

**Electromagnetic compatibility
and Radio spectrum Matters (ERM);
Short Range Devices (SRD);
Technical characteristics and test methods for
radio equipment in the frequency range 9 kHz to 25 MHz and
inductive loop systems in the frequency range 9 kHz to 30 MHz**



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Foreword

This European Standard (Telecommunications series) has been produced by ETSI Project Electromagnetic compatibility and Radio spectrum Matters (ERM), and is now submitted for the Public Enquiry phase of the ETSI standards Two-step Approval Procedure.

The present EN together with ETS 300 683 [6], is intended to become a Harmonized Standard, the reference of which will be published in the Official Journal of the European Communities referencing the Council Directive on the approximation of the laws of the Member States relating to electromagnetic compatibility ("the EMC Directive") (89/336/EEC as amended).

The technical parameters which are relevant to the EMC Directive are listed in normative annex G.

Proposed national transposition dates	
Date of latest announcement of this EN (doa):	3 months after ETSI publication
Date of latest publication of new National Standard or endorsement of this EN (dop/e):	6 months after doa
Date of withdrawal of any conflicting National Standard (dow):	36 months after doa

Introduction

The present document contains the technical characteristics for radio equipment referencing CEPT/ERC Decisions and Recommendations, including T/R 01-06 [1] and CEPT/ERC Recommendation 70-03 [2].

The present document is drafted on the assumption that type test measurements, performed in an accredited test laboratory will be accepted by the various National Regulatory authorities in order to grant type approval, provided the National Regulatory requirements are met. This is in compliance with CEPT Recommendation T/R 01-06 [1].

Included are methods of measurement for equipment, such as inductive loop systems, fitted with antenna connector and/or integral antennas. Equipment designed for use with an integral antenna may be supplied with a temporary or permanent internal connector for the purpose of testing, providing the characteristics being measured are not expected to be affected.

If equipment, which is available on the market, is required to be checked it should be tested in accordance with the methods of measurement specified in the present document.

Clauses 1 and 3 provide a general description on the types of equipment covered by the present document and the definitions and abbreviations used. Clause 4 provides as a guide the number of samples required in order that type tests may be carried out and any markings on the equipment which the applicant has to provide.

Clauses 5 and 6 provide general test conditions to be used.

Clauses 7 and 8 specify the spectrum utilization parameters which are required to be measured. These are maximum limits which have been chosen to minimize harmful interference to other equipment or services. The clauses provide details on how the equipment should be tested and the conditions which should be applied.

Clause 9 gives the maximum measurement uncertainty values.

Annex A provides normative specifications concerning radiated measurements.

Annexes B through E are normative graphical representations of Radio Frequency (RF) carrier current limits, H- and E-field strength carrier limits and spurious emission limits.

Annex F is normative describing the calculation guidelines for customized antennas.

Annex G is normative and details the parameters which are required to be measured for compliance with the EC Council Directive 89/336/EEC, ("the EMC Directive").

Annexes H and J are informative annexes describing test fixtures and E-fields.

1 Scope

The present document covers the minimum characteristics considered necessary for Short Range Devices (SRDs) in order to make the best use of the available frequencies. The term "The present document" refers to EN 300 330.

The present document is a generic standard for the frequency band 9 kHz to 25 MHz for radio equipment and 9 kHz to 30 MHz for inductive loop systems, which may be superseded by specific standards covering specific applications.

The present document contains the technical characteristics for radio equipment and is referencing CEPT/ERC Decisions and Recommendation for SRDs CEPT/ERC 70-03 [2].

The present document covers the minimum characteristics considered necessary in order to make the best use of the available frequencies.

The present document does not necessarily include all the characteristics which may be required by a user, nor does it necessarily represent the optimum performance achievable.

The present document applies to generic SRDs which are not covered by other specific product standards such as:

- inductive loop systems;
- with an antenna connection and/or with an integral antenna;
- for alarms, identification systems, telecommand, telemetry, etc.;
- applications with or without speech.

The parameters in clauses 7 and 8 of the present document are considered as spectrum utilization parameters. It is intended that these parameters will be measured by an accredited test laboratory for the purpose of type testing and approval.

The present document covers fixed stations, mobile stations and portable stations. If a system includes transponders, these are measured together with the transmitter.

All types of modulation for radio devices are covered by the present document, provided the requirements of subclause 7.3 are met.

Three types of measuring methods are defined in the present document due to the varied nature of the types of equipment used in this band. One method measures the RF carrier current, another measures the radiated H-field and the third the conducted power.

CEPT/ERC Recommendation 70-03 [2], on SRDs using an integral antenna, mentions in the frequency range 9 kHz to 30 MHz three Industrial, Scientific and Medical (ISM) frequency bands, 6,765 MHz to 6,795 MHz, 13,553 MHz to 13,567 MHz and 26,957 MHz to 27,283 MHz.

The radio equipment, covered by the classification SRD is divided into several classes based on the maximum radiated field strength. This classification is based on CEPT/ERC Recommendation 70-03 [2].

On non-harmonized parameters, national administrations can impose conditions on the type of modulation, channel/frequency separations, maximum transmitter output power/effective radiated power, equipment marking and the inclusion of an automatic transmitter shut-off facility, as a condition for the issue of an individual or general licence, or as a condition for use under licence exemption.

The present document covers requirements for radiated emissions below 30 MHz.

Additional standards or specifications may be required for equipment such as that intended for connection to the Public Switched Telephone Network (PSTN).

2 Normative references

References may be made to:

- a) specific versions of publications (identified by date of publication, edition number, version number, etc.), in which case, subsequent revisions to the referenced document do not apply; or
- b) all versions up to and including the identified version (identified by "up to and including" before the version identity); or
- c) all versions subsequent to and including the identified version (identified by "onwards" following the version identity); or
- d) publications without mention of a specific version, in which case the latest version applies.

A non-specific reference to an ETS shall also be taken to refer to later versions published as an EN with the same number.

- [1] CEPT/ERC Recommendation T/R 01-06: "Procedures for type testing and approval for radio equipment intended for non-public systems".
- [2] CEPT/ERC Recommendation 70-03 (1997): "Relating to the use of Short Range Devices (SRD)".
- [3] CISPR 16-1: "Specifications for radio disturbance and immunity measuring apparatus and methods". Part 1: Radio disturbance and immunity measuring apparatus".
- [4] ITU-T Recommendation O.153: "Basic parameters for the measurement of error performance at bit rates below the primary rate".
- [5] ETR 028: "Radio equipment and Systems (RES); Uncertainties in the measurement of mobile radio equipment characteristics".
- [6] ETS 300 683 (1997): "Radio Equipment and Systems (RES); ElectroMagnetic Compatibility (EMC) standard for Short Range Devices (SRD) operating on frequencies between 9 kHz and 25 GHz".

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the following definitions apply:

alarm: The use of radio communication for indicating an alarm condition at a distant location.

artificial antenna: A tuned reduced-radiating dummy load equal to the nominal impedance specified by the applicant.

assigned frequency band: The frequency band within which the device is authorized to operate.

conducted measurements: Measurements which are made using a direct connection to the equipment under test.

fixed station: Equipment intended for use in a fixed location.

H-field test antenna: An electrically screened loop or equivalent antenna, with which the magnetic component of the field can be measured.

identification system: Equipment consisting of a transmitter(s), receiver(s) (or a combination of the two) and an antenna(s) to identify objects by means of a transponder.

integral antenna: An antenna designed as an indispensable part of the equipment, with or without the use of an antenna connector.

magnetic dipole moment: The product of (Number of coil turns) \times (coil area) \times (coil current). (Air coils only)

mobile station: Equipment normally installed in a vehicle.

portable station: Equipment intended to be carried.

radiated measurements: Measurements which involve the absolute measurement of a radiated field.

telecommand: The use of radio communication for the transmission of signals to initiate, modify or terminate functions of equipment at a distance.

telemetry: The use of radio communication for indicating or recording data at a distance.

transponder: A device, that responds to an interrogation signal.

3.2 Symbols

For the purposes of the present document, the following symbols apply:

E	Electrical field strength
E _o	Reference electrical field strength, (see annex A)
f	Frequency
H	Magnetic field strength
H _o	Reference magnetic field strength, (see annex A)
m	Magnetic dipole moment
P	Power
R	Distance
R _o	Reference distance, (see annex A)
t	Time

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

EMC	ElectroMagnetic Compatibility
ETR	ETSI Technical Report
ISM	Industrial, Scientific and Medical
RF	Radio Frequency
Rx	Receiver
SRD	Short Range Device
Tx	Transmitter
VSWR	Voltage Standing Wave Ratio

4 General

4.1 Presentation of equipment for testing purposes

Each equipment submitted for testing shall fulfil the requirements of the present document on all frequencies over which it is intended to operate.

The applicant shall complete the appropriate application form when submitting the equipment for testing. Also, the applicant shall declare the frequency ranges, the range of operating conditions and power requirements, as applicable, to establish the appropriate test conditions.

Additionally, technical documentation and operating manuals, sufficient to make the test, shall be supplied.

Test fixtures may also be supplied by the applicant (see subclauses 6.3 and annex H).

If an equipment is designed to operate with different carrier powers, measurement of each Transmitter (Tx) parameter shall be performed, according to the present document, on samples of equipment defined in subclause 4.1.1.

4.1.1 Choice of model for testing

The applicant shall provide one or more samples of the equipment, as appropriate for testing.

Stand alone equipment shall be offered by the applicant complete with any ancillary equipment needed for testing.

If an equipment has several optional features, considered not to affect the RF parameters then the tests need only to be performed on the equipment configured with that combination of features considered to be the most complex, as proposed by the applicant and agreed by the test laboratory.

4.1.2 On-site testing

In certain cases it may not be possible to provide representative samples of antennas and/or equipment due to physical constraints. In these cases equivalent measurements to the present document shall be made at a representative installation of the equipment (on-site).

4.2 Mechanical and electrical design

4.2.1 General

The equipment submitted by the applicant should be designed, constructed and manufactured in accordance with sound engineering practice and with the aim of minimizing harmful interference to other equipment and services.

Txs and Receivers (Rxs) may be individual or combination units.

4.2.2 Controls

Those controls which, if maladjusted, might increase the interfering potentialities of the equipment shall not be easily accessible to the user.

4.2.3 Tx shut-off facility

If the Tx is equipped with an automatic Tx shut-off facility, it should be made inoperative for the duration of the test.

4.2.4 Rx mute or squelch

If the Rx is equipped with a mute, squelch or battery-saving circuit, this circuit shall be made inoperative for the duration of the tests.

4.2.5 Marking (equipment identification)

The equipment shall be marked in a visible place. This marking shall be legible and durable. Where this is not possible due to physical constraints, the marking shall be included in the users manual.

4.2.5.1 Equipment identification

The marking shall include as a minimum:

- the name of the manufacturer or his trade mark;
- the type designation.

4.2.5.2 Regulatory marking

The equipment shall be marked, where applicable, in accordance with CEPT/ERC Recommendation T/R 01-06 [1]. Where this is not applicable the equipment shall be marked in accordance with the National Regulatory requirements.

4.3 Declarations by the applicant

When submitting equipment for type testing, the applicant shall supply the necessary information according to the appropriate application form.

The performance of the equipment submitted for type testing shall be representative of the performance of the corresponding production model.

4.4 Auxiliary test equipment

All necessary test signal sources and set-up information shall accompany the equipment when it is submitted for type testing.

4.5 Interpretation of the measurement results

The interpretation of the results recorded on the appropriate test report for the measurements described in the present document shall be as follows:

- the measured value relating to the corresponding limit shall be used to decide whether an equipment meets the requirements of the present document;
- the measurement uncertainty value for the measurement of each parameter shall be included in the test report;
- the recorded value of the measurement uncertainty shall, for each measurement, be equal to, or lower than, the figures in the table of measurement uncertainty (clause 9).

5 Test conditions, power sources and ambient temperatures

5.1 Normal and extreme test conditions

Type testing shall be made under normal test conditions, and also, where stated, under extreme test conditions.

The test conditions and procedures shall be as specified in subclauses 5.2 to 5.4.

5.2 Test power source

The equipment shall be tested using the appropriate test power source as specified in subclauses 5.2.1 or 5.2.2. Where equipment can be powered using either external or internal power sources, then the equipment shall be tested using the external power source as specified in subclause 5.2.1 then repeated using the internal power source as specified in subclause 5.2.2.

The test power source used shall be stated in the test report.

5.2.1 External test power source

During type tests, the power source of the equipment shall be replaced by an external test power source capable of producing normal and extreme test voltages as specified in subclauses 5.3.2 and 5.4.2. The internal impedance of the external test power source shall be low enough for its effect on the test results to be negligible. For the purpose of the tests, the voltage of the external test power source shall be measured at the input terminals of the equipment. The external test power source shall be suitably de-coupled as close to the equipment battery terminals as practicable. For radiated measurements any external power leads should be so arranged so as not to affect the measurements.

