Selecting the Right EMI Antenna

Introduction

Performing an accurate radiated emission measurement requires a calibrated antenna, which is a key component of the compliance measurement system. Depending on the standard; consumer, commercial, medical, automotive or military, the distance between antenna and equipment under test (EUT) can commonly be 10, 3 or 1m.

EMI antennas are also used for radiated immunity testing, where a calibrated electric field of 3 to 50V/m (as high as 200V/m for military) is transmitted at an EUT to determine whether it will withstand common environmental radio frequency sources, such as nearby two-way radio, cellular telephone and commercial broadcast radio and television transmitters. This test much be performed in a shielded semi-anechoic chamber to avoid interference with established communications systems. The antennas used must also be able to accept high RF power levels.

Types of Antennas

Most EMI antennas are designed to cover broad ranges of frequencies and are so designated as "broadband" or "multi-band". These type antennas are generally a compromise as far as sensitivity (gain) across the specified frequency band and are usually less sensitive at the lower frequencies. EMC antennas will be supplied with a calibration factor or "antenna factor" (AF), which levels out the sensitivity and match to 50 Ohm system impedance. AF will be discussed further on.

However, there is a specialty antenna called a "precision dipole" with elements that can be adjusted for resonance at single frequencies. These antennas are used to help calibrate a measurement site or chamber. They also serve as an accurate reference measurement antenna should authorities ever question the data taken at a manufacturer's site or 3rd-party compliance test lab.

Let's discuss the various types of antennas and where they might be used.

Monopole - The monopole, or "rod" antenna (Figure 1) is a single 41-inch rod mounted to a metallic base plate or enclosure. It is used for measuring 9 kHz to 30 MHz (or higher) and is typically specified for automotive, military or aerospace testing. The Com-Power AM-741R is useable to specified to 30 MHz, but can be used to 60 MHz. Most monopoles are "active" antennas with a small amplifier built in to the housing.

Figure 1 - Active monopole antenna, model AM-741R, with frequency range of 9 kHz to 30 MHz.

Dipole - This was described previously and typically includes a set of adjustable dipole elements (Figure 2). The Com-Power AD-100A tunes from 30 to 1000 MHz. It will generally tune from 30 to 1000 MHz. It is usually just used as a reference according to the American National Standard (ANSI) C63.4 EMC standard and not generally for compliance testing.

Figure 2 - The AD-100A precision dipole antenna can be adjusted from 30 to 1000 MHz is generally used as a reference standard for more exact E-field measurement.

Biconical - This looks more like a double-eggbeater (Figure 3) and typically covers 20 to 200 MHz. There may be a shorting stub attached to the elements on one side to eliminate a known resonance.

Figure 3 - Pictured is the model ABF-900 biconical antenna with frequency range of 25 to 300 MHz, which is a collapsible version of the AB-900 biconical.

Log-Periodic - This one looks more like the conventional "over the air" TV antenna and typically tunes from 300 to 1000 MHz (Figure 4). The Com-Power ALC-100 is an example, but there are several other models with different frequency ranges.

Figure 4 - The model ALC-100 log-periodic antenna with frequency of 300 to 1000 MHz.

Biconical-Log (CombiLog) - this is a combination of (flattened) biconical mounted to the back of a log-periodic antenna. The Com-Power AC-220 (Figure 5) tunes from 20 MHz to 2 GHz. This wide frequency range covers most of the consumer/commercial band and can save a lot of time when testing, because antennas don't need to be changed in the middle of testing.

Figure 5 - The model AC-220 hybrid biconical log-periodic (CombiLog) that is resonant from 20 to 2000 MHz.

Horn - Horn antennas are generally used for the higher microwave bands above 1 GHz. The Com-Power AH-118 is a popular model (Figure 6), which tunes from 1 to 18 GHz. Military tests also specify the model AH-220, which tunes from 200 MHz to 2 GHz. Com-Power also sells model to 40 GHz and some with built-in broadband preamplifiers to boost the sensitivity.

Figure 6 - The wide-band AH-118 horn antenna that is resonant from 700 MHz to 18 GHz.

