NIST Antenna Calibration Services

Com-Power Corporation Calibration Capabilities and NIST Traceability

⚠ IMPORTANT NOTE: Com-Power provides NIST-traceable antenna calibrations but does not operate as an ISO/IEC 17025 accredited calibration laboratory for antenna calibration services. Com-Power's antenna calibrations are traceable to NIST through the three-antenna method and are suitable for use by ISO/IEC 17025 accredited EMC test laboratories. Test laboratories that specifically require ISO/IEC 17025 accredited antenna calibration certificates should contact NIST or other ISO/IEC 17025 accredited calibration providers.

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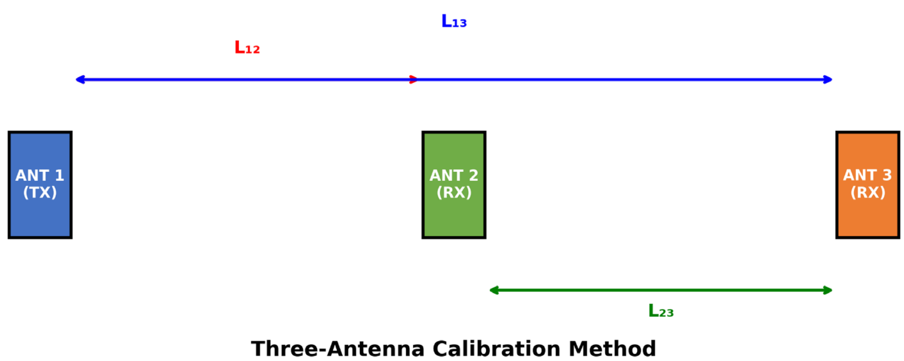
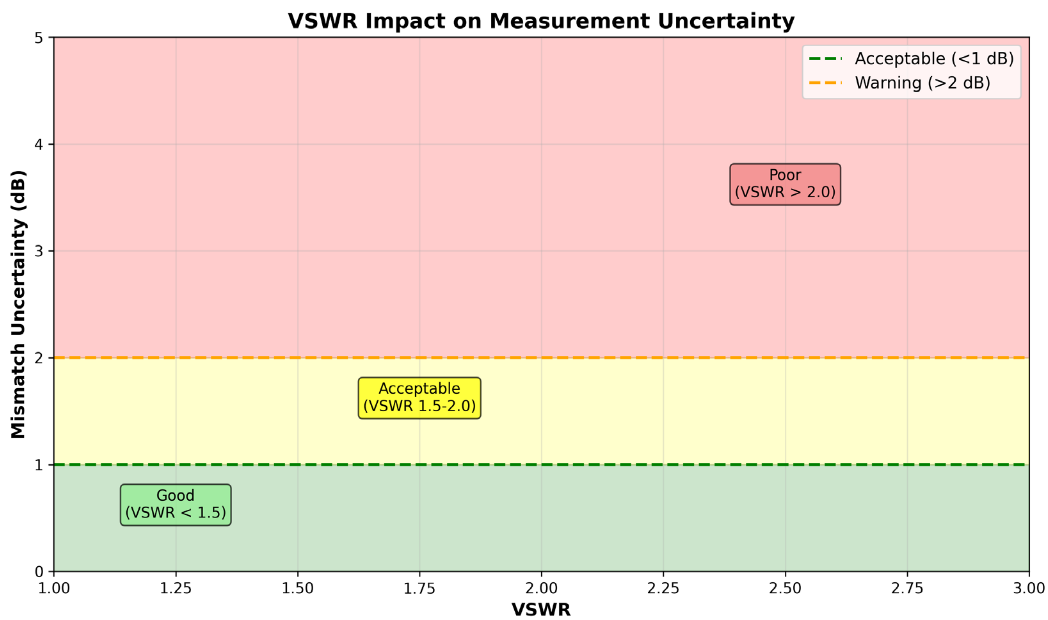
Figure 1: Three-Antenna Calibration Method



Com-Power Calibration Scope and Accreditation Status:
Com-Power provides NIST-traceable antenna calibration services using the three-antenna method. While Com-Power maintains rigorous quality standards and NIST traceability, the company does not currently hold ISO/IEC 17025 accreditation specifically for antenna calibration services. Customers requiring ISO/IEC 17025-accredited calibration certificates should specify this requirement and may need to use alternative calibration providers such as NIST or other accredited laboratories. For current calibration scope information, please visit: https://www.com-power.com/calibration/scope

Figure 3: VSWR Impact on Measurement Uncertainty



1. Overview of NIST Antenna Calibration Services

The National Institute of Standards and Technology (NIST) Communications Technology Laboratory (CTL) provides the highest level of antenna calibration services in the United States. These services establish the fundamental reference standards from which all other antenna calibrations derive their traceability.

