Technical Note: EMC Antenna Calibration

Requirements, Methodologies, and Best Practices for EMI/EMC Test Laboratories

Document Version: 1.0
Date: November 2025
Applicable Standards: ANSI C63.5, CISPR 16-1-6, IEC 61000-4-3

1. Introduction

Electromagnetic compatibility (EMC) testing relies heavily on accurate antenna calibration to ensure measurement reliability and repeatability. Antenna calibration determines the antenna factor (AF) or gain, which converts measured voltage to electric field strength or vice versa. This technical note provides comprehensive guidance on antenna calibration requirements for EMI/EMC test laboratories.

Key Topics Covered:

- Calibration standards and requirements
- Small vs. large antenna considerations
- Single vs. dual polarization calibration
- Single vs. multi-distance calibration
- Practical guidance for test laboratories

2. Fundamental Concepts

2.1 Antenna Factor and Gain

The antenna factor (AF) relates electric field strength to received voltage:

AF (dB/m) = E (dBμV/m) - V (dBμV)

For transmitting antennas, gain is the primary parameter. The relationship is:

AF (dB/m) = $20\log_{10}$(f_MHz) - G (dBi) - 29.78

2.2 Calibration Distance and Far-Field Criterion

Antennas must be calibrated in the far-field region where the electromagnetic field has stabilized. The far-field distance is determined by:

$R > 2D^2/\lambda$

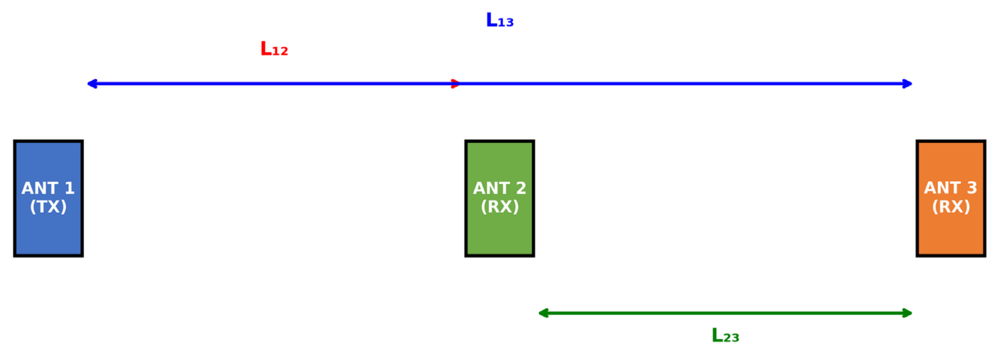
Where D is the largest antenna dimension and λ is wavelength. For small antennas like the AH-118 (D ≈ 0.27m) at 1 GHz (λ = 0.3m): R > 0.49m. Thus, calibration at 3 meters is well within far-field.

3. Three-Antenna Calibration Method

The three-antenna method is the most accurate absolute calibration technique, recommended by ANSI C63.5 and CISPR 16-1-6. It eliminates the need for a standard gain antenna.

3.1 Method Overview

Figure 1: Three-Antenna Calibration Setup



Three-Antenna Calibration Method

The method involves three measurements:

- L_{12}: Insertion loss between Antenna 1 and Antenna 2
- L_{13}: Insertion loss between Antenna 1 and Antenna 3
- L_{23}: Insertion loss between Antenna 2 and Antenna 3

3.2 Calculation Method

Antenna factors are calculated using:

$$\mathbf{AF_1 + AF_2 = L_{12} + K}$$

$$\mathbf{AF_1 + AF_3 = L_{13} + K}$$

$$\mathbf{AF_2 + AF_3 = L_{23} + K}$$

Where:

$$\mathbf{K = 20\log_{10}(f\_MHz) + 20\log_{10}(d\_m) - 27.55}$$

3.3 Three-Antenna Method Setup

- Setup Configuration:
- - Three antennas positioned in a calibration range
- - Antenna 1 (TX): Transmit antenna

- - Antenna 2 (RX): Receive antenna
- - Antenna 3 (RX): Second receive antenna
- - Fixed separation distance (typically 3m or 10m)
- - All antennas at same height above ground plane

- Measurement Process:
- 1. Measure insertion loss L_{12} (Antenna 1 to Antenna 2)
- 2. Measure insertion loss L_{13} (Antenna 1 to Antenna 3)
- 3. Measure insertion loss L_{23} (Antenna 2 to Antenna 3)
- 4. Calculate antenna factors from simultaneous equations
- 5. Verify results through consistency checks

- Key Advantages:
- - Absolute calibration (no reference standard needed)
- - Highest accuracy available (0.10 dB typical uncertainty)
- - No assumptions about antenna polarization required
- - Eliminates systematic errors from the transmitter and receiver
- - Direct traceability to fundamental electromagnetic theory
- - Internationally recognized and validated through BIPM comparisons

4. Ground Reflections and Site Effects

Ground reflections create interference patterns that significantly affect antenna calibration. The total received field is the vector sum of direct and reflected paths.

