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Radio Equipment and Systems (RES)
Wideband data transmission systems
Technical characteristics and test conditions for data transmission equipment operating in the 2,4 Ghz ISM band and using spread spectrum modulation techniques

ETSI

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Contents

Foreword

This European Telecommunication Standard (ETS) has been prepared by the Radio Equipment and Systems (RES) Technical Committee of the European Telecommunications Standards Institute (ETSI).

Annex A provides additional information concerning radiated measurements.

Annex B contains normative specifications for the adjustment of the measurement equipment and of the equipment to be measured in order to achieve correct results.

Transposition dates	
Date of latest announcement of this ETS (doa):	28 February 1995
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Introduction

Wideband radio data transmission systems are rapidly being introduced into a variety of commercial and industrial applications and the technology employed by these systems is still developing.

This ETS may be used by accredited test laboratories for the assessment of the performance of the equipment. The performance of the equipment submitted for type testing should be representative for the performance of the corresponding production model. In order to avoid any ambiguity in that assessment, this ETS contains instructions for the presentation of equipment for type testing purposes (clause 4), testing conditions (clause 6) and methods of measurement (clause 7).

This ETS assumes that:

- the type test measurements performed in an accredited test laboratory in one CEPT country would be accepted by the Type Approval Authority in another country provided that the national regulatory requirements are met (see CEPT Recommendation T/R 71-03 [3]);

- if equipment available on the market is required to be checked it would be tested in accordance with the methods of measurement specified in this ETS.

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1 Scope

This European Telecommunication Standard (ETS) covers equipment referred to in CEPT Recommendation T/R 10-01 [1]. This ETS covers the minimum technical characteristics for radio data transmission equipment having the following technical parameters:

- wideband radio modulation techniques;
- aggregate bit rates in excess of 250 kbits/s;
- operation in the 2,4 to 2,4835 GHz Industrial, Scientific and Medical (ISM) band;
- effective radiated power of up to - 10 dBW (100 mW);
- power density of up to - 10 dBW (100 mW) per 100 kHz for frequency hopping modulation;
- power density of up to - 20 dBW (10 mW) per 1 MHz for other forms of spread spectrum modulation.

This ETS only addresses the transceivers, transmitters and receivers of equipment offered for testing.

The equipment offered for testing may be used in fixed, mobile or portable applications, e.g.:

- stand-alone radio equipment with or without their own control provisions;
- combined radio equipment where the radio part is fully integrated within other types of equipment;
- plug-in radio devices intended for use with a variety of host systems, e.g. personal computers.

The equipment may be fitted with integral antennas and/or antenna connectors.

CEPT Recommendation T/R 10-01 [1] defines the total power and power density limits for systems using spread spectrum modulation together with a minimum aggregate bit rate of 250 kbits/s. The Recommendation does not address the details of these modulation techniques. Therefore, this ETS does not cover the design or operation of the equipment being tested but describes a common set of measurements to be applied to various types of such equipment, including those employing Frequency Hopping Spread Spectrum (FHSS) modulation and Direct Sequence Spread Spectrum (DSSS) modulation.

CEPT Recommendation T/R 10-01 [1] specifies that spread spectrum modulation be used and it gives power density values for FHSS and DSSS modulation. This ETS specifies the minimum technical parameters of FHSS modulation such that it can be clearly differentiated from other types of modulation, including DSSS modulation.

CEPT Recommendation T/R 01-04 [2] defines limits of spurious emissions for a variety of radio equipment; these limits are used in this ETS as appropriate.

This ETS describes measurements for operating frequency range(s), effective radiated power and power density as well as spurious emissions for transmitters and receivers.

The measurement methods have been adapted from ETR 027 [4] where possible.

This ETS specifies test site characteristics, test conditions, equipment calibration and methods of measurement.

This ETS is a general standard which may be superseded by specific standards covering specific applications.

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

2 Normative references

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

[1] CEPT Recommendation T/R 10-01: "Wideband Data Transmission in the 2,4 GHz to 2,5 GHz ISM band".

[2] CEPT Recommendation T/R 01-04: "Low Power Devices".

[3] CEPT Recommendation T/R 71-03: "Procedures for Type Testing and Approval for Radio Equipment intended for non-public systems".

[4] ETR 027: "Radio Equipment and Systems; Methods of measurement for mobile radio equipment".

[5] ETR 028: "Radio Equipment and Systems; Uncertainties in the measurement of mobile radio equipment characteristics".

[6] EN 55022: "Limits and methods of measurement of radio interference characteristics of information technology equipment".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of this ETS the following definitions apply:

aggregate bit rate: The bit rate at the air interface (see point D in figure 1) including protocol overhead where applicable and excluding the effects of signal spreading.

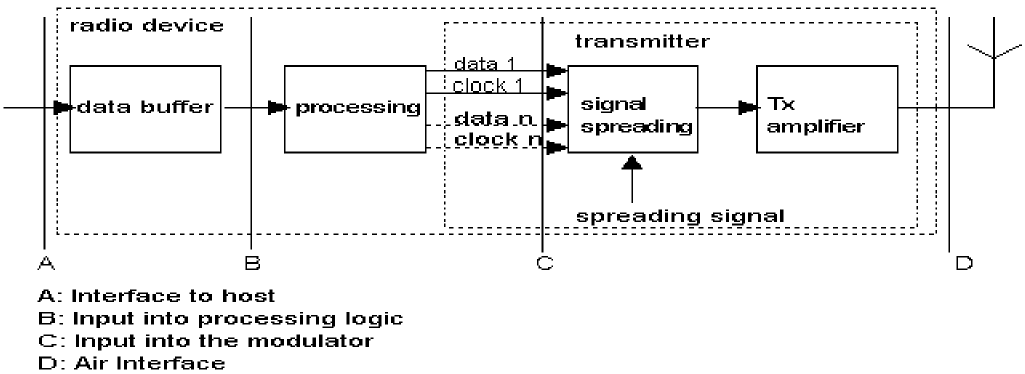


Figure 1: Parameters related to the aggregate bit rate

chip: A unit of modulation used in direct sequence spread spectrum modulation.

chip rate: The number of chips per second.

chip sequence: A sequence of chips with defined length and defined chip polarities.

Direct Sequence Spread Spectrum (DSSS) modulation: A form of modulation where a combination of data to be transmitted and a known code sequence (chip sequence) is used to directly modulate a carrier, e.g. by phase shift keying. The transmitted bandwidth is determined by the chip rate and the modulation scheme.

fixed station: Equipment intended for use in a fixed location and fitted with one or more antennas. The equipment may be fitted with either antenna socket(s) or integral antenna(s) or both.