1.1 NIST's Role in Antenna Metrology

NIST has been pioneering antenna measurement techniques for over 50 years. The Antenna Metrology Project at NIST combines theoretical models, analytical tools, and state-of-the-art facilities to:

- Develop and maintain primary antenna calibration standards
- Provide calibration services for standard gain horn antennas
- Advance near-field scanning techniques for antenna characterization
- Support development of 5G and millimeter-wave antenna systems
- Participate in international measurement comparisons through BIPM
- Ensure U.S. measurement equivalency with 16 National Metrology Institutes (NMIs)

1.2 NIST Calibration Service SKU63100S

NIST offers the "On-Axis Gain and Polarization Measurements Service" (SKU63100S) primarily for determining the absolute on-axis gain and polarization of standard gain horn antennas. These calibrated reference antennas are then used as transfer standards throughout the industry.

Key Service Parameters:

- Frequency Range: 2 GHz to 110 GHz
- Typical Uncertainty: 0.10 dB (2-30 GHz), 0.15 dB (above 30 GHz)
- Polarization Axial Ratio Uncertainty: 0.05 dB/dB
- Method: Extrapolation technique using the three-antenna method
- Facility: Robotically Enhanced Antenna Laboratory for Metrology (REALM)
- Turnaround Time: Typically 4-8 weeks depending on antenna and frequency range
- Traceability: Direct to SI units through NIST primary standards

2. NIST Calibration Methodology

2.1 Extrapolation Method

NIST employs the extrapolation method, which is considered the most accurate technique for absolute gain and polarization measurements. The method involves:

1. Three antennas are utilized in the measurement process
2. Three pairwise combinations are measured (Antenna 1-2, 1-3, 2-3)
3. Received signal is measured as a function of separation distance
4. Data is extrapolated to infinite separation to remove reactive near-field effects
5. Antenna gains are calculated using simultaneous equations
6. No standard gain antenna reference is required (absolute calibration)
7. Antennas need not be identical - the method works for dissimilar antenna types

Advantages of Extrapolation Method:

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

2.2 Near-Field Scanning Technique

For antennas that cannot be easily calibrated using the extrapolation method, NIST has pioneered near-field scanning techniques. This method involves:

- Measuring electromagnetic field at distances of a few centimeters from antenna
- Transforming near-field measurements to predict far-field performance
- Using mathematical algorithms developed at NIST
- Capable of operating at frequencies up to 500 GHz
- Used at hundreds of antenna test ranges worldwide
- Particularly suitable for large aperture antennas and complex antenna systems

2.3 NIST Facilities and Equipment

NIST's Robotically Enhanced Antenna Laboratory for Metrology (REALM) features:

- Two six-axis industrial robot arms for precision antenna positioning
- Large Antenna Positioning System (LAPS): 0.1 GHz to 50 GHz
- Configurable Robotic MilliMeter-wave Antenna (CROMMA): Up to 500 GHz
- 8-meter precision linear positioning rail

- Laser-guided alignment system for sub-millimeter positioning accuracy
- Climate-controlled environment (±1°C temperature stability)
- Electromagnetic interference (EMI) shielded enclosures
- State-of-the-art vector network analyzers and signal generators

The facility was renovated and upgraded in 2023, with the calibration service reinstated through comprehensive measurement campaigns validating equivalency with international standards.

3. NIST Calibration Uncertainties

NIST provides detailed uncertainty budgets for all calibration services. Understanding these uncertainties is crucial for laboratories establishing their own measurement uncertainty budgets.

