THE ANTENNA MEASUREMENT STANDARD IEEE 149 FINALLY GETS AN UPDATE

By Vince Rodriguez, Lars Foged and Jeff Fordham

In its current form, IEEE Std 149, "IEEE Standard Test Procedures for Antennas" [1], is a marginally useful document. While the standard is a good source for interesting and pertinent information, the document has not undergone a significant update since 1979. The instrumentation section, for example, describes in detail a chart recorder, an instrument that was common in antenna measurements in the 1970s and that can be found in the product catalogs of the era (see Figure 1). The basics of antenna measurement have not changed and the underlying theory has not changed as the physics behind it are still based in Maxwellian electromagnetics, the last of the classical physics fields. However, the document is mainly centered on outdoor ranges for the measurement of antennas (which represented the most common approach for antenna measurements at the time), and includes long discussions on elevated and ground reflection ranges. However, there are very limited discussions on anechoic chambers and on currently popular techniques, such as compact antenna test ranges (CATR) or near to far field measurements using mathematical transforms. These last two have become very important approaches in precision antenna measurements.

Over the years, the document survived in its current form by being periodically "re-affirmed," in which the sponsoring committee within IEEE votes to keep the standard as is and without changes. Recently, however, the IEEE Standards Association abolished

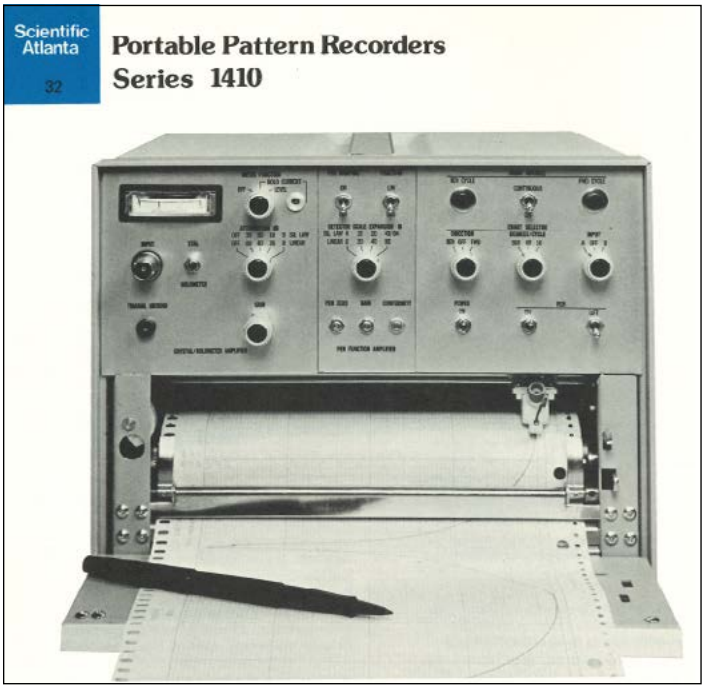

Figure 1: A chart recorder, circa 1979 (found in the 1978 Scientific Atlanta catalog)

Dr. Vince Rodriguez is a Staff Applications Engineer at NSI-MI, with extensive expertise in anechoic range design, antenna design and numerical methods. He has over 50 publications in technical journals, trade magazines and conferences, and holds two patents, one for EMC/RF absorber and another for a broad band horn antenna. He can be reached at vrodriguez@nsi-mi.com.

Lars Jacob Foged currently serves as the Scientific Director of the Microwave Vision Group (MVG) and as Associate Director of Microwave Vision Italy. He has contributed to five books and standards, and holds four patents. Lars can be reached at lars.foged@microwavevision.com.

Jeffrey A. Fordham is Vice-President, Advanced Antenna Solutions, at NSI-MI, and has decades of experience in the design and evaluation of antennas and antenna systems. He has published and presented technical papers in numerous leading journals and at various conferences, including AMTA and EuCAP. Jeff can be reached at jfordham@nsi-mi.com.

the practice of re-affirming standards. This change in policy was a blessing, as it forced the antenna measurement community to reexamine the document and to update it to address important issues, such as new techniques and discussion on uncertainties. Notably, representatives from throughout the antenna industry came together to update the document, thereby creating a standard that would be useful to the whole antenna measurement community, including both equipment manufacturers and antenna users.

