IEEE Standard Procedures for the Measurement of Electric and Magnetic Fields From Video Display Terminals (VDTs) From 5 Hz to 400 kHz

Sponsor

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Abstract: Procedures for the measurement of electric and magnetic fields in close proximity to video display terminals (VDTs) in the frequency range of 5 Hz to 400 kHz are provided. Existing international measurement technologies and practices are adapted to achieve a consistent and harmonious VDT measurement standard for testing in a laboratory controlled environment.
Keywords: electric field, magnetic field, video display terminal (VDT)

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Introduction

[This introduction is not part of IEEE Std 1140-1994, IEEE Standard Procedures for the Measurement of Electric and Magnetic Fields From Video Display Terminals (VDTs) From 5 Hz to 400 kHz.]

The purpose of this standard is to establish uniform procedures for the measurement of electric and magnetic fields from video display terminals (VDTs). The measurement practices in this standard follow the principles and procedures of MPR (National Board for Measurement and Testing) published in Sweden. The number of test points required, calibration levels, instrumentation and calibration procedures used, grounded and ungrounded system test methods, and calculation of measurement uncertainty are different from MPR. The measurement procedures outlined in this standard are for testing in a laboratory-controlled environment. The measurement distances indicated in this document are based on approximate human operator and VDT interaction distance. The electric field measurements attempt to approximate the field that is perturbed by human operator interaction. Due to insufficient information defining safe or unsafe electric or magnetic field levels for human operators, this document does not assume any human factors other than test distance.

This standard was revised 12 times to incorporate the comments of balloting members.

The first working draft was completed in February 1991 by an ad hoc group with the following membership:

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IEEE Standard Procedures for the Measurement of Electric and Magnetic Fields From Video Display Terminals (VDTs) From 5 Hz to 400 kHz

1. Scope

This standard provides procedures for the measurement of electric and magnetic fields in close proximity to video display terminals (VDTs) in the frequency range of 5 Hz to 400 kHz. This standard adapts existing international measurement technologies [B7][1] and practices to achieve a consistent and harmonious VDT measurement standard for testing in a laboratory controlled environment. Such measurements are needed for investigative studies that rely on the knowledge of electric and magnetic field levels near electronic equipment.

The requirements of the controlled laboratory test environment in which the characteristics specified in this standard are to be tested are difficult to establish at a user's installation. Therefore, it is recognized that the results obtained in the laboratory may be difficult to reproduce in the on-site environment.

This standard does not provide measurements at specific frequencies, but does provide one measurement for each of two frequency bands: 5 Hz to 2 kHz and 2 kHz to 400 kHz.

2. Definitions

2.1 band I: The frequency band 5 Hz to 2 kHz.

2.2 band II: The frequency band 2 kHz to 400 kHz.

[1]The numbers in brackets preceded by the letter B correspond to those of the bibliography in clause 8.

2.3 background fields: Any electric or magnetic field that does not originate from the VDT under test.

2.4 calibration: The process of determining the numerical relationship, within an overall stated uncertainty, between the observed output of a measurement system and the value, based on standard sources, of the physical quality being measured. (In terms of this standard, the physical quality being measured is electric and magnetic fields.)

2.5 center-center point: A point on a VDT screen [cathode ray tube (CRT) face panel] that is both the horizontal and vertical mid-point. The center-center point is represented by the bisector of the horizontal and vertical center lines on the VDT screen.

2.6 Class I equipment: Equipment in which protection against electric shock is achieved by: a) using basic insulation, and b) providing a means of connecting the conductive parts, which are otherwise capable of assuming hazardous voltages if the basic insulation fails, to the protective ground conductor in the building wire.

2.7 Class II equipment: Equipment in which protection against electric shock does not rely on basic insulation only, but also on the provision of additional safety precautions, such as double insulation or reinforced insulation. There is no provision for protective grounding or reliance upon installation conditions.

2.8 field measuring instrument: A device used to sense and read out the electric or magnetic field intensities surrounding a VDT under test. (For this standard, this instrumentation consists of three parts: probe; readout detector, where the signal from the probe is processed and the data displayed; and any leads between the probe and readout detector.)

2.9 measurement uncertainty: The limits of error for a measured value, between which the true value will lie with the confidence stated. (For this standard, measurement uncertainty is associated with measuring the absolute value of the electric and magnetic fields.)

2.10 tangential plane: The plane that is tangential to the surface of the VDT screen at the center-center point.

2.11 video display terminal (VDT): A device for the presentation of information by controlled excitation of a CRT screen for visual observation designed for interactive use by an operator. [For the purposes of this standard, the keyboard will not be included as part of VDT and is removed from the test area. This standard excludes liquid crystal display (LCD) terminals.]

3. General conditions

3.1 General

3.1.1 Location of VDT under test and measuring probe

The VDT under test, the measuring field sensor (probe), and the signal processor/display (readout device or detector) shall be positioned at least 1 m from all metallic structures and objects.

The VDT under test shall be connected to the mains supply with the power cord/cable supplied by the manufacturer as part of the equipment. The power cord/cable shall be positioned as follows: Horizontally for 0.1 m from the test object, and then vertically down for at least 1 m.

The power cord of the VDT under test shall be connected to the phase and neutral conductors of the mains power network. If the power plug permits an interchange of the phase and neutral conductors, measurements shall be taken with the connection that gives the highest Band I reading. If the VDT under test is designed to be grounded, then the ground connection of the power cord shall be connected to ground. If the power cord of the VDT under test has a grounded neutral, then the neutral shall be connected to the ground.

Additional units that are not part of the test—such as the central processing unit (CPU), video test pattern signal generators, and connecting cables necessary for the operation of the VDT—shall be positioned so their fields do not exceed the required ambient levels (see 3.2 and 3.3). It is acceptable to add shielding and cables to these additional units as a long as a clearance of 1 m is maintained from the closest metallic part of VDT under test or the measuring probe.

The cables between the measuring probe and the readout (detector) shall be positioned so that they do not influence the measured electric field values. The cables will not affect the magnetic field measurements.

3.1.2 Power line voltage

The power line voltage of the VDT under test shall be within 3% of its nominal value, as stated on the manufacturer's name plate. The nominal value of the power line voltage shall be specified in the test report and the actual measured value shall be recorded. If a voltage range is specified, the test shall be performed at the center of the specified range. For this latter case, the power line voltage and the range shall be recorded in the test report.

