terminals of antenna B. The measuring antenna A should also be a half-wave dipole. Its actual sensitivity will be included in the substitution calibration of the test configuration.

In the frequency range of 1 GHz to 18 GHz linearly polarized horn antennas are recommended.

2.6.4.3 EUT configuration

The EUT shall be placed on a non-conducting table with provision to rotate in the horizontal plane. The EUT shall be set up so that the geometric centre of the EUT coincides with the point earlier used as centre point for dipole B (Figure 22). If the EUT is comprised of more than one unit, each unit shall be measured separately. Detachable leads to the EUT should be removed if operation is not affected adversely. Required leads shall be provided with absorbing ferrite rings and be so positioned that they will not influence the measurements. For shielded EUTs, all connectors not used shall be terminated by shielded terminations.

2.6.4.4 Test procedure

With the EUT arranged as described in 2.6.4.3, the horizontally polarized measuring dipole A shall be placed in the same position as when checking the test site. The dipole shall be normal to a vertical plane through its centre and that of the EUT. The EUT is first measured in its normal table-standing position and secondly when tilted 90° to stand on a normally vertical side. In each position it shall be rotated 360° in the horizontal plane. The highest reading Y shall be the characteristic value for the EUT.

The measuring system is calibrated by replacing the EUT with a half-wave dipole B. The centre of this calibrating dipole B shall be placed in the same spot as the geometric centre of the previously measured EUT and parallel with the measurement antenna A, and be connected to a signal generator. The radiated power from the cabinet of the EUT is defined as the power at the terminals of the half-wave dipole B when the signal generator is adjusted to give the same reading on the measuring receiver as the maximum reading recorded earlier (Y), at each frequency of measurement.

When measurements are made with both horizontally and vertically polarized measuring dipoles, separate calibrations must be made for the two modes.

2.6.5 Measurements of *in situ* equipment

2.6.5.1 Applicability of and preparation for *in situ* measurements

In situ measurements may be necessary for the investigation of an interference problem at a particular location, i.e. where electrical equipment is suspected of causing interference to radio reception in its vicinity.

Where allowed by the relevant product standard, *in situ* measurements may be made for the evaluation of compliance, if it is not possible for technical reasons to make radiated emission measurements on a standard test site. Technical reasons for *in situ* measurements are excessive size and/or weight of the EUT or situations where the interconnection to the infrastructure for the EUT is too expensive for the measurement on standard test sites. *In situ* measurement results of an EUT type will normally deviate from site to site or from results obtained on a standard test site and can therefore not be used for type testing.

NOTE 1 In general, however, due to imperfections such as mutual coupling between the conductive structures present in the *in situ* environment, which may also be more or less polluted by ambient electromagnetic fields, and the measuring antenna/equipment under test, *in situ* measurements cannot fully replace measurements on a suitable test site (open-area test site or alternative test sites, for example, (semi-)anechoic chambers) as specified in CISPR 16-1.

The EUT usually consists of one or more devices and/or systems, is part of an installation, or is interconnected with an installation.

A perimeter connecting the outer parts of the EUT is usually taken as the reference point to determine the measurement distance. In some product standards, the exterior walls or boundaries of business parks or industrial areas are taken as the reference points.

Preliminary measurements shall be made to identify the frequency and amplitude of the disturbance field strengths amongst the ambient signals taking into account the potential sources of interference (for example, oscillators) in the EUT. For these measurements the use of a spectrum analyser is recommended in place of a receiver because a large frequency spectrum can be analysed. For the identification of the frequency and amplitude of the disturbance signals the use of a current probe on the connected cables, or near-field probes or the measurement antennas placed closer to the EUT is recommended.

Measurements shall also be made on selected frequencies to determine, where possible, the modes of operation in which the EUT generates the highest disturbance field strengths. The subsequent measurements shall be made with the EUT in these modes of operation.

NOTE 2 Where the EUT is a piece of equipment, the operating mode of which cannot be switched independently of the operation of other equipment, the selection of conditions producing the highest disturbances may be impossible. For some of them, these conditions may be dependent on time, particularly if they are on cyclic operation. In such cases, the period of observation should be chosen to approach the conditions of highest disturbance production.

Measurements shall be made around the EUT at approximately the same measurement distance on each of the selected frequencies to determine the direction of the highest disturbance field strength. The EUT should be tested in at least three different directions. The final disturbance field-strength measurements on each frequency shall be made in the directions of the highest disturbance field strengths (which may vary from frequency to frequency) taking into account the local conditions.