IEEE Std 149 is sponsored by the Standards Committee (SC) of the Antennas and Propagation Society (APS). The APS Standard Committee (SC) currently has about 20 members and is regulated by its own policies and procedures. The SC is responsible for six IEEE standards [1-6], ensuring that they are continuously up-to-date and encouraging Committee members to form working groups to renew or update expiring standards [7]. These six standards are highly regarded by the antenna community, having been downloaded in some form from the IEEE-SA website more than 25,000 times since their latest revision.

PROCEDURE TO REVIEW OR INITIATE A STANDARD

In order to review or initiate a standard under the scope of the APS, a working group with this specific goal must be formed under the APS Standards Committee. The group consist of a chair, vice-chair and a secretary. Any person can contribute to the development of a standard by simply joining a working group. However, chairs and vice chairs must be IEEE members.

A Project Authorization Request (PAR), a document that defines the scope, purpose, and contact points for the new project, is submitted to the IEEE Standards Association for its review and approval. Once the PAR has been approved, the working group has maximum of four years to complete the revision or writing of the standard. The time available for this work is reduced accordingly if the standard being revised is set to expire. To assist working groups reviewing or initiating a standard, the Standards Association gives working group members access to a dedicated tool called iMeet Central. This is a cloud-based application that provides working group members with group management tools, file-sharing capabilities, discussion forums, databases, and more. Through the iMeet Central platform, the working group managers can accomplish all steps in the successful revision or writing of a standard.

When a working group completes its work on a standard, the draft is submitted to the APS Standards Committee. If approved by a majority vote of the Standards Committee's working group chairs, the draft is then submitted to the IEEE Standards Association, who must review the draft for editorial and legal issues within one month. The Standards Association also forms a balloting group among its members, which has two months to submit comments and suggestions. A comment resolution process follows, under which the originating working group must address all comments. The ballot on the draft is then recirculated until approved by at least 75 percent of the balloting votes. Finally, the Standards Board of the IEEE Standards Association approves the standard and it is published.

PURPOSE OF IEEE STD 149

Beginning in 2013, members of the IEEE APS Standards Committee raised concerns about the potential irrelevance of IEEE Std 149, noting that, with the reaffirming practice outlawed, the document would become inactive unless updated. Ultimately, an unofficial working group was formed, and for the next two years the group worked on a project approval request (PAR). The main drive to complete the PAR occurred during the AMTA symposium in 2015. The PAR was submitted to IEEE on October 15, 2015. The PAR document was approved within a few months of its submission.

The PAR states the purpose of the document. The scope section of the PAR is very important. That section becomes part of the standard document. The first statement reads "This document comprises recommended practices for the measurement of antenna transmitting and receiving properties. It is a comprehensive revision and extension of ANSI/IEEE Std 149-1979." That statement conveys the purpose of the document. The purpose is to provide the user of the document with a set of recommended practices for the measurement of antennas. The statement from the PAR also mentions the document being a "comprehensive revision and extension." In the next sections of this article, the anticipated additions and changes to the document are discussed.

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CURRENT CHANGES TO THE STANDARD DRAFT

The main change to the 1979 version of the standard is reflected in the title. The original document was entitled "IEEE Standard Test Procedures for Antennas," while the new document bears the title "Recommended Practice for Antenna Measurements." That change from "Standard" to "Recommended Practice" is perhaps one of the most important changes to the document. An IEEE standard indicates some mandated procedure or approach, and generally uses the word "shall" throughout to indicate a mandatory practice. A recommended practice, on the other hand, generally uses the word "should" to indicate a preferred, but not an obligatory, approach.

The change was precipitated by the reality of the antenna measurement business itself. Today, antennas come in many forms and types, and it is almost impossible for a standard to dictate that one type of test be conducted on all antennas. Some antenna applications, for example, do not require strict measurements. So a standard that included mandatory requirements would have to be extremely flexible, or it would be of little use. At the same time, strict requirements would require expensive testing of certain antennas that might be irrelevant for a given application. Since the updated version of IEEE Std 149 has been developed as a recommended practice, it merely recommends use of the best-available industry practices in conducting a specific measurement.