Loop - Less commonly used for the usual electronic products, the AL-130R active loop antenna (Figure 7) is described in CISPR 16-1-4 and specified by FCC Part 18, CISPR 11, 13, 14 and 32, among others. The frequency coverage is 9 kHz to 30 MHz and includes a built-in broadband preamplifier to boost the sensitivity.

Figure 7 - The model AL-130R receiving loop antenna is designed for frequencies of 9 kHz to 30 MHz.

Com-Power also makes specialty passive loop antennas for MIL-STD-461 testing of RE101 and RS101.

Antenna Factor and Calculating E-Fields

An antenna's antenna factor (AF) is a comparison between the E-field level impinging on the antenna and the actual voltage produced by the antenna at its connector. This curve can be seen in Figure 8. Note, the antenna factor varies with frequency, so the voltage produced at the connector is not constant.

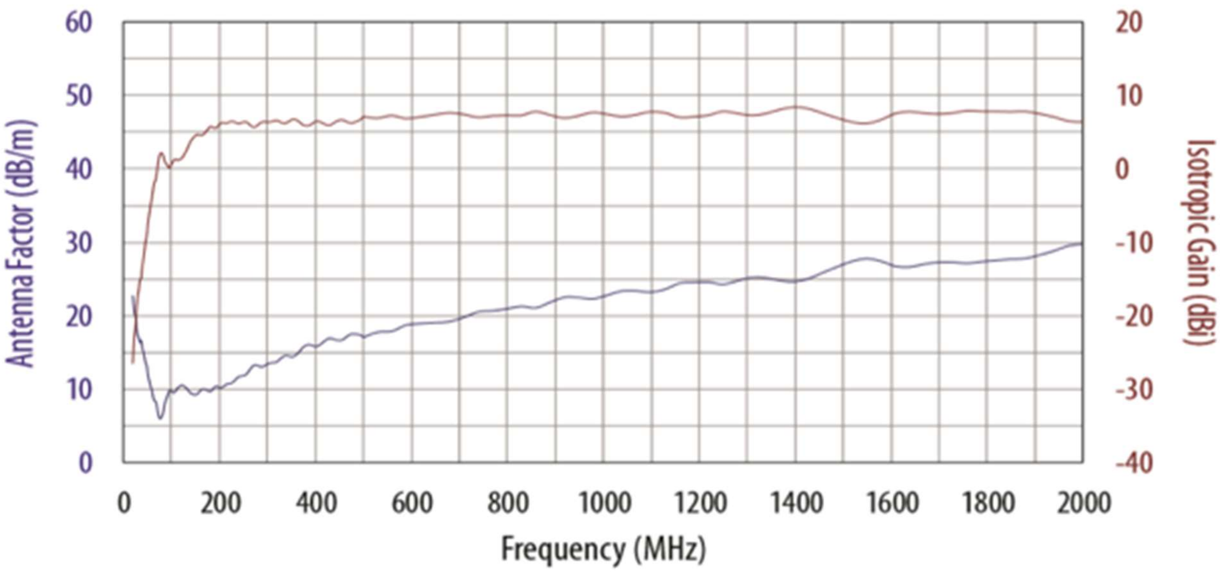

Figure 8 - A typical plot of antenna factor (AF) and antenna gain versus frequency for the AC-220 CombiLog antenna (20 to 2000 MHz).

Note, also, that the gain is very low from 20 to 60 MHz, because of the reduced physical size of the antenna compared to a full-sized dipole. For example, a resonant half-wave dipole antenna at 30 MHz would be 5m long from end-to-end.

This antenna factor (versus frequency) must be plugged into the total system gain/loss calculation in order to determine the E-field at the antenna. See Figure 9 for a block diagram of a typical system gain/loss calculation. Typically, it's a good idea to add a 6 dB attenuator to the antenna connector to "level out" the changing antenna impedance to make it look more like 50 Ohms.

