

BS EN 50383:2010

Incorporating corrigendum June 2013



BSI Standards Publication

Basic standard for the calculation and measurement of electromagnetic field strength and SAR related to human exposure from radio base stations and fixed terminal stations for wireless telecommunication systems (110 MHz - 40 GHz)

bsi.

...making excellence a habit.
AVA Documents™
Document Sharing Hub

National foreword

This British Standard is the UK implementation of EN 50383:2010, incorporating corrigendum June 2013. It supersedes BS EN 50383:2002 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GEL/106, Human exposure to low frequency and high frequency electromagnetic radiation.

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

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2016.
Published by BSI Standards Limited 2016

ISBN 978 0 580 93660 9

ICS 13.280; 17.220.20; 33.070.01

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 September 2010.

Amendments/corrigenda issued since publication

Date	Text affected
31 March 2016	Implementation of CENELEC corrigendum June 2013: Clause 6 renumbered

Basic standard for the calculation and measurement of electromagnetic field strength and SAR related to human exposure from radio base stations and fixed terminal stations for wireless telecommunication systems (110 MHz - 40 GHz)

Norme de base pour le calcul et la mesure des champs électromagnétiques et SAR associés à l'exposition des personnes provenant des stations de base radio et des stations terminales fixes pour les systèmes de radiotélécommunications (110 MHz - 40 GHz)

Grundnorm für die Berechnung und Messung der elektromagnetischen Feldstärke und SAR in Bezug auf die Sicherheit von Personen in elektromagnetischen Feldern von Mobilfunk-Basisstationen und stationären Teilnehmergeräten von schnurlosen Telekommunikationsanlagen (110 MHz bis 40 GHz)

This European Standard was approved by CENELEC on 2010-06-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Management Centre: Avenue Marnix 17, B - 1000 Brussels

Foreword

This European Standard was prepared by the Technical Committee CENELEC TC 106X, Electromagnetic fields in the human environment. It was submitted to the Unique Acceptance Procedure as a draft amendment and approved by CENELEC as a new edition on 2010-06-01.

This European Standard supersedes EN 50383:2002.

The main changes compared to EN 50383:2002 are as follows (minor changes are not listed):

- the frequency range has been extended to cover 300 MHz to 6 GHz now, was 300 MHz to 3 GHz before
- the references to EN 50361 have been updated with referring to EN 62209-2:2010 now and paragraphs have been removed, that are covered by EN 62210-2
- the former Annex A "Boundaries between field regions" has been replaced by an Annex "Considerations for using far-field method"

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

The following dates were fixed:

- latest date by which the EN has to be implemented
at national level by publication of an identical
national standard or by endorsement (dop) 2011-06-01
 - latest date by which the national standards conflicting
with the EN have to be withdrawn (dow) 2013-06-01
-

1 Scope

This basic standard applies to radio base stations and fixed terminal stations for wireless telecommunication systems as defined in Clause 4, operating in the frequency range 110 MHz to 40 GHz.

The objective of the standard is to specify, for such equipment, the method for assessment of compliance distances according to the basic restrictions (directly or indirectly via compliance with reference levels) related to human exposure to radio frequency electromagnetic fields.

2 Normative references

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

EN 62209-2:2010, *Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Human models, instrumentation, and procedures – Part 2: Procedure to determine the specific absorption rate (SAR) for mobile wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)*

ISO/IEC 17025:1999, General requirements for the competence of testing and calibration laboratories

ISO/IEC Guide 98-3:2008, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement* (GUM:1995)

Council Recommendation 1999/519/EC of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz) (Official Journal L 197 of 30 July 1999)

International Commission on Non-Ionizing Radiation Protection (1998), Guidelines for limiting exposure in time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). Health Physics 74, 494-522.

3 Physical quantities, units and constants

3.1.1 Quantities

The internationally accepted SI-units are used throughout the standard.

<u>Quantity</u>	<u>Symbol</u>	<u>Unit</u>	<u>Dimensions</u>
Current density	J	ampere per square metre	A/m^2
Electric field strength	E	volt per metre	V/m
Electric flux density	D	coulomb per square metre	C/m^2
Electric conductivity	σ	siemens per metre	S/m
Frequency	f	hertz	Hz
Magnetic field strength	H	ampere per metre	A/m
Magnetic flux density	B	tesla (Vs/m^2)	T
Mass density	ρ	kilo per cubic metre	kg/m^3
Permeability	μ	henry per metre	H/m
Permittivity	ϵ	farad per metre	F/m
Specific absorption rate	SAR	watt per kilogram	W/kg
Wavelength	λ	metre	m
Temperature	T	kelvin	K

3.1.2 Constants

<u>Physical constant</u>		<u>Magnitude</u>
Speed of light in a vacuum	c	$2,997 \times 10^8 \text{ m/s}$
Permittivity of free space	ϵ_0	$8,854 \times 10^{-12} \text{ F/m}$
Permeability of free space	μ_0	$4 \pi \times 10^{-7} \text{ H/m}$
Impedance of free space	η_0	$120 \pi \text{ (approx. } 377) \Omega$

4 Terms and definitions

4.1

antenna

device that serves as a transducer between a guided wave (e.g. coaxial cable) and a free space wave, or vice versa

4.2**average (temporal) absorbed power** P_{avg}

the time-averaged rate of energy transfer defined by:

$$P_{\text{avg}} = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} P(t) dt \quad (1)$$

where t_1 and t_2 are the start and stop time of the exposure. The period $t_2 - t_1$ is the exposure duration time

4.3**averaging time** t_{avg}

the appropriate time over which exposure is averaged for purposes of determining compliance with the limits

4.4**base station****BS**

in this standard, the term “Base Station” (BS) covers radio base stations as well as fixed terminal stations intended for use in wireless telecommunications networks

4.5**basic restriction**

restrictions on exposure to time-varying electric, magnetic and electromagnetic fields that are based directly on established health effects. In the frequency range from 110 MHz to 10 GHz, the physical quantity used is the specific absorption rate. Between 10 GHz and 40 GHz, the physical quantity is the power density

4.6**compliance boundary**

volume outside which any point of investigation is deemed to be compliant. Outside the compliance boundary, the exposure levels do not exceed the basic restrictions irrespective of the time of exposure