Frequency Hopping Spread Spectrum (FHSS) modulation: A spread spectrum technique in which the transmitter signal occupies a number of frequencies in time, each for some period of time, referred to as the dwell time. Transmitter and receiver follow the same frequency hop pattern. The frequency range is determined by the lowest and highest hop positions and the bandwidth per hop position (see subclause 5.2.1).

frequency range: The range of operating frequencies over which equipment can be adjusted.

hand-portable station: Equipment normally used on a stand-alone basis and to be carried by a person or held in the hand. The equipment may be fitted with one, or more antennas. The equipment may be fitted with either antenna socket(s), or integral antenna(s), or both.

host: Host equipment is any equipment which has complete user functionality when not connected to the radio equipment part and to which the radio equipment part provides additional functionality and to which connection is necessary for the radio equipment part to offer functionality.

integral antenna: An antenna designed to be connected to the equipment without the use of a standard 50 ohm connector and considered to be part of the equipment. An integral antenna may be fitted internally or externally to the equipment.

manufacturer: "Manufacturer" is understood to refer to the manufacturer, or applicant of equipment offered for testing.

mobile station: Equipment normally used in a vehicle or as a transportable station. The equipment may be fitted with one, or more antennas. The equipment may be fitted with either antenna socket(s), or integral antenna(s), or both.

operating frequency: The nominal frequency at which equipment is operated; this is also referred to as the operating centre frequency. Equipment may be adjustable for operation at more than one operating frequency.

plug-in radio device: Equipment intended to be used within a host, using its housing, control functions and power supply.

power envelope: The frequency/power contour within which the useful RF power is generated.

spread spectrum modulation: A modulation technique in which the energy of a transmitted signal is spread throughout a relatively large portion of the frequency spectrum.

stand-alone equipment: Equipment that is normally used on a stand-alone basis and that includes the radio unit and normally but not necessarily control logic and/or power supply contained within its housing.

3.2 Abbreviations

For the purposes of this ETS the following abbreviations apply:

ac	alternating current
dBW	dB relative to 1 Watt power
dBm	dB relative to 1 milliWatt power
DSSS	Direct Sequence Spread Spectrum
eirp	equivalent isotropically radiated power
FHSS	Frequency Hopping Spread Spectrum
ISM	Industrial, Scientific and Medical
ITE	Information Technology Equipment
RF	Radio Frequency
Rx	Receiver
Tx	Transmitter

4 General

4.1 Manufacturer declarations

The manufacturer shall declare the following specific characteristics of the equipment:

a) the aggregate bit rate (see subclause 3.1 for the definition);

b) the type of modulation used: FHSS modulation, DSSS modulation or any other type of spread spectrum modulation (see subclause 5.1);

c) where applicable, the duty cycle of the transmitter (Tx on/(Tx on + Tx off)) as well as the Tx on and Tx off times);

d) where FHSS modulation is used: the number of hopping channels, the dwell time per channel and the maximum time between two instances of use of the same channel; these values shall fall within the specifications given in subclause 5.1.1;

e) the operating frequency range(s) of the equipment and, where applicable, band(s) of operation (see subclause 5.2.1);

f) the type of the equipment, for example: stand-alone or plug-in radio device (see subclause 3.1). For plug-in radio devices the applicable types of host should be declared as well (see also subclause 6.5);

g) the extreme operating conditions that apply to the equipment offered for testing;

h) the gain of the antenna assembly(ies) intended for normal use, i.e. the transfer function between the conducted RF power and eirp;

i) the nominal ac/dc power voltages of the radio equipment.

Where the equipment to be tested can be equipped with one or more antennas, the manufacturer shall declare and provide for testing the antenna(s) with the equipment; all of these antennas shall be included in the radiated measurements described in this ETS. The characteristics of the antenna assembly(ies) intended for normal use as specified by the manufacturer will be included in the user documentation supplied with the equipment.

4.2 Presentation of equipment for type testing

4.2.1 Choice of model

The manufacturer shall offer one or more production models or equivalent preliminary models, as appropriate, for type testing. If type approval is given on the basis of tests on (a) preliminary model(s), then the corresponding production models shall be identical to the tested models in all respects relevant for the purposes of this ETS, except, where applicable, for the antenna.

Due to the low levels of RF signal and the wideband modulations used in this type of equipment, radiated RF power measurements are imprecise. Conducted measurements are much more precise; in combination with the declared antenna assembly gain(s) adequate assurance of the RF characteristics can be achieved. Therefore, equipment offered for testing shall provide a 50 ohm connector for conducted RF power measurements. Where this is not possible, the manufacturer shall provide a documented test fixture that converts the radiated signal into a conducted signal into a 50 ohm termination. Alternatively, radiated measurements shall be performed.

Where manufacturers submit equipment with an integral antenna only, two sets of equipment shall be provided, one set fitted with an RF test connector and one set fitted with the integral antenna.

4.2.2 Presentation

Stand-alone equipment shall be offered complete with any ancillary equipment needed for testing. The manufacturer shall declare the frequency range(s), the range of operating conditions and power requirements as applicable in order to establish the appropriate test conditions.

Plug-in radio devices may be offered for testing together with a suitable test jig and/or host equipment (see subclause 6.5). The manufacturer shall declare the frequency range(s), the range of operating conditions and power requirements that are applicable in order to establish the appropriate test conditions.

4.2.3 Choice of operating frequencies

Where equipment can be adjusted to, or operated at, different operating frequencies, a minimum of three operating frequencies shall be chosen such that the lower and higher limits of the operating range(s), as well as the middle of the operating range(s), of the equipment are covered, (see subclause 5.2.1).

4.3 Design

4.3.1 General

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

4.3.2 Controls

Those controls (of the radio part) which, if maladjusted, might increase the interfering potential of the equipment shall not be easily accessible to the user.

4.4 Marking

The marking shall be in accordance with the requirements of CEPT Recommendation TR 10-01 [1].

4.5 Interpretation of the measurement results

The interpretation of the test results recorded in a test report for the measurements described in this ETS shall be as follows:

a) the measured value related to the corresponding limit shall be used to decide whether an equipment meets the requirements of the ETS;

b) the actual measurement uncertainty of the test laboratory carrying out the measurements, for each particular measurement, in accordance with ETR 028 [5], shall be recorded in the test report.

The recorded value of the measurement uncertainty shall be, for each measurement, equal to or lower than the figures in clause 8 (measurement uncertainty).

5 Technical characteristics

5.1 Modulation

The manufacturer shall declare the modulation characteristics of the equipment to be tested. For the purpose of deciding which level of power density applies to equipment offered for testing, this ETS defines two categories of equipment:

- equipment conforming to the stated characteristics of FHSS modulation (see subclause 5.1.1); and

- equipment not conforming to these characteristics.

The latter category includes equipment using DSSS modulation (see subclause 5.1.2).

5.1.1 FHSS modulation

FHSS modulation shall make use of at least 20 well defined, non-overlapping channels or hopping positions separated by the channel bandwidth as measured at 20 dB below peak power. The dwell time per channel shall not exceed 0,4 seconds. While the equipment is operating (transmitting and/or receiving) each channel of the hopping sequence shall be occupied at least once during a period not exceeding four times the product of the dwell time per hop and the number of channels. Systems that meet these constraints shall be tested according to the requirements for FHSS modulation.

5.1.2 DSSS and other forms of modulation

For the purposes of this ETS, other forms of spread spectrum modulation which do not satisfy the constraints of the specification given in subclause 5.1.1, shall be considered equivalent to DSSS modulation. Systems using these other forms of modulation, shall be tested according to the requirements for DSSS modulation.

5.2 Transmitter parameter limits

5.2.1 Frequency range

The frequency range of the equipment is determined by the lowest and highest frequencies occupied by the power envelope.

f_H is the highest frequency of the power envelope; it is the frequency furthest above the frequency of maximum power where the output power drops below the level of - 80 dBm/Hz spectral power density (-30 dBm if measured in a 100 kHz bandwidth).

f_L is the lowest frequency of the power envelope; it is the frequency furthest below the frequency of maximum power where the output power drops below the level of - 80 dBm/Hz spectral power density (-30 dBm if measured in a 100 kHz bandwidth).