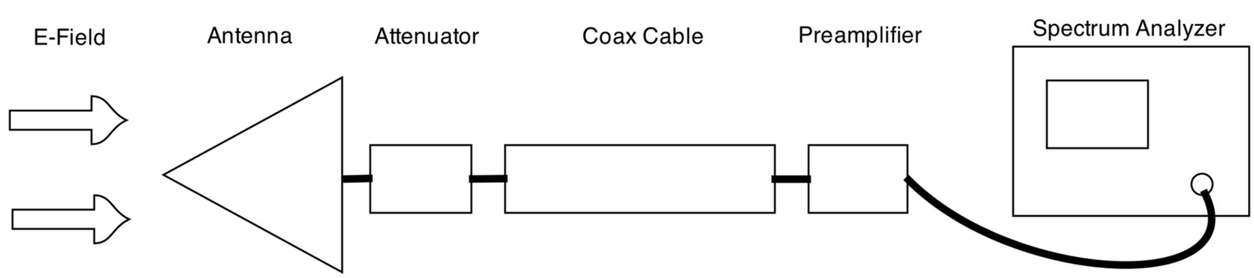

Figure 9 - A typical gain/loss block diagram to determine the measured E-field.

You can calculate the E-field (dBµV/m) by recording the dBµV reading of the spectrum analyzer and factoring in the coax loss, external preamp gain (if used), any external attenuator (if used), and antenna factor (from the antenna calibration provided by the manufacturer). This calculation can then be compared directly with the 3m or 10m radiated emissions test limits using the formula:

E-field (dBµV/m) = SpecAnalyzer (dBµV) - PreampGain (dB) + CoaxLoss (dB) + AttenuatorLoss (dB) + AntFactor (dB/m)

Example Calculation - Assuming a regulatory limit at a specific test distance, we can adjust this limit to match the actual distance used for the pre-compliance testing. Of course, if the limit is associated with, say, 3m, and we're the antenna-to-product distance is 3 m, then we can use that limit. We only need to back-calculate where the equivalent limit line is on the spectrum analyzer display.

Rearranging the equation above, we have:

SpecAn (dBμV/) = E-field (dBμV/m) + PreampGain (dB) – CoaxLoss (dB) – AttenLoss (dB) – AntFactor (dB)

For example, if you measure a harmonic at 50 MHz and at 3m test distance, then the FCC Class A limit is 50 dBμV/m. For a coax loss of 1dB, an antenna factor of 9 dB, and no external preamp or attenuator, then a signal on the spectrum analyzer at 40 dBμV would be right at the limit.

Calculating Limits for Distances Other Than for 3m or 10m - But say, the antenna-to-product distance was 2 m, rather than 3 m? We would merely raise the displayed limit by 20log(3/2), or 3.5dB. An easy way to remember whether to add or subtract this correction factor, is when the antenna gets closer to the product, the harmonics get higher and so does the regulatory limit (and vice versa).

Once you've calculated this limit at the harmonic frequency of concern, you can either move the display line to that amplitude or use the custom limit feature of your spectrum analyzer. I prefer to use the display line, as it's faster. Note that if you're using the built-in preamplifier, it's not necessary to plug this (approximate) 20 dB gain into the equation, because the analyzer already compensates for the gain leaving the signal amplitudes the same and effectively lowering the noise floor by the gain factor.

Compliance Testing

Here are examples of typical test setups for radiated emissions in accordance to the primary EMC standards for most products, including consumer, commercial, industrial, medical and military. Radiated immunity (or susceptibility) use the same test setups, except the measuring receiver or spectrum analyzer is replaced with an RF source feeding an RF amplifier to attain the required electric field levels per the appropriate standard. Be sure the antenna selected is designed to accept 100, or more, watts of RF power for immunity testing.