4.1 Two-Ray Model

Figure 3: Ground Reflection Interference Pattern (3m vs 10m)

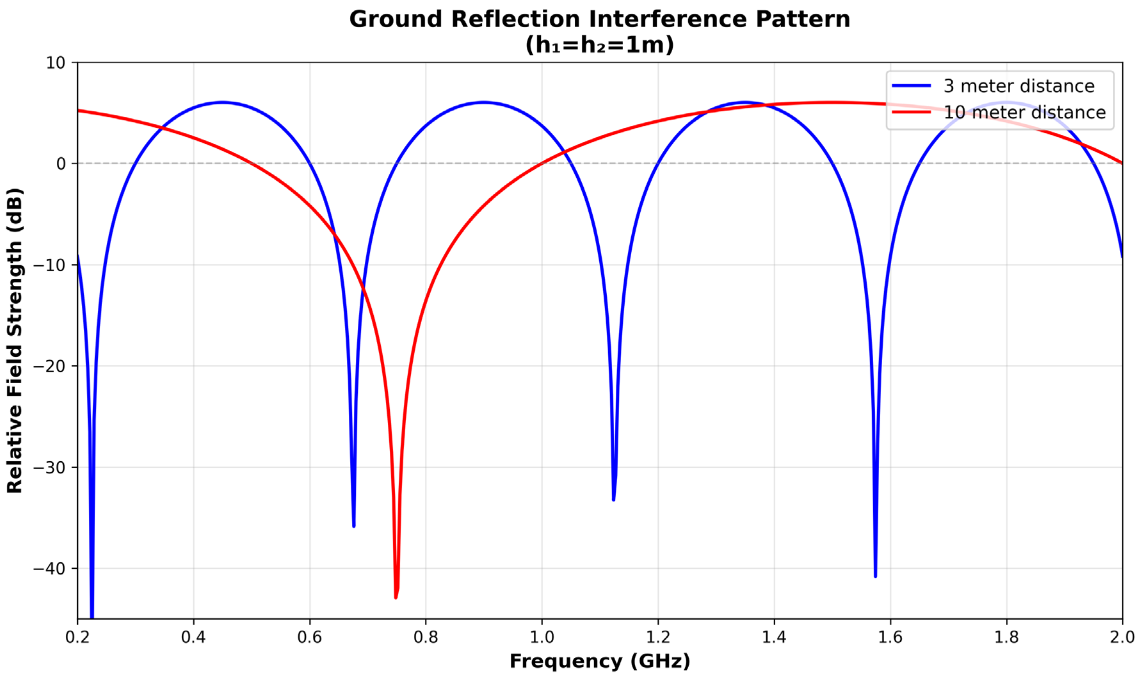
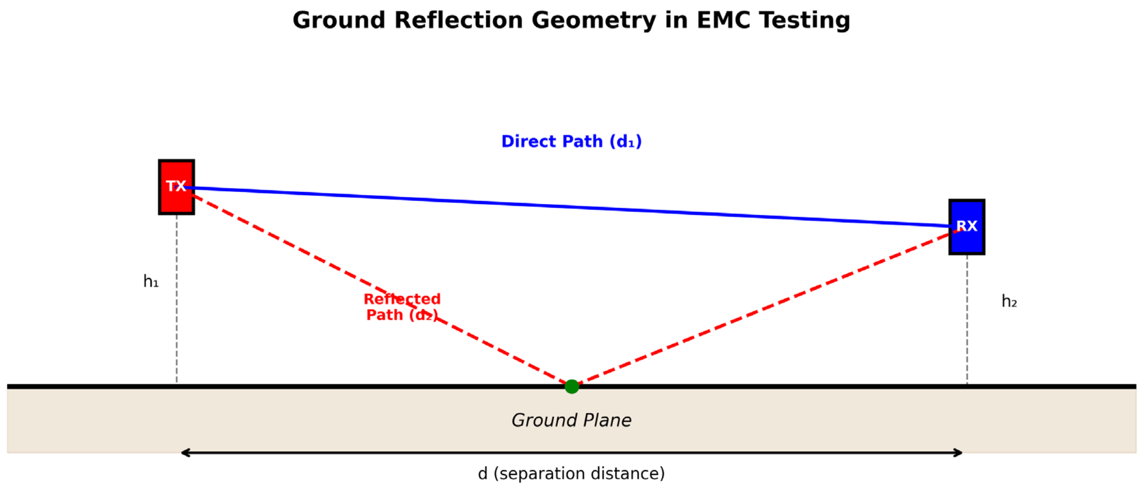