4.7**conductivity** σ

ratio of the conduction-current density in a medium to the electric field strength. Conductivity is expressed in units of siemens per metre (S/m)

4.8**continuous exposure**

exposure for a duration exceeding the averaging time

4.9**duty factor (duty cycle)**

ratio of the pulse duration to the pulse period of a periodic pulse train. A duty factor of unity corresponds to continuous-wave operation

4.10**electric field strength** E

the magnitude of a field vector at a point that represents the force (F) on a positive small charge (q) divided by the charge:

$$E = \frac{F}{q} \quad (2)$$

Electric field strength is expressed in units of volt per metre (V/m)

4.11

electric flux density

D

the magnitude of a field vector that is equal to the electric field strength (*E*) multiplied by the permittivity (ϵ):

$$D = \epsilon E \quad (3)$$

Electric flux density is expressed in units of coulomb per square metre (C/m²)

4.12

equipment under test

EUT

device (such as transmitter, base station or antenna as appropriate) that is the subject of the specific test investigation being described

4.13

fixed terminal station

a fixed terminal station, usually associated with the user, comprises the hardware, including transceivers, necessary to transmit and receive radio signals. Fixed terminal stations with integrated antennas, fixed terminal stations with connectors for external antennas and fixed terminal stations intended for use with external antennas not supplied by the same manufacturer are covered.

In this standard, the fixed terminal stations are covered by the term “base station”

4.14

intrinsic impedance (of free space η_0)

η

the ratio of the electric field strength to the magnetic field strength of a propagating electromagnetic wave. The intrinsic impedance of a plane wave in free space is 120π (approximately 377) ohm

4.15

isotropy

deviation of the measured value with regard to various angles of incidence of the measured signal. In this document, it is defined for incidences covering a hemisphere centred at the tip of the probe, with an equatorial plane normal to the probe and expanding outside the probe.

The axial isotropy is defined by the maximum deviation of the measured quantity when rotating the probe along its main axis with the probe exposed to a reference wave with normal incidence with regard to the axis of the probe. The hemispherical isotropy is defined by the maximum deviation of the measured quantity when rotating the probe along its main axis with the probe exposed to a reference wave with varying angles of incidences with regard to the axis of the probe in the half space in front of the probe

4.16

linearity

maximum deviation over the measurement range of the measured quantity from the closest linear reference curve defined over a given interval

4.17

loss tangent

the loss tangent $\tan(\delta)$ is the ratio of the imaginary part of the complex dielectric constant of a material to its real part

4.18

magnetic flux density

B

the magnitude of a field vector that is equal to the magnetic field strength *H* multiplied by the permeability (μ) of the medium:

$$B = \mu H \quad (4)$$

Magnetic flux density is expressed in units of tesla (T)

4.19**magnetic field strength** **H**

the magnitude of a field vector in a point that results in a force (F) on a charge q moving with the velocity v :

$$F = q(v \times \mu H) \quad (5)$$

The magnetic field strength is expressed in units of ampere per metre (A/m)

4.20**multi-band**

a multi-band equipment is operating in more than one frequency band, e.g. GSM 900 and GSM 1800

4.21**multi-mode**

a multi-mode equipment is operating with various radio communication systems, e.g. GSM and DECT

4.22**permeability** **μ**

the magnetic permeability of a material is defined by the magnetic flux density B divided by the magnetic field strength H :

$$\mu = \frac{B}{H} \quad (6)$$

where

μ is the permeability of the medium expressed in Henry per metre (H/m)

4.23**permittivity** **ε**

the property of a dielectric material (e.g. biological tissue) defined by the electrical flux density D divided by the electrical field strength E :

$$\varepsilon = \frac{D}{E} \quad (7)$$

The permittivity is expressed in units of farad per metre (F/m)

4.24**phantom**

in this context, a phantom is a simplified representation or a model similar in appearance to the human anatomy and composed of materials with electrical properties similar to the corresponding tissues

4.25**point of investigation****POI**

the location in space at which the value of E -field, H -field, Power flux density or SAR is evaluated. This location is defined in Cartesian, cylindrical or spherical co-ordinates relative to the reference point on the EUT

4.26**power flux density** **S**

power per unit area normal to the direction of electromagnetic wave propagation

4.27**radio base station**

a radio base station, usually associated with the network, comprises the hardware, including transceivers, necessary to transmit and receive radio signals. Radio base stations with integrated antennas, radio base stations with connectors for external antennas and radio base stations intended for use with external antennas not supplied by the same manufacturer are covered.

In this standard, the radio base stations are covered by the term “base station”

4.28

radio frequency

RF

for purposes of these safety considerations, the frequency range of interest is 110 MHz to 40 GHz

4.29

relative permittivity

ϵ_r

the ratio of the permittivity of a dielectric material to the permittivity of free space i.e.

$$\epsilon_r = \frac{\epsilon}{\epsilon_0} \quad (8)$$

4.30

root-mean-square

rms

value obtained by taking the square root of the average of the square of the value of the periodic function taken throughout one period

4.31

root-sum-square

rss

the rss value or the Hermitian magnitude of a vector v is obtained by the square root of the sum of the squared rms values of all three orthogonal components of vector v . The rss value is proportional to the joule heating and can be quite different from the rms amplitude of vector v

4.32

scanning system

the scanning system is the positioning system capable of placing the measurement probe at the specified positions

4.33

specific absorption rate

SAR

the time derivative of the incremental energy (dW) absorbed by (dissipated in) an incremental mass (dm) contained in a volume element (dV) of given mass density (ρ)

$$SAR = \frac{d}{dt} \left(\frac{dW}{dm} \right) = \frac{d}{dt} \left(\frac{dW}{\rho dV} \right) \quad (9)$$

SAR is expressed in units of watt per kilogram (W/kg)

NOTE SAR can be calculated by:

$$SAR = \frac{\sigma E_i^2}{\rho} \quad (10)$$

$$SAR = c_i \frac{dT}{dt} \quad (\text{time} = 0) \quad (11)^1$$

where

E_i	rms value of the electric field strength in the tissue in V/m
σ	conductivity of body tissue in S/m
ρ	density of body tissue in kg/m ³
c_i	heat capacity of body tissue in J/kg K
$\frac{dT}{dt}$	time derivative of temperature in body tissue in K/s

4.34

transmitter

device to generate radio frequency power for the purpose of communication but on its own is not intended to radiate it

5 Applicability of compliance assessment methods

5.1.1 Introduction

Guidelines and recommended limits on human exposure to radio waves give basic restrictions in terms of SAR or power flux density and also reference levels in terms of field strengths in the absence of the body.