During tests the test power source voltages shall be within a tolerance of $< \pm 1$ % relative to the voltage at the beginning of each test. The value of this tolerance can be critical for certain measurements. Using a smaller tolerance will provide a better uncertainty value for these measurements.

5.2.2 Internal test power source

For radiated measurements on portable equipment with integral antenna, fully charged internal batteries should be used. The batteries used should be as supplied or recommended by the applicant. If internal batteries are used, at the end of each test the voltage shall be within a tolerance of $< \pm 5$ % relative to the voltage at the beginning of each test.

If appropriate, for conducted measurements or where a test fixture is used, an external power supply at the required voltage may replace the supplied or recommended internal batteries. This shall be stated on the test report.

5.3 Normal test conditions

5.3.1 Normal temperature and humidity

The normal temperature and humidity conditions for tests shall be any convenient combination of temperature and humidity within the following ranges:

- temperature $+15^{\circ}\text{C}$ to $+35^{\circ}\text{C}$;
- relative humidity 20 % to 75 %.

When it is impracticable to carry out tests under these conditions, a note to this effect, stating the ambient temperature and relative humidity during the tests, shall be added to the test report.

5.3.2 Normal test power source

5.3.2.1 Mains voltage

The normal test voltage for equipment to be connected to the mains shall be the nominal mains voltage. For the purpose of the present document, the nominal voltage shall be the declared voltage, or any of the declared voltages, for which the equipment was designed.

The frequency of the test power source corresponding to the ac mains shall be between 49 Hz and 51 Hz.

5.3.2.2 Regulated lead-acid battery power sources

When the radio equipment is intended for operation with the usual types of regulated lead-acid battery power source, the normal test voltage shall be 1,1 multiplied by the nominal voltage of the battery (e.g. 6 V, 12 V etc.).

5.3.2.3 Other power sources

For operation from other power sources or types of battery (primary or secondary), the normal test voltage shall be that declared by the equipment applicant and agreed by the accredited test laboratory. Such values shall be stated in the test report.

5.4 Extreme test conditions

5.4.1 Extreme temperatures

5.4.1.1 Procedure for tests at extreme temperatures

Before measurements are made the equipment shall have reached thermal balance in the test chamber. The equipment shall be switched off during the temperature stabilizing period.

In the case of equipment containing temperature stabilization circuits designed to operate continuously, the temperature stabilization circuits shall be switched on for 15 minutes after thermal balance has been obtained, and the equipment shall then meet the specified requirements.

If the thermal balance is not checked by measurements, a temperature stabilizing period of at least one hour, or such period as may be decided by the accredited test laboratory, shall be allowed. The sequence of measurements shall be chosen, and the humidity content in the test chamber shall be controlled so that excessive condensation does not occur.

5.4.1.1.1 Procedure for equipment designed for continuous operation

If the applicant states that the equipment is designed for continuous operation, the test procedure shall be as follows:

- before tests at the upper extreme temperature the equipment shall be placed in the test chamber and left until thermal balance is attained. The equipment shall then be switched on in the transmit condition for a period of a half hour after which the equipment shall meet the specified requirements;
- for tests at the lower extreme temperature, the equipment shall be left in the test chamber until thermal balance is attained, then switched on for a period of one minute after which the equipment shall meet the specified requirements.

5.4.1.1.2 Procedure for equipment designed for intermittent operation

If the applicant states that the equipment is designed for intermittent operation, the test procedure shall be as follows:

- before tests at the upper extreme temperature the equipment shall be placed in the test chamber and left until thermal balance is attained in the oven. The equipment shall then either:
 - transmit on and off according to the applicants declared duty cycle for a period of five minutes; or
 - if the applicant's declared on period exceeds one minute, then:
 - transmit in the on condition for a period not exceeding one minute, followed by a period in the off or standby mode for four minutes; after which the equipment shall meet the specified requirements.
- for tests at the lower extreme temperature, the equipment shall be left in the test chamber until thermal balance is attained, then switched to the standby or receive condition for one minute after which the equipment shall meet the specified requirements.

5.4.1.2 Extreme temperature ranges

For tests at extreme temperatures, measurements shall be made in accordance with the procedures specified in subclause 5.4.1.1, at the upper and lower temperatures of one of the following ranges:

Category I (General): -20°C to + 55°C;

Category II (Portable): -10°C to + 55°C;

Category III (Equipment for normal indoor use): 0°C to + 55°C.

NOTE: The term "Equipment for normal indoor use" is taken to mean the minimum indoor temperature is equal to or greater than 5°C.

For special applications, the manufacturer can specify wider temperature ranges than given as a minimum above. This shall be reflected in manufacturers product literature.

The test report shall state which range is used.

5.4.2 Extreme test source voltages

5.4.2.1 Mains voltage

The extreme test voltages for equipment to be connected to an ac mains source shall be the nominal mains voltage $\pm 10\%$.

5.4.2.2 Regulated lead-acid battery power sources

When the radio equipment is intended for operation from the usual type of regulated lead-acid battery power sources the extreme test voltages shall be 1,3 and 0,9 multiplied by the nominal voltage of the battery (6 V, 12 V, etc.).

5.4.2.3 Power sources using other types of batteries

The lower extreme test voltages for equipment with power sources using batteries shall be as follows:

- for equipment with a battery indicator, the end point voltage as indicated;
- for equipment without a battery indicator the following end point voltages shall be used:
 - for the Leclanché or the lithium type of battery:
 - 0,85 multiplied by the nominal voltage of the battery;

- for the nickel-cadmium type of battery:
 - 0,9 multiplied the nominal voltage of the battery.
- for other types of battery or equipment, the lower extreme test voltage for the discharged condition shall be declared by the equipment applicant.

The nominal voltage is considered to be the upper extreme test voltage in this case.

5.4.2.4 Other power sources

For equipment using other power sources, or capable of being operated from a variety of power sources, the extreme test voltages shall be those agreed between the equipment applicant and the accredited test laboratory. This shall be recorded in the test report.

6 General conditions

6.1 Normal test signals and test modulation

The test modulating signal is a signal which modulates a carrier, is dependent upon the type of equipment under test and also the measurement to be performed. Modulation test signals only apply to products with an external modulation connector. For equipment without an external modulation connector, normal operating modulation shall be used.

6.1.1 Normal test signals for analogue speech

Normal test signals for analogue speech are specified as follows:

- A-M1: a 1 000 Hz tone;
- A-M2: a 1 250 Hz tone.

For angle modulation, the normal level of the test signals A-M1 and A-M2 shall be adjusted to produce a deviation of 12 % of the channel separation or any lower value as declared by the applicant as the normal operating level.

In the case of amplitude modulation, the normal modulation depth shall be 60 % or any lower value as declared by the applicant.

6.1.2 Normal test signals for data

Normal test signals for data are specified as follows:

- D-M2: a test signal representing a pseudo-random bit sequence of at least 511 bits in accordance with ITU-T Recommendation O.153 [4]. This sequence shall be continuously repeated. If the sequence cannot be continuously repeated, the actual method used shall be stated in the test report.
- D-M3: a test signal shall be agreed between the accredited test laboratory and the applicant in case selective messages are used and are generated or decoded within the equipment.

For angle modulation, the normal level of the test signal D-M3 shall produce a deviation of 20 % of the channel separation or any other value as declared by the applicant as the normal operating level.

In case of amplitude modulation, the modulation ratio shall be 60 %, or any value, as declared by the applicant, as the normal operating level.

6.2 Artificial antenna

Where applicable, tests shall be carried out using an artificial antenna which shall simulate the actual antenna configuration specified by the applicant.

6.2.1 Artificial antenna for inductive TxS (non 50 Ω)

For measurements of inductive TxS without a 50 Ω antenna impedance, a tuned reduced radiating load connected to the antenna connector shall be used as agreed with the accredited test laboratory.

The impedance shall be equal to the nominal load of the equipment specified by the applicant.

This method facilitates conducted measurements to be made of the following:

- Tx carrier loop currents up to 30 MHz;
- Tx spurious loop currents up to 30 MHz; and
- conducted spurious measurements in the range 30 MHz to 1 GHz.

The use of this non-50 Ω load during test shall be stated in the test report form.

6.2.2 Artificial antenna for TxS with 50 Ω impedance connector

For measurements on TxS with a normal 50 Ω antenna impedance, tests shall be carried out using an artificial antenna which shall be a substantially non-reactive non-radiating load with a 50 Ω resistor connected to the antenna connector. The Voltage Standing Wave Ratio (VSWR) at the 50 Ω connector shall not be greater than 1,2:1 over the frequency range of the measurement.

6.3 Test fixture

With equipment intended for use with an integral antenna, and not equipped with a 50 Ω RF output connector, the applicant shall supply a test fixture.

This fixture is a RF coupling device for coupling the integral antenna to a 50 Ω RF terminal at the working frequencies of the equipment under test. This allows certain measurements to be performed using conducted measuring methods. However, only relative measurements may be performed. The test fixture is normally only required for extreme temperature measurements and shall be calibrated only with the equipment under test.

The test fixture shall be fully described by the applicant. The accredited test laboratory shall calibrate the test fixture by carrying out the required field measurements at normal temperatures at the prescribed test site. Then the same measurements shall be repeated on the equipment under test using the test fixture for all identified frequency components.

In addition, the test fixture may provide:

- a connection to an external power supply;
- an audio interface either by direct connection or by an acoustic coupler;
- a connection to a data interface.

The performance characteristics of the test fixture shall be agreed upon with the accredited test laboratory and shall conform to the following basic parameters:

- the circuit associated with the RF coupling shall contain no active or non linear devices;
- the coupling loss shall not influence the measuring results;
- the coupling loss shall be independent of the position of the test fixture and be unaffected by the proximity of the surrounding objects or people;
- the coupling loss shall be reproducible when the equipment under test is removed and replaced;
- the coupling loss shall remain substantially constant when the environmental conditions are varied.

6.4 Test sites and general arrangements for radiated measurements

For guidance on radiation test sites, see annex A. Detailed descriptions of radiated measurement arrangements are included in this annex.

6.5 Modes of operation of the Tx

For the purpose of the measurements according to the present document, there should preferably be a facility to operate the Tx in an unmodulated state. The method of achieving an unmodulated carrier frequency or special types of modulation patterns may also be decided by agreement between the applicant and the accredited test laboratory. It shall be described in the test report. It may involve suitable temporary internal modifications of the equipment under test. If it is not possible to provide an unmodulated carrier then this shall be stated in the test report.

For Txs using a continuous wideband swept carrier the measurement shall be made with the sweep on.

For the purpose of type testing, the normal test signal, see subclauses 6.1.1 and 6.1.2, shall be applied to the input of the Tx under test with the normal input device disconnected (e.g. microphone).

6.6 Measuring Rx

The term "measuring receiver" refers to a selective voltmeter or a spectrum analyser. The bandwidth and detector type of the measuring receiver are given in table 1.

Table 1

Frequency: (f)	Detector type:	Bandwidth:
$9 \text{ kHz} \leq f < 150 \text{ kHz}$	Quasi Peak	200 to 300 Hz
$150 \text{ kHz} \leq f < 30 \text{ MHz}$	Quasi Peak	9 to 10 kHz
$30 \text{ MHz} \leq f \leq 1\,000 \text{ MHz}$	Quasi Peak	100 to 120 kHz

7 Tx requirements

To meet the requirements of the present document, the Tx shall be measured at the power level as declared by the applicant.

Where the Tx is designed with an adjustable carrier power, all parameters shall be measured using the highest output level as declared by the applicant. The equipment shall then be adjusted to the lowest setting, as declared by the applicant, and the spurious emissions measurement shall be repeated (see subclause 7.4).

When making Tx tests on equipment designed for intermittent operation, the duty cycle of the Tx, as declared by the applicant on the application form, shall not be exceeded. The actual duty cycle used shall be stated on the test report form.

If the equipment is supplied with both a permanent $50 \, \Omega$ antenna connector and a dedicated antenna, the full tests shall be carried out using the external connector and in addition:

- effective radiated power (radiated) (see subclauses 7.2.2.);
- spurious emissions (see subclause 7.2.2. and annex A)

tests shall be carried out with the dedicated antenna.

7.1 Tx definitions

Txs are divided into classes based on their radiated field and antenna type to be used. Class 2 and class 3 Txs may allow the customer to use his own loop antenna design based on the manufacturers design guidelines. The user's manual shall include the guidelines for the design of the antennas.

7.1.1 The inductive loop coil Txs

These Txs are characterized by:

- a) the loop coil antenna area A shall be $< 30 \text{ m}^2$;
- b) the circumference of any loop of the antenna shall be $< \frac{\lambda}{4}$ (or $< \frac{75}{f}$, where f is in MHz);
- c) antenna coil may have one or multiple turns.

7.1.2 The large size loop Txs

These Txs are characterized by:

- large loop antenna area $A > 30 \text{ m}^2$;
- large loop antenna with one turn only;
- frequency range limited from 9 kHz to 135 kHz only.

