EMC pre-compliance testing on your own bench

What CISPR specifies, which parts of it a general-purpose analyzer can reproduce, and how to make a bench scan that predicts a chamber result.

ABSTRACT

A first radiated emissions test fails often enough that most teams budget for it. The expensive part is not the chamber day, it is the loop between the failure and the retest. This paper sets out what CISPR 16-1-1 specifies for a scan: five bands, four resolution bandwidths defined at 6 dB rather than 3 dB, detector time constants that govern dwell, and an overload factor that governs headroom. It derives the corrections that turn an indicated level into a field strength, works the noise floor and common-mode current arithmetic, and quantifies what a bench result may claim. This paper describes pre-compliance practice with a spectrum analyzer, not a certified CISPR receiver mode.

WHO THIS PAPER IS FOR

Hardware and compliance engineers who own a product's first emissions test and want the failures found before the chamber is booked. **Test engineers** building a repeatable pre-compliance scan. **Engineering managers** deciding whether a bench, a chamber day, or both is the cheaper route to a certificate.

CONTENTS

1 What a failed emissions test costs

An accredited 3 m semi-anechoic chamber bills 2,000 to 4,000 US dollars a day, and a first radiated scan takes two or three of them [generic illustrative range]. The larger cost is the loop: the product fails at 240 MHz, somebody fits a ferrite, and the chamber is rebooked three weeks out. Two loops put a launch two months late.

The objection is that a bench is not a chamber. Correct, and not the end of it. A bench scan is not trying to produce a number a certification body will accept. It answers the three questions that set the loop count: which frequencies sit close to a limit, what is radiating them, and whether last night's change helped. None needs an accredited site. All three need the measurement made as the standard defines it, because a scan at the wrong bandwidth is not pessimistic, it is wrong.

2 What the standard specifies

CISPR 16-1-1 describes a measuring receiver, not a spectrum analyzer, and it pins down what an analyzer leaves to the operator: band boundaries, resolution bandwidth, detector time constants and overload factor. Table 1 collects them.

Bandwidth breaks bench scans twice. CISPR specifies it at the −6 dB points; analyzers specify it at the −3 dB points, a narrower filter for the same number. And a narrowband carrier reads the same at any bandwidth wide enough to hold it, while a clock edge does not, because a broadband emission follows bandwidth in volts rather than power:

$$B_3 = B_6 / \sqrt{2} \qquad \Delta L = 20 \log_{10}(B_2 / B_1) \tag{1}$$

where

B_3, B_6 is filter width at 3 dB and 6 dB, in hertz

B_1, B_2 is the bandwidth used and the bandwidth the standard specifies, in hertz; 9 kHz and 120 kHz for the band B and band C settings, so ΔL is the correction to add and Figure 1 plots its negative, the error made

ΔL is change in indicated level, in dB

> **THE 22.5 DB MISTAKE**
>
> Scan band C at the band B bandwidth, which is what happens when the conducted setup is reused, and a broadband emission reads 20 $\log_{10}$(120 kHz / 9 kHz) = 22.5 dB low. A product 12 dB over the limit is displayed 10.5 dB under it. Not lost precision. A reversed verdict.

