Corrigendum to EN 50383:2010

English version

Due to a mistake in the numbering, the whole Clause 6 needs to be renumbered.

Please note that the content of Clause 6 has not been modified.

Replace *the entire Clause 6 by the following:*

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 1.

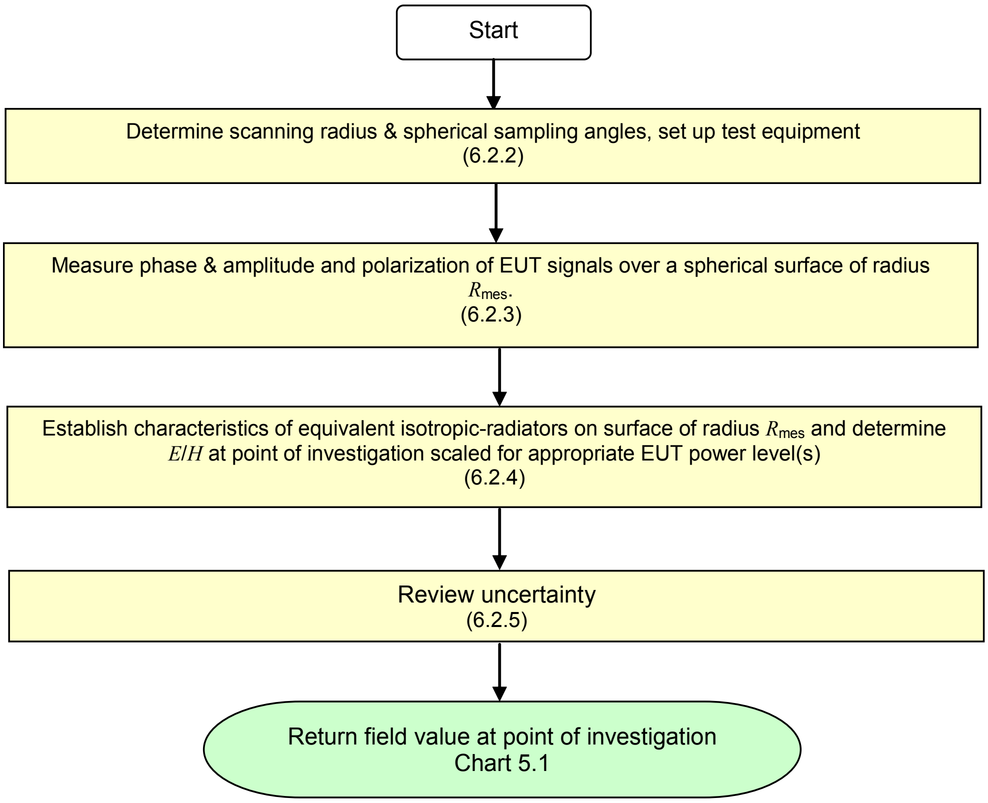


Figure 1 – Outline of the surface scanning methodology

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 2.

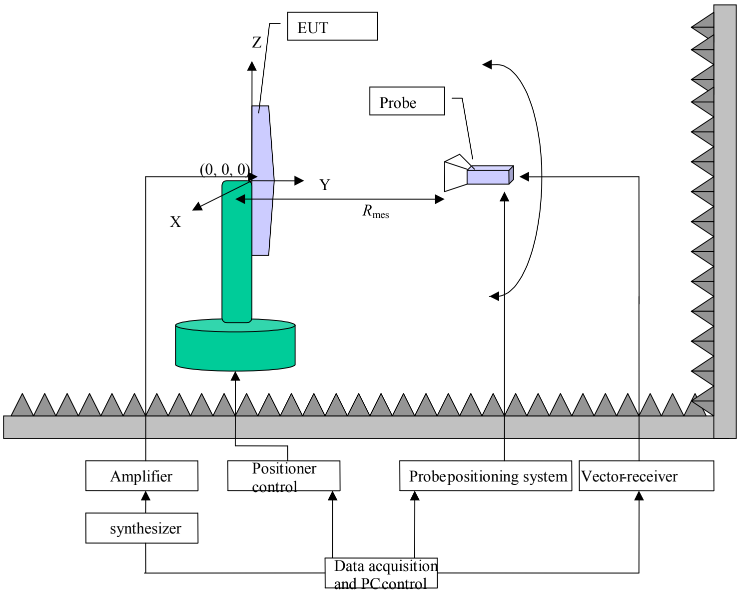


Figure 2 – Block diagram of the near-field antenna measurement system

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 λ/72 m i.e. a phase accuracy of better than 5 degrees [see reference Clause B.3].

