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Foreword

This European Telecommunication Standard (ETS) has been produced by the Equipment Engineering (EE) Technical Committee of the European Telecommunications Standards Institute (ETSI).

This ETS specifies the technical requirements for the radiated emission measurement procedure for physically large systems used within the public telecommunication network. A minimum representative system is defined, which is used for compliance testing of physically large telecommunication systems.

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1 Scope

This European Telecommunication Standard (ETS) specifies the technical requirements for the radiated emission measurement procedure for physically large systems used within the public telecommunication network, with the exception of radio equipment.

It applies to physically large systems which are comprised of equipments or systems requiring installation documentation specific for those sites at which they are to be installed. In order to demonstrate compliance of such systems, a minimum representative system is defined, which is used for compliance testing. Installations built from units of the complying minimum representative system are deemed to satisfy the radiated emission requirements.

The minimum representative system is representative of installed systems in terms of function (which includes at least one of each functional unit type) and electromagnetic radiation characteristics. The minimum representative system is subsequently referred to in this ETS as the Equipment Under Test (EUT), to be used for compliance testing.

Minimum representative systems shall be tested on an Open Area Test Site (OATS) or in a suitable chamber, the limits to be used are those as specified in EN 55022 [1].

2 Normative references

This ETS incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this ETS only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

[1] EN 55022 (1987): "Limits and methods of measurement of radio interference characteristics of information technology equipment".

[2] CISPR Publication No. 16: "CISPR/A(Central Office) 48 Revision to CISPR specification for radio interference measuring apparatus and measurement methods".

[3] IEC 50(161) (1990): "International Electrotechnical Vocabulary. Chapter 161: Electromagnetic compatibility".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of this ETS, the following definitions, together with those from IEC 50(161) [3], apply:

System: a set of sub-systems which, when connected together, produce a fully operational product and is intended to be marketed as such.

Sub-system: a grouping of functional units which perform specific functions within the host system and which communicates with other equipment via well-defined interfaces and protocols.

Functional unit: a grouping of electronic hardware which performs specific functions, but may be connected with other functional units to produce the required sub-system.

New functional module: a replacement and/or addition for any grouping or arrangement of electronic hardware (with its associated mechanical packaging and interconnections), which enhances or improves the system operation.

Test site: this should be an OATS, with reflecting ground plane, or a suitable chamber with reflecting ground plane.

Minimum representative system: the minimum representative system is representative of installed systems in terms of function (which includes at least one of each functional unit type) and electromagnetic radiation characteristics. This shall be equipped to at least the minimum configuration which could be offered for sale for use as an actual system. It excludes any operational equipment connected for the purpose of monitoring or system measurements and which are connected for a temporary period. An example of how the EUT is to be selected is given in figure 1.

Cable distribution point: the cable distribution point is the interface at which cabling shall be terminated; this unit is the point at which cabling from the system is connected to the cabling from external units.

Physically large system: a group of racks functionally connected to form a commercially specified system, which has a total dimension exceeding that which is practical for testing on a conventional 10 m test site.

3.2 Abbreviations

For the purposes of this ETS, the following abbreviations apply:

EUT	Equipment Under Test
OATS	Open Area Test Site

4 Requirements

For the purpose of defining the system boundary from which the test distance is taken, the equipment boundary shall be the straight line envelope around the EUT; this includes the cables specified for attachment to the EUT for the purpose of test. Measurement distances are to be taken from this line.

Physically large systems are modular in nature, i.e. they will generally be increased in size (and operational function) by the addition of like units. To ensure that the EUT is representative of installed systems, in terms of function and electromagnetic radiation, tests shall be repeated with the EUT configured with additional units.

If, by adding additional units, which generates synchronized noise, the emission levels do not increase 4 dB or more above the original maximum measured values, independent of frequency, then a minimum representative system in terms of radiation has been achieved. The additional units shall be composed to the largest possible extent of highest radiation sources, but they shall be typical of realistic installation.
If, with the increase of additional identical units, the radiation increases by more than 4 dB, then further additional units shall be added until the increase is less than 4 dB.

After the addition of identical units (as shown in figure 2), the measured field levels from the representative system shall not increase beyond compliance limits.

5 General operational conditions

5.1 Equipment configuration

The EUT shall conform to the manufacturer's normal installation practice. There exists for each EUT a minimum set of interface lines which is required for the operation of the system and this number shall be defined for each EUT and identified in the test report.

The sources of maximum emission shall be identified by measuring each functional unit on an individual basis and, where applicable, its position in a rack.

The EUT shall then be assembled in such a way that emissions are maximised within any limitations imposed by normal installation practice.

5.2 Equipment cable layout

5.2.1 Intra-system cabling

All cables internal to the system, and used for its operation, shall be connected and be of such a length and type required for the normal operation of the system. These shall be routed in accordance with the relevant system installation instructions, such that these are typical of an installed system.

If raised floor or overhead cabling systems are offered, both types of cabling systems shall be characterized by testing the equipment using those cable configurations (raised floor or overhead cabling). The worst case cable configuration shall be used in the EUT tests.

If raised floor systems be characterized as the worst case and used for testing, and if the inter-unit cable routing is into the raised floor system, the effect of the raised floor system shall be examined. The raised floor shall be left in place if it forms part of the system screen, but where the raised floor is not intended to be used as a screen, then in order to prevent incidental screening of emissions, the floor panels shall be removed for the duration of the test.

5.2.2 Interface cabling

Cables between the system, the distribution point and external units, shall be of the type as specified by the system supplier or as detailed by customer requirements, and shall follow the relevant system installation practice. Care must be taken to ensure that noise from the test and exercising equipment does not contribute to the emissions from the representative system. The method of orientating and terminating the cables shall be noted in the test report.

The emission contributions from the system, cables and distribution point (where all of these elements are involved) are difficult to separate; there are two cases to be considered:

1) unscreened cable systems;

2) screened cable systems.

Screening is achieved by one of two methods:

a) by use of screened cabling;

b) by the use of a screened floor or ducted systems in which unscreened cabling is run.