Consumer/Commercial Testing

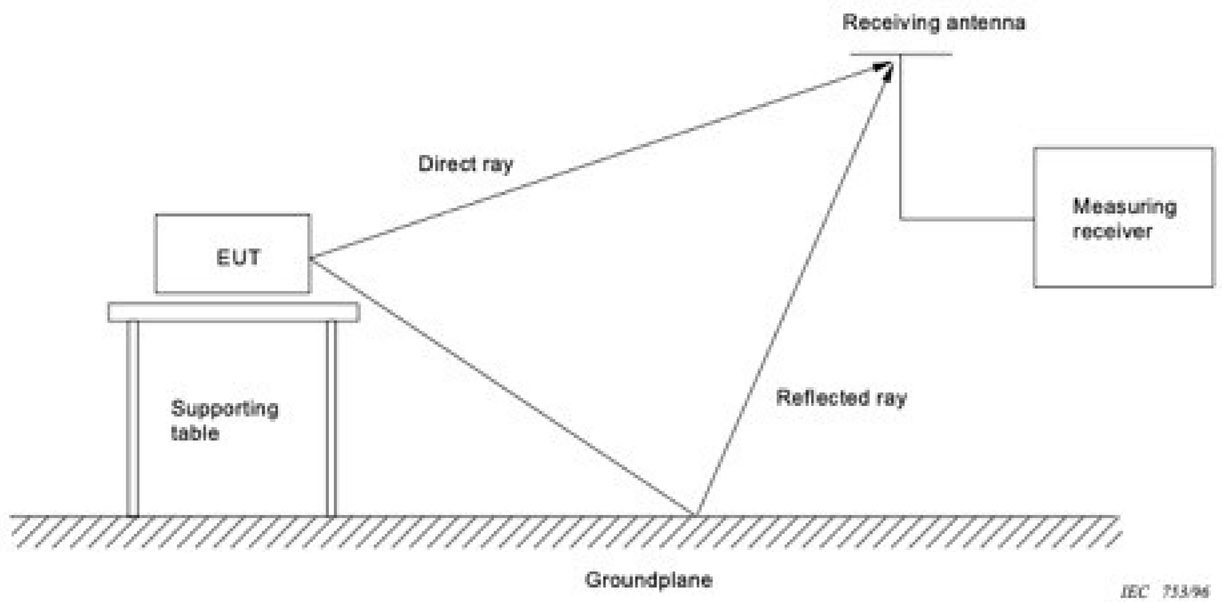

Figure 10 – The basic test setup for CISPR 11/32 radiated emissions according to CISPR 16-2-3. The table dimensions are the same as for the conducted emissions test.

The basic test setup for CISPR 11/32 radiated emissions according to CISPR 16-2-3 is shown in Figure 10. The antenna height is adjusted between 1 and 4m so the vector sum of the direct and reflected emissions are maximized at each harmonic frequency. The test distance between EUT and antenna is commonly 3m or 10m and is performed at an open area test site (OATS) or semi-anechoic chamber (SAC). Fully anechoic chambers (FAC) are also allowed and may be more accurate and consistent, while alleviating the need to adjust antenna height.

The CISPR 11/32 standards also require that attached cables need to be manipulated to generate peak emissions, and that the table be rotated while looking for peak emissions.

Automotive Testing

Most automotive EMC tests are tested in a similar environment to where the product is to be installed and are generally dictated by CISPR 25. Therefore, the test is performed on a metal tabletop with the power cable running 5 cm above the metal plane and stretched out to 2m length (Figures 11 and 12). Frequencies tested depend on the test Class of the standard and peak detection is used.