3.1 Uncertainty Components

Frequency Range	Gain Uncertainty (dB)	Polarization Uncertainty (dB/dB)	Contributing Factors
2 - 8 GHz	±0.10	±0.05	Mismatch, positioning, repeatability
8 - 18 GHz	±0.10	±0.05	Mismatch, positioning, repeatability
18 - 30 GHz	±0.10	±0.05	Mismatch, positioning, alignment
30 - 50 GHz	±0.15	±0.05	Mismatch, positioning, drift
50 - 75 GHz	±0.15	±0.06	Positioning, alignment, drift
75 - 110 GHz	±0.20	±0.07	Positioning, alignment, waveguide

3.2 Expanded Uncertainty (k=2)

NIST reports expanded uncertainty with a coverage factor k=2, providing approximately 95% confidence level. This uncertainty includes contributions from:

- Type A: Repeatability of measurements (statistical)
- Type B: Systematic effects including:
- - Mismatch uncertainty from impedance variations
- - Antenna positioning and alignment errors
- - Instrumentation drift and noise
- - Environmental effects (temperature, humidity)
- - Extrapolation fitting uncertainty
- - Multiple reflections and diffraction effects

4. Com-Power Calibration Services

Com-Power Corporation, established in 1989, provides comprehensive antenna calibration services with full NIST traceability. The company maintains an NIST-traceable calibration laboratory and has been calibrating EMC antennas for over 35 years.

4.1 NIST Traceability

Com-Power's calibration traceability chain:

- Level 1: NIST - Primary standards maintained by NIST CTL
- Level 2: Com-Power Reference Standards - Standard gain horns calibrated directly by NIST
- Level 3: Com-Power Transfer Standards - Secondary standards calibrated against NIST-calibrated horns
- Level 4: Customer Antennas - Calibrated using three-antenna or standard antenna method
- Traceability maintained through documented calibration chain
- All test equipment NIST-traceable with current calibration certificates
- Calibration procedures follow ANSI/NCSL Z540 requirements

4.2 ISO/IEC 17025 Compliance

Com-Power's calibration laboratory operates under an internal quality system based on NIST traceability standards "General requirements for the competence of testing and calibration laboratories."

Quality System Elements:

- Management System: Documented procedures and policies
- Personnel Competency: Trained and certified calibration technicians
- Facilities and Environmental Conditions: Climate-controlled calibration ranges
- Measurement Traceability: Complete traceability to NIST
- Calibration Procedures: Validated methods per ANSI C63.5, CISPR 16-1-6, SAE ARP958
- Uncertainty Evaluation: Documented uncertainty budgets per GUM
- Handling of Items: Secure storage and tracking system
- Records: Minimum 3 years hard copy, 10 years electronic backup
- Reporting Results: Certificates include all required information per ISO 17025
- Complaints and Appeals: Documented resolution process

4.3 Calibration Standards Followed

Com-Power performs antenna calibrations in accordance with:

- ANSI C63.5-2020: American National Standard for Antenna Calibration (9 kHz to 40 GHz)
- CISPR 16-1-6: EMC antenna calibration specifications
- SAE ARP958: Aerospace standard for antenna calibration
- IEEE Std 149-2021: Recommended Practice for Antenna Measurements

- MIL-STD-461G: Military standard for EMI control
- IEC 61000-4-3: Immunity test antenna calibration requirements

4.4 Multi-Distance Calibration Options

Com-Power offers flexible calibration distance options to meet various test requirements:

- 1 Meter Calibration:
- - Ideal for: Compact ranges, near-field measurements, loop antennas
- - Applications: MIL-STD-461 testing, automotive EMC
- - Typical antennas: Loop antennas, small horns, near-field probes

- 3 Meter Calibration:
- - Ideal for: Most EMC compliance testing per CISPR, FCC
- - Applications: Standard EMC test labs, pre-compliance testing
- - Typical antennas: Biconicals, log-periodics, horns, monopoles
- - Most common distance for commercial EMC testing

- 10 Meter Calibration:
- - Ideal for: Large product testing, automotive full vehicle
- - Applications: Automotive EMC (CISPR 12/25), aerospace
- - Typical antennas: Large horns, high-gain log-periodics, large LPDAs
- - Required for: SAE, ISO automotive standards

