TECHNICAL REPORT

ISO/TR 10305-1

First edition
2003-02-15

Road vehicles — Calibration of electromagnetic field strength measuring devices —

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

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

Partie 1: Appareils pour le mesurage des champs électromagnétiques de fréquence supérieure à 0 Hz

Reference number
ISO/TR 10305-1:2003(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.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 10305-1 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 3, *Electrical and electronic equipment*.

This first edition of ISO/TR 10305-1, together with that of ISO/TR 10305-2, 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, unchanged, 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 1:
Devices for measurement of electromagnetic fields at frequencies > 0 Hz

1 Scope

This part of ISO/TR 10305 specifies techniques for calibrating field strength measuring devices used in automotive testing for the measurement of electromagnetic fields at frequencies greater than 0 Hz, for both EMC and human protection applications. It has been prepared by German experts using devices including capacitor or coil arrangements, TEM cells and antenna arrangements in absorber-lined chambers. In the automotive field, these field strength measuring devices are used for measurements specified in the various parts of ISO 11451 and ISO 11452.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1
field strength measuring device
complete system, consisting of a field probe, data transmission system and display or control device

2.2
field probe
entire transducer unit (i.e. with antennas, detectors, filters, etc.), which converts the field strength into an electrical or optical signal

2.3
field sensor
part of the field probe that receives the field and transfers it for further evaluation

2.4
anisotropy
dependence of the indicated value of a field strength measuring device on the direction of incidence and the polarization of the field, the anisotropy factor being the ratio between the maximum and minimum values of the indicated field strength

2.5
linearity
measure of deviation from a first order polynomial of two variables such as the indication of a field strength measuring device and the field quantity being measured

2.6
calibration field
linearly polarized electrical or magnetic field with a known field strength, or travelling wave field with known energy flow per unit area, having a sufficiently homogeneous volume for the exposition of the field strength measuring device

NOTE The following vectorial field quantities are used:

— electric field strength, E, in volts per metre;

— magnetic field strength, H, in amperes per metre;

— magnetic flux density, B, in tesla;

— power flux density, S, or energy flow per unit area in watts per square metre.

2.7
reference system
orthogonal system of coordinates with one of its axes oriented along the field vector of interest for the particular calibration test

2.8
preferred axis
axis of a field probe determined either by the axis of symmetry (main axis) of the sensor or by the direction of the feed line

NOTE If its position is not obvious, it is determined, marked and documented by the calibration laboratory.

3 Layout and properties of field strength measuring devices

3.1 Layout and functional principles

The field strength measuring devices used for checking measured values against limits for the purpose of EMC or the protection of humans comprise the following:

— field sensor, for example, electrically short dipole (loaded or unloaded), loop antenna, horn antenna, capacitor arrangement;

— transducer for converting the field quantity into a current or voltage, for example, diode, thermocouple, bolometer or opto-modulator;

— data transmission line, for example, resistive cable, fibre optic cable, co-axial cable, wave guide;

— display unit.

Field sensor and transducer are usually combined in the field probe. Some field strength measuring systems allow the field sensor to be either connected to the data transmission line or directly to the display unit. Some designs incorporate both field sensor and display unit in one compact set-up.

The characteristics of field strength measuring devices for protection of humans and for EMC applications are usually broadband and not selective, for example, field strength measuring devices in the telecommunications field. Depending on the field quantities E, H, B or S, different field sensor/transducer combinations are applied.

See Figure 1.

3.2 Properties

3.2.1 General

The influence of all components of the field strength measuring device on the measurement result shall be known and shall be described in the technical documentation, to allow the conditions for calibration to be determined.

3.2.2 Field probes with diode-detectors

This type of field probe uses electrically short dipoles (< λ/4 of the highest measurable frequency) or small coils, dimensioned and frequency-corrected according to the measuring bandwidth, to which the diodes are connected directly or via frequency correction elements. The diode output is filtered, amplified and displayed as field strength value.

Advantages:

- high sensitivity (best suitable for low field strengths);
- high overload capacity;
- simple technology in probe manufacturing;
- short response time;
- good zero stability.

Disadvantages:

- linearity problems (i.e. small signals result in a voltage proportional to the square of the field strength while large signals are directly proportional to the field strength);

- simultaneous signals or pulsed fields may cause incorrect measuring results;
- results are not necessarily r.m.s. values for distinct types of signals;
- sensitive to light and infrared radiation (photo effect), and temperature changes (diffusion potential), which may result in zero-shifts and changes of sensitivity.

3.2.3 Field probes with thermocouple detectors

These field probes contain thin-film thermocouples which function as field sensors (i.e. electrically short dipoles) and also as absorbers for the RF energy. The DC-current supplied by the thermocouples is proportional to the squared field strength. In the ultra-high frequency range, the power flux density is also measured with ultra-high frequency power meters in combination with horn antennas, the coaxial power meter heads also being based on the thermocouple principle (disc-shaped 50 Ω terminating resistor with vapour deposited temperature detectors).

Advantages:

- large bandwidth;
- measuring signal is proportional to the square of the electric field strength and thus suited for direct measurement of the power flux density in the far field;
- true r.m.s. measurement for random signal types, especially when simultaneous signals or pulsed fields are present;
- relatively immune to ambient temperature changes, as the second connection of the thermocouple is located outside the field and acts as a reference compensating any changes of the ambient temperature.

Disadvantage: very low overload capacity, peak values of pulsed signals need to be carefully monitored.

3.2.4 Field probes with bolometer-detectors

The measurement principle is based on a bolometer element, usually a thermistor, heated by an RF current, its resistance change being evaluated in a bridge. Field probes of this type are exclusively used for power flux density measurements. The thermistor is located in either a wave guide or a coaxial thermistor head connected to, for example, a horn antenna as a field sensor.

Advantage: high overload capacity, since the resulting change of the resistance of the thermistor leads to a mismatch of the measuring head and thus to a limitation of the absorbed power.

Disadvantage: sensitive to changes of the ambient temperature, which may cause a zero-shift of the bridge unless a complicated balancing circuit with an additional thermistor is used.

3.3 Response characteristics

3.3.1 Field probes with isotropic response characteristics

The orthogonal arrangement of three field-sensor/detector-combinations results ideally in a field probe with isotropic response characteristics.

This simplifies the use of the probe, as it does not require adjustment in the field. A disadvantage is that the test engineer may not notice a failure of one or even two sensor elements.

3.3.2 Field probes with directional characteristics

Field probes with only one field-sensor/detector combination require an orientation of the sensor which leads to a maximum reading at the measuring device. Advantageous, however, is the clear recognition of polarization and direction of incidence of the field. This equally applies to combinations of a power meter with power measuring head and a matched horn antenna (in the case of circular polarization, additional correction is necessary) used for power flux density measurements in the far field.

4 General requirements for calibration procedures

Calibrations made in accordance with this part of ISO/TR 10305 shall result in correct field strength measuring results which may be used if requested for documentation in a quality assurance system. For this procedure, only those calibration procedures may be applied where the set field strength can be unambiguously traced back in a suitable way to the national standards. This may be achieved by two different methods: the generation of a calculable field (standard field or standard antenna method) of traceably measured values, or by setting the field strength via a traceably calibrated transfer sensor.

The total uncertainty of the calibration results from the uncertainty of the established field and the contribution of the device under test (DUT). In Clause 5, only the uncertainty of the established field is described.

Since the measurement values indicated on usual field strength measuring devices may be influenced by the chosen set-up and by handling details, the calibration procedure shall simulate the expected applications as closely as possible and shall show whether the requirements for the measuring device can be fulfilled, for example, through

- exposition of sensor or complete equipment,
- determination of the frequency response with frequency step sizes small enough to allow the detection of resonances,

— determination of the anisotropy (of respective sensors) through measurements with at least three different orthogonal field polarizations, one axis being in the preferred axis of the sensor (the rotation should take place around the centre of the field sensor),

— investigation of the linearity,

— investigation of the performance during, respectively, multiple frequency reception and modulation,

— recognition of E-field sensitivity of magnetic field sensors,

— monitoring of the function by means of a 360° rotation of the sensor under the analytical angle of 54° in order to recognize a failure of any sensor element, and

— consideration of the response time.

The cost of calibration may be reduced by suitable calibration intervals and — if possible — simplified calibration procedures, for example, in the case of

— limited frequency or dynamic range,

— known specified field structure,

— special equipment (i.e. “leakage tester”), or

— re-calibration, where the requirements for the determination of anisotropy may be reduced.

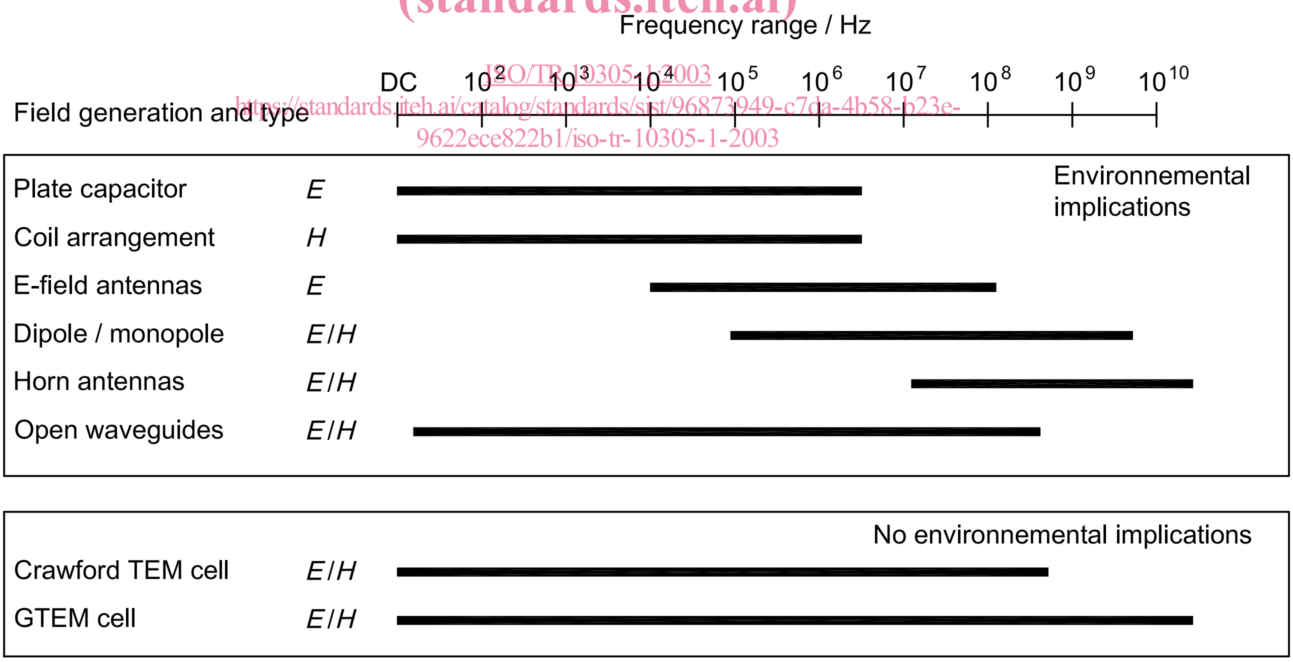


Figure 1 — Typical applications

5 Calibration procedures

5.1 Plate capacitor arrangement

5.1.1 General

For the generation of electrical field strengths for calibration purposes in the frequency range between 0 Hz and about 50 MHz, plate capacitor arrangements may be used, where the shape and distance of the plates are dictated by the requirements of the field homogeneity and the size of the field strength measuring device or field sensor under calibration. If very high field strengths are used in the low frequency range (e.g. 50 Hz), the edges of the plates shall be rounded to avoid corona discharges. The electrodes of the capacitors should be fed symmetrically to ground. A plate capacitor generates an electric field. The accompanying magnetic field may be disregarded.

5.1.2 Applicability and limits of procedure

5.1.2.1 General

Applicability and limits of the calibration procedure depend on the following factors, which are interdependent:

— the size of the capacitor plates vs. their distance;

— the existence of standing waves on the capacitor plates, if their dimensions are close to the wavelength used;

— the interaction of the DUT with the capacitor plates.

These factors determine the upper frequency limit of the procedure and useable test volume with homogeneous field distribution and influence the total uncertainty of the procedure.

5.1.2.2 Field inhomogeneities caused by stray capacitances

If the size of the electrodes of the capacitor in relation to their distance is too small, the field distribution in the capacitor is disturbed by stray capacitances, i.e. the true field strength, E_{actual}, in the region of the DUT is always below the value, E_0, calculated from the voltage at the capacitor, U_0, and the distance of the plates, d:

$$E_0 = \frac{U_0}{d} \quad (1)$$

The relation E_{actual}/E_0 vs. the plate size, a (which is the diameter of a circular plate or the length or width dimension of a rectangular plate), and the plate distance d, is given in 5.1.5.2.3. It results that for a homogeneous field distribution inside the capacitor:

$$\frac{a}{d} > 2 \quad (2)$$

is to be chosen.

5.1.2.3 Restrictions for frequency range caused by standing waves

The relation between the inhomogeneity of the field caused by standing waves on the plates and the maximum permitted plate dimensions is given in 5.1.5.2.1. It is assumed that the voltage along a capacitor plate follows a cosine function from the feeding point. If an inhomogeneity of, for example, 5 % is permitted, the maximum size, a_{max}, of a capacitor plate shall be

$$\cos 2\pi a/\lambda = 0{,}95;\ a_{\text{max}} = 0{,}05\lambda \quad (3)$$

At a frequency of 50 MHz, this leads to a_{max} = 0,3 m, i.e. only field probes with sizes below 30 mm may be calibrated.

5.1.2.4 Usable volume

The volume V_p that may be occupied by the DUT is situated in the geometrical centre between the plates, if the capacitor dimensions follow the requirements of 5.1.2.1 and 5.1.2.2.

Its maximum permitted size can be calculated from

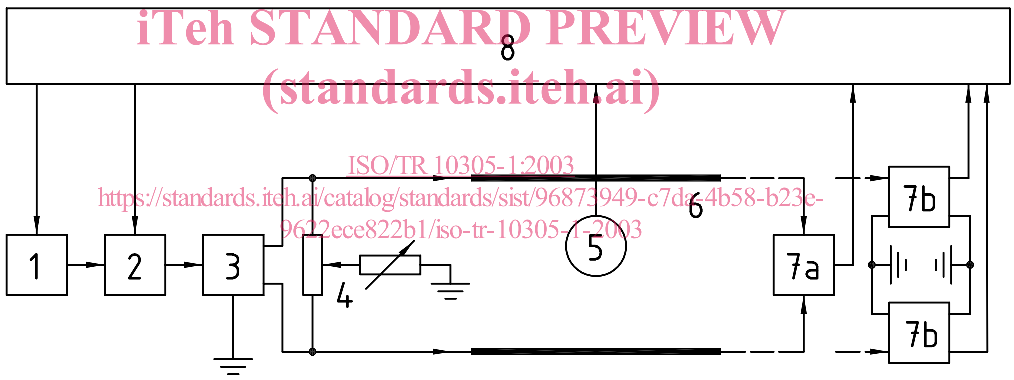
$$V_p = h^3;\ h \leqslant \frac{d}{5} \qquad (4)$$

5.1.2.5 Maximum generated field strength

The maximum field strength which may be generated with a capacitor arrangement is restricted only by the breakdown voltage of air and the material which supports the capacitor plates. It is possible to generate very high electric field strengths with low generator power.

5.1.3 Calibration set-up

Figure 2 shows the basic capacitor arrangement for the calibration of field strength measuring devices.



Key

1 signal generator

2 broadband amplifier

3 balun

4 circuit for changing potentials and impedances of the capacitor plates to ground

5 DUT

6 capacitor plate

7a symmetric voltmeter

7b voltage measurement with voltmeters with input and output symmetrical to ground

8 control unit

Figure 2 — Block diagram of the calibration configuration

The capacitor plates should be arranged vertically and in the centre of the measuring chamber to minimize environmental influences. In the vicinity of the capacitor, field disturbances caused by objects shall be avoided. If these requirements are fulfilled, the circuit (4 in Figure 2) for the change of potential and impedances is redundant. In the RF range, short cables with low inductance shall be used between balun and capacitor plates (band lead instead of a wire, input at the centre of the plate edges). If the symmetric voltage measurement according to Figure 2 is not feasible, because most RF voltmeters have asymmetric input and output terminals, the use of two voltmeters as shown additionally in Figure 2 is necessary; their measured