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BSI Standards Publication

Integrated circuits — Measurement of electromagnetic immunity

Part 9: Measurement of radiated immunity — Surface scan method

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A list of organizations represented on this committee can be obtained on request to its secretary.

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Circuits intégrés – Mesure de l'immunité électromagnétique – Partie 9: Mesure de l'immunité rayonnée – Méthode de balayage en surface

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INTEGRATED CIRCUITS – MEASUREMENT OF ELECTROMAGNETIC IMMUNITY –

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FOREWORD

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Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 62132-9, which is a technical specification, has been prepared by subcommittee 47A: Integrated circuits, of IEC technical committee 47: Semiconductor devices.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
47A/924/DTS	47A/936/RVC

Full information on the voting for the approval of this technical specification can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 62132 series, published under the general title *Integrated circuits – Measurement of electromagnetic immunity*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

Techniques for generating near-fields over integrated circuits and their surrounding environment can identify the areas susceptible to radiation, which could cause errors in the device. The ability to associate magnetic or electric field strengths with a particular location on a device can provide valuable information for improvement of an IC both in terms of functionality and EMC performance.

Near-field scan techniques have considerably evolved over recent years. The improved efficiency, bandwidth and spatial resolution of the probes offer analysis of integrated circuits operating into the gigahertz range. Post-processing can considerably enhance the resolution of a near-field scan test bench and the measured data can be shown in various ways per user’s choice.

INTEGRATED CIRCUITS – MEASUREMENT OF ELECTROMAGNETIC IMMUNITY –

Part 9: Measurement of radiated immunity – Surface scan method

1 Scope

This part of IEC 62132 provides a test procedure, which defines a method for evaluating the effect of near electric, magnetic or electromagnetic field components on an integrated circuit (IC). This diagnostic procedure is intended for IC architectural analysis such as floor planning and power distribution optimization. This test procedure is applicable to testing an IC mounted on any circuit board that is accessible to the scanning probe. In some cases it is useful to scan not only the IC but also its environment. For comparison of surface scan immunity between different ICs, the standardized test board defined in IEC 62132-1 should be used.

This measurement method provides a mapping of the sensitivity (immunity) to electric- or magnetic-near-field disturbance over the IC. The resolution of the test is determined by the capability of the test probe and the precision of the Probe-positioning system. This method is intended for use up to 6 GHz. Extending the upper limit of frequency is possible with existing probe technology but is beyond the scope of this specification. The tests described in this document are carried out in the frequency domain using continuous wave (CW), amplitude modulated (AM) or pulse modulated (PM) signals.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050 (all parts), *International Electrotechnical Vocabulary* (available at <http://www.electropedia.org>)

IEC 62132-1, *Integrated circuits – Measurement of electromagnetic immunity, 150 kHz to 1 GHz – Part 1: General conditions and definitions*

IEC TS 61967-3, *Integrated circuits – Measurement of electromagnetic emissions, 150 kHz to 1 GHz – Part 3: Measurement of radiated emissions – Surface scan method*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purpose of this document, the definitions and definitions given in IEC 62132-1, IEC 60050-131 and IEC 60050-161, as well as the following apply.

3.1.1
altitude
distance between the tip of the near-field probe and the reference plane of the scan (e.g. the PCB, the upper surface of the package)

Note 1 to entry: The term “altitude” refers to the vertical direction in a Cartesian coordinate system (Z-axis) in this document.

[SOURCE: IEC 61967-3:2014, 3.1.1]

3.1.2
probe factor
ratio of electric or magnetic field strength at a specified location in near-field evaluation to the signal level measured at the output connection or applied to the input connection of a probe

[SOURCE: IEC 61967-3:2014, 3.1.2]

3.1.3
spatial resolution
aptitude of a probe to distinguish measured field between two points

[SOURCE: IEC 61967-3:2014, 3.1.3]

3.2 Abbreviations

DUT: device under test

NFS: near-field scan

PCB: printed circuit board

[SOURCE: IEC 61967-3:2014, 3.2]

4 General

The electric and magnetic fields applied by scanning over the surface of an IC yields information on the relative sensitivity of blocks within the IC package. It enables the comparisons between different architectures to facilitate improvements in RF immunity of the IC. Default criteria are defined to determine the immunity level at a specific location.

Characterizing an IC involves the acquisition of a series of measurements of applied power to the probe at specific frequencies. Each scan over a die or package collects a large amount of data depending on the number of locations scanned and the number of frequencies measured at each location. Because of the required precision and the amount of measured data, this test method uses a computer-controlled probe-positioning and test system to achieve accurate and repeatable probe data. Control software shall be prepared or adapted to control the optical, precision stepper motors typically used in such systems. This method also requires an analysis and handling of a large amount of data typically performed by dedicated software programs. The scanning time depends on the number of frequencies, the number of locations tested, and the capability of the data collection system.

Due to the wide array of IC processes, packaging technologies, and their physical dimensions, this document does not specify the designs of probe-positioning systems or near-field probes. The designs of the positioning system and the probes depend on the desired testing frequency range, spatial resolution, field type, and the performance of the available components (such as stepper motors).

The spatial resolution depends on the physical dimensions and construction of the probe. If the spatial resolution is known it shall be included in the test report.

The altitude of the probe above the IC surface is not specified. The actual probe height shall be described in the test report.

The probe position step size shall be chosen to fully utilize the spatial resolution while minimizing the number of measurement points. Step size can be smaller in particular areas of the die or package for higher resolution. With post-processing the data for higher resolution, the spatial resolution at the measurement can be reduced, which allows larger step size.

5 Test Conditions

5.1 General

Test conditions shall meet the requirements as described in IEC 62132-1. In addition, the following test conditions shall apply.

5.2 Supply voltage

A supply voltage should follow the IC manufacturer's specification. If a user uses other voltage, it shall be documented in the test report.

5.3 Frequency range

An effective frequency range of this radiated immunity measurement procedure is 150 kHz to 6 GHz. If a single probe is not able to cover the whole frequency range, the frequency range may be divided into sub-ranges to allow the use of multiple probes, each of which suits individual frequency sub-range.

6 Test equipment

6.1 General

Test equipment shall meet the requirements as described in IEC 62132-1. In addition, the following test equipment requirements shall apply.

6.2 Shielding

Double shielded or semi-rigid coaxial cables are recommended for interconnections between the probe and the measuring equipment. Depending on the RF power applied to the near-field probe, it may also be necessary to carry out the tests in a shielded room.

6.3 RF disturbance generator

An RF disturbance generator with sufficient power-handling capabilities shall be used. The RF disturbance generator consists of an RF signal source with or without a modulation function, as required, and an optional RF power amplifier. The power amplifier shall be capable of handling the type of disturbing signal used (CW, AM or PM) without creating undue distortion. The VSWR (Voltage Standing Wave Ratio) at the output of the RF disturbance generator shall be less than 1,5 over the frequency range being measured. The output power of the RF disturbance generator terminated with a 50 Ω load shall have accuracy of +/- 0,5 dB or smaller.