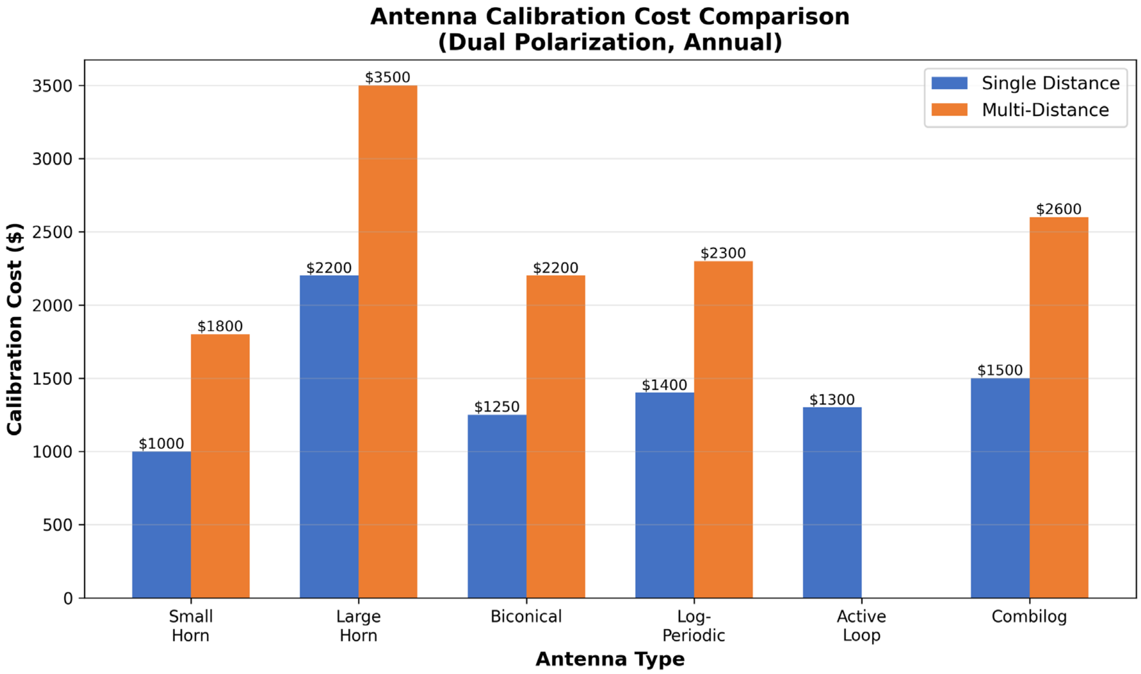
- Multi-Distance Calibration:
- - Provides: Calibration data at 3m AND 10m (or other combinations)
- - Benefits: Single antenna usable at multiple test distances
- - Cost: Approximately 50-75% more than single-distance
- - Recommended for: Labs performing testing at multiple distances

4.5 Frequency Coverage

Com-Power calibration laboratory frequency capabilities:

- 9 kHz to 30 MHz: Loop antennas, monopole antennas

Figure 2: Calibration Cost Comparison



- 30 MHz to 300 MHz: Biconical antennas, dipoles
- 200 MHz to 2 GHz: Log-periodic antennas, large horns, combilog
- 700 MHz to 18 GHz: Double-ridged horn antennas
- 18 GHz to 40 GHz: Millimeter-wave horn antennas
- Calibration frequency points per ANSI C63.5 recommendations
- Custom frequency points available upon request

5. Calibration Certificate Details

5.1 Certificate Contents

Each Com-Power calibration certificate includes the following information per NIST traceability requirements:

- Certificate Header:
- - Laboratory name and address
- - Certificate number (unique identifier)
- - Date of calibration
- - Customer information

- Equipment Identification:
- - Antenna model number
- - Serial number
- - Manufacturer
- - Physical condition upon receipt

- Calibration Parameters:
- - Frequency range
- - Test distance(s)
- - Polarization(s) measured
- - Environmental conditions (temperature, humidity)

- Measurement Results:
- - Antenna Factor (dB/m) vs. frequency for receive antennas
- - Gain (dBi) vs. frequency for transmit antennas
- - VSWR data
- - Data provided in tabular and/or graphical format

- Uncertainty Statement:
- - Expanded uncertainty (k=2)
- - Coverage probability (~95%)
- - Major uncertainty contributors

- Traceability Statement:
- - Reference to NIST traceability
- - Identification of reference standards used
- - Calibration dates of reference standards

