A Review of the Changes and Additions to the Antenna Measurement Standard IEEE Std 149

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***Abstract*—The IEEE Standard 149, Standard Test Procedures for Antennas, has not been revised since 1979. Over the years the Standard was reaffirmed, that is, its validity was re-established by the IEEE APS Standards Committee, without any changes. Recently however, the IEEE Standards Association stopped the practice of reaffirming standards. This change in policy by the IEEE has been the "medicine" that this Standard needed. A working group was organized and a project authorization request (PAR) was approved by IEEE for the document to be updated. In this paper, the expected changes to the document are described and commented. The main change is to convert the Standard to a recommended practice document. Additionally, some new techniques to measure antennas, such as the use of reverberation chambers for efficiency measurements and more information on compact ranges, is discussed. Other topics inserted are more guidance on indoor ranges and an updated section on instrumentation. Most importantly, a discussion on uncertainty is included. The result will be a very useful document for those designing and evaluating antenna test facilities, and those performing the antenna measurements.**

Keywords—IEEE Standards, Antenna Measurements

I. Introduction

The IEEE Std 149 [1] document, in its current form, is a marginally useful document. While it is full of very interesting and pertinent information, the document has not undergone a significant update since 1979. The basics of antenna measurement and the underlying theory have not changed as the physics behind it have not changed, that is a fact that cannot be argued. However, the document is mainly focused on outdoor ranges for the measurement of antennas. There are long discussions on elevated and ground reflection ranges [1]; however, there are very limited discussions on anechoic chambers and popular techniques such as compact antenna test ranges (CATR) or near-to-far-field measurements using mathematical transforms. Similarly, for instrumentation, there are long discussions about equipment no longer in use (see Figure 1) filling the pages of the current Standard, and these are in dire need of updating.

Over the years, the document survived in its current form by being re-affirmed periodically. This policy of re-affirming was a "easy way out" for the Standards Committee of APS. Recently, the IEEE Standards Association abolished the practice of re-affirming standards. This change in the IEEE policies was a blessing, as it forced the antenna measurement community to look back at the document and update it to include important things, such as new techniques and discussion on uncertainties.

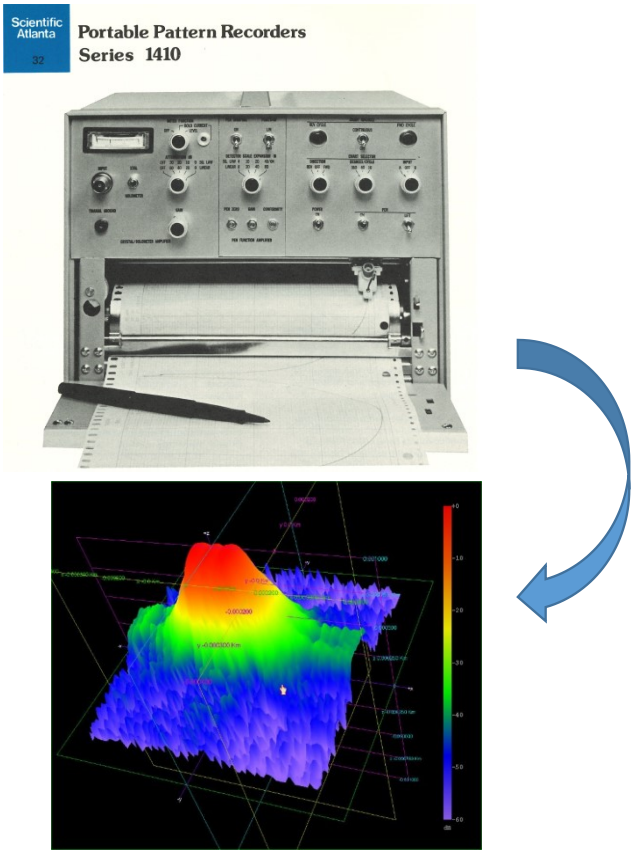

Figure 1. The 1979 version of the Standard spent several pages describing the chart recorder. Nowadays, computers are used to visualize the antenna patterns

II. Purpose of IEEE Std 149

A working group was formed, and a project approval request (PAR) was submitted to IEEE. The PAR document was approved and the purpose of the Standard was therein described.

The PAR was submitted on the 15th of October 2015 and approved on the 5th of December of the same year. The PAR states the purpose of the document. The first statement in the scope section of the PAR document 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." This 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".

Over the following years, work took place in re-writing and adding new chapters and material to the standard document and eliminating obsolete content, such as the description of the chart recorder (See Figure 1.) In June 2019, the IEEE Antennas and Propagation Standards Committee approved the Standard to go to balloting. In the next section, the new additions and changes to the document are discussed.

Figure 2. Antennas come in different varieties. There is not a "one fits all" solution for testing, thus standarizing the testing is not possible

III. CHANGES TO THE STANDARD

The main change to the Standard is in the title itself. While the original document is entitled "IEEE Standard Test Procedures for Antennas", the new document has changed the title to "Recommended Practice for Antenna Measurements". This change from "standard" to "recommended practice" is one of the big changes to the document. An IEEE Standard indicates some mandated procedure or approach. A Standard will contain statements with the grammatical statement "shall", whereas a recommended practice uses a more relaxed "should". This change is brought by the reality of the antenna measurement business itself. Antennas come in many forms and types (see Figure 2). A Standard cannot mandate the type of test that shall be performed on all antennas. Some applications do not require very strict measurements of the antenna. If the Standard was to be written as a mandatory document, it would have to be extremely relaxed and would be of little use in some applications. Since the Standard has been developed as a recommended practice, it does not mandate, but recommends the best industry practices of how to conduct a specific measurement.

