TECHNICAL REPORT

ISO/TR 10305-2

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Road vehicles — Calibration of electromagnetic field strength measuring devices —

Part 2: IEEE standard for calibration of electromagnetic field sensors and probes, excluding antennas, from 9 kHz to 40 GHz

Véhicules routiers — Étalonnage des appareils de mesure de l'intensité d'un champ électromagnétique —

Partie 2: Méthode normalisée de l'IEEE pour l'étalonnage des capteurs et des sondes de champ électromagnétique, à l'exclusion des antennes, entre 9 kHz et 40 GHz

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TR 10305-2 was prepared by the US Institute of Electrical and Electronics Engineers (IEEE) (as IEEE 1309-1996) and was adopted without modification by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 3, *Electrical and electronic equipment*.

This first edition of ISO/TR 10305-2, together with that of ISO/TR 10305-1, cancels and replaces the first edition of ISO/TR 10305, which has been technically revised.

ISO/TR 10305 consists of the following parts, under the general title *Road vehicles — Calibration of electromagnetic field strength measuring devices*:

— *Part 1: Devices for measurement of electromagnetic fields at frequencies > 0 Hz*

— *Part 2: IEEE standard for calibration of electromagnetic field sensors and probes, excluding antennas, from 9 kHz to 40 GHz*

Introduction

The necessity for EMC (electromagnetic compatibility) testing of road vehicles and their components has led to the publication of a number of standardized test procedures. The need, too, for a standardized method for the calibration of field strength measuring devices was seen by the responsible ISO subcommittee. As no such International Standard was at the time available from either ISO or IEC, ISO/TR 10305 was published in 1992, based on the amended 1975 edition of the US National Bureau of Standards (now the National Institute of Standards and Technology, NIST) report, NBSIR 75-804.

That document having been considered incomplete, two new calibration methods were independently developed by DIN, the German Institute for Standardization, and by IEEE, the US Institute of Electrical and Electronics Engineers. It was decided to publish the methods as the two parts of a Technical Report replacing ISO/TR 10305:1992. Part 1 is an English translation of part 26 of DIN VDE 0847 and part 2 is the adoption, without modification, of IEEE std 1309-1996. Each of the two parts should be considered as independent of the other, no effort having been made to combine them.

The user of either method is kindly requested to report on the experience to ISO/TC 22/SC 3.

In the event of IEC publishing a general calibration procedure as an International Standard, ISO/TR 10305 could be withdrawn, as there is no anticipated need for special calibration methods for use in the automotive industry.

Road vehicles — Calibration of electromagnetic field strength measuring devices —

Part 2:
IEEE standard for calibration of electromagnetic field sensors and probes, excluding antennas, from 9 kHz to 40 GHz

1 Scope

This part of ISO/TR 10305 specifies techniques for calibrating electromagnetic field sensors and probes, excluding antennas, used in automotive testing for the measurement of magnetic fields at frequencies from 9 kHz to 40 GHz. In the automotive field, these field strength measuring devices are used for measurements specified in the various parts of ISO 11451 and ISO 11452.

The scope and field of application are further detailed in clause 1 (see page 9) of the enclosed IEEE standard.

2 Requirements

For the purposes of international standardization, the following provisions shall apply to the specific clauses and paragraphs of IEEE std 1309-1996.

Pages i to iv (reproduced here as pages 3 to 6)

This is information relevant to the IEEE publication only.

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Add the following information to Annex J.

[1] ISO 11451 (all parts), *Road vehicles — Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy*

[2] ISO 11452 (all parts), *Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy*

[3] DIN VDE 0847, *Methods of measurement for the electromagnetic compatibility — Part 26: Calibration of field measuring receivers for EMC and personal safety applications for frequencies > 0 Hz*

[4] NBSIR 75-804, *Generation of Standard EM fields for Calibration of Power Density Meters 20 kHz to 1 000 MHz*

3 Revision of publication IEEE 1309-1996

It has been agreed with IEEE that ISO/TC 22, *Road vehicles*, Subcommittee SC 3, *Electrical and electronic equipment*, will be consulted in the event of any revision or amendment of IEEE std 1309-1996. To this end, ANSI, the American National Standards Institute, will act as liaison between IEEE and ISO.