The width of the power envelope is $f_H - f_L$ for a given operating frequency.

In equipment that allows adjustment or selection of different operating frequencies, the power envelope takes up different positions in the allocated band. The frequency range is determined by the lowest value of f_L and the highest value of f_H resulting from the adjustment of the equipment to the lowest and highest operating frequencies.

For all equipment the frequency range shall lie within the band 2,4 GHz to 2,4835 GHz (i.e. $f_L > 2,4$ GHz and $f_H < 2,4835$ GHz).

See clause 6 for the test conditions; see subclauses 7.2.1 and 7.2.2 for the measurement methods.

5.2.2 Effective radiated power

The effective radiated power is defined as the total power of the transmitter and is calculated according to the procedure given in subclause 7.2.3. The effective radiated power shall be equal to or less than

- 10 dBW (100 mW) eirp, see clause 6 for the test conditions; see subclause 7.2.3 for the measurement method.

5.2.3 Peak power density

The peak power density is defined as the highest instantaneous level of power in Watts per Hertz generated by the transmitter within the power envelope. For equipment using FHSS modulation, the power density shall be limited to - 10 dBW (100 mW) per 100 kHz eirp. For equipment using other types of modulation, the peak power shall be limited to - 20 dBW (10 mW per MHz) eirp, see clause 6 for the test conditions; see subclause 7.2.4 for the measurement and calculation methods.

5.2.4 Spurious emissions

Spurious emissions are emissions outside the declared frequency range(s) of the equipment offered for testing.

The level of spurious emissions shall be measured as either:

a) their power in a specified load (conducted spurious emissions); and

b) their effective radiated power when radiated by the cabinet or structure of the equipment (cabinet radiation); or

c) their effective radiated power when radiated by the cabinet and by the integral antenna, in case of equipment fitted with an antenna and no external connector intended for normal use.

The spurious emissions of the transmitter shall not exceed the values in table 1 in the indicated bands.

Table 1: Transmitter spurious emission levels

	Operating		Standby	
Frequency range	in 100 kHz	in 1 MHz	in 100 kHz	in 1 MHz
9 kHz - 1 GHz (conducted, case a)	- 36 dBm (250 nW)	n.a.	- 57 dBm (2 nW)	n.a.
30 MHz - 1 GHz (radiated, case b and c)				
47,0 - 74,0 MHz 87,5 - 118,0 HHz 174,0 - 230,0 MHz 470,0 - 862,0 MHz	- 54 dBm (4 nW)	n.a.	- 57 dBm (2 nW)	n.a.
1 GHz - 12,75 GHz conducted and radiated	n.a.	- 30 dBm (1 uW)	n.a.	- 47 dBm (20 nW)
890 - 960 MHz 1,8 - 1,9 GHz 5,15 - 5,3 GHz See note	- 56 dBm (3 nW)	n.a.	- 57 dBm (2 nW)	n.a.
NOTE: In these bands, the measurement of any spurious product found shall be repeated with a measurement bandwidth of 30 kHz. If the level observed remains within 2 dB of the previous measurement, the spurious product shall be considered a narrow band signal. For narrow band signals the limit value of - 36 dBm (250 nW) shall apply at frequencies below 1 GHz and the limit value of - 30 dBm (1 uW) shall apply at frequencies above 1 GHz.				

The bandwidths given in table 1 are the nominal Gaussian bandwidths (e.g. 100 kHz at - 3 dB or 120 kHz at - 6 dB) of the measuring equipment.

See clause 6 for the test conditions; see subclause 7.2.5 for the measurement methods.

5.3 Receiver parameter limits

5.3.1 General

This ETS does not impose limits on the receiver of the equipment to be measured other than spurious emission limits (see also subclause 5.2.4).

5.3.2 Spurious emissions

Spurious emissions are emissions outside the declared frequency range(s) of the equipment offered for testing.

The level of spurious emissions shall be measured as either:

a) their power in a specified load (conducted spurious emissions); and

b) their effective radiated power when radiated by the cabinet or structure of the equipment (cabinet radiation); or

c) their effective radiated power when radiated by the cabinet and by the integral antenna, in case of equipment fitted with an antenna and no external connector intended for normal use.

The spurious emissions of the receiver shall be limited to the values in table 2.

Table 2: Spurious emission limits for receivers

Frequency range	in 100 kHz	in 1 MHz
9 kHz to 1 GHz (conducted, case a))	- 57 dBm (2 nW)	n.a.
30 MHz to 1 GHz (radiated, case b) and c))		
1 GHz to 12,75 GHz (conducted and radiated)	n.a.	- 47 dBm (20 nW)

The bandwidths given in table 2 are the nominal Gaussian bandwidths (e.g. 100 kHz at - 3 dB or 120 kHz at - 6 dB) of the measuring equipment.

See clause 6 for the test conditions; see subclause 7.3 for the measurement methods.

6 Test conditions

6.1 Normal and extreme test conditions

Type tests shall be made under normal test conditions and where stated in the methods of measurement (see also clause 7), under extreme conditions, (see also subclause 6.4.1).

Exceptions to the measurement procedures given in this clause shall be recorded in the test report.

6.2 Power sources

6.2.1 Power sources for stand-alone equipment

During type tests, the power source of the equipment shall be replaced by a test power source capable of producing normal and extreme test voltages as specified in subclauses 6.3.2 and 6.4.2. The internal impedance of the test power source shall be low enough for its effect on the test results to be negligible. For the purpose of tests, the voltage of the power source shall be measured at the input terminals of the equipment.

For battery operated equipment the battery shall be removed and the test power source shall be applied as close to the battery terminals as practicable.

During tests the power source voltages shall be maintained within a tolerance of <±1% relative to the voltage at the beginning of each test. The value of this tolerance is critical to power measurements; using a smaller tolerance will provide better measurement uncertainty values.

6.2.2 Power sources for plug-in radio devices

The power source for testing plug-in radio devices shall be provided by a test jig or host equipment. Where the host system and/or the plug-in radio device is battery powered, the battery shall be removed and the test power source shall be applied as close to the battery terminals as practicable.

6.3 Normal test conditions

6.3.1 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°C to + 35°C;

- relative humidity: 20 % to 75 %.

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

The actual values during the tests shall be recorded in the test report.

6.3.2 Normal power source

6.3.2.1 Mains voltage

The normal test voltage for equipment to be connected to the mains shall be the nominal mains voltage. For the purpose of this ETS, 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 and 51 Hz.

6.3.2.2 Regulated lead-acid battery power sources used on vehicles

When radio equipment is intended for operation from the usual types of regulated lead-acid battery power source used on vehicles, then the normal test voltage shall be 1,1 times the nominal voltage of the battery (6V, 12V, etc.).

6.3.2.3 Other power sources

For operation from other power sources or types of battery (primary or secondary), the nominal test

voltage shall be as declared by the equipment manufacturer. This shall be recorded in the test report.

6.4 Extreme test conditions

6.4.1 Extreme temperatures

For tests at extreme temperatures, measurements shall be made in accordance with the procedures specified in subclause 6.4.3, at the upper and lower temperatures of the range as follows:

- temperature: - 20°C to + 55°C.