7.1.3 Other Txs

These Txs are characterized as either:

- E-field Txs, or;
- loop antenna Txs which are not meeting the criteria's in subclauses 7.1.1 and 7.1.2.

7.1.4 Product classes

The product classes are:

Class 1: Inductive loop coil Tx, type tested with an integral antenna; this means tested with either an integrated antenna or an external antenna supplied with the equipment.

The following restrictions apply to this class:

- 9 kHz to 30 MHz frequency range;
- integral antenna as defined above;
- no field customization of the antenna(s);
- loop antenna area $< 30 \text{ m}^2$; and
- circumference of any antenna loop element shall be $< \frac{\lambda}{4}$ (or $< \frac{75}{f}$, where f is in MHz).

The Tx carrier and spurious are limited by the maximum generated H-field, (see subclause 7.2.1 and subclauses 7.4.3 and 7.4.4 respectively).

Where a manufacturer provides a range of standard antennas, the equipment will be type tested as class 1 equipment, with the antenna(s) attached. The measurements shall be repeated for each of such antenna.

Class 2a: Inductive loop coil Tx, allowing field customization:

- a) for frequencies below 1 MHz customization is allowed according to the manufacturers design rules published in the equipment manual.
- b) for frequencies above 1 MHz customization is allowed by a selection from the manufacturers pre-designed loop antenna range published in the equipment manual.

Class 2a equipment is type tested as class 1 with two representative antennas supplied with the equipment. The two antennas must meet the manufacturers design rules published in the equipment manual and shall have maximum and minimum loop area respectively. Both antennas shall have the maximum magnetic dipole moment as declared by the manufacturer. The following additional restrictions apply to this class:

- 9 kHz to 30 MHz frequency range;
- loop antenna area $< 30 \text{ m}^2$; and
- circumference of any antenna loop element shall be $< \frac{\lambda}{4}$ (or $< \frac{75}{f}$, where f is in MHz).

The Tx carrier and spurious are limited by the maximum generated H-field, (see subclause 7.2.1 and subclauses 7.4.3 and 7.4.4 respectively).

Class 2b: The class 2b is intended for use with customized antennas in the 9 kHz to 135 kHz frequency range only. The inductive loop coil Tx is type tested without an antenna by using an artificial antenna.

The following additional restrictions apply to this class:

- loop antenna area $< 30 \text{ m}^2$; and
- circumference of any antenna loop element shall be $< \frac{\lambda}{4}$ (or $< \frac{75}{f}$, where f is in MHz).

The Tx carrier and spurious are limited by the maximum output loop current, (see subclause 7.2.2 and subclauses 7.4.2.1, 7.4.3 and 7.4.4 respectively).

Class 3: This class of equipment is intended for use with customized large size loop antennas only. The loop coil Tx is type tested without an antenna by using an artificial antenna.

The following additional restrictions apply to this class:

- 9 kHz to 135 kHz frequency range;
- loop antenna area $> 30 \text{ m}^2$;
- single loop only.

The Tx carrier and spurious are limited by the maximum output loop current, (see subclause 7.2.2.3 and subclauses 7.4.2.1, 7.4.2.1, 7.4.3 and 7.4.4 respectively).

Class 4: E-field Tx, type tested with each type of antenna to be used.

The Tx carrier and spurious are limited by the maximum generated E-field, measured as the equivalent H-field, (see subclause 7.2.3 and subclauses 7.4.3 and 7.4.4 respectively).

7.2 Tx carrier output levels

7.2.1 H-field (radiated)

7.2.1.1 Definition

In the case of a Tx with an integral antenna, the H-field is measured in the direction of maximum field strength under specified conditions of measurement.

7.2.1.2 Methods of measurement

The H-field produced by the equipment shall be measured at standard distance of 10 m or optionally 30 m as requested by the applicant. The measurements shall be made on an open field test site as specified in annex A.

The H-field is measured with a shielded loop antenna connected to a measurement Rx. The measuring bandwidth and detector type of the measurement Rx shall be in accordance with subclause 6.6.

The equipment under test shall operate where possible, without modulation. Where this is not possible, it shall be stated in the test report.

For Tx's using a continuous wideband swept carrier, the measurement shall be made with the sweep on.

For inductive Tx's having an antenna system performing a distance cancellation effect (increased attenuation with distance), the applicant may have the carrier H-field measured at 30 m distance.

If a 30 m measuring distance is used during the test, this shall be stated in the application and test report.

This 30 m test distance is only valid for the carrier frequency, other frequencies including spurious components shall be measured at the standard distance of 10 m.

For measuring equipment calibrated in dB μ V, the reading should be reduced by 51,5 dB to be converted to dB μ A/m.

7.2.1.3 Limits

The limits presented in the present document are the required field strengths to allow satisfactory operation of inductive systems. These levels were determined after careful analysis within ETSI and ERC/CEPT.

Exceptionally some National Administrations may have a need for SRDs to apply lower field strengths at particular frequencies. Details are available in CEPT/ERC Recommendation 70-03 [2].

Maximum field strength under normal and extreme conditions are given in tables 2 and 3.

Table 2: H-field limits at 10 m

Frequency range (MHz)	H-field strength limit (H_f) dB μ A/m at 10 m
$0,009 \leq f < 0,03$	72 or according to note
$0,03 \leq f < 0,07$ $0,119 \leq f < 0,135$	72 at 0,03 MHz descending 3 dB/oct or according to note
$0,07 \leq f < 0,119$	42
$0,135 \leq f < 1,0$	37,7 at 0,135 MHz descending 3 dB/oct
$1,0 \leq f < 4.462$	29 at 1,0 MHz descending 9 dB/oct
$4,642 \leq f < 30$	9
$6,765 \leq f \leq 6,795$ $13,553 \leq f \leq 13,567$ $26,957 \leq f \leq 27,283$	42
NOTE: For the frequency ranges 9 to 70 kHz and 119 to 135 kHz, the following additional restrictions apply to the higher limits: <ul style="list-style-type: none"> - for loop coil antennas with an area $\geq 0,16 \text{ m}^2$ table 2 applies directly; - for loop coil antennas with an area between $0,05 \text{ m}^2$ and $0,16 \text{ m}^2$ table 2 applies with a correction factor. The limit is: table value + $10 \times \log (\text{area}/0,16 \text{ m}^2)$; - for loop coil antennas with an area $< 0,05 \text{ m}^2$ the limit is 10 dB below table 2. 	

For equivalent graphical representation of table 2, see annex B.

Carrier limits for a measuring distance of 30 m are given in table 3.

Table 3: H-field limits at 30 m

Frequency range (MHz)	H-field strength limit (H_f) dB μ A/m at 30 m
$0,009 \leq f < 0,03$	43,5 or according to note
$0,03 \leq f < 0,07$ $0,119 \leq f < 0,135$	43,5 at 0,03 MHz descending 3 dB/oct or according to note
$0,07 \leq f < 0,119$	13,5
$0,135 \leq f < 1,26$	8,7 at 0,135 MHz descending 3 dB/oct
$1,26 \leq f < 30$	-1
$6,765 \leq f \leq 6,795$ $13,553 \leq f \leq 13,567$ $26,957 \leq f \leq 27,283$	32,5
NOTE: For the frequency ranges 9 to 70 kHz and 119 to 135 kHz, the following additional restrictions apply to the higher limits: <ul style="list-style-type: none"> - for loop coil antennas with an area $\geq 0,16 \text{ m}^2$ table 3 applies directly; - for loop coil antennas with an area between $0,05 \text{ m}^2$ and $0,16 \text{ m}^2$ table 3 applies with a correction factor. The limit is: table value + $10 \times \log (\text{area}/0,16 \text{ m}^2)$; - for loop coil antennas with an area $< 0,05 \text{ m}^2$ the limit is 10 dB below table 3. 	

For a graphical representation of table 3, see annex B.

7.2.2 RF carrier current

7.2.2.1 Definition

The RF carrier current is defined as the current delivered to an artificial load under specified conditions of measurement.

7.2.2.2 Methods of measurement

The Tx shall be connected to an artificial antenna, see subclause 6.2.1. The RF current delivered to this artificial antenna during a transmission duty cycle shall be measured up to 30 MHz. The current shall be measured either by using:

- a calibrated current probe connected to a measuring Rx; or
- a derived output from a calibrated artificial antenna connected to a measuring Rx, see annex H.

The measuring bandwidth and detector type shall be in accordance with subclause 6.6.

For Txs using a continuous wideband swept carrier the measurement shall be made with the sweep on.

This method of measurement for the Tx carrier current is used for:

- Class 2b and class 3 equipment operating at a frequency up to 135 kHz.

The measurements shall be made under normal and extreme test conditions, see subclause 5.4.

The relation between carrier current and antenna dimensions is given in annex H.

7.2.2.3 Limits

7.2.2.3.1 Class 2b

a) RF carrier current:

during extreme test conditions the measured value of RF carrier current shall not exceed the maximum permissible value derived from annex H, figure H.1.

b) equivalent H-field:

The maximum field strength is given in table 2.

It is unnecessary to measure the radiated H-field to obtain type testing. However, if subsequently there is a requirement to test the equipment measurements shall be made, with the customized antenna fitted, in accordance with subclause 7.2.1.2 and shall not exceed the limits as stated in subclause 7.2.1.3.

The type testing will be to a specific maximum RF carrier current, as declared by the manufacturer on the appropriate application form. This will allow the manufacturer to supply a customized antenna based on the minimum antenna factor, for a given maximum RF current, obtained from annex H, figure H.1. Customized antennas shall be approved by the manufacturer or the manufacturer's representative.

A detailed explanation of the relationship between the RF carrier current, antenna factor ($N \times A$) and the equivalent generated H-field is given in annex H.

7.2.2.3.2 Class 3

The maximum RF carrier current limit for Large size loop Txs is given in table 4.

Table 4: RF carrier current

Frequency range MHz	RF carrier current dBμA
0,009 - < 0,03	115
0,03 ≤ f < 0,07 0,119 ≤ f < 0,135	115 at 30 kHz descending 3 dB/oct
0,07 ≤ f < 0,119	85

See annex C for a graphical representation.

7.2.3 Radiated E-field (Class 4)

7.2.3.1 Definition

The radiated E-field is defined as the E-field in the direction of maximum field strength under the specified conditions of measurement. This is defined for a Tx with an integral antenna.

7.2.3.2 Methods of measurement

The Tx radiated E-field is based on the equivalent H-field, measured at 10 m.

The H-field is measured with a shielded loop antenna connected to a measurement Rx. The measuring bandwidth and detector type of the measurement Rx shall be in accordance with subclause 6.6.

For a detailed explanation of the relationship between E-field and H-field, see annex J.

7.2.3.3 Limits

In the frequency range 9 kHz to 4,78 MHz, the limits of H_{ef} follow the H-fields limits, H_f , as given in subclause 7.2.1.3, table 2 with an additional correction factor C. The factor given below is specific for a 10 m measuring distance.

The limit $H_{ef} = H_f + C$

where:

$$C = 20 \times \log (f_c / 4,78 \times 10^6) \text{ dB}$$

and where:

f_c is the carrier frequency in Hz

For a graphical representation of the correction factor C see annex D.

In the frequency range 4,78 MHz to 25 MHz limits are identical to the limits in subclause 7.2.1.3, table 2 without any correction factor.

7.3 Permitted frequency range of the modulation bandwidth

The permitted frequency range shall be stated by the applicant.

7.3.1 Definition

The modulation bandwidth contains all associated side bands above the following level:

- a) for frequencies below 135 kHz at the highest level of either:
 - 30 dB below the carrier or;
 - at the appropriate spurious limit, see subclause 7.4.
- b) for frequencies in the range 135 kHz to 30 MHz:
 - at the appropriate spurious limit, see subclause 7.4.

Where the assigned frequency band has been divided into sub-bands, the above measuring levels and bandwidths apply at the sub-band limits.

7.3.2 Method of measurement

The Tx shall be connected to an artificial antenna or if the Tx has an integral antenna a test fixture shall be used (see subclause 6.3). The RF output of the equipment shall be connected to a spectrum analyser via a 50 Ω variable attenuator.

The Tx shall be operated at the nominal carrier power or field strength measured under normal test conditions in subclause 7.2. The attenuator shall be adjusted to an appropriate level displayed at the spectrum analyser screen.

The Tx shall be modulated with standard test modulation (see subclauses 6.1.1 and 6.1.2). If the equipment cannot be modulated externally, the internal modulation shall be used.

For Tx's using a continuous wideband swept carrier the measurement shall be made with the sweep on.

The output of the Tx, with or without test fixture, shall be measured by using a spectrum analyser with a resolution bandwidth appropriate to accept all major side bands. The power level calibration of the spectrum analyser shall then be related to the power level or field strength measured in subclause 7.2. The calculation will be used to calculate the absolute level of the sideband power.

