Com-Power EMC Antenna Product Line

Complete Specifications and Calibration Requirements

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Coverage: 9 kHz - 40 GHz

Figure 1: Com-Power Antenna Frequency Coverage Overview

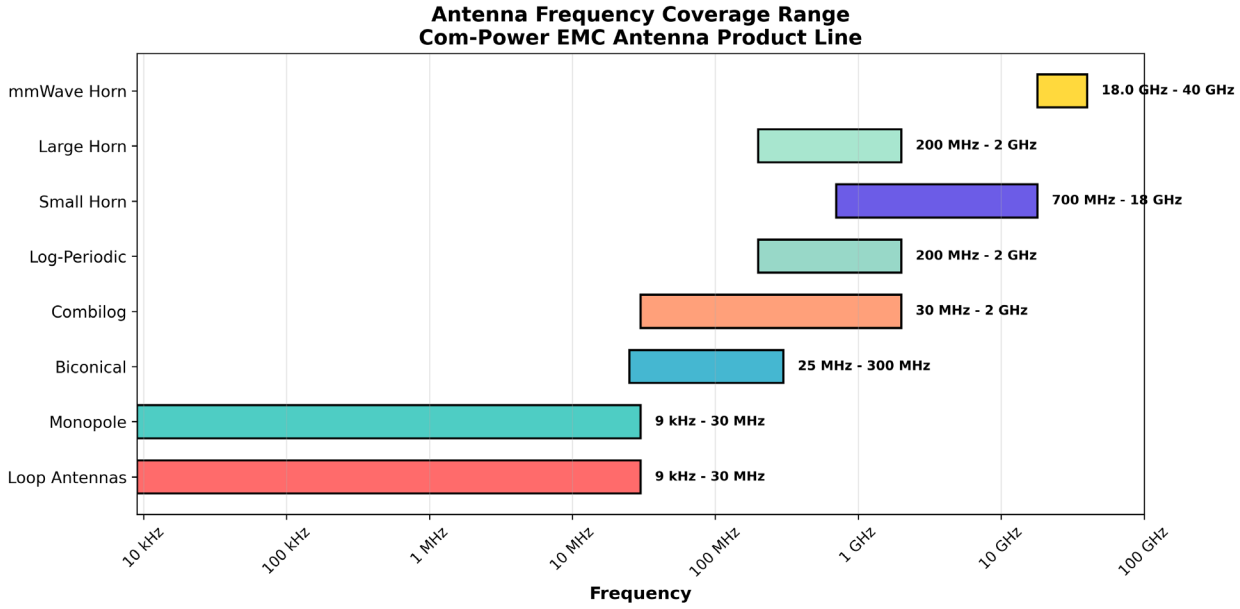
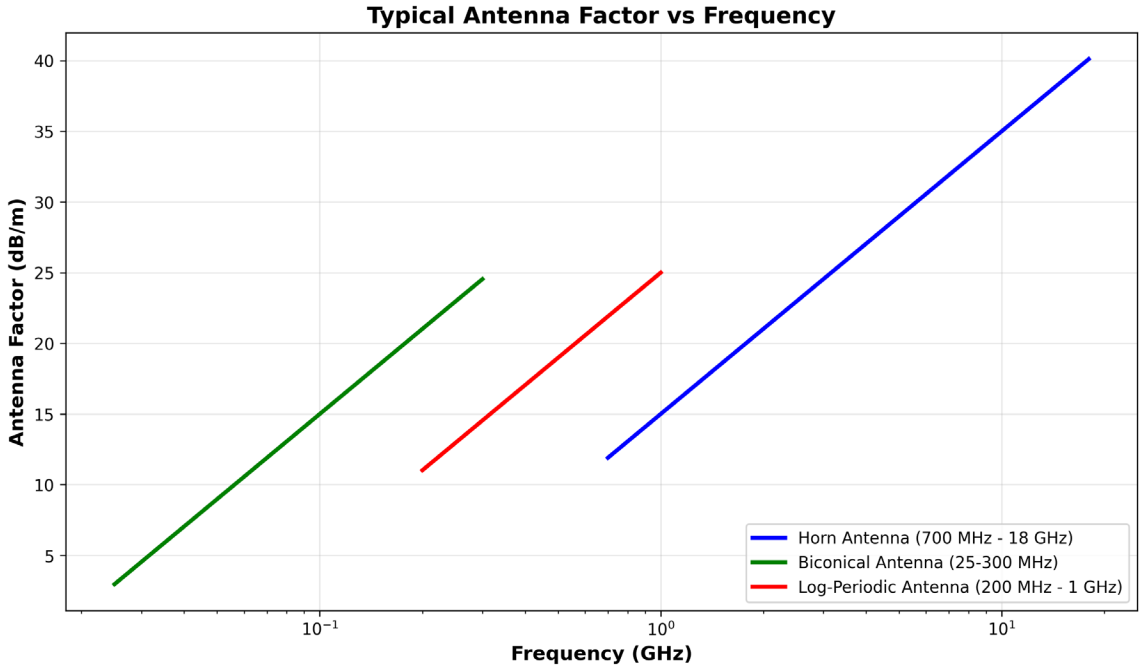


Figure 2: Typical Antenna Factor vs Frequency



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1. Active Horn Antennas

Active horn antennas integrate a low-noise preamplifier directly at the antenna output, maximizing signal-to-noise ratio for emissions testing. The built-in amplifier compensates for cable losses between the test site and control room.

1.1 AHA-118 Active Horn Antenna

Parameter	Specification
Model	AHA-118
Frequency Range	700 MHz - 18 GHz (usable 1-18 GHz)
Antenna Type	Double-ridged waveguide horn with integrated preamp
Preamplifier Gain	40 dB typical
Noise Figure	2.8 dB maximum
Power Handling	300 Watts CW (preamp bypassed)
Polarization	Linear (horizontal or vertical)
Impedance	50 Ω nominal
VSWR	2.0:1 maximum
Connector	N-type female
Dimensions (LxWxH)	7.8" × 9.5" × 5.6" (19.8 × 24.1 × 14.2 cm)
Weight	7 lbs (3.2 kg) maximum
Power Supply	12-15 VDC, supplied via bias-tee or external
Applications	EMI emissions testing, pre-compliance, surveillance
Standards	FCC, CISPR, EN, ETSI, MIL-STD-461, RTCA DO-160
Calibration	Individual NIST-traceable per ANSI C63.5 or SAE ARP958
Mounting	1/4"-20 threaded insert, includes right-angle bracket

Key Features:

- Built-in 40 dB preamplifier reduces measurement system noise floor
- Excellent sensitivity for detecting low-level emissions
- Can be used with preamp bypassed for immunity testing
- Lightweight and compact for easy positioning
- Corrosion-resistant aluminum construction
- Three-year manufacturer warranty

Calibration Requirements:

- Frequency Points: Every 100 MHz from 700 MHz to 18 GHz (per ANSI C63.5)

- Distance: Typically 3 meters (can be calibrated at 1m or 10m)
- Polarization: Single polarization (specify H or V) or dual polarization
- Method: Three-antenna method or standard antenna method
- Interval: Annually, or after repair/damage
- Special Notes: Preamp must be functional during receive calibration

1.2 AHA-840 Active Horn Antenna

Parameter	Specification
Model	AHA-840
Frequency Range	18 GHz - 40 GHz
Antenna Type	Double-ridged waveguide horn with integrated preamp
Preamplifier Gain	35 dB typical
Noise Figure	3.5 dB maximum
Power Handling	10 Watts with adapter, 200 W direct waveguide
Polarization	Linear
Impedance	50 Ω nominal
VSWR	2.5:1 maximum
Connector	2.92mm (K-type) female
Dimensions	TBD - Millimeter wave horn
Weight	Approximately 5-8 lbs
Power Supply	12-15 VDC via bias-tee
Applications	5G testing, radar, automotive ADAS, mm-wave emissions
Standards	FCC Part 15 Subpart E, CISPR 16, MIL-STD-461G
Calibration	NIST-traceable per ANSI C63.5
Mounting	1/4"-20 threaded insert

Calibration Requirements:

- Frequency Points: Every 200 MHz from 18 GHz to 40 GHz
- Distance: 1 meter or 3 meters typical
- Polarization: Single (H or V)
- Method: Standard antenna method using NIST-calibrated reference horn
- Interval: Annually
- Special Considerations: Millimeter-wave requires precise alignment

2. Passive Horn Antennas

Passive horn antennas are suitable for both emissions (receive) and immunity (transmit) testing. They offer high gain, broadband performance, and can handle significant power levels.