The compliance boundary defines the volume outside which the exposure levels do not exceed the basic restrictions irrespective of the time of exposure for the specific operating conditions of the EUT. The compliance boundary is determined via a procedure where sufficient points of investigation are assessed.

It is technically possible to determine the compliance boundary through measurements or calculations of SAR or electromagnetic fields relating to basic restrictions or reference levels, since compliance to the reference levels guarantees compliance to the basic restrictions. However, the choice of the most appropriate assessment method depends on a variety of other considerations.

Where the assessment is made through SAR, it should be noted that both localised and whole-body basic restrictions must be considered. Spatial averaging may be used with field strength assessments in order to assess whole-body SAR, however this approach may not be conservative over localised SAR, which shall be assessed separately.

5.2 Assessment procedure

5.2.1 Reference and alternative methodologies

This standard describes measurement and calculation methodologies that may be used to establish the compliance boundary. The current best evaluation techniques are assigned as the "reference" methodologies to be applied in the case of dispute.

¹⁾ This equation does not address thermal regulation in a live person.

However, simpler-to-apply alternative methodologies may provide more restrictive results than the reference methods and are therefore also acceptable. Compliance at a point of investigation may therefore be established via any of the described methods.

Table 1 establishes the reference and alternative methodologies as described in this specification.

Table 1 – Reference and alternative methodologies

	Applicable methodologies for each antenna region (see 8.2) ^{a,b}		
	Reactive near-field	Radiating near-field	Far-field
Reference	SAR evaluation Clause 7 ^{c,d}	SAR evaluation Clause 7 ^{c,d}	E-field or H-field calculation Clause 8 ^f
First alternative	<i>E</i> -field and <i>H</i> -field measurement Clause 6 ^e	<i>E</i> -field or <i>H</i> -field measurement Clause 6 ^e	<i>E</i> -field or <i>H</i> -field measurement Clause 6
Second alternative	<i>E</i> -field and <i>H</i> -field calculation Clause D.1 ^f	<i>E</i> -field or <i>H</i> -field calculation Clause 8 ^e	None
^a The reference methodology may be more complex to implement than the alternatives. ^b The alternative methodologies give valid conservative compliance assessments. ^c Methodology is not currently specified for whole body SAR evaluation above restricted power limits (see 7.1.2). ^d Localised SAR evaluation currently limited to • 110 MHz ≤ frequency < 6 000 MHz, • for investigation distances ≤ 400 mm. ^e Spatial averaging (Clause 9) provides a more accurate whole body evaluation of EM compliance than peak values, provided localised SAR compliance is assessed. ^f See general investigation methods for <i>E</i> & <i>H</i> calculations in Clause D.1.			

5.2.2 Alternative routes to determine compliance distances

Any of the alternative routes described in Figure 1 shall be used in accordance with Table 1 to establish if a point of investigation is compliant or not. Any completed route can be demonstrated to assure compliance to the "basic restriction" either directly or indirectly via compliance with the "reference level".

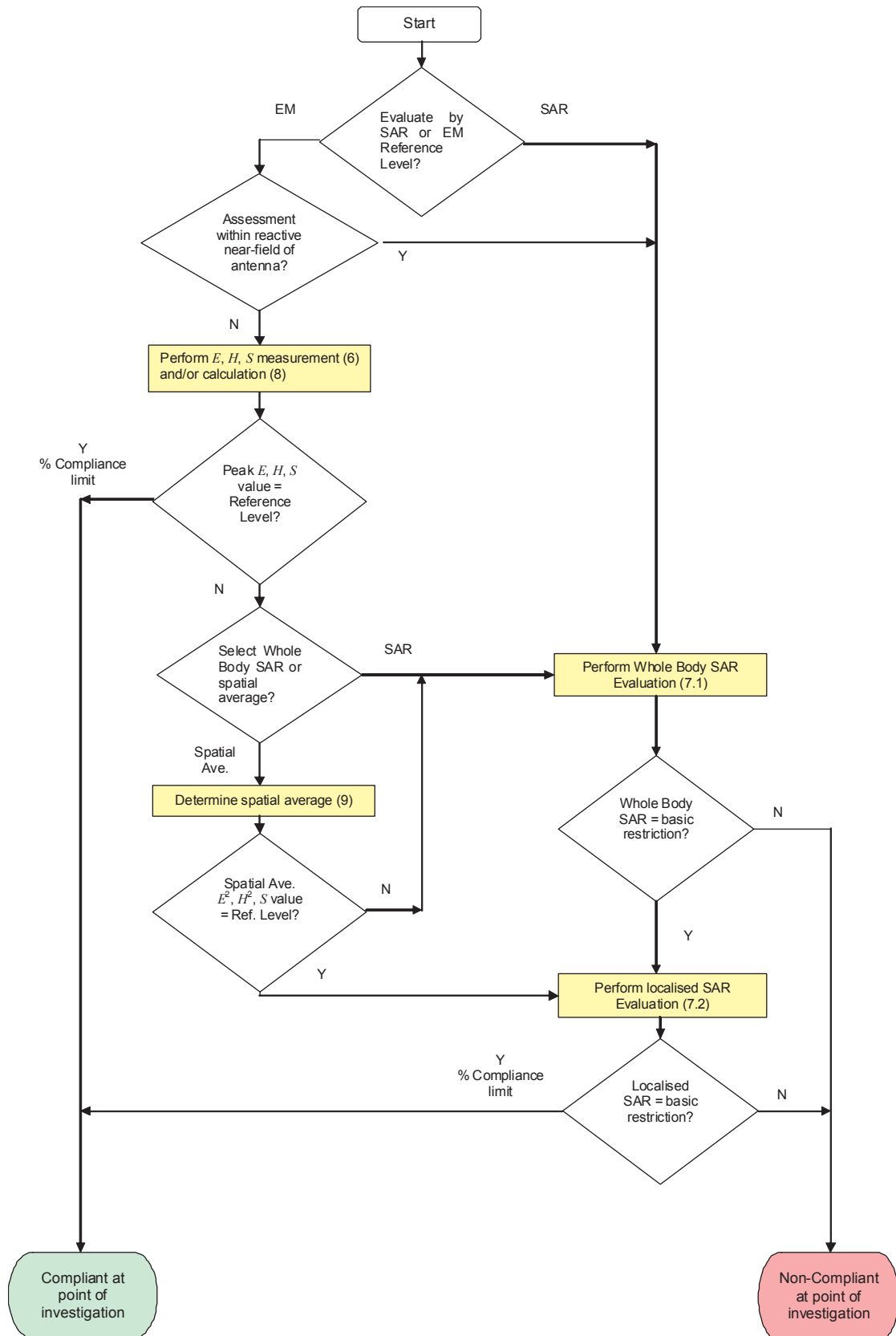


Figure 1 - Alternative routes to establish compliance at a point of investigation