The test laboratory shall ensure that the spectrum analyser's span is sufficiently wide enough to ensure that the carrier and all its major side bands are captured.

The frequencies of the upper and lower points, where the displayed power envelope of the modulation including frequency drift is equal to the appropriate level defined in subclause 7.3.1 is recorded as the modulation bandwidth.

The measurements shall be made during normal and extreme test conditions (subclauses 5.4.1 and 5.4.2 applied simultaneously).

7.3.3 Limits

The permitted range of the modulation bandwidth shall be within the frequency limits given in subclause 7.2.1.3, tables 2 or 3.

7.4 Spurious emissions

7.4.1 Definition

Spurious emissions are emissions at frequencies other than those of the carrier and sidebands associated with normal test modulation (subclause 6.1). The level of spurious emissions shall be measured at normal conditions (subclause 5.3) as either:

- 1) a) their power or current level in an artificial antenna (conducted spurious emission); and
- b) their effective radiated power or field strength when radiated by the cabinet and structure of the equipment (cabinet radiation);

or

- 2) their effective radiated power or field strength when radiated by the cabinet and the integral antenna.

7.4.2 Conducted spurious emissions

This subclause refers to the requirements in subclause 7.4.1; indent 1 a).

7.4.2.1 Class 2b and class 3

7.4.2.1.1 Methods of measurement (< 30 MHz)

The Tx shall be connected to an artificial antenna according to subclause 6.2.1. The measuring Rx shall be connected to the output of the artificial antenna and the current for both the carrier and the spurious components shall be measured. For further details of the artificial antenna, see annex H.

The method for deriving the spurious current limit I_s is calculated by the following formula:

$$I_c - I_s = H_c - H_s$$

where:

I_s is the measured conducted spurious current limit expressed in dB μ A;

I_c is the measured RF carrier current limit expressed in dB μ A, see subclause 7.2.2.3.1 a);

H_c is the limit for the generated H-field expressed in dB μ A/m, see subclause 7.2.1.3;

H_s is the limit for H-field spurious expressed in dB μ A/m, see subclause 7.4.3.2.

The term $(H_c - H_s)$ in the above formula is the required attenuation in dB of the spurious H-field. This requirement may vary with frequency due to varying limits with frequency.

The term $(I_c - I_s)$ (in dB) is the attenuation in dB of the spurious current below the carrier current.

7.4.2.1.2 Limits

Under normal test conditions the following condition shall be fulfilled:

$$(I_c - I_s) \geq (H_c - H_s)$$

7.4.2.1.3 Methods of measurement (≥ 30 MHz)

The Tx shall be connected to an artificial antenna according to subclause 6.2.2. The spurious components are measured by means of a selective voltmeter connected to the output of the Tx by means of an appropriate coupling device. For details of the artificial antenna, see annex H.

7.4.2.1.4 Limits

The power of any conducted spurious emission shall not exceed the values given in table 5.

Table 5

State	47 MHz to 74 MHz 87,5 MHz to 118 MHz 174 MHz to 230 MHz 470 MHz to 862 MHz	Other Frequencies between 30 to 1 000 MHz
Operating	4 nW	250 nW
Standby	2 nW	2 nW

7.4.3 Radiated field strength

This subclause refers to subclause 7.4.1; indent 1 b) and 2).

7.4.3.1 Methods of measurement (< 30 MHz)

This applies to all classes.

The field strength shall be measured for frequencies below 30 MHz. The equipment under test shall be measured at a distance of 10 m on an outdoor test site. The test antenna shall be a calibrated shielded magnetic field antenna. The equipment under test and test antenna shall be arranged as stated in annex A, clause A.1.

For classes 2b and 3 the Tx antenna connector of the equipment under test shall be connected to an artificial antenna (see subclause 6.2) and the output connector terminated.

The equipment under test shall be switched on with normal modulation. The characteristics of the modulation signal used shall be stated on the test report. The measuring Rx shall be tuned over the frequency range 9 kHz to 30 MHz, except for the frequency band on which the Tx is intended to operate.

At each frequency at which a relevant spurious signal is detected the equipment under test and the test antenna shall be rotated until maximum field strength is indicated on the measuring Rx. This level shall be noted.

If the Tx can be operated in the standby mode, then the measurements shall be repeated in the standby mode.

Convert reading by -51,5 dB for measuring equipment calibrated in dB μ V or dB μ V/m.

7.4.3.2 Limits

Radiated emissions below 30 MHz shall not exceed the generated H-field dB μ A/m at 10 m given in table 6.

Table 6

State	Frequency 9 kHz $\leq f < 4,78$ MHz	Frequency 4,78 MHz $\leq f < 30$ MHz
Transmit	26,5 dB μ A/m descending 3 dB/oct	-1 dB μ A/m
Standby	5,5 dB μ A/m descending 3 dB/oct	-22 dB μ A/m

For a graphical representation see annex E.

7.4.4 Effective radiated power

This subclause refers to the requirements of subclause 7.4.1 1., b) and 2).

7.4.4.1 Methods of measurement (≥ 30 MHz)

This method applies to all classes.

On a test site selected from annex A, the equipment shall be placed at the specified height on a non-conducting support and in the position closest to normal use as declared by the applicant.

For classes 2b and 3 the transmitter antenna connector shall be connected to an artificial antenna (see subclause 6.2).

The test antenna shall be oriented for vertical polarization. The output of the test antenna shall be connected to a measuring Rx.

The Tx shall be switched on with normal modulation, and the measuring Rx shall be tuned over the frequency range 30 MHz to 1 000 MHz.

At each frequency at which a relevant spurious component is detected, the test antenna shall be raised and lowered through the specified range of heights until a maximum signal level is detected on the measuring Rx.

The Tx shall then be rotated through 360° in the horizontal plane, until the maximum signal level is detected by the measuring Rx.

The maximum signal level detected by the measuring Rx shall be noted.

The substitution antenna shall be oriented for vertical polarization and calibrated for the frequency of the spurious component detected.

The frequency of the calibrated signal generator shall be set to the frequency of the spurious component detected. The input attenuator setting of the measuring Rx shall be adjusted in order to increase the sensitivity of the measuring Rx, if necessary.

The test antenna shall be raised and lowered through the specified range of heights to ensure that the maximum signal is received.

When a test site according to annex A, clause A.3 is used, there is no need to vary the height of the antenna.

The input signal to the substitution antenna shall be adjusted until an equal or a known related level to that detected from the Tx is obtained on the measuring Rx.

The input signal to the substitution antenna shall be recorded as a power level and corrected for any change of input attenuator setting of the measuring Rx.

The measurement shall be repeated with the test antenna and the substitution antenna oriented for horizontal polarization.

The measure of the effective radiated power of the spurious components is the larger of the two power levels recorded for each spurious component at the input to the substitution antenna, corrected for the gain of the substitution antenna if necessary.

If an unmodulated carrier cannot be obtained then the measurements shall be made with the Tx modulated by the normal test signal (see subclause 6.1.2) in which case this fact shall be recorded in the test report.

If standby mode is available, the measurements shall be repeated in that mode.

7.4.4.2 Limits

The power of any radiated emission shall not exceed the values given in table 7

Table 7

State	47 MHz to 74 MHz 87,5 MHz to 118 MHz 174 MHz to 230 MHz 470 MHz to 862 MHz	Other frequencies between 30 to 1 000 MHz
Operating	4 nW	250 nW
Standby	2 nW	2 nW

8 Rx requirement

8.1 Rx spurious radiation

These requirements do not apply to Rxs used in combination with permanently co-located Tx's continuously transmitting. Co-located is defined as < 3 m. In these cases the Rxs will be tested together with the Tx in operating mode (see subclause 7.4).

8.1.1 Definition

Spurious radiation from Rxs are emissions radiated from the antenna, the chassis and case of the Rx. It is specified as the radiated power of a discrete signal.

8.1.2 Methods of measurement

- 1) For radiation below 30 MHz see subclause 7.4.3.1.
- 2) For radiation at or above 30 MHz see subclause 7.4.4.1.

Convert reading by 51,5 dB for measuring equipment calibrated in dB μ V or dB μ V/m.

8.1.3 Limits

8.1.3.1 Radiated emissions below 30 MHz:

The spurious components below 30 MHz shall not exceed the generated H-field dB μ A/m values at 10 m according to table 8.

Table 8

Frequency $9 \text{ kHz} \leq f < 4,78 \text{ MHz}$	Frequency $4,78 \text{ MHz} \leq f < 30 \text{ MHz}$
5,5 dB μ A/m descending 3 dB/oct	- 22 dB μ A/m

For a graphical representation see annex E.

8.1.3.2 Radiated emissions above 30 MHz

The measured values shall not exceed 2 nW.

9 Measurement uncertainty

The accumulated measurement uncertainties of the test system in use for the parameters to be measured should not exceed those given below, this is in order to insure that the measurements remain within an acceptable standard.

RF frequency	$\pm 1 \times 10^{-5}$
RF power, conducted	$\pm 0,75$ dB
RF power, radiated	± 6 dB
Temperature	± 1 °C
Humidity	± 5 %

For the test methods according to the present document the uncertainty figures are valid to a confidence level of 95 % calculated according to the methods described in ETR 028 [5].

Annex A (normative): Radiated measurements

A.1 Test sites and general arrangements for measurements involving the use of radiated fields

A.1.1 Outdoor test site

The outdoor test site shall be on a reasonably level surface or ground. For measurements at frequencies below 30 MHz no artificial ground plane shall be used. For measurements at frequencies 30 MHz and above, a conducting ground plane of at least 5 m diameter shall be provided at one point on the site. In the middle of this ground plane, a non-conducting support, capable of rotation through 360° in the horizontal plane, shall be used to support the test sample in its standard position, at 1 m above the ground plane, with the exception of equipment with floor standing antenna. For this equipment, the antenna shall be raised, on a non-conducting support, 100 mm above the turntable, the point(s) of contact being consistent with normal use. The test site shall be large enough to allow the erection of a measuring or transmitting antenna at a distance of 10 m or optionally 30 m. The distance actually used shall be recorded with the results of the tests carried out on the site.

Sufficient precautions shall be taken to ensure that reflections from extraneous objects adjacent to the site do not degrade the measurements results.

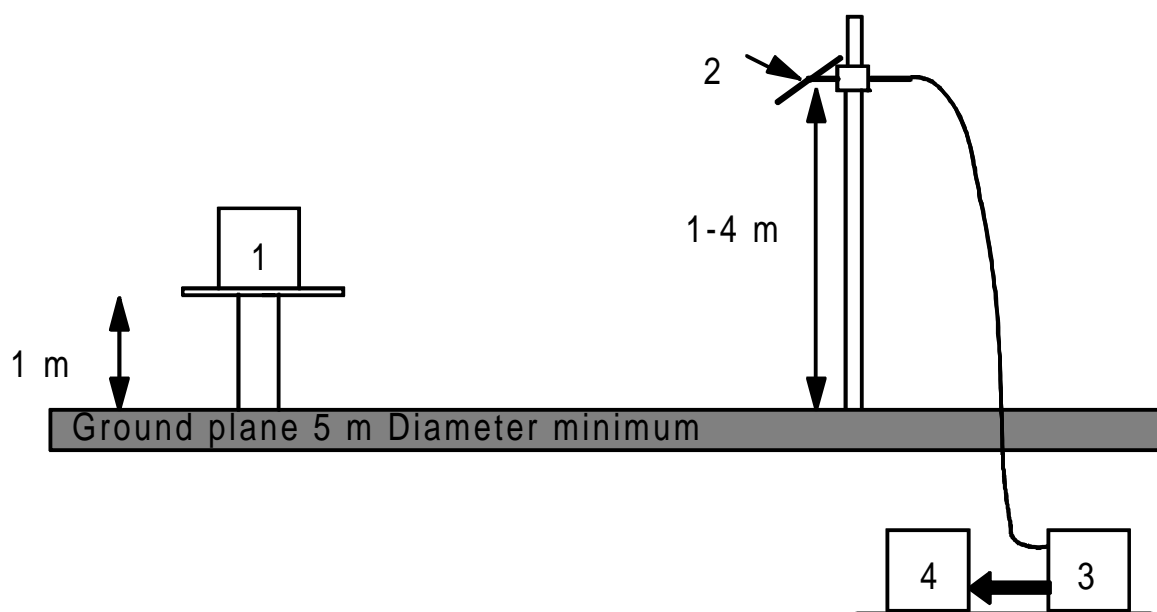


Figure A.1

A.1.1.1 Standard position

The standard position in all test sites, except for equipment which is intended to be worn on a person, shall be as follows:

- for equipment with an integral antenna, it shall be placed in the position closest to normal use as declared by the manufacturer;
- for equipment with a rigid external antenna, the antenna shall be vertical;
- for equipment with non-rigid external antenna, the antenna shall be extended vertically upwards by a non-conducting support.

For equipment intended to be worn close to the body or hand held, the non-conducting support may, at the request of the applicant be replaced with a simulated man, if appropriate. The use of the simulated man shall be stated in the test report.