Measurement of these installation practices is performed as described in subclauses 5.2.2.1 and 5.2.2.2**.**

5.2.2.1 Unscreened cable systems

Wherever the distribution point is located, measurement shall be made using a length of unscreened cabling configured as described in subclauses 5.2.2.1.1 and 5.2.2.1.2. Beyond this minimum length, the cabling shall be taken off the measurement site below the ground plane to the exercising equipment. Where this is not practicable, the cabling may run in screened sleeving which is bonded to the measurement site ground plane.

Two types of cable installation practice shall be considered.

5.2.2.1.1 Overhead cable systems

An overhead cable system is defined as one where cables are routed above the equipment. On exiting from the EUT, all cabling shall run perpendicularly from the EUT in the horizontal plane for 1,5 metres, before dropping to the ground plane.

Support of the cabling shall be of the type specified by the system supplier, or as detailed by customer requirements, and shall follow the relevant system installation practice. Where the system supplier or customer do not specify cable supports, then non-conducting unscreened cable supports shall be used. The height and position of the cables shall be noted in the test report (see figure 3). The cabling shall be taken off the measurement site below the ground plane to the exercising equipment. Where this is not practicable, the cabling may run in screened sleeving which is bonded to the measurement site ground plane.

5.2.2.1.2 Raised floors

Where a raised floor system is used (but the raised floor does not form part of the screen) then all cabling shall drop through the raised floor towards the ground plane and run perpendicularly from the EUT in the horizontal plane for 1,5 metres, the raised floor being removed (see subclause 5.2.1). The cabling shall then be taken off the measurement site below the ground plane to the exercising equipment. Where this is not practicable, the cabling may run in screened sleeving which is bonded to the measurement site ground plane. All exposed, unscreened cabling, shall be on a support at a height of 10 cm (see figure 4).

The support shall be of the type specified by the system supplier, or as detailed by customer requirements, and shall follow the relevant system installation practice. Where the system supplier or customer do not specify cable supports, then non-conducting, unscreened cable supports shall be used.

5.2.2.2 Screened cable systems

Where a screened cabling system is used throughout the installation, cabling typical of the installation practice shall be used during testing. Coaxial cables connected to the system is an example of screened cabling.

Where screened cabling is used between a system and an unscreened distribution point, and unscreened cabling is used beyond that point, then a test configuration shall be adopted which exposes the unscreened cabling to the measurement antenna. This shall be achieved by arranging the EUT with an unscreened distribution point located at the closest possible point to the system and forming part of the EUT. The unscreened cabling shall then be exposed, following the principles as defined in subclause 5.2.2.1.

The length of screened cabling between the system and the unscreened distribution point shall be the minimum length which could be used on any real installation. This minimum length shall be defined by the system supplier and the excess length shall be bundled for low inductance. This length should be 10 m, unless otherwise specified. Figure 5 shows an example of such a test set-up.

5.3 Exercising equipment

The exercising equipment shall be sufficiently isolated from the EUT such that the exercising equipment does not significantly influence the test results.

5.4 Laboratory environment

Unless otherwise specified, the test environment shall conform to the manufacturer's operating climatic conditions for the equipment.

6 Test results report

The test report shall include all test conditions and results together with the methods of test used. The selection shall show that the functional units so tested are those that would form the basis of a minimum installable system. Included in the test report shall be:

a) selection procedure for the EUT;

b) reasons for the selection of those functional units;

c) description of cable layout;

d) description of actions taken to maximise the emissions from the EUT;

e) a description of the exercising equipment used to exercise the EUT;

f) a detailed description of the operational modes of the EUT used during the tests;

g) a description of the test conditions including photographs and plan of the site and EUT where appropriate;

h) the test results;

i) a statement regarding the calibration status of the test equipment;

j) a description of the test site;

k) a detailed description of the equipment comprising the EUT;

l) a description of the software used to exercise the EUT.

7 Test site requirements

When testing large systems, considerable problems may be encountered when using most commercially available sites, one of which is the determination of system emissions in the presence of large ambient signals.

Most available techniques are not suitable since:

a) the EUT cannot easily be switched on or off;

b) moving the receive antenna closer to the EUT is not feasible due to the restricted capture of the emissions from large EUTs by the antenna.

Furthermore, for reasons of economy, it may be desirable to measure radiated emission and test of radiated immunity at the same facility.

It follows from the above that the use of large screened, semi-anechoic chambers is desirable. However, such chambers are unlikely to meet the requirements of CISPR Publication No. 16 [2] at all frequencies (in particular below 200 MHz) for the volume of EUT required for large systems. A compromise is therefore required. The method shown in Annex A is used to ensure that measurements obtained in chambers are of an adequate standard to meet the requirements of compliance testing.

The test equipment to be used and the conditions of the test site are described in EN 55022 [1], and CISPR Publication No. 16 [2]. Figure 6 is an example of a measurement arrangement which gives the minimum dimensions of an OATS. The test site shall meet the site attenuation requirements of CISPR Publication No. 16 [2].

If a chamber is used which does not meet the site attenuation requirements of CISPR Publication No. 16 [2], the values of the chamber and the grey factor shall be determined according to Annex A.

The chamber correction factor plus the absolute value of the grey factor shall be added to the field strength value measured in the chamber. This factor shall be added to those values for the frequencies at which the chamber does not meet the site attenuation requirements of CISPR Publication No. 16 [2].

If, in the frequency range 30 - 200 MHz, the site attenuation requirements cannot be met, chamber factors and grey factors shall be determined as described in Annex A. The values of chamber factors in the frequency range 30 - 200 MHz shall not be more than 10 dB and grey factors shall not be more than 5 dB, otherwise the chamber shall be deemed not acceptable.

It is recognised, however, that the measurement uncertainties associated with the corrected values may be larger than those associated with the results obtained by use of a compliant test site.

8 Measurement method

The EUT shall be working in accordance with its functional specification, and should be exercised as fully as necessary during testing, to ensure that the maximum emissions are achieved.

Where the EUT is not capable of being mounted on a turn-table, it shall be assembled on the ground plane (but isolated from it).