IEEE Standard for Calibration of Electromagnetic Field Sensors and Probes, Excluding Antennas, from 9 kHz to 40 GHz

Sponsor

IEEE Electromagnetic Compatibility Society

Approved 20 June 1996

IEEE Standards Board

Abstract: Consensus calibration methods for electromagnetic field sensors and field probes are provided. Data recording and reporting requirements are given, and a method for determining uncertainty is specified.

Keywords: calibration, electromagnetic, field probe, field sensor, probe antenna

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Introduction

(This introduction is not part of IEEE Std 1309-1996, IEEE Standard Method for the Calibration of Electromagnetic Field Sensors and Field Probes, Excluding Antennas, from 9 kHz to 40 GHz.)

This standard was prepared by the Working Group on Methods for Calibration of Field Sensors and Field Probes, Excluding Antennas, from 9 kHz to 40 GHz, and is sponsored by the Electromagnetic Compatibility Society.

The following is a list of committee members and significant contributors.

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Contents

ANNEX PAGE

IEEE Standard for the Calibration of Electromagnetic Field Sensors and Field Probes, Excluding Antennas, from 9 kHz to 40 GHz

1. Overview

1.1 Scope

This standard provides calibration methods for electromagnetic (EM) field sensors and field probes, excluding antennas per se, for the frequency range of 9 kHz to 40 GHz. Field injection probe (transmitting) calibration is not covered by this standard. This standard is not applicable to EMI emission measurement antennas, such as active and passive whip antennas, used in the general frequency range of 9 kHz to 30 MHz.

This standard also provides alternative calibration methods that are appropriate to various frequency ranges and various user requirements. These methods are applicable to any (active, passive, photonic, etc.) field sensor or field probe. Methods are provided for frequency domain and time (transient) domain calibration.

Methods for creating standard electric and magnetic fields are described in clause 5. Each method has known calculated field strength and associated errors. Each standard field method is individually addressed. The field generation information was obtained from IEEE Std 291-1991 and from IEEE Std C95.3-1991,[1] with additional information from sources listed in the bibliography.

Most electromagnetic field measurements are made in the frequency domain, either at a single frequency or at a number of frequencies. The ever-increasing susceptibility of electronic circuits has awakened interest in transient electromagnetic phenomena such as electrostatic discharge (ESD), electromagnetic pulse (EMP), and system-generated transients, such as automotive ignition noise. The measurement of these transient fields requires electromagnetic field probes and sensors that can faithfully replicate the transient waveshapes, thus requiring an equivalent bandwidth of decades. The calibration of time domain sensors necessitates procedures that are significantly different than those for the frequency domain sensors.

The electric or magnetic field sensor and/or field probe calibration requirements depend on the design and the manufacturer's specifications. The calibration shall address the amplitude response, frequency response, accuracy (uncertainty), linearity, and isotropy. Additionally the calibration may address response time, time constant, and response to signal modulation.

[1]Information on references can be found in clause 2.

1.2 Purpose

This standard provides consensus calibration methods for electromagnetic field sensors and field probes. Calibration organizations and others need uniform calibration methods to obtain consistent results. The calibration methods of this standard will produce results readily traceable to a national standards authority such as the National Institute of Standards and Technology (NIST) in the United States.

1.3 Background

Antenna calibration is the subject of existing standards, such as ANSI C63.5-1988. Though field sensors and field probes are in a broad sense antennas, the uses of antennas, field sensors, and field probes are different.

Antennas are designed to transmit or receive with maximum coupling to the electromagnetic field, thus they perturb the electromagnetic field. Field sensors and field probes are designed to measure an electromagnetic field with minimal perturbation.