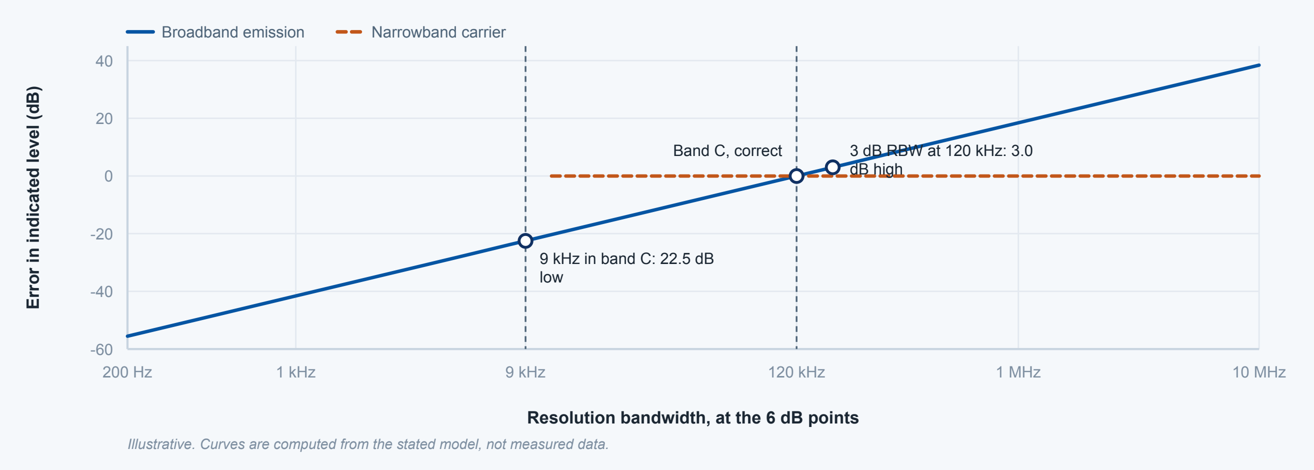

Figure 1. Bandwidth error is signed, and it lands only on broadband emissions: too narrow and a failing product passes, too wide and a passing one fails, while the narrowband carrier reads the same at every setting wide enough to hold it. Typing the CISPR 6 dB number into a 3 dB field over-reads by 3.0 dB. **DERIVED**

Figure 1 plots the error against bandwidth, and the sign is the thing to carry away. Table 1 then gives the settings the standard actually specifies, band by band.

Table 1. Columns three, seven and eight are from CISPR 16-1-1; the rest are derived from equation (1). The four bandwidths in column four are the whole of what makes a bench scan comparable to a laboratory scan. An instrument that cannot be set to 84.9 kHz cannot produce a CISPR-comparable band C or D measurement, and no post-processing recovers it, which is why a continuously settable resolution bandwidth matters more here than sensitivity does.

Band	Range	6 dB RBW	3 dB equiv.	Step	Points	τ_c/τ_d/meter (ms)	Overload
A	9 to 150 kHz	200 Hz	141 Hz	100 Hz	1,410	45 / 500 / 160	24 dB
B	0.15 to 30 MHz	9 kHz	6.4 kHz	4.5 kHz	6,633	1 / 160 / 160	30 dB
C, D	30 MHz to 1 GHz	120 kHz	84.9 kHz	60 kHz	16,167	1 / 550 / 100	43.5 dB
E	1 to 6 GHz	1 MHz	707 kHz	500 kHz	10,000	none	n/a

Verify: bandwidth ranges permitted in bands A and E; post-detector overload factors.

From an indicated level to a field strength

An analyzer displays the level at its connector; a limit is field strength at a distance. Everything between is a signed correction:

$$E = V_{\mathrm{ind}} + AF + L_{\mathrm{c}} - G_{\mathrm{p}} \tag{2}$$

where

E is field strength at the measurement distance, in dBμV/m

V_{ind} is level indicated at the analyzer input, in dBμV

AF is antenna factor, in dB(1/m); 17.5 at 240 MHz and 25 at 1 GHz [generic illustrative values]

L_c is cable and pad loss, in dB; 2.2 and 4.0 [generic illustrative values]

G_p is preamplifier gain, in dB; 30 [generic illustrative value]

The conducted case has the same shape, with the mains network voltage division factor replacing the antenna factor (Figure 2). Three terms vary with frequency, so a mid-band constant is decibels wrong at the edges.

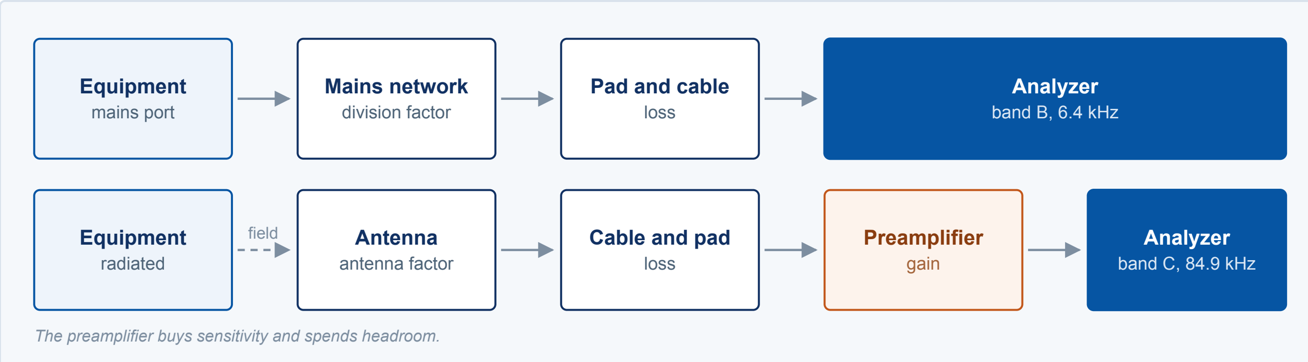

Figure 2. Four frequency-dependent corrections across the 16,167 points of bands C and D cannot be done by hand. They live in the instrument or nowhere. SCHEMATIC