The simulated man shall consist of an acrylic tube, filled with salt water (1,5 grams NaCl per litre of distilled water). The tube shall have a length of $1,7 \pm 0,1$ m and an internal diameter of 300 ± 5 mm with sidewall thickness of $1,5 \pm 0,5$ mm.

To reduce the weight of the simulated man it may be possible to use an alternative tube which has a hollow centre of 200 mm maximum diameter.

The sample shall be fixed to the surface of the simulated man, at the appropriate height for the equipment.

A.1.2 Test antenna

A.1.2.1 Below 30 MHz

A calibrated loop antenna shall be used to detect the field strength from the test sample. The antenna shall be supported in the vertical plane and be rotated about a vertical axis. The lowest point of the loop shall be 1 m above ground level.

A.1.2.2 Above 30 MHz

The test antenna is used to detect the radiation from both the test sample and the substitution antenna, when the site is used for radiation measurements. Where necessary, it is used as a transmitting antenna, when the site is used for the measurement of Rx characteristics.

This antenna is mounted on a support such as to allow the antenna to be used in either horizontal or vertical polarization and for the height of its centre above ground to be varied over the range 1 m to 4 m. Preferably a test antenna with pronounced directivity should be used. The size of the test antenna along the measurement axis shall not exceed 20 % of the measuring distance.

For Rx and Tx radiation measurements, the test antenna is connected to a measuring Rx, capable of being tuned to any frequency under investigation and of measuring accurately the relative levels of signals at its input.

A.1.3 Substitution antenna

When measuring in the frequency range up to 1 GHz the substitution antenna shall be a $\lambda/2$ dipole, resonant at the operating frequency, or a shortened dipole, calibrated to the $\lambda/2$ dipole. The centre of this antenna shall coincide with the reference point of the test sample it has replaced. This reference point shall be the volume centre of the sample when its antenna is mounted inside the cabinet, or the point where an external antenna is connected to the cabinet.

The distance between the lower extremity of the dipole and the ground shall not be less than 0,3 m.

The substitution antenna shall be connected to a calibrated signal generator when the site is used for spurious radiation measurements and Tx effective radiated power measurements. The substitution antenna shall be connected to a calibrated measuring Rx when the site is used for the measurement of Rx sensitivity.

The signal generator and the Rx shall operate at the frequencies under investigation and shall be connected to the antenna through suitable matching and balancing networks.

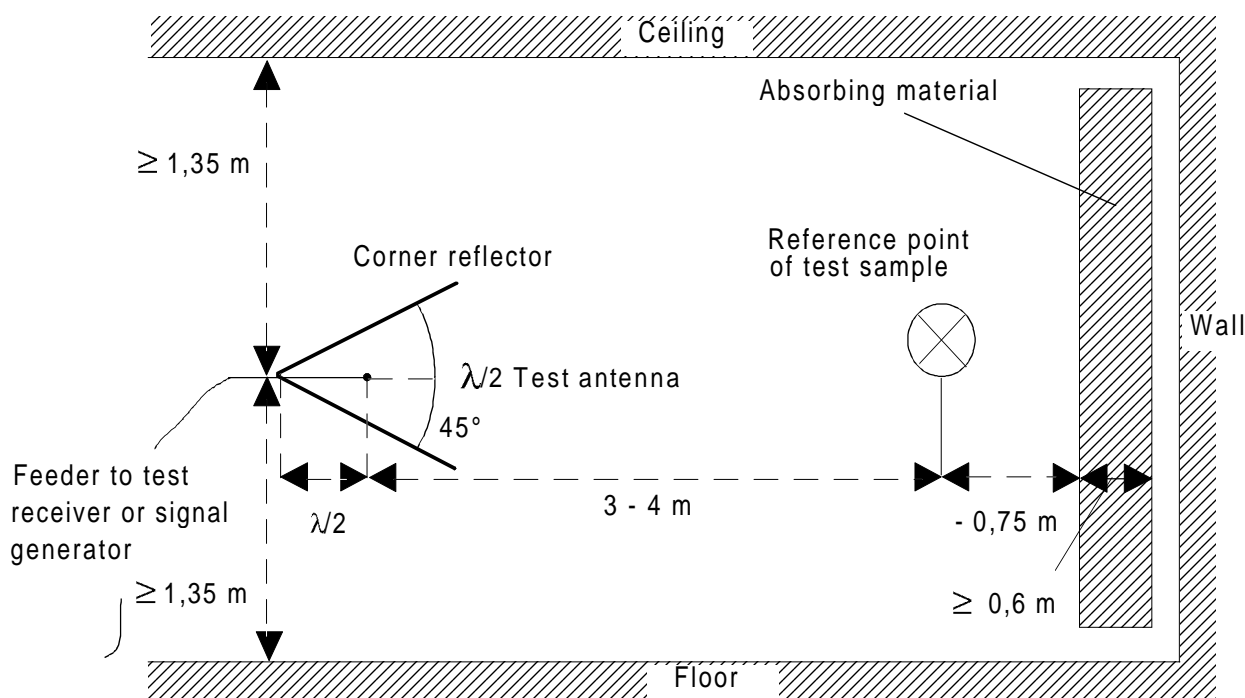


Figure A.2: Indoor site arrangement (shown for horizontal polarization)

A.1.4 Optional additional indoor site

When the frequency of the signals being measured is greater than 80 MHz, use may be made of an indoor test site. If this alternative site is used, this shall be recorded in the test report.

The measurement site may be a laboratory room with a minimum area of 6 m by 7 m and at least 2,7 m in height.

Apart from the measuring apparatus and the operator, the room shall be as free as possible from reflecting objects other than the walls, floor and ceiling.

The potential reflections from the wall behind the equipment under test are reduced by placing a barrier of absorbent material in front of it. The corner reflector around the test antenna is used to reduce the effect of reflections from the opposite wall and from the floor and ceiling, in the case of horizontally polarized measurements. Similarly, the corner reflector reduces the effects of reflections from the side walls for vertically polarized measurements. For the lower part of the frequency range (below approximately 175 MHz), no corner reflector or absorbent barrier is needed. For practical reasons, the $\lambda/2$ antenna in figure A.2 may be replaced by an antenna of constant length, provided that this length is between $\lambda/4$ and λ at the frequency of measurement, and the sensitivity of the measuring system is sufficient. In the same way, the distance of $\lambda/2$ to the apex may be varied.

The test antenna, measuring Rx, substitution antenna and calibrated signal generator are used in a way similar to that of the general method. To ensure that errors are not caused by the propagation path approaching the point at which phase cancellation between the direct and the remaining reflected signals occurs, the substitution antenna shall be moved through a distance of $\pm 0,1$ m in the direction of the test antenna as well as in the two directions perpendicular to this first direction.

If these changes of distance cause a signal change of greater than 2 dB, the test sample should be re-sited until a change of less than 2 dB is obtained.

A.2 Guidance on the use of radiation test sites

For measurements involving the use of radiated fields, use may be made of a test site in conformity with the requirements of clause A.1. When using such a test site, the following conditions should be observed to ensure consistency of measuring results.

A.2.1 Measuring distance

Evidence indicates that the measuring distance is not critical and does not significantly affect the measuring results, provided that the distance is not less than $\lambda/2$ at the frequency of measurement, and that the precautions described in this annex are observed. Measurements at low frequencies and distances less than $\lambda/2$ are considered in the present document and shall be followed. Measuring distances of 3 m, 5 m, 10 m and 30 m are in common use in European test laboratories.

A.2.2 Test antenna

Different types of test antenna may be used, since performing substitution measurements reduces the effect of the errors on the measuring results.

Height variation of the test antenna over a range of 1 m to 4 m is essential in order to find the point at which the radiation is maximum.

Height variation of the test antenna may not be necessary at the lower frequencies below approximately 100 MHz.

A.2.3 Substitution antenna

Variations in the measuring results may occur with the use of different types of substitution antenna at the lower frequencies below approximately 80 MHz. Where a shortened dipole antenna is used at these frequencies, details of the type of antenna used should be included with the results of the tests carried out on the test site. Correction factors shall be taken into account when shortened dipole antennas are used.

A.2.4 Artificial antenna

The dimensions of the artificial antenna used during radiated measurements should be small in relation to the sample under test.

Where possible, a direct connection should be used between the artificial antenna and the test sample. In cases where it is necessary to use a connecting cable, precautions should be taken to reduce the radiation from this cable by, for example, the use of ferrite cores or double screened cables.

A.2.5 Auxiliary cables

The position of auxiliary cables (power supply and microphone cables etc.) which are not adequately de-coupled, may cause variations in the measurement results. In order to get reproducible results, cables and wires of auxiliaries should be arranged vertically downwards (through a hole in the non conducting support), or as specified in the technical documentation supplied with the equipment.

Care shall be taken to ensure that test cables do not adversely effect the measuring result.

A.3 Further optional alternative indoor test site using an anechoic chamber

For radiation measurements, when test frequency of the signals being measured is greater than 30 MHz, use may be made of an indoor test site being a well-shielded anechoic chamber simulating a free space environment. If such a chamber is used, this shall be recorded in the test report.

The test antenna, measuring Rx, substitution antenna and calibrated signal generator are used in a way similar to that of the general method, clause A.1. In the range 30 MHz to 100 MHz, some additional calibration may be necessary.

An example of a typical measurement site may be an electrically shielded anechoic chamber being 10 m long, 5 m broad and 5 m high. Walls and ceiling should be coated with RF absorbers of 1 m height. The base should be covered with absorbing material 1 m thick, and a wooden floor, capable of carrying test equipment and operators. The construction of the anechoic chamber is described in the following subclauses.

A.3.1 Example of the construction of a shielded anechoic chamber

Free-field measurements can be simulated in a shielded measuring chamber where the walls are coated with RF absorbers. Figure A.3 shows the requirements for shielding loss and wall return loss of such a room. As dimensions and characteristics of usual absorber materials are critical below 100 MHz (height of absorbers < 1 m, reflection attenuation < 20 dB) such a room is more suitable for measurements above 100 MHz. Figure A.4 shows the construction of an anechoic shielded measuring chamber having a base area of 5 m by 10 m and a height of 5 m.

Ceilings and walls are coated with pyramidal formed RF absorbers approximately 1 m high. The base is covered with absorbers forming a non-conducting sub-floor or with special ground floor absorbers. The available internal dimensions of the room are 3 m × 8 m × 3 m, so that a maximum measuring distance of 5 m length in the middle axis of this room is available.

At 100 MHz the measuring distance can be extended up to a maximum of 2λ .

The floor absorbers reduce floor reflections so that the antenna height need not be changed and floor reflection influences need not be considered.

All measuring results can therefore be checked with simple calculations and the measurement uncertainties have the smallest possible values due to the simple measuring configuration.

A.3.2 Influence of parasitic reflections in anechoic chambers

For free-space propagation in the far field condition the correlation $E = E_0 (R_0/R)$ is valid for the dependence of the field strength E on the distance R , whereby E_0 is the reference field strength in the reference distance R_0 .

It is useful to use this correlation for comparison measurements, as all constants are eliminated with the ratio and neither cable attenuation, nor antenna mismatch, or antenna dimensions are of importance.

Deviations from the ideal curve can be seen easily if the logarithm of the above equation is used, because the ideal correlation of field strength and distance can then be shown as a straight line and the deviations occurring in practice are clearly visible. This indirect method more readily shows the disturbances due to reflections and is far less problematical than the direct measurement of reflection attenuation.

With an anechoic chamber of the dimensions suggested in clause A.3 at low frequencies up to 100 MHz, there are no far field conditions and therefore reflections are stronger so that careful calibration is necessary; in the medium frequency range from 100 MHz to 1 GHz the dependence of the field strength on the distance meets the expectations very well.

A.3.3 Calibration of the shielded RF anechoic chamber

Careful calibration of the chamber shall be performed over the range 30 MHz to 1 GHz.