3.2 Background electric field levels

Background electric field levels in the test area, including power line transmitted disturbances and internally generated noise in the measuring system, shall not together exceed 2 V/m in Band I and 0.2 V/m in Band II.

The background electric field levels shall be measured with the VDT in place prior to beginning the VDT electric field measurements. All signal, power, and peripheral equipment cables required for operation shall be on and terminated at the VDT. The VDT power cable shall be de-energized (otherwise the power cable will radiate an electric field) when making background measurements. If grounding and shielding of peripheral equipment is required to achieve the specified ambient levels, the grounds and shields shall be tied to a common ground and a minimum clearance of 1 m from the closest metallic part of VDT under test or the measuring probe shall be maintained.

If the measuring probe is repositioned, rather than the VDT being rotated, the background electric field levels shall be measured for each location of the measuring probe. The background level for each location shall be recorded in the test report.

3.3 Background magnetic field (magnetic flux density)

The background magnetic field in the test area, including power line transmitted disturbances and internally generated noise in the measuring system, shall not together exceed 40 nT in Band I, and 5 nT in Band II.

The background magnetic field levels shall be measured with the VDT in place prior to beginning the VDT magnetic field measurements. All signal, power, and peripheral equipment and cables required for operation shall be on and terminated at the VDT. The VDT shall be turned off when making background measurements. If grounding and shielding of peripheral equipment is required to achieve specified ambient levels, the grounds and shields shall be tied to a common ground and a minimum clearance of 1 m from the closest metallic part of VDT under test or the measuring probe shall be maintained.

If the measuring probe is repositioned, rather than the VDT being rotated, the background magnetic field shall be measured for each unique location of the measuring probe. The background level for each location shall be recorded in the test report.

4. Electric field test equipment

4.1 Electric field measuring probe

In most electromagnetic compatibility (EMC) standards, the interaction of probes, cables, and equipment typically is minimized to improve the measurement accuracy of field strengths toward ideal mathematical models. However, since VDTs are common operator interface equipment, the electric field probe design outlined in this standard attempts to approximate the field that is perturbed by human operator interaction.

The alternating electric field from the VDT under test shall be determined by measuring the displacement current induced on the surface of the field meter probe. It is noted that the measured electric fields will be perturbed intentionally in a fixed way by the instrumentation. This intentional disturbance results in concentration of the electric field at the surface of the measurement probe and is meant to approximate the perturbation caused by a human operator at ground potential. Electric field strength values obtained by following procedures in this standard should not be confused with unperturbed electric field measurements reported in the technical literature [B5].

The probe consists of a disk of double-sided, copper-clad, printed circuit board laminate with a radius r of 150.0 mm. The copper layer is removed on the front side of the board in the annulus between radii r_1 and r_2, (r_1 = 50 mm and r_2 = 52 mm). The radius r_1 should be one-third of outer radius r. The width of annulus $r_1 - r_2$ = 2 mm. The copper disk inside the annulus is the active measuring surface, and is connected to one input terminal of an operational amplifier with capacitive feedback. The other input terminal of the operational amplifier is connected to the backside of the board. The copper ring outside the active surface and the backside of the board are connected together around the circumference.

From Gauss' Law:

$$\varepsilon_0 EA = Q \tag{1}$$

where

- E is the average electric field strength across the sensing surface of the electric field probe
- A is the area of the sensing surface
- ε_0 is the permittivity of free space
- Q is the charge induced on the sensing surface by the electric field

Assuming that E varies sinusoidally with angular frequency, ω (where ω is equal to 2π times the frequency f), the induced charge also varies sinusoidally, resulting in an induced current, I, given by (assuming rms values for E and I)

$$I = \frac{dQ}{dt} = \varepsilon_0 \omega EA \tag{2}$$

For VDTs, the electric field will contain harmonics, and equation 2 will have additional terms on the right side. For the simplified circuit shown in figure A2 of annex A (normative), the output voltage V_0 is

$$V_0 = \left(\frac{I}{\omega C}\right) = \frac{\varepsilon_0 EA}{C} \tag{3}$$

where

- C is the feedback loop capacitance of the operational amplifier

The probe should be supported by a mechanical device made of a nonconducting, low dielectric constant material. Descriptions of a typical probe, detector circuit, and principle of operation are given in annex A (normative).

4.2 Probe filters and signal processing

The signals from the probe shall be filtered according to the specifications in table 1.

Table 1—Filter responses

	Band I	Band II
High-pass corner frequency	5 Hz	2 kHz
High-pass characteristic	4th order Butterworth	4th order Butterworth
Low-pass corner frequency	2000 Hz	400 kHz
Low-pass characteristic	2nd order Butterworth	2nd order Butterworth
Upper stop band attenuation	40 dB minimum	40 dB minimum

NOTE—Higher-order Butterworth or Chebyshev characteristic may be substituted. The ripple from the Chebyshev filter shall be < 0.5 dB.

The signal shall be processed by a true root mean square (rms) circuit to provide an indication of the electric field strength in both frequency bands. The signal processing and filtering circuits should be designed so that transients in the electric field do not cause spurious signals that may distort the waveform produced in these circuits.

If the vertical refresh rate of the VDT under test is near the power line frequency, the measured electric field strength may vary with time because of the presence of power frequency electric fields (both from the background and the unit under test) and the associated beat phenomenon. Because of this possible time variation, the maximum value of the rms electric field strength shall be measured using a true rms voltmeter. If the maximum field value varies by > ±5% with time because of limited measuring time, the measurement shall be repeated until the average of the maximum values of five measurements is stable, within ±5%. This average value shall be recorded.

4.3 Calibration

The probe, at ground potential [see figure A3, annex A (normative)], shall be calibrated using a parallel plate arrangement with the probe serving as one of the two plates. The active measurement surface of the probe (first of the two plates in the two parallel-plate system) shall be placed at a distance of 30 mm from the second (energized) parallel plate, which has a minimum diameter of 300 mm. The insulating handle that supports the probe in the electric field during measurement should be connected to the probe during these calibrations. During the calibrations, there shall be no ground planes (metallic structure or objects) within 1 m of the parallel plates.

The calibration field, E_c, is given by the equation

$$E_c = V/d$$

where

V is the sinusoidal voltage applied to the parallel plates

d is the parallel plate spacing (30 mm)

For example, to obtain a calibration electric field of 250 V/m, V should be 7.5 V. The total uncertainty (square root of sum of the squares) in the value of E_c due to uncertainties in the values of V and d shall be < ±5%.

