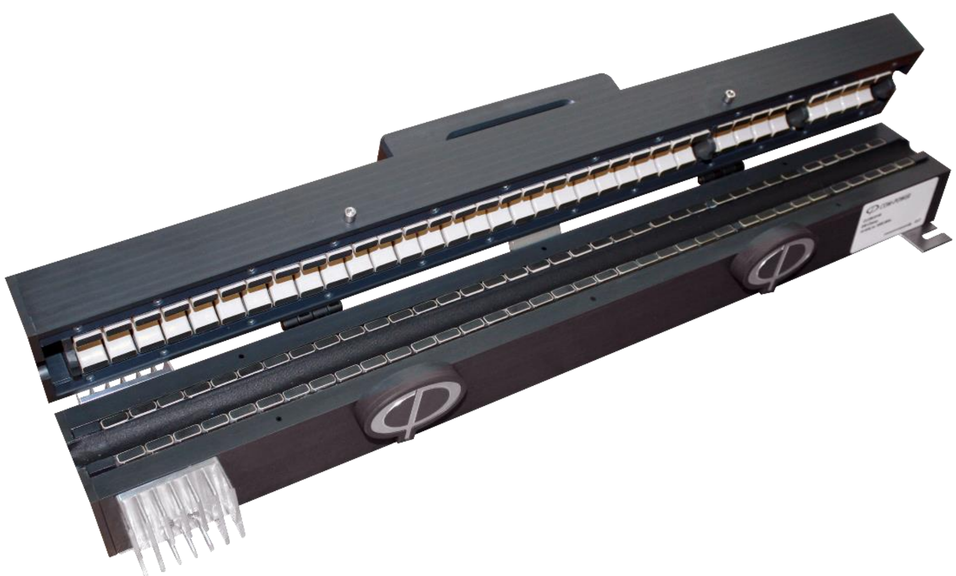
INSTRUCTION MANUAL

for

CLEM-6146

EM CLAMP



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1.0 Introduction

This manual includes description of product features, typical electrical performance parameters, product specifications, instructions for use, and step by step procedures for calibration of test levels and performing testing. Also included are important safety precautions, warranty, and maintenance information.

The test procedures and guidance provided herein is for general guidance and is correct to the extent of our knowledge and understanding of the current, relevant IEC/EN standards at the time that this manual was written. However, the information may become dated or may be inappropriate for some applications.

The user is cautioned to always refer to the appropriate editions of the IEC 61000-4-6, the applicable product family, product environment and/or product specific standard(s) to ensure proper application of the test and adherence to the most appropriate rules, procedures, practices, and/or relevant interpretations thereof for your particular application.

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2.0 Products Available from Com-Power


Antennas


Antenna Kits


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Coupling/Decoupling Networks (CDNs)


Comb Generators


Current Probes & Injection Probes


Emissions Test Systems


Conducted Immunity Test Systems


Impedance Stabilization Networks (ISNs)


Line Impedance Stabilization Networks (LISNs)


Antenna Masts


Near-Field Probe Sets


Preamplifiers


Power Amplifiers


Spectrum Analyzers


Surge Generators


Transient Limiters

Turntables


Antenna Tripods


Telecom Test Systems

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3.0 Product Information

3.1 Incoming Inspection

WARNING –If shipping damage to the product or any of the accessories is suspected, or if the package contents are not complete, contact Com-Power or your Com-Power distributor.

Please check the contents of the shipment against the package inventory in section 3.2 to ensure that you have received all applicable items.

3.2 Package Inventory

STANDARD ITEMS:

- ✓ **CLEM-6146** EM Clamp
- ✓ **ADA-515-CLEM** 150 ohm to 50 ohm Adapter Pair
- ✓ 4 mm Copper Rod (length: 68 cm)
- ✓ Calibration Certificate and Data

OPTIONAL ITEMS:

- ✓ **CLEMA-6146** Calibration Adapter Pair
- ✓ 4 mm Copper Rod (length: 63 cm)
- ✓ **DC**x-xxxx-**100W** Directional Coupler
- ✓ **ATTN-6-100W** 6 dB Attenuator
- ✓ **ATTN-30-100W** 30 dB Attenuator
- ✓ **TEP-050** 50Ω Termination

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3.3 Product Safety Information

3.3.1 Product Hazard Symbols Definitions

The hazard symbols appearing on the product exterior are defined below.

The yellow triangle with an exclamation mark indicates the presence of important operating and/or maintenance (servicing) instructions in the literature accompanying the product.

The yellow triangle with a lightning bolt indicates an alert to the user that uninsulated ***dangerous voltages*** are present within the product enclosure and on output connectors. These voltages may be of sufficient magnitude to constitute a risk of electric shock to persons.

The Ground symbol inside a circle indicates terminal which is intended for connection to an external conductor for protection against electric shock in case of a fault, or the terminal of a protective earth (ground) electrode.

~ To indicate on the rating plate that the equipment is suitable for AC current.

⎓ To indicate on the rating plate that the equipment is suitable for direct current.

3.3.3 General Safety Instructions

The following safety instructions have been included in compliance with safety standard regulations. Please read them carefully.

- **READ AND RETAIN INSTRUCTIONS** - Read all safety and operating instructions before operating the instrument. Retain all instructions for future reference.
- **HEED WARNINGS** - Adhere to all warnings on the instrument and operating instructions.
- **FOLLOW INSTRUCTIONS** - Follow all operating and use instructions.
- **WATER AND MOISTURE** - Do not use the instrument near water.
- **VENTILATION** - The instrument should be used/installed only in locations where the flow of air through the ventilation openings is not impeded.
- **HEAT** - The instrument should be situated away from heat sources such as heat registers or other instruments which produce heat.
- **GROUNDING** - Take precautions to ensure that the grounding of the instrument is not defeated. It is designed to be used with the metallic brackets secured to ground.
- **CLEANING** – Clean the instrument outside surfaces of the device with a soft, lint-free cloth. If necessary, a mild detergent may be used.
- **OBJECT AND LIQUID ENTRY** - Take care that objects do not fall into the instruments and that liquids are not spilled into the enclosure through openings.
- **DEFECTS AND ABNORMAL STRESS** - Whenever it is likely that the normal operation has been impaired, make the equipment inoperable and secure it against further operation.
- **SITTING OR CLIMBING** - Do not sit or climb upon the instrument or use it as a step or ladder.
- **ENVIRONMENTAL CONDITIONS** - This equipment is designed for indoor use. Ambient temperature range during operation should be between 5° C to 40° C.
- **STORAGE AND PACKAGING** - The device should only be stored at a temperature between –25 and +70 °C. During extended periods of storage, protect the device from dust accumulation. The original packaging should be used if the device is transported or shipped again. If the original packaging is no longer available, the device should be packed carefully to prevent mechanical damage.

3.3 Product Features

3.3.1 EM Clamp

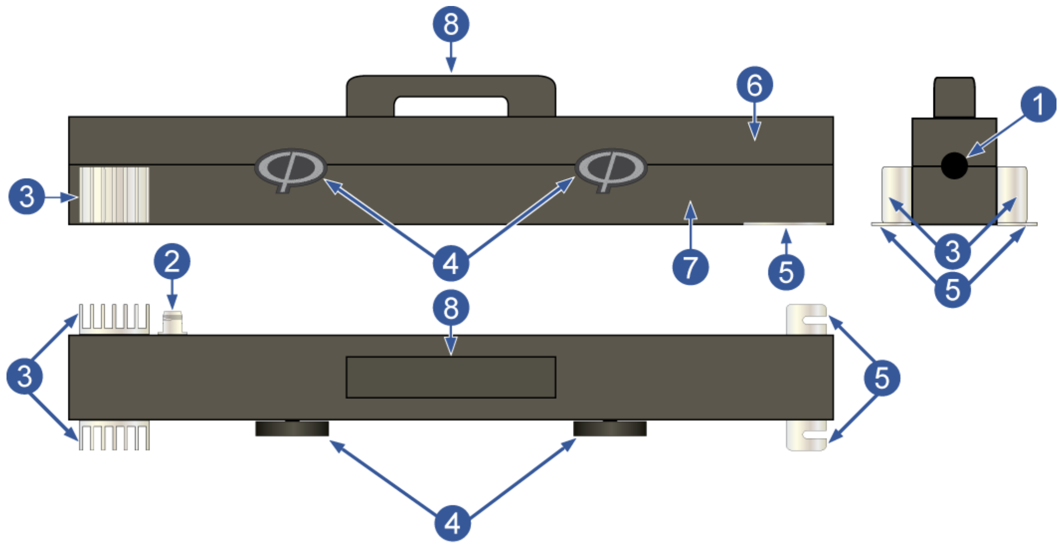

Figure 1 – Product Features - EM Clamp

1. **EUT Cable Opening**
   Cylindrical hole for EUT cable (during testing) and for 4 mm diameter copper rod (during calibration).
2. **RF Input Port**
   Port for connection to RF signal source. Port is equipped with an N-type coaxial connector.
3. **Heat Sinks**
   Metallic heat sinks for component cooling.
4. **Rotary Latches**
   Please refer to section 4.2 for instructions on operating the three-position rotary latches.
5. **Grounding Bracket**
   Brackets to be bonded to earth ground during calibration and/or testing.
6. **Upper half of EM Clamp**
7. **Lower half of EM Clamp**
8. **EM Clamp Handle**

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3.3.2 EM Clamp Adapters and Accessories

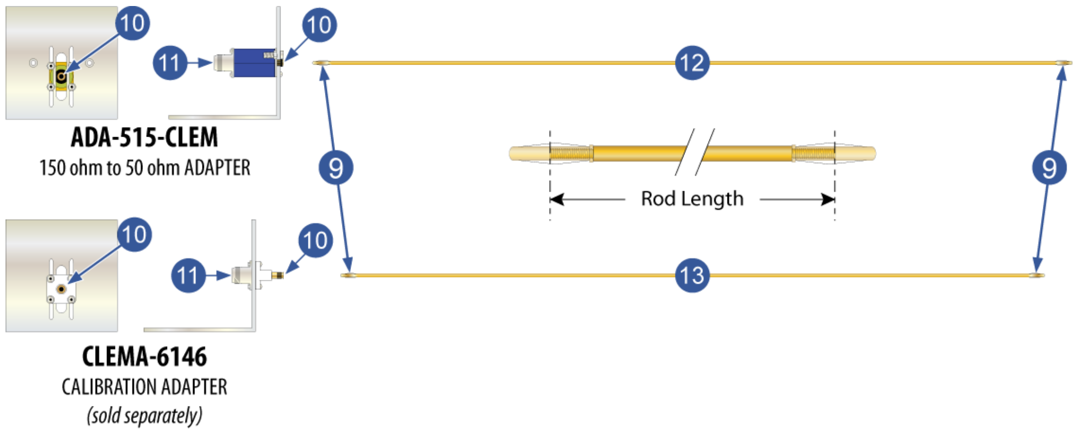


Figure 2 – Product Features - EM Clamp Adapters and Accessories

9 **4 mm Banana Plugs**
These banana plug connectors allow for connection to the 4 mm banana jacks located on the respective calibration adapters.