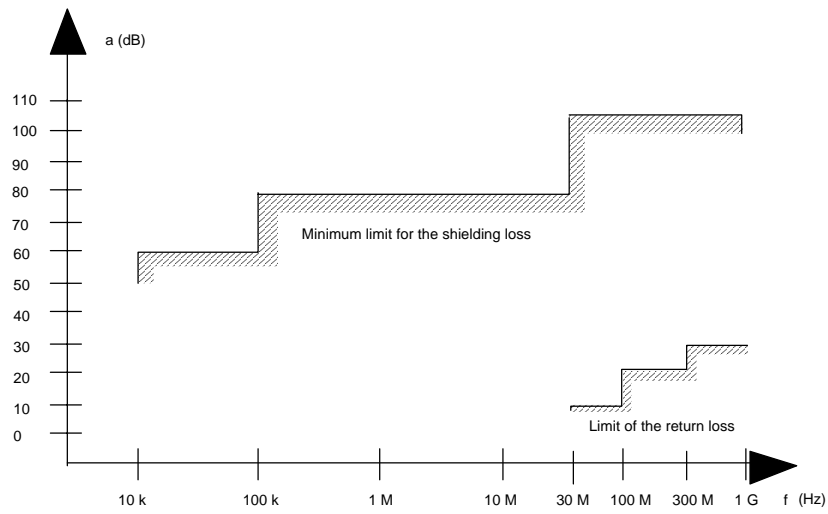
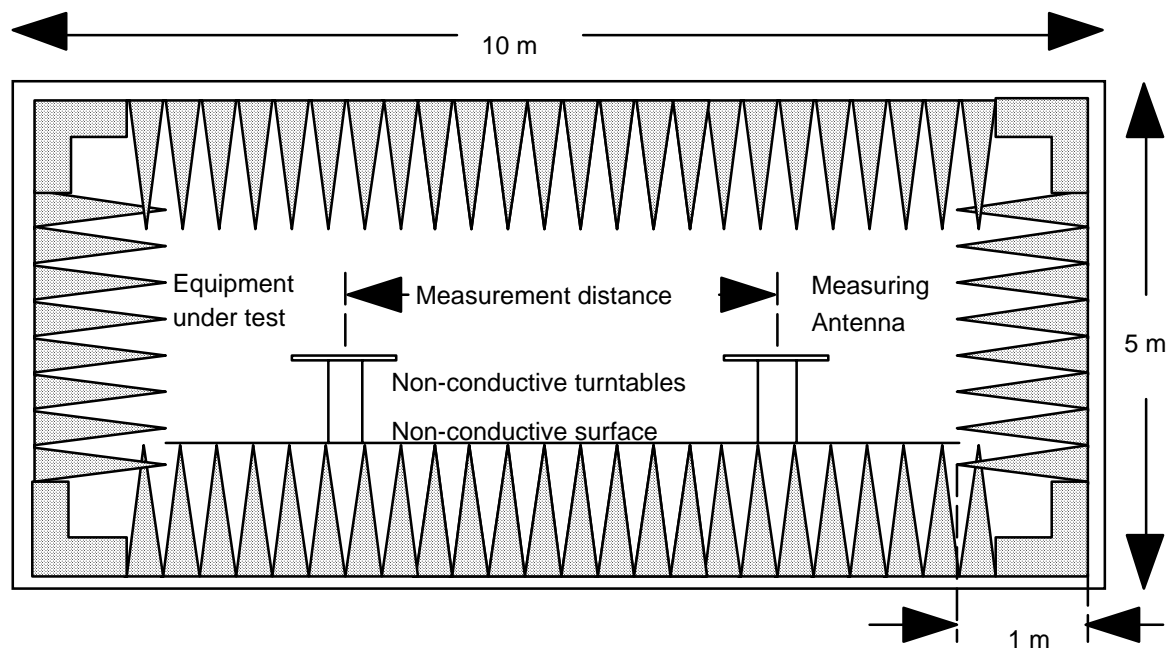