NOTE: Under consideration is the method where the representative system may be mounted on a large platform, sufficiently rigid to carry the EUT without undue flexing. The platform will need to be efficiently earthed to the ground plane and its maximum height will be 400 mm. Earthing of the platform will be by straps placed at regular intervals around the base of the platform and connected to the ground plane. The EUT will be insulated from the platform and earthed, following normal equipment earthing installation procedures.

The antenna shall be scanned in height between one and four metres in order to maximise the level of the received emissions. Measurement shall be made in both horizontal and vertical polarisations. The antenna shall be placed at 10 m from the border of the EUT, with cable layout as described in subclause 5.2 and with reference to figures 3, 4 and 5.

The measurements shall be performed according to one of the following procedures (the method used shall be indicated in the test report):

- measurement of the emission pattern shall be made at eight equally spaced radials;

- the measurement shall be performed in only one direction. In this case the EUT shall meet the specified limits minus 10 dB. The measurement direction shall be chosen as that considered to be likely to produce the worst case emissions (results from previous pre-compliance or shielding effectiveness tests, etc. can be used to help determine this). The direction chosen shall be indicated in the test report.

9 New functional modules

Functional modules used in the system tests may be individually characterized in a defined test facility (see subclause 5.1). This characterisation may then be used as a reference to determine the effect of any significant design changes.

Using this technique, the performance of new functional modules may be assessed and the test plan written in such a way as to demonstrate that the representative system continues to conform when a functional module has been replaced by a new functional module. The results obtained for new functional modules shall be compared with those from the previous module.

The manufacturer shall clearly demonstrate and document the reasons why a new functional module does not require a complete representative system re-test. If the module constitutes a major change to the system configuration, a complete representative system test shall be performed.

NOTE: A decision method for such a re-test is under consideration.