10 **4 mm Banana Jacks**
These banana jack connectors provide the receptacles for connection to the respective 4 mm diameter copper rod.

11 **Coaxial Port of Adapters**
Each coaxial adapter is fitted with an N-type coaxial connector.

12 **68 cm Copper Rod**
4 mm diameter copper rod with 4 mm banana connectors at each end. Used with ADA-515-CLEM 150Ω to 50Ω Adapters for measurement of coupling factor and calibration of test levels.

13 **63 cm Copper Rod**
4 mm diameter copper rod with 4 mm banana connectors at each end. Used with CLEMA-6146 Calibration Adapters for measurement of impedance and decoupling factor.

3.5 Product Specifications

Table 1 - Product Specifications for CLEM 6146 EM Clamp

CLEM 6146 EM Clamp	
Frequency Range	**150 kHz to 230 MHz**
Extended Frequency Range	**10 kHz to 1 GHz**
Nominal Impedance	**50Ω**
Input Connector	**Type-N** *(female)*
Clamp Opening Diameter	**0.79"** *(20 mm)*
Maximum Cable Diameter	**0.75"** *(19 mm)*
Height of Center of Cable Opening	**2.06"** *(52.5 mm)*
Distance from either end of Clamp to Ref. Point	**0.87"** *(22 mm)*
Maximum Output Power into 6 dB Attenuator *10 kHz to 100 MHz* *100 MHz to 230 MHz* *230 MHz to 1 GHz*	 **400 Watts for 15 minutes** **400 Watts for 3 minutes** **200 Watts for 3 minutes**
Dimensions (L) x (W) x (H)	**25.6" x 4.9" x 4.9"** *(650.2 mm x 124.5 mm x 124.5 mm)*
Weight	**13 lbs.** *(5.9 kg)*

All values are typical, unless specified.
All specifications are subject to change without notice.

Table 2 - Product Specifications - ADA-515-CLEM and CLEMA-6146 Adapters

ADA-515-CLEM and CLEMA-6146 Adapters	
Frequency Range	**150 kHz to 230 MHz**
Nominal Impedance (ADA-515-CLEM only)	**100Ω**
Input Connector	**4 mm Banana Jack**
Output Connector	**Type-N** *(female)*
Minimum Height for 4 mm Rod Jack	**0.9"** *(23 mm)*
Maximum Height for 4mm Rod Jack	**2.2"** *(56 mm)*
Distance from either end of Clamp to Ref. Point	**0.87"** *(22 mm)*
Power Rating (ADA-515-CLEM only)	**2.5 Watts** *(continuous)*
ADA-515-CLEM Dimensions (L) x (W) x (H)	**4" x 3.94" x 3.94"** *(102.4 mm x 100 mm x 100 mm)*
CLEMA-6146 Dimensions (L) x (W) x (H)	**4.94" x 3.94" x 3.94"** *(125.5 mm x 100 mm x 100 mm)*

All values are typical, unless specified.
All specifications are subject to change without notice.

