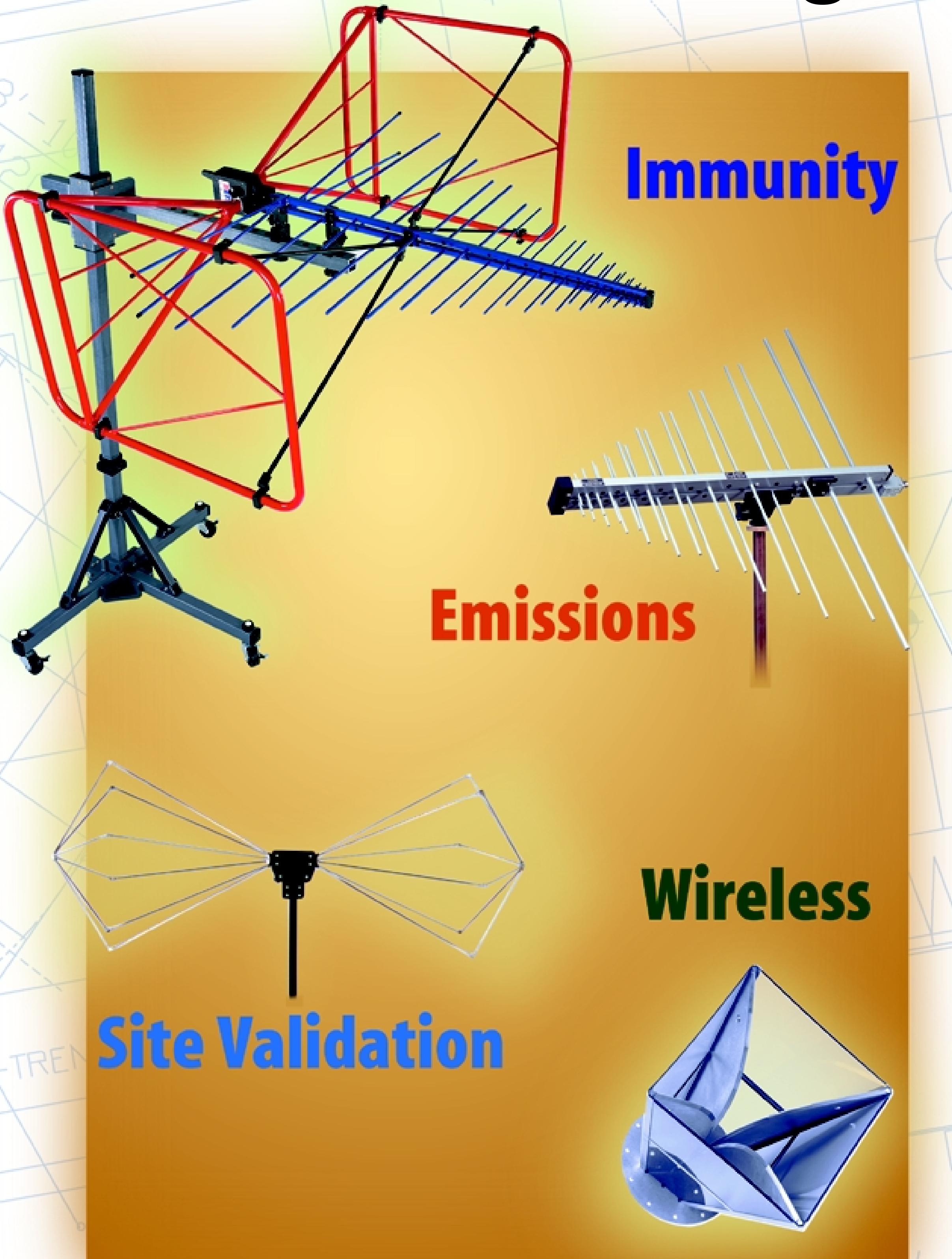
Antenna Catalog



ETS·LINDGREN™

An ESCO Technologies Company

99% of Our Customers
From Us Again!

Better Quality

Commitment To Quality

Our meticulous Quality Management System is modeled after the stringent ISO-9001 procedures and is designed to meet the following requirements: EN 29001-1987, BS 5750-Part 1, and ANSI/ASQC Q91-1987, Model for Quality Assurance in Design/Development, Production, Installation, and Servicing.

Our Quality Assurance personnel and skilled craftsmen have documented hundreds of processes and operations, including detailed work instructions for every antenna component that we manufacture. This enhances our consistency of workmanship, providing you with further assurance of measurement accuracy at your test site.

Procuring the highest quality raw materials possible is also a top priority. For most antennas we use high-grade 6061T6 aluminum. Critical components are made from aircraft-grade 2024T3 aluminum. After assembly, many models receive a tough, powder coat finish. This attractive protectant resists scratching and abrasions better than painted or bare surfaces.

Prior to shipment, every antenna receives a thorough inspection by a Quality Technician, who is certified by the American Society of Quality Control.

Better Support

Broad Selection & Two-Year Warranty

Today, we offer more than 25 superior-quality antenna models to meet your EMC immunity and emissions testing needs. We also have the capabilities to assist you with custom antennas for special applications. To ensure your satisfaction, all EMCO brand antennas are backed by a two-year materials and workmanship warranty.

A2LA Accredited Calibration Site

ETS-Lindgren *individually* calibrates the antennas we manufacture prior to shipment at our A2LA accredited calibration site.[2] Your antenna's calibration data is kept on file, and the antenna is assigned a calibration tracking number. The product manual includes the performance data of the antenna, the date of the test, and the individual serial number of the antenna. A Certificate of Conformance, verifying the authenticity and accuracy of the calibration, is included with each antenna. (For more information on Antenna Calibration, see page 65.)

Full-Time Technical Support

When you have a technical question relating to your antenna, you usually need your answer NOW! That's why our Sales Department is staffed with seasoned EMC veterans. When you call with a technical question, you can talk to a full-time Technical Support Representative. This individual has experience in our Calibration, Manufacturing and Engineering departments, so your questions are answered with authority.

Worldwide Presence

Our large network of knowledgeable and helpful representatives spans the globe. To locate one near you, please visit our website.

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www.ets-lindgren.com

Quick Find

Locate your model, its page, and other relevant information easily!

MODEL	DESCRIPTION	PAGE	FREQUENCY	TEST TYPE							
				U.S. REG.	EUR. REG.	VCCI	SAE	461E	285	NACSIM	WIRELESS
3101	Conical Log Spiral	56-59	200 MHz – 1 GHz			RI	RE, RI	RE, RI	PW	RE	
3102	Conical Log Spiral	56-59	1 GHz – 10 GHz			RI	RE, RI	RE, RI	PW	RE	
3103	Conical Log Spiral	56-59	100 MHz – 1 GHz			RI	RE, RI	RE, RI	PW	RE	
3104C	Biconical	10-17	20 MHz – 200 MHz	RE	RE	RE	RE	RE	PW	RE	
3109	Biconical	10-17	20 MHz – 300 MHz		RI		RI	RI	PW		
3110B	Biconical	10-17	30 MHz – 300 MHz	RE	RE	RE	RE	RE	PW	RE	
3124	Calculable Biconical	18-19	30 MHz – 300 MHz	RE	RE	RE	RE	RE	PW	RE	
3106	Double Ridged Guide	26-31	200 MHz – 2 GHz	RE	RE, RI	RI	RE, RI	RE, RI	PW	RE	
3115	Double Ridged Guide	26-31	1 GHz – 18 GHz	RE	RE, RI	RI	RE, RI	RE, RI	M	RE	X
3116	Double Ridged Guide	26-31	18 GHz – 40 GHz	RE	RE, RI		RE, RI	RE, RI	M	RE	
3164-03	Diag. Dual Polarized Horn	32-33	400 MHz – 6 GHz	RE	RE		RE	RE	M	RE	X
3160,61	Std Gain Octave Horns	34-39	960 MHz – 40 GHz	RE	RE, RI		RE, RI	RE, RI	M	RE	
3121C	Tuned Dipole	40-43	30 MHz – 1 GHz	RE	RE	RE, RI	RE				
3125	Fixed Dipole Set	44-45	440 MHz – 3 GHz								X
3140	BiConiLog	4-9	26 MHz – 2 GHz		RI	RI	RI	RI	PW		
3142B	BiConiLog	4-9	26 MHz – 2 GHz	RE	RI	RE, RI	RE, RI	RE, RI	PW	RE	
3142B	BiConiLog w/ End Plates	4-9	26 MHz – 2 GHz	RE	RI	RI	RI	RI	PW	RE	
3144	Log Periodic	20-25	80 MHz – 2 GHz	RE	RE,RI	RE, RI	RE, RI	RE, RI	PW	RE	
3147	Log Periodic	20-25	200 MHz – 5 GHz	RE	RE,RI	RE, RI	RE, RI	RE, RI	PW	RE	
3148	Log Periodic	20-25	200 MHz – 2 GHz	RE	RE,RI	RE, RI	RE, RI	RE, RI	PW	RE	
3301B	Monopole (Rod)	52-55	30 Hz – 50 MHz				RE	RE	EF	RE	
3303	Monopole (Rod)	52-55	1 kHz – 30 MHz						EF		
3305	Monopole Antenna Set	60-61	1 kHz – 30 MHz					RE	EF		
6502	Loop	46-51	10 kHz – 30 MHz	RE	RE		RE	RE	HF	RE	
6505	Loop Antenna Set	60-61	1 kHz – 30 MHz						HF		
6507	Loop	46-51	1 kHz – 30 MHz	RE	RE		RE	RE	HF	RE	
6509	Loop	46-51	1 kHz – 30 MHz		RI		RI		HF		
6511	Loop	46-51	20 Hz – 5 MHz	RE	RE			RE	HF	RE	
6512	Loop	46-51	10 kHz – 30 MHz	RE	RE		RE	RE	HF		
7603	Magnetic Field Coil	46-51	20 Hz – >50 kHz					RI	HF		
7604	Magnetic Field Coil	46-51	20 Hz – 500 kHz					RE	HF		
7605	Magnetic Field Coil	46-51	30 Hz – >50 kHz					RI	HF		
7606	Magnetic Field Coil	46-51	30 Hz – >50 kHz					RE, RI	HF		
3107B	Parallel Element E E-Field Generator	106	10 kHz – 30 MHz				RI	RI			

RE = Radiated Emissions
EF = E Field
RI = Radiated Immunity
HF = H Field
M = Microwave
PW = Plane Wave
X = Wireless Frequencies

All Conical Log Spiral Antennas have been dropped from MIL-STD-461/2D. They are still acceptable for testing conducted to earlier versions of this specification.

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Contents

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MODEL 3140 BiConiLog

Mounted on 7-TR Tripod

See Page 100 for the paper "Understanding the Measurement Uncertainties of the Bicon/Log Hybrid Antenna"

BiConiLog™

Model 3140
26 MHz – 2 GHz

Model 3142B
26 MHz – 2 GHz

- **Ultra Broadband: 26 MHz to 2.0 GHz**
- **New End Plate Element Design Improves Performance** (Patent Pending)
- **Up to 10 dB Gain Improvement at Low Freq. vs. Comparable Antennas**
- **Lower Power Requirements (RI), Higher Sensitivity (RE)**
- **Tough Powder Coat Finish**
- **Use in Compact Chambers**

INDIVIDUALLY CALIBRATED (3142B) QUALITY QA ASSURANCE TWO YEAR 2 YEAR WARRANTY

USERS OF EMCO'S BICONILOG™ ANTENNAS test faster than those who use multiple antenna setups. With the BiConiLog's ultra broadband frequency range, several antennas are no longer needed to perform wideband emissions and immunity tests. Users can sweep from 26 MHz to 2.0 GHz, making the BiConiLog ideal for ANSI C63.4, FCC-15, FCC-18 and EN 55022 emissions testing, IEC 61000-4-3 immunity testing, and other EMC test applications.

EMCO's BiConiLogs feature a patent-pending Bow-Tie element design that significantly improves low frequency performance compared to conventional biconical or bow-tie / log periodic hybrid antennas. Both models exhibit excellent symmetry.

EMCO BiConiLog Antenna Features

Ultra Broadband

Combining innovative designs with a compact size, our BiConiLog antennas enable users to measure from 26 MHz to 2.0 GHz in one sweep. This single sweep capability eliminates the need for multiple antennas and time-consuming equipment setups, which improves accuracy and saves time and money.

High Gain

From 26 MHz to 60 MHz, the Model 3142B BiConiLog antenna with optional end plates exhibits an average 5.5 dB gain improvement vs. typical hybrid antennas. At some frequencies, a 10 dB gain improvement is achieved. This benefits test engineers in several ways. For immunity measurements, amplifier requirements are reduced because of the antenna's enhanced impedance matching capability. This saves money if buying a new amplifier, and increases power reserves of existing amplifiers. For emission measurements, system sensitivity is increased, which can improve test accuracy.

Low VSWR

Both BiConiLog models feature an average VSWR of less than 2.0:1.

High Power Input Capacity

Both models accept 1 kW maximum continuous input at frequencies above 60 MHz. Below 60 MHz, it is recommended not to exceed 500 W with the Model 3140 and not to exceed 300 W with the Model 3142B.

Quality Construction

EMCO BiConiLog antennas are constructed of lightweight, corrosion-resistant aluminum, providing years of trouble-free indoor and outdoor service. In addition, both models receive a tough powder coat finish, which protects against scratching and abrasion better than painted or bare surfaces.

Choosing Your Model: Two Models Feature An Ultra Broadband Frequency Range of 26 MHz to 2 GHz

26 MHz to 2.0 GHz - Immunity Applications Only

The new Model 3140 BiConiLog is designed and optimized for immunity testing and is not recommended for emission measurements. For immunity applications, the antenna exhibits exceptional gain between 26 MHz to 80 MHz, requiring ≤300 W to generate 10 V/m above 30 MHz with 80% AM at a distance of 3 meters. Above 80 MHz, the antenna's VSWR is less than 2:1. Individual antenna calibration data for emission testing is not provided.

26 MHz to 2.0 GHz - Immunity and Emission Applications

The Model 3142B BiConiLog replaces the former EMCO Model 3142 and with optional end plates is identical to the former Model 3141. The Model 3142B is designed as a dual-purpose antenna that can be used for both immunity and emission

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applications. Optional end plates are available to improve gain for immunity testing. The end plates are easily attached and detached by hand using captive screw knobs. Individual antenna calibration data - without the end plates attached - is provided for emission testing.

Standard Configuration

- Antenna
- Model 3142B individually calibrated at 1 m per SAE ARP 958 and 3 and 10 m per ANSI C63.5. Actual antenna factors and a signed Certificate of Calibration Conformance included in Manual

f y i

BiConiLog™ technology combines two antennas; a biconical (or bow-tie) and log periodic, to create a single hybrid that covers the frequency range of both antennas. Changing antennas at bandbreaks (i.e. 300 MHz, 1 GHz) is eliminated, saving time and reducing errors. When the first EMCO BiConiLog was introduced in 1994, it immediately won a "Best In Test" Award from *Test & Measurement World* magazine.

Options

Optional T Bow-Tie End Plates (Part Number 106572)
Optional end plates are available for Model 3142B only.

Support Rod (See page 62-63)
Antenna mount with insert drilled to accept EMCO or other tripod with standard 1/4 in x 20 threads.

EMCO Tripod
EMCO offers several nonmetallic, non-reflective tripods for use at EMC test sites. For easy horizontal and vertical polarization changes, EMCO's Model 7-TR tripod is recommended.

Applications

MODEL	FCC-15	FCC-18	IEC/CISPR/EN	SAE J1113	SAE J551	MIL-STD-461E	MIL-STD-1541	NACSIM	VCCI
3140			RI	RI	RI	RI	RI		
3142B	RE	RE	RE, RI	RE, RI	RE,RI	RE, RI	RE, RI	RE	RE
106572	RE	RE	RE, RI	RE, RI	RE,RI	RE, RI	RE, RI	RE	RE

RE = Radiated Emissions RI = Radiated Immunity (Susceptibility)

Electrical Specifications

MODEL	FREQUENCY RANGE	VSWR RATIO (AVG)	MAXIMUM CONTINUOUS POWER	PEAK POWER	IMPEDANCE (NOMINAL)	CONNECTOR
3140	26 MHz – 2 GHz	2.0:1	1 kW [1]	1.3 kW	50 Ω	Type N female (1)
3142B	26 MHz – 2 GHz	2.0:1	1 kW [2]	1.3 kW	50 Ω	Type N female
106572	26 MHz – 2 GHz	2.0:1	1 kW [3]	1.3 kW	50 Ω	Type N female

[1] 3140: 750 W maximum recommended below 60 MHz.
[2] 3142B: 300 W maximum recommended below 60 MHz.
[3] 106572: 500 W maximum recommended below 60 MHz.

Physical Specifications

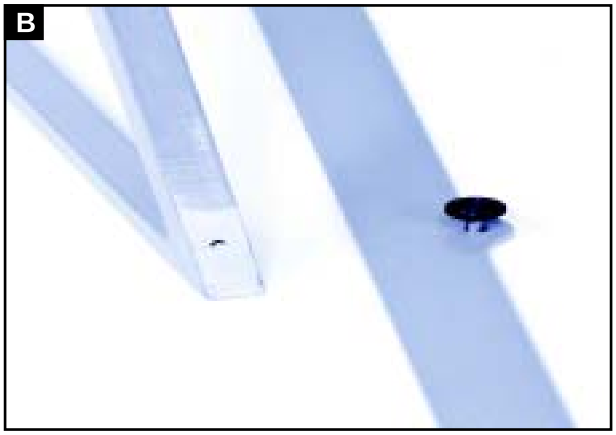
MODEL	WIDTH [4]	DEPTH	HEIGHT	WEIGHT
3140	161.5 cm 63.6 in	149.3 cm 58.78 in	76.65 cm 30.18 in	10.0 kg 22.0 lb
3142B	135.0 cm 53.1 in	124.5 cm 49.0 in	75.0 cm 29.5 in	4.0 kg 8.8 lb
106572	137.4 cm 54.1 in	132.1 cm 52.0 in	76.2 cm 30.0 in	6.7 kg 14.7 lb

[4] At widest point

Easy-to-Assemble Design Adds Convenience

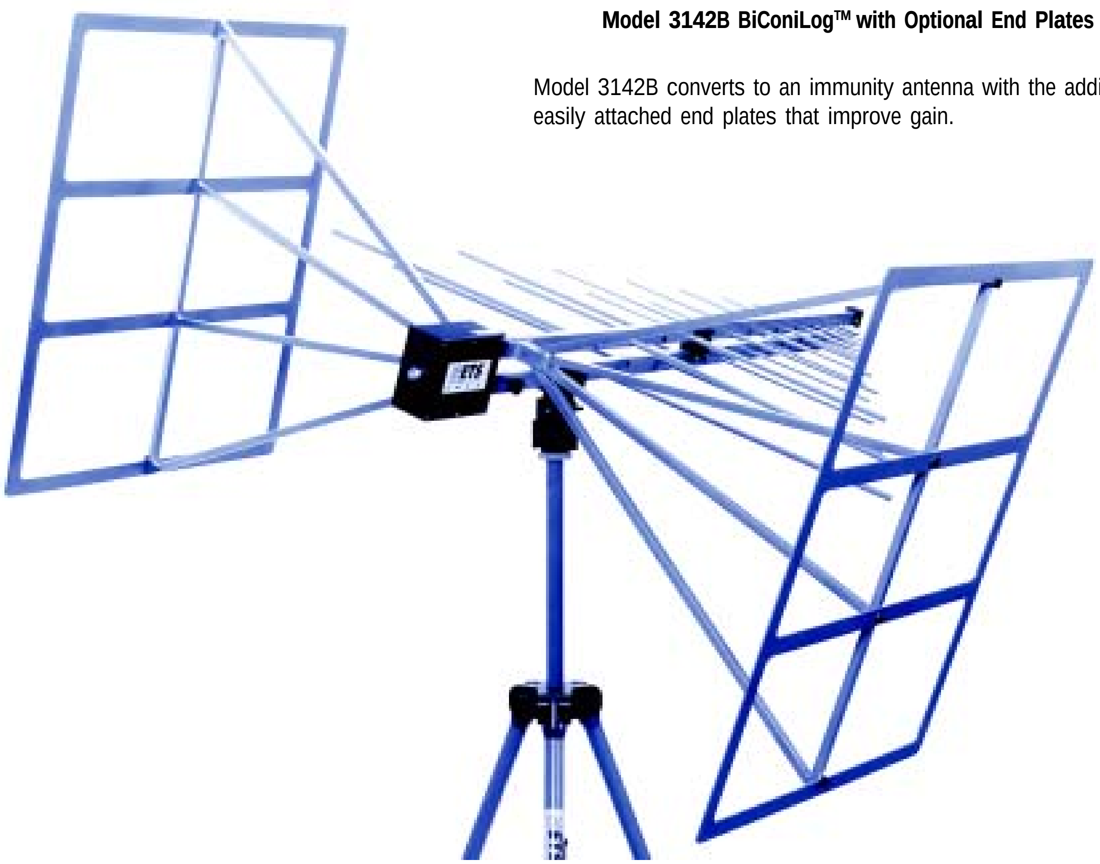
Our innovative T Bow-Tie element design is easy to assemble and disassemble without tools. This quick disassembly makes carrying the Model 3142B BiConiLog through doorways and hallways simple. It also frees up space in the lab, since the elements can be quickly removed and stored out of the way.

A screw knob secures each bow-tie to the antenna's boom (A). Four smaller screw knobs fasten the "T" element to the bow-tie (B). No tools are required and assembly can be completed in less than a minute.



Model 3142B BiConiLog™ with Optional End Plates

Model 3142B converts to an immunity antenna with the addition of easily attached end plates that improve gain.



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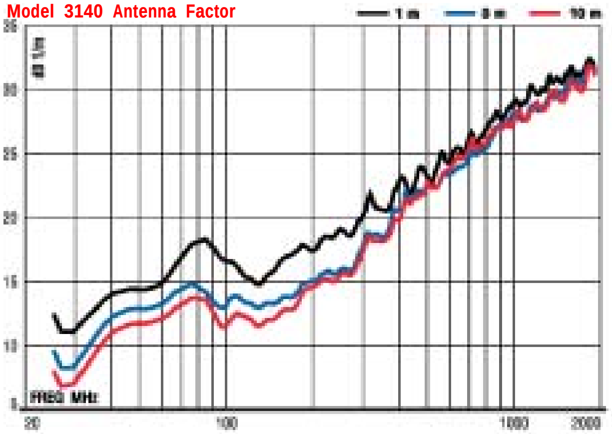
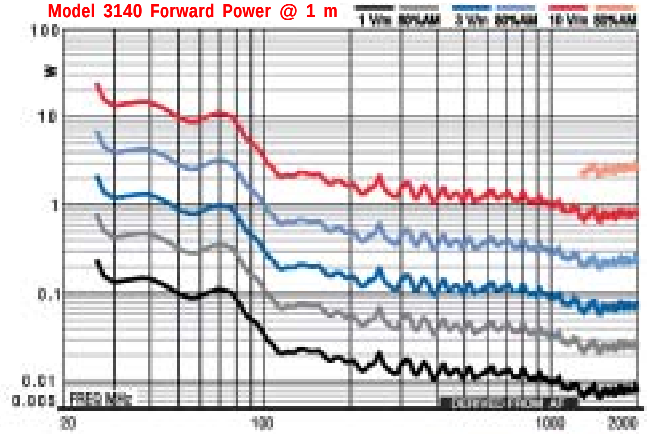
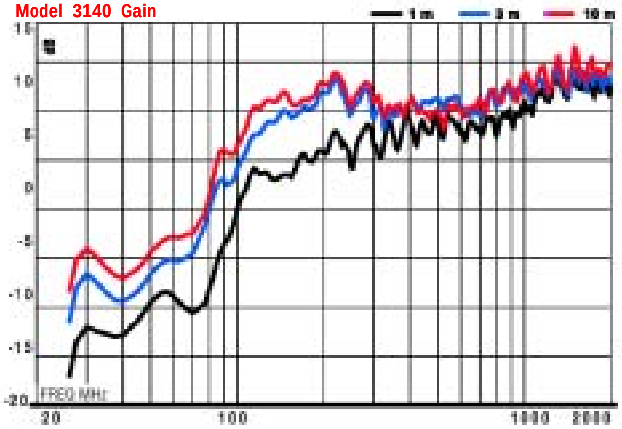
Model 3140 Antenna Factor



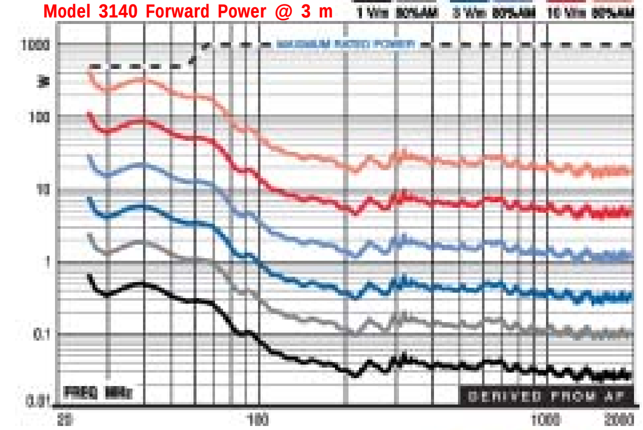
Model 3140 Forward Power @ 1 m



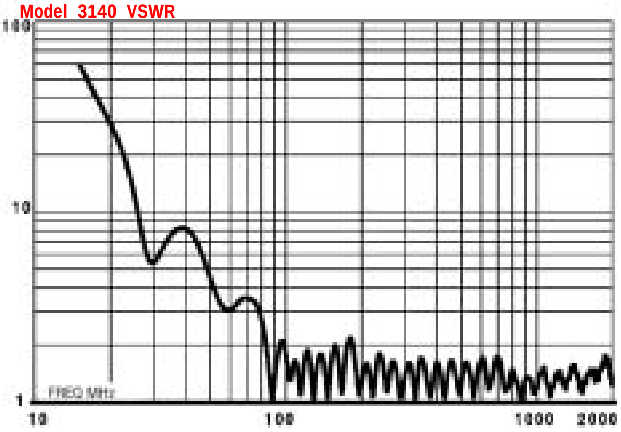
Model 3140 Gain



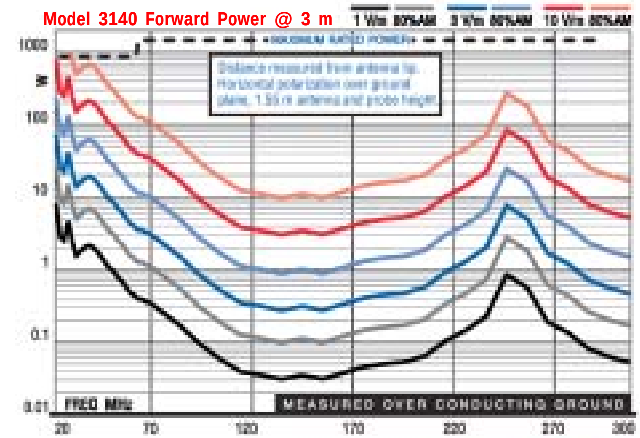
Model 3140 Forward Power @ 3 m



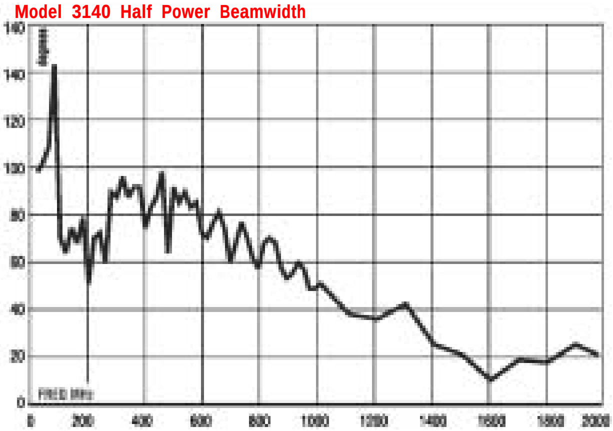
Model 3140 VSWR



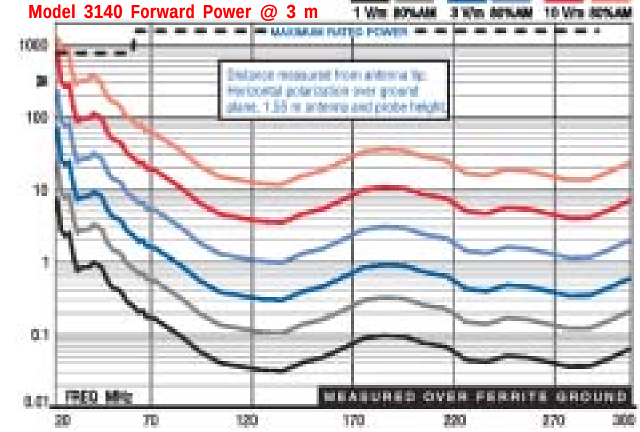
Model 3140 Forward Power @ 3 m



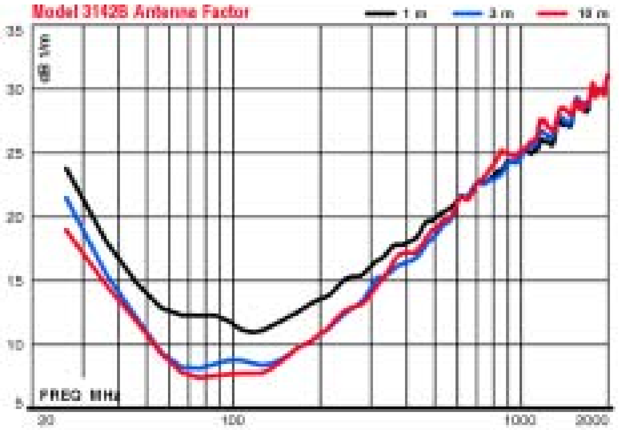
Model 3140 Half Power Beamwidth

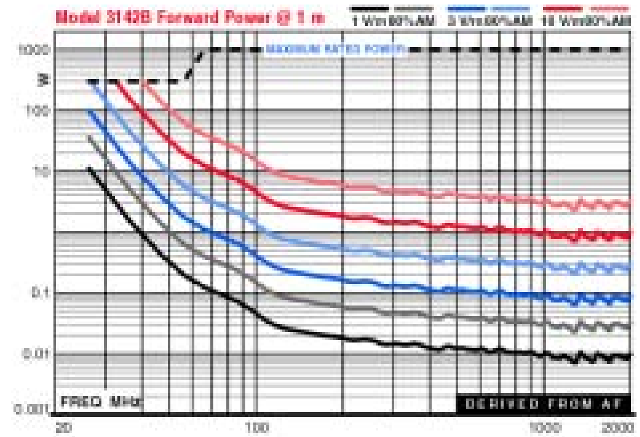


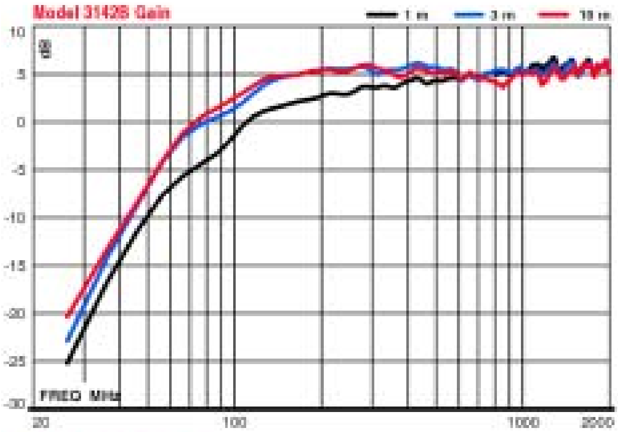
Model 3140 Forward Power @ 3 m

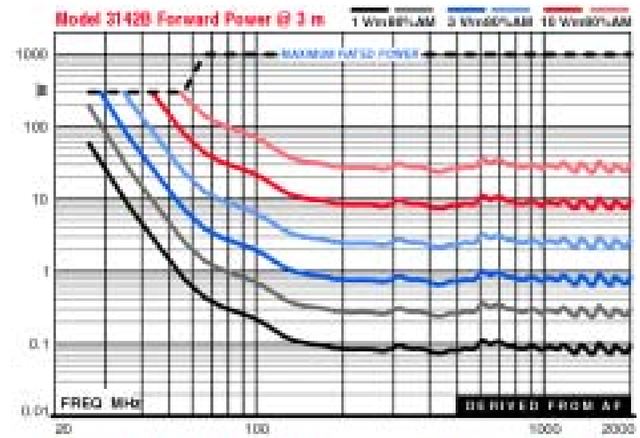


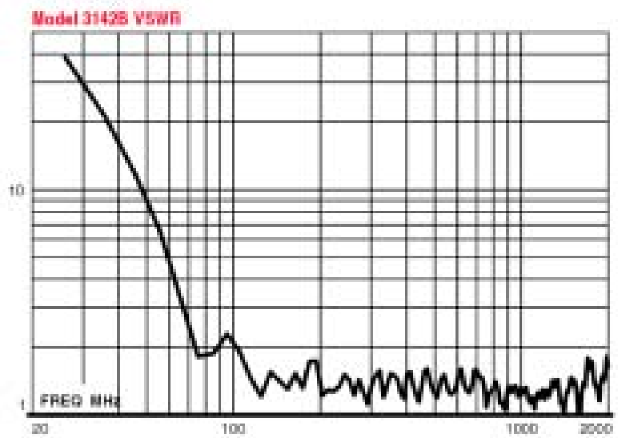
Model 3142B (Without Optional End Plates) Technical Data

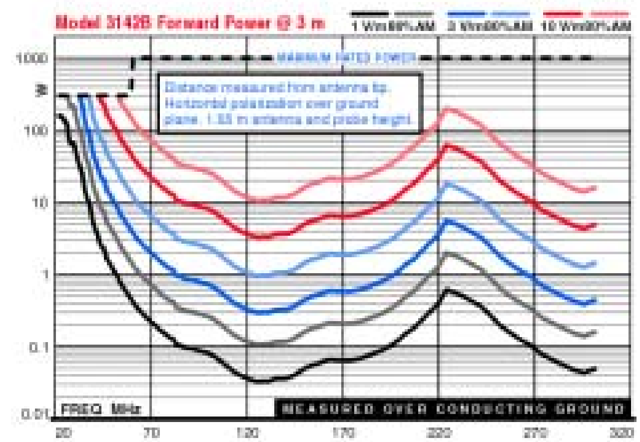












Model 3142B BiConiLog™ without Optional End Plates

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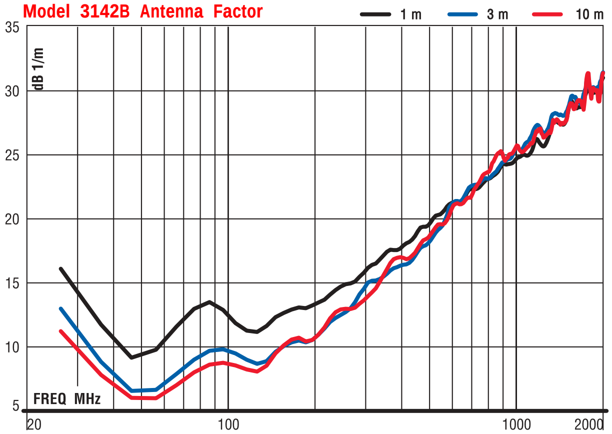
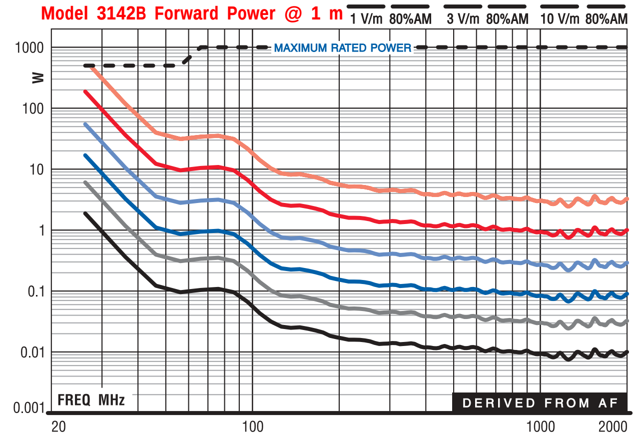
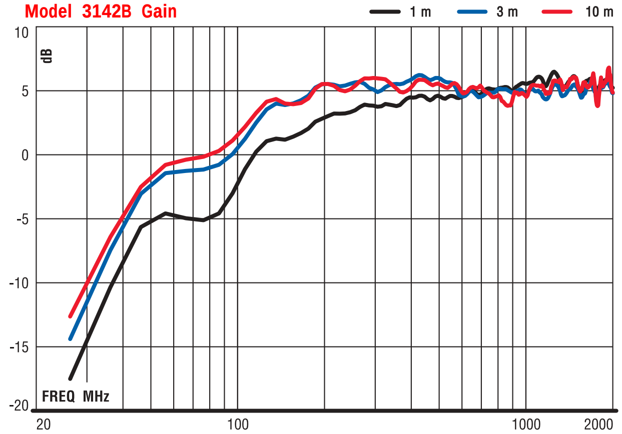
Model 3142B Antenna Factor



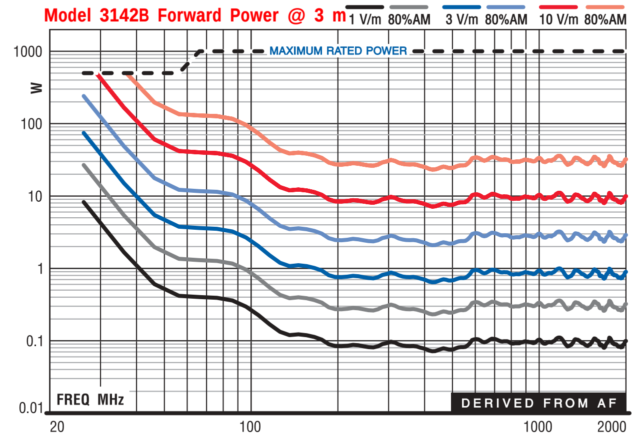
Model 3142B Forward Power @ 1 m



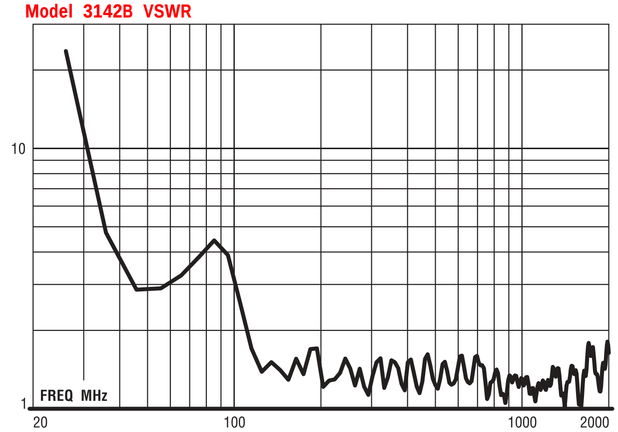
Model 3142B Gain



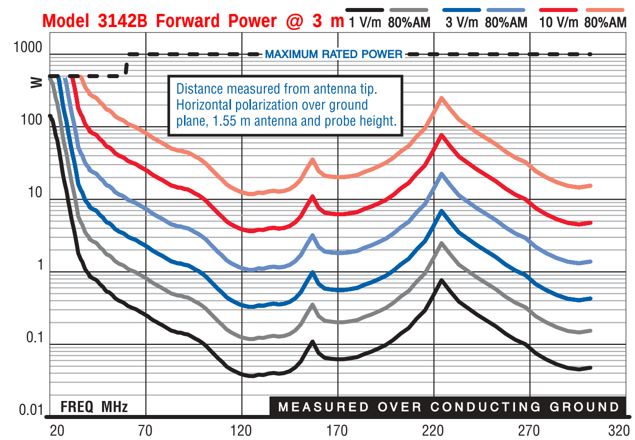
Model 3142B Forward Power @ 3 m



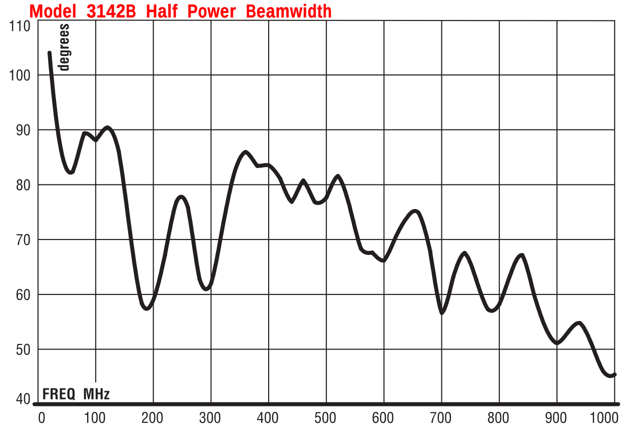
Model 3142B VSWR



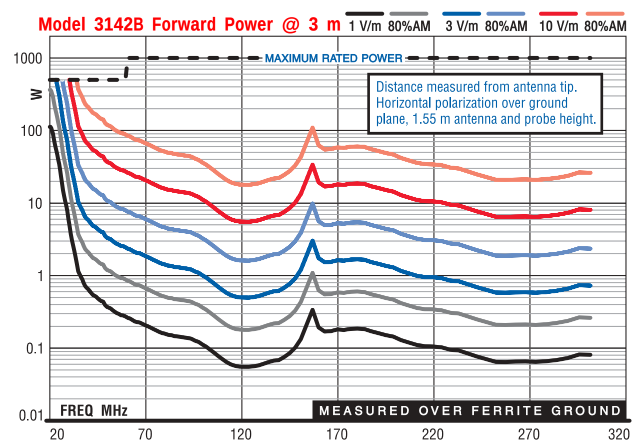
Model 3142B Forward Power @ 3 m

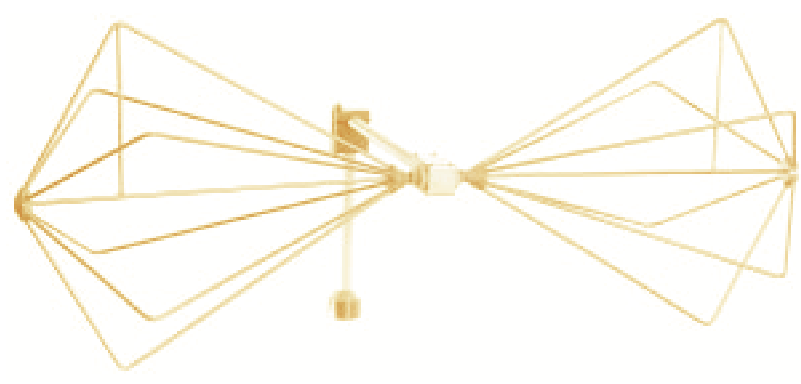


Model 3142B Half Power Beamwidth



Model 3142B Forward Power @ 3 m





M O D E L   3 1 1 0 B

Model 3104C
20 MHz – 200 MHz

Model 3109
20 MHz – 300 MHz

Model 3110B
30 MHz – 300 MHz

- **Unique Element Design to Improve Performance**
- **Improved Balun Design for Increased Efficiency**
- **Power Handling Capability Up to 3 kW**
- **Compact Size for Use in Limited Space**
- **Quality Construction for Trouble-Free Service**

INDIVIDUALLY CALIBRATED   QUALITY QA ASSURANCE   TWO YEAR 2 YEAR WARRANTY

Biconical

EMCO BICONICAL ANTENNAS are simplified, timesaving alternatives to dipole antennas. Although dipole antennas are extremely precise, they can be tedious to use because the elements must be manually adjusted each time a new frequency is measured. The same frequency range can be covered by using an EMCO biconical and log periodic antenna in tandem, or using an EMCO BiConiLog™ antenna alone. EMCO biconical antennas are light, easy to mount, polarization is easy to change, and the broadband characteristics make them ideal for automated measurements. Common applications include measurements to MIL-STD specifications; ANSI C63.4, FCC-18 and EN 55022 emissions testing; and IEC 61000-4-3 immunity testing.

EMCO offers three models of biconical antennas to provide a wide range of frequency and power handling capabilities. EMCO's biconical antennas are designed for maximum performance in the 20 to 300 MHz frequency range, and handle a broad power range — up to 3 kW. Two models feature excellent broadband sensitivity for emissions applications, and one has excellent power handling capability for immunity testing.

There's another advantage to EMCO biconical antennas. EMCO is the only manufacturer to offer optional extended elements. These elements are twice as long as standard elements and enable users to generate high fields at low frequencies with less than 25% of the power usually required.

EMCO Biconical Antenna Features

Unique Element Design
Some biconical antennas exhibit an electrical "bump" at 281 MHz, but EMCO's biconical element crosspiece design improves performance by eliminating this problem. The biconical's crosspiece connects the center element to the outer element diminishing the "bump". Another EMCO enhancement is element cages that cannot be overtightened when screwed into the balun.

Improved Balun Design
The Model 3109 uses a modified Guanella balun for optimal impedance-matching. The improved impedance-matching provides better high-frequency performance over other types of line transformers normally used in baluns. In addition, Guanella baluns are frequency-independent. EMCO's implementation of Guanella baluns provides superior performance at 300 MHz, with VSWR close to the ideal ratio of 1:1.

Power Handling Capability
Although all EMCO's biconical antennas provide good input power capabilities, the Model 3109 provides additional power input capability. Maximum continuous input power on the Model 3109 can exceed 2 kW, and 3 kW with limited duty cycle. Type N female connectors are provided on all models to handle the extended power and ensure repeatable test results.

Compact Size
The compact size of EMCO biconical antennas makes them ideal for anechoic chambers and shielded enclosures. Biconical antennas conserve limited space and help minimize proximity effects.

Quality Construction
Biconical elements are constructed of lightweight corrosion-resistant aluminum, providing years of trouble-free indoor and outdoor service. The mounting base on Models 3104C and 3110B uses standard 1/4 in x 20 threads to connect to an EMCO tripod or most other tripods for support. The Model 3109 has 1/4 in x 20 thread taps in its baluns for tripod mounting.

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UK: Tel +44.(0)1438.730.700 Fax +44.(0)1438.730.750
SINGAPORE: Tel +65.536.7078 Fax +65.536.7093
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Choosing Your Model: Three Models with Frequency Ranges of 20 to 300 MHz

Two biconical antenna models feature excellent broadband sensitivity for emissions applications, and one model has excellent power handling capability for immunity testing.

20 to 200 MHz for Emissions Testing
The Model 3104C biconical antenna has a traditional coaxial wound balun which provides a broad frequency range and moderate gain for both transmitting and receiving. Model 3104C may be used for radiated immunity measurements provided that the input power is limited to no more than 100 W peak.

20 to 300 MHz for Immunity Testing
The Model 3109 biconical antenna is ideal for IEC 61000-4-3 testing. It provides both a broad frequency and high input power. The unit uses a modified Guanella balun for impedance transformation and matching, and it is constructed of much heavier materials so that maximum continuous input power can reach 2 kW. While this antenna typically has a high VSWR at frequencies below 70 MHz, it is still capable of generating a high field strength with acceptable input power in this region of the band. The optional extended elements markedly improve its performance in this region.

30 to 300 MHz for Emissions Testing
The Model 3110B biconical antenna combines several unique features, achieving high levels of performance. The balun, feedline, and element cage design give the Model 3110B response curves that are almost linear, making it ideal for sweep measurements. The antenna's insensitivity to orientation in the vertical plane helps eliminate any unnoticed or unrecorded change in orientation as the cause for a change in test results.

To achieve this kind of performance, the balun is designed using an unbalanced-to-balanced transformer. This results in very even current transformation. Ferrites are also placed along the feedlines, reducing common mode current that can interfere with the antenna pattern in the vertically polarized measurements.

Standard Configuration

- Antenna elements
- Balun
- Base
- Balun acts as base on the Model 3109 and is drilled to accept an EMCO tripod or most other tripods
- Separate base on Models 3104C and 3110B is drilled to accept tripod mount with 1/4 in x 20 threads
- Individually calibrated at 1 m per SAE ARP 958 and 3 and 10 m per ANSI C63.5. Actual factors and a signed Certificate of Calibration Conformance included in Manual

Options

Portable Elements (P) (Part # 101946B)
Collapsible folding elements are available for all biconicals, making the antennas portable and ideal for field use. Both the standard rigid and optional folding elements attach to the balun using screw mounts. This makes interchanging between the two types of elements very easy and quick. Optional carrying cases are available to further enhance portability.

Extended Portable Elements (XP) (Part# 103032B)
An extended version of the portable elements is available for all models. These folding elements are twice as long as the standard elements. The longer elements enable you to generate high fields at low frequencies with less than 25% of the power usually required. These elements are most effective with Models 3104C and 3109.

Carrying Cases for Portable Models
Carrying cases for portable elements and biconical antennas are readily available.

Custom Carrying Cases
Custom cases for other models are available on request.

EMCO Tripod
EMCO offers several nonmetallic, non-reflective tripods for use at EMC test sites.

Support Rod **(See page 62-63)**
Antenna mount with insert drilled to accept EMCO or other tripod with standard 1/4 in x 20 threads.

f y i

Few EMC test engineers realize that the first biconical antenna was constructed 100 years ago. In 1897, Sir Oliver Lodge developed the biconical and today it is a common fixture at EMC test sites, finding use in both emissions and immunity applications.