There are several other areas where the revision has expanded the original document. One of them is guidance on the design of indoor ranges. The original document briefly mentions anechoic indoor ranges, but it mainly provides guidance for outdoor elevated ranges and ground reflection ranges and discusses very specific rules for the design of outdoor facilities. The updated version of the document adds guidance for the design of indoor ranges. Additionally, a new section has been written for the 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, have been used in applications for which they were not ideal.

Among the indoor ranges described in the Standard is the CATR. The 1979 version briefly mentions compact ranges in one paragraph. The new document provides more detail about the room design for the CATR, and guidelines for the evaluation of the quiet zone (QZ) of a CATR. More importantly, guidance on the evaluation of uncertainties for the measurements in a CATR are provided.

Uncertainties are essential in any measurement. The new revision has added 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 [2]. The added discussion pertains to identifying the uncertainty terms for each methodology and then provides guidance on how to evaluate the overall uncertainty using the terms and their expected probability distributions. This uncertainty discussion is one of the critical and most important additions to the Standard.

The other addition is the use of reverberation chambers for measuring the efficiency of antennas (see Figure 3). The inclusion of reverberation provides an additional methodology to the well-known Wheeler cap approach already described in the original document [1]. It should be noted that the reverberation chamber is, at this time, only used for efficiency

Figure 3. Interior of a reverberation chamber

measurements and not for other measurements, such as total radiated power, that are not within the scope of this standard.

IV. Table of Contents of the Standard

The Table of Contents of the Standard is presented in Table I.

TABLE I. The Table of Contents

Chapter	Title
1	Overview
2	Normative Referrences
3	Definitions
4	Antenna Range Design
5	Antenna Range Instrumentation
6	Antenna Range Evaluation
7	Antenna-Range Measurements of Radiation Patterns
8	Measurement of Antenna Patterns
9	Measurement of Gain and Directivity
10	Polarization
11	Determination of Radiation Efficiency
12	Measurement of Impedances
13	Special measurement techniques
14	Special measurement of angle-tracking antennas
15	Uncertainty evaluation
16	Antenna-Range operation
17	Electromagnetic radiation hazards
18	Environmental factors
19	Annexes (bibliography, field regions, reciprocity and OTA measurements)

The first three chapters are mandated by the IEEE Standards Association and they include: restating the PAR, a set of definitions not found in other Standards, and a set of reference Standards, such as the Definition Standard for Antennas (IEEE STD 145).

Chapter 4 contains guidelines for the design of outdoor ranges, as there were given in the original 1979 document. In addition, guidelines have been added for indoor rectangular, tapered and single-reflector compact range ranges.

Chapter 5 describes the instrumentation and positioning systems recommended for an antenna range, but also provides alignment procedures. This is an almost entirely newly written chapter.

Chapter 6 provides guidance on evaluating an antenna range. It provides guidance on using the free-space VSWR method and introduces spectral techniques for range diagnostics.

Chapter 7 serves as an introduction to Chapter 8. In Chapter 7 the field regions and the types of ranges are discussed, and the different pattern cuts are defined. Chapter 8 follows with descriptions of pattern measurements, both amplitude and phase, as well as phase center measurements.

Chapter 9 is one of the most important chapters. It provides information on the three-antenna method and the extrapolation range for absolute gain measurements of standards that can be used in gain-transfer measurements. Additionally, the chapter provides sources of uncertainty for gain measurements. Directivity measurements and gain-over-temperature measurements are also discussed in this chapter.

Chapter 10 deals with polarization and polarization measurements. This is followed by Chapter 11 that deals with efficiency measurements, with the introduction of the reverberation chamber being the most important addition. Chapter 12 discusses input impedance measurements and makes the relation of the input impedance mismatch and the realized gain.

These chapters are followed by a chapter of special measurement techniques. Details are not given, but the reader is referred to an extensive bibliography. Scale models, plane wave generators, including the compact range, focusing techniques and the use of drones are explored in Chapter 13. Chapter 14 provides an updated look at angle-tracking antenna systems.

Chapter 15 is the most important chapter in the view of the authors as it provides guidance on evaluating the uncertainty of the methods described in the document. A detailed study on the evaluation of uncertainty for compact ranges is provided.

The remaining chapters are informative. The antenna-range operation chapter (Chapter 16) provides recommendations on how to manage a test range. Related to this is Chapter 17, which gives the latest IEEE STD C95.1-2019 guidelines for human exposure to EM fields. Chapter 18 was rescued from the previous version and makes the reader aware of the necessity for antennas to operate in extreme environments.

The informative Annexes include an extensive bibliography and derivations of the field regions, reciprocity and over-the-air testing of antenna systems.

V. Conclusions

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 sets some boundaries to some of the industry accepted methods. Most importantly, the discussion on uncertainty makes the document extremely useful for the laboratories, as it provides the laboratory with a guide on how to evaluate the uncertainty of a given method.

References

[1] 149-1979 - IEEE Standard Test Procedures for Antennas

[2] ISO/IEC Guide 98-3:2008 (JCGM/WG1/100) Uncertainty of measurement -- Part 3: Guide to the expression of uncertainty in measurement (GUM:1995).