Figure 2: Ground Reflection Geometry



The classical two-ray model describes:

E_total = E_direct × [1 + ρ × e^(jΔφ)]

Where:

- ρ = ground reflection coefficient (≈-1 for conducting ground planes)
- $\Delta\varphi = 2\pi(d_2 - d_1)/\lambda$ = phase difference between paths
- d_1 = direct path length ≈ d (antenna separation)
- d_2 = reflected path length $\approx d + 2h_1h_2/d$
- h_1, h_2 = heights of transmit and receive antennas

4.2 Interference Patterns

Constructive interference (peaks) occur when $\Delta\varphi = 2\pi n$, and destructive interference (nulls) occur when $\Delta\varphi = \pi(2n+1)$. The first null height is:

h_null = λd/(4h_Tx)

4.3 Ground Reflection Effects on Calibration

- Impact on Small Antennas (e.g., AH-118):
- - Minimal ground reflection impact above 1 GHz
- - Far-field achieved at short distances
- - Single-distance calibration is usually sufficient
- - Interference pattern wavelength is small relative to test distance

- Impact on Large Antennas (e.g., AH-220):
- - Significant ground reflection effects at low frequencies (200-500 MHz)
- - Antenna factor can vary 3-6 dB between 3m and 10m distances
- - Multi-distance calibration strongly recommended
- - Pattern nulls and peaks occur at test frequencies

- Distance-Dependent Behavior:
- - At 3m: Interference pattern more compressed (more nulls)
- - At 10m: Interference pattern more spread out (fewer nulls)
- - Below 500 MHz: Significant difference between 3m and 10m
- - Above 1 GHz: Minimal difference between 3m and 10m

- Critical Frequencies:
- - 200-300 MHz: Maximum ground reflection impact
- - 300-500 MHz: Moderate ground reflection impact
- - 500 MHz-1 GHz: Reducing ground reflection impact
- - Above 1 GHz: Minimal ground reflection impact for small antennas

Note on Interference Pattern Graph:
The interference pattern graph (Figure 3 in PDF version) illustrates how ground reflection creates constructive and destructive interference at different frequencies. The blue line (3 meter) shows more frequent nulls and peaks compared to the red line (10 meter). This distance-dependent behavior necessitates multi-distance calibration for large antennas used below 1 GHz.

5. Small Antenna Calibration

5.1 Com-Power AH-118 / AHA-118 Series

Parameter	AH-118	AHA-118
Frequency Range	700 MHz - 18 GHz	1 GHz - 18 GHz
Typical Gain	5 - 15 dBi	6 - 16 dBi
Size (approx)	11" × 8.5" × 10.5"	10" × 8" × 9"
Polarization	Dual (H & V)	Single (H)
Application	Emissions & Immunity	Emissions
Active Preamp	No	Yes (40 dB gain)

5.2 Calibration Requirements for Small Horns

- Far-Field Distance:
- - Short far-field distance due to small aperture
- - At 1 GHz: R > 0.49m (well satisfied at 3m)
- - At 18 GHz: R > 0.03m (easily satisfied)

- Distance Selection:
- - Single distance calibration (3m) typically sufficient
- - Far-field criterion easily met at all frequencies
- - Minimal ground reflection impact above 1 GHz

- Polarization Requirements:
- - Dual polarization required if antenna is dual-ridged (AH-118)
- - Single polarization acceptable for single-ridge (AHA-118)
- - Both H and V needed for most commercial EMC testing

- Frequency Points:
- - Every 100 MHz recommended (700 MHz to 18 GHz)
- - Total: ~170 frequency points
- - Custom frequency points available

- Recalibration Interval:
- - Annually for AHA-118 (active preamp)
- - Every 2 years for AH-118 (passive)