Applications

MODEL	FCC-15	FCC-18	IEC/CISPR/EN	SAE J1113	SAE J551	MIL-STD-461E	MIL-STD-1541	MIL-STD-285	NACSIM	VCCI
3104C	RE	RE	RE	RE	RE	RE	RE	TX, RX	RE	RE
3109			RI	RI	RI	RI	RI	TX, RX		
3110B	RE	RE	RE	RE	RE	RE		RX	RE	RE

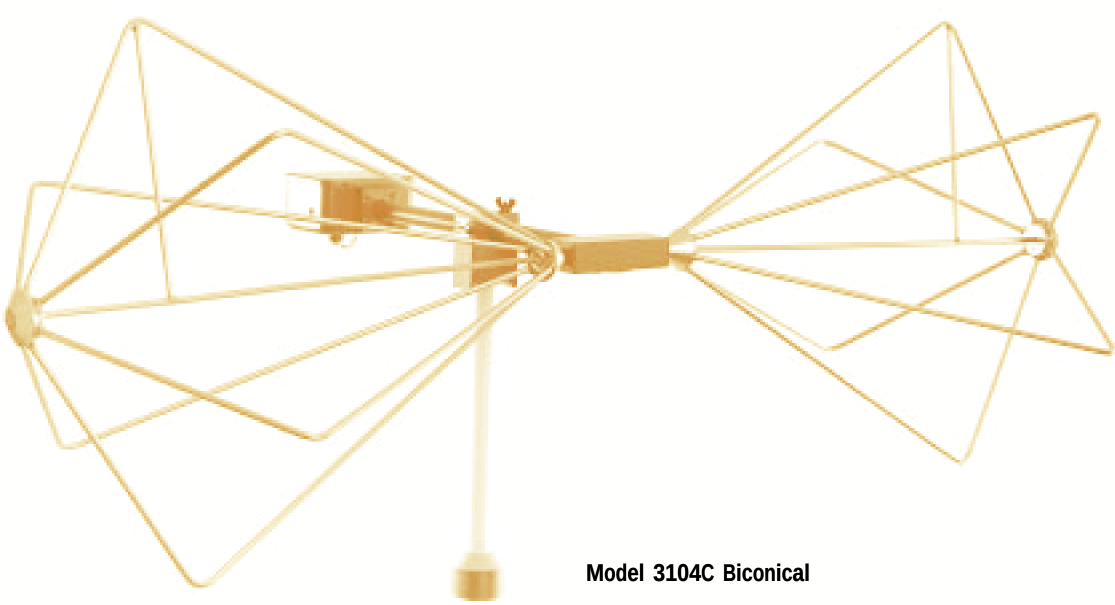
RE = Radiated Emissions RI = Radiated Immunity (Susceptibility) TX = Transmit RX = Receive

Electrical Specifications

MODEL	FREQUENCY RANGE	VSWR RATIO (AVG)	MAXIMUM CONTINUOUS POWER	PEAK POWER	IMPEDANCE (NOMINAL)	CONNECTOR
3104C	20 MHz – 200 MHz	2.8:1	50 W	100 W	50 Ω	Type N female
3109	20 MHz – 300 MHz	1.9:1	2 kW	3 kW	50 Ω	Type N female
3109XP	20 MHz – 200 MHz	1.9:1	2 kW	3 kW	50 Ω	Type N female
3110B	30 MHz – 300 MHz	2.0:1	250 mW	NA	50 Ω	Type N female

Physical Specifications

MODEL	WIDTH	DEPTH	DIAMETER	WEIGHT
3104C	143.5 cm 56.5 in	81.3 cm 32.0 in	52.0 cm 20.5 in	2.7 kg 6.0 lb
3109	133.0 cm 52.5 in	NA	52.0 cm 20.5 in	3.2 kg 7.0 lb
3110B	132.1 cm 52.0 in	55.9 cm 22.0 in	52.0 cm 20.5 in	2.7 kg 6.0 lb
P (each element)	66.0 cm 26.0 in	NA	61.0 cm 24.0 in	0.7 kg 1.5 lb
XP (each element)	121.9 cm 48.0 in	NA	76.2 cm 30.0 in	1.8 kg 4.0 lb



Model 3104C Biconical

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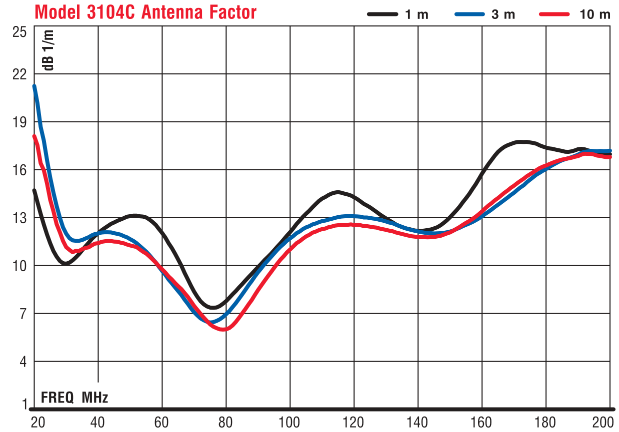
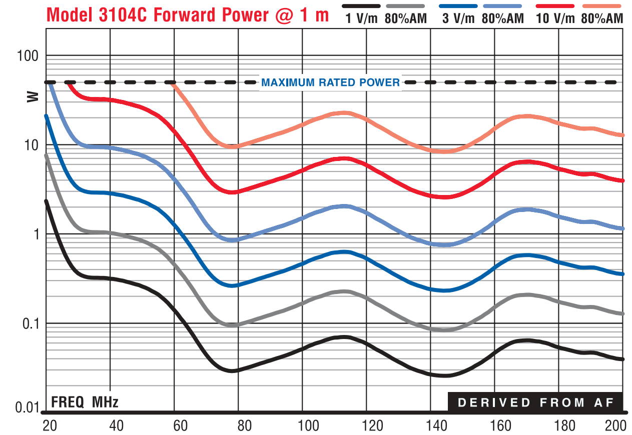
Model 3104C Technical Data

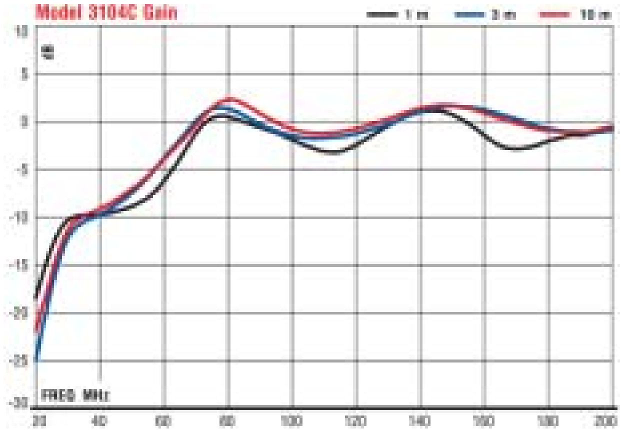
Model 3104C Antenna Factor



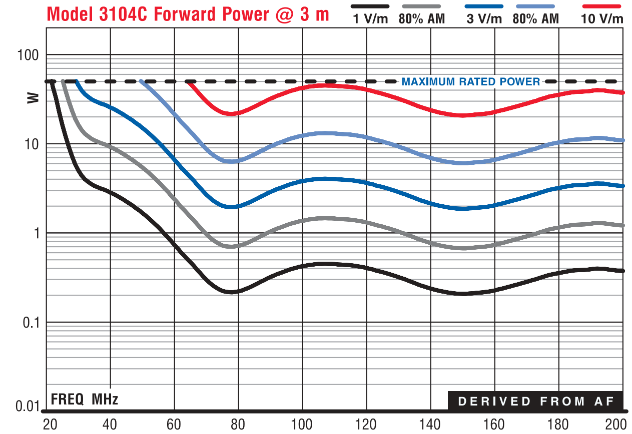
Model 3104C Forward Power @ 1 m



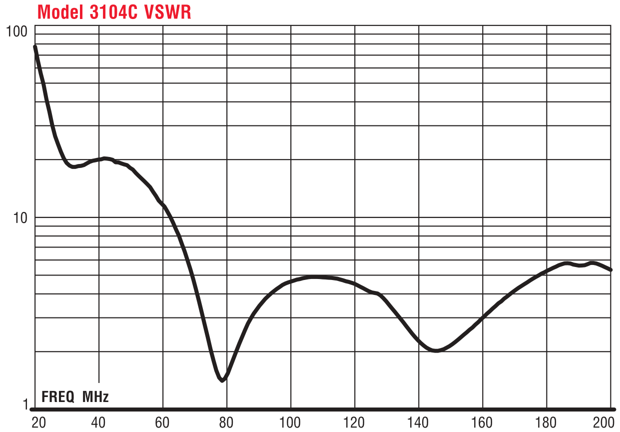
Model 3104C Gain



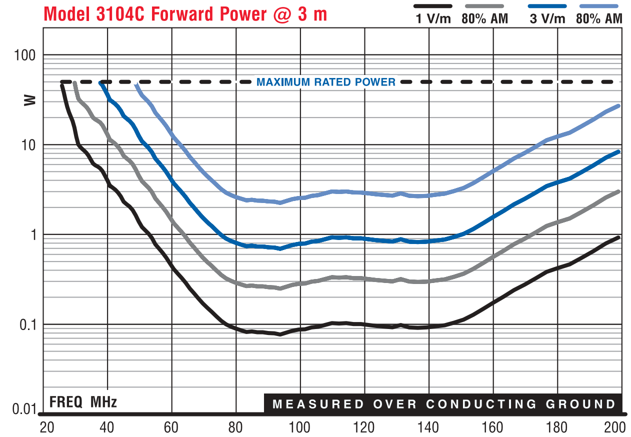
Model 3104C Forward Power @ 3 m



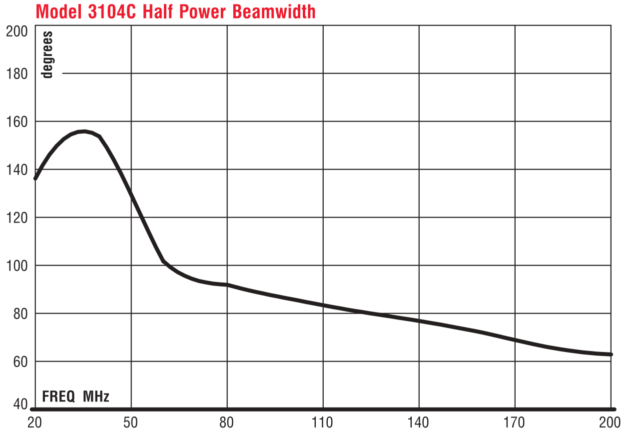
Model 3104C VSWR



Model 3104C Forward Power @ 3 m

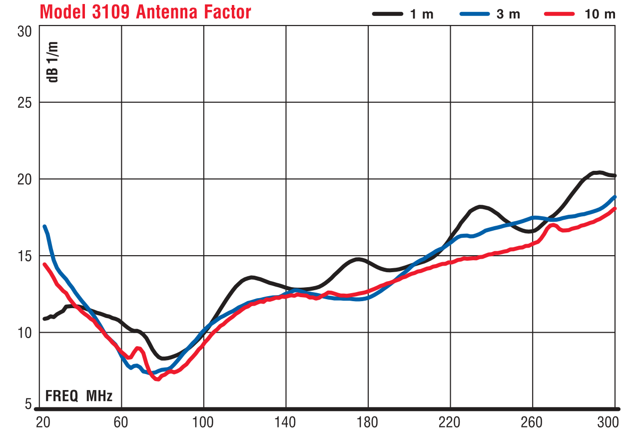


Model 3104C Half Power Beamwidth

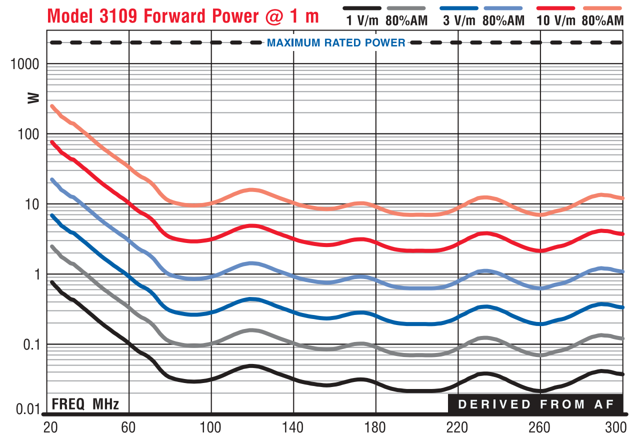


Model 3109 Technical Data

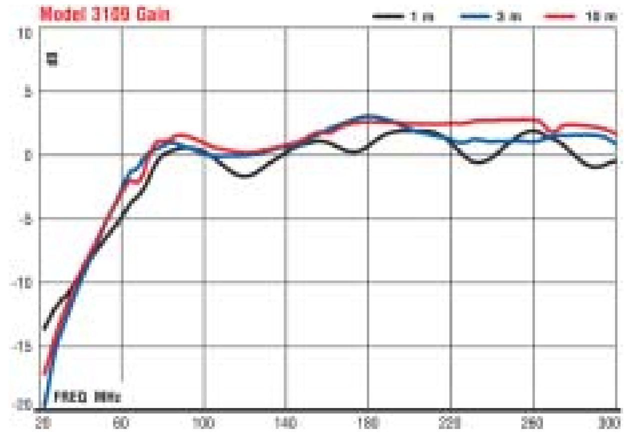
Model 3109 Antenna Factor



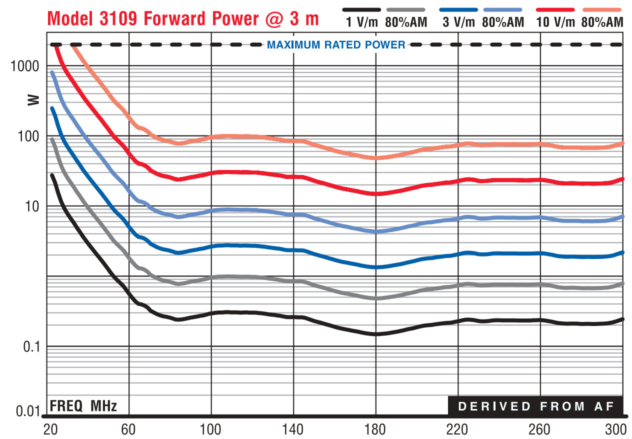
Model 3109 Forward Power @ 1 m



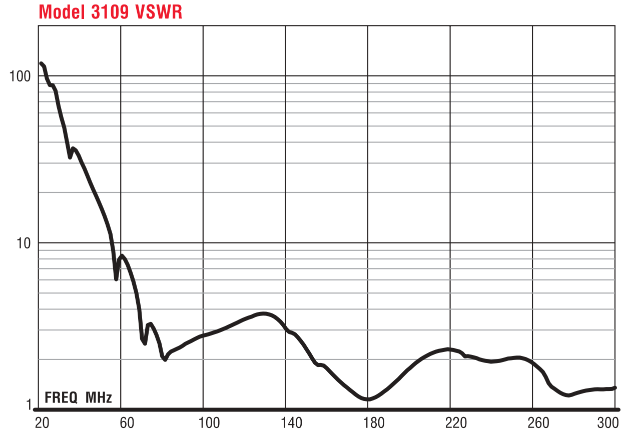
Model 3109 Gain



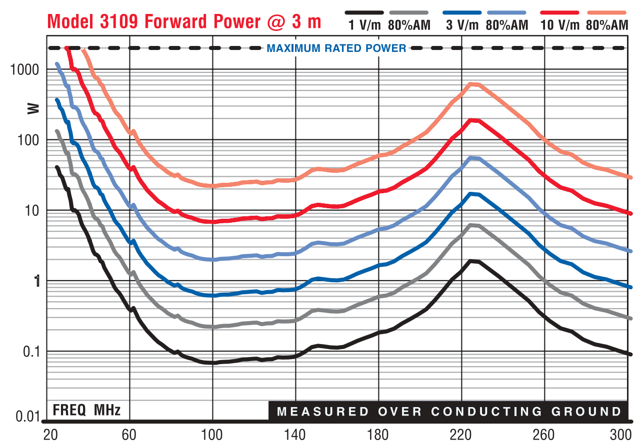
Model 3109 Forward Power @ 3 m



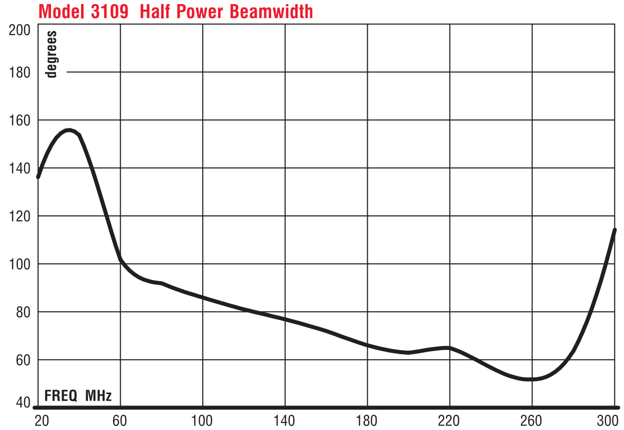
Model 3109 VSWR



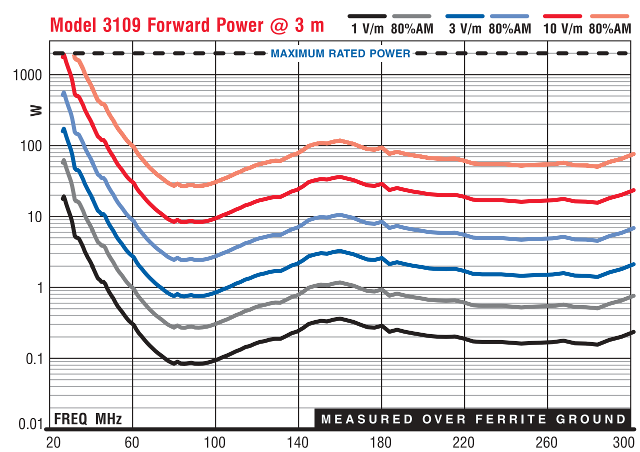
Model 3109 Forward Power @ 3 m



Model 3109 Half Power Beamwidth



Model 3109 Forward Power @ 3 m



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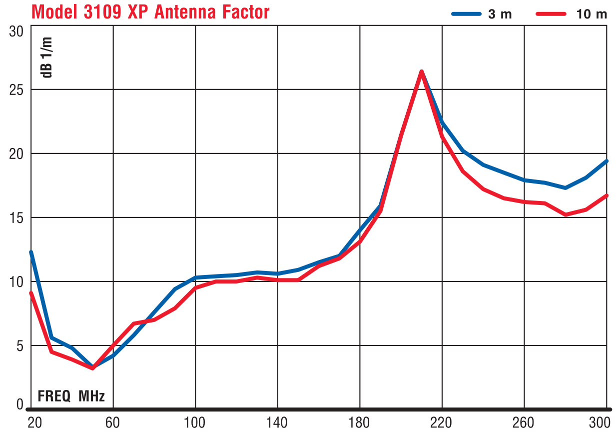
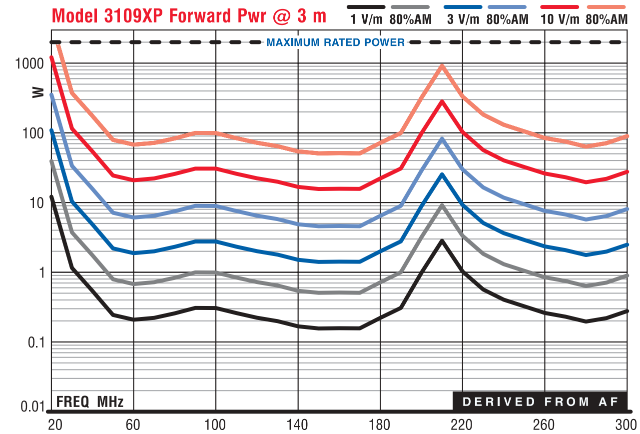
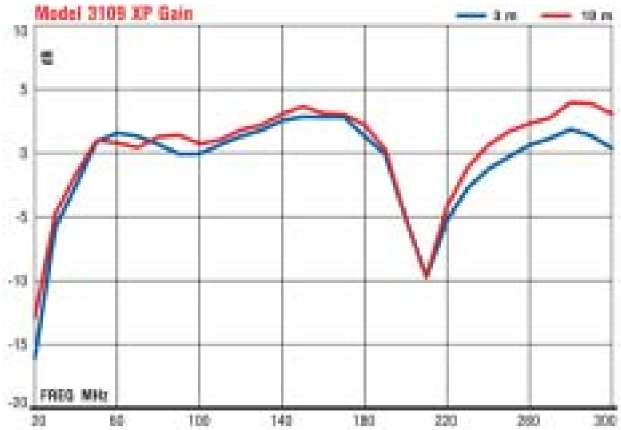
Model 3109 XP Antenna Factor



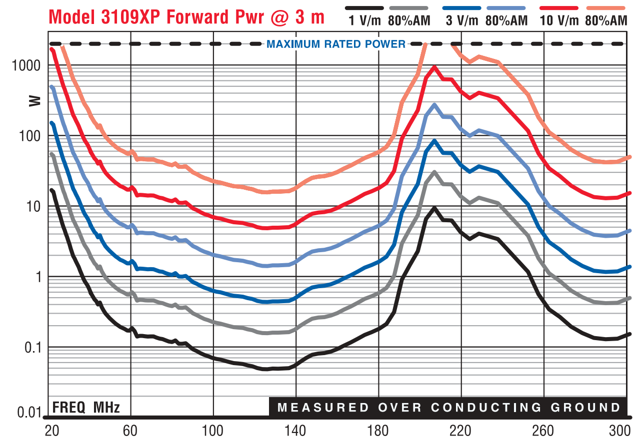
Model 3109XP Forward Pwr @ 3 m



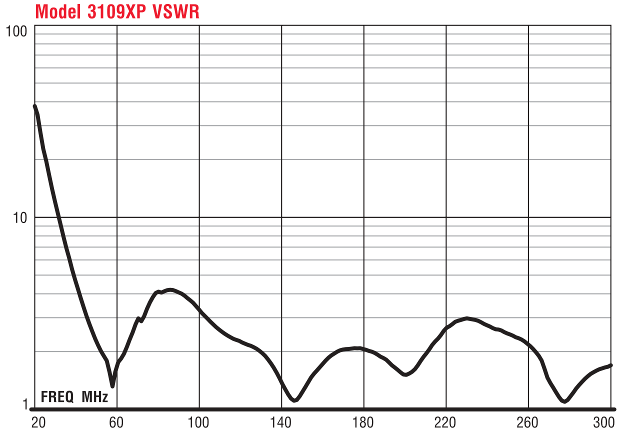
Model 3109 XP Gain



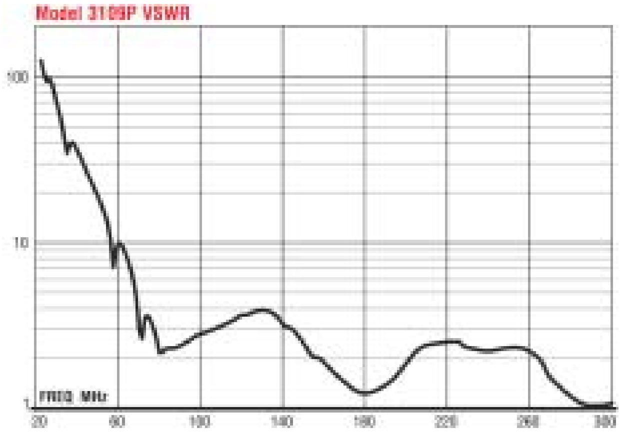
Model 3109XP Forward Pwr @ 3 m



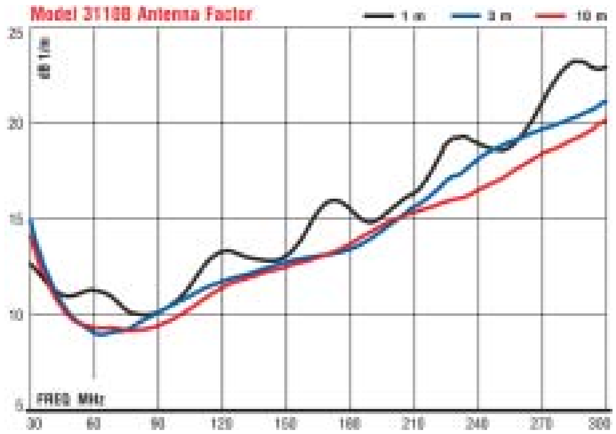
Model 3109XP VSWR

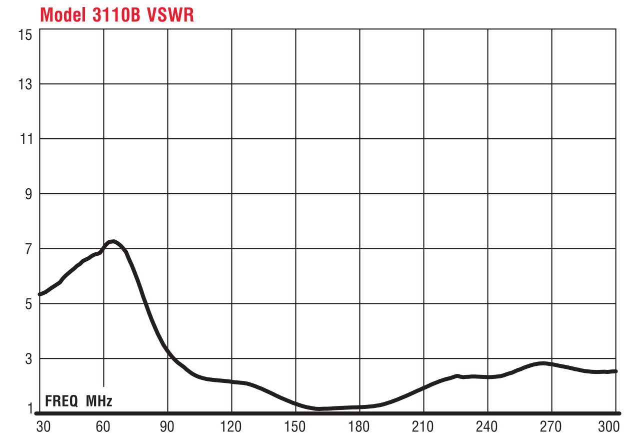


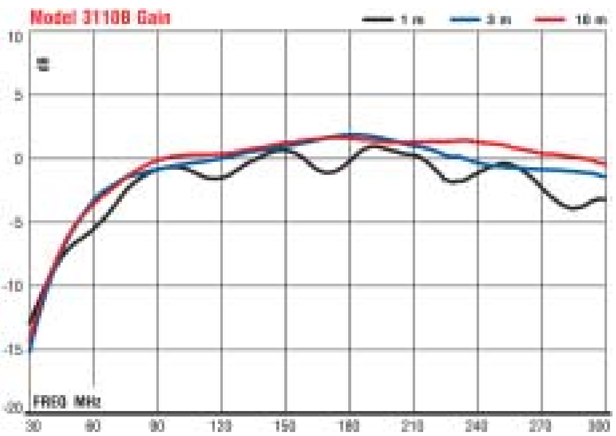
Model 3109P VSWR

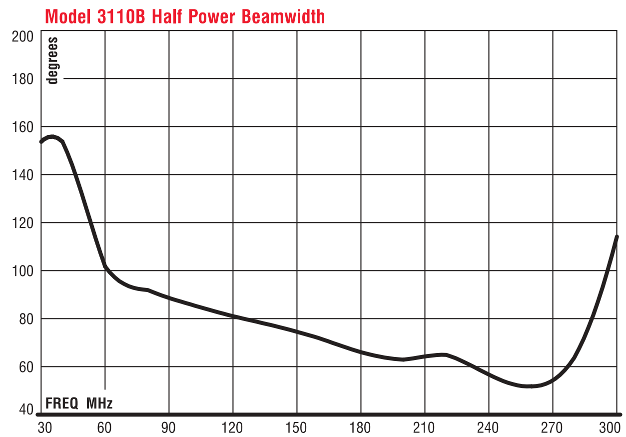


Model 3110B Technical Data









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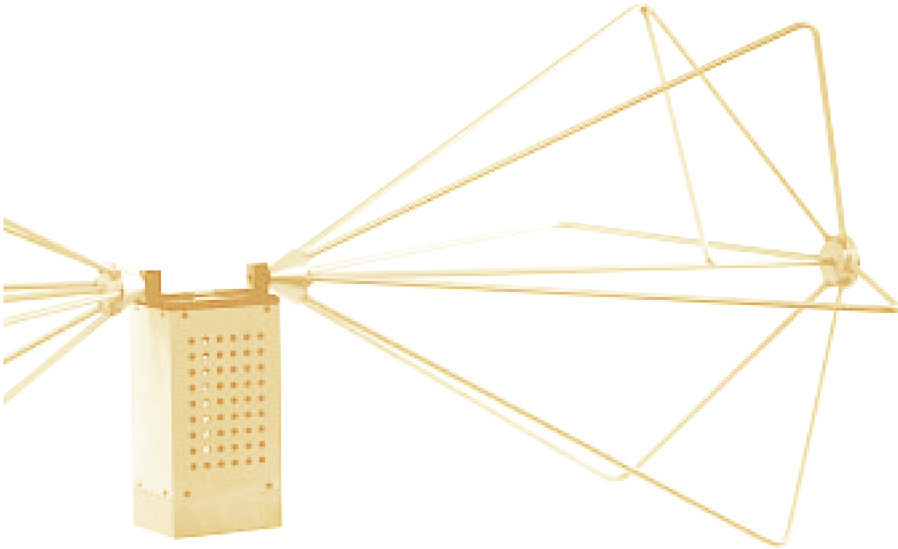


MODEL 3109

Extended and Portable Elements

- 30 MHz - 300 MHz Frequency Range
- <2:1 VSWR
- Theoretically Calculable Performance
- Excellent Balun Balance
- Precise Controlled Mechanical Construction
- Includes Precise Factors for ANSI C63.4/C63.5

MODEL 3124

Calculable Biconical

The **EMCO MODEL 3124 BICAL™ CALCULABLE BICONICAL ANTENNA** is a linearly polarized, low-uncertainty standard antenna, which can be used for both field measurement and low strength field generation. The antenna balun has an excellent phase balance of better than 180° ± 2°, with an amplitude balance of better than ±0.2 dB. The balun is measurable with a vector network analyzer. By combining the measured balun response with the numerical calculation of the antenna element response, the antenna factor (AF) and site attenuation (SA) between two antennas can be precisely calculated. For site characterization applications, two antennas are required.

Biconical antennas are a timesaving alternative to tunable dipole antennas. Although tunable dipoles are extremely precise, manual adjustment of the elements at each frequency makes them tedious and time consuming to use. When dipoles are used on an OATS or in a semi-anechoic chamber, site anomalies that don't coincide with tuned frequencies can be overlooked. The EMCO Model 3124 Biconical overcomes these problems, while providing the theoretically calculable feature of a tunable dipole antenna.

The antenna performance can be theoretically calculated based on the construction of the elements and the measured balun responses. As long as the antenna elements are maintained to their mechanical specifications, calibration on an OATS of the antenna factors or the gain of the Model 3124 is not necessary. The calibration only needs to be performed on the antenna balun.

A carrying case is included to protect the antenna from possible damage.

Applications

- Validation tests for scanned height OATS or semi-anechoic chambers per ANSI C63.4
- Low uncertainty free-space antenna factors for EUT emissions measurement
- Full Anechoic Room (FAR) validation
- Normalized Site Attenuation (NSA) and fixed height measurement
- Broadband site validation similar to CALTS procedure (CISPR 16-1)

Standard Configuration

- Antenna Elements, Balun, Software
- Support Rod, Clamp Block, Base, Manual
- Carrying Case

Options

- EMCO offers several nonmetallic, non-reflective tripods for use at EMC test sites.

Electrical Specifications

MODEL	FREQUENCY RANGE	VSWR RATIO (AVG)	MAXIMUM CONTINUOUS POWER	IMPEDANCE (NOMINAL)	CONNECTORS
3124	30 MHz–300 MHz	< 2:1	500 mW	50 Ω	Type N female (1) SMA (2) Calibration ports

Physical Specifications

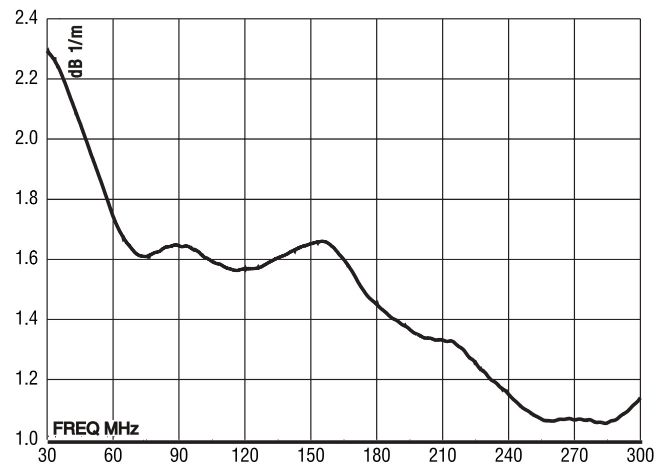
MODEL	WIDTH	DEPTH[1]	DIAMETER	WEIGHT
3124	24.5 cm 49.0 in	55.8 cm 22.0 in	52.0 cm 20.5 in	2.2 kg 4.8 lb

[1] Balun only

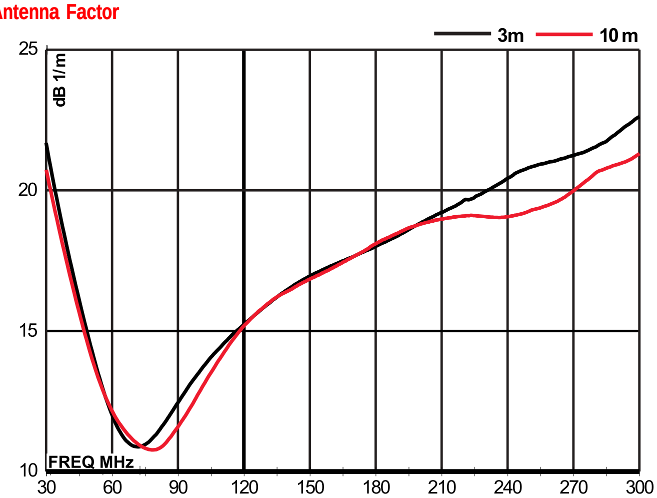
Uncertainties of the Calculated Parameters (with a 95% confidence level)

SA OR NSA FOR 2 ANTENNAS COMBINED	FREE-SPACE FACTOR
± 0.50 dB	± 0.25 dB

VSWR



Antenna Factor



Model 3124 BiCal™ with 4-TR tripod

M O D E L 3 1 4 8

Model 3144
80 MHz – 2 GHz

Model 3147
200 MHz – 5 GHz

Model 3148
200 MHz – 2 GHz

- High Gain
- Low VSWR
- Ultra Broadband
- Meets CISPR Cross Polarization Requirements
- High Power Input Capacity
- Tough Powder Coat Finish on Models 3144 and 3148

Log Periodic

FEATURING LOW VSWR, HIGH GAIN, AND BROADBAND FREQUENCY RANGES, EMCO'S LOG PERIODIC ANTENNAS are ideally suited for most types of EMC testing. Common applications include ANSI C63.4, FCC-15, FCC-18, EN 55022 emissions testing and IEC 61000-4-3 immunity testing.

EMCO log periodic antennas are a simplified, timesaving alternative to dipole antennas. Although dipole antennas are extremely precise, they can be tedious to use because the elements must be manually adjusted each time you measure a new frequency. You can cover the same frequency range by using an EMCO log periodic and biconical antenna in tandem, or using an EMCO BiConiLog™ antenna alone.

EMCO's selection allows you to choose the design that best meets your needs. We offer three ultra broadband designs, a high power input capacity design, and a compact-sized unit that is ultra lightweight and easy to handle.

EMCO Log Periodic Features

High Gain
EMCO log periodic antennas have gain greater than 5 dB.

Low VSWR
All of EMCO's log periodic antennas exhibit low VSWR performance across their frequency ranges.

High Power Input Capacity
The Model 3144 accepts 2 kW continuous input. Model 3148 accepts 1 kW continuous input.

Ultra Broadband
All of EMCO's log periodic antennas cover a wide bandwidth, enabling users to measure a broad frequency range in one sweep. This single sweep capability eliminates the need for multiple antennas and numerous equipment setups, which saves users time and money. The frequency range of this antenna series spans from 80 MHz up to 5 GHz. Refer to the individual descriptions below for the specific frequency range of each model.

Quality Construction
EMCO log periodic antennas are constructed of lightweight, corrosion-resistant aluminum, providing years of trouble-free indoor and outdoor service. In addition, some models receive a tough powder coat finish, which protects against scratching and abrasion better than painted or bare surfaces.

Precision construction and assembly of the boom and elements result in excellent VSWR and optimal phase relationship. These antennas feature relatively constant linear gain (measured in the far field) without any sudden "dips" or "bumps".

To provide a secure connection, all log periodic antennas are supplied with a Type N female connector for greater test accuracy and repeatable results.

Choosing Your Model: Log Periodic Series Frequency Range Spans 80 MHz to 5 GHz

80 MHz to 2.0 GHz
The **Model 3144** enables users to measure from 80 MHz to 2 GHz in one sweep, which saves time and money by eliminating the need for antenna changes at band breaks. In addition, the high power input capacity of the Model 3144 is ideal for IEC 61000-4-3 testing and applications requiring the generation of field strengths well in excess of 200 V/m.

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The Model 3144 features a tough powder coat finish, which protects against scratching and abrasion better than painted or bare surfaces.

200 MHz to 2.0 GHz

The EMCO Model 3148 Log Periodic Antenna is specifically designed for making CISPR 16-1 measurements which require a 20 dB difference in the cross polarization rejection. This is achieved using an engineering design and manufacturing process that offsets all elements in a precision pattern. The excellent cross-polarization property ensures minimum measurement uncertainty for radiated emissions and normalized site attenuation measurement. The precision construction of the assembly of the boom and elements result in excellent VSWR and optimal phase relationship. This antenna features relatively constant linear gain (measures in far field without any sudden “dips’ or “bumps”).

200 MHz to 5 GHz

The Model 3147 is primarily designed for use with FCC Part 15, Subpart A, Section 15.33. This model covers both the traditional (200 MHz to 1 GHz) and newer (1 to 5 GHz) frequency range requirements in a single unit. The frequency ratio of 25:1 is one of the widest responses obtainable in a commercially available EMC test antenna. In addition, the Model 3147 has excellent VSWR characteristics throughout the entire operating frequency range.

Standard Configuration

- Antenna
- Individually calibrated at 1 m per SAE ARP 958 and 3 and 10 m per ANSI C63.5. Actual antenna factors and a signed Certificate of Calibration Conformance included in Manual.

Options

Custom cases

Custom cases are available on request.

EMCO Tripod

EMCO offers several nonmetallic, non-reflective tripods for use at EMC test sites.

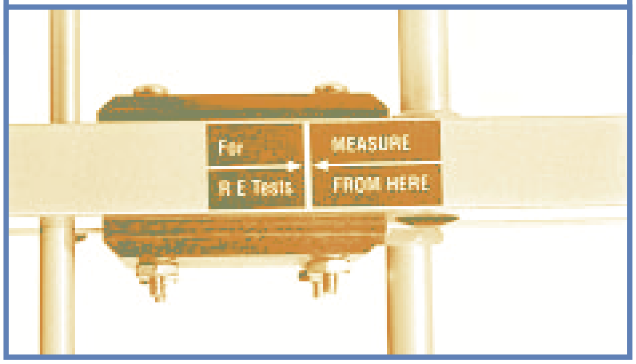
Support Rod (see page 62-63)

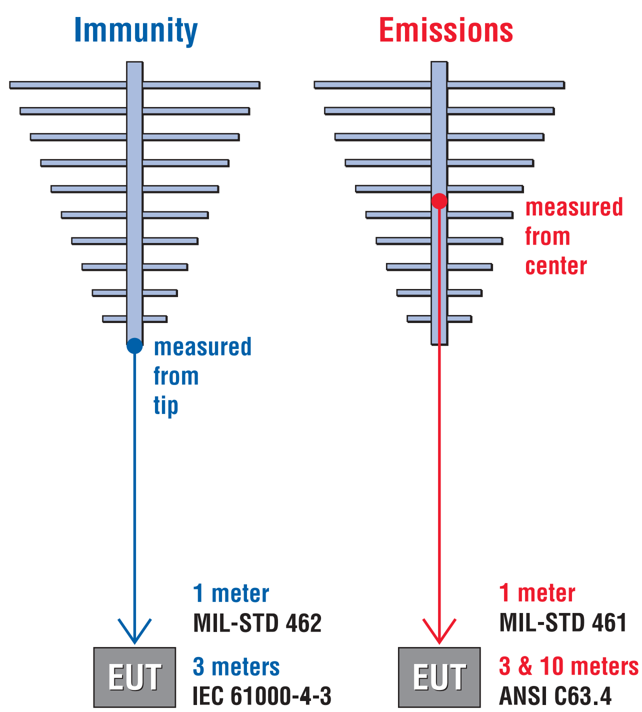
Antenna mount with insert drilled to accept EMCO or other tripod with standard 1/4 in x 20 threads.

tech tip

Log Periodic antennas are calibrated at different distances from the source, depending on the standard. For example, calibration for MIL-STD immunity testing is performed at a distance of *1 meter as measured from the tip of the antenna* to the source. However, calibration for commercial immunity testing is performed at a distance of *3 meters as measured from the tip of the antenna* to the source.* Calibration for MIL-STD emissions testing is performed at a distance of *1 meter as measured from the center of the antenna* to the source. Calibration for commercial emissions testing is performed at a distance of *3 and 10 meters as measured from the center of the antenna* to the source. EMCO Log Periodic and BiConiLog antennas feature convenient labels that pinpoint the antenna’s center-line and tip, serving to remind users where to perform their measurements.

* For IEC 61000-4-3 testing, a 3 meter distance from antenna tip to EUT is preferred. A 1 meter distance is allowed provided uniformity requirements are met.





Applications

MODEL	FCC-15	FCC-18	IEC/CISPR/EN	SAE J1113	SAE J551	MIL-STD-461E	MIL-STD-1541	MIL-STD-285	NACSIM	VCCI
3144	RE	RE	RE, RI	RE, RI	RE	RE, RI	RI			
3147	RE	RE	RE	RE	RE				RE	RE
3148	RE	RE	RE,RI	RE,RI	RE	RE,RI	RE,RI	TX, RX	RE	RE

RE = Radiated Emissions RI = Radiated Immunity (Susceptibility) TX = Transmit RX = Receive

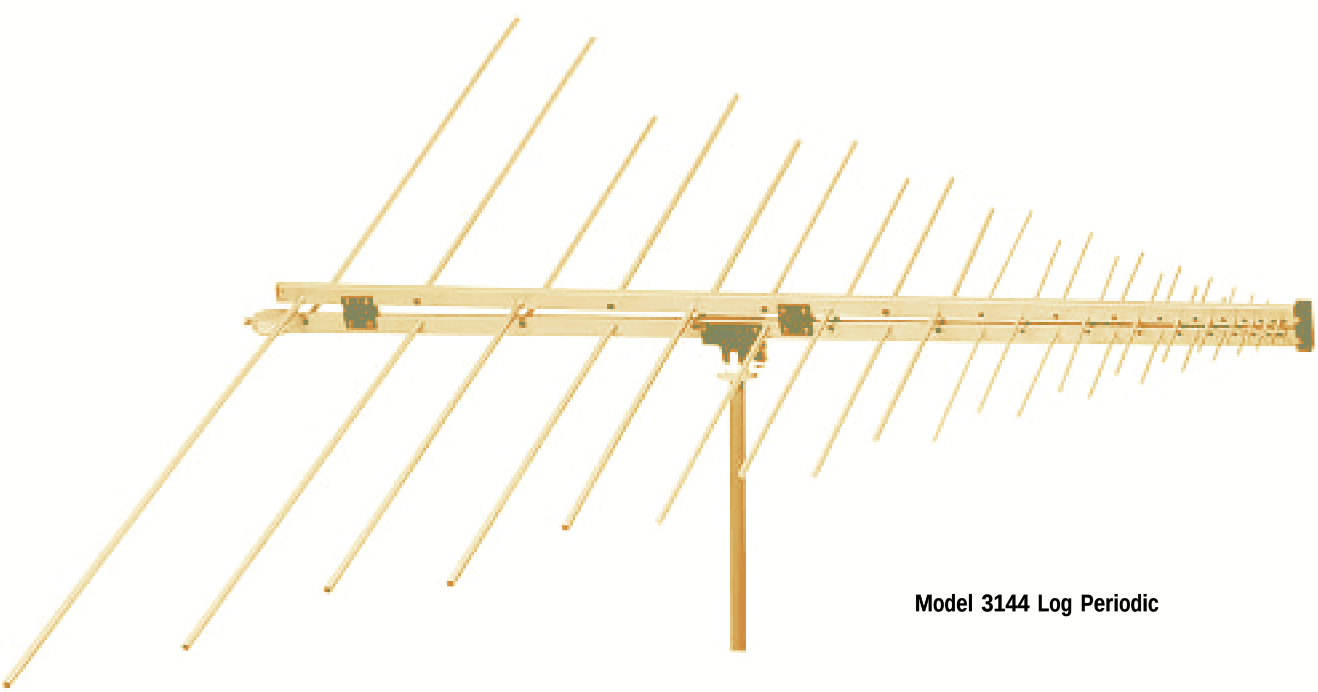
Electrical Specificationso

MODEL	FREQUENCY RANGE	VSWR RATIO (AVG)	MAXIMUM CONTINUOUS POWER	PEAK POWER	IMPEDANCE (NOMINAL)	CONNECTOR
3144	80 MHz – 2 GHz	1.2:1	1 kW	2.6 kW	50 Ω	Type N female
3147	200 MHz – 5 GHz	1.2:1	80 W	100.0 W	50 Ω	Type N female
3148	200 MHz – 2 GHz	1.2:1	1 kW	1.3 kW	50 Ω	Type N female

Physical Specifications

MODEL	WIDTH [1]	DEPTH	HEIGHT	WEIGHT
3144	210.8 cm 83.0 in	170.2 cm 67.0 in	9.5 cm 3.8 in	4.5 kg 10.0 lb
3147	92.0 cm 36.2 in	75.0 cm 29.5 in	3.1 cm 1.2 in	2.0 kg 4.5 lb
3148	85.6 cm 33.7 in	73.7 cm 29.0 in	6.4 cm 2.5 in	2.0 kg 4.5 lb

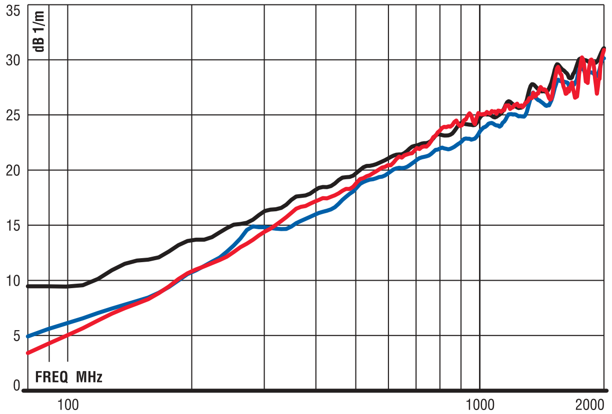
[1] At widest point



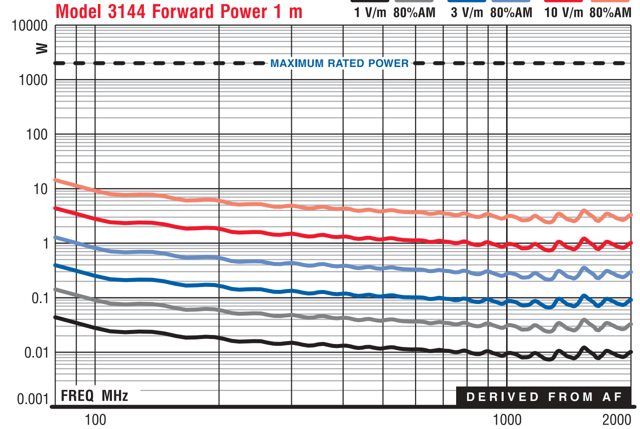
Model 3144 Log Periodic

USA: Tel +1.512.531.6400 Fax +1.512.531.6500
FINLAND: Tel +358.2.838.3300 Fax +358.2.865.1233
UK: Tel +44.(0)1438.730.700 Fax +44.(0)1438.730.750
SINGAPORE: Tel +65.536.7078 Fax +65.536.7093
ONLINE: info@ets-lindgren.com www.ets-lindgren.com

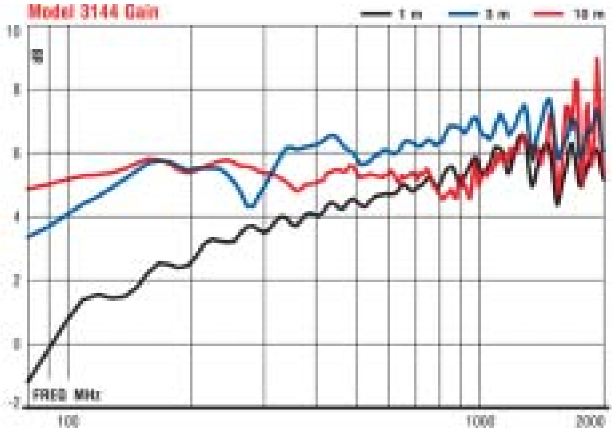
Model 3144 Antenna Factor



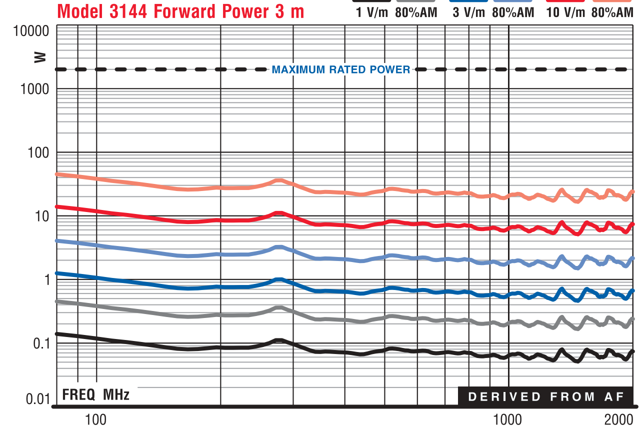
Model 3144 Forward Power 1 m



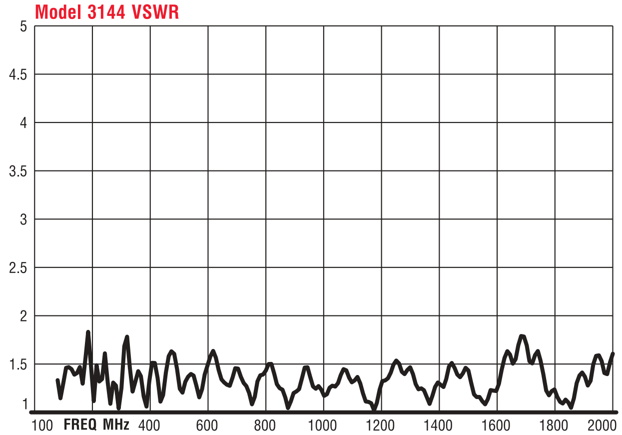
Model 3144 Gain



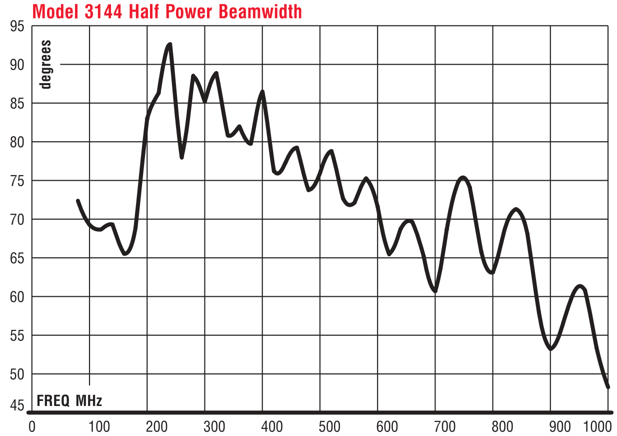
Model 3144 Forward Power 3 m



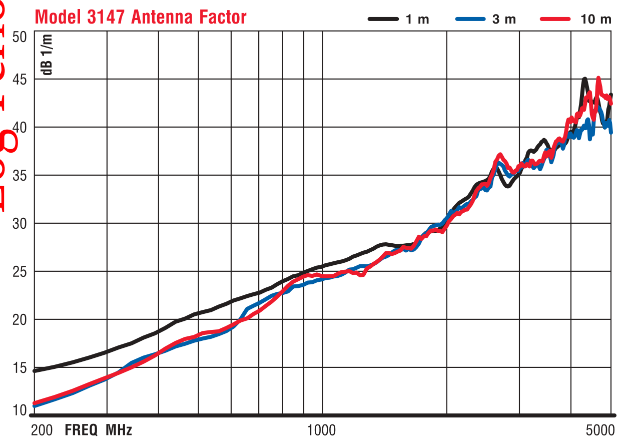
Model 3144 VSWR

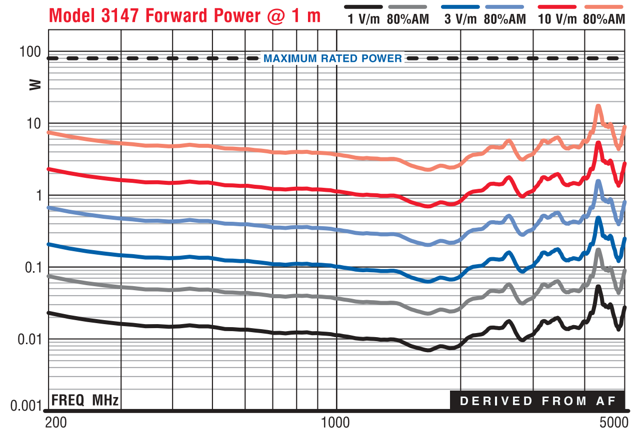


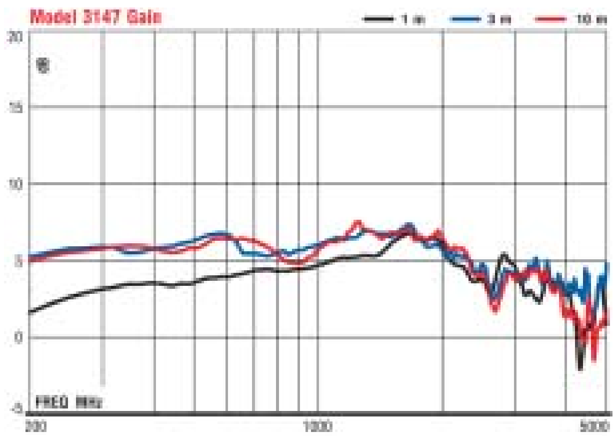
Model 3144 Half Power Beamwidth

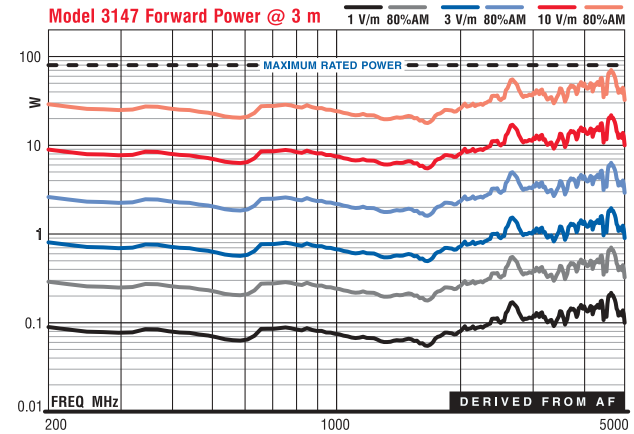


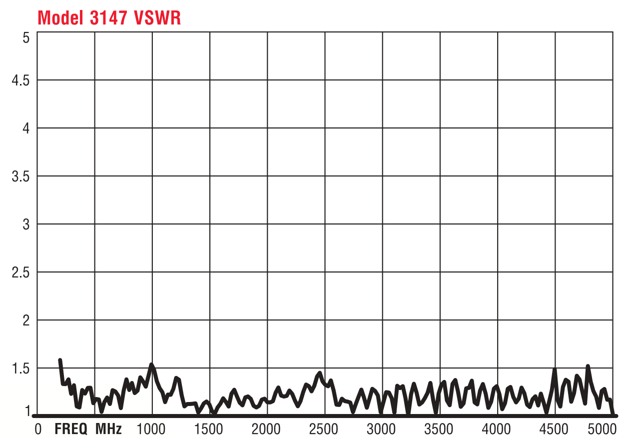
Model 3147 Technical Data

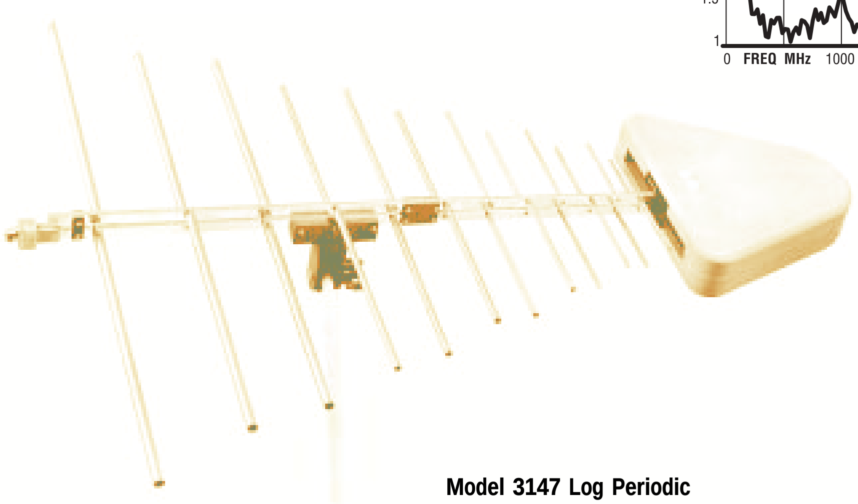












Model 3147 Log Periodic

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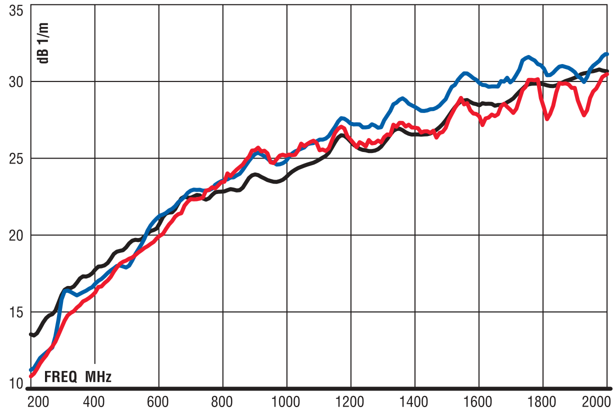
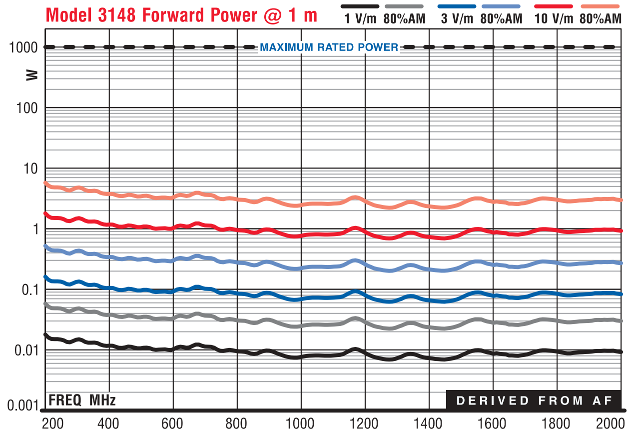
ONLINE: info@ets-lindgren.com www.ets-lindgren.com