The highest disturbance field strengths shall be measured with the antenna in vertical and horizontal polarization.

If the ratio of the measured disturbance field strength to any ambient emission is lower than 6 dB, the measurement methods described in Annex E can be used.

2.6.5.2 Field-strength measurements in the frequency range 9 kHz to 30 MHz

2.6.5.2.1 Measurement method

The magnetic disturbance field strength shall be measured in the direction of maximum radiation with the EUT in the mode of operation generating the highest disturbance field strength.

The horizontally polarized disturbance field strength shall be measured at the standard measurement distance d_{limit} using a loop antenna as described in 5.5.2.1 of CISPR 16-1 at a height of 1 m (between the ground and lowest part of the antenna). The maximum disturbance field strength shall be determined by rotating the antenna.

NOTE For the measurement of the maximum disturbance field strength from lines arranged in any direction, the antenna should be oriented in three orthogonal directions, and the measured field strength is calculated by

$$E_{\text{sum}} = \sqrt{E_x^2 + E_y^2 + E_z^2}$$

In cases where limits are given for the E field equivalent but the measured field strengths are the magnetic components, the H field strength can be converted to the corresponding E field strength using the free space impedance of 377 Ω by multiplying the H field reading by 377. The H field in this case is given by

$$H_{\text{sum}} = \sqrt{H_x^2 + H_y^2 + H_z^2}$$

This H field value can be used directly in cases where limits are directly given for the magnetic field strength.

If the antenna cannot be moved in three orthogonal directions, it can be turned by hand in the direction of maximum reading for the measurement of the maximum disturbance field strength.

2.6.5.2.2 Measurement distances other than the standard distance

If it is not possible to adhere to the standard distance d_{limit}, as specified in the product or generic standard, the measurements should be made at distances either less or greater than the standard measuring distance in the direction of the maximum radiation.

At least three measurements at different measuring distances less or greater than the standard measuring distance shall be used if it is not possible to use the standard distance.

The measurement results (in decibels) shall be plotted as a function of the measurement distance on a logarithmic scale. One line shall be drawn to join up the measurement results. This line represents the decrease in the field strength and can be used to determine the disturbance field strength at distances other than the measurement distance, for example, at the standard distance.

2.6.5.3 Field-strength measurements in the frequency range above 30 MHz

2.6.5.3.1 Measurement method

The electric disturbance field strength shall be measured in the direction of maximum radiation at the standard distance with the EUT in the mode of operation generating the highest disturbance field strength. The maximum horizontally and vertically polarized disturbance field strengths shall be measured using broadband antennas with, as far as practicable, a variable height of 1 m to 4 m. The highest value shall be taken as the measured value.

It is recommended that biconical antennas be used for measurements in the frequency range up to 200 MHz and log-periodic antennas for measurements in the frequency range above 200 MHz. The distance between the measuring antenna and any nearby metallic elements (including cables) should be greater than 2 m.

2.6.5.3.2 Measurement distances other than the standard distance

The standard measurement distance d_{std} is specified in the product or generic standard. If it is not possible to adhere to the standard measurement distance, the disturbance field strength shall be measured in different measuring distances as described in 2.6.5.2.2. A height scan of the antenna shall be used for each measurement The disturbance field strength at the standard distance d_{std} shall be determined according to 2.6.5.2.2 by plotting the measured field strength as a function of the measurement distance on a logarithmic scale.

If it is not possible to measure at different measuring distances and the measurement distance refers to the outer wall of a building or the border of the premises, the measurement results shall be converted to the standard distance using equation (5).

$$E_{\mathrm{std}} = E_{\mathrm{mea}} + n \times 20 \times \log \frac{d_{\mathrm{mea}}}{d_{\mathrm{std}}} \qquad (5)$$

where

E_{std} is the field strength at the standard distance in dB(μV/m) for comparison with the emission limit;

E_{mea} is the field strength at the measurement distance in dB(μV/m);

d_{mea} is the measurement distance in metres;

d_{std} is the standard distance in metres.

n depends on the distance d_{mea} as follows:

if 30 m $\le d_{\mathrm{mea}}$, $n = 1$;

if 10 m $< d_{\mathrm{mea}} <$ 30 m $n = 0{,}8$;

if 3 m $< d_{\mathrm{mea}} <$ 10 m $n = 0{,}6$.

