Keysight: Antenna Calibration

Using Periodic Calibration of Antennas to Ensure the Ongoing Performance of OTA Systems

Seen or unseen, antennas are essential to virtually every aspect of our connected world. In any over-the-air application—communication, navigation, radar, and so on—signal quality is heavily dependent on the performance of the transmitting and receiving antennas. In addition, when testing any of today's electronic devices for electromagnetic interference (EMI) and electromagnetic compatibility (EMC), the performance of the test antenna affects every pass/fail determination.

Within each of these scenarios, antenna calibration plays an essential supporting role. Calibration verifies the intended performance of any antenna, thereby helping ensure the performance of the system connected to that antenna. This has further importance because, when deployed in the field, antenna performance will change with the passage of time. For those antennas that can be easily disconnected and thoroughly calibrated, periodic checkups help account for the cumulative effects of physical and electrical impairments.

To illustrate the value of antenna calibration, this white paper covers four core topics: the two main types of antennas, the essential measures of antenna performance, ways to ensure accurate calibration, and the attributes of a qualified calibration lab.

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Contrasting the two major types

In general, most antennas are either narrowband or broadband. Each type has attributes that make it more or less suitable for specific applications.

Narrowband antennas cover a limited frequency range and can receive a small number of channels. Examples include dipoles and standard-gain horns. With these, it is easy to mathematically calculate gain factor based on the physical dimensions of the antenna. However, in practice, calculated gain factor does not account for effects such as loss through any connected cables, adaptors, baluns, and so on.

Broadband antennas cover a wide range of frequencies and can receive a large number of channels. Typical examples are biconical antennas (bicons), log periodic antennas (LPAs), bilogs (dual LPA), and dual-ridge waveguide horns. Due to the complexity of these designs, the mathematical calculation of gain factor can be difficult, even when using sophisticated antenna-modeling software.

Thus, for both types of antennas, real-world measurements are needed to accurately determine key characteristics such as gain factor and radiation pattern.

Characterizing antenna performance

We can use a few essential attributes to characterize and understand the performance of any antenna:

- Antenna gain factor
- Radiation pattern (Figure 1)
- Voltage standing wave ratio (VSWR) and return loss
- Polarization (e.g., horizontal, vertical, circular and free-space)
- Beam width (e.g., 3 dB or customer-defined)

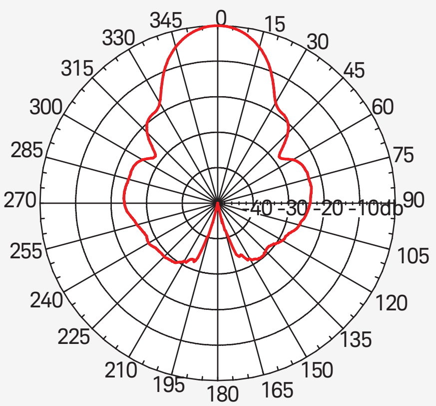

Figure 1. Displayed on a horizontal plane, this measurement shows the far-field antenna pattern of an X-band radar.

Depending on the antenna type and application, the major standards may also call for special measurements such as antenna symmetry or antenna balance. A thorough antenna calibration covers all aspects defined by the relevant set of standards.

When deployed in the field, antenna performance will degrade as flaws accumulate, gradually affecting physical condition and electrical behavior. Examples include foul weather, extreme physical stress, ice, seawater, sandstorms, and lightning strikes. Even if the antenna is known to have been repeatedly exposed to harsh conditions, the possible sources of impaired performance are not always apparent during a visual inspection: connector damage; changes in pin depth; loose or misaligned elements; weak or stressed solder joints; and even oxidation of metal parts.

Ensuring high quality calibration

Whether the antenna is part of a radar system on a ship or is used in an EMI/EMC test lab, reliable performance depends on regular checkups. Calibration is the periodic characterization of performance according to thoroughly documented sets of standards. Five of these are most prominent around the world:

- ANSI: American National Standards Institute
- CISPR: Comité International Spécial des Perturbations Radioélectriques (International Special Committee on Radio Interference)
- IEEE: Institute of Electrical and Electronics Engineers
- MIL-STD: US Department of Defense
- SAE: Society of Automotive Engineers

In addition, a qualified lab will also carry one or more of the following accreditations:

- ISO/IEC 17025:2005, which defines “general requirements for the competence of testing and calibration laboratories”
- American Association for Laboratory Accreditation (A2LA), which is intended to “inspire confidence in the quality of service and acceptance of results”
- International Laboratory Accreditation Cooperation (ILAC), which manages international agreements “between member accreditation bodies based on peer evaluation and mutual acceptance,” including calibration services

Accounting for physical and electrical issues

The widely used standard-gain horn provides a useful way to illustrate the importance of detecting and accounting for physical and electrical issues—hidden or visible.

According to the major standards, it is acceptable to calculate gain factor based solely on the dimensions of the horn aperture. However, in practice there are at least two problems with this simplistic approach: the horn itself may be damaged; the horn may be connected to a waveguide that has physical or electrical issues (e.g., cable connectors, internal components, etc.).

Characterizing a waveguide requires that we connect two together—one known, one unknown—and measure the insertion loss. Figure 2 provides measured results from a set of tests performed at the Keysight Iowa Center of Excellence (COE). The upper trace shows two responses: the red line is the response from a bad waveguide bolted to a known-good unit; and the blue line is the response from two good waveguides connected together. As shown by the blue trace, even with two known-good waveguides, the adaptors can cause significant amounts of loss (e.g., about 0.73 dB in this case).

The lower "Delta" trace shows the difference between the measurements of the good and bad waveguides. From 18 to 20.5 GHz, the delta was nearly 4 dB. Across the full span of 18 to 26.5 GHz, the average deviation was 1.93 dB.

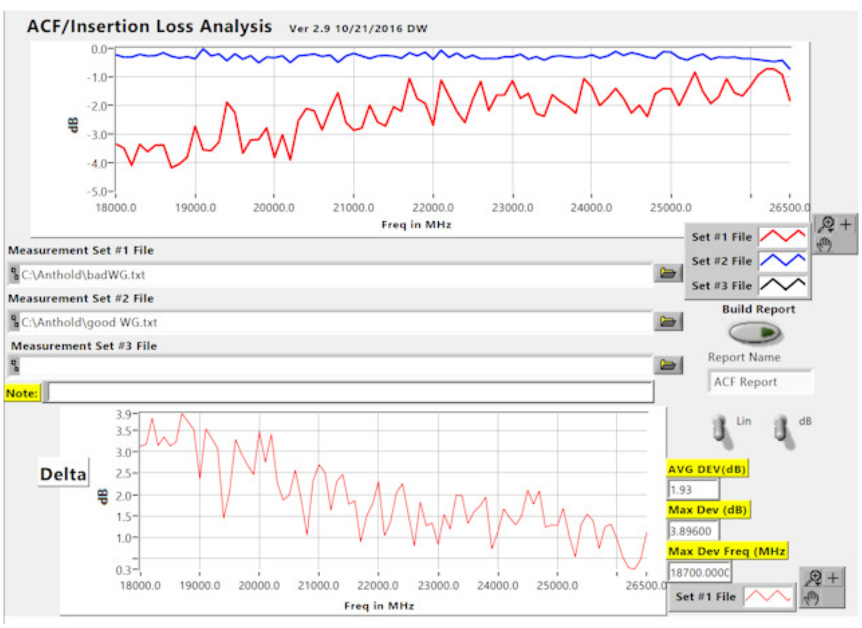

Figure 2. The upper measurement trace provides a comparison of insertion loss through two different pairs of waveguides: good/good (blue trace) and bad/good (red trace).

In the calibration process, accounting for unexpected loss has at least four important benefits:

- Reduces uncertainties based on assumptions
- Enhances the accuracy of antenna calibration
- Yields specific values for individual antennas
- Mitigates potential performance problems

For any test lab, improving its ability to reduce uncertainty is an ongoing quest.

Engaging expert calibration and flexible capacity

For every measurement tool an organization uses, the key to success is confidence in every result. Keysight's One-Stop Calibration services are the convenient way to enhance operational efficiency by ensuring the ongoing accuracy and availability of all your test assets.

Through our worldwide services organization, we help our customers in four ways. First, we ensure the ongoing accuracy and availability of their test equipment, including antennas. Next, we help them improve operational performance through faster calibration turnaround time that, in turn, supports increased readiness and availability. Third, we minimize logistical complexity and save time with single-point contact for all types of calibration. And, fourth, our approach reduces costs by eliminating financial surprises and achieving economies of scale in calibration.

Specific to antennas, the Keysight Iowa COE has been a staple in the antenna calibration industry for more than 30 years. Commercial and government organizations from around the world depend on our team to calibrate their antennas (Figure 3). As an example, major aerospace and defense organizations utilize our services.

As further testament to our expertise, standards bodies look to us for guidance during development of specifications. For instance, ANSI working groups have used our site during standards development. In addition, the COE team is on standards boards for ANSI and SAE.

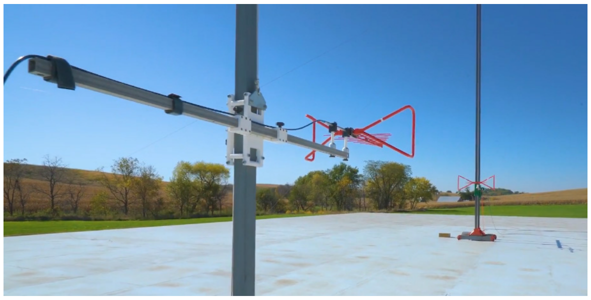

Figure 3. This CISPR antenna test was performed at our outdoor OATS on its CALTS-compliant ground plane.

Our range of capabilities spans the calibration of antennas and several types of associated devices:

- Antenna calibration: Accredited, traceable and standards-compliant
  - Pattern and gain measurements
  - Mature, new or prototype antenna designs

- Device calibration: Accredited, traceable and standards-compliant
  - ESD guns and targets
  - Isotropic field probes
  - Immunity generators and analyzers (1818.01-compliant)

- Supported standards: ANSI, CISPR, IEEE, MIL-STD, SAE, and many more

- Earned certifications: ISO 9001, ISO 17025:2005, ANSI/NCSL Z540-1-1994, A2LA accredited (#2123.01 and #1818.01)

To ensure delivery of results that meet your needs, we have invested in exceptional facilities for antenna calibration. Our open-area test site (OATS) is the world's largest, and the 50 x 80 m ground plane is compliant with calibration test site (CALTS) standards. The OATS also meets the ±2 dB criteria for normalized site attenuation (NSA).

In addition, we maintain multiple anechoic chambers for the testing of small, high-frequency antennas, the measuring of antenna pattern, and the calibration of devices such as field probes. Our chambers meet ANSI/CISPR site-validation requirements (chambers above 1 GHz) and are validated to test antenna calibration patterns above 1 GHz (CISPR 16-1-14).

Conclusion

Seen or unseen, antennas are essential to virtually every aspect of our connected world. Before deployment, manufacturers need to characterize antenna performance versus design goals. When deployed in the field, antenna performance will change with the passage of time. SI-traceable, standards-compliant antenna calibration ensures the ongoing performance of the antenna and therefore the system it is connected to—from radios to radar, and for EMI/EMC testing.

Keysight's Antenna Calibration team delivers traceable results for any organization that needs a proven provider of standards-compliant measurements. With the world's largest OATS, our facility is uniquely able to meet your specific requirements—ANSI, CISPR, IEEE, MIL-STD, SAE—with unmatched precision and repeatability.

Related Information

Antenna Calibration: https://www.keysight.com/us/en/products/services/calibration-services/antenna-calibration.html

Application Note: *Surveying the Best Ways to Test Antennas and Antenna Arrays*, publication 5992-1886EN

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