- - Immediately after repair or damage

5.3 Recommended Calibration Strategy for Small Horns

- Distance: Single distance at 3 meters
- Polarization: Both H and V for dual-ridged models
- Frequency Points: Every 100 MHz (700 MHz to 18 GHz)
- Method: Three-antenna method or standard antenna method
- Recalibration: Annually for active, every 2 years for passive
- Typical Cost: $800-1,200 for single distance, dual polarization
- Turnaround: 2-3 weeks standard

6. Large Antenna Calibration

6.1 Com-Power AH-220 Specifications

Parameter	Value
Frequency Range	200 MHz - 2 GHz
Typical Gain	8 - 15 dBi
Size (approx)	40" × 32" × 24"
Weight	~50 lbs
Polarization	Dual (H & V)
Power Handling	800 Watts CW
Application	High-power immunity, large product testing
Primary Use	MIL-STD-461 RE102, automotive immunity

6.2 Multi-Distance Calibration Need

Large antennas require multi-distance calibration because:

- Extended Far-Field Distance:
- - At 200 MHz, R > 1.3m (minimum far-field)
- - Practical testing uses 3m or 10m
- - Both distances well within far-field but with different characteristics

- Ground Reflection Effects:
- - Significant interference patterns at low frequencies (200-500 MHz)
- - Constructive and destructive interference varies with distance
- - Pattern nulls occur at different frequencies for 3m vs 10m

- Distance-Dependent Antenna Factor:
- - AF can vary 3-6 dB between 3m and 10m
- - Variation is frequency-dependent
- - Most significant at 200-400 MHz
- - Less significant above 1 GHz

- Multiple Test Scenarios:
- - Large products tested at 10m per automotive standards
- - Small products tested at 3m for pre-compliance
- - Both distances used in same laboratory

- Measurement Accuracy:
- - Using 3m calibration at 10m: ±2-6 dB additional error
- - Using 10m calibration at 3m: ±2-6 dB additional error
- - Multi-distance calibration eliminates extrapolation error

- Accreditation Requirements:
- - ISO/IEC 17025 requires calibration at the actual test distance
- - Extrapolation between distances not recommended below 1 GHz
- - Multi-distance calibration demonstrates compliance

6.3 Recommended Calibration Strategy for Large Antennas

- Distance: Multiple distances (3m AND 10m) - CRITICAL
- Polarization: Both H and V
- Frequency Points: Every 25-50 MHz (200 MHz to 2 GHz)
- Method: Three-antenna method preferred
- Recalibration: Annually
- Site Documentation: Record ground plane, absorber configuration
- Typical Cost: $2,000-3,500 for dual distance, dual polarization
- Turnaround: 3-4 weeks standard

- Cost-Benefit Analysis:
- - Single distance (3m): $1,200-1,800
- - Multi-distance (3m+10m): $2,000-3,500
- - Premium: ~$800-1,700 (60-80% more)
- - Break-even: After 3-4 single-distance recalibrations
- - Eliminates: ±2-6 dB extrapolation error
- - Essential for: Automotive testing, large product testing

CRITICAL NOTE: For the AH-220 and similar large antennas operating below 1 GHz, multi-distance calibration is strongly recommended and often essential. The cost premium is justified by the elimination of significant measurement errors and compliance with ISO/IEC 17025 requirements.

7. Practical Guidance for Test Labs

7.1 Calibration Decision Matrix

Antenna	Size	Freq Range	Test Dist	Polarizations	Cal Distances	Cost Range
AH-118	Small	0.7-18 GHz	3m	Both H+V	3m only	$900-1,200
AHA-118	Small	1-18 GHz	3m	H only	3m only	$1,000-1,400
AH-220	Large	0.2-2 GHz	3m, 10m	Both H+V	3m AND 10m	$2,000-3,500
AL-130R	Med	10kHz-30MHz	1m	N/A	1m only	$800-1,200
LPDA	Med	0.2-2 GHz	3m, 10m	Both H+V	3m AND 10m	$1,000-1,800

The following decision matrix provides comprehensive calibration recommendations for all Com-Power EMC antennas. This table helps test laboratories and in-house EMC engineers determine the appropriate calibration strategy based on antenna characteristics, frequency range, and test requirements.