2.1 AH-118 Double-Ridged Horn

Parameter	Specification
Model	AH-118
Frequency Range	700 MHz - 18 GHz
Typical Gain	5-15 dBi (frequency dependent)
Power Handling	300 Watts CW
Peak Power	3 kW
VSWR	2.0:1 maximum
Polarization	Linear
Impedance	50 Ω
Connector	N-type female
Dimensions	11" × 8.5" × 10.5"
Weight	4 lbs (1.8 kg)
Applications	Emissions & immunity, pre-compliance, full compliance
Calibration	NIST-traceable, ANSI C63.5 or SAE ARP958

2.2 AH-220 Large Broadband Horn

Parameter	Specification
Model	AH-220
Frequency Range	200 MHz - 2 GHz
Typical Gain	8-15 dBi
Power Handling	800 Watts CW
VSWR	2.5:1 maximum
Polarization	Linear (H or V)
Impedance	50 Ω
Connector	N-type female
Dimensions	40" × 32" × 24" (101.6 × 81.3 × 61 cm)
Weight	50 lbs (22.7 kg)
Primary Application	MIL-STD-461 RE102 (200 MHz - 1 GHz)
Secondary Use	Radiated immunity 200 MHz - 2 GHz
Calibration	NIST-traceable per ANSI C63.5

Critical Calibration Note for AH-220:
Due to large physical size and low-frequency operation, the AH-220 exhibits significant ground reflection effects. Multi-distance calibration (3m AND 10m) is STRONGLY RECOMMENDED for

laboratories performing tests at both distances. Antenna factor can vary by 3-6 dB between these distances at frequencies below 500 MHz.

2.3 AH-840 Millimeter-Wave Horn (18-40 GHz)

Parameter	Specification
Model	AH-840
Frequency Range	18 GHz - 40 GHz
Typical Gain	15-25 dBi
Power Handling	10 W with adapter, 200 W direct waveguide
Field Generation	>1000 V/m at 1 meter with 200W input
VSWR	2.0:1 typical
Polarization	Linear
Connector	2.92mm (K-type) female
Waveguide	WR-42 (18-26.5 GHz), WR-28 (26.5-40 GHz)
Applications	5G NR, automotive radar, mm-wave EMC
Standards	FCC Part 15 Subpart E, CISPR 16, MIL-STD-461G
Calibration	NIST-traceable ANSI C63.5

2.4 Additional Passive Horn Antennas

Other Com-Power horn antenna models:

- AH-640: Standard gain horn, 26.5 - 40 GHz
- AH-826: Standard gain horn, 18 - 26.5 GHz
- AH-8055: High-gain broadband horn, 800 MHz - 6.5 GHz
- AH-826-840: Combined frequency range 18-40 GHz

3. Biconical Antennas

Biconical antennas are broadband dipole antennas ideal for vertical and horizontal NSA measurements, as well as emissions and immunity testing from 25-300 MHz and beyond.

3.1 AB-900A Biconical Antenna

Parameter	Specification
Model	AB-900A
Frequency Range	25 MHz - 300 MHz
Power Handling	50 Watts CW
Polarization	Linear
Impedance	50 Ω nominal
VSWR	3:1 typical
Connector	N-type female
Dimensions	51.5" × 52.75" (length × width)
Weight	5 lbs (2.3 kg)
Elements	Rigid aluminum cones
Applications	ANSI C63.4 NSA, emissions, immunity per FCC/CISPR
Standards	FCC, CISPR, EN, MIL-STD-461
Calibration	NIST-traceable per ANSI C63.5

Calibration Requirements:

- Frequency Points: Every 25 MHz from 25 MHz to 300 MHz
- Distance: 3 meters (per ANSI C63.4), 10m optional
- Polarization: Both horizontal AND vertical required for NSA measurements
- Method: Three-antenna method preferred, standard antenna method acceptable
- Interval: Annually
- Special Notes: Large physical size requires careful positioning for vertical measurements

3.2 ABF-900A Flexible Biconical

Parameter	Specification
Model	ABF-900A
Frequency Range	25 MHz - 300 MHz
Power Handling	50 Watts CW
Unique Feature	Flexible, foldable conical elements
Storage Benefit	Compact storage and easy transport
Weight	10 lbs (4.5 kg)
Applications	Same as AB-900A, with portability advantage
Calibration	NIST-traceable per ANSI C63.5

3.3 ABM-6000 Microwave Biconical

Parameter	Specification
Model	ABM-6000
Frequency Range	1 GHz - 6 GHz
Application	CISPR 16-1-4 Site VSWR procedure above 1 GHz
Type	Precisely tuned mini-biconical dipole
Use	Transmit source for site validation
Polarization	Linear
Calibration	NIST-traceable

3.4 AB-300M Compact Biconical

Model AB-300M: Compact biconical dipole antenna operating from 25 to 300 MHz, similar to AB-900A but with more compact design for space-constrained installations.

4. Combilog Antennas

Combilog antennas combine biconical and log-periodic antenna elements into a single unit, providing continuous frequency coverage from low VHF through UHF bands. This design eliminates the need for antenna switching during sweep measurements.

