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Spectrum Management and Telecommunications

Interference-Causing Equipment Standard

Alternating Current High Voltage Power Systems

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Preface

Interference-Causing Equipment Standard ICES-004, issue 5, *Alternating Current High Voltage Power Systems*, replaces ICES-004, issue 4, published in June 2013.

This issue of the ICES-004 standard will come into force upon its publication on the Innovation, Science, and Economic Development Canada (ISED) website. However, a transition period is provided, according to section 2.1, within which compliance with either issue 4 or issue 5 of ICES-004 is accepted.

Listed below are the main changes:

1. updated the normative references (section 2.2) and the definitions (section 2.3);
2. clarified various aspects of the measurement procedure, such as the specific height of the loop antenna and the necessity to properly ground the counterpoise of the rod antenna (section 3.2);
3. reformatted the limit specification to allow a more straightforward and faster determination of compliance (section 3.3.1); the old format of limit specification is retained in annex B;
4. added a new annex providing the history of the requirements and limits in ICES-004 (annex A);
5. added an example measurement scenario (annex C).

Inquiries may be submitted by one of the following methods:

1. Online using the General Inquiry form (in the form, select the Directorate of Regulatory Standards radio button and specify “ICES-004” in the General Inquiry field)

2. By mail to the following address:

   Innovation, Science and Economic Development Canada
   Engineering, Planning and Standards Branch
   Attention: Regulatory Standards Directorate
   235 Queen Street
   Ottawa ON K1A 0H5
   Canada

3. By email to consultationradiostandards-consultationnormesradio@ised-isde.gc.ca.

Comments and suggestions for improving this standard may be submitted online using the Standard Change Request form or by mail or email to the above addresses.

All spectrum and telecommunications related documents are available on ISED's Spectrum Management and Telecommunications website.

Issued under the authority of the Minister of Innovation, Science and Industry

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Martin Proulx
Director General
Engineering, Planning and Standards Branch

Contents

1. Scope

This interference-causing equipment standard (ICES) sets out limits for radiated emissions between 150 kHz and 30 MHz generated by alternating current (AC) high voltage power systems, as well as corresponding measurement procedures.

This document does not apply to:

a. underground power systems;

b. radiated emissions associated with power line carrier current transmissions, which are subject to ICES-006, *AC Wire Carrier Current Devices (Unintentional Radiators)*;

c. high voltage direct current components of a power system in which the design for the construction of the direct current components of the system was initiated before January 1, 1991.

2. General requirements, references and definitions

This section defines the general requirements related to this standard, including the transition period, compliance with ICES-Gen, *General Requirements for Compliance of Interference-Causing Equipment*, the list of normative references, and the definitions of terms used in this standard.

2.1 Transition period

A transition period is provided, ending three months after the publication of this standard (i.e. on January 28, 2023), within which compliance with either issue 4 or issue 5 of ICES-004 is accepted. A copy of issue 4 of ICES-004 may be requested by emailing consultationradiostandards-consultationnormesradio@ised-isde.gc.ca.

All measurements on AC high voltage power systems subject to ICES-004 performed after the above transition period shall comply with issue 5.

2.2 Normative references

This standard refers to the following publications and, where such references are made, they shall be understood to be to the editions listed below:

- CAN/CSA-IEC CISPR 16-1-1:18, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-1: Radio disturbance and immunity measuring apparatus – Measuring apparatus* (IEC CISPR 16-1-1:2015, IDT).

- CISPR 16-1-4:2019+AMD1:2020, *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*.

These two standards can be purchased online from the Canadian Standards Association (CSA) store (CAN/CSA-IEC CISPR 16-1-1:18) and from the International Electrotechnical Commission (IEC) webstore (CISPR 16-1-4:2019+AMD1:2020).

Other editions of these standards are acceptable only if the content that is relevant to ICES-004 is identical to that in the editions listed above.

2.3 Definitions

The following definitions apply, in addition to those specified in ICES-Gen:

Alternating current high voltage power system, or **power system:** Any generating station, substation or power line, or any combination thereof, that is operated under common management for the generation, transmission or distribution of alternating current electric power.

Distribution line: An overhead power line that operates at nominal phase-to-phase voltages from 1 kV to 75 kV.

Distribution substation: A substation at which all power lines entering or leaving the substation are distribution lines.

Fair weather: Weather conditions that are absent of rain, snow and/or fog within a 10 km radius of the measuring location. For the conditions to be considered fair weather, insulators and conductors must be completely dry.

Power line: A transmission line or a distribution line.

Span: The horizontal distance between two consecutive towers/poles supporting a power line.

Substation: An assemblage of equipment (including switches, circuit breakers, buses, transformers and control devices) for the purpose of switching power circuits or transforming electric power from one voltage to another.

Transmission line: An overhead power line that operates at nominal phase-to-phase voltages above 75 kV and up to 800 kV.

Transmission substation: A substation where at least one of the power lines entering the substation is a transmission line.

3. Technical requirements

This section defines the technical requirements associated with this standard including measurement equipment, measurement methods and limits.

3.1 Measurement equipment

Compliance with the limits specified in ICES-004 shall be evaluated using a measuring receiver (or spectrum analyzer) with quasi-peak detector that complies with the applicable requirements stated in CAN/CSA-IEC CISPR 16-1-1:18. However, as an alternative to CISPR quasi-peak measurement, compliance with the emissions limits may be demonstrated using a measuring instrument employing a peak detector function, with a measurement bandwidth equal to, or greater than, the applicable CISPR quasi-peak bandwidth.

The measurement antenna shall be either a shielded loop antenna or a rod antenna, compliant with subclauses 4.3 and 4.4 of CISPR 16-1-4:2019+AMD1:2020. A rod antenna shall only be used if it is provided with a counterpoise and if this counterpoise is properly grounded at each location where measurements are performed. Measurements with a loop antenna are preferable as they provide more repeatable and reproducible results than those performed with a rod antenna.

Both the measurement instrument and the measurement antenna shall be calibrated, with the last calibration less than three years prior to the date when ICES-004 measurements are performed. The same applies for each coaxial cable, preamplifier, attenuator and/or filter used for connecting the measuring antenna to the measurement instrument.

3.2 Measurement methods

This section defines the measurement methods.

3.2.1 General considerations

All measurements shall be performed in fair weather.

The entire frequency range of 150 kHz to 30 MHz shall be measured for verifying that no emission, at any frequency within this range, exceeds the applicable limits.

In order to avoid affecting the measurement results, the person performing the measurements should be at least 2 m from the antenna, especially if a rod antenna is used.

For all measurements, the reading level obtained on the measurement instrument shall be corrected by adding the antenna factor and the loss of the cable or cables (and of any attenuators or filters used, if applicable). If a preamplifier is used, its gain shall be subtracted from the reading level obtained on the measurement instrument. All these factors shall be taken from the corresponding calibration certificates, at each measured frequency.

Factors at frequencies not specified in the calibration certificate shall be determined by linear interpolation between the values specified in the calibration certificate at the closest frequency above and the closest frequency below the measured emission frequency. The interpolation shall use a linear scale for the factor value expressed in logarithmic units and a logarithmic frequency scale. An example interpolation calculation is provided in annex C (while that example is related to the limits, the same formula applies for antenna factor, cable/filter loss, or preamplifier gain).