- Standards and Methods:
- - Calibration procedure reference (ANSI C63.5, SAE ARP958, etc.)
- - Measurement method (three-antenna, standard antenna method)

- Signatures:
- - Calibration technician
- - Technical reviewer
- - Date of certificate issuance

5.2 Measurement Uncertainty

Com-Power provides measurement uncertainty estimates based on comprehensive uncertainty analysis:

Uncertainty Component	Type	Typical Contribution	Notes
NIST standard uncertainty	B	±0.10 - 0.20 dB	From NIST certificate
Mismatch uncertainty	B	±0.20 - 0.40 dB	Depends on VSWR
Measurement repeatability	A	±0.10 - 0.20 dB	From repeated measurements
Cable stability	B	±0.05 - 0.10 dB	Cable phase/amplitude variation
Positioning uncertainty	B	±0.05 - 0.15 dB	Distance, height, alignment
Ground reflection effects	B	±0.10 - 0.30 dB	Frequency and distance dependent
Instrumentation uncertainty	B	±0.10 - 0.15 dB	From instrument calibration
Ambient effects	B	±0.05 - 0.10 dB	Temperature, humidity variations
Combined (RSS)	**-**	**±1.5 - 2.5 dB**	**Expanded uncertainty (k=2)**

Note: Actual uncertainty varies with antenna type, frequency range, and measurement conditions. Typical expanded uncertainty for Com-Power antenna calibrations ranges from ±1.5 dB to ±2.5 dB (k=2).

5.3 Traceability Chain Documentation

Complete traceability documentation is maintained and available upon request:

- NIST Calibration Certificates for Com-Power reference standards
- Calibration procedures with detailed step-by-step instructions
- Equipment calibration certificates (network analyzers, power meters, etc.)
- Environmental monitoring records (temperature, humidity logs)
- Measurement raw data and calculation spreadsheets
- Quality control check standard measurements
- Uncertainty budget calculations per GUM methodology
- Inter-laboratory comparison results (when available)

6. Calibration Intervals and Maintenance

6.1 Recommended Calibration Intervals

Antenna Type	Environment	Recommended Interval	Rationale
Horn (passive)	Indoor lab	2 years	Stable, no active components
Horn (passive)	Indoor/outdoor	1 year	Environmental exposure
Horn (active)	Indoor lab	1 year	Active electronics drift
Biconical	Indoor lab	1 year	Mechanical stress on elements
Log-periodic	Indoor lab	1 year	Multiple resonant elements
Log-periodic	Outdoor	6 months	Weather exposure
Loop (active)	Indoor lab	1 year	Active electronics
Loop (passive)	Indoor lab	2 years	Simple geometry, stable
Monopole	Indoor lab	1 year	Mechanical wear
After repair	Any	Immediate	Performance verification
After damage	Any	Immediate	Structural integrity check

6.2 Factors Affecting Calibration Stability

- Physical Damage: Drops, impacts, crushing force on antenna elements
- Environmental Stress: Temperature cycling, humidity, corrosion
- Connector Wear: Repeated mating cycles degrade connectors
- High Power Exposure: May cause permanent damage to active components or coatings
- Frequency of Use: High-use antennas may need more frequent calibration
- Storage Conditions: Poor storage can lead to oxidation and mechanical stress
- Transportation: Rough handling during shipping can cause misalignment

6.3 Intermediate Checks

Between formal calibrations, laboratories should perform intermediate checks:

- Quarterly comparison against a stable reference antenna
- Visual inspection for physical damage before each use
- VSWR check to verify connector and feedline integrity
- Pattern check (if chamber has pattern measurement capability)
- Documentation of any anomalies or deviations
- Immediate recalibration if check results exceed acceptance criteria (typically ±1 dB deviation)

7. Special Calibration Services

7.1 High-Power Antenna Calibration

For antennas used in high-power immunity testing (>100W), Com-Power offers specialized calibration:

- Verification of power handling capability
- High-power VSWR measurements
- Thermal imaging to identify hot spots
- Pattern measurements at rated power
- Burn-in testing for new antennas
- Post-high-power exposure verification

7.2 Custom Frequency Points

Standard calibrations follow ANSI C63.5 frequency point recommendations. For special applications, Com-Power can provide calibration at custom frequencies:

- ISM band frequencies (915 MHz, 2.45 GHz, 5.8 GHz)
- Cellular/wireless bands (LTE, 5G NR frequencies)
- Satellite communication frequencies
- Radar frequencies
- Military frequency allocations
- Dense frequency spacing for narrowband applications
- Reduced frequency points for cost-sensitive applications

7.3 Antenna Pattern Measurements

Beyond standard antenna factor/gain calibration, Com-Power offers:

- E-plane and H-plane pattern measurements
- 3D pattern characterization
- Beam width measurements (3 dB, 10 dB points)
- Front-to-back ratio determination
- Cross-polarization measurements
- Time-gated measurements for reducing multipath
- Pattern comparison before/after repairs

8. References

[1] NIST Communications Technology Laboratory, "CTL Metrology and Calibration Services," https://www.nist.gov/ctl/ctl-metrology-and-calibration-services

[2] Gordon, J. and Moser, B., "NIST's Antenna Gain and Polarization Calibration Service Reinstatement," Antenna Measurement Techniques Association, October 2023

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

[4] NIST, "Robotically Enhanced Antenna Laboratory for Metrology (REALM)," https://www.nist.gov/ctl/robotically-enhanced-antenna-laboratory-metrology-realm

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

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

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

[8] ANSI/NCSL Z540.3-2006, "Requirements for the Calibration of Measuring and Test Equipment"

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

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

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

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

[13] BIPM, "CIPM Mutual Recognition Arrangement (CIPM MRA)," https://www.bipm.org/en/cipm-mra

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

[15] Newell, A.C., "Error Analysis Techniques for Planar Near-Field Measurements," IEEE Transactions on Antennas and Propagation, Vol. AP-36, No. 6, June 1988

12. Cost Considerations and Budget Planning

12.1 Typical Calibration Costs by Antenna Type

Antenna Type	Single Dist, Single Pol	Single Dist, Dual Pol	Multi Dist, Dual Pol	Notes
Small Horn (AH-118)	$600-800	$900-1,200	$1,600-2,000	Most common config: 3m dual-pol
Active Horn (AHA-118)	$800-1,000	$1,000-1,400	$1,800-2,200	Includes preamp testing
Large Horn (AH-220)	$1,200-1,500	$1,800-2,500	$3,000-4,000	Multi-distance ESSENTIAL
mmWave Horn (AH-840)	$1,000-1,300	$1,500-2,200	N/A	Premium pricing 18-40 GHz
Biconical (AB-900A)	$700-900	$1,000-1,500	$1,800-2,500	25-300 MHz, both pols needed
Log-Periodic (AL-100)	$700-1,000	$1,000-1,600	$1,800-2,400	UHF band
Combilog (AC-220)	$900-1,200	$1,200-1,800	$2,000-2,800	Continuous 30MHz-2GHz
Active Loop (AL-130R)	$800-1,000	$1,200-1,800	N/A	3-axis calibration
Dipole Set (AD-100A)	$1,200-1,800	$1,500-2,500	$2,500-3,500	Multiple elements
Van Veen (ALT-930-2M)	$2,000-3,000	$2,500-4,000	N/A	Specialized 3-axis system

12.2 Annual Laboratory Calibration Budgets

- Small Laboratory (8-10 antennas):
- 2× Small horn antennas @ $1,000 = $2,000
- 1× Large horn antenna @ $3,500 = $3,500
- 2× Biconical antennas @ $1,200 = $2,400
- 2× Log-periodic antennas @ $1,300 = $2,600
- 1× Active loop @ $1,000 = $1,000
- 1× Active horn @ $1,200 = $1,200
- Shipping and contingency = $1,300
- TOTAL ANNUAL BUDGET: $14,000-16,000

- Medium Laboratory (20-25 antennas):
- 5× Small horns various @ avg $1,400 = $7,000
- 2× Large horns @ $3,500 = $7,000

- 4× Biconical antennas @ $1,200 = $4,800
- 4× Log-periodic antennas @ $1,400 = $5,600
- 3× Active antennas @ $1,200 = $3,600
- 2× Loop antennas @ $900 = $1,800
- 2× Dipole sets @ $2,000 = $4,000
- Shipping, insurance, contingency = $6,200
- TOTAL ANNUAL BUDGET: $40,000-45,000