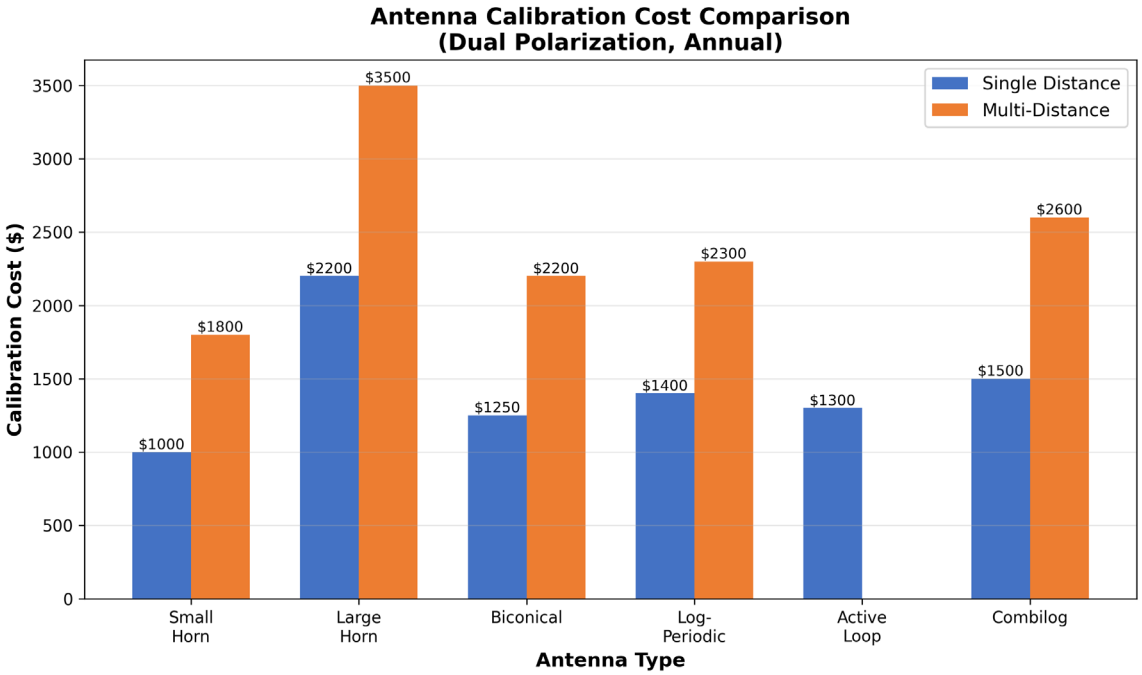
4.1 AC-220 Combilog Antenna

Parameter	Specification
Model	AC-220
Frequency Range	30 MHz - 2 GHz
Lower Band (Biconical)	30 MHz - 200 MHz
Upper Band (Log-Periodic)	200 MHz - 2 GHz
Typical Gain	0-8 dBi (frequency dependent)
Power Handling	100 Watts CW
VSWR	2.5:1 typical
Polarization	Linear (vertical or horizontal)
Impedance	50 Ω nominal
Connector	N-type female
Dimensions	Approximately 6 ft (1.83m) length
Weight	15-20 lbs (6.8-9.1 kg)
Applications	Emissions and immunity testing, continuous sweep
Standards	CISPR 22, FCC Part 15, EN 55022, MIL-STD-461
Calibration	NIST-traceable per ANSI C63.5

Key Advantages:

- Single antenna covers entire frequency range - no antenna switching
- Continuous sweep capability eliminates measurement gaps
- Optimized for both emissions and immunity applications
- Cost-effective alternative to separate biconical + log-periodic antennas
- Smooth transition between biconical and log-periodic elements
- Suitable for automated test systems

Figure 3: Calibration Cost Comparison by Antenna Type



Calibration Requirements:

- Frequency Points: Every 25 MHz from 30-200 MHz, every 50 MHz from 200 MHz-2 GHz
- Distance: 3 meters standard, 10 meters optional
- Polarization: Typically single (vertical), dual optional
- Method: Three-antenna method or standard antenna method
- Interval: Annually
- Special Note: Calibration should verify smooth transition at 200 MHz crossover point

5. Dipole Antennas

Tuned dipole antennas provide the most accurate calibration reference for site attenuation measurements. Each dipole is resonant at a specific frequency, offering excellent pattern control and predictable performance.

5.1 AD-100A Tuned Dipole Antenna Set

Parameter	Specification
Model	AD-100A
Frequency Range	30 MHz - 1000 MHz (discrete frequencies)
Standard	ANSI C63.4 specifications
Number of Elements	Typically 7-9 dipoles covering range
Dipole Lengths	Half-wavelength at resonant frequency
Resonant Frequencies	30, 50, 80, 100, 200, 400, 700, 900 MHz (typical set)
Power Handling	100 Watts CW per element
VSWR	<1.5:1 at resonance
Polarization	Linear (horizontal typical)
Impedance	50 Ω nominal
Connector	N-type female
Balun	Integrated 1:1 balun for each element
Applications	Site attenuation calibration, reference antenna
Standards	ANSI C63.4, CISPR 16-1-4
Calibration	NIST-traceable per ANSI C63.5

Usage Notes:

- Each dipole element must be changed for different frequency measurements
- Primary application: ANSI C63.4 Normalized Site Attenuation (NSA) measurements
- Considered the "gold standard" reference for site validation
- Better accuracy than broadband antennas for NSA measurements
- Requires careful assembly and balun verification before each use
- Elements should be stored in protective cases when not in use

Calibration Requirements:

- Each dipole element calibrated individually at its resonant frequency
- Distance: 3 meters and/or 10 meters per ANSI C63.4
- Polarization: Horizontal (standard for NSA), vertical optional
- Method: Three-antenna method preferred for highest accuracy
- Interval: Every 2 years (stable, passive design)
- Verification: VSWR check before each site validation

6. Log Periodic Antennas

Log Periodic Dipole Array (LPDA) antennas provide excellent broadband performance with good gain and directivity. They are workhorses in EMC testing for emissions and immunity applications from 200 MHz to 2 GHz and beyond.

6.1 AL-100 Log Periodic Antenna

Parameter	Specification
Model	AL-100
Frequency Range	200 MHz - 1000 MHz
Typical Gain	4-7 dBi
Power Handling	200 Watts CW
VSWR	2:1 typical
Polarization	Linear
Impedance	50 Ω
Connector	N-type female
Boom Length	Approximately 4-5 feet (1.2-1.5m)
Weight	8-12 lbs (3.6-5.4 kg)
Applications	Emissions testing, immunity testing, general RF
Standards	FCC Part 15, CISPR, EN, MIL-STD-461
Calibration	NIST-traceable per ANSI C63.5

6.2 ALC-100 Compact Log Periodic

Parameter	Specification
Model	ALC-100
Frequency Range	200 MHz - 1000 MHz
Feature	Compact design for space-limited installations
Typical Gain	3-6 dBi (slightly lower than AL-100)
Power Handling	100 Watts CW
Boom Length	Approximately 3 feet (0.9m)
Applications	Portable testing, compact chambers
Calibration	NIST-traceable per ANSI C63.5

6.3 ALP-100 High Power Log Periodic

Parameter	Specification
Model	ALP-100
Frequency Range	200 MHz - 1 GHz
Power Handling	1000 Watts CW (high-power capability)
Typical Gain	5-8 dBi
VSWR	<2:1
Applications	High-power immunity testing, automotive EMC
Special Feature	Reinforced elements for sustained high power

Weight	15-20 lbs (6.8-9.1 kg)
Calibration	NIST-traceable per ANSI C63.5

6.4 ALFM-80120 FM High Power Log Periodic

Parameter	Specification
Model	ALFM-80120
Frequency Range	80 MHz - 120 MHz (FM broadcast band)
Power Handling	2500 Watts CW (very high power)
Typical Gain	7-10 dBi
Application	High-power immunity testing in FM band
Special Design	Custom-designed for high power in narrow band
Calibration	NIST-traceable per ANSI C63.5 or SAE ARP958

Log Periodic Antenna Calibration Requirements:

- Frequency Points: Every 50 MHz across operating range
- Distance: 3 meters standard, 10 meters for automotive applications
- Polarization: Both horizontal AND vertical (LPDAs commonly used in both orientations)
- Method: Three-antenna method or standard antenna method
- Interval: Annually for active use, 2 years for occasional use
- Special Note: Outdoor antennas require more frequent calibration (6-12 months)

7. Active Loop Antennas

Active loop antennas are designed for low-frequency magnetic field measurements from 9 kHz to 30 MHz. The integrated preamplifier provides high sensitivity for detecting low-level emissions.

