Antenna calibration on a 3-m OATS

Using an inaccurately calibrated antenna can result in the erroneous rejection of a satisfactory test article.

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RADIATED EMISSION MEASUREMENTS of commercial products are usually performed on an open area test site (OATS). Test instrumentation and antennas are used to obtain the radiated emission data. The measurement error accumulated by each of the instruments, sensors, and OATS used in the measurement may create doubts as to the validity of observed data. The antenna is often one of the most common sources of error in radiated emission testing. Using an inaccurately calibrated antenna can result in the erroneous rejection of a satisfactory test article. Likewise, it can also lead to mistaken acceptance of an unsatisfactory test article—a decidedly undesirable situation.

The calibration of EMC antennas is usually performed by two methods as outlined in the ANSI C63.5-1988 specification, *i.e.*, the standard site method and the reference antenna method. Most commercial labs use 3-meter OATS to perform emission measurements. Given this practice, the author carried out a study to determine the most suitable and acceptable methods for calibrating antennas on a 3-meter OATS.

INTRODUCTION

When EMI testing of commercial products is carried out, the measurement accuracy depends upon the OATS, instruments, and antenna used. Standard procedures as per ANSI C63.4-1992 or its equivalent are used to check the suitability of the site. Also, the test receiver is usually calibrated at regular intervals.

The measurement error accumulated via the instrument sensors and OATS may create doubt as to the validity of collected data. Using EMC antennas (*i.e.*, sensors) in a rather rugged environment involves frequent handling and normal wear-and-tear of a mechanical structure. Hence, antennas must be validated periodically. For all their apparent simplicity, the antennas used in an EMC laboratory are specialized and as sophisticated as antennas used for other applications. These antennas feature wider bandwidth, and major design parameters include gain, VSWR, impedance, and antenna factor. The antenna factor is used to quantify the value of incident electric field strength at a known distance. Consistent, repeatable measurement of electric fields depends upon the characteristics of the OATS, antenna, and measurement system. Therefore, the calibration of antennas is crucial in attaining such consistent data.

ANTENNA FACTOR

Antenna factor is a key term used in radiated emissions testing. Essentially, the EMI analyzer converts the voltage level received by the antenna via the input terminal of an EMI analyzer into field strength units (dB) of the electromagnetic field producing that voltage. It indicates the value of the incident electric field to voltage induced at the output of the antenna. The antenna factor is expressed as:

$$\text{Antenna Factor} = \frac{\text{Electric Field (in V/m)}}{\text{Induced Voltage (in V)}}$$

$$AF = \frac{E}{V}$$

or, in dB

$$E\ (\text{dB}\mu\text{V/m}) = V\ (\text{dB}\mu\text{V}) + AF\ (\text{dB/m})$$

where
AF = Antenna Factor (dB/m)
E = Electric Field (dBμV/m)
V = Voltage at antenna terminal (dBμV)

CALIBRATION OF EMC ANTENNAS

Calibrating EMC antennas to determine the antenna factors is usually accomplished by using one of three methods.

- The *Standard Site Method* requires three site attenuation measurements taken in pairs under identical geometries using three different antennas.
- The *Standard Antenna Method* uses a dipole antenna of known dimensions and a known antenna factor. In this method, a field is determined first by using the standard antenna and then by substituting the antenna-under-test (AUT). The antenna factor can be determined from the two readings obtained.
- In the *Standard Field Method*, a known field is created at a specified location and is picked up by the antenna. The received voltage is measured by the test receiver, and the antenna factor is determined by expressing the values of field strength in dBμV/m and received voltage in dBμV. The antenna factor can be calculated as follows:

$$AF = \text{Field Strength (dB}\mu\text{V/m)} - \text{Received voltage (dB}\mu\text{V)}$$

INTERCOMPARISON METHODS

In the present study, the author determined the antenna factors of EMCO bi-conical and log-periodic models 3104C and 3146, respectively. Two methods were used and compared—namely, the standard site and standard antenna method on a 3-meter OATS. The detailed procedures followed are given below.

Standard Site Method

In the standard site method, three sets of measurements of site attenuation were taken under the identical geometrics using three different antennas, taking two at a time as shown in Figure 1. For the test setup, transmitting and receiving antennas were kept at a height of 2 meters and 1 to 4 meters, respectively. The distance between the transmitting and receiving antennas was kept at 3 meters. Three equations associated with three site attenuation measurements are given below. Note that Equation 4 is a general equation for the calculation of theoretical site attenuation.