NOTE Near-field probes usually present very poor return loss. If the probe does not present a good impedance match, the electric or magnetic field strength generated by the probe will vary with frequency. Moreover, in order to avoid damage to the power amplifier, specific care is to be taken during power amplifier selection in regards to its stability and ability to sustain high reflected power. If necessary, an attenuator capable of sustaining the power level can be inserted between the RF disturbance generator and the probe.

6.4 Cables

The scanning motion of the probe requires the use of flexible cables between the certain elements of the setup. Care shall be taken to choose cables that are durable for the scanning motion of the probe besides maintaining their high frequency performance. The cable losses as a function of frequency should be included in the test report.

Owing to the repeated movement of the cables, which can accelerate their deterioration, calibration of the cables shall be carried out regularly. When the test frequency is higher than 1 GHz, the cables shall be calibrated before each test.

6.5 Near-field probe

6.5.1 General

The near-field probe employed for surface scanning can take various forms depending on users' preferences, the type of field to be measured, the capabilities of the RF disturbance generator, and the desired spatial resolution of the test. Probe calibration is detailed in Annex A. Calibration of the probe provides the field strength at a given distance in the axis of the probe. In practice the probe is used to inject a disturbance into a DUT which, by its presence, modifies the field strength and direction at the point of interest. It is possible to use post-processing to correct any distortion of the field [1][1]. Some probes generate a field only in a specific direction. In order to generate fields in several directions, it is necessary to change the probe or rotate it during the scan process. A brief description of the probe(s) used for the testing shall be included in the test report. In order to improve the return loss of the probe, it is good practice to place a suitable resistive load in series with the probe or to insert an attenuator close to the probe. Various types of near-field probe are discussed in 6.5.2 and 6.5.3.

6.5.2 Magnetic (H) field probe

For magnetic field tests, a single turn, miniature magnetic loop probe is often used. The typical probe is composed of wire, coaxial cable, PCB traces, or any other suitable material. An example of a magnetic field probe is shown in Annex B and in IEC 61967-6 [2].

6.5.3 Electric (E) field probe

For electric field tests, a miniature electric field probe is typically used. The typical probe is composed of wire, coaxial cable, PCB traces, or any other suitable material. An example of electric field probe is shown in Annex B.

6.6 Probe-positioning and data acquisition system

A precise probe-positioning system and data acquisition system are required. The probe-positioning system shall be able to move the probe in at least two axes (parallel to the DUT surface) and shall be capable of positioning the probe with a mechanical step at least ten times less than the minimum required step size. Although this specification describes the use of Cartesian scanning (X, Y and, optionally, Z-axis), polar and cylindrical scanning are also possible. Annex C defines the three coordinate systems and how the position information can be converted between them. When using Cartesian coordinates, the right-hand system is preferred. If the left-hand system is used, it shall be indicated in the test report. In some cases the probe-positioning system has a mechanical structure to rotate the probe for adjusting probe orientation. It may be controlled by the data acquisition system.

The x, y and z position of the near-field probe may be out of alignment after the rotation. Care should be taken to compensate the resulting offset by repositioning the probe.

An example of a probe-positioning system is shown in Figure 1. Although not shown in Figure 1, the DUT is installed on a test circuit board that is typically mounted on a test fixture to improve stability.

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1 Numbers in square brackets refer to the Bibliography.

The data acquisition system is typically a computer with software enabling the desired scan parameters, controlling the measuring instrument and the probe scanning system, and acquiring the data. The system configurations and the controlling software shall be described in the test report.

6.7 DUT monitor

The DUT shall be monitored to detect any degradation of the performance. The monitoring equipment shall not be adversely affected by the injected RF disturbance signal.

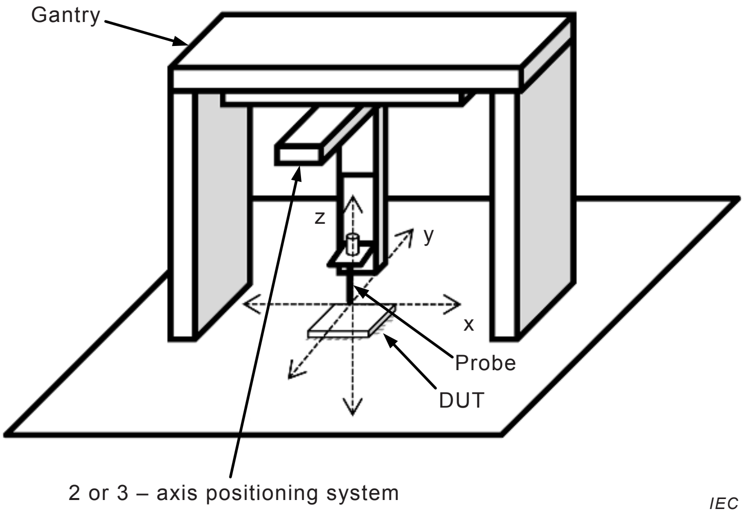

Figure 1 – Example of a probe-positioning system

7 Test setup

7.1 General

Test setup shall meet the requirements as described in IEC 62132-1. In addition, the following test setup requirements shall apply.

7.2 Test configuration

The general test setup is shown in Figure 2.