The calibration shall be performed at 12 points in Band I and 8 points in Band II, with sinusoidal voltages applied to the parallel plate capacitor at the levels and frequencies specified below:

Band I: 50 V/m, 250 V/m, and 1 kV/m at frequencies of 50 Hz, 100 Hz, 500 Hz, and 1 kHz.
Band II: 10 V/m and 100 V/m at frequencies of 15 kHz, 30 kHz, 60 kHz and, 120 kHz.

Recorded values shall be within ±5% of the calculated E_c. The room temperature at the time of calibration should be recorded and subsequent measurements of the electric field should be at approximately the same temperature (i.e., within ±3 °C). Battery-operated electric field meters should be checked for adequate battery voltage levels during calibration and subsequent use.

5. Electric field strength measurement procedure

5.1 VDT test setup

The VDT shall be positioned so that the horizontal plane is at a right angle to the tangential plane as shown in figure 1. The distance along the normal to the tangential plane through the center-center point between the screen surface and the back side of the VDT is L. The origin of the cylindrical coordinate system is chosen to be situated at a distance $L/2$ behind the screen surface on the normal to the tangential plane through the center-center point.

The z-axis shall be at a right angle to the horizontal plane. The angular reference direction is along the above mentioned normal in the direction pointing outwards from the screen. Angle θ is positive in the counterclockwise direction, as shown in figure 2.

5.2 Measurement procedure

The true rms value of the maximum electric field strength shall be measured in front of the test object for Band I and at 4 azimuths for Band II. During these measurements, the sensing surface of the probe shall be perpendicular to the radius of the measurement circle, R, as shown in figure 2.

Measurements shall be taken at all points having a minimum clearance of 0.3 m from the outer surface of the VDT, and with coordinates in a cylindrical coordinate system, according to

z = 0

R = $(L/2) + 0.5$ m

θ = 0° for Band I; 0°, 90°, 180°, 270° for Band II

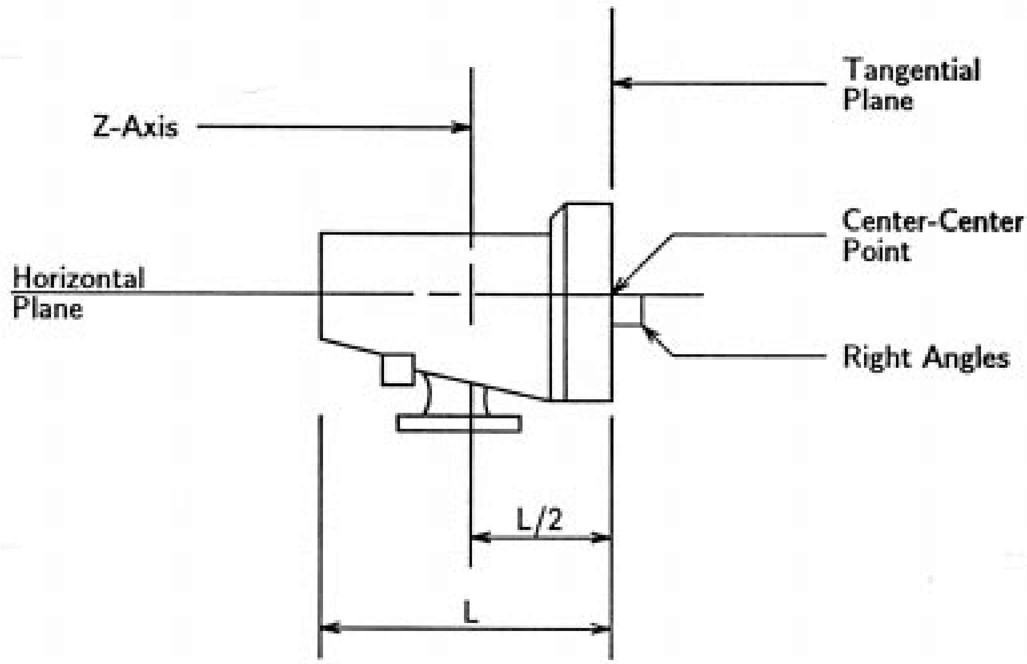


Figure 1—VDT test setup (side view)

Physically wider or larger VDTs, when rotated about the z-axis, can come very close to the measurement probe, producing a distorted result. Therefore, it is required that measurements be taken at the specified points only if the 0.3 m clearance is maintained.

All measurements shall be presented as true rms values of the electric field strength in V/m for Band I and Band II frequency ranges.

For all measurement setups, the measuring probe shall be connected to the common reference ground. When measuring Class I VDTs, the VDT ground wire shall be connected to the same common reference ground. Class II VDTs do not have a ground wire. The VDT shall display a full screen pattern of scrolling uppercase "H" [B1]. The variable user adjustments, such as brightness, contrast, and picture size controls, shall be set at the middle of the range. If the VDT has a stand-by mode, in which only a blinking cursor is displayed on the screen, the measurements shall be repeated for both modes of operation at $z = 0$, and $\theta = 0$. If the measured values at this point are within ±5% between the two modes for both Band I and Band II, additional measurements at $z = 0$ and $\theta = 90°$, 180°, and 270° are not necessary.

NOTE—Care needs to be taken when measuring electric fields since position and movement of test personnel and objects affect the results.

When a test is performed with a removable screen filter as part of the equipment under test, the type, manufacturer, and dimensions of the screen filter shall be reported.

5.3 Measurement uncertainty

The uncertainty associated with each measurement of the field shall be reported. Uncertainties in the measurement of maximum electric field strength arise from two source areas, as follows:

— The test procedures and test facility
— The measurement instrument

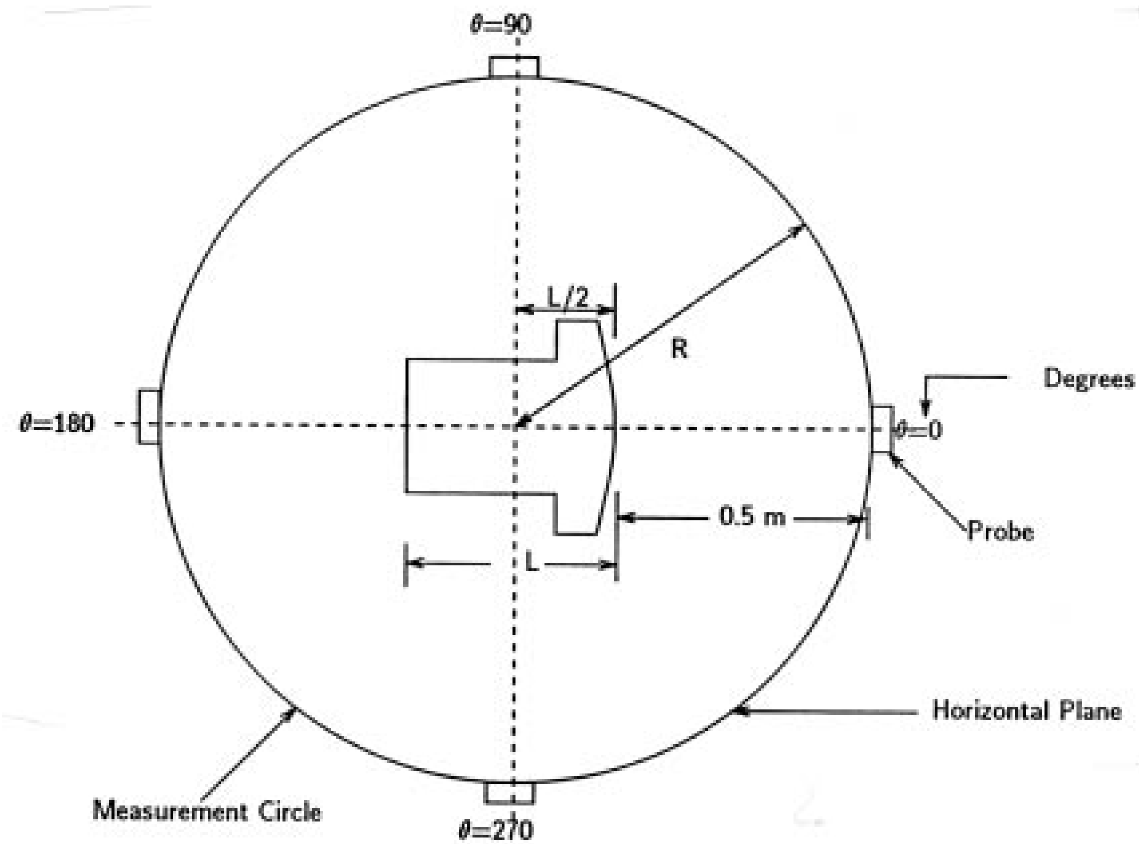


Figure 2—Position of VDT for electric field testing (top view)

Examples of uncertainties due to the electric field measurement include the following:

— Proximity effects of the observer and nearby objects
— Routing of the probe cable
— Background ac fields
— Placement of the probe in nonuniform fields

Because the spatial distribution of the electric field is unknown, the measurement uncertainty associated with placing the probe an at incorrect distance *R* from the VDT cannot be quantified. Therefore, the uncertainty in locating the probe at a distance *R* from the origin of the cylindrical coordinate system is limited arbitrarily to < ±2 cm. Proximity effects caused by the observer and nearby objects should be made negligible (i.e., <1%).

Examples of the measurement uncertainties due to the measurement instrument are uncertainties in the following:

— Calibration process
— Frequency response
— Nonlinearity
— Temperature
— Supply voltage response of the instrument

For a more formal explanation of measurement uncertainties for measurement instruments, see 3.2 of [B4].

For the purpose of this standard, all measurements shall be accompanied by information about the total measurement uncertainty (U_{Total}). U_{Total} shall be reported with its components, as follows:

— Instrument and calibration, design and use uncertainty (U_I)
— Background measurement uncertainty (U_{Back})

In addition to reporting U_I and U_{Back}, U_{Total} shall be reported as plus/minus percent (±%) uncertainty of the square root of the sum of the squares of U_I and U_{Back} in percent uncertainty, as shown in the following equation:

$$U_{Total} = [\pm\sqrt{(U_I^2 + U_{Back}^2)}]$$

U_I, U_{Back}, and U_{Total} are reported in percent (not decibels).

With the proper instrument design, calibrations, and use, U_I shall not exceed ±10%. The following equation gives U_{Back} in percent.

$$U_{Back} = \pm(F_{Back}/F_m) \cdot 100$$

where

F_{Back} is the maximum measured background field strength

F_m is the maximum measured field strength

The following example illustrates the reporting of the required information.

Suppose the *E* field background level is 2 V/m and the measured field is 10 V/m.

Then U_{Back} is 20%.

U_{Back} is reported with U_I (e.g., ±10%) and the measurement data.

U_{Total} also is reported as $22.4\%[\pm\sqrt{(20^2 + 10^2)\%}]$.

The information concerning the measurement uncertainties permits appropriate interpretation of the resulting data. It should be noted that this procedure does not place specific limits on total uncertainty. For example, as the measured fields approach the background field levels, the total uncertainty becomes large. Instead, the procedure seeks to make the documentation of the uncertainties consistent, and thereby clarify the interpretation of the results.

6. Magnetic field test equipment

6.1 Magnetic field measuring probe

The measurement probe shall consist of three mutually perpendicular concentric circular coils, each with an area of 0.01 m^2. The coils may depart from circular shape where they cross. The minimum inner diameter shall be 110 mm and the maximum outer diameter shall be 116 mm. The measuring coils shall not be sensitive to electric fields.

The resonant frequency of each coil appropriately connected to cables and amplifiers shall be >12 kHz for Band I and > 2.5 MHz for Band II (see 4.2). The resonances shall be suppressed by resistive loading of each coil. Each coil shall be followed by integrating networks and amplifiers to make the output voltage proportional to the magnetic flux density and independent of frequency. The requirement for the frequency response is given by the calibration procedure.

NOTE—The three-mutually-perpendicular-loop probe was chosen as the standard probe over a single-loop probe for the following reasons:

a) Ease of measurement.
b) Minimization of errors due to probe placement.
c) A single circular loop with an area of $0.01 m^2$ may be used to make these measurements. However, the user is to then assure that the placement of single-loop probe on each axis does not introduce significant error.

6.2 Probe filters and signal processing

The signals from the coil systems shall be filtered by high-pass and low-pass filters. The specifications of the filters are given in table 1.

The signals from the three coils in each coil set shall be used as input for calculations of the rms value of the magnetic flux density vector magnitude in both frequency bands. It is permissible to calculate the rms value for each of the coil signals separately and use the root of the sum of the squares of those rms values as the test result.