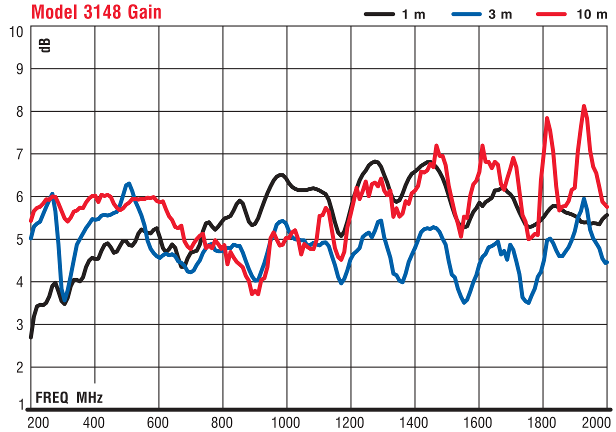
Model 3148 Antenna Factor



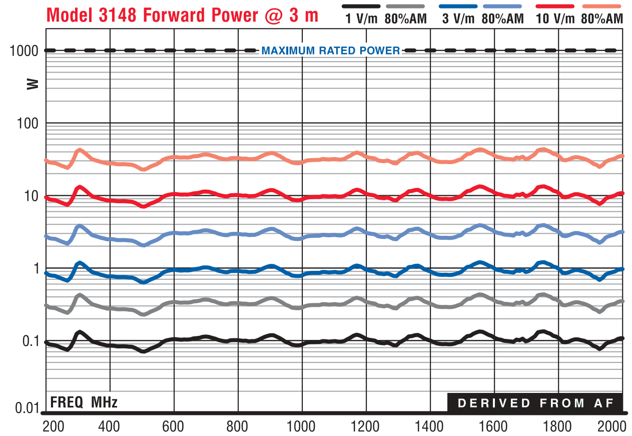
Model 3148 Forward Power @ 1 m



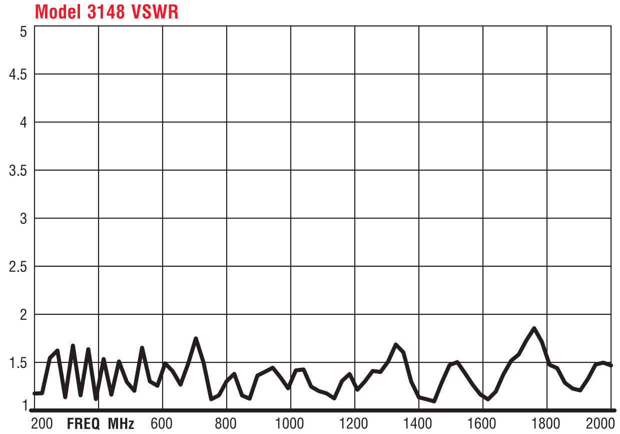
Model 3148 Gain



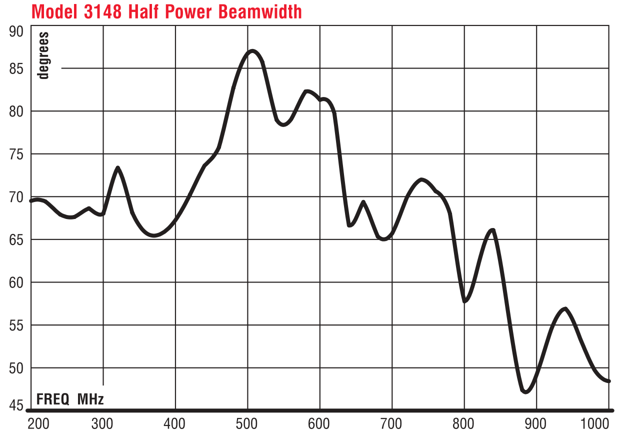
Model 3148 Forward Power @ 3 m

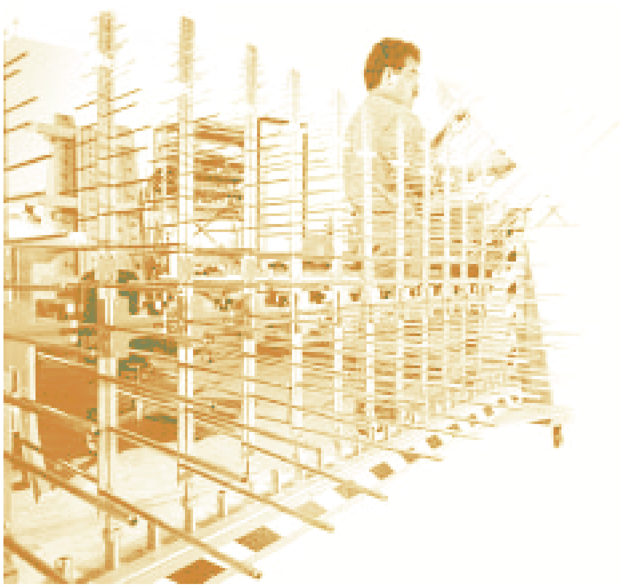


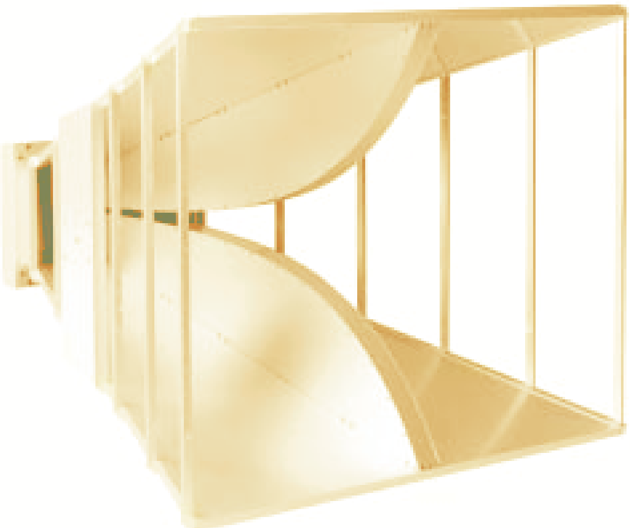
Model 3148 VSWR



Model 3148 Half Power Beamwidth







M O D E L   3 1 0 6

Model 3106
200 MHz – 2 GHz

Model 3115
1 GHz – 18 GHz

Model 3116
18 GHz – 40 GHz

- **Uniform Gain**
- **Power Handling up to 1.6 kW**
- **Low VSWR**
- **Quality Construction**

INDIVIDUALLY CALIBRATED · QUALITY QA ASSURANCE · TWO YEAR 2 YEAR WARRANTY

Double-Ridged Waveguide Horn

PROVIDING UNIFORM GAIN, LOW VSWR AND A BROAD FREQUENCY RANGE, EMCO's three models of Double-Ridged Waveguide Horn Antennas are ideally suited for IEC 61000-4-3 and MIL-STD 461E immunity tests and ANSI C63.4 and EN 55022 emissions testing.

As a set, these linearly polarized broadband antennas have an average VSWR of less than 1.6 to 1 and cover a multi-octave bandwidth of 200 MHz to 40 GHz. These antennas are specifically designed for EMI measurements, but can also be used for EW, antenna gain and pattern measurement, surveillance, and other applications.

The mounting brackets for Models 3115 and 3116 are adjustable for changing polarization of the antenna. Standard 1/4 in x 20 threads are used on the mounting brackets of all double-ridge waveguides for mounting on an EMCO tripod or most other tripods.

EMCO Double-Ridged Waveguide Horn Features

Uniform Gain

All models have uniform gain throughout their frequency span, providing efficient performance characteristics and directionality.

Power Handling

Model 3106 can handle 1600 W peak and 800 W continuously.

Low VSWR

EMCO's double-ridged waveguides have an average VSWR of less than 1.6:1.

Quality Construction

Double-ridged waveguide antennas are constructed of lightweight corrosion-resistant aluminum and fiberglass, providing years of trouble-free indoor and outdoor service. To maximize performance, Type N connectors are used on Models 3115 and 3106, and Type K connectors are used on Model 3116.

Choosing Your Model: Three Models with Frequency Ranges of 200 MHz to 40 GHz

200 MHz to 2 GHz

The Model 3106 has high gain and excellent VSWR characteristics over its entire frequency range. It is especially effective for generating high electromagnetic fields with relatively low power input. The antenna is also useful for receiving low-level signals where high gain characteristics are needed. Although large in size, 93.3 cm (36.7 in), this antenna weighs only 11.8 kg (26 lb). A Type N female connector is used for increased power handling.

1 to 18 GHz

The Model 3115 has excellent gain and VSWR characteristics. This antenna is small and portable with a length of 24.4 cm (9.6 in). The feed system uses a Precision Type N female connector so the antenna can handle considerable power with low losses above 12 GHz.

18 to 40 GHz

The Model 3116 is an extremely small antenna, offering portability and increased efficiency. The Model 3116 has a length of only 13.0 cm (5.25 in), and weighs just 135 g (4.74 oz). A Type K female connector is used for increased performance at high frequencies.

Standard Configuration

- Antenna
- Mounting bracket drilled to accept EMCO or other tripod mount with 1/4 in x 20 threads
- Individually calibrated at 1 m per SAE ARP 958. Calibration of Model 3115 at 3 m available at additional charge. Actual factors and signed Certificate of Conformance included in Manual.

Options

Custom sizes
Larger models for higher gain at lower frequencies are also available.

EMCO Tripod
EMCO offers several nonmetallic, non-reflective tripods for use at EMC test sites. The 7-TR has been specifically designed for the 3106.

f y i

One of the earliest horn antennas was constructed by Jagadis Chandra Bose in 1897. Horn antennas are essentially flared waveguides that produce a uniform phase front larger than the waveguide itself. Adding a ridged waveguide to the horn antenna increases its bandwidth by lowering the cut off frequency of the dominant mode, while raising the cut off frequency of the next higher order mode.

Applications

MODEL	FCC-15	FCC-18	IEC/CISPR/EN	SAE J1113	SAE J551	MIL-STD-461E	MIL-STD-1541	MIL-STD-285	IEEE STD 299	NACSIM
3106	RE	RE	RE, RI	RE, RI	RE, RI	RE, RI	RE, RI			RE
3115	RE	RE	RE, RI	RE, RI	RE, RI	RE, RI	RE, RI	TX, RX	RX	RE
3116	RE	RE				RE, RI	RE	TX, RX	RX	RE

RE = Radiated Emissions RI = Radiated Immunity (Susceptibility) TX = Transmit RX = Receive

Electrical Specifications

MODEL	FREQUENCY RANGE	VSWR RATIO (AVG)	MAXIMUM CONTINUOUS POWER	PEAK POWER	IMPEDANCE (NOMINAL)	CONNECTOR
3106	200 MHz – 2 GHz	< 1.6:1	800 W	1600 W	50 Ω	Type N female
3115	1 GHz – 18 GHz	< 1.5:1	300 W	500 W	50 Ω	Type N precision female
3116	18 GHz – 40 GHz	< 1.6:1	50 W	70 W	50 Ω	Type K female

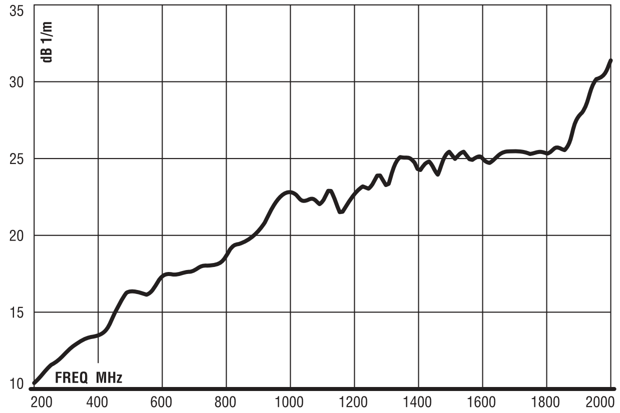
Physical Specifications

MODEL	WIDTH [1]	DEPTH	HEIGHT [1]	WEIGHT
3106	93.3 cm 36.7 in	97.8 cm 38.5 in	72.9 cm 28.7 in	11.8 kg 26.0 lb
3115	24.4 cm 9.6 in	27.9 cm 11.0 in	15.9 cm 6.2 in	1.8 kg 4.0 lb
3116	13.0 cm 5.2 in	10.0 cm 4.0 in	6.0 cm 2.4 in	135.0 g 4.7 oz

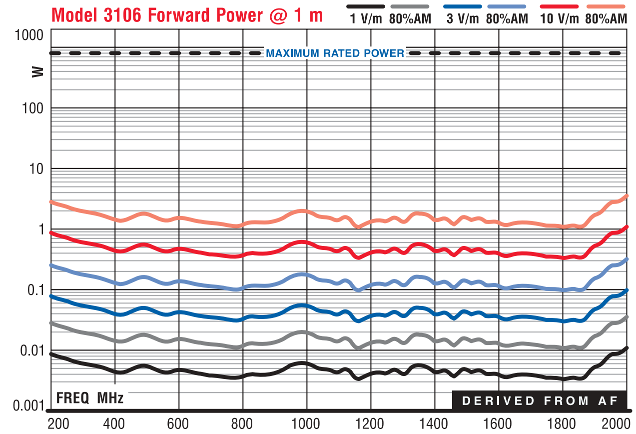
[1] At aperture

Model 3106 Technical Data

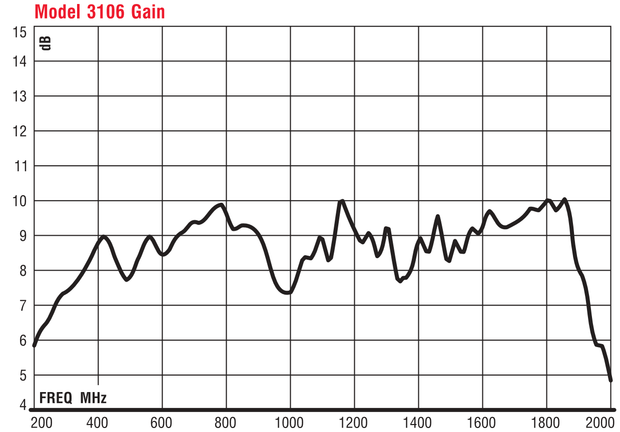
Model 3106 Antenna Factor



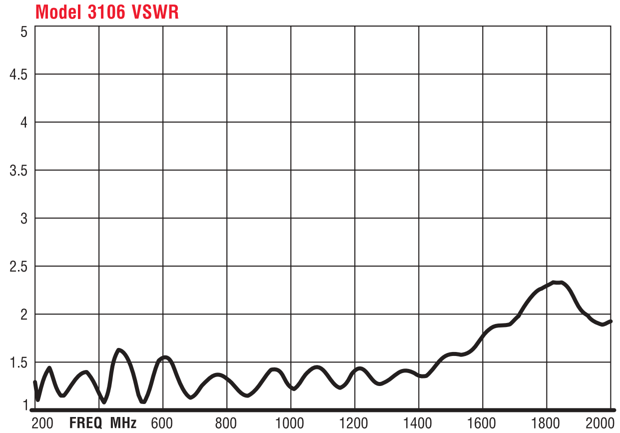
Model 3106 Forward Power @ 1 m



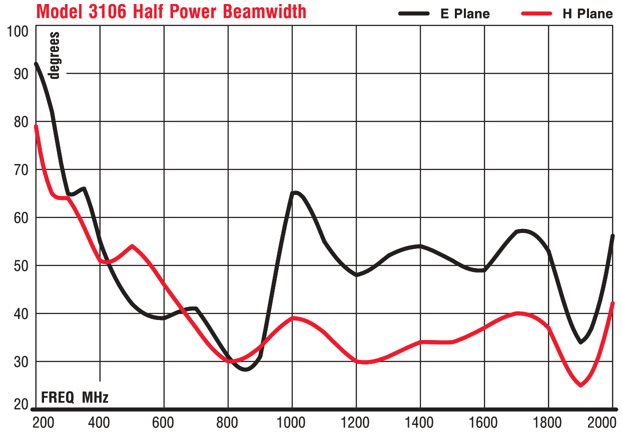
Model 3106 Gain



Model 3106 VSWR



Model 3106 Half Power Beamwidth



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Fax +1.512.531.6500

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Fax +358.2.865.1233

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SINGAPORE:
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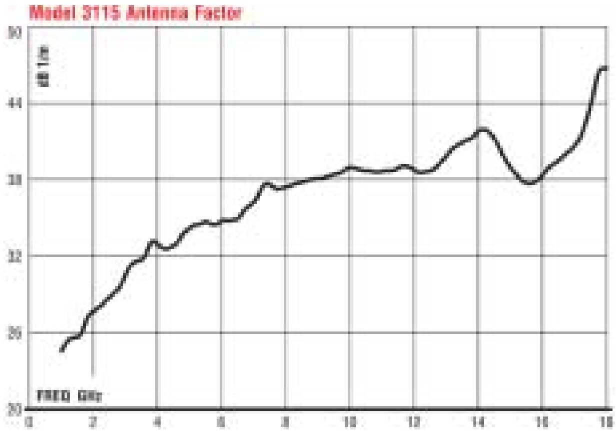
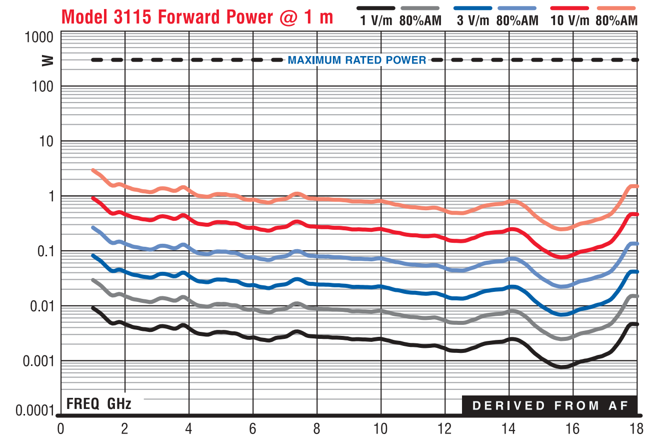
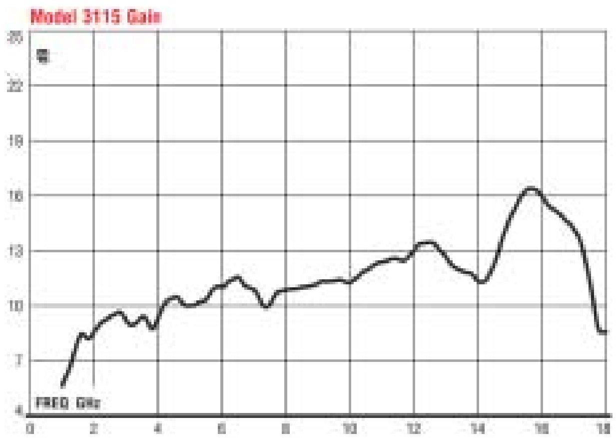
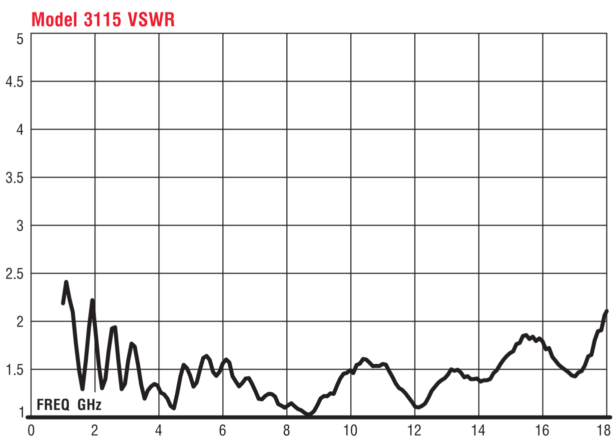
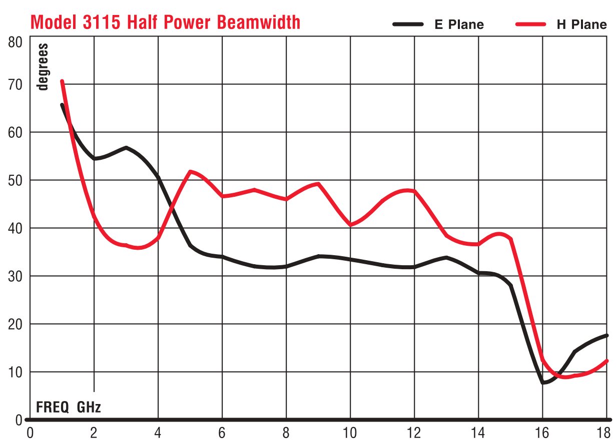
Double-Ridged Waveguide Horn

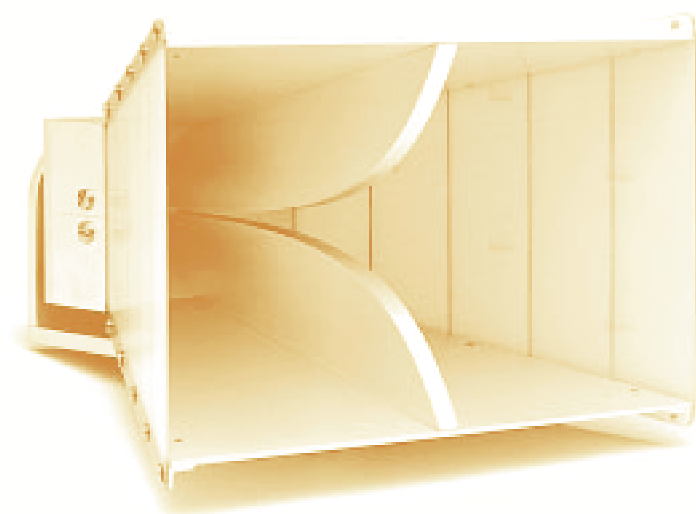






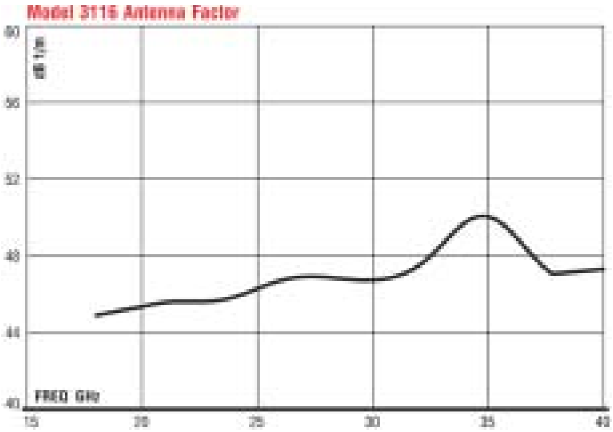


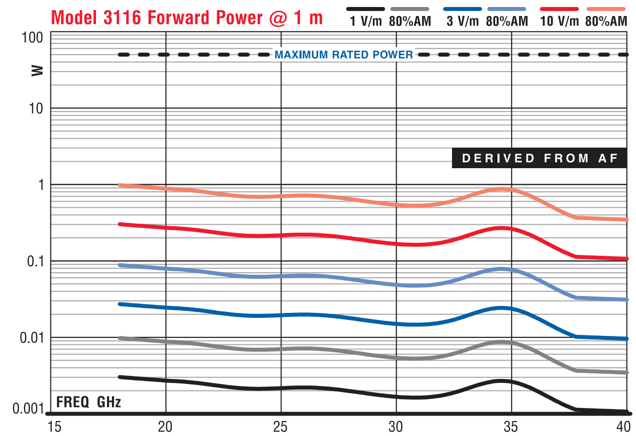


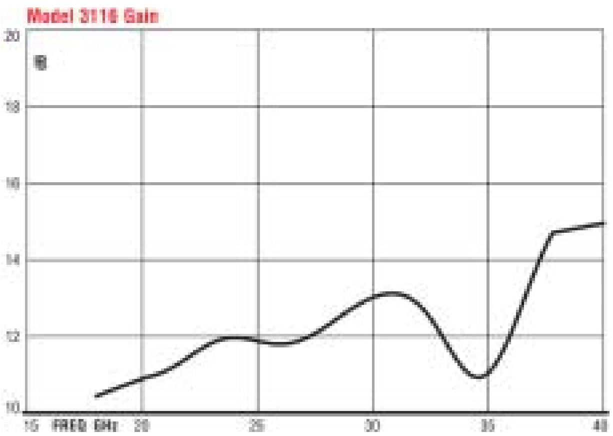


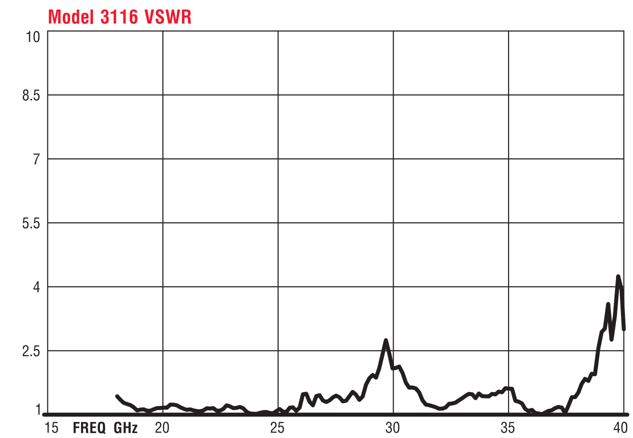
Model 3115 Double-Ridged Waveguide Horn

Model 3116 Technical Data









Double-Ridged Waveguide Horn

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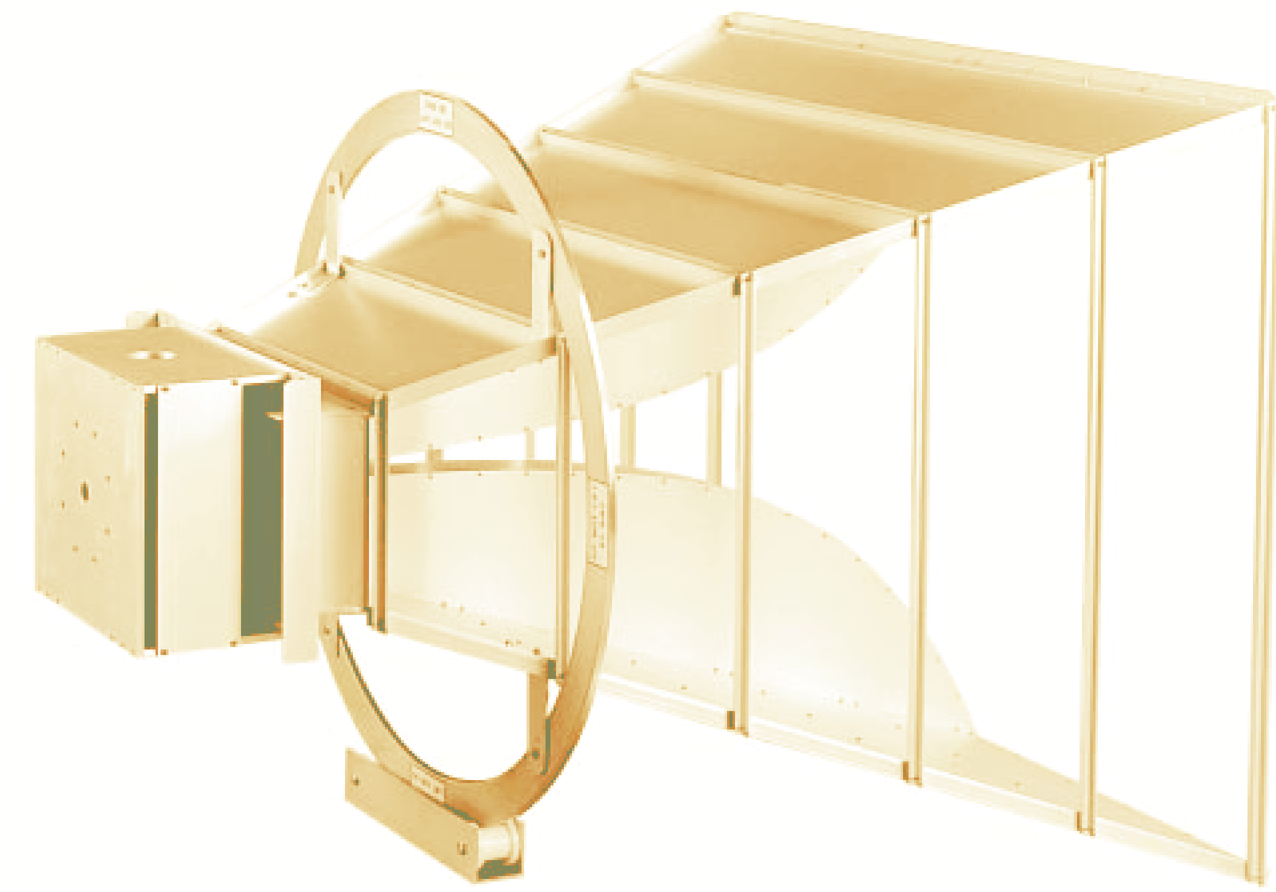

Custom Oversize Double-Ridged Waveguide Horn with Ring-Mount

- 400 MHz - 6 GHz Frequency Range
- Simultaneous Measurements for Both Horizontal and Vertical Polarization
- Cross Polarization Isolation Better Than 25 dB
- High RF Power Handling Capability

M O D E L 3 1 6 4 - 0 3

Diagonal Dual Polarized Horn

EMCO Model 3164-03 Diagonal Dual Polarized Horn Antenna is designed for wireless test applications and covers all known wireless service frequencies. The antenna has two orthogonally placed input feeds that permit simultaneous measurements for dual polarizations. The antenna can be used as both a linearly and circularly polarized antenna over a very broad frequency range. While intended as a receive antenna, the Model 3164 can be used as a radiator, with a 200 W maximum continuous power handling capability.

Standard Configuration

- Horn assembly with mounting flange
- Manual
- Individually calibrated

Options

None

New!
Released as we went to press.
Model 3164.04 700 MHz – 6 GHz

Electrical Specifications

MODEL	FREQUENCY RANGE	VSWR RATIO (AVG)	DIRECTIVITY GAIN OVER OPERATING FREQUENCY	CROSS-POLARIZATION ISOLATION	MAXIMUM CONTINUOUS POWER	IMPEDANCE (NOMINAL)	CONNECTOR
3164-03	400 MHz - 6 GHz	<2.5:1	5 dBi -18 dBi	>25 dB	200 W	50 Ω	SMA (2)

Physical Specifications

MODEL	LENGTH (OVERALL)	WIDTH (APERTURE)	HEIGHT (APERTURE)	WEIGHT
3164-03	50.8 cm 20.0 in	33.0 cm 13.0 in	33.0 cm 13.0 in	9.0 kg 20.0 lb

USA: Tel +1.512.531.6400 Fax +1.512.531.6500
FINLAND: Tel +358.2.838.3300 Fax +358.2.865.1233
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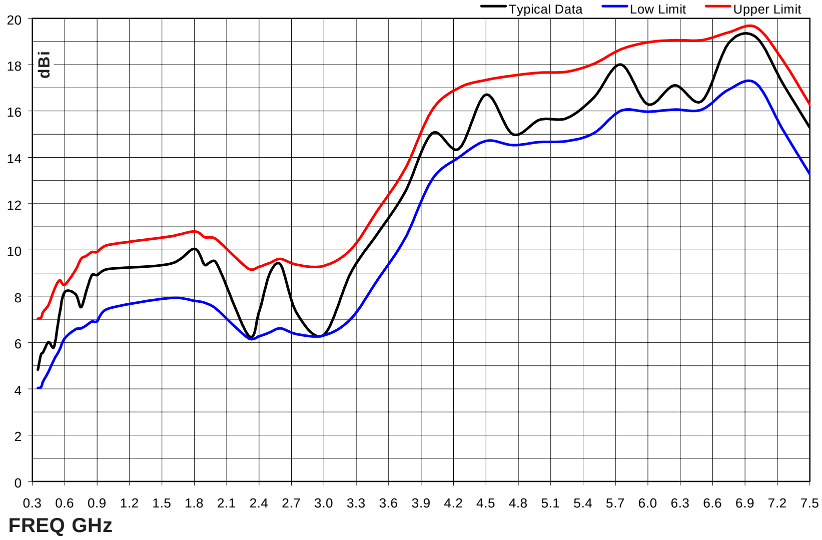
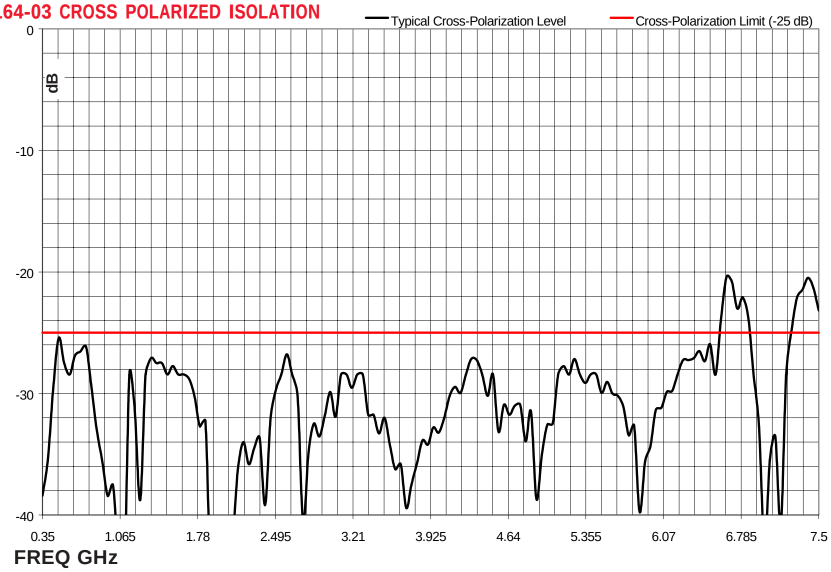
ONLINE: info@ets-lindgren.com www.ets-lindgren.com

Model 3164-03 Technical Data

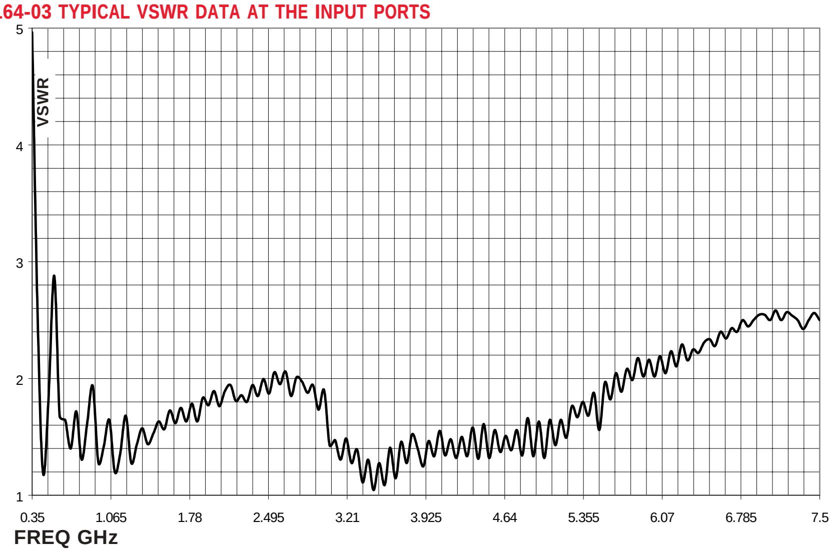
3164-03 DUAL POLARIZED ANTENNA GAIN CHARACTERISTICS

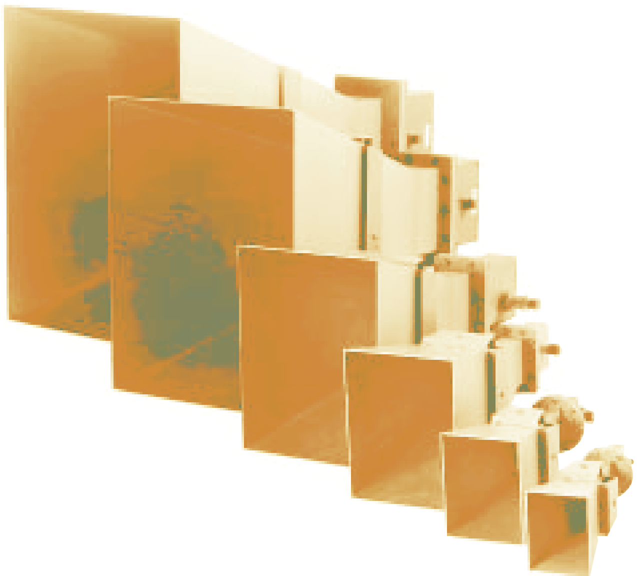


3164-03 CROSS POLARIZED ISOLATION



3164-03 TYPICAL VSWR DATA AT THE INPUT PORTS





Model 3160 01-10
.96 GHz – 40 GHz

Model 3161 01-03
1 GHz – 8 GHz

- **Constant Antenna Factor Over Frequency**
- **Increased Power Dissipation**
- **Optimal Beamwidth**
- **Low VSWR**
- **Complete with Feed, Waveguide, and Mount**

QUALITY ASSURANCE

TWO YEAR WARRANTY

M O D E L 3 1 6 0 0 1 - 0 6

Standard Gain & Octave Horn

EMCO'S COAXIAL FED PYRAMIDAL STANDARD GAIN & OCTAVE HORN ANTENNAS cover a multi-octave bandwidth of 1 to 40 GHz in contiguous ranges. All models in the series are linearly polarized, have medium gain, optimum half power beamwidth (equal in both horizontal and vertical planes), and low VSWR. Antenna factors are constant throughout the entire operating frequency range. Comparisons of measured versus computed gain have been found to be within ± 0.5 dB. ANSI C63.4 recommends the use of standard gain horn antennas as a reference standard above 1 GHz. Octave horns are essentially the same as our standard gain horns, except that they are equipped with waveguide-to-coaxial feeds which are matched in frequency to common octave bandwidth amplifier ranges.

Unlike other antennas of this type, each EMCO pyramidal horn antenna comes assembled with a high performance, low VSWR coaxial-to-waveguide adapter. When additional power input levels are required, the coaxial feeds are easily removed from the waveguides. Industry standard flanges mount directly to amplifiers equipped with waveguide ports. Precision Type N female connectors are used for antennas operating below 18 GHz. Type K female connectors are used above 18 GHz. A mounting bracket is included with all models and allows either vertical or horizontal polarization measurements.

Precision manufacturing contributes to the predictable performance of these antennas. Models 3160-01 through 06 are welded using precise tooling and aluminum sheet metal. Models 3160-07 and 08 are investment cast using an aluminum alloy. Models 3160-09 and 10 are electroformed using copper deposition at the rate of 0.001 inch per hour.

EMCO Standard Gain Horn Antenna Features

Constant Antenna Factor

EMCO's standard gain horns have a constant antenna factor across their entire operating frequency, eliminating lookup in multiple charts to calculate measurements. Above 1 GHz, the antennas can be used as a reference standard per ANSI C63.4.

Increased Power Dissipation

While the coaxial feed allows power input of up to 550 W (Model 3160-01, 02, 03), higher power input is possible by removing the detachable feed and direct mounting the flange to an amplifier waveguide port.

Optimal Beamwidth

The 3 dB beamwidth in both polarization planes is very nearly equal at approximately 30 degrees. This is an optimum design for EMC testing, providing good coverage of the EUT at reasonable distances without the aiming problems of "pencil beam" antennas.

Low VSWR

EMCO's Standard Gain Horn Antennas provide a VSWR of <1.5:1.

Complete with Feed, Waveguide, and Mount

Unlike most antennas of this type, EMCO supplies a complete unit with detachable coax-to-waveguide feed and mounting brackets for both horizontal and vertical polarization. The waveguide features industry-standard flange mounts.

Standard Configuration

- Standard gain or octave horn assembly consisting of coaxial feed, flanged waveguide, and mounting bracket.
- Mounting bracket with 1/4 x 20 threads
- Complete calibration factors and signed Certificate of Conformance included in Manual (Octave Horns only).

Calibration by measurement not applicable to Standard Gain Horns.

Options

None

f y i

The development of standard gain horn antennas was spurred by the arrival of World War II and with it, an increased interest in microwave frequencies. The standard gain horn is unique in that gain can be computed to a tenth of a decibel if the antenna is manufactured with precision. This characteristic allows these antennas to serve as primary standards for gain measurements. Standard gain horns also have the ability to realize specified beamwidths independently in the two principal planes.

Applications

MODEL	FCC-15	FCC-18	IEC/CISPR/EN	SAE J1113	SAE J1338	SAE J1507	SAE J1551	MIL-STD-461E	MIL-STD-1541	MIL-STD-285	NACSIM
3160	RE	RE	RE, RI	RI	RI	RI	RI	RE, RI	RE	RE, RI	RE
3161	RE	RE	RE, RI	RI	RI	RI	RI	RE, RI	RE	RE, RI	RE

RE = Radiated Emissions RI = Radiated Immunity (Susceptibility)

Electrical Specifications

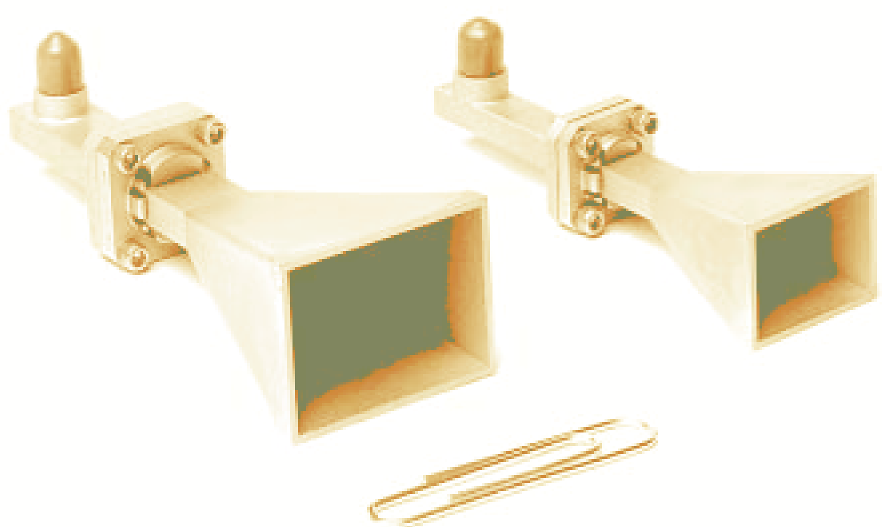
MODEL	FREQUENCY RANGE	GAIN	ANTENNA FACTOR	E - PLANE	H - PLANE	MAXIMUM CONTINUOUS POWER	TYPICAL FIELD STRENGTH
3160-01	0.96 – 1.46 GHz	16.5 dBi	15.4 dB (1/m)	26°	27°	550 W	700 V/m
3160-02	1.12 – 1.70 GHz	16.3 dBi	16.9 dB (1/m)	26°	26°	550 W	700 V/m
3160-03	1.70 – 2.60 GHz	16.3 dBi	20.6 dB (1/m)	27°	27°	500 W	650 V/m
3160-04	2.60 – 3.95 GHz	16.7 dBi	23.7 dB (1/m)	26°	27°	250 W	500 V/m
3160-05	3.95 – 5.85 GHz	16.7 dBi	27.3 dB (1/m)	26°	27°	250 W	500 V/m
3160-06	5.85 – 8.20 GHz	17.1 dBi	29.9 dB (1/m)	24°	25°	250 W	500 V/m
3160-07	8.20 – 12.40 GHz	16.9 dBi	33.5 dB (1/m)	26°	26°	250 W	500 V/m
3160-08	12.40 – 18.00 GHz	16.7 dBi	37.1 dB (1/m)	26°	27°	200 W	435 V/m
3160-09	18.00 – 26.50 GHz	16.8 dBi	40.3 dB (1/m)	27°	27°	50 W	220 V/m
3160-10	26.50 – 40.00 GHz	17.0 dBi	43.5 dB (1/m)	27°	27°	10 W	100 V/m
3161-01	1.00 – 2.00 GHz	16.3 dBi	16.9 dB (1/m)	26°	26°	550 W	700 V/m
3161-02	2.00 – 4.00 GHz	17.5 dBi	22.3 dB (1/m)	22°	22°	250 W	500 V/m
3161-03	4.00 – 8.00 GHz	17.5 dBi	28.3 dB (1/m)	22°	22°	250 W	500 V/m

Gain shown is for mid-band of the operating range. Antenna factor is flat within ± 0.5 dB over each frequency.
Field Strength shown is for 1 meter separation.

Physical Specifications

MODEL	WIDTH	DEPTH	HEIGHT	WEIGHT	WAVEGUIDE NUMBER	CONNECTOR
3160-01	63.22 cm 24.89 in	103.25 cm 40.65 in	47.50 cm 18.70 in	25.00 kg 55.00 lb	WR - 770	Type N female
3160-02	53.44 cm 21.04 in	88.29 cm 34.76 in	40.18 cm 15.82 in	10.00 kg 22.00 lb	WR - 650	Type N female
3160-03	34.65 cm 13.64 in	64.14 cm 25.25 in	64.14 cm 25.25 in	4.55 kg 10.00 lb	WR - 430	Type N female
3160-04	24.13 cm 9.50 in	55.25 cm 21.75 in	18.14 cm 7.14 in	2.27 kg 5.00 lb	WR - 284	Type N female
3160-05	16.33 cm 6.43 in	38.15 cm 15.02 in	12.24 cm 4.82 in	1.62 kg 3.50 lb	WR - 187	Type N female
3160-06	12.24 cm 4.82 in	29.90 cm 11.77 in	9.04 cm 3.56 in	0.80 kg 1.75 lb	WR - 137	Type N female
3160-07	8.06 cm 3.17 in	22.63 cm 8.91 in	6.26 cm 2.46 in	0.43 kg 0.95 lb	WR - 90	Type N female
3160-08	5.54 cm 2.18 in	14.00 cm 5.51 in	4.27 cm 1.68 in	0.28 kg 0.61 lb	WR - 62	Type N female
[1] 3160-09	3.84 cm 1.51 in	10.49 cm 4.13 in	2.95 cm 1.16 in	0.11 kg 0.24 lb	WR - 42	Type K female
[1] 3160-10	2.76 cm 1.09 in	8.69 cm 3.42 in	2.15 cm .85 in	0.06 kg 0.13 lb	WR - 28	Type K female
3161-01	53.14 cm 20.92 in	88.05 cm 34.67 in	39.86 cm 15.69 in	8.00 kg 17.60 lb	WR - 650	Type N female
3161-02	34.61 cm 13.63 in	59.34 cm 23.37 in	23.17 cm 9.12 in	5.00 kg 11.00 lb	WR - 320	Type N female
3161-03	17.47 cm 6.88 in	31.88 cm 12.55 in	11.74 cm 4.62 in	2.00 kg 4.40 lb	WR - 159	Type N female

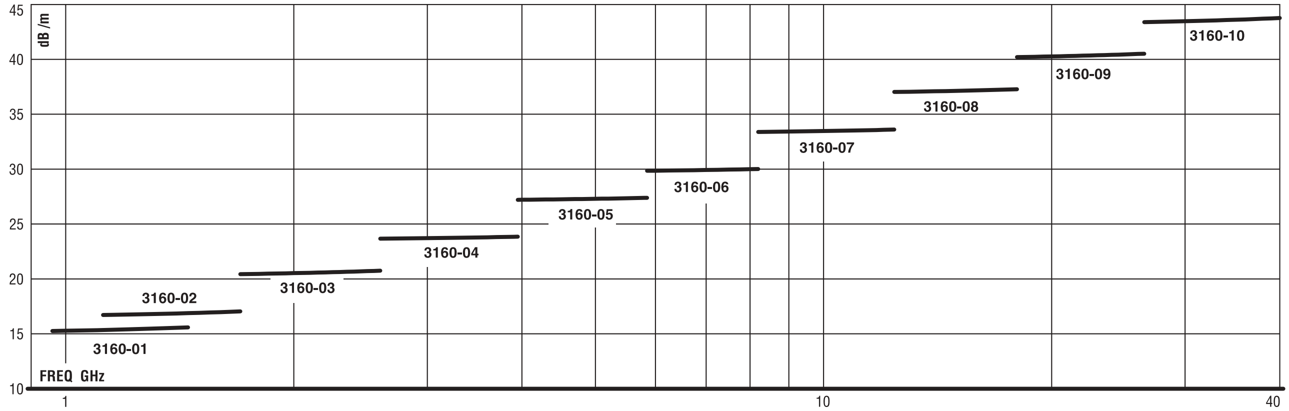
[1] Dimensions without mounting bracket.