Where the manufacturer's declared operating range does not include the range of - 20°C to + 55°C, the equipment shall be tested over the following temperature ranges:

a) 0°C to + 35°C for equipment intended for indoor use only, or intended for use in areas where the temperature is controlled within this range;

b) over the extremes of the operating temperature range(s) of the declared host equipment(s) in case of plug-in radio devices.

The frequency range as in subclause 5.2.1 and the eirp limit in subclause 5.2.2 shall not be exceeded.

The temperature range used in the type testing shall be recorded in the test report and shall be stated in the user manual.

6.4.2 Extreme power source voltages

6.4.2.1 Mains voltage

The extreme test voltage for equipment to be connected to an ac mains source shall be the nominal mains voltage ± 10 %.

Tests at extreme power source voltages are not required when the equipment under test is designed for operation as part of and powered by another system or piece of equipment. Where this is the case, the limit values of the host system or host equipment shall apply. The appropriate limit values shall be declared by the manufacturer and recorded in the test report.

6.4.2.2 Regulated lead-acid battery power sources used on vehicles

When radio equipment is intended for operation from the usual types of regulated lead-acid battery power source used on vehicles, then extreme test voltage shall be 1,3 and 0,9 times the nominal voltage of the battery (6V, 12V, etc.).

6.4.2.3 Power sources using other types of batteries

The lower extreme test voltages for equipment with power sources using the following types of battery, shall be:

- for the Leclanché or lithium type battery: 0,85 times the nominal voltage of the battery;

- for the mercury or nickel-cadmium type of battery: 0,9 times the nominal voltage of the battery.

In both cases, the upper extreme test voltage shall be 1,15 times the nominal voltage of the battery.

6.4.2.4 Other power sources

For equipment using other power sources, or capable of being operated from a variety of power sources (primary or secondary), the extreme test voltages shall be those declared by the manufacturer; these shall be recorded in the test report.

6.4.3 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 stabilizing circuits designed to operate continuously, these circuits shall be switched on for 15 minutes after thermal balance has been reached; at that time the equipment shall meet the specified requirements. For this type of equipment the manufacturer shall provide for the power source circuit feeding the crystal oven to be independent of the power source of the rest of the equipment.

If 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 testing 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.

6.4.3.1 Procedure for equipment designed for continuous operation

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 than be switched on in the transmit conditions for a period of half an 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 to the standby or receive condition for a period of one minute after which the equipment shall meet the specified requirements.

6.4.3.2 Procedure for equipment designed for intermittent operation

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 than be switched on for one minute in the transmit condition, followed by four minutes in the receive condition, 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 a period of one minute after which the equipment shall meet the specified requirements.

6.5 Testing of host connected equipment and plug-in radio devices

For equipment for which connection to or integration with host equipment is required to offer functionality, two alternative approaches are permitted. The manufacturer shall declare which alternative shall be used.

6.5.1 Alternative A: combined equipment

A combination of a radio equipment part and a specific type of host equipment may be used for testing according to this ETS.

Where more than one such a combination is intended, each combination shall be tested separately.

Type testing shall not be repeated for combinations of radio parts and host equipment where the latter are substantially similar in terms of mechanical and electrical characteristics as those offered for type testing.

6.5.2 Alternative B: use of a test jig and three hosts

Where the radio equipment part is intended for use with a variety of host systems, the manufacturer shall supply a suitable test jig. The test jig shall be designed such that alteration of the radio equipment's intrinsic emissions is minimized. Where connection between the radio equipment part and the host is by means of cables, optical fibres or similar means between control and/or power ports, the connection to the host shall be considered a suitable test jig.

The test jig shall allow the radio equipment part to be powered and stimulated in a way similar to the way it would be powered and stimulated when connected to or inserted into host equipment. Measurements shall be made to all requirements of this ETS.

In addition to tests on the test jig, the radio equipment part shall be tested when connected to or inserted into three different hosts, e.g. Information Technology Equipment (ITE). These hosts shall be provided by the manufacturer and shall be selected from the list of compatible hosts as published by the manufacturer as part of the user documentation supplied with the radio equipment part. The selection of hosts shall be agreed to by the applicable authority. National regulatory administrations shall have the discretion to require the manufacturer to inform them of each deletion from or addition to the list of compatible hosts as published in the user documentation.

For tests with the radio equipment part connected to, or inserted in, host equipment, the combination shall be tested against the requirements of this ETS except for cabinet radiation from the enclosure which shall be measured according to the requirements that apply to the host equipment. In case the host equipment is ITE, the requirements of EN 55022 [6] apply. The applicable class under EN 55022 [6], as identified in the user manual, shall be declared by the manufacturer and recorded in the test report.

6.6 Test data sequence

The manufacturer shall describe, and provide, a test data sequence with which the transmitter is modulated during the measurements described in this ETS. The test data sequence shall spread the transmitted power throughout the power envelope. Where the equipment is not capable of continuous RF transmission, the test data sequence shall be such that:

- the generated RF signal is the same for each transmission;

- transmissions occur regularly in time;

- sequences of transmissions can be repeated accurately.

The same test data sequence shall be used for all measurements on the same equipment.

For frequency hopping systems the manufacturer shall supply a means of selecting the hop frequencies required by this ETS.

7 Methods of measurement

7.1 General

The following subclauses describe methods of measurement for the following transmitter parameters:

- the frequency ranges(s);
- the effective radiated power;
- the maximum power density;
- the transmitter spurious emissions.

The following subclauses describe methods of measurement for the following receiver parameters:

- the receiver spurious emissions.

The following methods of measurement shall apply to the testing of stand-alone units and to the equipment configurations identified in subclause 6.5.

7.2 Measurements of transmitter parameters

7.2.1 Frequency range of equipment using FHSS modulation

Using applicable conducted measurement procedures, as described in annex B, the frequency range (see subclause 5.2.1) of the equipment shall be measured and recorded in the test report.

During these measurements the test data sequence as specified in subclause 6.6 shall be used.

The transmitter power level shall be set to the rated power level.

These measurements shall be performed under normal test conditions, see subclause 6.3, and extreme test conditions, subclauses 6.4.1 and 6.4.2 applied simultaneously..

The measurement procedure shall be as follows:

a) place the spectrum analyzer in video averaging mode with a minimum of 50 sweeps selected;

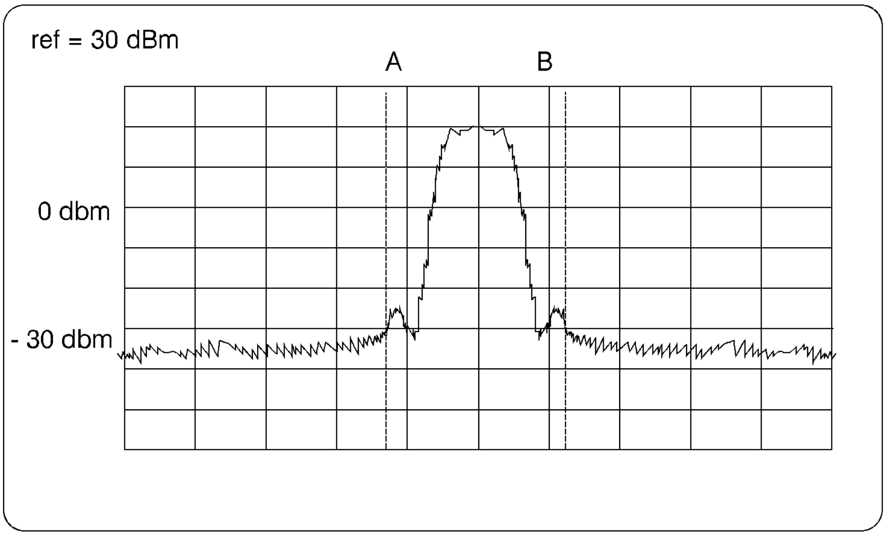
b) select the lowest operating frequency of the equipment under test and activate the transmitter with modulation applied. The display will form an image like that shown in figure 2;

c) find the lowest frequency below the operating frequency at which spectral power density drops below the level given in subclause 5.2.1. See A in figure 2. This frequency shall be recorded in the test report;

d) select the highest operating frequency of the equipment under test and find the highest frequency at which the spectral power density drops below the level given in subclause 5.2.1. See B in figure 2. This frequency shall be recorded in the test report;

e) the difference between the frequencies measured in steps c) and d) is the frequency range; it shall be recorded in the test report.