NOTE $n < 1$ accommodates the difference between the measuring distance and the distance to the EUT.

Measurement distances closer than 3 m shall not be used.

If it is not possible to measure at different measuring distances, and equation (5) is not used because the measurement distance does not refer to the outer wall of a building or boundary of premises, the field strength should be determined by measurement of the radiated disturbance power (see 2.6.5.4).

2.6.5.4 *In situ* measurement of the effective radiated disturbance power using the substitution method

2.6.5.4.1 General measurement condition

The substitution method can be used without additional conditions if, and only if, the EUT can be switched off and if the EUT can be removed for the substitution.

If the EUT cannot be removed, and if its front face is a large plane surface, the effect of this face on the substitution shall be taken into account (see equation (7b)). If the front surface of the EUT does not fit into a two-dimensional plane in the measurement direction, the additional measurement uncertainty is not considered.

If the EUT cannot be switched off, it is still possible to use the substitution method to measure the radiated power of a disturbance from the EUT at a particular frequency, by using a nearby frequency at which the field strength of the disturbance from the EUT is at least 20 dB below that at the frequency of interest (“nearby” means within one or two receiver IF-bandwidths). The frequency selected should, where possible, be chosen with regard to possible interference to radio services.

2.6.5.4.2 Frequency range 30 MHz to 1 000 MHz

2.6.5.4.2.1 Measurement distance

The measurement distance chosen shall be such that the measurement is made in the far field. This requirement is generally met, if

a) d is greater than $\dfrac{\lambda}{2\pi}$ and

b)
$$d \geq \frac{2 \times D^2}{\lambda} \qquad (6)$$

where

d is the measurement distance in meters;

D is the maximum dimension of the EUT with cabling in meters;

λ is the wavelength in meters;

or

the measurement distance d is equal to, or greater than, 30 m.

In the far field the exponent n in equation (5) may be assumed to be 1. If a shorter measurement distance is chosen, this assumption can be validated by using the procedure of 2.6.5.3.2 to verify that the field strength falls off inversely with distance.

If the local conditions require that a shorter measurement distance be chosen, this shall be indicated.

2.6.5.4.2.2 Measurement method

The effective radiated disturbance power shall be measured in the direction of maximum radiation with the EUT in the mode of operation generating the highest disturbance field strength. The measurement distance shall be chosen according to 2.6.5.4.2.1 and the highest disturbance field strength on the selected frequency determined by varying the antenna height at least in the range of 1 m to 4 m as far as practicable.

For the measurement of the effective radiated disturbance power, steps a) to g) shall be followed.

a) The EUT shall be disconnected and removed. A half-wave dipole or antenna with similar radiation characteristics and known gain G, relative to a half-wave dipole is substituted in its place. If it is impractical to remove the EUT, a half-wave or broadband dipole (in the frequency range lower than about 150 MHz to minimize mutual coupling to the EUT) is positioned in the vicinity of the EUT. The vicinity is a range up to 3 m.

b) The half-wave (or broadband) dipole shall then be fed by a signal generator operating on the same frequency.

c) The position and polarization of the half-wave dipole (or broadband antenna) shall be such that the measuring receiver receives the highest field strength. If the EUT is not removed, then, if possible, it shall be switched off and the dipole is moved in a range up to 3 m around the EUT.

d) The power of the signal generated shall be varied until the measuring receiver shows the same reading as when the highest disturbance field strength from the EUT was measured.

e) If the front of the EUT fills a large plane surface (for example, a building with a cable-TV network) the substitution antenna (half-wave dipole) is positioned about 1 m in front of the plane surface (in front of the building). The location of the substitution should be so chosen that an imaginary line between the substitution antenna and the measuring antenna is perpendicular to the direction of the face of the building.

f) The height, polarization and distance to the plane imaginary surface enclosing the half-wave dipole (or broadband antenna) and perpendicular to the measurement axis between the antenna and the location of the measuring antenna shall be varied such that the receiver receives the highest field strength.

g) The power of the signal generator shall be varied as in d) above.

For removed EUTs and EUTs whose front face is not contained within an imaginary large plane surface, the power at the signal generator P_G plus the gain G of the transmit antenna relative to a half-wave dipole yields the effective radiated disturbance power P_r to be measured:

$$P_r = P_G + G \tag{7a}$$

For EUTs that fit within an imaginary large plane surface (for example, buildings with telecommunication networks), the increase in gain of the dipole positioned in front of this surface is given by

$$P_r = P_G + G + 4 \text{ dB} \tag{7b}$$

where

P_r is in dB(pW);

P_G is in dB(pW); and

G is in dB.