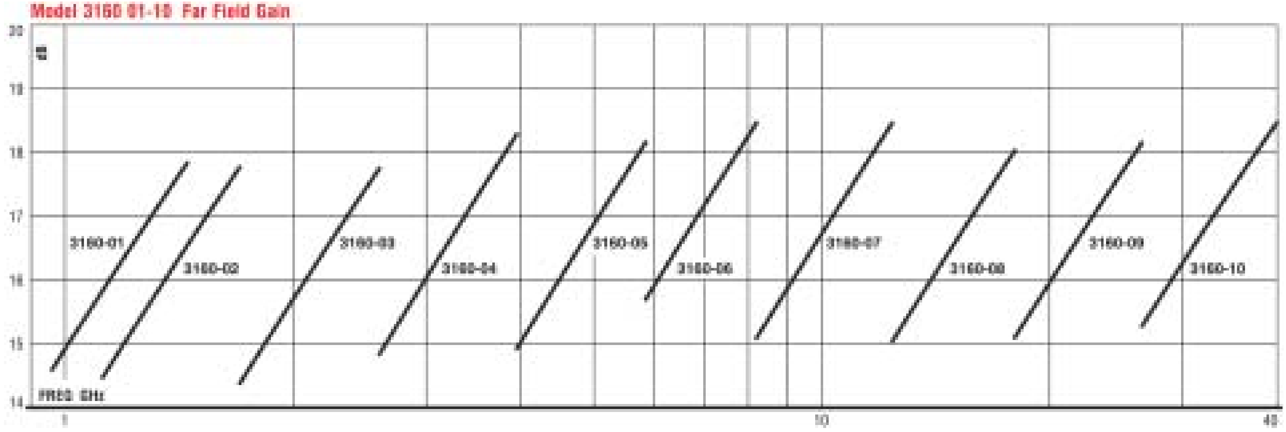
Models 3160-09 and 3160-10 Standard Gain Horn

USA: Tel +1.512.531.6400 Fax +1.512.531.6500
FINLAND: Tel +358.2.838.3300 Fax +358.2.865.1233
UK: Tel +44.(0)1438.730.700 Fax +44.(0)1438.730.750
SINGAPORE: Tel +65.536.7078 Fax +65.536.7093
ONLINE: info@ets-lindgren.com www.ets-lindgren.com

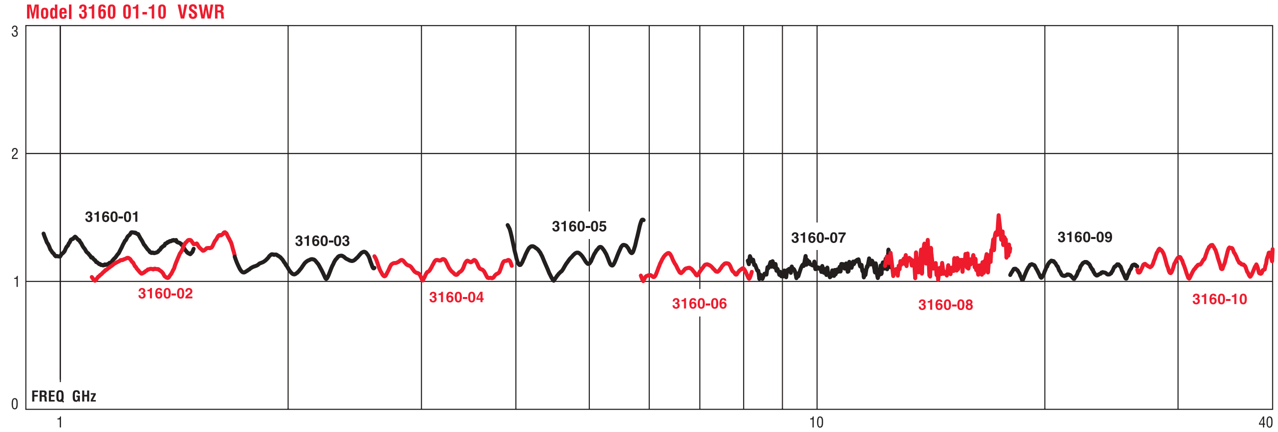
Model 3160 01-10 Antenna Factors



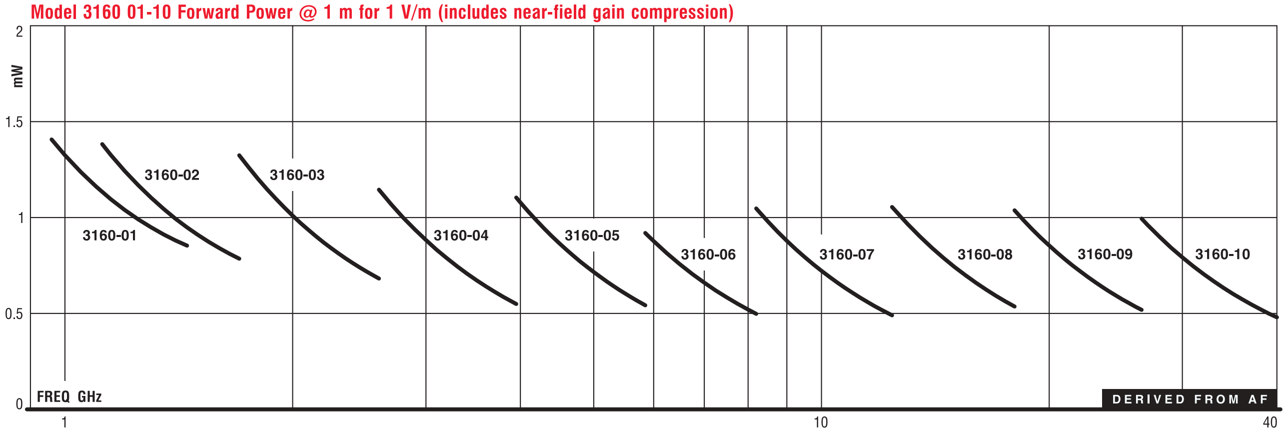
Model 3160 01-10 Far Field Gain



Model 3160 01-10 VSWR

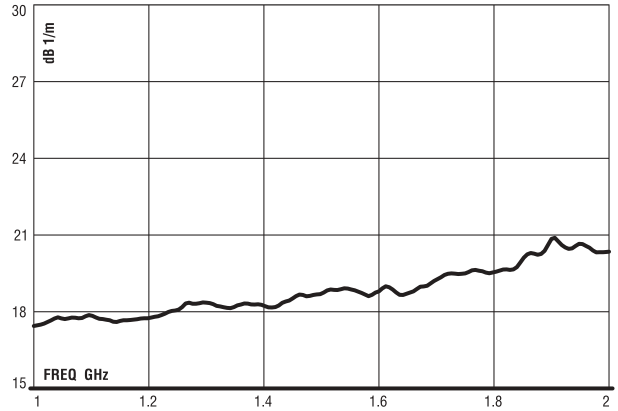


Model 3160 01-10 Forward Power @ 1 m for 1 V/m (includes near-field gain compression)

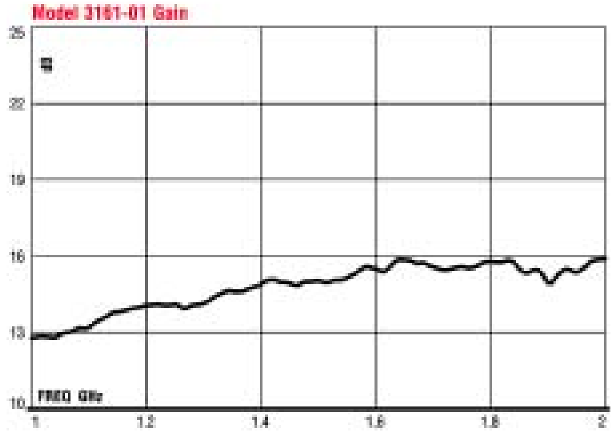


Model 3161-01 Technical Data

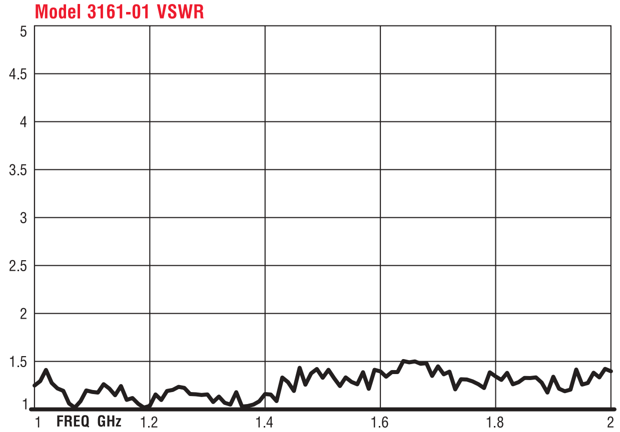
Model 3161-01 Antenna Factor



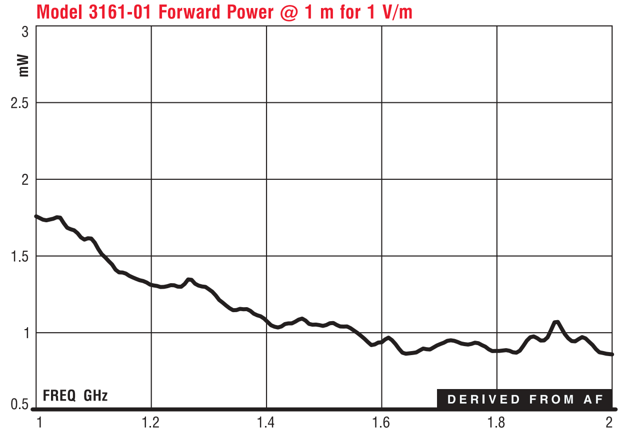
Model 3161-01 Gain



Model 3161-01 VSWR

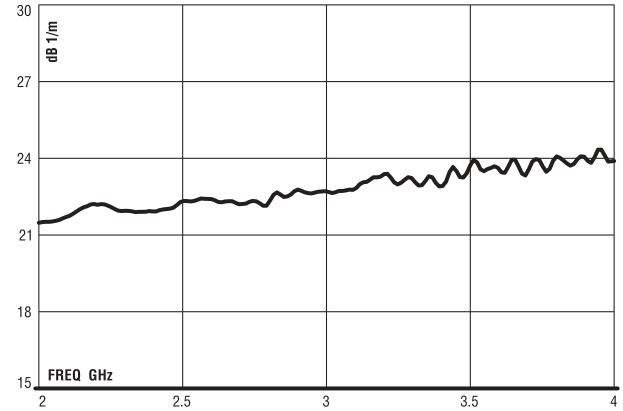


Model 3161-01 Forward Power @ 1 m for 1 V/m



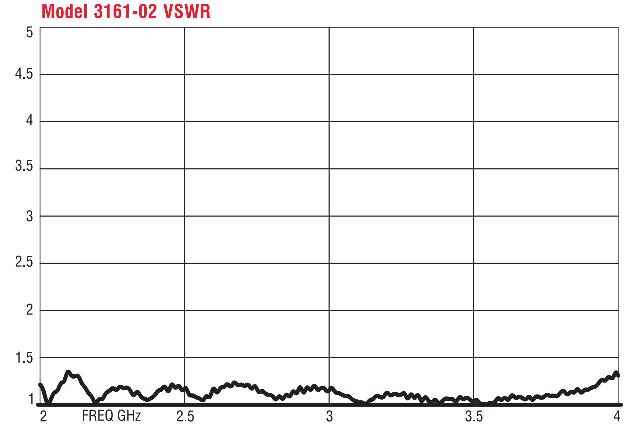
Model 3161-02 Technical Data

Model 3161-02 Antenna Factor

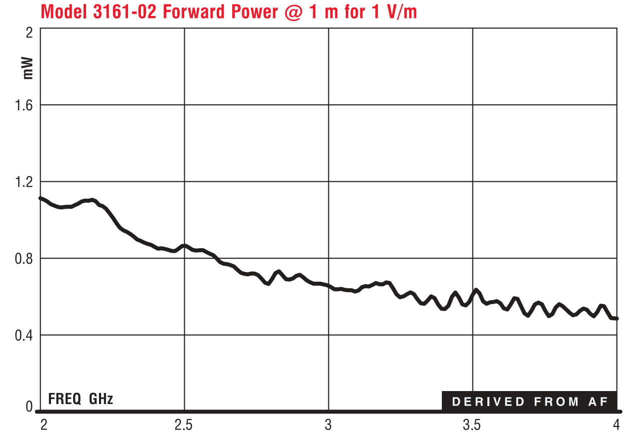


Model 3161-02 Gain

Model 3161-02 VSWR



Model 3161-02 Forward Power @ 1 m for 1 V/m



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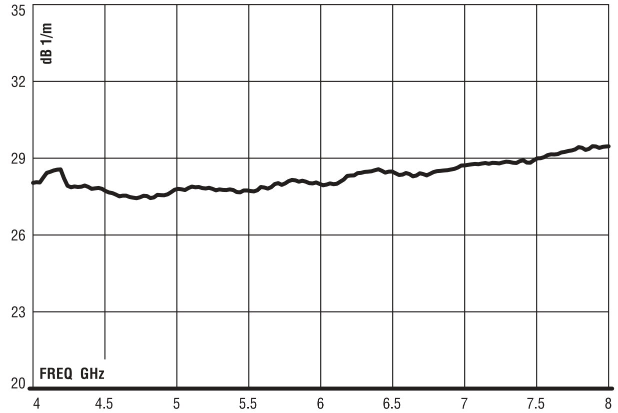
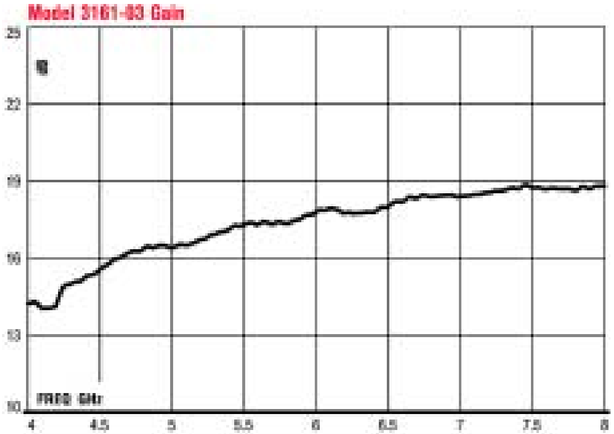
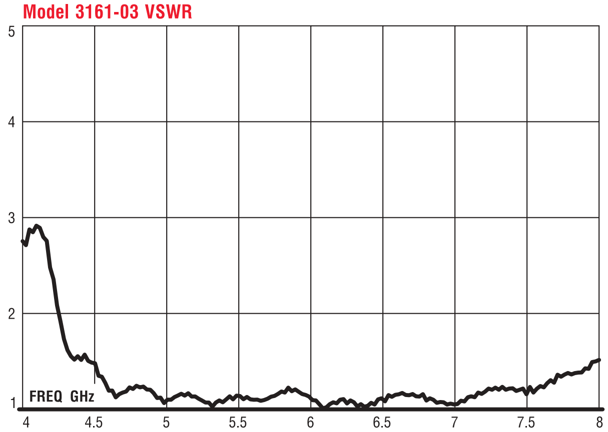
Model 3161-03 Antenna Factor



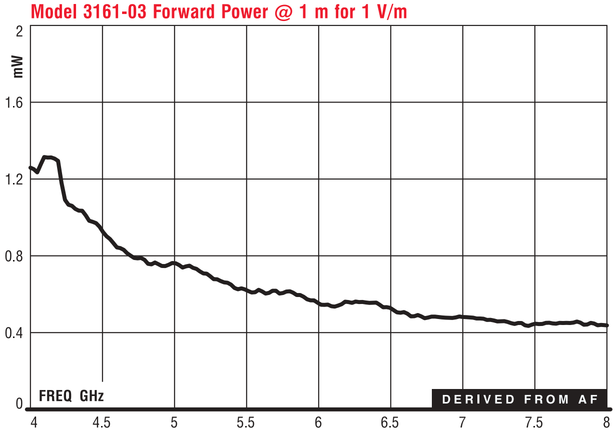
Model 3161-03 Gain



Model 3161-03 VSWR



Model 3161-03 Forward Power @ 1 m for 1 V/m



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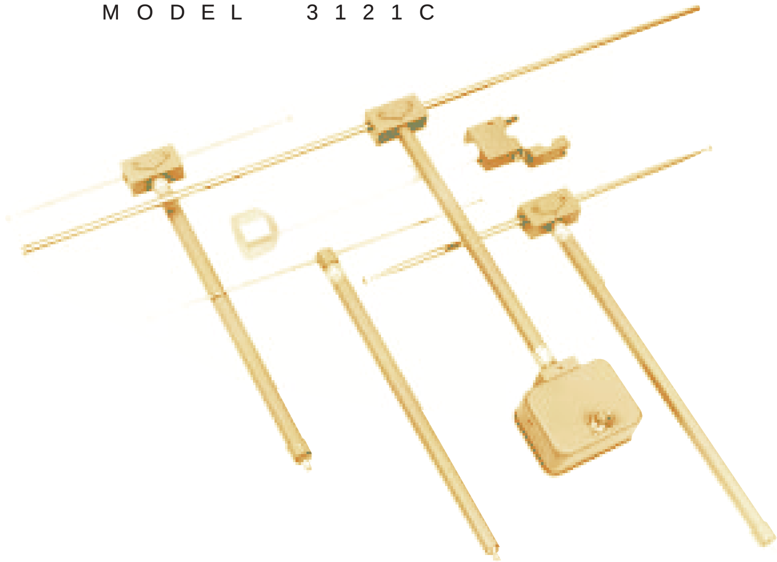


Model 3121C
30 MHz – 1 GHz

- **FCC Design**
- **Low VSWR and Balun Loss**
- **Appropriate for EMI Testing and Site Attenuation**
- **Quality Construction Complete with Accessories**

Tuned Dipole

EMCO'S MODEL 3121C TUNED DIPOLE ANTENNA is virtually identical to the optimally matched, compensated balun design used by Willmar K. Roberts while he was Assistant Chief Engineer at the FCC laboratory. EMCO has made select physical improvements to the original design assuring optimal performance and years of trouble-free use. For example, Type N connectors are used for both balun and cable connections instead of less secure BNC connectors.

EMCO's dipole offers an accurate standard for precise EMI measurements including FCC and EN compliance testing, site attenuation as described in EN55022 and ANSI C63.4, and antenna calibration as described in ANSI C63.5. The Model 3121C tuned dipole antenna covers a frequency range of 30 MHz to 1 GHz and its behavior approaches to the theoretically perfect lossless half-wavelength resonant dipole.

Each EMCO dipole is individually calibrated at 3 and 10 meters per ANSI C63.5, using the preferred three antenna method. All measurement equipment used is NIST traceable. These measurements are made without the use of attenuators, so antenna factors are a true presentation of actual performance. A printout of the calibration data of each antenna is included with the Manual and is also archived. Individual calibration and actual antenna factors are preferred over typical or theoretical factors and provide confidence of test data.

EMCO Tuned Dipole Antenna Features

FCC Design

EMCO has incorporated contemporary materials, precision manufacturing and select improvements (such as Type N connectors for balun and cable connections) to the optimally matched, compensated balun design used by Willmar K. Roberts at the FCC laboratory. The result is a quality product that provides years of use.

Low VSWR and Balun Loss

The Model 3121C tuned dipole antenna has an average VSWR of less than 1.6:1 and a balun loss of less than .5 dB throughout its frequency range of 30 MHz to 1 GHz.

Appropriate for EMI Testing and Site Attenuation

EMCO's tuned dipole antenna is suitable for both commercial and military EMI emissions and immunity testing. The Model 3121 also can be used to perform site attenuation per EN55022 and ANSI C63.4.

Quality Construction Complete with Accessories

EMCO's tuned dipole is constructed of lightweight corrosion-resistant elements, providing years of trouble-free indoor and outdoor service. A clamp block, delrin support rod, and aluminum mounting base are included in the set. The aluminum mounting base accepts standard 1/4 in x 20 threads from an EMCO tripod or most other tripods. All components, including a tape measure, and ruler which shows corresponding frequency, are included in a shock-resistant carrying case.

Standard Configuration

- Four element extension rods
- Two low-frequency adjustable elements
- Two medium frequency adjustable elements
- Four baluns: DB1 - 4 *(Orders for individual balun models include elements. Mounting assembly PN 101947 must be ordered separately for tripod mounting.)*
- Clamp block
- Support rod
- Base drilled to accept EMCO or other tripod mount with standard 1/4 in x 20 threads
- One 5 meter tape measure
- One high frequency ruler for DB4
- 7.6 m cable (25 ft) with Type N connectors
- Actual individual calibration factors and signed Certificate of Conformance included in a user manual
- Carrying case

tech

Tunable dipole antennas are the reference antenna for E-Field measurements, since the amplitude and pattern are fully calculable under controlled conditions such as use over a ground plane. A tunable dipole antenna is used to make the most precise measurements and is the antenna of choice for reference measurements.

Dipole input impedance is dependent on the length-to-diameter ratio of the elements. For accurate and repeatable results, maintain a consistent length-to-diameter ratio of the elements at their tuned frequency. Always fully extend the telescoping elements then retract the inner (or smallest diameter) elements first, following EMCO calibration practice.

Options

None

Applications

MODEL	FCC-15	FCC-18	IEC/CISPR/EN	SAE J551	MIL-STD-1541	MIL-STD-285	IEEESTD 299	NACSIM	VCCI
3121C	RE	RE	RE	RE	RE	PW	PW	RE	RE

RE = Radiated Emissions   PW = Plane Wave   Other:Site attenuation per EN 55022 and ANSI C63.4

Electrical Specifications

MODEL	FREQUENCY RANGE	VSWR RATIO (AVG)	MAXIMUM CONTINUOUS POWER	IMPEDANCE (NOMINAL)	CONNECTOR
3121C	30 MHz – 1000 MHz[1]	< 1.6:1		50 Ω	Type N female
Balun 1	30 MHz – 60 MHz		260 W		Type N female
Balun 2	60 MHz – 140 MHz		160 W		Type N female
Balun 3	140 MHz – 400 MHz		80 W		Type N female
Balun 4	400 MHz – 1000 MHz		50 W		Type N female

[1]Special calibrations available to 25 MHz.

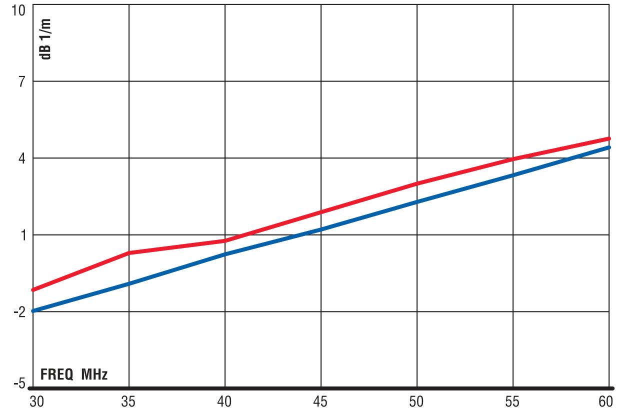
Physical Specifications

MODEL	WIDTH[2]	DEPTH	BALUN THICKNESS	BOOM THICKNESS	WEIGHT
3121C	5.2 m 17.0 ft	55.0 cm 21.6 in	7.0 cm 2.75 in	3.5 cm 1.38 in	9.5 kg 21.0 lb

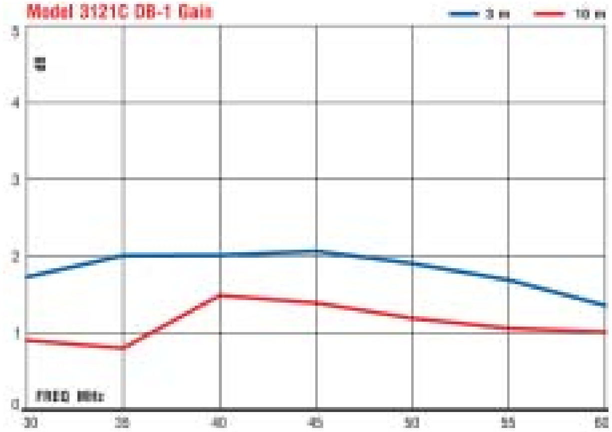
[2] Maximum extension, with elements attached.

Model 3121C DB-1 Technical Data

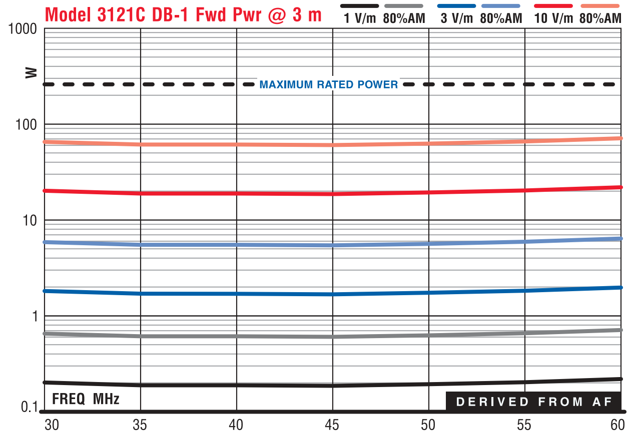
Model 3121C DB-1 Antenna Factor



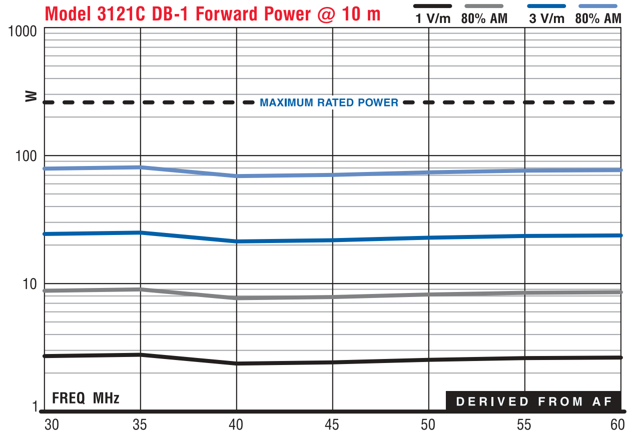
Model 3121C DB-1 Gain



Model 3121C DB-1 Fwd Pwr @ 3 m

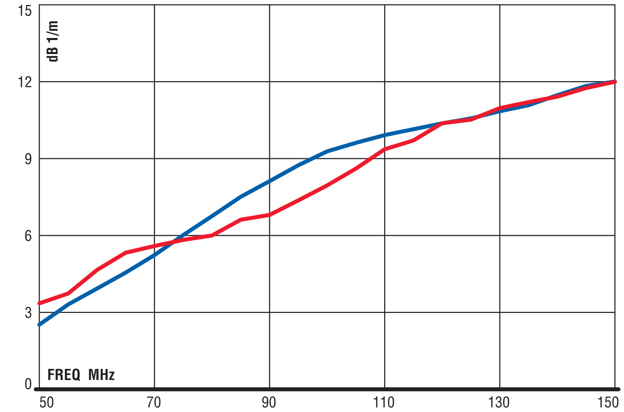


Model 3121C DB-1 Forward Power @ 10 m

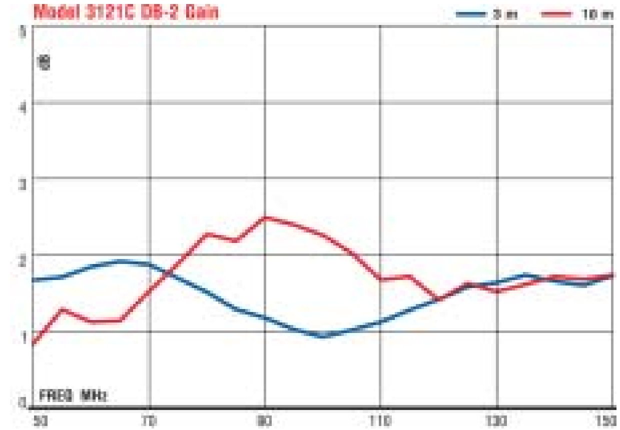


Model 3121C DB-2 Technical Data

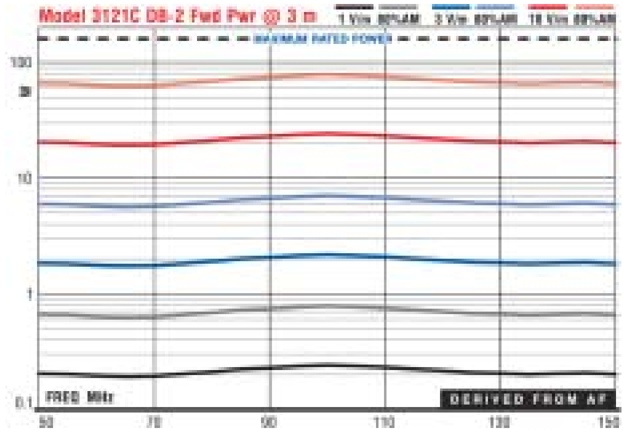
Model 3121C DB-2 Antenna Factor



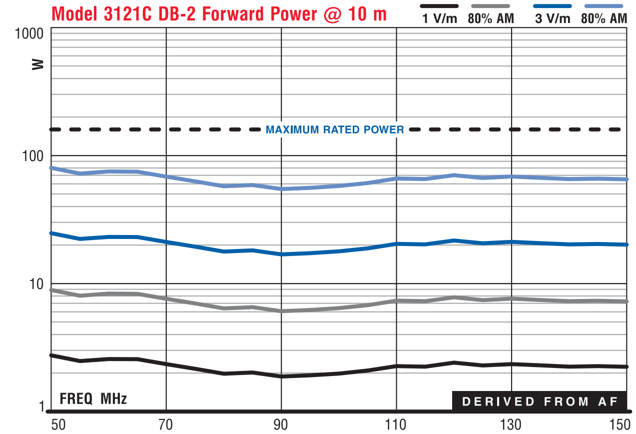
Model 3121C DB-2 Gain



Model 3121C DB-2 Fwd Pwr @ 3 m



Model 3121C DB-2 Forward Power @ 10 m



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ONLINE:
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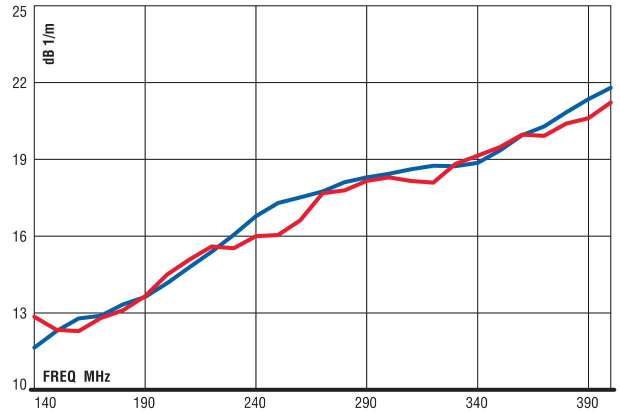
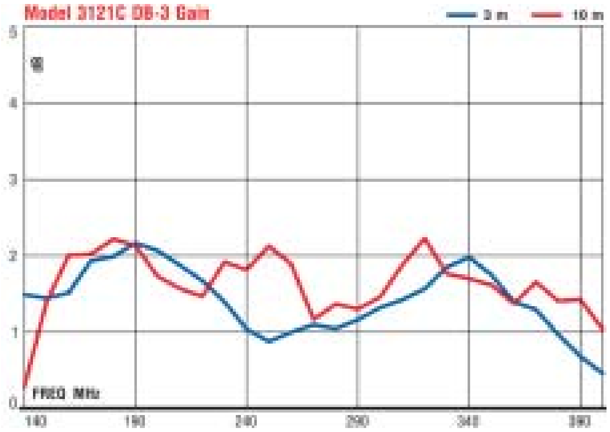
www.ets-lindgren.com

Model 3121C DB-3 Technical Data

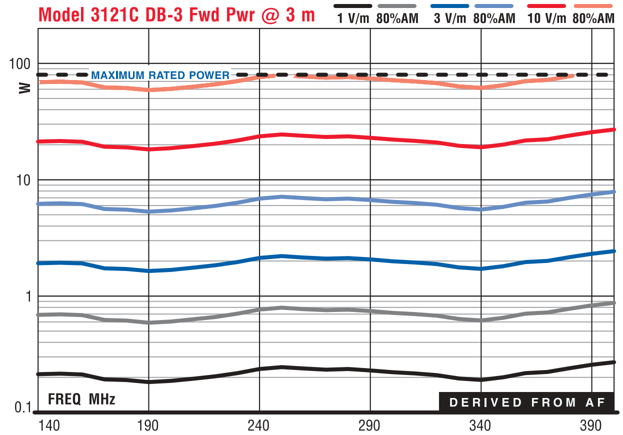
Model 3121C DB-3 Antenna Factor



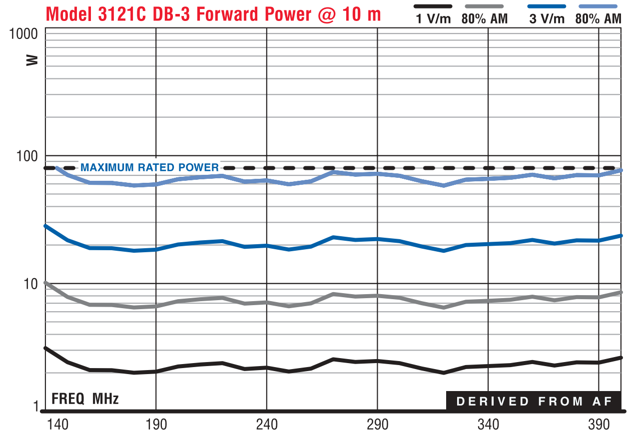
Model 3121C DB-3 Gain



Model 3121C DB-3 Fwd Pwr @ 3 m

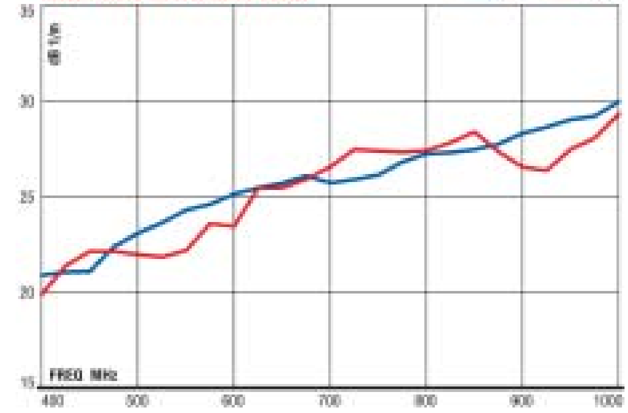


Model 3121C DB-3 Forward Power @ 10 m

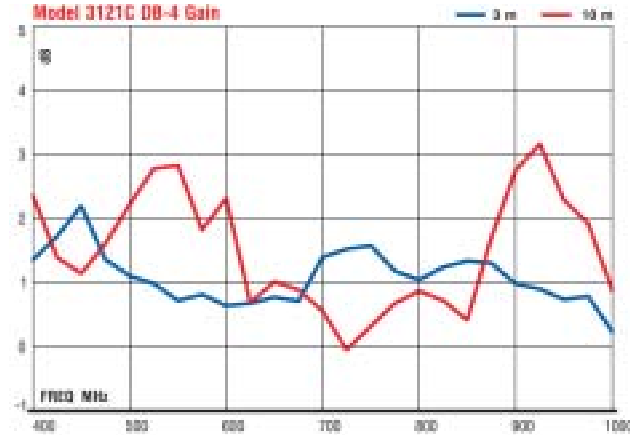


Model 3121C DB-4 Technical Data

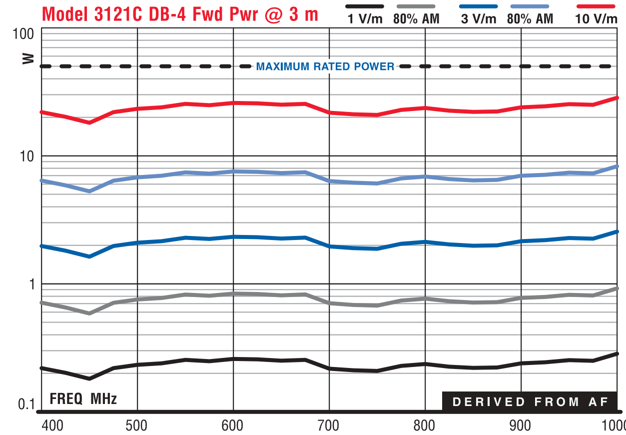
Model 3121C DB-4 Antenna Factor



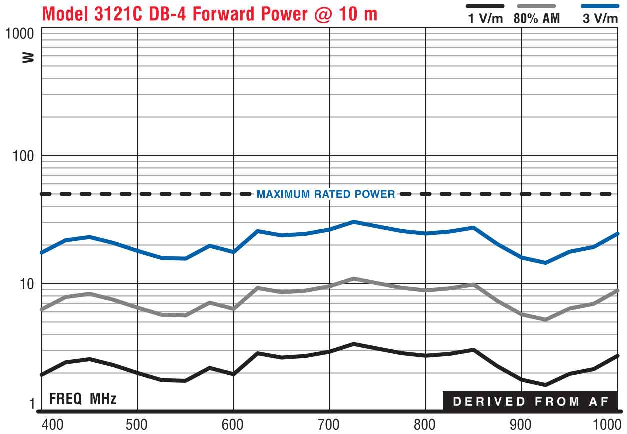
Model 3121C DB-4 Gain



Model 3121C DB-4 Fwd Pwr @ 3 m



Model 3121C DB-4 Forward Power @ 10 m



M O D E L 3 1 2 5

Model 3125-450
440 MHz - 460 MHz

Model 3125-600
590 MHz - 610 MHz

Model 3125-870
824 MHz - 915 MHz

Model 3125-950
935 MHz - 960 MHz

Model 3125-1610
1600 MHz - 1620 MHz

Model 3125-1750
1710 MHz - 1785 MHz

Model 3125-1840
1805 MHz - 1880 MHz

Model 3125-1880
1850 MHz - 1910 MHz

Model 3125-2450
2440 MHz - 2460 MHz

Model 3125-3000
2990 MHz - 3010 MHz

- IEEE SC 34 Design
- For AAMI & FDA Test Requirements
- Frequency Matched to Wireless Device Frequencies

Fixed Dipoles

EMCO'S MODEL 3125 BALANCED DIPOLE SETS for electromagnetic field testing are an omni-directional emissions source for immunity testing. These dipoles are designed with frequencies that match the operating frequencies of cellular phones and other wireless devices. In typical use, a chosen dipole is substituted for a wireless device of the same frequency. The substituted dipole then allows the test to be performed with greater repeatability and lower measurement uncertainty. Applications include immunity testing of pacemakers, hearing aids and defibrillators.

The dipoles are tuned half-wave length resonant with a series-parallel coaxial stub balun. Each antenna has fixed length dipole elements mounted in a Teflon support block. The coaxial balun is terminated into a type "SMA" receptacle.

EMCO Tuned Dipole Antenna Features

IEEE SC 34 DESIGN
EMCO's Balanced Dipole Sets are manufactured in accordance with a design specified in IEEE SC 34.

FOR AAMI & FDA TEST REQUIREMENTS
The dipoles are designed for testing products according to the requirements established by the American Association of Medical Instrumentation (AAMI) and the Federal Drug Administration (FDA).

Choosing Your Model

EMCO's Model 3125 Balanced Dipole Series covers a frequency range of 440 MHz to 3 GHz. Each dipole frequency is matched to the frequency used by a wireless device. Requests for dipoles with custom frequencies can be accommodated. Please contact our Sales Department to discuss your needs.

USA: Tel +1.512.531.6400 Fax +1.512.531.6500
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SINGAPORE: Tel +65.536.7078 Fax +65.536.7093
ONLINE: info@ets-lindgren.com www.ets-lindgren.com

Standard Configuration

- Antenna assembly
- Manual
- Actual individual calibration factors and signed Certificate of Conformance

Options

- Antenna mount drilled to accept EMCO or other tripod mount with standard 1/4 in x 20 threads

Electrical Specifications

MODEL	FREQUENCY RANGE	VSWR RATIO (AVG)	MAXIMUM CONTINUOUS POWER	IMPEDANCE (NOMINAL)	CONNECTOR
3125-450	440 MHz – 460 MHz	< 1.7:1	1 W	50 Ω	SMA
3125-600	590 MHz – 610 MHz	< 1.7:1	1 W	50 Ω	SMA
3125-870	824 MHz – 915 MHz	< 1.7:1	1 W	50 Ω	SMA
3125-950	935 MHz – 960 MHz	< 1.7:1	1 W	50 Ω	SMA
3125-1610	1600 MHz – 1620 MHz	< 1.7:1	1 W	50 Ω	SMA
3125-1750	1710 MHz – 1785 MHz	< 1.7:1	1 W	50 Ω	SMA
3125-1840	1805 MHz – 1880 MHz	< 1.7:1	1 W	50 Ω	SMA
3125-1880	1850 MHz – 1910 MHz	< 1.7:1	1 W	50 Ω	SMA
3125-2450	2440 MHz – 2460 MHz	< 1.7:1	1 W	50 Ω	SMA
3125-3000	2990 MHz – 3010 MHz	< 1.7:1	1 W	50 Ω	SMA

Physical Specifications

MODEL	WIDTH	DEPTH	HEIGHT
3125-450	31.24 cm 12.3 in	3.3 cm 1.3 in	20.32 cm 8.0 in
3125-600	23.62 cm 9.3 in	3.3 cm 1.3 in	16.51 cm 6.5 in
3125-870	18.2 cm 7.6 in	3.3 cm 1.3 in	12.7 cm 5.0 in
3125-950	14.99 cm 5.91 in	3.3 cm 1.3 in	10.67 cm 4.2 in
3125-1610	8.63 cm 3.4 in	3.3 cm 1.3 in	8.4 cm 3.3 in
3125-1750	8.4 cm 3.31 in	3.3 cm 1.3 in	8.13 cm 3.2 in
3125-1840	8.2 cm 3.23 in	3.3 cm 1.3 in	7.87 cm 3.1 in
3125-1880	8.1 cm 3.19 in	3.3 cm 1.3 in	7.6 cm 3.0 in
3125-2450	5.59 cm 2.2 in	3.3 cm 1.3 in	6.1 cm 2.4 in
3125-3000	4.57 cm 1.8 in	3.3 cm 1.3 in	5.6 cm 2.2 in

MODEL

6507

Model 6502 10 kHz – 30 MHz	**Model 7603** 20 Hz –>50 kHz
Model 6507 1 kHz – 30 MHz	**Model 7604** 20 Hz – 500 kHz
Model 6509 1 kHz – 30 MHz	**Model 7605** 30 Hz – >50 MHz
Model 6511 20 Hz – 5 MHz	**Model 7606** 30 Hz – >50 MHz
Model 6512 10 kHz – 30 MHz	

- **Saturation Indicator**
- **Remote Monitor Option**
- **Quality Construction**

INDIVIDUALLY CALIBRATED

QUALITY QA ASSURANCE

TWO YEAR 2 YEAR WARRANTY

Loop & Magnetic Field Coil

EMCO'S LOOP ANTENNAS AND MAGNETIC FIELD COILS provide for a wide range of magnetic field testing from 20 Hz to 30 MHz. Some models include active electronics for impedance matching, consistent linear antenna factors, and signal attenuation. Most include a balanced Faraday shield to reduce response to E-Fields for pure magnetic field measurements. Options like our remote status indicators add convenience. Whether used individually or as a set, our loop antennas provide an efficient and economical solution to magnetic field measurement.

EMCO offers five models of loop antennas. Every loop antenna is individually calibrated in accordance with IEEE-291 Section 2.3.1 methods, using NIST traceable equipment. By knowing the actual antenna factors and performance characteristics of an antenna instead of typical data, you can more accurately calculate field strength in your tests. The performance of the 7600 Series is calculated from theory. Because of precise antenna dimensions and low frequency range, the calculated performance of these models is much more accurate than could be measured.

EMCO Loop and Coil Features

Saturation Indicator

EMCO's loop antenna Models 6502 and 6507 have saturation indicators. If this indicator is lit, the input signal is exceeding the saturation level of the internal preamplifier. During all EMC tests, measurements taken with a signal level that exceeds the limits of the antenna could result in erroneous data. To prevent this, the saturation indicator lights, alerting you to lower the incoming signal. Model 6502 can receive signals up to 5 volts per meter before this indicator is activated, and Model 6507 can receive signals up to 10 volts per meter before the saturation indicator is activated.

Remote Monitor Option

An optional remote monitor is available that allows you to view the power and saturation indicators from up to 10 m (32.8 ft) away. See "Options" for additional information.

Quality Construction

All loop antennas and coil bases are constructed of lightweight aluminum, except Models 7603 and 7605 which are constructed of linen phenolic. This construction provides durability and reliability for years of trouble-free indoor and outdoor service. The base of the loop antennas, excluding Models 7603 and 7605, accept standard 1/4 in x 20 threads from an EMCO or other tripod.

Choosing Your Model: Nine Models with Frequency Ranges of 20 Hz to 30 MHz

Active Loop Antennas 1 kHz to 30 MHz, 10 kHz to 30 MHz

Models 6502 and 6507 are active receiving loop antennas. These antennas are specifically designed to measure shielding effectiveness in accordance with MIL-STD-285 and NSA-65-6. The Model 6502 has a frequency range of 10 kHz to 30 MHz, and the Model 6507 has a frequency range of 1 kHz to 30 MHz. A preamplifier is built into the base of these loop antennas and provides a 50-ohm output, which is used by a receiver. The preamplifier helps these loop antennas produce good sensitivity and almost constant antenna factors. Power for the preamplifier is supplied by rechargeable sealed batteries. Front panel controls and indicators for the preamplifier include a power switch, power-on indicator, and a receptacle for a battery

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SINGAPORE: Tel +65.536.7078 Fax +65.536.7093
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charger. A battery charger which is switch selectable for 115 VAC / 230 VAC operation is included. The charger operates at 50 Hz / 60 Hz.

Passive Loop Antennas
20 Hz to 5 MHz, 1 kHz to 30 MHz, 10 kHz to 30 MHz

EMCO offers three models of passive loop antennas; the **Model 6509, 6511 and 6512.** Model 6509 is designed for shielding effectiveness and immunity, while Models 6511 and 6512 are designed for emissions and immunity tests. Model 6509 has a frequency range of 1 kHz to 30 MHz, Model 6511 has a frequency range of 20 Hz to 5 MHz, and Model 6512 has a frequency range of 10 kHz to 30 MHz. The base of the Model 6509 loop antenna contains a Type N female connector and a manually switchable four-band transformer. The transformer gives the antenna greater efficiency resulting in a better conversion of power to field strength. Models 6511 and 6512 both use BNC connectors.

Passive Coils 20 Hz to 50 kHz, 20 Hz to 500 kHz

Both **Models 7603 and 7604** are built from the specifications in the original MIL-STD-461E document. The Model 7603 is a magnetic field generating coil 12.0 cm (4.75 in) diameter, made of delrin and wound with 10 turns of AWG-16 wire. Model 7604 is a magnetic field pick-up coil 13.3 cm (5.25 in) diameter, and has a loop that is constructed of aluminum. The loop has 36 turns of 7 x 41 Litz wire for lower inductance. Both models operate within the specified limits of MIL-STD-461E; Model 7604 operates from 20 Hz to over 500 kHz, and Model 7603 operates from 20 kHz to over 50 kHz. Female BNC connectors are used on Model 7604, and female banana jacks are used on Model 7603.

Radiating Loop Antenna and Sensor 30 Hz to 50 kHz

EMCO's **Model 7605 and 7606** Loops are precision built to the exact specifications as described in MIL-STD 461E for Method RS101. The Model 7605, a radiating loop, and the Model 7606, a sensing loop, are used as part of a system to verify the ability of an EUT to withstand radiated magnetic fields. The Model 7605 is a 20-turn coil of AWG-12 enamel-insulated copper wire and features a 5 cm spacing from the face of the loop to the center-point of the coils as per MIL-STD-461E. The Model 7606 sensing loop is a 4 cm diameter, electrostatically-shielded loop antenna which has 51 turns of 7-strand AWG-41 Litz wire.

Standard Configuration

- Antenna/coil assembly
- Mounting bracket drilled to accept an EMCO or other tripod mount with standard 1/4 in x 20 threads (except Models 7603, 7605, and 7606)
- Individually calibrated per IEEE STD 291. Actual individual calibration factors and signed Certificate of Calibration Conformance included in Manual (except 7600 Series Models)
- Battery charger (Model 6502, 6507 only)

Options

Custom Cases
Custom cases are available on request.

Remote Monitor Option
10 meter (32.8 ft) fiber optic Remote Monitor Option for remote display of power-on and saturation indicators (Models 6502, 6507 only).
(Part#'s 6502: 6502-RM; 6507: 6507-RM)

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Loop antennas have been used to measure field strength contours around radio broadcast stations since the advent of the vacuum tube. Today, EMC engineers find loop antennas useful to measure magnetic field emissions for a variety of test standards.

EMCO loop antennas are calibrated to the requirements of IEEE STD 291.

Remote Monitor Option

Applications

MODEL	VDE	FCC-18	IEC/CISPR/EN	SAE J1113	SAE J551	SAE J1816	MIL-STD-461E	MIL-STD-1541	MIL-STD-285	NSA 65-6	IEEE STD 299	NACSIM
6502	RE	RE	RE	RE	RE	RE		RE				RE
6507		RE	RE	RE	RE	RE		RE	RX	RX	RX	RE
6509			RI	RI	RI			RI	TX	TX	TX	
6511		RE	RE, RI					RE, RI				RE
6512			RE, RI		RE	RE						RE
7603							RI					
7604							RE					
7605							RI					
7606							RI					

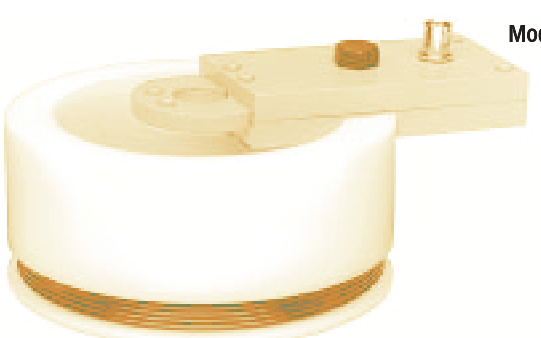
RE = Radiated Emissions RI = Radiated Immunity (Susceptibility) TX = Transmit RX = Receive

Electrical Specifications

MODEL	FREQUENCY RANGE	DYNAMIC RANGE	SENSITIVITY (TYPICAL)	1 DB COMPRESSION POINT	POWER REQUIRED	MAXIMUM INPUT POWER	IMPEDANCE (NOMINAL)	CONNECTOR
6502	10 kHz – 30 MHz	85 dB @10 kHz 125 dB @ 1 MHz	-1 dB(μA/m) @ 10 kHz -42 dB(μA/m) @ 1 MHz	5 V/m	13.8 VDC	NA	50 Ω	BNC female
6507	1 kHz – 30 MHz	76 dB @10 kHz 116 dB @ 1 MHz	11 dB(μA/m) @ 10 kHz -29 dB(μA/m) @ 1 MHz	10 V/m	13.8 VDC	NA	50 Ω	BNC female
6509	1 kHz – 30 MHz	NA	NA	NA	NA	1kW	varies w/freq[2]	Type N fem
Band1	1 kHz – 60 kHz							
Band2	60 kHz – 400 kHz							
Band3	400 kHz – 1 MHz							
Band4	1 MHz – 30 MHz							
6511	20 Hz – 5 MHz[1]	NA	NA	NA	NA	20 W	varies w/freq[2]	BNC female
6512	10 kHz – 30 MHz	NA	NA	NA	NA	20 W	varies w/freq[2]	BNC female
7603	20 Hz – >50 kHz	NA	NA	NA	NA	5 A	50 Ω[3]	Banana Jack-2
7604	20 Hz – 500 kHz	NA	NA	NA	NA	NA	50 Ω[3]	BNC female
7605	30 Hz – >50 kHz	NA	NA	NA	NA	NA	50 Ω[3]	Banana Jack-2
7606	30 Hz – >50 kHz	NA	NA	NA	NA	NA	50 Ω[3]	BNC female

1 Calibrated from 1 kHz - 5 MHz. Values from 20 Hz - 1 kHz are theoretical.
2 Calibrated in 50 Ω system.
3 Typical response provided for 50 Ω systems to 500 kHz and for high impedance to 50 kHz.