5.2.3 Multiple Frequency bands

Where the EUT can be simultaneously operated on multiple frequency bands, the fractions of the exposure limit shall be established on each band. The sum of all these fractions must be less than one for overall compliance at the point of investigation to be established as described in normative references (Clause 2). When this principle is applied to multi-band data, it will provide a clear algorithm specific for the case under investigation that may provide a number of compliant solutions with different power applied to each band for any given compliance boundary.

5.2.4 General requirements

The antenna is referenced by the centre of the rear reflector, in case of panel antennas, and by the centre of the antenna in case of omni-directional antennas. For other configurations, appropriate references must be defined.

Compliance boundary shall be established at least for the centre, the low-end and high-end frequencies of each frequency band.

5.2.5 Compliance boundary

The compliance boundary may have a simple (e.g. parallelepiped, sphere or cylinder) or a more complex shape. In any case, the points of investigation outside the compliance boundary shall be in compliance with the limits. Moreover, the shape of the compliance boundary shall be accurately described in the assessment report (Clause 10).

6 Electromagnetic field measurement

6.1 Introduction

This section describes the measurement procedures that may be used to assess, at points of investigation, the electromagnetic field components (E and H and therefore the power density) radiated by antennas.

The field measurements can be obtained either by surface or volume scanning.

The methods used are to measure directly or indirectly the E -field or H -field strength, deduce the field distribution for a given input power and frequency.

6.2 Surface scanning method

6.2.1 Introduction

Methods to perform surface scanning could be, but are not limited to, far-field, compact range, and planar, cylindrical or spherical near-field as long as the methodology is accurately defined and the uncertainty criteria (Annexes B and E) are fulfilled.

6.2.2 Spherical scanning method

Measurements of electric field amplitude, phase and polarisation are made at sufficient points on the surface of a sphere surrounding the EUT to establish the parameters to model a set of isotropic sources on that surface that will produce at the point of investigation the same field as the EUT. To make this valid, the scanned spherical surface shall contain all the relevant energy that is radiated from the EUT. The parameters of this set of isotropic-radiators are then used to calculate the field at the points of investigation required in order to establish the compliance boundary.

The principle steps are summarised in Figure 2.

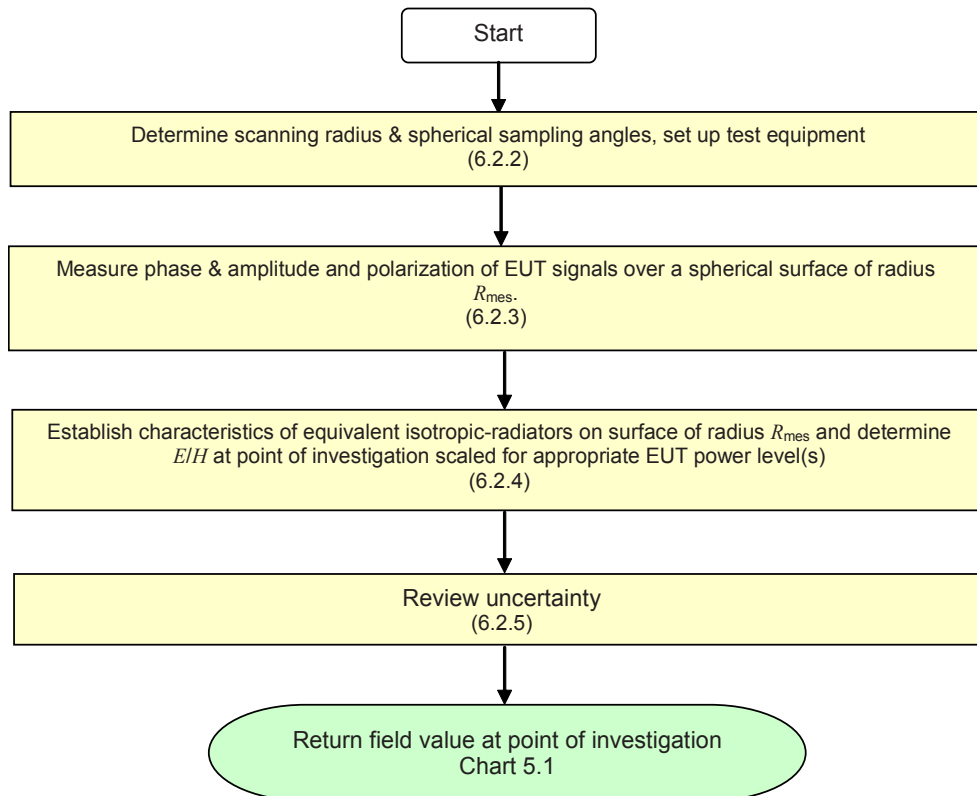


Figure 2 – Outline of the surface scanning methodology

6.2.2.1 Measurement equipment

6.2.2.1.1 General description

The surface scanning consists of an Equipment Under Test (EUT) mounted on an azimuthal positioner and the probe(s) mounted on a support structure at distance R_{mes} from the EUT. This method requires the ability to measure the phase of the signal. Detection shall consist of either one probe moved mechanically along the structure or one probe array switched electronically in order to perform an angular elevation scan of the electromagnetic fields.

Alternatively, the EUT can be moved to different elevation angles by means of an additional elevation positioner.

The near-field antenna measurement system shall be configured according to Figure 3.