The effective radiated disturbance power can be used to calculate the disturbance field strength at the standard measurement distance d_{std}. The free-space field strength E_{free} shall be calculated using the following equation:

$$E_{free} = \frac{7\sqrt{P_r}}{d_{std}} \tag{8}$$

where

E_{free} is in µV/m;

P_r is in pW; and

d_{std} is in metres.

If the calculated free-space field strength of equation (8) is compared with limits of disturbance field strength measured in standard test sites, it must be considered that the amplitude field strength measured at standard test sites is approximately 6 dB higher than the free space field strength of equation (8) due to the reflections from the ground plane. Equation (8) can be modified to take into account this increment. The disturbance field strength at the standard distance E_{std} can therefore be calculated for the vertical polarization using the following equation:

$$E_{std} = P_r - 20 \log d_{std} + 22{,}9 \tag{9a}$$

For horizontal polarization below 160 MHz the maximum field strength is not measured at standard test sites. Therefore the 6 dB factor must be corrected as follows:

$$E_{std} = P_r - 20 \log d_{std} + 16{,}9 + (6 - c_c) \tag{9b}$$

where

E_{std} is in dB(µV/m);

f is the measuring frequency;

d_{std} is in metres;

c_c is the correction factor for horizontal polarization. This was determined assuming the radiation source at 1 m in height.

f MHz	30	40	50	60	70	90	100	120	140	160	180	200	750	1 000
c_c dB	11	10,2	9,3	8,5	7,6	5,9	5,1	3,4	1,7	0	0	0	0	0

This method for determining the disturbance field strength can mainly be used if there are obstacles between the measuring antenna and the EUT.

2.6.5.4.3 Frequency range 1 GHz to 18 GHz

2.6.5.4.3.1 Measurement distance

The measurement distance chosen shall be such that the measurement is made in the far field. The far-field condition shall be verified by measuring the radiated disturbance power with a double-ridged waveguide horn or log-periodic antenna as a function of the distance. The requirement is met if the measurement distance is equal to, or greater than, the transition distance. The transition distance is marked by the transition point which shall be determined as shown in Figure 23. The measurement results shall be plotted and two parallel lines separated by 5 dB drawn to enclose as many of the measurement results; the transition point is the point where the lines intersect and after which the radiated power decreases by 20 dB/decade.

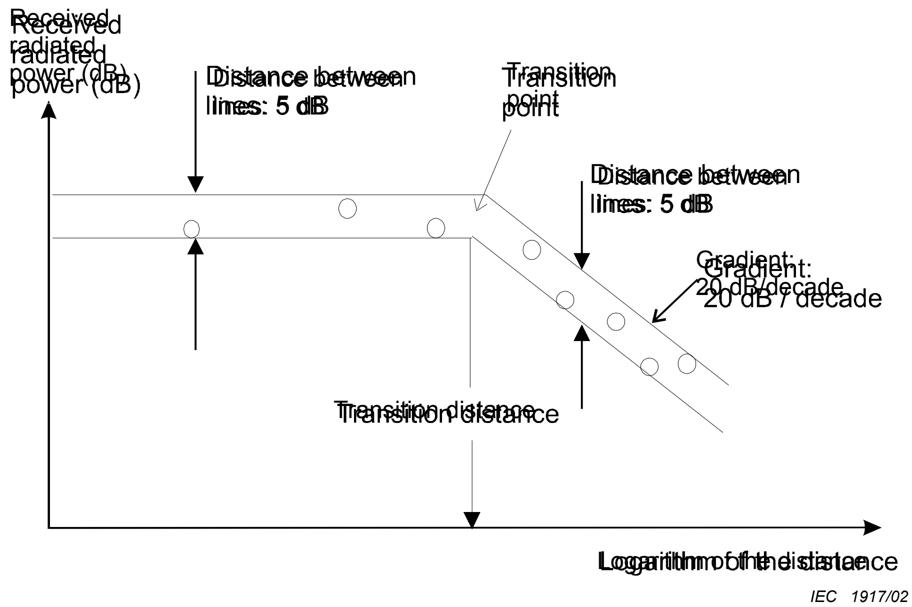

Figure 23 – Determination of the transition distance

2.6.5.4.3.2 Measurement method

The radiated disturbance power shall be measured in the direction of maximum radiation with the EUT in the mode of operation generating the highest disturbance field strength. A double-ridged waveguide horn or log-periodic antenna shall be used to determine the direction of maximum radiation. The measurement distance shall then be chosen according to 2.6.5.4.2.1 and the disturbance field strength on the selected frequency is measured. The antenna position shall be varied slightly to ensure that the measured field strength is not at a local minimum (due, for example, to reflections).