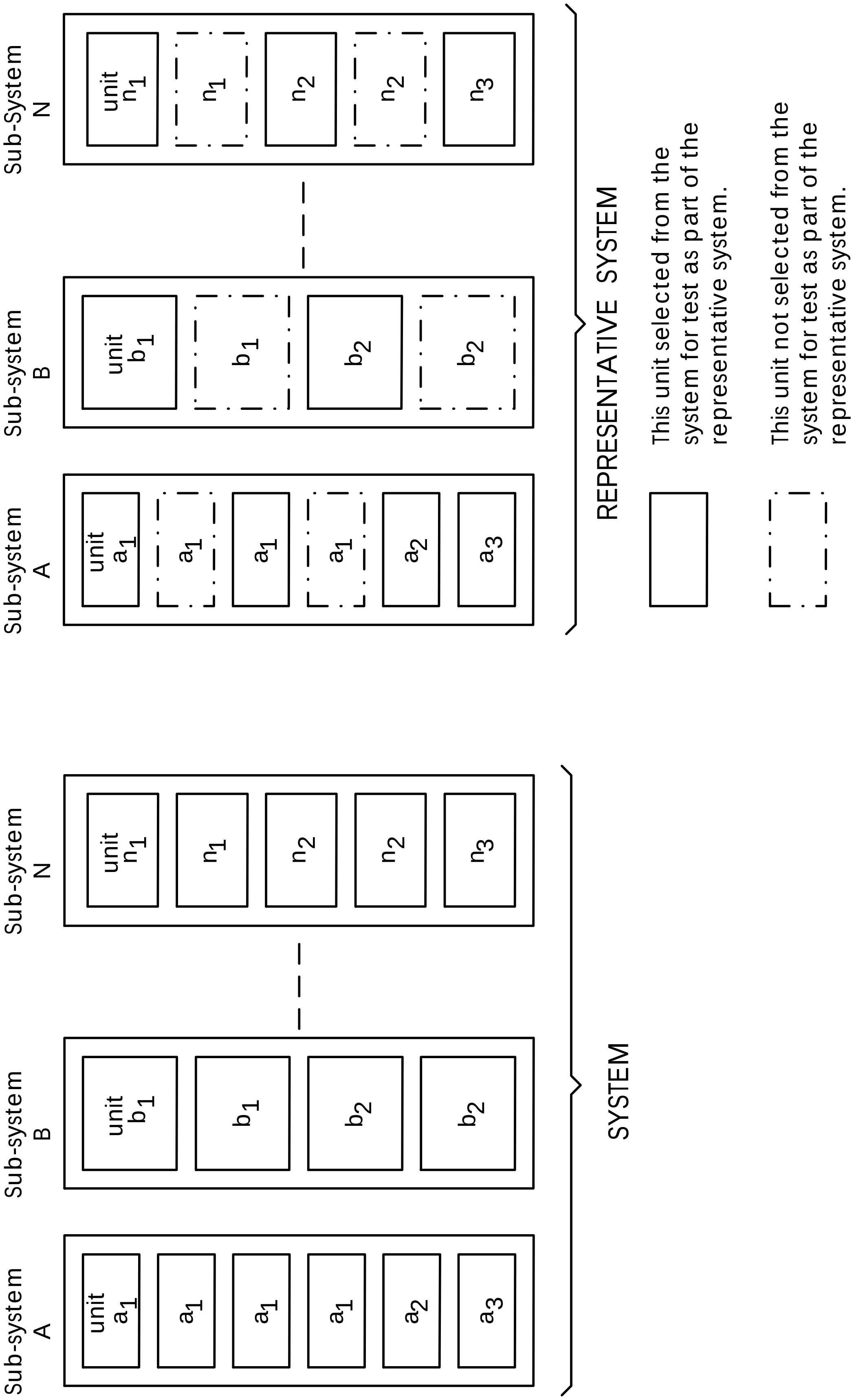


Figure 1: Example of selection of representative system

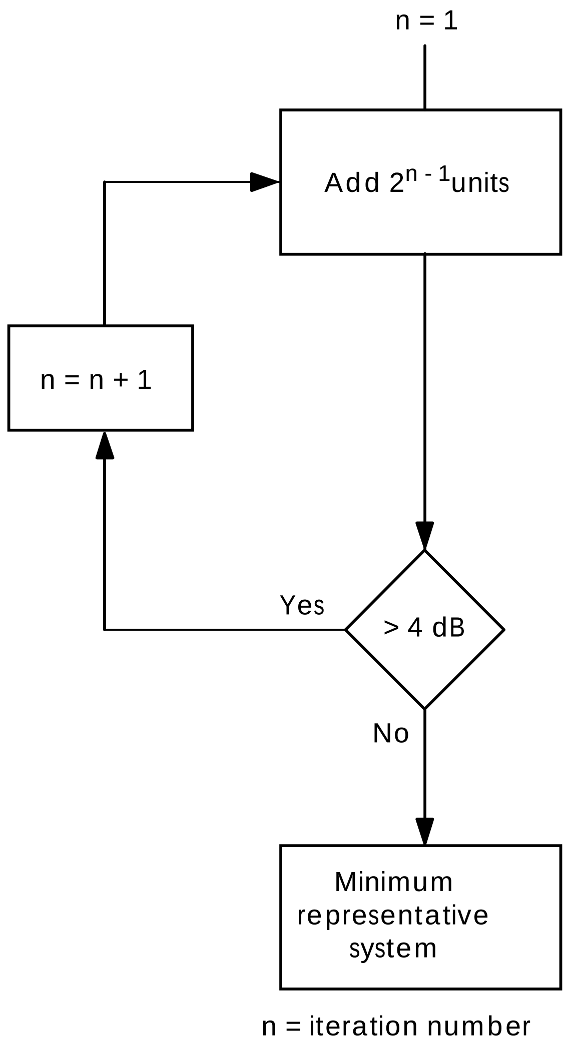
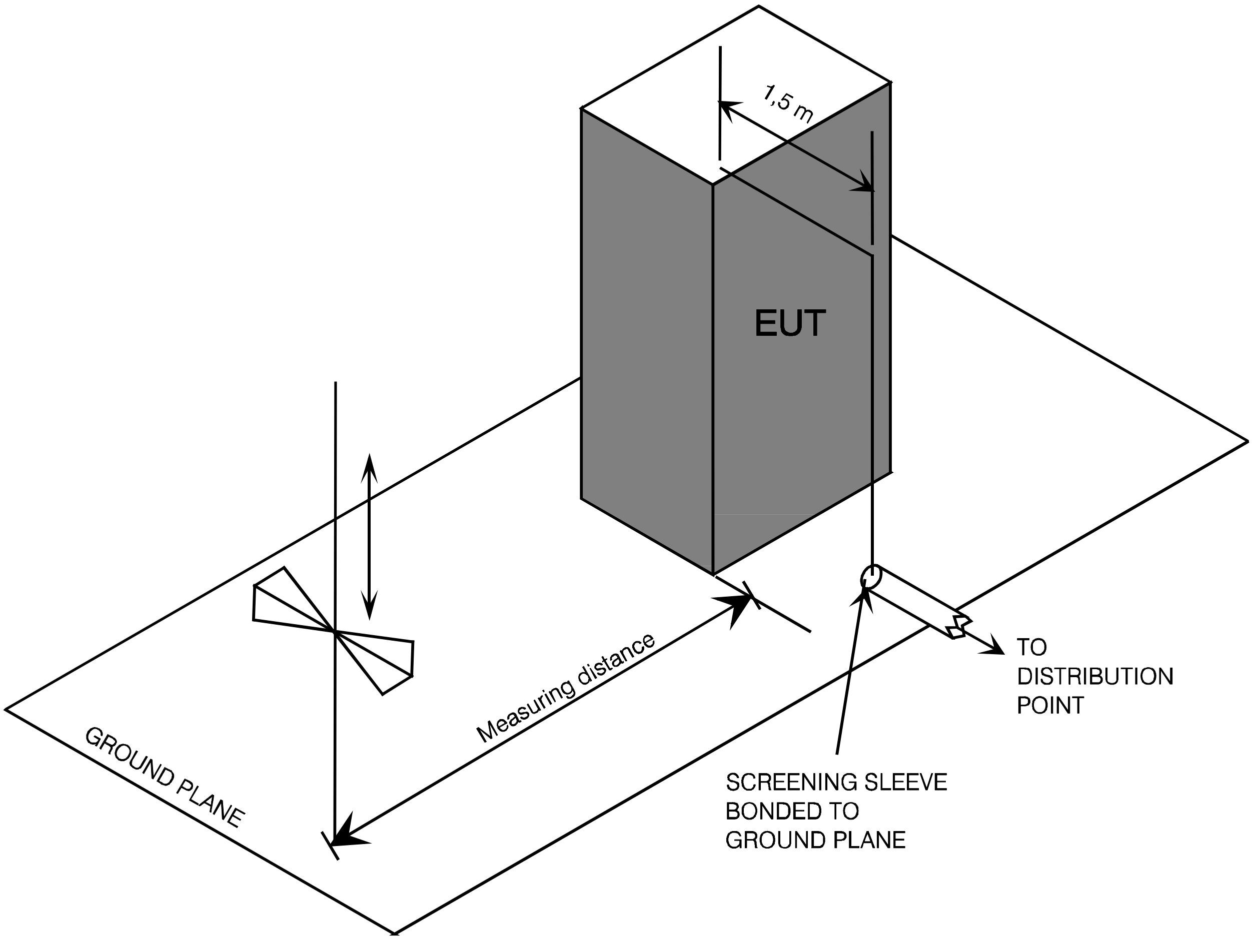


Figure 2: Basis for deciding on the number of additional functional units to be added to the EUT

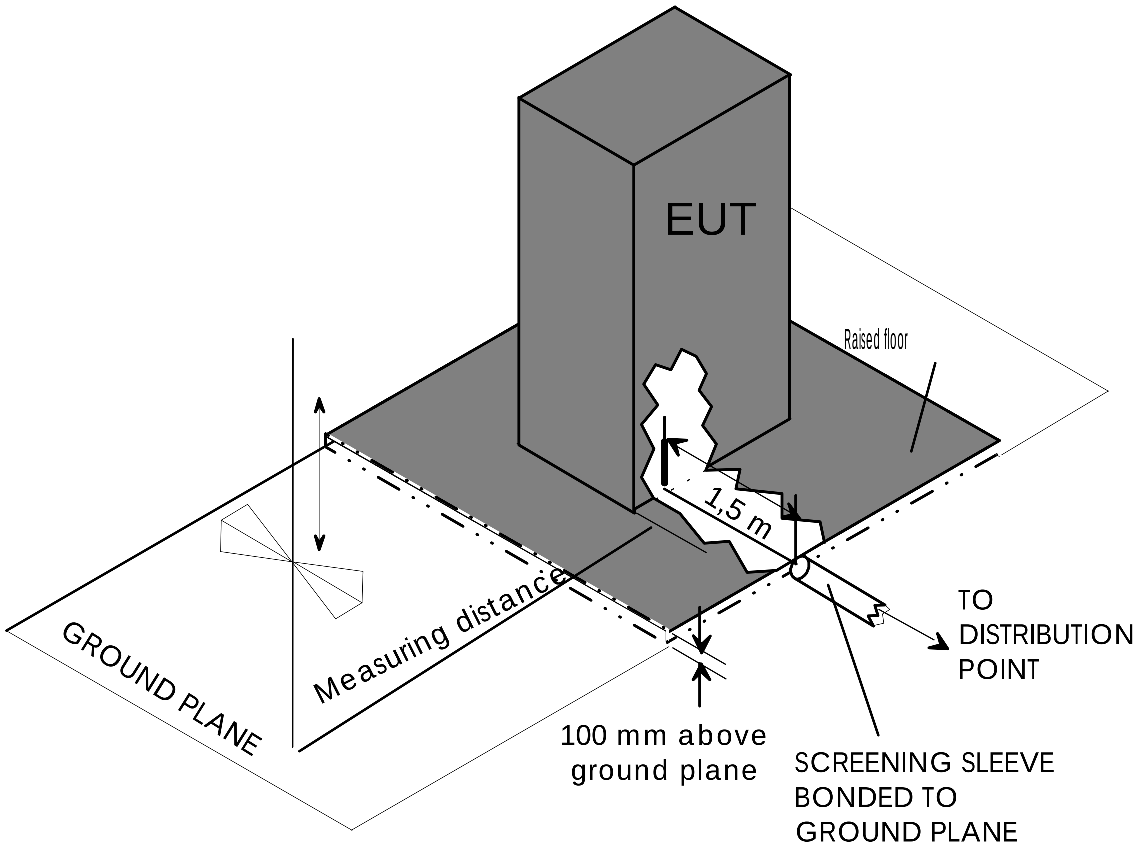


NOTE 1: The EUT is separated from the ground plane with an electrically isolating support, and electrically bonded to the site power supply ground using normal installation practice as possible.

NOTE 2: For clarity, only a single rack EUT is shown.

NOTE 3: Antenna scanned in height between 1 and 4 metres for horizontal and vertical polarisation.

Figure 3: Overhead cable systems - example for a test set-up

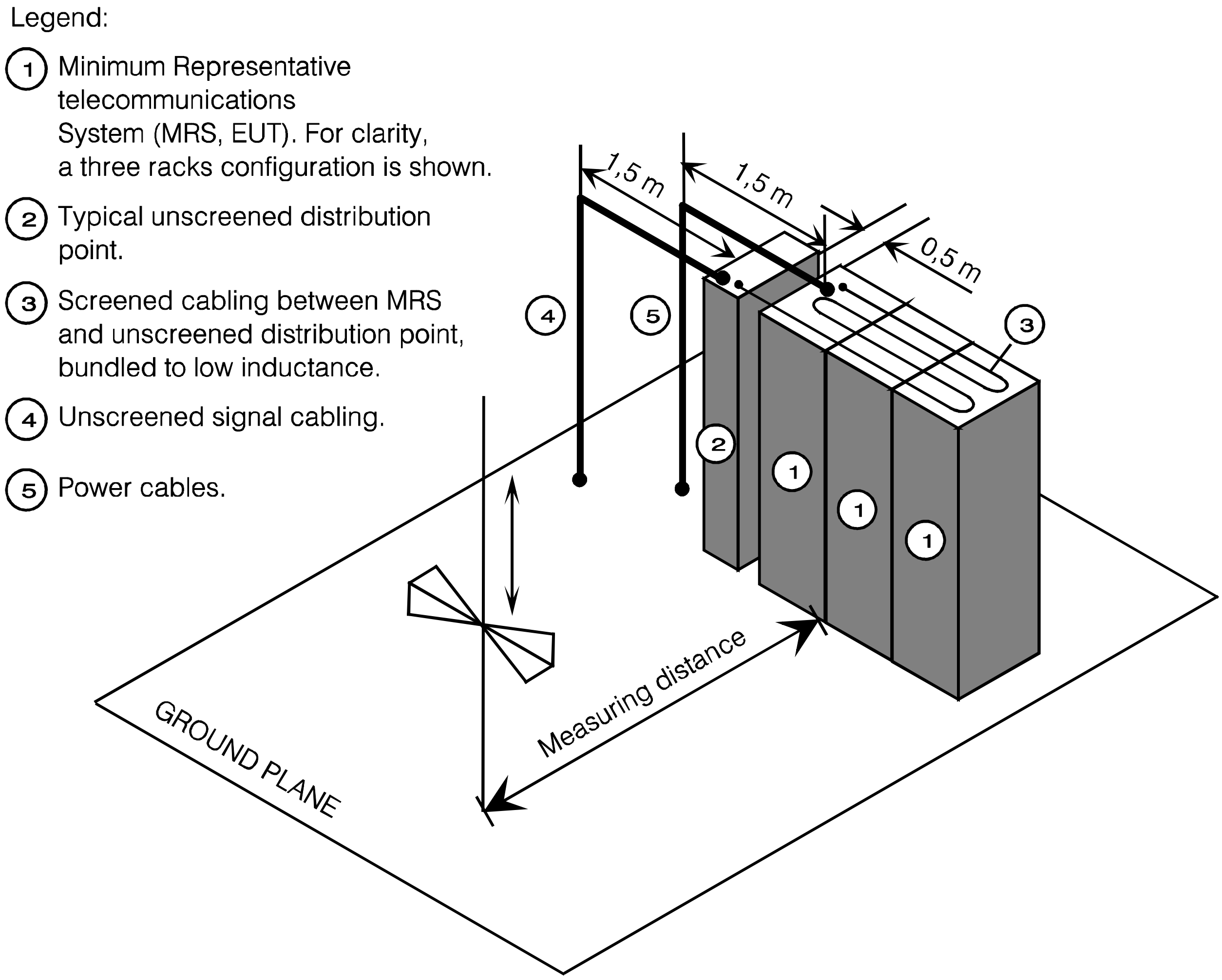


NOTE 1: If the raised floor does not form part of the screen the floor panels are removed. The raised floor is isolated from the EUT screen.

NOTE 2: For clarity, only a single rack EUT is shown.

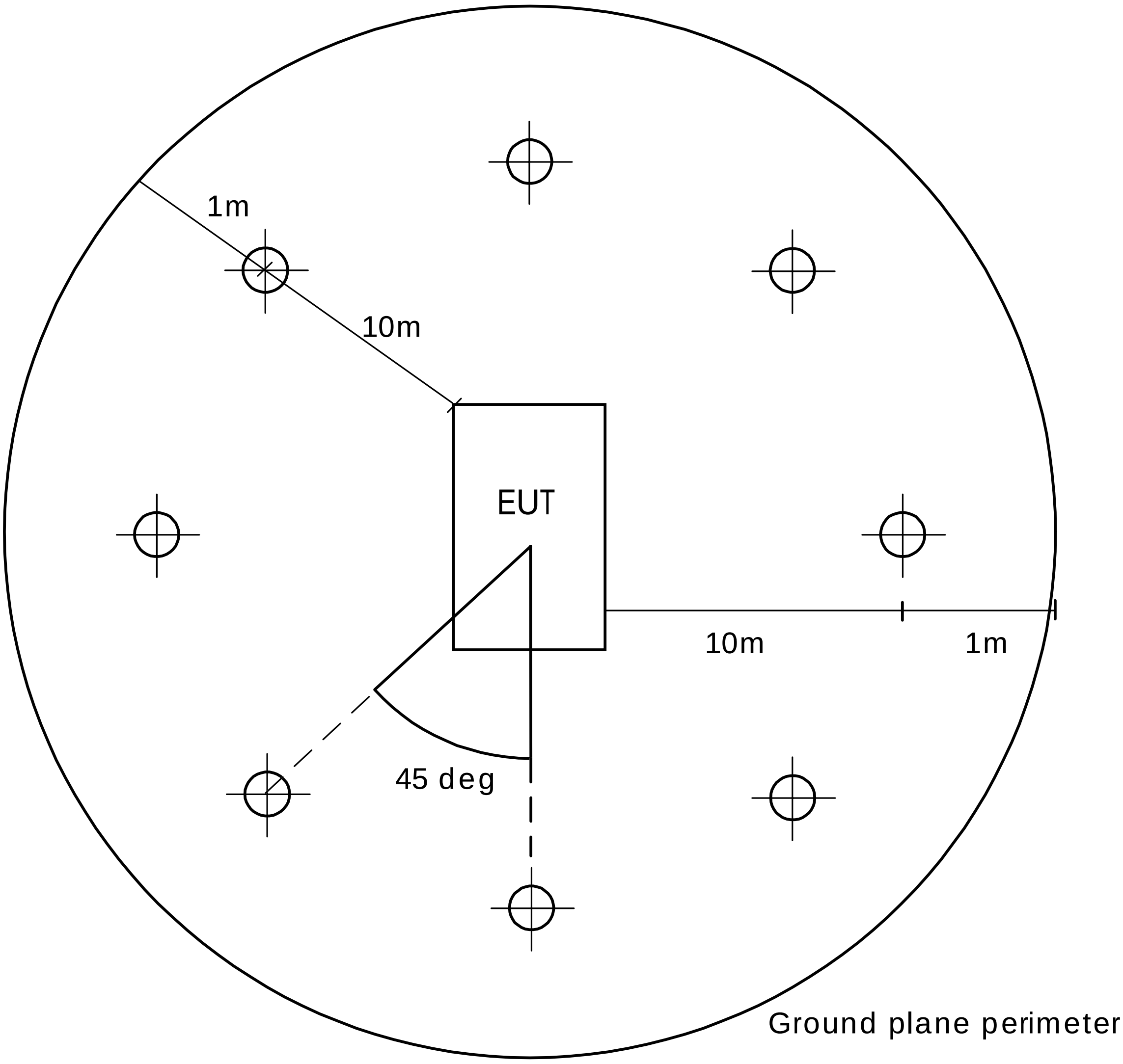
NOTE 3: Antenna scanned in height between 1 and 4 metres for horizontal and vertical polarisation.

Figure 4: Raised floor - example for a test set-up



NOTE: Antenna scanned in height between 1 and 4 metres for horizontal and vertical polarisation.

Figure 5: Screened cable systems with unscreened distribution point



NOTE: The envelope of the EUT in this figure includes the cables as shown in figures 3, 4 and 5.

Figure 6: Example of an 8 radial position measurement site

Annex A (normative): Chamber factor measurement

A.1 Definitions

A.1.1 Chamber factor

The chamber factor is a function of frequency, determined by calibration to the applicable specification, that is added to the measured emission level in order to obtain the "true level". It may be necessary to employ different values of chamber factor, dependent on the polarisation of the receive antenna.

The "true level" is that obtained on a test site meeting the site attenuation requirements of CISPR Publication No. 16 [2].

The chamber factor is affected by the properties of the enclosure, such as dimensions and the capability of the anechoic material to reduce the effect of reflections.

A.1.2 Grey factor

The grey factor is a function of frequency, which specifies the uncertainty in the chamber factor. This uncertainty is due to an unavoidable spread in the chamber factor valid for EUT having different radiation characteristics. It may be necessary to employ different values of grey factor, dependent on the polarisation of the receive antenna.

A.2 Theory of measurement

Calibration is carried out using transfer standard reference radiators. This transmitting equipment shall provide a stable output signal. The reference radiators shall simulate the radiation characteristics of actual EUT. This requirement particularly applies to the wave impedance in the near-field of the transmit antennas (see NOTE) and to the radiation pattern (amplitude and phase).

The transfer standard reference radiators are operated:

a) on a reference test site meeting the site attenuation requirements of CISPR Publication No. 16 [2]; and

b) in the chamber to be calibrated.

NOTE: The reflection characteristics of metal-backed absorber walls are functions of the source field wave impedance. Consequently, errors in field strength readings due to undesired wall reflections may be of different sizes for EUT consisting of different types of "transmit antennas". Therefore, the site calibration should be carried out for all values of wave impedances which can occur with different EUT. Dipoles and loops represent extreme cases.

At both site 1 and site 2, field-strengths are recorded according to the standard measuring method. These field-strengths are compared separately for each frequency and polarisation. The calibration factor H_i is calculated from the following equation:

$$H_i \text{ (dB)} = E_{Ref} \text{ (dB}\mu\text{V/m)} - E_{ALC} \text{ (dB}\mu\text{V/m)} \qquad \text{(equation 1)}$$

where:

E_{Ref} Field strength measured at the reference site;
E_{ALC} Field strength measured in the enclosure to be calibrated.

In emission measurements carried out in the calibrated enclosure the chamber factor H (in dB) shall be added to the measured result (in dBµV/m) to obtain the correct field strength value.

A.3 Equipment

The transmit antennae specified below shall be used as reference radiators:

a) Frequency range f ≤ 200 MHz:

1) a dipole antenna with balanced feed, having a constant overall length of 130 cm ± 10 %;

2) a single-turn square loop antenna with balanced feed, having a side length of 30 cm ± 10 %.

b) Frequency range f > 200 MHz:

1) a dipole antenna with balanced feed, having a constant overall length of 45 cm ± 10 %;

2) a single-turn square loop antenna with balanced feed, having a length of each side of 10 cm ± 10 %.

Care has to be taken to ensure that the feeders of the transmit antennae exhibit no parasitic secondary radiation. This would result in measurement errors and poor reproducibility of the test results.

Parasitic radiation is most reliably prevented by using a small, battery-powered signal generator, such as a comb generator, attached directly to the transmit antenna feed.

The transmit equipment shall not be connected to any metallic feed cables, otherwise these could also emit parasitic radiation.

Ferrites should be put around the receive antenna cable for all vertically polarized measurements.

The generator shall provide a frequency spectrum sufficient to ensure high frequency resolution (narrowband room resonances). The separation between two adjacent spectral lines shall be high enough so that the receiver (spectrum analyser) always measures sinewave signals. The following line spacings have been found useful:

30 MHz - 100 MHz:	line spacing ≤ 1 MHz;
100 MHz - 1 Ghz:	line spacing ≤ 5 MHz.

A.4 Test set-ups

A "test volume" is defined as that volume traced out by the largest equipment or system to be tested as it is rotated about its centre location through 360 degrees, such as by a turn-table. The reference radiators shall be set up at all those locations within the test volume, as shown in figure A.1. In contrast to CISPR Publication No. 16 [2], the receive antenna position shall be kept constant as is the case in emission tests of EUT. The transmit antenna configurations shown in figure A.2 are required at each point.

Reference values for the field strengths corresponding to each point need to be known from corresponding measurements on a reference site.

Reference radiator antenna heights above the ground plane (semi-anechoic enclosure) are 1 m and 2 m for horizontal polarisation, and 1 m and 1,5 m for vertical polarisation.

A.5 Measurement procedure

a) The reference radiators are operated on the reference site. Transmit antennas are chosen as specified in Clause A.3. All configurations of transmit and receive antenna given in figures A.1 and A.2 (if necessary) are used in turn.

Field strengths are recorded as functions of frequency and polarisation. These field strength measurements shall be carried out exactly the same way as is done in radiated emission measurements in the enclosure to be calibrated.

This means that:

- the same receiving equipment should be used (antennae, cables and receiver/spectrum analyser). If different equipment is used, differences in the absolute calibration should be taken into account;

- the same procedure shall be used (height scan in semi-anechoic enclosures).

b) The reference radiators are used as "transfer standard", as described in this ETS and are operated in the enclosure to be calibrated. Again, field strengths are recorded as functions of frequency and polarisation for all configurations used before.

A.6 Factors

a) For each polarisation and for each of the given configurations, the calibration factor (H_i) is determined from equation 1. Typically, for each polarisation and for each of the given configurations the results will be different.

b) For each frequency and polarisation, the upper and lower envelope curves of the calibration factor (H_i) are determined.

c) For each frequency and polarisation, the chamber factor H (in dB) is determined as the arithmetic mean value of the upper and lower envelope curve (in dB).

d) For each frequency and polarisation, the grey factor G (in dB) is determined as the difference between chamber factor and envelope curve.

A.7 Evaluation of the enclosure and application of the factors

The chamber factor shall satisfy the following conditions:

$$H\ (dB) \leq L - AF - C - RS - S/N \qquad \text{(equation 2)}$$

where:

H Chamber factor (dB);
L Specification Limit (dBµV/m);
AF Antenna Factor (dB/m);
RS Receiver Sensitivity in the measurement bandwidth (dBµV);
S/N Signal to noise ratio (dB);
C Cable loss (dB).

The S/N figure shall be greater than or equal to 6 dB. The maximum values for H and G are given in table A.1.