$$AF_1 \times AF_2 = \frac{FM\ ED_{max}}{279.1} A_1 \quad (1)$$

$$AF_1 \times AF_3 = \frac{FM\ ED_{max}}{279.1} A_2 \quad (2)$$

$$AF_2 \times AF_3 = \frac{FM\ ED_{max}}{279.1} A_3 \quad (3)$$

$$A = \frac{279.1 \times AF_r \times AF_t}{FM\ ED_{max}} \quad (4)$$

where
Ed_{max} = Maximum received field from Tables 1 and 2 of ANSI C63.5-1988

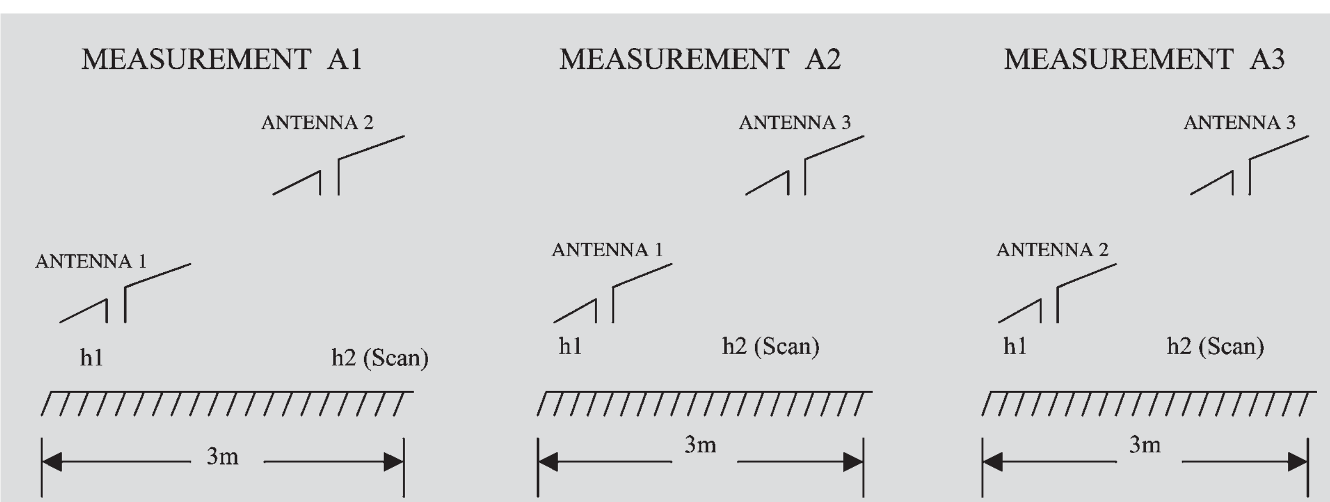

Figure. 1 *Three site attenuation using three different antennas in pairs.*

AF_1, AF_2, AF_3 = AF of Antennas 1, 2, and 3 in dB/m
A_1, A_2, A_3 = Measured Site Attenuations in dB
FM = Frequency in MHz
AF_t, AF_r = AF of transmitting and receiving antennas

Solving the equations above will determine the antenna factors of all three antennas. Note that these antenna factors can be expressed in dB as shown below in Equations 5, 6, and 7.

$$AF_1 = 10_{log}\,(FM) - 24.46 + ½\,(Ed_{max} + A_1 + A_2 - A_3) \quad (5)$$

$$AF_2 = 10_{log}\,(FM) - 24.46 + ½\,(Ed_{max} + A_1 + A_3 - A_2) \quad (6)$$

$$AF_3 = 10_{log}\,(FM) - 24.46 + ½\,(Ed_{max} + A_2 + A_3 - A_1) \quad (7)$$

The accuracy of the antenna factors determined by this method depends upon the accuracy of site attenuation measurements and the quality of the measuring site. An impedance mismatch at the output of signal source or at the input of the radio noise meter can result in reflections that could cause errors. This mismatch may be avoided by using padding attenuators of 10 dB, one each at the output end of both transmitting and receiving cables.

STANDARD ANTENNA METHOD

The standard antenna method of antenna calibration uses a dipole with an accurately matched balun. The antenna factor of any other antenna may be derived by the substitution against the reference—*i.e.*, standard antenna. The antenna factor measurement was carried out on the 3-meter OATS by keeping the distance of 3 meters between the transmitting antenna and the receiving antenna. The transmitting antenna was kept at a height of two meters, and the receiving antenna was kept at a height between 2.5 meters and 4 meters (Figure 2). To calibrate the antenna against the standard dipole antenna, first measure signal strength with the standard antenna at A2. Then, the antenna being calibrated should be substituted for the standard antenna, keeping the height and position the same as that of the standard dipole. The antenna factor for the antenna-under-test is calculated as follows:

$$V_1 + AF_1 = E$$

$$E - V_2 = AF_2$$

where
V_1 & V_2 = Received voltage (dBμV) of a standard antenna and an antenna-under-test
AF_1 & AF_2 = Antenna factor of standard and antenna-under-test (dB/m)
E = Field strength (dBμV/m)

The measurement of antenna factor accuracy depends upon the standard antenna used, the construction/geometry of the antenna-under-test, and the accuracy of the test instrumentation used.

TEST INSTRUMENTATION USED

The following types of EMI instrumentation were used for conducting the antenna factor measurements:

- Rohde & Schwarz EMI Receiver, Model ESVP
- EMCO Antenna Mast, Model 1050
- EMCO Adjustable Dipole, Model 3121C
- EMCO Bi-conical, Models 3109 and 3104
- EMCO Log Periodic Antenna, Model 3146
- Hewlett-Packard Attenuators, Model 455 C&D

OBSERVATIONS OF ANTENNA FACTOR

The data on antenna factors obtained by the two methods are given in Table 1. The observed data have been compared with the antenna factors supplied by the manufacturer.