For the measurement of the radiated disturbance power the EUT shall be disconnected and a double-ridged horn or log-periodic antenna positioned either in the immediate vicinity of the EUT or in its place. The antenna shall then be fed by a signal generator operating at the same frequency. The orientation of the antenna shall be such that the test receiver receives the highest field strength. This antenna position shall be fixed. The power of the signal generated shall be varied until the test receiver receives the same power as that generated by the EUT. The power at the signal generator P_G plus the gain G of the transmitting antenna relative to a half-wave dipole yields the required radiated disturbance power P_r:

$$P_r = P_G + G \tag{10}$$

where

P_r is in dB(pW);

P_G is in dB(pW); and

G is in dB.

2.6.5.5 Documentation of the measurement results

The particular circumstances and conditions of the *in situ* measurements should be documented to enable the operational conditions to be reproduced if the measurements are repeated. The documentation should include

– reasons for the *in situ* measurement instead of using a standard test site;
– description of the EUT;
– technical documentation;
– scale drawings of the measurement site, showing the points at which measurements were made;
– description of the measured installation;
– details of all connections between the measured installation and the EUT: technical data and details of their location/configuration;
– description of the operating conditions;
– details of the measuring equipment;
– measurement results:
  • antenna polarization;
  • measured values: frequency, measured level and disturbance level;

    NOTE The disturbance level is the level referred to the standard measuring distance.
  • assessment of the degree of interference (if applicable).

2.6.6 Measurement in a loop antenna system

The loop antenna system (LAS) considered in this subclause is suitable for indoor measurement of the magnetic field strength emitted by a single EUT in the frequency range 9 kHz to 30 MHz. The magnetic field strength is measured in terms of the currents induced into the LAS by the magnetic disturbance field of the EUT.

The LAS shall be validated regularly using the method described in Clause G.4 of CISPR 16-1, Annex G. That annex also gives a complete description of the LAS and a relation between the measuring results obtained with the LAS and those obtained as described in 2.6.2.

2.6.6.1 General measurement method

Figure 24 shows the general concept of measurements made with the LAS. The EUT is placed in the centre of the LAS. The current induced by the magnetic field from the EUT into each of the three large loop antennas of the LAS is measured by connecting the current probe of the large loop antenna to a measuring receiver (or equivalent). During the measurements the EUT remains in a fixed position.

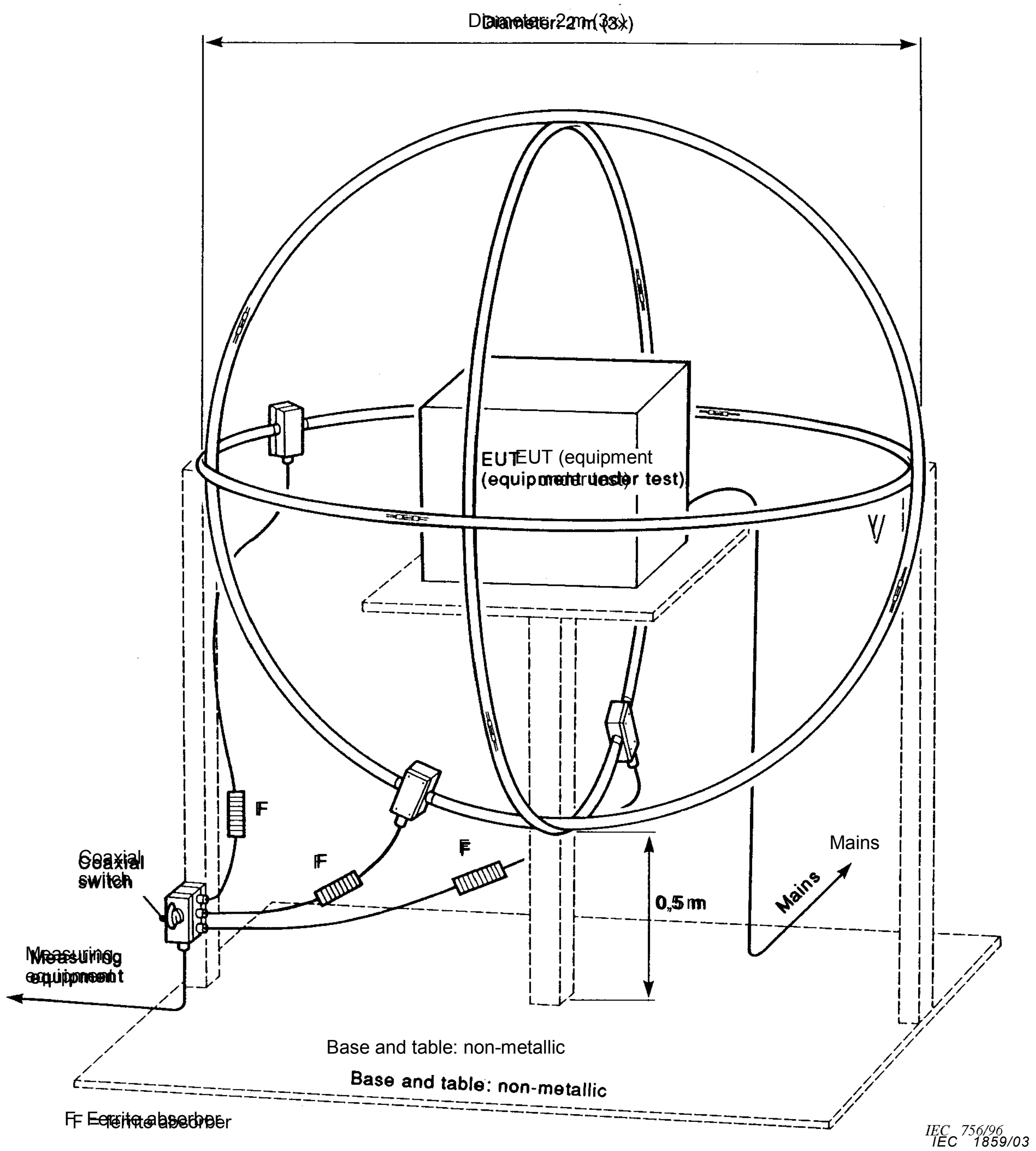

Figure 24 – Concept of magnetic field-induced current measurements made with the loop antenna system (see 2.6.6)

The currents in the three large loop antennas, originating from the three mutually orthogonal magnetic field components, are measured in sequence. Each current level measured shall comply with the emission limit, expressed in dBµA, as specified in the product standard.

The emission limit shall apply to a LAS having large loop antennas with the standardized diameter of 2 m.

2.6.6.2 Test environment

The distance between the outer perimeter of the LAS and nearby objects, such as floor and walls, shall be at least 0,5 m.

The currents induced in the LAS by an RF ambient field shall be judged in accordance with 5.6.4 of CISPR 16-1.

2.6.6.3 Configuration of the equipment under test

To avoid unwanted capacitive coupling between the EUT and the LAS, the maximum dimensions of the EUT shall allow a distance of at least 0,20 m between the EUT and the standardized 2 m large loop antennas of the LAS.

The position of the mains lead shall be optimized for maximum current induction. In general, this position will not be critical when the EUT complies with the conducted emission limit.

In case of a large EUT, the diameter of the loop antennas of the LAS may be increased up to 4 m. In that case:

a) the current values measured shall be corrected in accordance with Clause I.6 of CISPR 16-1; and

b) the maximum dimensions of the EUT shall allow a distance between the EUT and the large loops of at least $0,1 \times D$ m, where D is the diameter of the non-standardized loop.

3 Section 3: Immunity measurements

3.1 Immunity test criteria and general measurement procedures

Immunity measurements are based upon a judgement of the point when the effect of interference on the EUT (equipment under test) has reached a specified level.

Immunity measurements are performed in general by the application of a wanted test signal and an unwanted signal to the EUT. The fundamental basis of the measurement is set out in this clause, together with a listing of conditions which need to be specified in the detailed recommendations produced by the CISPR product committees. Sublause 3.2 deals with the general principals of conduction methods of measurement for immunity, and 3.3 with radiation methods.

3.1.1 General measurement method

Figure 25 sets out the fundamental concept upon which all methods of measurement of immunity are based.