This measurement shall be repeated for each operating frequency range declared by the manufacturer.



NOTE: This example assumes a 100 kHz resolution bandwidth.

Figure 2: Measuring the extreme frequencies of the power envelope

7.2.2 Frequency range of equipment using other forms of modulation

Using applicable conducted measurement procedures, as described in annex B, the frequency range(s) shall be measured and recorded in the test report.

During these measurements the test data sequence as specified in subclause 6.6 shall be used.

The transmitter power level shall be set to the rated power level.

These measurements shall be performed under normal test conditions, see subclause 6.3, and extreme test conditions, subclauses 6.4.1 and 6.4.2 applied simultaneously.

The measurement procedure shall be as follows:

a) place the spectrum analyzer in video averaging mode with a minimum of 50 sweeps selected;

b) select the lowest operating frequency of the equipment under test and activate the transmitter with modulation applied. The RF emission of the equipment shall be displayed on the spectrum analyzer. The display will form an image like that shown in figure 2;

c) using the marker of the spectrum analyzer, find the lowest frequency below the operating frequency at which spectral power density drops below the level given in subclause 5.2.1. See line A in figure 2. This frequency is recorded in the test report;

d) select the highest operating frequency of the equipment under test and find the highest frequency at which the spectral power density drops below the value given in subclause 5.2.1. See line B in figure 2. This frequency shall be recorded in the test report;

e) the difference between the frequencies measured in steps c) and d) is the frequency range; it shall be recorded in the test report.

This measurement shall be repeated for each frequency range declared by the manufacturer.

7.2.3 Effective radiated power

Using applicable measurement procedures, as described in annex B, the power output as defined in subclause 5.2.2 shall be measured and recorded in the test report.

If the transmitter power is adjustable by the user, the power level shall be set to the highest level available. The measurement shall be performed using normal operation of the equipment with modulation using the test data sequence applied.

The test procedure shall be as follows:

Step 1:

Using suitable attenuators, the output power of the transmitter is coupled to a diode detector. The output of the diode detector is connected to the vertical channel of an oscilloscope.

The combination of the diode detector and the oscilloscope shall be capable of faithfully reproducing the envelope peaks and the duty cycle of the transmitter output signal.

The observed duty cycle of the transmitter (Tx on/(Tx on + Tx off)) shall be noted as x, $(0 < x \leq 1)$ and recorded in the test report. For the purpose of testing, the equipment shall be operated with a duty cycle that is equal to or more than 0,1.

Step 2:

The average output power of the transmitter shall be determined using a wideband, calibrated RF power meter with a thermocouple detector or an equivalent thereof and, where applicable, with an integration period that exceeds the repetition period of the transmitter by a factor 5 or more. The observed value shall be noted as "A" (in dBm).

The eirp shall be calculated from the above measured power output A, the observed duty cycle x, and the declared antenna assembly gain(s) "G" in dBi, according to the formula:

$P = A + G + 10\log(1/x)$.

P shall not exceed the value specified in subclause 5.2.2, and shall be recorded in the test report.

Step 3:

The measurement set up as given under step 1 shall be used to determine, on the oscilloscope, the peak of the envelope of the output signal of the transmitter.

The maximum deviation of the Y-trace of the oscilloscope shall be noted as "B".

Step 4:

The transmitter shall be replaced by a signal generator. The output frequency of the signal shall be made equal to the centre of the frequency range occupied by the transmitter.

The signal generator shall be unmodulated. The output power of the signal generator shall be raised to a level such that the deviation of the Y-trace of the oscilloscope reaches level B, as indicated in step 3.

This output power level "C" (in dBm) of the signal generator shall be determined using a wideband, calibrated RF power meter with a thermocouple detector or an equivalent thereof.

Level C shall not exceed by more than 3 dB the value specified in subclause 5.2.2 minus the antenna assembly gain(s) G in dBi.

The measurement shall be repeated at the lowest, the middle, and the highest frequency of the declared frequency range. These frequencies shall be recorded in the test report. FHSS equipment shall be made to hop continuously to each of these three frequencies separately.

These measurements shall be performed at normal test conditions, see subclause 6.3, and extreme test conditions, subclauses 6.4.1 and 6.4.2 applied simultaneously.

The method of measurement shall be documented in the test report.

7.2.4 Peak power density

Using applicable measurement procedures as described in annex B, the maximum power density as defined in subclause 5.2.3 shall be measured and recorded in the test report. The power density shall be determined using a spectrum analyzer of adequate bandwidth for the type of modulation being used in combination with an RF power meter.

The equipment to be measured shall be operated as described in subclause 7.2.3.

Equipment where the transmitter is on for 10 ms or more shall be measured as follows:

- connect an RF power meter to the IF output of the spectrum analyser and correct its reading using a known reference source, e.g. a signal generator.

  NOTE: The IF output of the spectrum analyser may be 20 dB or more below the input level of the spectrum analyser. Unless the power meter has adequate sensitivity, a wideband amplifier may be required.

Step 1:

Calibrate the measurement set-up with a CW signal from a calibrated source; the reference signal should have a strength of 10 dBm.

The settings of the spectrum analyser shall be:

Centre Frequency:	equal to the signal source;
Resolution BW:	100 kHz for FHSS, 1 MHz for DSSS;
Video BW:	same;
Detector mode:	positive peak;
Averaging:	off;
Span:	zero Hz;
Amplitude:	adjust for middle of the instrument's range.

Step 2:

Reduce the calibrating signal power to 0 dBm and verify that the power meter reading also reduces by 10 dB.

Step 3:

Connect the equipment to be measured. Using the following settings of the spectrum analyser in combination with "max hold" function, find the frequency of highest power output in the power envelope.

Centre Frequency:	equal to operating frequency;
Resolution BW:	100 kHz for FHSS, 1 MHz for DSSS;
Video BW:	same;
Detector mode:	positive peak;
Averaging:	off;
Span:	> 3 times the spectrum width;
Amplitude:	adjust for middle of the instrument's range.

The frequency found shall be recorded in the test report.

Step 4:

Set the centre frequency of the spectrum analyser to found frequency and switch to zero span. The power meter indicates the measured power density. The power density eirp is calculated from the measured power density and the declared antenna assembly gain(s).

The above procedure shall be repeated for each of the three frequencies identified in subclause 7.2.3.

Where the spectrum analyser bandwidth is non-Gaussian, a suitable correction factor shall be determined and applied.

For equipment where the transmitter is normally on for less than 10 ms, the method of measurement shall be documented in the test report.