It is important to note that one of the currently-popular methodologies to measure antennas, the near-field measurement with mathematical transformation, originally mentioned in section 7.3 of [1], is referenced in the new draft, but, the new document does not have a thorough discussion. The reason for the omission of details regarding near-field measurements goes back to 2012, when the IEEE Std 1720-2012 was initially published [2]. That document is entitled a "Recommended Practice for Near-Field Antenna Measurements." A near-field measurement system is shown in Figure 2. Note also that, since the IEEE Std 1720 was published and approved in 2012, it will now have to undergo review by 2022, per the new IEEE Standards Association policies. The

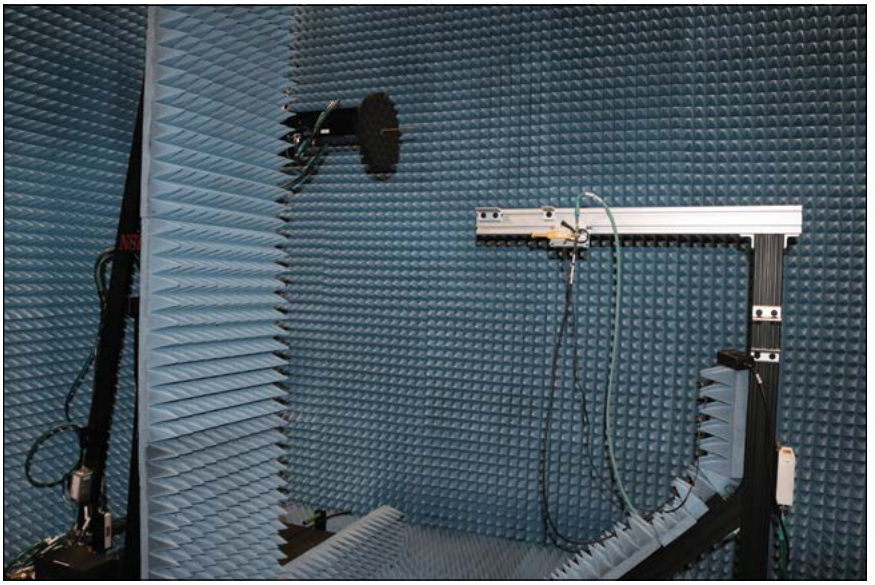

Figure 2: A planar near-field system. Used for measuring highly directive antennas, the electric field is measured in the near-field and a mathematical transform is used to obtain the far field radiation pattern. (photo courtesy of NSI-MI).

APS Standards Committee is currently in the process of setting up a preliminary working group to prepare a PAR for that revision.

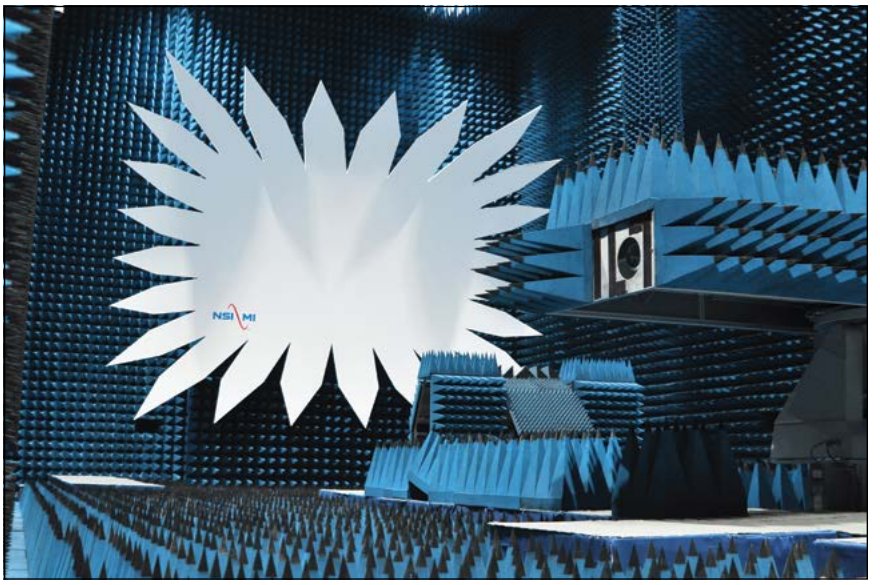

Figure 3: A CATR for testing base station antennas for cellular communications. (photo courtesy of NSI-MI)

Going back to the IEEE Std 149 revision, there are several areas in which the current draft has expanded the scope of coverage compared to the original document. One important area is guidance on the design of indoor ranges. The original document mentions anechoic indoor ranges, but the description was limited to less than one and a half pages. Instead, the document mainly provides guidance on outdoor elevated ranges and ground reflection ranges. These descriptions remain in the current draft and the discussion provides important information for potential users of the standard. Additionally, outdoor ranges are still being employed for antenna measurements, especially at frequencies where indoor ranges cannot provide adequate performance. This information has been supplemented in the current draft with the inclusion of guidance on the design of indoor ranges.

(Similarly, it should be mentioned that the potential changes to IEEE Std 1720 is the addition of a section on the proper anechoic layout for the different types of near-field measurement geometries. Currently, the standard has only half a paragraph on the subject of anechoic material layout.)

Additionally, a new section is available on evaluation of antennas test ranges. This section provides some guidance on the limitations of some industry-accepted methods for the evaluation of anechoic ranges that in many cases were used in applications for which they were not ideally suited. Among the indoor ranges described is the compact antenna test range (CATR). The original standard mentions compact ranges briefly, in about half a page. Today, CATRs are one of the workhorses for antenna measurements with reflectors ranging from small table top systems for mm-waves to huge reflectors for testing antennas up to 6m in diameter from 500 MHz to 40 GHz. Figure 3 shows a CATR system.

The new draft provides more detail about the room design for the CATR, mainly for the most common type of CATR, the prime focus single reflector system like the one shown in Figure 3. Additionally, guidelines for the evaluation of the quiet zone (QZ) of a CATR are provided, which are based on the amplitude and phase probing that was described in the original standard. More importantly, guidance is provided on the evaluation of uncertainties for the measurements in a CATR.

This takes us to another important addition to the draft document, the evaluation of uncertainties. Uncertainties are essential in any measurement. The new revision has added a discussion on the main uncertainty terms for the different methodologies described in the document. The uncertainties follow the guide to the expression of uncertainty in measurement [8].

The uncertainty discussions pertain to identifying uncertainty terms for each methodology. For example, when measuring gain, the methodologies suggested are the three-antenna method, the two-antenna method, and extrapolation ranges, and others. Uncertainty terms are provided throughout the

draft for each of the methods described. A chapter dedicated to uncertainty provides guidance on how to evaluate the overall uncertainty using the terms (that are given for each method) and their expected probability distributions. The uncertainty discussion is one of the critical and most important additions to the standard. The working group believes that the uncertainty will raise the usefulness of the standard to the antenna measurement community, and that its recommendations can be used by other standards that deal with antenna calibrations.

The other addition is the use of reverberation chambers for measuring the efficiency of antennas. The addition of reverberation provides an additional methodology to the well-known Wheeler cap approach already described in the original document [1]. The use of reverberation chambers for antenna efficiency measurements have been used by industry for at least 18 years. The addition of the methodology to the standard document provides a reference for users of reverberation chambers as well as guidance on the evaluation of uncertainty.

There have been suggestions to add information and recommendations about cellular phone testing and MIMO among other technologies that use antennas. However, the working group decided that most of the testing involved in cellphone characterization as well as MIMO systems are really hardware-in-loop (HWiL) testing and, as such, do not fall under the scope of the standard as described in the PAR. There are, however, annexes in the draft that provide some guidance and information on these types of tests.

There have also been calls for the current draft to include dosimetry measurements for RF exposure. But it was decided that the IEEE C95.1, "IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic and Electromagnetic Fields, 0 Hz to 300 GHz," handles that, and that the draft should simply direct readers to those other documents, while potentially providing some guidance regarding the allowed levels for exposure of technical personnel in restricted areas, for example, in the form of a couple of plots for full body and localized exposure as reported in [9] (see Figure 4).

CONCLUSION

The changes to the new version of the IEEE Std 149 will make the document an essential reference in any laboratory that conducts antenna measurements. Its discussion on quiet zone evaluation will set some boundaries to some of the industry-accepted methods, such as the free space VSWR method, and

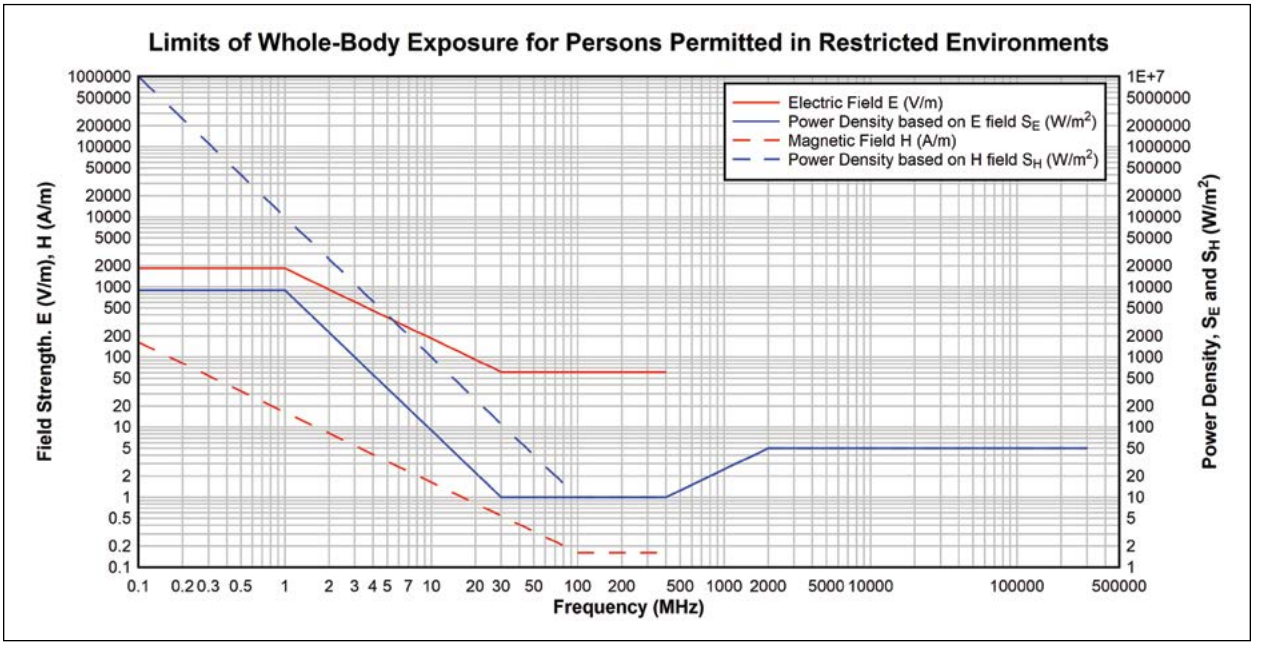

Figure 4: Limits of exposure for whole body for restricted environments like antenna ranges

also provide new methodologies that involve spectral domain methods for indoor range evaluation. In our collective opinion, the most important additions are the discussions and guidance on uncertainty. The guidance on uncertainty evaluation makes the document extremely useful for laboratories performing antenna measurements, as it provides the laboratory staff with a guide on how to evaluate the uncertainty of a given method.

REFERENCES

1. IEEE 149-1979, "IEEE Standard Test Procedures for Antennas."
2. IEEE 1720-2012, "IEEE Recommended Practice for Near-Field Antenna Measurements."
3. IEEE 145-2013, "IEEE Standard for Definitions of Terms for Antennas."
4. IEEE 211-1997, "IEEE Definitions of Terms for Radio Wave Propagation."
5. IEEE 356-2010, "IEEE Guide for Measurements of Electromagnetic Properties of Earth Media."
6. IEEE 1502-2007, "IEEE Recommended Practice for Radar Cross-Section Test Procedures."
7. Vikass Monebhurrun, "Revision of IEEE Antennas and Propagation Society Standards 149, 211, and 1502," IEEE Antennas and Propagation Magazine, Vol. 58, No. 3, June 2016, pp. 104 & 113.
8. ISO/IEC Guide 98-3:2008 (JCGM/WG1/100), "Uncertainty of measurement -- Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)."
9. IEEE C95.1-2005, "IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic and Electromagnetic Fields, 0 Hz to 300 GHz."