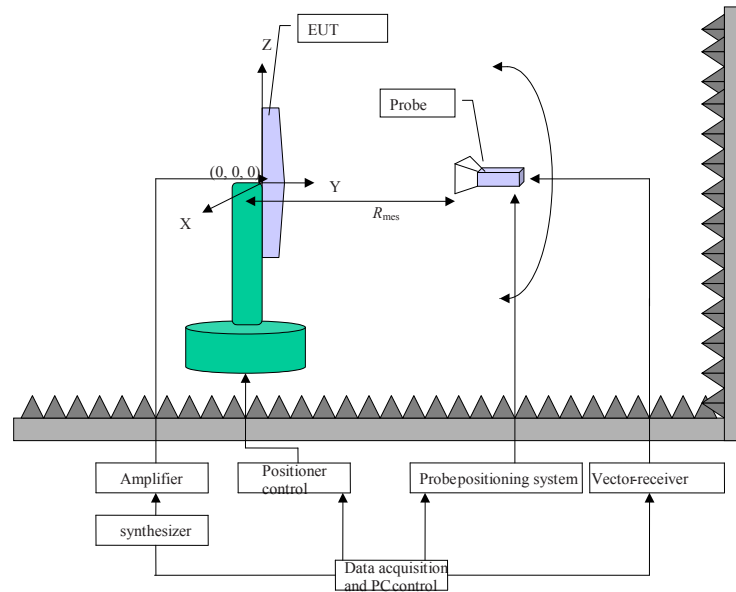


Figure 3 – Block diagram of the near-field antenna measurement system

The following equipment is required:

- anechoic chamber;
- electric probe(s) (antenna(s));
- support structure for probe(s);
- supporting structure;
- vector receiver;
- synthesiser and amplifier(s);
- probe positioning system or probe array controller system;
- EUT positioning system.

A computer controls the measurement equipment located in the anechoic chamber. The computer shall be placed so as not to influence the measurements.

The test shall be performed using probe antennas providing electric field measurements. The probe antennas shall be accurately positioned to measure the electric field distributions in a spherical surface around the EUT.

The measurement shall be carried out with a minimum of reflections from the environment in order to simulate free space conditions.

6.2.2.1.2 Scanning equipment: positioning and orientation requirements

6.2.2.1.2.1 General criteria

The measurement system shall be able to scan a specified spherical surface of the test environment. In order to provide sufficient data required combined with the resolution and accuracy needed for post-processing;

- the radius R_{mes} between the reference point of the EUT (0, 0, 0) and the probe(s) at each of the measurement points shall be chosen to satisfy the radius criteria (ref. 6.2.2.1.2.2) and shall be established within $\lambda/72$ m i.e. a phase accuracy of better than 5 degrees [see reference Clause B.3].

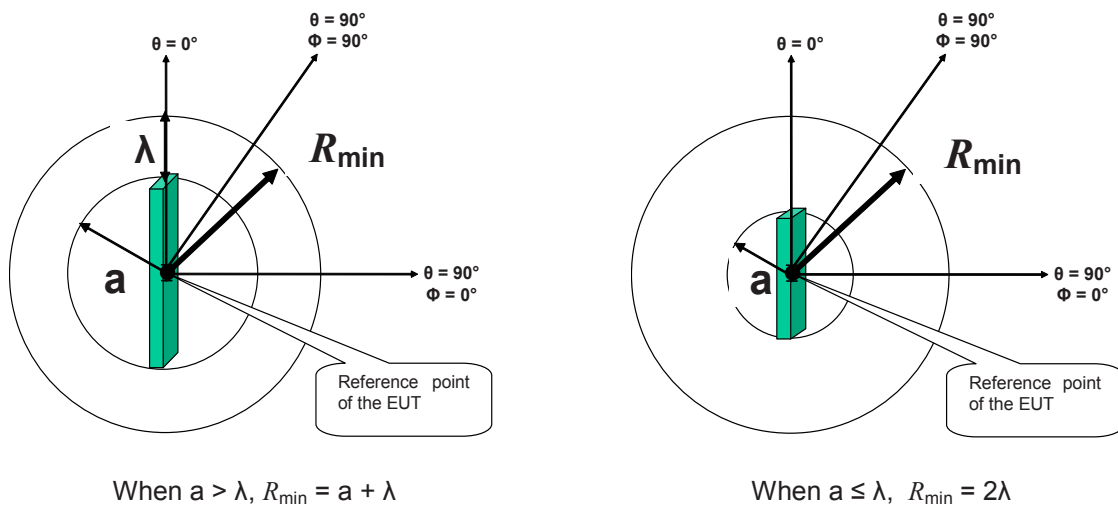
- the measurement system shall be able to provide measurements every $\delta\theta$ in elevation and $\delta\phi$ in azimuth to satisfy the sampling criterion as defined in 6.2.2.1.2.3 with an angular accuracy better than 0,5 degrees.

The sampling of the whole spherical surface is achieved through the rotation of the EUT or the structure supporting the probe(s). Several types of positioning systems are proposed in Annex B.

6.2.2.1.2.2 Radius criteria

R_{mes} the distance between the reference point of the EUT at origin of rotation and the measurement probe(s) shall be the greater of

- R_{min} in order to minimise the impact of the non-radiating near fields where R_{min} depends upon the maximum dimension of the EUT and the wavelength λ Figure 4; and
- the distance required to ensure that the probes and measurement equipment is operating within their calibrated level range for the power specifications of the EUT.



Where:

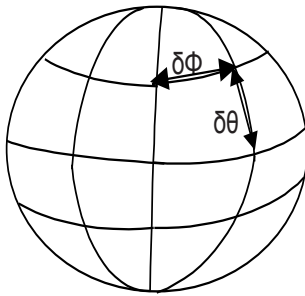
a = the minimum radius of a sphere, centred at reference point, that will encompass the EUT.

Figure 4 – Minimum radius constraint

6.2.2.1.2.3 Sampling criterion

The sampling criterion (also commonly called Nyquist criteria) requires a maximum angular spacing of the measurement points of $\lambda/2$ over the sphere circumscribing the EUT with radius R_{mes} .