Loop antenna

When using a loop antenna, the following conditions apply at each measurement location (see also figure C2 and figure C3 in annex C):

- the centre of the loop shall be at 1.3 m height above the ground;
- the plane of the loop shall be perpendicular to the ground;
- for each frequency where the measured emission level is within 10 dB of the limits specified in section 3.3, the loop antenna shall be rotated around the vertical axis connecting the centre of the loop with its projection on the ground until the maximum reading is obtained on the measurement instrument.

Rod antenna

When using a rod antenna, the following conditions apply at each measurement location:

- the rod antenna shall be placed directly on the ground, with the rod in a vertical position;
- the rod antenna's counterpoise shall be grounded at each measurement location (e.g. by bonding the counterpoise to a sufficiently long copper rod driven into the ground);
- great care should be exercised when using a rod antenna because there is a possibility that the tip of the antenna may go into corona when it is closer than 15 m from a power line of 230 kV or above.

3.2.2 Ambient noise

If the combined emission level (with the transmission line/substation under test energized) is at or below the limit, then the transmission line/substation is considered compliant at that frequency and at that measurement point.

In case the ambient noise at the measurement point is above the applicable limit level, the transmission line/substation is considered compliant at that frequency and measurement point only if it does not increase the ambient noise level. This determination is only possible if the ambient noise level can be measured, with the transmission line/substation under test deenergized. If it is not possible to deenergize the transmission line/substation and the emission level at a specific frequency is above the limit, further investigations shall be performed to determine if the transmission line/ substation complies.

To avoid the need to deenergize the transmission line/substation under test or to perform complex investigations to determine compliance, wherever possible, the measurement point shall be selected such that the ambient noise in the 150 kHz to 30 MHz frequency range is 6 dB or more below the applicable limit. For measurements on transmission lines, this may be achieved by moving the measurement point on the other side of the line under test, or by selecting a different span.

3.2.3 Measurement procedure for transmission lines

Measurements shall be performed at points located near both ends as well as near the middle of the transmission line. For each one of these three measurement locations, the following conditions apply:

- Wherever possible, the measurement point shall be at least 5 km from the nearest transmission or distribution substation, and from the power generating station.
- The measurement point should be sufficiently separated from any metal fences or other reflecting objects, as well as from any intersections with other power lines or communication lines, such that the influence of these objects/lines on the measurements is minimized.
- The measurement point shall be in the vertical plane that is perpendicular to the transmission line under test at the centre of its span.
- The measurement point shall be at a lateral separation distance of 15 m from the vertical plane containing the nearest conductor of the transmission line under test. However, when this is not possible, one of the two procedures specified in section 3.3.1.2 shall be used.

3.2.4 Measurement procedure for transmission substations

Measurements shall be performed, at a minimum, along each of any two adjacent sides of the transmission substation, as follows:

- The measurement points should be sufficiently separated from power lines and communication lines such that the influence of these lines on the measurements is minimized.
- The measurement points shall be at a lateral separation distance of 15 m from the property limit of the transmission substation under test. However, when this is not possible, one of the two procedures specified in section 3.3.1.2 shall be used.
- For each selected side of the transmission substation, preliminary exploratory measurements shall be performed along its entire length for determining the measurement point where the highest field strength level relative to the limit is obtained (from all detected emission frequencies within the 150 kHz to 30 MHz frequency range). The final measurement, for the selected side, shall be performed at this location by applying all the requirements specified in section 3.2.1 and in this section (3.2.4), as appropriate.
- If measurements are only performed on two adjacent sides of the transmission substation, the two sides likely to result in highest emission levels relative to the limit should be selected (e.g. where the property limit is closest to the transmission substation under test).

3.3 Limits

This section defines the limits for transmission lines and transmission substations as well as limits for distribution lines and distribution substations.

3.3.1 Limits for transmission lines and transmission substations

This section defines the limits for transmission lines/substations.

3.3.1.1 Primary limits (measurement distance of 15 m)

The maximum magnetic field strength radiated in the frequency range from 150 kHz to 30 MHz by a transmission substation or a transmission line, as measured in fair weather at a lateral distance of 15 m in accordance with section 3.2, shall not exceed the values set out in table 1 or table 2, respectively. Depending on the phase-to-phase voltage, the following limit (L_X, with X between 1 and 5) shall apply:

- L_1: phase-to-phase voltage between 76 kV and 200 kV;
- L_2: phase-to-phase voltage greater than 200 kV and up to 300 kV;
- L_3: phase-to-phase voltage greater than 300 kV and up to 400 kV;
- L_4: phase-to-phase voltage greater than 400 kV and up to 600 kV;
- L_5: phase-to-phase voltage greater than 600 kV and up to 800 kV.

For transmission substations where the nominal phase-to-phase voltages are within two or more of the ranges specified above, the limit corresponding to the highest phase-to-phase voltage used at that transmission substation shall apply.

At any other frequency within the frequency range of 150 kHz to 30 MHz (i.e. any frequency that is not listed in table 1 or table 2), the applicable limit value shall be calculated by linear interpolation between the limit values corresponding to the closest frequencies listed in table 1 or table 2 that are below and above the specific frequency. The interpolation shall use a linear scale for the limit value (expressed in logarithmic units) and a logarithmic frequency scale. An example interpolation calculation is provided in equation (C1) of annex C.

When using the “electrical” antenna factor for the loop antenna, or when using a rod antenna, the applicable limit specified in table 1 or table 2 shall be converted to an electric field strength limit using equation (1) below:

$$L_X^E = L_X^H + 51.5 \quad (1)$$

where

L_X^E is the electric field strength limit, in dB(μV/m),
L_X^H is the magnetic field strength limit, in dB(μA/m), from table 1 or table 2,
X is between 1 and 5, as applicable, and
51.5 is the impedance of the free space, in dBΩ.

Note that the "electrical" antenna factor that might be provided by an antenna calibration laboratory for a specific loop antenna is not the true electrical antenna factor of that antenna. Instead, it is just a quantity calculated from the magnetic antenna factor by using the free space impedance value. The true electrical antenna factor of the loop antenna would be much higher than this value, because the loop antenna is designed to have an optimum response to magnetic field and a poor response to electric field. See also Notice 2020 – DRS0023, *Guidance on magnetic field strength radiated emission measurements (9 kHz - 30 MHz)*.