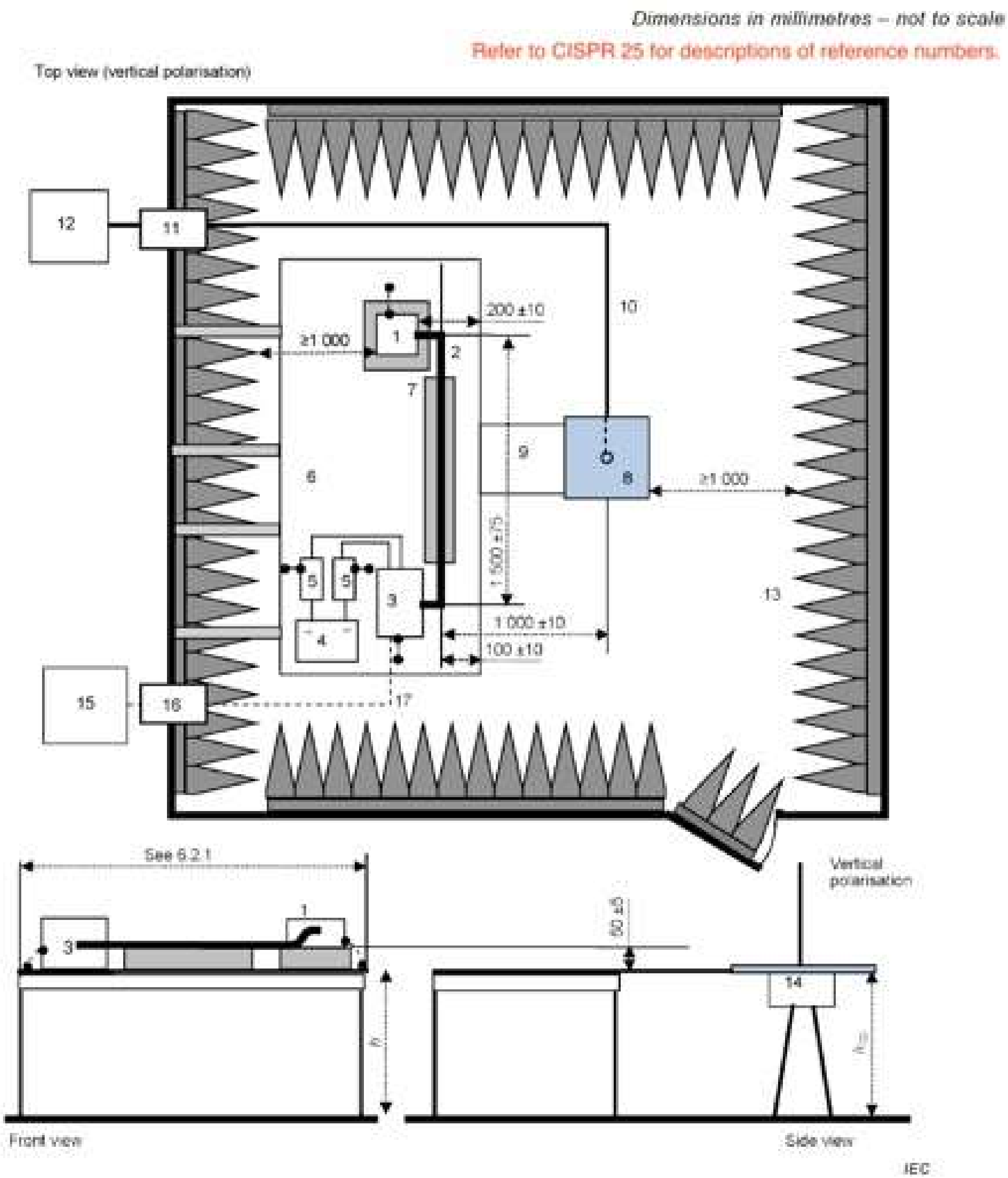

Figure 11 – An example test setup for CISPR 25 testing using the rod antenna for test frequencies from 150 kHz to 30 MHz. Note that the test setup is different than for MIL-STD-461. Testing components or modules uses a similar setup.

