Revision Progress: IEEE Std 1720 Recommended Practice for Near-Field Antenna Measurements

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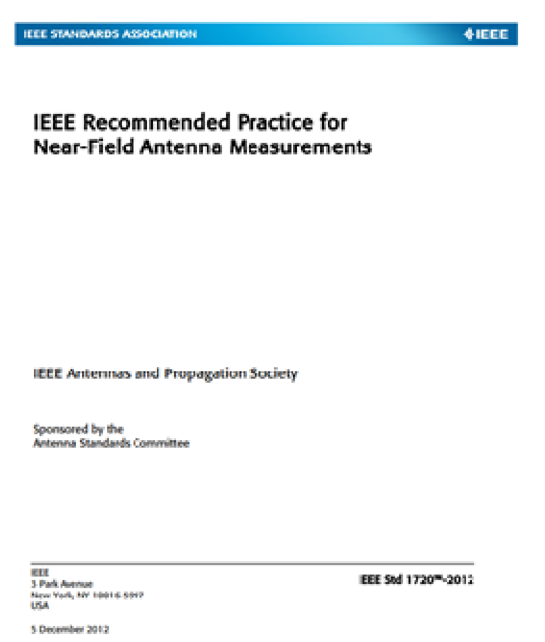
***Abstract*—The IEEE Std 1720™, "Recommended Practice for Near-Field Antenna Measurements," serves as a dedicated guideline for conducting near-field (NF) antenna measurements [1]. It serves as a valuable companion to IEEE Std 149-2021™, "IEEE Recommended Practice for Antenna Measurements," which outlines general procedures for antenna measurements [2]. IEEE Std 1720 was originally approved in 2012 as a completely new standard by the IEEE Standards Association Standards Board. It holds significant importance for users engaged in NF antenna measurements and contributes to the design and evaluation of NF antenna measurement facilities. With its ten-year term coming to an end in 2022, the standard will no longer remain active. Nonetheless, a "minor revision" of the existing standard is in progress and is expected to be completed in 2023. The objective of this paper is to provide insights into the ongoing activities surrounding the revision and to explore the proposed changes. It aims to facilitate a discussion on the modifications to and their implications for modern NF antenna measurements.**

I. Introduction

Near-field (NF) measurements are widely recognized as a highly accurate and versatile technique for testing antennas. Over four decades ago, NF measurements techniques emerged and soon became a preferred approach for testing antennas. Today, there are hundreds of near-field antenna test facilities installed across the globe, attesting to the method's proven effectiveness and global significance.

The IEEE Std 1720™ shown in Figure 1, was initially approved in 2012 as a completely new standard by the IEEE Standards Association Standards Board (SASB). However, due to advancements in technology and emerging developments since its first edition, a revision has become necessary to ensure the document is current. In 2019, the IEEE-SASB approved project authorization request (PAR), P1720, which aims to undertake a "minor revision" of the current standard. To accomplish this task, a dedicated Working Group (WG) has been formed under the Antennas and Propagation Society Standards Committee (APS/SC). Currently comprising around fifty committed volunteer members from industry, academia, and government, the WG is highly representative of the near-field measurement community, with both users and experts in the field.

Since 2019, the WG has been actively engaging in regular virtual meetings, with occasional face-to-face gatherings when possible. The primary focus of the WG has been on revising the existing material and identifying pertinent new NF measurement topics to be included in the updated standard. To facilitate smooth collaboration, the IEEE-SASB has provided a dedicated workspace with an accessible database for all WG members. This comprehensive platform houses up-to-date documents and a complete history of developments [3]. Additionally, the workspace enables rapid group decision-making through online discussions and electronic voting on various topics. The efficiency of this approach has significantly contributed to the progress of the WG's efforts.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IEEE Std 1720™-2012

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Figure 1. IEEE Std 1720™-2012 Recommended Practice for Near-Field Antenna Measurements [1].

II. CONTENT OF THE REVISED IEEE STD 1720™

As the document revision is considered "minor", the outline of the new document closely follows the original standard [1]. The main NF scanning geometries, planar, cylindrical, and spherical are covered in detail. This original material is being updated, reviewed, or rewritten depending on the level of review performed. The changes are intended to renew, update, and reflect widely accepted changes in technology and post-processing techniques. The draft outline is shown below along with annotations indicating the level of change from the original 2012 version of the standard:

1. Overview
2. Normative reference
3. Background (Updated)
4. Measurement systems (Updated)
5. Planar near-field scanning measurements (Reviewed)
6. Cylindrical near-field scanning measurements (Reviewed)
7. Spherical near-field scanning (Reviewed)
8. Non regular scanning techniques (New Clause)
9. Probes (Updated)
10. Uncertainty analysis (Updated)
11. Special topics

In Clause 11, dedicated to "special topics," various subjects of relevance to near-field antenna measurements and techniques are listed. New techniques, widely accepted in near-field antenna measurement post-processing are included in this Clause. The Clause 11 sub-clause list is shown below. New techniques that were not in the original 2012 standard are annotated:

11.1 Antenna system testing (New)
11.2 Back projections & diagnostics (New & Updated)
11.3 Probe position correction
11.4 Truncation mitigation
11.5 Time gating in near-field antenna measurements
11.6 Single Frequency Spatial Filtering Scattering Suppression Techniques (New)
11.7 Thermal Testing (New)
11.8 Phase retrieval methods
11.9 Facility comparison campaigns (New)

III. CHANGES TO THE MAIN CLAUSES

The IEEE standard time convention for time-harmonic electromagnetic fields is of the form exp(+jωt), where j is the imaginary unit, ω the angular frequency, and t is time. Using this convention, the corresponding propagation phase factor is exp(-jkr), where k is the wave number and r is the propagation distance. This notation is sometimes referred to as the *engineering* time notation. This differs from the *physics* notation wherein the "+" and "-" signs are interchanged in the above expressions. Throughout the standard, both time conventions are used without much distinction.

As the choice of convention does not matter if consistency is maintained, the group decided to preserve the mix of *engineering* and *physics* time conventions in the standard as foundational references exist using both conventions. Any new material based on commonly accepted practices will be in the engineering time convention. It is important that the convention used in the text is clear to the user of the standard.

In Clause 3, "Background", the *physics* time convention is used predominantly. The rest of the document mainly use the *engineering* convention. Mixed time conventions are commonly encountered in antenna measurements. It is particularly important that the system hardware/software implementations have the same convention to avoid erroneous results during near-field to far-field (NFFF) transformation.

Clause 4 of the standard is dedicated to the discussion of measurement systems used in near-field scanning. These systems require a combination of essential components, including a radio-frequency (RF) transmit and receive system, computerized scanning capabilities, data acquisition tools, and analysis software. The practical implementation of mechanical and electrical systems in these measurement setups can vary based on specific requirements, suitability, and the relative importance of different factors. The initial focus is on the acquisition of data on specific geometries, such as planes, cylinders, or spheres. This provides practitioners with valuable insights into the selection of appropriate scanning systems that align with their specific measurement needs. An important new addition to Clause 4 is a comprehensive discussion on modern anechoic chamber design, along with corresponding recommendations. This inclusion addresses the significance of optimizing the chamber environment for accurate and reliable near-field scanning measurements (see Figure 2).

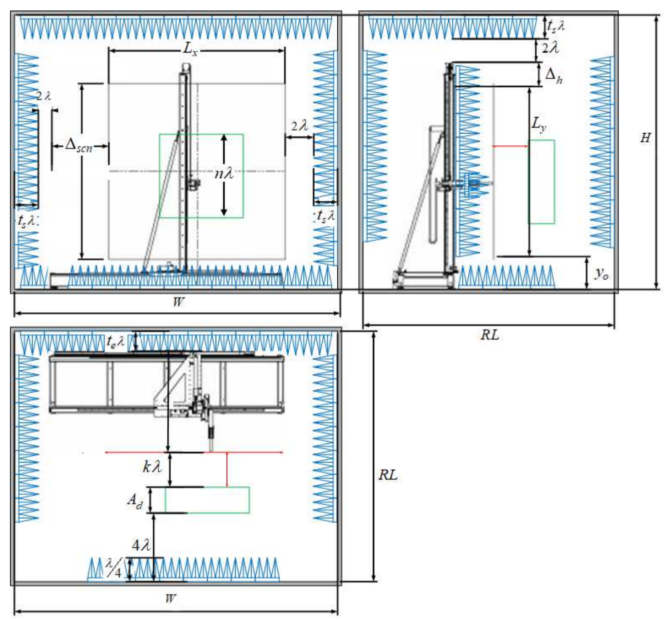

Figure 2. recommendations for range absorber coverage are now presented in Clause 4.

Clause 5 of the standard provides an overview of planar near-field theory along with practical implementation considerations. This method is particularly suitable for measuring antennas with moderate to high directivity. During planar near-field measurements, a probe is scanned over a planar surface located in front of the antenna under test (AUT). To transform the near-field measurements into the far-field domain, a fast Fourier transform is commonly employed. Planar near-field scanning is commonly employed for high directivity antennas due to the truncation of the scan area. The planar near-field scanning method was the first geometry for which probe correction theory was developed. The probe correction process is performed direction by direction, ensuring accurate and reliable results.