7.1 AL-130R Active Loop Antenna

Parameter	Specification
Model	AL-130R
Frequency Range	9 kHz - 30 MHz
Loop Diameter	Typically 60 cm
Preamplifier Gain	30-40 dB
Remote Control	Up to 30 meters via fiber optic or control cable
Output	Voltage proportional to H-field
Applications	MIL-STD-461 RE101, CISPR 11, conducted emissions
Impedance	50 Ω output
Connector	BNC or N-type
Power Supply	12-15 VDC, typically via USB or external adapter
Shielding	Electric field shielded, sensitive to H-field only
Standards	MIL-STD-461, CISPR 11, CISPR 16
Calibration	Factory calibration with NIST-traceable standards

Active Loop Calibration Requirements:

- Frequency Points: Every 1 MHz from 9 kHz-30 MHz, or per customer specification
- Distance: 1 meter typical (near-field measurement)
- Method: Calibrated H-field standard or Helmholtz coil
- Parameter: H-field sensitivity (dBµA/m per dBµV output)
- Interval: Annually
- Verification: Preamplifier gain check, frequency response

7.2 AM-Series Active Monopole Antennas

Active monopole antennas designed for shielded room testing in the 9 kHz to 30 MHz range.

Parameter	Specification
Frequency Range	9 kHz - 30 MHz
Type	Vertical monopole with active preamplifier
Applications	MIL-STD-461 RE102, DO-160, shielded room testing

Preamp Gain	20-30 dB typical
Output	Voltage proportional to E-field
Height	Typically 1 meter (adjustable)
Calibration	NIST-traceable per MIL-STD-461

8. Passive Loop Antennas

Passive loop antennas are used for MIL-STD-461 magnetic field measurements without active electronics. They provide reliable, stable measurements for both emissions and immunity testing.

8.1 AL-RE101 Passive Loop Antenna

Parameter	Specification
Model	AL-RE101
Standard	MIL-STD-461 RE101 Radiated Emissions, Magnetic Field
Frequency Range	30 Hz - 100 kHz
Loop Size	Typically 60 cm diameter
Shielding	Electrostatically shielded
Output	Passive voltage output proportional to H-field
Turns	Multiple turns for increased sensitivity
Connector	BNC female
Applications	Magnetic field emissions testing per MIL-STD-461
Calibration	NIST-traceable, transfer function provided

8.2 AL-RS101-SET Loop Antenna Set

Parameter	Specification
Model	AL-RS101-SET
Standard	MIL-STD-461 RS101 Radiated Susceptibility, Magnetic Field
Frequency Range	30 Hz - 100 kHz
Set Contents	Multiple loop sizes for different frequency bands
Applications	Magnetic field immunity testing per MIL-STD-461
Drive	Requires power amplifier for immunity testing
Calibration	NIST-traceable transfer function for each loop

Passive Loop Calibration Requirements:

- Parameter: Transfer function (voltage per A/m of H-field)
- Frequency Points: Per MIL-STD-461 requirements (typically 10-20 points)
- Method: Helmholtz coil or known H-field standard
- Distance: Not applicable (near-field device)
- Interval: Every 2 years (passive, stable)
- Verification: Resistance and inductance checks

9. Monopole (Rod) Antennas

Monopole antennas are vertical radiators used primarily for emissions testing in shielded environments and for specific military and aerospace applications.

9.1 AM-741R Active Monopole

Parameter	Specification
Model	AM-741R
Frequency Range	9 kHz - 60 MHz
Type	Active rod antenna with remote control
Element Length	1 meter (adjustable)
Preamplifier	Integrated active electronics
Remote Control	Up to 30 meters
Applications	MIL-STD-461, DO-160, shielded room testing
Standards	MIL-STD-461 RE102, RTCA DO-160
Mounting	Magnetic base or tripod mount
Connector	N-type or BNC
Calibration	NIST-traceable per MIL-STD-461

Monopole Antenna Features:

- Omnidirectional pattern in azimuth plane
- Vertical polarization only
- Ground plane dependent (requires conductive ground)
- Excellent for shielded room installations
- Low profile for compact test setups
- Remote operation minimizes operator influence
- Ideal for MIL-STD-461 RE102 (10 kHz - 18 GHz)

Calibration Requirements:

- Frequency Points: Every 1-5 MHz from 9 kHz to 60 MHz
- Distance: 1 meter typical
- Polarization: Vertical only
- Ground Plane: Must be calibrated with defined ground plane
- Method: Standard field method or comparison
- Interval: Annually
- Special Note: Ground plane size affects calibration significantly

10. Van Veen Triple Loop Antenna System

The Van Veen Triple Large Loop Antenna System (LAS) is specifically designed for three-axis magnetic field measurements as required by CISPR 15 (EN 55015) and CISPR 16-1-4 for lighting equipment testing.

10.1 ALT-930-2M Triple Loop System

Parameter	Specification
Model	ALT-930-2M
Standard	CISPR 15 (EN 55015) & CISPR 16-1-4
Frequency Range	9 kHz - 30 MHz
Measurement	Magnetic field induced current in X, Y, Z planes
Loop Configuration	Three orthogonal loops (2 meter diameter each)
Measurement Distance	10 meters from EUT
Output	Current measurement from each loop
Applications	Lighting equipment testing, three-axis H-field characterization
Shielding	Electrostatically shielded loops
Connector	BNC or N-type per loop
Support Structure	Non-metallic support frame
Calibration	NIST-traceable per CISPR 16-1-4

Van Veen System Features:

- Simultaneous three-axis measurement capability
- Large 2-meter diameter loops for far-field approximation
- Complies with CISPR 15 test setup requirements
- Non-conductive support structure minimizes interference
- Each loop independently calibrated
- Provides total H-field magnitude calculation
- Essential for lighting equipment EMC compliance
- Can be used for general three-axis magnetic field surveys

Calibration Requirements:

- Each of three loops calibrated individually
- Frequency Points: Per CISPR 16-1-4 (typically 150 kHz, 500 kHz, 5 MHz, 30 MHz)
- Method: Helmholtz coil or equivalent H-field standard
- Parameter: Transfer impedance (Ω) or current per H-field
- Distance: Not applicable (near-field measurement)
- Interval: Every 2 years

- Verification: Inter-loop isolation, orthogonality check

11. Calibration Requirements Summary

This section provides a comprehensive summary of calibration requirements for all Com-Power antenna types, organized by applicable EMC standards and test scenarios.

11.1 Calibration Requirements by Standard

Standard	Antenna Types	Distance	Polarization	Frequency Points
ANSI C63.4 (FCC Part 15)	Biconical, Log-Periodic, Dipoles	3m, 10m	H & V	Per C63.4 Table
CISPR 16-1-6	All antenna types	3m, 10m	As used	Every 50-100 MHz
MIL-STD-461 RE101	Loop antennas (passive)	1m	N/A (H-field)	30 Hz - 100 kHz
MIL-STD-461 RE102	Monopole, active loops	1m	Vertical	10 kHz - 18 GHz
IEC 61000-4-3 (Immunity)	Horns, log-periodics, biconicals	3m	H & V	80 MHz - 6 GHz
CISPR 15 (Lighting)	Van Veen triple loop	10m	N/A (3-axis)	9 kHz - 30 MHz
SAE Automotive	Large horns, LPDAs	3m, 10m	H & V	Per SAE standard
RTCA DO-160 (Avionics)	Monopole, loops, horns	1m	As specified	Per DO-160 Cat

11.2 Recommended Calibration Intervals

Antenna Type	Usage	Environment	Interval
Active horn	Regular	Indoor lab	1 year
Passive horn (small)	Regular	Indoor lab	1-2 years
Passive horn (large)	Regular	Indoor lab	1 year
Biconical	Regular	Indoor lab	1 year
Biconical	Outdoor	OATS	6 months
Log-periodic	Regular	Indoor lab	1 year
Log-periodic	High-power	Indoor/outdoor	6 months
Dipole set	Occasional	Indoor lab	2 years
Loop (active)	Regular	Indoor lab	1 year
Loop (passive)	Regular	Indoor lab	2 years
Monopole	Regular	Shielded room	1 year
Van Veen	Occasional	Indoor lab	2 years
Any antenna	After damage	Any	Immediate
Any antenna	After repair	Any	Immediate

4. Combilog Antennas

Combilog antennas combine biconical and log-periodic antenna designs into a single unit, providing continuous coverage across a wide frequency range with a single antenna system.