Model 7606 Sensing Loop



Model 7605 Radiating Loop

Model 7603 Magnetic Field Generating Coil

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Physical Specifications

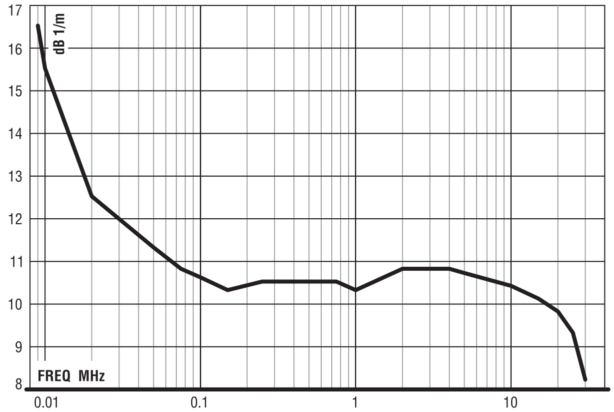
MODEL	BASE WIDTH	BASE DEPTH	HEIGHT	LOOP DIAMETER	WEIGHT
6502	19.0 cm 7.5 in	12.0 cm 4.7 in	67.3 cm 26.5 in	60.0 cm 23.6 in	2.0 kg 4.5 lb
6507	19.0 cm 7.5 in	12.0 cm 4.7 in	37.8 cm 14.9 in	30.4 cm 12.0 in	1.8 kg 4.0 lb
6509	8.0 cm 3.1 in	7.6 cm 3.0 in	47.8 cm 18.7 in	30.4 cm 12.0 in	1.3 kg 2.9 lb
6511	12.7 cm 5.0 in	3.8 cm 1.5 in	59.8 cm 23.5 in	56.0 cm 22.0 in	1.6 kg 3.5 lb
6512	12.7 cm 5.0 in	3.8 cm 1.5 in	59.8 cm 23.5 in	56.0 cm 22.0 in	1.6 kg 3.5 lb
7603	NA	NA	8.0 cm 3.1 in	12.0 cm 4.7 in	0.5 kg 1.0 lb
7604	6.3 cm 2.5 in	2.8 cm 1.1 in	17.8 cm 7.0 in	13.3 cm 5.2 in	0.9 kg 2.0 lb
7605	NA	NA	5.9 cm 2.3 in	13.2 cm 5.2 in	0.2 kg 0.3 lb
7606	5.1 cm 2.0 in	1.9 cm 0.7 in	13.5 cm 5.3 in	4.7 cm 1.8 in	0.4 kg 0.7 lb

Model 7604 Magnetic Field Pick-Up Coil

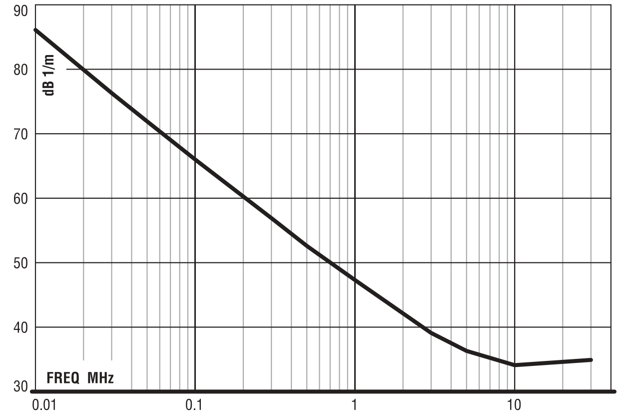
Model 6511 and 6512 Passive Loops

Models 6502, 6507, 6509, 6511, 6512 Technical Data

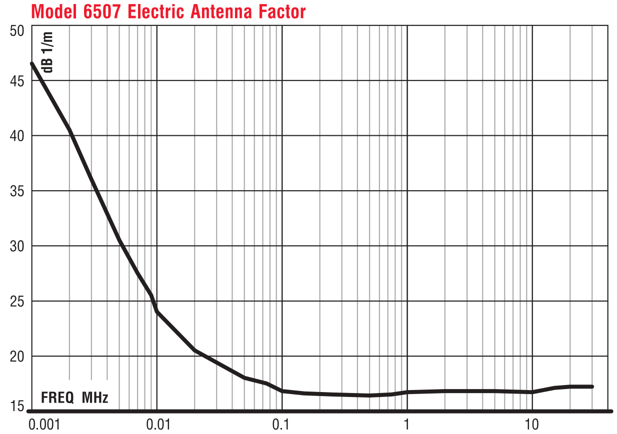
Model 6502 Electric Antenna Factor



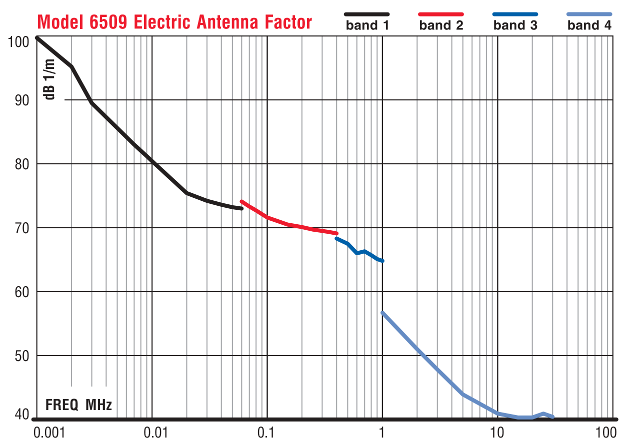
Model 6512 Electric Antenna Factor



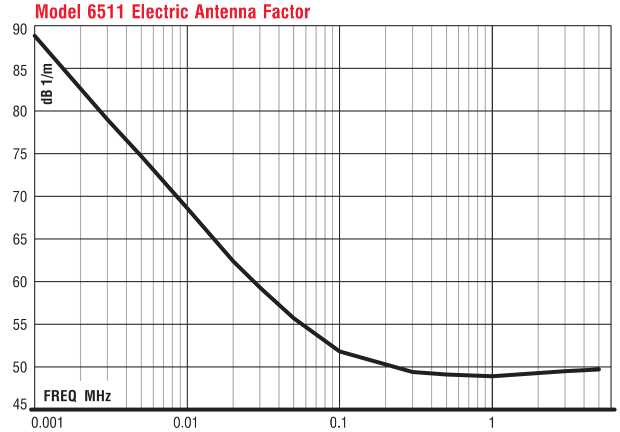
Model 6507 Electric Antenna Factor



Model 6509 Electric Antenna Factor



Model 6511 Electric Antenna Factor



Model 6509 Passive Loop

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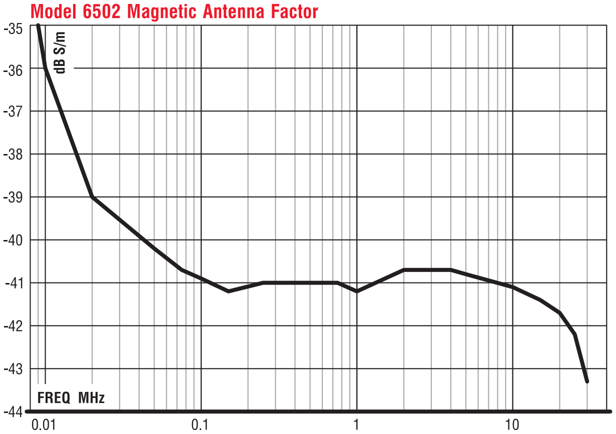
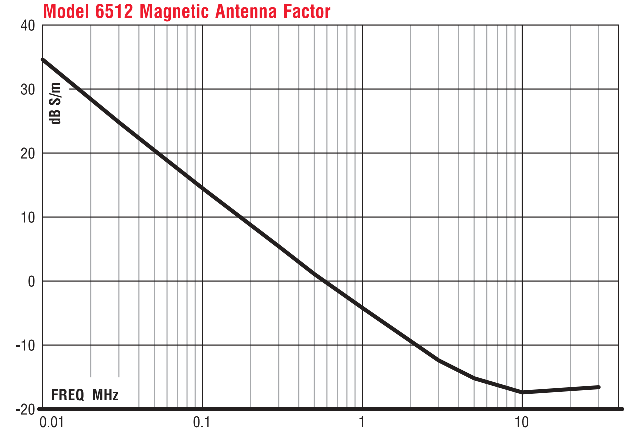
Models 6502, 6507, 6509, 6511, 6512 Technical Data

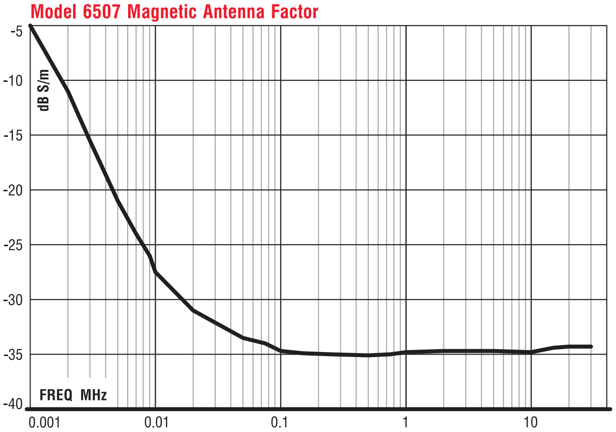
Model 6502 Magnetic Antenna Factor



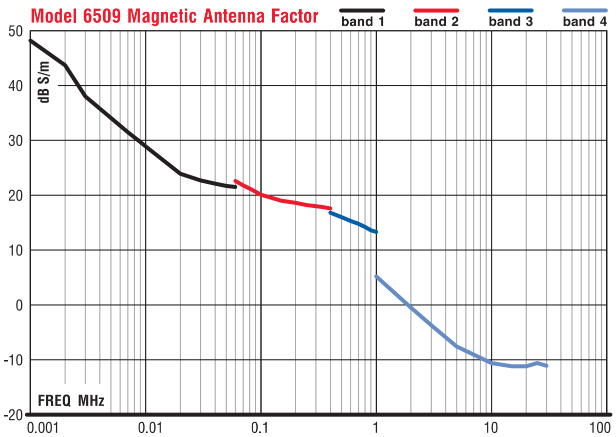
Model 6512 Magnetic Antenna Factor



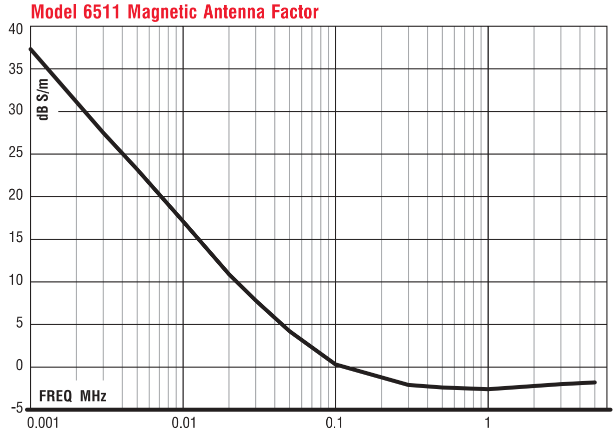
Model 6507 Magnetic Antenna Factor

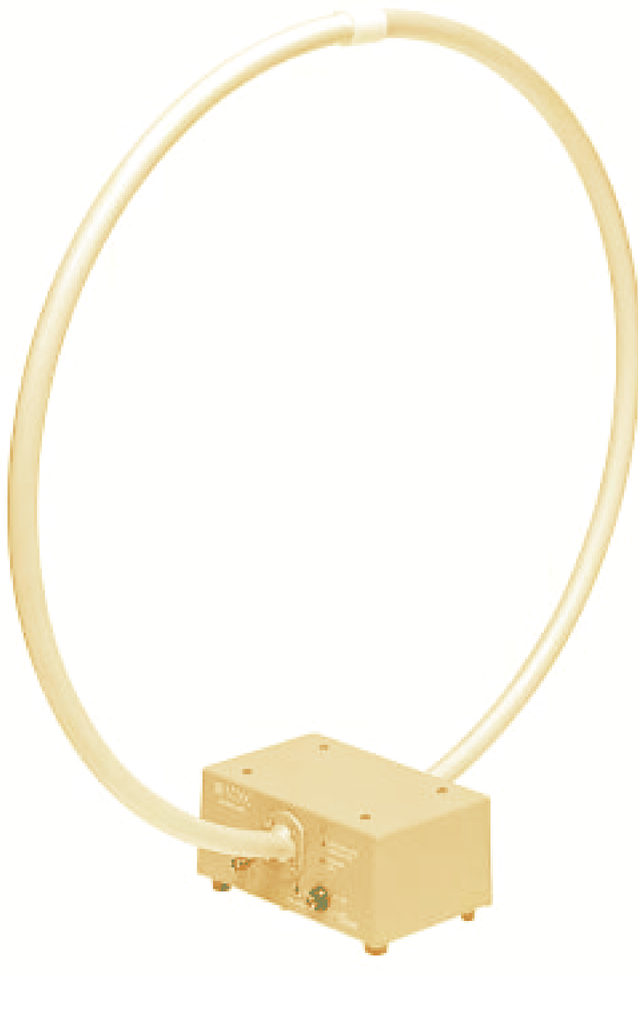


Model 6509 Magnetic Antenna Factor

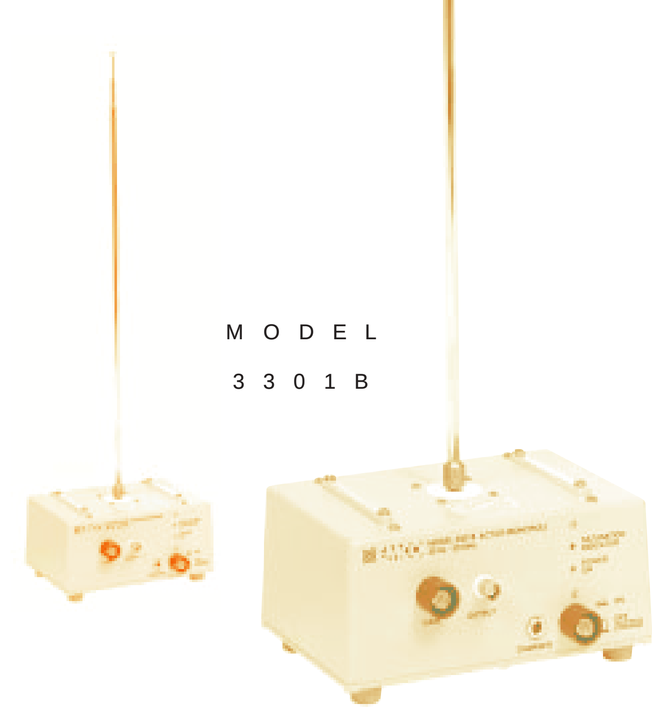


Model 6511 Magnetic Antenna Factor





Model 6502 Active Loop



Model 3301B
30 Hz – 50 MHz

Model 3303
1 kHz – 30 MHz

- Internal Attenuators to Increase Signal Strength
- Saturation Indicator to Prevent Electronic Damage
- Optional Remote Monitor Unit
- Quality Construction

Rod

EMCO'S ROD ANTENNAS are designed to provide a high level of efficiency in electric field measurements. Model 3301B has a frequency range of 30 Hz to 50 MHz and Model 3303 has a frequency range of 1 kHz to 30 MHz. Models 3301B and 3303 can be used separately, or as a cohesive testing unit for MIL-STD-285 and NSA 65-6 testing. These two models can be purchased together as a kit, known as the Model 3305.

Every rod antenna is individually calibrated in accordance with the equivalent capacitive substitution method (ECSM) and IEEE-291 methods using NIST traceable equipment. By knowing the actual antenna factors and performance characteristics of an antenna instead of typical data, you can more accurately calculate the field strength in your tests. Annual recalibration is recommended on rod antennas.

EMCO Rod Antenna Features

Saturation Indicator
Model 3301B contains a saturation indicator. If the indicator lights, the signal strength is exceeding the limit for the antenna. Without the use of internal attenuators the Model 3301B can receive signals up to 0.7 V/m before the saturation indicator lights.

Internal Attenuators
The Model 3301B's adjustable internal attenuators allow use of field strengths up to 22 V/m without damaging the internal active components of the antenna.

Optional Remote Unit
An optional remote monitor is available that allows you to view the power and saturation indicators from up to 10.0 m (32.8 ft) away. See "Options" for additional information.

Quality Construction
The base of both rod antennas is constructed of aluminum, providing both strength and portability. The receiving element is stainless steel. The mounting bases of these antennas accept standard 1/4 in x 20 threads of an EMCO tripod or most other tripods.

Choosing Your Model: Three Models with Frequency Ranges of 30 Hz to 50 MHz

Active Rod Antenna 30 Hz to 50 MHz
The Model 3301B is designed to provide reception of an electric field throughout its frequency range, in a single band, without tuning or bandswitching. The antenna factor 3 dB roll-off points are at 170 Hz and 35 MHz. Between 250 Hz and 20 MHz, the antenna factor is flat within ± 1dB. To prevent saturation by the low frequency signals, the lower 3 dB point is switch-selectable at 170 Hz, 1.9 kHz or 22 kHz. The Model 3301B is able to sense fields of +2 dB (µV/m) at 1 MHz with a 1 kHz bandwidth. Saturation will not occur below a field strength of 0.7 V/m resulting in an extremely wide dynamic range of 115 dB nominal at mid-band. Internal attenuators of 10 and 30 dB provide the ability to increase the upper limit of the antenna to 22 V/m, and boost dynamic range to 145 dB. The saturation indicator alerts you of the need to use the internal attenuators.

The Model 3301B consists of an adjustable rod, a counterpoise 61 cm x 61 cm (24 in x 24 in), a broadband high input impedance amplifier built into the base, and a battery charger (110 VAC/60 Hz or 220 VAC/50 Hz). The front panel contains controls and indicators for the internal amplifier. These controls and indicators include a power switch and power-on indicator, a receptacle for the battery charger, an isolated female BNC output connector, a gain control and a signal saturation indicator. Power is supplied by internal rechargeable sealed lead acid batteries.

Passive Rod Antenna 1 kHz – 30 MHz

The Model 3303 is a passive broadband electric field monopole transmitting antenna that has a frequency range of 1 kHz to 30 MHz. It features manual bandswitching between 0.001–5 MHz and 5 – 30 MHz. The maximum power handled by Model 3303 is 1 kW. The transmitting rod is stainless steel and is adjustable from 50.8 cm (20 in) to 104 cm (41 in). In normal test use, it is extended to 104 cm (41 in). The base is an aluminum housing which contains the bandswitching mechanism and a female Type N connector. The Model 3303 also may be used as a passive receive antenna.

Antenna Set 1 kHz – 30 MHz

Models 3301B and 3303 are sold separately, or as a set listed as Model 3305. Together these antennas are specifically designed to measure shielding effectiveness per MIL-STD-285 and NSA 65-6. The set operates from 1 kHz to 30 MHz. Maximum power required to measure the attenuation required by NSA 65-6 is 80 watts.

Standard Configuration

- Adjustable monopole element
- Antenna base:

  Model 3301B base has a built-in preamplifier and an isolated female BNC connector.

  Model 3303 base has a built-in manual bandswitching mechanism and Type N connector.
- Counterpoise
- Base drilled to accept EMCO or other tripod mounts with standard 1/4 in x 20 threads
- Batteries and battery charger (Model 3301B only)
- Individually calibrated per ECSM or IEEE Std. 291. Actual individual calibration factors and signed Certificate of Calibration Conformance included in Manual.

Options

Remote Monitor

A 10 meter (32.8 ft.) fiber optic Remote Monitor Option for remote display of power-on and Saturation indicators (Model 3301B only). (Part# 3301B-RM)

Battery Charger

A battery charger which is switch selectable for 115 VAC or 230 VAC operation is available for the Model 3301B only. The charger operates at 50 Hz or 60 Hz. (Part# 102615)

Custom Cases

Custom cases available on request.

EMCO Tripod

EMCO offers several nonmetallic, non-reflective tripods for use at EMC test sites.

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The passive rod antenna is electrically short, with an input capacitance of about 10 pF. To reduce the impedance mismatch to 50 ohms, typical designs have band-switched inductors which "tune-out" the capacitance. The EMCO active rod antenna solves this problem by using a high input impedance amplifier with a matched 50 ohm output. This approach results in the better matching and greater sensitivity of the active rod.

Remote Monitor Option

Applications

MODEL	CISPR/EC	SAE J1816	SAE J551	MIL-STD-461E	MIL-STD-285	NSA 65-6	NACSIM
3301B	RE	RE	RE	RE	RX	RX	RE
3303					TX	TX	

RE = Radiated Emissions TX = Transmit RX = Receive

Electrical Specifications

MODEL	FREQUENCY RANGE	MAXIMUM CONTINUOUS POWER	PEAK POWER	IMPEDANCE (NOMINAL)	CONNECTOR
3301B	30 Hz – 50 MHz	NA	NA	50 Ω	BNC female
3303	1 kHz – 30 MHz	300 W	1 kW	varies with freq[1]	Type N female

[1] Calibrated in 50 Ω system.

Physical Specifications

MODEL	BASE WIDTH	BASE DEPTH	BASE HEIGHT	ROD HEIGHT	WEIGHT
3301B	19.0 cm 7.5 in	12.0 cm 4.7 in	8.8 cm 3.5 in	50.8 – 104.0 cm 20.0 – 41.0 in	1.8 kg 4.0 lb
3303	7.6 cm 3.0 in	7.6 cm 3.0 in	15.2 cm 6.0 in	50.8 – 127.0 cm 20.0 – 50.0 in	1.3 kg 2.8 lb
Counterpoise	60.0 cm 24.0 in	60.0 cm 24.0 in	NA	NA	90.7 g 3.2 oz

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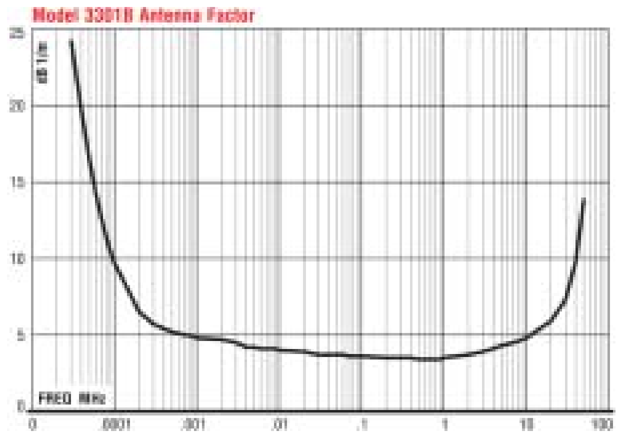
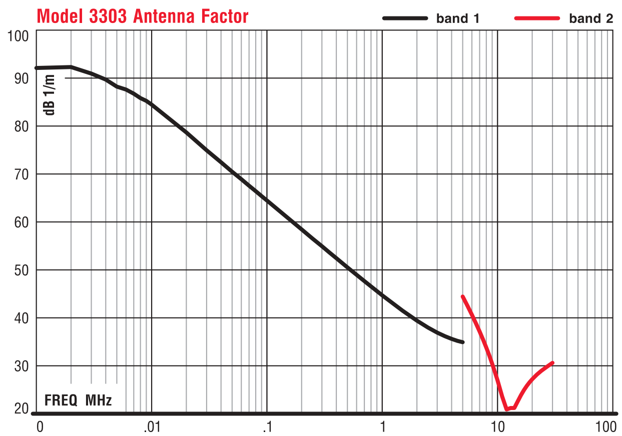
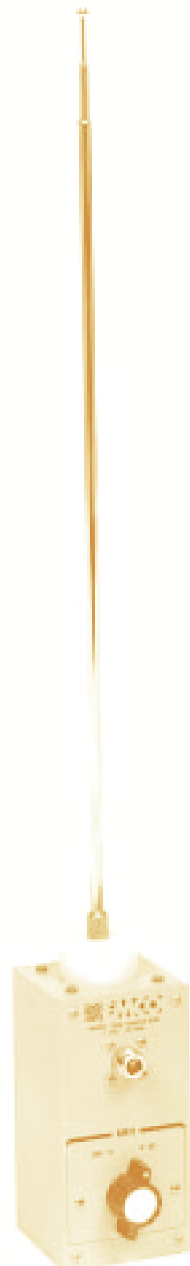
Models 3301B and 3303 Technical Data







Model 3303 Rod

MODEL 3101

Model 3101
200 MHz – 1 GHz

Model 3102
1 GHz – 10 GHz

Model 3103
100 MHz – 1 GHz

- Circular Polarization
- Extremely Low VSWR
- Compact Size
- Unique Applications
- Quality Construction

INDIVIDUALLY CALIBRATED · QUALITY ASSURANCE · TWO YEAR WARRANTY

Conical Log Spiral

EMCO'S BROADBAND CONICAL LOG SPIRAL ANTENNAS show minimal pattern change over their wide operating frequency range of 100 MHz to 10 GHz. All antennas in this series have moderate gain and low VSWR. Three models offer you a choice in size, frequency range, and polarization.

Once used exclusively for MIL-STD and SAE testing, conical log spiral antennas are effective for other types of measurements too. For example they can be used for close-in "quick-looks" to find the spectral characteristics of RF emissions. For immunity testing , conical log spirals generate reasonable field strengths with modest power input. By placing conical log spiral antennas in a vertical position with respect to the ground plane, they also can be used as omni-directional, horizontally polarized antennas for electromagnetic site surveys.

EMCO Conical Log Spiral Antenna Features

Circular or Linear Polarization

EMCO's conical log spiral antennas will receive both circular polarized and linear polarized fields (with a 3 dB variance for linear fields) under normal operating conditions.

Low VSWR

Average VSWR for the Model 3101 is 2.4:1. The Model 3102 averages a 1.6:1 VSWR and the Model 3103 averages 1.9:1 VSWR.

Compact Size

The compact size of EMCO's conical log spiral antennas makes them ideal for use in anechoic chambers and shielded enclosures where space is limited and proximity effects must be minimized.

Quality Construction

EMCO's conical log spiral antennas are made with spiral windings of coaxial cable attached to the outside of a fiberglass cone. Outside windings improve heat dissipation. This cone is attached to a delrin rod equipped with an aluminum base. The antenna mounting base accepts standard 1/4 in x 20 threads from an EMCO tripod or most other tripods.

Choosing Your Model: Three Models with Frequency Ranges of 100 MHz to 10 GHz

100 MHz to 1 GHz

The Model 3103 conical log spiral antenna is similar to Models 3101 and 3102 except that it has the lowest frequency range and it is largest in size. Length is 102.0 cm (40 in) diameter is 66.0 cm (26.0 in). The design is patterned on NASA drawings.

200 MHz to 1 GHz

The Model 3101 conical log spiral antenna was designed by the Department of Defense for MIL-STD-461E measurements. The original drawings provide the basis for our Model 3101. Length is 81.3 cm (32.0 in) and diameter is 33.0 cm (13.0 in).

1 to 10 GHz

The Model 3102 conical log spiral antenna is similar to the Model 3101 but has a higher frequency range and is smaller in size. Length is 38.1 cm (15 in) and diameter is 12.7 cm (5.0 in).

Standard Configuration

- Left-hand circular polarization
- Support rod
- Base drilled to accept EMCO or other tripod mount with standard 1/4 in x 20 threads
- Individually calibrated at 1 m per SAE ARP 958. Actual factors and a signed Certificate of Calibration Conformance included in Manual.

Options

Right-hand circular polarization
This option reverses the antenna windings for right-hand polarization.

Custom cases
Custom cases are available on request.

EMCO Tripod
EMCO offers several non-metallic, non-reflective tripods for use at EMC test sites.

f y i

The Conical Log Spiral antenna first came to the attention of the EMC community when it was listed as the preferred antenna for radiated emissions measurement in MIL-STD-826A, 20 Jan. 1964. At the time, this antenna was right-hand circularly polarized, following to the definitions in standards of the day. Per modern definitions, the original Model 3101 is left-hand circularly polarized (e.g. when observed along the direction of propagation, the rotation of the wave is counterclockwise, while the wave is left-hand circularly polarized). By modern definitions, EMCO's optional Model 3101L is right-hand circularly polarized. The current model numbers remain unchanged for reasons of continuity, but the description of their performance has changed to reflect modern definitions.

Applications

MODEL	SAE J1113	MIL-STD-461E	MIL-STD-1541
3101[1]	RI	RE, RI	RE
3102[1]	RI	RE, RI	RE
3103[1]	RI	RE, RI	RE

RE = Radiated Emissions RI = Radiated Immunity (Susceptibility)

Electrical Specifications

MODEL	FREQUENCY RANGE	VSWR RATIO (AVG)	MAXIMUM CONTINUOUS POWER	PEAK POWER	IMPEDANCE	CONNECTOR
3101[1]	200 MHz – 1 GHz	2.4:1	100 W	150 W	50 Ω	Type N female
3102[1]	1 GHz – 10 GHz	1.6:1	50 W	100 W	50 Ω	Type N female
3103[1]	100 MHz – 1 GHz	1.9:1	100 W	150 W	50 Ω	Type N female

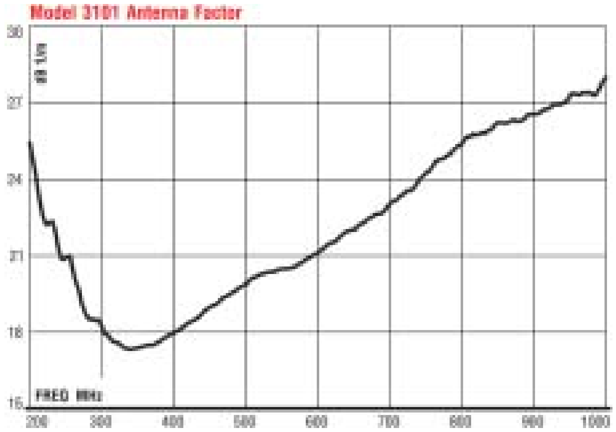
Physical Specifications

MODEL	DEPTH	DIAMETER	WEIGHT
3101[1]	81.3 cm 32.0 in	33.0 cm 13.0 in	4.5 kg 10.0 lb
3102[1]	38.1 cm 15.0 in	12.7 cm 5.0 in	3.6 kg 8.0 lb
3103[1]	102.0 cm 40.0 in	66.0 cm 26.0 in	10.0 kg 22.0 lb

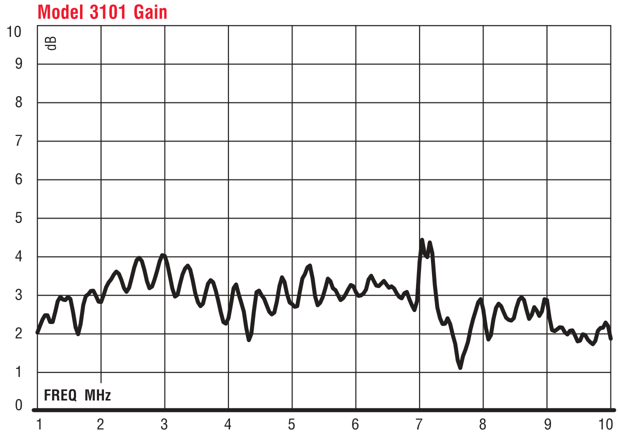
[1] Speciality Item. Call EMCO for lead time and pricing.

Model 3101 Technical Data

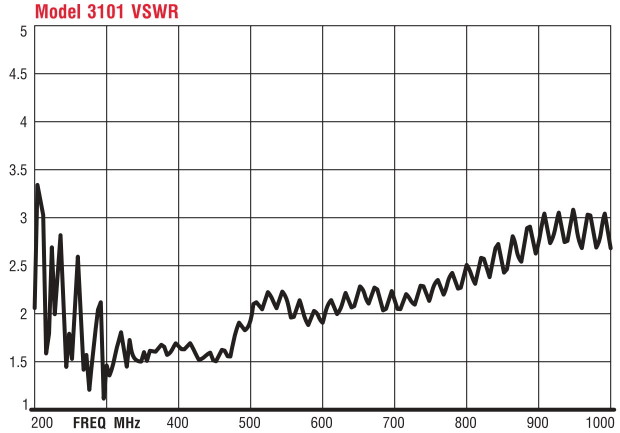
Model 3101 Antenna Factor



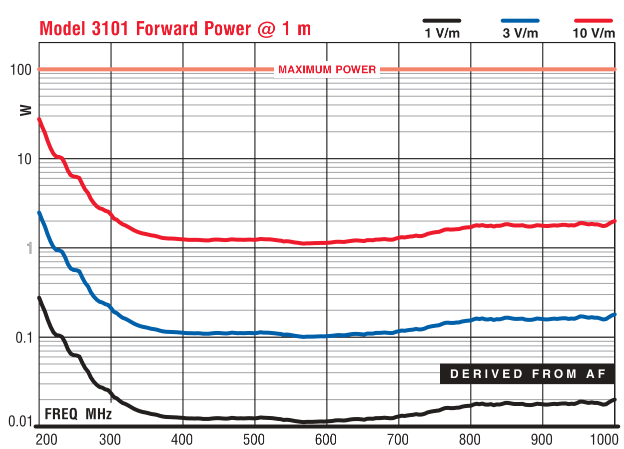
Model 3101 Gain



Model 3101 VSWR

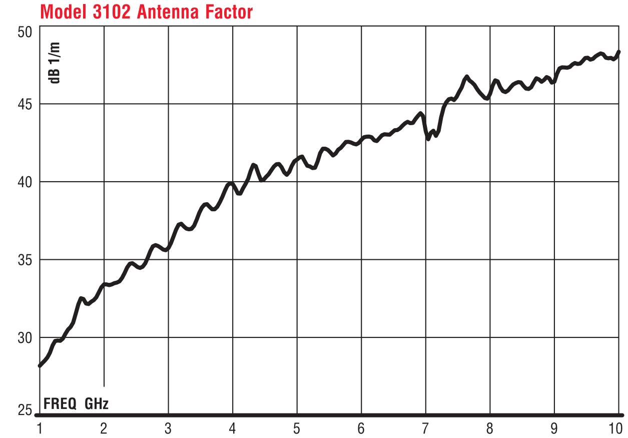


Model 3101 Forward Power @ 1 m

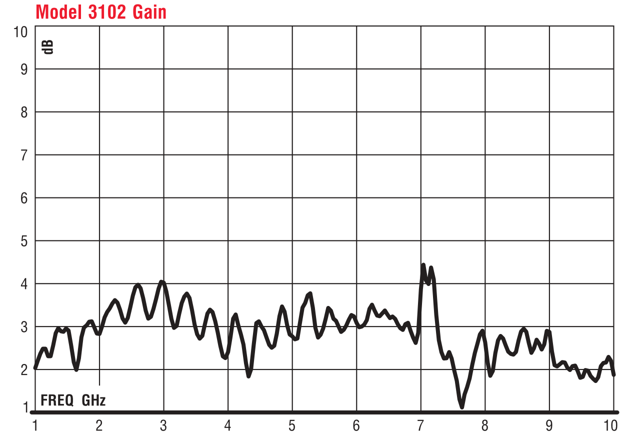


Model 3102 Technical Data

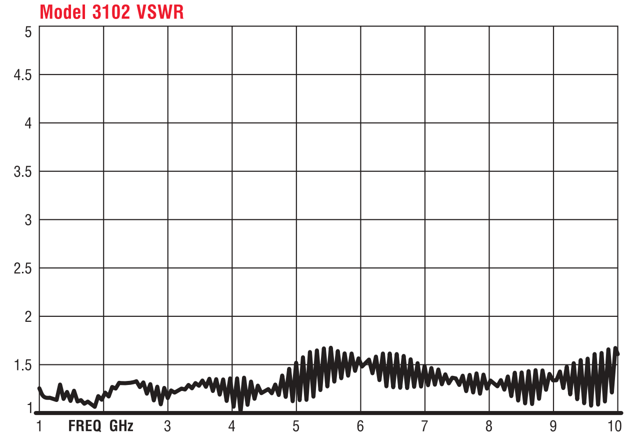
Model 3102 Antenna Factor



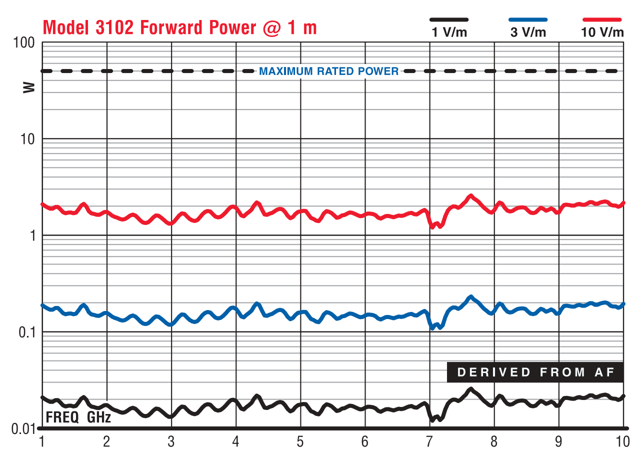
Model 3102 Gain



Model 3102 VSWR



Model 3102 Forward Power @ 1 m



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Fax +358.2.865.1233

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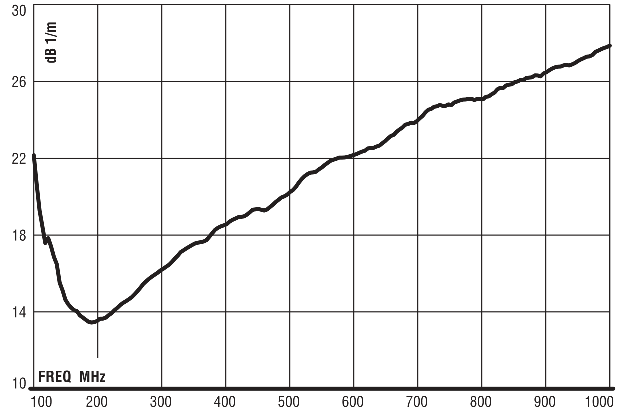
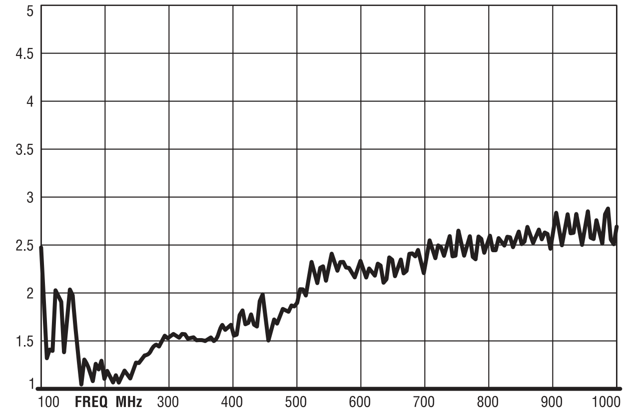
SINGAPORE:
Tel +65.536.7078
Fax +65.536.7093

ONLINE:
info@ets-lindgren.com
www.ets-lindgren.com

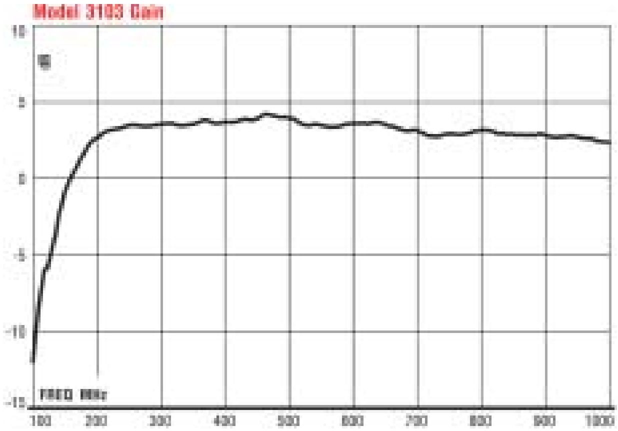
Model 3103 Antenna Factor



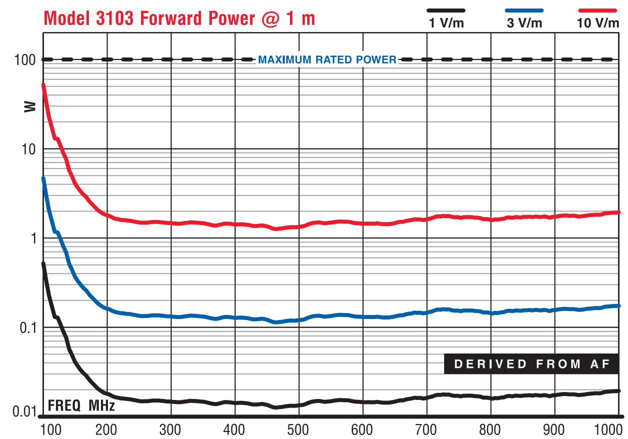
Model 3103 VSWR



Model 3103 Gain



Model 3103 Forward Power @ 1 m



Model 3103 Conical Log Spiral

Model 3102 Conical Log Spiral

MODEL 6505

H-Field Kit

Model 3305
1 kHz – 30 MHz

Model 6505
1 kHz – 30 MHz

- Matched for Performance
- Specially Priced

INDIVIDUALLY CALIBRATED · QUALITY ASSURANCE · TWO YEAR WARRANTY

E & H Field Shielding Effectiveness Test Kits

EMCO E & H FIELD SHIELDING EFFECTIVENESS TEST KITS offer a convenient and economical approach to having the antennas needed for MIL-STD 285 and NSA 65-6 shielding effectiveness testing. Each set is the pairing of an active and passive loop or rod to create a matched kit for a particular test. Active antennas include a battery charger which is switch selectable for 115 VAC or 230 VAC operation. The charger operates at 50 Hz or 60 Hz.

Choosing Your Kit: 2 Kits for Shielding Effectiveness

E-Field Shielding Effectiveness 1 kHz to 30 MHz
The Model 3305 is a set of rod antennas consisting of one Model 3301B active rod antenna with counterpoise and battery charger, and one Model 3303 passive rod antenna. The kit allows you to perform MIL-STD 285 and NSA 65-6 testing.

H-Field Shielding Effectiveness 1 kHz to 30 MHz
The Model 6505 is a set of loop antennas consisting of one Model 6507 active loop antenna with battery charger, and one Model 6509 passive rod antenna. The kit allows you to perform MIL-STD 285 testing.

tech tip

Several standards address shielding effectiveness testing. One of the best to follow however, is IEEE 299. This standard gives information regarding leakage path limitations for maximum shielding effectiveness values.

Standard Configuration

- Matched pair of antennas with battery chargers (Model 3305 includes counterpoise)
- Rods individually calibrated per ECSM IEEE Std 291. Loops individually calibrated per IEEE Std 291. Actual individual calibration factors and signed Certificate of Calibration Conformance included in Manual.

USA: Tel +1.512.531.6400 Fax +1.512.531.6500
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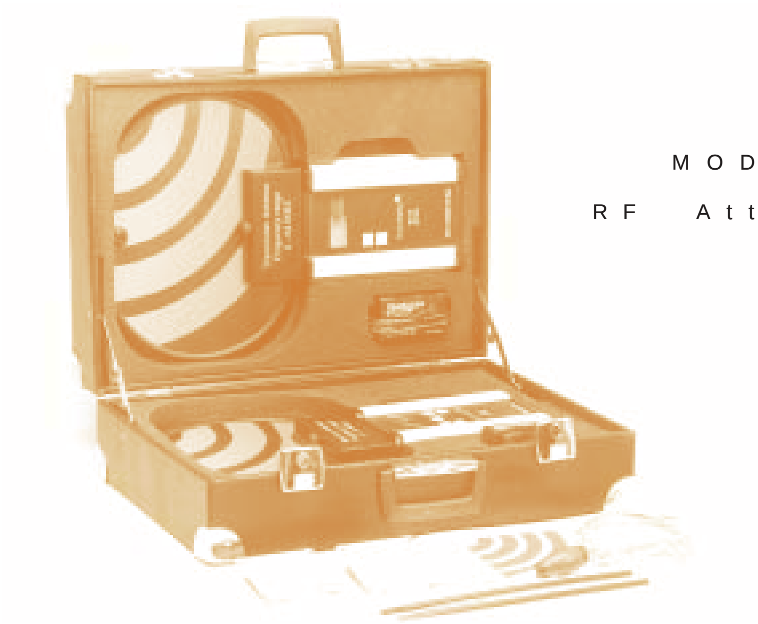
ONLINE: info@ets-lindgren.com www.ets-lindgren.com



MODEL MF-130D

RF Attenuation Meter

- Digital RF Attenuation Meter/RF Leak Detector
- Choice of Either Low Frequency (10 kHz, 156 kHz, 1 MHz, and 10 MHz) or High Frequency (8 MHz, 16 MHz, 32 MHz and 64MHz) Measurement Sets
- Stores Up to 63 Attenuation Levels at Each Frequency

THE MODEL MF-130D RF ATTENUATION METER, manufactured by Euroshield, simplifies shielded enclosure performance verification. Measurements can be performed at the following eight frequencies: 10 kHz, 156 kHz, 1 MHz, 8 MHz, 10 MHz, 16 MHz, 32 MHz and 64 MHz. Applications include MIL-STD-285, NSA 65-6 and IEEE STD-299.

The Model MF-130D consists of a portable, NiCad battery-operated transmitter and receiver. Frequency and attenuation calibration is automatically controlled by a microprocessor. The receiver is equipped with an LCD-display which shows the attenuation in dB at the normal operational mode. An alarm activates when the attenuation is less than the selected level at the preset limit mode.

Users can save 63 attenuation levels at each frequency and computer-download these values through a RS-232 serial connection. Windows™ compatible diskettes are provided for storage and review of the data.

Standard Configuration

- One transmit and one receive unit
- Primary antenna set in either low frequency or high frequency range
- Two battery chargers
- Software to download test data
- Carrying case

Options

- Secondary antenna set in either low frequency or high frequency range

Windows is trademark of Microsoft Corporation

Electrical Specifications

MODEL	FREQUENCIES	DYNAMIC RANGE	ATTENUATION ACCURACY	OUTPUT POWER	MEMORY	POWER SUPPLY
MF-130D	All Eight	MIL-STD 285 120 dB	+/- 2 dB	2 W max.	63 locations per freq.	6 X 1.2 V NiCd battery
		NSA 65-6 130 dB				
		IEEE STD 299 130 dB				

Physical Specifications

MODEL	WIDTH	DEPTH	HEIGHT	WEIGHT
MF-130D Case	53.0 cm	19.0 cm	39.0 cm	10.6 kg

Antenna Mounts and Tripods

Selection Table

MODEL	DESCRIPTION	PAGE	100989	102108	100733	101942B	105861B	106102
3101	Conical Log Spiral	56-59			S	S		
3102	Conical Log Spiral	56-59				S		
3103	Conical Log Spiral	56-59				S		
3104C	Biconical	10-17		S	O	O	S	O
3109	Biconical	10-17						O
3110B	Biconical	10-17		S	O	O	S	O
3121C	Dipole	40-43		S	O	O	S	O
3140	BiConiLog	4-9	S		O	O	S	
3142B	BiConiLog	4-9	S		O	O	S	
3144	Log Periodic	20-25	S		O	O	S	
3147	Log Periodic	20-25	S		O	O	S	
3148	Log Periodic	20-25	S		O	O	S	

S **STANDARD EQUIPMENT**
Included with antenna

O **OPTIONAL EQUIPMENT**
Order separately; not included with antenna

EMCO Model 4-TR Tripod

EMCO Model 7-TR Tripod (replaces Model 6-TR)
Especially suited for Model 3106, 3140 and 3142B

Model 7-TR
Standard Configuration

Model 7-TR/POL-MANUAL
Manual Polarization

Model 7-TR/POL-PNEUMATIC
Pneumatic Polarization

Model 7-TR/POL-3106
Specifically designed for the EMCO Model 3106 antenna
Consists of a mounting plate and an extended boom to allow 1 m center axis distance from the ground plane for both horizontal and vertical orientation

USA: Tel +1.512.531.6400 Fax +1.512.531.6500
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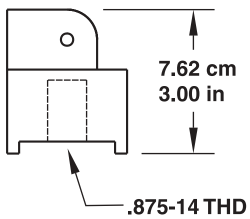
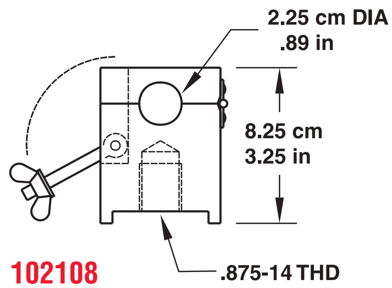
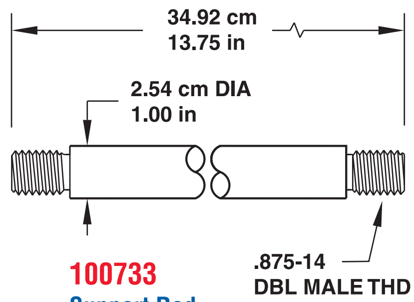
ONLINE: info@ets-lindgren.com www.ets-lindgren.com



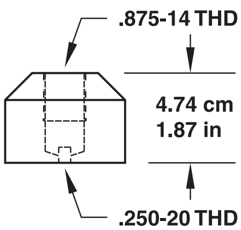
100989
Log Periodic Antenna Adaptor



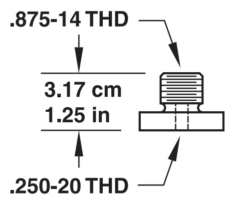
102108
Clamp Block



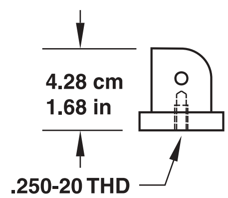
100733
Support Rod



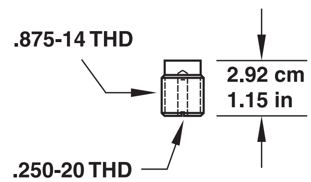
101942B
Support Base



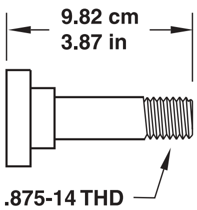
101938
Antenna Mount

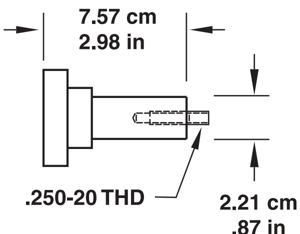


101939C
Antenna Mount

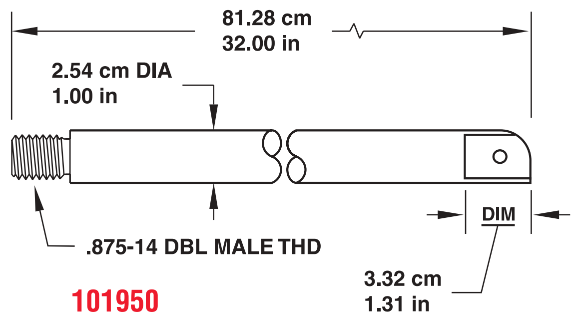


105861B
Thread Insert

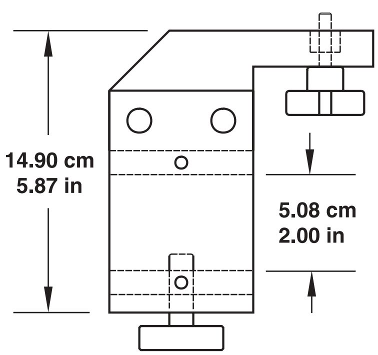




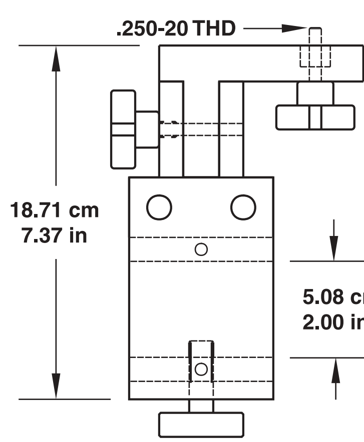
104136 **104169**
Boom Antenna Mount Knobs
Included with Tripod Model 6-TR
(Also used with EMCO Tower Models 2070, 2071 & 2075)



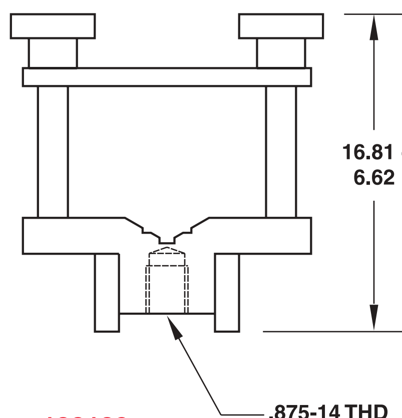
101950
Support Rod



101913
Fixed Antenna Mount
includes 101938 and 101939C
for mounting on 2" x 2" Cross Boom



101937
Swivel Antenna Mount
includes 101938 and 101939C
for mounting on 2" x 2" Cross Boom



106102
Universal Antenna Mount
for use with non-EMCO antennas

Cable Specifications

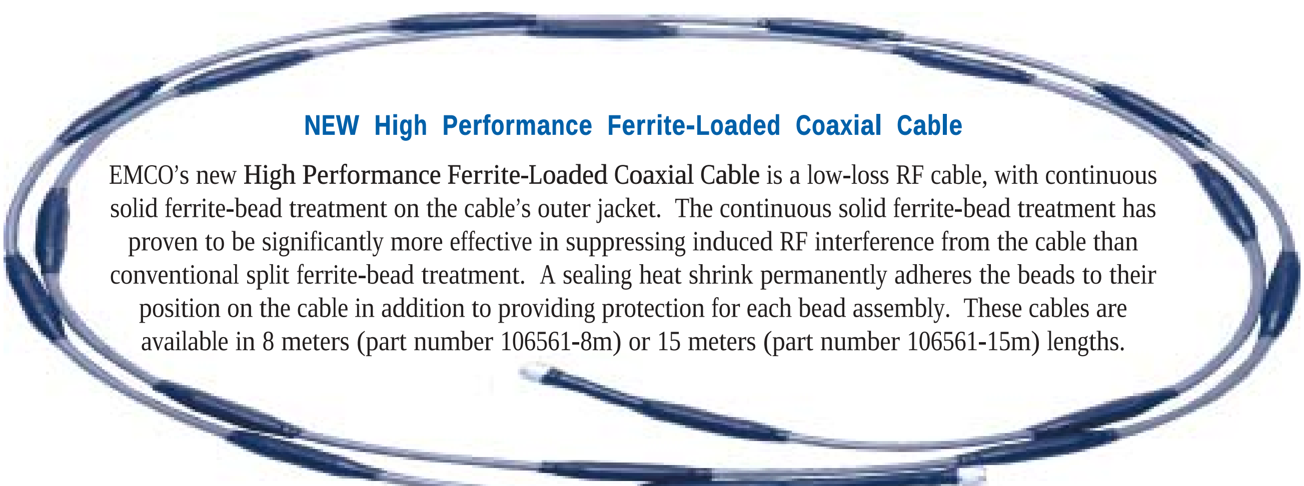
Cable Lengths and Connection

DESCRIPTION	CONNECTOR	LENGTH	EMCO PART #
BNC to N adapter	BNC to N	3.10 cm 1.25 in	514018
RG-214/U	Type N male	3.00 m 10.00 ft	106044-10
		6.00 m 20.00 ft	106044-20
		10.00 m 32.80 ft	106044-10M
		20.00 m 66.00 ft	106044-20M
		30.00 m 99.00 ft	106044-30M
RG-223/U	BNC male	3.00 m 10.00 ft	106043-10
		6.00 m 20.00 ft	106043-20

EMCO offers these standard lengths of coaxial antenna cable. Custom lengths are available on request.