3 Why a scan finds nothing and reports it as a pass

The second failure has nothing to do with amplitude: the emission was not there when the analyzer was. A stepped scan visits each cell for the fraction of the sweep set by bandwidth over span:

$$t_\mathrm{d} = T_\mathrm{sweep} \cdot B \,/\, S, \quad p = (t_\mathrm{d} + t_\mathrm{e}) \,/\, T_\mathrm{e}, \quad P_\mathrm{n} = 1 - (1 - p)^n \tag{3}$$

where

t_d, S, n is cell dwell; span, 970 MHz; sweeps in max hold

t_e, T_e is event duration and period, 5 ms and 2 s

Across 30 MHz to 1 GHz at 120 kHz with a one second sweep [generic illustrative value], t_d = 1 s × 120 kHz / 970 MHz = 124 µs, so p = (124 µs + 5 ms) / 2 s = 2.562 × 10^{-3}. One sweep finds a 5 ms commutation burst a quarter of one percent of the time (Figure 3).

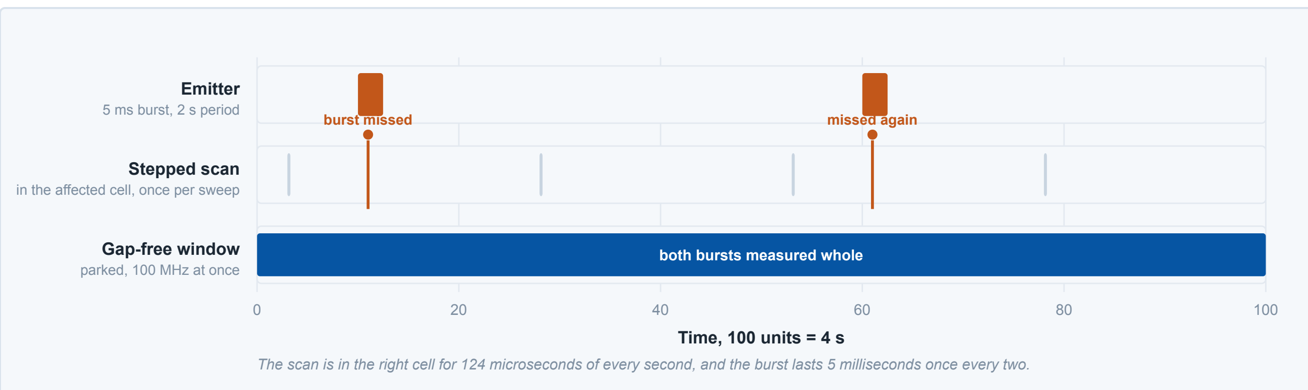

Figure 3. The geometry behind the arithmetic. The stepped scan is not slow, it is elsewhere: it visits the affected cell often but for 124 microseconds at a time, and the burst it is looking for arrives when it is somewhere else. Nothing about sweeping faster changes that, because a faster sweep shortens the dwell in the same proportion. Drawn for legibility rather than to scale: the true ratio is 124 microseconds of dwell inside a one second sweep against a 5 millisecond burst, which no drawing can show and the arithmetic below can. SCHEMATIC

Figure 3 is the same statement drawn rather than computed, and it is worth looking at before Figure 4, because that curve is a consequence and this is the cause.