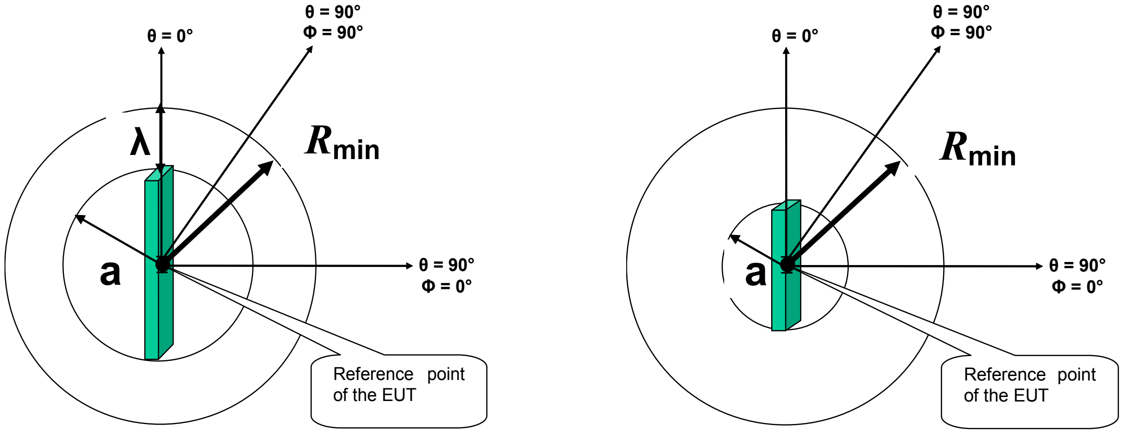
- the measurement system shall be able to provide measurements every $\delta\theta$ in elevation and $\delta\phi$ in azimuth to satisfy the sampling criterion as defined in 6.2.2.1.2.3 with an angular accuracy better than 0,5 degrees.

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 3; 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.



When a > λ, $R_{\text{min}} = a + \lambda$

When a ≤ λ, $R_{\text{min}} = 2\lambda$

Where:

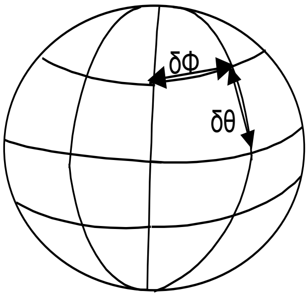
a = the minimum radius of a sphere, centred at reference point, that will encompass the EUT.

Figure 3 – 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 4.



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

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

Figure 4 – 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 3)

and

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

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 ± 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(δ) ≤ 0,05 and $\varepsilon_r \leq 5$.

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 $\delta\phi$, ϕ_{max}, $\delta\theta$, θ_{min}, θ_{max}, R_{mes} with:

$\delta\phi$	azimuthal increment;
ϕ_{max}	maximum azimuthal angle value from the reference;
$\delta\theta$	elevation increment;
θ_{min}	lower edge angle of the circular elevation path;
θ_{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 3);
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:

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

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_j) shall be derived from the estimate from statistical observations. When type B analysis is performed, u_j 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 ± 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 (SWEP) 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 SWEP 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.