Table A.1: Chamber and grey factor limits

Frequency range (MHz)	H (dB)	G (dB)
30 - 200	10	5

If an enclosure under evaluation fulfils these conditions then it should be considered suitable for performing emission measurements. The grey factor indicates the worst case uncertainty in the radiated emission test results due to enclosure imperfections. To increase accuracy of the final measured results, the data shall be corrected according to the following formula:

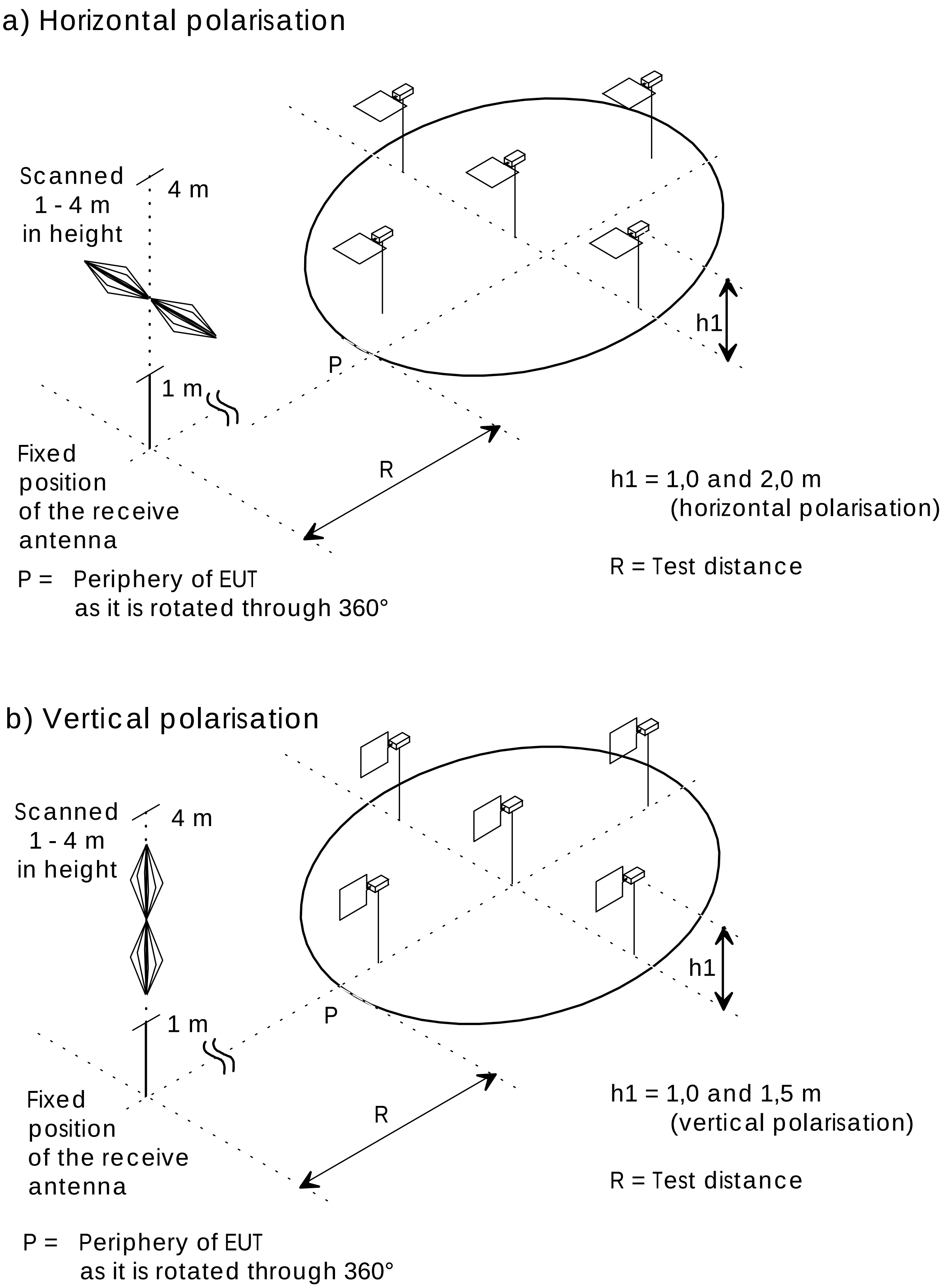
$$E_C\ (dB\mu V/m) = E_M\ (dB\mu V/m) + H\ (dB) + G(mod) \qquad \text{(equation 3)}$$

where:

E_M = measured field strength;

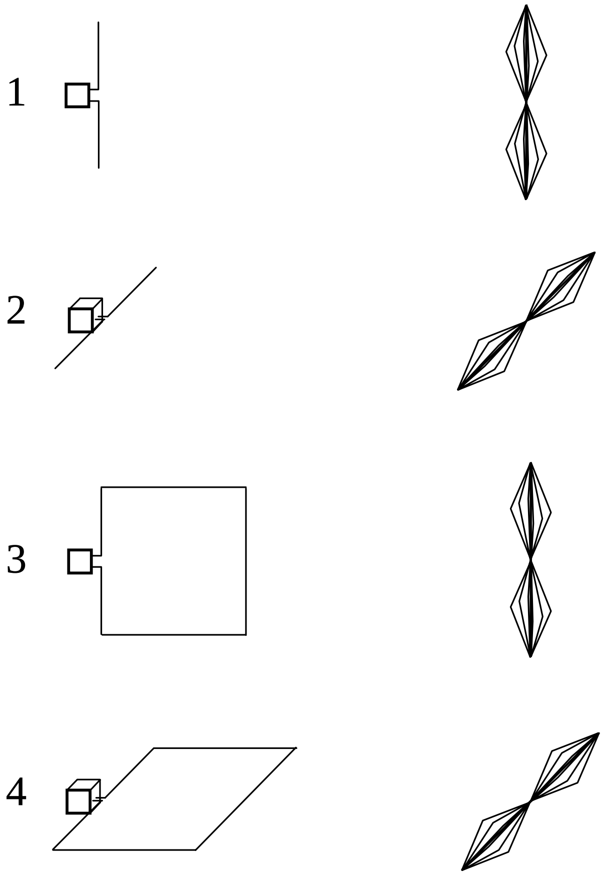
E_C = corrected field strength which could be measured on an ideal site.

If under-estimates of the emission of an EUT are to be avoided completely, the upper envelope curve of the calibration factor curves determined in item b) of Clause A.6 shall be used as the chamber factor.



NOTE: The centre of the reference radiators align with the periphery of the test volume with the exception of the centre radiator.

Figure A.1: Reference radiator positions required for the calibration



1 Vertical polarised dipoles
2 Horizontally polarised dipoles
3 Vertically polarised receiving dipole, vertically polarised transmitting loop (vertical loop area)
4 Horizontally polarised receiving dipole, horizontally polarised transmitting loop (horizontal loop area).

Figure A.2: Reference radiator configurations required for the calibration

History

Document history	
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