Figure A.3: Specification for shielding and reflections



Ground plan

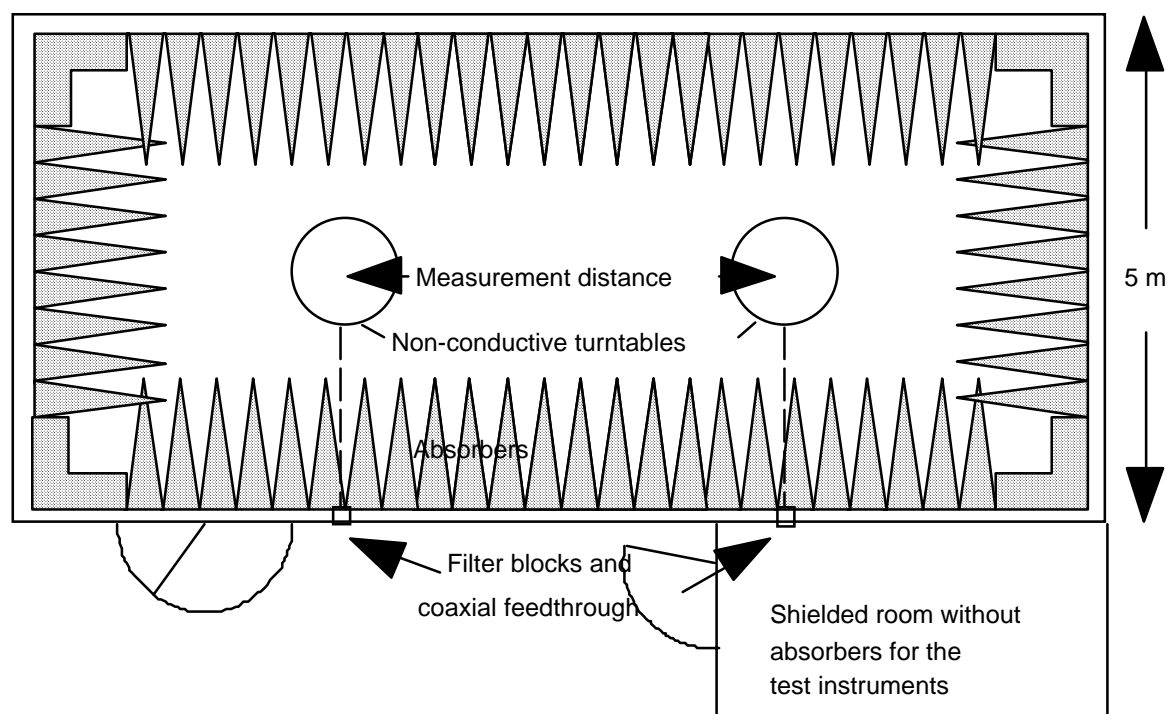


Figure A.4: Example of construction of an anechoic shielded chamber

Annex B (normative): Tx carrier limits

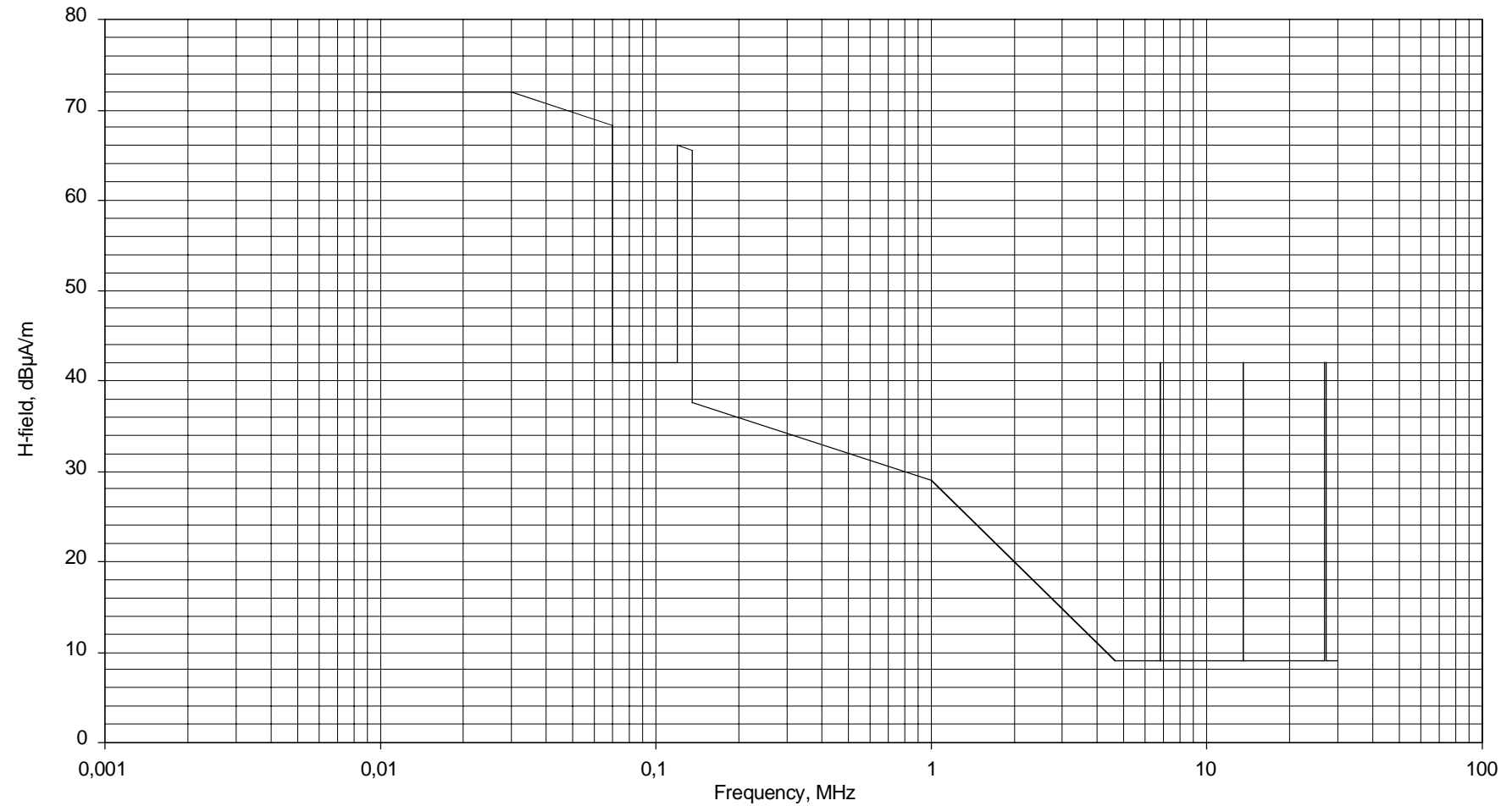


Figure B.1: Radiated H-field at 10 m distance

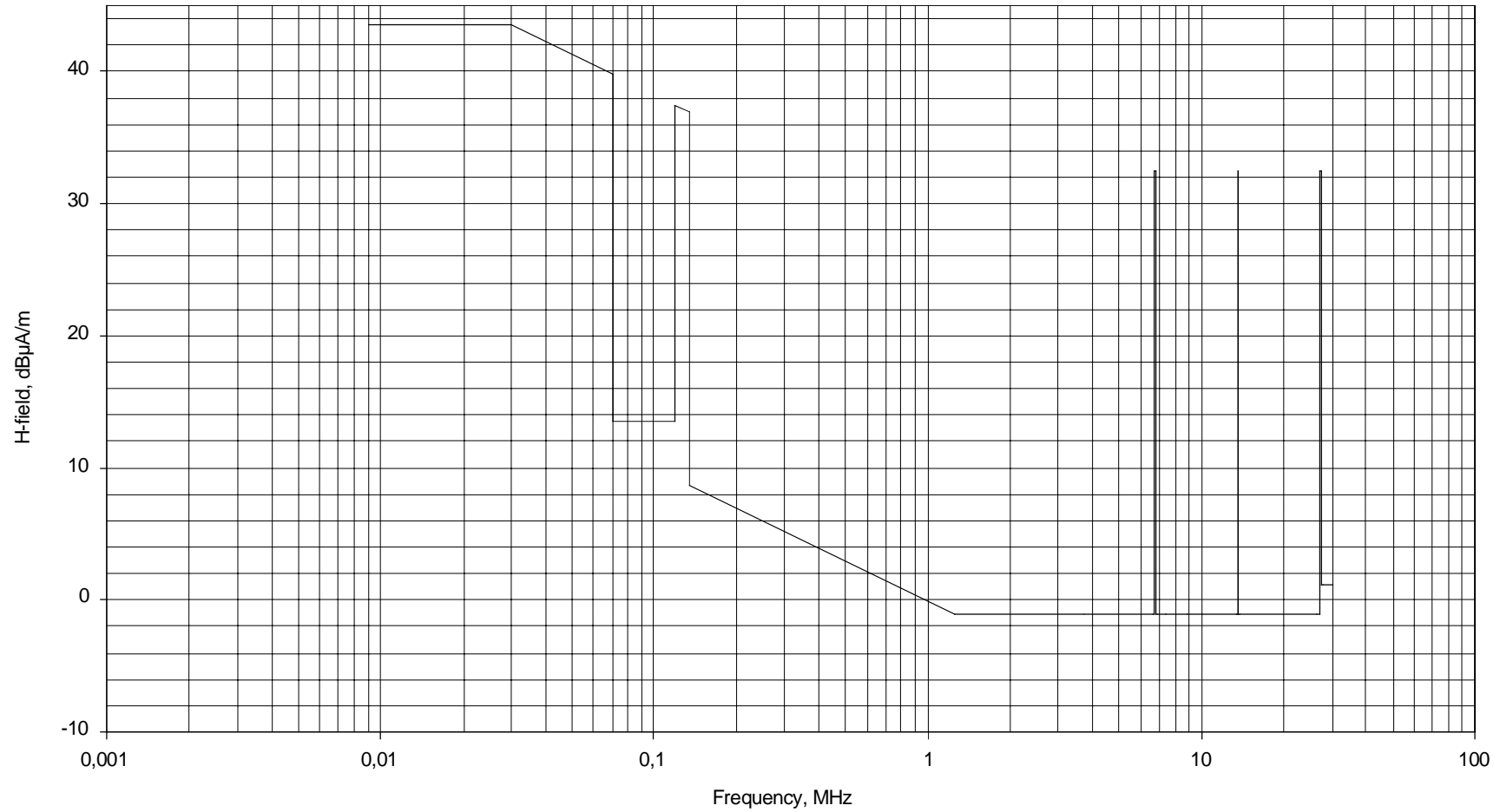


Figure B.2: Radiated H-field at 30 m distance

Annex C (normative): Tx RF carrier current limit for large size loop

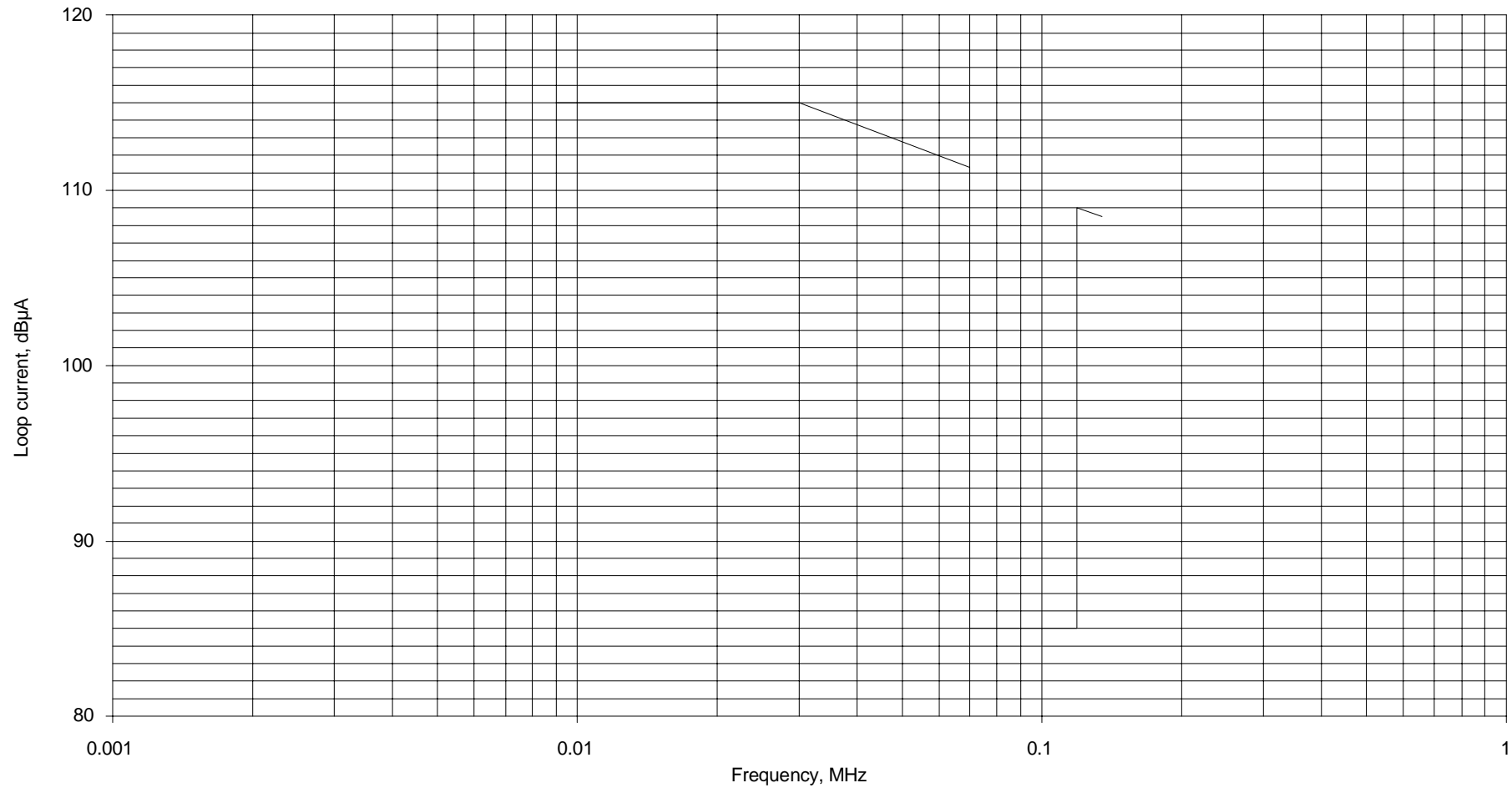


Figure C.1

Annex D (normative): H-field limit correction factor for generated E-fields

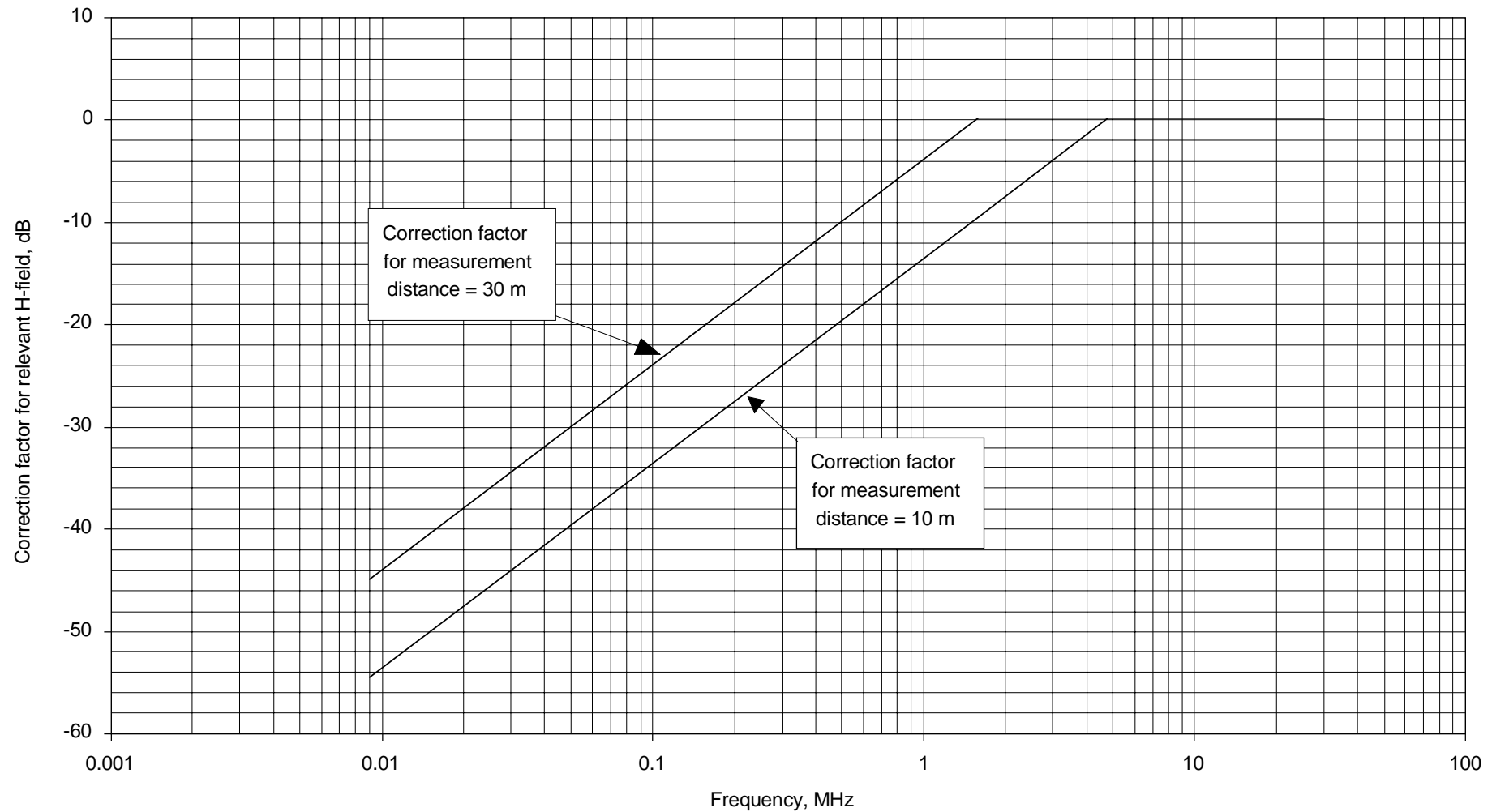


Figure D.1

Annex E (normative): Spurious limits, radiated H-field at 10 m distances

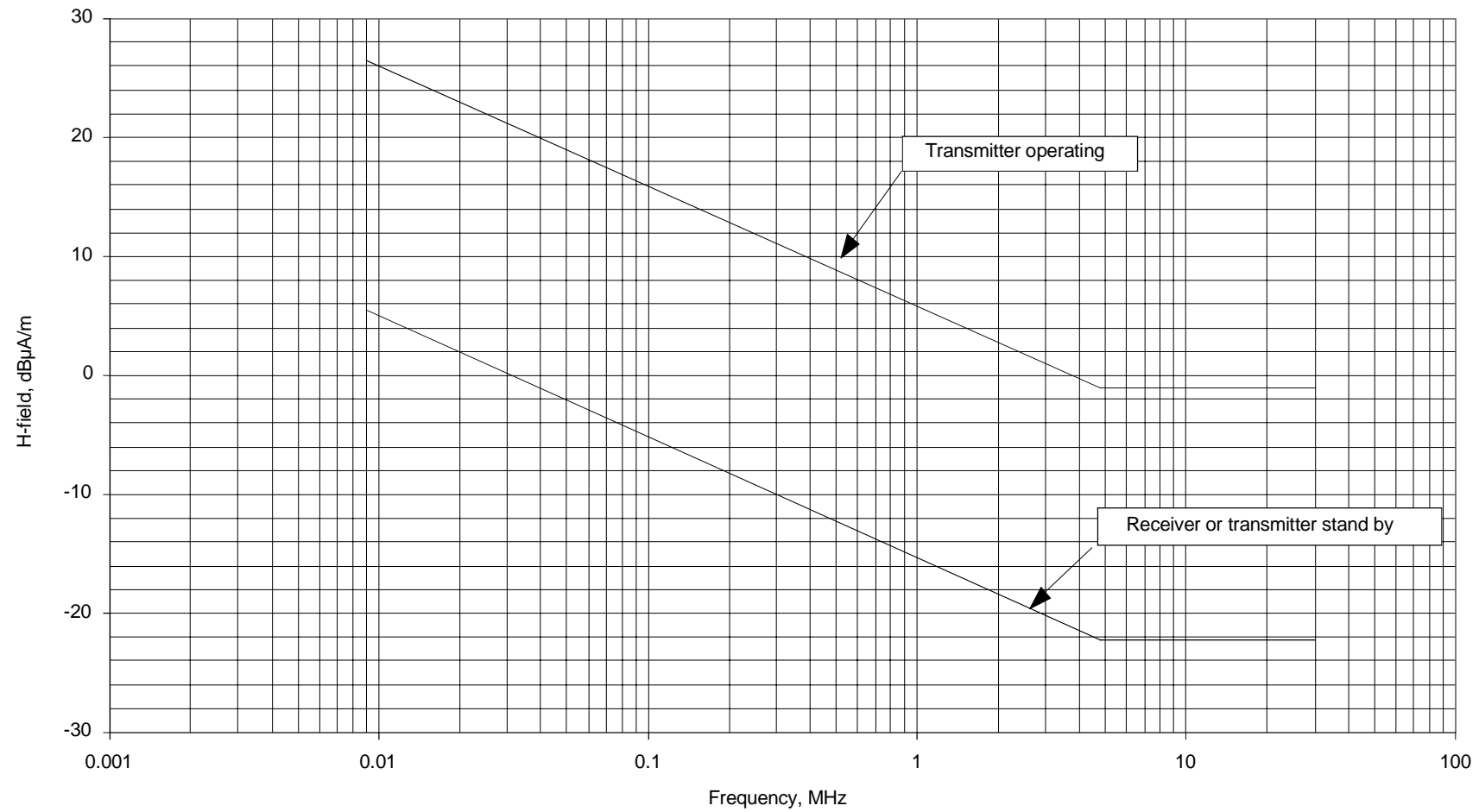


Figure E.1

Annex F (normative): Customized loop antennas

F.1 Equipment classes related to the antenna loop

The present document allows customization of loop antennas under the following restrictions:

- Class 1 is tested with an integral antenna. No antenna customization allowed;
- Class 2 is restricted to loop antenna areas $< 30 \text{ m}^2$ and a circumference of the antenna loop of less than $\lambda/4$.
Class 2a equipment is tested with two representative maximum and minimum size loop antennas supplied by the manufacturer. Class 2a allows:
 - a) for frequencies $> 1 \text{ MHz}$
 - customization by a selection from a "pre-designed antenna range" based on the manufacturer's design rules documented in the equipment manual.
 - b) for frequencies $< 1 \text{ MHz}$
 - customization of the loop antenna according to the manufacturers design rules documented in the equipment manual.
- Class 2b is only valid for the low frequency range 9 kHz to 135 kHz and the equipment is only tested with an artificial antenna.
 - allow customization of the loop antenna according to the manufacturer's design rules as documented in the equipment manual.
- Class 3 is restricted to loop antenna sizes $> 30 \text{ m}^2$. The equipment is tested with an artificial antenna only.
 - allow customization of a single turn large loop.