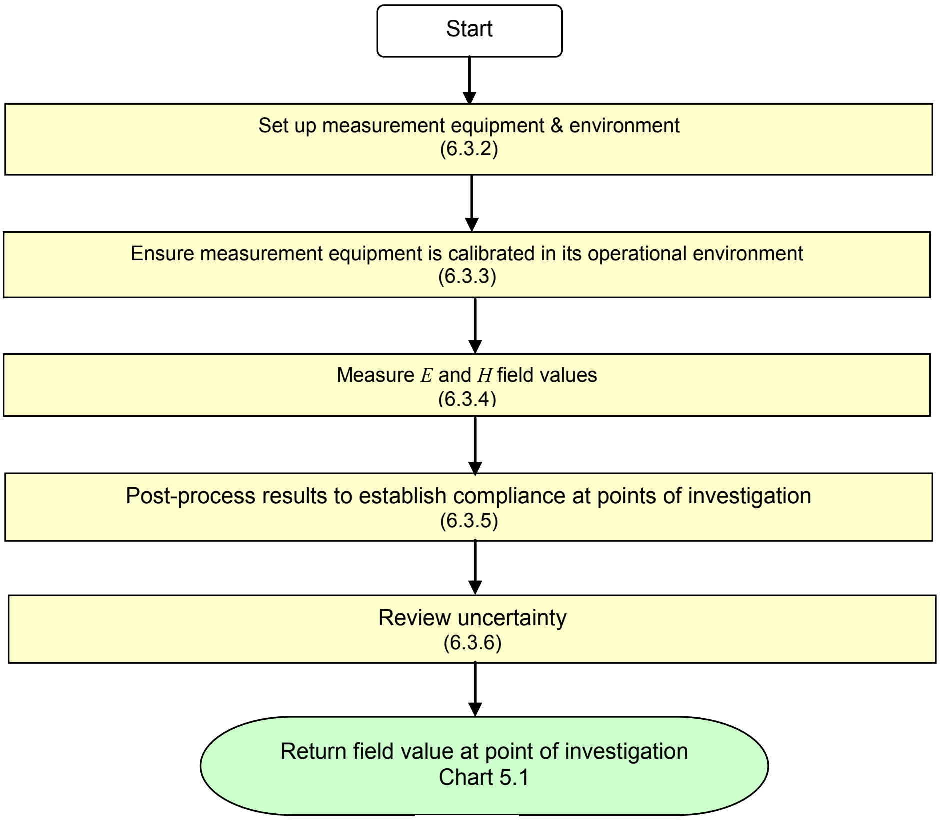


Figure 5 – Outline of volume scanning methodology

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:

- Anechoic chamber or suitable test site;
- Electric and/or magnetic isotropic probe;
- Supporting structure for isotropic probe;
- Supporting structure for the EUT;
- Synthesiser and amplifier(s);
- Isotropic probe positioning system or Probe array controller system;
- EUT positioning system;
- Receiver or other measurement device.

A computer may be used to control the measurement equipment. The test equipment shall be placed so as not to influence the measurements. A typical near-field EUT measurement system configuration is shown in Figure 6.

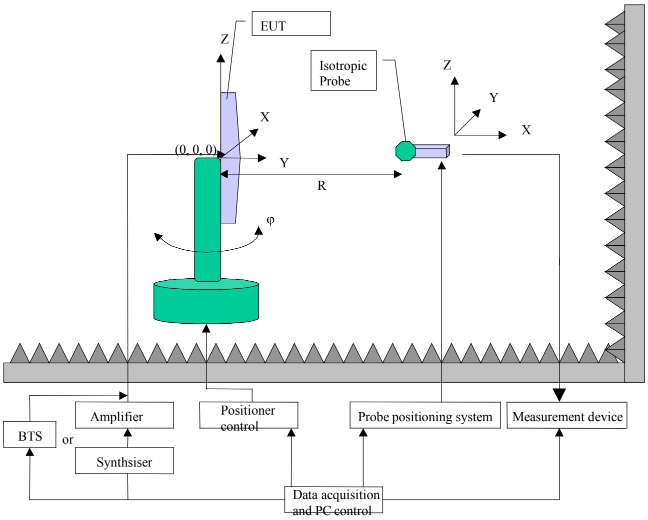


Figure 6 – Block diagram of the near-field EUT measurement system

6.3.2.2 Scanning equipment

The positioning system holding the EUT and the isotropic probe shall be able to scan a specified volume of the test environment.