Table 1: Magnetic field strength limits for transmission lines (at 15 m distance)

Freq.	L_1	L_2	L_3	L_4	L_5	**Freq.**	L_1	L_2	L_3	L_4	L_5
MHz	dBμA/m	dBμA/m	dBμA/m	dBμA/m	dBμA/m	MHz	dBμA/m	dBμA/m	dBμA/m	dBμA/m	dBμA/m
0.15	10.47	14.47	17.47	21.47	24.47	4	-24.63	-20.63	-17.63	-13.63	-10.63
0.2	7.47	11.47	14.47	18.47	21.47	4.5	-25.98	-21.98	-18.98	-14.98	-11.98
0.25	5.07	9.07	12.07	16.07	19.07	5	-27.23	-23.23	-20.23	-16.23	-13.23
0.3	3.07	7.07	10.07	14.07	17.07	5.5	-28.33	-24.33	-21.33	-17.33	-14.33
0.35	1.47	5.47	8.47	12.47	15.47	6	-29.33	-25.33	-22.33	-18.33	-15.33
0.4	-0.03	3.97	6.97	10.97	13.97	6.5	-30.33	-26.33	-23.33	-19.33	-16.33
0.45	-1.33	2.67	5.67	9.67	12.67	7	-31.23	-27.23	-24.23	-20.23	-17.23
0.5	-2.53	1.47	4.47	8.47	11.47	7.5	-32.13	-28.13	-25.13	-21.13	-18.13
0.55	-3.43	0.57	3.57	7.57	10.57	8	-32.93	-28.93	-25.93	-21.93	-18.93
0.6	-4.43	-0.43	2.57	6.57	9.57	8.5	-33.73	-29.73	-26.73	-22.73	-19.73
0.65	-5.23	-1.23	1.77	5.77	8.77	9	-34.53	-30.53	-27.53	-23.53	-20.53
0.7	-6.03	-2.03	0.97	4.97	7.97	9.5	-35.23	-31.23	-28.23	-24.23	-21.23
0.75	-6.73	-2.73	0.27	4.27	7.27	10	-35.93	-31.93	-28.93	-24.93	-21.93
0.8	-7.43	-3.43	-0.43	3.57	6.57	12	-38.23	-34.23	-31.23	-27.23	-24.23
0.85	-8.13	-4.13	-1.13	2.87	5.87	14	-40.23	-36.23	-33.23	-29.23	-26.23
0.9	-8.68	-4.68	-1.68	2.32	5.32	16	-41.93	-37.93	-34.93	-30.93	-27.93
0.95	-9.28	-5.28	-2.28	1.72	4.72	18	-43.43	-39.43	-36.43	-32.43	-29.43
1	-9.83	-5.83	-2.83	1.17	4.17	20	-44.63	-40.63	-37.63	-33.63	-30.63
1.5	-14.13	-10.13	-7.13	-3.13	-0.13	22	-45.93	-41.93	-38.93	-34.93	-31.93
2	-17.18	-13.18	-10.18	-6.18	-3.18	24	-47.03	-43.03	-40.03	-36.03	-33.03
2.5	-19.53	-15.53	-12.53	-8.53	-5.53	26	-47.93	-43.93	-40.93	-36.93	-33.93
3	-21.48	-17.48	-14.48	-10.48	-7.48	28	-48.88	-44.88	-41.88	-37.88	-34.88
3.5	-23.18	-19.18	-16.18	-12.18	-9.18	30	-49.63	-45.63	-42.63	-38.63	-35.63

Table 2: Magnetic field strength limits for transmission substations (at 15 m distance)

Freq.	L_1	L_2	L_3	L_4	L_5	Freq.	L_1	L_2	L_3	L_4	L_5
MHz	dBµA/m	dBµA/m	dBµA/m	dBµA/m	dBµA/m	MHz	dBµA/m	dBµA/m	dBµA/m	dBµA/m	dBµA/m
0.15	0.87	4.87	7.87	11.87	14.87	4	-9.33	-5.33	-2.33	1.67	4.67
0.2	0.07	4.07	7.07	11.07	14.07	4.5	-9.83	-5.83	-2.83	1.17	4.17
0.25	-0.53	3.47	6.47	10.47	13.47	5	-10.33	-6.33	-3.33	0.67	3.67
0.3	-1.03	2.97	5.97	9.97	12.97	5.5	-10.78	-6.78	-3.78	0.22	3.22
0.35	-1.53	2.47	5.47	9.47	12.47	6	-11.23	-7.23	-4.23	-0.23	2.77
0.4	-1.93	2.07	5.07	9.07	12.07	6.5	-11.63	-7.63	-4.63	-0.63	2.37
0.45	-2.23	1.77	4.77	8.77	11.77	7	-12.08	-8.08	-5.08	-1.08	1.92
0.5	-2.53	1.47	4.47	8.47	11.47	7.5	-12.48	-8.48	-5.48	-1.48	1.52
0.55	-2.73	1.27	4.27	8.27	11.27	8	-12.88	-8.88	-5.88	-1.88	1.12
0.6	-3.03	0.97	3.97	7.97	10.97	8.5	-13.28	-9.28	-6.28	-2.28	0.72
0.65	-3.28	0.72	3.72	7.72	10.72	9	-13.63	-9.63	-6.63	-2.63	0.37
0.7	-3.53	0.47	3.47	7.47	10.47	9.5	-14.03	-10.03	-7.03	-3.03	-0.03
0.75	-3.73	0.27	3.27	7.27	10.27	10	-14.35	-10.35	-7.35	-3.35	-0.35
0.8	-3.93	0.07	3.07	7.07	10.07	12	-15.73	-11.73	-8.73	-4.73	-1.73
0.85	-4.08	-0.08	2.92	6.92	9.92	14	-16.93	-12.93	-9.93	-5.93	-2.93
0.9	-4.25	-0.25	2.75	6.75	9.75	16	-18.13	-14.13	-11.13	-7.13	-4.13
0.95	-4.43	-0.43	2.57	6.57	9.57	18	-19.33	-15.33	-12.33	-8.33	-5.33
1	-4.58	-0.58	2.42	6.42	9.42	20	-20.43	-16.43	-13.43	-9.43	-6.43
1.5	-5.83	-1.83	1.17	5.17	8.17	22	-21.53	-17.53	-14.53	-10.53	-7.53
2	-6.68	-2.68	0.32	4.32	7.32	24	-22.73	-18.73	-15.73	-11.73	-8.73
2.5	-7.48	-3.48	-0.48	3.52	6.52	26	-23.83	-19.83	-16.83	-12.83	-9.83
3	-8.13	-4.13	-1.13	2.87	5.87	28	-25.03	-21.03	-18.03	-14.03	-11.03
3.5	-8.73	-4.73	-1.73	2.27	5.27	30	-26.23	-22.23	-19.23	-15.23	-12.23

The limits specified in table 1 or table 2 are presented graphically in figure 1 and figure 2, for information.