7.2.5 Spurious emissions

The following method of measurement shall apply to both conducted and radiated measurements.

In the case of radiated measurements, using a test site as described in annex A and applicable measurement procedures as described in annex B, the spurious emissions as defined in subclause 5.2.4 shall be measured and recorded in the test report.

In case of conducted measurements, the receiver shall be connected to the measuring equipment via a 50 ohm attenuator.

Tests of FHSS equipment shall be carried out while the equipment is hopping between the following operating frequencies:

- two frequencies separated by the maximum hop frequency change declared by the manufacturer, one of which is the lowest operating frequency; and

- two frequencies separated by the maximum hop frequency change declared by the manufacturer, one of which is the highest operating frequency.

During this test modulation shall be applied using the test data sequence.

If the equipment is fitted with an automatic shut-off facility it shall be made inoperative for the duration of this test unless it has to be left operative to protect the equipment. If the shut-off facility is left operative, the status of the equipment shall be indicated.

The measurement equipment shall be set for peak hold mode of operation.

The measurement procedure shall be as follows:

- the transmitter shall be operated at the rated output power;

- the spectrum outside the declared frequency range(s) (see subclauses 7.2.1 and 7.2.2) shall be searched for emissions that exceed the limit values given in subclause 5.2.4 or that come to within 6 dB below the limit values given in subclause 5.2.4. Each occurrence shall be noted in the test report;

- this measurement shall be made with the transmitter set to the lowest operating frequency and with the transmitter set to the highest operating frequency.

This measurement shall be repeated with the transmitter in standby mode where applicable.

Where these measurements are made with a spectrum analyser, the following settings and procedures shall be used:

Resolution BW:	100 kHz or 1 MHz as applicable;
Video BW:	same;
Detector mode:	positive peak;
Averaging:	off;
Span:	100 MHz;
Amplitude:	adjust for middle of the instrument's range;
Sweep time:	1 second.

For measuring emissions that exceed the level of 6 dB below the applicable limit the resolution bandwidth shall be switched to 30 kHz. If the level does not change by more than 2 dB, it is a narrowband emission; the observed value shall be recorded in the test report. If the level changes by more than 2 dB, the emission is a wideband emission; its value, as observed with the resolution bandwidth set to 1 MHz, shall be recorded in the test report.

NOTE 1: The main spectrum of the device being tested may saturate the spectrum analyser's input circuits and so cause ghost "spurious" signals. Ghosts can be distinguished from real signals by increasing the input attenuator by 10 dB. If the spurious signal disappears, it is a ghost and should be ignored.

NOTE 2: See also note in table 1.

7.3 Measurements of receiver parameters

7.3.1 General

This subclause only provides for the measurement of receiver spurious emissions.

7.3.2 Spurious emissions

The following method of measurement shall apply to both conducted and radiated measurements.

In the case of radiated measurements, using a test site as described in annex A and applicable measurement procedures as described in annex B, the spurious emissions as defined in subclause 5.2.4 shall be measured under the conditions given in subclause 5.3.2 and recorded in the test report.

In the case of conducted measurements, the receiver shall be connected to the measuring equipment via a 50 ohm attenuator.

The measurement procedure shall be as follows:

- with the transmitter disabled, the spectrum outside the declared operating range(s) (see subclauses 7.2.1 and 7.2.2) shall be searched for emissions that exceed the limit values given in subclause 5.3 or that come to within 6 dB below the limit values given in subclause 5.3. Each occurrence shall be recorded in the test report.

The limits shall apply to all operating conditions. However, for practical purposes, measurements shall be performed only under the following conditions:

- for FHSS equipment the mode of operation as described in subclause 7.2.2. shall apply except that the equipment shall be tested in both the receive and (where applicable) standby modes;

- for DSSS equipment the test shall be made at the lowest and highest operating frequencies in both receive and (where applicable) standby modes.

Where these measurements are made with a spectrum analyser, the following settings and procedures shall be used:

Resolution BW:	100 kHz or 1 MHz as applicable;
Video BW:	same;
Detector mode:	positive peak;
Averaging:	off;
Span:	100 MHz;
Amplitude:	adjust for middle of the instrument's range;
Sweep time:	1 second.

8 Measurement uncertainty values

The maximum values of the absolute measurement uncertainties of the measurements defined in this ETS shall not exceed the values given below:

Radio frequency:	± 1 x 10^{-5};
Total RF power, conducted:	± 1,5 dB;
RF power density, conducted:	± 3 dB;
Spurious emissions, conducted:	± 3 dB;
All emissions, radiated:	± 6 dB;
Temperature:	± 1o C;
Humidity:	± 5 %.

For the measurement methods according to this ETS these uncertainty figures are valid to a confidence level of 95 % calculated according to the methods described in ETR 028 [5].

Annex A (normative): Test sites and arrangements for radiated measurements

A.1 Test sites

A.1.1 Open air test sites

The term "open air" should be understood from a electromagnetic point of view. Such a test site may be really in open air or alternatively with walls and ceiling transparent to the radio waves at the frequencies considered.

An open air test site may be used to perform the measurements using the radiated measurement methods described in clause 7. Absolute or relative measurements may be performed on transmitters or on receivers; absolute measurements of field strength require a calibration of the test site.

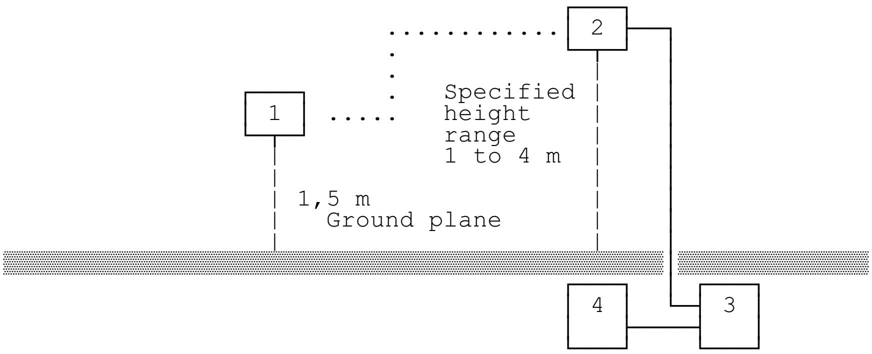
A measuring distance of at least 3 m shall be used for measurements at frequencies up to 1 GHz. For frequencies above 1 GHz, any suitable measuring distance may be used. The equipment size (excluding the antenna) shall be less than 20 % of the measuring distance. The height of the equipment or of the substitution antenna shall be 1,5 m; the height of the test antenna (transmit or receive) shall vary between 1 and 4 m.

Sufficient precautions shall be taken to ensure that reflections from extraneous objects adjacent to the site do not degrade the measurement results, in particular:

- no extraneous conducting objects having any dimension in excess of a quarter wavelength of the highest frequency tested shall be in the immediate vicinity of the site;

- all cables shall be as short as possible; as much of the cables as possible shall be on the ground plane or preferably below; and the low impedance cables shall be screened.

The general measurement arrangement is shown in figure A.1.



1) Equipment under test;
2) Test antenna;
3) High pass filter (necessary for strong fundamental Tx radiation);
4) Spectrum analyzer or measuring receiver.