The angles $\delta\phi$ (azimuth) and $\delta\theta$ (elevation) between adjacent measurements depend on the system but shall comply with the constraints of Figure 5.



$$\delta\phi \leq \frac{\lambda}{2R_{mes}}$$

$$\delta\theta \leq \frac{\lambda}{2R_{mes}}$$

Figure 5 – Maximum angular sampling spacing constraint

6.2.2.1.2.4 Constraints on EUT dimensions for specific measurement system

Given the radius R_{mes} equal to the constant distance between the center of rotation of the EUT and the probe(s), and given the number N equidistant sampling points in elevation or azimuth, each of the above criteria leads to a maximum dimension D_{max} for the EUT:

$$D_{max} < 2(R_{mes} - \lambda)$$

Where $D_{max} = 2a$ (see Figure 4)

and

$$D_{max} < 2\lambda\left(\frac{N}{2\pi} - 1\right)$$

Depending on the operating frequency, the maximum size will be limited by the most constraining of both criteria (i.e. the first criteria at lower frequencies and the second criteria at higher frequencies).

6.2.2.1.3 Measurement probe

The probe or probe array shall be designed and dimensioned such as not to disturb the electromagnetic fields generated by the EUT.

The probe(s) gain shall be calibrated with a measurement uncertainty less than $\pm 0,5$ dB.

The probe shall be able to provide orthogonal polarisation with cross-polar isolation better than 30 dB. Alternatively, a second scan with a probe rotated by 90 degrees could detect the cross-polar values.

Typically open-ended waveguides (OEW) or crossed dipoles are used, as they have a well-defined radiation characteristic and a low influence on the EUT.

6.2.2.1.4 Supporting structure

The antenna shall be mounted on a dielectric holder fixed on the positioning system. The holder shall be made of low conductivity and low relative permittivity material(s): $\tan(\delta) \leq 0,05$ and $\epsilon_r \leq 5$.

Alternatively, the antenna may be mounted on a metallic pipe mast, if this is the normal operating situation of the antenna. If the mounting situation differs from a free-space equivalent, this has to be documented in the measurement results.

The antenna shall be mounted so that the reference point (0, 0, 0) is in the centre of the sphere.

6.2.2.1.5 Vector-receiver

The dynamic range shall be more than 90 dB. To minimise external interference, a phase locked loop (PLL) system is preferred. The receiver shall be able to measure the magnitude and phase for every detection point.

6.2.2.2 Anechoic chamber

The level of perturbation due to reflections and/or noise, shall not exceed - 30 dB of the incident field where measurements are made.

If no PLL-system is used, the shielding level of the anechoic chamber enclosure should be better than 50 dB at the measurement frequencies.

The size and cover materials of the anechoic chamber shall be evaluated in order to minimise the level of perturbation due to reflections. The methodology to evaluate the chamber reflectivity is given in Clause B.3.

Ambient temperature shall be in the range of 10 °C to 30 °C and shall not vary by more than ± 5 °C during the test.

6.2.2.3 Measurement protocol

6.2.2.3.1 Calibration of the test facility

Four calibrations of the near field spherical test facility shall be performed:

- polarisation calibration;
- amplitude and phase calibration (uniformity between probe(s));
- gain calibration;
- electrical noise evaluation.

The measurement equipment shall be calibrated as a complete system at the appropriate frequencies according to the methodology defined in Annex B. Calibration guidelines are given in Clause B.6.

6.2.2.3.2 Test to be performed

The test shall be performed at the fixed power matched to the detection range of the measurement equipment.

Post-processing will derive the results at the desired input power values.

For multi-mode and multi-band EUTs, all the previous tests shall be performed in each operating transmitting band (see 5.2).

6.2.2.3.3 General requirements for the Equipment Under Test (EUT)

Surface scanning shall be used to define the EUT electromagnetic field parameters. The EUT shall be fed with frequencies comparable to normal configurations. A generator may replace the transmitter providing the input power to the EUT. Power scaling is addressed by the post-processing in 6.2.2.4.

For a base station with an integrated antenna, special care has to be taken to phase-lock the system.

6.2.2.3.4 Measurement procedure

6.2.2.3.4.1 Basic test configuration

The basic test configuration corresponds to an initial angle $\phi = \phi_0$ (azimuth).

The angular scan θ (elevation) shall start at one of the edges of the circular path and be incremented by a value $\delta\theta$. The angular scan in elevation shall be performed along the whole circular path.

At each $\theta_i = \theta_{i-1} + \delta\theta$ position of the probe(s), the received or emitted signal shall be recorded.

The basic test configuration will be repeated for each azimuthal increment $\delta\phi$.

6.2.2.3.4.2 Pre-test procedure

Check if the detection probe(s) can accept the power levels radiated during the measurements. Calibrate the electric and/or magnetic probe(s) in gain. Alternatively, confirm that the absolute values of the electromagnetic fields can be derived from the measurement data over the whole sphere.

Check the frequencies for the measurement. A minimum of 3 frequencies are required: F_c , $F_{\min}$ and $F_{\max}$ with:

F_c centre frequency;

$F_{\min}$ lower edge frequency;

$F_{\max}$ upper edge frequency.

Check the value of $\delta\phi$, $\phi_{\max}$, $\delta\theta$, $\theta_{\min}$, $\theta_{\max}$, R_{mes} with:

$\delta\phi$ azimuthal increment;

$\phi_{\max}$ maximum azimuthal angle value from the reference;

$\delta\theta$ elevation increment;

$\theta_{\min}$ lower edge angle of the circular elevation path;

$\theta_{\max}$ upper edge angle of the circular elevation path;

R_{mes} radius of the scan in elevation;

$D_{\max}$ largest dimension of the EUT (= 2a, Figure 4);

λ wavelength.

Confirm that the total contribution of interferences and reflected signals is less than – 30 dB below the incident signal.

6.2.2.3.4.3 Test procedure

- Confirm proper operation of the probe(s), measurement system and instrumentation.
- Mount the EUT in the measurement configuration.
- Configure the EUT for optimum output power, at the desired frequency and for the desired operating modes.
- Position (or configure) the probe(s) at the initial measurement location.
- Perform an initial elevation scan at the reference azimuth position and store the data.