The EUT is set up as specified to represent normal operating conditions. The unwanted signal is applied with increasing severity until the prescribed performance degradation is detected or the specified immunity level is reached, whichever is lower.

The unwanted signal may be introduced by direct radiation or by current/voltage injection. In most cases both the direct radiation and injection techniques will be needed to fully assess the immunity potential of EUTs. The injection method is most useful for frequencies under 150 MHz, although direct radiated tests above approximately 30 MHz are used. The direct radiated tests can be performed using fields launched by antennas and intercepted by the EUT. In some cases a “bounded” field is most efficient for EUTs of height less than 1 m. Examples of bounded fields occur with TEM cells, stripline antennas and mode-stirred enclosures.

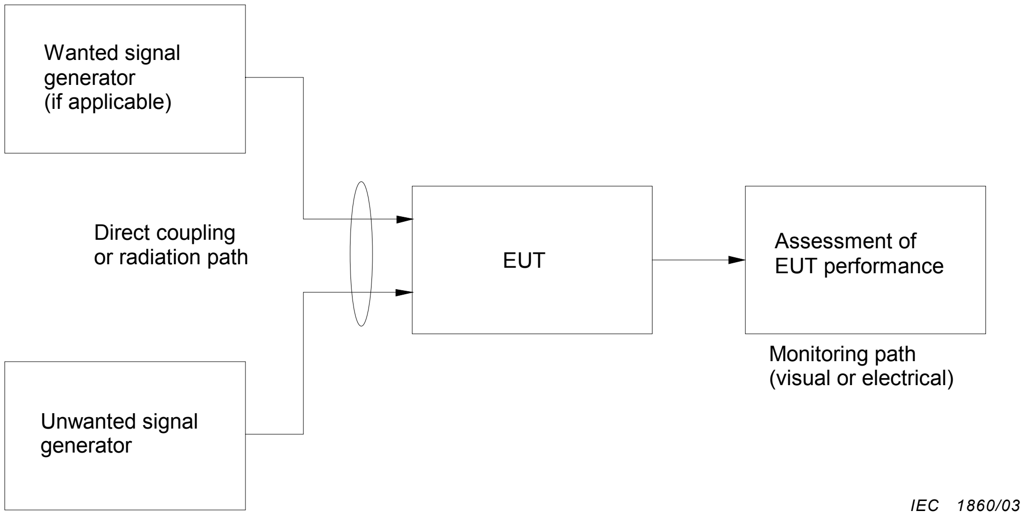

Figure 25 – Fundamental concept of immunity measurement (see 3.1.1)

3.1.1.1 Objective assessment of performance degradation

Objective assessment of EUT immunity is made by monitoring voltages, currents, specific signals, audio rectification levels, etc., which can be recorded using analogue or digital recording techniques.

As an example of one such assessment of performance degradation, the immunity of television receivers to AM modulated RF interference is presented below.

First the wanted test signal only is applied to the EUT. This produces a wanted audio signal which is measured. The control of the EUT or test set-up is adjusted to set this audio signal at the required level. The wanted audio signal is then removed either by switching off the modulation or the audio test signal. The unwanted signal is applied in addition and its level is adjusted to obtain an unwanted audio signal at the specified level below the wanted audio signal level. The level of the unwanted signal is the measure of immunity of the EUT at the test frequency concerned. Care should be taken in order not to damage the EUT by too high levels of the unwanted signal.

3.1.1.2 Subjective assessment of performance degradation

Subjective assessment of EUT immunity is made by visual and/or aural monitoring of performance degradation for EUTs with such visual or aural or both presentations. This technique differs from that in 3.1.1.1 in that specific electrical or similar signals and levels are not directly recorded with an analogue or digital format. Instead, performance degradation is not formulated in measurable terms but in human sensory terms, e.g., human audio or visual perception of an annoying effect. The unwanted immunity signals can be the same or similar to those used for objective immunity assessment measurements.

As an example of one such subjective assessment of performance degradation, the immunity of television receivers to an unwanted signal, as perceived by humans as degraded visual and aural presentations, is given below.

In the case of picture interference, the wanted test signal produces a standard picture and the unwanted signal produces a degradation of the picture. The degradation may be in a number of forms, such as a superposed pattern, sync disturbance, geometrical distortion, loss of picture contrast or colour, etc.

The criterion of what constitutes performance degradation needs to be prescribed, and the conditions under which the subjective assessment is to be made must be specified.