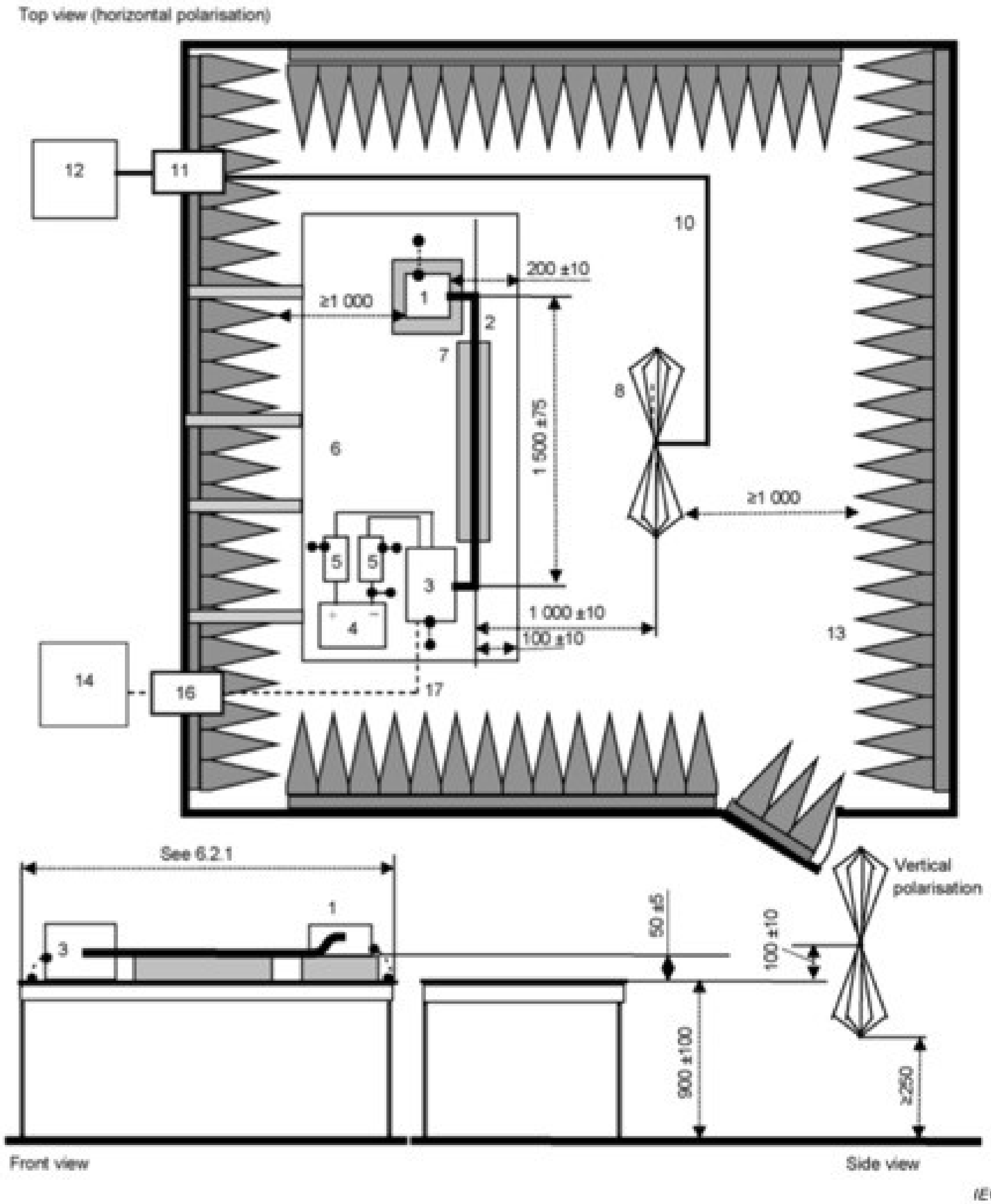

Figure 12 – An example test setup for CISPR 25 testing using a biconical antenna and testing frequencies from 30 to 300 MHz. Higher frequency bands require a log-periodic antenna (200 to 1000 MHz) or a horn antenna (1000 to 2500 MHz). Tests with these antennas are performed with both horizontal and vertical polarizations. The test setups for all three antennas are the same. Testing components or modules uses a similar setup.

Military/Aerospace

Most military or aerospace EMC tests are tested in a similar environment to where the product is to be installed. Therefore, the test is generally performed on a metal tabletop with the power cable running 5 cm above the metal plane and stretched out to 2m length (Figure 13). Frequencies tested and test limits are usually specified by the procuring authority, but could range from 10 kHz to 18 GHz, or higher, depending upon the application.