4.1 AC-220 Combilog Antenna

Parameter	Specification
Model	AC-220
Frequency Range	30 MHz - 2 GHz (continuous coverage)
Low Frequency	30-200 MHz (biconical section)
High Frequency	200 MHz - 2 GHz (log-periodic section)
Typical Gain	0-8 dBi (frequency dependent)
Power Handling	200 Watts CW typical
Polarization	Linear (H or V)
Impedance	50 Ω nominal
VSWR	3:1 maximum
Connector	N-type female
Dimensions	Approximately 60" × 48" deployed
Weight	Approximately 15-20 lbs
Applications	Emissions and immunity testing, single antenna solution
Standards	CISPR 16, EN 55022, FCC Part 15, MIL-STD-461
Advantages	Eliminates need for antenna switching at 200 MHz
Calibration	NIST-traceable per ANSI C63.5

Calibration Requirements:

- Frequency Points: Every 25 MHz from 30-200 MHz, every 50 MHz from 200 MHz-2 GHz
- Distance: 3 meters standard, 10 meters for automotive applications
- Polarization: Both H and V if used in both orientations
- Method: Three-antenna method (two combilog + one reference)
- Interval: Annually
- Special Notes: Transition region (180-220 MHz) requires careful calibration

Key Advantages:

- Eliminates antenna changeover, reducing test time
- Consistent measurements across transition frequency
- Single mount position for entire frequency range
- Ideal for automated test systems
- Cost-effective alternative to separate biconical and log-periodic

5. Dipole Antennas

Tuned dipole antennas are considered reference antennas for EMC site validation and calibration. They provide precise, narrowband performance at specific frequencies.

5.1 AD-100A Tuned Dipole Antenna Set

Parameter	Specification
Model	AD-100A
Type	Tuned half-wave dipole set
Frequency Range	30 MHz - 1000 MHz
Number of Elements	9 dipole pairs (30-80 MHz, 80-200 MHz, 200-300 MHz, etc.)
Design Standard	ANSI C63.4 specifications
Primary Use	Site calibration and NSA measurements
Impedance	50 Ω at resonance
VSWR	<1.5:1 at resonant frequency
Connector	N-type female on balun
Elements	Telescoping aluminum tubes
Balun	Integrated wideband balun
Applications	ANSI C63.4 NSA, antenna calibration reference
Standards	ANSI C63.4, CISPR 16-1-4
Calibration	NIST-traceable per ANSI C63.5

Calibration Requirements:

- Frequency Points: At resonant frequency of each dipole element
- Additional Points: ±10% of resonant frequency for verification
- Distance: 3 meters per ANSI C63.4
- Polarization: Horizontal (standard), vertical (optional)
- Method: Three-antenna method or substitution against NIST-calibrated reference
- Interval: Every 2 years (stable, passive design)
- Special Notes: Elements must be properly assembled to correct length for each frequency

Usage Notes:

- Considered "gold standard" for site attenuation measurements
- More accurate than biconical but requires element changes
- Each dipole resonant at specific frequency (λ/2 length)
- Balun converts balanced dipole to unbalanced coaxial
- Requires careful assembly and length verification
- Not suitable for broadband sweep measurements

6. Log Periodic Antennas

Log-periodic dipole array (LPDA) antennas provide broadband coverage with relatively constant gain and impedance. They are excellent for both emissions and immunity testing across the 200 MHz - 2 GHz range.

6.1 AL-100 Log Periodic Antenna

Parameter	Specification
Model	AL-100
Frequency Range	200 MHz - 1000 MHz
Typical Gain	5-8 dBi
Power Handling	300 Watts CW
Polarization	Linear (H or V)
Impedance	50 Ω nominal
VSWR	2:1 typical
Connector	N-type female
Boom Length	Approximately 48-60"
Weight	8-12 lbs
Elements	Multiple dipole elements in log-periodic array
Applications	Emissions and immunity per CISPR, FCC, EN standards
Calibration	NIST-traceable per ANSI C63.5

6.2 ALP-100 High Power Log Periodic

Parameter	Specification
Model	ALP-100
Frequency Range	200 MHz - 1000 MHz
Power Handling	600 Watts CW (high power version)
Typical Gain	6-9 dBi
Primary Use	Radiated immunity testing (transmit antenna)
VSWR	2:1 maximum
Weight	Approximately 15 lbs (heavier construction)
Applications	IEC 61000-4-3 immunity, automotive immunity
Calibration	Gain calibration per IEC 61000-4-3

6.3 ALC-100 Compact Log Periodic

Model ALC-100: Compact version of the AL-100 with similar frequency coverage but reduced physical size for space-constrained test environments. Typical gain: 4-7 dBi, suitable for pre-compliance testing.

6.4 ALFM-80120 FM Band High Power LPDA

Parameter	Specification
Model	ALFM-80120
Frequency Range	80 MHz - 120 MHz (FM broadcast band)
Power Handling	2500 Watts CW (ultra-high power)
Application	FM broadcast immunity testing
Typical Gain	6-8 dBi
Special Design	Heavy-duty elements and feedline
Primary Use	Automotive immunity to FM broadcast signals
Calibration	Gain calibration every 5 MHz

General LPDA Calibration Requirements:

- Frequency Points: Every 50 MHz from 200 MHz - 1 GHz
- Distance: 3 meters standard, 10 meters for automotive
- Polarization: Both H and V (LPDAs commonly rotated during testing)
- Method: Three-antenna method or standard antenna method
- Interval: Annually
- Multi-Distance: Recommended for labs testing at 3m and 10m
- Special Notes: Orientation affects pattern, verify both polarizations if used in both

7. Active Loop Antennas

Active loop antennas are used for low-frequency magnetic field measurements, typically from 9 kHz to 30 MHz. The integrated preamplifier provides high sensitivity for conducted and radiated emissions testing per MIL-STD-461.

7.1 AL-130R Active Loop Antenna

Parameter	Specification
Model	AL-130R
Frequency Range	9 kHz - 30 MHz
Loop Diameter	Approximately 60 cm
Preamplifier Gain	20-30 dB (frequency dependent)
Impedance	50 Ω output
Power Supply	12 VDC, remote supply up to 30 meters
Remote Control	Fiber optic or long cable
Connector	N-type female or BNC
Applications	RE101 testing (MIL-STD-461), CISPR low-frequency emissions
Standards	MIL-STD-461 RE101, CISPR 16-1-4
Calibration	NIST-traceable antenna factor

Calibration Requirements:

- Frequency Points: 10 kHz, 50 kHz, 100 kHz, then every 1 MHz to 30 MHz
- Distance: 1 meter (standard for loop antennas)
- Orientation: Three orthogonal positions (X, Y, Z axes)
- Method: Helmholtz coil or known H-field reference
- Interval: Annually
- Parameter: Antenna Factor for H-field (dB/A/m)
- Special Notes: Active electronics require functional check, battery backup recommended

7.2 AM-Series Active Monopole Antennas

Parameter	Specification
Model	AM-741R / AM-630R
Type	Active monopole (rod antenna)
Frequency Range	9 kHz - 60 MHz (AM-741R)
Element Length	41" telescoping rod
Preamplifier	Integrated low-noise preamp
Applications	Shielded room testing, MIL-STD-461, DO-160
Remote Control	Up to 30 meters
Power	12 VDC via bias-tee or external supply
Calibration	NIST-traceable antenna factor

8. Passive Loop Antennas

Passive loop antennas are used for magnetic field measurements per MIL-STD-461 requirements. They provide calibrated H-field measurements without active electronics.

8.1 AL-RE101 Loop Antenna (Receive)

Parameter	Specification
Model	AL-RE101
Application	MIL-STD-461 RE101 radiated emissions, magnetic field
Frequency Range	30 Hz - 100 kHz
Loop Size	Per MIL-STD-461 specifications
Output	Direct to spectrum analyzer or receiver
Type	Shielded loop
Calibration	Antenna factor in dB/A/m

8.2 AL-RS101-SET Loop Antenna Set (Transmit)

Parameter	Specification
Model	AL-RS101-SET
Application	MIL-STD-461 RS101 radiated susceptibility, magnetic field
Frequency Range	30 Hz - 100 kHz
Set Contents	Multiple loop sizes per MIL-STD-461G
Primary Use	Generating calibrated H-field for immunity testing
Power Handling	Varies by frequency and loop size
Calibration	Transfer impedance (current to H-field)

MIL-STD-461 Loop Calibration Requirements:

- Frequency Points: Per MIL-STD-461G tables (typically 30 Hz, 50 Hz, 60 Hz, discrete points to 100 kHz)
- Distance: 7 cm (standard per MIL-STD-461)
- Method: Helmholtz coil reference or calculable loop method
- Interval: Every 2 years (passive, stable)
- Special Notes: Must meet MIL-STD-461 specifications for loop size and positioning

9. Monopole Antennas

Monopole (rod) antennas are vertical polarization antennas used primarily for conducted and radiated emissions testing in the 9 kHz to 30 MHz range, particularly in shielded enclosures.

9.1 Passive Monopole Specifications

Parameter	Specification
Typical Model	AM-series passive monopoles
Frequency Range	9 kHz - 30 MHz (some models to 200 MHz)
Element	41" telescoping rod antenna (typical)
Ground Plane	Requires conducting ground plane (1m × 1m minimum)
Polarization	Vertical
Impedance	50 Ω at feedpoint
Connector	BNC or N-type
Applications	MIL-STD-461 RE102, shielded room testing, low-frequency emissions
Calibration	Antenna factor calibration

Calibration Requirements:

- Frequency Points: Every 1 MHz from 10 kHz - 30 MHz
- Distance: 1 meter from ground plane
- Ground Plane: Must use standardized ground plane during calibration
- Method: Standard site method or comparison to reference monopole
- Interval: Annually
- Special Notes: Highly dependent on ground plane size and quality
- Verify: Element length and ground plane condition before calibration

Important Notes:

- Monopole performance strongly depends on ground plane
- Vertical polarization only (no horizontal calibration)
- Resonances occur at odd quarter-wavelengths
- Best suited for frequencies where wavelength >> element length
- Common in MIL-STD-461 testing (10 kHz - 18 GHz frequency range coverage)
- Often used in combination with other antennas for full frequency coverage

10. Van Veen Triple Loop Antenna System

The Van Veen Triple Loop Antenna System (also called Large Loop Antenna System - LAS) is used for three-axis magnetic field measurements per CISPR 15 (EN 55015) for lighting equipment testing.

10.1 ALT-930-2M Triple Large Loop System

Parameter	Specification
Model	ALT-930-2M
Application	CISPR 15 / EN 55015 magnetic field induced-current measurement
Frequency Range	9 kHz - 30 MHz
Measurement Axes	X, Y, Z (three orthogonal planes)
Loop Configuration	Three mutually perpendicular 2-meter loops
Measurement	Induced current in loops from magnetic field
Standard	CISPR 16-1-4 specifications
Output	Current measurement from each loop
Typical Use	Lighting equipment magnetic emissions per CISPR 15
Calibration	Transfer factor (H-field to current)

System Components:

- Three 2-meter × 2-meter wire loops (X, Y, Z axes)
- Support structure maintaining orthogonal orientation
- Current measurement devices for each loop
- Calibrated per CISPR 16-1-4 requirements
- Typically floor-mounted with vertical support for Z-axis loop
- Equipment under test placed at center of loop system

Calibration Requirements:

- Frequency Points: Per CISPR 15 table (9 kHz, 50 kHz, 150 kHz, discrete points to 30 MHz)
- Method: Helmholtz coil calibration or calculable reference field
- Distance: Equipment at geometric center of loop system
- Each Axis: Calibrated independently (X, Y, Z)
- Parameter: Transfer factor (A/m per A measured)
- Interval: Every 2 years
- Verification: Annual check against reference source
- Special Notes: Very specialized, primarily for lighting equipment manufacturers

11. Calibration Requirements Summary by Antenna Type

This section provides a comprehensive summary of calibration requirements for all Com-Power antenna types, organized by applicable standards and test laboratory needs.

11.1 Calibration Decision Matrix - Complete

Antenna Model	Freq Range	Std Distance	Alt Distance	Polarizations	Freq Spacing	Standards
AHA-118	0.7-18 GHz	3m	1m	Single (H or V)	100 MHz	ANSI C63.5
AHA-840	18-40 GHz	1m	3m	Single	200 MHz	ANSI C63.5
AH-118	0.7-18 GHz	3m	1m, 10m	Dual (H & V)	100 MHz	ANSI C63.5
AH-220	0.2-2 GHz	3m, 10m	-	Dual (H & V)	25-50 MHz	ANSI C63.5, MIL-STD-461
AH-640	26.5-40 GHz	1m	3m	Single	500 MHz	ANSI C63.5
AH-826	18-26.5 GHz	1m	3m	Single	250 MHz	ANSI C63.5
AH-840	18-40 GHz	1m	3m	Single	200 MHz	ANSI C63.5
AH-8055	0.8-6.5 GHz	3m	10m	Dual	100 MHz	ANSI C63.5
AB-900A	25-300 MHz	3m	10m	Dual (H & V)	25 MHz	ANSI C63.4, C63.5
ABF-900A	25-300 MHz	3m	10m	Dual	25 MHz	ANSI C63.5
ABM-6000	1-6 GHz	3m	-	Single (H)	100 MHz	CISPR 16-1-4
AB-300M	25-300 MHz	3m	-	Dual	25 MHz	ANSI C63.5
AC-220	30MHz-2GHz	3m	10m	Dual (H & V)	25-50 MHz	CISPR 16, C63.5
AD-100A	30-1000 MHz	3m	-	H (std)	Resonant Freq	ANSI C63.4
AL-100	0.2-1 GHz	3m	10m	Dual (H & V)	50 MHz	ANSI C63.5
ALP-100	0.2-1 GHz	3m	10m	Dual	50 MHz	IEC 61000-4-3
ALC-100	0.2-1 GHz	3m	-	Dual	50 MHz	ANSI C63.5
ALFM-80120	80-120 MHz	3m	10m	Dual	5 MHz	Custom
AL-130R	9kHz-30MHz	1m	-	3-axis	1 MHz	MIL-STD-461 RE101
AM-741R	9kHz-60MHz	1m	-	Vertical	1 MHz	MIL-STD-461
AL-RE101	30Hz-100kHz	7cm	-	3-axis	Per MIL-STD	MIL-STD-461 RE101
AL-RS101-SET	30Hz-100kHz	7cm	-	N/A	Per MIL-STD	MIL-STD-461 RS101
ALT-930-2M	9kHz-30MHz	Center	-	3-axis (X,Y,Z)	Per CISPR 15	CISPR 15/16-1-4
Monopole	9kHz-30MHz	1m	-	Vertical only	1 MHz	MIL-STD-461

11.2 Calibration Requirements by Standard

ANSI C63.4 (Site Attenuation):

- Antennas: Tuned dipoles (AD-100A) preferred, biconical (AB-900A) acceptable
- Distance: 3 meters or 10 meters
- Polarization: Both horizontal and vertical required
- Frequency: Per ANSI C63.4 table (30-1000 MHz)
- Method: Three-antenna method or substitution
- Uncertainty: ±1.5 dB desired

ANSI C63.5 (Antenna Calibration):

- Applicable to: All broadband antennas (horns, biconicals, log-periodics)

- Distance: At intended use distance (1m, 3m, or 10m)
- Frequency Points: 50 MHz spacing <1 GHz, 100 MHz spacing >1 GHz
- Polarization: As used in testing (H, V, or both)
- Method: Three-antenna method or standard antenna method
- Uncertainty: ±2 dB typical, ±1.5 dB achievable
- Interval: Annually or after damage/repair

MIL-STD-461G:

- RE101 (30 Hz - 100 kHz): Loop antennas (AL-RE101), 7 cm distance
- RE102 (10 kHz - 18 GHz): Monopoles, biconicals, horns, log-periodics per frequency
- RS101 (30 Hz - 100 kHz): Loop antenna set (AL-RS101-SET)
- RS103 (10 kHz - 40 GHz): Various antennas per frequency and field strength
- Calibration: Per MIL-STD-461G procedures
- Traceability: NIST required for most programs

IEC 61000-4-3 (Radiated Immunity):

- Antennas: Biconicals (80-300 MHz), log-periodics (200-1000 MHz), horns (>1 GHz)
- Calibration: Antenna gain required
- Distance: 3 meters typical
- Field Uniformity: ±6 dB over test volume
- Frequency: Test frequencies per standard
- Traceability: ISO 17025 accredited calibration lab

CISPR 15/16 (Lighting Equipment):

- Magnetic Field: Van Veen triple loop system (ALT-930-2M)
- Electric Field: Standard EMC antennas per frequency
- Distance: Per CISPR 16-1-4 specifications
- Calibration: CISPR 16-1-6 methods
- Frequency: 9 kHz - 400 MHz (lighting), up to 6 GHz (other)

11.3 Recommended Calibration Strategies by Laboratory Type

Commercial EMC Lab (FCC, CISPR, EN):

- Essential Antennas: Biconical (AB-900A), LPDA (AL-100), Horns (AH-118, AH-840)
- Calibration Distance: 3 meters primary
- Polarization: Dual (H & V) for all antennas
- Frequency Coverage: 30 MHz - 18 GHz minimum, 40 GHz preferred
- Interval: Annual
- Cost Estimate: $3000-5000 annually for complete set
- Multi-Distance: Optional unless testing at 10m regularly

Automotive EMC Lab (CISPR 12/25, ISO):

- Essential Antennas: Biconical, Combilog (AC-220), LPDA, Horns
- Calibration Distance: 3m AND 10m (multi-distance required)
- Polarization: Dual (H & V)
- Frequency Coverage: 30 MHz - 6 GHz
- Special: High-power LPDA for immunity (ALP-100)
- Interval: Annual
- Cost Estimate: $5000-8000 annually (multi-distance adds cost)

Military/Aerospace (MIL-STD-461, DO-160):

- Essential Antennas: Complete set - loops, monopoles, biconicals, LPDAs, horns
- Frequency Coverage: 30 Hz - 40 GHz (full MIL-STD-461 range)
- Special: Loop antennas (AL-RE101, AL-RS101-SET) for RE101/RS101
- Calibration: Per MIL-STD-461G procedures
- Distance: Multiple (1m, 3m per requirement)
- Traceability: NIST required
- Interval: Per contract requirements (typically annual)
- Cost Estimate: $8000-15000 annually

Pre-Compliance Lab (Budget-Conscious):

- Minimum Set: Biconical (AB-900A), LPDA (AL-100), Small horn (AH-118)

- Calibration: Single distance (3m), single polarization acceptable
- Frequency: 30 MHz - 6 GHz covers most commercial products
- Interval: Every 2 years acceptable for pre-compliance
- Consider: Active antennas (AHA-118) for better sensitivity
- Cost Estimate: $1500-2500 for basic set
- Upgrade Path: Add dual polarization and additional frequencies as needed

12. Application Guide - Antenna Selection by Test

12.1 Emissions Testing Antenna Selection

Frequency Range	Antenna Type	Models	Notes
9 kHz - 30 MHz	Loop or Monopole	AL-130R, AM-741R	Loop for H-field, monopole for E-field
30 - 300 MHz	Biconical	AB-900A, ABF-900A	Vertical orientation standard
200 MHz - 1 GHz	Log-Periodic or Combilog	AL-100, AC-220	Broadband sweep capability
700 MHz - 6 GHz	Horn (small)	AH-118, AHA-118, AH-8055	Active horn for low emissions
1 - 18 GHz	Horn (double-ridge)	AH-118, AHA-118	Dual polarization available
18 - 40 GHz	Horn (mm-wave)	AH-840, AHA-840	5G, automotive radar
Transition 30-200 MHz	Combilog	AC-220	No antenna change required

12.2 Immunity Testing Antenna Selection

Frequency Range	Antenna Type	Models	Power Requirement
25 - 300 MHz	Biconical	AB-300M	50W typical
200 MHz - 1 GHz	Log-Periodic	ALP-100	600W for high field
80 - 120 MHz	LPDA (FM)	ALFM-80120	2500W ultra-high
700 MHz - 2 GHz	Horn	AH-220	800W
1 - 18 GHz	Horn	AH-118	300W
18 - 40 GHz	Horn	AH-840	200W (waveguide)

12.3 Site Validation Antenna Requirements

Test	Standard	Antennas Required	Distance
NSA (Normalized Site Atten)	ANSI C63.4	Tuned dipoles (AD-100A) or Biconical + LPDA	3m or 10m
SVSWR (Site VSWR)	CISPR 16-1-4	ABM-6000 + horn antennas	3m
Field Uniformity	IEC 61000-4-3	Transmit antenna + field probe	3m
Chamber Validation	Various	Broadband antennas per frequency	Per standard

Final Recommendations:

- Always calibrate antennas at the distance(s) they will be used
- Dual polarization calibration if antenna will be rotated during testing
- Active antennas (AHA series) provide 15-20 dB better sensitivity than passive
- Large antennas (<500 MHz) require multi-distance calibration
- Budget for annual calibration - critical for ISO 17025 accreditation
- Maintain calibration records for minimum 3 years
- Perform quarterly intermediate checks between calibrations
- Com-Power provides NIST-traceable calibration for all antenna models
- Contact Com-Power for custom calibration requirements

12. Complete Application Guide by Test Standard

12.1 FCC Part 15 (Unintentional Radiators)

- Required Antennas for Full FCC Part 15 Coverage:

- 30-300 MHz:
- Primary: AB-900A Biconical (both H and V polarization)
- Alternative: AD-100A Tuned Dipole Set (for NSA measurements)
- Calibration: 3m for Class B products, 10m for Class A
- Cost: $1,000-1,500 single distance, $1,800-2,500 multi-distance

- 200 MHz - 2 GHz:
- Option 1: AC-220 Combilog (eliminates antenna changeover)
- Option 2: AL-100 Log-Periodic (traditional approach)
- Calibration: 3m standard, 10m for Class A
- Cost: $1,000-1,800

- 1-18 GHz:
- Receive: AHA-118 Active Horn (best sensitivity)
- Transmit/Receive: AH-118 Passive Horn
- Calibration: 3m, dual polarization
- Cost: $900-1,400

- Complete FCC Part 15 Lab Setup:
- 1× AB-900A Biconical: $1,200
- 1× AC-220 Combilog OR AL-100 LPDA: $1,400
- 1× AHA-118 Active Horn: $1,200
- Total initial calibration: ~$3,800
- Annual recalibration: ~$3,800

12.2 MIL-STD-461G (Military Equipment)

- Complete MIL-STD-461G Antenna Requirements:

- RE101 (30 Hz - 100 kHz) - Magnetic Field:
- Antenna: AL-RE101 Loop
- Distance: 7 cm per MIL-STD-461G
- Calibration: NIST-traceable H-field calibration
- Cost: $1,000-1,500

- RE102 (10 kHz - 18 GHz) - Electric Field:
- 10 kHz - 30 MHz: AL-130R Active Loop or AM-741R Active Monopole
- 30-200 MHz: AB-900A Biconical
- 200 MHz - 1 GHz: AL-100 Log-Periodic or AH-220 Horn
- 1-18 GHz: AH-118 Horn
- Distance: 1 meter (critical for MIL-STD-461)
- Calibration: ALL at 1 meter distance

- RS101 (30 Hz - 100 kHz) - Magnetic Field Susceptibility:
- Antenna: AL-RS101-SET Loop Set
- Distance: 7 cm
- Calibration: Transfer impedance calibration
- Cost: $2,000-3,000

- RS103 (10 kHz - 40 GHz) - Radiated Susceptibility:
- Same antennas as RE102 but for transmit
- Must handle high power (200W+ typical)
- Distance: 1 meter
- Calibration: Gain calibration, 1 meter

- Complete MIL-STD-461 Lab Setup:
- RE101: AL-RE101 Loop: $1,200
- RE102 Low Freq: AL-130R or AM-741R: $1,200
- RE102 VHF: AB-900A Biconical: $1,200 (1m cal)
- RE102 UHF: AL-100 or AH-220: $1,500-2,500

- RE102 Microwave: AH-118: $1,000 (1m cal)
- RS101: AL-RS101-SET: $2,500
- RS103: High-power versions of RE102 antennas
- Total initial calibration: ~$10,000-12,000
- Annual recalibration: ~$10,000-12,000

- CRITICAL NOTE:
- ALL antennas must be calibrated at 1-meter distance
- Do NOT use 3m calibrations for MIL-STD-461 testing
- High-power antennas required for RS103

12.3 Automotive EMC (CISPR 12/25, ISO 11451/11452)

- Automotive Testing Requirements:

- CISPR 12 (Vehicle Level Emissions) - 10 Meter Distance:
- 30-300 MHz: AB-900A Biconical
- 200 MHz - 1 GHz: AL-100 Log-Periodic or AC-220 Combilog
- Calibration: 10 meters ESSENTIAL
- Multi-distance (3m + 10m): STRONGLY RECOMMENDED
- Both H and V polarization required

- CISPR 25 (Component Level):
- Various setups per manufacturer specifications
- Typically 1 meter for component testing
- 150 kHz - 2.5 GHz coverage

- ISO 11451 (Vehicle Immunity) - 10 Meter Distance:
- 80-120 MHz: ALFM-80120 High-Power LPDA (2,500W rating)
- 200 MHz - 1 GHz: ALP-100 High-Power LPDA (600W rating)
- 1-18 GHz: AH-118 or AH-220 Horn (300-800W rating)
- Field Strength: 20-200 V/m typical
- Calibration: 10 meters, gain calibration

- ISO 11452 (Component Immunity):
- Varies by sub-part (stripline, BCI, TEM cell, etc.)
- Antenna requirements specific to test method

- Complete Automotive Lab Setup:
- AB-900A Biconical (3m+10m dual-pol): $2,200
- AL-100 or AC-220 (3m+10m dual-pol): $2,400
- AH-220 Large Horn (3m+10m dual-pol): $3,500
- ALP-100 High-Power LPDA (10m dual-pol): $2,000
- ALFM-80120 FM Band LPDA (10m): $1,800
- Total initial calibration: ~$12,000-14,000
- Annual recalibration: ~$12,000-14,000

- CRITICAL NOTE for Automotive:
- 10-meter calibration is MANDATORY
- Multi-distance calibration highly recommended
- Large antennas essential due to vehicle size
- High-power ratings required for immunity

13. Advanced Cost Optimization Strategies

13.1 Multi-Distance Decision Calculator

- Use this calculator to decide if multi-distance calibration is worthwhile:

- Step 1: Determine your testing pattern
- Percentage of tests at 3m: ____%
- Percentage of tests at 10m: ____%

- Step 2: Calculate cost scenarios over 5 years

- Scenario A (Single Distance - 3m only):
- Initial calibration cost: $_____
- Annual recalibration (4 times): $_____ × 4 = $_____
- Measurement error when testing at 10m: ±2-6 dB
- Risk: Non-compliance, failed audits
- 5-Year Total: $_____

- Scenario B (Single Distance - 10m only):
- Initial calibration cost: $_____
- Annual recalibration (4 times): $_____ × 4 = $_____
- Measurement error when testing at 3m: ±2-6 dB
- Risk: Non-compliance, failed audits
- 5-Year Total: $_____

- Scenario C (Multi-Distance - 3m + 10m):
- Initial calibration cost: $_____
- Annual recalibration (4 times): $_____ × 4 = $_____
- Measurement error: Minimized (<±1 dB)
- Risk: Low, full compliance
- 5-Year Total: $_____

- Decision Rules:

- If >80% of tests at one distance: Single distance may be acceptable
- If 40-60% split between distances: Multi-distance ESSENTIAL
- For automotive labs: Multi-distance MANDATORY
- For large antennas <1 GHz: Multi-distance ESSENTIAL
- For small antennas >1 GHz: Single distance usually acceptable

13.2 Laboratory Size-Based Recommendations

Lab Size	Annual Tests	Antenna Count	Annual Cal Budget	Optimization Strategy
Startup (<50 tests/yr)	<50	5-8 antennas	$8,000-12,000	Minimal set, single distance, extend intervals
Small (50-200 tests/yr)	50-200	10-15 antennas	$15,000-25,000	Essential antennas, selective multi-distance
Medium (200-500 tests/yr)	200-500	20-30 antennas	$35,000-55,000	Full coverage, multi-distance for large antennas
Large (500+ tests/yr)	500+	40-60 antennas	$75,000-120,000	Complete coverage, consider in-house capability
Automotive Specialist	Varies	25-40 antennas	$50,000-80,000	All 10m calibration, multi-distance essential