Antenna Model	Size	Frequency Range	Test Dist	Polarizations	Cal Distances	Cal Interval
AL-130R (Active Loop)	Small	10 Hz - 30 MHz	1m	N/A	1m only	Annual
AM-741R (Active Monopole)	Small	9 kHz - 30 MHz	1m	Vertical	1m only	Annual
AB-300M (Biconical)	Medium	25 - 300 MHz	3m, 10m	Both H & V	3m AND 10m	Annual
AC-220 (Combilog)	Medium	30 MHz - 2 GHz	3m, 10m	Both H & V	3m AND 10m	Annual
ACL-6000 (Combilog)	Medium	30 MHz - 6 GHz	3m, 10m	Both H & V	3m AND 10m	Annual
ALP-100 (Log-Periodic)	Medium	200 MHz - 1 GHz	3m, 10m	Both H & V	3m AND 10m	Annual
AH-118 (Small Horn)	Small	700 MHz - 18 GHz	3m	Both H & V	3m only	Annual
AHA-118 (Small Horn)	Small	1 - 18 GHz	3m	H only	3m only	Annual
AH-220 (Large Horn)	Large	200 MHz - 2 GHz	3m, 10m	Both H & V	3m AND 10m	Annual
AH-640 (mmWave Horn)	Medium	18 - 40 GHz	3m	Both H & V	3m only	Annual

Decision Matrix Key:

- Active antennas (ACL-6000, AN-200) require calibration at 1m due to near-field operation characteristics

Typical Annual Calibration Costs:

The following table provides approximate annual calibration costs for different antenna types and calibration configurations. Actual costs may vary by calibration laboratory and specific requirements.

Antenna Type	Single Distance Single Polarization	Single Distance Dual Polarization	Multi-Distance Dual Polarization
Active Loop/Monopole	$800 - $1,000	N/A	N/A
Small Horn (AH-118)	$600 - $800	$1,000 - $1,200	N/A
Biconical (AB-300M)	$800 - $1,000	$1,200 - $1,500	$2,000 - $2,500
Log-Periodic/Combilog	$900 - $1,100	$1,400 - $1,600	$2,200 - $2,800
Large Horn (AH-220)	$1,200 - $1,500	$2,000 - $2,500	$3,200 - $3,800
mmWave Horn (AH-640)	$700 - $900	$1,200 - $1,500	N/A

- Annual calibration interval recommended per ANSI C63.5-2020 and ISO/IEC 17025:2017

- Emergency or expedited calibration services typically add 50-100% premium to standard pricing
- Volume discounts may be available when calibrating multiple antennas simultaneously
- Dual polarization calibration costs approximately 50-70% more than single polarization
- Multi-distance calibration costs 60-80% more than single-distance but eliminates ±2-6 dB extrapolation uncertainty
- Costs shown are typical annual calibration fees from NIST-traceable calibration laboratories
- Dual polarization (H & V) calibration required when antenna is used in both horizontal and vertical orientations
- Multi-distance calibration is essential for antennas operating below 1 GHz due to significant ground reflection effects
- Cal Distances: "3m only" indicates single-distance calibration is sufficient; "3m AND 10m" indicates multi-distance calibration required
- Test Distance: Typical separation distances used in EMC test chambers
- Size Classification: Small (≤12"), Medium (2-4 ft), Large (>3 ft)

7.2 Summary Recommendations

- Small Antennas (AH-118, AHA-118):
- - Single-distance (3m) calibration
- - Dual-polarization if dual-ridged
- - Every 100 MHz frequency points
- - Annual calibration for active, biennial for passive

7.2.1 Detailed Recommendations by Antenna Category

Low Frequency Antennas (9 kHz - 30 MHz):

- Budget: $800-1,200 per antenna annually.

Mid-Range Antennas (25 MHz - 2 GHz):

- Budget: $1,800-3,500 per antenna annually depending on size and distance requirements.

High Frequency Antennas (700 MHz - 40 GHz):

- Budget: $800-1,500 per antenna annually.
- Primary use: Wireless devices, 5G, ISM, radiated emissions 1-40 GHz.
- mmWave Horn (AH-640): Single distance at 3m, dual polarization. Specialized for 5G and mmWave testing.
- Small Horn (AH-118, AHA-118): Single distance at 3m sufficient. AH-118 dual-pol, AHA-118 single-pol.
- Primary use: FCC Part 15 Class A/B, CISPR 11/22/32, automotive immunity.
- Large Horn (AH-220): Multi-distance (3m + 10m), dual polarization. High power handling for immunity.
- Log-Periodic (ALP-100): Multi-distance (3m + 10m), dual polarization. Excellent for 200 MHz - 1 GHz.
- Combilog (AC-220): Multi-distance (3m + 10m), dual polarization. Covers 30 MHz - 2 GHz in a single antenna.
- Combilog (ACL-6000): Multi-distance (3m + 10m), dual polarization. Covers 30 MHz - 6 GHz in a single antenna.
- Biconical (AB-300M): Multi-distance (3m + 10m), dual polarization. Critical for 30-300 MHz testing.
- Active Monopole (AM-741R): Single distance at 1m, vertical polarization only. Calibrate with the ground plane.
- Active Loop (AL-130R): Single distance at 1m, annual calibration required. No polarization considerations.
- - Cost: $900-1,400