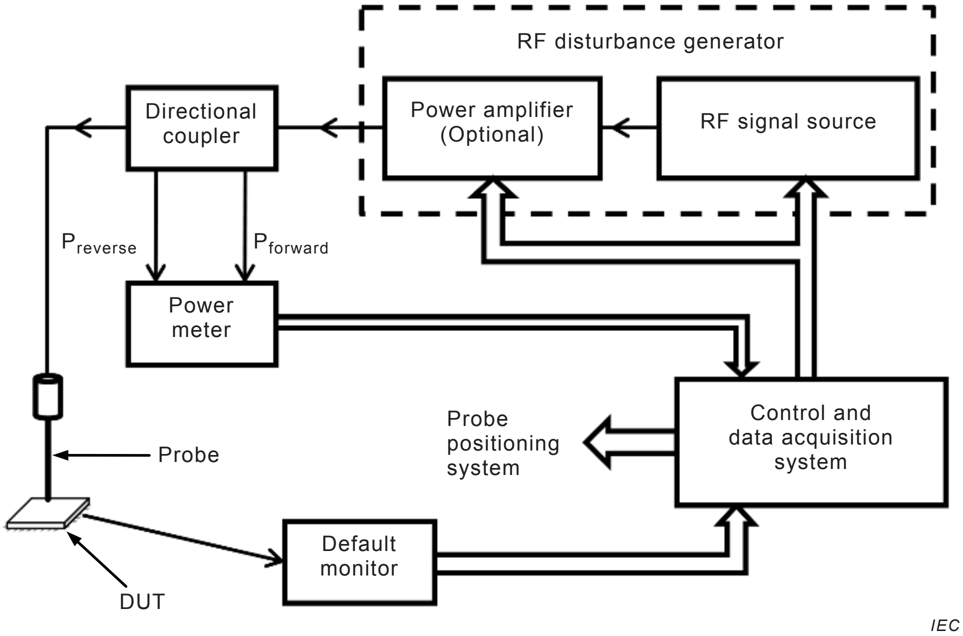

Figure 2 – Test setup

7.3 Test circuit board

The test circuit board, on which the DUT is mounted and scanned, may be any board accessible to the scanning probe. If ICs are to be evaluated for comparison purposes, they shall be tested on identical PCBs. The PCB may be an application PCB or a standardized test circuit board designed in accordance with IEC 62132-1.

The test circuit board shall be firmly installed in the probe-positioning system to enhance test reproducibility. This shall be accomplished by the use of a test fixture having a minimum impact on the radiated field.

7.4 Probe-positioning system software setup

After the DUT and its test circuit board are set up, verify that the probe-positioning system software is configured for the desired scan parameters, in particular those concerning the desired area to be scanned. Ensure that there are no obstacles that could damage the probe within the desired scan area. Some scanner software requires reference points to compensate for alignment errors, origin offsets, etc., as well as to improve the reproducibility of the tests. Cameras, lasers and other such artifices may be used to assist the alignment. Images of the DUT may be recorded and used as a background for the field tests (see 9.4). The brief description of such procedures shall be included in the test report.

7.5 DUT Software

Appropriate software shall be implemented in the DUT during the measurement to meet the requirements of IEC 62132-1. The description of the software shall be included in the test report.

8 Test procedure

8.1 General

The test procedure shall be in accordance with IEC 62132-1 except as modified herein. These default test conditions are intended to assure a consistent test environment. The following steps shall be performed:

a) operational check (see 8.2);

b) immunity test (see 8.3).

If other test conditions are applied, they shall be documented in the test report.

8.2 Operational check

Energize the DUT and complete an operational check to verify proper function of the device (i.e. Run DUT software) in the ambient test condition. During the operational check, the RF disturbance generator and any monitoring equipment shall be powered; however, the output of the RF disturbance generator shall be disabled and the probe positioned well away from the DUT. The performance of the DUT shall not be degraded by ambient conditions.

8.3 Immunity test

8.3.1 General

With the test circuit board energized and the DUT operated in the intended test mode, measure the level of the injected RF disturbance signal over the desired frequency range, while monitoring the DUT for performance degradation.

8.3.2 Amplitude modulation

The RF disturbance signal can be:

- CW (continuous wave, no modulation)
- sinusoidal modulated with 80 % amplitude modulated by a 1 kHz sine wave, and
- pulse modulated with 50 % duty cycle and 1 kHz pulse repetition rate.
- other modulation can be applied if appropriate.

8.3.3 Test frequency steps and ranges

The RF immunity of the DUT is generally evaluated in the frequency range from 150 kHz to 6 GHz. Test frequencies shall be applied according to Table 1.

Table 1 – Frequency step size versus frequency range

Frequency range (MHz)	0,15 to 1	1 to 100	100 to 1 000	1 000 to 6 000
Linear steps (MHz)	≤0,1	≤1	≤10	≤20
Logarithmic steps	≤5 % increment			

Immunity scanning over a wide range of frequencies is extremely time-consuming. In order to reduce the test time, the RF immunity of the DUT may be evaluated only at and near critical frequencies. Critical frequencies are frequencies critical to DUT; including crystal frequencies, oscillator frequencies, clock frequencies, data frequencies; which are generated by, received by, or operated on by the DUT.

8.3.4 Test levels and dwell time

The applied test level shall be incrementally changed and the DUT shall be monitored according to 8.3.6.2. The step size and test level shall be documented in the test report.

At each test level and frequency, the RF disturbance signal shall be applied for the time necessary for the DUT to respond and for the monitoring system to detect any performance degradation (typically 1 s).

8.3.5 DUT monitoring

The DUT shall be monitored to identify its susceptibility using the appropriate test equipment, as required in IEC 62132-1.

8.3.6 Detailed procedure

8.3.6.1 Field strength determination

At each test frequency, the signal generator setting shall be determined to achieve the desired field strength by applying the appropriate probe factor depending on the altitude of the probe as described in Annex A.

The small size of probes often limits the power level that can be applied. Excessive applied power may change the probe performance or, at worst, permanently damage it. Care should be taken to limit the applied power to avoid such effects.

8.3.6.2 Immunity test flow

The brief test processes are described below.

The procedure depends on the configuration of the DUT, the test equipment, the positioning system and data acquisition system, as well as users' preferences. For example, it is possible to position the probe at a specific location, measure data over the whole range of frequencies and then move to the next location. However, it may be preferred to measure data at a specific frequency over the entire surface before changing the test frequency and rescanning the entire surface.

Before starting the immunity test, a maximum signal level to be applied to the probe shall be defined. This maximum signal level may depend on various criteria including the maximum power rating of the probe, the maximum output level of the RF disturbance generator, a field strength considered dangerous for the DUT (e.g. potentially causing permanent damage to the DUT).

At each location and frequency one of the following two methods can be employed for this test:

a) The output of the RF disturbance generator shall be set at a low value (e.g. 20 dB below the predefined maximum signal level) and slowly increased up to the predefined maximum signal level while monitoring the DUT for performance degradation. Any performance degradation at or below the predefined maximum signal level shall be recorded.
b) The output of the RF disturbance generator shall be set at a predefined maximum signal level while monitoring the DUT for performance degradation. Any performance degradation at the predefined maximum signal level shall be recorded. The output of the RF disturbance generator shall then be reduced until normal function returns. This level shall also be recorded.

If the DUT's responses are different between the two methods, performing both a) and b) methods is recommended. Additionally, in some cases it might be necessary to reset or restart the DUT to come back to proper operation.

For the probe that generates a field in a single-direction, the probe may rotate automatically at each location to generate, for example, X- and Y-fields. If the rotation is manual, it is usual to scan the entire surface with the probe fixed in one direction and then turn it by 90° before rescanning the surface. A similar procedure is used if the probe is changed to switch from, for example, an applied field in the XY-plane to a field in the Z plane. In all cases care shall be taken to ensure the angle and position of the probes, after change, with respect to the DUT.