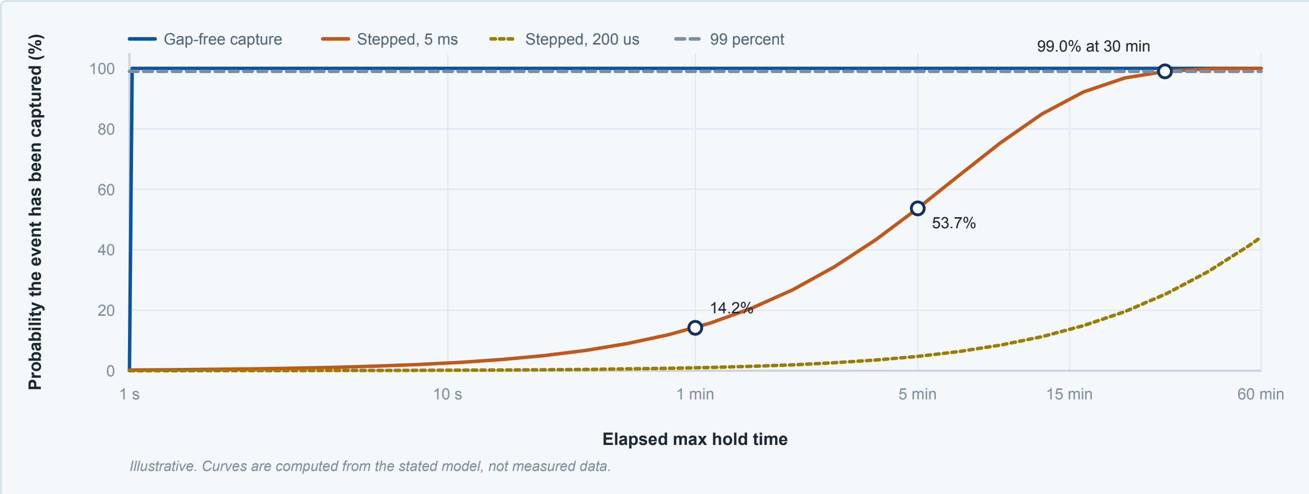

Figure 4. Thirty minutes of max hold to reach 99 percent confidence on a 5 ms emission that repeats every two seconds, or a single pass with gap-free capture. A one minute max hold finds it 14 percent of the time, and the faint trace, a 200 microsecond burst on the same period, has reached only 44 percent after a full hour and needs 7.9 hours for 99. Most pre-compliance scans that found nothing were not measurements of a clean product. They were measurements of too little time. DERIVED

4 Requirements for a pre-compliance bench

None of the above names an instrument. Table 2 converts it into six requirements.

Table 2. Six requirements, derived rather than asserted. R1 and R4 are the two a general-purpose analyzer meets only if it was selected with them in mind.

	Requirement	The number	From
R1	Bandwidth at the CISPR 3 dB equivalents	141 Hz, 6.4 kHz, 84.9 kHz, 707 kHz	Eq. (1)
R2	Coverage of the applicable bands	9 kHz to 1 GHz; 6 GHz above 108 MHz clocks	Bands A to E [verify]
R3	Step at half bandwidth, dwell at the meter constant	16,167 points, 100 ms	Table 1
R4	Headroom for the overload factor	43.5 dB, bands C and D	Table 1
R5	Corrections applied per point	Four terms	Eq. (2)
R6	A capture that does not rely on luck	99 percent in one pass	Eq. (3)

5 Meeting the requirements, and what it costs

The ICX-FieldHawk family is a general-purpose real-time analyzer, not a compliance receiver. **R1 and R2.** The datasheets publish a swept resolution bandwidth of 1 Hz to 10 MHz and coverage of 9 kHz to 9.5 GHz on the ICX-090 models or 40 GHz on the ICX-400 models, so all four CISPR equivalents fall inside. Whether that range is continuously settable, and 84.9 kHz can be set exactly, is not stated and is marked verify below.

R3 and R5. A CISPR-shaped scan is built, not selected. SCPI is standard, with C, Python, MATLAB, Qt and LabVIEW on Windows and Linux: a short script steps center frequency in 60 kHz increments across band D, 300 MHz to 1 GHz, holds 100 ms and records the peak. Antenna Factor, Amplitude Offset and amplitude correction are published functions on all three datasheets, so SpectraCore applies equation (2) per point from the antenna table and the measured cable loss. Note what that dwell costs: at 100 ms a point, a compliant pass over bands C and D takes 27 minutes. The one second sweeps of the intercept arithmetic above are the search, and the 100 ms dwell is the confirmation of what the search found. Running the confirmation scan as a search is the commonest way a bench turns into an afternoon.