The sampling of the specified volume is achieved through the relative displacements, translation and rotation, between the structure supporting the probe and the EUT. The measurement then may be carried out as a set of scans on cylindrical, spherical or planar surfaces.

Accuracy

The accuracy of the probe tip positioning over the measurement area shall be less than ± 0,5 cm.

Sampling resolution

The sampling resolution is the step at which the measurement system is able to perform measurements. The sampling resolution shall be $\lambda/10$ or less.

Co-ordinate systems

Alternative co-ordinate systems may be used Figure 7.

The reference axes are defined by:

- X the distance in front of the antenna, or $\theta = 90^\circ$ $\Phi = 0^\circ$ in the spherical co-ordinate system;
- Y the distance on the side of the antenna, or φ the angle in the cylindrical co-ordinate system;
- Z the height along the antenna axis, or $\theta = 0^\circ$ in the spherical co-ordinate system.

The origin of the co-ordinate system shall be defined, for instance by the centre of the back panel in case of panel antennas, and the centre of the antenna in case of omni-directional antennas.

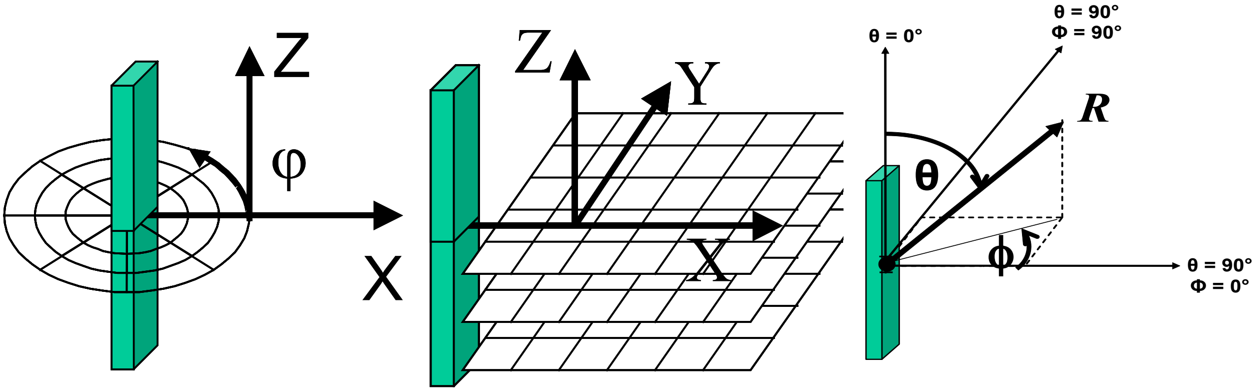


Figure 7 – Cylindrical, Cartesian and Spherical co-ordinates defined relative to the EUT

6.3.2.3 Measurement equipment

The measurement equipment shall be composed of the isotropic probe and the measurement device (e.g. voltmeter).

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

The measurement equipment shall have a measurement range compatible with the RF power levels used in the test and the resulting fields at the points of observation.

Typically, if an E-field measurement equipment is used:

- the minimum detection limit shall be lower than 3 V/m and the maximum detection limit shall be higher than 200 V/m.

Typically, if an H-field measurement equipment is used:

- the minimum detection limit shall be lower than 0,03 A/m and the maximum detection limit shall be higher than 0,6 A/m.

The linearity of E-field and H-field measurement equipment shall be within ± 1 dB within the measurement range and the isotropy of measurements shall be within ± 1 dB.

6.3.2.4 Supporting structure for the EUT

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 $\varepsilon_r \leq 5$.

Alternatively, the antenna may be mounted at a metallic support, if this is the normal operating situation of the antenna. If the mounting situation differs from a free-space equivalent, this shall be documented in the measurement results.

6.3.2.5 Input power specifications

The EUT shall be fed with frequencies comparable to normal configurations. A RF source, e.g. a generator or a synthesiser & amplifier, may replace the transmitter providing the input power to the EUT. Power scaling is provided by post-processing in 6.2.2.4.