If the vertical refresh rate of VDT under test is near the power line frequency, the magnetic flux density that is measured may vary with time because of the presence of power frequency magnetic fields (both from the background and the unit under test) and the associated beat phenomenon. Because of this possibility of time variation, the maximum value of the rms magnetic flux density shall be measured with a true rms voltmeter. If the maximum field value varies by > ±5% with time because of limited measuring time, the measurement shall be repeated until the average of the maximum values of five measurements is stable within ±5%. This average value shall be recorded.

6.3 Calibration

Calibrations of ac magnetic field meters are normally performed by placing the magnetic field probe into a known field generated by a coil system. This procedure cannot be applied in most laboratories for magnetic field meters used for measuring Band I magnetic fields from VDTs because background power frequency magnetic fields (of order 100 nT) can significantly perturb the calibration field. An alternative approach for calibrating the sensitive scales of the magnetic field meter is through the use of a voltage injection technique [B2]. Using this procedure, the volts/tesla produced by each coil probe (when connected to the detector circuit) should be determined at each frequency of interest using a magnetic field at least two orders of magnitude larger than the background field. The magnetic field should be produced with Helmholtz coils having a radius of at least 20 cm. Voltages corresponding to smaller magnetic fields are then injected into the detector circuit to calibrate the more sensitive scales of the magnetic field meter in Band I. A voltage divider with a well-known ratio, an ac voltage source (e.g., a function generator), an accurate voltmeter, and adequate electric shielding may be used to inject the known voltages at the frequencies specified in this standard. In order to carry out the calibration, the frequency dependence of the voltage divider ratio also should be known.

If the background magnetic fields with frequencies in Band II are negligible compared with the fields used for calibrations, a Helmholtz coil may be used directly to calibrate the field meter. In this case, the resonance frequency of the Helmholtz coil should be known, and the calibration frequencies should be removed sufficiently from the resonance frequency to avoid significant perturbation of the field during calibrations. Otherwise, the voltage injection technique may be extended to frequencies in Band II.

The total uncertainty (square root of the sum of the squares) in determining the magnetic field produced by the Helmholtz coil (due to uncertainties in current measurement and coil dimensions) or equivalent voltage using the voltage injection technique (due to uncertainties in voltage measurement and divider ratio value) should be < ±5%. Calibrations shall be performed at 12 points in Band I and at 8 points in Band II, with sinusoidal fields at the levels and frequencies specified below.

Band I: 40 nT, 250 nT, and 20 000 nT at frequencies of 50 Hz, 100 Hz, 500 Hz, and 1 kHz.
Band II: 25 nT and 250 nT at frequencies of 15 kHz, 30 kHz, 60 kHz, and 120 kHz.

When using the voltage injection technique, recorded values shall be within ±5% of the calculated calibration field of the Helmholtz coil or equivalent field. The room temperature at the time of calibration should be recorded and subsequent measurements of the magnetic field should be at approximately the same temperature (i.e., within ±3 °C). Battery operated magnetic field meters should be checked for adequate battery voltage levels during calibration and subsequent use.

When calibrations are performed with a coil system, the calibration shall be performed in the three individual planes of the measuring coils—and for one orientation where approximately the same flux passes through all three coils.

7. Magnetic flux density measurement procedure

7.1 VDT test setup

The VDT shall be positioned so that the horizontal plane is at a right angle to the tangential plane, as shown in figure 1. The right angle distance along the normal to the tangential plane through the center-center point between the screen surface and the back side of the VDT is L. The origin of the cylindrical coordinate system is chosen to be situated at a distance $L/2$ behind the screen surface on the normal to the tangential plane through the center-center point, as shown in figure 3.

The z-axis shall be at a right angle to the horizontal plane. The angular reference direction is along the above mentioned normal in the direction pointing outwards from the screen. Angle θ is positive in the counterclockwise direction, as shown in figure 3.

7.2 Measurement procedure

The true rms value of the maximum flux density shall be measured at 10 points on a cylindrical surface around the test object for both Band I and Band II. The frequency ranges are selected by special filters in the measuring equipment.

The measuring geometry is illustrated in figures 3 and 4 and the measuring points are defined mathematically below.

Measurements shall be taken at all points having a minimum clearance of 0.3 m to the outer surface from the VDT, and with coordinates in a cylindrical coordinate system, according to

$z = 0$
$R = L/2 + 0.5$ m
$\theta = p \cdot 45°$, where p represents all integers in the range $0 \le p \le 7$

and

$z = -0.3$ m and $z = +0.3$ m
$R = L/2 + 0.5$ m
$\theta = 0°$ only

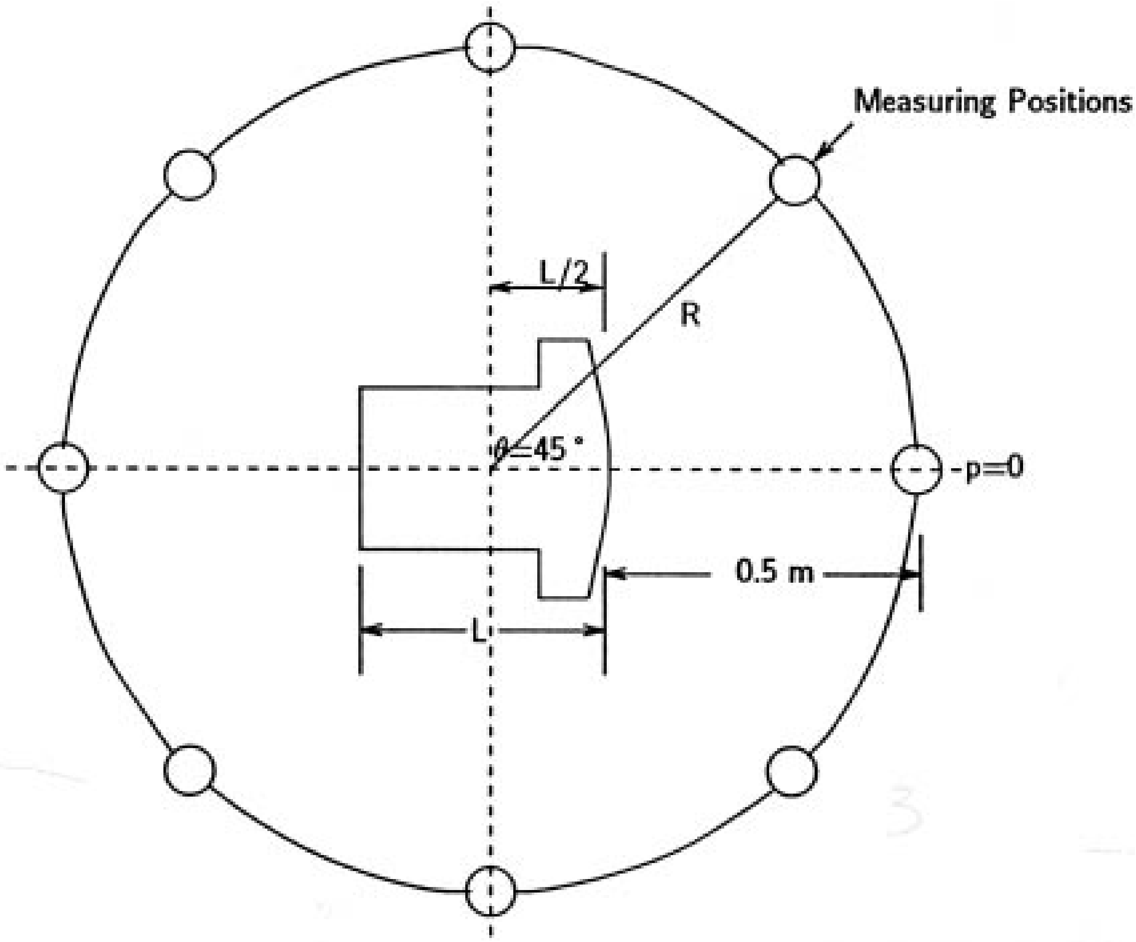


Figure 3—Position of VDT for magnetic field testing (top view)

Typically, emission levels in front of VDTs are highest at the $z = 0$ and $\theta = 0°$ position. If it is found that the above is not true in any test, the following additional tests shall be performed.

z = –0.3 m and z = +0.3 m

R = $L/2$ + 0.5 m

θ = $p \cdot 45°$, where p represents all integers in the range $0 \leq p \leq 7$

If the VDT has a standby mode, in which only a blinking cursor is displayed on the screen, the measurements shall be repeated for both modes of operation at $z = 0$, and $\theta = 0$. If the measured value at this point is within ±5% between the two modes for both Band I and Band II, measurements at other points are not necessary.

Measurements shall be taken at all points having a minimum clearance distance of 0.3 m from the measuring probe to the closest point of the VDT under test. Physically wider or larger VDTs, when rotated about the z-axis, can come very close to the measurement probe, producing distorted results. Therefore, it is required that a measurement be taken at the specified points only if this 0.3 m clearance is maintained.

The measuring coils shall be stationary during the measurements.

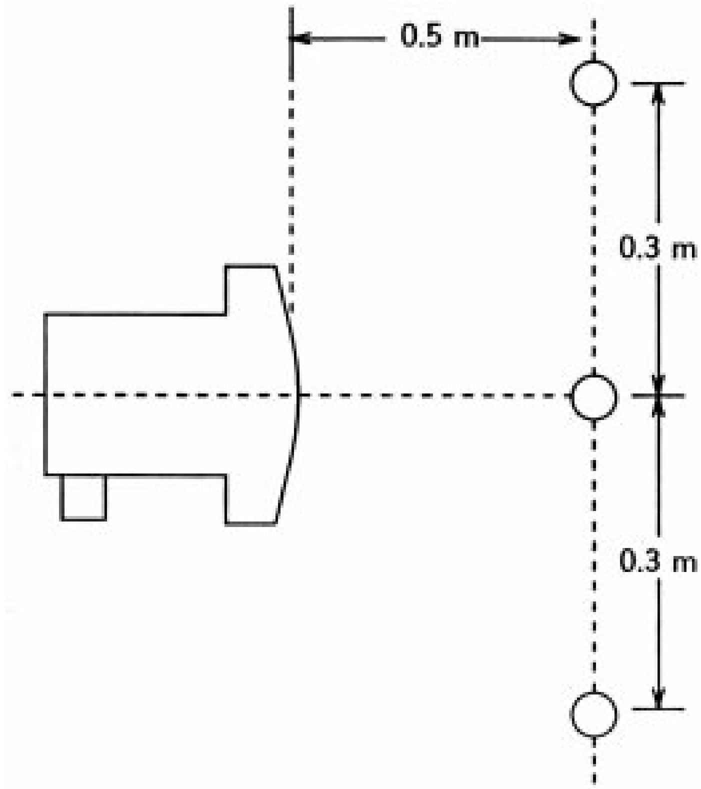


Figure 4—Position of VDT for magnetic field testing (side view)

The VDT shall display a full screen of scrolling uppercase “H” [B1]. The variable user adjustments, such as brightness, contrast, and picture size controls, shall be set to middle of the range.

If the VDT has a standby mode, in which only a blinking cursor is displayed on the screen, the measurements shall be repeated for both modes of operation at $z = 0$, $\theta = 0$. If the measured values at this point differ by > ±5% between the two modes, all points shall be measured in both modes.

7.3 Measurement uncertainty

The uncertainty associated with each measurement of the field shall be reported. Uncertainties in the measurement of the maximum magnetic flux density arise from two source areas, as follows:

— The test procedures and test facility
— The measurement instrument

Examples of measurement uncertainties due to the test procedures and test facility include the following:

— Background ac fields
— Placement of the probe in nonuniform fields
— Variation of the field reading due to the beat phenomena (see 6.2)
— Proximity effects of nearby ferromagnetic objects

It should be noted that the uncertainty can exceed 100% when the field produced by the unit under test approaches the background field value. Because the spatial distribution of the magnetic field is unknown, the measurement uncertainty associated with placing the probe at an incorrect distance *R* away from the VDT cannot be quantified. Therefore, the uncertainty in locating the probe at a distance *R* from the origin of the cylindrical coordinate system is limited arbitrarily to < ±2 cm.

Examples of the measurement uncertainties due to the measurement instrument are uncertainties in the following:

— Calibration process
— Frequency response
— Nonlinearity
— Electric field pickup (i.e., inadequate electric field shielding)
— Supply voltage response of the instrument

For a more formal explanation of measurement uncertainties for measurement instruments, see 3.2 of [B4].