- The detected electromagnetic fields amplitude and phase in both polarisations shall be output in ISU (International System Unit, V/m for electric field and A/m for magnetic field). Any conversion shall be done using the appropriate factors delivered from the calibration.
- Measure and acquire the electromagnetic fields distribution.
- The EUT or the probe(s) are moved incrementally in azimuth with $\Delta\phi$ angle step around a vertical axis that corresponds also to a symmetry axis for the sphere to be scanned.
- Repeat the electromagnetic fields measurement until $\phi_i = \phi_{\max}$ (with $\phi_i = \phi_{i-1} + \delta\phi$, with $i_{\min} = 1$).
- After measurements, perform again a final elevation scan at the reference azimuth position and compare the data with the initial elevation scan. Verify that the final values at the maximum levels are within 5 % of the initial values (influence of the drift due to surrounding equipment and environment).
- If the drift is greater than 5 %, repeat the measurements.

6.2.2.4 Post-processing

6.2.2.4.1 General

The electromagnetic field values shall be obtained by applying a post-processing technique on the set of measured near field data (see Clauses B.4 and B.5).

6.2.2.4.2 Determining electromagnetic field values outside the scanned surface

The electromagnetic fields from the EUT shall be modelled by a number of isotropic sources radiating from the scanned surface. At a point of investigation, the vector sum of the fields radiated by these sources is the same as from the EUT. The input to this model is the tangential electromagnetic field measured on the surface surrounding the EUT. The electromagnetic field values shall be calculated for points of investigation outside the scanned surface for the EUT as described in the Clause B.4.

6.2.2.4.3 Determining electromagnetic field values within the scanned surface

The electromagnetic field values shall be calculated for points of investigation inside the volume surrounded by the scanned surface but outside the minimum sphere surrounding the EUT (see Clauses B.4 and B.5).

6.2.2.4.4 Scaling measurements to a given input power

The calculated E -field (resp. H -field), E_o (resp. H_o), is obtained for a given input power P_o . As the E -field (resp. H -field) is proportional to the square root of the input power, the E -field (H -field), E (resp. H) for another input power P is given by:

$$E = \sqrt{\frac{P}{P_o}} E_o \quad H = \sqrt{\frac{P}{P_o}} H_o$$

Where a number of frequencies may be operated simultaneously on one or more bands, scaling of the E^2 , H^2 and S values shall be applied linearly on each band separately according to the number of equal powered transmit frequencies on each band.

6.2.2.5 Uncertainty estimation

6.2.2.5.1 General requirements

The assessment of uncertainty in the measurement of the electromagnetic fields values shall be based on the general rules provided by the ISO/IEC Guide 98-3. An evaluation of type A as well as type B of the standard uncertainty shall be used.

When a Type A analysis is performed, the standard uncertainty (u_i) shall be derived from the estimate from statistical observations. When type B analysis is performed, u_i comes from the upper (a_+) and lower (a_-) limits of the quantity in question, depending on the distribution law defining $a = (a_+ - a_-)/2$, then:

- Rectangular law: $u_i = a/\sqrt{3}$
- Triangular law: $u_i = a/\sqrt{6}$
- Normal law: $u_i = a/k$ where k is a coverage factor
- U-shaped (asymmetric): $u_i = a/\sqrt{2}$

6.2.2.5.2 Components contributing to uncertainty

6.2.2.5.2.1 Contribution of the measurement equipment

6.2.2.5.2.1.1 Calibration of the measurement equipment

A protocol for evaluation of sensitivity (or calibration) is given in Annex B including an approach to uncertainty assessment. The uncertainty in the sensitivity shall be evaluated assuming a normal probability distribution.

6.2.2.5.2.1.2 Probe linearity

The receiver and probe linearity shall be assessed according to the protocol defined in Annex B. A correction shall be performed to establish linearity. The uncertainty is considered after this correction. The uncertainty due to linearity shall be evaluated assuming it has a rectangular probability distribution.

6.2.2.5.2.1.3 Measurement device

The uncertainty contribution from the measurement device (e.g. vector receiver) shall be assessed with reference to its calibration certificates. The uncertainty due to the measurement device shall be evaluated assuming a normal probability distribution.

6.2.2.5.2.1.4 Electrical Noise

This is the signal detected by the measurement system even if the EUT is not transmitting. The sources of these signals include RF noise (lighting systems, the scanning system, grounding of the laboratory power supply, etc.), electrostatic effects (movement of the probe, people walking, etc.) and other effects (light detecting effects, temperature, etc.).

The noise level shall be determined by three different coarse scans with the RF source switched off or with an absorbing load connected to the output of the transmitter. None of the evaluated points shall exceed - 30 dB of the lowest incident field being measured. Within this constraint, the uncertainty due to noise shall be neglected.

6.2.2.5.2.1.5 Integration time

The integration time shall not introduce additional error if the EUT emits a continuous wave (CW) signal. This uncertainty depends on the signal characteristics and must be evaluated prior to any electromagnetic fields measurements. If a non-CW signal is used, then the uncertainty introduced must be taken into account in the global uncertainty assessment. The uncertainty due to integration time shall be evaluated assuming it has a normal probability distribution.

6.2.2.5.2.1.6 Contribution of the power chain

The mismatch in the power chain leads to an uncertainty in the evaluation of the emitted power from the power measured by the power meter. See Annex B for an evaluation of this uncertainty in a typical case.

6.2.2.5.2.2 Contribution of the mechanical constraint

6.2.2.5.2.2.1 Mechanical constraints of the positioning system

The mechanical constraints of the positioning system introduce uncertainty to the electromagnetic fields measurements through the accuracy and repeatability of positioning. These parameters shall be assessed with reference to the positioning system's specifications and the uncertainty they introduce shall be neglected provided that the specifications comply with the criteria defined for the equipment.

6.2.2.5.2.2.2 Matching between probe and EUT reference points

Before each scan the alignment between position of the probe and the EUT shall be verified using three reference points.

6.2.2.5.2.3 Contribution of physical parameters

6.2.2.5.2.3.1 Drift in input power of the EUT, probe, temperature and humidity

The drift due to electronics of the EUT and the measurement equipment, as well as temperature and humidity, are controlled by the first and last step of the measurement process defined in the measurement procedure and the resulting error is less than $\pm 5\%$. The uncertainty shall be evaluated assuming a rectangular probability distribution.

6.2.2.5.2.3.2 Perturbation of the environment

The perturbation of the environment results from various contributing factors:

- reflection of wave in the laboratory;
- influence of the EUT and probe(s) positioners;
- influence of cables and equipment's;
- background level of electromagnetic fields.