Cable Power and Loss

	RG-214/U		RG-223/U		RG-393	
Frequency	Max Pwr Handling Avg Input Pwr	Nominal Loss per 30.5 m (100 ft)	Max Pwr Handling Avg Input Pwr	Nominal Loss per 30.5 m (100 ft)	Max Pwr Handling Avg Input Pwr	Nominal Loss per 30.5 m (100 ft)
10 MHz	2,700 W	.66 dB	1700 W	1.2 dB	25,000 W	.6 dB
50 MHz	1,120 W	1.50 dB	700 W	3.2 dB	9,500 W	1.4 dB
100 MHz	780 W	2.30 dB	480 W	4.8 dB	6,300 W	2.1 dB
200 MHz	550 W	3.30 dB	320 W	7.0 dB	4,300 W	3.1 dB
400 MHz	360 W	5.00 dB	215 W	10.0 dB	2,800 W	4.5 dB
1,000 MHz	200 W	8.80 dB	120 W	16.5 dB	1,700 W	7.5 dB
3,000 MHz	100 W	18.00 dB	60 W	30.5 dB	880 W	14.0 dB
5,000 MHz	60 W	27.00 dB	40 W	46.0 dB	620 W	21.0 dB
10,000 MHz	37 W	47.00 dB	10 W	85.0 dB	280 W	31.1 dB



NEW High Performance Ferrite-Loaded Coaxial Cable

EMCO's new High Performance Ferrite-Loaded Coaxial Cable is a low-loss RF cable, with continuous solid ferrite-bead treatment on the cable's outer jacket. The continuous solid ferrite-bead treatment has proven to be significantly more effective in suppressing induced RF interference from the cable than conventional split ferrite-bead treatment. A sealing heat shrink permanently adheres the beads to their position on the cable in addition to providing protection for each bead assembly. These cables are available in 8 meters (part number 106561-8m) or 15 meters (part number 106561-15m) lengths.

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SINGAPORE: Tel +65.536.7078 Fax +65.536.7093
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Recalibration Selection

Recalibration - Quick Selection Guide

Model	Distance			Standard Polarization	Impedance	Insertion Loss	Transfer Impedance
	1 Meter	3 Meter	10 Meter				
BiConiLog (3142B)	●	●	●	H			
Biconical	●	●	●	H			
Log Periodic	●	●	●	H			
Standard Gain & Octave Horn	●			H			
Double Ridged Waveguide Horn	●			Model 3106- V All other models - H			
Tuned Dipole		●	●	H			
Loop	●			-			
Rod	●			-			
Conical Log Spiral	●			-			
LISN				-	●	●	
Current Probes				-			●

The above guide shows standard calibration services. Please contact EMCO for custom calibrations.

Annual Recalibration is Recommended

To ensure reliable and repeatable long-term performance, annual recalibration of your antennas by EMCO's experienced technicians is recommended. Our staff can recalibrate almost any type or brand of antenna. If you need a calibration for an antenna or equipment not listed, contact us and we will give you a quote for a custom calibration. Please call to receive an RMA number prior to sending an antenna to us for calibration.

Calibration Services from EMCO include:

- Expert Calibration for any brand of EMC antenna
- The industry's only A2LA accredited EMC antenna calibration site
- Cutting edge test equipment and software for superior calibration accuracy
- NIST traceable equipment and ISO 9000 compliance processes
- Online access to conveniently place and track orders 24 hours a day, 7 days a week
- Fastest average turnaround time of 3-5 days
- Option for EMCO product repair, rush delivery and data on disk
- Exceptional customer service with prompt, attentive response

ACCREDITED
www.a2la.org

We calibrate non-EMCO products.
Call or click for a quote.

Unsurpassed Calibration Services From the Industry's Testing Leader

Recognized as the industry leader, ETS-Lindgren is the largest and longest-established EMC antenna calibration service in the world. We have provided comprehensive calibration services for customers around the globe since 1953. And who better to calibrate antennas than a highly successful antenna manufacturer? By offering superior accuracy and maximum convenience, We continue to solidify our position as a world-class resource for EMC antenna calibration.

Comprehensive Services

We provide calibration services for all brands of EMC antennas, as well as isotropic field probes, current probes, absorbing clamps, LISNs, attenuators, RF cables, and a wide range of other test equipment. With fast, dependable repair services, we can also restore its own products to like-new condition if needed.

Once calibration is complete, equipment is promptly returned to customers with a full report including test data, uncertainty values and a signed Certificate of Conformance. As a convenience, most data is available on diskette in Excel format for a nominal fee.

Higher Calibration Accuracy

Featuring the industry's only A2LA-accredited calibration site, we deliver a higher level of calibration accuracy than any other resource. Thanks to ISO 9000 processes and NIST-traceable equipment, customers also enjoy complete confidence that their equipment will meet applicable industry standards.

But our most significant competitive advantage can be found in the advanced test equipment and proprietary software used to automate and enhance the calibration process. For example, the high-end vector network analyzers used for many of the calibrations provide continuous frequency response traces of up to 1601 points. Add this to their superior linearity and external signal rejection in comparison to the typical signal/tracking generator/spectrum analyzer combination, and it's clear why we can deliver superior accuracy every time. When the data is delivered on diskette, the increased number of frequency points available reduces interpolation error, resulting in lower measurement uncertainties.

On-line Convenience

By visiting our web site, customers can access the company's tremendous calibration expertise around the clock. Even in the middle of the night, they can go online to instantly obtain cost estimates, place their orders, and receive RMA numbers. Then they simply ship their antennas for calibration. Online tracking further helps customers stay connected with their order.

Fast Response

Typically completing service in 3-5 business days, we maintain the fastest calibration turnaround time in the industry. As an option, we even offer expedited calibration in just 48 hours. Customers also know that weather-related service delays are vastly minimized when they choose us, since our test site is located in the sunny, dry climate of Austin, Texas.

Competitive Pricing

Always working to better support its customers with maximum value, we takes pride in offering exceptional services with competitive pricing.

USA: Tel +1.512.531.6400 Fax +1.512.531.6500
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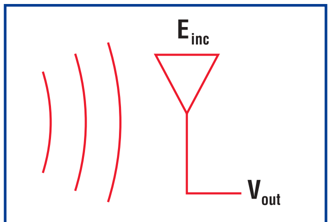
Common EMC Measurement Terms

According to Krause[1], “A *radio* antenna may be defined as the structure associated with the region of transition between a guided wave and free space, or vice versa”. The EMC test community uses specialized versions of *radio* antennas for measuring electric and magnetic field amplitudes over a very broad frequency spectrum.

EMC test engineers must perform very precise measurements. Sometimes the terms used in describing these measurements can be confusing. This section describes the meaning of some of these terms.

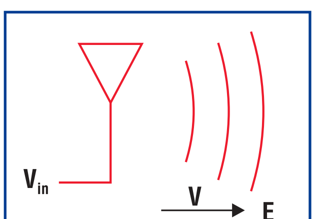
Antenna Factor



$E(dB\mu V/m)=V(dB\mu V)+AF(dBm^{-1})$

This is the parameter of an EMC antenna that is used in the calculations of field strength during radiated emissions measurement. It relates the voltage output of a measurement antenna to the value of the incident field producing that voltage. The units are volts output per volt/meter incident field or reciprocal meters. As can be seen in the derivations, the analytical expression for Antenna Factor (AF) has the equivalent of frequency in the numerator, thus AF will typically increase with increasing frequency. EMCO antennas used for radiated emissions testing are individually calibrated (the AF is directly measured) at all appropriate measurement distances. The calibrations produce values that are defined as the “equivalent free space antenna factor”. This antenna factor is measured by EMCO using the three antenna measurement method over a ground plane. The calibration procedure corrects for the presence of the reflection of the antenna in the ground plane, giving the value that would be measured if the antenna were in “free space”. The typical antennas used for measurements are broadband antennas such as BiConiLog™ and log periodic antennas. In case of any disagreement, a “reference antenna”—a tuned resonant dipole—is considered to be the arbiter for measurement purposes.

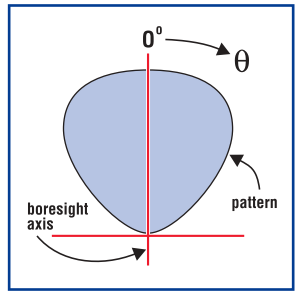
Transmit Antenna Factor



$EdB(V/m)=V_m(dBV)+TAF(dBm^{-1})$

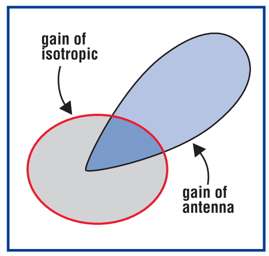
The Transmit Antenna Factor (TAF) is similar to the AF in that it describes the performance of an EMC antenna over its frequency range of operation. This parameter relates the E-field produced by an antenna, at a given distance, to the input voltage at the input terminals of the antenna. The units are volts/meter produced per volt of input, so the final units are reciprocal meters just as the AF. The AF and TAF are not the same nor are they reciprocal, though the AF and TAF can be computed from each other. The expressions for these computations may be found in the section “Antenna Terms and Calculations”. The TAF is **not** a direct function of frequency, but it is a function of distance.

Antenna Pattern



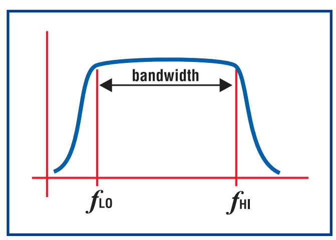
The antenna pattern is typically a polar plot of the relative response of an antenna as a function of viewing angle. The “on-axis” viewing angle where the response of the antenna is a maximum is called “the boresight axis”. The pattern shows the response of the antenna as the viewing angle is varied. Typically, simple antennas exhibit a “dipole response” where the pattern of the antenna is donut shaped with the dipole on the common axis of the donut. More complex antenna patterns are approximately pear shape with the bottom of the pear facing away from the antenna.

Gain



The gain of the antenna is a parameter that describes the directional response of the antenna compared to an isotropic source, a theoretical antenna that radiates the same amount in all directions. The higher the gain, the better the antenna concentrates its beam in a specific direction. The simple example is a light bulb compared to a flashlight. The flashlight, with its reflector, concentrates the light in one direction, where the light bulb produces light in all directions.

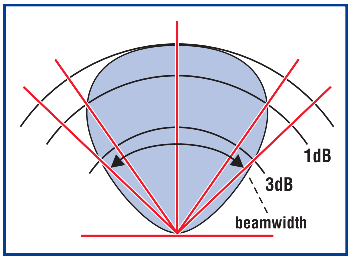
Bandwidth



The bandwidth of an antenna is the operating frequency range of the antenna and is expressed in MHz.

Typical EMC antennas will have a ratio of upper useful frequency to lowest useful frequency on the order of 5 to 1. Some unique designs provide ratios of as much as 25 to 1. This ratio is a dimensionless ratio, i.e., it has no units.

Beamwidth



This parameter is the descriptor of the viewing angle of the antenna, in the plane of measurement, typically where the response has fallen to one half the power received when the antenna is perfectly aligned. EMC antennas are normally designed to provide a viewing angle in the primary plane, approaching 60° between the half power points where the response of the incident is 3 dB down, if at all possible. The only specific requirements are found in IEC 801 - 3 and IEC 1000 - 4 - 3, which, if the analysis of the requirement is performed, translates into a minimum viewing angle of 28 ° (± 14 °) at the 1 dB down points. The 1 dB down response is usually compatible with the 3 dB down value of 60 °.

Reflection Coefficient

The voltage reflection coefficient, typically ρ, is the ratio of the voltage reflected from the load of a transmission line to the voltage imposed on the load of the same transmission line. Its values vary from zero to one. When the load impedance is "matched" to the source impedance (has the same value), and the characteristic impedance of the transmission line, then the reflection coefficient is quite small (no reflection), approaching zero. When there is "mismatch" (the load impedance differs from the characteristic impedance) the reflection coefficient can approach one (almost all incident power is reflected).

The reflection coefficient is usually determined by a measurement of the Voltage Standing Wave Ratio.
It is then computed from:

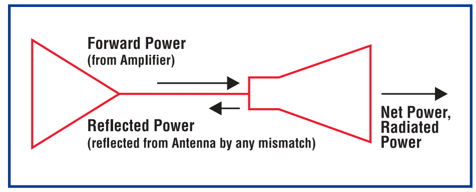
$$|\rho| = \frac{(VSWR-1)}{(VSWR+1)}$$

VSWR

The Voltage Standing Wave Ratio (VSWR) is a measure of the mismatch between the source and load impedances. Numerically, it is the ratio of the maximum value of the voltage measured on a transmission line divided by the minimum value.

When the value is high, most of the power delivered from a generator is reflected from the antenna (load) and returned to the generator. The amount of power not reflected is radiated from the antenna. This means that the generator rating for an antenna with a high VSWR can be quite high. Users should choose an antenna with a low VSWR when possible. As a practical matter, this may not always be possible, particularly at lower frequencies.

RF Power Terms As Applied To Antennas



There are several ways of discussing RF power as used to excite antennas for the generation of electromagnetic fields. This set of related definitions is provided to understand the definitions as used in this catalog.

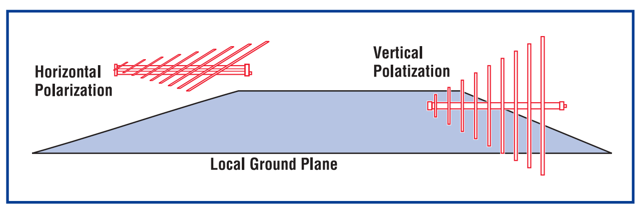
Forward Power — The output from an amplifier that is applied to an antenna input to generate an electromagnetic field.

Reflected Power — When mismatch exists at the antenna port, a fraction of the power applied (the forward power), is reflected from the antenna back toward the amplifier. This is termed the reflected power.

Net Power — The power applied to the antenna that is actually radiated is called the net power or radiated power. It is the difference between the forward power and the reflected power. Usually, this value cannot be directly measured, but is computed from the direct measurement of forward and reflected power by taking the difference:

$$P_{net}(W) = P_{forward}(W) - P_{reflected}(W)$$

In this catalog the Net Power is the power value that is required as an input to an antenna to generate a specific E-field level.



Polarization

The orientation of the measurement axis of a linearly polarized antenna with respect to the local ground plane. Vertical polarization occurs when the measurement axis of the antenna is perpendicular to the local ground plane. Horizontal polarization occurs when the measurement axis is parallel to the local ground plane. Most EMC test specifications require measurements in both vertical and horizontal polarizations of the measurement antenna.

[1] John D. Krause, Ph.D., Antennas, McGraw-Hill, New York, 1950, p. 1.

Antenna Calculations

1 Definition of Antenna Factor

This term is traditionally tied to the recieve antenna factor, the ratio of field strength at the location of the antenna to the output voltage across the load connected to the antenna.

.❶ $$AF = \frac{E}{V}$$

where:

AF = Antenna Factor, meters $^{-1}$
E = Field Strength, V/m or µV/m
V = Load Voltage, V or µV

Converting to dB (decibel) notation gives:

.❷ $$AF_{dB(m^{-1})} = 20 \log \left(\frac{E}{V} \right)$$

or:

.❸ $$AF_{dB(m^{-1})} = E_{dB(V/m)} - V_{dB(V)}$$

The antenna factor is directly computed from:

.❹ $$AF = \frac{9.73}{\lambda \sqrt{g}} \ (m^{-1})$$

where:

λ = Wavelength (meters)
g = Numeric Gain

In the same sense, for magnetic fields, as seen by loop antennas:

.❺ $$AF_{H\,dB(S/m)} = H_{dB(A/m)} - V_{dB(V)}$$

In terms of flux density (B-Field):

.❻ $$AF_B = AF_H + 20 \log (\mu)$$

.❼ $$AF_B = AF_H - 118, \ T/V$$

Loop antennas are sometimes calibrated in terms of equivalent electric field, where:

.❽ $$AF_{E\,dB(m^{-1})} = AF_{H\,dB(S/m)} + 20 \log \eta$$

.❾ $$AF_{E\,dB(m^{-1})} = AF_{H\,dB(S/m)} + 20 \log (120\,\pi), \text{ or}$$

$$= AF_{H\,dB(S/m)} + 51.5 \text{ dB}$$

where:

η = the Impedance of Free Space
$= 120\,\pi \ \Omega$

2 Conversion of Signal Levels from mW to µV in a 50Ω System

Voltage and power are equivalent methods of stating a signal level in a system where there is a constant impedance. Thus:

.❶ $$P = \frac{V^2}{R}$$

where:

P = Power in Watts
V = Voltage Level in Volts
R = Resistance Ω

For power in milliwatts (10^{-3} W), and voltage in microvolts (10^{-6} V),

.❷ $$V_{dB(\mu V)} = P_{dBm} + 107$$

3 Power Density to Field Strength

An alternative measure of field strength to electric field is power density:

.❶ $$P_d = \frac{E^2}{120\,\pi}$$

where:

E = Field Strength (V/m)
P = Power Density (W/m²)

Common Values:

E	P_D
200 V/m	10.60 mW/cm²
100 V/m	2.65 mW/cm²
10 V/m	26.50 µW/cm²
1 V/m	0.265 µW/cm²

4 Power Density at a Point

.❶ $$P_d = \frac{P_t G_t}{4\,\pi\, r^2}$$

In the far field, where the electric and magnetic fields are related by the impedance of free space:

P_d = Power Density (W / m²)
P_t = Power Transmitted (W)
G_t = Gain of Transmitting Antenna
r = Distance from Antenna (meters)

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5

Friis Transmission Formula

The Friis Transmission formula describes Power received by an antenna in terms of power transmitted by another antenna:

.❶ $$P_r = \frac{P_t G_t G_r \lambda^2}{(4 \pi r)^2}$$

where:

P_r = Power Received (W)

P_t = Power Transmitted (W)

G_r = Numeric Gain of Receiving Antenna

G_t = Numeric Gain of Transmitting Antenna

r = Separation Between Antennas (meters)

λ = Wavelength (meters).

6

Electric Field vs Power Transmitted (Far Field)

The electric field strength at a distance from a transmitting antenna such that the electric and magnetic field values are related by the impedance of free space is:

.❶ $$E_{V/m} = \frac{\sqrt{30 P_t G_t}}{r}$$

where the terms are as defined above.

For simple radiating devices having low gain, far field conditions exist when:

.❷ $$r \geq \frac{\lambda}{2 \pi}$$

where:

λ = Wavelength (meters)

For more complex antennas having higher gain values, far field conditions exist when:

.❸ $$r \geq \frac{2D^2}{\lambda}$$

where:

D = Maximum Dimension of the Antenna (m)

Relationship of Antenna Factor and Gain in a 50Ω System

7

.❶ $$G_{dB} = 20 \log \left(f_{MHz}\right) - AF_{dB(m^{-1})} - 29.79$$

Power Required to Generate a Desired Field Strength at a Given Distance when Antenna Factors are Known

8

.❶ $$P_{dB(W)} = 20 \log_{10} \left(E_{desired\ (V/m)}\right) + 20 \log_{10} \left(d_m\right) - 20 \log_{10} \left(f_{MHz}\right) + AF_{dB(m^{-1})} + 15$$

Relationship Between Frequency and Wavelength in Free Space

9

.❶ $$f \lambda = c$$

where:

f = Frequency (Hz)

λ = Wavelength (meters)

c = Velocity of Light

= 3×10^8 m/s

a simpler relationship is:

.❷ $$\lambda = \frac{300}{f_{MHz}}$$

Decibel Formulas

10

A decibel is one tenth of a Bel, and is a ratio measure of relative amplitude. In terms of power, the number of decibels is ten times the logarithm to the base 10 of the ratio.

In terms of power:

.❶ $$dB = 10 \log_{10} \left(P_1 / P_2\right)$$

where P_1 and P_2 are in watts.

In a constant impedance system, power references can be made between different measurement points. They can also be related to voltage or current measurements:

.❷

$$\text{Power Ratio} = 10\log_{10}\left(P_1/P_2\right)$$

$$= 10\log_{10}\left(\frac{V_1^2/R_1}{V_2^2/R_2}\right)$$

$$= 20\log_{10}\left(\frac{V_1}{V_2}\right)$$

$$- 10\log_{10}\left(\frac{R_1}{R_2}\right)$$

for a constant impedance system.

.❸ $$R_1 = R_2$$

and:

.❹

$$\text{Pwr Ratio (dB)} = 20\log_{10}\left(\frac{V_1}{V_2}\right)$$

Also:

.❺ $$G_{dB} = 10\log(g)$$

.❻ $$V_{dB(reference)} = 20\log\left(V/V_{reference}\right)$$

.❼ $$P_{dB(reference)} = 10\log\left(P/P_{reference}\right)$$

where a typical reference for voltage is microvolts and a typical reference for power is milliwatts.

The reverse relationships are:

.❽ $$g = 10^{G_{dB}/10}$$

.❾ $$V = 10^{V_{dB\,(reference)}/20}$$

.❿ $$P = 10^{P_{dB\,(reference)}/10}$$

11 Transmit Antenna Factor

The transmit antenna factor of an antenna is computed from the gain or receive antenna factor, and is a measure of the transmitting capabilities of that antenna. It is valid under the conditions of measurement of the receive antenna factor, in a 50 Ω system.

.❶ $$TAF_{dB\,(m^{-1})} = G_{dB} - 2.22 - 20\log_{10}\left(d_m\right)$$

Where:

$TAF_{dB\,(m^{-1})}$ = Transmit Antenna Factor

G_{dB} = Antenna Gain of Transmitting Antenna

d_m = Distance (m)

Alternatively:

.❷ $$TAF_{dB} = 20\log\left(f_{MHz}\right) - AF_{dBm^{-1}}$$

$$- 32.0 - 20\log\left(r_m\right)$$

12 Computing Power Required for a Specific Field Intensity Given Power Required to Generate 1 Volt/meter

Antenna transmitting capabilities are often given in terms of the input power to an antenna to generate 1V/m at one or more distances. The input power required to develop a different electric field level value is found by:

.❶ $$P_{dB(W)} = P_{dB(W)\,(1\,V/m)} + 20\log_{10}\left(E_{desired\,V/m}\right)$$

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SI Prefixes, Multipliers, & Abbreviations

PREFIX	MULTIPLIER	SYMBOL
pico	10^{-12}	p
nano	10^{-9}	n
micro	10^{-6}	μ
milli	10^{-3}	m
kilo	10^{3}	k
Mega	10^{6}	M
Giga	10^{9}	G

SI Base Units

QUANTITY	NAME	SYMBOL
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A

SI Prefixes, Multipliers, & Abbreviations

CONSTANT	COMPUTATIONAL VALUE
Speed of light in a vacuum:	$c = 2.99792458 \times 10^{8}$ m/s $\approx 3.00 \times 10^{8}$ m/s
Permittivity constant:	$\epsilon_0 = 1/(\mu c^2)$ F/m $\approx 8.85 \times 10^{-12}$ F/m
Permeability constant:	$\mu_0 = 4\pi \times 10^{-7}$ H/m $\approx 1.26 \times 10^{-6}$ H/m

SI Derived Units

QUANTITY	NAME	SYMBOL	
area	square meter	m^2	
volume	cubic meter	m^3	
frequency	hertz	Hz	s^{-1}
mass density	kilogram per cubic meter	kg/m^3	
speed, velocity	meter per second	m/s	
angular velocity	radian per second	rad/s	
acceleration	meter per second squared	m/s^2	
angular acceleration	radian per second squared	rad/s^2	
force	newton	N	$kg{\bullet}m/s^2$
pressure	pascal	Pa	N/m^2
work, quantity of heat	joule	J	N•m
power	watt	W	J/s
quantity of electricity	coulomb	C	A•s
potential difference	volt	V	W/A
electric field strength	volt per meter	V/m	
electric resistance	ohm	Ω	V/A
capaticitance	farad	F	A•s/V
magnetic flux	weber	Wb	V•s
inductance	henry	H	V•s/A
magnetic flux density	tesla	T	Wb/m^2
magnetic field strength	ampere per meter	A/m	
admittance	siemens	S	1/Ω
electricantenna factor	per meter	1/m	
magnetic antenna factor	siemens per meter	s/m	

Conversion Table for Magnetic Units

	TO CONVERT FROM:				
Unit System:	SI (MKS)		CGS		
Magnetic Qty.:	B	H	B	H	B
Units:	**tesla**	**amp-turn/m**	**gauss**	**oersted**	**gamma**
TO: **tesla**	1	$4\pi \times 10^{-7\dagger}$	10^{-4}	$10^{-4\dagger}$	10^{-9}
TO: **amp-turn/m**	$7.96 \times 10^{5\ddagger}$	1	$79.57747^{\ddagger}$	79.57747	$7.96 \times 10^{-4\ddagger}$
TO: **gauss**	10^{4}	$4\pi \times 10^{-3\dagger}$	1	$1^{\dagger}$	10^{-5}
TO: **oersted**	$10^{4\ddagger}$	$4\pi \times 10^{-3}$	$1^{\ddagger}$	1	$10^{-5\ddagger}$
TO: **gamma**	10^{9}	$4\pi \times 10^{2\dagger}$	10^{5}	$10^{5\dagger}$	1
	MULTIPLY BY ABOVE VALUE				

† Assumes $\mu = 1$; if $\mu \neq 1$, multiply by value of μ to convert from *H* to *B*.
‡ Assumes $\mu = 1$; if $\mu \neq 1$, divide by value of μ to convert from *B* to *H*.
1 tesla ≡ 1 weber/m^2.

For example,
1 tesla = 10^4 gauss.
1 gauss = 79.6 ampere-turns/m in an unloaded coil ($\mu = 1$).
If $\mu = 2.50$, 1 tesla = $7.96 \times 10^5 / 2.50 = 3.18 \times 10^5$ amp-turns/m.

Understanding Radiated Emissions Testing

In a radiated emissions test, electromagnetic emissions emanating from the equipment under test (EUT) are measured. The purpose of the test is to verify the EUT's ability to remain below specified electromagnetic emissions levels during operation. A receive antenna is located either 3 or 10 meters from the EUT. In accordance with ANSI C63.4, the receive antenna must scan from 1 to 4 meters in height. The scanning helps to locate the EUT's worst-case emissions level.

Figure 1 shows a block diagram of an emissions test system such as might be used for ANSI C63.4 testing. The test set-up is composed of a receive antenna, a first interconnecting cable, a preamplifier, a second interconnecting cable, and a radio noise meter (receiver or spectrum analyzer).

The purpose of each of the components of the radiated emissions test setup are:

The Receive Antenna

The performance measure of this antenna in relating the value of the incident E-field to the voltage output of the antenna is the Antenna Factor. This is usually provided by the manufacturer in dB with units of inverse meters. A variety of antennas can be used for these measurements. Typically, a combination of two antennas is used to cover the frequency range from 30 MHz to 1000 MHz—a biconical covering the frequency range of 30 to 200 MHz and a log periodic covering the frequency range of 200 to 1000 MHz. New antenna technology, such as EMCO's BiConiLog™ antenna, can cover the complete frequency range. This Antenna Factor is shown at A.

The First Interconnecting Cable

This cable connects the antenna output to the preamplifier input. There is a reduction in measured signal amplitude due to losses in the cable. To increase accuracy, these losses need to be added to the measured value of the voltage out of the antenna to compensate for the losses. Cable loss is shown at B.

The Preamplifier

The preamplifier is typically used with spectrum analyzers to compensate for the high input noise figure typical of such devices. Receivers may not need this device. The amplifier makes the measured signal larger, thus the final answer must be corrected by subtracting the gain of the preamplifier. Preamplifier gain is shown at C.

The Second Interconnecting Cable

This cable connects the output of the preamplifier to the radio noise meter. There is a reduction in measured signal amplitude due to losses in the cable. To increase accuracy, these losses need to be added to the measured value of the voltage out of the antenna to compensate for the losses. Cable loss is shown at D.

The Radio Noise Meter

Typically, the radio noise meter is either a receiver or a spectrum analyzer. Either is essentially a 120 kHz bandwidth, tunable, RF microVolt meter calibrated in dB µV. A signal response is shown in Figure E.

The calculation of the measured E-field signal level is then given by:

$$E(dB\mu V/m) = V(dB\mu V) + CL_1(dB) - PAG(dB) + CL_2(dB) + AF(dBm^{-1})$$

where:

$E(dB\mu V/m)$	=	Measured E-field
$V(dB\mu V)$	=	Radio Noise Meter Value
$CL_1(dB)$	=	Loss in Cable 1
$PAG(dB)$	=	Preamplifier gain
$CL_2(dB)$	=	Loss in Cable 2
$AF(dBm^{-1})$	=	Antenna Factor

This computed value can be compared to the published specification limit for determination of whether the measured value is less than the specification limit, thus showing compliance with the requirement.

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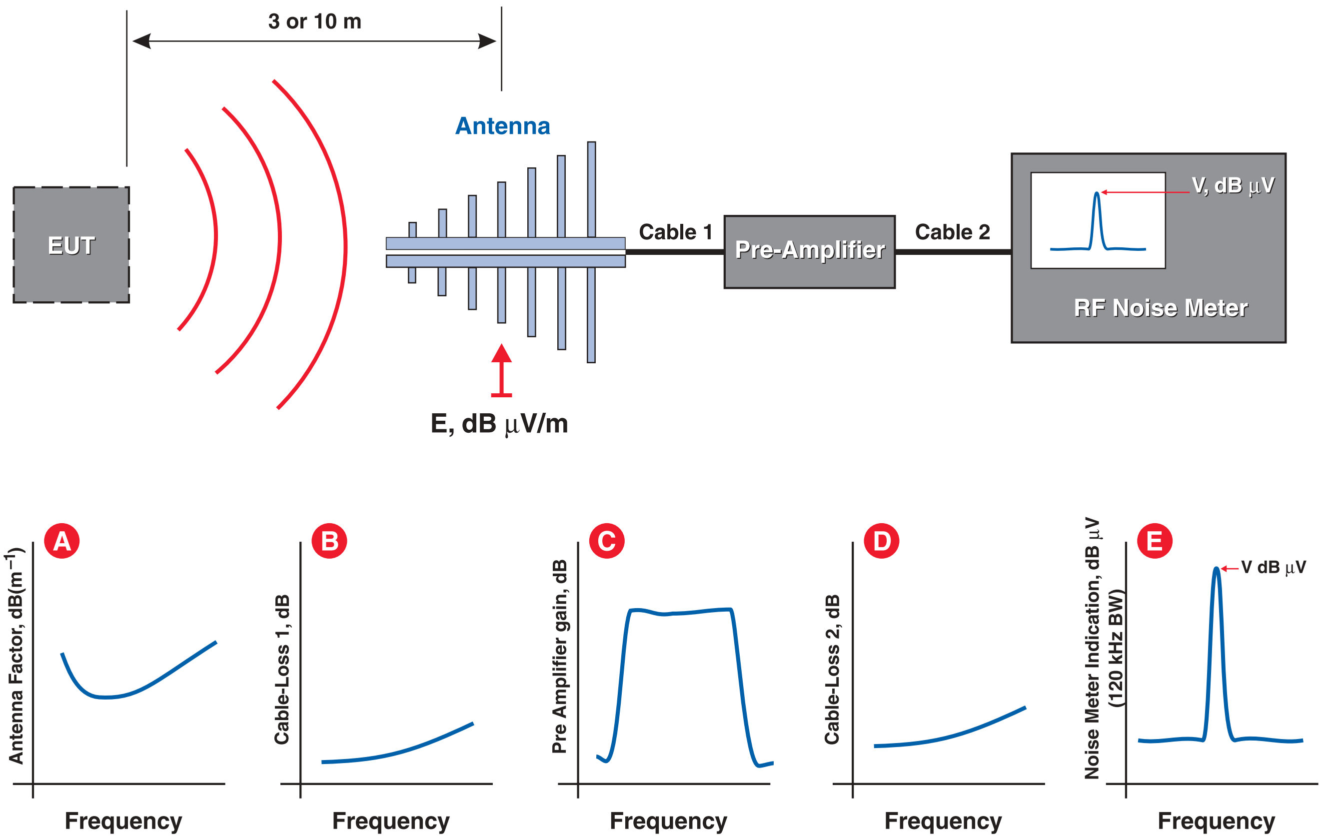

Figure 1. Radiated Emissions Test

$$E(dB\,\mu\,V/m) = V(dB\,\mu\,V) + CL_1(dB) - PAG(dB) + CL_2(dB) + AF(dBm^{-1})$$

Figure 1. Radiated Emissions Test

Notes on Figure 1

A is the Antenna Factor (AF) versus frequency. The units are meters^{-1}. The AF relates the RF voltage output of an antenna to the E-Field causing the voltage to appear.

B, D are the reduction in signal that is caused by losses in the interconnecting coaxial cables.

C is the low noise figure preamplifier gain, which can vary with frequency.

E is the value measured at some frequency by the 120 kHz bandwidth radio noise meter.

Understanding Radiated Immunity Testing

In a radiated immunity test, a test signal of RF energy, typically three or ten volts per meter, is directed at the equipment under test (EUT), and the EUT's reaction to this test signal is analyzed. The purpose of the test is to demonstrate the ability of the EUT to withstand the excitation of the signal, without showing degraded performance or failure. The more immune a product is to this test signal, the better it should operate when other electronic or electrical equipment is present in its environment.

Figure 1 shows a block diagram of an immunity test system such as might be used for IEC 61000-4-3 testing. The test setup is composed of a signal generator, an amplifier, a forward/reverse power coupler with its associated power meter, a radiating antenna, and an omni-directional E-field probe system.

The purpose of each of the components of the radiated immunity test setup is:

The Signal Generator
The signal generator is used to provide the test signal. It should have adequate output resolution to allow precise setting of the reference level of the E-field to within 1 % of the desired level. The signal generator must be capable of providing the desired 80 % AM with a 1 kHz sine wave for testing. A typical signal generator output is shown at A.

The Amplifier
The amplifier increases the test signal strength to levels, that when applied to the antenna, will produce the desired E-field levels. Note that EMC test amplifiers are specified with a minimum gain. Due to the extremely wide bandwidth, they can show ripple of several dB in the pass band. The amplifier must be operated in a linear mode to assure repeatability. A typical amplifier response is shown at B.

The Forward / Reverse Power Coupler
The forward / reverse power coupler is placed in-line with the amplifier output to the antenna input, as near to the antenna as practical. The difference in the forward and reverse power (the net power) is recorded to determine the input level necessary for developing the desired test signal, and to show that this desired input to the antenna is developed during testing. This is shown at C.

The Antenna
The antenna generates the desired E-field. Its performance in generating the E-field is given by the Transmit Antenna Factor (TAF), as shown at D.

The Omni-directional Probe System
The probe system is used to directly measure the value of the field strength, at E.

Figure 2 shows a graphical display of the signals of the immunity test system. This figure also includes computations of the signal levels at a specific frequency of 100 MHz.

The output level is given by:

$$E(dB\,\mu\,V/m) = SG_{out}(dB\,\mu\,V) + AG(dB) + TAF(dB)\,m^{-1})$$

where:

$E(dB\,\mu\,V/m)$	=	The E-field test level
$SG_{out}(dB\,\mu\,V)$	=	The signal generator output
$AG(dB)$	=	Amplifier gain
$TAF(dB)\,m^{-1})$	=	The transmit antenna factor

The variables and terms in the expression above are used for calibration test setups. They demonstrate how instrumentation and facility factors contribute to meet the typically required E-field uniformity value of – 0.0 dB, + 6.0 dB. Remember that actual testing to demonstrate that the EUT will not malfunction when exposed to the desired level requires the addition of 80 % amplitude modulation with a 1 kHz sine wave to the test signal. This, in turn, requires an additional 5.1 dB $\{10 \times \log_{10} [(1.8)^2]\}$ of linear gain from the amplifier than is found during calibration.

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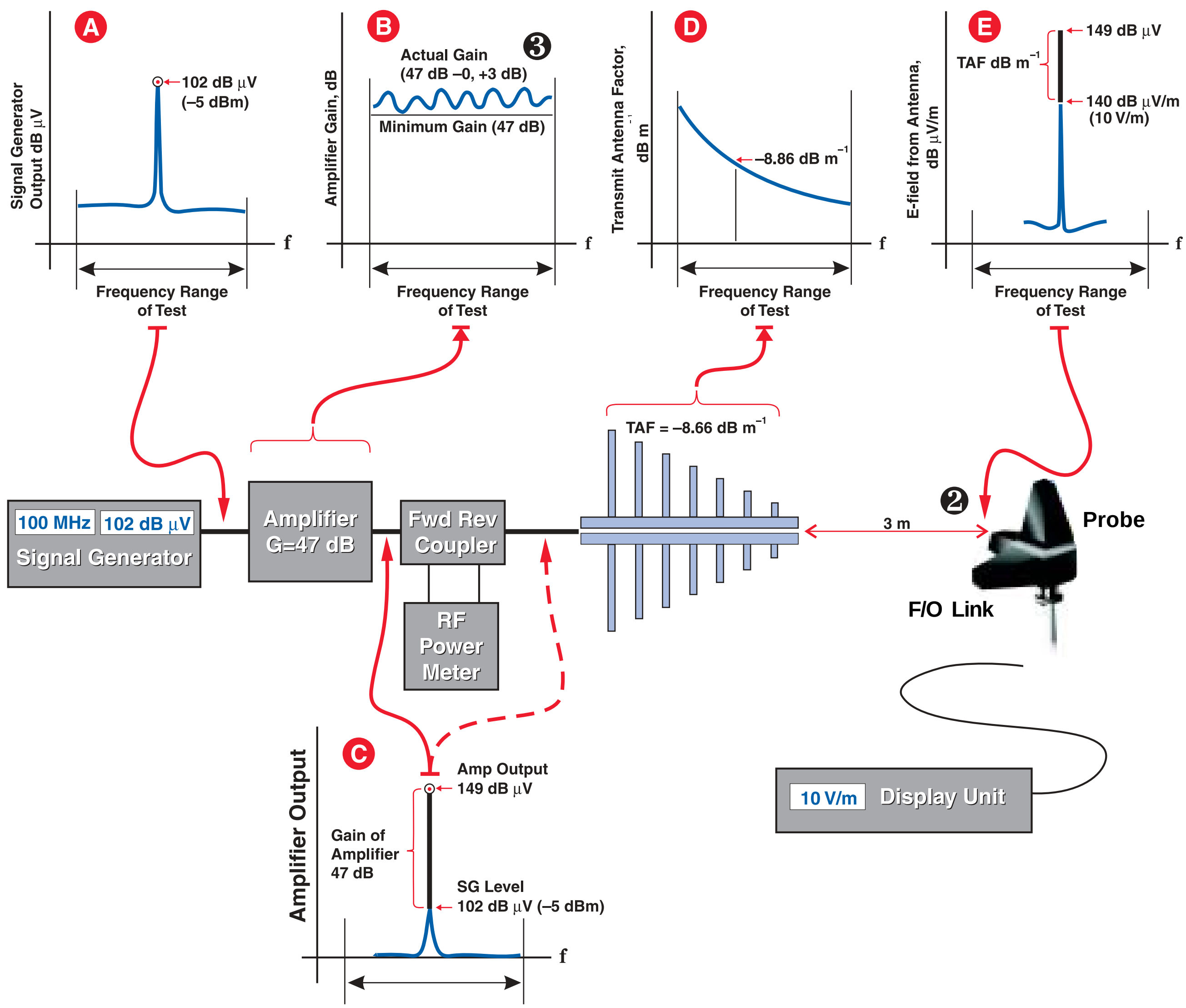

Figure 1. Block Diagram of Typical Immunity Test Setup with Signal Levels & Characteristics Added

Figure 1. Radiated Immunity Test

Notes on Figure 1

❶

A is signal generator output.

B is amplfier gain versus frequency.

C is signal generator output + amplifier gain (= input to antenna.

D is transmit antenna factor (TAF).

E is E-field level generated (= input to antenna + (TAF).

❷ For immunity testing, test distance is from tip of antenna.

❸ Immunity amplifiers are typically specified at minimum gain. Pass band ripple is result of extra wide bandwidths.

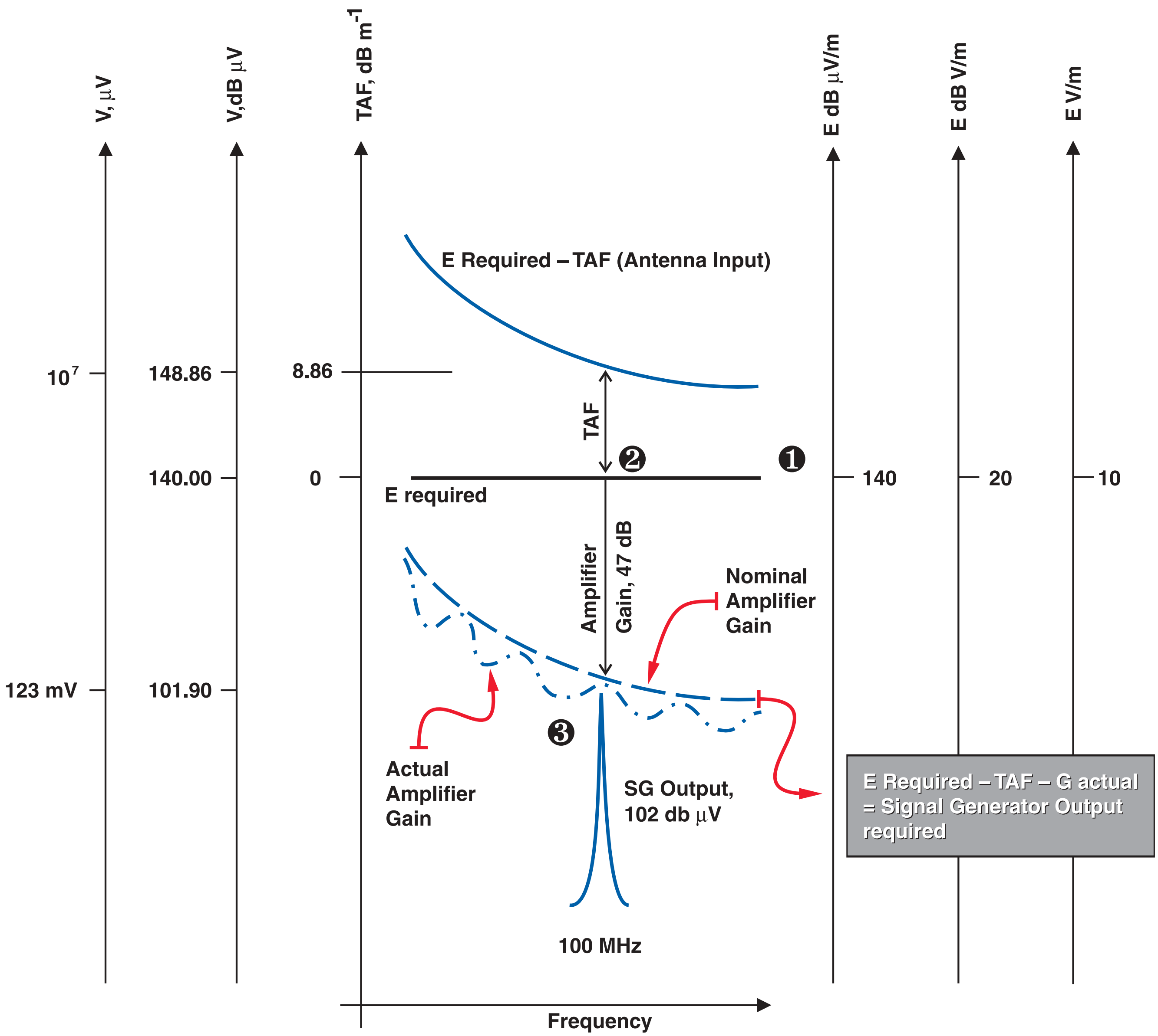

Figure 2. Graphical Representation of Immunity Test System Signal

Figure 2. Radiated Immunity Test

Notes on Figure 2

❶ Required test field is
10 V/m (= 20 dB V/m = 140 dB µ V/m).

❷ At 100 MHz TAF is – 8.66 dB => V_{in} to Antenna is
140 – (–8.66) = 148.66 dB µV.

❸ At 100 MHz Signal Generator Output is
Antenna Input – Amplifier gain
(= 148.86 – 47 = 101.86 dB µV = 123 µV).

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EMC Antenna Parameters and Their Relationships

JOHN D. M. OSBURN

INTRODUCTION

The basics of the EMC profession often get buried under the day-to-day effort of continuous measurement and the volume of test and reporting paperwork. The fundamental parameter of the most common of technical tools, the EMC antenna, is used over and over without thought as to its actual meaning. This parameter is the antenna factor (AF). A review of the basics behind this parameter, and a related parameter, the transmit antenna factor (TAF), provides a basis for the use of the numerical values, and a more fundamental understanding of radiated EMC measurements.

EMC ANTENNAS

EMC antennas are used for EMC measurements in rather rugged environments involving frequent handling, rapid replacement with a different antenna for another frequency band and the normal wear and tear of day-in, day-out usage, two shifts a day, six days a week, in almost all weather conditions.

For all their apparent simplicity, antennas used in an electromagnetic compatibility (EMC) laboratory are as specialized and as sophisticated as antennas for any other application. These antennas are different in that their application makes broad bandwidths the most important design parameter, and gain, efficiency, and low input voltage standing wave ratio (VSWR) become secondary. Broad bandwidths are driven by the broad frequency spectrum covered in the performance of EMC radiated emission and immunity measurements.

The concepts of antenna factor and transmit antenna factor are integral to understanding radiated EMC measurements.

The antenna parameters that are familiar to most antenna designers are then secondary design objectives in the development of these antennas. For all the importance of the bandwidth, however, the antenna parameter most often used, the AF, does relate to the performance of the antenna. The AF is used to quantify the value of incident electric fields, and its companion parameter, the TAF, is used to determine the value of the electric field at a known distance from the generating antenna.

EMC antennas are used for two types of measurements: radiated emissions (RE) and radiated immunity (RI). In the first case, formal calibration of the antenna and the use of traceable standards are required. In the second case, calibration is not required as the calibrations are usually performed as part of a complete EMC test setup.

Each of these types of measurements employs a separate descriptive parameter. For radiated emissions measurements, the parameter is the AF. For radiated immunity or susceptibility measurements, it is the TAF.

These two parameters are illustrated in Figure 1. This figure also illustrates other relationships between parameters used in the following derivations.

ANTENNA FACTOR

The antenna factor is the term applied in radiated emissions testing to convert a voltage level fed by a transducer to the input terminals of an EMI analyzer into the field-strength units of the electromagnetic field producing that voltage.[1] It relates the value of the incident electric or electromagnetic field to the voltage at the output of the antenna. For an electric field antenna, this is expressed as

$$AF = \frac{E}{V_L} \quad (1)$$

where
AF = antenna factor, m^{-1}
E = electric field, V/m
V_L = voltage at antenna terminals, V

The AF is usually expressed in dB and when used to determine the value of an incident electric field, the expression is

$$E_{[dB(\mu V/m)]} = V_{[dB(\mu V)]} + AF_{[dB(m^{-1})]} \quad (2)$$

The derivation of the AF is straightforward and is based on several fundamental relationships in antenna theory. The relationships can be stated as: *"The ratio of power in the terminating resistance to the power density of the incident wave is defined as the effective aperture."*[2]

Thus

$$A_e = \frac{P_{out}}{P_d} \quad (3)$$

where
A_e = effective receiving antenna, m^2
P_{out} = power delivered by antenna, W
P_d = power density of the incident wave, W/m^2

Following this, then

$$P_{out} = P_d A_e \qquad (4)$$

In addition, from the ITT Handbook[3]

$$A_e = \frac{G_r \lambda^2}{4\pi} \qquad (5)$$

where:
G_r = gain of the receiving antenna
λ = wavelength, m

The output voltage from the antenna V_L and the output power are related by the impedance seen by the antenna.

$$P_{out} = \frac{V_L^{\ 2}}{Z} \qquad (6)$$

where
P_{out} = power delivered at the output of the antenna, W
V_L = output voltage, V
Z = load impedance of the device connected to the antenna, Ω

Finally, the relationship between electric field strength and power density of the incident and the electric field strength is

$$P_d = \frac{E^2}{120\pi} \qquad (7)$$

where
P_d = power density of the incident wave, W/m^2
E = electric field, V/m

Substituting Equations (4), (5) and (6) into Equation (7), gives, for a plane wave

$$\frac{V_L^2}{Z} = \frac{E^2}{120\pi} \times \frac{G_r \lambda^2}{4\pi} \qquad (8)$$

Solving for the AF gives

$$AF = \frac{E}{V_L} = \sqrt{\frac{480\pi^2}{Z\lambda^2 G_r}} \qquad (9)$$

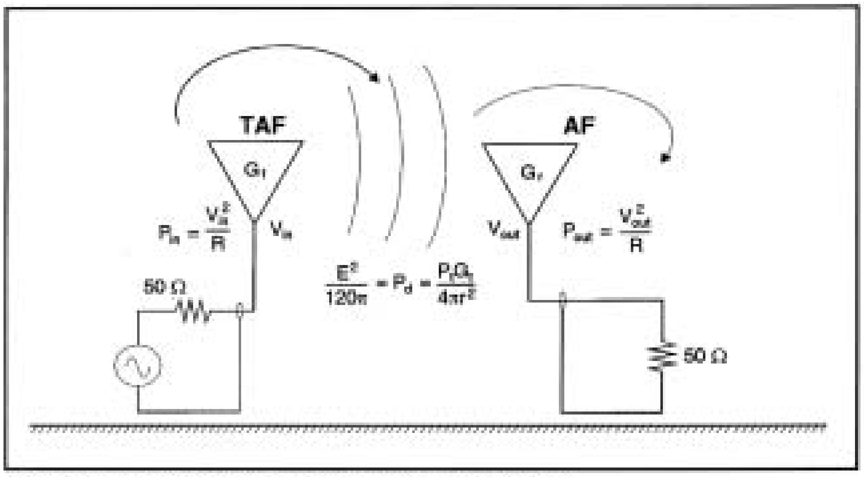

***Figure 1**. The Relationship Between Antenna Parameters.*

In a 50-ohm system this becomes

$$AF = \frac{9.73}{\lambda \sqrt{G_r}} \qquad (10)$$

In dBs, this becomes (in units of inverse meters)

$$AF = 19.8 - 20 \times \log(\lambda) - 10 \times \log(G_r) \quad (11)$$

TRANSMIT ANTENNA FACTOR

The TAF provides a means of computation of the input voltage to the antenna to provide a given value of electric or electromagnetic field at a stated distance from the antenna. The transmit antenna factor relates the value of the electric or electromagnetic field generated by an antenna as a function of its input. Thus, the fundamental relationship is

$$TAF = \frac{E_{(dBV/m)}}{V_{(dBV)}} \qquad (12)$$

The transmit antenna factor is, then, expressed in terms of dB

$$E_{[dB(V/m)]} = V_{in[dB(V)]} + TAF_{[dB(m^{-1})]} \quad (13)$$

or:

$$V_{in[dB(V)]} = E_{[dB(V/m)]} - TAF_{[dB(m^{-1})]} \quad (14)$$

Derivation of the TAF proceeds from three standard relationships. The first is a variation of the Friss transmission formula[4]

$$P_d = \frac{P_t G_t}{4\pi r^2} \qquad (15)$$

where
P_d = radiated power density at distance r from the antenna, W/m^2
P_t = power input to the antenna, W
G_t = numerical gain of the antenna
r = distance from the antenna where the power density is evaluated, m

The second is Ohm's Law[5]

$$P = \frac{V^2}{R} \qquad (16)$$

where
P = power dissipated in a load, w
V = voltage across the dissipating element, V
R = resistance (impedance) of dissipating element or load, Ω

The third relationship is Ohm's Law for Free Space[6]

$$P_d = \frac{E^2}{\eta} = \frac{E^2}{120\pi} \qquad (17)$$

where
P_d = power density of the incident wave, W/m^2
E = electric field strength at that point in space, V/m
η = impedance of free space, 120πΩ = 377 Ω

Combining Equations (15) and (16) leads to a familiar expression

$$E = \frac{1}{r}\sqrt{30\,P_t G_t} \qquad (18)$$

which relates the electric field strength at a point *r* away from the transmitting antenna having input power P_t and gain G_t.

