2nd URSI AT-RASC, Gran Canaria, 28 May – 1 June 2018

Antenna Calibration with Improved Accuracy in a Semi-Anechoic Chamber

Narjes Jalali, Inès Barbary, Lars Ole Fichte*, Marcus Stiemer
Helmut Schmidt University, Hamburg, Germany

Abstract

A method to improve the quality of antenna calibration in a semi-anechoic chamber is discussed, which is based on a compensation of unwanted reflections at chamber walls with the help of destructive interference. To this end, several measurements are carried out and averaged in a favorable way. This method significantly increases the accuracy of antenna calibration when employed in connection with the standard site method or the three antenna method. For validation, this method is applied in a standard isotropy test scenario, showing that anisotropies of a non optimal chamber are drastically reduced. Results are presented in terms of the antenna factors for several transmission lines computed via a two antenna variant of the three antenna method.

1. Introduction

The current dynamic dissemination of wireless communication systems for many vital purposes relies on the functioning of systems even under adverse environmental conditions. For that important purpose, the electromagnetic compatibility (EMC) of any device must be guaranteed by thorough testing of

a) the device's susceptibility to external interference, and

b) its potential to emit unwanted signals.

The EMC test environments used for these sort of tests consequently require precisely calibrated antennas to generate and measure field magnitudes at defined positions in high accuracy. This means that the antenna factor (see [1,2] for its definition) of an unknown antenna can be determined in a sufficient accuracy. To achieve this goal, national and international standards define various measurement procedures that cover all technically relevant antenna types, test environments, and operating frequencies (c.f. [2]). Since reference antennas with precisely known antenna factor are expensive and difficult to maintain, methods have been invented that allow for a determination of the antenna factor by measurements of the insertion losses of antenna transmission lines between completely unknown antennas within an environment with well known wave propagation properties. These methods comprise particularly the standard site method, that strongly depends on the environment's properties, and the more robust three antenna method (c.f. CISPR 16-1-4 [2]). Moreover, there exists a variant of the three antenna method, where the third antenna is omitted and virtually replaced by a fictitious third antenna that is identical to one of the available antennas. This omission will result in additional uncertainties, and hence requires a better environment.

The purpose of this work is to apply a method, firstly proposed and analyzed by [1], to obtain enhanced calibration results with the method mentioned above, even in an absorber chamber with a conductive ground, i.e., a semi-anechoic chamber (SAC), that fails to provide the isotropy properties demanded by the standard. Thus, it is intended to show that an antenna calibration method relying on an environment with exact wave propagation properties can, nevertheless, be applied in a non optimum environment, if suitable compensation strategies are applied: Unwanted reflections at walls or equipment are a major cause of inaccuracies in measuring antenna factors. Depending on the phase difference between direct and reflected signal at the observation point, constructive or destructive interferences with the wanted signals may lead to significant aberrations. Yet, after multiple measurements with (slightly) different, suitably chosen antenna positions, the average of the measured complex transmission parameter S_{21} (see [4] for details on scatter parameters) is significantly released by the influence of the unwanted reflections, since contributions to unwanted wave propagation paths have cancelled out by destructive interference. Consequently, the insertion loss is also freed from such influences, which is the basic quantity to determine the antenna factor according to the three antenna method or its variants. To validate the proposed method, five differently oriented antenna transmission lines consisting of a transmitting and a receiving antenna are established in the SAC at hand. For validation, antenna factors are computed via the two antenna variant of the three antenna method both in case of a direct measurement and for the averaging method.

2. Antenna factor measurements

To validate the mitigation strategy proposed in [1], we consider five differently oriented antenna transmission lines in a SAC and determine the transmission coefficient S_{21} between transmitting and receiving antenna with a vector network analyzer (VNA, Rohde & Schwarz, ZVA8). Knowing S_{21} immediately yields the insertion loss of the SAC. The antennas exemplarily used are two logarithmic-periodic dipole antennas (LPDA) as displayed in Fig. 1. All antennas were at first operated at equal heights over the conducting ground plane. The five transmission paths (see Fig. 2) chosen for the method's validation correspond to a standardized isotropy test in accordance with CISPR 16-1-6 [3], that has to be carried out in a SAC before the measurements. During the tests, the transmission coefficients for five different configurations were recorded. In each case, a constant antenna distance of d=1m was chosen. The receiving antenna (RX) is located on a circle, while the position of transmitting antenna (TX) is shifted along the symmetry axis of the chamber. The last measurement is performed with the receiving antenna in the center of the circle. According to the standard CISPR 16-1-6, the insertion losses of different configurations should stay sufficiently small if the SAC is to be used for calibration.