The design formulas given under subclauses F.1.1 and F.1.2 are given as guidelines only.

F.1.1 Antenna loops below 1 MHz

The radiated magnetic field H from a loop coil antenna in the near field is given by:

$$H = \frac{NIA}{2\pi d^3} \text{ A / m} \quad (1)$$

where:

N is the number of turns of the loop coil antenna;
I is the current in Ampere in the loop coil antenna;
A is the area in m^2 of the loop coil antenna;
d is the distance in metre from the Tx.

The formula is valid at low frequencies under the following conditions:

- Length of the coil wire: $l < \lambda / 2\pi$
- Distance from coil: $d < \lambda / 2\pi$

The product of NIA is the magnetic dipole moment m of the coil.

Equation (1) gives:

$$m = NIA = H \cdot 2\pi d^3 \quad \text{Am}^2 \quad (2)$$

In the present document the reference measuring distances d are 10 m or 30 m.

If 10 m is inserted into (2):

$$m = NIA = H_{10} \times 6283 \quad \text{Am}^2 \quad (3)$$

where:

H_{10} is the H-field limit @ 10 m in A/m (see subclause 7.1.1).

Equation (3) can also be used for the 30 m field limit H_{30} . The equation is only valid up to 1 MHz.

For method of measurement for loop current into an artificial antenna, see annex H.

F.1.2 Antenna loops above 1 MHz

For frequencies above 1 MHz the maximum dipole moment can be derived from:

$$P_{erp} = \frac{8\mu_0 \pi^3 M^2 f^4}{3c^3} \quad (4)$$

Equation (4) after rearrangement:

$$m = NIA = \frac{1}{f^2} \sqrt{\frac{3c^3}{8\mu_0 \pi^3} P_{erp}} \quad (5)$$

Above 1 MHz the NAI limit is determined by equation (5) and is descending with f^2 or 12 dB/oct.

Below 1 MHz the NAI limit is determined by equation (3), see subclause F.1.1.

Relevant erp limits of tables 2 and 3 of subclause 7.2.1.3 are 250 nW, 2,5 μ W and 10 mW all erp. The corresponding $N \times I \times A$ products are calculated in examples (6), (7) and (8):

For erp = 250 nW erp in (5):

$$N I A = \frac{0,255}{f^2} \quad \text{A} \times \text{m}^2 \quad (6)$$

For erp = 2,5 μ W erp in (5):

$$N I A = \frac{0,806}{f^2} \quad \text{A} \times \text{m}^2 \quad (7)$$

For erp = 10 mW erp in (5):

$$N I A = \frac{50,98}{f^2} \quad \text{A} \times \text{m}^2 \quad (8)$$

where the frequency f is in MHz in (6), (7) and (8).

For method of measurement for loop current into an artificial antenna, see annex H.

Annex G (normative):

Subclauses of the present document relevant for compliance with the essential requirements of relevant EC Council Directives

Table G.1: Subclauses of the present document relevant for compliance with the essential requirements of relevant EC Council Directives

Clause/subclause number and title		Corresponding article of Council Directive 89/336/EEC	Qualifying remarks
7.4	Spurious emissions	4(a)	for Txs and transceivers
8.1	Spurious radiations	4(a)	for Rxs only

Annex H (informative): Test fixture for measuring inductive Tx carrier and harmonic currents by use of an artificial antenna

The artificial antenna is used for equipment with an antenna connector and submitted for type testing without an antenna. The radiated fields for the carrier and spurious are proportional to the RF carrier and spurious currents. Therefore, measurements are made to determine the RF carrier and spurious currents in the artificial antenna.

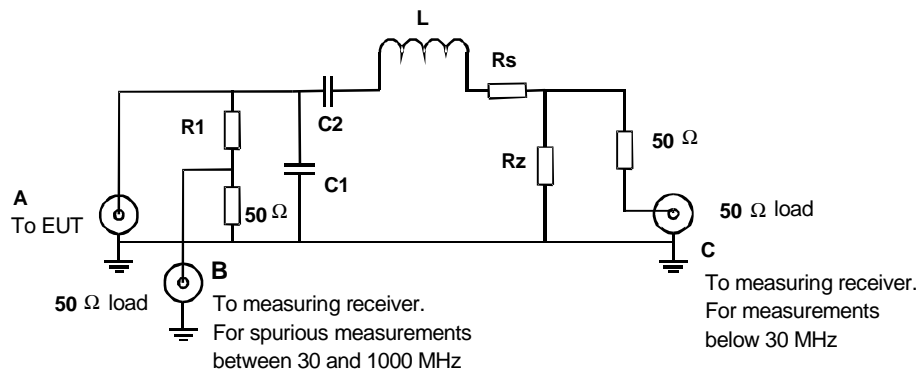


Figure H.1

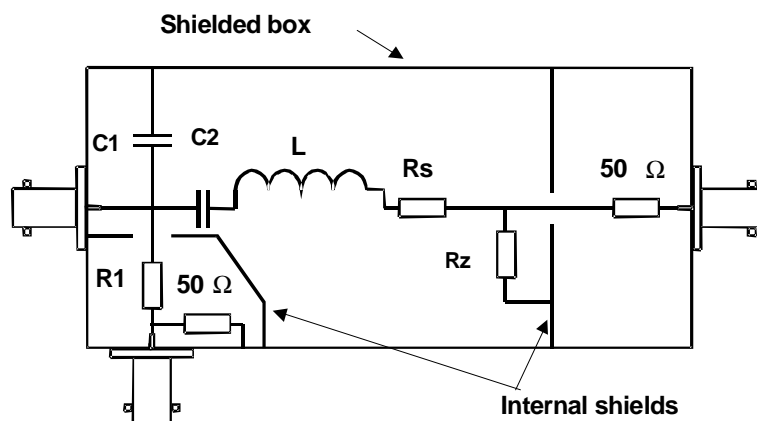


Figure H.2

An example of the mechanical layout and the equivalent electric circuit of the components is given in figures H.2 and H.1 respectively.

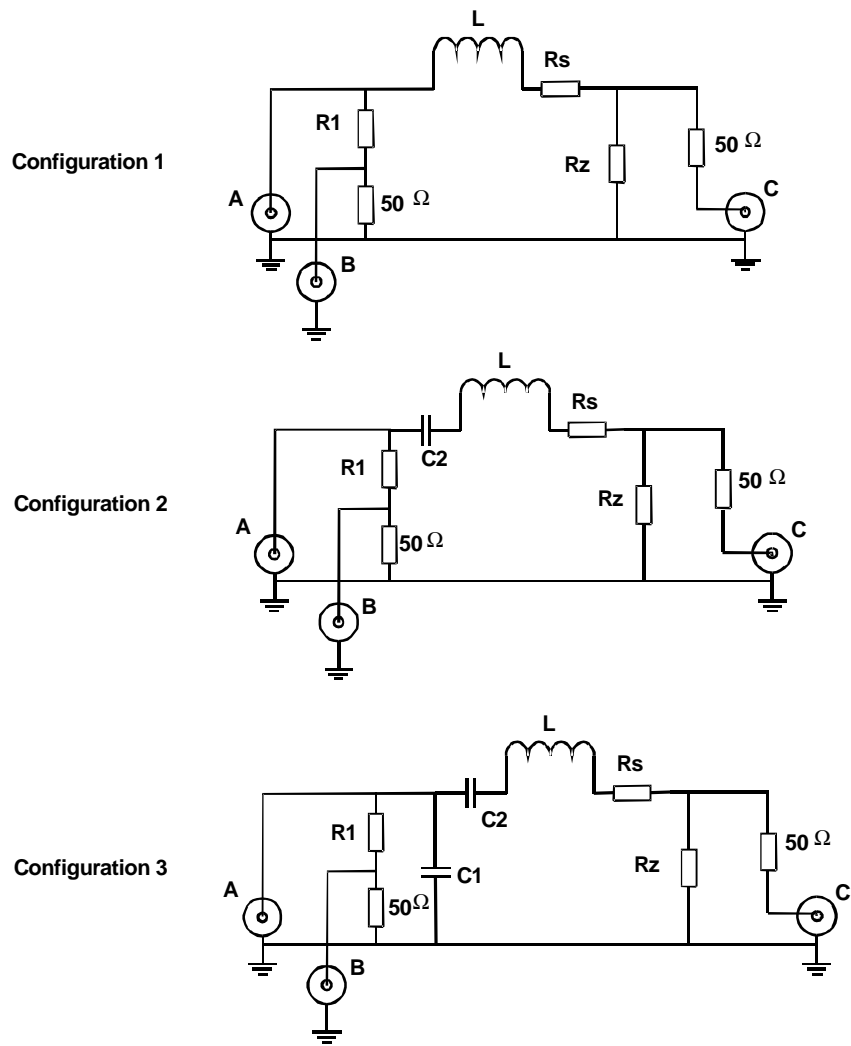
If the manufacturer uses several values of antenna inductance, two artificial antennas having maximum and minimum inductance L should be supplied as agreed with the accredited test laboratory. This fact is stated in the test report.

R_z is a low value non-reactive resistor. The voltage across R_z is proportional to the conducted carrier and spurious loop currents. These can be measured at connector C.

R_s in combination with R_z ensures that the artificial antenna has the same Q the actual loop antenna.

Resistor R_1 together with a $50\ \Omega$ load resistor provides an attenuation of EUT output signal at connector B used for conducted spurious measurements between 30 MHz and 1 GHz.

Capacitors C_1 , C_2 are optional components together with L to be used as appropriate by the manufacturer to simulate the actual loop antenna configuration. Other possible configurations are shown in figure H.3.

**Figure H.3**

The test fixture configuration used by the manufacturer is stated in the application and test report.

Annex J (informative): E-fields in the near field at low frequencies

E-field at low frequencies is often in the near field and it is in reality only possible to measure with the shielded loop antenna; in this case there is also a relation between the E-field and the H-field by the wave impedance Z . In the near field the wave impedance is highly dependent on the type of radiating antenna (loop or open end wire) and the wavelength. If the power density at a certain distance is the same for a H-field and an E-field generated signal, the following calculation can be made:

In the direction of maximum power in the near field, the power density S is:

$$S = \frac{E^2}{Z_e} = H_e^2 Z_e = H_m^2 Z_m \quad (1)$$

where:

S = power density;

E = electrical field generated by an E-field antenna at distance d ;

H_e = magnetic field generated by an E-field antenna at distance d ;

H_m = magnetic field generated by a H-field antenna at distance d ;

Z_e = wave impedance of a field generated by an E-field antenna at distance d ;

Z_m = wave impedance of a field generated by an H-field antenna at distance d .

$$Z_m = Z_0 2\pi \frac{d}{\lambda} \quad \text{if } d < \frac{\lambda}{2\pi} \quad (\text{near field}) \quad (2)$$

$$Z_e = Z_0 \frac{\lambda}{2\pi d} \quad \text{if } d < \frac{\lambda}{2\pi} \quad (\text{near field}) \quad (3)$$

Equation (1) gives:

$$H_e = H_m \sqrt{\frac{Z_m}{Z_e}} \quad (A/m) \quad (4)$$

Equation (2) and (3) into (4) gives:

$$H_e = H_m \frac{2\pi d}{\lambda} = H_m \frac{2\pi d f_c}{300} \quad (5)$$

where f_c is the carrier frequency in MHz.

For $2\pi d/\lambda = 1$, $d = 10$ and $f_c = 4,78$ MHz, and using equation (5), this gives:

$$H_e = H_m \frac{f_c}{4,78} \quad (f \text{ in MHz}) \quad (6)$$

For $2\pi d/\lambda < 1$ if $f_c < 4,78$ MHz then equation (5) is valid, (i.e. near field).

For $2\pi d/\lambda \geq 1$ if $f_c > 4,78$ MHz then $H_e = H_m$, (i.e. far field).

The method allows an electric generated E-field to be measured as a magnetic generated H-field by adding a correction factor derived from (6).

For a graphical representation of the correction factor, see annex D.

Annex K (informative): Bibliography

The following material, though not specifically referenced in the body of the present document, gives supporting information.

- ERC Report 44 (1997): "Sharing between Inductive Systems and Radio Communications Systems in the Band 9 - 135 kHz".

History

Document history		
V1.2.1	April 1998	Public Enquiry PE 9831: 1998-04-03 to 1998-07-31