Figure 1: Magnetic field strength limits for transmission lines (at 15 m distance)

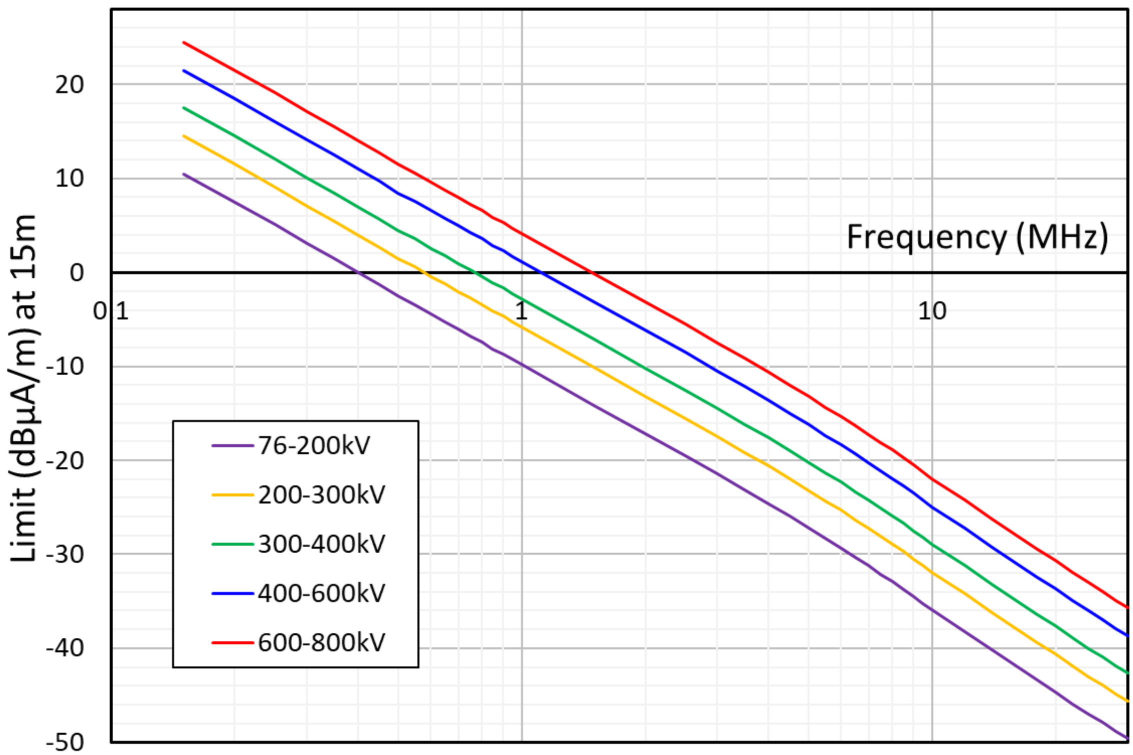
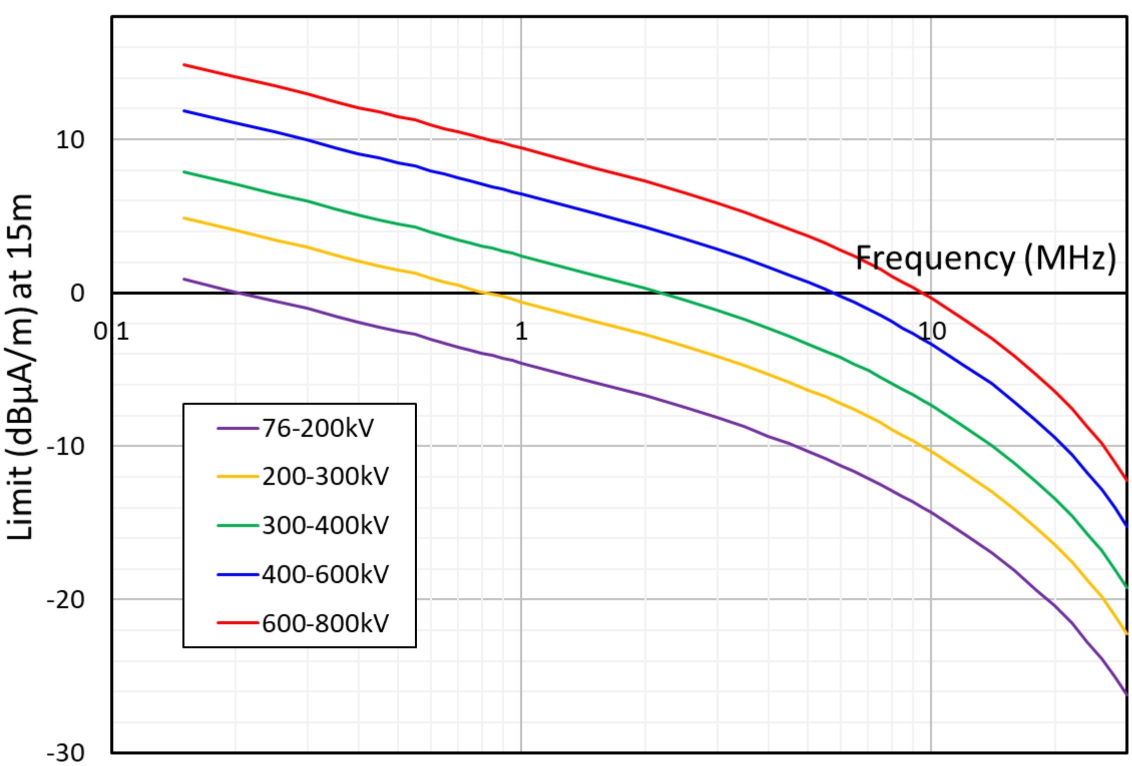


Figure 2: Magnetic field strength limits for transmission substations (at 15 m distance)



3.3.1.2 Measurement distances other than 15 m

When measurements cannot be performed at a lateral distance of 15 m, one of the two following procedures shall be used.

Preferred procedure
In this procedure at least two measurements shall be performed, at different distances, and the field strength level at 15 m lateral distance shall be calculated by linear interpolation between the results obtained from measurements, at each emission frequency. This is the preferred procedure, as actual measurements are more reliable than extrapolation using the correction factor specified in table 3. The interpolation shall use a linear scale for the field strength value (expressed in logarithmic units) and a logarithmic distance scale. An example interpolation calculation is provided in equation (C3) of annex C. The selected measurement distances shall include at least one that is smaller than 15 m and at least one that is greater than 15 m.

Alternate procedure
For this procedure, measurements at one distance are sufficient, but it can only be applied for transmission substations and for transmission lines having the lowest conductor at 9 m or 15 m height above ground. In this alternate procedure, the applicable limit level (from table 1 or table 2 of section 3.3.1.1) shall be modified by subtracting the correction factor specified in table 3, as per equation (2):

$$L_X^H(D) = L_X^H(15m) - C_Y(D) \quad (2)$$

where

D is the lateral distance where the measurements were performed, in m,

$L_X^H(D)$ is the magnetic field strength limit for the lateral measurement distance D, in dB(µA/m),

$L_X^H(15m)$ is the magnetic field strength limit for a lateral measurement distance of 15 m, in dB(µA/m), from table 1 or table 2,

X is between 1 and 5, as applicable,

$C_Y(D)$ is the correction factor corresponding to distance D, in dB, from table 3,

Y = A for transmission lines having the lowest conductor at 15 m height above ground, and

Y = B for transmission lines having the lowest conductor at 9 m height above ground, or for transmission substations.

At any other distance (i.e. any distance that is not listed in table 3), the applicable correction factor value shall be calculated by linear interpolation between the values corresponding to the closest distances listed in table 3 that are below and above the specific distance. An example interpolation calculation is provided in equation (C2) of annex C.

The distance correction factor specified in table 3 is presented graphically in figure B1 of annex B.

The field strength obtained through actual measurements (either at 15 m distance or by means of multiple measurements performed at different distances) is preferred, instead of extrapolating the field strength measured at a distance other than 15 m using the correction factor specified in table 3.

Table 3: Correction factor for measurement distances other than 15 m

Dist.	C_A	C_B	Dist.	C_A	C_B	Dist.	C_A	C_B	Dist.	C_A	C_B
m	dB	dB	m	dB	dB	m	dB	dB	m	dB	dB
10	-2.25	-3.75	23	3.8	5	36	8.8	10.85	49	12.9	15.25
11	-1.85	-2.95	24	4.2	5.6	37	9.15	11.2	50	13.2	15.6
12	-1.4	-2.2	25	4.65	6.2	38	9.45	11.6	51	13.45	15.85
13	-0.95	-1.45	26	5.1	6.7	39	9.8	11.95	52	13.75	16.15
14	-0.45	-0.7	27	5.45	7.15	40	10.15	12.3	53	14	16.4
15	0	0	28	5.9	7.65	41	10.45	12.65	54	14.25	16.7
16	0.55	0.7	29	6.3	8.1	42	10.8	12.95	55	14.5	16.95
17	1.05	1.35	30	6.65	8.52	43	11.1	13.3	56	14.75	17.2
18	1.53	2	31	7.05	8.93	44	11.4	13.6	57	15	17.45
19	2	2.65	32	7.45	9.3	45	11.7	13.95	58	15.2	17.75
20	2.5	3.3	33	7.75	9.7	46	12	14.3	59	15.45	18
21	2.95	3.87	34	8.1	10.1	47	12.3	14.6	60	15.65	18.25
22	3.4	4.5	35	8.5	10.5	48	12.6	14.95	–	–	–

3.3.2 Limits for distribution lines and distribution substations

No limit applies to emissions from distribution lines or distribution substations. However, if the radiated emissions from a distribution line or a distribution substation cause harmful interference to either the reception of:

- a Canadian broadcasting signal in the medium frequency (MF) band that measures at least 54 dB(μV/m) at the location of the receiver suffering interference; or
- any signal that is received in the performance of any other radio service,

then the radiated emissions from that distribution line or that distribution substation shall be limited to the level at which the harmful interference is eliminated.

4. Determination of harmful interference

Operators of transmission lines, transmission substations, distribution lines, and distribution substations shall be aware that even when they comply with all requirements of the *Radiocommunication Act*, the *Radiocommunication Regulations*, and this technical standard, they are required to take all practical steps to minimize the likelihood of harmful interference occurrences.

ISED will not normally respond to a request from a complainant to make a formal determination of harmful interference, unless it can be demonstrated that all other reasonable courses of action to resolve the problem have been explored. ISED fully expects complainants and operators of transmission lines, transmission substations, distribution lines, and distribution substations to cooperate with one another in order to resolve interference issues.

As a last resort, ISED may decide to make a determination of harmful interference. If this is the case, the operator of the transmission line, transmission substation, distribution line, or distribution substation alleged to be the source of the interference may be required to submit a record of the measurements and the test results of such equipment/installation (i.e. to demonstrate compliance with ICES-004) to ISED for review. If the transmission line, the transmission substation, the distribution line, or the distribution substation is found to cause harmful interference to radiocommunication, the operator of this line or substation shall immediately take corrective action.

5. Test report

The test report shall comply with the requirements in ICES-Gen.

Annex A: (informative) History of ICES-004

ICES-004 draws its roots from the first years after World War II, more specifically from the C22.4 No. 103 standard published by the Canadian Standards Association (CSA) in 1948, titled *Tolerable Limits and Special Methods of Measurement of Radio Interference from High Voltage Lines and Apparatus*. CSA further updated that first edition in 1975, changing its designation and title to C108.3.1 *Tolerable Limits and Methods of Measurement of Electromagnetic Interference from Alternating Current High Voltage Power Systems 0.15 MHz – 30 MHz*, and then again in 1984, with CAN3-C108.3.1-M84 *Limits and Measurement Methods of Electromagnetic Noise from AC Power Systems, 0.15 MHz – 30 MHz*.

The limits and measurement methods specified in these CSA standards were reflected in the Radio Interference Regulations, chapter 1374, published by Communications Canada (the precursor of ISED). In 1991, these limits and corresponding measurement methods were published as a separate regulatory standard, ICES-004 (issue 1, June 1991). Since then, ICES-004 went through three revisions (January 1999, December 2001 and June 2013), but with no modifications to the limits or measurement methods.

This revision (issue 5) does not constitute a technical change, since it continues to maintain the same limits and measurement methods that were in place for so many years. However, it adds detailed guidelines on how to perform the measurements, including an example measurement scenario, and reformats the limits to allow a simplified, more straightforward, and faster determination of compliance.

Annex B: (informative) Limits specification in previous editions of ICES-004

This annex is for information purposes only and shall not be used for demonstrating compliance with ICES-004. Instead, the limits specified in section 3.3 shall be applied.

All previous editions of ICES-004 specified the applicable limit at 500 kHz, for a lateral measurement distance of 15 m, for various phase-to-phase voltage ranges (see table B1), and supplemented this with two separate correction factors: one for other measurement distances and one for other frequencies. Both correction factors were only provided in graphical form.

Table B1: Maximum field strength at 500 kHz

Nominal phase-to-phase voltage kV	**Maximum electric field strength at 15 m lateral distance** dB(µV/m)
greater than 75 and up to 200	49
greater than 200 and up to 300	53
greater than 300 and up to 400	56
greater than 400 and up to 600	60
greater than 600 and up to 800	63

If measurements are performed at a lateral distance different than 15 m, the distance correction factor is added to the measured field strength before comparing with the limit in table B1. Specifically, the correction factor A applies for transmission lines with the lowest conductor 15 m above ground, while the correction factor B applies for transmission lines with the lowest conductor 9 m above ground and for transmission substations.

If measured field strength levels are at frequencies other than 500 kHz, the frequency correction factor is added to the measured field strength before comparing with the limit in table B1. This correction factor is different for transmission lines and transmission substations.

The two correction factors are included here, in figure B1 and figure B2. This way of specifying the limit, in particular the frequency-dependent correction factor, does not allow for a quick determination of compliance at a given frequency (except if that frequency is 500 kHz). This is why this fifth edition of ICES-004 takes a different approach and directly specifies the field strength limit at all frequencies by combining table B1 and figure B2. The limit specified in section 3.3.1 can therefore be directly applied to determine if a specific measured field strength value (at any frequency within the 150 kHz to 30 MHz frequency range) is compliant with ICES-004 or not.

Figure B1: Correction factor for lateral distances other than 15 m

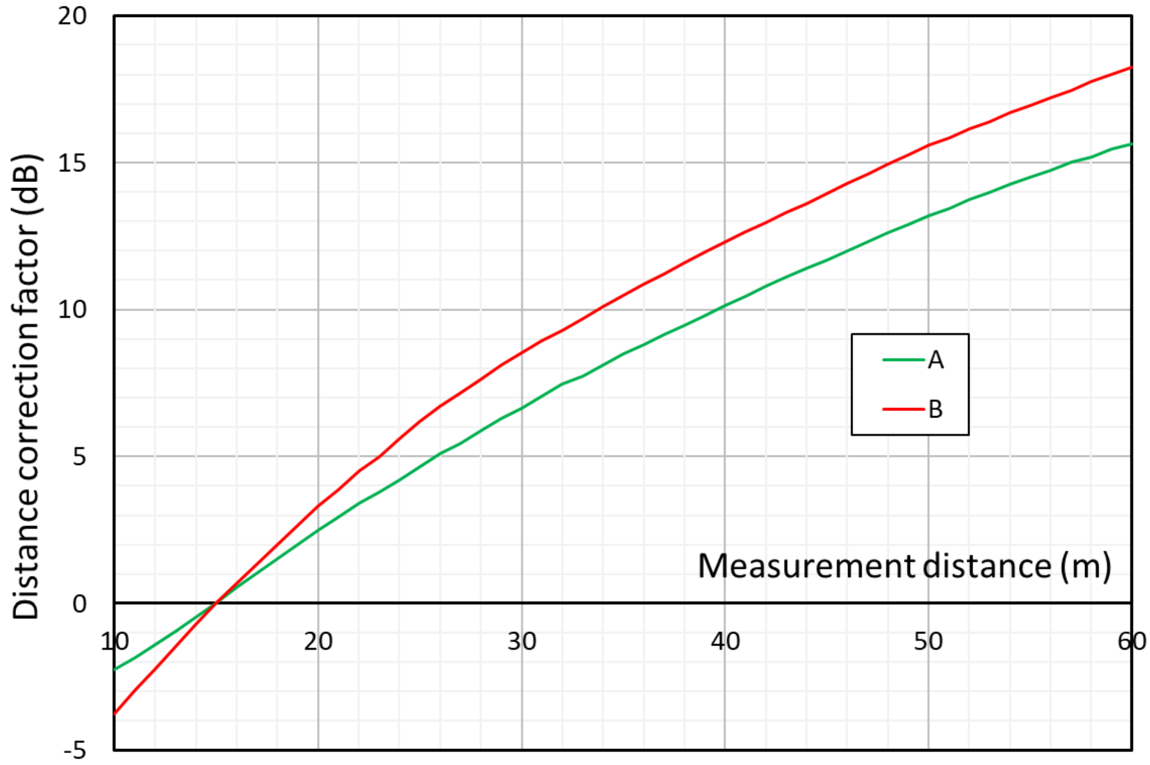
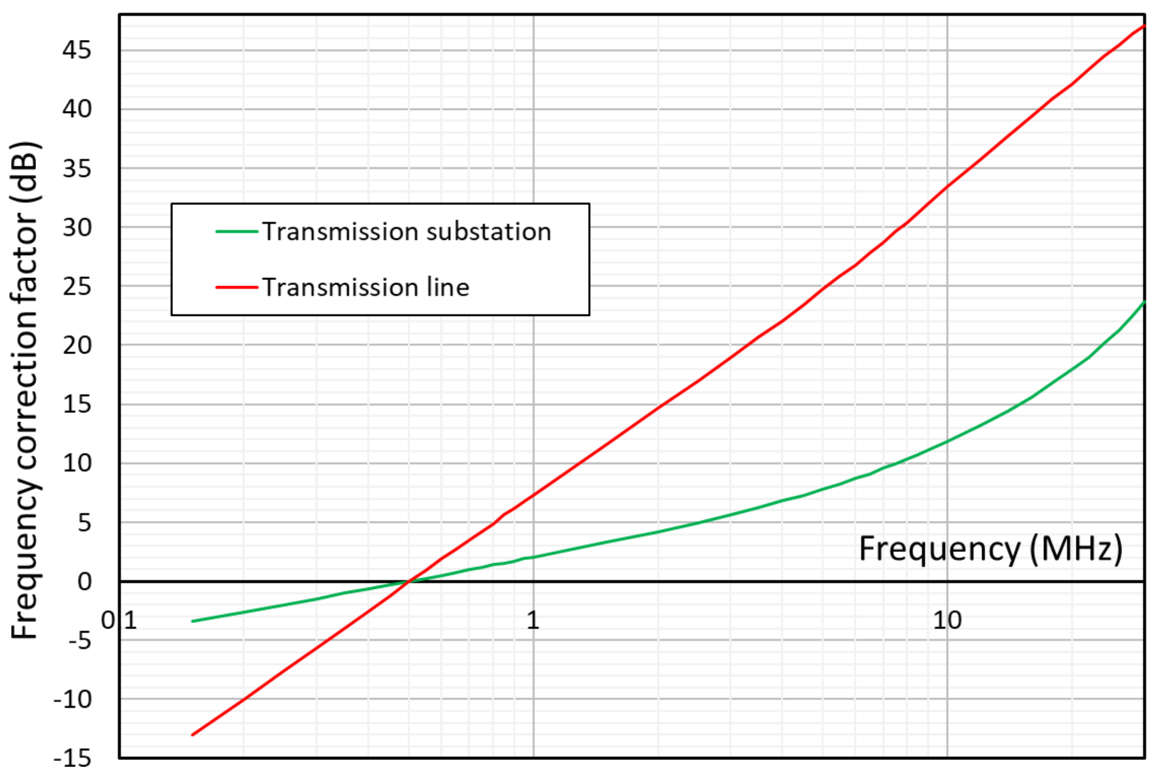


Figure B2: Correction factor for frequencies other than 500 kHz

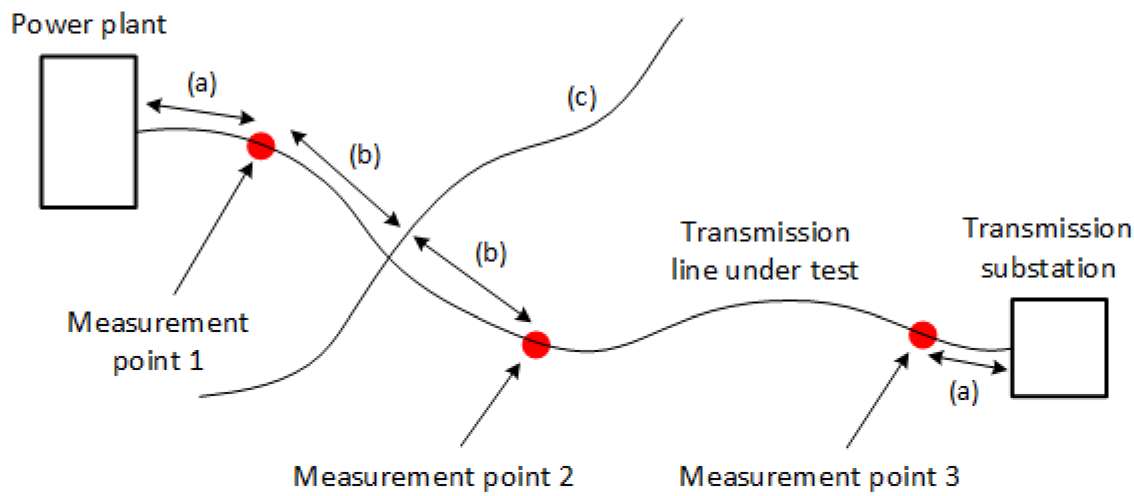


Annex C: (informative) Example measurement scenario

This annex provides an example measurement scenario for a transmission line.

Before starting the measurements, the three measurement points need to be selected. These, as per section 3.2.3, must be near the two ends and near the middle of the transmission line (see figure C1). Sufficient separation needs to exist between each measurement point and other objects, power lines, or communication lines, such that their influence on the emissions measurement is minimized. Note that figure C1 shows each measurement point on the transmission line; however, for each location, measurements are taken at a lateral distance from the transmission line.

Figure C1: Measurement points selection for a transmission line



(a) ≥ 5 km
(b) Sufficient separation
(c) Other power line

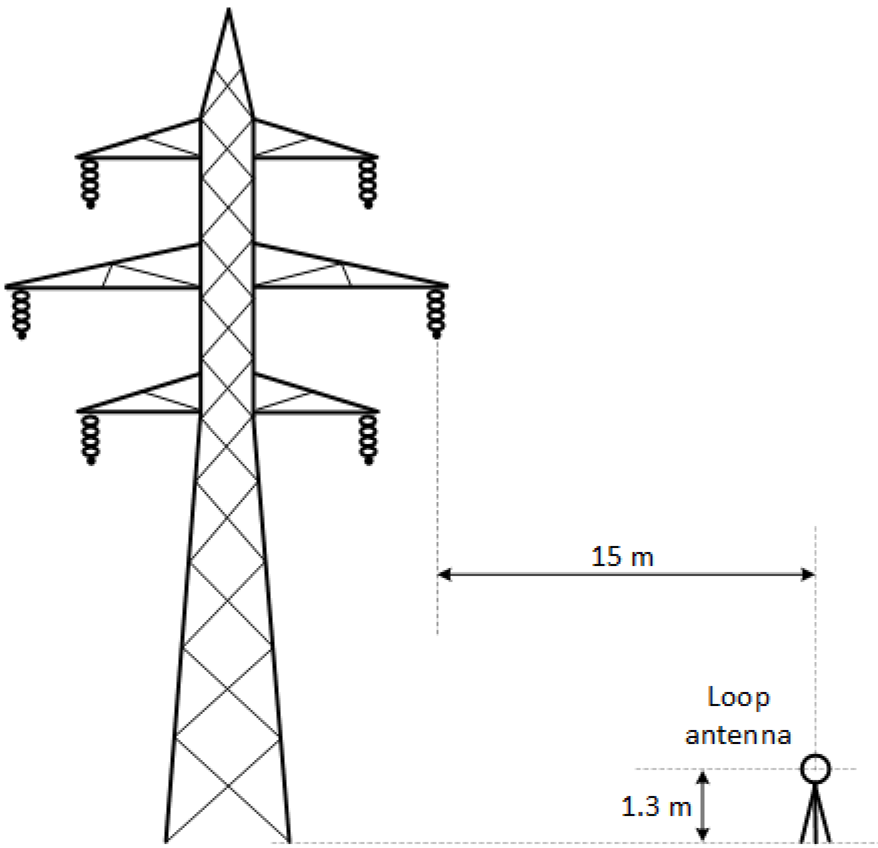
If possible, it is preferred that the measurements are performed with a loop antenna, which should be placed on a tripod so its plane is vertical and its centre is at 1.3 m above the ground level. The antenna cable should be routed straight down to the ground and then to the measurement instrument.

If a rod antenna is used instead of a loop antenna, it needs to have a counterpoise. The rod antenna is placed at the measurement location with its rod in vertical position and its counterpoise flat against the ground. The counterpoise of the antenna shall be properly grounded (e.g. by bonding it to a sufficiently long copper rod driven into the ground at the measurement location).

Both the measurement instrument and the person performing the measurements should be at least 2 m away from the antenna to minimize the risk of influencing the measurement.

If possible, the antenna (loop or rod) should be placed at a lateral distance of 15 m from the vertical plane passing through the closest power line (see figure C2).

Figure C2: Antenna position (transversal view)

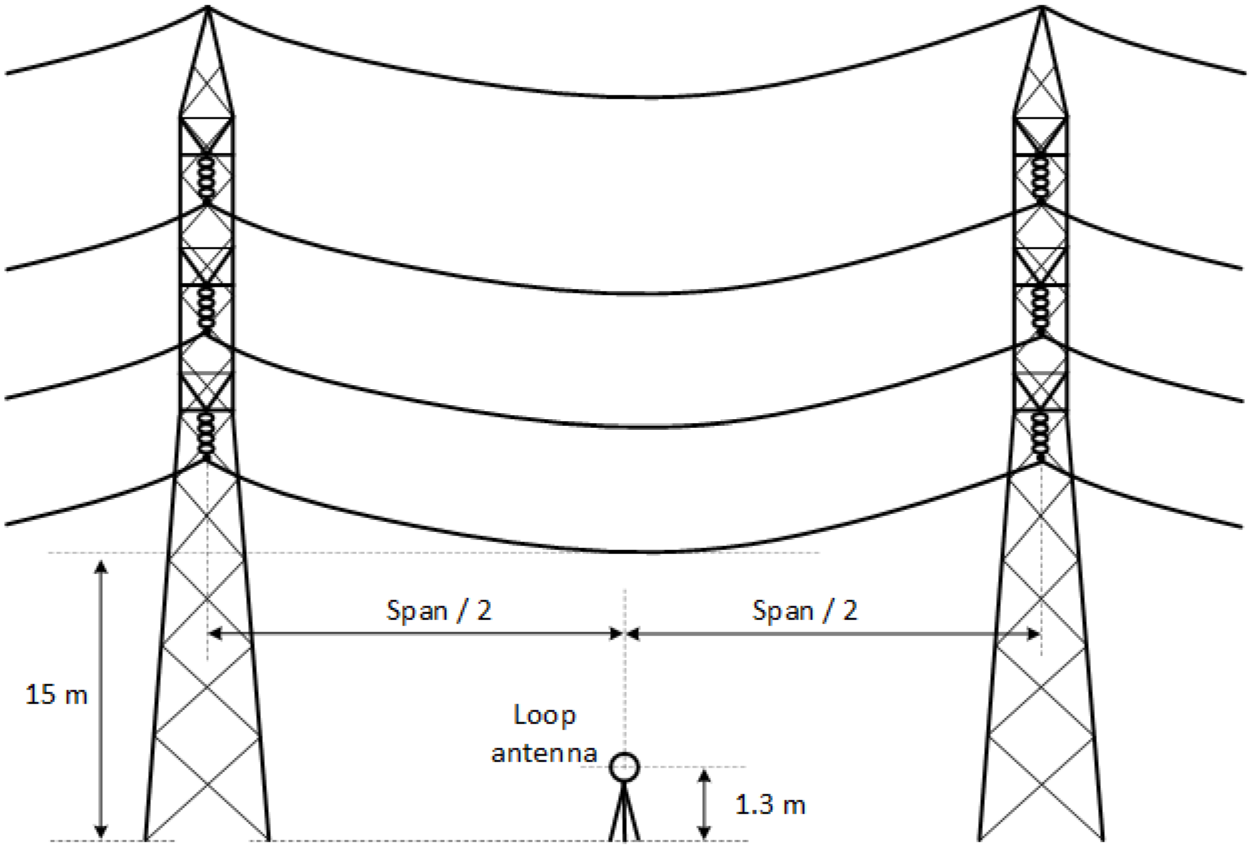


If the measurement cannot be taken at a 15 m lateral distance, then either scenario described below shall be used (see sections 3.2.3 and 3.3.1.2):

- two (or more) measurements shall be taken, at different distances, with at least one smaller than 15 m and at least one greater than 15 m, or
- if the lowest conductor of the transmission line under test is at 9 m or 15 m height above ground, only one measurement may be performed, with the antenna placed at the nearest convenient distance, but not closer than 10 m lateral distance.

At each measurement point, the antenna is placed in the vertical plane that passes through all the conductors of the power line at the middle of the span, i.e. at the mid-distance between two consecutive transmission towers (see figure C3).

Figure C3: Antenna position (longitudinal view)



The measurement instrument is set up with a quasi-peak detector and a resolution bandwidth of 9 kHz, in accordance with CAN/CSA-IEC CISPR 16-1-1:18 (see section 3.1). When using a spectrum analyzer, the MaxHold trace mode shall be used and the measurement results shall be recorded only after there are no more variations in the displayed spectrum. When using a receiver, the measurement time shall be sufficiently long for recording the maximum level at each frequency.

For the initial measurement, it is recommended that an attenuator of at least 10 dB is inserted in front of the measurement instrument's input, in order to protect the front end of the measuring instrument in case there are very high ambient signals at the specific measurement location. If, after taking the first scan of the electromagnetic spectrum, no high ambient signals are detected, the attenuator can then be removed to obtain greater sensitivity.

A measurement is then taken over the entire frequency range where limits are prescribed in section 3.3.1 (i.e. 150 kHz to 30 MHz).

For easier and faster determination of compliance, it is beneficial to input a correction factor table in the measurement instrument (if it has that feature) with the combined antenna factor and cable loss (and other loss/gain, as applicable), both in logarithmic units. If a rod antenna is used for measurements, the free-space impedance of 51.5 dBΩ shall be subtracted from the measured electric field strength level before comparing with the limit [see equation (1) in section 3.3.1.1].

The measurement instrument will then display all measured emissions directly in units of field strength, allowing each to be directly compared with the applicable limit. Some measurement instruments also permit uploading a limit (defined by multiple frequency-level points), which would further streamline the test by immediately providing either an overall passing result or identifying those emissions that are above the limit.

If the antenna factor and the cable loss (and other loss/gain, as applicable) are not inserted as a correction factor in the measurement instrument, then each measured emission level shall be corrected with these factors after taking the measurement. While the cable loss is usually low in this frequency range, both the antenna factor and the limit (see section 3.3.1) vary with frequency. As such, if the measurement instrument does not automatically correct the result by accounting for the antenna factor, a determination of compliance cannot be performed directly from the measured data. The measurement process will be longer because each detected emission will have to be first corrected with the antenna factor and cable loss (and other loss/gain, as applicable), at that frequency, before comparing with the limit at the same frequency.

All emissions found to be within 10 dB of the corresponding limit shall be further investigated by rotating the loop antenna around the vertical axis connecting the centre of the loop with its projection on the ground for maximizing the measured level. To avoid influencing the measurements (the person performing the measurements shall not be close to the loop antenna when taking the measurement), either a motorized loop antenna positioner shall be used (allowing remotely controlling its angle) or multiple measurements shall be taken with various angles of the loop antenna. Alternatively, exploratory measurements can be taken by manually rotating the loop antenna and, after finding the angle resulting in the highest reading, the antenna is fixed in this position and the person performing the measurements backs off for taking the final measurement at that frequency.

If the measurements were taken at a 15 m lateral distance, each detected emission, after correcting it with the antenna factor and cable loss (and other loss/gain, as applicable) corresponding to that frequency, is compared with the limit in table 1. If the measured emission's frequency is not listed in the table, the limit level is calculated using linear interpolation. For example, if the emission frequency is 21.5 MHz, then the limit is calculated from the limit levels corresponding to the closest adjacent frequencies listed in table 1 (i.e. 20 MHz and 22 MHz):

$$L_X^H(21.5) = L_X^H(22) - [L_X^H(22) - L_X^H(20)]\frac{\log_{10}(21.5/20)}{\log_{10}(22/20)} \quad \text{(C1)}$$

where

$L_X^H(f)$ is the magnetic field strength limit for 15 m lateral measurement distance at frequency f, in dB(µA/m), from table 1, and f is the frequency, in MHz.

Assuming the limit applicable to the transmission line under test is L_1, the resulting limit at 21.5 MHz is −44.94 dB(µA/m).

If the measurement cannot be taken at 15 m lateral distance, then the level measured at each frequency is further corrected with the distance correction factor in table 3 (see section 3.3.1.2). Assuming the measurement distance was 10 m, the correction factor that shall be added to each measured emission level is −2.25 dB. This factor is not dependent on frequency, thus the same value must be added to all measured emission levels, at all frequencies detected at the specific measurement location. This is possible because the transmission line under test has the lowest conductor at 15 m height above ground (see figure C3). If the height of the lowest conductor was instead 9 m, then the distance correction factor, for a measurement distance of 10 m, would have been −3.75 dB.

If the measurement distance employed is not listed in table 3, the distance correction factor is calculated using linear interpolation (but using a logarithmic scale for the distance) between the values corresponding to the closest adjacent distances listed in the table:

$$C_Y(d) = C_Y(d_1) - [C_Y(d_1) - C_Y(d_2)]\frac{\log_{10}(d/d_1)}{\log_{10}(d_2/d_1)} \quad \text{(C2)}$$

where

$C_Y(d)$ is the distance correction factor applicable to measurements on transmission lines at a lateral measurement distance *d*, in dB;

d is the distance, in m;

Y = A for transmission lines having the lowest conductor at 15 m height above ground; and

Y = B for transmission lines having the lowest conductor at 9 m height above ground.

Assuming the transmission line has the lowest conductor at 15 m height above ground (Y = A) and that measurements were performed at a lateral distance of 17.5 m, the resulting correction factor is $C_A(17.5)$ = 1.29 dB (closest adjacent distances are 17 m and 18 m).

In case the height of the lowest conductor of the transmission line under test were neither 15 m nor 9 m, and the first set of measurements were taken at 10 m lateral distance, then an additional measurement (over the entire frequency range of 150 kHz to 30 MHz) would be required, at a distance that is greater than 15 m. Then, at each detected emission frequency, the two results (at the two different distances) are used for calculating the field strength at a 15 m distance, by linear interpolation, before comparing with the limit in table 1:

$$H(15) = H(d_1) - [H(d_1) - H(d_2)]\frac{\log_{10}(15/d_1)}{\log_{10}(d_2/d_1)} \quad \text{(C3)}$$

where

H(*d*) is the magnetic field strength for the lateral measurement distance *d*, in dB(µA/m), while *d* is the distance, in m.