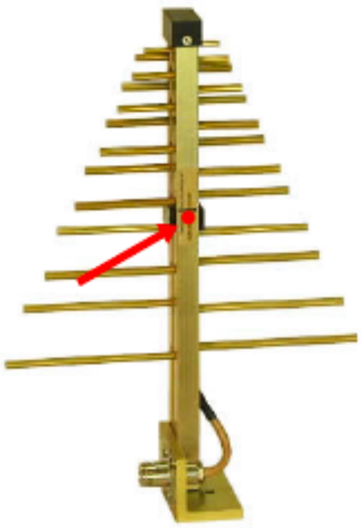

Figure 1. LPDA SAS-519-4, 650 MHz – 4 GHz. A. H. Systems Inc., Chatsworth, CA, USA. The red dot is used to determine the distances between the antennas. Corrections for the frequency dependent phase center are considered after measurement.

To be able to validate these results and to relate them to the antenna data provided by the producer, the antenna factors of both antennas are in addition estimated from this measurement, using the conversions for the three antenna method as given by the standard [2], where we replaced the third antenna fictitiously by one of the two at hand. Originally, in the three antenna method, the transmission coefficients S_{21} are measured between any possible combination of two of the interesting three antennas. No prior knowledge about the antennas under test is necessary.

3. Directly measured results

To compare the new method with a direct measurement, the latter is first carried out. To this end, positions for transmitting (TX) and receiving antenna (RX) are employed that are usually prescribed for an analysis of the chamber isotropy according to the standard [3], with constant distance between the marked antenna points. A frequency depending phase center correction has then to be applied a posteriori.

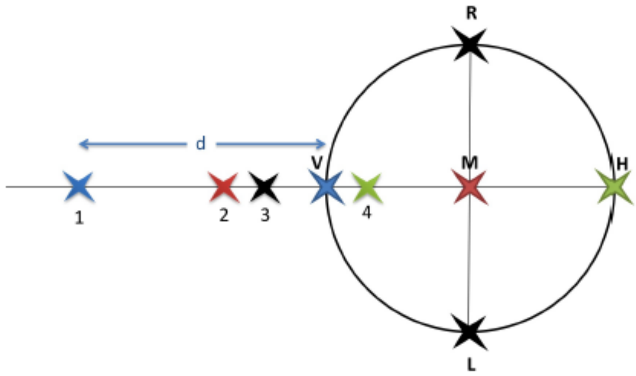

Figure 2. Placement of TX and RX antenna inside the semi-anechoic chamber.

Table 1 displays the measurement plan, i.e. the antenna positions to establish.

	Position of antenna				
TX	**1**	**3**	**4**	**2**	**3**
RX	**V**	**L**	**H**	**M**	**R**

Table 1. Placement of antennas in chamber. One pair of TX/RX positions have the same color in Fig. 2.

In Figure 3 the resulting antenna factor is plotted as a function of the frequency. It clearly shows that results from all five consecutive measurements are similar, indicating only a moderate anisotropy. They differ from the manufacturers data by less than 2 dB. Note that the maximum error occurs at $f \approx 725$ MHz, which is near the upper limits of the ferrite absorbers' domain of efficacy and the lower limit of the pyramid absorbers' frequency realm used in the SAC.

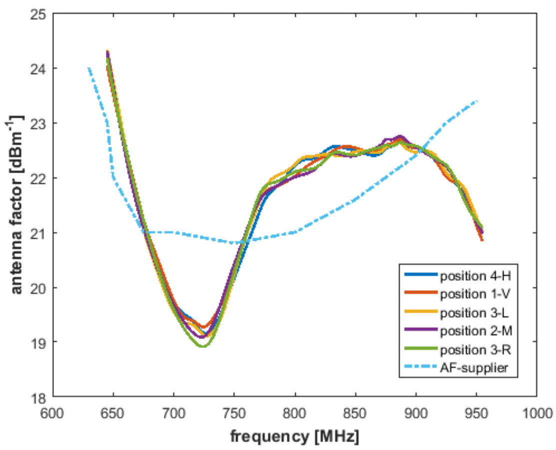

Figure 3. Results for measurements according to standard, for LPDA, horizontal polarization.