Clause 6 of the standard focuses on NFFF transformation techniques using cylindrical scanning. While this approach introduces a moderate increase in analytical and computational complexity compared to planar scanning, it offers the advantage of reconstructing the complete radiation pattern of the antenna, excluding the regions near the positive and negative cylindrical axes. In cylindrical scanning the near-field data is acquired along a cylindrical grid and is thus particularly well-suited for fan-beam type antennas. By accounting for the effects of the probe, it becomes possible to accurately determine the far-field pattern of the AUT. A brief introduction to advanced scanning techniques aimed at reducing the number of measurements points (and thus measurement time) and the associated processing is also included.

Clause 7 of the standard is dedicated to spherical scanning techniques. It starts by providing a fundamental explanation of the theory behind spherical scanning, highlighting the use of probes with special symmetry properties, specifically the $\mu = \pm 1$ probes. The benefits and advantages of employing these probes are thoroughly explained, emphasizing their significance in achieving accurate measurements. The clause has been further enhanced by an expanded discussion on higher-order probe compensation strategies. By incorporating probe compensation techniques of any order, practitioners can effectively minimize the impact of probe characteristics and enhance the accuracy of the measured results for a wider variety of probes. This comprehensive coverage of probe compensation techniques ensures that practitioners have the necessary tools and knowledge to perform precise spherical near-field scanning measurements. The clause also includes a new comprehensive discussion on various techniques for AUT gain determination. Different approaches, applied to spherical near-field measurements, providing practitioners with a comprehensive understanding of the measurement process.

Clause 8, titled "Non-regular scanning techniques," encompasses the implementation of non-redundant sampling representations in different canonical scanning geometries such as planar, cylindrical, and spherical configurations. The primary objective of these techniques is to minimize measurement time. Furthermore, this clause also provides guidance on techniques applicable in the growing trend of sampling over non-canonical surfaces, highlighting the increased use of airborne drones and robotic systems for this purpose.

In Clause 9 of the standard, the selection and calibration of probes for near-field measurement applications are thoroughly discussed. The choice of suitable probes for near-field measurements is crucial as it directly affects the accuracy of the calculated far-field characteristics of the AUT. To ensure precise determination of the far field of an AUT using near-field data, it is essential to account for the probe's influence during the measurement process. This necessitates knowledge of the probe's on-axis gain, polarization characteristics, as well as its co-polarization and cross-polarization patterns. This clause provides detailed instructions on measuring and determining these probe properties, enabling practitioners to accurately characterize the probe's behaviour. The clause offers guidance on selecting an appropriate probe for specific measurement scenarios. Factors such as the scan surface geometry and the desired measurement accuracy are taken into consideration to aid practitioners in making informed decisions regarding probe selection.

Clause 10 of the standard is dedicated to the analysis of uncertainty in near-field antenna measurements. It serves as a comprehensive resource for practitioners to understand and address the sources of uncertainty that can arise during the measurement process. The clause has been updated and revised to reflect recent changes and follows standardized procedures in line with widely recognized guidelines.

IV. Changes to Special Topics clause

Clause 11 is dedicated to "special topics", where various themes of relevance to near-field antenna measurements and post-processing techniques are described. Among these are several new techniques that are now widely accepted by near-field antenna measurement practitioners.

Subclause 11.1 is dedicated to antenna system testing. The term *antenna system* describes a device-under-test that consists of one or more passive radiating (or receiving) antennas that are connected to one or more active electronic devices and typically remain connected for the duration of the test. The testing of such systems typically aims at determining the receive and/or transmit power performance parameters of the electronic devices connected to the antenna. The subclause outlines and gives recommendations on common methods of testing such parameters.

Subclause 11.2, titled "Back projections & diagnostics," introduces field expansion techniques suitable for diagnostic purposes (see Figure 3). This subclause discusses the use of standard planar, cylindrical, and spherical near-field theory to evaluate fields on canonical surfaces near the AUT. In cases where a non-canonical evaluation surface is desired, this subclause describes the use of equivalent currents/sources as non-orthogonal expansion functions. This approach is also commonly employed in NFFF transformations for measurements conducted on non-canonical scanning surfaces as addressed in Clause 8 "Non regular scanning techniques". Additionally, such methods also serve as a spatial filtering technique, further discussion on this aspect can be found in subclause 11.6.

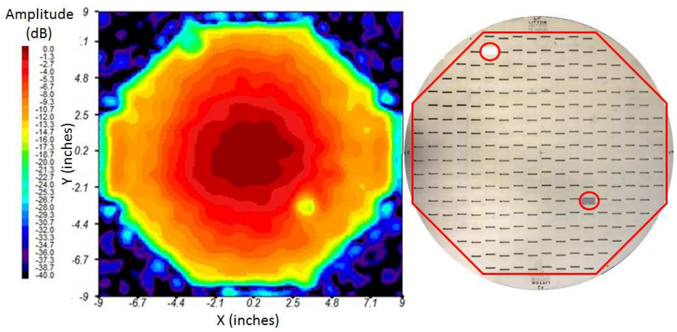

Figure 3. A back projection on a slot array antenna showing an element that has been covered with tape. Back projections can be used for diagnostics of array antennas.