For the purpose of this standard, all measurements shall be accompanied by information on the total measurement uncertainty (U_{Total}). U_{Total} shall be reported with the following components:

— Instrument and calibration, design and use uncertainty (U_I)
— Background measurement uncertainty (U_{Back})

In addition to reporting U_I and U_{Back}, U_{Total} shall be reported as plus/minus percent (±%) uncertainty of the square root of the sum of the squares of U_I and U_{Back} in percent uncertainty, as shown in the following equation.

$$U_{Total} = [\pm\sqrt{(U_I^2 + U_{Back}^2)}]$$

U_I, U_{Back}, and U_{Total} are reported in percent (not in decibels).

With the proper instrument design, calibrations, and use, U_I shall not exceed ±10%. The following equation gives U_{Back} in percent.

$$U_{Back} = (\pm F_{Back}/F_m) \cdot 100$$

where

F_{Back} is the maximum measured background flux density

F_m is the maximum measured flux density

The following example illustrates the reporting of the required information.

Suppose the *B* field background level is 20 nT and the measured field is 100 nT.

Then U_{Back} is 20%.

U_{Back} is reported with U_I (e.g. ±10%) and the measurement data.

U_{Total} also is reported as $22.4\%[\pm\sqrt{(20^2 + 10^2)\%}]$.

The information concerning the measurement uncertainties permits appropriate interpretation of the resulting data. It should be noted that this procedure does not place specific limits on the uncertainty. For example, as the measurement fields approach the background field levels the total uncertainty becomes large. Instead, it seeks to make the documentation of the uncertainties consistent, thereby clarifying the interpretation of results.

8. Bibliography

[B1] ANSI C63.4-1992, American National Standard Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronics Equipment in the Range of 9 kHz to 40 GHz.[2]

[B2] Fulcomer, P. M., "NBS ambient magnetic field meter for measurement and analysis of low-level power frequency magnetic fields in air," *NBS Report*, NBSIR 86–3330, 1985.

[B3] IEEE C95.1-1991, IEEE Standard Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz (ANSI).[3]

[B4] IEEE C95.3-1991, IEEE Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields—RF and Microwave (ANSI).

[B5] Jokela, K., Aalton, J., and Lukkarian, "Measurement of electromagnetic emissions from video display terminals at the frequency range from 30 Hz to 1 MHz," *Health Physics*, vol. 57, pp. 79–88, 1989.

[B6] Kanda, M. and Hill, D. A., "A three-loop method for determining the radiation characteristics of an electrically small source," *IEEE Transactions on Electromagnetic Compatibility*, vol. 34, no. 1, Feb. 1992.

[B7] MPR (Mat och Provstyrelse), Swedish National Metrology and Testing Council 1990:10, Test Methods for Visual Display Units.

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

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

Annex A

(normative)

Electric field measuring probe—principle of operation

The pickup probe recommended in this standard is based on capacitive coupling. Figure A1 shows a simplified setup. The voltage source is tied to plate A and ground; plate B is connected to ground. Initially, assume that there is no charge on either plate, and therefore no electric field between them. For the potential of plate A to rise, the voltage source must inject charge onto plate A, thereby creating an electric field. An equal amount of opposite polarity charge must flow onto plate B if its potential is to remain at ground. This is the origin of the displacement current. A conductor requires charge movement (current) in order to maintain a fixed potential in a changing electric field. Conversely, if plate B is disconnected from ground, its potential will rise and fall in sympathy with the changes at plate A.

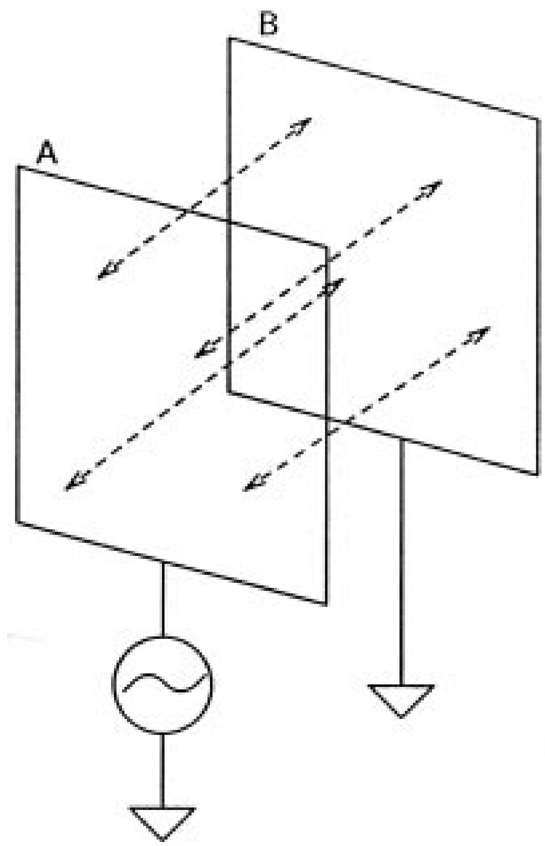
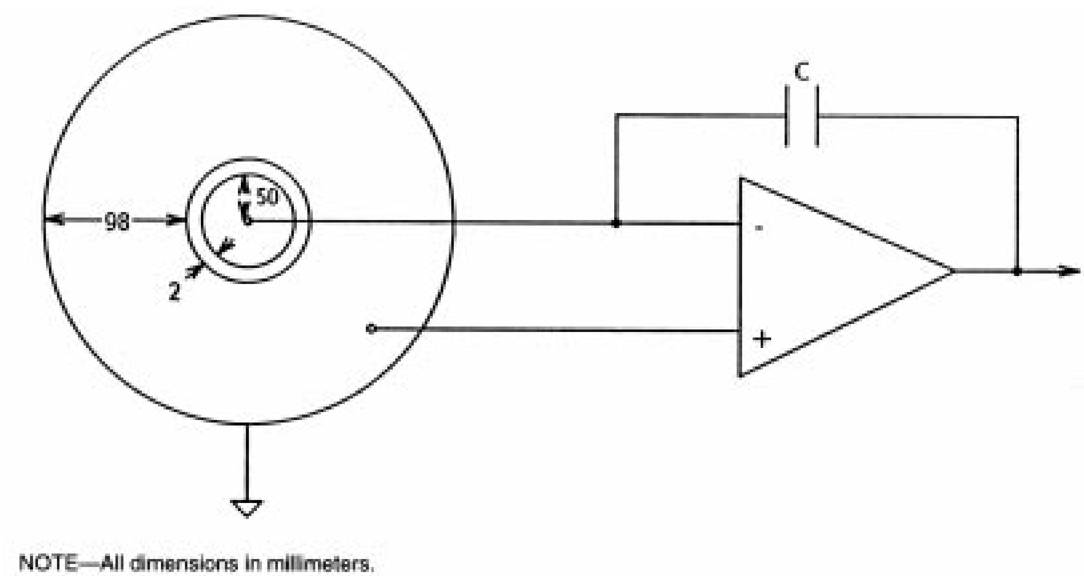