- Large Laboratory (40-50 antennas):
- Multiple antenna types across full frequency range
- Extensive multi-distance calibrations
- Some mmWave antennas (premium pricing)
- Expedited services occasionally needed
- TOTAL ANNUAL BUDGET: $75,000-100,000

12.3 Cost Factors Affecting Calibration Pricing

- 1. Frequency Range Complexity:
- Low freq (9kHz-30MHz): Higher cost due to time-intensive measurements
- VHF/UHF (30MHz-2GHz): Standard pricing
- Microwave (2-18GHz): Standard to moderate pricing
- mmWave (18-40GHz): Premium pricing (+30-50%)

- 2. Number of Polarizations:
- Single polarization: Base price
- Dual polarization: +50-75% of base
- Circular polarization or 3-axis: +100-150%

- 3. Number of Distances:
- Single distance (1m, 3m, or 10m): Base price
- Two distances (3m + 10m): +60-80%
- Three distances: +120-150%

- 4. Number of Frequency Points:
- Standard spacing per ANSI C63.5: Included in base
- Dense spacing (double points): +20-30%
- Sparse spacing (half points): -10-15%

- Custom ISM/cellular bands: No extra charge typically

- 5. Turnaround Time:
- Standard (3-4 weeks): Base price
- Expedited (1-2 weeks): +25-50%
- Rush (<1 week): +100%

- 6. Special Services:
- Pattern measurements: +$500-2,000
- High-power testing: +$300-1,000
- Witness calibration: +$500-1,500
- On-site calibration: Custom quote (typically $5,000-15,000)

- 7. Laboratory Location and Accreditation:
- NIST direct: $5,000-15,000 (premium, long turnaround)
- A2LA accredited commercial: $600-4,000 (standard)
- ISO 17025 internal quality: May be lower cost
- International labs: Varies, add shipping/customs

12.4 Cost Optimization Strategies

- Strategy 1: Prioritize Multi-Distance for Large Antennas Only
- Invest in multi-distance calibration for AH-220, large biconicals, large LPDAs
- Use single-distance for small horns operating above 1 GHz
- Savings: $800-1,500 per antenna annually

- Strategy 2: Extend Calibration Intervals for R&D Antennas
- Compliance test antennas: Annual calibration (required)
- Pre-compliance antennas: 18-month interval
- R&D/development antennas: 24-month interval
- Backup antennas: Calibrate when moved to active use
- Savings: 20-30% of annual calibration budget

- Strategy 3: Batch Calibrations for Volume Discounts
- Send 5+ antennas at once: 10-15% discount typical
- Annual contracts: 15-20% discount
- Establish relationship with 2-3 vendors for competitive pricing
- Savings: $2,000-6,000 annually for medium labs

- Strategy 4: Strategic Timing
- Avoid September-October (peak season)
- Schedule during lab downtime periods
- Plan 6-8 weeks before calibration due date
- Avoid rush charges by planning ahead
- Savings: $1,000-3,000 annually by avoiding expedite fees

- Strategy 5: Selective Polarization Calibration
- If antenna always used in one orientation: Single polarization
- Typical use: Both H and V needed
- Document usage pattern before deciding
- Savings: $400-800 per antenna (but use with caution)

- Strategy 6: In-House Calibration Development (Large Labs Only)
- Initial investment: $150,000-300,000

- Includes: Equipment, facility, accreditation, training
- Break-even: 3-5 years for labs with 30+ antennas
- Annual operating cost: $50,000-80,000
- Best for: Labs with 40+ antennas needing frequent calibration

14. Complete References and Resources

14.1 Primary Calibration Standards

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

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

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

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

[5] IEC 61000-4-3:2020, "Electromagnetic compatibility (EMC) - Part 4-3: Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test"

14.2 Test Method Standards

[6] ANSI C63.4-2014, "American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz"

[7] CISPR 15:2018, "Limits and methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment"

[8] CISPR 22:2008, "Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement" (superseded by CISPR 32)

[9] CISPR 32:2015, "Electromagnetic compatibility of multimedia equipment - Emission requirements"

[10] MIL-STD-461G, "Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment"

[11] RTCA DO-160G, "Environmental Conditions and Test Procedures for Airborne Equipment"

[12] ISO 11451-1:2015, "Road vehicles - Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy"