Subclause 11.3, titled "Probe-position correction," is intricately connected to the discussion presented in Clause 8 "Non regular scanning techniques." Many of the techniques employed to enable NFFF transformation on intentionally non-regular grids can also be applied during the processing stage to correct non-intentional but known probe position errors.

Subclause 11.4, titled "Truncation mitigation," and subclause 11.5, titled "Time gating in near-field antenna measurements," are completely rewritten to reflect recent changes in the techniques that are now commonly accepted. These revisions reflect the current state-of-the-art practices in the field and provide updated guidance to potential users, enabling them to make informed decisions when implementing these techniques in their near-field antenna measurements.

The subject matter addressed in subclause 11.6, titled "Single frequency spatial filtering scattering suppression techniques," was introduced but received minimal treatment in the prior revision of the standard. Scattering suppression techniques have been utilized in antenna measurements for several years. Various methods and techniques are included in this revision. The techniques discussed in this subclause deviate from those described elsewhere in the standard. They operate within the frequency domain, requiring only a single frequency measurement, and do not necessitate any specialized dedicated hardware. The most widely adopted approach involves decomposing the fields into a set of modes. Within this mode domain, the modes primarily associated with the test antenna are effectively separated from those primarily associated with the scattered signal. This separation allows the extraction of unwanted spurious signals from the antenna pattern, resulting in their significant reduction.

As antenna systems grow increasingly complex and find application in diverse fields, ensuring high reliability becomes crucial. It is often necessary to verify that antenna or device performance remains unaffected by its surrounding environment. While environmental characteristics can vary based on the application, temperature is a common factor that can potentially impact the antenna and/or device performance. Subclause 11.7, titled "Thermal testing," provides recommendations on the utilization of climate chambers for performing radiated testing of devices across different temperature ranges. By subjecting the antenna to various operating temperatures it may encounter during use, thermal testing ensures that the antenna functions as intended. This type of testing is particularly beneficial for antenna systems operating in environments with extreme temperature conditions, antennas designed to handle high levels of RF power, or antennas intended for space applications. Within the subclause, guidance is provided on the setup of thermal testing, selection of system components, considerations for potential issues or challenges, and data processing techniques.

Subclause 11.8, titled "Phase retrieval methods," addresses the issue of performing near-field measurements without having reference phase information on the measured field. Precise knowledge of both amplitude and phase data at specific distances and frequencies on a defined surface is required for performing the NFFF transformation in all near-field techniques. However, in situations where phase information is unavailable or challenging to obtain accurately, phase retrieval methods prove to be valuable tools. A classification of phase retrieval techniques reveals three categories: four magnitudes techniques, indirect holography techniques, and multiple scan techniques utilizing iterative and optimization methods. The literature also presents various combinations or variations of these techniques. To reflect recent developments, the subclause has been completely rewritten and updated, providing the most up-to-date information on phase retrieval methods.

Subclause 11.9, titled "Facility comparison campaigns," introduces a new and significant topic. Over the past years, numerous measurement facilities have actively engaged in facility comparison campaigns, recognizing the vital role these activities play in documenting and validating laboratory proficiency and competence. Such campaigns have proven instrumental in enhancing antenna measurement procedures and protocols within facilities and standards. This paragraph provides a recommendation regarding the organization and participation in these campaigns. It emphasizes the importance of actively participating in facility comparison campaigns to assess and improve the performance of measurement facilities, thereby contributing to the advancement of overall measurement quality and credibility. By engaging in these campaigns, facilities can benchmark their capabilities, identify areas for improvement, and foster collaboration and knowledge sharing among industry peers.

V. Conclusion and Acknowledgement

The IEEE Std 1720-2012™ "Recommended Practice for Near-Field Antenna Measurements" expires in 2022. A WG of the APS/SC has been formed to update the standard. The authors recognise the hard work of the P1720 WG [3] for their continued dedication to the review of the current standard.

References

[1] "IEEE Recommended Practice for Near-Field Antenna Measurement", in *IEEE Std 1720-2012*, 5 Dec 2012.

[2] "IEEE Recommended Practice for Antenna Measurements," in IEEE Std 149-2021 (Revision of IEEE Std 149-1979), 18 Feb. 2022.

[3] https://ieee-sa.imeetcentral.com/p1720workinggroup/