Figure A.1: Measuring arrangement

A.1.2 Anechoic chamber

A.1.2.1 General

An anechoic chamber is a well shielded chamber covered inside with radio frequency absorbing material and simulating a free space environment. It is an alternative site on which to perform the measurements using the radiated measurement methods described in clause 7. Absolute or relative measurements may be performed on transmitters or on receivers. Absolute measurements of field strength require a calibration of the anechoic chamber. The test antenna, equipment under test and substitution antenna are used in a way similar to that at the open air test site, but are all located at the same fixed height above the floor.

A.1.2.2 Description

An anechoic chamber should meet the requirements for shielding loss and wall return loss as shown in figure A.2. Figure A.3 shows an example of the construction of an anechoic chamber having a base area of 5 m by 10 m and a height of 5 m. The ceiling and walls are coated with pyramidally formed absorbers approximately 1 m high. The base is covered with special absorbers which form the floor. The available internal dimensions of the chamber are 3 m x 8 m x 3 m, so that a maximum measuring distance of 5 m in the middle axis of this chamber is available (see clause A.4 3)). The floor absorbers reject floor reflections so that the antenna height need not be changed. Anechoic chambers of other dimensions may be used.

A.1.2.3 Influence of parasitic reflections

For free-space propagation in the far field, the relationship of the field strength E and the distance R is given by $E = E_o \times (R_o/R)$, where E_o is the reference field strength and R_o is the reference distance. This relationship allows relative measurements to be made as all constants are eliminated within the ratio and neither cable attenuation nor antenna mismatch or antenna dimensions are of importance.

If the logarithm of the foregoing equation is used, the deviation from the ideal curve may be easily seen because the ideal correlation of field strength and distance appears as a straight line. The deviations occurring in practice are then clearly visible. This indirect method shows quickly and easily any disturbances due to reflections and is far less difficult than the direct measurement of reflection attenuation.

With an anechoic chamber of the dimensions given above at low frequencies below 100 MHz there are no far field conditions, but the wall 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 to the distance meets the expectations very well. Above 1 GHz, because more reflections will occur, the dependence of the field strength to the distance will not correlate so closely.

A.1.2.4 Calibration and mode of use

The calibration and mode of use is the same as for an open air test site, the only difference being that the test antenna does not need to be raised and lowered whilst searching for a maximum, which simplifies the method of measurement.

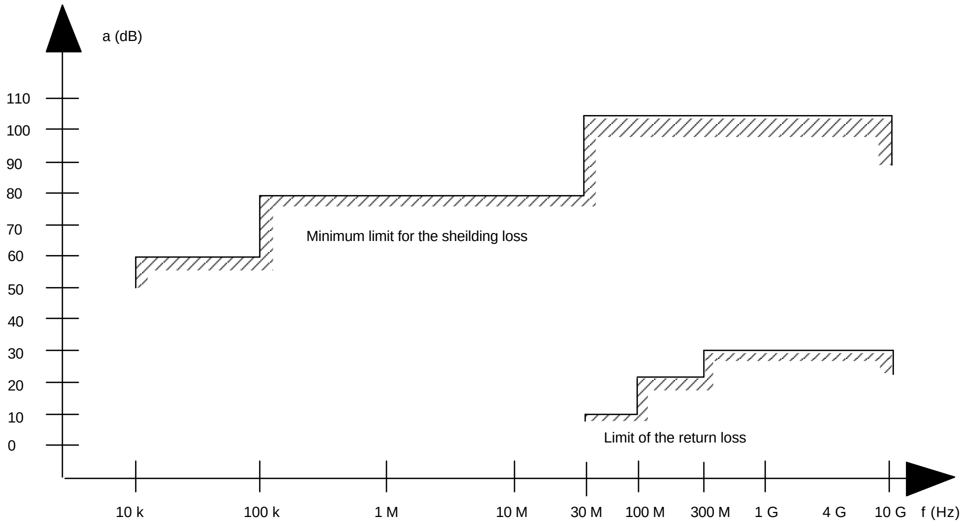


Figure A.2: Specification for shielding and reflections

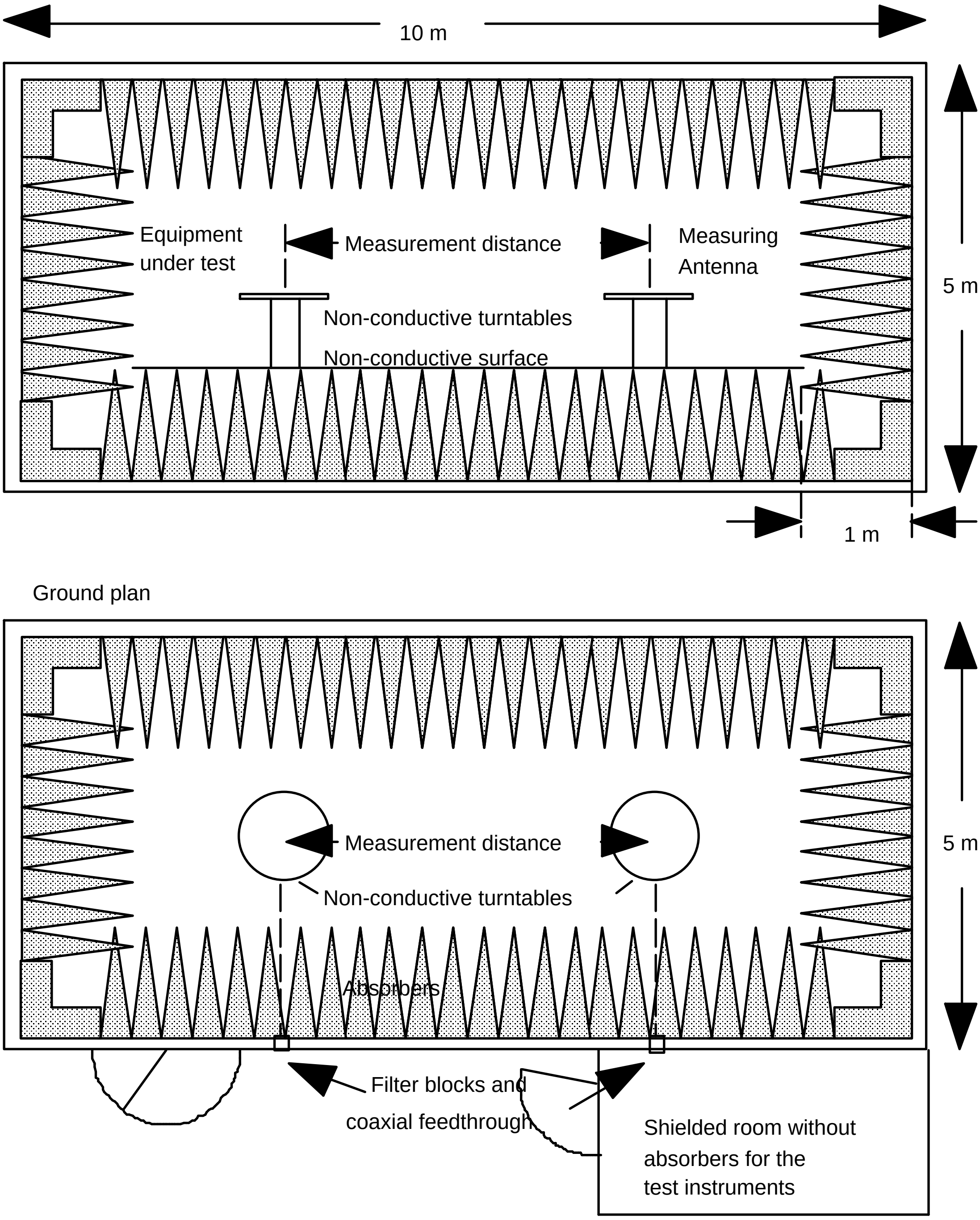


Figure A.3: Anechoic shielded chamber for simulated free space measurements

A.2 Test antenna

When the test site is used for radiation measurements the test antenna shall be used to detect the field from both the test sample and the substitution antenna. When the test site is used for the measurement of receiver characteristics the antenna shall be used as a transmitting antenna. This antenna shall be mounted on a support capable of allowing the antenna to be used in either horizontal or vertical polarization and for the height of its centre above the ground to be varied over the specified range. Preferably test antennas with pronounced directivity should be used. The size of the test antenna along the measurement axis shall not exceed 20 % of the measuring distance.