By rearranging Equation (16) we have

$$V_{in} = \sqrt{P_i R} \qquad (19)$$

Recalling the definition of the transmit antenna factor, the ratio of the E-field developed to the input voltage to the antenna, we can find the TAF by taking the ratio of the E-field produced from Equation (17) to the power dissipated in the antenna given in Equation (18)

$$TAF = \frac{E}{V} = \frac{\frac{1}{r}\sqrt{30\,P_t G_t}}{\sqrt{P_{in} R}} \qquad (20)$$

Remembering that the transmitted power P_t is identical to the power dissipated in the load, P_{in}, and R is 50 Ω, Equation (19) simplifies to

$$TAF = \frac{1}{r}\sqrt{0.6 G_t} \qquad (21)$$

This result is reasonable, as the TAF should be an inverse function of distance from the source, and a direct function of the gain of the transmitting antenna, and should be independent of power input. It should be noted that the gain value in Equation (17) is the effective gain of the antenna, calculated from the measured values of the AF. The TAF as used above incorporates antenna efficiency, the effect of antenna mismatch and other losses.

The TAF expression can be converted to dB form by taking 20 x $\log_{10}$ of both sides of Equation (20). This gives

$$TAF_{(dB)} = G_{t(dB)} - 2.22 - 20 \times \log_{10}(r_{(m)}) \qquad (22)$$

Note that the TAF is proportional to the gain of the antenna and inversely proportional to the distance from the antenna. This is rational and suggests that the derivation is correct.

CONVERSION BETWEEN AF AND TAF

As can be seen from the derivations, although the AF and TAF have the same units, m^{-1}, *they are neither identical nor reciprocal.* They are connected by the fact that the gain is identical for both expressions. This fact allows the TAF to be computed from the AF by recalling that $f\lambda = c$, and rewriting Equation (11) as

$$G_{(dB)} = 20 \times \log_{10}(f_{(MHz)}) - AF_{dB(m^{-1})} - 29.79 \qquad (23)$$

Substituting Equation (22) for Equation (23) gives

$$TAF_{(dB)} = 20 \times \log_{10}(f_{(MHz)}) - AF_{dB(m^{-1})} - 32.0 \qquad (24)$$

(at the distance of calibration)

This conversion is valid for the conditions from which either the AF or TAF is measured. If the AF is measured over a ground plane (typical condition), then the TAF computed from the AF is valid for a similar condition.

Remember that the concept of reciprocity, as it applies to antennas, relates to the transmit and receive pattern. As such, the reciprocity does not include the effects of impedance mismatch, efficiency or other factors. These factors are included in the measured AF. Thus, if measured antenna factors are used, the TAF computed from these values will be accurate when the antenna is used under the same conditions, over a ground plane. A semi-anechoic chamber also fulfills the same conditions, subject to the constraint that, over the frequency range of the application of this concept, the RF absorber must be effective.

SUMMARY

The above discussions have provided simple derivations of two parameters of an EMC antenna, the AF and the TAF. These parameters are in daily use by many, but the source of the values is not well-known. It is the purpose of this paper to provide the derivations of these parameters to illustrate the use of antennas and why they work as they do.

ACKNOWLEDGMENTS

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Computing Required Input Power for a Given E-Field Level at a Given Distance

Introduction

This Application Note explains three separate methods for the calculation of input power to an antenna to achieve a specific value of E-field for immunity or susceptibility testing, at a specific distance from the antenna. The estimates of required power agree well between the three methods (See Table 2.), so any of the three methods can be used as a function of information available regarding the antenna.

Calculations

This section describes three completely different, independent methods for calculating the input power required for a given E-field value as a function of frequency, at a given distance from the antenna. Inherent assumptions are that bore-sight alignment exists from the antenna to the point where the E-field is evaluated, and that ideal propagation conditions exist.

The three methods are:

- The Friis Transmission Formula
- The Transmit Antenna Factor
- Using information from published catalog or data sheet values of E-field for a given reference level of E-field.

Input power to an antenna to develop specified E-field value is readily accomplished, given some combination of the following information:

- numerical gain, G_i
- gain in dB, G_i, *(dB)*, and
- antenna factor, *AF* $(dB\, m^{-1})$.

The required information is:

- distance from the transmitting antenna reference point,
- frequency, and
- required E-field level.

Expressions for computing any of these input variables, given a value for one, are shown in Table 1.

Table 1.

Expressions for Computing G_i, G_i *(dB)*, and *AF*$(dB\ m^{-1})$, Given A Value for One Parameter

	$AF(m^{-1})$	G_i	$G_i(dB)$
$AF(m^{-1})$		$20\times\log\left(\frac{9.73}{\lambda\sqrt{G_i}}\right)$	$20\times\log[f\,(MHz)]$ $-29.79-G_i(dB)$
G_i	$\left(\frac{9.73\times f\,(MHz)}{(300)\times 10^{\frac{AF}{20}}}\right)^2$		$10^{\frac{G_i(dB)}{10}}$
$G_i(dB)$	$20\times\log[f\,(MHz)]$ $-29.79-AF(m^{-1})$	$10\times\log\,(G_i)$	

Sample values, at 100 MHz, used in the calculations are:

- numerical gain over an isotropic antenna, G_i, = 2.05,
- gain in dB of the antenna, G_i, *(dB)* = 3.1 dB,
- Antenna Factor , *AF* $(dB\, m^{-1})$ = 7.1 dB m^{-1}

Figure 1 shows the geometry assumed for the calculations, and some of the important variables.

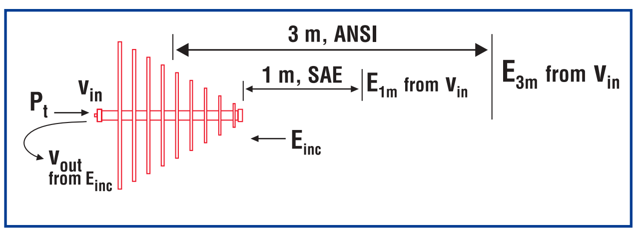

Figure 1.

Geometry for the Calculation of Input Power for a Given E-Field

Note that the reference point for calibration is different for the two standards applied for calibration of E-field generating antennas. The Society of Automotive Engineers *Aerospace Recommended Practice 958* is applied for calibration of antennas used in MIL-STD testing, for a spacing of 1 meter, tip-to-tip. The American National Standards Institute C63.5 is applied from

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feed point for biconical dipole antennas, and, as shown, from the mid-point of all elements of a log periodic antenna's element array. These measurement reference points on the antennas are important because they define the starting point of the distance to the point in free space, where the value of the E-field is defined.

These calculations are valid for estimates of input power when testing will be conducted in an anechoic chamber. The ARP and ANSI calibration methods produce a value for AF that is referred to as the "equivalent free space antenna factor". This means that the effects of the calibration environment are removed from the antenna factor, and that the numerical values are very close to that which would be measure if the antenna had, in fact, been calibrated under true free space conditions.

Method I Using the Relationship for E-field at a Distance Derived from Ohm's Law for Free Space and the Friss Transmission Formula:

A variant of the Friss transmission formula is:

$$E\,(V/m) = \frac{1}{r}\sqrt{30 \times P_t\ (W) \times G_t}$$

It relates the E-field [*E (V/m)*] produced at a distance [*r (m)*] due to net input RF power [P_t *(W)*] being applied to an antenna with known gain[G_t], (see Figure 1).

Solving for input power gives:

$$P_t = \frac{E^2 r^2}{30 \times G_t}$$

As an example calculation, suppose that a 10 V/m field was required at 3 meters for immunity testing. If the antenna chosen is a log periodic antenna with a gain of 2.05 at 100 MHz, the input power required is:

$$P_t = \frac{(10.0)^2 \times (3)^2}{30 \times 2.05} = 14.64\ W$$

Method II Using Transmit Antenna Factor

The transmit antenna factor is a measure of the effectiveness of the given antenna in transmitting electromagnetic power. It relates the RF voltage [V_{in} *(Volts)*] to the E field [$E|_d$ *(V/m)*] at a distance [*d(m)*] from the antenna, as determined at the distance of calibration of the antenna. (See Figure 1.) It is given by:

$$TAF\,(dBm^{-1})\Big|_d = G\,(dB_i) - 2.22 - 20 \times \log[d\,(m)]$$

For the example given, $G_t = 3.1\ dB$ and $d = 3m$

Thus:

$$TAF(dBm^{-1})\Big|_{3m} = 3.1 - 2.22 - 20 \times \log[3m] = -8.66\,dB\,(m^{-1})$$

Remembering that:

$$E\,(dB\,V/m) = V_{in}\,(dBV) + TAF\,(dB\,m^{-1})$$

Then:

$$V_{in}\,(dBV) = E\,(dB\,V/m) - TAF\,(dB\,m^{-1})$$

or:

$$V_{in}\,(dBV) = 20 \times \log\,[V\,(V/m)] - TAF\,(dB\,m^{-1})$$

and:

$$V_{in}\,(dBV) = 20 \times \log\,[10(V/m)] - (-8.66) = 28.66\ (dB\,V)$$

To compute input power requirements, a linear value for voltage is required:

$$V_{in}(V) = 10^{\frac{V_{in}(dBV)}{20}} = 10^{\frac{28.66(dBV)}{20}} = 27.10\ V$$

Then the required power input is:

$$P_t(W) = \frac{V_{in}\,(V)^2}{R\ (\Omega)} = \frac{(27.1)^2}{50} = 14.64\ W$$

Method III Calculation of Required Input Power Using Published Graphical Data:

Using the graphical data, it is estimated that the input power required for 10 V/m at 3 meters is 0.15 W. A typical plot of input power for a given E-field level is shown in Figure 2.

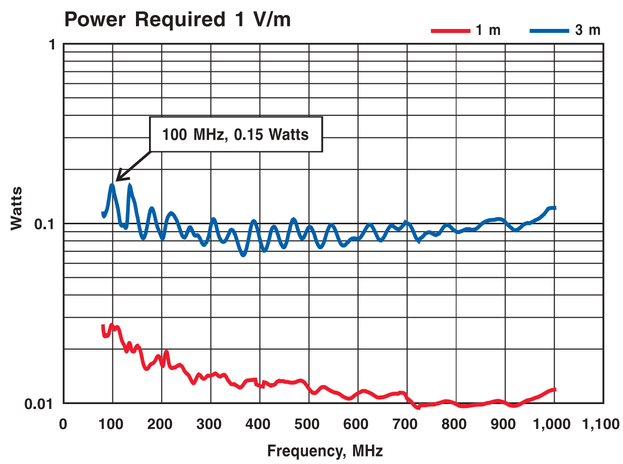

Figure 2.

Typical Plot of the Input power for a Specific E-Field Value

As seen in Figure 2, the 100 MHz value for input power for 1 V/m is approximately 0.15 W.

Computing the input power in dB:

$$P_{in}(dB\ W)\big|_{10V/m\,@\,3m} = 10\times\log[0.15\ (W)] = -8.24\ dB\,W$$

The desired E-field strength is 10 V/m:

$$E(dB\,V/m)\ = 20\times\log\ [10(V/m)] = 20\,dB\,V/m$$

Then power for 10 V/m is

$$P_{in}(dB\ W) = P_{in(chart)}(W) + E(dB\,V/m)$$

Or, substituting the actual values:

$$P_{in}(dB\ W) = 20\,dB\,V/m\ -\ (8.24\ dB\,W) = 11.76\ dB\,W$$

The linear value of the input power is:

$$P_{in}(W)\big|_{10V/m@3m} = 10^{\frac{11.76}{10}} = 15.00\ W$$

Comments

Three different computations of the desired input power, as shown above, give three similar answers. The results are summarized in Table 2. Examination of these answers reveals that the variance of the three answers is just under 2.5%, using the largest of the answers as a reference.

Table 2.

Summary of Results

Method of Computation	Answer
Friss Transmission Formula	14.63 *W*
Transmit Antenna Factor	14.69 *W*
Using Published Chart Values	15.00 *W*

The larger value obtained from using the Chart Values is likely to be due to inaccuracy in reading the chart. This value is 4.67 % (about 0.2 dB) larger than the other values, with more precise input. Comparing the two values with numerical input data gives a 0.03 dB difference.

Note that the Friss Transmission Formula, used in Method l, does not consider the effects of the ground plane. The answer derived from this formula agrees with the answer derived using Method ll's "equivalent free space antenna factor" value methodology. The results from these first two Methods also agree with Method lll's answer. This is derived using a graphical portrayal of the transmit antenna factor as computed from the measured antenna factor.

Cautions

These computed values are based on the nominal conditions of "free space" testing, *i.e.*, testing in a Anechoic Chamber, to contain the fields generated. They are useful estimates for other conditions, but engineering judgment must be applied to the selection of amplifier in all cases.

Other adjustments for sizing the input amplifier include the antenna input VSWR. At the upper and lower ends of their bandwidth, some antennas will have a VSWR that far exceeds the nominal value. In this case a correction, as shown in Figure 3, should be applied.

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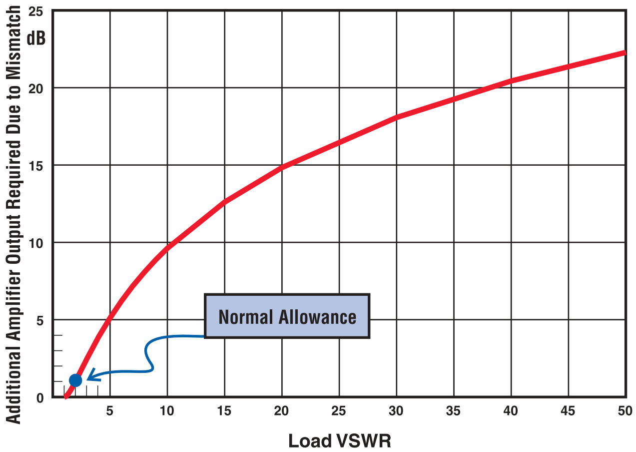

Figure 3.

Correction for Input Power Required, when the Antenna Input VSWR Exceeds 2:1.

If a numerical result is desired, the VSWR correction can be computed from:

$$VSWR\ \ Correction = 20 \times \log\left(\frac{1}{1-\left(\frac{VSWR-1}{VSWR+1}\right)^2}\right)$$

Remember also that the amplifier must be operated in its linear operating range, at least 1 dB below the 1 dB compression point.

In addition, no amplifier is as reliable running close to or at maximum rated power, thus an allowance for rating to assure that the amplifier is running at about 90 % of rated power will produce almost indefinite operation. This adds another approximately 1 dB to the required output power.

Note that the ANSI calibration distance for measurement of the antenna factor (AF) of log periodic antennas (at the center of the element array), is different than the distance where the immunity test calibration is performed (measured from the tip of the antenna). The ratio of these distances, in dB, should be added to the power amplifier rating to more closely estimate the required power input level. For a typical EMCO large log periodic antenna, this difference in distance is just under 1 meter. If the calibration distance is 3 meters from the tip of the antenna, the correction would be 20 x *log* [4m ÷ 3m] = 2.5 dB. Smaller antennas will need a lesser allowance.

With respect to sizing the amplifier for use with a given antenna, remember that most calibration measurements are conducted with continuous wave (CW) excitation of the antenna. When actual testing is accomplished, it is usually accomplished with amplitude (AM) modulation. The most recently published specification requires 80 % AM with a 1 kHz sine wave. This requires an amplifier with 1.8 times the linear voltage output range of the CW signal. This, in turn, requires the amplifier output to be $(1.8)^2$ larger than for the CW case, since power input increases as the square of the input voltage. This means that the power amplifier gain will need to be 10 x *log* $[(1.8)^2]$ = 5.1 dB greater than needed for the CW case.

A summary of these factors is shown in Table 3.

Table 3.

Summary of Input Power Allowances for Sizing an Amplifier

Factor	Allowance (dB)
True Linear Operation	1.0
Calibration Distance	2.5
Modulation Allowance	5.1
TOTAL	8.6

Thus, any amplifier input computed for use may actually need a 8.6 dB higher rating for proper continuous operation.

In addition, if the antenna input VSWR is more than 2:1, additional compensation for the reflected power from the antenna port is required.

NOTE: Cable loss is not considered in this allowance table since it is a factor of cable length.

DERIVATION AND USE OF FORWARD POWER GRAPHS

Forward Power graphs in this catalog are derived from several methods and each chart indicates which method was used. Since SAE and ANSI antenna factors are typically within a few dB of free-space antenna factors, graphs indicating "Forward Power Derived From AF" are valid for free-space environments, such as a fully anechoic chamber or an absorber-treated ground plane. Graphs indicating "Forward Power Measured Over Conducting Ground" are valid only for the specific geometry listed (antenna/field probe height and separation) on an OATS or in a large high quality semi-anechoic chamber. Graphs indicating "Forward Power Measured Over Ferrite Ground" generally fall between the ground plane and free-space values. As with the ground plane numbers, these results are strictly valid for the same geometry on an OATS or a semi-anechoic chamber with comparable ferrite panels on the floor. Small chamber power requirements depend on the chamber's dimensions and antenna location. Typically, small chamber power requirements will fall in the vicinity of the conducting and ferrite-ground results.

Antenna Selection by Test Type

FCC 15 — RADIATED EMISSIONS

20 MHz - 200 MHz	3104C Biconical
30 MHz - 300 MHz	3110B Biconical
30 MHz - 300 MHz	3124 Calculable Biconical
200 MHz - 2 GHz	3106 Dbl RdgWaveguide
1 GHz - 18 GHz	3115 Dbl Rdg Waveguide
18 GHz - 40 GHz	3116 Dbl Rdg Waveguide
30 MHz - 1 GHz	3121C Dipole
26 MHz - 2 GHz	3142B BiConiLog™
80 MHz - 2 GHz	3144 Log Periodic
200 MHz - 5 GHz	3147 Log Periodic
200 MHz - 2 GHz	3148 Log Periodic
960 MHz - 40 GHz	3160 Std Gain Horns
960 MHz - 40 GHz	3161 Std Gain Horns

FCC 18 — RADIATED EMISSIONS

20 MHz - 200 MHz	3104C Biconical
30 MHz - 300 MHz	3110B Biconical
200 MHz - 2 GHz	3106 Dbl Rdg Waveguide
1 GHz - 18 GHz	3115 Dbl Rdg Waveguide
18 GHz - 40 GHz	3116 Dbl Rdg Waveguide
30 MHz - 1 GHz	3121C Dipole
30 MHz - 300 MHz	3124 Calculable Biconical
26 MHz - 2 GHz	3142B BiConiLog™
80 MHz - 2 GHz	3144 Log Periodic
200 MHz - 5 GHz	3147 Log Periodic
200 MHz - 2 GHz	3148 Log Periodic
960 MHz - 40 GHz	3160 Std Gain Horns
960 MHz - 40 GHz	3161 Std Gain Horns
10 kHz - 30 MHz	6502 Loop - Active
1 kHz - 30 MHz	6507 Loop - Active
20 Hz - 5 MHz	6511 Loop - Passive

VCCI — RADIATED EMISSIONS

20 MHz - 200 MHz	3104C Biconical
30 MHz - 300 MHz	3110B Biconical
30 MHz - 300 MHz	3124 Calculable Biconical
30 MHz - 1 GHz	3121C Dipole
26 MHz - 2 GHz	3142B BiConiLog™
200 MHz - 5 GHz	3147 Log Periodic
200 MHz - 2 GHz	3148 Log Periodic

VCCI — RADIATED IMMUNITY

200 MHz - 1 GHz	3101 Conical Log Spiral
200 MHz - 2 GHz	3106 Dbl Rdg Waveguide
1 GHz - 18 GHz	3115 Dbl Rdg Waveguide
30 MHz - 1 GHz	3121C Dipole
26 MHz - 2 GHz	3140 BiConiLog™
26 MHz - 2 GHz	3142B BiConiLog™
80 MHz - 2 GHz	3144 Log Periodic
200 MHz - 2 GHz	3148 Log Periodic
1 kHz - 30 MHz	6509 Loop - Active

VDE — RADIATED EMISSIONS

10 kHz - 30 MHz	6502 Loop - Active

CISPR/EC — RADIATED EMISSIONS

30 Hz - 50 MHz	3301B Rod - Active

IEC/CISPR/EN — RADIATED EMISSIONS

20 MHz -200 MHz	3104C Biconical
30 MHz - 300 MHz	3110B Biconical
30 MHz - 300 MHz	3124 Calculable Biconical
200 MHz - 2 GHz	3106 Dbl Rdg Waveguide
1 GHz - 18 GHz	3115 Dbl Rdg Waveguide
30 MHz - 1 GHz	3121C Dipole
26 MHz - 2 GHz	3142B BiConiLog™
80 MHz - 2 GHz	3144 Log Periodic
200 MHz - 5 GHz	3147 Log Periodic
200 MHz - 2 GHz	3148 Log Periodic
960 MHz - 40 GHz	3160 Std Gain Horns
960 MHz - 40 GHz	3161 Std Gain Horns
10 kHz - 30 MHz	6502 Loop - Active
1 kHz - 30 MHz	6507 Loop - Active
20 Hz - 5 MHz	6511 Loop - Passive
10 kHz - 30 MHz	6512 Loop - Passive

IEC/CISPR/EN — RADIATED IMMUNITY

20 MHz - 300 MHz	3109 Dbl Rdg Waveguide
200 MHz - 2 GHz	3106 Dbl Rdg Waveguide
1 GHz - 18 GHz	3115 Dbl Rdg Waveguide
26 MHz - 2 GHz	3140 BiConiLog™
26 MHz - 2 GHz	3142B BiConiLog™
80 MHz - 2 GHz	3144 Log Periodic
200 MHz - 5 GHz	3147 Log Periodic
200 MHz - 2 GHz	3148 Log Periodic
960 MHz - 40 GHz	3160 Log Periodic
960 MHz - 40 GHz	3161 Log Periodic
1 kHz - 30 MHz	6509 Loop - Passive

SAE J551 — RADIATED EMISSIONS

20 MHz - 200 MHz	3104C Biconical
30 MHz - 300 MHz	3124 Calculable Biconical
30 MHz - 300 MHz	3110B Biconical
200 MHz - 2 GHz	3106 Dbl Rdg Waveguide
1 GHz - 18 GHz	3115 Dbl Rdg Waveguide
30 MHz - 1 GHz	3121C Dipole
26 MHz - 2 GHz	3142B BiConiLog™
80 MHz - 2 GHz	3144 Log Periodic
200 MHz - 5 GHz	3147 Log Periodic
200 MHz - 2 GHz	3148 Log Periodic
30 Hz - 50 MHz	3301B Rod - Active
10 kHz - 30 MHz	6502 Loop - Active
1 kHz - 30 MHz	6507 Loop - Active
10 kHz - 30 MHz	6512 Loop - Passive

SAE J551 — RADIATED IMMUNITY

20 MHz - 300 MHz	3109 Biconical
200 MHz - 2 GHz	3106 Dbl Rdg Waveguide
1 GHz - 18 GHz	3115 Dbl Rdg Waveguide
26 MHz - 2 GHz	3140 BiConiLog™
26 MHz - 2 GHz	3142B BiConiLog™
960 MHz - 40 GHz	3160 Std Gain Horns
1 kHz - 30 MHz	6509 Loop - Active

SAE J1338 — RADIATED IMMUNITY

960 MHz - 40 GHz	3160 Std Gain Horns
960 MHz - 40 GHz	3161 Std Gain Horns

SAE J1113 — RADIATED EMISSIONS

200 MHz - 1 GHz	3101 Conical Log Spiral
1 GHz - 10 GHz	3102 Conical Log Spiral
100 MHz - 1 GHz	3103 Conical Log Spiral
20 MHz - 200 MHz	3104C Biconical
30 MHz - 300 MHz	3124 Calculable Biconical
30 MHz - 300 MHz	3110B Biconical
200 MHz - 2 GHz	3106 Dbl Rdg Waveguide
1 GHz - 18 GHz	3115 Dbl Rdg Waveguide
30 MHz - 1 GHz	3121C Dipole
26 MHz - 2 GHz	3142B BiConiLog™
80 MHz - 2 GHz	3144 Log Periodic
200 MHz - 5 GHz	3147 Log Periodic
200 MHz - 2 GHz	3148 Log Periodic
10 kHz - 30 MHz	6502 Loop - Active
1 kHz - 30 MHz	6507 Loop - Active

SAE J1113 — RADIATED IMMUNITY

200 MHz - 1 GHz	3101 Conical Log Spiral
1 GHz - 10 GHz	3102 Conical Log Spiral
100 MHz - 1 GHz	3103 Conical Log Spiral
20 MHz - 300 MHz	3109 Dbl Rdg Waveguide
200 MHz - 2 GHz	3106 Dbl Rdg Waveguide
1 GHz - 18 GHz	3115 Dbl Rdg Waveguide
26 MHz - 2 GHz	3140 BiConiLog
26 MHz - 2 GHz	3142B BiConiLog™
80 MHz - 2 GHz	3144 Log Periodic
200 MHz - 2 GHz	3148 Log Periodic
960 MHz - 40 GHz	3160 Log Periodic
960 MHz - 40 GHz	3161 Log Periodic
1 kHz - 30 MHz	6509 Loop - Passive

SAE J1507 — RADIATED IMMUNITY

960 MHz - 40 GHz	3160 Std Gain Horns
960 MHz - 40 GHz	3161 Std Gain Horns

SAE J1551 — RADIATED IMMUNITY

960 MHz - 40 GHz	3160 Std Gain Horns
960 MHz - 40 GHz	3161 Std Gain Horns

SAE J1816 — RADIATED EMISSIONS

30 Hz - 50 MHz	3301B Rod - Active
10 kHz - 30 MHz	6502 Loop - Active
1 kHz - 30 MHz	6507 Loop - Active
10 kHz - 30 MHz	6512 Loop - Passive

NSA 65-6 — TRANSMIT

1 kHz - 30 MHz	3303 Rod - Active
1 kHz - 30 MHz	6509 Loop - Passive

NSA 65-6 — RECEIVE

30 Hz - 50 MHz	3301B Rod - Active
1 kHz - 30 MHz	6507 Loop - Active

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MIL-STD-285 TRANSMIT

20 MHz - 200 MHz	3104C Biconical
20 MHz - 300 MHz	3109 Biconical
1 GHz - 18 GHz	3115 Dbl Rdg Waveguide
18 GHz - 40 GHz	3116 Dbl Rdg Waveguide
960 MHz - 40 GHz	3160 Std Gain Horns
960 MHz - 40 GHz	3161 Std Gain Horns
26 MHz - 2 GHz	3140 BiConiLog™
26 MHz - 2 GHz	3142B BiConiLog™
200 MHz - 2 GHz	3148 Log Periodic
1 kHz - 30 MHz	3303 Rod - Passive
1 kHz - 30 MHz	6509 Loop - Passive

MIL-STD-285 RECEIVE

20 MHz - 200 MHz	3104C Biconical
20 MHz - 300 MHz	3109 Biconical
30 MHz - 300 MHz	3110B Biconical
1 GHz - 18 GHz	3115 Dbl Rdg Waveguide
18 GHz - 40 GHz	3116 Dbl Rdg Waveguide
960 MHz - 40 GHz	3160 Std Gain Horns
960 MHz - 40 GHz	3161 Std Gain Horns
26 MHz - 2 GHz	3142B BiConiLog™
200 MHz - 2 GHz	3148 Log Periodic
30 Hz - 50 MHz	3301B Rod - Active
1 kHz - 30 MHz	6507 Loop - Active

TELECOM

440 MHz - 460 MHz	3125 Dipole (450)
590 MHz - 610 MHz	3125 Dipole (600)
824 MHz - 915 MHz	3125 Dipole (870)
935 MHz - 960 MHz	3125 Dipole (950)
1600 MHz -1620 MHz	3125 Dipole (1610)
1710 MHz -1785 MHz	3125 Dipole (1750)
1805 MHz -1880 MHz	3125 Dipole (1840)
1850 MHz -1910 MHz	3125 Dipole (1880)
2440 MHz -2460 MHz	3125 Dipole (2450)
2990 MHz -3010 MHz	3125 Dipole (3000)
400 MHz - 6 GHz	3164 Diag Dual Polar Horn

MIL-STD-461E RADIATED EMISSIONS

200 MHz - 1 GHz	3101 Conical Log Spiral
1 GHz - 10 GHz	3102 Conical Log Spiral
100 MHz - 1 GHz	3103 Conical Log Spiral
20 MHz - 200 MHz	3104C Biconical
30 MHz - 300 MHz	3110B Biconical
30 MHz - 300 MHz	3124 Calculable Biconical
200 MHz - 2 GHz	3106 Dbl Rdg Waveguide
1 GHz - 18 GHz	3115 Dbl Rdg Waveguide
18 GHz - 40 GHz	3116 Dbl Rdg Waveguide
400 MHz - 6 GHz	3164 Diag. Dual Polar Horn
960 MHz - 40 GHz	3160 Std Gain Horns
960 MHz - 40 GHz	3161 Std Gain Horns
26 MHz - 2 GHz	3142B BiConiLog™
80 MHz - 2 GHz	3144 Log Periodic
200 MHz - 2 GHz	3148 Log Periodic
30 Hz - 50 MHz	3301B Rod - Active
20 Hz - 500 kHz	7604 Coil - Transducer

MIL-STD-461E RADIATED SUSCEPTIBILITY

200 MHz - 1 GHz	3101 Conical Log Spiral
1 GHz - 10 GHz	3102 Conical Log Spiral
100 MHz - 1 GHz	3103 Conical Log Spiral
20 MHz - 300 MHz	3109 Biconical
200 MHz - 2 GHz	3106 Dbl Rdg Waveguide
1 GHz - 18 GHz	3115 Dbl Rdg Waveguide
18 GHz - 40 GHz	3116 Dbl Rdg Waveguide
960 MHz - 40 GHz	3160 Std Gain Horns
960 MHz - 40 GHz	3161 Std Gain Horns
26 MHz - 2 GHz	3140 BiConiLog™
26 MHz - 2 GHz	3142B BiConiLog™
80 MHz - 2 GHz	3144 Log Periodic
200 MHz - 2 GHz	3148 Log Periodic
20 Hz - >50 kHz	7603 Magnetic Field Coil
30 Hz - >50 kHz	7605 Magnetic Field Coil
30 Hz - >50 kHz	7606 Magnetic Field Coil

MIL-STD-1541 RADIATED EMISSIONS

200 MHz - 1 GHz	3101 Conical Log Spiral
1 GHz - 10 GHz	3102 Conical Log Spiral
100 MHz - 1 GHz	3103 Conical Log Spiral
20 MHz - 200 MHz	3104C Biconical
30 MHz - 300 MHz	3110B Biconical
30 MHz - 300 MHz	3124 Calculable Biconical
200 MHz - 2 GHz	3106 Dbl Rdg Waveguide
1 GHz - 18 GHz	3115 Dbl Rdg Waveguide
18 GHz - 40 GHz	3116 Dbl Rdg Waveguide
30 MHz - 1 GHz	3121C Dipole
960 MHz - 40 GHz	3160 Std Gain Horns
960 MHz - 40 GHz	3161 Std Gain Horns
26 MHz - 2 GHz	3142B BiConiLog™
200 MHz - 2 GHz	3148 Log Periodic
10 kHz - 30 MHz	6502 Loop - Active
1 kHz - 30 MHz	6507 Loop - Active
20 Hz - 5 MHz	6511 Loop - Passive

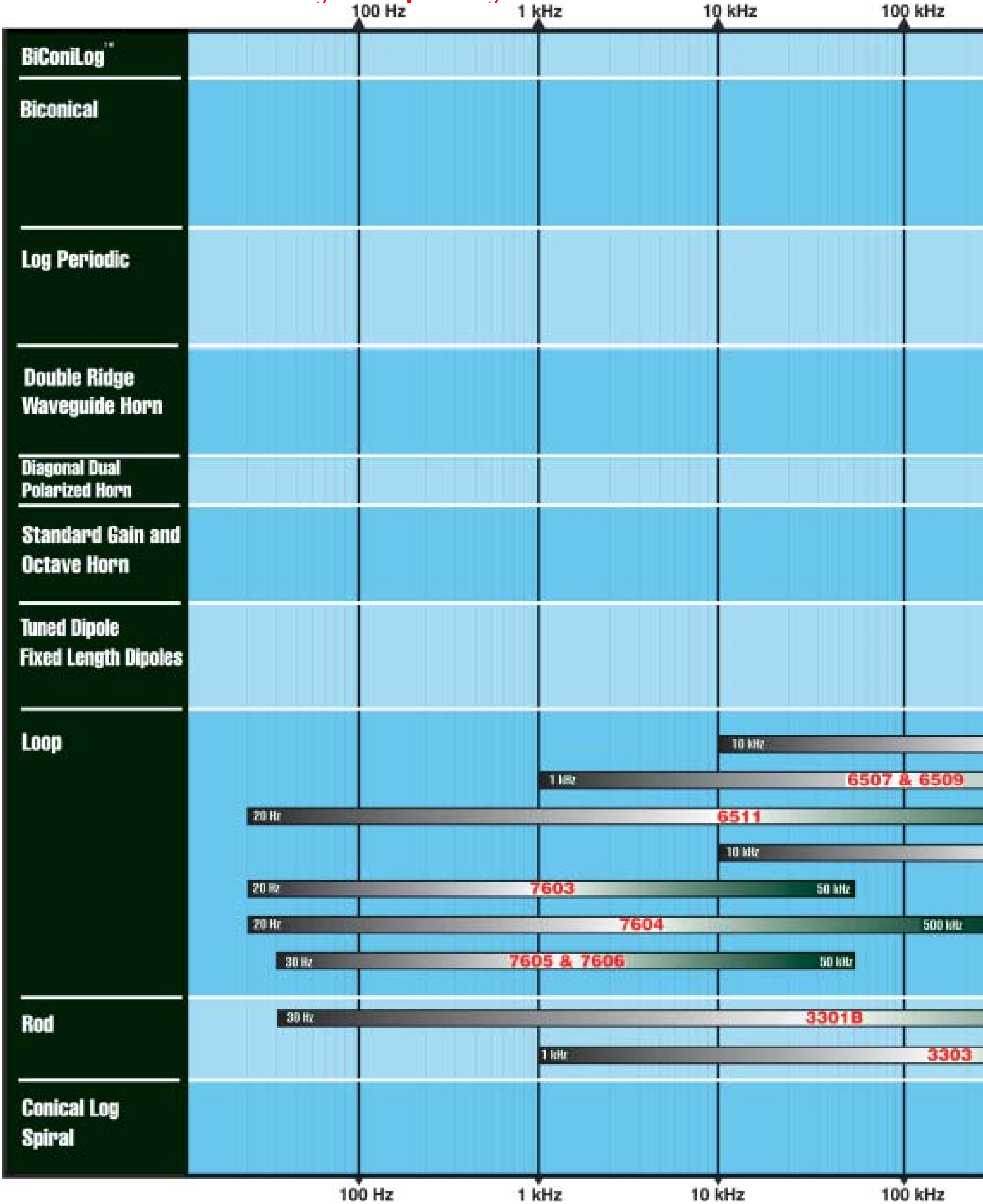
MIL-STD-1541 RADIATED SUSCEPTIBILITY

100 MHz - 1 GHz	3103 Conical Log Spiral
20 MHz - 300 MHz	3109 Biconical
200 MHz - 2 GHz	3106 Dbl Rdg Waveguide
1 GHz - 18 GHz	3115 Dbl Rdg Waveguide
26 MHz - 2 GHz	3140 BiConiLog™
26 MHz - 2 GHz	3142B BiConiLog™
80 MHz - 2 GHz	3144 Log Periodic
200 MHz - 2 GHz	3148 Log Periodic
960 MHz - 40 GHz	3160 Std Gain Horns
1 kHz - 30 MHz	6509 Loop - Passive
20 Hz - 5 MHz	6511 Loop - Passive

NACSIM RADIATED EMISSIONS

200 MHz - 1 GHz	3101 Conical Log Spiral
1 GHz - 10 GHz	3102 Conical Log Spiral
100 MHz - 1 GHz	3103 Conical Log Spiral
20 MHz - 200 MHz	3104C Biconical
30 MHz - 300 MHz	3110B Biconical
30 MHz - 300 MHz	3124 Calculable Biconical
200 MHz - 2 GHz	3106 Dbl Rdg Waveguide
1 GHz - 18 GHz	3115 Dbl Rdg Waveguide
18 GHz - 40 GHz	3116 Dbl Rdg Waveguide
400 MHz - 6 GHz	3164 Diag Dual Polar Horn
960 MHz - 40 GHz	3160 Std Gain Horns
960 MHz - 40 GHz	3161 Std Gain Horns
26 MHz - 2 GHz	3142B BiConiLog™
200 MHz - 5 GHz	3147 Log Periodic
200 MHz - 2 GHz	3148 Log Periodic
30 Hz - 50 MHz	3301B Monopole (Rod)
10 kHz - 30 MHz	6502 Loop - Active
1 kHz - 30 MHz	6507 Loop - Active
20 Hz - 5 MHz	6511 Loop - Passive

Antenna Selection by Frequency



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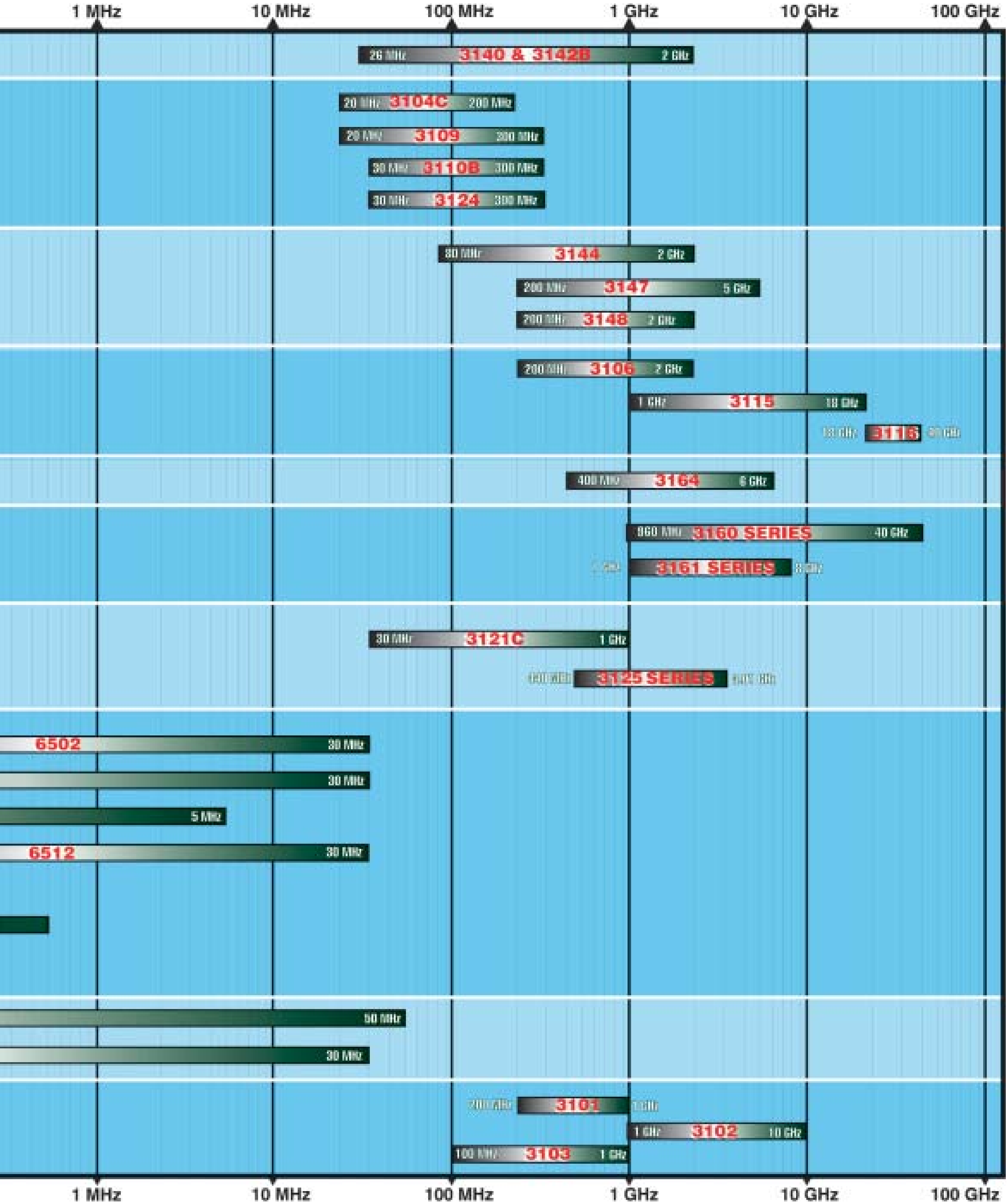
1 MHz
10 MHz
100 MHz
1 GHz
10 GHz
100 GHz
26 MHz 3140 & 3142B 2 GHz
20 MHz 3104C 200 MHz
20 MHz 3109 300 MHz
30 MHz 3110B 300 MHz
30 MHz 3124 300 MHz
80 MHz 3144 2 GHz
200 MHz 3147 5 GHz
200 MHz 3148 2 GHz
200 MHz 3106 2 GHz
1 GHz 3115 18 GHz
3116
400 MHz 3164 6 GHz
960 MHz 3160 SERIES 40 GHz
3161 SERIES
30 MHz 3121C 1 GHz
3125 SERIES
6502 30 MHz
30 MHz
5 MHz
6512 30 MHz
50 MHz
30 MHz
3101
1 GHz 3102 10 GHz
100 MHz 3103 1 GHz
1 MHz
10 MHz
100 MHz
1 GHz
10 GHz
100 GHz

Expanded Uncertainty Values for Antenna Calibrations (95% Confidence)

TYPE	MODEL NUMBER	FREQUENCY RANGE	SAE, ARP 958 1M	ANSI C63.5 3M	ANSI C63.5 10M	IEEE 291, IEEE 1309, ANSI C63.4
Conical Log Spiral (L&R)	**3101**	200MHz-1GHz	200-300 MHz +/- 2.8 dB 300-850 MHz +/- 0.8 dB 850-1000 MHz +/- 1.4 dB			
Conical Log Spiral (L&R)	**3102**	1GHz-10GHz	1-10 GHz +/- 0.8 dB			
Conical Log Spiral (L&R)	**3103**	100MHz-1GHz	+/- 2.0 dB Type B			
Biconical	**3104C**	20MHz-200MHz	20-200 MHz +/- 1.2 dB	200MHz +/- 0.9 dB	20-30 MHz +/- 1.0 dB 30-200 MHz +/- 0.9 dB	
Biconical	**3109**	20MHz-300MHz	20-30 MHz +/- 1.0 dB 30-200 MHz +/- 1.4 dB 200-300 MHz +/- 2.0 dB	20-30 MHz +/- 0.9 dB 30-300 MHz +/- 0.9 dB	20-30 MHz +/- 1.0 dB 30-300 MHz +/- 0.9 dB	
Biconical	**3110B**	30MHz-300MHz	30-200 MHz +/- 1.2 dB 200-300 MHz +/- 2.2 dB	20-200 MHz +/- 0.8 dB	20-30 MHz +/- 1.0 dB 30-300 MHz +/- 0.9 dB	
BiCal	**3124**	30MHz-300MHz		300MHz - 300 MHz +/-0.50 dB		
Double-Ridged Waveguide Horn	**3106**	200MHz-2GHz	0.2-1.9 GHz +/- 1.0 dB 1.9-2.0 GHz +/- 1.3 dB			
Double-Ridged Waveguide Horn	**3115**	1GHz-18GHz	1-18 GHz +/- 0.3 dB			
Double-Ridged Waveguide Horn	**3116**	18GHz-40GHz	18-30 GHz +/- 0.8 dB 30-40 GHz +/- 1.3 dB			
Diagonal Dual Polarized Horn	**3164**	400 MHz - 6 GHz	.4-6 GHz +/- 1.0 dB			
Octave Horns	**3161-01**	1GHz-2GHz	1-2 GHz +/- 0.9 dB			
Octave Horns	**3161-02**	2GHz-4GHz	2-4 GHz +/- 0.5 dB			
Octave Horns	**3161-03**	4GHz-8GHz	4-4.5 GHz +/- 1.0 dB 4.5-7.5 GHz +/- 0.4 dB 7.5-8 GHz +/- 1.3 dB			
Dipole	**3121C 4 Balun Kit**	30MHz-1GHz				
Dipole	**3121C Balun 1**	30MHz-60MHz		30-60 MHz +/- 0.9 dB	30-60 MHz +/- 1.0 dB	
Dipole	**3121C Balun 2**	60MHz-140MHz		60-140 MHz +/- 0.7 dB	60-140 MHz +/- 0.7 dB	

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Expanded Uncertainty Values for Antenna Calibrations (95% Confidence)

TYPE	MODEL NUMBER	FREQUENCY RANGE	SAE, ARP 958 1M	ANSI C63.5 3M	ANSI C63.5 10M	IEEE 291, IEEE 1309, ANSI C63.4
Dipole	**3121C Balun 3**	140MHz-400MHz		140-375 MHz +/- 1.0 dB 375-400 MHz +/- 1.4 dB	140-375 MHz +/- 1.0 dB 375-400 MHz +/- 1.4 dB	
Dipole	**3121C Balun 4**	400MHz-1GHz		400-700 MHz +/- 1.0 dB 700-1000 MHz +/- 1.4 dB	400-700 MHz +/- 1.6 dB 700-1000 MHz +/- 2.1 dB	
DB3&4 Tuned				140-400 MHz +/- 0.8 dB 400-1000 MHz +/- 1.0 dB	140-400 MHz +/- 0.8 dB 400-1000 MHz +/- 1.0 dB	
BiConiLog	**3142B**	26MHz-2GHz/ 26MHz-1.1GHz	26-30 MHz +/- 1.4 dB 30-1000 MHz +/- 0.8 dB 1-2 GHz +/- 1.2 dB	26-30 MHz +/- 1.5 dB 30-1000 MHz +/- 1.0 dB 1-2 GHz +/- 1.3 dB	26-30 MHz +/- 2.1 dB 30-1000 MHz +/- 1.0 dB 1-2 GHz +/- 1.4 dB	
LPA	**3144**	80MHz-2GHz	+/- 2.0 dB, Type B	80-2000 MHz +/- 0.9 dB	80-2000 MHz +/- 0.8 dB	
LPA	**3147**	200MHz-5GHz	200-2000 MHz +/- 0.5 dB 2-5 GHz +/- 1.6 dB	200-1000 MHz +/- 0.8 dB 1-2 GHz +/- 0.9 dB 2-5 GHz +/- 1.5 dB	200-1000 MHz +/- 0.8 dB 1-2 GHz +/- 1.0 dB 2-5 GHz +/- 1.5 dB	
LPA	**3148**	200MHz-2GHz	200-1000 MHz +/- 0.6 dB 1-2 GHz +/- 1.41 dB	200-1000 MHz +/- 0.9 dB 1-2 GHz +/- 0.9 dB	200-1000 MHz +/- 0.8 dB 1-2 GHz +/- 0.9 dB	
Rod	**3301B 41 inch Rod**	30Hz-50MHz				30Hz-50MHz +/- 0.3 dB
Rod	**3303**	1kHz-30MHz				1kHz-10kHz +/- 1.0 dB 10kHz-30MHz +/- 0.1 dB
Loop	**6502**	10kHz-30MHz				(TBD)
Loop	**6507**	1kHz-30MHz				(TBD)
Loop	**6509**	1kHz-30MHz				(TBD)
Loop	**6511**	20Hz-5MHz				(TBD)
Loop	**6512**	10kHz-30MHz				(TBD)
Coil	**7603**	20Hz-50kHz				No Cal/VSWR Only
Coil	**7604**	20Hz-500kHz				No Cal/VSWR Only
Coil	**7605**	30Hz-50kHz				No Cal Req
Coil	**7606**	30Hz-50kHz				No Cal Req

Data effective 8 June 1998. EMCO Laboratory capabilities include all products produced by EMCO and models of the same technology produced by other manufacturers. Uncertainty values reflect the uncertainty analysis conducted using 1997 data. Values released are valid with a 2 sigma (95%) confidence level and are representative of the measurement quality conducted by the EMCO Laboratory using the industry recognized standards listed above.

Laboratory Standards Compliance List

SAE, ARP 958 - 1997, Society of Automotive Engineers, Aerospace Recommended Practice 958, Electromagnetic Interference Measurement Antennas; Standard Calibration Method.

ANSI C63.4 - 1992, American National Standard, Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz.

ANSI C63.5 - 1988, American National Standard, Calibration of Antennas Used for Radiated Emission Measurements in Electromagnetic Interference (EMI) Control.

ANSI C63.6 - 1988, American National Standard, Guide for the Computation of Errors in Open Area Test Site Measurements.

ANSI C63.7 - 1992, American National Standard, Guide for Construction of Open-Area Test Sites for Performing Radiated Emission Measurements.

ANSI Z540-1 - 1994, American National Standard, Calibration Laboratories and Measuring and Test Equipment - General Requirements.

ANSI Q91 - 1994, Quality Systems - Model for Quality Assurance in Design, Development, Production, Installation and Servicing.

ISO Guide 25 - 1990, International Standards Organization, General Requirements for the Competence of Calibration and Testing Laboratories.

IEEE 291 - 1991, Institute of Electrical and Electronics Engineers, Standard Methods for Measuring Electromagnetic Field Strengths of Sinusoidal Continuous Waves, 30 Hz to 30 GHz.

IEEE Std 1309 - 1996, Institute of Electrical and Electronics Engineers, Standard for Calibration of Electromagnetic Field Sensors and Probes, Excluding Antennas, from 9 kHz to 40 GHz.

NIST Technical Note 1297, 1994 edition, National Institute of Standards and Technology, Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results.

NIS 81, Edition 1, May 1994, NAMAS, The Treatment of Uncertainty in EMC Measurements.

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A Statistical Approach to Measurement Uncertainty

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Despite the fact that most authors have skirted the subject of Type A analyses, the method is not so difficult that it should be avoided altogether.

Introduction

Over the past couple of years, the topic of measurement uncertainty has come to the forefront in the international EMC community. In brief, the intention of measurement uncertainty is to take the more traditional terms of precision, accuracy, random error, and systematic error used in scientific circles and replace them with a single term. This term represents the total contribution to the expected deviation of a measurement from the actual value being measured[1-2].

In general, precision is a measure of random error, or how closely repeated attempts hit the same point on a target, while accuracy is a measure of systematic error, or how close those attempts are to the center of the target. It is obvious that both contributions must be accounted for in order to determine the quality of a measurement, although the combination of the two can sometimes be more subtle than might be expected. There has been some discussion over whether the term reproducibility is also replaced by uncertainty since the concept of reproducibility must contain variations in the equipment under test (EUT) and therefore does not represent the same quantity as measurement uncertainty[3].

The methods for determining a measurement uncertainty have been divided into two generic classes:

- Type A represents a statistical uncertainty based on a normal distribution.
- Type B represents uncertainties determined by any other means.

In last year's ITEM, Manfred Stecher wrote an article describing the introduction of uncertainty evaluations into various EMC standards and explained the technique typically used to determine measurement uncertainties for EMC measurements[4]. (A similar paper was also presented at the 1996 IEEE International EMC Symposium in Santa Clara, CA.[5]) The article gives an adequate introduction to the Type B evaluation method, which uses individual measurements, manufacturers specifications, and even educated guesses to determine a combined uncertainty. However, the author is a little too quick to discard the statistical Type A uncertainty measurement as impractical. To be sure, the Type A analysis does suffer from the very pitfalls which Mr. Stecher points out. However, with a bit of care it is possible to obtain a significant amount of useful information from the technique.

The advantage of a Type A uncertainty measurement is that when done correctly, the resulting value is irrefutable since it has been determined from real world measurements. The biggest complaint I hear from engineers being exposed to the Type B uncertainty budget method for the first time is the fact that too many of the terms are either poorly defined by equipment manufacturers or must simply be estimated. In many cases, the chosen values may be too stringent in order to provide a safety margin. On the other hand, the desire for smaller total uncertainties can lead to using smaller estimations than is realistic for some terms that are hard to determine.

Antenna manufacturers have easy access to a vast database of antenna calibrations with which to determine statistical trends. However, as the data shown here will demonstrate, it is not necessary to have an extremely large sample to get acceptable results. The real issue in using a statistical approach is in determining where it fails and using a Type B analysis to fill in the gaps. The document NIS 81, "The Treatment of Uncertainty in EMC Measurements", released by NAMAS[1], recommends this exact approach.

Certainly a Type A analysis of a set of measurements can be expected to include all random errors of the entire measurand and none of its systematic errors. But does that mean that the Type A uncertainty

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contains only the random portion of the individual terms which might be used in a Type B analysis? Certainly not. It is not possible to completely separate random and systematic effects into individual categories[2]. Random effects such as positioning error[6] or cable length and frequency dependence of standing waves can serve to randomize such systematic errors as site imperfections or mismatch errors. Intentionally varying the setup between repeated measurements can do the same.

The discussion presented here will focus primarily on antenna calibration measurements, which have many similarities to radiated emissions measurements. However, many of the techniques demonstrated will be applicable to radiated susceptibility and conducted tests. Despite the fact that most authors have skirted the subject of Type A analyses, the method is not so difficult that it should be avoided altogether. In fact, many of the more difficult terms to determine for a typical Type B analysis are already included in the random error of the total measurement, thus reducing the overall task.

Type A Evaluation of Uncertainty

Random effects cause repeated measurements to vary in an unpredictable manner. The associated uncertainty can be calculated by applying statistical techniques to the repeated measurements. An estimate of the standard deviation, $s(q_k)$, of a series of n readings, q_k, is obtained from

$$s(q_k) = \sqrt{\frac{1}{(n-1)}\sum_{k=1}^{n}(q_k - \overline{q})^2}$$

where $\overline{q}$ is the mean value of measurements. The random component of the uncertainty may be reduced through repeated measurements of the EUT. In this case, the standard deviation of the mean, $s(\overline{q})$, given by:

$$s(\overline{q}) = \frac{s(q_k)}{\sqrt{n}}$$

represents the uncertainty of the resulting mean. This last point has been misinterpreted by some due to a confusing statement in section 3.2.6 of NIS 81, "The standard uncertainty, $u(x_i)$, of an estimate x_i of an input quantity q is therefore $u(x_i) = s(\overline{q})$." This statement is certainly true, but some readers have construed it to mean that the standard uncertainty of a single measurement q_k is given by $s(\overline{q})$.[7-8] This is true if $n = 1$ so that $s(\overline{q}) = s(q_k)$. This is explained more clearly in section 3.2.3 of NIS 81 where the concept of predetermination is discussed.

Time constraints and other practical considerations will often make it unfeasible to perform more than a single measurement on an EUT. However, repeat measurements can be performed on a similar EUT to predetermine $s(q_k)$ as the expected standard uncertainty of an individual measurement. If a smaller uncertainty due to random errors is desired, multiple measurements can be made and the value of $s(\overline{q})$ reduced accordingly. The value of used in this case is the number of measurements made on the EUT, not the number of measurements used in the predetermination.

It should be noted that variations in the EUT as a function of time, as well as that of multiple like EUTs as in the method demonstrated here, will be included in the uncertainty determined through this method. For this reason, and to provide a means to determine some of the systematic contributions to the uncertainty, it is recommended that a stable reference radiating source such as a comb generator or amplified noise source be used as the EUT for uncertainty determinations. This provides a repeatable EUT which, when used in conjunction with "round robin" type testing, can allow determination of even the systematic elements of your measurement uncertainty to within the uncertainty of the round robin test. This type of EUT also provides a broad continuous frequency range for uncertainty determination as opposed to the random spectrum points of a typical EUT. If a reference source is not available, a number of the same benefits may be obtained using a stable signal generator and appropriate radiating antenna. However, transmit cable placement and other effects will add some additional random error and this method does not lend itself to inter-site comparisons.

Uncertainty Example: Antenna Calibration

Antenna calibrations have uncertainty aspects similar to that of both radiated emissions and susceptibility tests. However, the one systematic element missing from the test is the absolute value of the fields (or signal levels) involved. Thus, the test only depends on the linearity of the instrumentation and not its absolute calibration. However, this does not effect the validity of this method for determining Type A uncertainties for EMC tests since the systematic error in field level cannot be determined by this method without inter-site comparisons or other tests using multiple methods to determine the absolute field level.

To obtain the data shown here, a sample of 26 different antennas calibrated over a three-and-a-half month period was used. The antennas were identical log-periodic antennas with a frequency span of 200

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MHz to 1 GHz. The time period spanned from mid-August through the end of October, providing a significant variation in temperature and weather conditions. The data were measured at 1601 frequency points using a vector network analyzer, low loss cables, and a positioning tower with 0.1 cm positioning resolution. The test was performed at a 10-meter separation, 2-meter transmit height, and 1- to 4-meter scan height per ANSI C63.5 on an open area test site (OATS). The vector network analyzer used has over 100 dB of available dynamic range and superior external noise rejection, making it ideal for use on an OATS where ambients would be a problem for traditional spectrum analyzer/tracking generator combinations. Since the network analyzer does not offer a max-hold or other such functionality traditionally seen on a spectrum analyzer, it is necessary to perform the max-hold by transferring individual traces to a controlling PC and allowing the test software to perform the max-hold.

To facilitate this method, it is also necessary to step the tower and take frequency sweeps at discrete heights since the network analyzer cannot sweep the entire frequency band fast enough to get acceptable height resolution when the tower moves continuously. Tests with tuned dipoles have shown that the variation in the antenna factor at 1 GHz for a 1-cm step, a 5-cm step, and a single frequency point continuous motion max-hold is less than ±0.02 dB. If the tower step size was too large, or the sweep time too slow in the case of a continuous motion, the measurement could be expected to introduce a systematic error since missing a peak signal would always result in a measurement lower than the real value. This error exists for scanned height radiated emissions tests as well as antenna calibrations. For an antenna calibration, this error would result in a larger antenna factor than is actually the case.

The standard deviation of the 26 antenna factors and their maximum deviations from the average are shown as a function of frequency in Figure 1. The negative of the standard deviation is also shown for comparison to the negative deviation. The symmetry of the positive and negative deviations is a first indication of how closely the sample approximates a normal distribution. An asymmetrical envelope would be a cause for concern and indicate the need for separate positive and negative uncertainty values at the minimum.

Neglecting, for the moment, any additional contributions to the uncertainty due to systematic errors, these data indicate that the expanded uncertainty ($k = 2$) of an individual calibration is less than ±0.5 dB at all frequencies. That means that an uncertainty of ±0.5 dB with greater than 95% confidence can be claimed for this

Uncertainty Terms from NIS-81

- Estimated standard deviation from a sample of readings:

$$s(q_k) = \sqrt{\frac{1}{(n-1)}\sum_{k=1}^{n}(q_k - \overline{q})^2}$$

- Standard deviation of the mean of readings:

$$s(\overline{q}) = \frac{s(q_k)}{\sqrt{n}}$$

- Standard uncertainty (of the mean of readings) resulting from a type A evaluation:

$$u(x_i) = s(\overline{q})$$

- Standard uncertainty for contributions with a normal probability distribution:

$$u(x_i) = \frac{U}{k}$$

where U represents the expanded uncertainty of the normal distribution (last item below).

- Standard uncertainty for contributions with rectangular probability distribution:

$$u(x_i) = \frac{a_{i+} - a_{i-}}{2\sqrt{3}}$$

for an asymmetrical distribution, where a_{i+} and a_{i-} are the bounds of the rectangular region, or

$$u(x_i) = \frac{a_i}{\sqrt{3}}$$

for a symmetrical region with bounds $\pm a_i$.

- Standard uncertainty for contributions with U shaped probability distribution:

$$u(x_i) = \frac{a_{i+} - a_{i-}}{2\sqrt{2}}$$

for an asymmetrical distribution, where a_{i+} and a_{i-} are the bounds of the U shaped region, or

$$u(x_i) = \frac{a_i}{\sqrt{2}}$$

for a symmetrical region with bounds $\pm a_i$ or where a_i is the larger of a_{i+} or a_{i-}.

- Standard uncertainty in terms of the measured quantity:

$$u_i(y) = c_i \cdot u(x_i)$$

- Combined standard uncertainty:

$$u_c(y) = \sqrt{\sum_{i=1}^{N} u_i^2(y)}$$

- Expanded uncertainty:

$$U = k \cdot u_c(y) \quad \text{or} \quad U = k_p \cdot u_c(y)$$

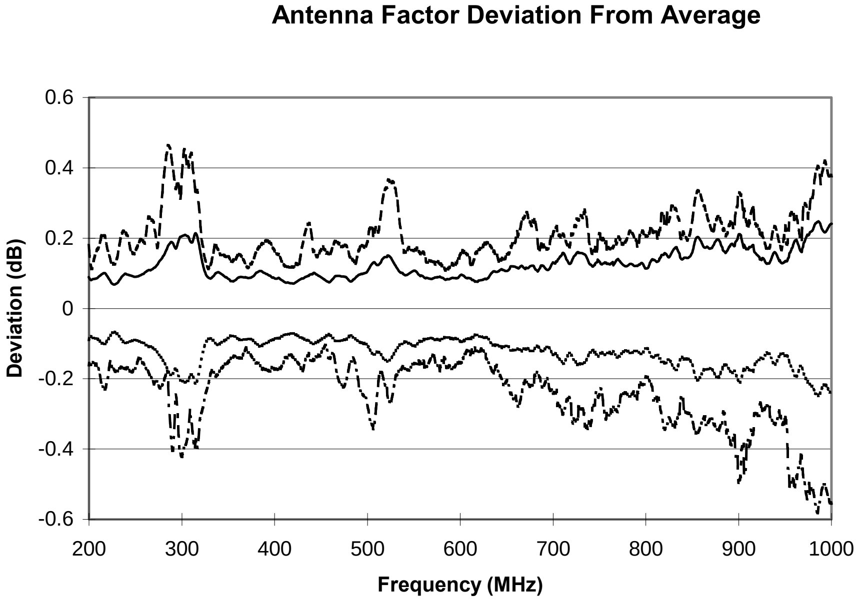

Figure 1. The Standard Deviation, Maximum Minus Average, and Minimum Minus Average of the Antenna Factors from a Set of Twenty-six Identical Antennas. Neglecting any additional systematic errors, the expanded uncertainty (k=2) for an individual antenna factor would then be twice the standard deviation for a value of approximately ±0.5 dB with greater than 95% confidence at all frequencies.

calibration. A second verification of this claim is the fact that, with the exception of the negative deviation above 950 MHz, none of the antennas in the sample had antenna factors which deviated from the average more than ±0.5 dB. This provides an added level of confidence in the quality of this uncertainty value.

It should be noted that this data represents calibrations of 26 different antennas performed at different times. About fifty percent of the antennas were directly off the production line, but the other half were re-calibrations of antennas as many as ten years old. Although one might expect a batch of antennas to be as close to identical as possible, this sample surely must contain some amount of manufacturing uncertainty. If this manufacturing uncertainty is non-zero, then it must also be contained within the above uncertainty. Since the "perfect" antenna, in terms of manufacturing quality, is defined by the average of all antennas, this uncertainty must be totally random.

Although this manufacturing uncertainty may add to the total calibration uncertainty measured by this technique, as long as the resulting uncertainty is within an acceptable range, it does not matter whether or not the contribution is large or small. In this case, there is also the added benefit that the intentional introduction of totally random effects due to

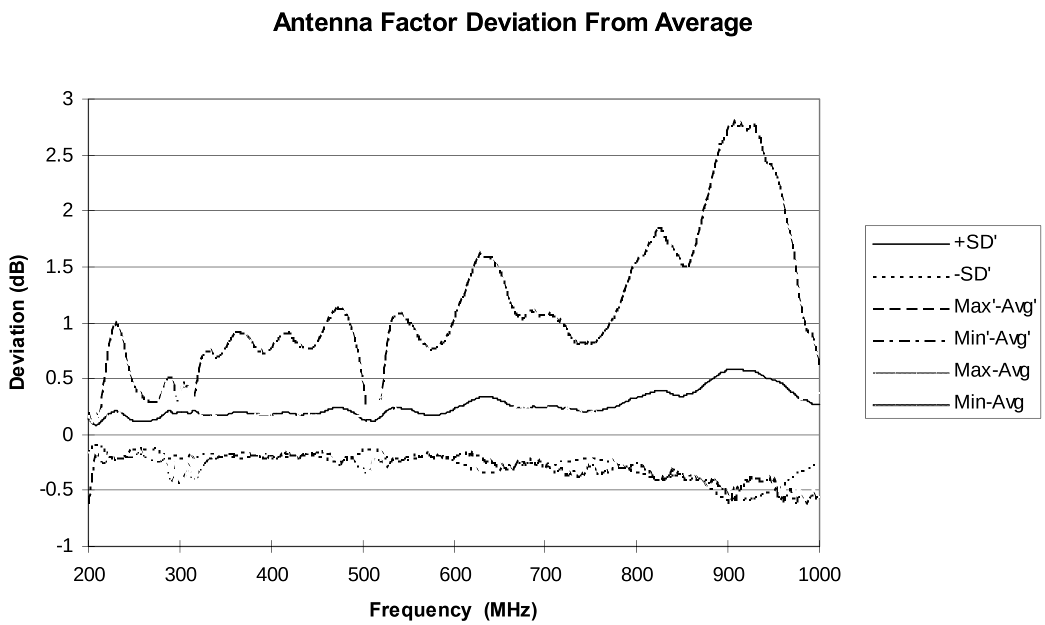

Figure 2. The Effect of EUT Variation on the Standard Deviation. Note the Difference in the Maximum Deviation for the Primed Sample Vs. Un-primed. The effect on the standard deviation is sufficient to equal or surpass the maximum deviation in the un-primed sample.

the antennas may help to randomize the systematic contributions to the total measurement uncertainty. For emissions measurements, this is equivalent to using multiple identical EUTs to determine the Type A uncertainty. As long as variations in the EUTs do not add excessive contributions to the random error, it is possible to obtain a suitable uncertainty value from tests of multiple EUTs.

This is not to say that multiple EUTs always provide an acceptable method for performing this type of uncertainty calculation. One or two EUTs with significant deviations from the norm can introduce a significant change to the resulting uncertainty, as demonstrated in Figure 2. One additional antenna, a different model which varies significantly from the average at different frequencies, was introduced to the sample to demonstrate the possible effects.

Note that for most of the frequency range, the deviation is below 1 dB, yet the contribution of one additional antenna is sufficient to change the standard deviation such that it is larger than the original maximum deviations at most frequencies. As this example shows, when working with relatively small samples, it is important not to introduce factors which may exaggerate the error in the measurement. Likewise, it is important to avoid arbitrarily discarding data because it makes the result look bad!

Figure 2 also demonstrates the difference between systematic errors and random errors. One sample with a large systematic error (not present in the other samples) can have a significant effect on the uncertainty, since it changes not only the standard deviation, but also the mean of the samples. This causes the negative maximum deviation (minimum - average) to be larger than before, even though the absolute value of the minimum curve is the same.

Note that the standard deviation shown in Figure 2 would still allow the claim of ±0.5 dB for the expanded uncertainty from 200 to 600 MHz. It is perfectly acceptable (and often necessary due to band breaks in equipment) to generate frequency dependent uncertainties. The expanded uncertainty from 600 to 800 MHz could then be set at ±0.8 dB and from 800 MHz to 1 GHz at ±1.2 dB.

Cleanup: Type B Evaluation

In order to develop a final value for the expanded uncertainty, it is necessary to make an evaluation of all of the typical contributions to uncertainty to determine which terms are included in the Type A result. In this case, nearly every effect exerts a random contribution due to the considerable variation in test setup and conditions over the allotted time period. Factors such as temperature and humidity effects, ground plane quality due to ground moisture, ground plane warping with temperature , test cable lengths, cable connection quality, cable calibration, etc. all varied significantly over the sample. Table 1 lists some of the typical entries in a Type B uncertainty budget and suggests which ones are likely to be totally random, systematic, or a combination of the two. The listed distribution type repre-

Contribution	Distribution Type	Random	Systematic	AF Cal	RE	RI
Antenna factor	Normal		X		X	
Cable calibration	Normal	X		X	X	
Coupler calibration	Normal		X			X
Receiver/probe linearity	Rectangular	X	x	X	X	X
Receiver level detection	Rectangular	x	X		X	X
Antenna directivity	Rectangular	X			X	
AF variation with height	Rectangular		X		X	
Antenna phase center	Rectangular		X		X	
Field uniformity	Rectangular	X				X
Frequency interpolation	Rectangular	X	x		X	X
Distance measurement	Rectangular	X	x	X	X	X
Height measurement	Rectangular	X	x	X	X	
Site imperfections	Rectangular	X	x	X	X	
Mismatch	U-shaped	X	x	X	X	X
Temperature effects	Rectangular	X		X	X	X
Setup repeatability	Type A	X		X	X	X
Ambient signals	Rectangular	X	x	X	X	
EUT repeatability	Type A	X			X	X

Table 1. *Various Possible Contributions to Measurement Uncertainty, along with Typical Accepted Distribution Types and Possible Contributions to Both Random and Systematic Errors. (For items which might have both random and systematic contributions, a lowercase X represents the typically smaller or less likely contribution.)*

sents the typical accepted distribution type for that entry. Note that most calculated values are assumed to be rectangular, which may often be a more stringent criteria than is necessary.

For the antenna calibration example given, only a few possible systematic errors may need to be accounted for. In general, a purely systematic error is likely to have a U-shaped distribution since it always represents a deviation to one side of the real value. A common example of this type of contribution is that of cable mismatch. Since a perfect match is represented by zero reflection and a mismatch in any direction results in non-zero reflection, the statistical probability that there is some mismatch causes the peaks of the distribution to occur away from the zero (matched) value. The effect of mismatch is to change the detected level by reflecting the power back towards the source. It can also generate standing waves in cables which then serve to increase or decrease the detected signal based on the frequency and cable length. A standing wave is a systematic error in a fixed system for a given frequency. However, over frequency, the effect is either constructive or destructive, giving a net random contribution. In the case of antenna calibrations, the mismatch at the antenna is a part of the calibration, so standing waves are the only contribution of concern. All other cable contributions are included in the cable calibration, which is part of the random error contribution.

Another systematic error contribution which generates a U-shaped distribution is the max-hold height step. For continuous height scanning, this is a function of sweep time versus tower speed. Since the "correct" value is a maximum, any deviation from the correct value can only be less than the correct value. As mentioned previously, this error was verified to be less than ±0.02 dB. This error is a good example of the difference between performing a Type B analysis of an entire test setup or using a mixed Type A and Type B analysis. The height step has both random and systematic components, but the random components would be measured in a Type A analysis. Thus the contribution to the mixed Type B analysis is not the same as that for the Type B-only analysis.

The final and most troubling contribution is that of site imperfections. Fortunately several factors mitigate this contribution somewhat. Temperature changes over the test period caused dimensional changes in the surface of the metal ground plane which would have randomized the effects somewhat. Also, similar to the effects of standing waves, the imperfections in the ground plane will have different effects at different frequencies. Variations in antenna positioning with respect to site defects will randomize these effects as well[6, 9]. Thus there is a high probability that there will be "worst case" points throughout the frequency band which will capture the site imperfection effects in a Type A analysis. However, there is always the likelihood of a significant systematic effect which is not easily determined. It should also be noted that NIS-81 classifies site imperfections as a rectangular distribution. This is largely due to the fact that existing site verification techniques do not provide for individual determination of the random and systematic contributions from the site.

For EMC measurements, a good pair of antennas may be used to determine the normalized site attenuation (NSA) of a test site and use the deviation of that value from theoretical for the site contribution. However, in the case of antenna calibration, this option is circular. Since the uncertainty of an NSA measurement can be no better than that of the antenna calibration, the uncertainty of the resulting antenna calibration could never be better than the NSA measurement plus its uncertainty!

Two options remain for antenna calibrations. The first is to attempt "round-robin" testing to compare one site to others and use the average value as the perfect site. The second method, to be published as an amendment to CISPR 16-1 in 1998, involves using calculable dipoles to verify that a site matches a perfect theoretical ground plane through an exhaustive sequence of tests[10].

Comparisons between antenna measurements made using the same test system on the NIST (Boulder, CO) OATS and the OATS used for the antenna calibrations given in the examples show the variation between the sites to be on the order of 0.5 dB. This variation is of the same order of magnitude as the random uncertainty contribution and thus an individual test is insufficient to draw a conclusion on the systematic error contribution of the site. It should be reiterated here that the assumption of a "golden site" for comparison purposes is not recommended. Instead the use of round-robin testing for determination of a statistically perfect site, or the new CISPR method for site verification is recommended for validation of an antenna calibration site.

Total Uncertainty

The combined standard uncertainty, $u_c(y)$, of a quantity y is computed from the square root of the sum of squares (RSS) of the individual contributions $u(x_i)$. If an individual

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uncertainty component does not directly correspond to the measurand, it must first be converted into the proper form by applying the appropriate conversion factor or function, $u_i(y) = c_i \cdot u(x_i)$. For example, a positioning uncertainty in centimeters must be converted into its effect on the field in dB before it can be applied to the antenna factor uncertainty. Then, for N uncorrelated individual components, the combined standard uncertainty is:

$$u_c(y) = \sqrt{\sum_{i=1}^{N} u_i^2(y)}\,.$$

The expanded measurement uncertainty, U, is then determined by multiplying the combined standard uncertainty by the desired coverage factor, k, which determines the level of confidence in the uncertainty value. Thus, $U = k \cdot u_c(y)$. For the recommended 95% level of confidence, $k = 2\cdot$

Using 0.5 dB for the expanded uncertainty of the random contribution and 0.75 dB as a rectangular distribution for the remaining contribution due to site imperfections and any other systematic effects,

$$u_c(y) = \sqrt{\left(\frac{0.5}{2}\right)^2 + \frac{0.75^2}{3}} = 0.5$$

Using k =2 this results in a total combined expanded measurement uncertainty of 1.0 dB. Since the random error contribution is a significant portion of the total $(u_c(y)/u(q_k) < 3)$ it is necessary to use an adjusted value for the coverage factor, k_p. In this case, the value is around 2.01, but in the case of only a few samples, this value could be as large as 3 to 14.

Conclusion

While there are inherent difficulties in performing a Type A analysis of a test setup, it is important not to dismiss the concept altogether. It is a relatively simple matter to obtain sufficient measurement data to produce an acceptable measure of the total random contribution to the uncertainty. This has the advantage of providing a measured value and thus limits the number of assumptions necessary to arrive at a total expanded uncertainty value. The ability to prove uncertainty claims with measured data is likely to become more important as new EMC regulations are put into effect.

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Understanding the measurement uncertainties of the bicon/log hybrid antenna

Measurement uncertainty associated with the bicon/log hybrid antenna for radiated emissions and site validation tests relate to many factors, including height dependency, polarization and loading.

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Since their first introduction in 1994 at the Roma International Symposium on EMC,[1] bicon/log hybrid antennas have become very popular in EMC labs worldwide. Because there are no band breaks in frequency sweep, test time and effort are reduced. EMC engineers have assumed that performance of these antennas is simply that of a biconical antenna at a lower frequency range until it transitions to a regular log periodic dipole array (LPDA) antenna at higher frequencies. Questions have been raised about this assumption, and some have suggested that a higher measurement uncertainty (U) should be used due to the characterization of the phase center position and antenna pattern variation from that of a dipole on which emission and site validation standards are based. Very limited research has been conducted on the uncertainty evaluation of these hybrid antennas, despite the fact that more and more EMC engineers have come to realize that predicting and reducing measurement uncertainty has become an important aspect of EMC testing.

Most antenna manufacturers and calibration labs provide individually calibrated antenna factors (AF) with associated U values. A thorough understanding of these values is essential. EMI and normalized site attenuation (NSA) tests are performed over a conducting ground plane. Calibration labs may be able to provide very accurate calibrations of the free-space AFs, which are intrinsic properties of the antennas. Studies have shown that antenna performance can change by a few decibels over a ground plane, and this effect is antenna type specific. In many cases, the performance of a bicon/log hybrid antenna over a ground plane is different from that of a bicon or a log antenna. A good free-space AF with a low U does not always translate into a low U in the EMI or NSA measurement due to the influence from the conducting ground.

This article will address several aspects of measurement uncertainty related to the bicon/log hybrid antenna application. They are: the height dependency of the hybrid antenna AF above a conducting ground plane; the geometry and polarization-dependent AF and NSA measurement; active phase center variation with frequency; antenna beam pattern; and the comparisons of a bicon/log hybrid with separate bicon and log antennas. Some manufacturers also apply capacitive loading on the bow tie elements to improve the low frequency performance of these antennas. This article also explains how this loading impacts the measurement U.

HEIGHT/POLARIZATION DEPENDENCY ABOVE A CONDUCTING GROUND PLANE

AF is defined as the ratio of the incident electric field over the receive voltage at a 50-ohm load connected to the feed point of the antenna. The free-space AF is obtained when the antenna is in free-space and the incident electromagnetic field is a plane wave. The free-space AF is an intrinsic property of the antenna, just like the physical length of a ruler, and should not vary no matter how the calibration is performed. However, just like heat or cold can change the length of a ruler, the environment in which the antenna is used can also impact the AF. EMI and NSA measurements are performed over a conducting ground plane, and unlike temperature, which does not change a ruler all that much, the ground plane can change the AF by as much as 2 or 3 dB depending on the polarization and height. Different types of antennas also interact with the ground plane differently, causing the effect on the AF to be antenna specific.

Figure 1 shows a traditional bicon/log hybrid antenna, while Figure 2 shows an enhanced model for improved low frequency performance. Let us use the traditional model shown in Figure 1 to illustrate the dependency of the AF on height above a conducting ground plane. Figures 3 and 4 show numerically-calculated AFs at heights of 1 m, 2 m, 3 m and 4 m for a horizontally or vertically-polarized antenna. Note again that the EMI or NSA measurements are typically performed for a height scanning from 1 m to 4 m. If we were to use a free-space AF or an AF calibrated at a fixed height to do a measurement at a different height, no matter how accurate the calibration is, there exists an error.

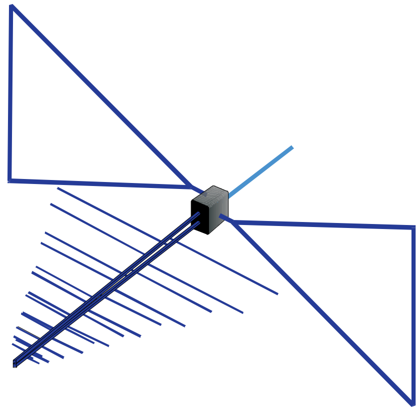

Figure 1. Traditional bicon/log hybrid antenna.

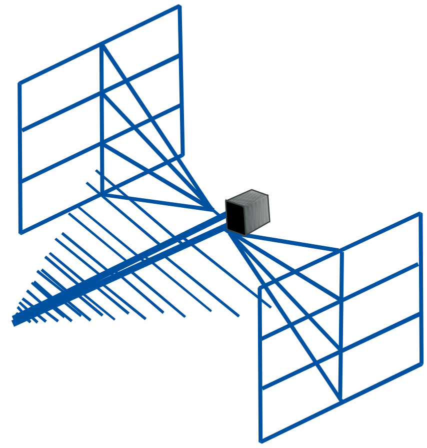

Figure 2. Enhanced model of the bicon/log hybrid antenna.

We may be tempted to say we just need to use a matrix of AFs, so that at each different height we could use a different AF. However, for different frequencies, AFs are different; for different polarizations, AFs are different; for different separation distances, AFs are also different. It becomes a practical issue for calibration in all these different cases and requires applying a complicated multi-dimensional matrix of AFs during an EMI test.

Instead of this complicated web of AFs, is there an acceptable compromise if we are willing to sacrifice a little bit of accuracy? It turns out that the free-space AF provides an acceptable average. As shown in Figure 3, the free-space AF falls right in the middle for most of the frequencies. This is also why the ANSI, CISPR and other international standards have moved toward the use of free-space AF for product EMI test in recent years. However, it is also clear that we may be able to get a near perfect free-space AF, but it would not be perfect for our typical EMI or NSA measurements, simply because a typical measurement condition is not free-space. For total measurement U, in addition to the antenna calibration U obtained from antenna calibration labs, we must assess additional uncertainty values for the antenna and geometry-dependent test setups.

... for different frequencies, AFs are different; for different polarizations, AFs are different; for different separation distances, AFs are also different.

STANDARD SITE METHOD CALIBRATION AND IMPLICATIONS ON NSA MEASUREMENTS

ANSI C63.5 calibration calls for a three-antenna-method calibration over a ground plane, commonly known as the standard site method. In this measurement, the receive antenna is scanned in heights from 1 m to 4 m. NSA measurement as defined in ANSI C63.4 is simply the reverse of the ANSI C63.5 antenna calibration procedure. The only significant difference is that for NSA measurement, the site is the unknown, where for antenna calibration, the AFs are the unknowns.

A common question when following the NSA measurement procedures is "I calibrated my antennas very recently. When I use the AF to do my test, with separate bicons and

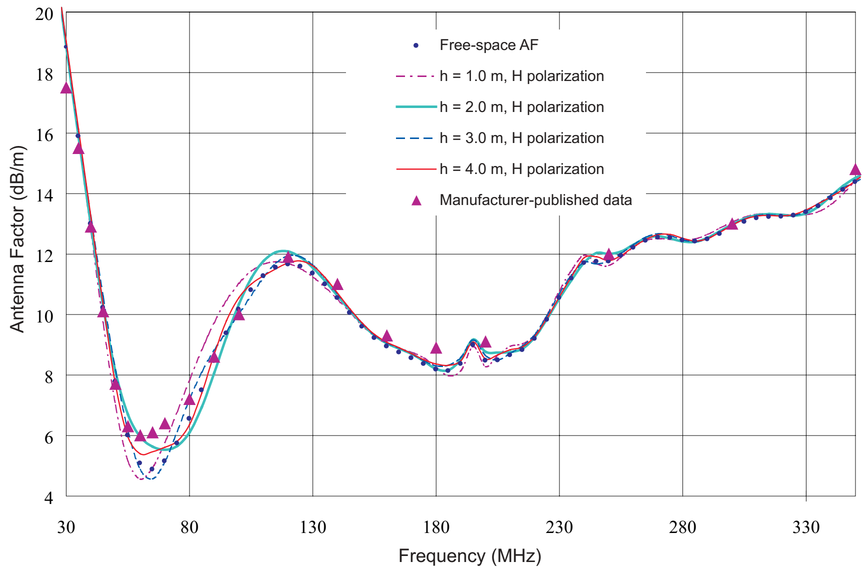

Figure 3. Numerically-calculated bicon/log hybrid AF at different heights for horizontal polarization above a conducting ground plane. Manufacturer-published data are also shown as triangles.

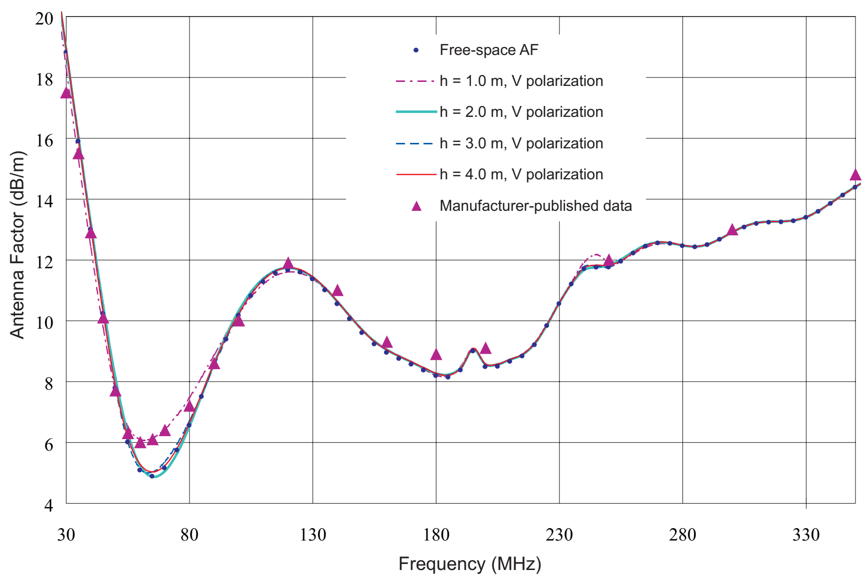

Figure 4. Numerically-calculated bicon/log hybrid AF at different heights for vertical polarization above a conducting ground plane. Manufacturer-published data are also shown as triangles.

log antennas, I can pass the NSA requirement, but when I use the hybrid antennas, I failed the test. Is that due to my antennas or my site?" Other questions are "I need to calibrate my antennas for site validation; which AFs do I need?", and "Do I need free-space AF, 3-m or 10-m calibration, and how about height and polarization?"

It was explained above how AFs change under different geometries and how free-space AF can be used for product EMI test as an acceptable average. To better answer the above questions, we need to quantify exactly how much different geometries affect the performance of a specific antenna. For NSA measurement, since we are dealing with a tighter tolerance, we want to decrease our measurement uncertainties. We will show that the free-space AF approximation becomes inadequate. Let us first look at some antennas calibrated per the ANSI C63.5 standard site method. Figure 5 shows the resulting AFs for a separation distance of 3 m, with the receive antenna scanned from 1 to 4 m in height.

In the standard site method, the discrepancy results not only from the height variation, but also from other factors, such as the non-plane wave illumination of the receive antenna, mutual coupling between the transmit and receive antennas, and the dipole antenna pattern assumption made in the theoretical model.[2] As shown in Figure 5, using a single AF to do an NSA test for all these geometries is a crude approximation. One thing to note is that Figure 5 only shows the difference in the AF for a single antenna under different geometries.

For an NSA measurement, there are two antennas involved, transmit and receive. The resulting difference is the sum of two antennas. For example, at 180 MHz, the free-space AF is different from the AF for the vertical polarization (h1 = 1.5 m) by 2 dB. If a free-space AF were to be used for an NSA site validation measurement, the NSA error just due to the AF difference would be 4 dB (2 dB from the transmit antenna, and 2 dB from the receive antenna). Thus, it is unlikely a site would pass the NSA 4-dB requirement under this condition.

This answers the first question of whether the NSA failure is due to the antenna or site: it is probably neither the site or the antenna calibration that is at fault. Perhaps the answer lies in the method being used, and whether the correct AF is applied. Because the NSA procedure is simply the reverse of the procedure for an ANSI antenna calibration, if the NSA geometry stays the same as the calibration geometry, the errors shown in Figure 5 exactly cancel.

This also answers the second question of which antenna calibration is needed for a site validation test; the geometries for site validation and antenna calibration need to be identical to get the lowest mea-

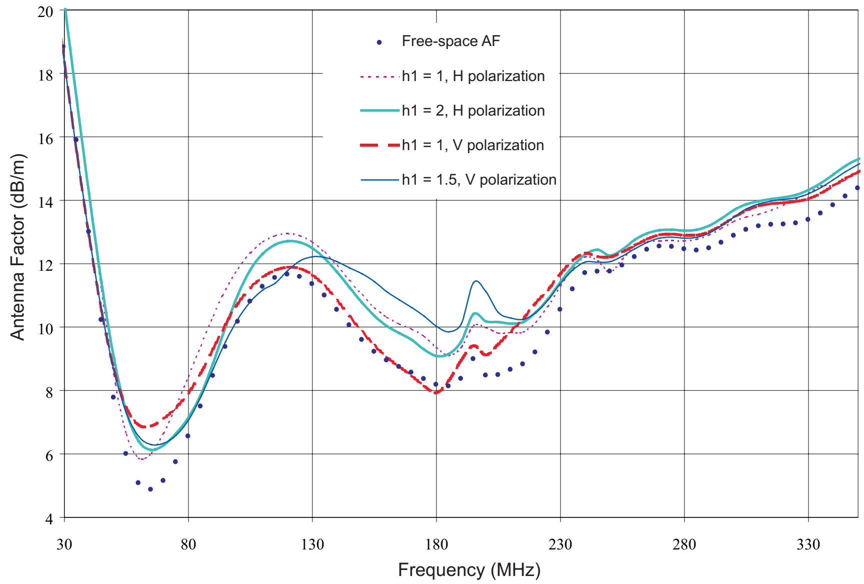

Figure 5. Numerically-calculated bicon/log hybrid AF obtained using the 3-m ANSI C63.5 standard site method. The receive antenna is scanned from 1 to 4 m with a step size of 0.05 m. "h1" is transmit height.

surement uncertainty. However, there is one catch. The antenna calibration site needs to be very good, because any errors generated in the antenna calibration will be transferred to the site validation test.

Let us look at the results in Figure 5 from another perspective. If we assume that the transmit antenna is the equipment under test for an emission measurement, and we use the free-space AF to qualify the EMI from this piece of equipment, the difference between the different geometries and the free-space AF is the error in our measurement. For the example given in Figure 5, this error is 2 dB in some cases. The biconical antenna was also studied for the same circumstances,[2] and the errors were shown to be about 1 dB smaller. For lowest U, a biconical antenna is recommended.

ACTIVE PHASE CENTER VARIATION WITH FREQUENCY

The radiating elements for a bicon/log hybrid antenna move from the bigger elements in the back to the smaller elements in the front as the frequency goes up. The radiating position for a specific frequency is commonly referred to as the active phase center. It appears that the electromagnetic fields are radiated from that center.

Because the phase center moves with frequency, other common questions people ask are: "Where do I measure the distance from the bicon/log hybrid antenna for my test? Should I measure from the tip of the antenna or from the center of the antenna?" A typical answer is to measure from the tip for an immunity test, and from the center for an emission measurement, as specified by the ANSI, CISPR and IEC standards. It is rather clear that this position is just an approximation during the frequency sweep. Thus, uncertainties are introduced in the measurements by assuming a fixed position.

The question arises for bicon/log hybrid antennas from different manufacturers; these antennas may not have the same design or the same length. Are their uncertainties different in an EMI test? The answer is absolutely yes. The next question is whether this error can be estimated. This question may be answered by simply looking at the E^d_{max} formulation.*

If we can assume that a bicon/log hybrid antenna acts like a series of dipoles radiating in different positions at different frequencies, E^d_{max} should not be calculated for a fixed distance. For example, when we perform a 3-m calibration below 100 MHz, the bow tie elements are active. If the antenna is 1 m long and the reference position is the center of the antenna, we are in fact performing a 4-m test (0.5 m addition for each antenna). Figure 6 shows the E^d_{max} values for a horizontally-polarized antenna with the transmit antenna at 1 m height. It shows that more than 2 dB of error can be expected just due to the active elements being different from the reference point.

For antenna calibration, if the active center can be accurately characterized, applying E^d_{max} for the correct distances will rectify the error. For a radiated emission test, if the free-space antenna factor is used, this error cannot be amended, and becomes part of the measurement uncertainty. On the other hand, if a biconical or dipole antenna is used, this phase center is well-defined, and a lower measurement uncertainty is achieved. A log antenna can suffer from the same phase center error, but conceivably, a single log antenna is shorter than the hybrid. The phase center error would be smaller. For a critical test where low measurement uncertainty is desired, a simple dipole, bicon and/or log antenna are preferred over the hybrid antenna.

ANTENNA DIRECTIVITY AND BEAM PATTERN

The intent of the ANSI C63.4 NSA and emission measurement is to use a field sensor with a dipole pattern (because the Roberts' Dipole is the undisputed reference). If the antenna pattern is different from a dipole, it would not be an issue if the measurement were performed in a free-space environment as long as we can keep the antenna pointing to the equipment under test at all heights (boresighting).

For a measurement over a conducting ground plane, however, there is a signal reflection from the

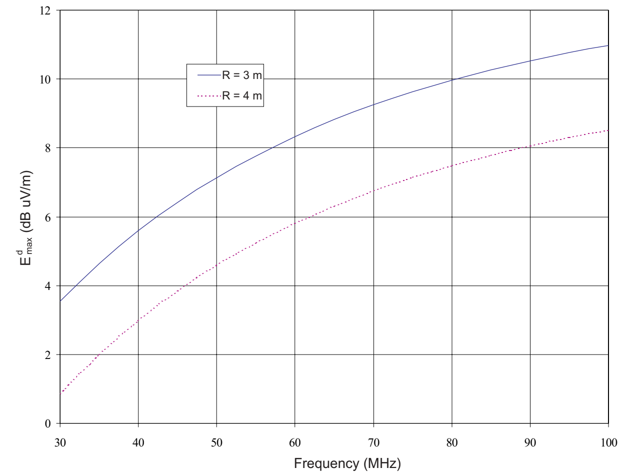

Figure 6. E^d_{max} for 3-m and 4-m separation distance for a horizontally-polarized antenna. The transmit antenna height is 1 m, and the receive antenna height is scanned from 1 to 4 m.

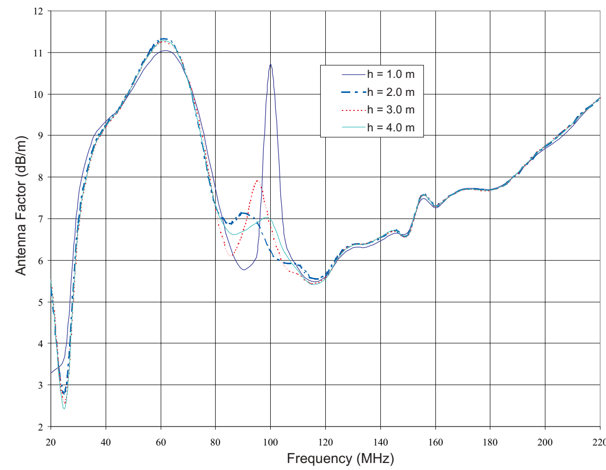

Figure 7. Numerically-modeled AF for a vertically-polarized bicon/log hybrid with an L-shaped end-loading.

ground plane. The reflected field enters the antenna pattern at an angle. The addition of the direct and reflected signal will not add the same way if the antenna pattern is different. There are certain pattern variations from that of a dipole for the hybrid antenna.[1] Any deviation due to the antenna pattern needs to be treated as a source of measurement uncertainty. Bicon antenna patterns have been illustrated to be close to those of dipoles,[4] so, again, this error is smaller for the biconical antennas.

CAPACITIVE-LOADING (LOW-FREQUENCY IMPROVEMENTS) FOR CERTAIN BICON/LOG HYBRID

The VSWR for a hybrid such as the sample shown in Figure 1 is on the order of 20:1 at the 30-MHz range, which means that about 80% of the forward power is reflected back to the source. To generate a certain field level for a radiated immunity test, a huge amplifier is sometimes needed. Several manufacturers introduced capacitive-loading to their antennas, such as shown in Figure 2, to improve the mismatch condition. This improvement is most useful for radiated immunity tests.

For emission tests, the loading elements can couple strongly with the ground when polarized vertically. Figure 7 is an example of the antenna factors at different heights for a vertically-polarized antenna with an L-shaped enhancement. This L-shaped enhancement is a variation of the T-shaped bow tie shown in Figure 2. Even though we could treat such coupling as part of the measurement uncertainty, this value would be unacceptably large, as is the case in Figure 7 (on the order of 5 dB).

The solution for making such an antenna suitable for both radiated emission and radiated immunity testing is to make the end-loadings removable. For immunity testing, the end-loadings are left on to gain the better match (thus requiring a smaller amplifier for a fixed field level). Since the purpose of the immunity test is to generate a given field level, as long as we can measure the generated field, this coupling is not an issue. In addition, most immunity tests are performed in a fully-lined anechoic room, or over a partially absorber-lined ground plane, and this coupling is not as significant.

For an emission measurement, the end-loading should be removed. The antenna in that case would simply perform like a traditional bicon/log hybrid antenna. One thing to note is that the antenna does not need to be calibrated for use in immunity mode, thus saving the cost of calibration for both emission and immunity configurations.

CONCLUSIONS

This article has presented several issues of measurement uncertainties related to the bicon/log hybrid application. Many general measurement uncertainty related issues are not discussed here since they are not particular to this type of antenna. These include cable mismatch uncertainty, site irregularity, site edge diffractions, etc. In an actual measurement, these factors all play important roles in the total measurement uncertainty evaluation. On the other hand, an important issue which tends to be ignored by many EMC engineers is the antenna-specific uncertainties. In most cases, care must be taken when using different antennas and their associated antenna factors. A compromise must be made between the ease of measurement and the accuracy of the measurement.

* *E^d_{max} is a concept introduced by Smith, German, and Pate[3] and later adopted by the ANSI C63 standard site method and NSA formulation. It represents the maximum electric field in a height scan for a tuned dipole with a radiated power of 1 pW.*

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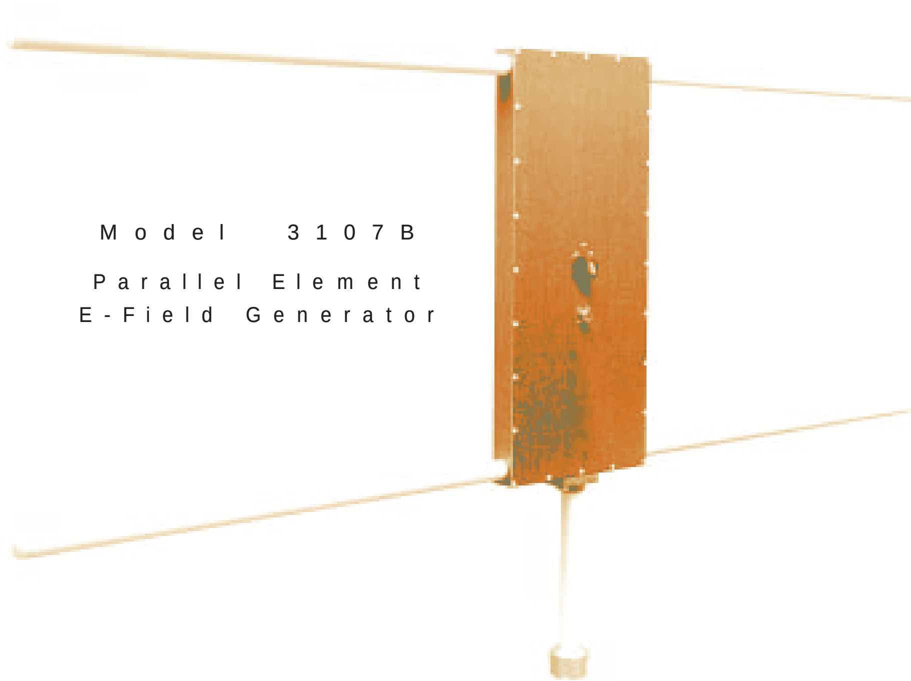

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- Linear Polarization
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- Insulated Elements for Safety
- Quality Construction

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Standard Configuration

- Four insulated aluminum elements
- Linen phenolic antenna body
- Delrin support rod
- Aluminum base drilled to accept EMCO or other tripod mount with standard 1/4 in x 20 in threads
- Manual

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MODEL	FREQUENCY RANGE	MAXIMUM CONTINUOUS POWER	PEAK POWER	IMPEDANCE	CONNECTOR
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Physical Specifications

MODEL	WIDTH	WIDTH w/elements	DEPTH	HEIGHT	WEIGHT
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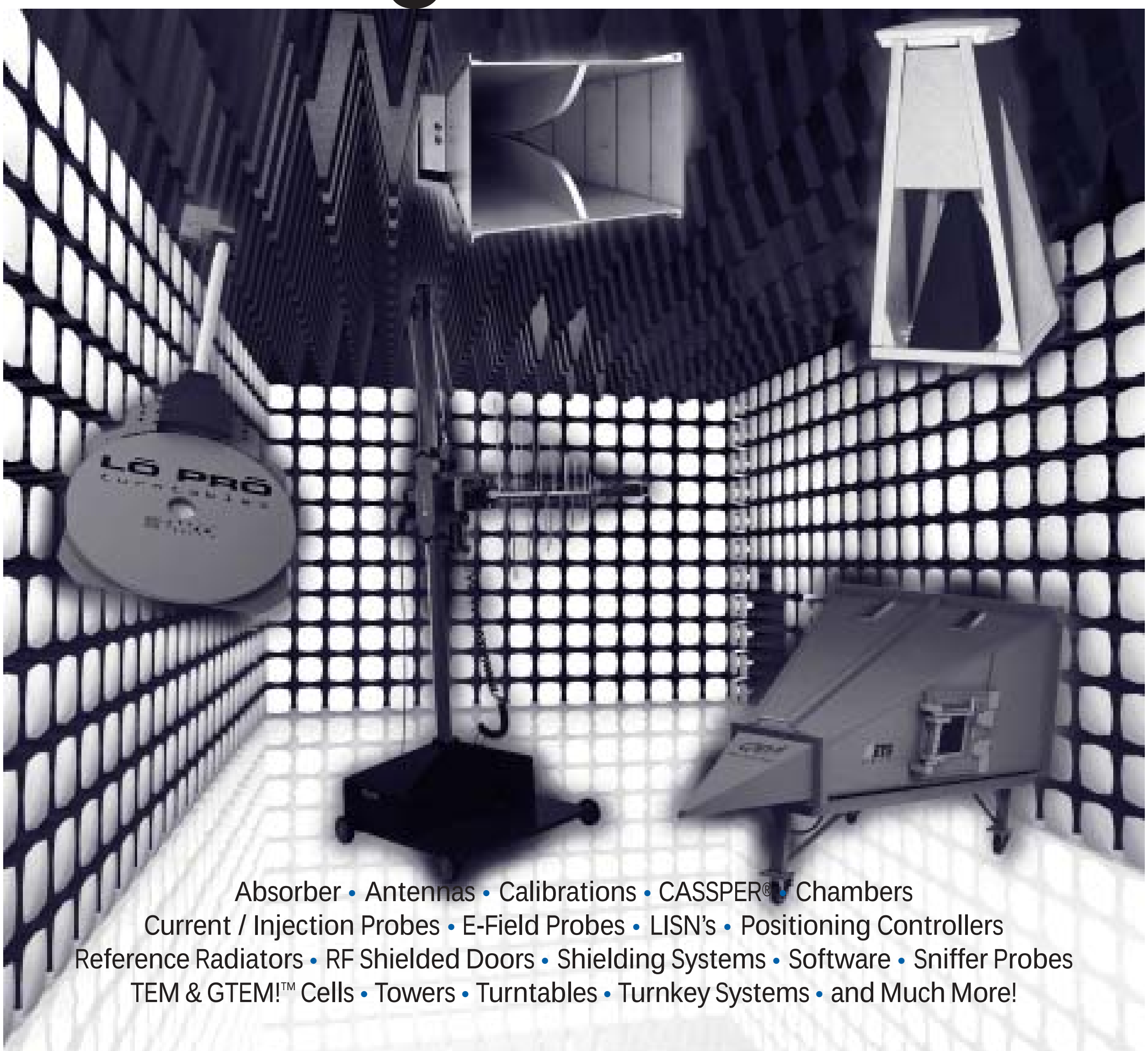

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