Enough power shall be available to generate a field level in the detection range of the measurement equipment at the greatest measurement distance.

The power chain is typically composed of a signal synthesiser with a power amplifier, a coupler connected to a power meter and a cable to the antenna.

The test signal source / Base Station System shall be operated according to the manufacturer's instructions in order to ensure the RF power output stability throughout the test campaign. Typically, this may require the signal source / Base Station System to be operational at the required output power for 1 h prior to commencement of the test campaign in order to achieve thermal equilibrium.

The power chain shall be carefully evaluated in order to estimate accurately the input power fed into the antenna.

6.3.2.6 Test site

The test site shall be evaluated in order to minimise the level of perturbation due to reflections or ambient noise, which shall not exceed - 25 dB of the incident field at any point of observation. The methodology to evaluate the test site 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.

6.3.3 Calibration of the test facility

6.3.3.1 General

The measurement system shall be calibrated as a whole system at appropriate frequencies. Guidelines for calibration are proposed in Clause B.2.

6.3.3.2 Isotropy

The probe shall be exposed to a reference wave with varying angles of incidences. The hemispherical isotropy shall be determined by rotating either the probe or the polarisation of the reference wave. The angles of incidence shall vary from 90° (axial) to 0° (normal) with a step of less than 30°. For each incidence, the probe shall be rotated with a range of 360° and a step less than 15°.

6.3.3.3 Linearity

The evaluation of the linearising functions is performed in free space by a power sweep covering the requested detection range.

The linearity is defined by the maximum deviation over the measurement range of the measured quantity from the closest linear reference curve defined over the linearity interval. The power shall be increased by steps no larger than 1 dB over the linearity interval.

6.3.3.4 Detection limits

The lower detection limit is defined by the noise level plus 0,5 dB.

The upper detection limit is defined by the saturation level minus 0,5 dB.

The lower detection limit is related to the noise level, offset and asymmetry of the measurement system. Saturation and other non-linearity effects define the upper detection limit. The lower and upper limit can be assessed with various set-ups. It is defined as the level from which the response deviates from linearity by more than 0,5 dB. In actual operational conditions of the measurement system, the lower detection limit may be impaired by the background EM environment.

6.3.4 Measurement Protocol

6.3.4.1 General

6.3.4.1.1 Simplified performance checking

The measurement system shall be validated performing a scan of a calibrated reference antenna, e.g. a dipole.

For instance the measurements may be compared, in the far field, to the reference field given by the far-field formula:

$$E = \frac{\sqrt{30.P.G}}{R} \qquad H = \frac{E}{\eta_0} = \frac{\sqrt{P.G}}{69.R}$$

where

P is the input power of the reference antenna (W);

G is the gain in the main beam of the reference antenna;

R is the distance between the probe and the reference antenna (m);

η_0 is the impedance of free space.

The tolerable error on the performance checking shall be below ± 1 dB.

6.3.4.1.2 General requirements for scanning sampling

Different coordinate systems may be used for scanning sampling (see Figure 7).

The angular orientation of the antenna in relation to the measurement point shall be established within 2 % of the nominal - 3 dB beamwidth of the antenna under test, in E and H planes as appropriate.

The measurements shall not be performed in the reactive near-field of the EUT if it cannot be shown that the field disturbance due to coupling is below 3 %.

For Cartesian and cylindrical scans, at distances X shorter than 3λ, the sampling step shall be shorter than $\lambda/2$ in the Z and Y (resp. φ) axis, and shorter than λ after.

For Spherical scans, at distances R shorter than 3λ, the step in sampling angles Φ, θ shall be chosen so that the shortest distance along the surface of the sphere between adjacent points of investigation is less than $\lambda/2$ and less than λ after.

6.3.4.2 Measurement procedure

- Mount the EUT in the measurement configuration.
- Configure the EUT for optimum output power at the desired frequency and for the desired operating modes.
- Perform an initial E-field or H-field measurement at the reference position P_r close to the antenna (but greater than $\lambda/2$) and store the data for the power drift check.
- Perform 3D scanning around the EUT, according to the general requirements defined in 6.3.4.1.2 to acquire the electromagnetic fields distribution.
- As a final step in the test, repeat the E-field or H-field measurement at the reference position P_r. If the field value deviates more than 5 % from the initial values then the power chain shall be checked, and the test repeated.