Scans can be made in a plane that is parallel or perpendicular to the surface of the IC or in a series of planes to form a three-dimensional mapping. The test frequency can be varied to evaluate the effect of frequency on the immunity pattern of the IC. The distance between multiple test planes from the surface of the IC can be varied to create a three-dimensional map of the immunity pattern of the IC. The scanned plane and the stepping of the probe can be determined arbitrarily for the purpose of the test. Although scans are usually carried out at a constant altitude above the DUT, they may also follow the contours of the DUT and surrounding area.

The data acquisition system stores the level of the RF disturbance applied to the probe at each location, probe orientation and frequency. Post-processing can correct for losses introduced by attenuators, cables, etc. Probe calibration data can allow conversion from applied signal level to magnetic or electric field strength.

9 Test report

9.1 General

The test report shall meet the requirements of IEC 62132-1 as well as the following.

9.2 Test conditions

All test conditions shall be documented in the test report. Typical test conditions include scan frequency, scan area, scan probe height, scan step size, and probe orientation. Any useful information on the data acquisition software and alignment aids may also be included.

9.3 Probe design and calibration

The physical design of the probe, the calibration procedure and calibration data shall be described in the test report.

9.4 Test data

The quantity of data acquired by near-field scan tests can be very large and difficult to view and analyse. In order to provide meaningful information on the near-field immunity of the DUT, the data may be represented as an array or a series of arrays with a greyscale or colour scale representing the applied signal level or field strength. The data array may be overlaid on an image of the DUT, thereby facilitating localization of various areas of low immunity. Figure 3 shows an example of a data array. The yellow (bright) colour indicates the lowest immunity area and the black the highest immunity area. In this example, the probe factor at the specific altitude has been used to convert the signal level applied to the test probe to magnetic field strength in dBA/m.

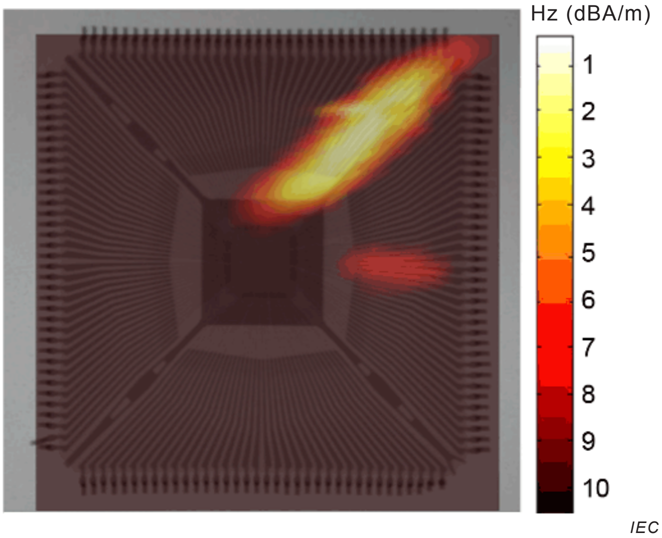

Figure 3 – Example of data overlaid on an image of the DUT

Test data may also be included in the form of graphs, tables or any other representation allowing the user to appreciate the results.

9.5 Post-processing

Post-processing of the acquired near-field scan data can considerably enhance its resolution and display, as well as reducing the data acquisition time.

Any post-processing applied to the data shall be described with, when applicable, references to specific software or bibliography.

9.6 Data exchange

In order to facilitate the exchange of data between users, the XML format described in IEC TR 61967-1-1 [3] should be used.

Annex A
(informative)

Calibration of near-field probes

A.1 General

Calibration of a probe compensates variations of generated magnetic or electric field strength with frequency and allows conversion of the signal level at its input to magnetic or electric field strength. Applied signal level and field strength are related by the probe factor of the probe. The following equations are possible and all are commonly used. It is not the intention of this specification to impose one or the other and therefore all are described.

When applying voltage or current to the input of the probe, the probe factor may be calculated according to one of the following equations:

$$F_{PA} = \frac{M_F}{F} \quad (A.1)$$

or $$F_{PB} = \frac{F}{M_F} \quad (A.2)$$

where:

F_{PA} and F_{PB} are the probe factors;

M_F is the level of the signal applied to the probe in volts (V) or amperes (A);

F is the field strength in volts per metre (V/m) or amperes per metre (A/m).

F_{PA} and F_{PB} are simply reciprocals of the other.

When the power applied to the probe is measured, the equations for calculating the probe factor become:

$$F_{PC} = \frac{M_F}{F^2} \quad (A.3)$$

or $$F_{PD} = \frac{F^2}{M_F} \quad (A.4)$$

where:

F_{PC} and F_{PD} are the probe factors;

M_F is the level of the signal applied to the probe in watts (W);

F is the field strength in volts per metre (V/m) or amperes per metre (A/m);

F_{PC} and F_{PD} are simply reciprocals of the other.

The probe factor may also be expressed in dB.

The applicable relationship can be readily recognised by the units in which the probe factor is expressed. Table A.1 and Table A.2 show permitted combinations of units. In order to avoid confusion, scaling factors (k, m, μ, etc.) should not be used. The use of parentheses in the units avoids confusion with other units (e.g. dBm for dB milliwatt and dB(m) for dB metre).

Table A.1 – Probe factor linear units

Probe factor		F_{PA} or F_{PC}		F_{PB} or F_{PD}	
Field strength units (F)		**A/m**	**V/m**	**A/m**	**V/m**
Applied signal units (M_F)	**V**	Ω·m (A.1)	m (A.1)	S/m (A.2)	1/m (A.2)
	A	m (A.1)	S·m (A.1)	1/m (A.2)	Ω/m (A.2)
	W	$\Omega\cdot\text{m}^2$ (A.3)	$\text{S}\cdot\text{m}^2$ (A.3)	S/m^2 (A.4)	Ω/m^2 (A.4)
NOTE The number in brackets refers to the appropriate equation.					

Table A.2 – Probe factor logarithmic units

Probe factor		F_{PA} or F_{PC}		F_{PB} or F_{PD}	
Field strength units (F)		**dBA/m**	**dBV/m**	**dBA/m**	**dBV/m**
Applied signal units (M_F)	**dBV**	dB(Ω·m) (A.1)	dB(m) (A.1)	dB(S/m) (A.2)	dB(1/m) (A.2)
	dBA	dB(m) (A.1)	dB(S·m) (A.1)	dB(1/m) (A.2)	dB(Ω/m) (A.2)
	dBW	dB($\Omega\cdot\text{m}^2$) (A.3)	dB($\text{S}\cdot\text{m}^2$) (A.3)	dB(S/m^2) (A.4)	dB(Ω/m^2) (A.4)
NOTE The number in brackets refers to the appropriate equation.					