4. Improved results

The use of a SAC, i.e. an environment with a conductive ground plane, means that both the direct propagation from the TX to RX antenna as well as the reflection on the ground is intentional and contributes to the transmission coefficient (and, consequently, to the antenna factor). Unintended contributions to the transmission factor result from reflections on ceiling and walls of the chamber. To suppress the influence of these reflections, both TX and RX antennas were moved within the test volume of the chamber according to Fig. 4: first to the right (to pos. 2 along the red line), then forward (i.e. into the direction of the TX antenna) along the blue line and finally upwards, each time by approximately one quarter of the wavelength $\lambda/4$ corresponding to the excitation frequency. The exact difference between two consecutive antenna positions has to be chosen in such a way that two corresponding unwanted propagations paths obtain a path difference of $\lambda/2$, to cancel out by destructive interference. The exact distance d to move the antennas is influenced by the distance D between the antennas and the height h and width w of the chamber [1, Eqs. 4 and 5]. If the antennas are moved up or down in the chamber, this distance reads

$$d = \frac{\lambda}{4}\sqrt{1+\left(\frac{D}{h}\right)^2}\,, \qquad (1)$$

while a lateral shift would result in

$$d = \frac{\lambda}{4}\sqrt{1+\left(\frac{D}{w}\right)^2}, \qquad (2)$$

under the assumption that the chamber and the test setup is symmetric with respect to the center line. Finally, a translation along the central line requires a dislocation of exactly $\lambda/4$.

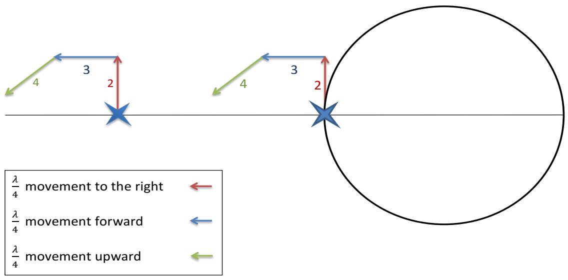

Figure 4. Antenna placement for multiple measurements

By calculating suitable averages of the transmission factor, we can successfully suppress the contribution of the indirect propagation paths. Favorable combinations of individual measurements follow as the solution of a matrix equation with integer coefficients and solution. The results of the antenna factor measurement are displayed in Fig. 5 and show the average antenna factor of the five configurations. The accuracy of the results is generally improved to less than 1,5 dB. Additionally, the outlier at 725 MHz is nearly totally suppressed by removing the influence of the unwanted reflections from the final results.

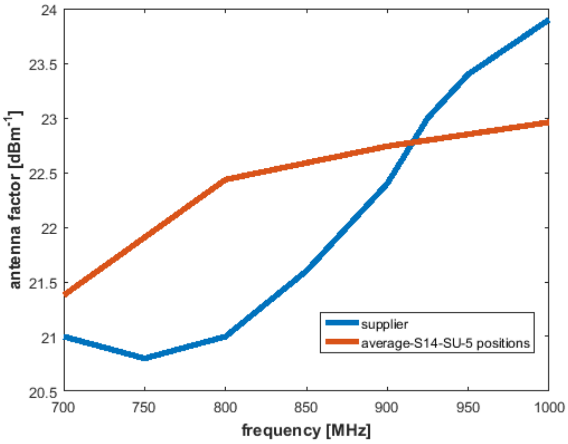

Figure 5. Improved results by utilizing multiple measurements and averaging to exclude multipath reflections by destructive interference.

5. Conclusions

Averaging complex transmission coefficients of suitably shifted antenna transmission paths can be arranged such that unwanted propagation paths cancel out by destructive interference. With this method, the antenna measurement procedures recommended by CISPR 16-1-6 to determine the antenna factor can be significantly enhanced with respect to accuracy inside a semi-anechoic chamber, particularly for methods that rely on the quality of the test site. Favorable combinations of measurement can be identified via linear systems of equations with integer coefficients and solution. Future work will be devoted to identifying the influence of single propagation paths on the measurement result as a site-diagnostics, which is also possible by the method, and gives additional information about the quality of the chamber and its absorbers.

6. References

1. Pythoud, F., “Quasi free-space calibration antenna calibration in anechoic chamber”, Proc. EMC Zurich 2005, pp. 195-198.
2. CISPR 16-1-4, “Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-4: Radio disturbance and immunity measuring apparatus - Antennas and test sites for radiated disturbance measurements”.
3. CISPR 16-1-6, “Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-6: Radio disturbance and immunity measuring apparatus - EMC antenna calibration”.
4. Pozar, D., “Microwave Engineering”, 3rd ed., John Wiley & Sons, 2005.