[13] ISO 11452-2:2019, "Road vehicles - Component test methods for electrical disturbances from narrowband radiated electromagnetic energy"

14.3 Quality and Accreditation Standards

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

[15] ANSI/NCSL Z540.3-2006, "Requirements for the Calibration of Measuring and Test Equipment"

[16] JCGM 100:2008, "Evaluation of measurement data - Guide to the expression of uncertainty in measurement (GUM 1995 with minor corrections)"

[17] ILAC-P14:01/2013, "ILAC Policy for Uncertainty in Calibration"

14.4 Technical References and Publications

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

[19] Paul, C. R., "Introduction to Electromagnetic Compatibility," 2nd Edition, John Wiley & Sons, 2006

[20] Ott, H. W., "Electromagnetic Compatibility Engineering," John Wiley & Sons, 2009

[21] Smith, A. A., German, R. F., Pomeroy, J. B., "Calculation of Site Attenuation from Antenna Factors," IEEE Transactions on Electromagnetic Compatibility, Vol. EMC-24, No. 3, August 1982

[22] Newell, A. C., "Error Analysis Techniques for Planar Near-Field Measurements," IEEE Transactions on Antennas and Propagation, Vol. AP-36, No. 6, June 1988

14.5 Online Resources

- NIST Resources:
- https://www.nist.gov/ctl/antenna-metrology - NIST Antenna Metrology Project
- https://www.nist.gov/ctl/ctl-metrology-and-calibration-services - NIST Calibration Services

- Standards Organizations:
- https://www.c63.org - ANSI C63 Committee (EMC Standards)
- https://www.iec.ch/emc - International Electrotechnical Commission (EMC)
- https://www.ieee.org/communities/societies/emcs - IEEE EMC Society

- Accreditation Bodies:
- https://www.a2la.org - American Association for Laboratory Accreditation
- https://www.nist.gov/nvlap - National Voluntary Laboratory Accreditation Program
- https://www.ilac.org - International Laboratory Accreditation Cooperation

- Com-Power Corporation:
- https://www.com-power.com - Main website
- https://www.com-power.com/services/calibration - Calibration services

15. Appendix A: Calibration Standards Summary

Standard	Region	Scope	Method	Uncertainty Goal
ANSI C63.5-2020	US/North America	9 kHz - 40 GHz	Three-antenna, standard antenna	±1.5 dB (k=2)
CISPR 16-1-6:2017	International	9 kHz - 18 GHz	Three-antenna, standard antenna	±1.5 dB (k=2)
SAE ARP958 Rev D	Aerospace	10 MHz - 40 GHz	Standard antenna	±2.0 dB (k=2)
IEEE Std 149-2021	General	All frequencies	Various methods	Method dependent
IEC 61000-4-3	Immunity	80 MHz - 6 GHz	Gain calibration	±0.5 dB

16. Appendix B: Uncertainty Budget Example

Example uncertainty budget for Com-Power AH-118 horn antenna calibration at 3 meters, 1 GHz, using the three-antenna method:

Source	Type	Distribution	Value	Divisor	Std Unc (dB)	Notes
NIST reference std	B	Normal (k=2)	±0.15 dB	2	0.075	From NIST cert
Mismatch (VSWR 1.5:1)	B	Rectangular	±0.35 dB	√3	0.202	Calculated
Measurement repeat	A	Normal	±0.12 dB	1	0.120	10 measurements
Cable stability	B	Rectangular	±0.10 dB	√3	0.058	Spec sheet
Distance positioning	B	Rectangular	±0.08 dB	√3	0.046	±5mm at 3m
Height positioning	B	Rectangular	±0.10 dB	√3	0.058	±10mm height
Ground reflections	B	Rectangular	±0.20 dB	√3	0.115	Estimated
VNA uncertainty	B	Normal (k=2)	±0.10 dB	2	0.050	From VNA cert
Ambient temperature	B	Rectangular	±0.05 dB	√3	0.029	±2°C variation
				RSS:	**0.302**	
				k=2:	**0.604**	**~95% confidence**

Conclusion: The combined standard uncertainty is 0.30 dB. With a coverage factor k=2, the expanded uncertainty is ±0.60 dB, providing approximately 95% confidence level. This is well within the ±1.5 dB goal of ANSI C63.5.