For an immunity scan the probe generates a field (electrical or magnetic) whose strength falls off as the distance from the radiator increases. The relationship between the distance and the field strength depends on the type of probe. The probe factor is therefore defined as a function of frequency and altitude. Care should be taken to include sufficient frequencies and altitudes to describe the characteristic accurately.

Typical graphs for probe factor against frequency are shown in Figures A.1 and A.2.

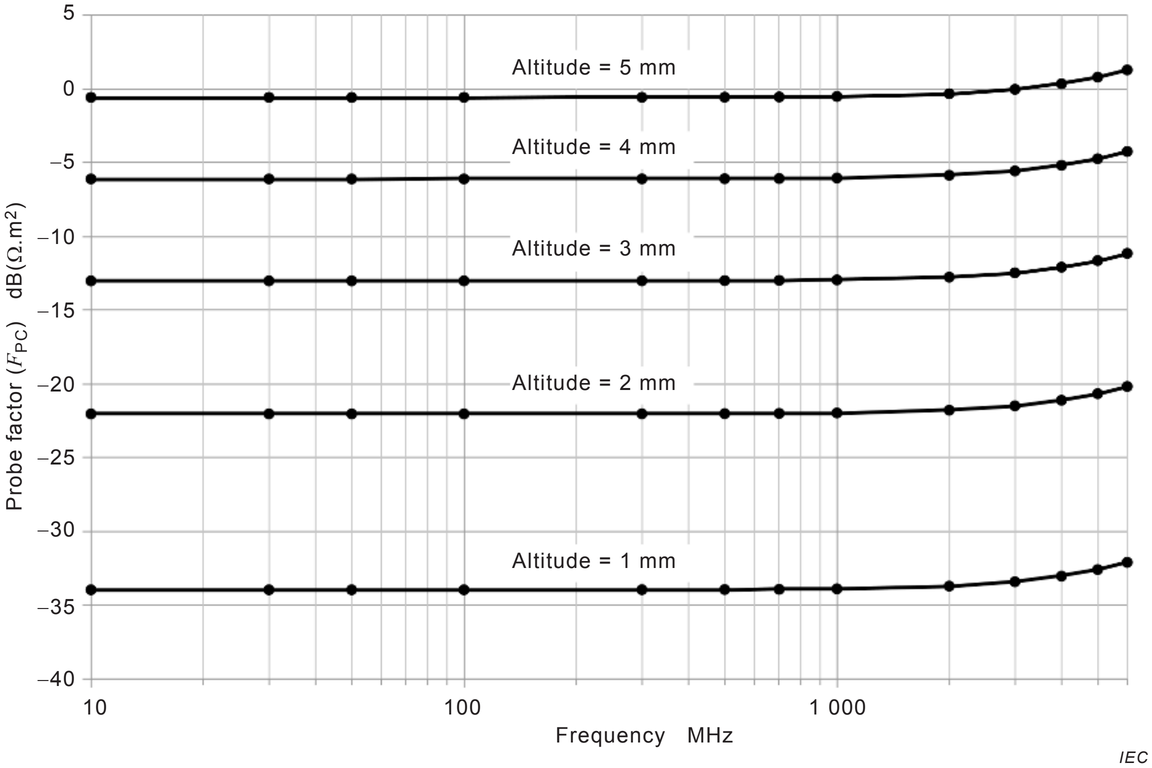

Figure A.1 – Typical probe factor in dB (Ω.m²) against frequency

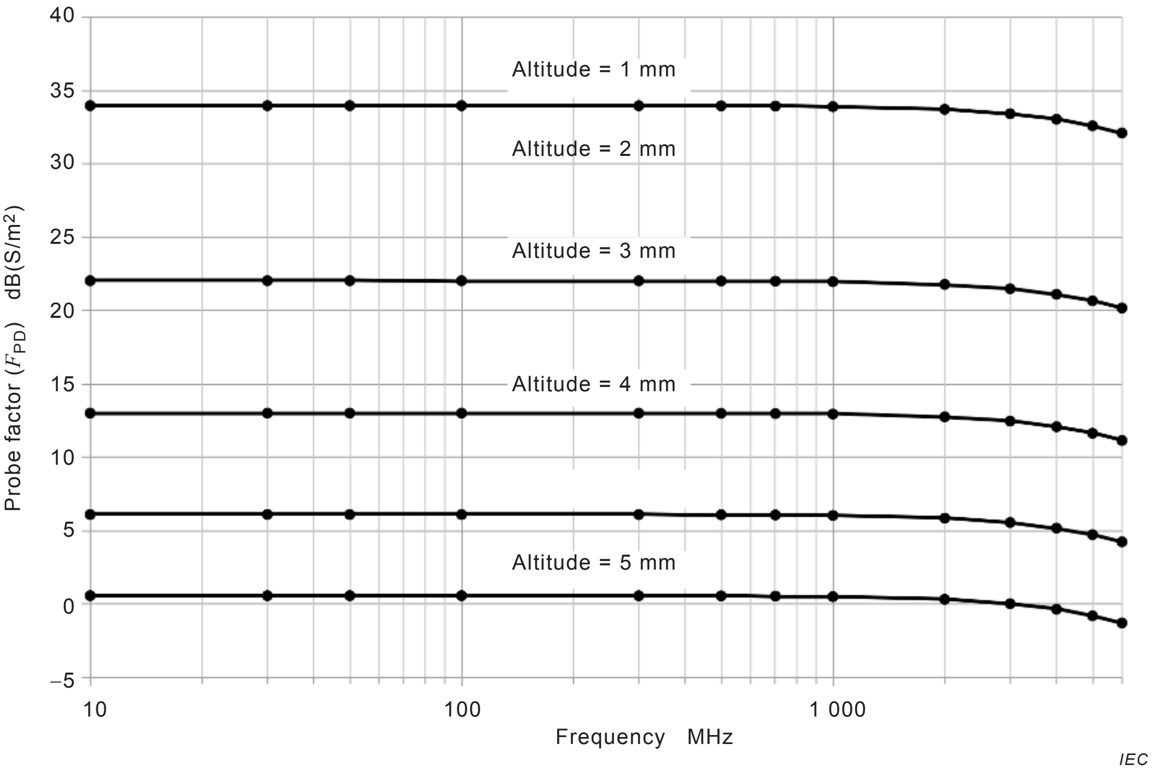

Figure A.2 – Typical probe factor in dB (S/m²) against frequency

Suppliers may provide calibration data with the probe. In that case calibration by the method described below is not required. Nevertheless, verification shall be carried out periodically using the following method.

The probes used for the test shall be calibrated in accordance with the procedure described below. In order to obtain the probe factor of the probe, the generated field is measured with a calibrated NFS emission probe of the appropriate type (magnetic, electric) and field orientation [4] [5]. The method consists of applying a known RF signal level to the immunity probe and measuring the field strength at various distances from the probe in the appropriate direction. The probe factor is the ratio between the applied signal level and the measured field strength. This calibration method should be performed using the surface scan test setup described above to minimize test errors and to ensure a high level of repeatability.