- Large Antennas (AH-220, large biconicals, large LPDAs):
- - Multi-distance (3m + 10m) calibration - ESSENTIAL
- - Dual-polarization (H and V)

- - Every 25-50 MHz frequency points
- - Annual calibration
- - Cost: $2,000-3,500

- Specialized Antennas (Loops, monopoles):
- - Single-distance per application (typically 1m)
- - Polarization as required by standard
- - Frequency points per MIL-STD-461 or CISPR
- - Annual calibration for active, biennial for passive
- - Cost: $600-1,800

- Budget Priority Guidelines:
- 1. Multi-distance for large antennas (highest priority)
- 2. Dual-polarization for primary test antennas
- 3. Annual calibration for compliance testing antennas
- 4. Extended intervals (2 years) for R&D antennas
- 5. Single polarization acceptable for dedicated-use antennas

7.3 Common Calibration Mistakes to Avoid

- Using Single-Distance Calibration for Large Antennas Below 1 GHz:
- - Error: Calibrating AH-220 at only 3m when testing at 10m
- - Impact: ±3-6 dB measurement error at 200-500 MHz
- - Solution: Always use multi-distance calibration for large antennas

- Calibrating Only One Polarization:
- - Error: H-polarization only when antenna is rotated during testing
- - Impact: Invalid calibration for V-polarization measurements
- - Solution: Calibrate both polarizations if antenna is rotated

- Using Expired Calibration Certificates:
- - Error: Using antenna beyond calibration due date

7.3 Guidance for Industrial In-House EMC Testing

Industrial companies performing in-house EMC pre-compliance or troubleshooting have different calibration needs than accredited test laboratories. The following guidance addresses cost-effective calibration strategies while maintaining measurement confidence.

7.3.1 Pre-Compliance Testing Requirements

Calibration Priorities:

- Cost savings: Can reduce annual calibration costs by 50-70% compared to full accredited lab requirements.

7.3.2 Troubleshooting and Design Validation

- Near-field probes: Consider uncalibrated near-field probes (H-field, E-field) for troubleshooting hotspots.

7.3.3 Recommended Antenna Sets for In-House Use

Basic Set (Budget: ~$2,000 calibration/year):

- AH-118 or AHA-118: Covers 700 MHz - 18 GHz, 3m only, single or dual-pol

Advanced Set (Budget: ~$4,500 calibration/year):

- Optional AH-220: For large product immunity testing at 10m distance

7.3.4 Cost Optimization Strategies

- Risk-based approach: Fully calibrate antennas used for final compliance verification; lighter calibration for early-stage design work.

7.3.5 When Full Calibration IS Required

Even for in-house testing, full NIST-traceable calibration is required when:

- Military/aerospace: MIL-STD-461 testing requires fully calibrated and accredited measurements.

7.3.6 Test Lab vs. In-House Calibration Comparison

- Automotive: CISPR 25 and automotive OEM requirements typically mandate calibrated equipment.
- Medical/safety-critical: Products where EMC failure could cause harm.
- High-value products: Cost of compliance failure exceeds calibration investment.
- Risk mitigation: Product has a history of marginal compliance - need accurate measurements.
- Contractual requirements: Customer or regulatory requirements specify calibration.
- Pre-certification testing: Final testing before sending it to an accredited lab for certification.
- Comparison calibration: Maintain one "reference" antenna with full NIST calibration, verify others against it.
- Manufacturer data: Use manufacturer-provided data with periodic in-house verification for non-critical applications.
- Extend intervals: Use 2-year intervals for pre-compliance antennas (document risk acceptance).
- Skip multi-distance: For antennas used at only one test distance, skip additional distance calibrations.
- Single polarization: Specify only H-pol or V-pol calibration based on your primary test orientation.
- Bundle calibrations: Calibrate multiple antennas simultaneously to reduce per-antenna costs.
- AH-118: High frequency 700 MHz - 18 GHz, dual-pol
- ALP-100 (Log-Periodic): 200 MHz - 1 GHz coverage, dual-pol, single distance
- AB-300M (Biconical): Dedicated 25-300 MHz, dual-pol, single distance

- AL-130R: Low-frequency coverage with active loop
- AC-220 (Combilog): Single antenna covers 30 MHz - 2 GHz, dual-pol, 3m only
- Focus on repeatability: Consistent measurement setup is more important than absolute accuracy.
- Minimal calibration: Consider manufacturer calibration data with in-house verification every 2 years.
- Antenna verification: Annual verification against a known good antenna may suffice instead of full NIST calibration.
- Relative measurements: Antenna factor accuracy less critical when comparing design iterations.
- Antenna verification checks: Perform quarterly verification checks using stable RF sources between formal calibrations.
- Extended calibration intervals: Consider 2-year calibration cycles for pre-compliance work (not for compliance testing).
- Single distance calibration: For small products tested at 3m only, multi-distance calibration is unnecessary.
- Single polarization acceptable: If your products primarily emit in one orientation, calibrate only that polarization to reduce cost by 40-50%.
- - Impact: Non-compliance with ISO/IEC 17025, invalid test results
- - Solution: Track calibration due dates, schedule 6-8 weeks in advance

- Not Matching Calibration to Test Distance:
- - Error: Using 10m calibration for 3m testing (or vice versa)
- - Impact: Measurement error, especially below 1 GHz
- - Solution: Match calibration distance to test distance

- Ignoring Ground Plane Differences:
- - Error: Calibrating on metal ground plane, testing on ferrite tile
- - Impact: Reflection coefficient mismatch affects results
- - Solution: Document ground plane configuration in calibration

- Insufficient Frequency Points:
- - Error: Too few calibration points (e.g., every 500 MHz)
- - Impact: Missing resonances, poor interpolation accuracy
- - Solution: Follow ANSI C63.5 recommendations (typically every 50-100 MHz)

8. Applicable Standards Summary

Standard	Key Requirement	Application
ANSI C63.5-2020	Calibrate at distance and frequency of use	Primary US antenna calibration standard
CISPR 16-1-6	Three-antenna method, ±1.5 dB uncertainty	International EMC antenna calibration
IEC 61000-4-3	Immunity antennas require gain calibration	Radiated immunity testing
ISO/IEC 17025	Traceable calibration required for accreditation	Laboratory accreditation
ANSI C63.4	Site validation using NSA measurements	EMC test site validation
FCC Part 15	Requires calibrated antennas for compliance	Unintentional radiators
MIL-STD-461G	Specific antenna types and calibration distances	Military EMC requirements
SAE ARP958	Aerospace antenna calibration standard	Aerospace EMI testing

8.1 Standard-Specific Requirements

- ANSI C63.5-2020:
- - Primary US standard for antenna calibration
- - Frequency range: 9 kHz to 40 GHz
- - Specifies three-antenna method and standard antenna method
- - Requires calibration at actual test distance
- - Recommends specific frequency point spacing

- CISPR 16-1-6:
- - International equivalent to ANSI C63.5
- - Harmonized with ANSI C63.5 requirements
- - Specifies ±1.5 dB combined standard uncertainty
- - Requires documentation of measurement uncertainty

- ISO/IEC 17025:
- - Laboratory accreditation standard
- - Requires NIST-traceable calibrations
- - Mandates documented measurement uncertainty
- - Requires proper equipment maintenance and records

- MIL-STD-461G:
- - Specifies 1-meter test distance for most measurements
- - Requires specific antenna types (loops for RE101, horns for RE102)
- - Calibration must match 1-meter test distance
- - Frequency-specific requirements for different test procedures

9. References

[1] ANSI C63.5-2020, "Electromagnetic Compatibility—Radiated Emission Measurements in EMI Control—Calibration of Antennas (9 kHz to 40 GHz)"

[2] CISPR 16-1-6:2017, "Specification for radio disturbance and immunity measuring apparatus - Part 1-6: EMC antenna calibration"

[3] IEC 61000-4-3:2020, "Electromagnetic compatibility - Part 4-3: Radiated, radio-frequency, electromagnetic field immunity test"

[4] ANSI C63.4-2014, "Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical Equipment (9 kHz to 40 GHz)"

[5] ISO/IEC 17025:2017, "General requirements for the competence of testing and calibration laboratories"

[6] MIL-STD-461G, "Requirements for the Control of Electromagnetic Interference Characteristics"

[7] IEEE Std 149-2021, "IEEE Recommended Practice for Antenna Measurements"

[8] Smith, A. A., et al., "Calculation of Site Attenuation from Antenna Factors," IEEE Trans. EMC, Vol. EMC-24, No. 3, 1982

[9] Weston, D. A., "Electromagnetic Compatibility: Principles and Applications," 2nd Ed., Marcel Dekker, 2001

[10] Paul, C. R., "Introduction to Electromagnetic Compatibility," 2nd Edition, Wiley, 2006

[11] NIST, "Antenna Metrology Project," https://www.nist.gov/programs-projects/antenna-metrology-project

[12] Com-Power Corporation, "Antenna Calibration Services," https://www.com-power.com/services/antenna-calibration

[13] SAE ARP958 Rev D, "Electromagnetic Interference Measurement Antennas, Standard Calibration Method for"

[14] JCGM 100:2008, "Evaluation of measurement data - Guide to the expression of uncertainty in measurement (GUM)"

[15] A2LA, "G104 - Guide for Estimation of Measurement Uncertainty in Testing," 2014

Appendix A: Additional Technical Information

A.1 Uncertainty Budget Example

Source of Uncertainty	Type	Typical Value	Notes
NIST reference standard	B	±0.10-0.20 dB	From NIST certificate
Mismatch uncertainty	B	±0.20-0.40 dB	Function of VSWR
Measurement repeatability	A	±0.10-0.20 dB	Statistical analysis
Cable stability	B	±0.05-0.10 dB	Phase/amplitude variation
Positioning uncertainty	B	±0.05-0.15 dB	Distance, height, alignment
Ground reflections	B	±0.10-0.30 dB	Frequency dependent
Instrumentation	B	±0.10-0.15 dB	VNA, power meter specs
Environmental effects	B	±0.05-0.10 dB	Temperature, humidity
Combined RSS (k=1)	**-**	**±0.35-0.70 dB**	**Root sum square**
Expanded (k=2)	**-**	**±0.70-1.40 dB**	**~95% confidence**

Note: This is a typical uncertainty budget for small horn antenna calibration using the three-antenna method at 3 meters. Actual values vary based on antenna type, frequency range, and specific measurement conditions.

A.2 Frequency Point Recommendations

- Low Frequency (9 kHz - 30 MHz):
- - Logarithmic spacing: 10 kHz, 50 kHz, 100 kHz, 500 kHz, 1 MHz
- - Then every 1-2 MHz to 30 MHz

- VHF (30 MHz - 300 MHz):
- - Every 25 MHz (biconical antennas)
- - Every 50 MHz (horn antennas)

- UHF (300 MHz - 2 GHz):
- - Every 50 MHz (log-periodic, combilog)
- - Every 100 MHz (horn antennas)

- Microwave (2 GHz - 18 GHz):
- - Every 100 MHz from 2-10 GHz
- - Every 200 MHz from 10-18 GHz

- Millimeter-wave (18 GHz - 40 GHz):
- - Every 200-500 MHz
- - Density depends on application requirements

Document Information

- Document Title: Technical Note - EMC Antenna Calibration
- Version: 1.0
- Date: November 2025
- Authors: EMC Technical Documentation Team
- Purpose: Practical guidance for EMC test laboratories
- Scope: Antenna calibration requirements and methodologies
- Intended Audience: EMC test lab personnel, quality managers, compliance engineers

- Related Documents:
- - NIST-Calibration-and-Com-Power-Services-COMPLETE.docx (detailed reference)
- - Com-Power-Antenna-Specifications-COMPLETE.docx (product specifications)

- Contact Information:
- Com-Power Corporation
- Email: calibration@com-power.com
- Phone: +1-714-528-8800
- Website: www.com-power.com

Requirement	Accredited Test Lab	In-House Pre-Compliance
Calibration Interval	Annual (per ISO 17025)	1-2 years acceptable
Polarization	Both H & V required	Single pol acceptable
Test Distances	All distances used	Primary distance only
Traceability	NIST/A2LA required	Manufacturer + verification OK
Uncertainty Budget	Fully documented	Simplified acceptable
Cost (typical 3-antenna set)	$4,000-8,000/year	$1,500-3,500/year
Recalibration triggers	Annual, after damage	2-year or after damage
Documentation	Full per ISO 17025	Internal records sufficient