Figure 5. Max hold against clear-write, 100 MHz span at 30 kHz resolution bandwidth, captured at 2.44 GHz rather than in band D because the traffic there is denser and the effect is identical. The upper trace is what accumulation buys, the lower one is a single instant, and the gap between them, 20 dB and more in places, is what a single sweep reports as absent. **MEASURED**

Figure 5 is the same effect on a screen, at a different frequency and bandwidth. A scan reported from a clear-write trace reports one instant per point, and everything intermittent is missing from it by construction.

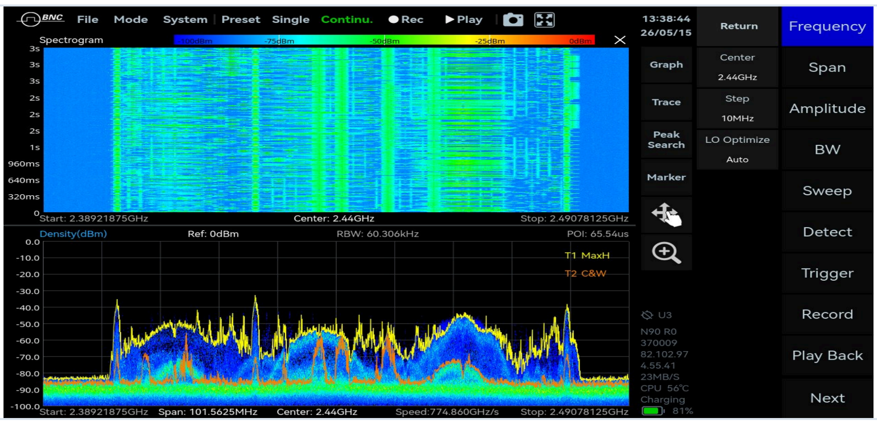

Figure 6. Real-time density with its spectrogram on an ICX-FieldHawk, 2.389 to 2.491 GHz in a 101.56 MHz span at 60.3 kHz resolution, outside every CISPR band this paper scans. Density accumulates every transform rather than the peak of a sweep, so an intermittent emitter resolves into a persistent trace with its duty cycle visible. **MEASURED**

R6. Figure 6 answers the intercept problem. The published engine is an FPGA transform with no missing samples across 100 MHz of analysis bandwidth, and its relation is published too: 100 percent probability of intercept equals 2 × N × D × 8 ns, or 32.768 μs at 2048 points. A 5 ms burst is 150 times that, so it is measured at true amplitude on the first pass. The window is 100 MHz wide, so band D, 300 MHz to 1 GHz, takes seven placements. Put equation (3) to that case and the comparison stops being rhetorical: seven placements parked for one event period each cover the band in 14 seconds at a probability of one, against the 1,795 sweeps and thirty minutes the stepped scan needs for 99 percent.

Worked example: what the bench can see

Referred to field strength, the noise floor is:

$$E_n = -174 + NF + 10\log_{10}B + 107 + AF \qquad (4)$$

where

-174 is thermal noise density at 290 K, in dBm/Hz; 107 converts dBm to dBμV in 50 Ω

NF is noise figure from antenna terminals to display, cable included; 15 dB for the analyzer alone [generic illustrative], consistent with the published −159.9 dBm/Hz at 1 GHz, RBW 1 kHz

In band D at 240 MHz, 10 $\log_{10}$(84,900) = 49.3 dB. With 2.2 dB of cable ahead of a 15 dB analyzer the system noise figure is 17.2 dB, so E_n = −174 + 17.2 + 49.3 + 107 + 17.5 = 17.0 dBμV/m against a 46 dBμV/m FCC Class B limit at 3 m: 29 dB of clearance. A 3 dB, 30 dB preamplifier [generic illustrative values] takes the system noise factor to 1.66 × (1.995 + 30.62/1000) = 3.362, or 5.3 dB, buying **11.9 dB** on the 17.2 dB bare figure. Put the preamplifier at the antenna instead of at the analyzer and the cable stops costing anything at all: 3.1 dB, which buys 14.1 dB.

It also spends headroom, which is R4 arriving as a bill. At +10 dBm output-referred 1 dB compression [generic illustrative value] it compresses at −20 dBm in, or 87 dBμV.

Band C wants 43.5 dB of overload factor, so the highest uncompressed level is 43.5 dBµV, or 63.2 dBµV/m at the antenna, 17 dB above the limit. Measure a badly failing product with the preamplifier out. That ceiling assumes the preamplifier at the analyzer; move it to the antenna and it sees the extra 2.2 dB, so the ceiling falls to 61.0 dBµV/m. The antenna position buys 2.2 dB of noise figure and spends 2.2 dB of headroom, which is the same trade run in both directions.

The same arithmetic in band E at 1 GHz gives 35.5 dBµV/m bare against a 54 dBµV/m limit, and the conducted scan sits nearly 60 dB below its own. Sensitivity rarely fails a pre-compliance bench. R4 and R5 decide whether a scan is trustworthy.

6 Measurement practice

1. **Start with the conducted scan.** A mains network, a 10 dB pad and 150 kHz to 30 MHz find much of what fails a mains-powered product. If yours is a mains box with no radio and one short cable, that scan and a limit line may be all the pre-compliance you need.
2. **Use a current probe before an antenna.** Cable common mode dominates below 1 GHz. Rearranging the short-radiator relation, $I_{CM} = 2rE / (\mu_0 fL)$: at 200 MHz on a 1 m cable against the Class B limit of 150 µV/m at 3 m, that is $(2 \times 3 \times 150 \times 10^{-6}) / (1.2566 \times 10^{-6} \times 2 \times 10^{8})$ = **3.6 µA**, or 11.1 dBµA. Through a 15 dBΩ transfer impedance [generic illustrative value] that is 26.1 dBµV, well clear of the noise floor. Four microamps of common mode on a one meter cable fails Class B, and a clamp finds it.
3. **Hold the near-field probe still.** Loop field falls as the cube of distance, so 5 mm to 10 mm changes the reading by $60 \log_{10}(2)$ = **18.1 dB**, more than any margin you are chasing. Near-field probing ranks sources, it does not measure them.
4. **Take the dwell from Table 1 and the max hold from Figure 4, with the peak detector for both.** Thirty minutes if anything intermittent is suspected. Quasi-peak never exceeds peak, so a peak scan that clears the limit clears it under any detector. Keep one scan with the equipment off, and give the analyzer its published 10 minutes at 25 °C first.

7 What the bench cannot tell you

Uncertainty separates a bench result from a certificate; Table 3 compares two benches.

Table 3. Combined in quadrature and expanded at $k = 2$, discipline is worth 6.2 dB, more than most products carry in margin. The site term dominates both columns, so a ground plane and a fixed geometry beat an instrument upgrade.

Contribution	Careful ±dB	u_i	Casual ±dB	u_i
Receiver accuracy, antenna factor	2.0, 1.3	1.38	2.0, 3.5	2.32
Cable loss and mismatch	0.6, 1.2	0.92	2.0, 2.5	2.12
Site, height and polarization	3.0	1.73	7.0	4.04
Preamplifier and repeatability	1.0, 1.6	1.70	2.0, 3.0	3.21
Expanded, k = 2		**U = 5.9**		**U = 12.1**

Illustrative. Verify the CISPR 16-4-2 figure against the current edition.

THE HONEST LIMITATION

No EMC measurement function appears in any published Berkeley Nucleonics specification table, and nothing here is claimed for one, though a pre-compliance software option was released in August 2026 *(verify)* and has not reached those tables yet; the quasi-peak detector of Table 1 is not published on this family. Everything above uses general-purpose datasheet functions, and a peak scan bounds a quasi-peak result rather than replacing it. That is what makes peak scanning safe for pre-compliance and wrong for compliance.

Three further limits. A bench gives no legally defensible number, because the site is not validated. It does not reproduce a 10 m open area result by arithmetic: extrapolating by $20 \log_{10}(10/3)$ = 10.46 dB assumes a far-field single-source geometry a real product lacks below 100 MHz. And 5.9 dB of expanded uncertainty means a reading 4 dB under the limit is not a pass. Class A equipment gets 10 dB more room, so this bench suits industrial products best.

Field evidence

An honest note on maturity. An EMC pre-compliance software option was released on this platform in August 2026, and it appears in no published specification table yet, so nothing in this paper rests on it: every scan above is built from general-purpose analyzer functions that are published. Nor is there deployment history to report, because no bench of ours has yet run a product through a chamber afterwards to score the prediction. Every requirement is derived from CISPR 16-1-1 and evaluated against the base instrument's published figures, and the arithmetic in sections 2 to 4 is the part that does not change whatever SpectraCore becomes.

8 Summary and selection

Nothing above is a compliance measurement. The scan is shaped like CISPR's, the instrument is not a CISPR receiver, and the certificate still comes from an accredited site. Table 4 collects the published values with their conditions.

Table 4. Published values with their conditions.

Quantity	Relation or value	Condition
CISPR 3 dB equivalents	141 Hz, 6.4 kHz, 84.9 kHz, 707 kHz	Gaussian filter
Swept bandwidth, coverage	1 Hz to 10 MHz; 9 kHz to 9.5 or 40 GHz	settability marked verify
Amplitude accuracy, max CW input	±2.0 dB to 9.5 GHz, ±3.0 above; +23 dBm	10 min warm-up, 25 °C, spur reject; preamp off
100 percent intercept	2 × N × D × 8 ns	32.768 μs at N = 2048, D = 1

Source: the ICX-FieldHawk datasheets.

Bands A to D cover a mains-powered product with clocks below 108 MHz, and the module form sits beside the host running the script. Above 108 MHz, band E to 6 GHz is mandatory [verify the cap]; the handheld and rugged forms take that script outdoors.

9 Definitions, symbols and further reading

Overload factor

The margin in dB by which an impulse peak may exceed the indicated level without any stage compressing.

Quasi-peak detector

A detector with defined charge, discharge and meter time constants, so its reading depends on repetition rate as well as amplitude. It never exceeds a peak detector.

Symbols used in this paper.

Symbol	Meaning	Units
E	Field strength at the measurement distance	dBμV/m
E_n	Noise floor referred to field strength	dBμV/m
V_{ind}	Level indicated at the analyzer input	dBμV
B_1, B_2	Bandwidth used; bandwidth the standard specifies	Hz
AF, L_c, G_p, NF, F	Antenna factor; cable loss; preamplifier gain; noise figure and factor	dB(1/m), dB
B_3, B_6, S, τ_c, τ_d, t_d, t_e, T_e, r, L	Bandwidth at 3 dB and 6 dB; span; quasi-peak constants; dwell; event duration and period; distance and radiator length	Hz, s, m
I_{CM}, Z_T, μ_0	Common-mode current; transfer impedance; permeability of free space	dBμA, dBΩ, H/m
p, P_n, n, N, D, u_c, U, k	Intercept probability and cumulative form; sweeps; transform size; decimation; uncertainty; coverage factor	dB, dimensionless

AF antenna factor

AMN artificial mains network

CISPR Comité International Spécial des Perturbations Radioélectriques

EMC electromagnetic compatibility

RBW resolution bandwidth

SCPI standard commands for programmable instruments

Further reading

- CISPR 16-1-1, *Measuring apparatus*, the source of Table 1; CISPR 16-2-3, *Radiated disturbance measurements*; CISPR 16-4-2, *Measurement instrumentation uncertainty*; CISPR 32, *Emission requirements for multimedia equipment*.
- 47 CFR Part 15 Subpart B, §15.107 and §15.109, with ANSI C63.4 as incorporated; H. W. Ott, *Electromagnetic Compatibility Engineering*, Wiley, 2009, ch. 12 and 18.

If you are building a pre-compliance bench and want the bandwidth, dwell and headroom arithmetic worked against your own product, our application engineers would be glad to help.

VERIFICATION NOTE

The following values in this paper are not yet confirmed against a published Berkeley Nucleonics datasheet and are marked verify in the text. They must be confirmed before this paper is released.

- Whether the ICX-FieldHawk resolution bandwidth is continuously settable across its published 1 Hz to 10 MHz range, so 84.9 kHz and 141 Hz can be entered exactly. R1 turns on the answer.
- Standard editions: CISPR 16-1-1, 16-2-3, 16-4-2, CISPR 32; ANSI C63.4 as incorporated in 47 CFR Part 15; the 6 GHz cap; the CISPR 16-4-2 figures; §15.109(g); bandwidth ranges in bands A and E; post-detector overload factors.
- An EMC pre-compliance option was released in August 2026 but appears in no published specification table, so no EMC function, quasi-peak detector or limit-line set is claimed here and nothing above depends on one. Every instrument parameter in the worked examples is generic and illustrative, labeled at each use.
- This paper reports no deployment history and no measured pre-compliance result. The two instrument captures are general-purpose measurements rather than band C or D scans, and their conditions are stated in their captions.

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