Figure A1—Simplified setup

The pickup probe is shown schematically in figure A2. Its design relies on the concepts discussed above, which can be realized in practice, as follows:

a) The outer copper ring of the probe is tied to ground—its potential will not vary, and it will provide a reference voltage to the non-inverting input of the amplifier.
b) The central disk, connected to the inverting input of the amplifier, is isolated electrically from the outer copper ring.
c) The output of the amplifier is connected to the inverting input through a feedback capacitor.

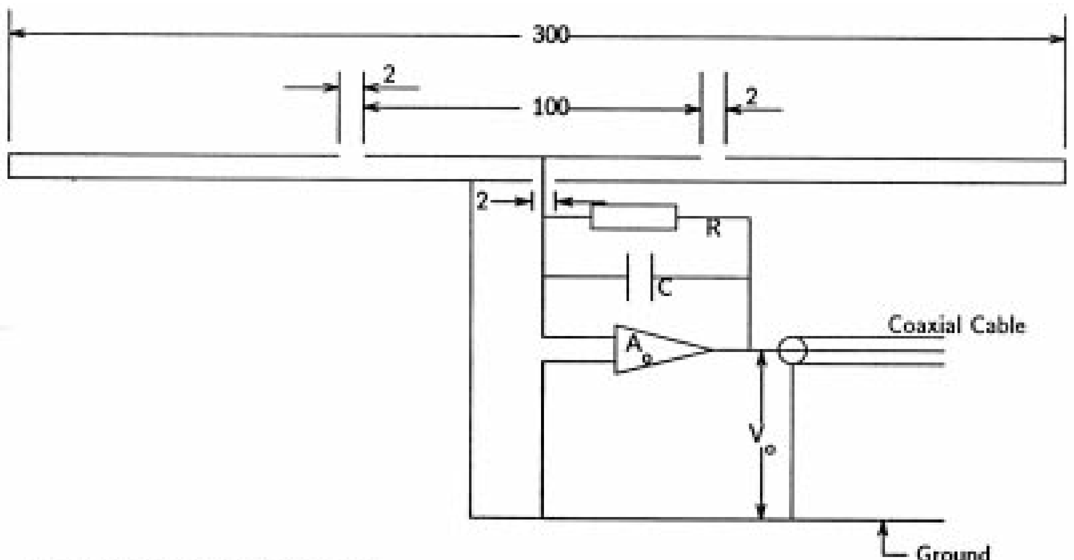
In this fashion, the amplifier will attempt to keep its two inputs at the same voltage by changing its output and transferring charge from its output through the feedback capacitor onto the disk. The amount of charge required is proportional to the electric field impinging on the disk. Thus, the output voltage of the amplifier is proportional to the electric field at the disk.



NOTE—All dimensions in millimeters.

Figure A2—Schematic of simplified probe

Details of the simplified probe and detector circuit are shown in the figure A3. The probe consists of a disk of double-sided, printed circuit board laminate with a diameter of 300 mm. The copper layer is removed on the front side of the board in the annulus between radii 50 mm and 52 mm. The copper disk (diameter 100 mm) inside the annulus is the active measuring surface and is connected to one input terminal of an operational amplifier with capacitive feedback. The other input terminal of the operational amplifier is connected to both the copper ring outside the active disk and to the backside of the board. These two surfaces are connected to ground.



NOTE—All dimensions in millimeters.

Figure A3—Simplified electric field meter probe and detector circuit

Annex B

(normative)

VDT characterization—typical data recording format

Manufacturer: ______________________________

Model: ______________________________

Serial number: ______________________________

Nominal line voltage/voltage range: ______________________________

Measured line voltage: ______________________________

Test mode: background / scrolling H's / standby mode

Brightness and contrast position: ______________________________

Software: ______________________________

Tested by: ______________________________

Test date: ______________________________

Magnetic flux density (nT)

Angle	*z* = –0.3 m		*z* = 0		*z* = 0.3 m	
	Band	Band	Band	Band	Band	Band
θ	I	II	I	II	I	II
0						
45						
90						
135						
180						
225						
270						
315						

Electric Field Levels (V/m)

Angle	Band	
θ	I	II
0		
90	not applicable	
180	not applicable	
270	not applicable	

Annex C

(normative)

Measurement uncertainty—typical data recording format

Manufacturer: ____________________

Model: ____________________

Serial number: ____________________

Test mode: scrolling H's / standby mode

Tested by: ____________________

Test date: ____________________

Measurement uncertainty—magnetic flux density measurements

Instrument uncertainty (U_I) (%): ____________________

Angle θ	*z* = –0.3 m				*z* = 0				*z* = 0.3 m			
	Band				Band				Band			
	I		II		I		II		I		II	
	U_{Back} (%)	U_{Total} (%)	U_{Back} (%)	U_{Total} (%)	U_{Back} (%)	U_{Total} (%)	U_{Back} (%)	U_{Total} (%)	U_{Back} (%)	U_{Total} (%)	U_{Back} (%)	U_{Total} (%)
0												
45												
90												
135												
180												
225												
270												
315												

Measurement uncertainty—electric field measurements

Instrument uncertainty (U_I) (%): ____________________

Angle θ	Band			
	I		II	
	U_{Back}	U_{Total}	U_{Back}	U_{Total}
0				
90	not applicable	not applicable		
180	not applicable	not applicable		
270	not applicable	not applicable		

Annex D

(normative)

Measurement instrumentation used

Band I (B)
Make ____________________ Model ____________________ Serial no. _________________
Calibration date____________

Band II (B)
Make ____________________ Model ____________________ Serial no. _________________
Calibration date____________

Band I (E)
Make ____________________ Model ____________________ Serial no. _________________
Calibration date____________

Band II (E)
Make ____________________ Model ____________________ Serial no. _________________
Calibration date____________

Comments ____
____
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