There is agreement on antenna calibration methods. Attempts to apply antenna calibration methods to field sensors and field probes have resulted in inconsistent results between calibration organizations and others. This standard is intended to provide consistent methods and results for different calibration services.

1.4 Grades of calibration

The extent to which a field probe or field sensor is calibrated and characterized depends on its intended use and the degree of detail required by the user. However, for each characteristic measured, the calibration method and specific test points measured (if applicable) and a statement of uncertainty (error) shall be provided to the user. Applicable characteristics of the calibration include, but are not limited to, the following:

- Method of calibration
- Type of calibration (time domain or frequency domain)
- Amplitude level(s) measured
- Frequencies measured
- Response time
- Time constant
- Modulation response
- Isotropy
- Uncertainty

1.5 Generic Probe Types

Field probes and sensors are grouped into one of two categories based on the location of the field measured with respect to the ground plane. This standard thus defines field probes and sensors as either being ‘ground plane’ or ‘free field.’ Detailed definitions are presented in clause 3 of this standard. Specific calibration instrumentation, procedures, and field generation methods may be different between these two groups of probes and sensors. This standard is applicable to both types of field probes and field sensors; the free field probes and sensors being placed in a field that completely surrounds them, and the ground plane field probes and sensors being mounted on the ground plane with respect to the field source.

There are two differences between time derivative (*B*-dot and *D*-dot) sensors and direct field reading (*E*-Field and *H*-Field) sensors. Traditionally, the first difference is that *E*-field sensors are the Thevenin equivalent circuit for an electrically small electric dipole, while the *D*-dot sensor is the Norton equivalent circuit. Similarly, the *H*-Field sensor is the Norton equivalent circuit for an electrically small electric dipole, while the *B*-dot sensor is the Thevenin equivalent circuit. The second difference is that the constitutive parameters ε and μ

Table 1—Generic EM field probes and sensors

Free field	Ground plane field
E-Field (dipole)	*E*-Field (monopole)
H-Field (loop)	*H*-Field (half-loop)
D-dot	*D*-dot
B-dot	*B*-dot

relating the electric and magnetic field quantities are, in general, not linear, time invariant, or isotropic; if they were, then Maxwell's equations would contain only two parameters instead of four. These constitutive parameters are tensor quantities that can change with time and field strength, and do indeed exhibit these non-constant properties in certain situations in which the sensors have been used (for example, in nuclear source regions). A more detailed explanation is contained in [B9][2].

This standard also applies to field probes that indicate power density; it is realized that the response of these field probes is based on the strength of an *E*-Field or *H*-Field and that far-field conditions are assumed.

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CAUTION

Depending upon the field strengths, frequency ranges, and other factors, the field intensities required to calibrate *E*-field and *H*-field probes may be hazardous. The user of this standard is advised to observe all appropriate safety measures for nonionizing radiation. See IEEE Std C95.1-1991, IEEE Std C95.3-1991, and the references cited in these documents, as well as other appropriate documents.

2. References

This standard shall be used in conjunction with the following publications.

ANSI C63.5-1988, Electromagnetic Compatibility—Radiated Emission Measurements in Electromagnetic Interference (EMI) Control—Calibration of Antennas.[3]

ANSI C63.14-1992, Dictionary for Technologies of Electromagnetic Compatibility (EMC), Electromagnetic Pulse (EMP), and Electrostatics Discharge (ESD).

ANSI Z540-1-1994, Calibration—Calibration Laboratories and Measuring and Test Equipment—General Requirements.

IEEE Std 100-1992, The New IEEE Standard Dictionary of Electrical and Electronics Terms (ANSI).[4]

IEEE Std 291-1991, IEEE Standard Methods for Measuring Electromagnetic Field Strength of Sinusoidal Continuous Waves, 30 Hz to 30 GHz (ANSI).

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[2]The numbers in brackets preceded by the letter B correspond to those of the bibliography in annex J.

[3]ANSI publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

[4]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.