An alternative approach such as 3D electromagnetic simulation of the probe [6] may also be used. The calibration method used shall be indicated in the test report.

A.2 Test equipment

The test equipment used for calibration of the probes shall comply with Clause 6 for the signal generator and IEC TS 61967-3 for the measurement of the radiated field strength.

A.3 Calibration setup

The test setup used for calibration of the probes shall comply with Clause 7 for excitation of the immunity probe and IEC TS 61967-3 for the measurement of the radiated field strength. Figure A.3 shows the test setup for calibration.

In order to conform to the definition of altitude, it should be measured between tips of the facing probes.

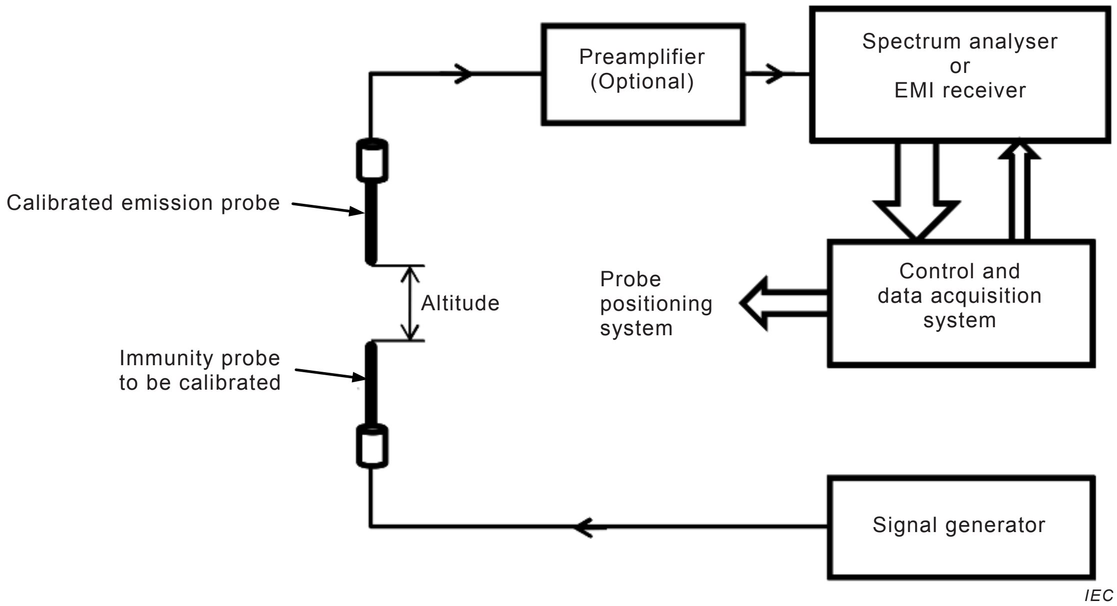

Figure A.3 – Probe calibration setup

A.4 Calibration procedure

The calibration factor of the probe is determined by driving the immunity probe with a signal at the desired frequency and measuring the signal level at the output of the calibrated emission probe. The applying power shall be chosen to produce signals having a noise margin of at least 20 dB at all calibration frequencies.

The following procedure shall be used:

a) Mount the probes in a suitable test fixture such that the distance between the probe tips corresponds to the desired altitude. Care should be taken to ensure that the immunity probe and calibrated emission probe are aligned so as to maximise the measured signal level at the output of the calibrated emission probe. In order to facilitate the calibration over a wide range of frequencies and at various altitudes, one probe may be mounted in a suitable test fixture on the scan table and the other on the mobile part of the probe-positioning system. In this case the probe-positioning system may be used to scan in the X- and Y-directions at a constant altitude and the maximum signal level at the output of the calibrated emission probe noted.

b) Connect a signal generator to the immunity probe to be calibrated.

c) Connect the output of the calibrated emission field probe to a measuring instrument as shown in Figure A.3.

d) Set the signal generator to the first frequency to be calibrated.

e) Set the appropriate output power from the signal generator. This will excite an electromagnetic field around the immunity probe to be calibrated.

f) Record the level output from the calibrated emission probe as measured with the measuring instrument. If applicable, perform a limited scan in the X- and Y-directions and record the levels output from the calibrated emission probe as measured with the measuring instrument. Note the maximum signal level.

g) Calculate the generated field strength by applying the probe factor of the calibrated emission probe to the measured signal level.

h) Calculate the probe factor of the immunity probe from the measured field strength and the applied signal level using the appropriate Equation: (A.1), (A.2), (A.3) or (A.4).

i) Repeat the measurement at a minimum of three discrete frequencies per decade up to the maximum desired frequency.

j) Plot the probe factor against frequency.

k) Repeat steps a) to j) for each desired altitude.

Annex B
(informative)

Electric and magnetic field probes

B.1 General

Discrete electric and magnetic field probes or combined electromagnetic field probes can be utilized to perform surface scan tests. Using a discrete electric or magnetic field probe can simplify the test setup and data processing provided that it meets the needs of the user. The design and construction of the discrete electric and magnetic field probes is not specified to allow the use of a variety of probes to meet the specific needs of the user. A combined electromagnetic field probe for emission measurements is described in IEC TS 61967-3.

The test system and data-processing program for gathering and organising measured data varies depending on the type of probe used and the desired purpose.

Examples of possible discrete electric and magnetic field probes are provided below.

B.2 Probe electrical description

The equivalent circuit of the discrete electric and magnetic field probes and their inputs are shown in Figure B.1. The figure illustrates how the field probes generate electric and magnetic fields. The signals applied to the electric and magnetic field probes induce the electric or magnetic field, respectively. In the case of a magnetic field probe, the current $\mathbf{I}_M$ flowing in the loop generates a magnetic field. In the case of an electric field probe, the voltage V_E applied across the radiator generates an electric field.