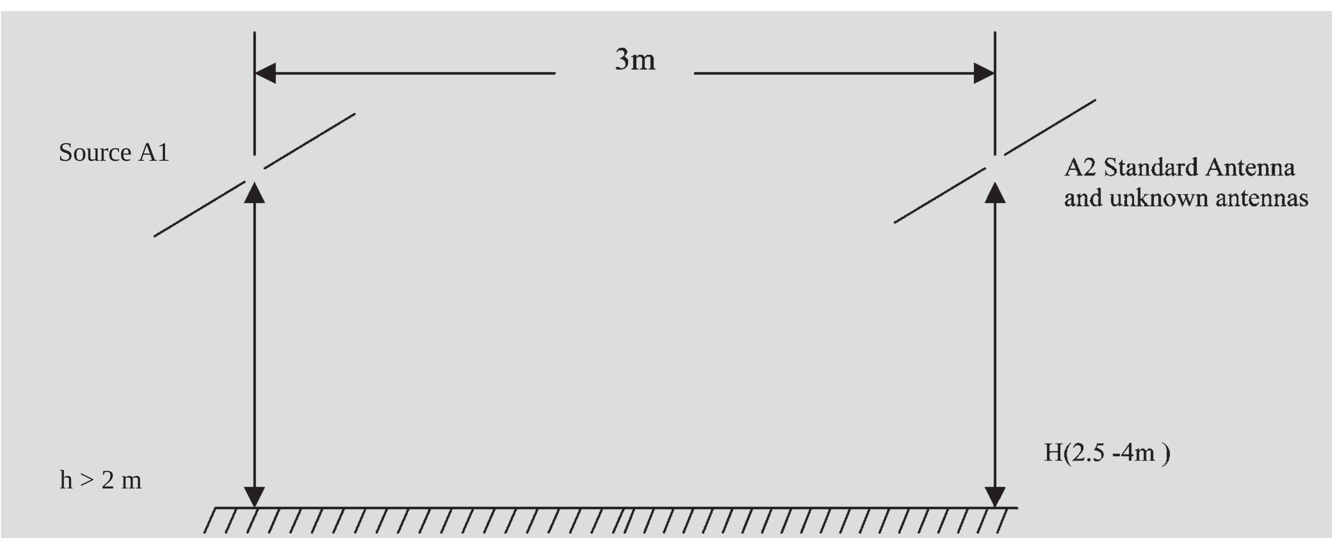

Figure 2. *Geometry for calibration of antennas against the reference antennas.*

Freq (MHz)	Antenna Factor Observation		Antenna Factor Supplied by Manufacturer
	Standard Site	Standard Antenna	
30	13.5	15.3	3.6
50	10.8	11.8	10.4
80	7.6	7.6	7.7
100	9.8	9.2	10.0
150	12.1	12.6	12.8
200	10.6	11.2	11.6
250	12.7	12.1	12.2
300	15.1	13.9	14.3
350	14.9	12.0	14.7
400	16.4	18.2	15.8
500	18.4	22.4	18.0
600	19.5	22.6	19.0
800	20.9	22.6	21.7
900	23.2	23.4	23.1
1000	24.8	20.9	24.9

Table 1. *Antenna factor observations.*

ANALYSIS

Antenna factor measurement of bi-conical (20–200 MHz) and log periodic antennas (200–1000 MHz) were carried out by using both the standard site method and the standard antenna method. The observed data have been compared with the data provided by the manufacturer. In comparing the data collected by the standard site method, we found that the variation of the antenna factor in comparison to the data provided by the manufacturer is within ± 1 dB. However, when we compare the data obtained via the standard antenna method, we found that variations with respect to the data provided by the manufacturer were quite significant (*i.e.*, max. 4.4 dB). The probable causes of such variations might be:

- The 3-meter distance between the transmitting and receiving antennas might cause antenna-to-antenna mutual coupling and consequent errors in measurement.
- The fixed height of the antenna-under-test and the standard antenna might cause a variation in pickup of field strength because of the numbers of peaks and nulls and the variations in size/geometry between the standard antenna and the antenna being calibrated.

CONCLUSIONS

ANSI C63.5 specifies a distance of 10 meters for the standard antenna method of calibration. However, radiated emission measurements for commercial specification are usually carried out on a 3-meter OATS because of space limitations and the higher costs of creating a 10-meter OATS. In this study, the author sought to determine a practical calibration method using a 3-meter OATS. From our observations, we have concluded that the standard antenna method results in an unacceptable level of variation in antenna factors obtained and that this method is therefore unsuitable for calibration in a 3-meter OATS. Hence, we reached the conclusion that the standard site method (3-antenna method) is a more accurate and practical solution for calibrating the EMC antennas used on a 3-meter OATS.

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