6.2.2.5.2.4 Contribution of post-processing

This is the uncertainty due to the post-processing applied to the measured data. The post-processing covers a series of mathematical operations to transform the electromagnetic fields measured over a spherical surface into the electromagnetic fields inside or outside of a volume around the antenna.

The post-processing uncertainty depends on five main error contributions:

- error due to the finite angular sampling (Nyquist criteria);
- error due to the interpolation process if applied (interpolation of measured data to increase the sampling resolution);
- error due to the probe correction (approximation of the probe by a dipole);
- error due to the finite number of Spherical Wave Expansion (SWEF) coefficients retained for the retro-propagation (truncation of a series of infinite number of terms);
- errors depending on the distance of retro-propagation: ideally, the retro-propagation can be performed until the minimum sphere enclosing the radiating EUT. Practically, this minimum distance depends on the number of SWEF coefficients that have been retained during the retro-propagation process.

The resulting uncertainty shall be evaluated assuming a rectangular probability distribution.

6.2.2.5.3 Uncertainty assessment

6.2.2.5.3.1 Combined and expanded uncertainties

The contributions of each component of uncertainty shall be registered with their name, probability distribution, and sensitivity coefficient and uncertainty value. The results shall be recorded in a table of the following form. The combined uncertainty shall then be evaluated according to the following formula:

$$u_c = \sqrt{\sum_{i=1}^m c_i^2 \cdot u_i^2}$$

where

c_i is the weighting coefficient (sensitivity coefficient).

The expanded uncertainty shall be evaluated using a confidence interval of 95 %.

Table 1 – Uncertainty assessment

UNCERTAINTY SOURCES	Description (subclause)	Uncertainty Value %	Probability Distribution	Divisor	c_i	Standard Uncertainty %
Measurement Equipment	6.2.2.5.2.1					
Calibration			Normal	1 or k	1	
Linearity			Rectangular	$\sqrt{3}$	1	
Measurement device			Normal	1 or k	1	
Noise			Normal	1	1	
Integration time			Normal	1	1	
Power chain			Normal	1	1	
Mechanical constraints	6.2.2.5.2.2					
Positioning system			Rectangular	$\sqrt{3}$	1	
Matching between probe and the EUT			Rectangular	$\sqrt{3}$	1	
Physical Parameters	6.2.2.5.2.3					
Drifts in output power of the EUT, probe, temperature and humidity			Rectangular	$\sqrt{3}$	1	
Perturbation by the environment			Rectangular	$\sqrt{3}$	1	
Post-Processing	6.2.2.5.2.4					
Contribution of post-processing			Rectangular	$\sqrt{3}$	1	
Combined standard uncertainty			$u_c = \sqrt{\sum_{i=1}^m c_i^2 \cdot u_i^2}$			
Expanded uncertainty (confidence interval of 95 %)			Normal			$u_e = 1,96 u_c$

6.2.2.5.3.2 Maximum expanded uncertainty

After scaling post-processing, the expanded uncertainty shall not exceed 30 % of the E or H fields for values between 30 % and 200 % of the referred limits. For E and H values below 30 % of the referred limits, the absolute uncertainty (derived from the expanded uncertainty) shall not exceed 30 % of the referred limits.

6.3 Volume scanning method

6.3.1 General

Direct measurements of electric and magnetic fields are made at sufficient points of investigation in a volume surrounding the EUT to establish the compliance boundary.

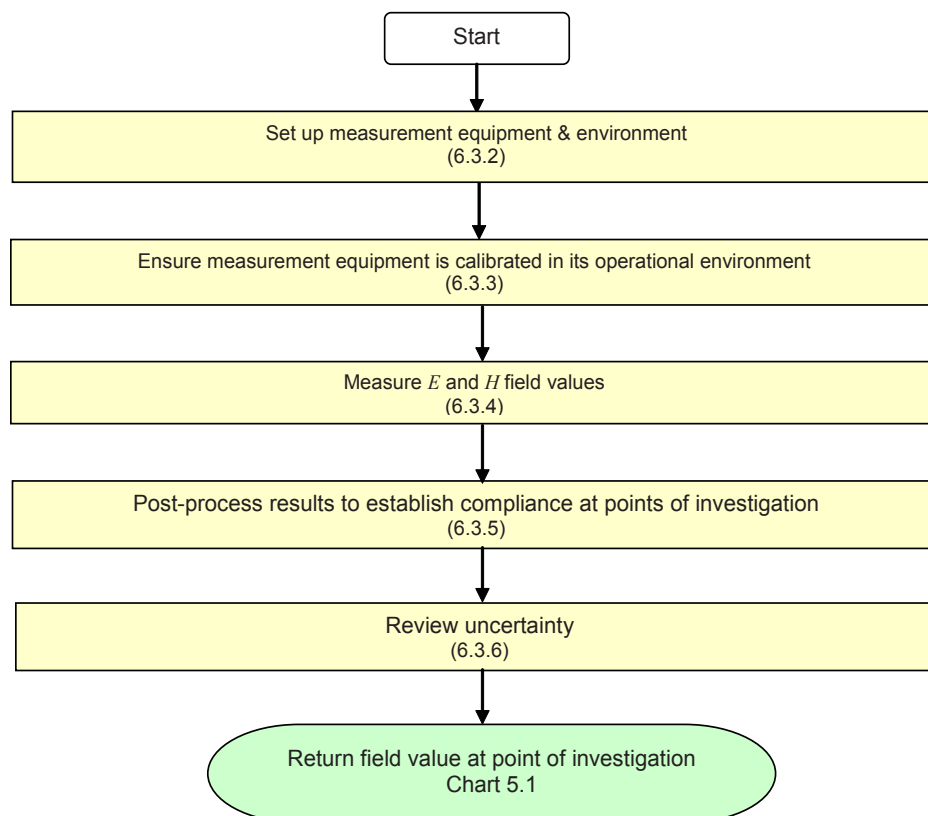


Figure 6 – Outline of volume scanning methodology

6.3.2 Measurement equipment and test environment

6.3.2.1 General description

The volume scanning equipment consists of an isotropic probe and a structure to hold the EUT and the probe allowing a 3D movement between the two all located in a suitable test site.

The following equipment may be required: