

EXHIBIT D

Industry Standards Addressing Distance Extrapolation

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Abstract:

Most regulations for emissions for various unlicensed devices control conducted emissions below 30 MHz and radiated emissions above 30 MHz. For this reason, there are relatively few standards or regulations that govern radiated measurements below 30 MHz. However, those that do generally support measurement procedures that may extrapolate measurements made at one distance to an estimate of field strength at a different distance. ANSI C63.12, Telcordia GR-1089, CISPR 18 and CISPR 11 and 47 C.F.R. Part 18 all offer alternatives for distance extrapolation that apply below 30 MHz. None of these standards or regulations specify a 40 dB/decade extrapolation below 30 MHz. By various means and with some minor variation in break points, all stipulate that electric fields (E) or magnetic fields be extrapolated at 20 dB/decade, except in the reactive near field region, nominally taken to be bounded by a distance of $\lambda/2\pi$ from the radiating source. 47 C.F.R. Part 15 stands alone in specifying a 40 dB/decade extrapolation below 30 MHz.

Standards:

ANSI C63.12-1999:

American National Standard Recommended Practice for Electromagnetic Compatibility Limits (have) – Note 11

Description: C63.12 is an ANSI Recommended Practice that describes what criteria should govern the setting of limits in American standards. One section of the document describes how to extrapolate from a measurement point to a limit specified at a different distance from the radiating source. This is found in Note 11 in the document (emphasis added):

“It is understood that a radiation level expressed (as shown in Figure 3) in $\mu\text{V}/\text{m}$ implies electric and magnetic field levels related by the free space impedance of 377Ω . It is true that the free space impedance may not hold in the near field, that is, at frequencies where the measuring distance is less than $\lambda/2\pi$ where λ is the wavelength in meters (frequencies below 1600 kHz for a measuring distance of 30 m; frequencies below 4800 kHz for a measuring distance of 10 m and below 16 MHz for a measuring distance of 3 m). Extrapolation of the electric field limit

values at a particular frequency to a different measuring distance requires a knowledge of the source of the emissions and the effects of a conducting ground plane over which these measurements are usually performed. In the simplest case, this would be either a small electric dipole or a small magnetic loop. In a free field, extrapolation of the limits at a particular frequency to distances less than $\lambda/2\pi$ requires extrapolation of the level at that frequency back to the $\lambda/2\pi$ distance using a $1/d$ extrapolation and then further extrapolation from the level at the $\lambda/2\pi$ distance to the final distance using a $1/d^3$ or $1/d^2$ relation (depending on an electric or magnetic source, respectively). Extrapolation of the limits at a particular frequency to distances greater than $\lambda/2\pi$ requires that the level at that frequency first be extrapolated to the $\lambda/2\pi$ distance using a $1/d^3$ or $1/d^2$ relation (depending on whether the source is electric or magnetic, respectively) and then further extrapolating the limit from the $\lambda/2\pi$ distance to the final distance using a $1/d$ relationship. It follows that limit extrapolation for distances greater than 3 m above 16 MHz, 10 m above 4800 kHz or 30 m above 1600 kHz requires only a simple $1/d$ extrapolation. Thus, translation of the guidelines requires a knowledge of the type of source causing the emissions, and may require experimental validation, especially to account for ground plane effects.

(emphasis added)

Conclusions to be drawn from C63.12: This consensus recommended practice supports the position that within the distance of $\lambda/2\pi$, magnetic-field measurements should be extrapolated at 40 dB/decade. It then states that beyond that region, extrapolation should be made at 20 dB/decade. It correctly notes that at a distance of 10 meters or more, measurements made above 4.8 MHz would be in the 20 dB/decade region so should be extrapolated across that region at 20 dB/decade.

Telcordia GR-1089:

Electromagnetic Compatibility and Electrical Safety - Generic Criteria for Network Telecommunications Equipment

Description: Telcordia GR-1089 is a long-standing successful standard used mostly within the US to control the compatibility of telecommunications systems. Most of these systems have a lot in common with BPL systems in that they are physically large systems that conduct signals on wiring that is often overhead. Although most access BPL systems have a greater potential for interference because the differential conductors used to conduct the desired signals are physically separated by distances of 1 meter or more, the standard should apply reasonably well to the extrapolation of field strength with distance, due to the similarities of the common-mode signal found in both technologies.

GR-1089 does not directly specify extrapolation. It does, however, specify emissions limits for different frequencies based on the premise that field strength decays rapidly in the near-field region of distances closer than $\lambda/2\pi$, and decays at a 20 dB/decade rate beyond that region. This

standard uses a formula that includes distance factor and frequency factors that account for electric field strength varying at 60 dB/decade in the near-field region and 20 dB/decade at distances greater than wavelength $\lambda / 2\pi$.

Class B limits:

For Class B limits, the formulae that set the limits based on frequency and distance are:

For frequencies from 1.59 to 2 MHz:

$$\text{dBuV/m} = 126.2 - 60\log_{10}(D_{\text{meters}}) - 40\log_{10}(F_{\text{MHz}})$$

For frequencies from 2 MHz to 88 MHz:

$$\text{dBuV/m} = 49.5 - 20\log_{10}(D_{\text{meters}})$$

Above 2 MHz, the limits are set at 29.54 dBuV/m at 30 meters distance, matching the present FCC rules for carrier-current devices.

Class A limits:

For frequencies from 1.59 MHz to 88 MHz:

$$\text{dBuV/m} = 59.1 - 20\log_{10}(D_{\text{meters}})$$

At 30 meters distance, for all frequencies above 1.59 MHz, the Class A limit at 30 meters calculates to be 29.55 dBuV/m. Above 2 MHz, the Class B limit is 19.96 dBuV/m.

At 10 meters distance, the $60\log_{10}(D)$ and $20\log_{10}(F)$ functions in the formula combine to set a limit that is extrapolated upward by 60 dB/decade (for the E field) within the $\lambda/2\pi$ region and 20 dB/decade beyond that distance. Table 1 below shows the limits at a distance of 10 meters. The formula for Class A limits in GR-1089 sets limits that follow the near-field/far-field boundary set by $\lambda/2\pi$, applying that formula to large radiators with structure similar to access and/or in-premise BPL.

Table 1: GR-1089 limits at 10 meters distance

Frequency	Class A Limit at 10 meters distance	Class B Limit (dBuV/m) at 10 meters distance
2 MHz	54.2 dBuV/m	54.2 dBuV/m
4.77 MHz	39.1 dBuV/m	39.1 dBuV/m
5 MHz	39.1 dBuV/m	38.2 dBuV/m
6.05 MHz	39.1 dBuV/m	34.9 dBuV/m
10 MHz	39.1 dBuV/m	34.9 dBuV/m

20 MHz	39.1 dBuV/m	34.9 dBuV/m
30 MHz	39.1 dBuV/m	34.9 dBuV/m

Conclusions to be drawn from GR-1089: This industry specification supports the position that within the distance of $\lambda/2\pi$, electric-field measurements should be extrapolated at 60 dB/decade. It then states that beyond that region, extrapolation should be made at 20 dB/decade. It indirectly, but correctly notes that at a distance of 10 meters or more, measurements made above 4.8 MHz would be in the 20 dB/decade region so should be extrapolated across that region at 20 dB/decade.

CISPR 18-2: 1986

Radio interference characteristics of overhead power lines and high-voltage equipment -- Part 2: Methods of measurement and procedure for determining limits

Description: The CISPR 18 series are international standards that have strong applicability to power lines. These standards have evolved over decades, based on significant power industry experience, measurements and practice. CISPR 18, amendment 2 specifically addresses in two areas the distance extrapolation issue related to power lines:

Attenuation (extrapolation) in CISPR 18:

Section 2.3.5.1 discusses how signals attenuate laterally from power lines, expressed as an exponent rather than an attenuation factor. In this clause, CISPR 18-2 states that signals from 0.4 to 1.7 MHz will attenuate at $D^{-1.65}$, or 33 dB/decade. The standard describes that from 30 MHz to 100 MHz, signals attenuate at $D^{-1.2}$, or 24 dB/decade. Inexplicably, it does not outline a factor between 1.7 and 30 MHz, but states, “Presumably, the factor of 1.65 is somewhat valid between 1.7 MHz and 30 MHz.” The standard then goes on to explain that the mechanism and also the attenuation law are dependent on the type of noise source, for example conductor corona or gap-type discharge at fittings.

A reasonable conclusion to draw from this would be that, as seen in other standards, the increase in the rate of field-strength change vs distance that applies in the $\lambda/2\pi$ region would tend to make the lower part of the 1.7 MHz frequency range closer to 33 dB/decade, as applies at 1.7 MHz and closer to 24 dB/decade, as applies at 30 MHz, at least along the ground.

CISPR 18-2, Amendment 2: 1996

Amendment 2 of CISPR 18-2 did add to the information in CISPR 18 on extrapolation. This amendment primarily deals with the EMC issues of high-voltage DC (HVDC) converter stations. In this amendment, CISPR deals with the way that fields vary with distance from the line from these devices.

Section 5.3.2 Lateral attenuation

This section describes the coupling mechanism from HVDC converters as being a radiating loop, equivalent in nature to a vertical electrical dipole. The section concludes that the attenuation of the noise level from these devices is approximately proportional to the inverse of the square of the distance for frequencies up to 1 MHz (40 dB/decade) and becomes proportional to the inverse of the distance (20 dB/decade) for frequencies of 10 MHz and higher.

This is also shown graphically in Figure 17 of the Amendment, shown below.

Conclusions to be drawn from CISPR 18-2, Amendment 2: The standard, especially Figure 17, clearly shows that within the distance of $\lambda/2\pi$, fields below 30 MHz decay at a rate of 60 dB/decade for electric fields, 40 dB/decade for magnetic fields and, at distances greater than $\lambda/2\pi$ both fields decay at 20 dB/decade.

- 20 - CISPR 18-2 amend. 2 © CEI:1996

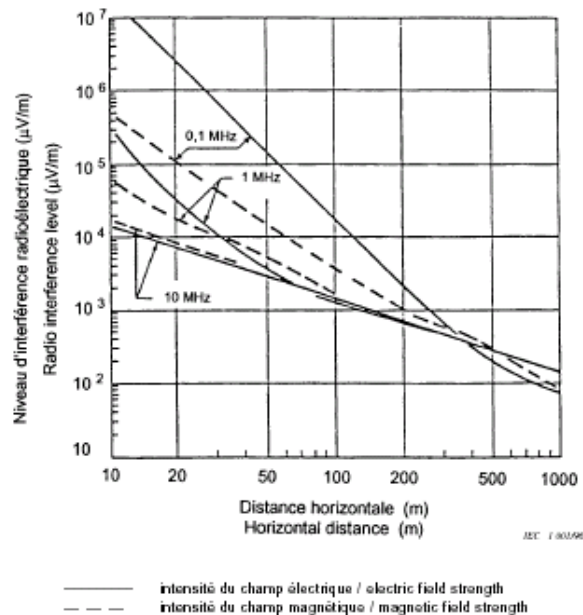


Figure 17 – Atténuation du niveau perturbateur en fonction de la distance sur un plan horizontal pour différentes fréquences (Valeurs calculés de la radiation libre provoquée par un dipôle électrique vertical; voir référence [77])

Attenuation of the field strength as a function of the distance on a horizontal plane, for different frequencies (Calculated levels for free wave propagation of a radiation caused by a vertical electrical dipole; see reference [77]).

CISPR 11:

Industrial, scientific and medical equipment -- Radio-frequency disturbance characteristics -- Limits and methods of measurement.

Description: CISPR 11 applies specifically to ISM equipment, but the test methods in CISPR 11 are based on electromagnetic-theory principles found in many standards.

The issue of distance extrapolation below 30 MHz is dealt with in several places within CISPR. Section 8.3.4, Radiation measurement (9 kHz to 1 GHz) states: “For test site measurements in the frequency range below 30 MHz, the conversion factor deviates from 20 dB per decade. In this case, the appropriate limits set out in Table 9 and 11 can be used, respectively.”

This is saying that extrapolations below 30 MHz cannot be done reliably. This is why the standard requires that the limits be met, not extrapolated. Table 11 is most useful to accomplish this, because it sets limits at both 10 meters and 30 meters distance.

Table 2: Examples of the limits described in Table 11 of CISPR 11

Frequency	H field limit at 30 meters	H field limit at 10 meters	dB/decade difference
0.15-0.49 MHz	33.5 dBuA/m	57.5 dBuA/m	50.3 dB/decade
0.49-1.705 MHz	23.5 dBuA/m	47.5 dBuA/m	50.3 dB/decade
2.194-3.95 MHz	23.5 dBuA/m	43.5 dBuA/m	42 dB/decade
3.95-20 MHz	8.5 dBuA/m	18.5 dBuA/m	21 dB/decade
20-30 MHz	-1.5 dBuA/m	8.5 dBuA/m	21 dB/decade

Conclusions to be drawn from CISPR 11: Again, at lower frequencies where the fields are reactive and vary at greater than 20 dB/decade, this standard sets limits at 10 and 30 meters approximately based on the boundary set by the $\lambda/2\pi$ region. Beyond that region, the limits are set 10 dB difference for 10 and 30 meters distances, using an extrapolation in the limits very close to 1/R or 20 dB/decade.

FCC CFR 47 Part 18:

Industrial, Scientific and Medical Equipment (ISM)

Description: Sec. 18.305(b) and (c) set limits for ISM equipment outside the ISM bands. These limits are specified as applying to “any non ISM frequency.” ISM equipment operates on specific bands from 6.78 MHz to 245 GHz. The limits and test methods in Part 18 apply to spectrum below and above 30 MHz.

Note 2 of Sec. 18.305(b) and (c) outlines how to deal with distance extrapolation:

“2. Testing for compliance with these limits may be made at closer distances, provided a sufficient number of measurements are taken to plot the radiation pattern, to determine the major lobes of radiation, and to determine the expected field strength level at 30, 300, or 1600 meters. Alternatively, if measurements are made at only one closer fixed distance, then the permissible field strength limits shall be adjusted using $1/d$ as an attenuation factor.”

Conclusions to be drawn from FCC 47 CFR Part 18: Part 18 is very clear that at all frequencies for which measurements are made to establish compliance with Part 18, if extrapolations are made, a 20 dB/decade extrapolation factor should be used.