequency ranges. Recommended maximum IVL in Table B.1 are based on higher margin than values in Table B.2.

B.3 Rationale for the recommendation of additional limitations on the spectral density of non-intentional emissions

B.3.1 Rationale

Following the publication of compatibility levels between 9 kHz and 150 kHz in IEC 61000-2-2:2002, IEC 61000-2-2:2002/AMD1:2017 and IEC 61000-2-2:2002/AMD2:2018, emission limits have been directly derived in this document, taking into account both cumulative effect of equipment connected to the same public low-voltage public supply network and the conversion from differential mode to unsymmetrical emissions according to CISPR 16 measurements methods.

In addition and according to Annex D of IEC 61000-2-2:2002, IEC 61000-2-2:2002/AMD1:2017 and IEC 61000-2-2:2002/AMD2:2018, MCS performance depends not only on the amplitude of disturbances but also on the shape and number of spectral lines. In receiving mode, MCE is actually listening to a frequency range varying from a few kHz, for single-carrier technologies, up to several tens of kHz, for multi-carrier technologies (the typical spectrum of a multi-carrier MCE transmitter is shown in Figure B.1). Therefore, the signal-to-noise ratio experienced by each MCE receiver depends not only on the noise, including emissions generated by NIE sources, over the entire operating bandwidth, but also on the modulation scheme and the selectivity of the MCE's input filter.

Yet, CISPR 16 standard series were developed with respect to the characteristics of radio receivers, which frequency selectivity does not exceed 200 Hz in the 9 kHz to 150 kHz band. By nature, individual 200 Hz measurements cannot accurately assess the effect of disturbance from NIE over a broader frequency band. Indeed, the sole definition of 200 Hz quasi-peak limits would not prevent a single NIE source to generate broadband noise with amplitudes reaching levels up to the limit in each 200 Hz band, throughout the whole 9 kHz to 150 kHz frequency band. The aggregated NIE voltage, seen by the MCE in receiving mode, would then lead to a negative signal-to-noise ratio impairing MCE performance.

For this reason, in order to better reflect the noise level typically captured by MCE, the new concept of "Integral Voltage Levels" is introduced. This concept aims at assessing the broadband noise arising from the NIE in addition to the normative emission limits defined in this document.

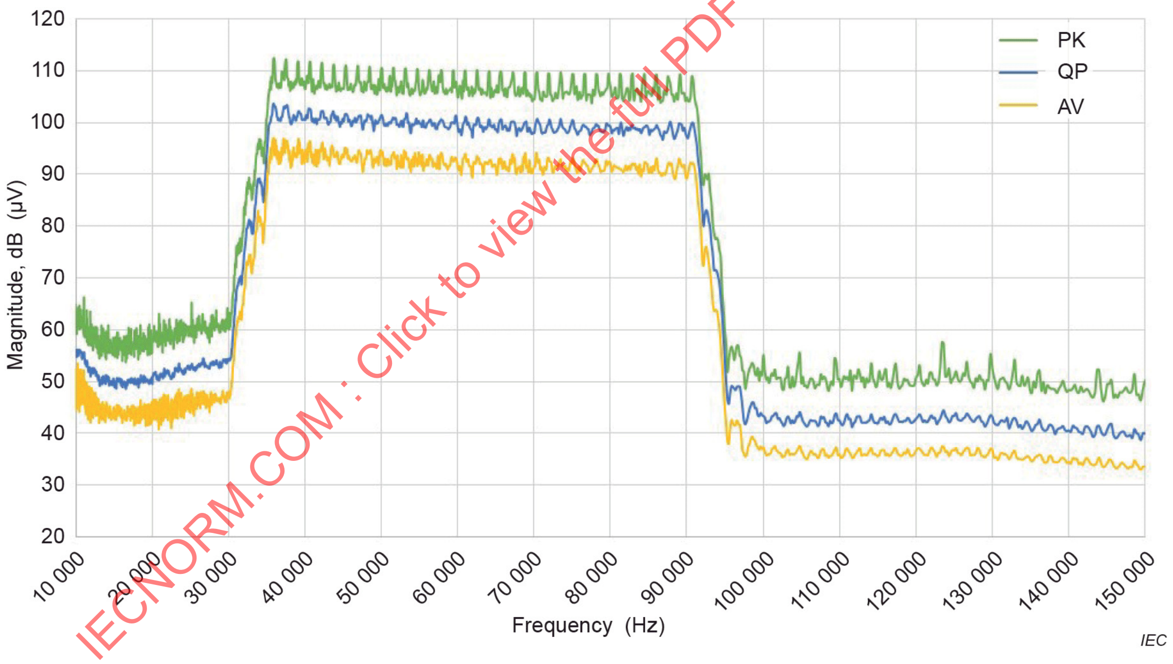


Figure B.1 – Example of a multi-carrier MCE spectrum

B.3.2 Relationship between MCE performances and Integral Voltage Levels

B.3.2.1 General test setup

MCE communication performance depends on its physical layer design (modulation type, error correction codes, input filter, etc.) and on the signal-to-noise ratio experienced by MCE in receiving mode. The signal-to-noise ratio measured at MCE in receiving mode is both affected by the propagation of the signal over the powerline, as attenuation is added to the original signal generated by MCE in transmitting mode, and the aggregation of NIE voltages over its operating bandwidth.