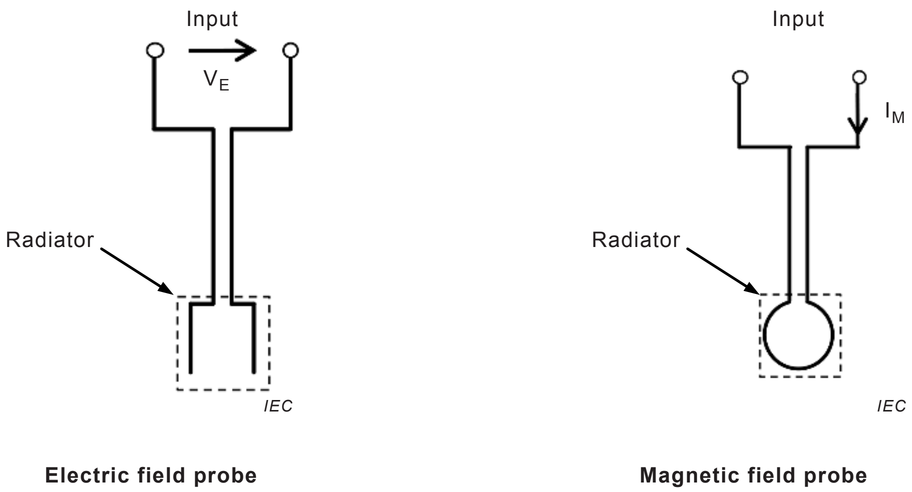

Figure B.1 – Basic structure of electric and magnetic field probe schematics

B.3 Probe physical description

B.3.1 Probe construction

While there are many structures for electric and magnetic field probes, the examples described here are constructed using semi-rigid coaxial cable. The benefit of cable construction is small size and easy impedance control. Drawbacks of this probe type include difficult assembly and potential probe damage.

B.3.2 Electric field probe

An example of electric field probe is shown in Figure B.2. The electric field radiator is the centre conductor. Note that the shield of the cable may be extended to cover the centre conductor. The generated field direction is parallel to the conductor (in this case E_Z).

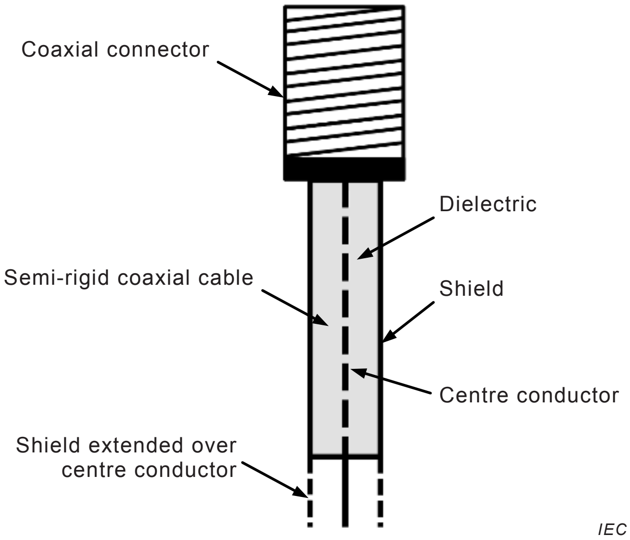

Figure B.2 – Example of electric field probe construction (E_Z)

B.3.3 Magnetic field probe

An example of magnetic field probe is shown in Figure B.3. The magnetic field radiator is the single loop formed by the centre conductor and terminated to the shield The generated field direction is perpendicular to the plane of the loop (in this case H_X or H_Y).

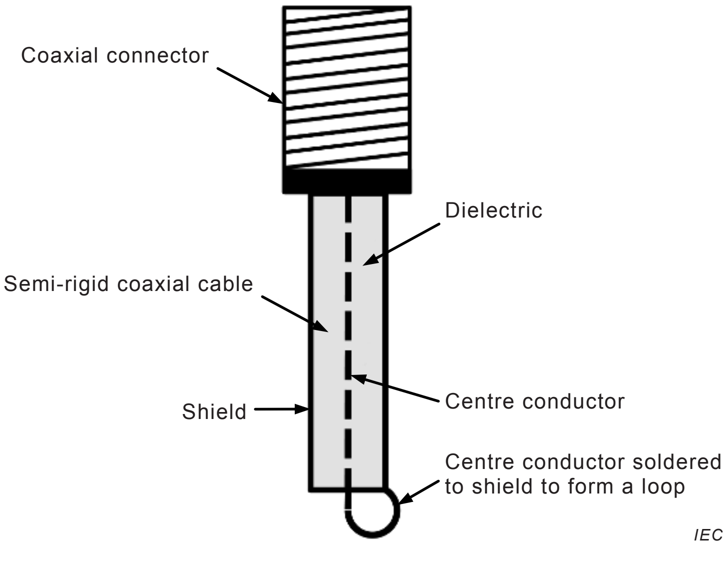

Figure B.3 – Example of magnetic field probe construction (H_X or H_Y)

Annex C
(informative)

Coordinate systems

C.1 General

Three coordinate systems may be used for near-field scans:

– Cartesian coordinates (x, y, z)
– Cylindrical coordinates (r, A, h)
– Spherical coordinates (r, A, B)

The most commonly used system is the Cartesian coordinate systemThe coordinate system concerns not only the positioning of the probe, but also the field directions. Both the probe-positioning and the field direction shall use the same coordinate system.

As described in Clause C.5, the coordinate systems or field directions can be easily converted to another coordinate system.

C.2 Cartesian coordinate system

In order to accommodate different scan table coordinate systems, Cartesian coordinates may be either right-hand system (see Figure C.1) or left-hand system (see Figure C.2). However, the right-hand Cartesian coordinate system is preferred and shall be used whenever possible.

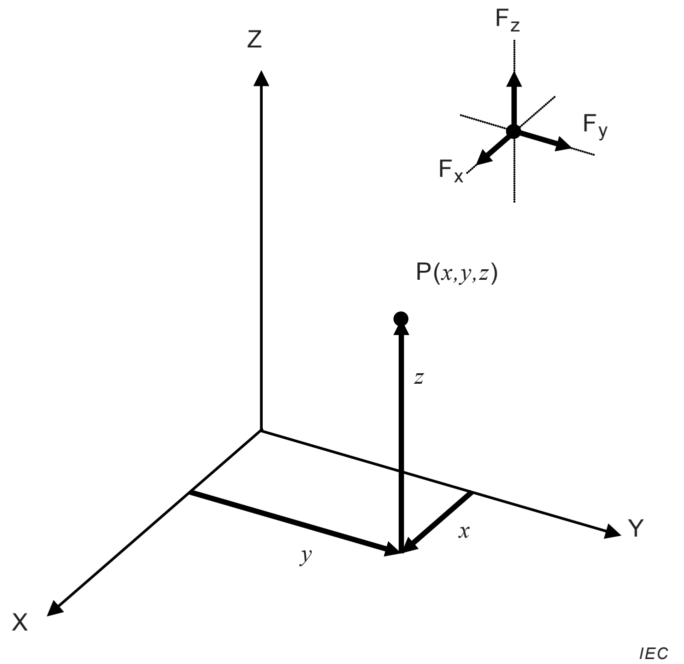

Figure C.1 – Right-hand Cartesian coordinate system (preferred)

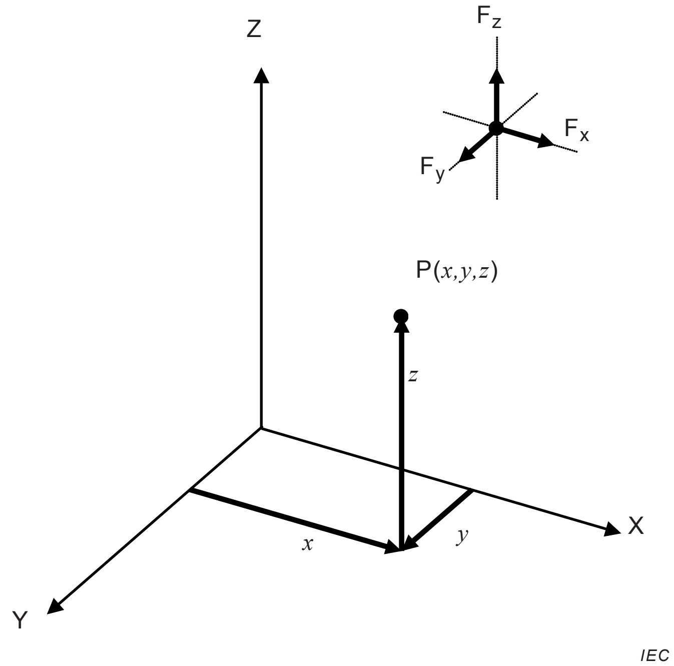

Figure C.2 – Left-hand Cartesian coordinate system

C.3 Cylindrical coordinate system

The cylindrical coordinate system assumes that, regardless of the orientation of the scan equipment, the polar plane (r, A) lies in the XY plane of a Cartesian coordinate system and that the linear axis (h) lies in the z-direction of a Cartesian coordinate system, as shown in Figure C.3.

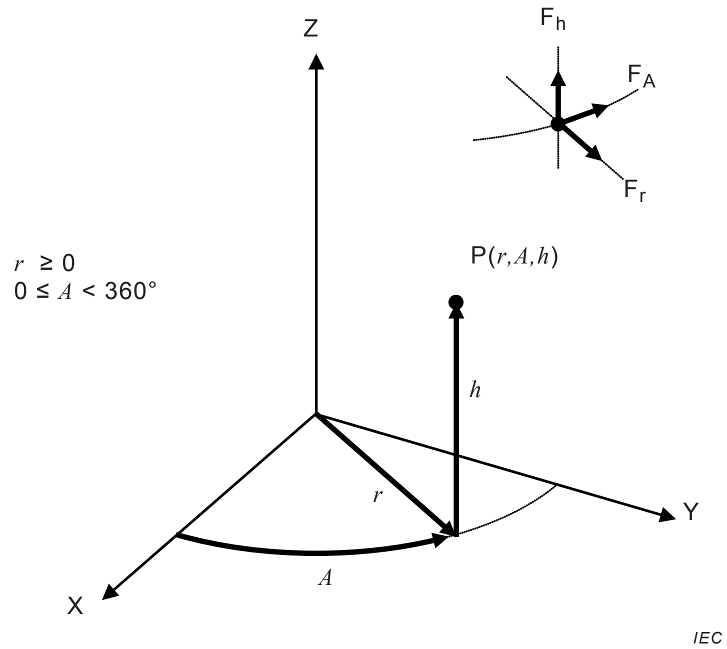

Figure C.3 – Cylindrical coordinate system

C.4 Spherical coordinate system

The spherical coordinate system assumes that, regardless of the orientation of the scan equipment, the azimuth angle (A) lies in the XY plane of a Cartesian coordinate system and that the zenith angle (B) lies between the Z-axis of a Cartesian coordinate system and the vector r, as shown in Figure C.4. In order to avoid the use of negative angle values, the zenith angle B shall be used in preference to the elevation angle (angle between the XY-plane and the vector r), which is used for antenna radiation diagrams, for example.

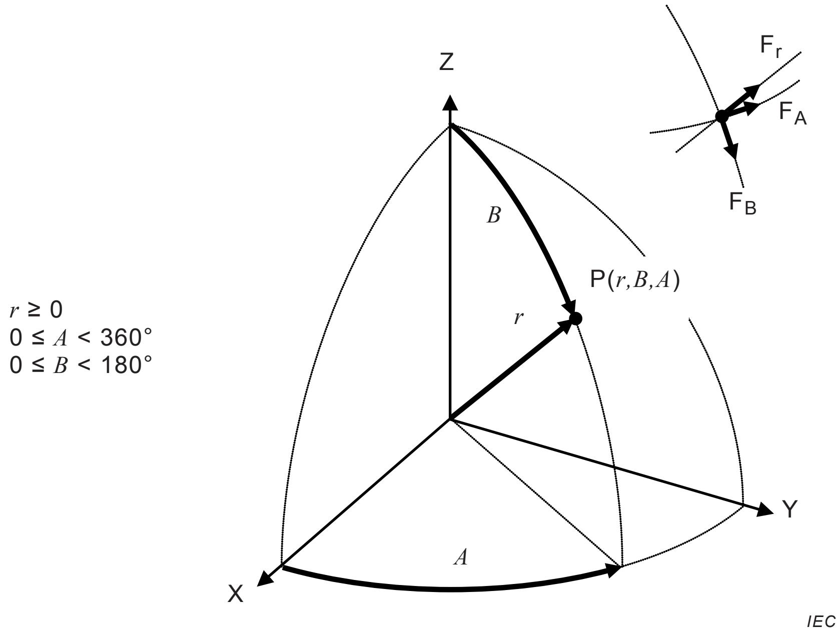

Figure C.4 – Spherical coordinate system

C.5 Coordinate system conversion

Table C.1 summarises the relationships between the coordinate systems described above.

Table C.1 – Coordinate system conversion

		To		
		Cartesian	**Cylindrical**	**Spherical**
From	**Cartesian**	To convert from between left- and right-hand Cartesian coordinates: $x_R = x_L, y_R = -y_L, z_R = z_L$	$r = \sqrt{x^2 + y^2}$ $A = \arctan(y/x)$ $h = z$	$r = \sqrt{x^2 + y^2 + z^2}$ $A = \arctan(y/x)$ $B = \arccos\left(z \middle/ \sqrt{x^2 + y^2 + z^2}\right)$
	Cylindrical	$x = r \cos A$ $y = r \sin A$ $z = h$		$r_S = \sqrt{h^2 + r_C^2}$ $A_S = A_C$ $B = \arccos\left(h \middle/ \sqrt{h^2 + r_C^2}\right)$
	Spherical	$x = r \cos A \sin B$ $y = r \sin A \sin B$ $z = r \cos B$	$r_C = r_S \sin B$ $A_C = A_S$ $h = r_S \cos B$	

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