A.3 Substitution antenna

The substitution antenna shall be used to replace the equipment under test in substitution measurements. For measurements below 1 GHz the substitution antenna shall be a half wavelength dipole resonant at the frequency under consideration, or a shortened dipole, calibrated to the half wavelength dipole. For measurements between 1 and 4 GHz either a half wavelength dipole or a horn radiator may be used. For measurements above 4 GHz a horn radiator shall be used. 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 outside antenna is connected to the cabinet.

The distance between the lower extremity of the dipole and the ground shall be at least 30 cm.

NOTE: The gain of a horn antenna is generally expressed relative to an isotropic radiator.

A.4 Informative references

1) IEC Publication 489-3 Second edition (1988) Appendix F pages 130 to 133.

2) IEC Publication 489-3 Second edition (1988) Appendix J pages 156 to 164.

3) Ketterling, H.-P.: Verification of the performance of fully and semi-anechoic chambers for radiation measurements and susceptibility/immunity testing, 1991, Leatherhead/Surrey, ERA Report 91-0028.

Annex B (normative): General description of measurement methods

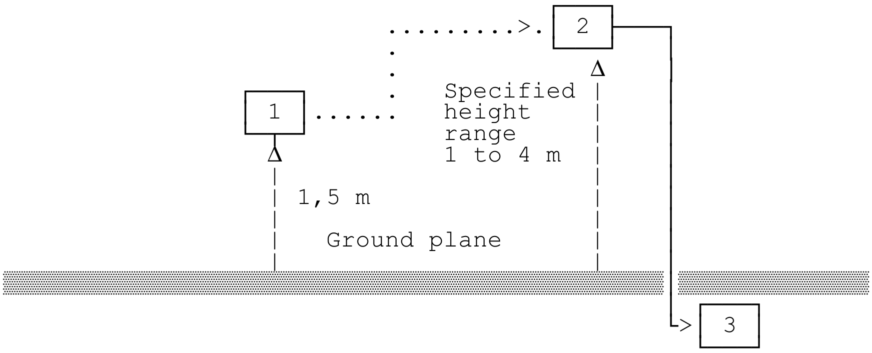
This annex gives the general methods of measurements for RF signals using the test sites and arrangements described in annex A.

B.1 Conducted measurements and use of test fixture

In view of the low power levels of the equipment to be tested under this ETS, conducted measurements may be applied to equipment provided with an antenna connector, e.g. by means of a spectrum analyzer.

Where the equipment to be tested does not provide a suitable connector, a test fixture may be provided, (see subclause 4.2.1).

B.2 Radiated measurements



1) Transmitter under test;
2) Test antenna;
3) Spectrum analyzer or selective voltmeter.

Figure B.1: Measurement arrangement No 1

Radiated measurements shall be performed with the aid of a test antenna and measurement instruments as described in annex A. The test antenna and measurement instrument shall be calibrated according to the procedure defined in this annex. The equipment to be measured and the test antenna shall be oriented to obtain the maximum emitted power level. This position shall be recorded in the measurement report. The frequency range shall be measured in this position.

Preferably, radiated measurements shall be performed in an anechoic chamber. For other test sites corrections may be needed (see annex A). The following test procedure applies:

a) a test site which fulfils the requirements of the specified frequency range of this measurement shall be used. The test antenna shall be oriented initially for vertical polarization unless otherwise stated and the transmitter under test shall be placed on the support in its standard position (annex A, subclause A.1.1) and switched on;

b) for average power measurements a non-selective voltmeter or wide band spectrum analyzer shall be used. For other measurements a spectrum analyzer or selective voltmeter shall be used and tuned to the measurement frequency;

c) the transmitter shall be rotated through 360° about a vertical axis until a higher maximum signal is received;

d) the test antenna shall be raised or lowered again, if necessary, through the specified height range until a maximum is obtained. This level shall be recorded.

NOTE: This maximum may be a lower value than the value obtainable at heights outside the specified limits.

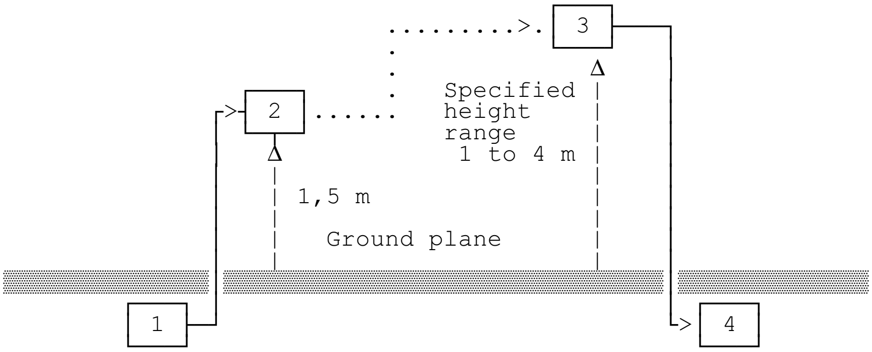
In either case a) or b), the test antenna shall be raised or lowered, if necessary, through the specified height range until the maximum signal level is detected on the spectrum analyzer or selective voltmeter.

The test antenna need not be raised or lowered if the measurement is carried out on a test site according to annex A, subclause A.1.2. This measurement shall be repeated for horizontal polarization.

B.3 Substitution measurement

The actual signal generated by the measured equipment may be determined by means of a substitution measurement in which a known signal source replaces the device to be measured, (see figure B.2).

Preferably, this method of measurement shall be used in an anechoic chamber. For other test sites corrections may be needed, (see annex A).



1) Signal generator;
2) Substitution antenna;
3) Test antenna;
4) Spectrum analyzer or selective voltmeter.

Figure B.2: Measurement arrangement No 2

a) Using measurement arrangement No 2, the substitution antenna shall replace the transmitter antenna in the same position and in vertical polarization. The frequency of the signal generator shall be adjusted to the measurement frequency. The test antenna shall be raised or lowered, if necessary, to ensure that the maximum signal is still received. The input signal to the substitution antenna shall be adjusted in level until an equal or a known related level to that detected from the transmitter is obtained in the test receiver.

    The test antenna need not be raised or lowered if the measurement is carried out on a test site according to annex A, subclause A.1.2.

    The radiated power is equal to the power supplied by the signal generator, increased by the known relationship if necessary and after corrections due to the gain of the substitution antenna and the cable loss between the signal generator and the substitution antenna.

b) This measurement shall be repeated with horizontal polarization.

History

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