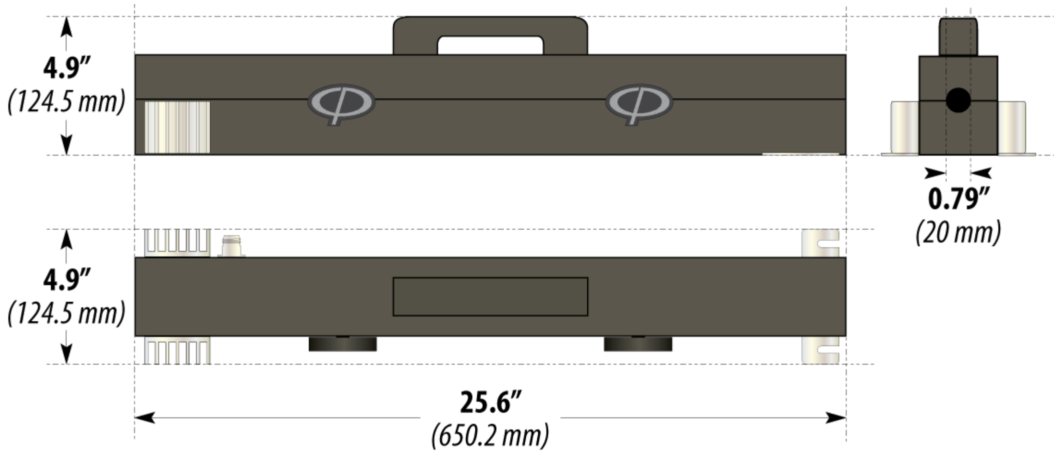


Figure 3 - Product Dimensions - EM Clamp

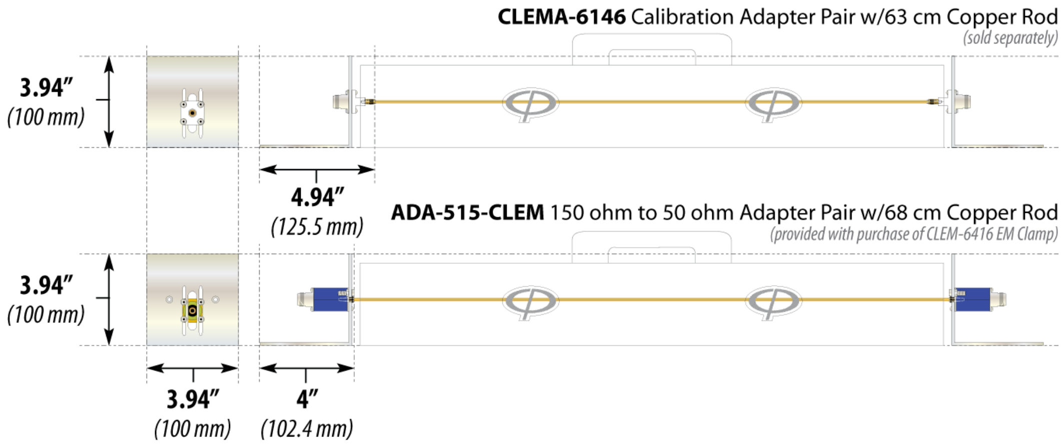


Figure 4 - Product Dimensions - EM Clamp Adapters and Accessories

3.6 Typical Performance Data

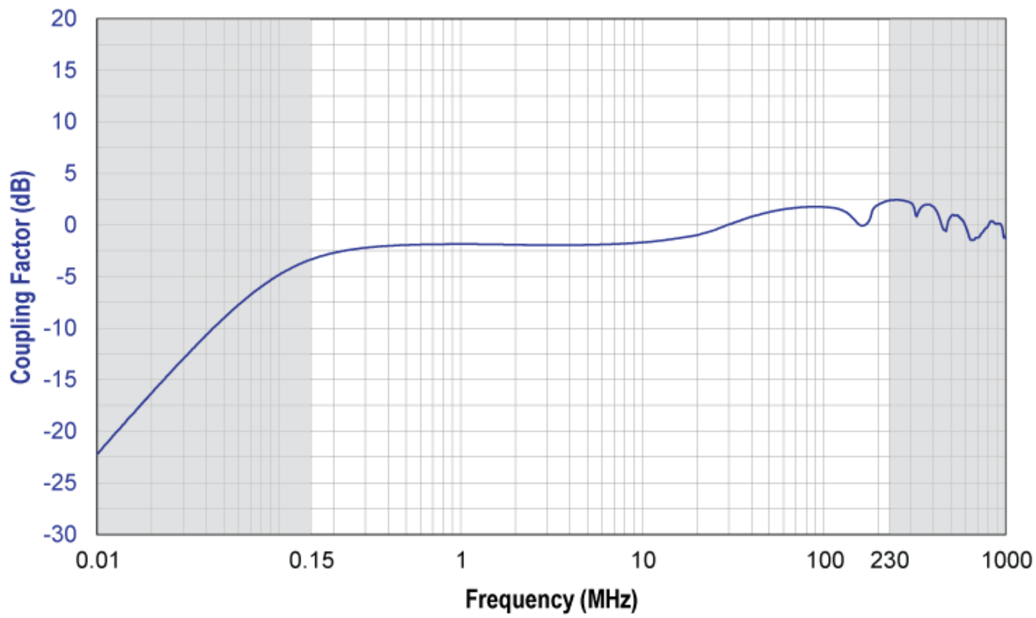


Figure 5 - Typical Coupling Factor Data

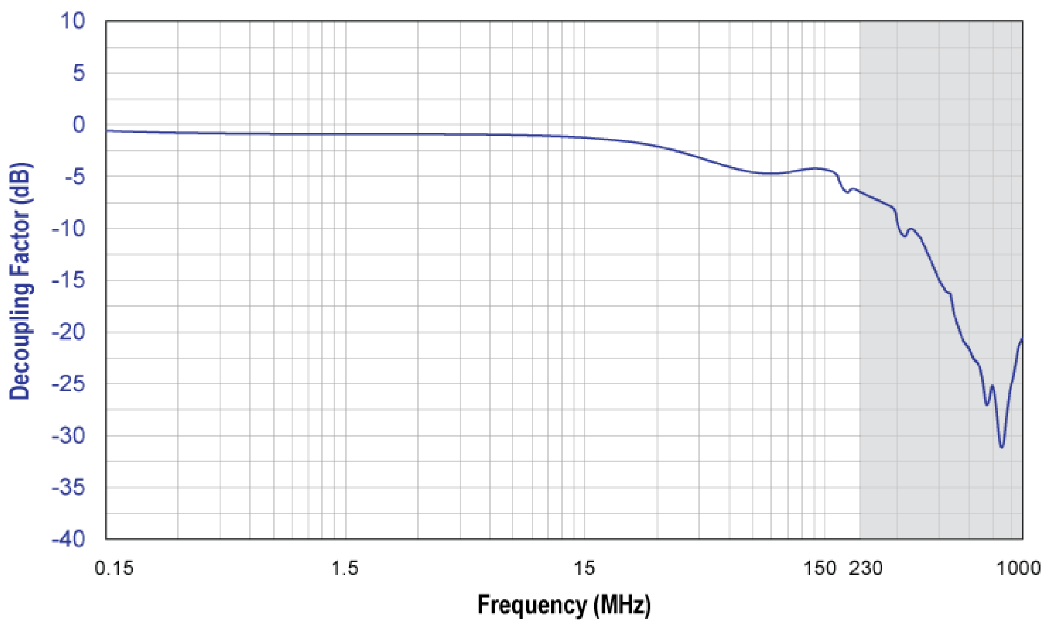


Figure 6 - Typical Decoupling Factor Data

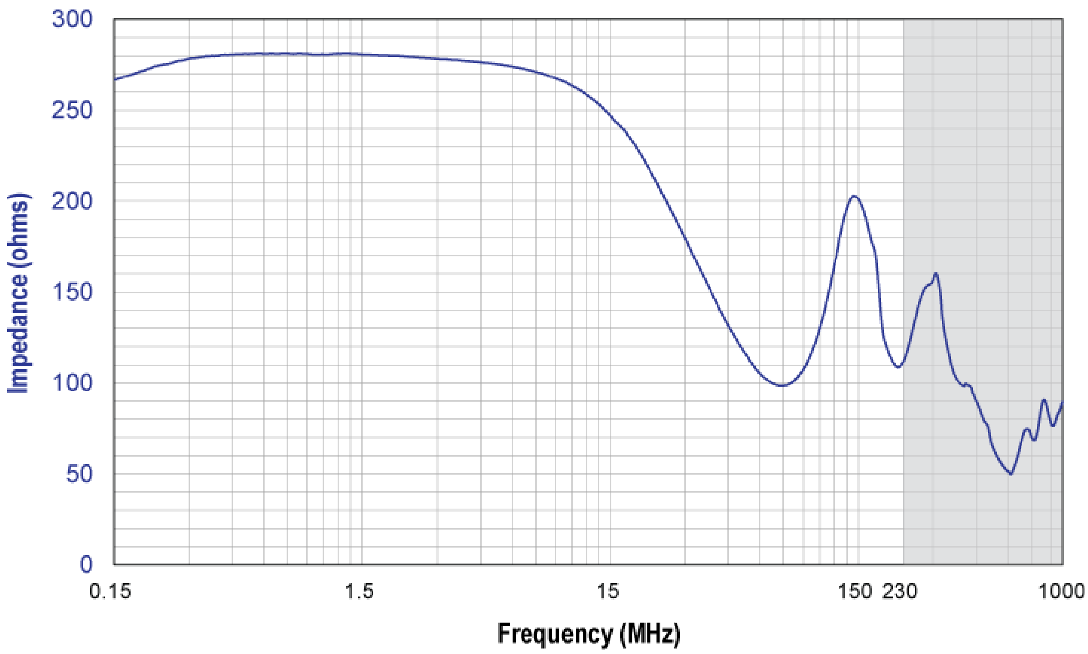


Figure 7 - Typical Impedance Data

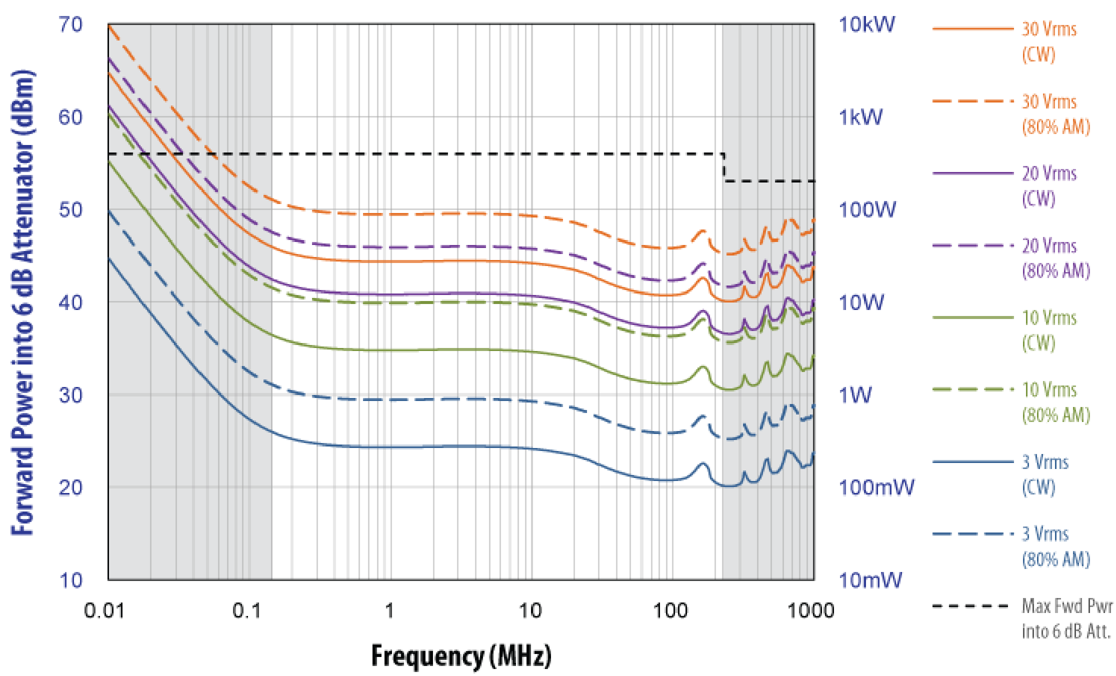


Figure 8 - Typical Forward Power Levels

4.0 Product Application

4.1 EM Clamp Theory

The CLEM-6146 EM Clamp is designed specifically for immunity to conducted disturbances testing as per IEC 61000-4-6.

When no CDN is available for the type of port to be tested, clamp injection may be used (i.e.: EM Clamp or Bulk Current Injection Probe). The EM Clamp offers two key advantages over Bulk Current Injection Probes:

a) Typically requires only about 15% of the power necessary to achieve a given test level.

b) The EM Clamp provides AE decoupling (especially at higher frequencies), where the Bulk Current Injection Probe offers none.

The EM Clamp establishes both capacitive and inductive coupling to the EUT cable.

4.2 Rotary Latches - Positions

The rotary latches can be set to three (3) positions, as shown in Figure 9.

The UNLATCHED positions allow the upper half of the EM Clamp to hinge open and closed, so that the cable under test can be placed in the cable channel.

Whenever the EM Clamp is not in use, the STORAGE positions allow the upper half of the clamp to be secured without contact between the ferrites. This prevents the ferrites from shattering should the clamp be dropped, and also prolongs the life of the ferrite spring assemblies.

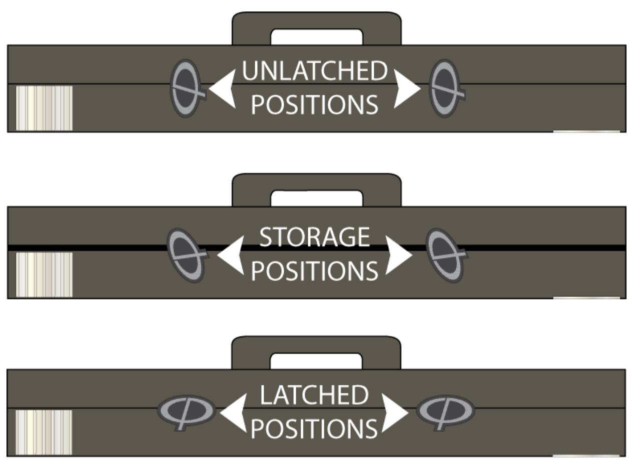


Figure 9 - EM Clamp Rotary Latch Positions

The LATCHED positions must be used whenever measurements are being performed. In the LATCHED position, the upper and lower halves of the ferrites are compressed together. The EM Clamp will not measure properly unless the rotary latches are in the LATCHED positions.

4.3 Height Adjustment of 4 mm Copper Rod(s)

The ADA-515-CLEM 150 ohm to 50 ohm Adapters and the CLEMA-6146 Calibration Adapters allow for adjustment of the height of the 4 mm copper rod. For each adapter set, the height adjustment is made by loosening the four screws shown circled in **red** on Figure 10, adjusting the height up or down, then re-tightening the screws.

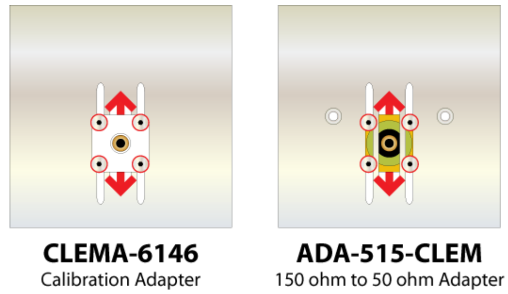


Figure 10 - Height Adjustment of Calibration Adapters

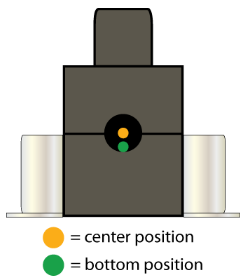
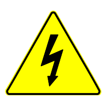


Figure 11 - Rod Positions

For **coupling factor** and **test level calibration** measurements using the ADA-515-CLEM Adapters, the height should be adjusted so that the 4 mm rod is located in the ***bottom position*** of the clamp opening, as shown in Figure 11.

For **impedance** and **decoupling factor** measurements using the CLEMA-6146 Adapters, the height should be adjusted so that the 4 mm rod is located in the ***center position*** of the clamp opening, as shown in Figure 11.

4.4 Safety Considerations



It is critical that the EM Clamp be installed in a manner which ensures that EACH of following conditions are satisfied:

- The metallic mounting bracket must be connected to earth ground.
- The input signal power must not exceed the ratings/time durations specified in the product specifications table in section 3.5.

Failure to comply with any of these points may damage the equipment and/or pose an electrical hazard.

5.0 Calibration - EM Clamp

Calibration of EM Clamps can be divided into two categories.

The first category includes the calibration/measurement of its electrical performance parameters, such as Coupling Factor, Decoupling Factor and Impedance.

These calibrations are typically performed on a periodic basis in order to verify that the product continues to be in proper working order, (i.e.: functioning within its prescribed specifications and/or in compliance with the applicable requirements. These calibrations are discussed in the following subsections.

The second category includes test level calibrations, which will be discussed in detail in section 6.

5.1 Calibration of Electrical Performance Parameters of EM Clamp

5.1.1 Coupling Factor Measurement

In order to measure the coupling factor, a 50 ohm signal source and 50 ohm measuring instrument are needed. These may be separate instruments or may be combined into a single instrument, such as a network analyzer, or spectrum analyzer with tracking generator.

Also needed are the ADA-515-CLEM 150 ohm to 50 ohm Adapter Pair with the 68 cm length, 4 mm diameter copper rod, along with a 50 ohm termination.

A typical test setup for instrument normalization and measurement of coupling factor is illustrated in Figure 12. For coupling factor measurements, the height of the 4 mm copper rod must be adjusted to be in the bottom position of the clamp opening (see section 4.3).

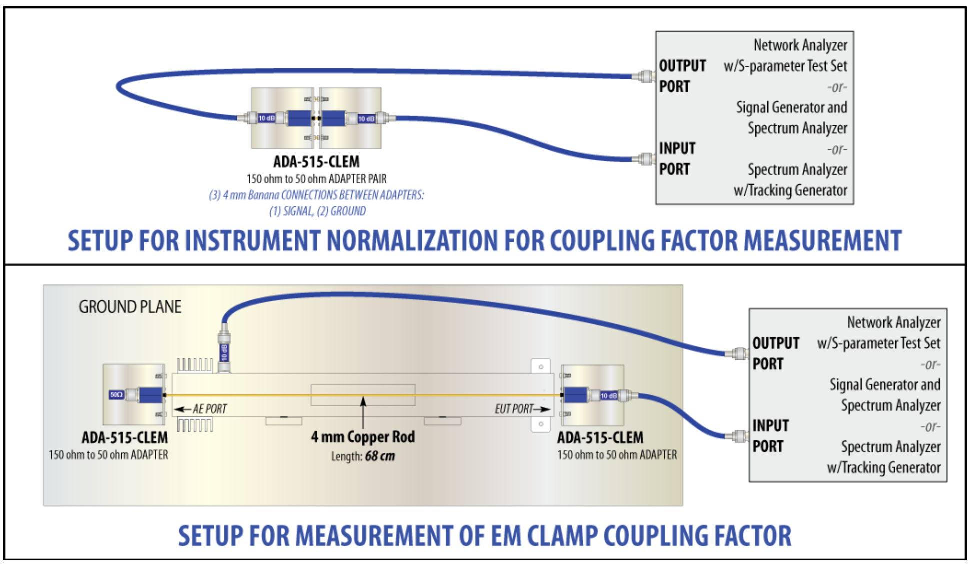


Figure 12 - Calibration and Measurement Setup - COUPLING FACTOR

The coupling factor, at each test frequency, is equal to the measured amplitude difference between the normalization setup and the measurement setup shown in Figure 12.

No limits are defined for coupling factor. Typical CLEM-6146 EM Clamp data are shown in Figure 5 of the present document.

Typical performance curves for three (3) different clamps are provided in Figure A.11 in Edition 4.0 of IEC 61000-4-6.

5.1.2 S-Parameter Measurements for Impedance and Decoupling Factor Calibration

The decoupling factor and impedance measurements must be performed using a Vector Network Analyzer with a [minimum] two-port S-parameter Test Set. Also needed is the CLEMA-6146 Calibration Adapter Pair with the 63 cm length, 4 mm diameter copper rod, and 50 ohm termination.

For decoupling factor and impedance measurements, the height of the 4 mm copper rod must be adjusted to be in the center position of the clamp opening (see section 4.3).

Calibration of Impedance and Decoupling Factor is based on S11, S21, S12 and S22 measurement data in a 50 ohm system (**Z_{ref}**). However, the characteristic impedance of the test jig (**Z'_{ref}**) is different from 50 ohms. It is determined by the height of the clamp opening above the ground plane. Using ABCD transformation, a set of transformed parameters independent from **Z_{ref}** is obtained using the ABCD Transformation Equations given later in this section.

Prior to performing the measurements, a full 2-port calibration must be performed (2-port reflection, transmission, and isolation). Illustrated in Figure 13 are examples of the setup for the network analyzer calibration, as well as the appropriate accessories and connections for the S-Parameter measurements of the EM Clamp.

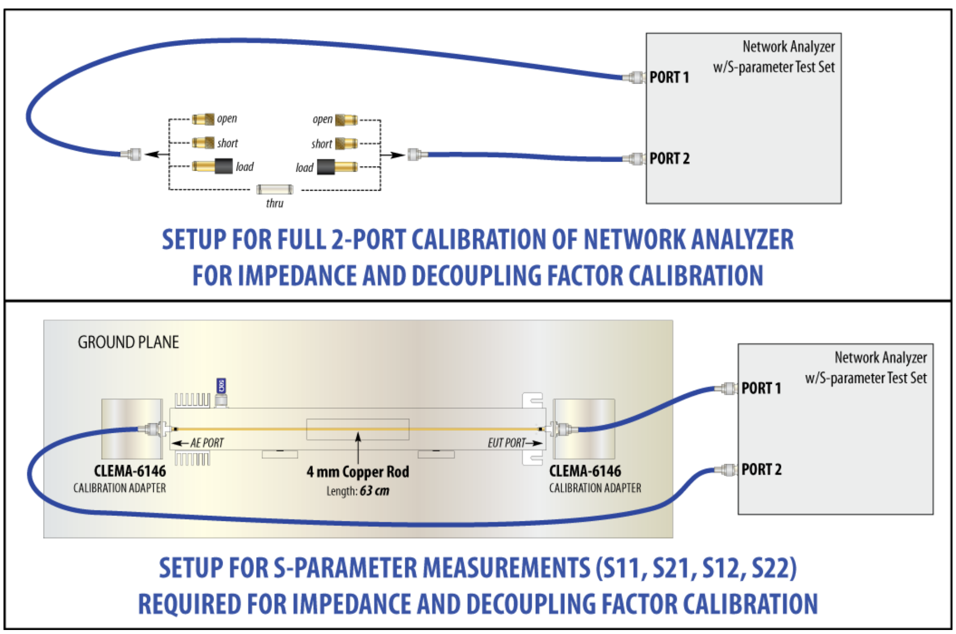


Figure 13 - Full 2-Port Cal of Network Analyzer for Decoupling Factor/Impedance Measurements

Four sets of data are required: **S11**, **S21**, **S12** and **S22**; each set consisting of magnitude and phase values at each test frequency.

NOTE: It is recommended that a spreadsheet program, such as Microsoft Excel, be utilized for the ABCD transformation calculations contained in the following subsections. Please refer to Table 3 below for an example format of an S-parameter data table.

Table 3 - Example Table of Real and Imaginary Values for S_{11}, S_{21}, S_{12} and S_{22}

Frequency	S_{11}		S_{21}		S_{12}		S_{22}	
(MHz)	Real	Imaginary	Real	Imaginary	Real	Imaginary	Real	Imaginary
0.15	0.2539	0.1382	0.7448	-0.1395	0.7466	-0.1377	0.2499	0.1370
0.151749519	0.2551	0.1372	0.7435	-0.1386	0.7455	-0.1368	0.2511	0.1361
0.153499038	0.2565	0.1362	0.7421	-0.1379	0.7441	-0.1359	0.2528	0.1351
↓	↓	↓	↓	↓	↓	↓	↓	↓
1000	0.3386	0.4357	0.0936	-0.0574	0.0926	-0.0550	0.3777	0.4905

The majority of the following ABCD transformation formulae are common to both the decoupling factor and impedance calculations.

ALL CALCULATIONS ARE PERFORMED WITH COMPLEX NUMBERS

ABCD Transformation Equations:

$$Z_{ref} = 50\Omega$$

$$A = \frac{(1 + S_{11})(1 - S_{22}) + S_{12}S_{21}}{2S_{21}}$$

$$B = \frac{(1 + S_{11})(1 + S_{22}) - S_{12}S_{21}}{2S_{21}} Z_{ref}$$

$$C = \frac{(1 - S_{11})(1 - S_{22}) - S_{12}S_{21}}{2S_{21}} / Z_{ref}$$

$$D = \frac{(1 - S_{11})(1 + S_{22}) + S_{12}S_{21}}{2S_{21}}$$

$$Z'_{ref} = 60\Omega * \cosh^{-1}\left(\frac{2h}{d}\right) = 237.63\Omega \text{ (typical)}$$

where...

d = *jig conductor diameter (4 mm)*

h = *height of the center of the jig conductor above the ground plane (typically 52.5 mm)*

$$B' = B \;/\; Z'_{ref}$$

$$C' = C * Z'_{ref}$$

$$S'_{11} = \frac{A + B' - C' - D}{A + B' + C' + D}$$

$$S'_{12} = \frac{2\,(AD - BC)}{A + B' + C' + D}$$

$$S'_{21} = \frac{2}{A + B' + C' + D}$$

$$S'_{22} = \frac{-A + B' - C' + D}{A + B' + C' + D}$$

In the above ABCD transformation equations, S_{11}, S_{21}, S_{12} and S_{22} refer to a ***'complex number'*** converted from the real and imaginary values.

Using Microsoft Excel, the real and imaginary values at a given frequency are converted into a complex number format using the ***COMPLEX*** function, as shown below:

=complex(*[real value]****,****[imaginary value]****)***

EXAMPLE:

In the following example, we will calculate 'A', based on the sets of S_{11}, S_{21}, S_{12} and S_{22} real and imaginary values given in Table 4 using the following equation:

$$A = \frac{(1 + S_{11})(1 - S_{22}) + S_{12}S_{21}}{2S_{21}}$$

Table 4 - Example Values of Real and Imaginary Values for S_{11}, S_{21}, S_{12} and S_{22}

S_{11}		S_{21}		S_{12}		S_{22}	
Real	*Imaginary*	*Real*	*Imaginary*	*Real*	*Imaginary*	*Real*	*Imaginary*
0.2539	0.1382	0.7448	-0.1395	0.7466	-0.1377	0.2499	0.1370

Using the COMPLEX function in Excel, the respective real and imaginary values listed in Table 4 are converted into complex values for S_{11}, S_{21}, S_{12} and S_{22}:

S-Parameter	Excel Formula	Complex Number
S_{11}	=complex(**0.2539**,**0.1382**)	**0.2539+0.1382i**
S_{21}	=complex(**0.7448**,**-0.1395**)	**0.7448-0.1395i**
S_{12}	=complex(**0.7466**,**-0.1377**)	**0.7466-0.1377i**
S_{22}	=complex(**0.2499**,**0.137**)	**0.2499+0.137i**

Adding, subtracting, multiplying, and dividing complex numbers in Excel is done using the IMSUM, IMSUB, IMPRODUCT, and IMDIV functions, respectively.

So, performing the **[1 + S_{11}]**, **[1 - S_{22}]**, **[1 + S_{11}]*[1 - S_{22}]**, **[S_{12} * S_{21}]**, *and* **[2 * S_{21}]** *calculations are done as follows:*

Function	Excel Formula	Resultant Value
1 + S_{11}	=***IMSUM(***[*1*], [***0.2539+0.1382i***]***)***	**1.2539+0.1382i**
1 - S_{22}	=***IMSUB(***[*1*], [***0.2499-0.137i***]***)***	**0.7501-0.137i**
[1 + S_{11}]*[1 - S_{22}]	=***IMPRODUCT(***[***1.2539+0.1382i***], [***0.7501-0.137i***]***)***	**0.9595-0.0681i**
S_{12} * S_{21}	=***IMPRODUCT(***[***0.7466-0.1377i***], [***0.7448-0.1395i***]***)***	**0.5369-0.2067i**
2 * S_{21}	=***IMPRODUCT(***[2], [***0.7448-0.1395i***]***)***	**1.4896-0.279i**

Using the above calculated values, the calculations solving for 'A' are shown on the following page.

$$A = \frac{(1 + S_{11})(1 - S_{22}) + S_{12}S_{21}}{2S_{21}}$$

$$= \frac{(1 + [0.2539+0.1382i])(1 - [0.2499+0.137i]) + [0.7466-0.1377i]\,[0.7448-0.1395i]}{2[0.7448-0.1395i]}$$

$$= \frac{[0.9595-0.0681i] + [0.5369-0.2067i]}{[1.4896-0.279i]}$$

using IMSUM, solve the top half of the above equation { =IMSUM(0.9595-0.0681i,0.5369-0.2067i) }

$$= \frac{[1.4964-0.2748i]}{[1.4896-0.279i]}$$

finally, using IMDIV, solve the equation { =IMDIV(1.4964-0.2748i,1.4896-0.279i) }

$$= [\mathbf{1.0039+0.0036i}]$$

5.1.2.1 Decoupling Factor Calculation

Using the S-Parameter data and the ABCD Transformation Equations given in section 5.1.2, calculate the Decoupling Factor of the EM clamp at each test frequency using the equation given below.

Equation 1 – Calculation of Decoupling Factor

$$\text{Decoupling Factor (dB)} = 20\log_{10}(\text{ABS}(S'_{21}))$$

for Microsoft Excel users, use the following formula:

=20*log10(IMABS([insert cell reference here])

No limits are defined for decoupling factor. Typical CLEM-6146 EM Clamp data are shown in Figure 6 of the present document.

Typical decoupling factor performance curves for three (3) different clamps are provided in Figure A.8 in Edition 4.0 of IEC 61000-4-6.

5.1.2.2 Input Impedance Calculation

Using the S-Parameter data and the ABCD transformation equations given in Section 5.1.2, calculate the input impedance of the EM Clamp at each test frequency using the equation given below.

Equation 2 – Calculation of Input Impedance

$$\text{Input Impedance } (Z_{in}) = Z'\text{ref}\left(\frac{1 + S'_{11}}{1 - S'_{11}}\right)$$

No limits are defined for the input impedance. Typical CLEM-6146 EM Clamp input impedance data are shown in Figure 7 of the present document.

Typical decoupling factor performance curves for three (3) different clamps are provided in Figure A.7 in Edition 4.0 of IEC 61000-4-6.

6.0 Test Level Calibration

The following sections describe the calculations, measurement setups, as well as a step-by-step procedure for performing test level calibration per the IEC 61000-4-6 standard.

Test level calibration is typically performed prior to the start of a test, for the purpose of setting the specific level for the test to be performed (i.e.: 1 Vrms, 3 Vrms, 10 Vrms, etc.).

This calibration, as well as the actual test, is performed at a minimum of 633 discrete frequencies. While it is possible to perform these processes manually (without software), it is highly recommended that it be performed as an automated process, under software control.

6.1 Calibration Methods

Per the IEC 61000-4-6 standard, there are two acceptable methods for monitoring/recording the test generator output level when the appropriate test level is obtained at any given frequency during the calibration, so that the same respective level can be reproduced during the actual testing process. For the purposes of this procedure, we will refer to these methods as **METHOD A (Signal Generator Output Method)** and **METHOD B (Forward Power Method)**. Shown in Figure 14 are examples of the Test Generator Equipment used for the two respective methods.

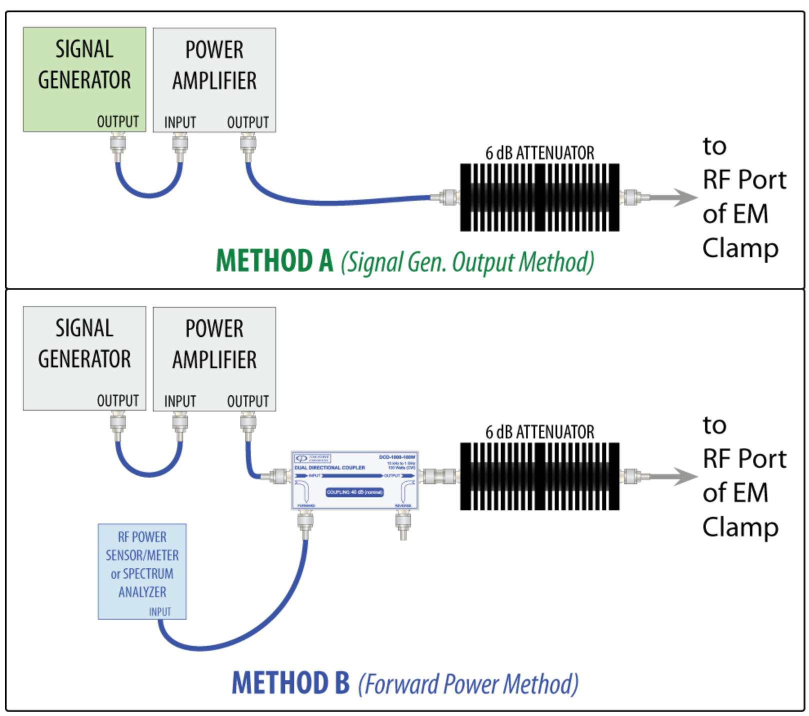


Figure 14 - Examples of Test Generator Equipment

In the following procedures, instructions are included for both methods. **Instructions common for both METHOD A and METHOD B are shown in BLACK text. Any instructions applicable only for METHOD A are shown in GREEN text. Any instructions applicable only for METHOD B are shown in BLUE text.**

For each method, as will be discussed later in this chapter, the test generator equipment is used to inject the test signal via the RF port of the EM Clamp. The test level is set by measuring the amplitude of the test signal at the output of the 150Ω to 50Ω Adapter connected to the EUT port of the EM Clamp (through a power attenuator). For each test frequency, the amplitude of the injected RF is adjusted incrementally until the measured amplitude reaches the appropriate level **(U_{mr})**.

The primary difference between the two methods relates to:

a) the method with which the test generator output is quantified at each frequency during calibration when the appropriate test level is achieved; and,

b) the method by which the same test generator output level set during calibration is reproduced at each frequency during actual EUT testing.

METHOD A: For method A, once the appropriate amplitude is measured at any given frequency during calibration process, the signal generator output level is recorded, along with the frequency.

Then, during the test, the signal generator output level at any given frequency will be set to the respective level that was recorded during the calibration process.

METHOD B: For method B, once the appropriate amplitude is measured at any given test frequency during the calibration process, the forward power of the test generator and frequency is recorded. The forward power can be measured with an RF power meter/sensor, or it can be measured with a spectrum analyzer/EMI receiver. The measuring instrument is typically connected to the forward port of a directional coupler installed in series with the drive line, between the RF output of the power amplifier and the input port of the EM Clamp.

During the test, the signal generator output level is adjusted so that the forward power measured on the power meter or spectrum analyzer/EMI receiver at any given test frequency is equal to the respective forward power level recorded during the calibration process.

6.2 Calibration-related Calculations

6.2.1 Test Level Calculations

Prior to the start of the calibration process, U_{mr} must be calculated. U_{mr} represents the voltage to be measured at the output of the 150Ω to 50Ω Adapter connected to the EUT port of the EM Clamp; and must not be confused with the ***open circuit test level*** (U_o) for the calibration (i.e.: 1 Vrms, 3 Vrms, 10 Vrms, etc., as specified in Table 1 of IEC 61000-4-6). The relationship between U_{mr} and U_o for EM Clamp calibration is given in Equation 3:

Equation 3 – U_o vs U_{mr} Relationship

$$\underset{\text{(in dB}\mu\text{V)}}{U_{mr}} - \underset{\text{(in dB)}}{U_{mr}\ \text{Loss}\ @f_X} = \underset{\text{(in dB}\mu\text{V)}}{U_{mr\text{-}ATT(xx)}\ @f_X}$$

where...

$U_{mr\text{-}ATT(xx)}$ = *voltage measured (across 50Ω input impedance of measuring instrument) at the output of the U_{mr} measurement line, which consists of the attenuator and cable(s) connected between the [output of the 150Ω to 50Ω adapter connected to the EUT port of the CDN] and the measuring instrument; with "xx" representing the rated attenuation value (in dB)*

U_{mr} = *voltage measured (across 50Ω input impedance of measuring instrument) at the [output of the 150Ω to 50Ω adapter connected to the EUT port of the CDN]*

U_{mr} **Loss** = *combined, measured loss of the attenuator and cable(s) connected between the [output of the 150Ω to 50Ω adapter connected to the EUT port of the CDN] and the input of the measuring instrument*

$@f_x$ = *at any given frequency*

NOTE: The 6:1 ratio, or factor of 6 *(15.6 dB)* is due to the following:

a) the open circuit voltage is double the matched load voltage, yielding a **2:1** voltage ratio; and,

b) the EUT port of the EM Clamp is terminated by 150 ohms (150Ω to 50Ω Adapter (100 ohms) in series with the 50 ohm input impedance of the measuring instrument). So, the measurement is made across one-third of the total load impedance, yielding a **3:1** voltage ratio.

So, for instance, for calibration performed at an ***open circuit test level*** (U_o) of ***10 Vrms***:

in linear terms...

$$\frac{10\ \text{Vrms}\ [U_o]}{6} = 1.67\ \text{Vrms}\ [U_{mr}]$$

in logarithmic terms...

$$140\ \text{dB}\mu\text{V}\ [U_o] - 15.6\ \text{dB} = 124.4\ \text{dB}\mu\text{V}\ [U_{mr}]$$

Additionally, shown in Figure 15 are the coaxial cables and attenuator installed between the output of the 150Ω to 50Ω Adapter (where U_{mr} is measured) and the measuring instrument.

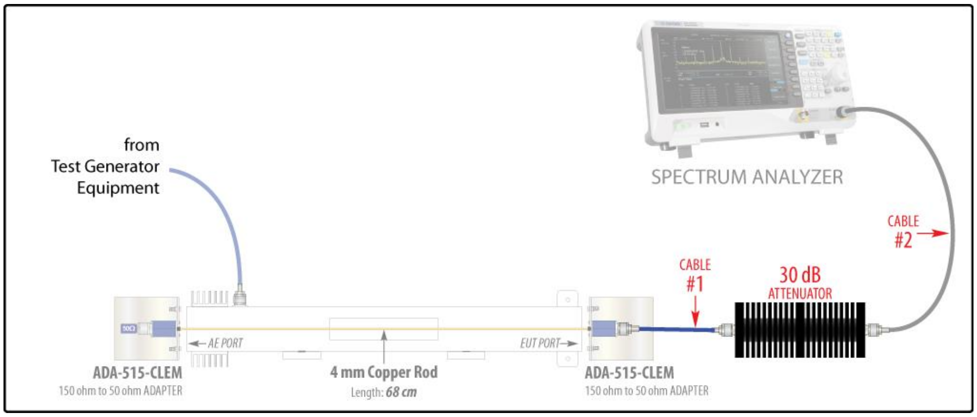


Figure 15 - U_{mr} Measurement Line

The calculated U_{mr} value must be corrected for the attenuation of the attenuator and the insertion losses of Cable #1 and Cable #2 shown in Figure 15. These losses are frequency dependent and should be quantified over the entire frequency range of the calibration, preferably as a system. Illustrated in Figure 16 is the setup for instrument normalization and the system-level insertion loss measurement.

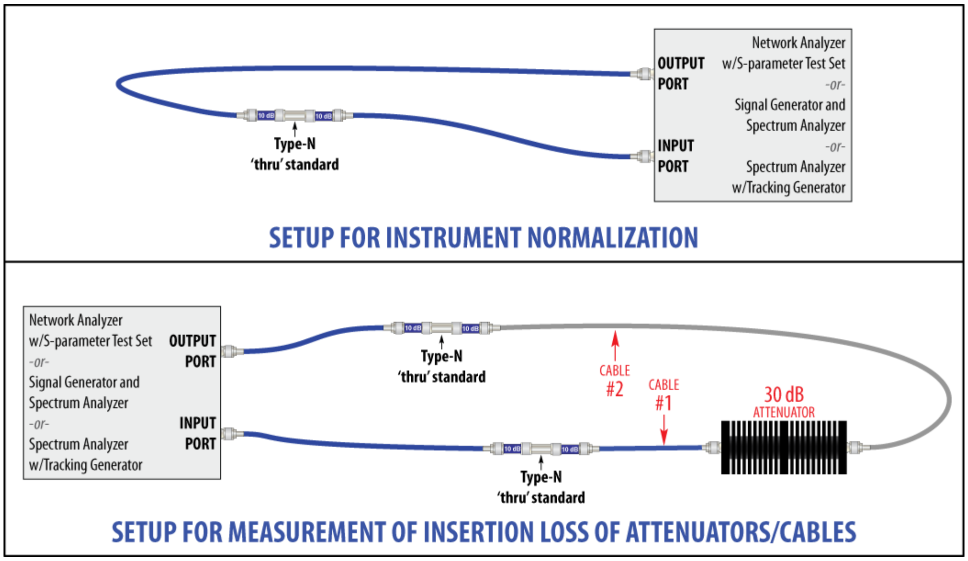


Figure 16 - Calibration of U_{mr} Measurement Line

Using the U_{mr} Measurement Line calibration results, the U_{mr} value calculated using Equation 3 can now be corrected using Equation 4. As the calibration results are frequency-dependent, the corrections must be applied with respect to frequency.

Equation 4 - Correction of U_{mr} for Attenuator and Insertion Loss of Measurement Cables

$$\underset{\text{(in dB}\mu\text{V)}}{U_{mr}} - \underset{\text{(in dB)}}{U_{mr}\,\textbf{Loss}\,@f_X} = \underset{\text{(in dB}\mu\text{V)}}{U_{mr\text{-}ATT(xx)}\,@f_X}$$

where...

$U_{mr\text{-}ATT(xx)}$ = *voltage measured (across 50Ω input impedance of measuring instrument) at the output of the U_{mr} measurement line, which consists of the attenuator and cable(s) connected between the [output of the 150Ω to 50Ω adapter connected to the EUT port of the CDN] and the measuring instrument; with "xx" representing the rated attenuation value (in dB)*

U_{mr} = *voltage measured (across 50Ω input impedance of measuring instrument) at the [output of the 150Ω to 50Ω adapter connected to the EUT port of the CDN]*

U_{mr} **Loss** = *combined, measured loss of the attenuator and cable(s) connected between the [output of the 150Ω to 50Ω adapter connected to the EUT port of the CDN] and the input of the measuring instrument*

$@f_x$ = *at any given frequency*

Again, for calibration to be performed at an ***open circuit test level*** of ***10 Vrms***, and assuming a measured 31 dB loss for the U_{mr} Measurement Line, which included the 30 dB attenuator and both cables:

$$\underset{[U_{mr}]}{124.4\text{ dB}\mu\text{V}} - \underset{[U_{mr}\text{ Loss}]\,@f_X}{31\text{ dB}} = \underset{[U_{mr\text{-}ATT(30)}]\,@f_X}{94.4\text{ dB}\mu\text{V}}$$

So, when the measured value at the output of the attenuator connected to the 150Ω to 50Ω Adapter connected to the EUT port of the EM Clamp is equal to the calculated $U_{mr\text{-}ATT(xx)}$ value for any given frequency, the test level has been achieved.

6.2.2 Test Level Offset Calculations

If the EM Clamp will be used for multiple test levels (1 Vrms, 3 Vrms, 10 Vrms, etc.), calibration should be performed at the highest test level. Calibration data for the lower test levels can then be calculated as shown in Equation 5.

Equation 5 - Calculation of U_{offset}

$$U_{offset\,(\text{in dB})} = 20 \cdot \log\left(\frac{U_{cal\,(\text{in Vrms})}}{U_{calc\,(\text{in Vrms})}}\right) \quad \text{-or-} \quad U_{offset\,(\text{in dB})} = U_{cal\,(\text{in dB})} - U_{calc\,(\text{in dB})}$$

where...

U_{cal} = calibrated test level
U_{calc} = calculated test level

For instance, if the calibration was performed for a test level of 10 Vrms, and the offset is needed for a test level of 3 Vrms:

$$20 \cdot \log\left(\frac{10\ \text{Vrms}\ [U_{cal}]}{3\ \text{Vrms}\ [U_{calc}]}\right) = 10.46\ \text{dB}\ [U_{offset}] \quad \text{-or-} \quad 140\ \text{dB}\mu\text{V}\ [U_{cal}] - 129.54\ \text{dB}\mu\text{V}\ [U_{calc}] = 10.46\ \text{dB}\ [U_{offset}]$$

The offset factor calculated above can then be applied to the calibration results at the higher test level using Equation 6.

Equation 6 - Applying U_{offset} to Calibration Data

$$SGout_{calc\,(\text{in dB})} = SGout_{cal\,(\text{in dB})} - U_{offset\,(\text{in dB})}$$

$$FWDpwr_{calc\,(\text{in dB})} = FWDpwr_{cal\,(\text{in dB})} - U_{offset\,(\text{in dB})}$$

where...

$SGout_{calc}$ = calculated signal generator output for lower test level
$SGout_{cal}$ = calibrated signal generator output for higher test level
$FWDpwr_{calc}$ = calculated forward power for lower test level
$FWDpwr_{cal}$ = calibrated forward power for higher test level

6.2.3 Test Frequency Calculations

The frequency range of the test is, in most cases, 150 kHz to 80 MHz; and, in some cases, 150 kHz to 230 MHz. The calibrations and tests are performed at discrete, logarithmically spaced frequencies (as opposed to a frequency sweep). The logarithmic spacing of the test frequencies means that the actual step size increases after each step. The maximum step size at any given frequency is equal to 1% of the present frequency, as calculated using Equation 7.

Equation 7 - Calculation of Frequency Step Sizes

$$f_{step} = (f * 0.01)$$
$$f_{next} = f + f_{step}$$

-or-

$$f_{next} = f + (f * 0.01)$$

where...

f_{next} = next calibration frequency
f = current calibration frequency
f_{step} = frequency step size from current to next frequency

A truncated example of the test frequencies, showing the respective step sizes is shown in Table 5.

Table 5 - Truncated Table of Calibration Frequencies and Step Sizes

	TEST FREQUENCY (MHz)	STEP SIZE (kHz)
1	0.15	1.5
2	0.1515	1.515
3	0.153015	1.53
4	0.154545	1.545
5	0.15609	1.561
6	0.157651	1.577
7	0.159228	1.592
8	0.16082	1.608
9	0.162428	1.624
10	0.164052	1.641

	TEST FREQUENCY (MHz)	STEP SIZE (kHz)
11	0.165693	1.657
12	0.16735	1.674
13	0.169024	1.69
14	0.170714	1.707
15	0.172421	1.724
16	0.174145	1.741
17	0.175886	1.759
18	0.177645	1.776
19	0.179421	1.794
20	0.181215	1.812

	TEST FREQUENCY (MHz)	STEP SIZE (kHz)
21	0.183027	1.83
22	0.184857	1.849
23	0.186706	1.867
↓	↓	↓
631	79.16929	791.69
632	79.96098	799.61
633	80.76059	807.606

	TEST FREQUENCY (MHz)	STEP SIZE (kHz)
634	81.568196	815.682
635	82.383878	823.839
636	83.207717	832.077
↓	↓	↓
737	227.312	2273.12
738	229.58512	414.88
739	230	

6.3 Equipment Setup

On a conductive ground plane, connect the EM Clamp and Calibration Accessories/Adapters as shown in Figure 17. The bottom surface of the EM Clamp, and both 150Ω to 50Ω Adapters should be flush against the top surface of the ground plane, and should be either:

a) fastened using bolts or screws directly to the ground plane (through their respective mounting holes); or,

b) bonded to the ground plane using copper tape with conducted adhesive (3M #1181 HD recommended).

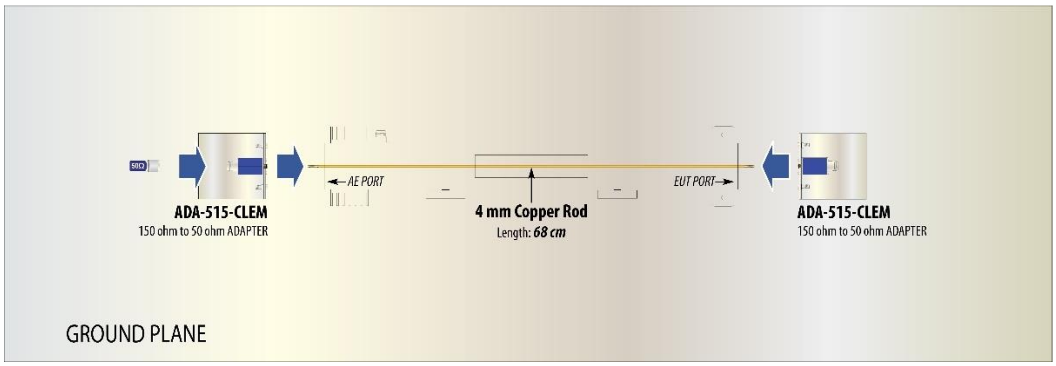


Figure 17 - Connection of EM Clamp Calibration Accessories

The ADA-515-CLEM 150Ω to 50Ω Adapter is a non-inductive 100 ohm resistor as defined in the IEC 61000-4-6 standard.

The TEP-050 50Ω Termination is a 2.5W, 50 ohm termination.

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As shown in Figure 18, complete the calibration setup for **METHOD A** or **METHOD B,** as appropriate.

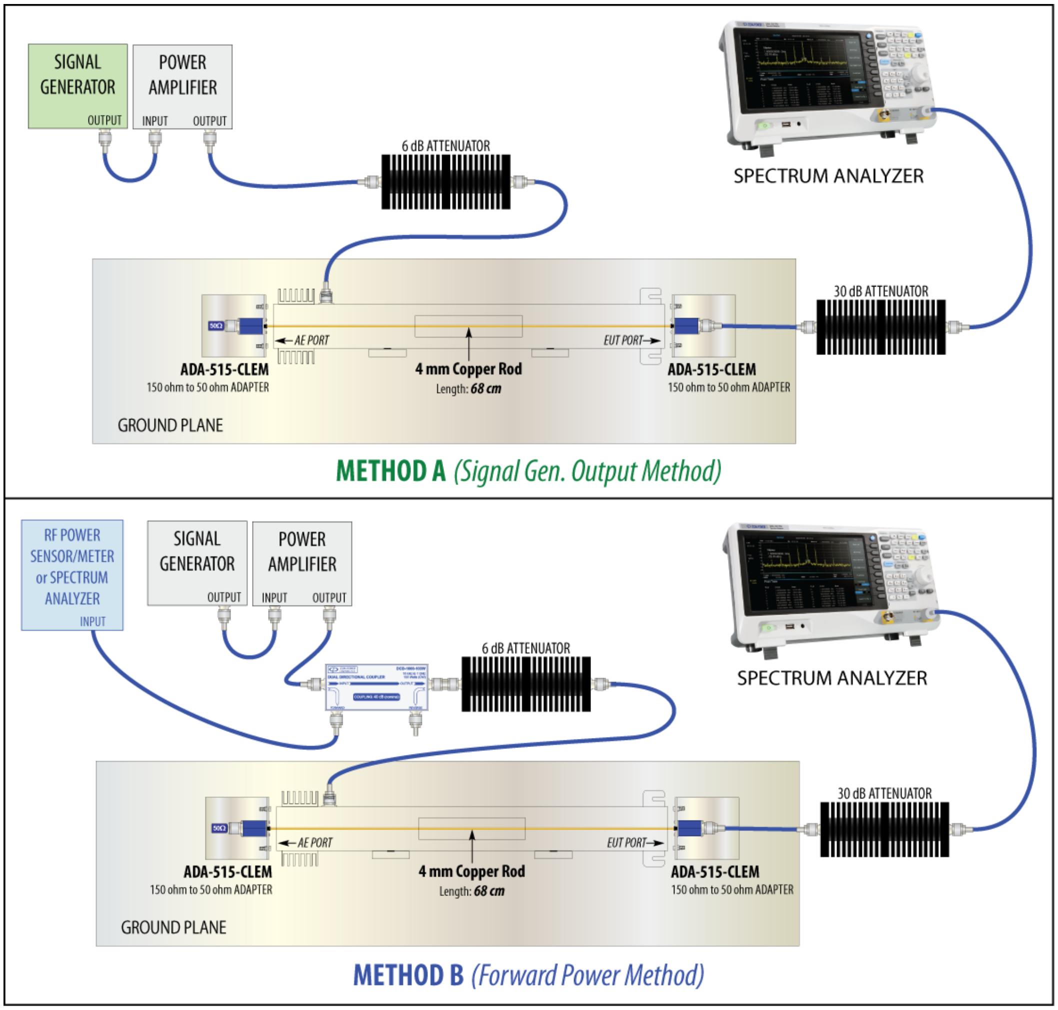

Figure 18 - Example Equipment Arrangements for Test Level Calibration

6.4 Level Setting Process

Step #1 With the calibration test setup configured as shown in Figure 18, set the frequency of the signal generator and measuring instrument to 150 kHz (without modulation).

Step #2 WITHOUT exceeding **[the 1 dB gain compression point of the power amplifier *minus 5.1 dB*]**, adjust the amplitude setting of the signal generator until the amplitude measured on the measuring instrument is equal to the $\mathbf{U_{mr\text{-}ATT(xx)}}$ value (±1.5 dB) calculated as described in section 6.2.1 for the open circuit test level (U_O) for which calibration is being performed.

Step #3 **Record *either:***

the frequency **(f_x)** and amplitude setting of the signal generator **(SGout)**

-or-

the frequency **(f_x)** and measured forward power **(FWDpwr)**

See examples of calibration data/results tables below.

Table 6 - Examples of Test Level Calibration Data/Result Tables

#	TEST FREQ (f_x) (MHz)	SIGNAL GEN OUTPUT SGout (dBxx)
1	0.15	xx.xx
2	0.1515	xx.xx
3	0.153015	xx.xx
↓	↓	↓
633 or 739	80 or 230	xx.xx

#	TEST FREQ (f_x) (MHz)	FORWARD POWER FWDpwr (dBxx)
1	0.15	xx.xx
2	0.1515	xx.xx
3	0.153015	xx.xx
↓	↓	↓
633 or 739	80 or 230	xx.xx

Step #4 Increase the frequency of the signal generator and measuring instrument by a maximum of 1% of the present frequency, as described in section 6.2.3.

Step #5 Repeat steps 2 through 4 until the next frequency in the sequence would exceed the highest frequency of the calibration/test. For tests up to 80 MHz, there should be at least 633 test frequencies; and for tests up to 230 MHz, there should be at least 739 test frequencies.

6.5 Amplifier Saturation Check

Step #1 Set the frequency of the signal generator to 150 kHz (without modulation).

Step #2 Adjust the signal generator output to *either*:

the respective **SGout** value determined during calibration for the present test frequency.

-or-

the level at which the power indicated by the power meter is equal to the respective **FWDpwr** value determined during calibration for the present test frequency.

Step #3 Record the amplitude measured on the measuring instrument as U_{mr}.

Step #4 Increase the signal generator output by 5.1 dB, and record the amplitude measured on the measuring instrument as $U_{mr(inc)}$. The difference between U_{mr} and $U_{mr(inc)}$ must be between 3.1 dB and 7.1 dB.

Step #5 Increase the frequency of the signal generator to the next test frequency.

Step #6 Repeat steps 2 through 5 until the next frequency in the sequence would exceed the highest frequency of the test.

7.0 Performing the Test

7.1 Test Summary and Setup

Examples of typical test setups for **METHOD A** and **METHOD B** are shown in Figure 19

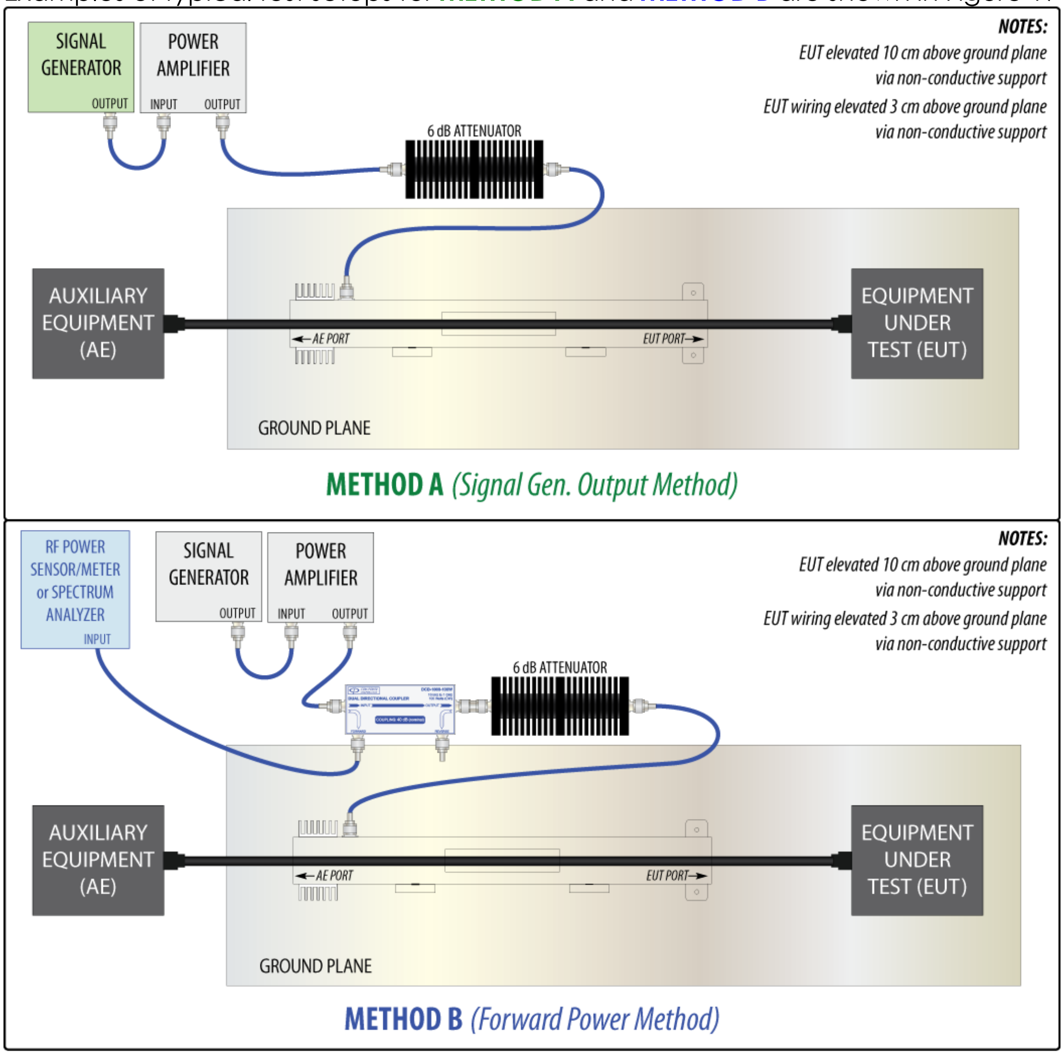

Figure 19 - Examples of Typical Test Setups

Test setups for devices having multiple I/O ports are more complex, and usually require multiple CDNs of different types. Refer to the IEC 61000-4-6 standard for guidance.

Only one CDN in the setup should be terminated with 50Ω. The remaining CDNs in the setup are employed as decoupling networks, by leaving their RF ports open.

The test is typically performed starting from the lowest test frequency up to the highest test frequency, one test frequency at a time, with a one to three second dwell time at each test frequency, depending on the reaction time of the EUT. The RF carrier is usually 80% amplitude modulated with a 1 kHz sine wave.

Refer to the applicable IEC 61000-4-6 and/or relevant product family or product environment standard(s) to ensure the proper application of the test.

7.2 Test Process

The same Test Generator equipment used for the calibration is used to inject the RF energy onto the EUT lines under test via the EM Clamp during the test.

Step #1 With the test setup configured as shown in Figure 19, and/or as required by the applicable standard(s), and with the EUT being exercised as required for the test, set the frequency of the signal generator to 150 kHz, modulated as required (usually 1 kHz AM @ 80%).

Step #2 Using the appropriate calibration data/result table for the test level at which the test will be performed, set the signal generator output to *either*:

a) *the respective **SGout** value determined during calibration for the present test frequency; or,*

b) *the level at which the power indicated by the power meter is equal to the respective **FWDpwr** value determined during calibration for the present test frequency*.

Step #3 Dwell at the present frequency no less than the time necessary for the EUT to be exercised and to respond, but in no case less than 500 ms.

Step #4 Decrease the amplitude by a few dB, then set the frequency of the signal generator to the next test frequency.

Step #5 Repeat steps 2 through 5 until the next frequency in the sequence would exceed the highest frequency of the test.

8.0 Warranty

Com-Power warrants to its Customers that the products it manufactures will be free from defects in materials and workmanship for a period of three (3) years. This warranty shall not apply to:

- Transport damages during shipment from your plant.
- Damages due to poor packaging.
- Products operated outside their specifications.
- Products Improperly maintained or modified.
- Consumable items such as fuses, power cords, cables, etc.
- Normal wear
- Calibration
- Products shipped outside the United States without the prior knowlege of Com-Power.

In addition, Com-Power shall not be obliged to provide service under this warranty to repair damage resulting from attempts to install, repair, service or modify the instrument by personnel other than Com-Power service representatives.

Under no circumstances does Com-Power recognize or assume liability for any loss, damage or expense arising, either directly or indirectly, from the use or handling of this product, or any inability to use this product separately or in combination with any other equipment.

When requesting warranty services, it is recommended that the original packaging material be used for shipping. Damage due to improper packaging will void warranty.

In the case of repair or complaint, Please visit our website www.com-power.com and fill out the service request form (http://com-power.com/repairservicereq.asp). Our technical assistance personnel will contact you with an RMA number. The RMA number should be displayed in a prominent location on the packaging and on the product, along with a description of the problem, and your contact information.

9.0 Maintenance

This product contains no user serviceable parts. If the unit does not operate or needs calibration, please contact Com-Power Corporation. Any modifications or repairs performed on the unit by someone other than an authorized factory trained technician will void warranty.

The exterior surface may be cleaned with mild detergent and then be wiped with a dry, clean, lint-free cloth. Use care to avoid liquids or other foreign objects entering the chassis.