6.3.5 Post-processing

6.3.5.1 Interpolation of measurements

Evaluation of the E or H field at points of investigation shall be done by direct measurement and/or by interpolation between measurement points.

6.3.5.2 Scaling measurements to a given input power

The measured 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:

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

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.

6.3.6 Uncertainty estimation

6.3.6.1 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_j) shall be derived from the estimate from statistical observations. When Type B analysis is performed, u_j 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): $u_i = a/\sqrt{2}$

6.3.6.2 Components contributing to uncertainty

6.3.6.2.1 Contribution of the measurement equipment

6.3.6.2.1.1 Calibration of the measurement equipment

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

6.3.6.2.1.2 Probe isotropy

The hemispherical isotropy of the probe shall be measured according to the protocol defined in B.2.4. The uncertainty due to isotropy shall be evaluated with a rectangular probability distribution.

6.3.6.2.1.3 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.

6.3.6.2.1.4 E-field or H-field values out of measurement range

Errors may be introduced if local measurements are outside the measurement range of the measurement device. If an E-field or H-field level is below the lower detection limit, then the value of the measurement device detection limit shall be used. If the E-field or H-field level is above the upper measurement device limit then the measurement shall be considered invalid.

The uncertainty due to detection limits shall be evaluated assuming it has a rectangular probability distribution.

6.3.6.2.1.5 Measurement device

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

6.3.6.2.1.6 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 electrical 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 - 25 dB of the lowest incident field being measured. Within this constraint, the uncertainty due to noise shall be neglected.

6.3.6.2.1.7 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.

6.3.6.2.1.8 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.

6.3.6.2.2 Contribution of the mechanical constraint

6.3.6.2.2.1 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. The uncertainty in distance between the measurement point and the EUT shall be added directly to the compliance distance and shall play no other part in uncertainty calculations.

6.3.6.2.2.2 Matching between probe and EUT references

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

6.3.6.2.3 Contribution of physical parameters

6.3.6.2.3.1 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 ± 5 %. The uncertainty shall be evaluated assuming a rectangular probability distribution.

6.3.6.2.3.2 Perturbation by the environment

The perturbation of the environment results from various contributing factors:

- reflection of wave in the laboratory;
- influence of the EUT and isotropic probe positioned;
- influence of cables and equipment;
- background level of electromagnetic fields.

6.3.6.2.4 Contribution of the post-processing

6.3.6.2.4.1 Interpolation

The error introduced by the extrapolation and interpolation algorithms shall be evaluated assuming a normal probability distribution.

6.3.6.3 Uncertainty assessment

6.3.6.3.1 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 (Table 3) 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 2 – Uncertainty assessment

UNCERTAINTY SOURCES	**Description (subclause)**	**Uncertainty Value for E and H** %	**Probability Distribution**	**Divisor**	c_i	**Standard Uncertainty** %
Measurement Equipment	6.3.6.2.1					
Calibration			Normal	1 or k	1	
Isotropy			Rectangular	$\sqrt{3}$	1	
Linearity			Rectangular	$\sqrt{3}$	1	
Fields out of measurement range			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	6.3.6.2.2					
Positioning system			Rectangular	$\sqrt{3}$	1	
Matching between probe and the EUT			Rectangular	$\sqrt{3}$	1	
Physical Parameters	6.3.6.2.3					
Drifts in output power of the EUT, probe, temperature and humidity			Rectangular	$\sqrt{3}$	1	
Perturbation by the environment			Rectangular	$\sqrt{3}$	1	
Combined standard uncertainty			$u_c = \sqrt{\sum_{i=1}^{m} c_i^2 \cdot u_i^2}$			
Expanded uncertainty (confidence interval of 95 %)			**Normal**	$u_e = 1{,}96\, u_c$		

6.3.6.3.2 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.

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