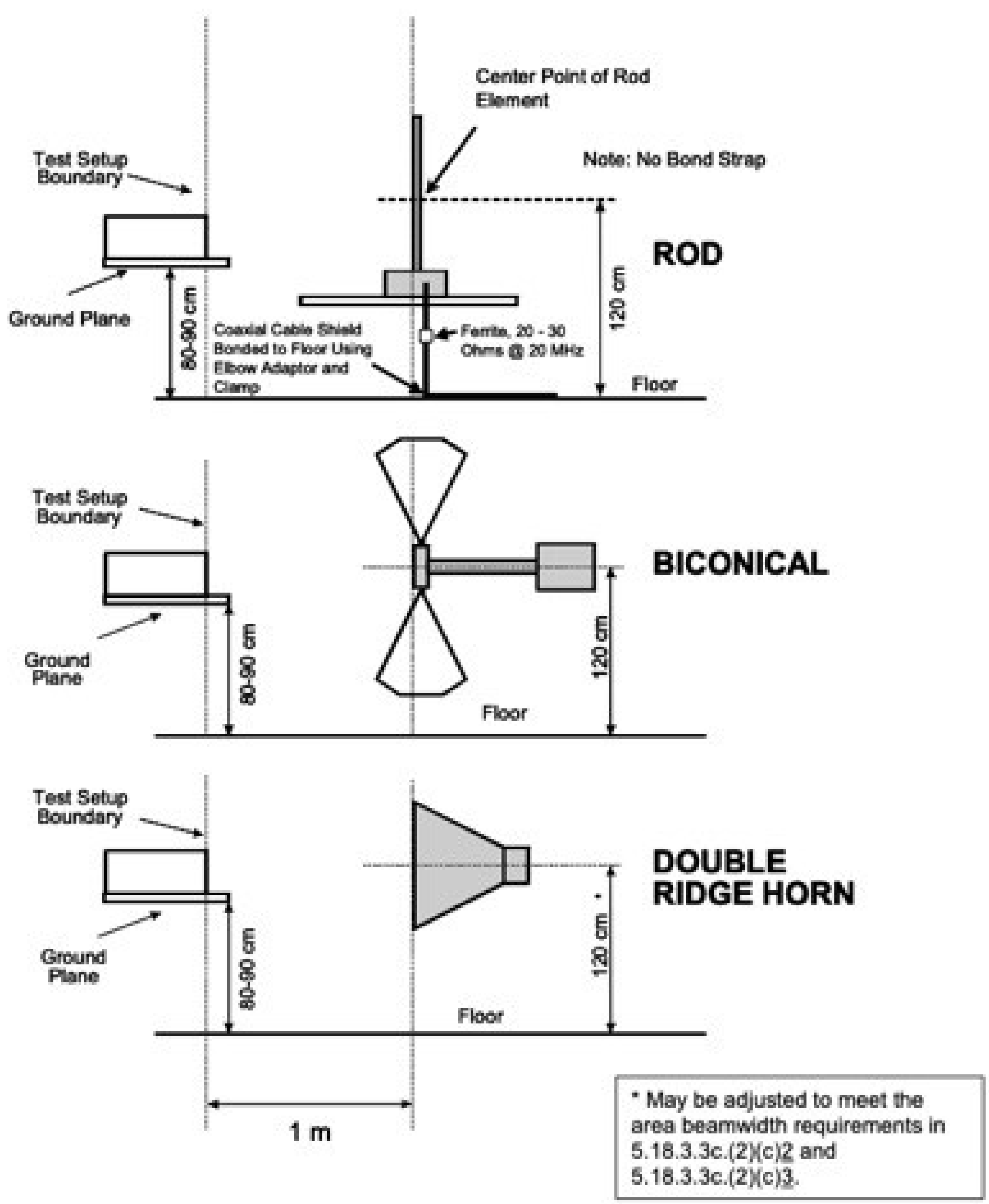

Figure 13 – An example of the test setup for RE-102 radiated emissions per MIL-STD-461. All tests are performed at a 1m test distance and typically inside a semi-anechoic chamber.

Calibrating Antennas

While outside the scope of this application note, a simple way to generate antenna factor (AF) data for an antenna would be to illuminate it with a known field strength at a specific frequency, and use a receiver to measure the volts produced at the antenna connector. This must be done in steps across the specified frequency range.

A more accurate method would be to use a calibrated RF source and compare the unknown antenna with a known calibrated one using that same calibrated source.